ALTITUDE CORRECTION TABLES 10°–90°—SUN, STARS, PLANETS

SUN

OCT.—MAR. App. Alt.	Lower Limb	Upper Limb	APR.—SEPT. App. Alt.	Lower Limb	Upper Limb
° ′	′	′	° ′	′	′
9 34	+10·8	−21·5	9 39	+10·6	−21·2
9 45	+10·9	−21·4	9 51	+10·7	−21·1
9 56	+11·0	−21·3	10 03	+10·8	−21·0
10 08	+11·1	−21·2	10 15	+10·9	−20·9
10 21	+11·2	−21·1	10 27	+11·0	−20·8
10 34	+11·3	−21·0	10 40	+11·1	−20·7
10 47	+11·4	−20·9	10 54	+11·2	−20·6
11 01	+11·5	−20·8	11 08	+11·3	−20·5
11 15	+11·6	−20·7	11 23	+11·4	−20·4
11 30	+11·7	−20·6	11 38	+11·5	−20·3
11 46	+11·8	−20·5	11 54	+11·6	−20·2
12 02	+11·9	−20·4	12 10	+11·7	−20·1
12 19	+12·0	−20·3	12 28	+11·8	−20·0
12 37	+12·1	−20·2	12 46	+11·9	−19·9
12 55	+12·2	−20·1	13 05	+12·0	−19·8
13 14	+12·3	−20·0	13 24	+12·1	−19·7
13 35	+12·4	−19·9	13 45	+12·2	−19·6
13 56	+12·5	−19·8	14 07	+12·3	−19·5
14 18	+12·6	−19·7	14 30	+12·4	−19·4
14 42	+12·7	−19·6	14 54	+12·5	−19·3
15 06	+12·8	−19·5	15 19	+12·6	−19·2
15 32	+12·9	−19·4	15 46	+12·7	−19·1
15 59	+13·0	−19·3	16 14	+12·8	−19·0
16 28	+13·1	−19·2	16 44	+12·9	−18·9
16 59	+13·2	−19·1	17 15	+13·0	−18·8
17 32	+13·3	−19·0	17 48	+13·1	−18·7
18 06	+13·4	−18·9	18 24	+13·2	−18·6
18 42	+13·5	−18·8	19 01	+13·3	−18·5
19 21	+13·6	−18·7	19 42	+13·4	−18·4
20 03	+13·7	−18·6	20 25	+13·5	−18·3
20 48	+13·8	−18·5	21 11	+13·6	−18·2
21 35	+13·9	−18·4	22 00	+13·7	−18·1
22 26	+14·0	−18·3	22 54	+13·8	−18·0
23 22	+14·1	−18·2	23 51	+13·9	−17·9
24 21	+14·2	−18·1	24 53	+14·0	−17·8
25 26	+14·3	−18·0	26 00	+14·1	−17·7
26 36	+14·4	−17·9	27 13	+14·2	−17·6
27 52	+14·5	−17·8	28 33	+14·3	−17·5
29 15	+14·6	−17·7	30 00	+14·4	−17·4
30 46	+14·7	−17·6	31 35	+14·5	−17·3
32 26	+14·8	−17·5	33 20	+14·6	−17·2
34 17	+14·9	−17·4	35 17	+14·7	−17·1
36 20	+15·0	−17·3	37 26	+14·8	−17·0
38 36	+15·1	−17·2	39 50	+14·9	−16·9
41 08	+15·2	−17·1	42 31	+15·0	−16·8
43 59	+15·3	−17·0	45 31	+15·1	−16·7
47 10	+15·4	−16·9	48 55	+15·2	−16·6
50 46	+15·5	−16·8	52 44	+15·3	−16·5
54 49	+15·6	−16·7	57 02	+15·4	−16·4
59 23	+15·7	−16·6	61 51	+15·5	−16·3
64 30	+15·8	−16·5	67 17	+15·6	−16·2
70 12	+15·9	−16·4	73 16	+15·7	−16·1
76 26	+16·0	−16·3	79 43	+15·8	−16·0
83 05	+16·1	−16·2	86 32	+15·9	−15·9
90 00			90 00		

STARS AND PLANETS

App. Alt.	Corrⁿ
° ′	′
9 56	−5·3
10 08	−5·2
10 20	−5·1
10 33	−5·0
10 46	−4·9
11 00	−4·8
11 14	−4·7
11 29	−4·6
11 45	−4·5
12 01	−4·4
12 18	−4·3
12 35	−4·2
12 54	−4·1
13 13	−4·0
13 33	−3·9
13 54	−3·8
14 16	−3·7
14 40	−3·6
15 04	−3·5
15 30	−3·4
15 57	−3·3
16 26	−3·2
16 56	−3·1
17 28	−3·0
18 02	−2·9
18 38	−2·8
19 17	−2·7
19 58	−2·6
20 42	−2·5
21 28	−2·4
22 19	−2·3
23 13	−2·2
24 11	−2·1
25 14	−2·0
26 22	−1·9
27 36	−1·8
28 56	−1·7
30 24	−1·6
32 00	−1·5
33 45	−1·4
35 40	−1·3
37 48	−1·2
40 08	−1·1
42 44	−1·0
45 36	−0·9
48 47	−0·8
52 18	−0·7
56 11	−0·6
60 28	−0·5
65 08	−0·4
70 11	−0·3
75 34	−0·2
81 13	−0·1
87 03	0·0
90 00	

App. Alt.	Additional Corrⁿ
VENUS	
Jan. 1–Jan. 10	
°	′
0	+0·5
6	+0·6
20	+0·7
31	
Jan. 11–Feb. 14	
°	′
0	+0·6
4	+0·7
12	+0·8
22	
Feb. 15–Feb. 21	
°	′
0	+0·5
6	+0·6
20	+0·7
31	
Feb. 22–Mar. 9	
°	′
0	+0·4
11	+0·5
41	
Mar. 10–Apr. 4	
°	′
0	+0·3
46	
Apr. 5–May 19	
°	′
0	+0·2
47	
May 20–Dec. 31	
°	′
0	+0·1
42	
MARS	
Jan. 1–Sept. 3	
°	′
0	+0·1
60	
Sept. 4–Dec. 31	
°	′
0	+0·3
34	+0·2
60	+0·1
80	

DIP

Ht. of Eye	Corrⁿ	Ht. of Eye	Ht. of Eye	Corrⁿ
m		ft.	m	
2·4	−2·8	8·0	1·0 —	1·8
2·6	−2·9	8·6	1·5 —	2·2
2·8	−3·0	9·2	2·0 —	2·5
3·0	−3·1	9·8	2·5 —	2·8
3·2	−3·2	10·5	3·0 —	3·0
3·4	−3·3	11·2	See table	
3·6	−3·4	11·9		
3·8	−3·5	12·6	m	
4·0	−3·6	13·3	20 —	7·9
4·3	−3·7	14·1	22 —	8·3
4·5	−3·8	14·9	24 —	8·6
4·7	−3·9	15·7	26 —	9·0
5·0	−4·0	16·5	28 —	9·3
5·2	−4·1	17·4		
5·5	−4·2	18·3	30 —	9·6
5·8	−4·3	19·1	32 —	10·0
6·1	−4·4	20·1	34 —	10·3
6·3	−4·5	21·0	36 —	10·6
6·6	−4·6	22·0	38 —	10·8
6·9	−4·7	22·9		
7·2	−4·8	23·9	40 —	11·1
7·5	−4·9	24·9	42 —	11·4
7·9	−5·0	26·0	44 —	11·7
8·2	−5·1	27·1	46 —	11·9
8·5	−5·2	28·1	48 —	12·2
8·8	−5·3	29·2	ft.	
9·2	−5·4	30·4	2 —	1·4
9·5	−5·5	31·5	4 —	1·9
9·9	−5·6	32·7	6 —	2·4
10·3	−5·7	33·9	8 —	2·7
10·6	−5·8	35·1	10 —	3·1
11·0	−5·9	36·3	See table	
11·4	−6·0	37·6	←	
11·8	−6·1	38·9		
12·2	−6·2	40·1	ft.	
12·6	−6·3	41·5	70 —	8·1
13·0	−6·4	42·8	75 —	8·4
13·4	−6·5	44·2	80 —	8·7
13·8	−6·6	45·5	85 —	8·9
14·2	−6·7	46·9	90 —	9·2
14·7	−6·8	48·4	95 —	9·5
15·1	−6·9	49·8		
15·5	−7·0	51·3	100 —	9·7
16·0	−7·1	52·8	105 —	9·9
16·5	−7·2	54·3	110 —	10·2
16·9	−7·3	55·8	115 —	10·4
17·4	−7·4	57·4	120 —	10·6
17·9	−7·5	58·9	125 —	10·8
18·4	−7·6	60·5		
18·8	−7·7	62·1	130 —	11·1
19·3	−7·8	63·8	135 —	11·3
19·8	−7·9	65·4	140 —	11·5
20·4	−8·0	67·1	145 —	11·7
20·9	−8·1	68·8	150 —	11·9
21·4		70·5	155 —	12·1

App. Alt = Apparent altitude = Sextant altitude corrected for index error and dip.
For daylight observations of Venus, see *Nautical Almanac* page 260.

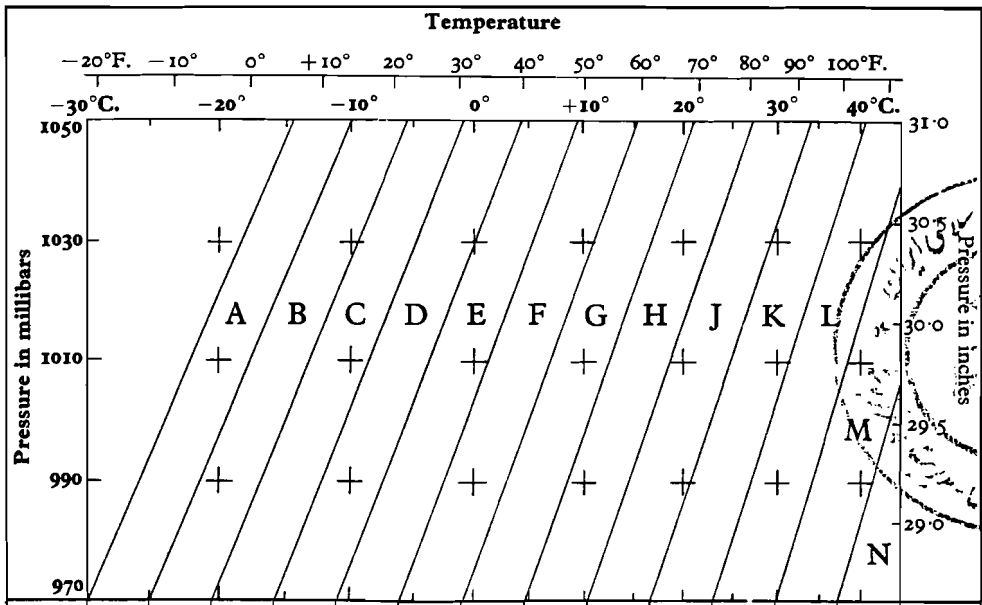
ALTITUDE CORRECTION TABLES 0°–10°—SUN, STARS, PLANETS

App. Alt.	OCT.–MAR. SUN Lower Limb	OCT.–MAR. SUN Upper Limb	APR.–SEPT. SUN Lower Limb	APR.–SEPT. SUN Upper Limb	STARS PLANETS
° ′	′	′	′	′	′
0 00	−18·2	−50·5	−18·4	−50·2	−34·5
03	17·5	49·8	17·8	49·6	33·8
06	16·9	49·2	17·1	48·9	33·2
09	16·3	48·6	16·5	48·3	32·6
12	15·7	48·0	15·9	47·7	32·0
15	15·1	47·4	15·3	47·1	31·4
0 18	−14·5	−46·8	−14·8	−46·6	−30·8
21	14·0	46·3	14·2	46·0	30·3
24	13·5	45·8	13·7	45·5	29·8
27	12·9	45·2	13·2	45·0	29·2
30	12·4	44·7	12·7	44·5	28·7
33	11·9	44·2	12·2	44·0	28·2
0 36	−11·5	−43·8	−11·7	−43·5	−27·8
39	11·0	43·3	11·2	43·0	27·3
42	10·5	42·8	10·8	42·6	26·8
45	10·1	42·4	10·3	42·1	26·4
48	9·6	41·9	9·9	41·7	25·9
51	9·2	41·5	9·5	41·3	25·5
0 54	− 8·8	−41·1	− 9·1	−40·9	−25·1
0 57	8·4	40·7	8·7	40·5	24·7
1 00	8·0	40·3	8·3	40·1	24·3
03	7·7	40·0	7·9	39·7	24·0
06	7·3	39·6	7·5	39·3	23·6
09	6·9	39·2	7·2	39·0	23·2
1 12	− 6·6	−38·9	− 6·8	−38·6	−22·9
15	6·2	38·5	6·5	38·3	22·5
18	5·9	38·2	6·2	38·0	22·2
21	5·6	37·9	5·8	37·6	21·9
24	5·3	37·6	5·5	37·3	21·6
27	4·9	37·2	5·2	37·0	21·2
1 30	− 4·6	−36·9	− 4·9	−36·7	−20·9
35	4·2	36·5	4·4	36·2	20·5
40	3·7	36·0	4·0	35·8	20·0
45	3·2	35·5	3·5	35·3	19·5
50	2·8	35·1	3·1	34·9	19·1
1 55	2·4	34·7	2·6	34·4	18·7
2 00	− 2·0	−34·3	− 2·2	−34·0	−18·3
05	1·6	33·9	1·8	33·6	17·9
10	1·2	33·5	1·5	33·3	17·5
15	0·9	33·2	1·1	32·9	17·2
20	0·5	32·8	0·8	32·6	16·8
25	− 0·2	32·5	0·4	32·2	16·5
2 30	+ 0·2	−32·1	− 0·1	−31·9	−16·1
35	0·5	31·8	+ 0·2	31·6	15·8
40	0·8	31·5	0·5	31·3	15·5
45	1·1	31·2	0·8	31·0	15·2
50	1·4	30·9	1·1	30·7	14·9
2 55	1·6	30·7	1·4	30·4	14·7
3 00	+ 1·9	−30·4	+ 1·7	−30·1	−14·4
05	2·2	30·1	1·9	29·9	14·1
10	2·4	29·9	2·1	29·7	13·9
15	2·6	29·7	2·4	29·4	13·7
20	2·9	29·4	2·6	29·2	13·4
25	3·1	29·2	2·9	28·9	13·2
3 30	+ 3·3	−29·0	+ 3·1	−28·7	−13·0

App. Alt.	OCT.–MAR. SUN Lower Limb	OCT.–MAR. SUN Upper Limb	APR.–SEPT. SUN Lower Limb	APR.–SEPT. SUN Upper Limb	STARS PLANETS
° ′	′	′	′	′	′
3 30	+ 3·3	−29·0	+ 3·1	−28·7	−13·0
35	3·6	28·7	3·3	28·5	12·7
40	3·8	28·5	3·5	28·3	12·5
45	4·0	28·3	3·7	28·1	12·3
50	4·2	28·1	3·9	27·9	12·1
3 55	4·4	27·9	4·1	27·7	11·9
4 00	+ 4·5	−27·8	+ 4·3	−27·5	−11·8
05	4·7	27·6	4·5	27·3	11·6
10	4·9	27·4	4·6	27·2	11·4
15	5·1	27·2	4·8	27·0	11·2
20	5·2	27·1	5·0	26·8	11·1
25	5·4	26·9	5·1	26·7	10·9
4 30	+ 5·6	−26·7	+ 5·3	−26·5	−10·7
35	5·7	26·6	5·5	26·3	10·6
40	5·9	26·4	5·6	26·2	10·4
45	6·0	26·3	5·8	26·0	10·3
50	6·2	26·1	5·9	25·9	10·1
4 55	6·3	26·0	6·0	25·8	10·0
5 00	+ 6·4	−25·9	+ 6·2	−25·6	− 9·9
05	6·6	25·7	6·3	25·5	9·7
10	6·7	25·6	6·4	25·4	9·6
15	6·8	25·5	6·6	25·2	9·5
20	6·9	25·4	6·7	25·1	9·4
25	7·1	25·2	6·8	25·0	9·2
5 30	+ 7·2	−25·1	+ 6·9	−24·9	− 9·1
35	7·3	25·0	7·0	24·8	9·0
40	7·4	24·9	7·2	24·6	8·9
45	7·5	24·8	7·3	24·5	8·8
50	7·6	24·7	7·4	24·4	8·7
5 55	7·7	24·6	7·5	24·3	8·6
6 00	+ 7·8	−24·5	+ 7·6	−24·2	− 8·5
10	8·0	24·3	7·8	24·0	8·3
20	8·2	24·1	8·0	23·8	8·1
30	8·4	23·9	8·1	23·7	7·9
40	8·6	23·7	8·3	23·5	7·7
6 50	8·7	23·6	8·5	23·3	7·6
7 00	+ 8·9	−23·4	+ 8·6	−23·2	− 7·4
10	9·1	23·2	8·8	23·0	7·2
20	9·2	23·1	9·0	22·8	7·1
30	9·3	23·0	9·1	22·7	7·0
40	9·5	22·8	9·2	22·6	6·8
7 50	9·6	22·7	9·4	22·4	6·7
8 00	+ 9·7	−22·6	+ 9·5	−22·3	− 6·6
10	9·9	22·4	9·6	22·2	6·4
20	10·0	22·3	9·7	22·1	6·3
30	10·1	22·2	9·8	22·0	6·2
40	10·2	22·1	10·0	21·8	6·1
8 50	10·3	22·0	10·1	21·7	6·0
9 00	+10·4	−21·9	+10·2	−21·6	− 5·9
10	10·5	21·8	10·3	21·5	5·8
20	10·6	21·7	10·4	21·4	5·7
30	10·7	21·6	10·5	21·3	5·6
40	10·8	21·5	10·6	21·2	5·5
9 50	10·9	21·4	10·6	21·2	5·4
10 00	+11·0	−21·3	+10·7	−21·1	− 5·3

Additional corrections for temperature and pressure are given on the following page.
For bubble sextant observations ignore dip and use the star corrections for Sun, planets, and stars.

ADDITIONAL REFRACTION CORRECTIONS FOR NON-STANDARD CONDITIONS



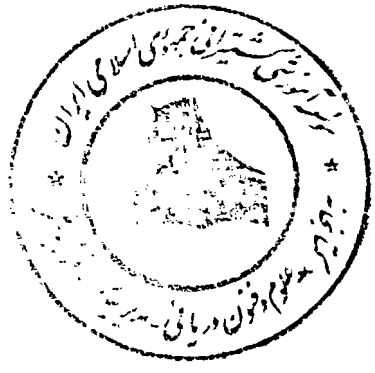
App. Alt.	A	B	C	D	E	F	G	H	J	K	L	M	N	App. Alt.
° ′	′	′	′	′	′	′	′	′	′	′	′	′	′	° ′
0 00	−6·9	−5·7	−4·6	−3·4	−2·3	−1·1	0·0	+1·1	+2·3	+3·4	+4·6	+5·7	+6·9	0 00
0 30	5·2	4·4	3·5	2·6	1·7	0·9	0·0	0·9	1·7	2·6	3·5	4·4	5·2	0 30
1 00	4·3	3·5	2·8	2·1	1·4	0·7	0·0	0·7	1·4	2·1	2·8	3·5	4·3	1 00
1 30	3·5	2·9	2·4	1·8	1·2	0·6	0·0	0·6	1·2	1·8	2·4	2·9	3·5	1 30
2 00	3·0	2·5	2·0	1·5	1·0	0·5	0·0	0·5	1·0	1·5	2·0	2·5	3·0	2 00
2 30	−2·5	−2·1	−1·6	−1·2	−0·8	−0·4	0·0	+0·4	+0·8	+1·2	+1·6	+2·1	+2·5	2 30
3 00	2·2	1·8	1·5	1·1	0·7	0·4	0·0	0·4	0·7	1·1	1·5	1·8	2·2	3 00
3 30	2·0	1·6	1·3	1·0	0·7	0·3	0·0	0·3	0·7	1·0	1·3	1·6	2·0	3 30
4 00	1·8	1·5	1·2	0·9	0·6	0·3	0·0	0·3	0·6	0·9	1·2	1·5	1·8	4 00
4 30	1·6	1·4	1·1	0·8	0·5	0·3	0·0	0·3	0·5	0·8	1·1	1·4	1·6	4 30
5 00	−1·5	−1·3	−1·0	−0·8	−0·5	−0·2	0·0	+0·2	+0·5	+0·8	+1·0	+1·3	+1·5	5 00
6	1·3	1·1	0·9	0·6	0·4	0·2	0·0	0·2	0·4	0·6	0·9	1·1	1·3	6
7	1·1	0·9	0·7	0·6	0·4	0·2	0·0	0·2	0·4	0·6	0·7	0·9	1·1	7
8	1·0	0·8	0·7	0·5	0·3	0·2	0·0	0·2	0·3	0·5	0·7	0·8	1·0	8
9	0·9	0·7	0·6	0·4	0·3	0·1	0·0	0·1	0·3	0·4	0·6	0·7	0·9	9
10 00	−0·8	−0·7	−0·5	−0·4	−0·3	−0·1	0·0	+0·1	+0·3	+0·4	+0·5	+0·7	+0·8	10 00
12	0·7	0·6	0·5	0·3	0·2	0·1	0·0	0·1	0·2	0·3	0·5	0·6	0·7	12
14	0·6	0·5	0·4	0·3	0·2	0·1	0·0	0·1	0·2	0·3	0·4	0·5	0·6	14
16	0·5	0·4	0·3	0·3	0·2	0·1	0·0	0·1	0·2	0·3	0·3	0·4	0·5	16
18	0·4	0·4	0·3	0·2	0·2	0·1	0·0	0·1	0·2	0·2	0·3	0·4	0·4	18
20 00	−0·4	−0·3	−0·3	−0·2	−0·1	−0·1	0·0	+0·1	+0·1	+0·2	+0·3	+0·3	+0·4	20 00
25	0·3	0·3	0·2	0·2	0·1	−0·1	0·0	+0·1	0·1	0·2	0·2	0·3	0·3	25
30	0·3	0·2	0·2	0·1	0·1	0·0	0·0	0·0	0·1	0·1	0·2	0·2	0·3	30
35	0·2	0·2	0·1	0·1	0·1	0·0	0·0	0·0	0·1	0·1	0·1	0·2	0·2	35
40	0·2	0·1	0·1	0·1	−0·1	0·0	0·0	0·0	+0·1	0·1	0·1	0·1	0·2	40
50 00	−0·1	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	+0·1	+0·1	+0·1	+0·1	50 00

The graph is entered with arguments temperature and pressure to find a zone letter; using as arguments this zone letter and apparent altitude (sextant altitude corrected for dip), a correction is taken from the table. This correction is to be applied to the sextant altitude in addition to the corrections for standard conditions (for the Sun, planets and stars from the inside front cover and for the Moon from the inside back cover).

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NICHOLLS'S CONCISE GUIDE

Volume 1



NICHOLLS'S CONCISE GUIDE

TO

NAVIGATION

VOLUME 1

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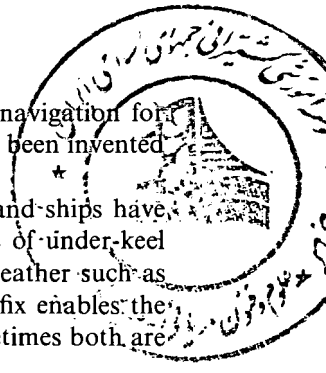
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Foreword

by

COMMODORE G. G. GREENFIELD, RD* FNI RNR
President of The Nautical Institute



Nicholls's Concise Guide was one of the first all embracing text books on navigation for officers of the mercantile marine. In 1902 when it first appeared, radar had not been invented and using soundings to find a position line was practised regularly.

There have been many changes since then, crews have become smaller and ships have become more powerful. Many large vessels are operating to finer tolerances of under-keel clearance and there are additional aids providing accurate positions in all weather such as Loran, Decca and satellites. In most cases the extra power or the electronic fix enables the navigator to correct the course in good time to prevent a grounding, but sometimes both are contributory factors in an accident.

For example, a ship in a narrow channel can easily run aground if there is not a planned route being carefully monitored. An electronic navigational aid whose basic co-ordinates have been improperly entered or which has been prone to slip or even an interrupted power supply, can and has put ships ashore.

The need for a sound knowledge of the principles of navigation and extended practice in applying that knowledge correctly, in the right sequence at sea by day and night particularly when tired or over-stressed, is paramount. A ship which runs aground or has a collision, cannot deliver her cargo, fight a battle or win a race. It is the responsibility of all navigating officers to ensure the safe and timely movement of vessels entrusted to their care.

All forms of navigation have advanced beyond the wildest dreams of the original authors, Messrs. Nicholls and Brown. Notwithstanding, when all else fails, the mariner must still have the basic skill to navigate his vessel safely, relying on "log, latitude and lead". Fortunately, these basic skills are still contained in the syllabuses of most maritime nations and still command a prominent position in this volume.

It is for this reason that I am delighted to write the foreword to this modernised and completely revised edition of Nicholls's Concise Guide. The book has expanded considerably from its original format and rightly so. New chapters embrace subjects such as ice navigation, gyro compasses and radar plotting. The more accurate tidal prediction methods are used throughout. The old point nomenclature has been replaced with degrees and the whole comprehensively metricated.

The Nautical Institute's chartwork convention has been used and is a further indication of the measures which have been taken to encourage more consistent and effective teaching methods. Each diagram is to scale so that angles and tracks can be checked when practicing the many and varied examples and questions provided.

In deciding to provide such a comprehensive volume, the publishers, have recognised that

people will use this book for their own purposes and at their own level. It is unlikely that scuba divers will study astro-navigation and the competent mathematician will not need the first few chapters. However, the carefully designed index makes selection easy and the cross referencing provides an additional check to the wider application of the contents.

The Nicholls's Concise Guide is a self-contained text book of particular value to anybody wishing to understand the theory and practice of navigation at sea.



COMMODORE G. G. GREENFIELD, RD*, FNI, RNR
President, The Nautical Institute, London

Preface

The first edition of *Nicholls's Concise Guide to Navigation* was published in 1902 at a time when the British merchant fleet totalled more than 9,000 vessels—almost 45% of the total world tonnage. *Nicholls's* met with immediate success and was soon included as a standard item in the kit list of every cadet and apprentice.

Since then, *Nicholls's* has been used both by successive generations of Merchant Navy officers and more serious amateur navigators, not only in this country but all round the world—for English, after all, is the international language of the sea.

This then, after 9 earlier editions and countless reprints, is the "85th Anniversary Edition" of *Nicholls's Concise Guide to Navigation*—Volume 1, the 10th edition since 1902. Advance orders have already been received from 25 countries.

With nearly 1,100 pages, the new *Nicholls's* has over 400 more pages than the previous edition. Eleven entirely new chapters have been added and the others extensively revised, rewritten and updated. But the book still retains much of its original character—a practical text book for practical people and an extremely comprehensive guide to navigation—30 chapters, 400 worked examples, 450 illustrations, over 1,000 problems.

The new *Nicholls's* is extremely "user friendly" and includes checklist and "step by step" instructions, clear layout, frequent use of sub-headings, full page calculations and extensive use of illustrations and worked examples. Immediate reference facilities to illustrations, relevant collision avoidance rules and "M" notices are also included, as standard.

Indexing is very comprehensive. It includes a Quick Index, Main Index, separate indexes for Chartwork Figures, Chartwork, Tides, Tidal Streams and the Sextant (topics likely to be of particular interest to Yachtmasters and Divers and included under that heading) and separate indexes for each set of extracts. All indexes are "controlled" by a separate, single side, Master Index—also included, on card, as a separate page-marker. These indexing facilities are likely to be of considerable interest to busy consultants and will help speed referencing procedures for all users.

Other special additions are also likely to be of particular interest to amateurs as well as professionals. The chapters on Chartwork, Tides and Tidal Streams, for example, have been specially designed and written for use either by professional or complete beginner. Learning times should be greatly reduced.

The new *Nicholls's* is completely self contained—altitude correction tables, over 200 pages of *Admiralty Tide Table*, *Tidal Stream Atlas* and *Nautical Almanac* extracts, proformas, *English Channel* Admiralty practice chart and a reduced size copy of *Symbols and Abbreviations* NP 5011—features likely to be of interest to schools and training centres (particularly those lacking full resources) and also to those involved in private study and distance learning.

Numerous technical improvements have been made. Astro-Navigation problems have been metricated and reworked on more recent altitude correction tables. Navigational errors have been included.

The new *Nautical Institute* chartwork terminology and 3 figure notation is used throughout. Distance scales are included in all plots and "high accuracy" chartwork plots incorporate the appropriate part of the latitude scale in each figure—course, bearing and distance can be accurately measured from the plot shown and the problem then attempted on the *Admiralty Practice Chart* supplied. Tidal stream data, accurate for both time and position is also included, where appropriate, and can be checked as an additional exercise.

"High accuracy" sextant illustrations, in which even the vernier readings can be read, and full page, scale radar plots are also included.

Graphical methods of interpolation are demonstrated, and new NP 204 *Admiralty Tidal Prediction Forms*, together with the new tidal diagrams, are used for all tide calculations.

The latest British fibre glass binnacles, magnetic and gyro compass equipment, chronometers and sextants are featured amongst the 450 illustrations and diagrams.

Appropriately, the final chapter deals with the use of calculators and computers in navigation. It emphasises correct methodology, practical uses and the essential need to have a thorough understanding of first principles when using electronic aids and when designing and writing programs.

And as previously mentioned, in order to make the book completely self-contained and to avoid the need to make immediate reference to other publications, the relevant collision avoidance rules, "M" Notices, *Nautical Almanac* and Tide Table extracts are included, where relevant, in the text and in the 200 page extracts appendix.

Regarding use as a teaching and learning aid, it is relevant to point out that the new *Nicholls's* incorporates many of the better features of a programmed text book (plus a few "extras") and is designed and written to reduce learning times. Various sections have been written with the beginner in mind and should prove ideal either for classroom use, self study or distance learning.

Though not specifically stated, this new *Nicholls' Concise Guide* is arranged, very broadly, in 10 sections:

1. DTp Examination Syllabus (for professionals) and Altitude Correction Tables—Front and Back.

2. The "Maths of Navigation"—in which all examples and all figures (save geometry) are now numbered for ease of reference. Chapters 1–6.
   These chapters have been retained for reference to first principles and use by schools, beginners, late-starters and ratings.

3. Aspects of navigation which are a necessary introduction to both Coastal and Ocean Navigation—the Compass, Sphere, Course and Distance (Sailings), Dead Reckoning, Radar Plotting for collision avoidance, and Publications. Chapters 7–11.

4. Coastal Navigation—Chartwork, 150 pages with 52 worked examples; Passage Planning and model example; Tides and Tidal Streams, 22 (new method) worked examples covering the world; and also Search and Rescue and Navigation in Ice. Chapters 12–16.

5. The Marine Sextant—which forms a natural introduction to "Astro-Nav" and which can be used for position fixing, by both coastal and ocean navigators, and for position location, by divers. Chapter 17.

6. Astro-Navigation—the principles, practice and errors and including use of the Traditional and Quartz Crystal Chronometer. Chapters 18–28.

7. Gyro Compass Principles and the use of Calculators and Computers in Navigation—an introduction to the methodology and practical applications. Chapters 29 and 30.
8. Extracts Appendix—which includes everything necessary to use the book and learn navigation—*Nautical Almanac*, Tide Tables, Tidal Stream Atlas and Proformas.
9. Index—Quick Index, Main (Professional) Index, Yachtmaster's and Diver's Index (including individual indexes for Chartwork Figures [for Instructors], Chartwork Index, Tidal Stream Index, and Tides Index), Answers Index, separate indexes for each set of extracts, and DTp Indexes—a total of 20 separate indexes controlled by a "single side" Master Index.
10. Pocket—containing a full size English Channel Admiralty Practice Chart, a reduced size copy of NP 5011 *Symbols and Abbreviations* and a Supplement—very similar to the frequently overlooked, but all important, Admiralty Supplements, (errata have been purposely placed in the new *Nicholls's Supplement*—simply to get the reader accustomed to using them).

Given a set of instruments and navigational tables this volume contains almost everything required to learn navigation—it is completely self-contained.

Attention is drawn to the list of Acknowledgements and all those who have assisted, in a variety of ways, in the preparation of this volume. I wish to again record my special thanks to:

My friend and former colleague, the late, Captain Philip Rowland Lewis, Extra Master RD RNR, who assisted with several chapters, particularly those on astro-navigation.

Captain Gordon Watkins for assistance with the chapters on the compass, tides and latitude and for careful proof reading and valued comment on several others.

Commodore G. G. Greenfield, RD* FNI RNR, President of *The Nautical Institute*, for consenting to write the Foreword in which he makes important comment which can only add to the value of this book.

Alison Stenhouse for her excellent illustrations, particularly those in connection with chartwork and the sextant.

Finally, the publishers, Brown Son and Ferguson Ltd of Glasgow. Publication of so large a volume has been costly and time consuming and has required great patience. In producing this new edition, I doubt I shall be alone in thinking they have made a significant contribution to Merchant Navy training.

At the start of this preface, I mentioned that when *Nicholls's Concise Guide* was first published the British merchant fleet totalled more than 9,000 vessels—almost half of world tonnage. For one who was sent by the Government of this country to help develop Merchant Navy training in another country, it is particularly sad to note that, today, as the 10th Edition of this famous book is published, only 400 vessels (of over 500 tons) are now registered in the United Kingdom—just 2·1% of world tonnage.

The last 8 years, since my return from the developing world, has also seen a parallel loss of some of the best British Merchant Navy training centres—London included.

Recent events must surely demonstrate the importance (to every Nation) of a strong, wholly independent Merchant Fleet. Indeed, a strong independent Merchant Fleet (for every maritime nation) is perhaps the greatest peace keeping force of all for it ensures national integrity and freedom of supply, it avoids the potential for exerting undue economic pressure.

But one thing, above all, is quite certain, it takes many years beyond that of formal training to make a Master Mariner, a pilot, a specialist instructor, a Dept of Transport examiner. For the moment, Britain still retains a great depth of expertise and has much to offer the maritime world. But the infrastructure of maritime practice and training is complex. Once allowed to decline, it cannot be quickly rebuilt and it may be lost forever.

As a seafarer, and a member of that international brotherhood, it is my hope that this new edition of *Nicholls's Concise Guide* will make some small contribution to navigation and to Merchant Navy training in all maritime nations.

As a British seafarer, I must also hope that this book will support the strenuous efforts currently being made by *The Marine Society*, *The Nautical Institute* and others, and assist in the training of new, young, British officers and ratings—so that, when the upturn comes, as surely must be encouraged and made possible, Britain can remain a maritime nation.

Edward Coolen
London, England
December 1987.

ACKNOWLEDGEMENTS
Part 1

We wish to acknowledge special services and the supply of various items which have been reproduced in this volume:

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BA 1164	Small portions of, pages 308, 376, 399, 400.
BA 2675	Small portions of, page 336.
BA 5011	*Symbols and Abbreviations*—page 18 'O'—facing page 282. A reduced size (black and white) copy of NP 5011 is included in the Pocket.
BA 5053	*English Channel Practice Chart*, small portions of, pages 288, 338, 339, 371 inserts facing 289 and 432. Small sections of the latitude scale (only) have been incorporated into chartwork plots, included on pages in the range 293–428 (see also "Chartwork Figures Index").
No 150	*Admiralty Notices to Mariners* (1984) page 280.

Publications

Vol A	*Admiralty List of Lights and Fog Signals*—Volume A.
HD 574	Luminous Range Diagram page 409 and 410, 411, 412, 414.
HD 586	Geographical Range Table page 408.
Vol 2	*Admiralty List of Radio Signals*—Volume 2, Radiobeacon Information pages 391, 395.
Vol 1	*Admiralty Tide Tables*—Volume (data 1982, tidal diagrams 1988) pages 817–844, 856, 866, 868–869. (Parts of these extracts also included on pages 444–459). Table 1 pages 864–865.
Vol 2	*Admiralty Tide Tables*—Volume 2 (1982) pages 845–852. Standard Curves Diagram (1987) page 867 (repeated on 460c).
Vol 3	*Admiralty Tide Tables*—Volume 3 (1982) page 853.

NP 159 *Admiralty Method of Tidal Prediction* pages 462–468 (Parts of these extracts repeated on 861–863). Box Diagram 865.

NP 204 *Admiralty Tidal Prediction Form* pages 854–855 and repeated on pages 446–448, 450, 452, 455, 458, 460(b).

NP 249 *Tidal Stream Atlas* pages 871–878.

Meteorological Observer's Handbook
Definition and factors affecting visibility (part), pages 403, 404.

NP 100 *The Mariner's Handbook*
Pages 477–486 incorporate paragraphs 1, 2, 3, 7 (part), 8 and 9 of NP 100. Sub-headings have been inserted to draw attention to particular points, of interest to navigators.

Other Publications

Department of Transport

M 1058 *Merchant Shipping Notice* page 487.

M 1242 *Merchant Shipping Notice* page xxxvii.

No 6, 7 *Deviation Cards* pages 333, 774.

Syllabus *Deck Syllabuses* Class 1–5 (navigational content **only**) pages xx–xxxvi.

Papers *Specimen Examination Papers* 760–773.

Nautical Almanac

A2-A4 & Moon "Altitude Correction Tables A2, A3, A4", Moon, initial pages at front and pages 1011–1012 at back.

Arc/Time "Conversion of Arc to Time Table" page inside Front Cover.

Polaris "Pole Star Tables", ("undated"–year 1958 removed) for examples, pages 1008–1010.

Polaris "Pole Star Tables", 1976 for DTp *Specimen Papers* (see 1976 extracts).

Daily Pages Selected pages, 1958 *Nautical Almanac*, ("undated"–year removed) for examples, pages 880–907, "Increment" pages 908–935.

Daily & Other Selected pages, 1976 *Nautical Almanac*, for DTp *Specimen Papers* pages 938–953.

Polaris "Pole Star Tables", 1976, 954–956. (See also 1958 extracts.)

Mer Pas Meridian passage information, 1958, page 599.

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"The standard work on navigation—for over 85 years"

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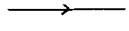
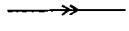
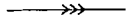
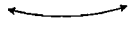
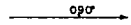
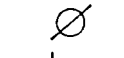
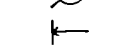
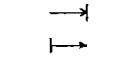
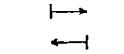
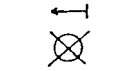
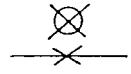
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SYMBOLS, ABBREVIATIONS AND DEFINITIONS

The symbols, abbreviations and conventions used in D.Tp examinations will follow the SI system and will generally be in accordance with the list prepared by the Council of Technical Examining Bodies.

The following symbols and abbreviations include those symbols which will be used in D.Tp Examinations.

True	T
Magnetic	M
Compass	C
Gyro	G
Course	Co
Azimuth	az
Chronometer	chron
Sextant Altitude	Sext alt
Index Error	IE
Height of Eye	HE
Lower limb	LL
Upper limb	UL

Course steered		
Course made good		
Tidal stream vector		
Range		
Position line	P/L	
Transferred position line		
Clearing line		
In transit		
Left hand edge		
Right hand edge		
Abeam to starboard		
Abeam to port		
Observed position or fix	Obs Pos	
Dead reckoning position	DR	
Estimated position	EP	
Chosen position	CP	

Hf	The horizontal component of the Earth's magnetic field.
Z	The vertical component of the Earth's magnetic field.
Sext alt	The sextant altitude is that read off a sextant.
CP	The chosen position is that position nearest to the observer chosen so that the latitude is an integral degree and the longitude is such that the local hour angle of the body at the time of observation is also an integral degree.
DR	The dead reckoning position is that obtained by allowing for courses steered and distances run only.
EP	The estimated position is that obtained by allowing for courses and distances and for leeway and current if any.

DEPARTMENT OF TRANSPORT

DECK SYLLABUSES FOR THE CLASS 5—CLASS 1 MASTER MARINER EXAMINATIONS IN CERTIFICATE OF COMPETENCY NAVIGATION AND NAVIGATIONAL AIDS

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Important Notes:

1. In the Oral Examination (for any class of certificate) the examiner may ask the candidate questions arising out of the written work, if it is deemed necessary on account of weakness shown by the candidate.
2. Refer to M. Notice 1242 for Examination Changes commencing January 1987–March 1989.

CLASS 5 CERTIFICATE OF COMPETENCY

Chartwork and Practical Navigation

Paper 1 (3 hours practical and written)

Chartwork

(a) Given variation and the deviation of the magnetic compass, or gyro error, to convert true courses into compass courses and vice versa.
Given a sample table of deviations to extract the deviation thence to convert true courses into magnetic and compass courses.
To find the compass course between two positions.
The effect of current on speed.
Allowance for leeway.

Given compass course steered, the speed of the ship and direction and rate of the current, to find the true course made good.
To find the course to steer allowing for a current.
Given the course steered and distance run, to determine the set and rate of the current experienced between two positions.

(b) To fix a position on a chart by simultaneous cross bearings, by bearing and range, by positional information from radio aids to navigation or by any combination, applying the necessary corrections. The use of lattice charts.

(c) To fix the position by bearings of one or more objects with the run between, allowing for a current, and to find the distance at which the ship will pass off a given point.
The use of position lines obtained by any method, including terrestrial position lines and position circles. The use of transit bearings.

(d) Elementary knowledge of passage planning and execution. Landfalls in thick and clear weather. The selection of suitable anchorages, approaching anchorage and entering narrow waters. The use of clearing marks and horizontal and vertical danger angles. Distance of sighting lights.

(e) To find the time and height of high and low water at Standard ports and at Secondary ports by tidal differences using Admiralty Tide Tables, Vol. 1; the use of tide curves as published in the Admiralty Tide Tables.

(f) The interpretation of a chart or plan; particularly the information given about Lights, Buoys, Radio Beacons and other navigational aids; Depths and height contours; Tidal streams; Traffic lanes and separation zones.

Recognition of the coast and radar responsive targets.
Chart correction.
Depths and nature of bottom. Use of soundings.

Note:
Questions may be set in this paper requiring descriptive answers as well as work on the chart provided. Oral questions, which may relate to any part of the syllabus, may also be asked.

Practical Navigation

(a) Practical questions on plane and Mercator sailing.

(b) The use of the traverse tables to obtain the position of the ship at any time, given compass courses, variation, deviation and the run recorded by log or calculated by time and estimated speed, allowing for the effects of wind and current.

(c) To find compass error by observation of heavenly bodies and, for a magnetic compass, the deviation for the direction of the ship's head.

CLASS 4 CERTIFICATE OF COMPETENCY

Chartwork

Paper 2 (2 hours excluding Oral questions)

(a) Given variation and the deviation of the magnetic compass or gyro error, to convert true courses into compass courses and vice versa.
Given a sample table of deviations, to extract the deviation thence to convert true courses into magnetic and compass courses.
To find the compass course between two positions.
The effect of current on speed.
Allowance for leeway.
Given compass course steered, the speed of the ship and direction and rate of the current, to find the true course made good.
To find the course to steer allowing for a current.
Given the course steered and distance run, to determine the set and rate of the current experienced between two positions.

(b) To fix a position on a chart by simultaneous cross bearings, by bearing and range, by positional information from radio aids to navigation or by any combination, applying the necessary corrections. The use of lattice charts.

(c) To fix the position by bearings of one or more objects with the run between, allowing for a current and to find the distance at which the ship will pass off a given point.
The use of position lines obtained by any method, including terrestrial position lines and position circles. Use of transit bearings.

(d) Elementary knowledge of passage planning and execution. Landfalls in thick and clear weather. The selection of suitable anchorages, approaching anchorage and entering narrow waters. The use of clearing marks and horizontal and vertical danger angles. Distance of sighting lights.

(e) To find the time and height of high and low water at Standard ports and at Secondary ports by tidal differences, using Admiralty Tide Tables, Volume 1.
The use of tables and tide curves to find the time at which the tide reaches a specified height or the height of the tide at a given time and thence the approximate correction to be applied to soundings or to charted heights of shore objects.

(f) The interpretation of a chart or plan; particularly the information given about Buoys, Lights, Radio beacons and other navigational aids; Depth and height contours; Tidal streams; Traffic lanes and separation zones.

Recognition of the coast and radar responsive targets.
Chart correction.
Depths and nature of bottom. Use of soundings.
The use of gnomonic charts.

Note:

Questions may be set in this paper requiring descriptive answers as well as work on the chart provided. Oral questions, which may relate to any part of the syllabus, may also be asked.

CLASS 4 CERTIFICATE OF COMPETENCY

Practical Navigation

Paper 3 (2 hours written)

(a) Practical problems on plane and Mercator sailing.

(b) The use of the traverse tables to obtain the position of the ship at any time, given compass courses, variation, deviation and the run recorded by log or calculated by time and estimated speed, allowing for the effects of wind and current, if any.

(c) To find the latitude by meridian altitude of a heavenly body, above or below the Pole. Latitude by observation of Polaris.

(d) From an observation of any heavenly body near or out of the meridian, to find the direction of the position line and a position through which it passes.

(e) To obtain a position by the use of position lines obtained from two or more observations with or without run.

(f) To find the true bearing of a heavenly body, the compass error and thence the deviation of the magnetic compass for the direction of the ship's head.

(g) To calculate the approximate time (to the nearest minute) of the meridian passage of a heavenly body; to calculate an approximate altitude for setting on the sextant to obtain the meridian altitude of a heavenly body.

Oral[1]

(a) (i) To read and understand a barometer, thermometer, hydrometer and hygrometer. The instruments supplied by the Meteorological Office will be taken as standard.

(ii) To use an azimuth mirror, pelorus (bearing plate) or other instrument for taking bearings.

(iii) To use a sextant for taking vertical and horizontal angles; to read a sextant both on and off the arc.

(iv) To correct a sextant into which has been introduced one or more of perpendicularity, side or index errors.

(v) To find the index error of a sextant.

(vi) The care, winding, rating and comparing of chronometers.

(vii) Use, care and limitations of the magnetic and gyro compass and associated equipment, including automatic pilot.

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[1] Navigational content *only*.

CLASS 3 CERTIFICATE OF COMPETENCY

Chartwork

Paper 2 (2 hours excluding Oral questions)

(Syllabus as for Class 4, Paper 2)

Practical Navigation

Paper 3 (2 hours written)

(Syllabus as for Class 4, Paper 3)

CLASS 3 CERTIFICATE OF COMPETENCY

Principles of Navigation

Paper 6 (2 hours written)

(a) The shape of the earth. Poles, equator, meridians, parallels of latitude. Position by latitude and longitude. Direction, bearing, distance, units of measurement. Difference of latitude, difference of longitude, departure, mean latitude, difference of meridional parts and the relationship between them.
Great circles, great circle course and distance, small circles on a sphere.

(b) The celestial sphere; definitions on the celestial sphere, apparent motion on the celestial sphere. Declination. Azimuth. Sidereal hour angle. The position of a body on the celestial sphere; azimuth with altitude or declination with sidereal or local hour angle. The rising, culmination and setting of heavenly bodies.

(c) Solar system, earth-moon system, planetary motion. Earth's rotation and movement in orbit, mean sun, ecliptic, first point of Aries. Equinox and solstice, sunrise, sunset, twilight.

(d) Time; Greenwich and other standard time, zone time, mean time, apparent time, sidereal time, equation of time, relationship between longitude and time.

(e) Local hour angle of a heavenly body in time and arc.
Greenwich hour angle of Sun, Moon, planets and Aries.

(f) Correction of sextant altitudes; dip, refraction, horizontal parallax, parallax in altitude, semi-diameter and augmentation.

(g) Geographical position of a heavenly body. A circle of position and its practical application, i.e. position line. Intercept.

(h) Simple properties of Mercator and gnomonic charts. Latitude and Longitude scales; measurement of distance. Rhumb lines.
Great circles and composite tracks.

(i) The relationship between the tides and the phases of the moon.

(j) Principle of position fixing by measurement of difference of distance from two or more fixed points. The hyperbolic lattice on navigational charts.

(k) Properties of the free gyroscope. Relationship between applied force and precession. Drift and tilt. Outline principle of developing a North-seeking instrument by gravity control.

(l) Basic principles of position fixing by satellite.

Oral

The syllabus is the same as that for Class 4 Oral examination (see previous pages).

CLASS 2 CERTIFICATE OF COMPETENCY

Coastal Navigation

Paper 1 ($2\frac{1}{2}$ hours excluding Oral questions)

In addition to the syllabus for Class 4, Chartwork:

(a) Approaching the coast under any circumstances.

(b) Planning a coastal passage or entry into harbour. Verification of position. Selection of suitable anchorages.

(c) Execution of a passage. Monitoring progress. Effect of constraints such as weather and tide, traffic, and state of ship's equipment.

(d) The use of sailing directions and other publications relevant to coastal navigation which are required to be carried by British Merchant Ships, including Admiralty Tide Tables, Volumes 1 and 3.

(e) The use of aids to navigation, including Radar, Echo Sounder and visual aids, in coastal navigation and pilotage, including the use of Radar in collision avoidance.

Notes:
(1) Questions will be set in this paper requiring descriptive answers as well as work on the chart provided. Oral questions, which may relate to any part of the syllabus, may also be asked.
(2) A radar plot may be set in this paper.

Ocean and Offshore Navigation

Paper 2 (2½ hours written)

(a) Astronomical Navigation as in paragraphs (c) to (g) of Practical Navigation, Class 4.

(b) Great circle and composite sailing.

(c) Position fixing; fixed and variable errors, area of probability. Obtaining a position from two or more observations of any type, with or without run.

(d) The use and understanding of Aids to Navigation, including all those radio and electronic aids which are installed in a high proportion of British Merchant Ships. Questions will be directed towards ensuring that candidates have a proper understanding of the essential principles and operation of these aids and can make full use of their capabilities whilst appreciating their limitations.

Signals[1]

(b) The practical use of shipborne radio direction finders, knowledge of the functions, characteristics and methods of using special types of radio beacons which are listed in *Admiralty List of Radio Signals Vol. II*, for example: rotating beacons and directional beacons.

[1] Navigational content *only*.

CLASS 1 CERTIFICATE OF COMPETENCY MASTER MARINER

Navigation

Paper 2 ($2\frac{1}{2}$ hours written)

Questions may be asked on any aspect of navigation covered in the lower grades, including matters pertinent to navigation covered in other subjects. Candidates will be required to show a full understanding of the techniques involved and must be able fully to relate the various aspects one to another, and to show their ability to make full use of all the navigational and meteorological information which is available to a ship's Master, including his own observations.

The form of the paper will vary from examination to examination. As examples, it may consist of one question only, such as a detailed and extensive exercise in passage planning; one such question, slightly less extensive, and a shorter question such as a radar plot or an exercise in position finding; or several questions covering different aspects of navigation and related subjects. The following syllabus is to be read in the light of this guidance:

1. (a) Voyage planning, The selection of ocean routes. Shore-based weather routeing and self-routeing.
   (b) Planning and executing a coastal passage. Approaching the coast. Approaching and entering harbour.
   (c) Navigation in pilotage waters, whether with or without a pilot on board.
   (d) Approaching and passing through traffic separation schemes and adjacent areas.

2. (a) The optimum course and speed for two ships wishing to rendezvous for any purpose.
   (b) Search and rescue procedures.
   (c) Navigational procedures when approaching off-shore installations, and when working with helicopters or small craft.
   (d) Navigation in extreme weather conditions.

3. Bridge procedures at sea, in harbour, and whilst berthing or anchoring.

4. (a) The interpretation and use of navigational and meteorological information.
   (b) The interpretation and use of information from navigational aids, including the use of radar in collision avoidance.
   (c) The effects of systematic and random errors in position fixing by any method.
   (d) Advantages and disadvantages of various navigation systems and methods; considerations underlying the choice of navigational systems for differing trades and geographical regions.

Navigational Aids and Instruments

Paper 5 (3 hours written)

(a) The construction, siting, care and maintenance of the magnetic compass and associated

equipment. Causes of deviation, the production of a table of deviations. Co-efficients A, B, C, D and E. The evaluation of the approximate co-efficients from given data and their relationship with the deviation. An appreciation, without calculations, of the effects of permanent magnetism and induced magnetism. Principles of compass adjustment and methods of adjustment. Heeling error, Gaussian error and retentive error.

(b) Principle of the gyro compass. Errors associated with the gyro compass, including latitude, course and speed error and correction; ballistic deflection and its relation to change of speed error; rolling error and how it is minimized. The principal parts of a gyro compass; fundamental differences in the construction and operation of the better known gyro compasses.

(c) Principles, operation and use of gyro and transmitting magnetic compass repeater systems; automatic pilot; projector compasses; rate of turn indicators.

(d) Navigational and collision avoidance radar: characteristics, application, capabilities and limitations. Assessment of performance. Knowledge of the Radar Rules, Marine Radar Performance Specification and of Merchant Shipping Notices relating to radar. Secondary radar systems. Doppler radar.

(e) Decca, Loran, Consol, Omega, direction-finding and satellite navigation systems; the characteristics, applications, capabilities and limitations of each system. The comparative accuracy of position fixing systems of all types, including non-radio systems and methods. Errors associated with the various systems. Knowledge of relevant Merchant Shipping Notices.

(f) Principle and practical application of echo sounding devices, logs and speed indicators.

(g) An outline knowledge of recent developments in navigational aids.

Oral[1]

(a) (i) Assisting a ship or aircraft in distress. The use of direction finding for homing on to a casualty.
(ii) Navigation in the vicinity of ice.

(b) Compensation and adjustment of compasses; candidates will be questioned on the practical adjustment of the magnetic compass using a ship's binnacle and compass.

(c) Port Radio Information Services. Knowledge of the types of service available to aid vessels entering ports and berthing as indicated in *Admiralty List of Radio Signals Port Radio Stations and Pilot Vessels.*

[1] Navigational content *only.*

MASTER (MIDDLE TRADE) ENDORSEMENT

Magnetic and Gyro Compasses and Navigational Aids

Paper 3 (2 hours written)

(a) The earth's magnetic field, poles and equator. The earth's total magnetic force, angle of dip, horizontal and vertical components. Variation.

(b) Deviation, its cause and effect. An understanding of the effect of semi-permanent and induced magnetic fields on the deviation of the compass. The means used to compensate for these effects.

(c) Siting of magnetic compasses with reference to proximity of magnetic material and electrical appliances. Precautions to be taken with electric wiring in vicinity of the compass.

(d) To find the magnetic bearing of a distant object from compass bearings taken on equidistant headings and construct a table of deviations.

(e) The principle of the free gyroscope.
Tilt and drift.
Precession. Control and damping. Correction for latitude, course and speed error.
Care and maintenance of different types of compasses.

(f) The practical application of electronic and radio aids to navigation.
Appreciation and interpretation of data.
Position fixing; fixed and variable errors, area of probability.
The use of Radar as an aid to collision avoidance.

(g) The use of navigational publications and information commonly supplied or available to ships.

Oral[1]

(c) (i) A thorough knowledge of search and rescue procedures. The use of direction finding for homing onto a casualty.
(ii) Navigation in the vicinity of ice.

[1] Navigational content *only*.

MASTER (NEAR CONTINENTAL) ENDORSEMENT

Magnetic Compass and Navigational Aids

Paper 2 (2 hours written)

(a) The earth's magnetic field, poles and equator. The earth's total magnetic force, angle of dip, horizontal and vertical components. Variation.

(b) Deviation. Elementary ideas of the effect of hard iron, vertical and horizontal soft iron on the compass. The means used to compensate for these effects with special reference to near continental ships. Siting of magnetic compasses with reference to proximity of magnetic material and electrical appliances. Precautions to be taken with electric wiring in vicinity of the compass.

(c) To find the magnetic bearing of a distant object from compass bearings taken on equidistant headings and construct a table of deviations.

(d) The practical application of electronic and radio aids to navigation. Appreciation and interpretation of data. Position fixing; fixed and variable errors, area of probability. The use of Radar as an aid to collision avoidance.

(e) The use of navigational publications and information commonly supplied or available to ships.

Oral[1]

(c) (i) A thorough knowledge of search and rescue procedures. The use of direction finding for homing onto a casualty.
(ii) Navigation in the vicinity of ice.

[1] Navigational content *only*.

Oral Syllabus for Watchkeeping Licence for Persons Serving as Master or Mate in Ships Operating within closely defined limits

This syllabus gives the standards of knowledge and practical ability recommended for persons serving as Masters and Mates on ships, operating within closely defined limits, which are exempted by the Department of Trade from the provisions of the "Merchant Shipping (Certification of Deck Officers) Regulations 1977" (see paragraph 7 of "Certificates of Competency in the Merchant Navy: Deck Officer Requirements", obtainable from Her

Majesty's Stationery Office). The possession of such a "Watchkeeping Licence" is not an obligatory requirement under the Deck Officers' Regulations for service on such exempted ships and the Department does not propose at present to conduct any examinations for a "Watchkeeping Licence", but possession of a "Watchkeeping Licence" may become a statutory requirement at a later date. In that event special provision will then be made by the Department to enable those employed at that time as Master or Mate on such ships to continue to be so employed, without examination.

Section 1

General

(a) The syllabus is designed to allow candidates to be examined by means of a practical test on board the vessel in which the applicant serves, although any such examinations would as a rule be conducted at the Department's examination centres.

(b) A candidate will be required to show proficiency in the use of navigational aids, fire-fighting equipment and life-saving equipment installed in the class of vessel in which he serves, and in practical first aid.

(c) A candidate will be required to show that he has a reasonable knowledge of the navigation bye-laws which apply to the relevant defined waters.

Section 2

Practical Navigation, Chartwork and Pilotage

(a) A working knowledge of tides and tidal streams within the trading area.

(b) A practical demonstration of chartwork within the context of the equipment on board the vessel, as follows:

Given variation and the deviation of the magnetic compass, to convert true courses into compass courses and vice versa.
To find the compass course between two positions.
The effect of current on speed.
Allowance for leeway.
Given compass course steered, the speed of the ship and direction and rate of the current, to find the true course made good.
To fix a position on a chart by bearing and range.
To find the course to steer allowing for a current.
Given the course steered and distance run, to determine the set and rate of the current experienced between two positions.
To fix a position on a chart by simultaneous cross bearings.

(c) An examination on information given on a chart, reference:
Buoys
Lights
Radio Beacons
Navigational Aids
Depths and nature of bottom and use of soundings
Depth and height contours
Tidal streams, traffic lanes and separation zones
Recognition of the coast
Chart correction.

(d) Candidates will be examined on the selection of suitable anchorages, approaching anchorages and entering narrow waters; landfalls in thick and clear weather.

(e) The practical use of electronic aids to navigation fitted in the vessel.

Section 3

Practical Seamanship and Signals[1]

(a) Ability to take a compass bearing or bearings.
Ability to check compass bearings by transit.
To read and understand a barometer and thermometer.
The care and maintenance of liquid compasses. The avoidance of electrical and magnetic interference.
(i) Search and Rescue.

[1] Navigational content *only*.

PRESCRIBED MARKING

CLASS 5 CERTIFICATE OF COMPETENCY

	Time	*Total marks*	*Percentage pass*
1 Chartwork and Practical Navigation	3 hrs	200	70%
2 General Ship Knowledge	2 hrs	150	50%

Orals: as arranged by Examiner

CLASS 4 CERTIFICATE OF COMPETENCY

	Time	*Total marks*	*Percentage pass*
First day			
1 General Ship Knowledge	3 hrs	200	50%
2 Chartwork	2 hrs	150	70%
Second day			
3 Practical Navigation	2 hrs	150	70%
4 Meteorology	2 hrs	150	50%
		650	Aggregate 60%

Orals: as arranged by Examiner.

CLASS 3 CERTIFICATE OF COMPETENCY

	Time	*Total marks*	*Percentage pass*
First day			
1 General Ship Knowledge	3 hrs	200	50%
2 Chartwork	2 hrs	150	70%
Second day			
3 Practical Navigation	2 hrs	150	70%
4 Meteorology	2 hrs	150	50%
Third day			
5 Applied Science	3 hrs	200	50%
6 Principles of Navigation	2 hrs	150	50%
Fourth day			
7 Mathematics	$2\frac{1}{2}$ hrs	150	50%
		1150	Aggregate 60%

Orals: as arranged by Examiner

CLASS 2 CERTIFICATE OF COMPETENCY

	Time	*Total marks*		*Percentage pass*
First day				
1 Coastal Navigation	2½ hrs	200		70%
2 Ocean and Offshore Navigation	2½ hrs	150	Part A Part B	70% 60% 50%
Second day				
3 Meteorology	2½ hrs	150		50%
4 Ship-board Operations	2½ hrs	150		50%
Third day				
5 Ship Construction and Stability	3 hrs	200		50%
6 Business and Law	2 hrs	150		50%
		1000	Aggregate	60%

Orals: as arranged by Examiner

CLASS 1 CERTIFICATE OF COMPETENCY MASTER MARINER

	Time	*Total marks*		*Percentage pass*
First day				
1 Business and Law	3 hrs	200		50%
2 Navigation	2½ hrs	200		60%
Second day				
3 Ship Construction and Stability	3 hrs	200		60%
4 Engineering and Control Systems	2½ hrs	200		50%
Third day				
5 Navigational Aids and Instruments	3 hrs	200		60%
		1000	Aggregate	60%

Orals: as arranged by Examiner.

MASTER (MIDDLE TRADE) ENDORSEMENT

	Time	*Total marks*	*Percentage pass*
First day			
1 Ship Construction and Stability	3 hrs	200	60%
2 Business and Law	2 hrs	150	50%
Second day			
3 Magnetic and Gyro Compasses and Navigational Aids	2 hrs	150	60%
4 Ship-board Operations	$2\frac{1}{2}$ hrs	150	50%
		650	Aggregate 60%

Orals: as arranged by Examiner

MASTER (NEAR CONTINENTAL) ENDORSEMENT

	Time	*Total marks*	*Percentage pass*
1 Ship Construction and Stability	2 hrs	150	60%
2 Magnetic Compass and Navigational Aids	2 hrs	150	60%
		300	Aggregate 60%

Orals: as arranged by Examiner.

DEPARTMENT OF TRANSPORT MERCHANT SHIPPING NOTICE NO. **M.1242**

CHANGES IN EXAMINATION ARRANGEMENTS FOR CERTIFICATES OF COMPETENCY: DECK OFFICERS (MERCHANT SHIPS)

Notice to Owners, Masters and Officers of Merchant Ships and to Nautical Colleges

1. INTRODUCTION

1.1 Certain changes are to be made both in the administration and form of the examinations for deck officer certificates of competency. The changes are to be phased-in between January 1987 and March 1989 and, while they affect each class of certificate, the particular attention of candidates for the Class 4, Class 2 and Class 1 certificates is drawn to the major changes which will be introduced in January 1988.

1.2 The principal changes will be:

(i) all written examinations for Extra Master, Class 5 and command endorsements will in future be set and marked entirely under Scottish Vocational Education Council (SCOTVEC) administration on a UK national basis. The remaining Class 4 and Class 2 written examinations (see sub-paragraph iv below) will be divided into theoretical and practical safety parts; candidates knowledge of the former to be assessed for the award of Business and Technician Education Council (BTEC) or SCOTVEC nationally recognised educational qualifications and examinations in the latter to be set and marked under SCOTVEC administration on a UK national basis. These assessments and examinations will be conducted in all cases on nautical college premises and some will entail attendance at full-time college courses.

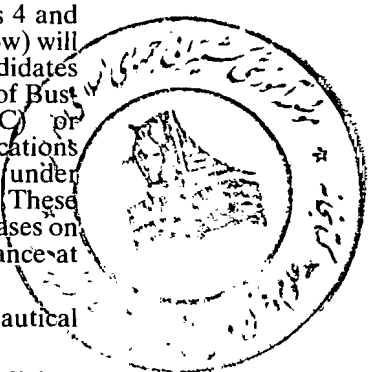
(ii) all signals examinations will be conducted by approved nautical college examiners on college premises.

(iii) certain changes will be made to the arrangement of syllabus content.

(iv) the written examinations for Class 2 and Class 1 certificates will be combined into a single written examination to be taken at the Class 2 stage.

(v) the procedure for admission to oral examinations has been amended.

(vi) the validity of passes in the written, oral and signals parts of the examinations will be extended to 2 years.



1.3 All oral examinations will continue to be conducted by the Department's examiners.

1.4 Notwithstanding the changes described above, the Department will continue to set and monitor *all* examination standards and ensure that all other requirements have been met before certificates of competency are issued.

2. RE-ARRANGEMENT OF EXAMINATION SYLLABUSES

2.1 There will be no changes in the total content of the syllabuses for deck officer examinations. The Extra Master, Class 3 Bridging, Class 5 and Command Endorsement syllabuses will not be affected, but certain topics have been re-arranged in the other examinations.

2.2 The salient features are:

(i) The Class 4 examination will be re-arranged. Certain topics will be transferred from the oral examination to the written papers and the syllabuses for the written examinations will be re-arranged in a new format.

(ii) The major change in the deck officer examinations will be at the Class 2 and Class 1 levels. It has been possible to take the Class 1 written examination immediately after completing Class 2 for some time. It has now been decided to merge the two written examinations into one, to be taken at the Class 2 stage. The resultant Class 2 examination will, as at present, consist of written, signals and oral parts.

(iii) The Class 1 examination will consist of an oral examination only after the required watchkeeping service has been accrued.

2.3 Details of all the revised syllabuses will be published well in advance of their introduction.

3. TIMETABLE FOR CHANGES

3.1 **1 January 1987**

(i) The conduct of all signals examinations will pass to colleges.

(ii) Extra Master, Class 5, Limited European Command Endorsement and Extended European Command Endorsement and related Tugmaster and Master (Restricted) written examinations will be conducted by colleges under SCOTVEC adminstration.

3.2 **1 January 1988**

(i) Syllabus changes for Classes 4, 2 and 1 will be implemented.

(ii) Class 4 and Class 2 written examinations will be conducted under the new arrangements. Except as provided for in the transitional arrangements (see Section 7), there will be no further written examinations under the existing arrangements for candidates for Class 4 and Class 2 and there will be no further separate written papers for Class 1 candidates.

4. CONDUCT OF EXAMINATIONS

4.1 When the new arrangements are implemented the Department will cease to be directly involved in the administration of the written examinations, which will be conducted by colleges in accordance with procedures laid down by the examining bodies concerned. Results will be notified to candidates by the organisations concerned.

4.2 Class 3 Bridging examinations will continue under the arrangements described in Merchant Shipping Notice No. M.1060.

4.3 After applying for a Notice of Eligibility, as described in Section 6, candidates will be required to make arrangements for the written and signals examinations with the college of their choice (see Appendix A) and, for the oral examination, with the Department of Transport examiner at one of the Marine Offices listed in Appendix B.

5. FEES

5.1 The fee payable to the Department at the time of application for a Notice of Eligibility will be for the oral examination and the charge for administration and subsequent issue of the certificate or endorsement.

5.2 Any fees for the written and signals examinations will be payable separately to the organisations conducting those examinations.

6. APPLICATION FOR NOTICE OF ELIGIBILITY TO SIT AN EXAMINATION

6.1 Candidates sitting the existing DTp written examination papers either before the relevant implementation date in Section 3 or under the transitional arrangements in Section 7 should continue to apply as at present (M Notice 1182 refers).

6.2 When the new arrangements are implemented in accordance with the timetable in Section 3, the administrative arrangements for the processing of applications to sit examinations for the issue of certificates will continue to be carried out at Companies House in London.

6.3 Applications, together with the appropriate supporting documentation and examination fee, should be sent by post to:

Administration of Marine Examinations
Department of Transport
Marine Directorate
4th Floor, Companies House
55–71 City Road
London EC1Y 1BB

6.4 Applicants are recommended to use the Recorded Delivery Service of the Post Office which provides a record of posting and delivery of documents. The top left-hand corner of the envelope should be clearly marked DECK.

6.5 Application forms (EXN2) may be obtained either from marine colleges in the United Kingdom which provide preparatory courses for these examinations, from the London and Wallasey offices of NUMAST, or from the above address. The Department's Marine Offices do not hold stocks of application forms, nor will they accept completed application forms nor the payment of fees.

6.6 Candidates for examination under the revised arrangements should first of all apply for a Notice of Eligibility as follows:

(i) As early as possible, preferably before attending any college course but at least 4 weeks before the date of the first examination to be taken, send the completed EXN2, fee and supporting documentation to the address in paragraph 6.3.

(ii) At this stage the only documents required are:— Certificate of Competency already held (if any), evidence of nationality (eg birth certificate, passport or British Seaman's Card), discharge book or other evidence of sea service, watchkeeping certificates, testimonials and evidence of any sea service remission being claimed.

6.7 CANDIDATES ARE ADVISED TO ENSURE AS EARLY AS POSSIBLE THAT THEY WILL BE CAPABLE OF MEETING THE REQUIREMENTS FOR A MEDICAL CERTIFICATE (AND/OR A SIGHT TEST CERTIFICATE DEPENDING ON THE CLASS OF CERTIFICATE OF COMPETENCY/ENDORSEMENT SOUGHT). FAILURE TO OBTAIN SUCH A CERTIFICATE (OR CERTIFICATES) WILL MEAN THAT THE CERTIFICATE OF COMPETENCY OR ENDORSEMENT CANNOT BE ISSUED.

6.8 Assuming that the application is in order, a NOTICE OF ELIGIBILITY will be issued.

6.9 The Notice of Eligibility will authorise admission of a candidate to the written, signals, and oral parts of the examination, as appropriate. It will be

required by the college where the written and signals examinations are to be taken and by the DTp examiner conducting the oral examination.

6.10 A SCOTVEC and, where appropriate, a BTEC certificate will be issued to candidates who are successful in the written examinations. A college certificate will be issued to those successful in the signals examinations. In the event of failure or referral in any part of the written examinations or signals candidates should make arrangements to re-take the examination, or re-sit referred papers, directly with the college concerned and pay the appropriate fees.

6.11 The result of the oral examination will be entered on the Notice of Eligibility by the examiner. To apply for re-examination in the event of failure in the oral examination, the Notice of Eligibility together with the appropriate fee should be submitted to the address given in paragraph 6.3 when a fresh Notice of Eligibility will be issued.

6.12 When all sections of the examination have been passed and all ancillary qualifications and certificates obtained, they should all be forwarded together with the completed Notice of Eligibility to the address given in paragraph 6.3 for the issue of the appropriate Certificate of Competency or command endorsement.

7. TRANSITIONAL ARRANGEMENTS

7.1 No special transitional arrangements will be required in respect of signals examinations, nor the Extra Master, Class 3 Bridging, Class 5 or Command Endorsement examinations.

7.2 Class 4 and Class 2 candidates who fail or who are referred in the written examinations before 31 December 1987 will be able to re-take these examinations under the present syllabuses until 31 December 1988.

7.3 Class 1 candidates who fail or who are referred in the written examinations before 31 December 1987 will be able to re-take the examination under the present syllabuses until 31 March 1989.

7.4 Candidates who pass the Class 2 written examination before 31 December 1987 will be allowed to sit the Class 1 written examination under the present syllabus until 31 March 1989.

7.5 After the periods quoted in paragraphs 7.2, 7.3 and 7.4 all further examinations will be conducted under the new arrangements.

Department of Transport
Marine Directorate
London WC1V 6LP
1986

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APPENDIX A

LIST OF NAUTICAL COLLEGES

Aberdeen	Aberdeen Technical College Gallowgate Aberdeen AB9 1DN
Belfast	University of Ulster Jordanstown Newtonabbey N Ireland BT37 0QB
Cardiff	South Glamorgan Institute of Higher Education Western Avenue Cardiff CF5 2YB
Fleetwood	The Nautical College Broadwater Fleetwood FY7 8JZ
Glasgow	Glasgow College of Nautical Studies 21 Thistle Street Glasgow G5 9XB
Hull	Humberside College of Higher Education Queen's Gardens Hull HU1 3DH
Liverpool	Liverpool Polytechnic Byrom Street Liverpool L3 3AF South Mersey College Riversdale Road Liverpool L19 3QR
London	Merchant Navy College Greenhithe Kent DA9 9NY
Lowestoft	Lowestoft College of Further Education St Peters Street Lowestoft Suffolk NR32 2NB

Plymouth	Plymouth Polytechnic Drake Circus Plymouth PL4 8AA
Southampton	The College of Maritime Studies Warsash Southampton SO3 6ZL
South Shields	South Tyneside College St Georges Avenue South Shields Tyne and Wear NE34 6ET

APPENDIX B

DEPARTMENT OF TRANSPORT MARINE OFFICES

District	*Address*
Aberdeen	Blaikies Quay Aberdeen AB9 2AZ
Belfast	Custom House Belfast BTL 3 ET
Cardiff	Oxford House Hills Street Cardiff CF1 2TD
Glasgow	15 Muirhouse Street Glasgow G41 1QW
Hull	Posterngate Hull HU1 2LW
Leith	1 John's Place Leith Edinburgh EH6 7EL
Liverpool	2nd Floor, Graeme House Derby Square Liverpool L2 7SQ
Newcastle upon Tyne	Government Buildings Broadway West Gosforth Newcastle upon Tyne NE3 2JL
Southampton	South Western House Canute Road Southampton SO 1NP

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Chapter 1

Algebra

SIGNS, SYMBOLS AND FRACTIONS USED IN MATHEMATICS

This chapter is included for the purpose of revision.

Before proceeding to investigate the functions of the trigonometrical ratios and the solution of triangles, it is necessary that the student should be familiar with the following signs, symbols and abbreviations:

$a-b$ means the value of "b" is to be subtracted from the value of "a". When this sign is used the larger quantity must be put down first, as it is impossible to take a large quantity from a smaller one. If this is not done the result will be a negative quantity; thus, if we have $6-3$ we know the remainder will be 3; but if we have $3-6$ the result will be a negative 3, that is, $3-6=-3$.

$a \sim b$ This sign means the difference between "a" and "b", and is preferential to the minus sign, inasmuch that it is quite immaterial as to the order in which the quantities are written down. The larger or smaller quantity may be put in the first position, thus $a \sim b = b \sim a$.

$\therefore$ Therefore.

$=$ Equal to.

a^2 The result of "a" multiplied by "a".

$\sqrt{a}$ A quantity, which being multiplied by itself, produces "a", i.e. the square root of "a".

$(a+b)(a+b)$ The sum of "a" and "b" multiplied by the sum of "a" and "b", the $\times$ is omitted for brevity. It could also be written $(a+b)^2$.

$(a-b)(a-b)$ The difference of "a" and "b" multiplied by the difference of "a" and "b". This could also be written $(a-b)^2$.

$\frac{b}{c}$ A fraction. It means that "b" is to be divided by "c" to obtain the value of the expression. If "b" is greater than "c" the result will be more than 1; if "b" is less than "c" the result will be less than 1.

In both cases it gives us the proportion or ratio that "b" bears to "c", whether larger or smaller. It is, therefore, the most convenient method of writing down the proportion or ratio that exists between two quantities. The value of the expression $\frac{1}{2}$ means the proportion that 1 is to 2, which is a half. The value of the fraction $\frac{3}{2}$ is as 3 is to 2, which is one and a half. The upper value is called the numerator and the lower part the denominator. In any fraction, we can multiply or divide the numerator

and denominator by the same amount without altering the value of the fraction. Thus

$$\frac{1}{4} = \frac{1\times4}{4\times4} = \frac{4}{16} = \frac{4\div2}{16\div2} = \frac{2}{8} = \frac{1}{4}.$$

$\frac{A}{2}$ A divided by 2, or the half of A.

$\frac{a+b+c}{2}$ Half the sum of "a" and "b" and "c".

$\sqrt{2^2}$ The square root of 2 multiplied by the square root of 2, which is 2, for $2\times2=4$, and $\sqrt{4}=2$. Similarly $\sqrt{a^2}=a$.

$\sqrt{\frac{1}{4}}$ The square root of 1 divided by the square root of 4; this becomes $\frac{\sqrt{1}}{\sqrt{4}} = \frac{1}{2}$, for $\sqrt{1}=1$, and $\sqrt{4}=2$.

$\left(\frac{1}{2}\right)^2$ 1^2 divided by 2^2; this becomes $\frac{1^2}{2^2} = \frac{1}{4}$.

The root sign $\sqrt{\ }$ is used in *evolution*, which means the lowering of quantities from higher to lower powers; for example, $\sqrt[3]{8}=2$, that is to say the cube root of 8 is 2.

Involution

This expression means the raising of a quantity to a higher power, this being the reverse to evolution.

$a\times a\times a = a^3$ a is the *base* and 3 is the *index* or exponent.

$3\times3=3^2=9$ Here 3 is the base, 2 is the index or exponent and 9 is the power.

Coefficient

The coefficient of a term may be a number preceding it, as in $2x$, where 2 is the coefficient of x. The expression is equivalent to $x+x$.

A coefficient, however, is not always a number; *e.g.* in the expression ax, a is the coefficient of x. It may also take a compound form as in $2ax$, where $2a$ is the coefficient of x. The expression might be written as $(a+a)x$.

ADDITION

"To add together any number of expressions containing numbers or letters."

Rule

Collect in vertical columns all the terms in which the letters and powers are the same. Add together in each column the numbers with + sign in front; add together those with − sign in front. Then take the difference between these two sums giving the result the sign of the greater value.

Example 1

Add together $3a-2b+4c+18d$; $4b-2a-7c-9d$; $4d-6c+11b$. Arranging as described above:

$$\begin{array}{rr} & 3a- \ 2b+4c+18d \\ & -2a+ \ 4b-7c- \ 9d \\ & \quad +11b-6c+ \ 4d \\ \hline \textit{Answer} & \quad a+13b-9c+13d \end{array}$$

The answer must be left in this form till we know the respective values of a, b, c and d.

Example 2

Find the sum of $3x^2+2x+2y$; $-4x^2-5y$; $2x^2+4y-3x$,

$$\begin{array}{rr} & 3x^2+2x+2y \\ & -4x^2 \quad -5y \\ & 2x^2-3x+4y \\ \hline \textit{Answer} & x^2- \ x+ \ y \end{array}$$

Exercise 1

Add 1. $3x-2y+z$; $-2x+7y-2z$; $3x+4y-7z$.
2. $a+b+c+d$; $2a-3b+3c-4d$; $6a-5b-3c+4d$.
3. $5s-2t+4u$; $-6u+7t-8s$; $-5t+7s-8u$.
4. $5p-3r+14s-7q$; $-7r-3s+7q-8p$; $13p-2s+3r-5q$.
5. $2x^2+3y^2-3z^2$; $-3x^2+4y^2+7z^2$; $4x^2-5y^2+7z^2$.
6. $\frac{1}{4}x-1\frac{1}{2}y-4z$; $-\frac{3}{8}x-\frac{7}{8}y-5\frac{1}{2}z$; $-x+2\frac{3}{4}y-4\frac{1}{2}z$.

SUBTRACTION

"To subtract one expression from another."

Rule

Change the sign of each term in the expression to be subtracted and then proceed as in addition. (The change of sign is generally effected mentally.)

Example 3

Subtract $4a-3b+c$ from $2a-3b-c$.

Arrange as in addition, but always putting the one to be subtracted below the other.

$$\begin{array}{r} 2a-3b-c \\ 4a-3b+c \\ \hline -2a \quad -2c \end{array} \quad \text{or} \quad \left.\begin{array}{r} 2a-3b-c \\ -4a+3b-c \end{array}\right\} \text{add} \quad \begin{array}{r} \\ \\ \hline -2a \quad -2c \end{array}$$

The signs of the bottom expressions were changed mentally and the two expressions added in the first version; and this method will be adopted in future examples.

Example 4

From	$10a^2b^2+15ab^2+8a^2b$
Take	$-10a^2b^2-15ab^2-8a^2b$
Answer	$20a^2b^2+30ab^2+16a^2b$

Exercise 2

1. From x^3+x^2-x+1 take x^3-x^2+x+1.
2. „ $\frac{1}{2}x^2-\frac{1}{3}xy-\frac{3}{2}y^2$ take $-\frac{3}{2}x^2+xy-y^2$.
3. „ $-8ab^2+15a^2b+b^3$ take $a^3-b^3+8ab^2-7a^2b$.
4. „ $5x^4-8x^3-2x^2+7$ take $x^4+5+x-3x^3$.
5. „ $\frac{1}{3}x^2-\frac{1}{2}x+\frac{1}{6}$ take $\frac{1}{3}x-1+\frac{1}{2}x^2$.
6. „ $5x^3+3x+1$ subtract the sum of $2x-5+7x^2$ and $3x^2+4-2x^3+x$.
7. „ the sum of $2+8a^2-a^3$ and $2a^3-3a^2+a-2$ take $3a-7a^3+5a^2$.
8. „ $2a^3+5a$ take $4a^3+3a^2-2a$ and subtract the result from $5a^2+3a-5$.

BRACKETS

Rule 1

When a bracket is immediately preceded by a + sign, the bracket may be removed without altering the signs of the expressions.

Rule 2

When the bracket is immediately preceded by a − sign, the sign of every term must be changed when the bracket is removed. These rules may be readily demonstrated as follows:

1. $(8+4)+(7-3)=8+4+7-3=19-3=16$. None of the signs have been changed here as each pair of brackets was preceded by a + sign.
2. $-(8+4)-(7-3)=-8-4-7+3=-19+3=-16$. All the signs have been changed here as each bracketed quantity was preceded by a minus sign (−).
3. Remove the brackets from the following expressions, collect similar terms and simplify:

$$(4a+3b-c)-(2a-b+3c)$$
$$=4a+3b-c-2a+b-3c.$$

Arranging similar terms alongside one another, we have:

$$=4a-2a+3b+b-c-3c=2a+4b-4c.$$

4. $-(3x+5y-4z)+(5x-3y-10z)$
$=-3x-5y+4z+5x-3y-10z$
$=2x-8y-6z$ *Answer.*

Exercise 3

Remove the brackets and simplify the following expressions:

. $(a+2b-3c)-(4a-10b-c)$.
. $-(6a-3b+4c)+(8a-7b+6c)$.
. $(12a-14b-6c)-(a+b-3c)$.

BRACKETS PRECEDED BY A NUMBER

Example 5

$(a+b+c)-2(a+b+c)$.

Each term inside the first pair of brackets is multiplied by 2; each term inside the second pair is multiplied by -2, and we obtain

$$2a+2b+2c-2a-2b-2c=0$$

because the plus and minus quantities are equal.

Brackets Enclosing Brackets

Example 6

$3[2(2a-3b+4c)-4(3a+5b-2c)]$.

Remove the inner brackets first:

$$3[4a-6b+8c-12a-20b+8c].$$

Now remove the outer bracket and collect the terms:

$$12a-18b+24c-36a-60b+24c$$
$$=-24a-78b+48c \quad \textit{Answer.}$$

In this case every term inside the outer brackets is affected by the number 3 which precedes it, so the inner bracket was removed first and then the outer one.

Exercise 4

Remove brackets from the following, then collect and simplify:

1. $5[2a-3b-2(a-2b+3c)+4(2b-c)]$.
2. $-3[4a-5(b-c)+3(a-b)+c]$.
3. $2[3(a+b)-c+4(a-c)-2(b-c)]$.
4. $-4[b-2a-3(4a+b-c+12)-4c-7]$.

Insertion of Brackets

In algebraic operations it is very often necessary to enclose groups of terms within brackets.

Rule

If the sign immediately in front of the bracket is $+$ make no change in the signs of the term embraced by the bracket; but if the sign is $-$ then change the sign of every term inside the bracket.

The expression $a+b-c-d$ could be arranged thus: $(a+b)-(c+d)$. Note here that it w necessary to change the signs of c and d because the brackets enclosing them were precede by a minus sign. In the expression $ab+ac+ad$, a is a factor common to each term; i.e. a ca be divided into each of the values b, c and d. The expression could therefore be arranged thus

$$a(b+c+d).$$

Example 7

Enclose the following expressions in brackets taking out the common factors:

(a) $ab+bc+cd-de$
$= b(a+c)+d(c-e)$ *Answer.*
b is a common factor to the first two terms, and d is common to the last two terms.

(b) $a^2-ac-2abc-ab^2$
$= a(a-c)-ab(2c+b)$
$= a[(a-c)-b(2c+b)]$ *Answer.*
In the first step a is common to the first two terms and ab is common to the second tw terms. It can now be seen that a is still a common factor in each of the groups. The a ca therefore, be placed outside the larger bracket as shown in the last step.
A useful practice for the student is to work backwards by clearing the brackets to verify.

(c) $4b^2c^2+8bd^2-12bd-4d$
$= 4(b^2c^2+2bd^2-3bd-d)$
$= 4[b(bc^2+2d^2-3d)-d]$ *Answer.*

Each of the four terms can be divided by 4 and this is taken out as a first step. b is commc to the first three terms and is therefore bracketed to them, the 4 being placed outside the larg bracket enclosing the four terms to which it is common.
The last step in this example could have been arranged thus:

$$4[b(bc^2+2d^2)-d(3b+1)].$$

Verify these examples of clearing the brackets from both arrangements and workir backwards.

SUBSTITUTION

An **equation** is simply a statement that two expressions are equal to one another.
The equation, $a = 4b$, where $b = 3$, can be solved by the method of "substitution", i.e. b substituting for b in the equation the value 3. We now have $a = 4 \times 3 = 12$.

Example 8

(a) $a = 3b+5$, when $b = 2$
$a = 3\times 2+5 = 6+5 = 11$ *Answer.*

(b) $x^2 = 4y^2+3y+5$, when $y = 4$
$x^2 = 4\times 4^2+3\times 4+5$
$x^2 = 4\times 16+12+5$
$x^2 = 64+17 = 81$ $\therefore x = \sqrt{81} = 9$ *Answer.*

(c) $2x^2 = 3y^2 + 2\sqrt{y} + 39$, when $y = 9$

$$2x^2 = 3 \times 9^2 + 2\sqrt{9} + 39$$
$$= 3 \times 81 + 2 \times 3 + 39$$
$$= 243 + 6 + 39$$
$$2x^2 = 288$$
$$x^2 = \frac{288}{2} = 144 \quad \therefore x = \sqrt{144} = 12 \quad \textit{Answer.}$$

The treatment of brackets can be shown in the following examples.

(d) If $a = 7, b = 4$ and $c = 2$, evaluate:

$$a^2(a-b) + b^2(b-c) + c^2(a-c)$$
$$= 7^2(7-4) + 4^2(4-2) + 2^2(7-2)$$
$$= 49 \times 3 + 16 \times 2 + 4 \times 5$$
$$= 147 + 32 + 20 = 199 \quad \textit{Answer.}$$

(e) If $a = 7, b = 4$ and $c = 2$, evaluate:

$$bc\{(a^2 - c^2) - 2(b + 2c)\}$$
$$= 8\{(49 - 4) - 2(4 + 4)\}$$
$$= 8\{45 - 16\}$$
$$= 8 \times 29 = 232 \quad \textit{Answer.}$$

Exercise 5

Find the value of y in each of the following examples:

1. $3y = 4x - 2$, when $x = 4$.
2. $y = 3a^3 + 2b^2 - c$, when $a = 3, b = 2, c = 1$.
3. $2y = 3a^2b^3c$, when $a = 3, b = 2, c = 1$.
4. $y = \sqrt[3]{4c}\left\{5b(a^2 - b^2) - bc\left(\frac{4b + 2c}{4}\right)\right\}$, when $a = 5, b = 3, c = 2$.
5. $4y = 4a(b^2 - c^2) - ac\left\{c(8a - 3b) + \frac{4a - c}{3}\right\}$, when $a = 4, b = 3, c = 1$.
6. $y = \frac{3}{5}x^2 - a^2z + 7abx - \frac{5}{2}z^3$, when $a = 5, b = 0, x = 7, z = 1$.

MULTIPLICATION AND INVOLUTION

The product of a and b is simply written as ab; i.e. $a \times b = a.b = ab$. When algebraic values are denoted by letters of the alphabet, a dot between such letters has the same meaning as the multiplication sign.

$a \times a = a^2$, just as in arithmetic $3 \times 3 = 3^2$. In these two cases the 2 is the index of the power to which a and 3 have been raised.

$a \times a \times a = a^3$. Here 3 is the index of the power to which a has been raised. If it were desired to find the product of a^3 and a^2, we could set it down as follows:

$$a^3 = a.a.a, \text{ and } a^2 = a.a \quad \therefore a^3 \times a^2 = a.a.a \times a.a = a^5.$$

Again $a^4 \times a^3 \times a^2 = a.a.a.a \times a.a.a \times a.a = a^9$. The simple and orthodox method in such cases is to add together the indices as follows.

Example 9

(a) $a^3 \times a^2 = a^{3+2} = a^5$.
(b) $a^4 \times a^3 = a^{4+3} = a^7$.
(c) $a^6 \times a^3 \times a^2 = a^{6+3+2} = a^{11}$.

When the terms are preceded by numerical coefficients these coefficients are multiplied as in arithmetic.

Example 10

(a) $3a^2 \times 2a^8 = 6a^{2+8} = 6a^{10}$.
(b) $10x \times 3x^3 = 30x^{1+3} = 30x^4$.
(c) $5b^2 \times 3b^3 = 15b^{2+3} = 15b^5$.

When the expressions to be multiplied together contain powers of different letters, the method is as follows:

Example 11

(a) $ab \times a^2b^2 = a.b \times a.a \times b.b = a.a.a \times b.b.b = a^3b^3$ from which it will be observed that the indices of the a's are added together and also the indices of the b's.

Example 12

(a) $5a^3b^2 \times 8a^2bx^3 = 40a^{3+2}.b^{2+1}x^3 = 40a^5b^3x^3$.

(b) $5x^3y^3 \times 3x^2y^2 \times 2x = 30x^{3+2+1}y^{3+2} = 30x^6y^5$.

(c) $\dfrac{3b^2c^2}{4a} \times \dfrac{2b^2c}{y} = \dfrac{6b^{2+2}c^{2+1}}{4ay} = \dfrac{6b^4c^3}{4ay} = \dfrac{3b^4c^3}{2ay}$.

Note that in Example 12(c) numerators are multiplied together and denominators are multiplied together as in arithmetic.

MULTIPLICATION OF COMPOUND EXPRESSIONS

$a+b$ is a compound expression, a is a simple expression.

(a) $a(a+b) = a^2 + ab$. Each of the two terms enclosed by the brackets is multiplied by a.

(b) Similarly, $x(x-y) = x^2 - xy$.

Rule of Signs

The product of two terms with like signs is positive. The product of two terms with unlike signs is negative.

The expression $(a+b)^2$ may be written in the form $(a+b)(a+b)$ which may further be changed to the form $a(a+b)+b(a+b)$, which means the sum of the products $a(a+b)+b(a+b)$.

$$\left.\begin{array}{l} a(a+b) = a^2+ab \\ b(a+b) = \quad ab+b^2 \end{array}\right\}\text{add}$$

$$\therefore \underline{(a+b)^2} = \underline{a^2+2ab+b^2}$$

The usual way of setting this down is

$$\begin{array}{ll} a+b & \\ \underline{a+b} & \\ a^2+ab & a(a+b) \\ \quad +ab+b^2 & b(a+b) \\ \underline{a^2+2ab+b^2} & \end{array}$$

Procedure

Commencing with the left hand one, each term of the bottom line is multiplied into the whole of the top line and the results are then added, similar terms being properly arranged under each other.

Example 13

(a) $(b+c+d)(b-2c+2d)$

rewrite for multiplying

$$\begin{array}{llll} b-2c+2d & & & \\ \underline{b+\ c+\ d} & & & \\ b^2-2bc+2bd & & & \text{(e)} \\ \quad +\ bc & +2cd-2c^2 & & \text{(f)} \\ \quad\quad +\ bd & -2cd & +2d^2 & \text{(g)} \\ \underline{b^2-bc+3bd} & & \underline{-2c^2+2d^2} & \textit{Answer.} \end{array}$$

Line (e) is the product $b(b-2c+2d)$, line (f) is the product $c(b-2c+2d)$ and line (g) is the product $d(b-2c+2d)$. Note the necessity of keeping similar terms in vertical columns for convenient adding.

(b) $(x^4+x^2y^2+y^4)(x^2-xy+y^2)$

$$\begin{array}{llll} x^4+x^2y^2+y^4 & & & \\ \underline{x^2-xy+y^2} & & & \\ x^6 \quad +x^4y^2 & & +x^2y^4 & \\ \quad -x^5y & -x^3y^3 & & -xy^5 \\ \quad\quad +x^4y^2 & & +x^2y^4 & +y^6 \\ \underline{x^6-x^5y+2x^4y^2-x^3y^3+2x^2y^4-xy^5+y^6} & & & \textit{Answer.} \end{array}$$

The terms are placed here so that powers of x are arranged in descending order from left to right, i.e. the highest power of x is the left one, the lowest power of x being in the 6th term of the answer.

(c) $(4x^2+3x+6)(2x^2-5)$

$$\begin{array}{l} 4x^2+3x+6 \\ 2x^2-5 \\ \hline 8x^4+6x^3+12x^2 \\ \qquad -20x^2-15x-30 \\ \hline 8x^4+6x^3-\ 8x^2-15x-30 \end{array}$$ *Answer.*

(d) $(2a^2+4b^2-3ab)(3ab-5a^2+4b^2)$

$$\begin{array}{l} 2a^2-3ab+4b^2 \\ -5a^2+3ab+4b^2 \\ \hline -10a^4+15a^3b-20a^2b^2 \\ \qquad +\ 6a^3b-\ 9a^2b^2+12ab^3 \\ \qquad\qquad +\ 8a^2b^2-12ab^3+16b^4 \\ \hline -10a^4+21a^3b-21a^2b^2 \qquad +16b^4 \end{array}$$ *Answer.*

Exercise 6

Multiply together:

1. $x+y, x-y$.
2. $c-d, c-d$.
3. $3x^2-2x-5, 2x-5$.
4. $a-b+3c, a+2b$.
5. $a+b+c, a+b-c$.
6. $x^2+xy+y^2, x-y$.
7. $(a^2-2ax+4x^2)(a^2+2ax+4x^2)$.
8. $(2x^2+3x-5)(2x^2+3x-5)$.

DIFFERENCE OF TWO SQUARES

Products written down by inspection:

$$(4+2)(4-2) = 4^2-2^2 = 16-4 = 12$$
$$(a+b)(a-b) = a^2-b^2.$$

This is known as the difference of two squares. This result occurs when the two terms in each of the two expressions to be multiplied together are similar but are separated by different signs.

Example 14

(a)

$$\begin{array}{l} a+b \\ a-b \\ \hline a^2+\cancel{ab} \\ \qquad -\cancel{ab}-b^2 \\ \hline a^2 \qquad -b^2 \end{array}$$

The middle term cancels, leaving the difference between the square of a and the square of b.

(b) $(x+4)(x-4) = x^2-4^2 = x^2-16$.

c) $(3a+5)(3a-5) = (3a)^2 - 5^2 = 9a^2 - 25.$
d) $(2x+4y)(2x-4y) = (2x^2) - (4y^2) = 4x^2 - 16y^2.$

These results can be verified by multiplying out in the usual way:

e) $(6)^2 = (4+2)^2 = 4^2 + 2^2 + 2(4 \times 2) = 16 + 4 + 16 = 36$
or $(6)^2 = (8-2)^2 = 8^2 + 2^2 - 2(8 \times 2) = 64 + 4 - 32 = 36.$

Method If the above results be examined, the student will see that they consist of the first term squared + the second term squared + or − twice the product of the two terms according as the sign separating the two terms is + or −.

1. $(a+b)^2 = (a+b)(a+b) = a^2 + b^2 + 2ab.$

2. $(a-b)^2 = (a-b)(a-b) = a^2 + b^2 - 2ab.$

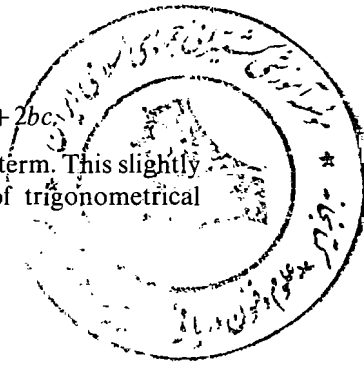
Example 15

(a) $(x+4)^2 = (x+4)(x+4) = x^2 + 4^2 + (2)(4)(x) = x^2 + 16 + 8x.$

(b) $(2a-2b)^2 = (2a-2b)(2a-2b)$
$= (2a)^2 + (2b)^2 - (2)(2a)(2b) = 4a^2 + 4b^2 - 8ab.$

(c) $(a+b-c)(a-b+c) = [a+(b-c)][a-(b-c)]$
$= a^2 - (b-c)^2 = a^2 - (b^2 + c^2 - 2bc) = a^2 - b^2 - c^2 + 2bc.$

The two terms in (c) are a and $(b-c)$, the latter being treated as a single term. This slightly complicated example has been quoted because it occurs in the proof of trigonometrical formulae used by nautical students.



DIVISION AND EVOLUTION

Division of Simple Expressions

Example 16

(a) $\frac{a^4}{a^2} = \frac{\not{a}.\not{a}.a.a}{\not{a}.\not{a}} = a^2$, or $a^4 \div a^2 = a^{4-2} = a^2.$

(b) $\frac{a^5}{a^2} = \frac{\not{a}.\not{a}.a.a.a}{\not{a}.\not{a}} = a^3$, or $a^5 \div a^2 = a^{5-2} = a^3.$

(c) $\frac{x^6}{x^3} = \frac{\not{x}.\not{x}.\not{x}.x.x.x}{\not{x}.\not{x}.\not{x}} = x^3$, or $x^6 \div x^3 = x^{6-3} = x^3.$

The above results indicate that "the index of the power of the quotient is the divisor index subtracted from the dividend index".

(d) $\frac{-9x^5}{3x^2} = -3x^{5-2} = -3x^3.$

(e) $\frac{-27a^3b^4}{-3ab^2} = 9a^{3-1}b^{4-2} = 9a^2b^2.$

Division of a Compound Expression by a Simple Expression

Example 17

(a) $a^2b^2+3b \div b$ could be arranged thus

$$b \,|\, \underline{a^2b^2+3b}$$
$$\underline{a^2b+3} \quad \textit{Answer.}$$

b is divided into a^2b^2 giving a^2b and into $3b$ giving 3.

(b) $4x^2y^2+2x^2y \div 2x = \dfrac{4x^2y^2+2x^2y}{2x}$

$$= 2xy^2+xy \quad \textit{Answer.}$$

(c) $6a^3b^3+4a^2b^2 \div 3ab = \dfrac{6a^3b^3+4a^2b^2}{3ab}$

$$= 2a^2b^2+\tfrac{4}{3}ab \quad \textit{Answer.}$$

Division of Compound Expressions

Example 18

(a) $a^2-2ab+b^2 \div a-b = a-b.$

Divisor	Dividend	Quotient
$a-b)$	$a^2-2ab+b^2$	$(a-b$
	$\underline{a^2-\ ab}$	
	$-ab+b^2$	
	$\underline{-ab+b^2}$	

Method Arrange as above, divide the first term of the divisor into the first term of th dividend $\left(\dfrac{a^2}{a}=a\right)$ and multiply the divisor by the result $[a(a-b)=a^2-ab]$, placing it unde the dividend and then subtracting from the latter. Repeat this procedure as far as necessar always writing down the quotient to the right of the dividend.

(b) Divide $2x^3-12x^2+16x-30$ by $x-5$:

$$\underline{x-5}\,\big|\,2x^3-12x^2+16x-30\,\big|\,\underline{2x^2-2x+6} \quad \textit{Answer.}$$
$$\underline{2x^3-10x^2}$$
$$-2x^2+16x-30$$
$$\underline{-2x^2+10x}$$
$$6x-30$$
$$\underline{6x-30}$$

(c) $x^6-y^6 \div x^2-y^2$:

$$
\begin{array}{r|l}
x^2-y^2 & x^6-y^6 \quad x^4+x^2y^2+y^4 \quad \textit{Answer.} \\
\cline{2-2}
 & \underline{x^6-x^4y^2} \\
 & \quad +x^4y^2-y^6 \\
 & \quad \underline{+x^4y^2-x^2y^4} \\
 & \qquad\quad x^2y^4-y^6 \\
 & \qquad\quad \underline{x^2y^4-y^6}
\end{array}
$$

Exercise 7

1. $2x^3y^3 \div xy$.
2. $36a^3b^2-24a^2b^5-20a^4b^2 \div 4a^2b$.
3. $x^2+3x+2 \div x+1$.
4. $a^2-11a+30 \div a-5$.
5. $6a^5-13a^4+4a^3+3a^2 \div 3a^3-2a^2-a$.
6. $x^4+2x^3-7x^2-8x+12 \div x^2-3x+2$.

Division and Evolution

Evolution is really a form of division, just as involution is a form of multiplication.

$\sqrt{a^2} = a$ or $-a$, *i.e.* the root quantity multiplied by itself must give the quantity inside the square root symbol as in arithmetic, where $\sqrt{16} = +4$ or -4.

$$a \times a = a^2; \quad -a \times -a = a^2; \qquad \therefore \sqrt{a^2} = \pm a.$$

In further examples of this type it will be assumed that all results are positive and the minus sign will be omitted.

Example 19

(a) $\sqrt{a^4x^2} = a^2x$. This can also be shown as follows:

$$\sqrt{a^4x^2} = \sqrt{a^4} \,.\, \sqrt{x^2} = a^2 \,.\, x = a^2x.$$

Rule

The root of a product is found by halving the index.

(b) $\sqrt{b^4y^4} = b^2y^2$ (c) $\sqrt{4x^2y^4} = 2xy^2$ (d) $\sqrt{16a^4b^2} = 4a^2b$

$$\sqrt{\frac{a^4}{a^2}} = \sqrt{a^2} = a.$$

In this case the demoninator is divided into the numerator and the root is then extracted. An alternative method is:

$$\sqrt{\frac{a^4}{a^2}} = \frac{\sqrt{a^4}}{\sqrt{a^2}} = \frac{a^2}{a} = a.$$

Example 20

(a) $\sqrt{\frac{x^4}{x^2}} = \sqrt{x^{4-2}} = \sqrt{x^2} = x.$

(b) $\sqrt{\frac{a^4}{a^2}} = \sqrt{a^{4-2}} = \sqrt{a^2} = a.$

(c) $\sqrt{\frac{16b^{16}}{4b^4}} = \sqrt{4b^{16-4}} = \sqrt{4b^{12}} = 2b^6.$

Example 21

$$\sqrt{\frac{16a^4b^2}{4x^2y^2}} = \frac{\sqrt{16a^4b^2}}{\sqrt{4x^2y^2}} = \frac{4a^2b}{2xy} = \frac{2a^2b}{xy}.$$

The above example is a fraction and division cannot take place before extracting the root except in the case of the 16 and 4. It could have been written as follows:

$$\sqrt{\frac{16a^4b^2}{4x^2y^2}} = \sqrt{\frac{4a^4b^2}{x^2y^2}} = \frac{2a^2b}{xy} \quad \textit{Answer.}$$

Example 22

$$\sqrt{\frac{16x^{16}y^2}{8a^2b^2}} = \sqrt{\frac{2x^{16}y^2}{a^2b^2}} = \frac{\sqrt{2}x^8y}{ab} \quad \textit{Answer.}$$

Note here that 2 is not a perfect square as its square root is not a whole number. The simplest form in which it can be expressed is $\sqrt{2}$, its value being 1·414, to three decimal places.

The student is warned against the following:

$\sqrt{a^2+b^2}$ is *not* $a+b$.
$\sqrt{a^2+2ab+b^2} = a+b$ because $(a+b)^2 = a^2+2ab+b^2$.
$\sqrt{16+4} = \sqrt{20}$ and cannot be $\sqrt{16}+\sqrt{4}$ or $4+2$.

The rules given apply to products and division and not to sums and differences.

Exercise 8

Write down the square roots of the following expressions:

1. $\frac{24a^4}{6a^2}$ 2. $\frac{4x^4y^3}{a^2x^2y}$ 3. $\frac{a^{16}b^8}{16}$ 4. $\frac{12a^2b^3x^3}{4bx}$.

SIMPLE EQUATIONS

An equation consists of two expressions whose values are equal. A simple equation is one in which the unknown quantity is of the first degree as in $x+2=3$, where x is the unknown

quantity. The equation, $x^2+2x=4$, is of the second degree and is known as a quadratic equation.

In the example quoted above, viz., $x+2=3$, the value of x can be found by subtracting 2 from each side: $x+2-2=3-2=1$. This result is said to satisfy the equation if it be substituted for x and still produces equality:

$$x+2=3 \quad \text{but} \quad x=1 \quad \therefore 1+2=3.$$

If $3x=9$ the value of x can be found by dividing both sides by 3, viz.:

$$\frac{3x}{3}=\frac{9}{3} \quad \therefore x=3.$$

In the first of the two examples above, the same amount is subtracted from both sides of the equation; in the second example both sides are divided by the same quantity. Similarly, if any quantity be added to one side of the equation the same quantity must also be added to the other side; further, if one side be multiplied by a certain quantity, the other side must be multiplied by the same quantity. It should also be stated that both sides of an equation can be raised to the same power, or the same roots extracted from both sides; in short, the two sides must be treated so that the equality may not be disturbed.

Quantities may be shifted from one side to the other and still maintain equality as follows.

Rules for Transposing

When a quantity is shifted from one side of the equation to the other, the sign of operation preceding the quantity is reversed; $+$ becomes $-$ and vice versa; $\div$ becomes $\times$ and vice versa.

Example 23

(a) $x+4=7 \quad \therefore x=7-4=3.$
The $+4$ when changed over becomes -4.

(b) $x-12=4 \quad \therefore x=4+12=16.$
The -12 when changed over becomes $+12$.

(c) $3x=15 \quad \therefore x=\frac{15}{3}=5.$
The coefficient 3 becomes a divisor of 15 when transposed.

(d) $\frac{x}{5}=2 \quad \therefore x=2\times 5=10.$
The divisor of x becomes a multiplier of 2 when changed over.

(e) $x^3=27.$
Extract the cube root of each side and we have $\sqrt[3]{x^3}=\sqrt[3]{27} \quad \therefore x=3.$

(f) $\sqrt{x}=2.$
Square both sides and we have $(\sqrt{x})^2=(2)^2 \quad \therefore x=4.$

In examples (e) and (f) note that both sides of each equation undergo similar treatment.

Example 24

(a) Solve the equation $3(x-7)-3=x-4$.

$$\begin{aligned} 3(x-7)-3 &= x-4 \\ 3x-21-3 &= x-4 \\ 3x-x &= -4+21+3 \\ 2x &= 20 \\ x &= \tfrac{20}{2} = 10 \quad \textit{Answer.} \end{aligned}$$

Part of the left side is enclosed within brackets which should, therefore, be cleared off first. The terms in x are collected on the left side and the numbers on the right side. A useful practice is to verify the equation by substituting for x its numerical value 10.

$$\begin{aligned} 3(x-7)-3 &= x-4 \\ 3(10-7)-3 &= 10-4 \\ 3\times 3-3 &= 10-4 \\ 6 &= 6 \quad \therefore x = 10 \text{ satisfies the equation.} \end{aligned}$$

(b) *Solve and verify*:

$$(x+1)(2x+1) = (x+3)(2x+3)-14.$$

Solution:

$$\begin{aligned} (x+1)(2x+1) &= (x+3)(2x+3)-14 \\ 2x^2+3x+1 &= 2x^2+9x+9-14 \\ 9x-3x &= 1-9+14 \\ 6x &= 6 \quad \therefore x = 1 \quad \textit{Answer.} \end{aligned}$$

Verification:

$$\begin{aligned} (x+1)(2x+1) &= (x+3)(2x+3)-14 \\ (1+1)(2+1) &= (1+3)(2+3)-14 \\ 6 &= 20-14 = 6 \quad \therefore x = 1, \text{ satisfies the equation.} \end{aligned}$$

In the above solution note that brackets were cleared before transposing took place. It is usual to arrange the unknown quantity on the left side.

(c) *Solve and verify*:

$$\tfrac{1}{3}(x+3)-\tfrac{1}{4}(x-1) = \tfrac{2}{5}(2x+2)-6.$$

Solution:

$$\begin{aligned} \tfrac{1}{3}(x+3)-\tfrac{1}{4}(x-1) &= \tfrac{2}{5}(2x+2)-6 \\ \frac{x+3}{3}-\frac{x-1}{4} &= \frac{2(2x+2)}{5}-6. \end{aligned}$$

The lowest common denominator of 3, 4 and 5 is 60.

$$\frac{20(x+3)-15(x-1)}{60} = \frac{24(2x+2)-6\times 60}{60}.$$

By multiplying each side by 60 the denominator disappears and we have

$$\begin{aligned} 20(x+3)-15(x-1) &= 24(2x+2)-6\times 60 \\ 20x+60-15x+15 &= 48x+48-360 \\ 5x+75 &= 48x-312 \\ -48x+5x &= -75-312 \\ -43x &= -387. \end{aligned}$$

Multiply each side by -1 to get rid of the minus sign and

$$43x = 387$$
$$x = \tfrac{387}{43} = 9 \quad \textit{Answer.}$$

Verification:

$$\tfrac{1}{3}(x+3)-\tfrac{1}{4}(x-1) = \tfrac{2}{5}(2x+2)-6$$
$$\tfrac{1}{3}(9+3)-\tfrac{1}{4}(9-1) = \tfrac{2}{5}(18+2)-6$$
$$4-2 = 8-6$$
$$2 = 2 \qquad \therefore\ x = 9 \text{ satisfies the equation.}$$

(d) *Solve and verify*:

$$(x+4)^2-(3-x)^2 = 21x.$$

Solution:

$$(x+4)^2-(3-x)^2 = 21x.$$

By multiplying out we get

$$(x^2+8x+16)-(9-6x+x^2) = 21x$$

and removing brackets we have

$$\cancel{x^2}+8x+16-9+6x-\cancel{x^2} = 21x$$
$$14x+7 = 21x$$
$$7x = 7$$
$$\therefore\ x = 1 \quad \textit{Answer.}$$

Verification:

$$(x+4)^2-(3-x)^2 = 21x$$
$$(1+4)^2-(3-1)^2 = 21$$
$$5^2-2^2 = 21$$
$$25-4 = 21$$
$$\therefore\ x = 1 \text{ satisfies the equation.}$$

Exercise 9

Solve the following equations:

1. $x+4 = 7-2x$
2. $2(x-3)-x = 3(x-7)+1$
3. $(x-3)(3x-7) = 3x^2-5x+12$
4. $\tfrac{1}{7}(x+7)+\tfrac{1}{3}(x-3) = \dfrac{x}{3}+\dfrac{11}{7}$
5. $\tfrac{1}{5}(x-5)+\dfrac{3x}{20} = \dfrac{13x}{4}+\dfrac{3}{5}$
6. $(4x-3)^2+12(x-2)+3 = 16x^2-2x-10$
7. $4x-\tfrac{1}{2}(x-1) = x+\tfrac{2}{5}(x-1)+24$
8. $(3x-7)(12x+3) = (6x-7)^2+9$

SIMULTANEOUS EQUATIONS

When two equations of the first degree connect two unknown quantities, they are said to be "Simple Simultaneous Equations". Consider the equation $x+y = 4$, in which there are two

unknown quantities, x and y. The information given in this equation is obviously insufficient to find a numerical value for either x or y. If, however, two such equations containing x and y were given, they could be brought together and so operated upon as to eliminate y, thus leaving a numerical value for x.

Example 25

$$\left.\begin{array}{ll}\text{(a)} & x+y=4\\ \text{(b)} & x-y=2\end{array}\right\}\ \text{add (a) and (b)}$$

$$\begin{array}{ll} & 2x=6\\ \therefore & x=3.\end{array}$$

By substituting this value of x in either equation (a) or (b) the value of y may be found.

(a) $x+y=4$

$3+y=4 \qquad \therefore y=4-3=1.$ *Answers* $x=3; y=1$

which may be verified by substituting those values of x and y in the equations.

Example 26

Solve

(a)	$2x+y=10$	Substitute $x=2$ in (b)
(b)	$x+3y=20$	
Multiply (a) by 3 to obtain (c)	$6x+3y=30$	$x+3y=20$
(b)	$x+3y=20$	$2+3y=20$
by subtraction	$5x=10$	$3y=20-2=18$
	$x=2$	$y=6$

Answers $x=2; y=6$

Either (a) or (b) has to be altered before one of the unknowns can be eliminated. In this case (a) was multiplied throughout by 3 giving (c); then (b) was subtracted from (c) to eliminate y.

Example 27

Solve

(a)	$3x-12y=-135$	Substitute $x=7$ in (b)
(b)	$13x+8y=195$	
Multiply (a) by 2 and (b) by 3 to obtain (c)	$6x-24y=-270$	$13x+8y=195$ $91+8y=195$
(d)	$39x+24y=585$	$y=\frac{104}{8}=13$
by addition	$45x=315$	
	$x=7$	*Answers* $x=7, y=13$

Example 28

Solve

(a) $\frac{1}{2}x+\frac{1}{5}y = 5$

(b) $\frac{1}{3}x-\frac{1}{2}y = -3$

(c) $5x+2y = 50$

(d) $2x-3y = -18$

(e) $15x+6y = 150$

(f) $4x-6y = -36$

$19x = 114$

$\therefore x = 6$

Substitute $x = 6$ in (c)

$5x+2y = 50$

$30+2y = 50$

$2y = 20$

$y = 10$

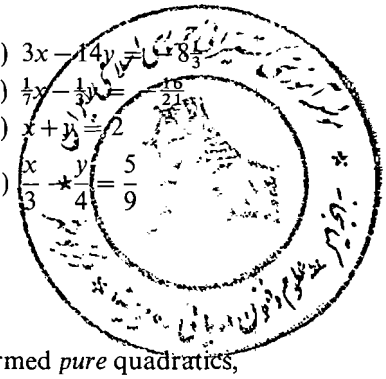
Answers $x = 6; y = 10$

(a) and (b) are first cleared of fractions, for which purpose (a) is multiplied by 10 and (b) by 6, giving (c) and (d) respectively. (c) is then trebled and (b) doubled in order to equalise the coefficient of y, giving (e) and (f) respectively, the sum of which eliminates y and thus solves the equation for x.

Exercise 10

Solve the following simultaneous equations:

1. (a) $x+y = 13$ (b) $x-y = 3$
2. (a) $2x+y = 47$ (b) $x-3y = 6$
3. (a) $3x-8y = 6$ (b) $2x-3y = -13\frac{1}{3}$
4. (a) $2x+3y = 1$ (b) $3x-2y = 21$
5. (a) $7x+y = 5$ (b) $3x-14y = -8\frac{1}{3}$
6. (a) $\frac{1}{3}x-\frac{1}{5}y = 2\frac{3}{5}$ (b) $\frac{1}{7}x-\frac{1}{3}y = \frac{16}{21}$
7. (a) $\frac{3}{4}x-\frac{2}{5}y = 3\frac{4}{5}$ (b) $x+y = 2$
8. (a) $\frac{x}{2}-\frac{y}{3} = 1$ (b) $\frac{x}{3}+\frac{y}{4} = \frac{5}{9}$



QUADRATIC EQUATIONS

Equations which involve the square only of the unknown quantity are termed *pure* quadratics, such as (a) $ax^2 = b$; (b) $3x^2+12 = 150$; (c) $11(x^2-4) = 5(x^2+2)$.

Example 29

Solve

(a) $ax^2 = b \quad \therefore x^2 = \frac{b}{a}; \quad x = \pm\sqrt{\frac{b}{a}}.$

(b) $3x^2+12 = 150 \quad \therefore 3x^2 = 138; \quad x^2 = 46; \quad x = \pm\sqrt{46}.$

Note the $\pm$ signs because $-\sqrt{46} \times -\sqrt{46} = +46 = x^2$.

(c) $11(x^2-4) = 5(x^2+2)$.

Simplifying $11x^2-44 = 5x^2+10$

Transposing $6x^2 = 54, \quad x^2 = 9, \quad x = \pm 3$ *Answer.*

Equations which involve both the square and the simple power of the unknown quantity are termed complete, or adfected quadratics, such as (a) $ax^2+bx = c$; (b) $(x-3)^2 = 25$; (c) $2x^2+34 = 20x+2$; (d) $3x^2-2x = 65$.

Example 30

Solve

(b) $(x-3)^2 = 25$.

Multiplying $x^2-6x+9 = 25$

Rearranging $x^2-6x-16 = 0$

Factorising $(x-8)(x+2) = 0$ $\therefore x = 8$ or -2 *Answer.*

(c) $2x^2+34 = 20x+2$.

Transposing $2x^2-20x+32 = 0$

Dividing by 2 $x^2-10x+16 = 0$

Factorising $(x-8)(x-2) = 0$ $\therefore x = 8$ or 2 *Answer.*

Both examples (b) and (c) lend themselves to factorisation, but when this cannot be done the method of completing the square is adopted to arrive at a solution using the following order of work.

1. Transpose all the known quantities, when necessary, to one side of the equation, arrange all the terms involving the unknown quantity on the other side, and reduce the equation to the form $ax^2+bx = c$, x being the only unknown.
2. Divide each side of the equation by the coefficient of x^2.
3. Add to each side of the equation the square of half the coefficient of the simple power of x.

That member of the equation which involves the unknown quantity will thus be rendered a perfect square, and extracting the root on both sides, the equation will be reduced to one of the first degree, which may be solved in the usual manner. Taking Example 30(c) for illustration we have

$$x^2-10x = -16.$$

Add to each side the square of half the coefficient of x.

$$x^2-10x+(5)^2 = -16+(5)^2$$
$$(x-5)^2 = -16+25 = 9.$$

Extract root of both sides $x-5 = \pm\sqrt{9} = \pm 3$

$\therefore x = 5+3$ or $5-3 = 8$ or 2 *Answer.*

Solve

(d) $3x^2-2x = 65$.

Dividing by 3 $x^2-\frac{2}{3}x = \frac{65}{3}$.

Completing the square $x^2-\frac{2}{3}x+(\frac{1}{3})^2 = \frac{65}{3}+(\frac{1}{3})^2$

$(x-\frac{1}{3})^2 = \frac{65}{3}+\frac{1}{9} = \frac{196}{9}$.

Extract root both sides $x-\frac{1}{3} = \pm\sqrt{\frac{196}{9}} = \pm\frac{14}{3}$

$\therefore x = \frac{1}{3}+\frac{14}{3}$ or $\frac{1}{3}-\frac{14}{3} = 5$ or $-4\frac{1}{3}$ *Answer.*

Solve $(x+1)(2x+3) = 4x^2-22$.

Multiply out $2x^2+5x+3 = 4x^2-22$.

Transpose $-2x^2+5x = -25$.

Divide by 2 and change the signs $x^2 - \frac{5}{2}x = \frac{25}{2}$.

Complete the square $x^2 - \frac{5}{2}x + (\frac{5}{4})^2 = \frac{25}{2} + (\frac{5}{4})^2$

$$(x - \tfrac{5}{4})^2 = \frac{200+25}{16} = \tfrac{225}{16}.$$

Extract the root $x - \frac{5}{4} = \pm\sqrt{\frac{225}{16}} = \pm\frac{15}{4}$

$\therefore x = \frac{5}{4} + \frac{15}{4}$ or $\frac{5}{4} - \frac{15}{4} = 5$ or $-\frac{5}{2}$ *Answer.*

Exercise 11

1. $x^2 + x - 2 = 0$
2. $x^2 + 14x = 32$
3. $x^2 - x = 72$
4. $x^2 - x = 156$
5. $12x - 210 = 210 - 3x^2$
6. $5x^2 + 14x = 55$
7. $5x^2 + 11x = 12$
8. $x^2 + 6x = 187$

Exercise 12 (Miscellaneous problems)

1. Two ships 150 miles apart steer on opposite courses to meet each other. Ship *A* steams at 8 knots, and *B* at 7 knots. In what time will they meet?
2. A tank can be emptied by two taps of unequal bore in 12 minutes, but by one of the taps alone in 30 minutes. How many minutes should it take to empty the tank if the other tap alone were turned on?
3. The boatswain and the carpenter have the same income. The boatswain saves $\frac{1}{5}$ of his yearly income, but the carpenter by spending £500 per year more than the boatswain finds at the end of the year that he is £250 in debt. What are their incomes?
4. A post is $\frac{1}{4}$ in the mud, $\frac{1}{3}$ in the water and 10 feet above the water. What is its whole length?
5. The new third officer bought a second hand sextant, some navigation books and some kit etc. for £600. The sextant cost twice as much as the books and the kit was twice the price of the sextant and books. What did he give for each?
6. The chief officer and chief engineer invest equal sums of money in different concerns. The officer gains £126, and the engineer loses £87, and the chief officer's money is now double that of the chief engineer's. What did each lay out?
7. After paying away one-quarter and one-third of his wages for a run job, the second officer finds he has £69·50 left. What was he paid off with?
8. The chief officer's wage per month is double the third officer's, and the third officer's is treble that of the senior apprentice, the total sum being £2000 per month. How much per month had each?
9. A stevedore's gang were due £30 each, but the stevedore found that he had not money enough to pay them in full by £80, so he gave each man £20 to account and had £30 remaining. How many men were in the gang?
10. After steaming 105 miles it is found that if the speed had been 2 knots less the ship would have been 6 hours longer in covering the distance. What was her speed?
11. A hydroplane travelling at 40 knots covers a certain distance in 3 hours less than another hydroplane whose speed is 30 knots. Find the distance.
12. Two rowing boats cross a bay in opposite directions, one at 5 miles per hour, the other at 4 miles per hour. The distance is 30 miles, when will they meet?
13. A person can row down stream at the rate of 6 miles per hour, and against it at 2 miles per hour. Find his rate and the rate of the stream.

14. A man rows 20 miles up a river in 3 hours 20 mins, and back in 2 hours. Supposing him to row uniformly, calculate the velocity of the current.
15. To cover a distance of 90 miles, 3 hours less would suffice if the ship went 5 miles an hour faster. What was the ship's speed?
16. In a concert hall, 800 persons are seated on benches of equal length. If there were 20 fewer benches it would be necessary that two persons more should sit on each bench. Find the number of benches.
17. A motor boat which goes 9 knots in still water takes twice as long to go up a river against the tide as she takes to go down with the tide. Find the rate of the tidal stream.
18. Find five consecutive numbers whose sum is 45.
19. Divide 85 into two parts such that one-fourth of one part may be equal to one-sixth of the other part.
20. The fourth officer is paid off with three times as much as the senior apprentice and between them they have £4000. What has each?
21. If A can do a job of work in 5 hours, B in 8 hours, and C in 10 hours, in what time can they do it working together.
22. Two speed boats set out at the same time from places 390 miles apart to meet each other. One travels at 30 miles per hour, and the other at 22 miles per hour, when will they meet?
23. A boat's crew can row up and down a stretch of river 16 miles long in 10 hours, the flow of the stream being 3 miles per hour. Required the speed of rowing in still water.
24. A stevedore's gang No. 1 can discharge a ship's cargo in 10 days, gang No. 2 in 12 days, gang No. 3 in 15 days. In what time can they do it working together?

(Answers in the rear Answer Section.)

Chapter 2

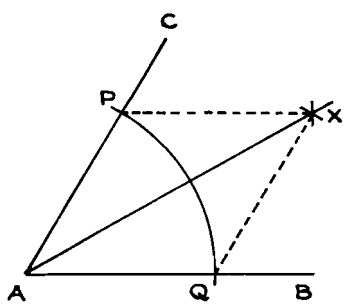
Geometry

Much of navigation is based on trigonometry, and trigonometry is a combination of algebra and geometry. The following pages include the elementary principles of practical geometry as they enter largely into the application of theoretical and practical navigation. This chapter is intended to provide practice in the use of compasses, scale and ruler. The student who does not draw separate and independent figures should, at least, go over each figure with the compasses and ruler and be satisfied that the explanations are accurate and the figures correctly drawn.

Bisecting an Angle

Given the angle BAC to be bisected.

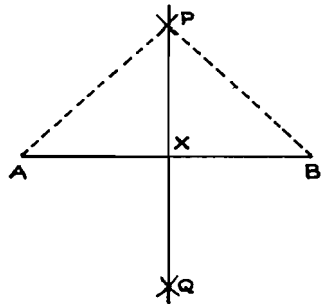
With centre A and any radius, describe an arc cutting AC and BC in P and Q respectively. With centres P and Q and same radius PQ, draw two arcs cutting at X. Join AX. Then AX is the bisector of the angle BAC. If PX and QX be joined it will be seen that $\triangle APX = \triangle AQX$ in all respects $\therefore \angle PAX = \angle QAX$.



Bisecting a Straight Line

Given the straight line AB to be bisected.

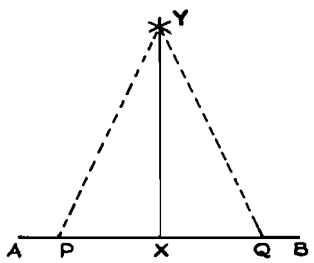
With centre A and any radius more than half AB, draw an arc on each side of it. With centre B and the **same** radius draw an arc on each side of AB to cut the first arcs at P and Q.



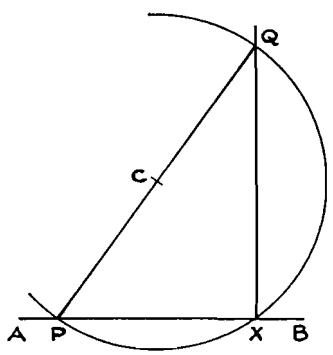
Join P and Q. Then PQ bisects AB at X. If PA and PB be joined it will be seen that $\angle AXP = \angle BXP$ and these being adjacent angles each must be 90°.

To Draw a Straight Line Perpendicular to a Given Straight Line from a Given Point on that Line

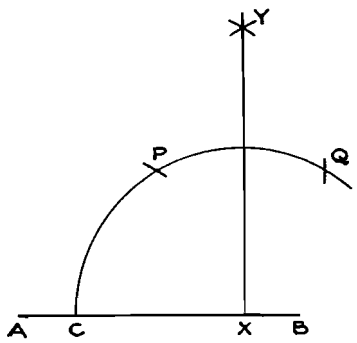
Method 1 Given the straight line AB. Required to erect a perpendicular from the given point X. With centre X cut off any two equal parts XP and XQ from AB. With centres P and Q and any radius draw two arcs cutting at Y. Join XY. Then YX is perpendicular to AB because $\angle YXP = \angle YXQ = 90°$.



Method 2 Take any point C outside AB and with centre C and radius CX draw a circle cutting AB at P and X. Join PC and produce to cut the circle at Q. Join QX. Then QX is perpendicular to AB because **the angle in a semicircle is a right angle**, and PXQ is a semicircle of which PCQ is the diameter.

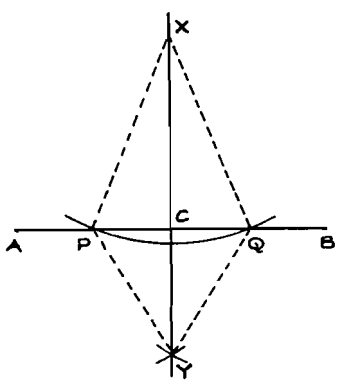


Method 3 With centre X and any radius describe a circle cutting AB at C. With centre C and the **same** radius draw an arc cutting the first at P. With centre P and the **same** radius draw an arc cutting the first at Q. With centres P and Q and still the **same** radius draw two arcs cutting at Y. Join XY. Then XY is perpendicular to AB.

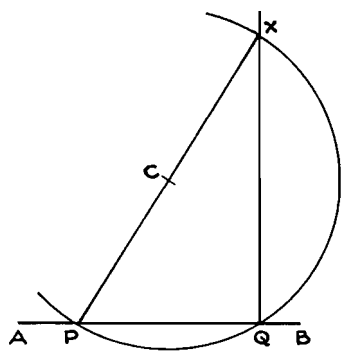


To Draw a Straight Line Perpendicular to a Given Straight Line from an External Point

Method 1 Given the straight line AB and X a point outside of it. Required to draw a straight line perpendicular to AB from X. With centre X and any radius draw an arc cutting AB at P and Q. With centres P and Q draw two arcs cutting at Y. Join XY cutting AB at C. Then CX is perpendicular to AB because $\triangle CXQ = \triangle CXP$ by construction and therefore $\angle XCQ = \angle XCP = 90°$.



Method 1

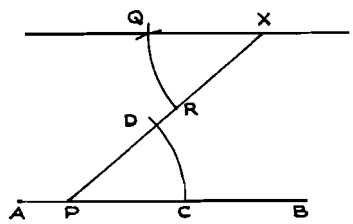


Method 2

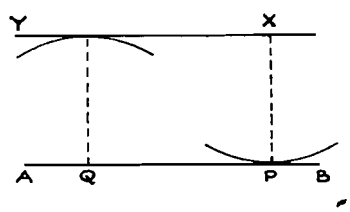
Method 2 Take any point P in AB and join PX. With centre C (the mid point of PX) and radius CX draw a circle cutting AB at Q. Join QX. Then QX is perpendicular to AB because **the angle in a semicircle is a right angle**. This is an important theorem which enters into the solution of many nautical problems in trigonometry.

To Draw a Straight Line Parallel to a Given Straight Line Through any Given Point

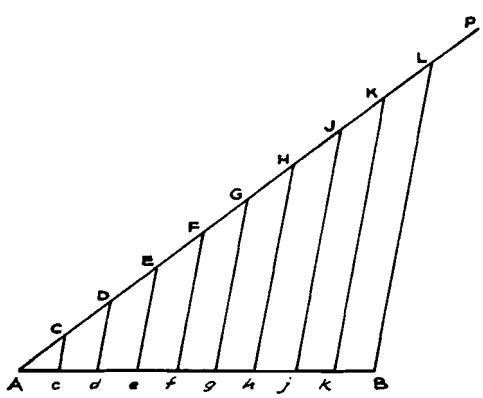
Method 1 Given AB a straight line and X any point. Required to draw a straight line through X parallel to the given line AB. Take any point P in AB. Join PX. With centre P and any radius draw the arc DC, and with centre X and the **same** radius draw an arc cutting XP at R. With centre R and chord DC cut off RQ. Join QX. Then QX is parallel to AB because **the alternate angles QXP and XPB are equal.**



Method 2 With centre X draw an arc to which AB will be a tangent. Take any point Q in AB and with the **same** radius draw a similar arc on the same side of AB as X. From X draw XY a tangent to the second arc. Then XY is parallel to AB. **The perpendicular distance between two parallel straight lines is the same at all points.**



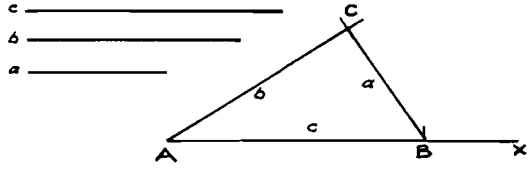
To Divide a Given Straight Line into any Number of Equal Parts



Given AB. Required to divide it into any number of equal parts (say 9). From A draw AP of **any** length and making **any** angle with AB. From AP mark off 9 equal parts of **any** convenient length with the compasses, viz., AC, CD, DE, EF, FG, GH, HJ, JK and KL. Join LB, and through C, D, E, F, G, H, J and K, draw parallels to LB meeting AB respectively at c, d, e, f, g, h, j and k. Then since these parallels cut off 9 equal parts from AP they also cut off 9 equal parts from AB.

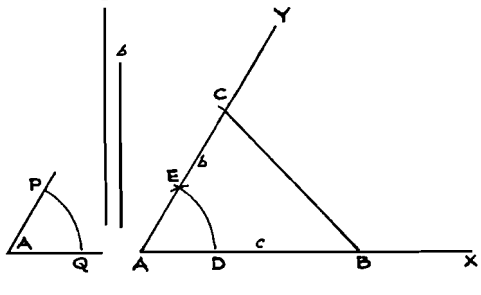
To Draw a Triangle From Given Data

In order to completely determine the size of triangles **three** parts must be known (although any three parts do not necessarily serve the purpose).

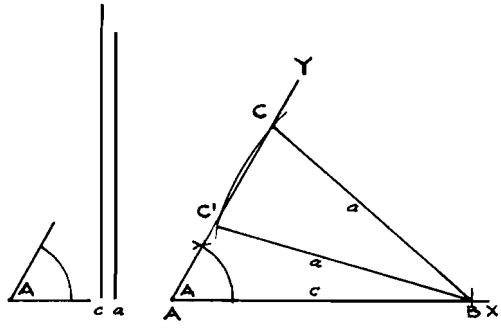


1. **Given three sides** a, b and c of given length. Required to form them into a triangle ABC. Draw any straight line AX and cut off $AB = c$. With centre A and radius b describe an arc. With centre B and radius a describe an arc cutting the first arc at C. Join BC and AC. Then ABC is the required triangle because $AB = c$, $AC = b$ and $BC = a$.

Note a, b and c may be understood as three actual lines to which the sides of the triangle are to be equal or three numbers expressing the lengths of the sides in linear units, thus 8, 6 and 4.

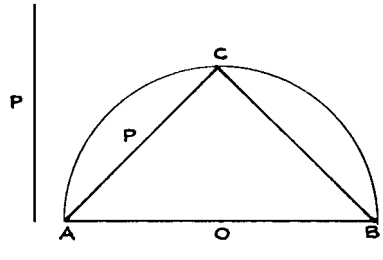


2. **Given two sides and the included angle.** Given lines c and b and angle A. Required to construct $\triangle ABC$. Take any straight line AX and from it cut off $AB = c$. Take any radius and describe the arc PQ. With **same** radius and centre A describe the arc DE. With centre D and chord PQ cut off DE. Join AE and produce to Y. From AY cut off $AC = b$. Join CB. Then ABC is the triangle required, because $AB = c$, $AC = b$ and $\angle BAC = \angle a$.



3. **Given two sides and an angle opposite one of them.** Given a, c and A. Required to construct the $\triangle ABC$. Take any straight line AX and cut off $AB = c$. At A make $\angle XAY = \angle A$ as in (2). With centre B and radius a draw an arc cutting AY. If this arc cuts AY in two points C and C' both on the same side of A, both $\triangle$s ABC and ABC' satisfy the conditions.

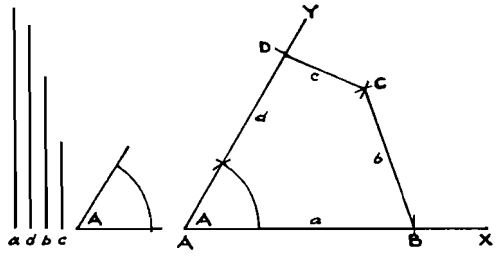
This is the **Ambiguous Case and will occur when a is less than c; *i.e.* when the side opposite the given angle is less than the other given side.**



4. **Given hypotenuse and one side of a right-angled triangle.** Given AB the hypotenuse and P the given side. Required to draw a right-angled triangle ABC. Bisect AB at O. With centre O and radius OA describe a semicircle on AB. With centre A and radius P draw an arc to cut the semicircle at C. Join AC and BC. Then ABC is the required triangle. $\angle ACB$ **is a right angle, being the angle in a semicircle, and** $AC = P$.

To Draw a Quadrilateral From Given Data

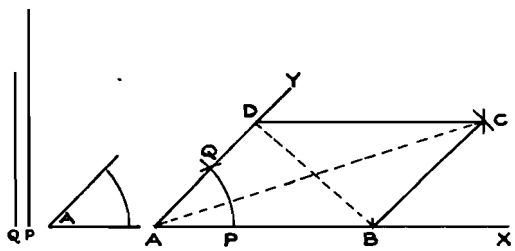
In order to completely determine the size of any quadrilateral **5 parts** must be known.



Given the lengths of 4 sides a, b, c and d, and one angle A. Required to draw the quadrilateral $ABCD$. Take any straight line AX and from A cut off $AB = a$. At A make $\angle BAY = \angle A$. From AY cut off $AD = d$. With centre B and radius $= b$ draw an arc. With centre D and radius $= c$ draw an arc to cut the previous one at C. Join DC and BC. Then $ABCD$ is the required quadrilateral.

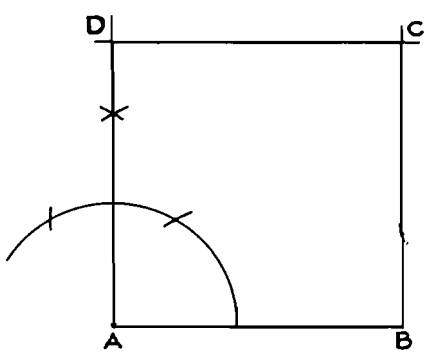
To Draw a Parallelogram When Given Two Adjacent Sides and the Included Angle

Given P and Q the two adjacent sides of a parallelogram and angle A the angle contained by them. Take any straight line AX and from it cut off $AB = P$. At A make the angle $BAY = \angle A$. From AY cut off $AD = Q$. With centre D and radius P draw an arc. With centre B and radius Q draw an arc cutting the first at C. Join DC and BC. Then $ABCD$ is the required parallelogram.



To Draw a Square on a Given Side

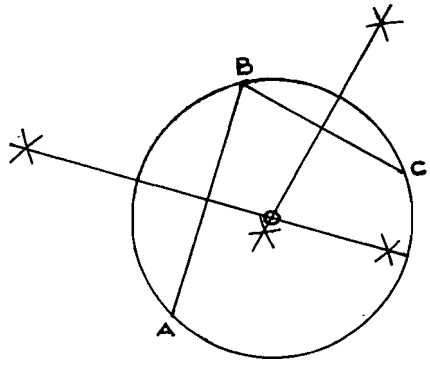
Given the side AB. Required to draw a square on AB as one side. At A erect a perpendicular by any of the methods previously described and cut off $AD = AB$. With centre B and radius AB describe an arc. With centre D and radius AB describe an arc cutting the first at C. Join DC and BC. Then $ABCD$ is the required square; the sides AB, BC, CD and DA being equal and all the angles being right angles.



To Draw a Circle Through any Three Points

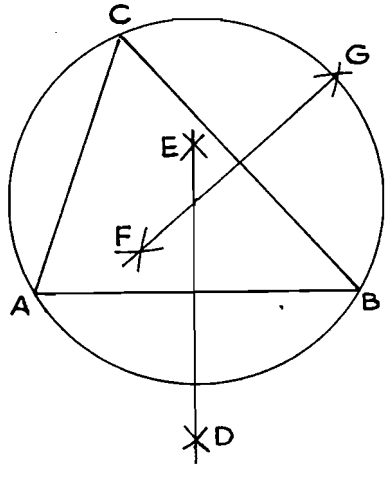
Given the three points *A*, *B* and *C*. Required to draw a circle passing through them. Join *AB* and *BC* and bisect each line, *AB* and *BC*. The point *O* at the intersection of the bisectors is the centre of the circle passing through *A*, *B* and *C*.

Because the line bisecting a chord at right angles passes through the centre of the circle and, conversely, a line drawn from the centre of the circle perpendicular to any chord bisects that chord.



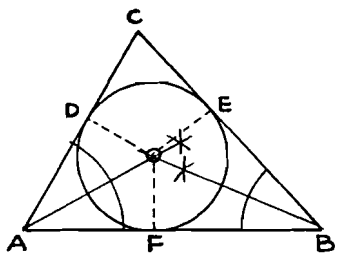
To Describe a Circle About a Triangle

Given the triangle *ABC*. Required to circumscribe a circle about it, that is a circle passing through the points *A*, *B* and *C*. Bisect any two sides, say *AB* and *BC*. Then *O* the point of intersection of the bisectors is the centre of the required circle. With centre *O* and radius *OA* or *OB*, or *OC*, draw a circle which will pass through *A*, *B* and *C*.



To Draw a Circle Inside a Triangle

Given the triangle ABC. Required to draw a circle inside it; touching the three sides of the triangle. Bisect any two angles, say A and B. Then O the point of intersection of the bisectors is the centre of the required circle. From O drop OF perpendicular to AB. With centre O and radius OF draw the inscribed circle to touch the three sides of the triangle at D, E and F.

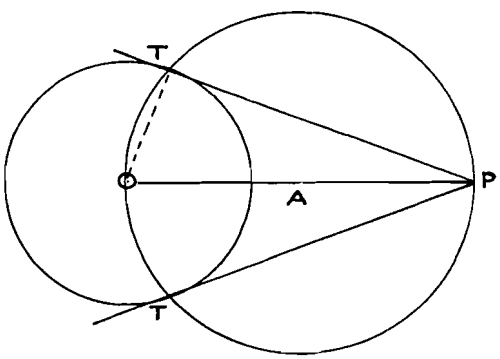


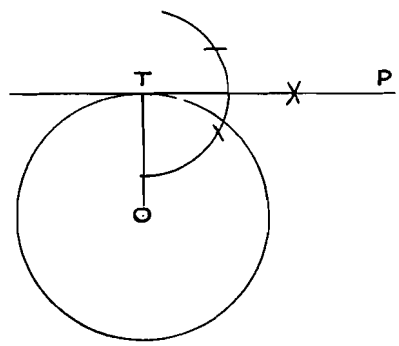
To Draw a Tangent to a Given Circle (1) From a Given External Point, (2) From a Given Point on the Circumference

1. Given any circle and P a point outside it. Required to draw a tangent to the circle from P. Find O the centre of the circle. Join OP. Bisect OP at A and with AO as radius draw a circle to cut the given circle at T and T'. Join PT and PT'. Then PT and PT' are the only tangents that can be drawn to the circle from P.

The radius OT drawn from the point of contact T is always at right angles to the tangent and, conversely, the perpendicular to the tangent drawn from the point of contact T passes through the centre of the circle.

PT must, therefore, be the tangent because **the angle in a semicircle, $\angle PTO$, is a right angle.**

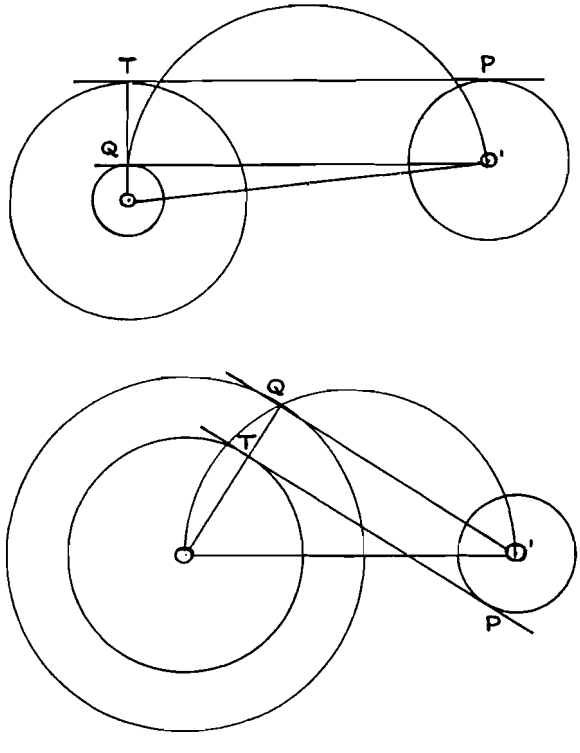




2. Given any circle and T any point on the circumference. Required to draw a tangent to the circle at T. Join T to O the centre of the circle, at T erect a perpendicular by any of the methods previously described. Then TP is the required tangent because **it is at right angles to the radius OT.**

To Draw a Common Tangent to Two Circles

Given two circles with centres O and O'. Required to draw a common tangent to both circles. With centre O and radius equal to the **difference** of the radii of the two given circles, $OT - O'P = OQ$, describe a circle and draw the tangent from O' to touch it at Q. Join OQ and produce to meet the outer circle at T. Through O' draw the radius $O'P$ parallel to OT. Join PT. Then PT is the common tangent to both circles because $\angle OTP$ and $\angle O'PT$ are right angles.

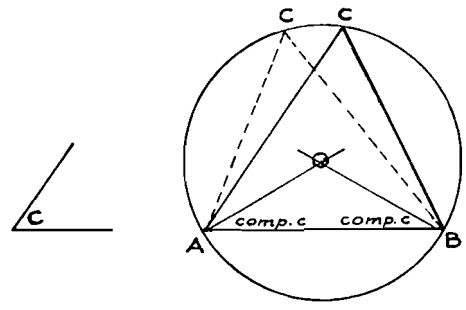


Construction is the same as above but with centre O and radius equal to the **sum** of the radii of the two given circles, $OT + O'P = OQ$, describe a circle with OQ as radius. Join OO'. Bisect OO' and describe a semicircle cutting the constructional circle at Q. Join $O'Q$. Draw TP parallel to QO'. TP is the tangent required.

On a Given Straight Line to Draw a Segment of a Circle Which Shall Contain a Given Angle

Method 1 Given the straight line AB and the angle C. Required to draw a circle through A and B which will contain the angle C at the circumference, standing on the chord AB. At A and B lay off the complement of the angle C. Then O is the centre of the required circle.

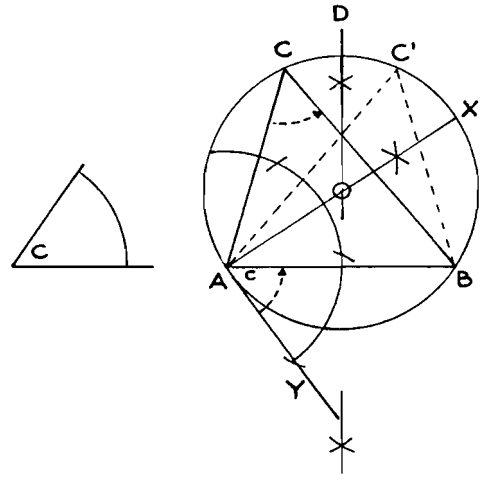
The angle at the centre of a circle is twice the angle at the circumference standing on the



same chord. If we take a value for $\angle C$, say 40°, the complement of 40° is 50°, *i.e.* $\angle BAO = 50°$ and $\angle ABO = 50°$, $\therefore \angle AOB = 80°$.

The angle at the circumference standing on the same chord is half the angle at the centre, $\therefore \angle ACB = \frac{1}{2} \angle AOB = 40°$.

All the angles in the same segment of any circle standing on the same chord or arc are equal, *i.e.* $\angle ACB = \angle AC'B$.



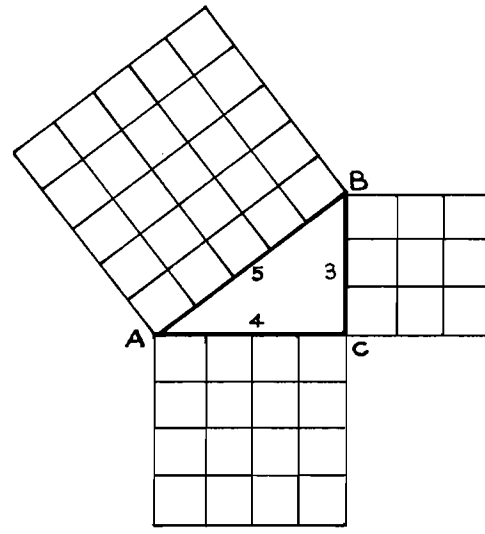
Method 2 Given a straight line AB and any angle C. Required to draw a circle through A and B to contain an angle equal to C. Bisect AB, OD is the bisector. At A make $\angle BAY = \angle C$. At A make AX perpendicular to AY meeting the bisector of AB at O. Then O is the centre of the required circle.

The angle between the tangent and the chord in any circle is equal to the angle in the alternate segment, ***i.e.*** $\angle BAY = \angle ACB$.

To Demonstrate the Pythagoras Theorem by Construction

Construct a right-angled triangle ABC whose sides AB, AC and BC are respectively equal to 5, 4 and 3 units and angle $C = 90°$.

On AB describe a square. Divide each side into 5 equal parts and join the corresponding points each to each so that the square on AB is divided into 25 equal squares.



On AC describe a square. Divide each side into 4 equal parts and join the corresponding points each to each so that the square on AC is divided into 16 equal squares.

On BC describe a square and divide it similarly into 9 equal squares.

The area of the square on AB is equal to the area of the square on BC plus the area of the square on AC. This is obvious from the figure, for if the square on AC were lifted up and placed on the square on AB it would cover 16 of the small squares, leaving 9 of them to be covered by the 9 small squares in the square on BC.

$$\begin{aligned} AB^2 &= AC^2 + BC^2 \\ 5^2 &= 4^2 + 3^2 \\ 25 &= 16 + 9 \\ 25 &= 25 \end{aligned}$$

thus demonstrating this important theorem which enters largely into trigonometry and navigation.

SUMMARY OF PROPERTIES OF TRIANGLES AND CIRCLES

The geometrical properties of triangles and circles deduced from the foregoing propositions may be summarised as follows.

Triangles

An **equilateral** triangle has three sides and three angles equal. An **isosceles** triangle has two sides and two angles equal.

1. Two triangles are equal in all respects, if

(a) Three sides in one are equal to three sides in the other each to each.
(b) Two sides and the included angle in one are equal to the corresponding two sides and the included angle in the other.

(c) Two angles and one side are equal to the corresponding two angles and one side in the other, or two sides and an angle of one are equal to the corresponding two sides and angle of the other.
(d) In a right-angled triangle the hypotenuse and one side in one are equal to the hypotenuse and the corresponding side in the other.

2. Two triangles are similar or equiangular if the three angles are equal, and if two triangles are similar the corresponding sides are proportional.

Parallel Lines

3. If a straight line cuts two parallel straight lines the alternate and the corresponding angles are equal.
4. The perpendicular distance is the shortest distance between two parallel straight lines.
5. The opposite sides of a parallelogram are equal and parallel and the diagonals bisect each other.

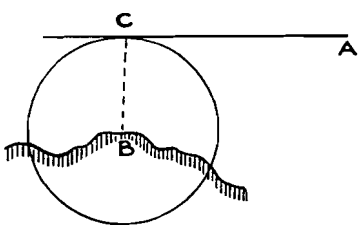
Circles

6. A line which bisects a chord of a circle at right angles passes through the centre, and conversely a line drawn from the centre of a circle perpendicular to a chord bisects it.
7. The radius drawn to the point of contact is perpendicular to the tangent.
8. The angle at the centre of a circle is twice the angle at the circumference subtended by the same chord or arc.
9. The angle in a semicircle is a right angle.
10. The angle between a tangent and a chord is equal to the angle in the alternate segment.

The following examples may serve to illustrate the practical application of geometrical principles to navigational problems.

Example 1

To lay off on a chart the course to steer to pass a given distance from a shore object.



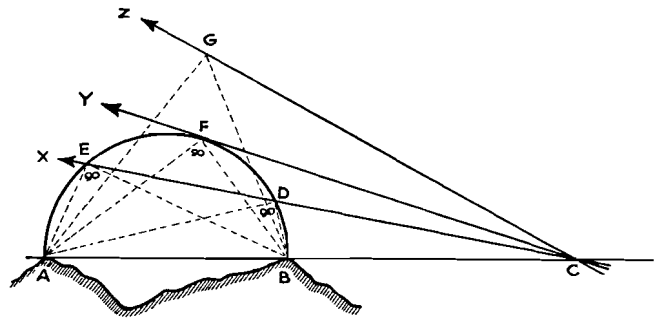
Given B a lighthouse and A the position of the ship, it is required to lay off the course to pass 5 miles from B. With centre B and radius 5 miles describe a circle. From A draw the tangent to this circle as described above. Then the tangent AC is the course to steer and BC is the beam bearing. In practice the tangent AC is drawn in by eye.

Example 2

The maximum horizontal angle between two points.

Suppose A and B to be any two conspicuous objects, then ABC will be their transit line of bearing. Bisect AB and draw a semicircle AFB. The angle in a semicircle is a right angle.

Imagine a ship at position C having A and B in transit, and let us trace out the changes in the horizontal angle subtended by A and B when she sails on three selected courses.



1. If she sails along the line CX, the horizontal angle between A and B will gradually open out, it will be 90° when the ship is at D, increase to a maximum greater than 90° when she is within the circle, then diminish and be 90° again when the ship reaches position E.

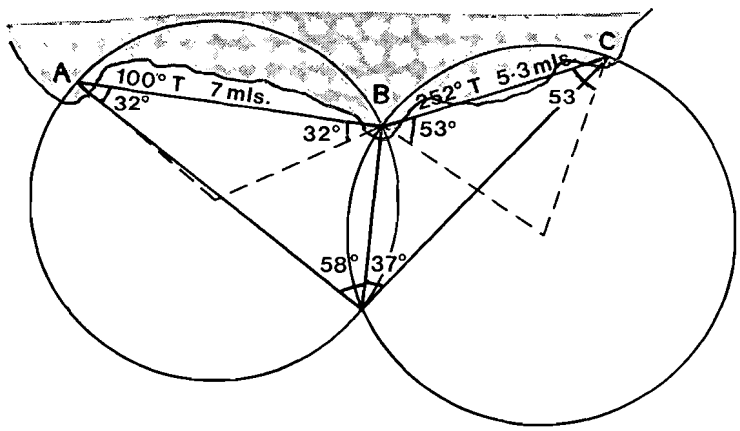
2. If she sails along the line CY, then the horizontal angle increases and reaches a maximum of 90° when the ship is at position F, because F is the point of contact of the tangent course CY. After passing F the angle decreases.

3. If she sailed along the line CZ, the horizontal angle will increase from 0° at position C, as before, to a maximum angle which, obviously, will be less than 90°, say at position G, and beyond G the angle will decrease.

Example 3

The geometry of the station pointer.

The horizontal sextant angles between A and B is 58°, and between B and C 37° (usually written A 58° B 37° C), find the position of the ship if B bears 100° T from A, distant 7 miles, and 252° T from C, distant 5·3 miles.

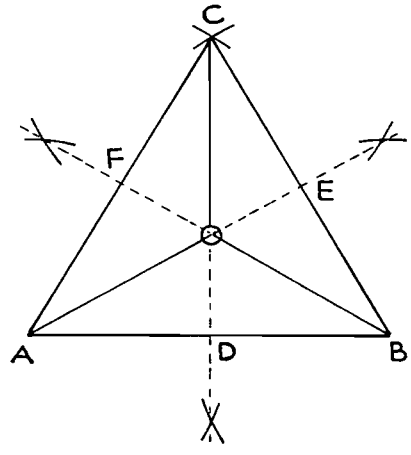


Lay off the points A, B and C relatively to each other. Join A and B. At A and B lay off angles equal to the complement of the horizontal angle between them, $90° - 58° = 32°$. With the point of intersection of these lines as centre draw a circle through A and B. The angle at the centre of this circle is therefore 116° and at the circumference 58°. The ship is somewhere

on the circumference of this circle. Join BC, and at B and C lay off angles equal to the complement of the horizontal angle between them, $90° - 37° = 53°$. With the point of intersection of these lines describe a circle passing through B and C. The angle at the centre of this circle is 74°, and on its circumference the angle is 37°. The ship is somewhere on this circle and must therefore be at the intersection of the two circles. Join OA, OB and OC. The angle $AOB = 58°$, and angle $BOC = 37°$, or as stated in the question A 58° B 37° C.

Example 4

A ship is moored within a triangle formed by three buoys A, B and C. Each buoy is 2 miles apart and the ship is in such a position that the horizontal angles between each pair of buoys are equal. Find, by measurement, the distance of the ship from either of the buoys.



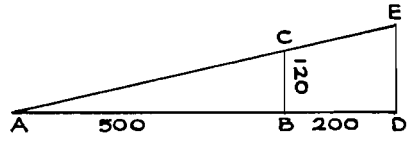
Draw the triangle ABC making $AB = BC = AC = 2$. Drop perpendiculars from A, B and C to CB, AC and AB respectively. The point of intersection of these perpendiculars is the position of the ship. By measurement OC is 1·155 miles.

Note In any equilateral triangle a straight line drawn from any apex perpendicular to the opposite side bisects the triangle.

Example 5

The height of the foremost of two leading lighthouses is 120 ft and the rear lighthouse is 200 ft directly behind the fore one. An observer 500 ft from the fore lighthouse sees the tops of both in line. Deduce from your figure the height of the rear lighthouse.

Draw AB (500) to scale to represent the distance of the observer from the rear lighthouse. Erect a perpendicular BC (120). Make BD 200 to represent the distance between the lighthouses. Erect a perpendicular at D. Join AC and produce to meet the perpendicular at E.



$\triangle$s ABC and ADE are similar because $\angle A$ is common to both triangles. Angle AED = ACB (corresponding angles) and angle ABC = $\angle ADE$ (corresponding angles).

$$\frac{DE}{BC} = \frac{AD}{AB} = \frac{AE}{AC}$$

$$\frac{DE}{BC} = \frac{AD}{AB} \qquad \therefore DE = \frac{AD \,.\, BC}{AB}$$

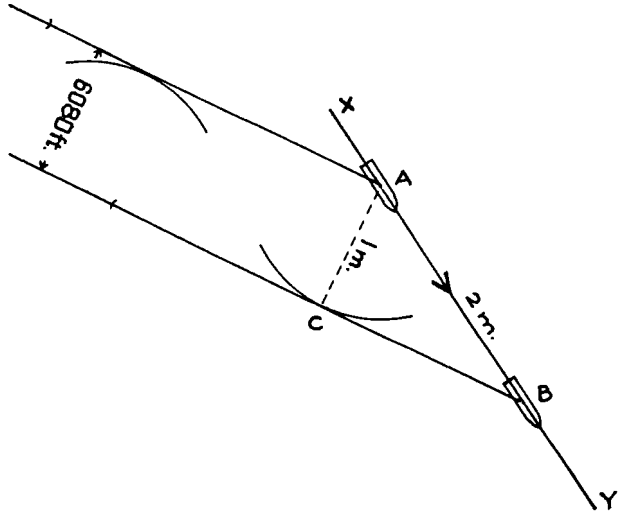
$$= \frac{700 \times 120}{500}$$

$$= \frac{840}{5}$$

$$= 168 \text{ ft.}$$

Example 6

Two measured mile posts were observed in line on the starboard quarter. Ship sailed 140° T 2 miles when the other two posts were observed in line on the same bearing. Find, from a figure drawn to scale, the course to steer on the measured mile and the transit bearings of the mile posts.



Draw XY in a 140° T direction. From any point A in XY measure AB 2 miles, from any convenient scale, to B. With centre A and radius 1 mile describe an arc of a circle.

From B draw BC a tangent to the arc and through A draw a line parallel to BC. These two parallel lines indicate the bearings of the mile posts. Join A to the point of contact C with the first arc. Then AC indicates the direction of the course to steer on the measured mile.

AB = 2 miles. AC = 1 mile. $\therefore BC = \sqrt{3}$ miles.

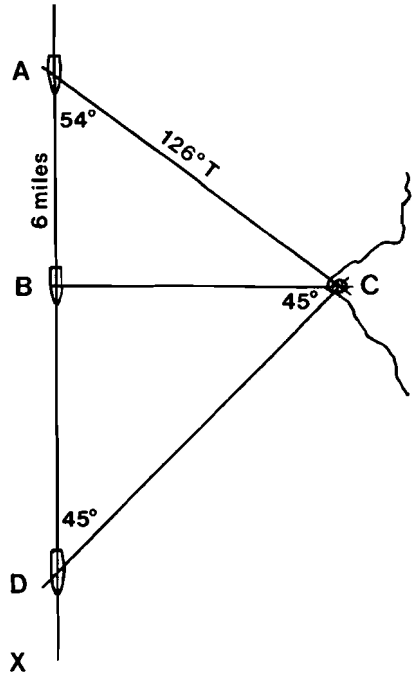
$\triangle ABC$ is half of an equilateral $\triangle$ each side of which is 2 miles. $\angle ABC = 30°$.

$\therefore \angle BAC = 60°$. Direction of AC is 200° T or 020° T.

Bearing of mile posts is therefore 290° T.

Example 7

A point bore 126° T and after steaming South for 36 minutes at 10 knots it was abeam. Find by construction the distance off when abeam, also when it was 4 points abaft the beam.



Draw a line AX due South. At A lay off the bearing 126° T. From A measure 6 miles (the distance steamed in 36 mins) to B. At B erect a perpendicular cutting the first bearing at C. At C make $BCD = 45°$. D is the position of the ship when the point was 4 points abaft the beam. Measure BC the beam distance and DC the distance when 4 points abaft the beam. Triangle BCD is a right-angled isosceles triangle.

Answer By measurement $BC = 8$ miles the beam distance, and $DC = 11$ miles, the distance off when 4 points abaft the beam.

Exercise 1

1. Draw a circle with 2-inch radius and divide it into 2, 4, 8, 16 and 32 equal parts and complete the figure as a mariner's compass similar to that given at the beginning of the book, and learn the points of the compass.
2. Construct triangles ABC from the following data, and measure the remaining parts.
   (a) $AB = 3$ inches; $\angle A = 60°$: $\angle B = 70°$.
   (b) $AB = 7$ cm; $BC = 8$ cm; $AC = 9$ cm.
   (c) $AB = 5$ cm; $BC = 7$ cm; $\angle B = 70°$.
3. From a ship steaming North two beacons were observed, one bearing North distant 3 miles, and the other East 4 miles. Find the alteration of course necessary to pass midway between them.

4. A lighthouse bore 040° T distant 6 miles by vertical sextant angle. After steaming for 1 hour at 9 knots the distance off was the same. Find by measurement the course steered and the distance off on the starboard beam.
5. A ship is moored within a triangle formed by three buoys *A*, *B* and *C*. Each buoy is 2 miles distant from the other and the ship is in such a position that the horizontal angle between *A* and *B* is 90° and the horizontal angles between *A* and *C* and between *B* and *C* are equal. Find by construction the distance of the ship from *C*.
6. Two points are in transit bearing 315° T. Ship steamed 340° T 10 miles, and the horizontal angle between the points was then at its maximum, namely 90°. Find the distance between the points.
7. Two measured mile posts were observed in line on the port quarter bearing 310°, and after steaming 1·7 miles the other pair were observed on the same bearing. Find the course steered between the bearings.
8. A ship at anchor observed the following horizontal sextant angles between three conspicuous objects *A*, *B* and *C*. *A*. 39° *B* 60° *C*. *A* bore West distant 2·5 miles from *B*, and *C* bore 080° T distant 3 miles from *B*. Find by construction and measurement the bearing and distance of the ship from *B*.
9. With $1\frac{1}{4}$-inch radius draw a semicircle. Draw a triangle in the semicircle with the diameter as one side. Find the sum of the areas of the squares on the two lesser sides and verify by drawing the squares on each side and measuring the areas.

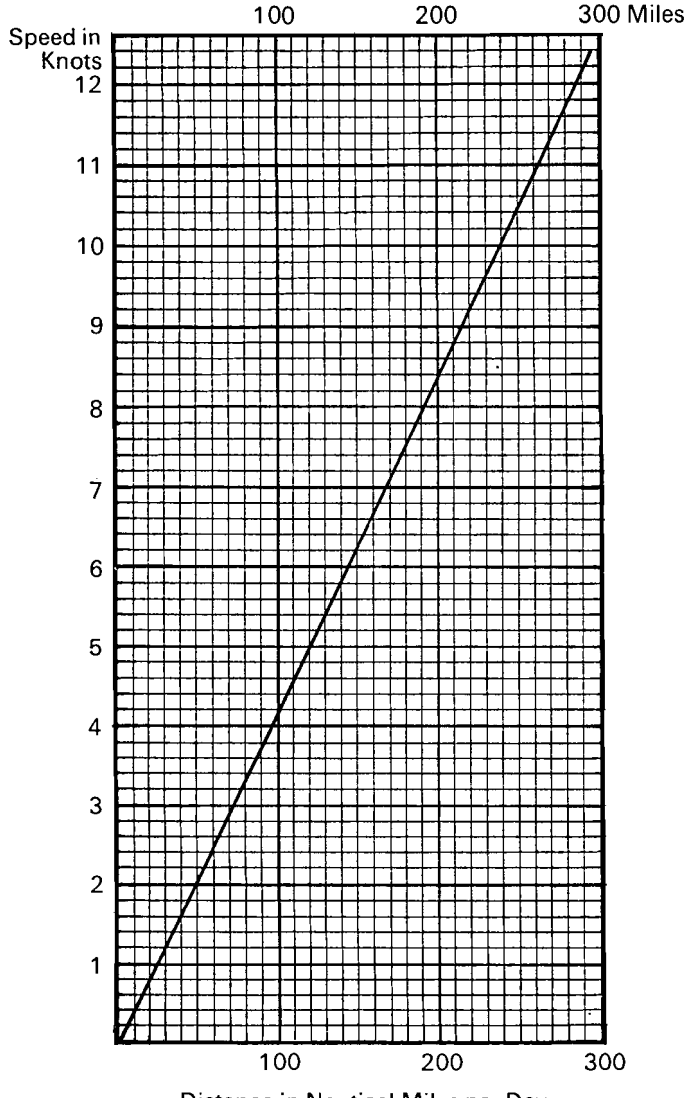
Answers

1. By construction.
2. (a) $\angle C = 50°$; $a = 3{\cdot}4$ inches; $b = 3{\cdot}7$ inches.
   (b) $\angle C = 48\frac{1}{2}°$; $\angle B = 72\frac{1}{2}°$; $\angle A = 59°$.
   (c) $\angle C = 41\frac{1}{2}°$; $\angle A = 68\frac{1}{2}°$; $b = 7{\cdot}1$ cm.
3. Alter course 53° to starboard.
4. Course 358·5° T; beam distance 3·97 miles.
5. Distance 0·732 miles.
6. Distance 9·32 miles.
7. Course 094° T.
8. Bearing 342° T; distance 2·18 miles.
9. Areas 6·25.

Chapter 3

Graphs

Graph 1
SPEED AND DISTANCE



Graphical methods are frequently employed in applied science and economics to represent statistical information in such a manner that fluctuation in values of a quantity which depend upon changes in another quantity may be seen at a glance. Squared paper is generally used, the horizontal lines are called "abscissae" and the vertical lines "ordinates".

When several successive values have been calculated and the results plotted as spots on the sectional paper, a line, called a graph, is then drawn from point to point from which values intermediate between those calculated may be read off. When the value of one variable quantity varies in direct proportion to the other the graph is a straight line.

GRAPH 1

Construct a graph to connect speed and distance per 24 hours.

1. From the zero point at the bottom left hand corner of the paper number the squares horizontally from left to right to represent distance.
2. Number off the squares vertically upwards from zero in knots.
3. Select a speed, say 10 knots, then 10 knots × 24 hours = 240 miles per day.
4. Find 240 miles on the distance scale and run up its vertical line until it cuts the horizontal line passing through 10 knots. Make a mark and join this spot to the zero point, and produce it as far as convenient. This straight line is the graph required.

To Read the Graph

Example 1

A ship's speed has averaged 11·4 knots, required the distance steamed per day.

Find 11·4 knots on the vertical scale, then trace along the horizontal line it indicates until the graph is reached, and run the eye up, or down, the vertical line and read off the distance on the horizontal scale.

Answer 274 miles.

Example 2

The distance made good by a ship from noon to noon was 160 miles, required the average speed.

Find 160 miles on the distance scale and trace this vertical line upwards to the graph, then run the eye to the left along the horizontal line passing through this point and read off the speed on the vertical scale.

Answer 6·6 knots.

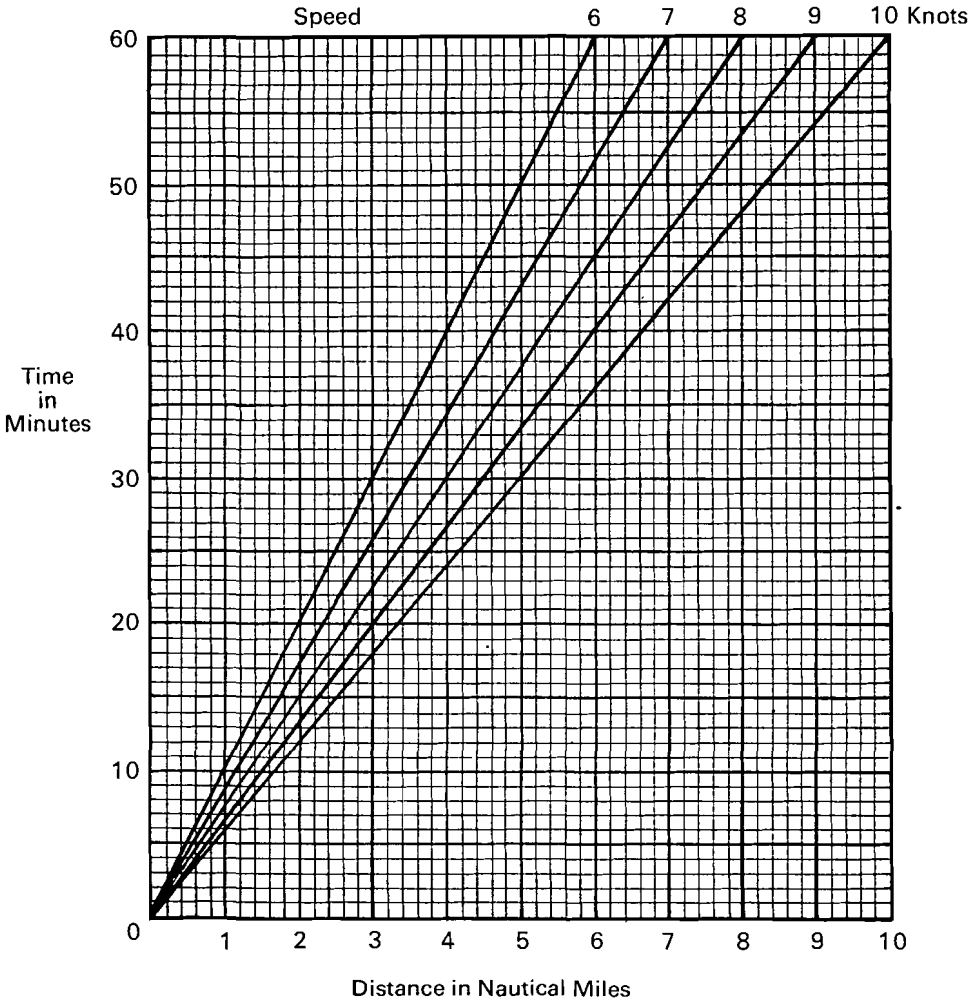
This graph is simply a "ready reckoner", but at the same time it should not be forgotten that the graphical representation is generally not so accurate as the figures upon which it is based.

GRAPH 2

This graph is similar to Graph 1 and connects speed and time. The abscissa, or horizontal scale, represents speed in knots; and the ordinate, or vertical scale, minutes of time up to

Graph 2

TIME, SPEED AND DISTANCE



1 hour. The diagonal lines radiating from the zero point represent successive graphs for speeds from 6 knots to 10 knots. The graphs have been drawn as follows: the point where the speed ordinate, say 6 knots, cuts the abscissa through 60 minutes, has been joined to the zero point and this line is the graph of 6 knots.

Example 3

A ship's speed is 6 knots, required the distance covered in 40 minutes.

Find 40 minutes on the vertical scale, run along the horizontal line until the graph is reached, then trace up, or down, the vertical line and read off the distance.

Answer 4 miles.

Example 4

A ship steams 6·2 miles in 37 minutes, required her speed.

Find 6·2 miles on the horizontal scale and 37 minutes on the vertical scale, then run the index finger of the right hand up the vertical line and the index finger of the left hand along the horizontal line. The two lines intersect on the 10-knot graph.

Answer Speed 10 knots.

Example 5

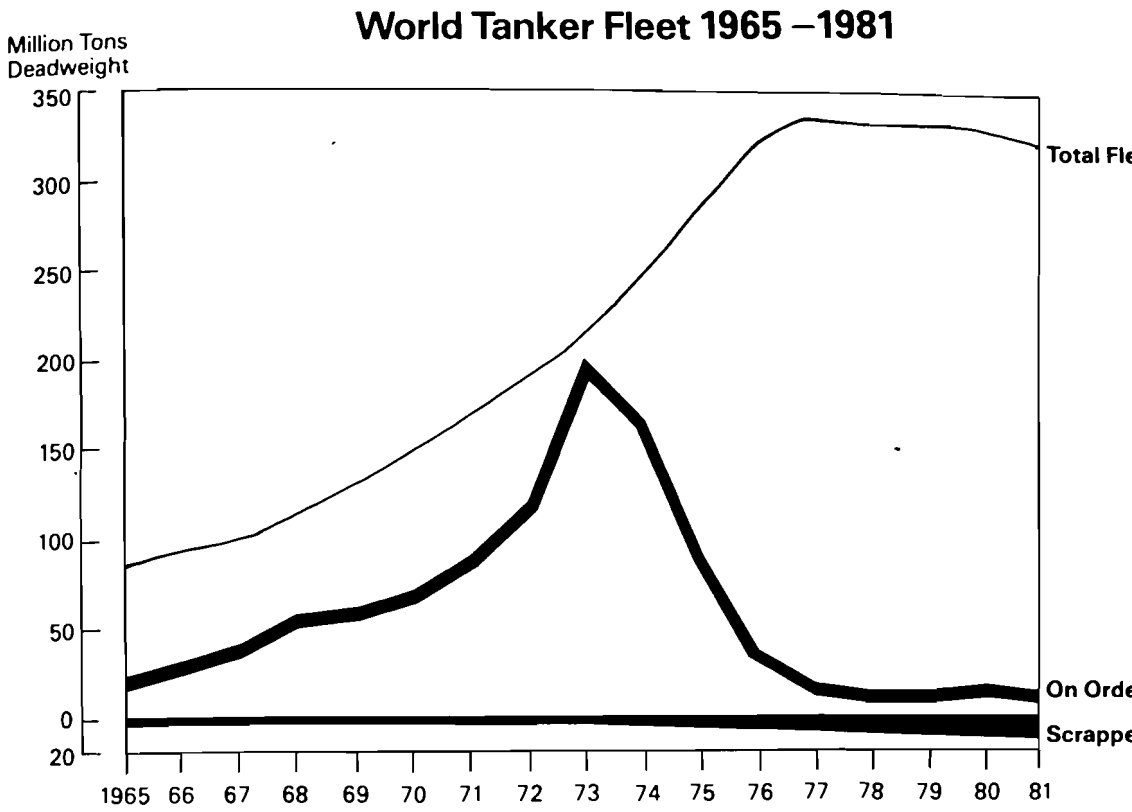
Two ships set out at the same time on the same course, one at 6 knots, the other at 9 knots; how far apart will they be in 40 minutes?

Find 40 minutes on the vertical scale, note where this abscissa cuts the 6 knot graph and the 9 knot graph, then count the number of squares which separate the two spots horizontally. There are 2 of them.

Answer Distance apart 2 miles.

GRAPH 3

Statistical records offer interesting data for graphical presentation. Graph 3 is taken from the *BP Statistical Review of World Energy, 1981*, Statistical Graph.



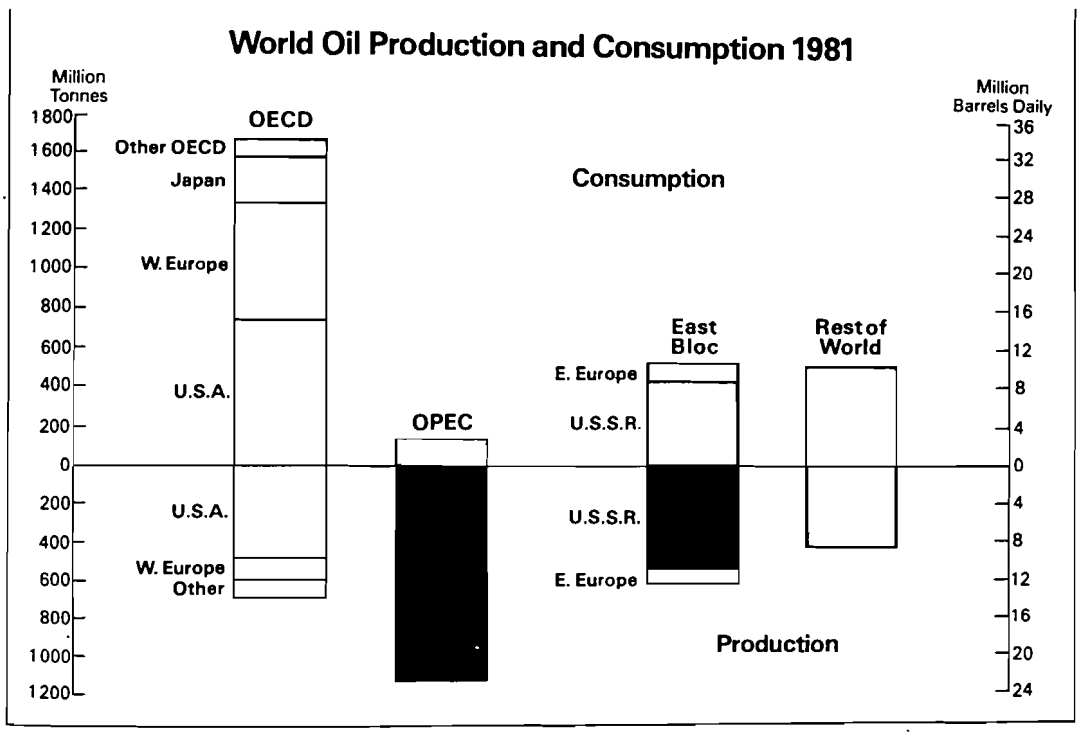
Example 6

(a) What was the peak year for tankers on order?
Answer 1973.

(b) When did the world tanker fleet reach its maximum size?
Answer October 1976.

GRAPH 4 (Bar Chart)

Statistical information, which is to be used for purposes of comparison, can sometimes be more easily shown on a bar chart. The bar chart shown below is taken from the *BP Statistical Review of World Energy, 1981*.



Example 7

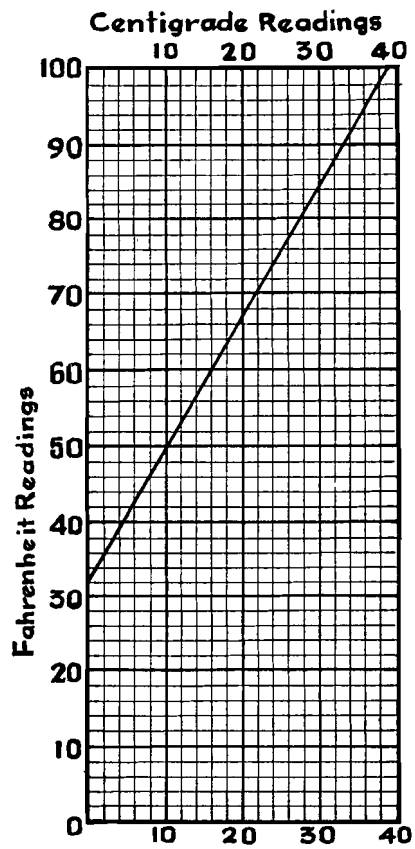
(a) Is the consumption of oil in U.S.A. matched by its production?
Answer No. The U.S.A. consumes approximately 250 million tonnes more than it produces.

(b) Is the consumption of oil in the U.S.S.R. matched by its production?
Answer Yes. The U.S.S.R. produces sufficient oil to meet its own consumption and that of Eastern Europe.

GRAPH 5

This graph illustrates the ratio between the Fahrenheit and Centigrade thermometer scales. It will be remembered that the two fixed points on a thermometer scale are freezing point and boiling point. The space between those two marks on the thermometer tube is divided into 180 equal parts in the Fahrenheit scale, the divisions being numbered from 32 to 212, whilst the Centigrade thermometer is divided into 100 equal parts and numbered 0 to 100. The proportion between the two scales is, therefore, as 180 is to 100, or as 9 is to 5, so that a Fahrenheit reading corresponding to a given Centigrade reading is equal to the reading in degrees $C \times \frac{9}{5} + 32$.

Graph 5
THERMOMETER SCALES



Example 8

Find the Fahrenheit reading which corresponds to 35° Centigrade.

$$\text{Fahr.} = (35 \times \tfrac{9}{5}) + 32 = 63 + 32 = 95°.$$

Find 95° on the Fahrenheit scale and trace the horizontal line across until it meets the vertical line drawn downwards from 35° Centigrade.

If this spot be now plotted on sectional paper, the abscissa which is in Centigrade

readings and the ordinate in Fahrenheit readings, and the spot joined to 32° Fahr., the straight line graph so formed will link up the intermediate readings of both thermometers.

(a) Convert 82° Fahr. into Centigrade.

Find 82° on the Fahrenheit scale, trace along the horizontal line to the graph and then run up, or down, the vertical line and read off on the Centigrade scale.

Answer 28° Centigrade.

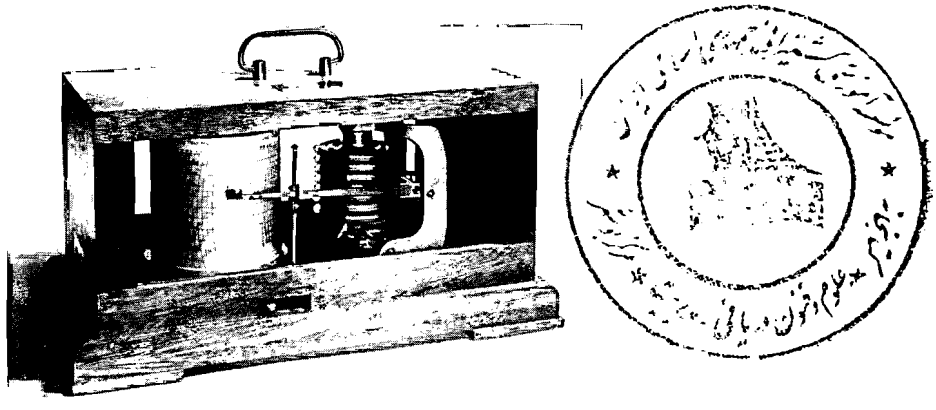
(b) Convert 20°C into Fahrenheit.

Find 20° on the Centigrade scale, run up the vertical line to the graph, then along the horizontal line to the left and read off on the Fahrenheit scale.

Answer 68° Fahrenheit.

GRAPH 6

Readings from weather recording apparatus are freely represented by graphs, the most familiar being the trace marked out by the pen of a barograph in contact with the paper wrapped round the revolving drum.



Barograph

A clock inside the drum causes the cylinder to rotate on a vertical axis at a uniformly timed speed. The pen is attached to a lever which is actuated by the motion of the corrugated metal boxes, partially exhausted of air, the sides of which move in and out in response to increases and decreases in the pressure of the atmosphere.

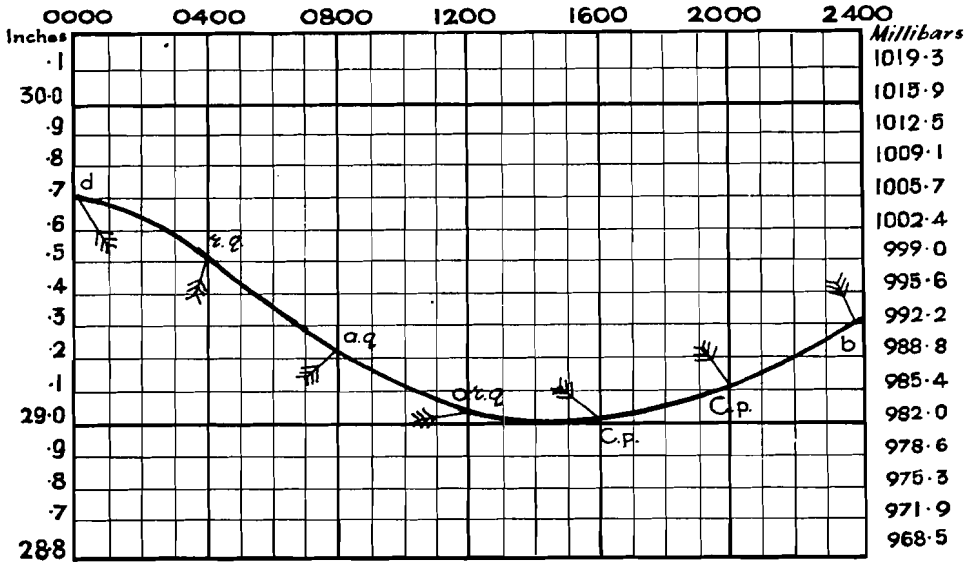
Barometer readings typical of an atmospheric depression passing over places in high Northern latitudes are shown in Graph 6.

The abscissa is divided into hourly periods for a day from midnight to midnight, and the ordinate into barometer readings; the left hand side gives the mercury inches and the right hand side the corresponding pressure units called millibars.

The arrows at intervals along the barometer graph show the direction of the wind and the number of strokes indicates its force, 4 strokes being a moderate breeze, 8 strokes a wind of gale force having a velocity of 40 miles per hour, etc. The small letters at the wind arrows are from the Beaufort notation describing the appearance of the sky, *d* means drizzle, *r* rain, *q* squalls, *o* overcast, *c* detached clouds, *p* passing showers, *b* blue sky, all of which secures an

Graph 6

BAROMETER READINGS, WIND AND WEATHER



economy in writing and conveys, at a glance, the whole information regarding wind and weather at a given time.

This graph and the weather information associated with it is read as follows: the *barometer* has fallen from 29·7 inches at midnight to 29·0 inches at 1400, and has then risen to 29·3 inches at the next midnight. The *wind* meanwhile has changed from SE, force 4, to a strong SW wind, force 7, at 0800, the to West, force 8, at noon, after which it has hauled to NW still at gale force, hauling more Northerly and decreasing in force with a rising barometer. The *sky* during this period has changed from drizzle to rain squalls, to overcast, rain and squalls at midday, and then to detached clouds and passing showers when the wind hauled to NW.

This graph is drawn from the information as it might be recorded in a log book.

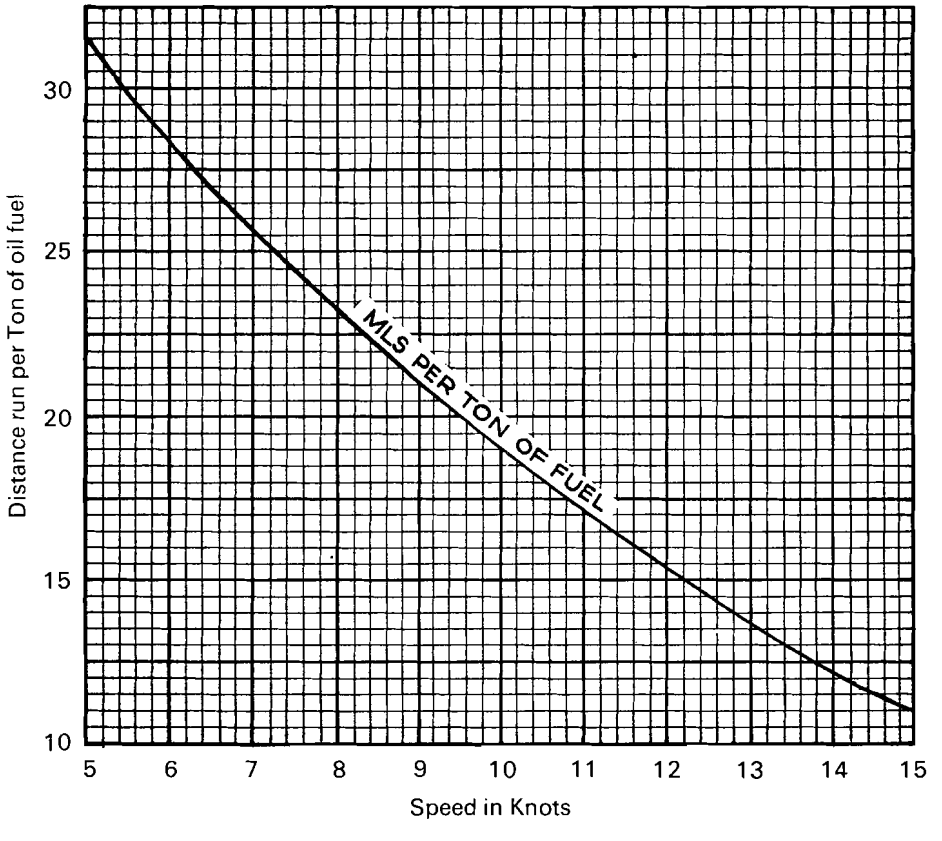
LOG BOOK

Time	Barometer		Wind	Force	Sky
	Inches	Millibars			
0000	29·70	1005·7	SE	4	Drizzle
0400	29·53	1000·0	SSW	5	Rain squalls
0800	29·22	989·2	SW	7	Overcast, squally
1200	29·03	983·0	W	8	Overcast, rain, squally
1600	29·02	982·7	NW	8	Detached clouds, passing showers
2000	29·12	986·0	NNW	5	Detached clouds, passing showers
2400	29·30	992·2	NNW	4	Blue

GRAPH 7

This graph is an illustration of connecting fuel consumption, speed and distance as deduced from the steaming trials of a ship. The curve represents 1 ton of oil fuel; the abscissa is the speed in knots, and the ordinate is the distance run on a consumption of 1 ton of fuel.

Graph 7



Note that the horizontal scale is 5 squares to the knot and the vertical scale 2 squares to the mile. At a speed of 7 knots the ship can go $25\frac{1}{2}$ miles on 1 ton of oil. Find 7 knots on the abscissa, run vertically upwards to the curve, then horizontally across to the ordinate, which gives $25\frac{1}{2}$ miles. At 10 knots the distance covered is 19 miles, at 12 knots the distance is $15\frac{1}{4}$ miles, at 14 knots the distance is down to $12\frac{1}{4}$ miles on an expenditure of 1 ton of fuel.

The graph demonstrates, incidentally, the question of the economical speed of a ship by connecting the expenditure of energy, speed and distance. When the speed is 10 knots 1 ton of fuel enables this particular ship to go 19 miles, but when the speed is reduced to 7 knots then 1 ton of fuel enables her to go $25\frac{1}{2}$ miles under the same conditions of wind and weather, a useful thing to know in the event of bunker oil running short.

GRAPH 8

Various graphs and curves are used by ship designers by which irregular areas, positions of centres of gravity and of buoyancy and other variable elements may be co-ordinated. This graph is a displacement curve, the displacement tonnage of a ship being the weight of the volume of water she displaces at her mean floating draught.

The abscissa is divided off into tons and the ordinate into a scale of draught in feet. The displacement in tons for several draughts having been calculated and plotted on the paper, a fair curve, or graph, is drawn through the points.

From this displacement curve we are told that at the light draught of 11 feet the weight of the ship is 1200 tons. There is no cargo in the ship, so this represents the weight of hull, machinery and equipment.

Follow the dotted lines on the figure and note in the following examples that:

at 13 feet draught the displacement is 1450 tons
at 14 feet draught the displacement is 1590 tons
at 16 feet draught the displacement is 1880 tons.

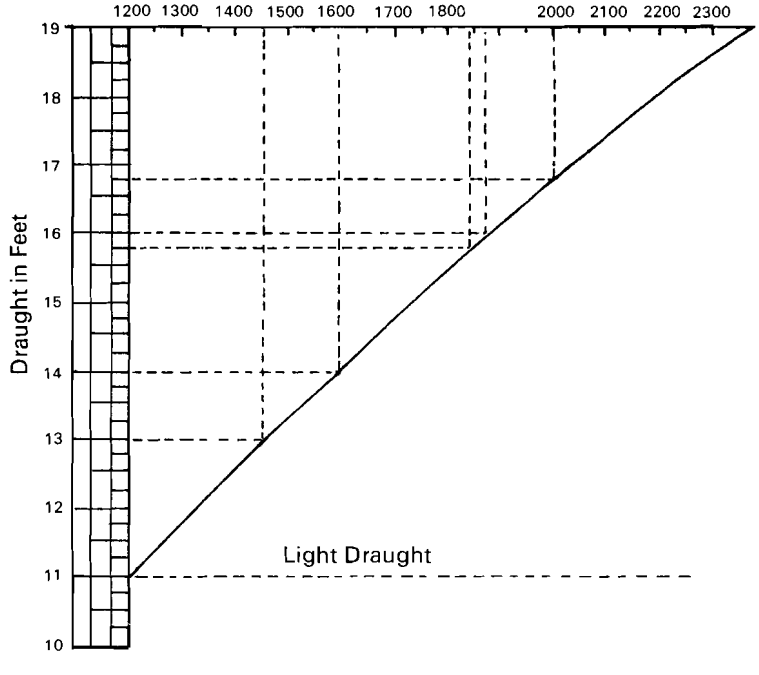
Example 9

How many tons weight are required to increase the ship's draught from 13 feet to 16 ft 9 in?

at 13 ft the displacement is 1450 tons
at 16 ft 9 in the displacement is 2000 tons
Difference 550 tons

Answer 550 tons.

Graph 8
TONS DISPLACEMENT



Example 10

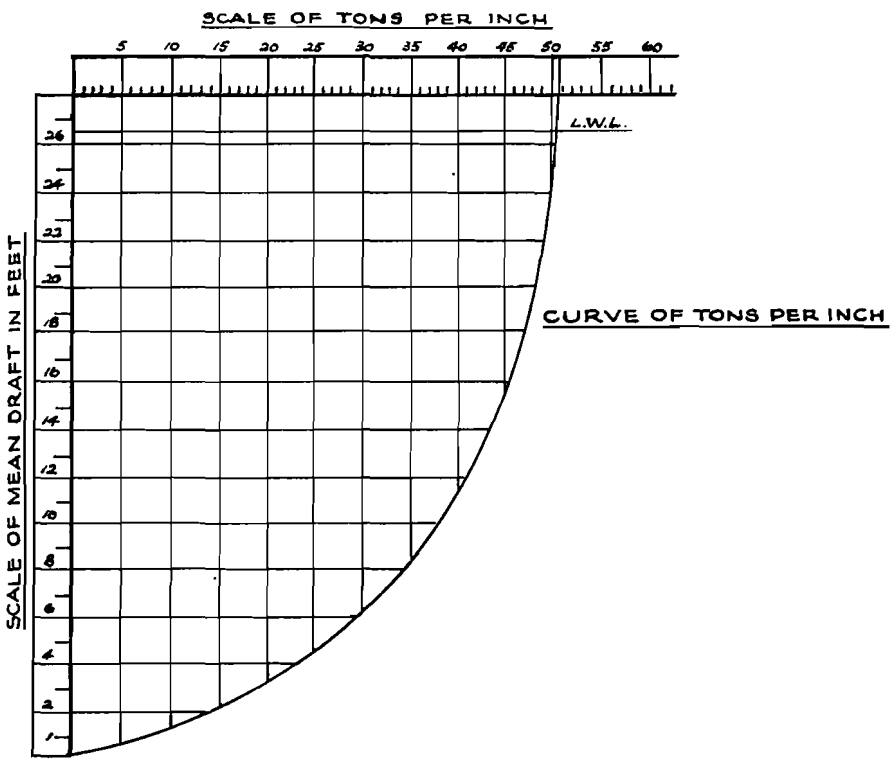
The ship's draught is 14 feet and 250 tons weight of cargo is to be put on board. What will the new draught be?

at 14 feet draught the displacement is	1590 tons
weight to be added	250 tons
new displacement	1840
new draught	15 ft 9 in

GRAPH 9

A curve of Tons Per Inch immersion (T.P.I) is useful on board ship. The curve is only applicable to each particular ship unless, of course, in cases where ships are almost identical in form and dimensions.

Graph 9



The abscissa is a scale which represents the number of tons to be placed on board, or taken out of the ship, to alter her mean draught 1 inch. This quantity is not the same at all draughts. The ordinate is a scale of mean draughts in feet.

Example 11

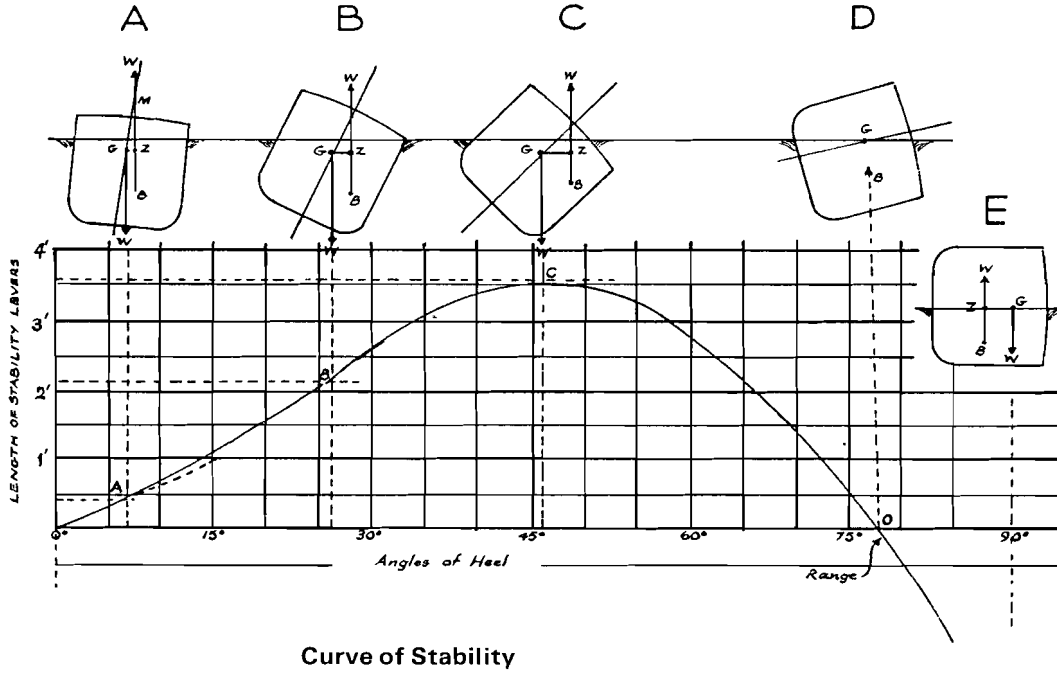
Find (a) Required the tons per inch immersion at a draught of 24 feet from the T.P.I. curve.
(b) Required the tons per inch at a draught of 12 feet.

Find 24 feet on the draught scale, and trace a horizontal line to the right until the curve is reached, then trace a line vertically upwards from this point and read off from the scale of tons.

Answer (a) 50 tons.
(b) 42 tons.

GRAPH 10

A curve of stability is one which shows graphically the relative leverages exerted by the ship to restore herself to a position of equilibrium when she has been forcibly inclined by the wind or sea. The reading of this curve calls for a general understanding of the principles of stability which we do not propose to enter into here, but a brief note may serve our purpose.



Curve of Stability

The figures of the inclined ship show a vessel at different angles of heel, and in each case *G* represents the centre of gravity of the ship which is a fixed position unless the weights in the ship are altered. The whole weight of the ship acts vertically downwards through *G* as represented by *GW*.

B is the centre of buoyancy of the ship and is the centre of the volume of the water displaced. It changes its position along with the change in shape of the underwater form of the

ship. The total upward pressure of the water, which is equal to the whole weight of the ship, acts vertically upwards through *B* in the direction *BW*.

The horizontal distance *GZ* between those two opposite vertical forces is called the righting lever or righting arm. When *GZ* disappears the ship is in equilibrium and exhibits no tendency to heel to one side or the other. When she is forcibly inclined the *GZ* increases in length and a powerful lever is produced as shown in the figures, where the downward force through *G* and the upward force through *B* are both exerting a leverage, called a "couple", to bring the ship to an upright position. This force is expressed in foot-tons. Suppose the weight of the ship to be 5000 tons and the length of *GZ* to be 1 foot, then the righting moment is said to be 5000 foot-tons, which is equivalent to the turning effect of a 5000-ton weight suspended at the end of a rod 1 foot long, or of a 1-ton weight suspended at the end of a rod 5000 feet long.

In the successive figures A, B and C the righting arm *GZ* is progressively increased, and the ship has an increasing tendency to return to an upright position. But in figure D the *GZ* has disappeared, the ship is in neutral equilibrium, she is inert and cannot by her own effort return to an upright position. Figure E illustrates the ship in a position of unstable equilibrium, because it will be seen that the downward force through *G* and the upward force through *B* have conspired to produce a lever *GZ* which will capsize the ship.

Perhaps this brief explanation may enable the student to read intelligently the stability curve shown as Graph 10.

The abscissa is a scale of degrees to represent angles of heel of the ship and the ordinate is a scale of feet to represent the length of *GZ* the righting arm.

To Read the Stability Curve

Figure A represents the ship heeled to an angle of 7°. Find 7° on the horizontal scale, move vertically upwards to the curve at *A*, then horizontally to the left and read off the length of *GZ* from the scale. The righting arm or lever is $5\frac{1}{2}$ inches long, or 0·45 feet. If the weight of the ship is 5000 tons, then the turning power exerted by the ship to bring herself to an upright position is 5000 tons × 0·45 feet = 2250 foot-tons.

Figure B represents a heel of 26°. The length of *GZ* from the curve is 2·2 feet, the moment, or turning power, would be 5000 tons × 2·2 feet = 11,000 foot-tons.

Figure C represents a heel of 46°, the length of *GZ* from the curve is about 3·6 feet, the righting moment would be 5000 tons × 3·6 feet = 18,000 foot-tons. This is the position of maximum effort, for it will be seen that as the angles of heel increase beyond 45° the ship becomes more reluctant to return to the upright as evidenced by the diminishing lengths of the righting arms, and at an angle of about 78° *GZ* disappears and the "range" of the stability curve is complete, for on heeling beyond 78° the ship will capsize if left to herself.



Chapter 4

Measurement, Area and Volume

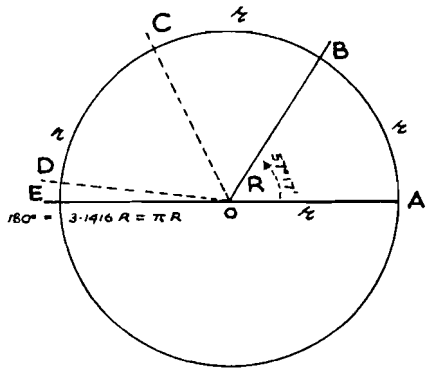
In navigation there are various systems of measurement. For example, the size of an angle is usually expressed in degrees, minutes and seconds (or tenths of minutes) of arc.

$$1^\circ = 60', \quad \text{and} \quad 1' = 60''$$

Another method for measuring the size of an angle is known as Circular Measure.

CIRCULAR MEASURE

Circular Measure is a method of expressing the size of an angle in terms of the radius of a circle, the angle being described as so many radians instead of degrees. Circular measure is not much used in nautical problems although it can be applied, on occasions, quite usefully under certain circumstances.



In the figure, OA is a radius of the circle. If the radius is lifted up and bent to the curvature of the circumference so that AO coincides with AB, then the length of the arc AB will be equal to the radius OA. The arc AB subtends the angle AOB, which is called a **Radian** (R) and this angle always measures the same, no matter how big or how small the circle may be, because the arcs of circles are proportional to their radii.

$$\text{One radian} = 57^\circ\,17'\,45'' \qquad \text{or approximately } 57{\cdot}3^\circ.$$

When the arc AB is stepped round the circumference then $AB = BC = CD$, each arc subtending an angle of one radian. But three radians fall short of 180° by the small arc DE, which is equal to 0·1416 radians, so that 180° = 3·1416 radians. The number 3·1416 is called "π" and is equal to $\frac{22}{7}$ nearly or $3\frac{1}{7}$.

Let the circumference of a circle be denoted by $C°$, its radius by "r" and a radian by R,

$$\text{then a semi-circle} \quad \frac{C°}{2} = 180° = \pi R = 3{\cdot}1416R$$

$$\text{and the circumference} \quad C° = 360° = 2\pi R = 6{\cdot}2832R$$

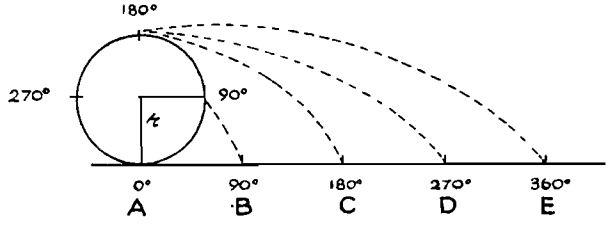
$$\text{and a quarter circle} \quad \frac{C°}{4} = 90° = \frac{\pi R}{2} = 1{\cdot}5708R.$$

The unit R is usually dropped and the angle expressed as a number, thus, $90° = 1{\cdot}5708$, $180° = 3{\cdot}1416$.

Now the arc AB is exactly the same length as the radius "r", and if the circumference of a circle were cut and straightened out its length would be expressed by $2\pi r$. A simple illustration of the application of this system of measure is the turning of a wheel.

Example 1

The wheels of a bicycle are each 28 inches in diameter and make 1000 turns. How far along the road did it travel?



The figure represents the wheel, r being 14 inches. The wheel rolls along the road and when it makes

$\frac{1}{4}$ turn 90°, the point of contact is at B
$\frac{1}{2}$ turn 180°, the point of contact is at C
$\frac{3}{4}$ turn 270°, the point of contact is at D
1 turn 360°, the point of contact is at E

so that AE is the length of the whole circumference of the wheel. But one turn is the length of the circumference $= 2\pi r$ and

$$\begin{aligned} 1000 \text{ turns} &= 1000 \times 2\pi r \\ &= 1000 \times 2 \times \frac{22}{\cancel{7}} \times \frac{\cancel{14}^{2}}{1} \\ &= 88{,}000 \text{ inches} \\ &= 7333 \text{ feet} \\ &= \underline{1{\cdot}39 \text{ miles}} \quad \textit{Answer.} \end{aligned}$$

One land mile is 5280 feet.

Example 2

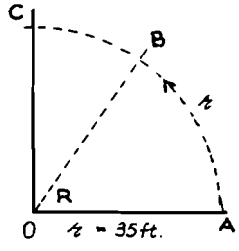
The paddle wheels of a steamer are 21 feet in diameter and make 2000 revolutions. How many nautical miles did the ship go, neglecting slip?

$$\begin{aligned}
\text{One turn} &= 2\pi r \\
\text{2000 turns} &= 2000 \times 2\pi r \\
&= 2000 \times 2 \times \frac{22}{7} \times \frac{10 \cdot 5}{1} \\
&= 132{,}000 \text{ feet} \\
&= \underline{21 \cdot 7 \text{ miles}} \quad \textit{Answer.}
\end{aligned}$$

One nautical mile is 6080 feet.

Example 3

The horizontal distance between the heel of a derrick and the cargo fall when hanging plumb is 35 feet. What distance will the derrick head travel when swung through an arc of 90° horizontally.



In figure OA represents the derrick in plan at first position and OC at the second position, $\angle AOC = 90°$. AC represents the circular distance swung through at the head of the derrick.

$$\begin{aligned}
\tfrac{1}{2} \text{ turn } 180° &= \pi r \\
\tfrac{1}{4} \text{ turn } 90° &= \tfrac{1}{2}\pi r \\
\text{the distance therefore} &= \frac{1}{2} \times \frac{22}{7} \times \frac{35}{1} \\
&= 55 \text{ feet} \quad \textit{Answer.}
\end{aligned}$$

This type of example is sometimes reasoned out as follows.

In figure, $\angle AOB$ = a radian = 57·3° (constant), $\angle AOC = 90°$, given in question, arc AB = radius OA = 35 feet as given in question. Required to find the length of arc AC.

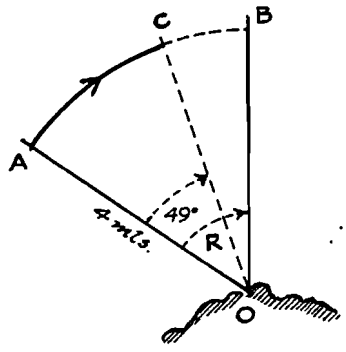
$$\frac{\text{Arc } AC}{\text{Arc } AB} = \frac{\angle AOC}{\angle AOB} \quad \text{or} \quad \frac{AC}{35} = \frac{90°}{57 \cdot 3°}$$

$$\therefore AC = \frac{35 \times 90}{57 \cdot 3} = 55 \text{ feet} \quad \textit{Answer.}$$

Example 4

A ship sails a circular course round a point and maintains a constant distance of 4 miles from it until the point alters its bearing 49°. Required the distance sailed.

In figure, O represents the point, OA 4 miles, $\angle AOC = 49°$, $\angle AOB$ = one radian = 57·3°. Required to find the length of arc AC.



An arc of $180° = \pi r$.

$$\text{An arc of } 49° = \pi r \times \frac{49°}{180°}$$

$$= \frac{22}{7} \times \frac{4}{1} \times \frac{49^{7}}{180_{45}}$$

$$\therefore \text{ distance sailed} = \frac{154}{45} = 3{\cdot}42 \text{ miles}$$

or, as described in example 3

$$\frac{\text{Arc } AC}{\text{Arc } AB} = \frac{\angle AOC}{\angle AOB} \qquad AB = 4 \text{ miles}$$

$$\angle AOC = 49°$$

$$\angle AOB = 57{\cdot}3°$$

$$\therefore AC = \frac{4 \times 49}{57{\cdot}3} = 3{\cdot}42 \text{ miles} \quad \textit{Answer.}$$

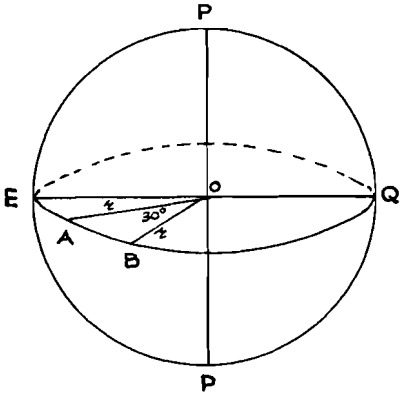
This type of question also appears in Chartwork.

Example 5

Two places situated on the equator are separated by 30° of longitude. Assuming the earth's radius to be 4000 miles, find their distance apart.

In figure, O represents the centre of the earth, OA and OB are radii of the earth, 4000 miles; $\angle AOB$ is the difference of longitude between the places A and $B = 30°$. Required to find the distance along the arc AB.

If the places were 180° apart the distance would be πr. The places are 30° apart therefore



$$\text{Distance} = \pi r \times \frac{30°}{180°}$$

$$= \frac{\pi r}{6}$$

$$= \frac{22}{7} \times \frac{4000}{6_{3}}$$

$$= \frac{44{,}000}{21}$$

$$= 2095 \text{ miles} \quad \textit{Answer.}$$

Or $$\frac{\text{Arc } AB}{r} = \frac{\angle AOB}{57{\cdot}3°}$$

$$\therefore AB = \frac{r \times AOB}{57{\cdot}3} = \frac{4000 \times 30}{57{\cdot}3} = 2094 \text{ miles.}$$

Example 6

The barrel of a wire reel is 3 feet in diameter and $3\frac{1}{2}$ feet long. Find (a) the number of turns of 3-inch wire which will go on the drum to complete a single layer and (b) the length of wire in the layer.

(a) The size of a rope is the measure of its circumference, in this case 3″. Required its diameter.

$$\odot^{ce} = 2\pi r \qquad \therefore 2r = \frac{\odot^{ce}}{\pi}$$

but $2r$ being twice the radius is the diameter of the wire.

$$\therefore 2r = \text{diam} = \frac{3}{1} \times \frac{7}{22} = \frac{21}{22} \text{ inches.}$$

One turn of the wire takes up $\frac{21}{22}$ inches and the drum is 3′ 6″, or 42 inches long.

$$\therefore \text{number of turns} = \frac{42^{2}}{1} \times \frac{22}{21} = 44 \text{ turns}$$

(b) We must now find the length of the circumference of the barrel of the winch and multiply it by 44 to get the length of the wire.

$$\odot^{ce} = 360° = 2\pi r$$
$$= \frac{2}{1} \times \frac{22}{7} \times \frac{3}{2}$$
$$= 9\tfrac{3}{7} \text{ feet}$$
$$44 \text{ turns} = 44 \times 9\tfrac{3}{7}$$
$$= 414\tfrac{6}{7} \text{ feet}$$

Answer (a) 44 turns.
(b) Length of wire $414\frac{6}{7}$ feet.

Exercise 1 (use $\pi = \frac{22}{7}$)

1. A bicycle wheel 28 inches in diameter makes 4000 revolutions. What distance has it travelled?
2. How many revolutions does a bicycle wheel 21 inches in diameter make in going 20 miles?
3. A paddle steamer goes 35 nautical miles, the diameter of her paddle wheels being 14 feet. How many revolutions did they make?
4. The diameter of a cylinder is 14 inches. What length of steel bar is required to form a ring to fit closely inside the cylinder?
5. A ship in rounding a point maintains a constant distance of 3 miles from it whilst the bearing of the point alters 65°. What distance in miles did she sail?
6. Two places differ in latitude 42°. How far are they apart assuming the earth's radius to be 4000 miles?
7. It is required to make an iron tyre for a cart wheel which is 5 feet in diameter. How long will the steel bar forming the tyre be?

8. There are 20 turns of wire on the barrel of a winch the diameter of which is 28 inches. Find the length of the wire in feet.
9. A ship on steaming trials is turning in a circle on port helm. She takes $6\frac{1}{2}$ minutes steaming at 5 knots to complete the circle. Find (a) the distance travelled by the ship; (b) the diameter of her turning circle.
10. Explain what is meant by circular measure.

Answers

1. 29,333 feet or 5·55 miles
2. 19,200 revolutions
3. 4836 revolutions
4. 44 inches
(5) 3·4 miles
6. 2932 miles
7. 15·7 feet
8. 146·6 feet
9. (a) 3293 feet; (b) 1048 feet

MEASUREMENT, DENOMINATE AND COMPOUND DENOMINATE NUMBERS

Denominate Number

A number which refers to a unit of measurement which has been established by law or general usage, e.g. 1 metre, 3 hours, etc.

Compound Denominate Number

A number which consists of two or more units of the same kind, e.g. 1 metre 5 millimetres, 3 hours 6 minutes, etc.

Denominate numbers are used to express measurements such as:

1. Linear (length)
2. Square (area)
3. Cubic (volume)
4. Weight (Newtons)
5. Time
6. Angular
7. Currency systems (various)
8. Foreign systems of weight and measurement

1. Length or Linear Measure

Metric System

	Unit		*Metres*		*Feet and inches*
	1 millimetre (mm)	=	0·001	=	0·03937 in
10 millimetres	= 1 centimetre (cm)	=	0·01	=	0·3937 in
10 centimetres	= 1 decimetre				
10 decimetres	= 1 metre				
100 centimetres	= 1 metre (m)	=	1·0	=	39·3701 in
1000 metres	= 1 kilometre (km)	=	1000·0	=	0·621371 mile

English System

12 inches (in) = 1 foot (ft) = 0·3048 metres (m)
3 feet or 36 inches = 1 yard (yd) = 0·9144 metres
1760 yards = 1 mile
5280 feet = 1 mile = 1·60934 kilometres (km)
1 league = 3 miles
$5\frac{1}{2}$ yards = 1 rod or pole
40 poles = 1 furlong
8 furlongs = 1 mile

Nautical Measure

1 International Nautical Mile = 1852 m = 6076 ft approx
1 fathom = 6 ft
1 cable = 600 ft
10 cables = 1 Nautical Mile (approx)

$69\frac{1}{9}$ land miles or 60 nautical miles make 1 degree (1°), which is one three hundred and sixtieth part of the earth's circumference. Nautical miles × 1·151 = statute miles.

Surveyor's Land Measure

In measuring land, surveyors use a **chain** (called Gunter's chain) which is 22 yards long and is subdivided into 100 equal parts, each of which is called a link.

100 links = 1 chain = 22 yards
10 chains = 220 yards = 1 furlong

2. Square Measure

Length and width are used to measure the area of a two dimensional surface

Metric Square Measure

100 square millimetres (mm^2) = 1 square centimetre (cm^2) = 0·155 in^2
100 square centimetres (cm^2) = 1 square decimetre (dm^2) = 15·5 in^2
100 square decimetres (dm^2) = 1 square metre (m^2) = 1·19599 yd^2
10^6 square millimetres = 1 square metre
100 square metres = 1 are (a) = 119·599 yd^2
100 ares = 1 hectare (ha) = 2·47105 acres
100 hectares = 1 square kilometre (km^2) = 247·105 acres
10^6 square metres = 1 square kilometre

English Square Measure

144 square inches (in^2) = 1 square foot (ft^2) = 0·092903 m^2
9 square feet = 1 square yard (yd^2) = 0·836127 m^2
$30\frac{1}{4}$ square yards = 1 square rod, square pole, or perch
40 perches = 1 rood
4 roods = 1 acre
4840 square yards = 1 acre
640 acres = 1 square mile = 2·58999 km^2

3. Cubic Measure

Cubic measure or capacity is used to find the volume of space within the boundaries of three dimensional figures.

Metric Measure of Capacity

1000 cubic millimetres (mm^3) = 1 cubic centimetre (cm^3) = 0·0610237 in^3
1000 cubic centimetres = 1 cubic decimetre (dm^3) = 0·0353147 ft^3
1 cubic decimetre = 1 litre (l)
1000 cubic decimetres = 1 cubic metre (m^3) = 1·30795 yd^3
10^9 cubic millimetres = 1 cubic metre

Measurements of volume should be given in the basic units of m^3, dm^3, cm^3, and mm^3. A litre is regarded as a special name for 1 dm^3.

English Cubic Measure

1 cubic inch (in^3) = 16·387 1 cm^3
1728 cubic inches (in^3) = 1 cubic foot (ft^3) = 0·0283168 m^3
27 cubic feet (ft^3) = 1 cubic yard (yd^3) = 0·764555 m^3
35 cubic feet = 1 ton sea water
36 cubic feet = 1 ton fresh water
100 cubic feet = 1 gross ton

Liquid Measure of Capacity

4 gills (gi) = 1 pint (pt) = 0·568 litre (l)
2 pints = 1 quart (qt) = 1·137 litre
4 quarts = 1 gallon (gal) = 4·546 litre
54 gallons = 1 hogshead = $1\frac{1}{2}$ barrels
72 gallons = 1 puncheon = 2 barrels
108 gallons = 1 butt = 3 barrels
$6\frac{1}{4}$ gallons = 1 cubic foot fresh water
10 pounds = 1 gallon fresh water
224 gallons = 1 ton fresh water

The Imperial gallon is used in the United Kingdom.

1 Imperial gallon = 1·20094 U.S. gallons

Dry Measure

2 pints = 1 quart 4 pecks = 1 bushel
4 quarts = 1 gallon 8 bushels = 1 quarter
2 gallons = 1 peck 5 quarters = 1 load

4. Measures of Mass

These are used to measure the quantity of matter contained in a body.

Metric System

1000 milligrammes (mg) = 1 gramme (g) = 0·035274 oz

1000 grammes	= 1 kilogramme (kg)	= 2·20462 lb
1000 kilogrammes	= 1 megagramme (Mg)	= 2204·62 lb
1000 kilogrammes	= 1 tonne (t)	

English System

16 drams	= 1 ounce	
16 ounces (oz)	= 1 pound (lb)	= 0·45359237 kg
14 pounds	= 1 stone (st)	= 6·35029 kg
2 stones	= 1 quarter (qtr)	= 12·7006 kg
4 quarters	= 1 hundredweight (cwt)	
112 pounds (lb)	= 1 hundredweight (cwt)	= 50·8023 kg
2240 pounds (lb)	= 1 ton	= 1016·05 kg

Troy Weight

24 grains	= 1 pennyweight
20 pennyweights	= 1 ounce
12 ounces	= 1 pound

5. Measures of Time

1000 milliseconds	= 1 second (s)
60 seconds	= 1 minute (min)
1000 seconds	= 1 kilosecond (ks)
60 minutes	= 1 hour (h)

Solar

24 hours	= 1 day (d)
7 days	= 1 week
2 weeks	= 1 fortnight
365 days	= 1 common year
366 days	= 1 leap year
12 calendar months	= 1 year
10 years	= 1 decade
100 years	= 1 century (C)
23 h 56 min 4 sec	= 1 Siderial day

6. Angular or Circular Measure

60 seconds (″)	= 1 minute (′)
60 minutes	= 1 degree (°)
90 degrees	= 1 right angle (or quadrant)
360 degrees	= 4 right angles
180 degrees	= πr = 3·1416r

Circumference of the earth = 24 855 miles (approx)
Diameter of the earth = 7900 miles (approx).

7. Money

United States Money
10 cents = 1 dime (d)
10 dimes = 1 dollar ($)
10 dollars = 1 eagle (E)

English Money
100 new pence = 1 pound (£)

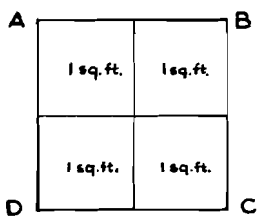
AREAS AND PERIMETERS

The **area** of a figure is the amount of surface enclosed by its boundary.

The **perimeter** of a figure is the sum of all its sides. The perimeter of a circle is its circumference, and the perimeter of a square is four times the length of one side. A **square** is a rectangle in which all the sides are equal and all the angles are right angles.

Figure *ABCD* is a square, each side of which is 2 feet long.

Area of *ABCD* = 2 ft × 2 ft = 4 square feet as indicated in the figure.



Perimeter of *ABCD* = 2 ft × 4 sides = 8 lineal feet, which is simply the length of the four sides formed into one straight line.

The abbreviation 2*s* stands for perimeter, *s* for semi-perimeter.

A **rectangle** is a four-sided figure in which opposite sides are equal and all the angles are right angles.

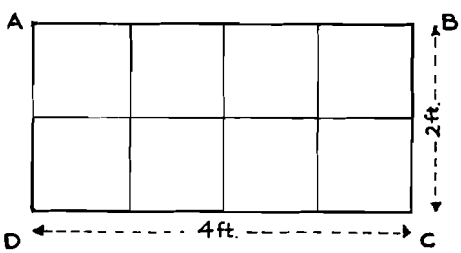


Figure *ABCD* is a rectangle in which pairs of opposite sides are 4 feet and 2 feet respectively.

Area of rectangle = length × breadth.

Area of *ABCD* = 4 ft × 2 ft = 8 square feet.

Perimeter of a rectangle = sum of its four sides.
Perimeter of $ABCD = 2(4+2) = 12$ lineal feet.

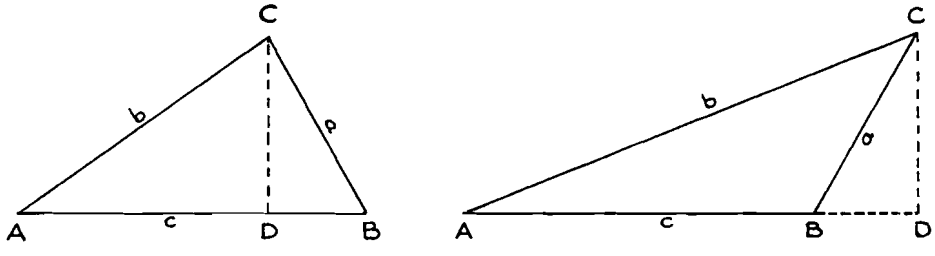
Example 7

An awning is 25 feet long and 15 feet wide, find its area and the length of the rope round its edges.

Area = length × breadth = 25 ft × 15 ft = 375 square feet.
Perimeter = sum of sides = $2(25+15) = 80$ lineal feet. Answer

AREA OF TRIANGLE

Given the length of base and altitude of a triangle. Area = $\frac{1}{2}$ base × altitude.
Area of $\triangle ABC = \frac{1}{2}AB \times CD$. Where AB is the base, CD is the altitude.



Given the lengths of the three sides of a triangle.

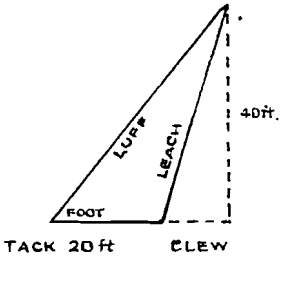
Area = $\sqrt{s(s-a)(s-b)(s-c)}$ where $s = \frac{1}{2}(a+b+c)$.

Given two sides and the included angle.

Area = $\frac{1}{2}a.b\sin C$, where a and b are the two given sides and C is the angle included between them.

Example 8

A jib is laid flat on deck. The foot measures 20 feet long and the length from foot to head, measured perpendicular to the foot, is 40 feet. Required the number of square yards of canvas in the sail.



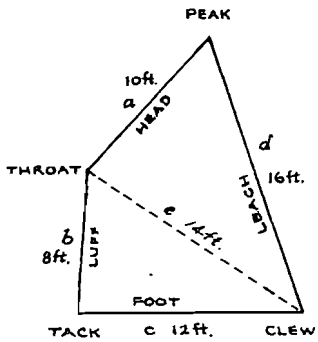
Area = $\frac{1}{2}$ base × altitude.

Area = $\frac{1}{2}$ 20 ft × 40 ft = 400 square feet = $\frac{400}{9}$ square yards.

Answer $44\frac{4}{9}$ square yards.

Example 9

A boat's standing lugsail has the following measurements: head 10 feet, luff 8 feet, foot 12 feet, after leach 16 feet, diagonal from throat to clew 14 feet. What is the area of the lugsail? The figure gives the nautical names for the corners and edges of the sail.



$$\text{Area of upper triangle} = \sqrt{s(s-a)(s-d)(s-e)}$$

$$s = \tfrac{1}{2}(a+d+e) = \tfrac{1}{2}(10+16+14) = 20$$

$$\text{Area} = \sqrt{20(20-10)(20-16)(20-14)}$$

$$\text{Area} = \sqrt{20\times 10\times 4\times 6} = \sqrt{4800} = 69{\cdot}2 \text{ sq ft.}$$

$$\text{Area of lower triangle} = \sqrt{s(s-b)(s-c)(s-e)}$$

$$s = \tfrac{1}{2}(b+c+e) = \tfrac{1}{2}(8+12+14) = 17$$

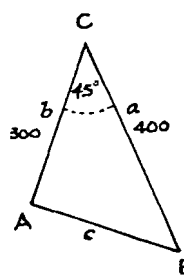
$$\text{Area} = \sqrt{17\times(17-8)(17-12)(17-14)}$$

$$\text{Area} = \sqrt{17\times 9\times 5\times 3} = \sqrt{2295} = 47{\cdot}9 \text{ sq ft.}$$

$$\text{Total area} = 69{\cdot}2+47{\cdot}9 = 117{\cdot}1 \text{ sq ft.}$$

Example 10

A prohibited area, triangular in shape, is marked off in a harbour by three buoys, *A*, *B* and *C*. The distance from *A* to *C* is 300 yards, from *B* to *C* 400 yards, and the horizontal sextant angle at buoy *C* subtended by the buoys *A* and *B* is 45°. Required the area of the enclosed space.



$$\text{Area} = \tfrac{1}{2}a.b\sin C'$$

$$\text{Area} = \tfrac{1}{2}\times 400\times 300\times \sin 45°$$

$$= 60{,}000\times\frac{1}{\sqrt{2}} = \frac{60{,}000}{1{\cdot}414} = 42{,}433 \text{ sq yards} \quad \textit{Answer.}$$

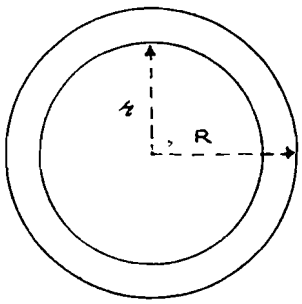
THE CIRCLE

Circumference $= 2\pi r$, area $= \pi r^2$.

Where $\pi = 3{\cdot}1416$, or $\frac{22}{7}$ where great accuracy is not required, and r = radius of the circle.

Example 11

Find the area of a piston ring whose external diameter is 12 inches and internal diameter 10 inches. Let R = radius of the outer circle and r = radius of the inner circle.



Area of ring = area of outer circle − area of inner circle

$= \pi R^2 - \pi r^2$

$= \pi(R^2 - r^2)$ which factorises into

$= \pi(R+r)(R-r)$

$= \frac{22}{7}(6+5)(6-5)$

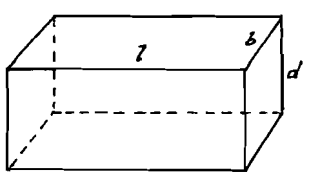
$= \frac{22}{7} \times \frac{11}{1} = 34\frac{4}{7}$ square inches *Answer.*

SURFACE AREAS OF BODIES

Box-shaped body The surface area of a box-shaped body is the sum of the areas of its six sides; each side is a rectangle.

Example 12

Find the surface area of a rectangular case measuring 6 feet long, 3 feet broad and 2·5 feet deep.



Area of top + bottom $= 2(l \times b)$

$= 2(6 \times 3) \quad = 36$ sq ft

Area of two sides $= 2(l \times d)$

$= 2(6 \times 2{\cdot}5) = 30$ sq ft

Area of two ends $= 2(b \times d)$

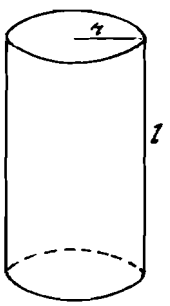
$= 2(3 \times 2{\cdot}5) = \underline{15}$ sq ft

Answer Total area = $\underline{81}$ square feet.

Cylinder A cylinder is a circular body whose ends are parallel circles. Surface area of a cylinder = area of the two ends + area of the curved surface.

Example 13

Find the surface area of an oil drum 2 feet high, its diameter being 1 foot.



$$\text{Area of the two ends} = 2\pi r^2$$

$$= \frac{2}{1} \times \frac{22}{7} \times \left(\frac{1}{2}\right)^2$$

$$= \frac{11}{7} \text{ sq ft.}$$

$$\text{Area of curved surface} = 2\pi r \times \text{height}$$

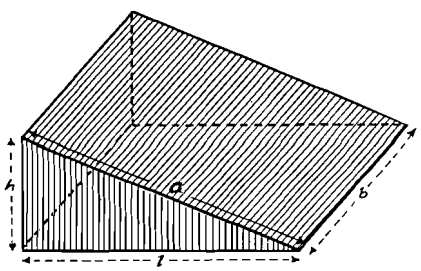
$$= \frac{2}{1} \times \frac{22}{7} \times \frac{1}{2} \times \frac{2}{1}$$

$$= \frac{44}{7} \text{ sq ft.}$$

$$\text{Total area} = \frac{11}{7} + \frac{44}{7} = \underline{7\tfrac{6}{7}} \text{ sq ft} \quad \textit{Answer.}$$

Note If the curved surface of the cylinder were cut vertically and flattened out it would form a rectangle whose base would be $2\pi r$ feet in length and breadth 2 feet.

Wedge In the figure h = height of the wedge perpendicular to the base.



a = slant length
l = length of base
b = breadth.

Total area = area of top + bottom + end + both sides

$$\text{area} = (a \times b) + (l \times b) + (h \times b) + 2(\tfrac{1}{2}h \,.\, l)$$

$$\text{area} = b(a+l) + h(b+l).$$

Example 14

Find the total surface area of a wedge of height 3 feet, slant length 5 feet, base length 4 feet, breadth 2 feet.

$$\text{Area} = b(a+l) + h(b+l)$$

$$= 2(5+4) + 3(2+4)$$

$$= 18 + 18$$

$$= \underline{36} \text{ square feet} \quad \textit{Answer.}$$

VOLUMES

The volume of a body is the amount of space which it occupies.

Box-shaped bodies The volume of a box 1 foot long, 1 foot broad and 1 foot deep is 1 cubic foot. The volume of any rectangular shape is the product of length, breadth and depth.

$$\text{Volume} = l \times b \times d.$$

Example 15

Find the volume of a tank 10 feet long, 8 feet broad and 20 feet deep. How many gallons of fresh water will it hold? Refer to the figure of a box-shaped body.

$$\text{Volume} = l \times b \times d = 10 \times 8 \times 20 = 1600 \text{ cubic feet}$$

$$1 \text{ cubic foot of F.W.} = 6\tfrac{1}{4} \text{ gallons}$$

$$\text{Capacity in gallons} = 1600 \times 6\tfrac{1}{4} = 10{,}000 \text{ gallons.}$$

Cylinder

$$\text{Volume} = \pi r^2 \times l$$

πr^2 = area of the end and l = length.

Example 16

Find the volume of a cylinder whose length is 12 feet and diameter 3 feet. Refer to the figure of a cylinder.

$$\text{Volume} = \pi r^2 l$$

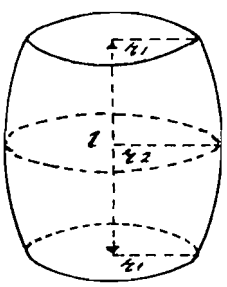
$$= \tfrac{22}{7} \times (\tfrac{3}{2})^2 \times 12 = \tfrac{22}{7} \times \tfrac{9}{4} \times \tfrac{12}{1} = 84\tfrac{6}{7} \text{ cubic feet} \quad \textit{Answer.}$$

A **Barrel** differs from a cylinder in that its radius varies along its length. The mean radius is approximately the half sum of the bilge radius and the head radius.

Volume of a barrel = $\pi r^2 l$ where r is the mean radius and l the length of the barrel.

Example 17

Find the gallons of fresh water contained in a barrel 3 feet long whose bilge diameter is 2 feet and head diameter $1\frac{1}{2}$ feet.



$$\text{Mean radius } r = \tfrac{1}{2}(r_2 + r_1) = \tfrac{1}{2}(1 + \tfrac{3}{4}) = \tfrac{7}{8} = r$$

$$r^2 = (\tfrac{7}{8})^2 = \tfrac{49}{64}$$

$$\text{Volume} = \pi r^2 l$$

$$= \tfrac{22}{7} \times \tfrac{49}{64} \times \tfrac{3}{1} = \tfrac{231}{32} \text{ cubic feet}$$

$$\text{Quantity of water} = \tfrac{25}{4} \times \tfrac{231}{32} = 45{\cdot}118 \text{ gallons.}$$

Note 1 cubic foot F.W. = $6\frac{1}{4}$ gallons.

Wedge The volume of a wedge is equal to half the volume of a rectangular shape having the same height, length and breadth. Refer to the figure of a wedge.

$$\text{Volume of wedge} = \tfrac{1}{2}(\text{length} \times \text{breadth} \times \text{height}).$$

Example 18

A wedge-shaped heap of coal is piled up in a ship's hold against a bulkhead to a height of 10 feet and extending along the ceiling for 15 feet, the breadth being 30 feet. Find how many tons there are, assuming 42 cubic feet to the ton.

$$\text{Volume of wedge} = \frac{l \times b \times h}{2}$$

$$= \tfrac{1}{2}(15 \times 30 \times 10) = 2250 \text{ cubic feet.}$$

$$\text{Weight of coal} = \tfrac{2250}{42} = 53\tfrac{4}{7} \text{ tons} \quad \textit{Answer.}$$

A Sphere

$$\text{Area of curved surface} = 4\pi r^2. \qquad \text{Volume of a sphere} = \frac{4\pi r^3}{3}.$$

Example 19

The diameter of a school globe of the world is 20 inches. Find its surface area and volume.

$$\text{Area} = 4\pi r^2 = \frac{4}{1} \times \frac{22}{7} \times \frac{10^2}{1} = \frac{8800}{7} = 1257 \text{ square inches.}$$

$$\text{Volume} = \frac{4\pi r^3}{3} = \frac{4}{1} \times \frac{22}{7} \times \frac{10^3}{1} \times \frac{1}{3} = \frac{88{,}000}{7 \times 3} = 4190{\cdot}5 \text{ cubic inches.}$$

Answer Area 1257 square inches, volume 4190·5 cubic inches.

Example 20

The outer and inner radii of a hollow spherical shell are 8 inches and 7 inches respectively. Find the volume of the shell. Let R = the outer radius and r = the inner radius.

$$\text{Volume of solid sphere} = \frac{4\pi R^3}{3}.$$

$$\text{Volume of space} = \frac{4\pi r^3}{3}.$$

$$\text{Volume of metal} = \frac{4\pi R^3}{3} - \frac{4\pi r^3}{3}.$$

The common denominator is 3, and the equation can be simplified to:

$$\text{Volume of shell} = \frac{4\pi(R^3 - r^3)}{3}$$

$$= \tfrac{4}{3} \times \tfrac{22}{7}(8^3 - 7^3)$$

$$= \tfrac{88}{21} \times \tfrac{169}{1}$$

$$= 708 \text{ cubic inches}$$

$$= \tfrac{708}{1728} = 0{\cdot}41 \text{ cubic feet} \quad \textit{Answer.}$$

Suppose the specific gravity of the metal to be 9·5. Find the weight of the shell.

1 cubic ft of F.W. weighs 62·5 lbs.
1 cubic ft of metal weighs $62{\cdot}5 \times 9{\cdot}5$ lbs.
The weight of metal $= 0{\cdot}41 \times 62{\cdot}5 \times 9{\cdot}5$ lbs
$= \underline{243 \text{ lbs}}$ *Answer*

SUMMARY OF FORMULAE

Rectangle
Area = length × breadth.
Perimeter = sum of its four sides.

Triangle
Area $= \frac{1}{2}$ base × altitude
$= \sqrt{s(s-a)(s-b)(s-c)}$ where $s = \frac{1}{2}(a+b+c)$
$= \frac{1}{2}a.b \sin C.$

Circle
Circumference $= 2\pi r.$
Area $= \pi r^2.$

Cylinder
Area = area of ends + area of curved surface.
Volume $= \pi r^2 l.$

Wedge
Area = areas of top + bottom + end + both sides.
Volume $= \frac{1}{2}$(length × breadth × height).

Sphere
Area $= 4\pi r^2.$
Volume $= \dfrac{4\pi r^3}{3}.$

Exercise 2

1. How many tiles, 6 inches by 6 inches, will be required to cover the galley floor which measures 20 feet across and 10 feet fore and aft?
2. The messroom measures 20 feet across, 10 feet fore and aft and 7 feet in height. How many pounds of paint will be required to give the roof and four walls one coat, assuming 1 lb covers 5 square yards?
3. A steel plate measuring 12 feet by 4 feet weighs 1100 lbs. Two circular pieces of radius 1 foot are cut out of it. How much lighter will it be?
4. A side bunker is 18 feet deep, 30 feet long and 14 feet broad at the top and 10 feet broad at the bottom. How many tons of coal could be stowed in it at 42 cubic feet per ton?
5. What is the surface of a steel rectangular plate measuring 6 feet 3 inches by 7 feet 10 inches?
6. Find the number of square yards of canvas required to make a trysail, the luff being 40 feet, the foot 30 feet; the foot is at right angles to the luff. How much would the canvas cost at £8 per lineal yard, the width of sail canvas being 2 feet? (*Note*: $4\frac{1}{2}$ feet lineal × 2 feet wide = 1 square yard.)
7. A tank measures 20 feet by 30 feet by 6 feet. Find how many tons of fresh water it would contain; also how long it would take to fill it if the water meter registers a flow of 500 gallons per minute?
8. The diameter of a funnel is 10 feet and its height 40 feet. Required its surface area in square

yards. Find also how much the paint would cost to give it one coat if 1 gallon of mixed paint cost £16 and covers 70 square yards.

9. How many square yards of canvas would it take to cover a hatch measuring 19 feet by 15 feet; allow an overlap of 1 foot more all round to reach the battening cleats. Tarpaulin canvas is 3 feet wide.
10. A ship's No. 2 'tween decks measures 80 feet long, 50 feet broad, 9 feet high. Required its cubic capacity in feet. Find also the number of bales of wool that could be stowed into it if each bale measures 4 feet by 3 feet 6 inches by 2 feet; and no broken stowage.
11. A double bottom ballast tank measures in length 90 feet, breadth 40 feet, depth 4 feet. Find its capacity in tons of sea water. (One ton sea water = 35 cubic feet.)
12. A steamer's paddle wheel is 20 feet in diameter and makes 2000 revolutions. How many nautical miles should the ship go through the water, neglecting slip?
13. A cargo ship has been converted into an oil tanker by building cylindrical tanks into her holds. No. 2 tank is 20 feet and 50 feet in diameter. Find how many tons of crude oil it will contain, assuming 1 ton equals 30 cubic feet.
14. When rounding a lighthouse 160 feet high, it subtended a vertical angle of 0° 45′ (this figures out at 2 miles off) when bearing 020° T. The ship's course is gradually altered to maintain this vertical angle until the lighthouse bears 120° T. Calculate the length of the arc traversed by the ship.
15. A sheet of lead 2 feet 4 inches square is of such a thickness that each square foot weighs 3 lbs. Find the weight of the sheet.
16. A fresh water tank is 10 feet long, 7 feet broad and 7 feet deep. What is the area in square yards?
17. How many tiles measuring 6 inches by 4 inches would be required to line the wall of a corridor 20 yards long to a height of 5 feet?
18. A parallelogram has an area of 250 square metres, and one side is 25 metres long. Find its breadth.
19. One side of a triangular field is 320 metres long, and the length of the perpendicular to this side from the opposite is 135 metres. Find the area of the field.
20. Find the weekly rent of a triangular field whose sides are 180 yards, 122 yards and 90 yards long, respectively, at £4 per acre.
21. The sides of a triangular yacht course are 10 miles, 8 miles and 5 miles long. Find the area of the enclosed space. Use your answer to calculate the shortest distance from the longest side across to the opposite corner of the triangle.
22. A block of concrete is 2 feet long, 18 inches broad and 15 inches high; if the specific gravity of concrete is 2·6, what is the weight of the block?
23. If a petrol tin measures $9\frac{1}{2}$ inches by $5\frac{1}{2}$ inches and is 11 inches high, how many gallons does it hold? What will be the weight of the petrol if its specific gravity is 0·85?
24. A cylindrical oil tank is 12 feet in diameter and it is required to place a vertical scale in the tank marked at every 1000 gallons. At what distance apart must the graduations be placed? (1000 gallons = 160 cubic feet.)
25. How many square feet of steel plates are required to make a rectangular tank 10 feet long, 8 feet broad and 6 feet high? (Add 10 per cent for overlapping.)
26. The radius of a sphere is 2·5 metres. Find the volume of the sphere and the area of its surface.
27. A cast-iron ball for a safety valve is 6 inches in diameter; if the specific gravity of the iron is 7·2, what is the weight of the ball?

28. The outer diameter of a hollow iron sphere is 12 inches, the inner diameter is 10 inches. Find the volume of the shell.
29. Find how many gallons, also tons weight, are in a tank full of water whose depth is 10 feet, breadth 8 feet, length 6 feet.
30. Find how many casks of the following dimensions would be required to hold the water in the above tank, length 5 feet, bilge diameter 30 inches, end diameter 26 inches.
31. The external and internal diameters of a steel tube 14 feet long are 12 inches and 10 inches respectively. Find (1) the volume of the enclosed space, (2) the volume of the steel forming the tube, (3) the weight of the tube, the specific gravity of steel being 7·84.

Chapter 5

Logarithms

DEFINITION A logarithm is the exponent of the POWER to which a fixed number called the BASE must be raised to produce a certain other number.

The common logarithms used in navigation are calculated to **base 10**, and consist of a whole number called the **index**, and a decimal fraction called the **mantissa**, the latter generally being given to 6 places of decimals.

If $a^x = N$, then x is called the logarithm of N to the base a for example,

$a^x = N$ ∴ the log of N to base $a = x$
$10^1 = 10$ ∴ the log of 10 to base 10 = 1
$10^2 = 100$ ∴ the log of 100 to base 10 = 2
$10^3 = 1000$ ∴ the log of 1000 to base 10 = 3
$10^4 = 10{,}000$ ∴ the log of 10,000 to base 10 = 4.

The mantissa of the log of any number **in between these** will be a decimal fraction other than 000000. Calculating these fractions involves a considerable amount of work. But it is not necessary to do this as they are published in tabular form in Nautical Tables, and many mathematical books.

Looking at one of the pages in the Table of Logs, it can be seen that the left-hand margin a column headed **"No."** (number), and then ten columns of other numbers, each containing five figures; these are the logs, but they are not complete as they are printed (except for numbers less than 100). They require to have a decimal point and what is called an **index** prefixed. The **index** is very easily found mentally, the following being the rule for all numbers greater than one. Numbers less than one, i.e. numbers consisting entirely of decimals, will be considered later.

RULE The index of the log of any given number is one less than the number of figures before the decimal point in the given number.

Thus the index of the log of 42648·5 is 4, because there are five figures before the decimal point, also any other number which has 5 figures before the decimal point would have 4 as the index of its log.

Similarly the index of 3974·21 is 3
Similarly the index of 397·421 is 2
Similarly the index of 84·83 is 1
Similarly the index of 6·54 is 0.

You will see from the foregoing that **the index depends entirely upon the place occupied by the decimal point**, and does not depend upon the actual figures. The index of 349·8 is 2 and is the same as that of 947·643, because in each case there are the same number of figures (3) before the decimal point.

To Find the Log Corresponding to a Number

The following notes and examples should be verified by reference to a table of logarithms.

Example 1

Find the log of 438.

Look for 438 in the left hand column headed "*No.*", and in the column headed 0 we find 64147. The index will be 2 because there are three digits in 438, therefore

the log of 438 is 2·64147
and the log of 4380 is 3·64147
and the log of 43800 is 4·64147

and so on for as many ciphers as are tacked on to the number, the mantissa being the same in each case, the only difference being in the index.

When there are four figures in the number the fourth figure is given at the head of the columns, thus the log of 4387 is 3·64217; that is, look for 438 in the left hand column and in the same line but in the column headed 7 we find 64217. Similarly the log of 43·86 is 1·64207.

Exercise 1

Find the logs of the following numbers:

1. 3465	4. 374	7. 9·8	10. 99990
2. 346·5	5. 980	8. 35090	11. 100·1
3. 62·84	6. 98	9. 6100	12. 1

When the number of which the log is required consists of more than four figures, proceed as follows. Write down the log of the first four figures as before, and at the same time write down the number in the **"diff."** (difference) column in the same line, at the right-hand margin; multiply this **"diff."** by the remaining figures, and point off from the right as many figures as there are in the number after the first four. What is left is the correction to add to the log taken from the tables, and the sum with the proper index prefixed, will be the log required.

Example 2

Find the log of 265·88.

Here we have **three** digits in the whole number, therefore the index will be 2.

			To find corr.
The log of the first four figures 2658 is	42456	Diff. =	16
Correction for remaining figure 8 is	+13	Multiply by	8
The log of 265·88 is	2·42469		12·8

To find the correction, the "diff." 16 was multiplied by the figure remaining after the first four, which was 8; then, as there was only **one** figure left, **one** figure (the 8) was cut off from the product, leaving as the correction 13. This being added to the log of the first four figures and index 2 prefixed gives the log of the number 265·88.

The quantity given in the **"diff."** column is just the difference between two consecutive logs; if there are five figures in the number for which the log is sought then it will be the **"diff."** for 10 parts; if there are six figures in the number it will be the difference for 100 parts, and for a seven figure number it will be the difference for 1000 parts. The proportion for the above

example would read as follows. If 16 is the log **diff.** for a change of 10 in the number, what will be the log diff. for a change of 8 in the number

$$\frac{\text{Cor}}{16} = \frac{8}{01} \qquad \therefore \text{cor} = \frac{16 \times 8}{10} = 12{\cdot}8.$$

Example 3

Find the log of 24625·9.

The log of	2462 is	39129
Correction for	59 is	+11
The log of	24625·9	4·39140

Cor = Diff. $18 \times 59 = 10{\cdot}62$. Point of two digits for the two figures 59 and call the correction 11 because the first figure after the point is over 5.

Exercise 2

Find the logs of the following numbers:

1. 497·38	4. 82478·53	7. 9810·09	10. 132·4009
2. 376·485	5. 40·8269	8. 86000	11. 10000·9
3. 8916·4	6. 713·05	9. 61380·65	12. 100000

To Find the Number Corresponding to a Log

Example 4

Find the number of which 2·40071 is the log.

On finding 40071 amongst the logs we get from the left-hand margin, in the No. column, the first three figures 251, and from the top the fourth figure, which is 6. Therefore the figures are 2516. We now look at the index which, being 2, tells us there must be three figures before the decimal point, making the number 251·6.

If the log had been 5·40071, that is index 5 instead of index 2, the procedure would be the same and we would get the figures 2516 from the table, but in this example, the index being 5, there must be six figures before the decimal point, so in this case (but only because the log comes out exact) we tack on ciphers to make up the requisite number of digits and the number then becomes 251600.

Exercise 3

Find the numbers corresponding to the following logs:

1. 2·29425	4. 2·86273	7. 5·82387	10. 6·00087
2. 4·41447	5. 1·91908	8. 4·85733	11. 2·00000
3. 0·56926	6. 3·90314	9. 0·93450	12. 0·00000

To Find Numbers Containing More Than Four Figures

We can always get from the table the first four figures of a number corresponding to a log, but when the given log cannot be found in the table but fits in between two of the tabulated logs we proceed as follows.

Write down the number corresponding to the next lesser log and put in the decimal point as indicated by the index of the log.

Example 5

Find the number of which 2·41386 is the log.

The next lower log is 41380 which corresponds to the natural number 2593, therefore the number required is 259·3 because the index is 2.

But had the log been 5·41386 then we would need six figures in the whole number, and as it is usual to give answers to at least one or two decimal places we would need to find at least three more digits and tack them on to the number 2593 as follows:

Under the given log 5·41386
write the next lower from table ·41380
and divide the difference 8 by

the difference tabulated in the right hand column and in the same line, viz., 17 as shown at side. Add a cipher to the 6 making it 60 and continue the long division sum until there are figures enough to make up the requisite number of digits when tacked on to 2593. The number is 259335·29 and its log is 5·41386.

Diff. Corr.
17)60(3529
51
90
85
50
34
160
158

The tabulated difference is merely the difference between two successive logs for 10 parts in the natural number, or for 100 parts, or for 1000 parts depending on whether we want one figure more than four in our answer, or two more or three more respectively. In the above example we wanted at least seven figures in our number, that is three more than the four (2593) we lifted from the table so the proportion is: if the log diff. is 17 for 1000 parts in the number how many parts will a difference of 6 give?

$$\frac{\text{Cor}}{1000} = \frac{6}{17} \qquad \therefore \text{Cor} = \frac{6 \times 1000}{17} = \frac{6000}{17} = 353$$

in short, add to our difference the same number of ciphers as the additional figures wanted (in this case three), and divide by the tabulated difference.

Example 6

Find the number to three decimal places of which 4·79055 is the log.

The given log is 4·79055
next lower log from table is ·79050
difference 5

The number is 61737·143

Diff. Corr.
7)50(71428
49
10
7
30
28
20
14
60
56

The index tells us that five figures are required in the whole number and with the three decimal places we need four additional figures, so add four ciphers to our difference 5 and the $\text{Cor} = \frac{50000}{7} = 7143$.

Exercise 4

Find the numbers corresponding to the following logs:

1. 4·68444	4. 5·69760	7. 4·96137	10. 5·00346
2. 5·57353	5. 3·77820	8. 3·99998	11. 6·04140
3. 6·58967	6. 5·87506	9. 0·56844	12. 5·00000

THE USE OF LOGS

Logarithms convert the operation of multiplication into addition and division into subtraction. We can only multiply two numbers together or divide one into the other by means of logs, and they simplify the working of certain problems which would be very complicated, if not impossible, under the rules of arithmetic.

If $a \times b = c$, then $\log a + \log b = \log c$.

If $3 \times 4 = 12$, then $\log 3 + \log 4 = \log 12$

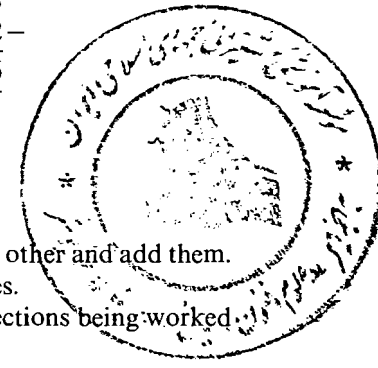
and for convenience would be written

	3 log 0·47712
	4 log 0·60206 +
Answer	12 log 1·07918

If $a \div b = c$, then $\log a - \log b = \log c$.

If $12 \div 3 = 4$, then $\log 12 - \log 3 = \log 4$

	12 log 1·07918
	3 log 0·47712 −
Answer	4 log 0·60206



Multiplication by Logs

Rule Find the log corresponding to each number, place them under each other and add them. The sum is the log of the answer which can be found as in the last examples.

The work should be arranged as in the following examples, the corrections being worked in the margin.

Example 7

Multiply 374·8 by 1250 by common logs.

	Log 374·8 + log 1250	= log x
	374·8	log 2·57380
	1250	log 3·09691
Answer	468500	log 5·67071

Example 8

Multiply 2901·6 by 198·5 by logs.

Minor correction

	46255	Diff.	15
Cor +	9		6
	46264		+9·0

$$\text{Cor} = \frac{5000}{8} = 625$$

	Log 2901·6 + log 198·5	= log x
	2901·6	log 3·46264
	198·5	log 2·29776
Answer	575962·5	log 5·76040
	Next lower log	76035
		8)50(

Exercise 5

Multiply the following numbers by logs, working the answer as far as the first decimal figure.

1. 348 by 475
2. 527·5 by 27·48
3. 547·5 by 37·48
4. 3654 by 500
5. 30057 by 40
6. 963 by 48·9
7. 8764·32 by 436·43
8. 7654·2 by 65·47
9. 9876·98 by 986·34
10. 1234·2 by 689·78
11. 9000·12 by 1001·1
12. 3704·16 by 27800·5
13. 710·842 by 100·008
14. 76583·9 by 276·542
15. 50·4006 by 20·0004
16. 6743·98 by 64·537

DIVISION BY LOGS

Rule Find the log of each number, and subtract the log of the divisor from the log of the dividend; the remainder is the log of the answer.

Example 9

Divide 1326·6 by 2·948 by logs.

Minor corrections

12254	Diff.	33
20		6
12274		19·8

Log 1326·6 − log 2·948 = log x

1326·6	log	3·12274
2·948	log	0·46953
Answer 450	log	2·65321

Example 10

Divide 89480·18 by 3·95008 by logs.

95173	Diff.	5
0		018
95173		·090

59660	Diff.	11
1		08
59661		·88

Log 89480·18 − log 3·95008 = log x

89480·18	log	4·95173
3·95008	log	0·59661
Answer 22652·6		4·35512
	log	35507

Diff. 19)50(26

38

120

114

6

Exercise 6

Work the following by logs:

1. Divide 1065 by 2·84
2. Divide 846·96 by 4·38
3. Divide 298·46 by 2·146
4. Divide 387600 by 120
5. Divide 69120 by 12
6. Divide 97·648 by 1·47
7. Divide 66889·2 by 99
8. Divide 999·43 by 67·832
9. Divide 8491·9 by 98·4
10. Divide 8465·32 by 23·42

11. Divide 9876·4 by 24·1
12. Divide 71·0842 by 10·0001
13. Divide 89·6438 by 60·008
14. Divide 346040 by 15604
15. Divide 7000·08 by 30·0006
16. Divide 287642 by 68421

LOGS OF DECIMAL NUMBERS

So far, we have been dealing only with numbers greater than one; that is, those which contain whole numbers. When the number of which the log is required consists entirely of decimals, the index is negative; that is, it is a figure with the minus (−) sign attached to it.

No.	Index	Mantissa	
325	log 2·	51188	
32·5	log 1·	51188	
3·25	log 0·	51188	
·325	log $\bar{1}$·	51188	or $\bar{1}+10 = \log 9{\cdot}51188$
·0325	log $\bar{2}$·	51188	or $\bar{2}+10 = \log 8{\cdot}51188$
·00325	log $\bar{3}$·	51188	or $\bar{3}+10 = \log 7{\cdot}51188$

The negative sign introduces a slight complication in working, and in order to avoid the difficulty of negative signs in the index of logs used in navigation the artifice of adding 10 to the index is adopted as above, the rule being to count the decimal and the ciphers which follow it and subtract from 10, any multiples of 10 being rejected from the log of the answer. This artifice is also followed in the Tables of Log Sines, Tangents, Secants, etc.

MULTIPLICATION

Rule Take out the log of each number as before and add them together; the sum is the log of the answer.

1. If both the numbers to be multiplied consist entirely of decimals the answer will only contain decimals.

2. If one contains whole numbers, and the other only decimals, the answer will be a whole number if, after adding, the index comes to 10 or more; but if index is less than 10 the answer will be entirely decimal.

Note When the index comes over 10 reject 10, or multiples of 10, from it.

Example 11

Multiply 28·048 by ·0025 by logs.

44778	Diff.	16		
13		8		
44791		12·8	*Answer*	·07012

Log 28·048 + log ·0025 = log x

28·048	log 1·44791
·0025	log 7·39794
·07012	log 8·84585

In this example one of the numbers is entirely decimal, and the other contains whole numbers; therefore as, after adding, the index is less than 10, by Rule 2 the answer will only contain decimals. The index being 8, one cipher must be placed after the decimal point, followed by the four figures corresponding to the nearest log found in the tables.

Example 12

Multiply 346·75 by ·00048 by logs.

		Diff.
	53995	13
	7	5
	54002	6·5

	Log 346·75 + log ·00048	= log x
	346·75	log 2·54002
	·00048	log 6·68124
Answer	·1664	log 9·22126

Example 13

(a) Multiply 987·6 by ·084 by logs.

	Log 987·6 + log ·084	= log x
	987·6	log 2·99458
	·084	log 8·92428
Answer	82·96	log 1·91886

After adding the logs in this example the index comes to 11, therefore reject 10 from the index and the remainder is 1, which is the index of a whole number.

(b) Multiply ·0463 by ·0089 by logs.

	Log ·0463 + log ·0089	= log x
	·0463	log 8·66558
	·0089	log 7·94939
Answer	·0004121	log 6·61497

In this example both the quantities are decimal numbers therefore the answer is a decimal. The index 6 indicates that three ciphers are to be put in immediately after the decimal point.

Exercise 7

Multiply by logs the following numbers:

1. ·175 by ·0048
2. 398·7 by ·064
3. 27·98 by ·00018
4. 24·586 by ·00075
5. 846·2 by ·50001
6. ·00463 by ·00085

DIVISION

Rule 1. If a greater number is divided by a smaller one, the answer will contain whole numbers.

2. If a smaller number is divided by a greater one, the answer will consist entirely of decimals.

Example 14

(a) Divide 6·482 by 98·16 by logs.

	Log 6·482	− log 98·16	= log x
	6·482	log	0·81171
	98·16	log	1·99193
Answer	·06604	log	8·81978

The answer is a decimal because a smaller number has been divided by a greater number.

(b) Divide ·0641 by ·0097 by logs.

	Log ·0641 − log ·0097	= log x
	·0641	log 8·80686
	·0097	log 7·98677
Answer	6·608	log 0·82009

The answer contains whole numbers because ·0641 is greater than ·0097.

(c) Find the value of $\dfrac{\cdot 2 \times \cdot 02 \times \cdot 22}{5}$.

$$\text{Log } \cdot 2 + \log \cdot 02 + \log \cdot 22 - \log 5 = \log x.$$

Take out the logs of ·2, ·02 and ·22. Add them, reject 10's from the index, then subtract the log of 5 from their sum. The result is the log of the answer.

	·2 log 9·30103	The index of the log in each case having been increased by 10 to avoid the minus index, all multiples of ten have to be rejected from the sum of the log, thus 26 is written as 6 only.
	·02 log 8·30103	
	·22 log 9·34242	
	log 6·94448	
	5 log 0·69897	
Answer	·000176 log 6·24551	

Exercise 8

1. Divide 32·49 by 562·8
2. Divide ·0645 by ·00025
3. Divide ·645 by 2·5
4. Divide ·0467 by ·075
5. Divide ·0008674 by ·00005
6. Divide ·00642 by ·09
7. Find the value of $\dfrac{\cdot 05 \times \cdot 5 \times \cdot 55}{5}$
8. Find the value of $\dfrac{\cdot 6 \times \cdot 06 \times \cdot 66}{8}$

INDICES AND LOGARITHMS

Logs obey the laws of indices and this seems to be a suitable place to introduce a few remarks on the theory of indices as the value of logs in reducing arithmetical calculations is very apparent when dealing with powers and roots. A logarithm is merely an index and has the same properties, thus $3^2 = 9$, $\therefore$ 2 is the log of 9 to the base 3. If

$$a^3 = x \qquad \text{then} \qquad 3 \log a = \log x$$

because

$$a^3 = a \times a \times a \qquad \therefore \log a^3 = \log a + \log a + \log a = 3 \log a.$$

Thus

$$4^3 = 4 \times 4 \times 4 = 64 \qquad \therefore 3 \log 4 = \log 64.$$

Rule When multiplying together powers of the same number add its indices but subtract the indices when dividing, thus:

$$\frac{a^4 \times a^5}{a^2 \times a^3} = \frac{a^{4+5}}{a^{2+3}} = \frac{a^9}{a^5} = a^{9-5} = a^4 \qquad \text{because} \qquad \frac{a^9}{a^5} = \frac{\not{a} \times \not{a} \times \not{a} \times \not{a} \times \not{a} \times a \times a \times a \times a}{\not{a} \times \not{a} \times \not{a} \times \not{a} \times \not{a}} = a^4.$$

Now $\dfrac{3^9}{3^5} = 3^{9-5} = 3^4 = 81$

but,

$$\log 3^4 = 4 \log 3 = 4(0{\cdot}47712) = 1{\cdot}90848 \text{ which is the log of } 81.$$

Rule When raising a number to a higher power, multiply its log by the power and we then get the log of the answer.

Now $5^3 = 125 = \text{say } x$

$$\therefore 3\log 5 = \log x = 3 \times 0{\cdot}69897 = 2{\cdot}09691, \text{ which is the log of 125.}$$

Example 15

Find the value of $(208 \times 2)^3 \div (156 \times 3)^2$.

Let the required value be x and rewrite the question by getting the product of the bracketed quantities.

$$x = 416^3 \div 468^2$$
$$\therefore \log x = 3\log 416 - 2\log 468$$
$$= 3\log 2{\cdot}61909 - 2\log 2{\cdot}67025$$
$$= \log 7{\cdot}85727 - \log 5{\cdot}34050 = \log 2{\cdot}51677 \text{ which is the log of } 328{\cdot}7.$$

Answer 328·7.

One is less liable to make mistakes when subtracting if the quantities be placed under each other, so copying down the above we have,

	416^3	$\log 7{\cdot}85727$
	468^2	$\log 5{\cdot}34050$
Answer	$328{\cdot}7$	$\log 2{\cdot}51677$

Fractional indices are treated in the same way. $a^{\frac{1}{3}}$ may be written as $\sqrt[3]{a}$ and $a^{\frac{4}{5}}$ as $\sqrt[5]{a^4}$. $27^{\frac{1}{3}} = \sqrt[3]{27} = 3$ or $\frac{1}{3}\log 27 = \frac{1}{3}(1{\cdot}43136) = 0{\cdot}47712$, which is the log of 3.

Rule When extracting the root of a number by logs, divide its log by the root and we have the log of the answer.

Example 16

Simplify and find the value of $a^{\frac{2}{3}} \times a^{\frac{5}{6}}$ if $a = 12$.

$$a^{\frac{2}{3}} \times a^{\frac{5}{6}} = a^{\frac{4+5}{6}} = a^{\frac{9}{6}} = a^{\frac{3}{2}} = \sqrt{a^3}.$$

If $a = 12$, then $a^{\frac{3}{2}} = 12^{\frac{3}{2}}$ and

$$\log 12^{\frac{3}{2}} = \frac{3}{2}\log 12 = \frac{3\log 1{\cdot}07918}{2} = \frac{\log 3{\cdot}23754}{2} = \log 1{\cdot}61877,$$

which is the log of 41·57 the answer required.

Fractional quantities may be transferred from the numerator to the denominator of an expression, or *vice versa*, by merely changing the sign of the index as follows:

$$\frac{2a^{-3}}{6b^{-2}c} = \frac{a^{-3}b^2c^{-1}}{3} \text{ the } \frac{2}{6} \text{ cancels to } \frac{1}{3}$$

but if we wished to arrange the quantities so that they would appear with positive indices only, we would simply transfer those having negative indices, as follows:

$$\frac{a^{-3}b^2c^{-1}}{3} = \frac{b^2}{3a^3c}.$$

Example 17

Simplify and find its value when $a = 4$ of $\dfrac{3a^{\frac{1}{2}} \times \sqrt[3]{a^2} \times a^{-\frac{7}{3}}}{9a^{-\frac{5}{3}} \times \sqrt{a^3}}$.

Rewrite the question in index form and all in one line by transferring the denominator, not forgetting to change the sign of its indices, thus

$$\frac{3}{9}a^{\frac{1}{2}} \times a^{\frac{2}{3}} \times a^{-\frac{7}{3}} \times a^{\frac{5}{3}} \times a^{-\frac{3}{2}}$$

then get the algebraic sum of the indices.

$$\frac{1}{3}a^{\frac{1}{2}+\frac{2}{3}-\frac{7}{3}+\frac{5}{3}-\frac{3}{2}} = \frac{1}{3}a^{\frac{17-23}{6}} = \frac{1}{3}a^{-\frac{6}{6}} = \frac{a^{-1}}{3} = \frac{1}{3a} = \frac{1}{12} \qquad \text{because } a = 4.$$

A quantity when raised to power zero is always equal to unity, that is $a^0 = 1$, because $0 \times \log a = 0 = \log 1$, so that the log of any quantity when multiplied by power 0 always comes to 000, which is the log of 1, thus $12^0 = 1$; $156^0 = 1$.

Example 18

(a) Find the value of $16^{\frac{3}{4}}$. This is simply $\sqrt[4]{16^3}$, but the 4th root of 16 is 2, and $2^3 = 8$ *Answer.*

(b) Find the value of $\dfrac{1}{25^{-2}}$. This is written as 25^2 or $25 \times 25 = 625$ *Answer.*

(c) Find the value of $\left(\dfrac{8}{27}\right)^{-\frac{1}{3}}$. This is written as

$$1 \div \left(\frac{8}{27}\right)^{\frac{1}{3}} \text{ or as } 1 \div \sqrt[3]{\frac{8}{27}} = 1 \div \frac{2}{3} = \frac{3}{2} \quad \textit{Answer.}$$

(d) Find the value of $\dfrac{27^2 \times 3^3 \times 6^{-2}}{27^{\frac{7}{3}} \times 3^2 \times 6^{-3}}$.

Rewrite the question as $27^{\frac{2}{1}-\frac{7}{3}} \times 3^{3-2} \times 6^{-2+3} = 27^{-\frac{1}{3}} \times 3 \times 6$

$$= \frac{3 \times 6}{27^{\frac{1}{3}}} = \frac{3 \times 6}{3} = 6 \quad \textit{Answer.}$$

Exercise 9

Find the value of the following expressions without using logarithms.

1. $125^{\frac{2}{3}}$ 2. $243^{\frac{2}{5}}$

3. $36^{-\frac{3}{2}}$

4. $4^{-\frac{5}{2}}$

5. $8^{-\frac{2}{3}}$

6. $\left(\frac{81}{16}\right)^{\frac{3}{4}}$

7. $\left(\frac{32}{243}\right)^{-\frac{7}{6}}$

8. 55^0

Simplify and express with positive indices

9. $\frac{a^3 \times a^{-2} \times a^{\frac{1}{2}}}{a^{-4} \times a^5}$ and find value if $a = 9$

10. $\frac{x^{\frac{2}{3}} \times x^{-\frac{1}{2}} \times x^{-1}}{x^{\frac{4}{3}} \times x^{-3}}$

11. $(\sqrt{a^2b^3})^6$

12. $\frac{a^{\frac{1}{2}}b^3c^{-\frac{1}{2}}}{a^{\frac{3}{4}}b^{-1}c^0}$ and find the value of the expression if $a = 81, b = 4, c = 64$

Exercise 10

Find the values of the following expressions by common logs:

1. $\sqrt{6814}$

2. $\sqrt[3]{1800+397}$

3. $\sqrt[3]{1800 \times 397}$

4. $\sqrt{\frac{19\frac{1}{4} \times 18\frac{6}{10}}{21\frac{4}{5}}}$

5. $\frac{(23)^2 \times (16)^3}{\sqrt{3880}}$

6. $\frac{\sqrt[3]{182\frac{3}{4} \times 200{\cdot}7}}{20\frac{4}{5}}$

7. $\sqrt[3]{\left(\frac{1\frac{4}{5} \times 2\frac{4}{10}}{4\frac{1}{4}}\right)^2}$

It would simplify examples like those of question (4) to turn the vulgar fractions into decimal fractions and rewrite the question $\sqrt{\frac{19{\cdot}25 \times 18{\cdot}6}{21{\cdot}8}}$ then carry on the solution by logs the logarithmic form being, $\log x = \frac{1}{2}(\log 19{\cdot}25 + \log 18{\cdot}6 - \log 21{\cdot}8)$.

Exercise 11

Find the values of the following expressions by common logs:

1. $(\cdot 6628)^2$
2. $(\cdot 761)^3$
3. $(\cdot 222)^5$
4. $(\cdot 266 \times \cdot 008)^2$
5. $(\cdot 818 \times 1{\cdot}08)^3$
6. $(112 \div 150)^4$

The artifice of adding 10 to the index of the log of a decimal number in order to avoid a negative index introduces a slight complication when extracting the root of a fraction or when raising it to a power, but the difficulty is got over by writing in front of the index a figure one less than the root to be extracted; for a square root this figure would be 1; for a cube root it would be 2; for a fourth root 3.

The index and log is then divided by 2 if the square root is required, by 3 for the cube root and by 4 for the fourth root and so on.

Example 19

(a) Find the value of $\sqrt{\cdot 0025}$.

$\frac{1}{2}\log \cdot 0025 = \log x$

$\cdot 0025 \log\ 2)\overline{17 \cdot 39794}$

Answer $\underline{\cdot 05}$ log $\underline{8 \cdot 69897}$

(b) Find the value of $\sqrt[3]{\cdot 8684}$.

$\frac{1}{3}\log \cdot 8684 = \log x$

$\cdot 8684 \log\ 3)\overline{29 \cdot 93872}$

Answer $\underline{\cdot 9541}$ log $\underline{9 \cdot 97957}$

Example 20

Find the value of $\sqrt[5]{\cdot 818 \times \cdot 076}$.

$\frac{1}{5}(\log \cdot 818 + \log \cdot 076) = \log x$

$\cdot 818 \log\ 9 \cdot 91275$

$\cdot 076 \log\ \underline{8 \cdot 88081}$

$5)\overline{48 \cdot 79356}$*

Answer $\underline{\cdot 5737}$ log $\underline{9 \cdot 75871}$

* The multiples of 10 are rejected so that index 18 becomes 8, and then a 4 is written in front of the 8 before dividing by 5 to get the log of the 5th root.

Exercise 12

Find the value of the following expressions by common logs:

1. $\sqrt{\cdot 569}$ 3. $\sqrt{2 \cdot 36 \times \cdot 009}$ 5. $\sqrt[3]{\cdot 0088 \times \cdot 0099}$
2. $\sqrt[3]{\cdot 008}$ 4. $\sqrt[4]{\cdot 05 \times \cdot 005}$ 6. $\sqrt[5]{\cdot 626 \div \cdot 962}$

Example 21

Find the value by logs of $\sqrt[3]{\left(\frac{294 \times 125}{42 \times 35}\right)^2}$.

Let the answer be x, then

$$\log x = \tfrac{2}{3}\{(\log 294 + \log 125) - (\log 42 + \log 35)\}.$$

Numerator		Denominator	
294 log	2·46835	42 log	1·62325
125 log	2·09691	35 log	1·54407
log	4·56526	log	3·16732
log	3·16732		
	$3)\overline{1 \cdot 39794}$		
	0·46598		
	2		

Answer 8·53 log $\underline{0 \cdot 93196}$

But it so happens that the bracketed quantity lends itself to cancelling and simplifications.

$$\left(\frac{\overset{7}{\cancel{294}} \times \overset{25}{\cancel{125}}}{\underset{5}{\cancel{42} \times \cancel{35}}}\right)^{\frac{2}{3}} = 25^{\frac{2}{3}} \qquad \therefore \log x = \tfrac{2}{3}\log 25$$

$$= \tfrac{2}{3}(1 \cdot 397940)$$

$$= 0 \cdot 931960$$

$$\therefore x = 8 \cdot 53 \quad \textit{Answer.}$$

Quantities do not always cancel down and they may sometimes be joined up by plus and minus signs and in such cases the sums cannot be entirely solved by logs which in their operation are restricted to multiplication, division, powers and roots.

For example, evaluate by logs $\sqrt[3]{\dfrac{8{\cdot}06^2+18{\cdot}696}{8{\cdot}06^2-18{\cdot}696}}$.

Take out the log of 8·06, multiply the log by 2, this gives the log of $8{\cdot}06^2$, the number being 64·964 then add to it 18·696 for the numerator and subtract from it 18·696 for the denominator, the question will then read $\sqrt[3]{\dfrac{83{\cdot}660}{46{\cdot}268}}$; the layout of the work may be as follows:

8·06	log	0·90634	*Minor corrections*
		2	Diff. $\frac{30}{7}$ = 42, call it 4
64·964	log	1·81268	
		5	
±18·696		Diff. 3	
83·660	log	1·92252	Diff. 9 × 8 = 7·2 = corr. for log.
46·268	log	1·66528	
		3)0·25724	
Answer 1·218	log	0·08575	

Example 22

Evaluate by logs $\dfrac{\sqrt{{\cdot}0076\times 31{\cdot}683}}{\frac{3}{4}(408)^{\frac{3}{4}}}$.

It is perhaps better to tidy up the denominator first because we have to find three-quarters of 408 when it is raised to the power of three-fourths.

$\frac{3}{4}\log 408 =$ 2·61066

3

4)7·83198

$(408)^{\frac{3}{4}} =$ 90·78 log 1·95799

3

4)272·34

68·085 which is the value of $\frac{3}{4}(408)^{\frac{3}{4}}$.

The question now reads $\dfrac{\sqrt[3]{{\cdot}0076\times 31{\cdot}683}}{68{\cdot}085} = x$ and in logarithmic form it is written as

$\log x = \frac{1}{3}(\log {\cdot}0076 + \log 31{\cdot}683) - \log 68{\cdot}085$

	·0076	log	7·88081	*Corr of logs*
	31·683	log	1·50083	Diff. $14 \times 3 = 4{\cdot}2$
			3)29·38164	
	Numerator	log	9·79388	
	68·085	log	1·83305	Diff. $6 \times 5 = 3$.
Answer	·009138	log	7·96083	

Exercise 13—Various Examples

Solve the following expressions by logs:

1. $\sqrt{\dfrac{88\frac{1}{4} \times 16\frac{4}{5}}{24\frac{1}{10}}}$.

It usually simplifies working to express vulgar fractions as decimal fractions, rewrite the question in logarithmic form and solve for x. The above question would then appear as

$$\tfrac{1}{2}(\log 88{\cdot}25 + \log 16{\cdot}8 - \log 24{\cdot}1) = \log x.$$

2. $\left(\dfrac{8\sqrt{15}}{4{\cdot}1^3}\right)^2$.

In logarithmic form this would be

$$2(\log 8 + \tfrac{1}{2}\log 15 - 3\log 4{\cdot}1) = \log x.$$

3. $\dfrac{(14\frac{1}{5})^2 \times (17\frac{1}{2})^2}{(15\frac{1}{10})^3}$.

Write, $2\log 14{\cdot}2 + 2\log 17{\cdot}5 - 3\log 15{\cdot}1 = \log x$, and solve for x

4. $\sqrt{\dfrac{{\cdot}16 \times {\cdot}016 \times {\cdot}0016}{25}}$

5. $\sqrt[3]{\dfrac{14\frac{3}{10} \times 16\frac{1}{4}}{23}}$

6. $\sqrt{\dfrac{3\frac{1}{4} \times 8\frac{1}{2}}{3\frac{2}{5}}}$

7. ·0032 × 721·4 to four decimal places

8. $\sqrt{\dfrac{74\frac{1}{5} \times 26\frac{3}{5}}{224\frac{3}{5} \div 4{\cdot}5}}$

9. $\sqrt{\dfrac{{\cdot}9 \times {\cdot}09 \times {\cdot}009}{33}}$

10. $\sqrt[4]{\dfrac{(32{\cdot}6 \times 16{\cdot}5)^2}{(6{\cdot}5 \times 7{\cdot}2)^3}}$

11. $\sqrt{\dfrac{2{\cdot}25 \times 7{\cdot}6}{2{\cdot}5}}$

12. $\sqrt[3]{\left(\dfrac{4\frac{4}{5} \times 2\frac{8}{10}}{4\frac{1}{4}}\right)^2}$

13. $\dfrac{(13\frac{1}{5})^2 \times (46\frac{1}{4})^3}{(18\frac{3}{4})^4}$

14. $\sqrt[3]{\dfrac{19\frac{1}{4} \times 18\frac{6}{10}}{21\frac{4}{5}}}$

15. $\sqrt[3]{\dfrac{{\cdot}000125}{5}}$

16. $\sqrt{\dfrac{{\cdot}3 \times {\cdot}03 \times {\cdot}003}{7}}$

17. $\sqrt[3]{\dfrac{8496 + 345}{\sqrt{7} + \sqrt{9}}}$

Answers at the end of the book.

Sometimes candidates are restricted to the use of a few logs only such as $\log 2 = 0{\cdot}30103$, $\log 3 = 0{\cdot}47712$, $\log 5 = 0{\cdot}69897$, $\log 7 = 0{\cdot}84510$, and are asked to find the logs of numbers which are made up of multiples of 2, 3, 5 or 7, or combinations of them.

Example 23

(a) Using only the logs of 2, 3, 5 and 7, find the log of 1575.

Divide the number by 2 or 3 or 5 or 7 and see how many times any or all of them will go into the number without leaving a remainder.

3)1575
3) 525
5) 175
5) 35
7

The number is made up of $3 \times 3 \times 5 \times 5 \times 7$ or $3^2 \times 5^2 \times 7$

$$\therefore \log 1575 = 2\log 3 + 2\log 5 + \log 7$$
$$= (2 \times 0{\cdot}47712) + (2 \times 0{\cdot}69897) + (0{\cdot}84510)$$
$$= 0{\cdot}95424 + 1{\cdot}39794 + 0{\cdot}84510$$
$$\log 1575 = 3{\cdot}19728 \quad \textit{Answer.}$$

(b) Find log ·05 having given log 2 only.

$$\log 5 = \log 10 - \log 2 = 1{\cdot}00000 - {\cdot}30103 = {\cdot}69897 \qquad \therefore \log {\cdot}05 = 8{\cdot}69897.$$

(c) Find the log of $\sqrt[3]{1372}$ having given log 7 and log 2.

7)1372
7) 196
7) 28
2) 4
2

$$1372 = 7^3 \times 2^2$$
$$\log 1372 = 3\log 7 + 2\log 2$$
$$\log \sqrt[3]{1372} = \tfrac{1}{3}\log 1372 = \tfrac{1}{3}(3\log 7 + 2\log 2)$$
$$= \log 7 + \tfrac{2}{3}\log 2$$
$$= (0{\cdot}84510) + \tfrac{2}{3}(0{\cdot}30103)$$
$$\log \sqrt[3]{1372} = 1{\cdot}04578 \quad \textit{Answer.}$$

(d) Find log sine 60°.

$$\text{nat sin } 60° = \frac{\sqrt{3}}{2}. \quad \textit{See} \text{ page 109}$$

$$\therefore \log \sin 60° = \log \frac{\sqrt{3}}{2} = \tfrac{1}{2} \times {\cdot}47712 - {\cdot}30103 = 9{\cdot}93753.$$

Given log 2 and log 3, find the log of:

$$\sqrt[5]{24} \times 54^{\frac{1}{3}} \div \sqrt[10]{6}$$
$$24 = 2^3 \times 3 \text{ and } 54 = 3^3 \times 2 \text{ and } 6 = 2 \times 3$$
Rewrite the question: $(2^3 \times 3)^{\frac{1}{5}} \times (3^3 \times 2)^{\frac{1}{3}} \div (2 \times 3)^{\frac{1}{10}}$
Remove brackets: $2^{\frac{3}{5}} \times 3^{\frac{1}{5}} \times 3^{\frac{3}{3}} \times 2^{\frac{1}{3}} \times 2^{-\frac{1}{10}} \times 3^{-\frac{1}{10}}$

Collect indices of each number: $2^{\frac{3}{5}+\frac{1}{3}-\frac{1}{10}} \times 3^{\frac{1}{5}+\frac{1}{1}-\frac{1}{10}} = 2^{\frac{5}{6}} 3^{\frac{11}{10}}$

$$\log x = \tfrac{5}{6}\log 2 + \tfrac{11}{10}\log 3$$
$$= \tfrac{5}{6}({\cdot}30103) + \tfrac{11}{10}({\cdot}47712)$$
$$= {\cdot}25086 + {\cdot}52483 = {\cdot}77569 \quad \textit{Answer.}$$

Exercise 14

1. Given log 2 and log 3, find the log of (a) 72, (b) 1080, (c) ·00096, (d) $6\sqrt{6}$, (e) $(8\frac{1}{3})^{\frac{1}{5}}$, (f) Sec 30°, (g) tan 60°.
2. Given log 2 and log 7, find the log of ·00196.
3. Given the log 2, log 5 and log 3, find the log of $\frac{16}{15}$.

The answers can be checked by looking up the log table.

The following type of equation in which the unknown quantity appears as an index may be solved by using logarithms and it is here shown by way of demonstrating the method.

Solve the equation $a^{4x}b^{2-5x} = c^{3x+3}$.

Rewrite the equation in logarithmic form.

$$4x \log a + (2-5x)\log b = (3x+3)\log c.$$

Multiply out:

$$4x \log a + 2\log b - 5x \log b = 3x \log c + 3 \log c.$$

x is common to the 1st, 3rd and 4th terms.

$$\therefore x(4\log a - 5\log b - 3\log c) = 3\log c - 2\log b$$

$$\therefore x = \frac{3\log c - 2\log b}{4\log a - 5\log b - 3\log c}.$$

If the value of a, b and c be known the value of the unknown x can be found by logs and the problem solved.

Transformation of Common Logarithms to Another Base

By definition, already stated and again repeated, the *log* of a number, to a given *base*, is the *index* of the power to which the *base* must be raised to produce the number,

i.e. if $a^x = b$, then x is called the log of b to the base a.

$3^4 = 81$ ∴ the index 4 is the log of 81 to the base 3
$2^4 = 16$ ∴ the index 4 is the log of 16 to the base 2
$10^3 = 1000$ ∴ the index 3 is the log of 1000 to the base 10.

The system of logs used in practical work are those to the base 10 and are called common logs.

The transformation of common logs to another base is occasionally given in academic work to test a student's knowledge of the definition of a log, for example:

Example 24

Find the log of 34 to the base 8.

By definition, $(\text{base})^{\text{power}} = \text{number}$

$\therefore 8^x = 34$ ∴ x is the log of 34 to the base 8

$$x \log 8 = \log 34$$

$$\therefore x = \frac{\log 34}{\log 8} = \frac{1{\cdot}53148}{0{\cdot}90309} = 1{\cdot}696$$

when the numerator is divided out by the denominator.

Answer Log 34 to base 8 = 1·696.

To be strictly correct we should have written $x = \frac{\log_{10} 34}{\log_{10} 8}$ to show that we were using the logs of 34 and 8 to the base 10, but this is to be taken for granted as we have only the common logs to work with.

Example 25

Find log 63 to base 5.

$$5^x = 63, \qquad \therefore x \log 5 = \log 63$$

$$x = \frac{\log 63}{\log 5} = \frac{1{\cdot}79934}{0{\cdot}69897} = 2{\cdot}574.$$

Answer Log 63 to base 5 = 2·574.

Exercise 15

Find 1. log 76 to base 5
2. log 134 to base 6
3. log 347 to base 7
4. log 16 to base 8
5. log 276 to base 9

Answers in rear *Answer Section.*

Chapter 6

Trigonometry

Trigonometry is that branch of mathematics which deals with the relationships between the sides and angles of a triangle. The triangle may be **right angled plane, oblique angled plane, right angled spherical** or **oblique angled spherical.**

The relation between any two sides and one of the acute angles in a right angled triangle is called the trigonometrical ratio of that angle. The three sides of a triangle can be arranged in six different pairs, consequently there must be six ratios, each of which has a distinctive name: they are, Sine, Tangent, Secant, Cosine, Cotangent, Cosecant, abbreviated respectively to sin, tan, sec, cos, cot, cosec.

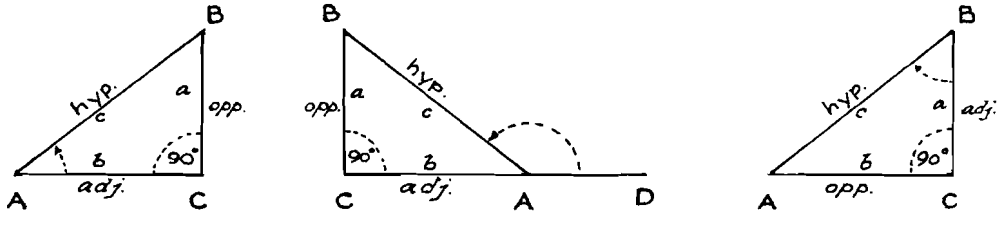


Figure 1.

In triangle ABC, where angle A is referred to, either internal or external, then

Side BC is **opposite** to the angle (opp.)
AC is **adjacent** to the angle (adj.)
AB is the **hypotenuse** (hyp.)

But if angle B is referred to then

Side AC is **opposite** to the angle (opp.)
BC is **adjacent** to the angle (adj.)
AB is the **hypotenuse** (hyp.)

TRIGONOMETRIC FUNCTIONS OF AN ANGLE

In Fig. 2 the angle under consideration is $\angle DOC$, which is equal to $\angle FEO$ as FE and OC are parallel lines. Any ratio of $\angle DOC$ must be the same ratio of $\angle FEO$; let these angles be known as θ.

A geometrical conception of the trigonometric functions of angle θ, that is sine, tan, sec, etc., is conveyed by certain lines on the figure which follows:

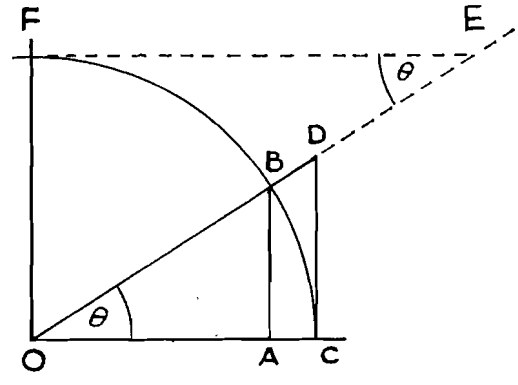


Figure 2.

sine	$\theta = AB$	cosine	$\theta = OA$
tangent	$\theta = CD$	secant	$\theta = OD$
cotangent	$\theta = FE$	cosecant	$\theta = OE$

The unit of measure is the length of the radius of the circle, and when each line is divided by a radius the following ratios are established.

$$\sin\theta = AB = \frac{AB}{\text{a radius}} = \frac{AB}{OB} = \frac{\text{opp}}{\text{hyp}}$$

$$\tan\theta = CD = \frac{CD}{\text{a radius}} = \frac{CD}{OC} = \frac{\text{opp}}{\text{adj}}$$

$$\sec\theta = OD = \frac{OD}{\text{a radius}} = \frac{OD}{OC} = \frac{hyp}{adj}$$

$$\cos\theta = OA = \frac{OA}{\text{a radius}} = \frac{OA}{OB} = \frac{\text{adj}}{\text{hyp}}$$

$$\cot\theta = FE = \frac{FE}{\text{a radius}} = \frac{FE}{OF} = \frac{\text{adj}}{\text{opp}}$$

$$\text{cosec}\,\theta = OE = \frac{OE}{\text{a radius}} = \frac{OE}{OF} = \frac{\text{hyp}}{\text{opp}}.$$

It will be noted that the radius selected as denominator is a side in the same triangle as the numerator associated with it. Another function of an angle used frequently in navigation is called the **haversine**, the abbreviation of which is **hav**.

In figure, $\text{versine}\,\theta = AC = OC - OA = 1 - \cos\theta$

$$\text{haversine}\,\theta = \frac{\text{versine}\,\theta}{2} = \frac{1-\cos\theta}{2}.$$

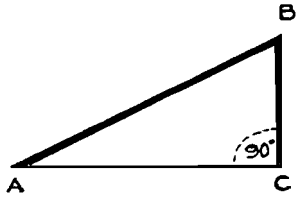
Haversine means half the versine.

Having now established the ratios, the student should memorise them thoroughly as they form the fundamentals of the trigonometrical alphabet from which various formulae are evolved. We shall write them down again in terms of A, remembering that $\angle A$ represents one of the two smaller angles of any right angled plane triangle.

$$\sin A = \frac{\text{opp}}{\text{hyp}} \qquad \sec A = \frac{\text{hyp}}{\text{adj}} \qquad \tan A = \frac{\text{opp}}{\text{adj}} \qquad \text{cosec } A = \frac{\text{hyp}}{\text{opp}} \qquad \cos A = \frac{\text{adj}}{\text{hyp}}$$

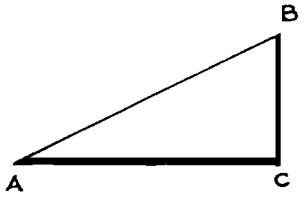
$$\cot A = \frac{\text{adj}}{\text{opp}} \qquad \text{vers } A = 1 - \cos A \qquad \text{hav } A = \frac{1 - \cos A}{2}$$

In naming the sides of a triangle it is often convenient to name the side opposite $\angle A$ as "a", the side opposite $\angle B$ as "b" and the side opposite $\angle C$ as "c".



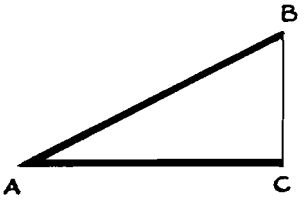
$$\sin A = \frac{\text{opp}}{\text{hyp}} = \frac{a}{c} \qquad \text{cosec } A = \frac{\text{hyp}}{\text{opp}} = \frac{c}{a}$$

$$\cos B = \frac{\text{adj}}{\text{hyp}} = \frac{a}{c} \qquad \sec B = \frac{\text{hyp}}{\text{adj}} = \frac{c}{a}$$



$$\tan A = \frac{\text{opp}}{\text{adj}} = \frac{a}{b} \qquad \cot A = \frac{\text{adj}}{\text{opp}} = \frac{b}{a}$$

$$\cot B = \frac{\text{adj}}{\text{opp}} = \frac{a}{b} \qquad \tan B = \frac{\text{opp}}{\text{adj}} = \frac{b}{a}$$



$$\sec A = \frac{\text{hyp}}{\text{adj}} = \frac{c}{b} \qquad \cos A = \frac{\text{adj}}{\text{hyp}} = \frac{b}{c}$$

$$\text{cosec } B = \frac{\text{hyp}}{\text{opp}} = \frac{c}{b} \qquad \sin B = \frac{\text{opp}}{\text{hyp}} = \frac{b}{c}$$

Figure 3.

In the following figure there are three similar triangles, ABC, ADE and AFG, angle A being common to all.

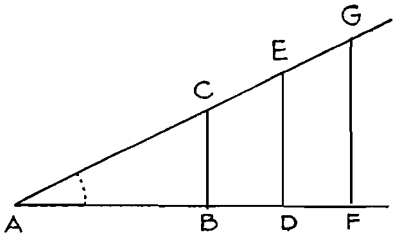


Figure 4.

$$\sin A = \frac{BC}{CA} = \frac{DE}{EA} = \frac{FG}{GA} = \frac{\text{opp}}{\text{hyp}} \quad \text{in every case}$$

$$\text{cosec } A = \frac{AC}{CB} = \frac{AE}{ED} = \frac{AG}{GF} = \frac{\text{hyp}}{\text{opp}} \quad \text{in every case}$$

$$\tan A = \frac{CB}{AB} = \frac{DE}{DA} = \frac{FG}{FA} = \frac{\text{opp}}{\text{adj}} \quad \text{in every case}$$

$$\cot A = \frac{AB}{BC} = \frac{AD}{DE} = \frac{AF}{FG} = \frac{\text{adj}}{\text{opp}} \quad \text{in every case}$$

$$\sec A = \frac{AC}{AB} = \frac{AE}{AD} = \frac{AG}{AF} = \frac{\text{hyp}}{\text{adj}} \quad \text{in every case}$$

$$\cos A = \frac{AB}{AC} = \frac{AD}{AE} = \frac{AF}{AG} = \frac{\text{adj}}{\text{hyp}} \quad \text{in every case}$$

Obviously, the values of the ratios depend upon the **relative** values of numerator and denominator and not on their actual values when considered separately.

$\sin A = \frac{1}{2} = \frac{2}{4} = \frac{4}{8}$; here the fractions are different but all represent the same values.

The ratios for angles A and B may be tabulated as follows:

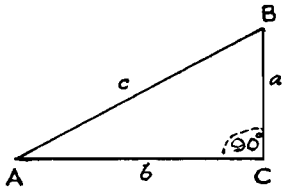


Figure 5.

Angle	Sin	Cosec	Tan	Cot	Sec	Cos
A	$\frac{a}{c}$	$\frac{c}{a}$	$\frac{a}{b}$	$\frac{b}{a}$	$\frac{c}{b}$	$\frac{b}{c}$
B	$\frac{b}{c}$	$\frac{c}{b}$	$\frac{b}{a}$	$\frac{a}{b}$	$\frac{c}{a}$	$\frac{a}{c}$

It will be observed that $\sin A = \frac{a}{c} = \cos B$, $\tan A = \frac{a}{b} = \cot B$, $\sec A = \frac{c}{b} = \operatorname{cosec} B$.

But $\angle B$ is the complement of $\angle A$, that is to say $\angle B = (90° - A)$

$\therefore$ sine of an angle = cos of its complement
tan of an angle = cot of its complement
sec of an angle = cosec of its complement

Note, however, that all three statements are only strictly true when the angle and its complement are both less than 90°. This will be more fully dealt with later on.

Note The student should draw a triangle and repeat the six ratios over and over again as facility in recognising them at a glance is imperatively essential to an understanding of theoretical and practical trigonometry.

RECIPROCAL RELATIONSHIPS

The reciprocal of $\frac{2}{5}$ is $\frac{5}{2}$, the reciprocal of $\frac{x}{y}$ is $\frac{y}{x}$, and the product of a quantity when multiplied by a fraction is equal to that quantity divided by the reciprocal of the fraction; for example $10 \times \frac{2}{5} = 10 \div \frac{5}{2} = 4$, $10 \times \frac{x}{y} = 10 \div \frac{y}{x} = \frac{10x}{y}$.

A quantity when multiplied by its reciprocal is equal to unity; for example, $\frac{2}{5} \times \frac{5}{2} = 1$ and $\frac{x}{y} \times \frac{y}{x} = 1$.

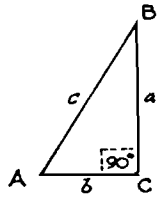


Figure 6.

Referring to the ABC triangle, $\angle C = 90°$, we have $\sin A = \frac{a}{c}$ and $\operatorname{cosec} A = \frac{c}{a}$ but $\frac{a}{c} \times \frac{c}{a} = 1$, therefore $\sin A \times \operatorname{cosec} A = 1$.

$$\tan A = \frac{a}{b}, \cot A = \frac{b}{a} \qquad \therefore \text{ tan and cot are reciprocals}$$

$$\sec A = \frac{c}{b}, \cos A = \frac{b}{c} \qquad \therefore \text{ sec and cos are reciprocals and, as shown above, sin and cosec are reciprocals.}$$

Example 1

$$\frac{x}{\sin A} = x \times \operatorname{cosec} A; \qquad \frac{x}{\cot A} = x \tan A; \qquad \frac{x}{\cos A} = x \sec A.$$

The beginner should guard against confusing reciprocal ratios with complementary ratios.

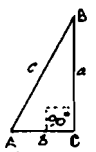


Figure 7.

	Reciprocals	Complements
$\sin A$	$= \frac{1}{\operatorname{cosec} A}$	$= \cos(90° - A)$
$\tan A$	$= \frac{1}{\cot A}$	$= \cot(90° - A)$
$\sec A$	$= \frac{1}{\cos A}$	$= \operatorname{cosec}(90° - A)$

COMPLEMENTARY RATIOS

Example 2

(a) Prove $\cos(90° - A) = \sin A$.

$$\angle A + \angle B + \angle C = 180°$$
$$\text{subtract } \angle C = 90$$
$$\therefore A + B = 90$$
$$\text{and } \angle B = (90° - A).$$
$$(90° - A) = \angle B$$
$$\therefore \cos(90° - A) = \cos B = \frac{a}{c} = \sin A.$$

(b) Prove $\tan(90° - A) = \cot A$.

$$(90° - A) = \angle B$$
$$\therefore \tan(90° - A) = \tan B = \frac{b}{a} = \cot A.$$

(c) Prove $\operatorname{cosec}(90° - A) = \sec A$.

$$(90° - A) = \angle B$$
$$\therefore \operatorname{cosec}(90° - A) = \operatorname{cosec} B = \frac{c}{b} = \sec A.$$

Similarly $\sin(90° - A) = \cos A$.

$$\cot(90° - A) = \tan A, \qquad \sec(90° - A) = \operatorname{cosec} A.$$

RECIPROCAL RATIOS

Example 3

(a) Prove $\sin A \operatorname{cosec} A = 1$. Referring to $\triangle ABC$, $\angle C = 90°$.

$$\sin A \operatorname{cosec} A = \frac{a}{c} \times \frac{c}{a} = 1.$$

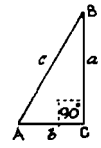


Figure 8.

(b) Prove $\sec A \cos A = 1$.

$$\sec A \cos A = \frac{c}{b} \times \frac{b}{c} = 1.$$

(c) Prove $\dfrac{1}{\cot A} = \tan A$.

$$\frac{1}{\cot A} = 1 \div \cot A = 1 \div \frac{b}{a} = 1 \times \frac{a}{b} = \frac{a}{b} = \tan A.$$

(d) Prove $\dfrac{1}{\sec A} = \cos A$.

$$\frac{1}{\sec A} = 1 \div \sec A = 1 \div \frac{c}{b} = 1 \times \frac{b}{c} = \frac{b}{c} = \cos A.$$

(e) Prove $\dfrac{\sin A \cot A}{\cos A} = 1$.

$$\frac{\sin A \cot A}{\cos A} = \sin A \cot A \sec A = \frac{a}{c} \times \frac{b}{a} \times \frac{c}{b} = 1.$$

(f) Prove $\dfrac{\operatorname{cosec} A \tan A}{\sin A \cot A} = \dfrac{c^2}{b^2}$.

$$\begin{aligned} \frac{\operatorname{cosec} A \tan A}{\sin A \cot A} &= \operatorname{cosec} A \tan A \times \operatorname{cosec} A \tan A \\ &= \operatorname{cosec}^2 A \times \tan^2 A \\ &= \frac{c^2}{a^2} \times \frac{a^2}{b^2} = \frac{c^2}{b^2}. \end{aligned}$$

SIMPLE RELATIONSHIPS

In Fig. 8, C = 90°.

Tan $A = \dfrac{a}{b}$, divide numerator and denominator of the fraction by the remaining side of the triangle, in this case c, and we have:

(a) $\tan A = \dfrac{a}{b} = \dfrac{\frac{a}{c}}{\frac{b}{c}} = \dfrac{\sin A}{\cos A}$ (c) $\sin A = \dfrac{a}{c} = \dfrac{\frac{a}{b}}{\frac{c}{b}} = \dfrac{\tan A}{\sec A}$

(b) $\cot A = \dfrac{b}{a} = \dfrac{\frac{b}{c}}{\frac{a}{c}} = \dfrac{\cos A}{\sin A}$ (d) $\sec A = \dfrac{c}{b} = \dfrac{\frac{c}{a}}{\frac{b}{a}} = \dfrac{\operatorname{cosec} A}{\cot A}$

Similarly $\cos A = \dfrac{\cot A}{\operatorname{cosec} A}$, and $\operatorname{cosec} A = \dfrac{\sec A}{\tan A}$.

The identities $\tan A = \dfrac{\sin A}{\cos A}$ and $\cot A = \dfrac{\cos A}{\sin A}$ are important and should be committed to memory.

To Construct an Angle of Given Ratio and to Establish the Other Ratios

Example 4

Construct an angle whose sine is $\frac{3}{5}$, and find the values of the other ratios.

Let the angle be A, then $\sin A = \frac{3}{5} = \dfrac{\text{opp}}{\text{hyp}}$.

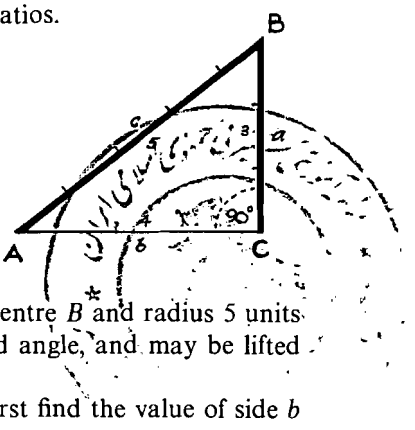


Figure 9.

Construction Make $\angle ACB = 90°$ and $CB = 3$ units. With centre B and radius 5 units describe an arc cutting AC at A. Join BA. $\angle BAC$ is the required angle, and may be lifted off the figure with a protractor. It measures approximately 37°.

Before the values of the other ratios can be found we must first find the value of side b as follows:

$$b^2 = c^2 - a^2 = 5^2 - 3^2 = 25 - 9 = 16 \qquad \therefore b = \sqrt{16} = 4.$$

From the figure we now find the Natural Values as follows:

$$\sin A = \tfrac{3}{5} = 0{\cdot}600 \qquad \operatorname{cosec} A = \tfrac{5}{3} = 1{\cdot}666$$
$$\tan A = \tfrac{3}{4} = 0{\cdot}750 \qquad \cot A = \tfrac{4}{3} = 1{\cdot}333$$
$$\sec A = \tfrac{5}{4} = 1{\cdot}250 \qquad \cos A = \tfrac{4}{5} = 0{\cdot}800$$
$$\operatorname{hav} A = \frac{1-\cos A}{2} = \frac{1-\frac{4}{5}}{2} = \frac{\frac{1}{5}}{2} = \frac{1}{10} = 0{\cdot}1.$$

Now look up the Table in Norie's of natural sines, tangents and secants and find that:

nat sin A 0·600 gives $\angle A = 36° 52\frac{1}{2}'$ nearly
nat tan A 0·750 „ „
nat sec A 1·250 „ „
nat cosec A 1·666 „ „
nat cot A 1·333 „ „
nat cos A 0·800 „ „

Logarithmic Values

It might also be pointed out here that the logs sin, cos, tan, etc., of $\angle A$ may be derived from their natural numbers, and we would refer the student to the explanation on how to use these Tables given at the beginning of the Nautical Tables.

To continue with this example we have nat sin $A = 0{\cdot}6$. Look up the common log of 0·6 and find 9·77815. The log sine A is therefore 9·77815. Find this logarithm in the sine column of the Logarithmic Table and against it find 36° 52′ and some odd seconds as this log comes between the two given logs 9·77812 and 9·77820. Angle $A = 36°\ 52'$ to the nearest minute.

Similarly nat tan $A = 0{\cdot}750$, $\therefore$ log tan A = log of 0·750 = log 9·87506. Find 9·87506, or the nearest logarithm to it, in the tangent column and again it indicates an angle of 36° 52′ to the nearest minute.

Nat sec $A = 1{\cdot}250$, $\therefore$ log sec A = log of 1·250 = log 10·096910. Find this log in the secant column and again we get $\angle A = 36°\ 52'$. Note that the index of the logarithms in this Table have been increased by 10 to avoid a negative index.

The logs of cosec A, cot A and cos A are found in the same manner and the student should check the figures for himself by looking up the respective Tables.

Function	Natural number	Log number	Angle
cosec	1·666	10·22168	36° 52′
cot	1·333	10·12483	36° 52′
cos	0·800	9·90309	36° 52′

The haversine is given in another Table in which the natural values and the log values of the angles are given side by side. In the foregoing example we found nat hav $A = \frac{1}{10} = {\cdot}10000$, $\therefore$ log hav A = log of ·10000 = 9·00000 and we find nat hav ·10000 and log hav 9·0000 beside each other against 36° 52′ 15″ in the Haversine Table. The angle given above 36° 52′ is to the nearest minute as the natural numbers have been worked to the third decimal place only so that their corresponding logs do not give exactly the same angle.

Example 5

The secant of an angle is $\frac{6}{5}$, find the values of the other ratios.

Construction In $\triangle ABC$, make $AC = 5$ units and erect CB perpendicular to AC. With centre A and radius 6 units make an arc cutting CB at B. Join AB, then CAB is the angle required, call it $\angle A$. It measures approximately $33\frac{1}{2}°$ with a protractor.

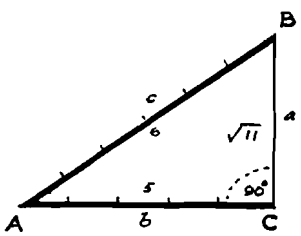


Figure 10.

$$\sec A = \frac{\text{hyp}}{\text{adj}} = \frac{6}{5}$$

$$a^2 = c^2 - b^2 = 6^2 - 5^2 = 36 - 25 = 11 \qquad \therefore a = \sqrt{11}.$$

$$\sin A = \frac{\sqrt{11}}{6} \qquad \text{cosec } A = \frac{6}{\sqrt{11}}$$

$$\tan A = \frac{\sqrt{11}}{5} \qquad \cot A = \frac{5}{\sqrt{11}}$$

$$\sec A = \frac{6}{5} \qquad \cos A = \frac{5}{6}$$

$$\text{hav } A = \frac{1-\cos A}{2} = \frac{1-\frac{5}{6}}{2} = \frac{\frac{1}{6}}{2} = \frac{1}{12}.$$

Note that $\sqrt{11}$ is the simplest form in which the value of "a" can be stated.

Example 6

The tangent of an angle is 1·5, find the values of the other ratios.

$$\tan A = 1{\cdot}5 = \frac{3}{2} = \frac{\text{opp}}{\text{adj}}.$$

Construct $\triangle ABC$, so that $C = 90°$, $CB = 3$ units and $AC = 2$ units. Angle CAB will be the required angle. It measures approximately 56°.

To find side c.

$$c^2 = a^2 + b^2 = 3^2 + 2^2 = 9 + 4 = 13 \qquad \therefore c = \sqrt{13}.$$

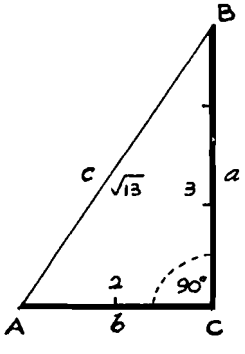


Figure 11.

$$\sin A = \frac{3}{\sqrt{13}} \qquad \text{cosec } A = \frac{\sqrt{13}}{3}$$

$$\tan A = \frac{3}{2} \qquad \cot A = \frac{2}{3}$$

$$\sec A = \frac{\sqrt{13}}{2} \qquad \cos A = \frac{2}{\sqrt{13}}$$

$$\text{hav } A = \frac{1-\cos A}{2} = \frac{1-\frac{2}{\sqrt{13}}}{2} = \frac{\sqrt{13}-2}{2\sqrt{13}}$$

Exercise 1

1. The cosine of an angle is $\frac{3}{4}$. Find the values of the other ratios.
2. The cosecant of an angle is 2. Find the values of the other ratios.
3. The cotangent of an angle is 0·8. Find the values of the other ratios.
4. Find the sine and cosine of an angle whose tangent is 0·6.

Answers

1. $\sin\frac{\sqrt{7}}{4}$ $\tan\frac{\sqrt{7}}{3}$ $\sec\frac{4}{3}$ $\text{cosec}\frac{4}{\sqrt{7}}$ $\cot\frac{3}{\sqrt{7}}$ $\cos\frac{3}{4}$ $\text{hav}\frac{1}{8}$.
2. $\sin\frac{1}{2}$ $\tan\frac{1}{\sqrt{3}}$ $\sec\frac{2}{\sqrt{3}}$ $\text{cosec}\,2$ $\cot\sqrt{3}$ $\cos\frac{\sqrt{3}}{2}$ $\text{hav}\frac{2-\sqrt{3}}{4}$.
3. $\sin\frac{10}{\sqrt{164}}$ $\tan\frac{10}{8}$ $\sec\frac{\sqrt{164}}{8}$ $\text{cosec}\frac{\sqrt{164}}{10}$ $\cot\frac{8}{10}$ $\cos\frac{8}{\sqrt{164}}$ $\text{hav}\frac{\sqrt{164}-8}{2\sqrt{164}}$.

4. $\sin\dfrac{6}{\sqrt{136}}$ or $\dfrac{3}{\sqrt{34}}$ $\cos\dfrac{10}{\sqrt{136}}$ or $\dfrac{5}{\sqrt{34}}$ $\tan\dfrac{6}{10}$ or $\dfrac{3}{5}$ if the given value of the tangent be cancelled down to its lowest denominator.

IDENTITIES

An identity differs from an equation in the fact that in an equation the expressions are equal only when the variables involved have certain definite values, but in an identity the two expressions are equal for all values of the variables involved in them.

Thus $\tan A = \dfrac{\sin A}{\cos A}$ is an identity because it is true whatever the value of angle A may be.

In solving an identity the more complicated side of the expression is written down and transformed, step by step, until it assumes the form of the other side.

Example 7

(a) In triangle ABC, $C = 90°$, prove $\sin A = \dfrac{\cot A \tan A}{\operatorname{cosec} A}$.

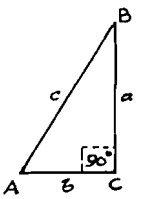


Figure 12.

$$\frac{\cot A \tan A}{\operatorname{cosec} A} = \frac{\dfrac{\not b}{\not a} \times \dfrac{\not a}{\not b}}{\dfrac{c}{a}} = \frac{1}{\dfrac{c}{a}} = \frac{a}{c} = \sin A.$$

(b) Prove $\dfrac{\sin A}{\cos A} + \dfrac{\sec A}{\operatorname{cosec} A} = 2\tan A$.

$$\frac{\sin A}{\cos A} + \frac{\sec A}{\operatorname{cosec} A} = \frac{\dfrac{a}{c}}{\dfrac{b}{c}} + \frac{\dfrac{c}{b}}{\dfrac{c}{a}}$$

$$= \frac{a}{\not c} \times \frac{\not c}{b} + \frac{\not c}{b} \times \frac{a}{\not c}$$

$$= \frac{a}{b} + \frac{a}{b}$$

$$= 2\frac{a}{b}$$

$$= 2\tan A.$$

(c) Prove $\cot A = \dfrac{\sin A}{\cos A \tan^2 A}$.

$$\frac{\sin A}{\cos A \tan^2 A} = \frac{\dfrac{a}{c}}{\dfrac{b}{c} \times \dfrac{a^2}{b^2}} = \frac{\not a}{\not c} \times \frac{\not c}{\not b} \times \frac{b^{\not 2}}{a^{\not 2}} = \frac{b}{a} = \cot A.$$

(d) Prove $\sin^2 A + \cos^2 A = 1$.

$$\sin A = \frac{a}{c} \qquad \therefore \sin^2 A = \frac{a^2}{c^2}$$

$$\cos A = \frac{b}{c} \qquad \therefore \cos^2 A = \frac{b^2}{c^2}$$

$$\text{add, } \sin^2 A + \cos^2 A = \frac{a^2}{c^2} + \frac{b^2}{c^2} = \frac{a^2+b^2}{c^2} = \frac{c^2}{c^2} = 1.$$

(e) Prove $\sec^2 A = 1 + \tan^2 A$.

$$\sec A = \frac{c}{b} \qquad \therefore \sec^2 A = \frac{c^2}{b^2} = \frac{b^2+a^2}{b^2} = \frac{b^2}{b^2} + \frac{a^2}{b^2} = 1 + \tan^2 A.$$

(f) Prove $\operatorname{cosec}^2 A = 1 + \cot^2 A$.

$$\operatorname{cosec} A = \frac{c}{a} \qquad \therefore \operatorname{cosec}^2 A = \frac{c^2}{a^2} = \frac{a^2+b^2}{a^2} = \frac{a^2}{a^2} + \frac{b^2}{a^2} = 1 + \cot^2 A.$$

In Example 7 (d), (e) and (f) are important fundamental theorems and are often introduced into trigonometrical identities and equations.

Example 8

(a) In triangle DEF, $F = 90°$. Prove $\dfrac{1}{\sin^2 D} = \dfrac{1}{\tan^2 D \cos^2 D}$.

$$\frac{1}{\tan^2 D \cos^2 D} = \frac{1}{\frac{d^2}{e^2} \times \frac{e^2}{f^2}} = \frac{1}{\frac{d^2}{f^2}} = \frac{1}{\sin^2 D}.$$

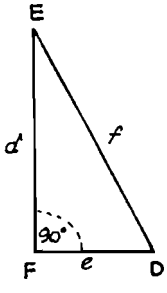


Figure 13.

(b) Prove $\sin D = \sqrt{1 - \cos^2 D}$.

$$\sqrt{1-\cos^2 D} = \sqrt{1 - \frac{e^2}{f^2}} = \sqrt{\frac{f^2}{f^2} - \frac{e^2}{f^2}} = \sqrt{\frac{d^2}{f^2}} = \frac{d}{f} = \sin D.$$

(c) Prove $\cot D = \sqrt{(\operatorname{cosec} D + 1)(\operatorname{cosec} D - 1)}$.

$$\sqrt{(\operatorname{cosec} D + 1)(\operatorname{cosec} D - 1)} = \sqrt{\operatorname{cosec}^2 D - 1} \text{ when multiplied out}$$

$$= \sqrt{\frac{f^2}{d^2} - \frac{d^2}{d^2}}$$

$$= \sqrt{\frac{e^2}{d^2}}$$

$$= \frac{e}{d}$$

$$= \cot D.$$

(d) Prove $(\sin D + \sec D)(\sin D - \sec D) = -\cos^2 D - \tan^2 D$.

$$(\sin D + \sec D)(\sin D - \sec D) = \sin^2 D - \sec^2 D$$

$$= \frac{d^2}{f^2} - \frac{f^2}{e^2} \qquad \text{(expand } d^2 \text{ and } f^2\text{)}$$

$$= \frac{f^2 - e^2}{f^2} - \left(\frac{d^2 + e^2}{e^2}\right)$$

$$= \frac{f^2}{f^2} - \frac{e^2}{f^2} - \frac{d^2}{e^2} - \frac{e^2}{e^2}$$

$$= 1 - \cos^2 D - \tan^2 D - 1$$

$$= -\cos^2 D - \tan^2 D.$$

Exercise 2

Prove the following identities in triangle ABC, $C = 90°$.

1. $\sin A = \tan A \cos A$.
2. $\cos A = \dfrac{\tan A \cot A}{\sec A}$.
3. $\dfrac{\sec A}{\sin A} = \dfrac{\operatorname{cosec} A}{\cos A}$.
4. $\dfrac{\cot A}{\operatorname{cosec} A} + \dfrac{\sin A}{\tan A} = 2\cos A$.
5. $\dfrac{\operatorname{cosec} A}{\cot A \sec^2 A} = \cos A$.
6. $\dfrac{\tan A}{\sec A \sin^2 A} = \operatorname{cosec} A$.
7. $\dfrac{1}{\cos^2 A} = \dfrac{1}{\cot^2 A \sin^2 A}$.
8. $\dfrac{1}{\tan^2 A} = \dfrac{1}{\sin^2 A \sec^2 A}$.
9. $(\operatorname{cosec} A + \cot A)(\operatorname{cosec} A - \cot A) = 1$.
10. $(\sec A + \sin A)(\sec A - \sin A) = \tan^2 A + \cos^2 A$.
11. $(\operatorname{cosec} A - \sin A)(\operatorname{cosec} A + \sin A) = \cot^2 A + \cos^2 A$.
12. $(\operatorname{cosec} A - \cos A)(\operatorname{cosec} A + \cos A) = \cot^2 A + \sin^2 A$.
13. $\tan A = \sqrt{(\sec A + 1)(\sec A - 1)}$.
14. $\sin A = \sqrt{\dfrac{1}{1 + \cot^2 A}}$.
15. $\tan A = \sqrt{\dfrac{1}{\cos^2 A} - 1}$.

16. $\sin A \tan A = \dfrac{1-\cos^2 A}{\cos A}$.

17. $\tan A \cot A \sec A = \dfrac{1}{\cos A}$.

18. $\sin^2 A \operatorname{cosec} A + \cos^2 A \sec A = \sin A + \cos A$.

TRIGONOMETRIC FUNCTIONS OF 0°

Consider the radius vector, which is the name given to the rotating arm OC, to trace out an angle AOB or $\angle\theta$. Draw BA and DC perpendicular to OC, then BA is the sine, DC the tangent and OD the secant.

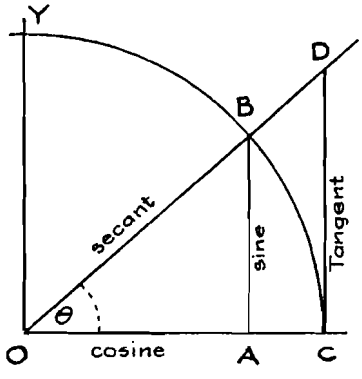


Figure 14.

(a) $\sin\theta = \dfrac{AB}{OB}$ (b) $\tan\theta = \dfrac{DC}{OC}$ (c) $\sec\theta = \dfrac{OD}{OC}$.

But the radius is fixed in length and is the unit of measure to which all other lines on the figure are referred, so all radii = 1.

Suppose now the radius vector OD to close in on OC, thus decreasing angle θ and causing AB and CD to become gradually smaller and to ultimately disappear when $\theta = 0°$, then the points B and D will both coincide with C, OB and OD will be coincident with, and equal to, OC, the triangles AOB and COD will disappear so that $AB = 0$, $CD = 0$, and $OD = OC = 1$, when $\angle\theta = 0$.

Substituting those values in (a), (b) and (c) we have

(a) $\sin\theta° = \dfrac{AB}{OB}$ and $\sin 0° = \dfrac{O}{OC} = \dfrac{0}{1} = 0$

(b) $\tan\theta° = \dfrac{CD}{OC}$ and $\tan 0° = \dfrac{O}{OC} = \dfrac{0}{1} = 0$

(c) $\sec\theta° = \dfrac{OD}{OC}$ and $\sec 0° = \dfrac{OC}{OC} = \dfrac{1}{1} = 1$

and by introducing reciprocals in (a), (b) and (c) we have

(d) $\operatorname{cosec} 0° = \dfrac{1}{\sin 0°} = \dfrac{1}{0} = \infty$

(e) $\cot 0° = \dfrac{1}{\tan 0°} = \dfrac{1}{0} = \infty$

(f) $\cos 0° = \dfrac{1}{\sec 0°} = \dfrac{1}{1} = 1.$

An infinite quantity is one which cannot be described in definite terms or measured by any known standards; it is represented by the symbol ∞. When infinity enters into an equation the answer is ∞, either infinitely great or infinitely small, the answer being something so immeasurably great or so infinitesimally small that it cannot be conceived.

The values of $\operatorname{cosec} 0°$ and $\cot 0°$ may be illustrated geometrically as follows:

(d) $\operatorname{cosec} \theta = \dfrac{OE}{OY}$

(e) $\cot \theta = \dfrac{EY}{OY}.$

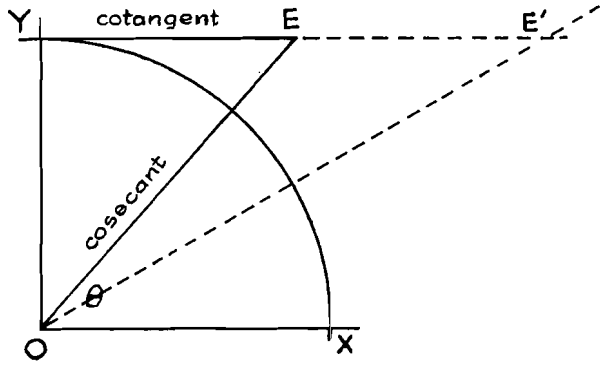


Figure 15.

When angle θ decreases, the radius vector OE turns towards OX and both OE and YE increase as represented by OE' and YE' respectively until $\angle \theta = 0°$. OE will then lie along OX and be parallel to YE' so that the two lines although produced to infinity can never meet to form the cotangent and cosecant.

Hence (d) $\operatorname{cosec} 0° = \infty$. (e) $\cot 0° = \infty$.

TRIGONOMETRIC FUNCTIONS OF 90°

In Fig. 16 $\angle XOB = \theta$, $\angle XOB' = \theta'$ and these are angles traced out by the radius vector. Make BA and $B'A'$ perpendicular to OX, AB varies in length as angle θ changes but the radius is constant.

(a) $\sin \theta = \dfrac{AB}{OB}$ (b) $\tan \theta = \dfrac{AB}{OA}$ (c) $\cos \theta = \dfrac{OA}{OB}.$

Assume angle θ is gradually increasing, then AB will gradually increase to $A'B'$ and ultimately to OY when $\theta = 90°$. At the same time OA will decrease to OA' and ultimately disappear when $\theta = 90°$, for then AB will coincide with, and be equal to, OY. When $\theta = 90°$, $AB = OY = 1$ and $AO = 0$. Hence

(a) $\sin\theta^\circ = \dfrac{AB}{OB}$ and $\sin 90^\circ = \dfrac{OY}{OY} = \dfrac{1}{1} = 1$

(b) $\tan\theta^\circ = \dfrac{AB}{OA}$ and $\tan 90^\circ = \dfrac{OY}{O} = \dfrac{1}{0} = \infty$

(c) $\cos\theta^\circ = \dfrac{OA}{OB}$ and $\cos 90^\circ = \dfrac{O}{OY} = \dfrac{0}{1} = 0$

(d) $\operatorname{cosec} 90^\circ = \dfrac{1}{\sin 90^\circ} = \dfrac{1}{1} = 1$

(e) $\cot 90^\circ = \dfrac{1}{\tan 90^\circ} = \dfrac{1}{\infty} = 0$

(f) $\sec 90^\circ = \dfrac{1}{\cos 90^\circ} = \dfrac{1}{0} = \infty.$

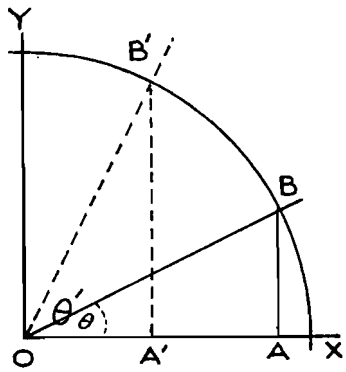


Figure 16.

The values of cosec 90° and cot 90° may be illustrated geometrically as follows:

(d) $\operatorname{cosec}\theta = \dfrac{OE}{OY}$ $\cot\theta = \dfrac{EY}{YO}.$

When the radius vector OE approaches OY, then angle θ increases, but OE decreases and ultimately becomes coincident with, and equal to, the radius OY, hence, when $\theta = 90°$, $OE = OY = 1$. Concurrently with an increase of angle θ, YE decreases in length and disappears when E coincides with Y, hence when $\theta = 90°$, $EY = 0$.

Substituting these values we have:

(d) $\operatorname{cosec}\theta^\circ = \dfrac{OE}{OY}$ and $\operatorname{cosec} 90^\circ = \dfrac{OY}{OY} = \dfrac{1}{1} = 1$

(e) $\cot\theta^\circ = \dfrac{EY}{OY}$ and $\cot 90^\circ = \dfrac{O}{OY} = \dfrac{0}{1} = 0.$

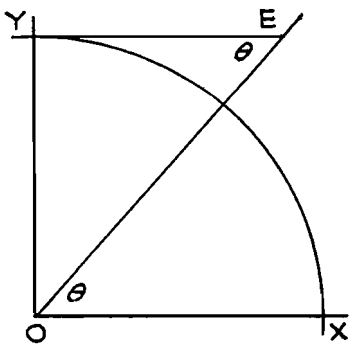


Figure 17.

RATIOS OF 45°

Construct a right angled isosceles triangle ABC, making $C = 90°$, $CB = 1$ unit, $CA = 1$ unit

and find the ratios of 45°

$$\angle A = \angle B = 45°, \text{ and}$$
$$AB = \sqrt{2} \text{ units because}$$
$$AB^2 = CA^2 + CB^2 = 1^2 + 1^2 = 1 + 1 = 2$$
$$\therefore \quad AB = \sqrt{2}.$$

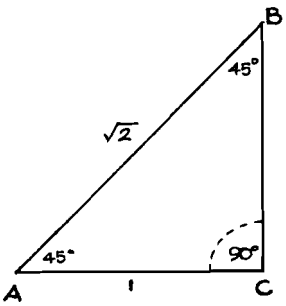


Figure 18.

From figure we may now write:

$$\sin 45° = \frac{1}{\sqrt{2}} \qquad \operatorname{cosec} 45° = \frac{\sqrt{2}}{1} = \sqrt{2}$$

$$\tan 45° = \frac{1}{1} = 1 \qquad \cot 45° = \frac{1}{1} = 1$$

$$\sec 45° = \frac{\sqrt{2}}{1} = \sqrt{2} \qquad \cos 45° = \frac{1}{\sqrt{2}}.$$

RATIOS OF 30° AND 60°

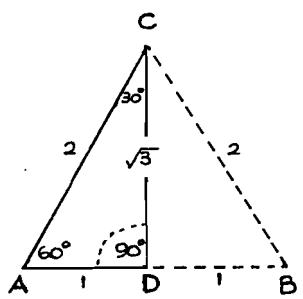


Figure 19.

Construct an equilateral triangle each side equal to 2 units, then angles A, B and C are each equal to 60°. Drop CD perpendicular to AB. CD bisects $\angle C$ and also side AB, so that $AD = DB = 1$ unit, $\angle ACD = 30°$ and $CD = \sqrt{3}$ units, because

$$CD^2 = AC^2 - AD^2 = 2^2 - 1^2 = 4 - 1 = 3$$
$$\therefore \quad CD = \sqrt{3}.$$

From Fig. 19 we find:

$$\sin 60° = \frac{\sqrt{3}}{2} \qquad \operatorname{cosec} 60° = \frac{2}{\sqrt{3}}$$

$$\tan 60° = \frac{\sqrt{3}}{1} = \sqrt{3} \qquad \cot 60° = \frac{1}{\sqrt{3}}$$

$$\sec 60° = \frac{2}{1} = 2 \qquad \cos 60° = \frac{1}{2}$$

and

$$\sin 30° = \frac{1}{2} \qquad \operatorname{cosec} 30° = \frac{2}{1} = 2$$

$$\tan 30° = \frac{1}{\sqrt{3}} \qquad \cot 30° = \frac{\sqrt{3}}{1} = \sqrt{3}$$

$$\sec 30° = \frac{2}{\sqrt{3}} \qquad \cos 30° = \frac{\sqrt{3}}{2}.$$

Values for haversine 60°, 30° and 45° may be found as follows:

$$\operatorname{hav} 60° = \frac{\operatorname{vers} 60°}{2} = \frac{1-\cos 60°}{2} = \frac{1-\frac{1}{2}}{2} = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$$

$$\operatorname{hav} 30° = \frac{\operatorname{vers} 30°}{2} = \frac{1-\cos 30°}{2} = \frac{1-\frac{\sqrt{3}}{2}}{2}$$

$$= \frac{2-\sqrt{3}}{2} \times \frac{1}{2}$$

$$= \frac{2-\sqrt{3}}{4}$$

$$\operatorname{hav} 45° = \frac{\operatorname{vers} 45°}{2} = \frac{1-\cos 45°}{2} = \frac{1-\frac{1}{\sqrt{2}}}{2}$$

$$= \frac{\sqrt{2}-1}{\sqrt{2}} \times \frac{1}{2}$$

$$= \frac{\sqrt{2}-1}{2\sqrt{2}}$$

$$\operatorname{hav} 60° = \frac{1}{4} \qquad \operatorname{hav} 30° = \frac{2-\sqrt{3}}{4} \qquad \operatorname{hav} 45° = \frac{\sqrt{2}-1}{2\sqrt{2}}.$$

These values for special angles may be arranged in a table as follows:

Ratio	0°	30°	45°	60°	90°
sin	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1
cosec	∞	2	$\sqrt{2}$	$\frac{2}{\sqrt{3}}$	1
tan	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	∞
cot	∞	$\sqrt{3}$	1	$\frac{1}{\sqrt{3}}$	0
sec	1	$\frac{2}{\sqrt{3}}$	$\sqrt{2}$	2	∞
cos	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0

An inspection of the table will reveal that as the angle increases

sine increases from 0 to 1, cosec decreases from ∞ to 1
tan increases from 0 to ∞, cot decreases from ∞ to 0
sec increases from 1 to ∞, cos decreases from 1 to 0

and these variations may be further verified by reference to the Table of Log Sines, Secants, etc., in which it will be seen that the log sine, tangent and secant increase as the angle increases and the logs, cosecant, cotangent and cosine decrease as the angle increases.

The ratio values may be plotted on graph paper and curves drawn through the spots. We show here the sine and cosine curves only as the tangent and secant with their complements

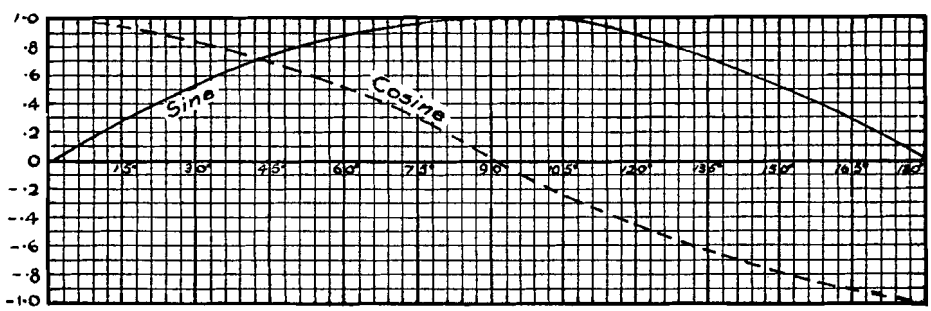


Figure 20.

lead off the paper towards infinity. The abscissa represents degrees and the ordinate the natural values of the angles. The values of the sine and cosine for every 15° were taken from the tables, laid off on their respective vertical lines and a curve drawn through the spots, the sine curve firm, the cosine curve dotted. The values of intermediate angles may be lifted off. The value of sine 39°, for example, is 0·62, and cos 39° = 0·78; sin 45° = cos 45° = 0·7; sin

$126° = 0{\cdot}8$ and $\cos 126° = -5{\cdot}8$. The values are positive when the curve is above the line of abscissa and negative when below it. Cos 90° to cos 180° is negative. The curves show at a glance the change in the values of those two functions of the angle.

Example 9

Find the numerical value of $2 \sin 30° \cos 30° \cot 60° \tan 45°$.

Write down the question, substitute the values of the ratios and reduce the result to its simplest form.

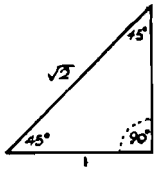


Figure 21a.

$$2 \sin 30° \cos 30° \cot 60° \tan 45$$

$$\frac{\cancel{2}}{1} \times \frac{1}{\cancel{2}} \times \frac{\sqrt{\cancel{3}}}{2} \times \frac{1}{\sqrt{\cancel{3}}} \times \frac{1}{1} = \frac{1}{2} \quad \textit{Answer}$$

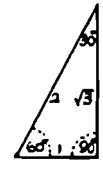


Figure 21b.

Example 10

Find the numerical value of $\sec 60° \operatorname{cosec} 30° \cos^2 30° \cot^2 60°$

$$\sec 60° \operatorname{cosec} 30° \cos^2 30° \cot^2 60°$$

$$\frac{\cancel{2}}{1} \times \frac{\cancel{2}}{1} \times \frac{\sqrt{\cancel{3}}}{\cancel{2}} \times \frac{\sqrt{\cancel{3}}}{\cancel{2}} \times \frac{1}{\sqrt{\cancel{3}}} \times \frac{1}{\sqrt{\cancel{3}}} = 1 \quad \textit{Answer}$$

Example 11

Find the value of $\cos^2 30° - \sin^2 30° + \cos^2 60° - \tan^2 45°$

$$\cos^2 30° - \sin^2 30° + \cos^2 60° - \tan^2 45°$$

$$= \left(\frac{\sqrt{3}}{2}\right)^2 - \left(\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2 - \left(\frac{1}{1}\right)^2$$

$$= \frac{3}{4} - \frac{1}{4} + \frac{1}{4} - \frac{1}{1} = -\frac{1}{4} \quad \textit{Answer}$$

Example 12

Find the value of $\frac{1}{3}\sin^2 60° - \frac{1}{2}\sec 60° \tan^2 30° + \frac{4}{3}\sin^2 45° \tan^2 60°$

$$\frac{1}{3}\sin^2 60° - \frac{1}{2}\sec 60° \tan^2 30° + \frac{4}{3}\sin^2 45° \tan^2 60°$$

$$= \frac{1}{3}\left(\frac{\sqrt{3}}{2}\right)^2 - \frac{1}{2} \times \frac{2}{1}\left(\frac{1}{\sqrt{3}}\right)^2 + \frac{4}{3}\left(\frac{1}{\sqrt{2}}\right)^2 \left(\frac{\sqrt{3}}{1}\right)^2$$

$$= \frac{1}{4} - \frac{1}{3} + \frac{2}{1}$$

$$= \frac{3-4+24}{12} = \frac{23}{12} = 1\frac{11}{12} \quad \textit{Answer}$$

Example 13

Prove $\tan^2 30° \sin^2 60° \sec^2 45° = \frac{1}{2}$

$$\tan^2 30° \sin^2 60° \sec^2 45° = \left(\frac{1}{\sqrt{3}}\right)^2 \times \left(\frac{\sqrt{3}}{2}\right)^2 \times \left(\frac{\sqrt{2}}{1}\right)^2$$

$$= \frac{1}{3} \times \frac{3}{4} \times \frac{2}{1}$$

$$= \frac{1}{2} \quad \textit{Answer}$$

Exercise 3

Find the numerical values of the following quantities:

1. $\sin 45° \cos 30° \cot 60°$
2. $\sec 30° \cos 60° \tan 45°$
3. $\sin^2 30° \cot^2 45° \sec^2 30°$
4. $3 \tan^2 30° 2 \cos^2 45° 4 \sin^2 30°$
5. $2 \operatorname{cosec}^2 45° - 3 \sec^2 30°$
6. $3 \sec^2 30° + 4 \cos^2 45° + \tan^2 60°$
7. $\sec^2 45° - 2 \cot^2 60° + \frac{1}{2} \operatorname{cosec}^2 60°$
8. $\cos 60° - \tan^2 45° + \frac{3}{4} \tan^2 30° + \cos^2 30° - \sin 30°$

Answers

1. $\frac{1}{2\sqrt{2}}$
2. $\frac{1}{\sqrt{3}}$
3. $\frac{1}{3}$
4. 1
5. 0
6. 9
7. 2
8. 0

SIGNS OF AN ANGLE

It should now be obvious that trigonometry is a combination of geometry and algebra, and in order to combine trigonometrical angles with algebraic equations a convention of signs has been established as summarised in the following table and indicated in the figure on the next page.

Function	1st Quadrant 0° to 90°	2nd Quadrant 90° to 180°	3rd Quadrant 180° to 270°	4th Quadrant 270° to 360°
sine and cosec	+	+	−	−
tan and cot	+	−	+	−
sec and cos	+	−	−	+

The values of an angle and its supplement are equal, but they may differ in sign according to the quadrant in which the revolving line lies, as follows:

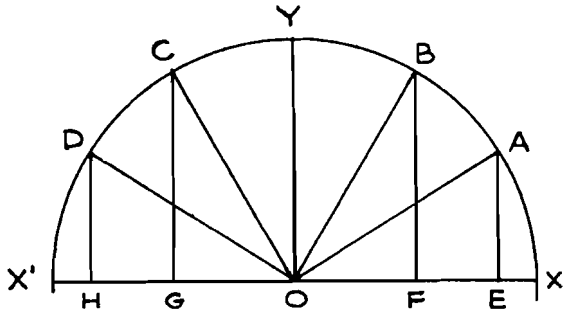


Figure 22.

	$\sin 45° =$	$\sin 135° =$	$-\sin 225° =$	$-\sin 315°$
Natural values	$+0{\cdot}71$	$+0{\cdot}71$	$-0{\cdot}71$	$-0{\cdot}71$
	$\tan 60° =$	$-\tan 120° =$	$-\tan 240° =$	$-\tan 300°$
Natural values	$+1{\cdot}73$	$-1{\cdot}73$	$+1{\cdot}73$	$-1{\cdot}73$
	$\sec 30° =$	$-\sec 150° =$	$-\sec 210° =$	$\sec 330°$
Natural values	$+1{\cdot}15$	$-1{\cdot}15$	$-1{\cdot}15$	$+1{\cdot}15$

The radius vector in rotating anti-clockwise from X through A, B, Y, C, D to X' in succession makes the angle at O increase progressively from 0° through 90° to 180°. Angles from 0° to 90° are said to be in the 1st quadrant, and those from 90° to 180° in the 2nd quadrant.

The trigonometric angles formed at O by the rotating of the radius vector are conceived to increase up to 360° when one turn is completed, but in navigation, however, angles are limited to 180°.

Referring to the figure, all the perpendiculars to $X'OX$ are given a + or positive sign, and the horizontal lines drawn to the right of OY are given a + or positive sign, whilst those drawn to the left of OY are given a − or negative sign. The radii are all positive, e.g.

$$\sin AOE = \frac{+AE}{+OA}, \text{ or just } \frac{AE}{OA}, \tan BOF = \frac{+BF}{+OF}$$

$$\sin COE = \sin COG = \frac{+CG}{+CO}, \tan COE = \tan COG = \frac{+CG}{-OG}$$

$$\cos DOE = \cos DOH = \frac{-OH}{+OD}, \sec DOE = \sec DOH = \frac{+OD}{-OH}$$

CIRCULAR FUNCTIONS OF $(90° + A)$

It has already been shown that $\sin A = \cos(90° - A)$, $\tan A = (\cot 90° - A)$, $\sec A = \operatorname{cosec}(90° - A)$, etc., the ratios of A and $(90° + A)$ will now be considered.

Call $\angle AOB$ angle A. Draw OC perpendicular to OB, then $\angle AOC = (90° + A)$. From B and C drop BA and CD each perpendicular to $X'OX$.

In $\triangle ABO$, $\angle ABO = \text{comp } AOB$, but $\angle COD$ is also a complement of $\angle AOB$, as together they make up 90°, and as complements of the same thing must be equal to one another it follows that $\angle COD = \angle ABO$.

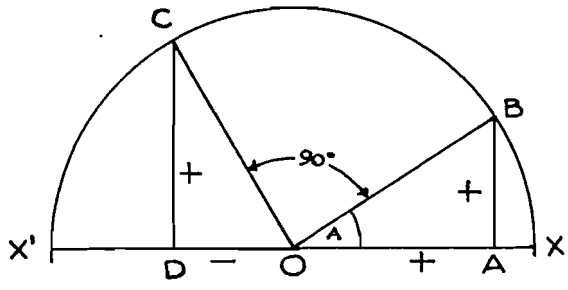


Figure 23.

Comparing triangles AOB and COD we have $\angle A = \angle D = 90°$ by construction; $OB = OC$ radii; $\angle ABO = \angle COD$ both complements of $\angle AOB$; $\therefore \triangle AOB = \triangle COD$ in every respect, $\angle C = \angle AOB$, which we are calling $\angle$A for short.

$$OA = CD \text{ (numerically)} = CD \text{ (algebraically)}$$
$$AB = OD \text{ (numerically)} = -OD \text{ (algebraically).}$$

In figure $(90° + \text{A}) = \angle AOC =$ supplement $\angle COD$

$$\sin\ (90° + \text{A}) = \sin\ AOC = \frac{CD}{OC} = \frac{OA}{OB} = \cos \text{A}$$

$$\cos\ (90° + \text{A}) = \cos\ AOC = \frac{OD}{OC} = \frac{-AB}{OB} = -\sin \text{A}$$

$$\tan\ (90° + \text{A}) = \tan\ AOC = \frac{CD}{OD} = \frac{OA}{-AB} = -\cot \text{A}$$

$$\cot\ (90° + \text{A}) = \cot\ AOC = \frac{OD}{CD} = \frac{-AB}{OA} = -\tan \text{A}$$

$$\sec\ (90° + \text{A}) = \sec\ AOC = \frac{OC}{OD} = \frac{OB}{-AB} = -\operatorname{cosec} \text{A}$$

$$\operatorname{cosec}\ (90° + \text{A}) = \operatorname{cosec}\ AOC = \frac{OC}{CD} = \frac{OB}{OA} = \sec \text{A}$$

$\angle$A represents the value of any angle less than 90°.

Example 14

Find the value of $\sin 120° \times \tan 150°$

$$\begin{aligned}\sin 120° \times \tan 150° &= \sin(90° + 30°) \times \tan(90° + 60°)\\ &= \cos 30° \times -\cot 60°\\ &= \frac{\sqrt{3}}{2} \times -\frac{1}{\sqrt{3}}\\ &= -\frac{\sqrt{\not{3}}}{2\sqrt{\not{3}}} = -\frac{1}{2} \quad \textit{Answer}\end{aligned}$$

Example 15

Find the value of cot 135° × sec 120°

$$\begin{aligned}\cot 135° \times \sec 120° &= \cot(90°+45°) \times \sec(90°+30°)\\ &= -\tan 45° \times -\operatorname{cosec} 30°\\ &= -1 \times -2\\ &= 2 \quad \textit{Answer}\end{aligned}$$

CIRCULAR FUNCTIONS OF $(180° - A)$

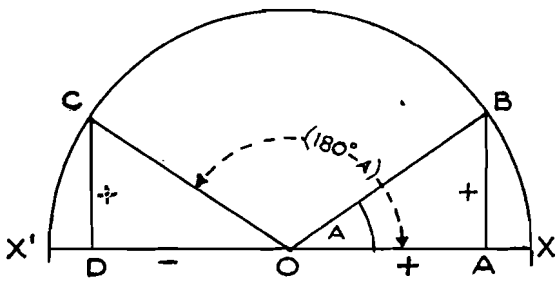


Figure 24.

In fig. let $\angle AOB$ be named A. Make $\angle DOC = \angle AOB = A$, then $\angle AOC = (180° - A)$. Drop BA and CD each perpendicular to $X'OX$. $\triangle AOB = \triangle DOC$ because $\angle A = \angle D = 90°$, $\angle AOB = \angle DOC$ construction. $OB = OC$ radii. Therefore $AB = DC$, $OA = -OD$, $\angle B = \angle C$.

$$(180° - A) = \angle AOC = \text{supplement } \angle DOC$$

$$\sin(180° - A) = \sin AOC = \sin DOC = \frac{DC}{OC} = \sin A$$

$$\cos(180° - A) = \cos AOC = \cos DOC = \frac{-OD}{OC} = -\cos A$$

$$\tan(180° - A) = \tan AOC = \tan DOC = \frac{DC}{-DO} = -\tan A.$$

Similarly

$$\cot(180° - A) = -\cot A$$

$$\sec(180° - A) = -\sec A$$

$$\operatorname{cosec}(180° - A) = \operatorname{cosec} A.$$

Exercise 4

1. Draw a right-angled plane triangle and write down the six trigonometrical ratios of the two angles.
2. What is a "haversine"?
3. Write down the reciprocals and the complements of the sine, tangent and secant.
4. Prove that $\sin A \times \operatorname{cosec} A = 1$.
5. Look up the tables and write down the nat tan 30° and nat sec 60°, the log sec 45°, and the nat hav and log hav 76° 18′ 30″.

6. Prove $\sin A \tan A = \sec A \sin^2 A$.
7. Prove $(\sin A - \cos A)^2 = 1 - 2 \sin A \cos A$.
8. Draw a figure and show geometrically that $\sec 0° = 1$, and that $\cot 0°$ and $\operatorname{cosec} 0° = \infty$.
9. What is meant by the term "infinity"?
10. Show that $\sin 90° = 1$; $\sec 90° = \infty$; and $\cot 90° = 0$.
11. Prove (a) $\tan 45° = 1$, (b) $\sin 45° = \frac{1}{\sqrt{2}}$, (c) $\sec 60° = 2$, (d) $\operatorname{cosec}\ 60° = \frac{2}{\sqrt{3}}$, (e) $\tan 30° = \frac{1}{\sqrt{3}}$, (f) $\cos 30° = \frac{\sqrt{3}}{2}$, (g) $\operatorname{hav} 45° = \frac{\sqrt{2}-1}{2\sqrt{2}}$.
12. Find the value of nat hav 30°.
13. Prove $\sin^2 30° = \frac{1}{4}$; $\tan^2 60° = 3$.
14. Draw a figure and give the signs of the functions of an angle up to 180°.
15. Prove $\sec(90° + A) = -\operatorname{cosec} A$. Prove $\cos(180° - A) = -\cos A$.
16. Prove $\tan 135° \sin 120° \sec 45° = -\sqrt{\frac{3}{2}}$.

SOLUTION OF RIGHT-ANGLED PLANE TRIANGLES

The student when solving triangles should first read the question carefully, reading it a second time if it appears to be an awkward problem in order to visualise what is given and what the question asks for, then draw a figure approximately correct to scale, when an approximation to the answers will be evident from the figure.

Three parts of any triangle must be known before it can be solved. The position of the 90° angle in a right-angled plane triangle is indicated in the question and also the values of either two sides, or one side and one angle. A triangle cannot be solved if the three angles only are given. We must know at least one side.

1. **An angle** can only be found when two sides are given.
   Rule to find an angle

$$\frac{\text{a known side}}{\text{another known side}} = \text{a ratio of the } \textit{required} \text{ angle}$$

2. **A side** can only be found when one side and one angle are given. The establishing of a formula for solving the triangle can be stated briefly in the form of an equation.
   Rule to find a side

$$\frac{\text{the } \textit{required} \text{ side}}{\text{any known side}} = \text{a ratio of the given angle.}$$

We shall now draw the attention of the student to the four methods of solution:

(1) By construction; (2) by the natural values of the ratios; (3) by the logarithmic values of the ratios; (4) by inspection of the Traverse Table.

Methods (2) and (3) are rigorous calculations and give accurate results; (1) and (4) give

approximate answers and serve as a check on the calculated answers. The procedure may probably be best described by means of a few examples worked out in detail.

TO FIND AN ANGLE

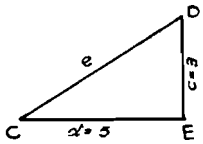


Figure 25.

Example 16

In triangle CDE, given $\angle E = 90°$, $DE = 3$ miles, $CE = 5$ miles. Find angles C and D (a) by construction, (b) by calculation, (c) by logarithms and (d) by Traverse Tables.

(a) **By Construction** Make $\angle E = 90°$, make $EC = 5$ units, $ED = 3$ units. Join CD, then CDE is the required triangle and angles C and D may be lifted off with a protractor to within a degree or so.

(b) **By Calculation** (Natural Numbers) To find $\angle C$

$$\frac{\text{a known side}}{\text{another known side}} = \text{a ratio of the } \textit{required} \text{ angle}$$

$$\frac{c}{d} = \frac{\text{opp}}{\text{adj}} = \tan C \qquad \therefore \frac{3}{5} = \cdot 6 = \tan C.$$

Entering the Natural Tangent Tables with the value ·60000, the nearest number to this that can be found is ·60007, giving 30° at the top of the column and 58′ in the left hand side column in the same line as ·60007.

angle $C = 30°\ 58'$, $\angle D = (90° - C)$	$90°\ 00'$
subtract C	$30\ \ 58$
angle D	$59\ \ 02$

It does not matter which known side is written in the numerator. Suppose for $\frac{\text{known side}}{\text{known side}}$ = ratio of angle we had written $\frac{d}{c} = \frac{\text{adj}}{\text{opp}} = \cot C$, then nat cot $C = \frac{5}{3} = 1{\cdot}66667$.

Enter the Natural Cotangent Tables and find 1·66667 or the number nearest to it. The nearest number is 1·66647, which gives 30° at the bottom of the column and 58′ in the right hand side column

	$\angle C = 30°\ 58'$
subtract from	$90\ \ 00$
	$\angle D = 59\ \ 02$ *the same answers* as before.

It would be equally easy to calculate angle D instead of angle C.

$$\frac{\text{known side}}{\text{known side}} = \text{ratio of required angle}, \frac{d}{c} = \frac{\text{opp}}{\text{adj}} = \tan D$$

$$\therefore \text{nat tan } D = \frac{5}{3} = 1{\cdot}66667.$$

Look up the Natural Tangent Tables with 1·66667 and find 59° at the top of the column and 2′ at the left hand side of the page.

$$\left.\begin{array}{rr} \angle D = & 59°\ 02' \\ \text{subtract from} & 90\ \ 00 \\ \angle C = & \underline{30\ \ 58} \end{array}\right\} \textit{Answers}$$

The answers are of course the same in each case as the tan and cot are reciprocals. On again looking at triangle DCE we note that:

$$\frac{c}{d} = \tan C, \quad \frac{d}{c} = \cot C, \quad \text{and} \quad \angle D = (90° - C)$$

$$\frac{c}{d} = \cot D, \quad \frac{d}{c} = \tan D, \quad \text{and} \quad \angle C = (90° - D).$$

(c) **By Calculation** (Logarithms)

$$\frac{\text{known side}}{\text{known side}} = \text{ratio of angle}$$

$$\therefore \frac{c}{d} = \frac{\text{opp}}{\text{adj}} = \tan C \qquad \therefore \log C - \log d = \log \tan C$$

$$\left.\begin{array}{rlrrrr} & c\ 3 & \log & 0{\cdot}47712 & \angle C & 30°\ 57'\ 50'' \\ & d\ 5 & \log & \underline{0{\cdot}69897} - & & \underline{90\ \ 00\ \ 00} \\ C\ \underline{30°\ 57'\ 50''} & \tan & & \underline{9{\cdot}77815} & \angle D & \underline{59\ \ 02\ \ 10} \end{array}\right\} \textit{Answers}$$

The indices of log sines, tangents, etc., are increased by 10 to avoid negative indices. The real value of the index of log tan C is -1, add 10 to it and we have 9, which is the value given to the tabular index. In the above subtraction we added 10 mentally to the index of log c.

Alternatively to the above equation we could have written:

$$\frac{d}{c} = \cot C \qquad \therefore \log d - \log c = \log \cot C$$

$$\begin{array}{rlrr} & d\ 5 & \log & 0{\cdot}69897 \\ & c\ 3 & \log & \underline{0{\cdot}47712} - \\ C\ \underline{30°\ 57'\ 50''} & \cot & & \underline{10{\cdot}22185} \end{array}$$

The real index of cot C is 0, and has been increased by 10 to give the tabular index.

(d) **By Inspection** (Traverse Table) The Traverse Table gives the solution of a series of right-angled plane triangles in which the angles are increased progressively by 1 degree and the hypotenuse by 1 unit. The degrees are given at the top and bottom of the pages and the lengths of the hypotenuse for successive values from 1 to 600 units in the left hand column called Distance (Dist.). The lengths of the other two sides are given in two adjoining columns named Difference of Latitude (D. Lat.),and Departure (Dep.). Each opening of the Table gives the solution of 600 separate triangles, the whole comprising answers to 27,000 distinct triangles; and why not use it when we can?

The student is referred to the explanation on the use of Traverse Tables which is given at the front of *Norie's Nautical Tables.*

The Traverse Table is intended specially to facilitate the working up of the courses and distances sailed by a ship, but any right-angled plane triangle that comes within the limits of the Table can be solved from it by inspection, accurately solved when the information given in the triangle fits in exactly with the figures given in the Table, but approximately only by interpolation when the information falls between the tabulated figures. The Table is laid out as follows:

32 Degrees

Dist.	D. Lat.	Dep.
hyp 6	*adj* 5·1	*opp* 3·2

The angle at the top of the page is the Course.
The hypotenuse is the Dist.
The adjacent side is the D. Lat.
The opposite side is the Dep.
The abbreviations *hyp.*, *adj.*, and *opp.* in their respective columns are ours.
Referring again to the triangle CDE, to find $\angle C$, given $EC = 5$ miles, $ED = 3$ miles.
Enter the Traverse Table and find

$EC = 5$, the *adj* side in the D. Lat. column
$ED = 3$, the *opp* side in the Dep. column

so that the two quantities are side by side. The nearest is 5·1 and 3·2, the angle corresponding to this is given at the top of the page 32°, and the length of the hypotenuse as 6 miles in the Dist. column. Angle C by inspection is 32°.

Example 17

In triangle LMN, given $\angle M = 90°$, $LM = 36$ miles, $LN = 58$ miles. Find angles L and N by (a) construction, (b) calculation using Natural Numbers, (c) calculation using logarithms and (d) inspection of Traverse Tables.

(a) **By Construction** Make $\angle M = 90°$, make $ML = 36$ units; centre L and radius 58 units describe an arc cutting MN at N. Join LN, then LMN is the required triangle. Lift off angles L and N with a protractor.

(b) **By Calculation** (Natural Numbers)

$$\frac{\text{known side}}{\text{known side}} = \text{ratio of } \textit{required} \text{ angle.}$$

$$\frac{m}{n} = \frac{\text{hyp}}{\text{adj}} = \sec L \qquad \therefore \text{ nat sec } L = \frac{58}{36} = 1{\cdot}61111$$

Nat Sec Table gives $\angle L = 51° 38'$
subtract from $90\ 00$
$\angle N = \underline{38\ 22}$ } *Answers*

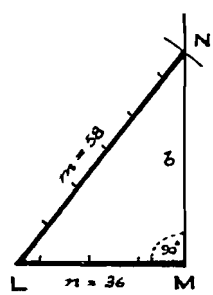


Figure 26.

(c) **By Calculation** (Logarithms)

$$\frac{m}{n} = \sec L \qquad \therefore \log m - \log n = \log \sec L$$

m	58	log	1·76343
n	36	log	1·55630
$\angle L$	51° 38′	sec	10·20713

(d) **By Inspection** (Traverse Table)

$m = 58$ (hyp) in Dist. col.
$n = 36$ (adj) in D. Lat. col. } gives $51\frac{1}{2}°$ angle

$\therefore \angle L = 51\frac{1}{2}°$ by inspection.

Note that
58·0 as Dist.
36·5 as D. Lat. } gives 51° at the bottom of the page

58·0 as Dist.
35·7 as D. Lat. } gives 52° at the bottom of the page.

The required angle therefore lies between 51° and 52° because side n which is 36 fits in between 36·5 and 35·7, the two quantities tabulated as *D. Lat.* Make sure of getting into the proper columns when the angle is given at the bottom of the page.

Example 18

A perpendicular flagstaff 35 metres in height casts a shadow on the ground 54 metres long. Find the altitude of the sun.

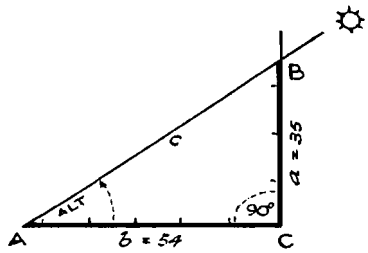


Figure 27.

(a) **By Construction** In figure CB is the flagstaff = 35 m. CA is the shadow = 54 m. $\angle CAB$ is the altitude of the sun required.

(b) **By Calculation**

$$\frac{\text{known side}}{\text{known side}} = \text{ratio of } \textit{required} \text{ angle.}$$

$$\frac{a}{b} = \frac{\text{opp}}{\text{adj}} = \tan A$$

$$\therefore \text{nat tan } A = \frac{35}{54} = \cdot 648148$$

$$\therefore A = 32° 57'$$

(c) $\dfrac{a}{b} = \tan A$

$$\therefore \log a - \log b = \log \tan A$$

a	35	log	1·54407
b	54	log	1·73239
A	32° 57′	tan	9·81168

Sun's altitude 32° 57′ *Answer*

(c) **By Inspection**

$$\left.\begin{array}{l} a = 35\,\text{m (opp) in Dep. col.} \\ b = 54\,\text{m (adj) in D. Lat. col.} \end{array}\right\} \text{gives } 33° \text{ at top of the page.}$$

Exercise 5

Construct a figure and solve the following triangles by natural numbers and by logs. Check your answers by inspection of the Traverse Tables.

1. Triangle ABC, $\angle C = 90°$, AC 39 miles, BC 27 miles. Find angles A and B.
2. Triangle BCD, $\angle B = 90°$, b 2720 metres, c 1916 metres. Find angles C and D.
3. Triangle MNO, $\angle M = 90°$, m 372 metres, n 272 metres. Find angles N and O.
4. Triangle XYZ, $\angle X = 90°$, x 382·8 metres, z 91·2 metres. Find angles Y and Z.
5. An observer is $9\frac{1}{2}$ miles distance from a cliff 600 feet high. Find the vertical angle subtended by the cliff.
6. A vessel steams along a course making good 89 miles North and 72 miles East. Find the course steered.

Answers

1. $\angle A$ 34° 41½′ $\angle B$ 55° 18½′
2. $\angle C$ 44° 47′ $\angle D$ 45° 13′
3. $\angle N$ 46° 59′ $\angle O$ 43° 01′
4. $\angle Y$ 76° 13′ $\angle Z$ 13° 47′
5. Vertical angle 0° 35¾′
6. Course 038° 58½′

TO FIND A SIDE

Example 19

In $\triangle ABC$, given $\angle B = 90°$, $\angle A = 60°$ and AB 200 metres. Find the remaining sides by (a) construction, (b) calculation using Natural Values, (c) calculation using logarithms and (d) Traverse Tables.

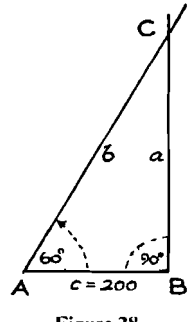


Figure 28.

(a) **By Construction** Make $\angle BAC = 60°$, make $AB = 200$ units, make BC perpendicular to AB. ABC is the required triangle. The lengths of AC and BC can be measured off on the scale of equal parts.

(b) **By Calculation**

Rule

$$\frac{\textit{required}\ \text{side}}{\text{any known side}} = \text{ratio of given angle.}$$

(b) $\dfrac{b}{c} = \dfrac{\text{hyp}}{\text{adj}} = \sec A$

$b = c \text{ nat sec } A$
$b = 200 \times \text{nat sec } 60°$
$b = 200 \times 2$
$b = \underline{400}\,\text{m}$

$\dfrac{a}{c} = \dfrac{\text{opp}}{\text{adj}} = \tan A$

$\therefore\ a = c \text{ nat tan } A$
$a = 200 \times \text{nat tan } 60°$
$a = 200 \times 1{\cdot}732$
$a = \underline{346{\cdot}4}$

(c) $\dfrac{b}{c} = \sec A$

$\therefore\ b = c \sec A$
$\log b = \log c + \log \sec A$

c	200	log	2·30103
A	60°	sec	10·30103
b	400	log	2·60206

$\dfrac{a}{c} = \tan A$

$\therefore\ a = c \tan A$
$\log a = \log c + \log \tan A$

c	200	log	2·30103
A	60°	tan	10·23856
a	346·4	log	2·53959

Answer Side a 346·4 m, side b 400 m.

Ten has been rejected from the sum of the logs because the tabular index of both the secant and tangent has been increased by ten.

(c) **By Traverse Tables**

$\angle A = 60°$ at the bottom of the page
$c = 200$ (adj) in D. Lat. column
gives $b = 400$ (hyp) in Dist. column
gives $a = 346{\cdot}4$ (opp) in Dep. column.

Example 20

In triangle PRS given $\angle P$ 90°, $\angle S$ 58°, RS 1846 feet. Find the remaining parts by (a) construction, (b) calculation using logarithms, (c) Traverse Tables.

(a) **By Construction** Make $\angle S = 58°$, make $SR = 1846$ units, from R drop RP perpendicular to SP. RSP is the required triangle. Measure SP and PR from the same scale of equal parts.

(b) **By Calculation**

Rule

$$\frac{\textit{required}\ \text{side}}{\text{a known side}} = \text{ratio of given angle.}$$

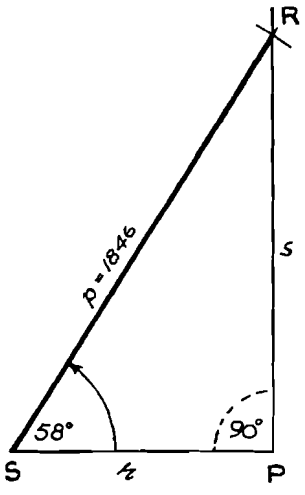


Figure 29.

$$\frac{s}{p} = \frac{\text{opp}}{\text{hyp}} = \sin S$$

$\therefore s = p \text{ nat sin } S$

$s = 1846 \text{ nat sin } 58°$

$s = 1846 \times 0{\cdot}848048$

$s = \underline{1565{\cdot}497}$ feet

$$\frac{s}{p} = \sin S$$

$\therefore s = p \sin S$

$\log s = \log p + \log \sin S$

p	1846	log 3·26623
S	58°	sin 9·92842
s	1565·5	log 3·19465

$$\frac{r}{p} = \frac{\text{adj}}{\text{hyp}} = \cos S$$

$\therefore r = p \text{ nat cos } S$

$r = 1846 \text{ nat cos } 58°$

$r = 1846 \times 0{\cdot}5299$

$r = \underline{978{\cdot}2}$ feet

$$\frac{r}{p} = \cos s$$

$\therefore r = p \cos S$

$\log r = \log p + \log \cos S$

p	1846	log 3·26623
S	58°	cos 9·72421
r	978·2	log 2·99044

It will be obvious that the multiplication in the natural number method is rather tedious and that the method by logs is more convenient when the numbers are big.

Answers $\therefore R = (90° - S) = (90° - 58°) = 32°$
side $s = 1565{\cdot}5$ feet, side $r = 978{\cdot}2$ feet.

(c) **Check by Inspection**

$\therefore S = 58°$ at the bottom of the page
$p = 184\frac{1}{2}$ (hyp) in Dist. column
gives $s = 156{\cdot}5$ (opp) in Dep. column
$r = 97{\cdot}8$ (adj) in D. Lat. column.

The quantities corresponding to s and r have to be interpolated for as the nearest numbers given in the Dist. column to 1846 are 184 and 185; we entered with 184·5 by pointing off the fourth figure and so 156·5 becomes 1565 and 97·8 becomes 978.

Example 21

Two vessels A and B start from the same point, A sails 225°T 27·5 miles, B sails 315°T 33·5 miles . Find how far they are apart by (a) construction, (b) calculation using logarithms and (c) Traverse Tables.

(a) **Construction** Mark a spot C, draw CB 315°T, 33·5 units in length, draw CA 225°T 27·5 units in length. Join AB. ABC is the required triangle. $\rightarrow C = 90°$, AB represents the distance apart of the two ships. Measure it from the same scale of units as before.

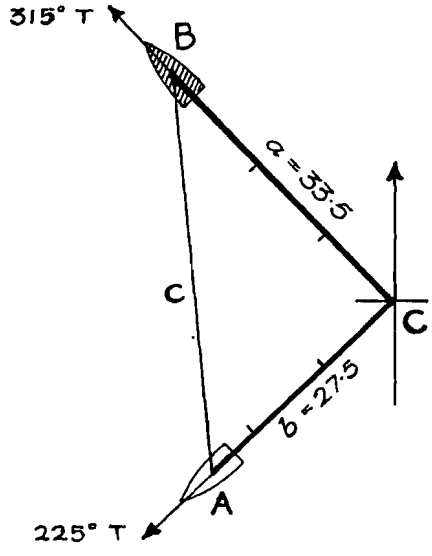


Figure 30.

(b) **Calculations** Find an angle and then use it to find side AB.

$$\frac{\text{known side}}{\text{known side}} = \text{ratio of angle} \qquad \frac{\textit{required}\ \text{side}}{\text{known side}} = \text{ratio of angle}$$

$$\frac{a}{b} = \tan A \qquad \frac{c}{b} = \sec A \quad \therefore\ c = b \sec A$$

$$\log a - \log b = \log \tan A \qquad \log c = \log b + \log \sec A$$

a	33·5	log	1·52505	b	27·5	log	1·439333
b	27·5	log	1·43933	A	50° 37′	sec	10·197564
A	50° 37′	tan	10·08572	c	43·34	log	1·636897

Answer Distance apart 43·34 miles.

(c) **Traverse Tables**

a = 334·8 (opp) in Dep. column
b = 280·8 (adj) in D. Lat. column
} gives 50° and Dist. 437.

a = 334·9 (opp) in Dep. column
b = 271·2 (adj) in D. Lat. column
} gives 51° and Dist. 431.

The mean of those values will be the approximate answers. Angle $50\frac{1}{2}°$, distance 43·4.

Example 22

A vessel having steamed 72·4 miles due North and 30·5 miles due East. Find the course and distance made good by (a) construction and (b) calculation using logarithms.

(a) **Construction** Make $AB = 72{\cdot}4$ units due North. Make $\angle B = 90°$. Make $BC = 30{\cdot}5$ units due East. Join AC. ABC is the required triangle. Angle A is the course, measure it with a protractor. AC is the distance, measure it from the same scale of units.

(b) **Calculation** To find angle A.

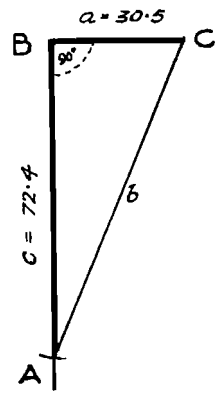


Figure 31.

Rule

$$\frac{\text{known side}}{\text{known side}} = \text{ratio of } \textit{required} \text{ angle.}$$

$$\frac{a}{c} = \frac{\text{opp}}{\text{adj}} = \tan A \quad \therefore \log a - \log c = \log \tan A$$

a	30·5	log 1·48430
c	72·4	log 1·85974
A	22° 50½′	tan 9·62456

To find side b

Rule

$$\frac{\textit{required}\ \text{side}}{\text{known side}} = \text{ratio of given angle}$$

$$\frac{b}{a} = \frac{\text{hyp}}{\text{opp}} = \operatorname{cosec} A \quad \therefore b = a \operatorname{cosec} A$$

$$\log b = \log a + \log \operatorname{cosec} A$$

a	30·5	log	1·48430
A	22° 50½′	cosec	10·41096
b	78·57	log	1·89526

Answers Course 022° 50½′ T.
Distance 78·57 miles.

(c) **Check by Traverse Table**

$c = 72{\cdot}4$ (adj) in D. Lat. column
$a = 30{\cdot}5$ (opp) in Dep. column

Under 22° we get 72·3 beside 29·2, giving a distance of 78.

Under 23° we get 72·7 beside 30·9, giving a distance of 79; so the course corresponding to our figures must be about 22½° and distance 78½ miles.

Exercise 6

1. In triangle ABC, $B = 90°$, $A = 52° 36'$, side $c = 486$ feet; find the remaining parts.
2. In triangle MNO, $\angle N = 90°$, $\angle O = 57° 22'$, side $n = 318{\cdot}4$ feet; find the other parts.
3. In triangle XYZ, $\angle Z = 90°$, $X = 35°$, side $z = 4750$ feet; find the remaining parts.
4. In triangle MNO, $O = 90°$, $MO = 107{\cdot}8$ feet, $NO = 166$ feet; find the remaining parts.
5. A ship sails 321° T true and makes 113 miles of Westing; what distance did she sail?
6. A vessel in sailing from A to B makes 107 miles of Northing and 132·1 miles of Easting; required the course and distance she has sailed.
7. A point of land is bearing 040° T, distant 15 miles. If the vessel is steering North, speed 9 knots, in what time will the point be abeam and what will the beam distance be?
8. A point B is 9 miles due East from A, and C, which lies due South of B, is 16 miles from A. Find the distance between B and C.

Answers

1. C 37° 24′, a 635·7 feet, b 800·2 feet.
2. M 32° 38′, m 171·7 feet, O 268·1 feet.
3. Y 55° 00′, x 2724 feet, y 3891 feet.
4. N 33° 00′, M 57° 00′, MN 197·9 feet.
5. Distance 179·6 miles.
6. Course 051° T. Distance 170 miles.
7. Time 1 h 16·6 m. Beam distance 9·64 miles.
8. Distance 13·23 miles.

Miscellaneous Examples

We shall now work out some miscellaneous examples of navigational problems. Read the questions carefully, exercise the imagination and construct an approximate diagram to illustrate the question.

These examples are, in effect, a test of nautical intelligence. Having drawn the appropriate figure and noted the information provided and what is required, the solution of the problem is resolved into the solution of right-angled plane triangles.

Example 23

The angle of elevation of a ship's masthead 126 feet above the sea is observed from a boat to be $14\frac{1}{2}°$ above the horizontal plane of the observer's eye. The observer's eye was 6 feet above the sea. How far was he from the ship?

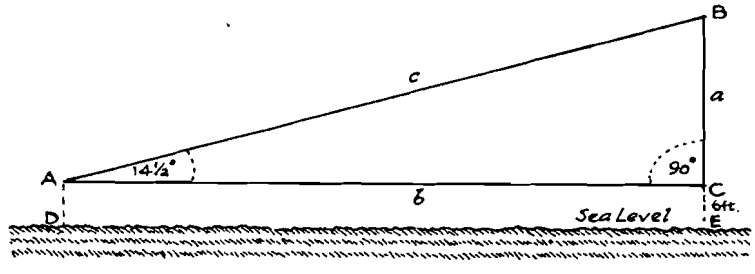


Figure 32.

In triangle ABC, let A represent the observer's eye, the angle at A being $14\frac{1}{2}°$.

As the masthead is 126 feet above the sea and the observer's eye is 6 feet above the sea, the masthead must be 120 feet above the horizontal plane of the observer's eye. The height of the masthead above the observer's eye is, therefore, represented by the side BC.

The dotted lines AD and CE below the triangle represent the height of eye, 6 feet (not to scale).

We now have given the angle A and side BC, and are required to find the side AC which is the distance of the ship from the observer.

$$\frac{b}{a} = \frac{\text{adj}}{\text{opp}} = \cot A \qquad b = a \cot A$$

$$\therefore\ b = a \times \text{nat cot } A \qquad \therefore\ \log b = \log a + \log \cot A$$

$b = 120 \text{ nat cot } 14\frac{1}{2}°$

$b = 120 \times 3{\cdot}8667$

$b = 464$ feet

a	120	log	2·07918
A	14° 30′	cot	10·58734
b	464	log	2·66652

Answer 464 feet.

Example 24

A vessel sails 337° T for 4 hours at 9·5 knots through a current setting 247° T at 2·5 knots, find the course and distance made good.

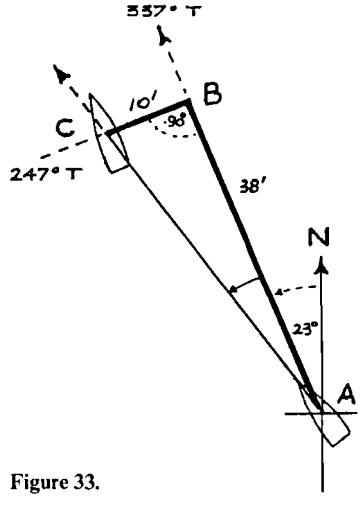


Figure 33.

Construction Draw AN to represent North, make $\angle NAB = 23°$, AB = distance by patent log in 4 hours = 38 miles. $\angle ABC = 90°$, BC = drift of current in 4 hours = 10 miles. Join AC. $\angle NAC$ is the course made good and AC is the distance made good.

Calculation In triangle ABC, given $\angle B = 90°$, $AB = 38'$, $BC = 10'$, find (1) $\angle BAC$ and thence the course; (2) side AC.

(1) $\cot A = \frac{AB}{CB} = \frac{38}{10}$

$\text{nat cot } A = \frac{38}{10} = 3{\cdot}8$

$\therefore \angle BAC = 14° 44\frac{1}{2}'$

$\angle NAB = 23\ 00$

$\therefore \angle NAC = 37\ 44\frac{1}{2}$

(2) $\frac{AC}{BC} = \text{cosec } A$

$\therefore AC = BC \text{ nat cosec } A$

$AC = 10 \text{ nat cosec } 14° 44\frac{1}{2}'$

$AC = 10 \times 3{\cdot}93$

$AC = 39{\cdot}3$ miles

Course made good 322° $15\frac{1}{2}'$ T. Distance 39·3 miles.

Example 25

A vessel steering 056° T sights two beacons of a measured mile in line on the port quarter. After steaming 1·5 miles the other two beacons come into line also on the port quarter. What course would a vessel have to steer when running the measured mile?

Construction Mark a spot C and draw CF 056°T, the direction ship has sailed. Make $CF = 1{\cdot}5$ units. With centre C and radius 1 unit describe an arc, then draw FG a tangent to this arc, and extend it beyond G. Join GC. CG is the direction to steer on the measured mile,

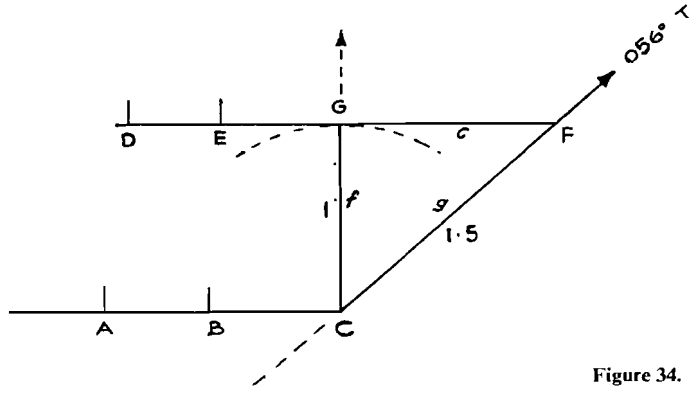


Figure 34.

it is exactly 1 mile long and is at right angles to the transit bearings of the mile posts. The two transit bearings are FG with two posts D and E shown on it, and CA with two posts A and B shown on it. CA is parallel to FG.

If a ship steers obliquely across the measured mile the distance sailed will be greater than 6080 feet. Ships when on steaming trials must steer a course parallel to the direction of CG.

Calculation In triangle CFG, given $G = 90°$, $CF = 1{\cdot}5$ miles, $CG = 1$ mile, find $\angle GCF$.

$$\text{nat sec } C = \frac{CF}{CG} = \frac{1{\cdot}5}{1} = 1{\cdot}5$$

$\therefore \angle FCG = 48° 11\frac{1}{2}'$

but C to F is 056 00

$\therefore C$ to G is $007° 48\frac{1}{2}'$ T

Answer Course to steer 007° $48\frac{1}{2}'$ T.

Example 26

Two points A and B in transit bearing 315° T from a vessel steaming 340° T at 10 knots. After 1 hour A and B subtend their **maximum** horizontal angle 90°. Required the distance between A and B.

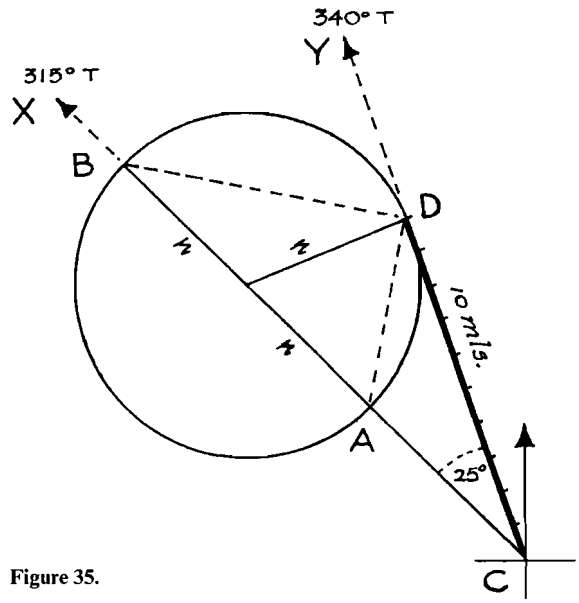


Figure 35.

Construction Lay off CX 315°T and CY 340°T' $\angle C = 25°$. Make $CD = 10$ miles, and from D erect DO perpendicular to CY. With centre O and radius OD describe a circle cutting CX at A and B. This circle also passes through the ship's position at D where the given maximum horizontal angle ADB is 90°. A and B are the two points. Radius OD is perpendicular to the tangent CD $\therefore$ $\angle ODC = 90°$, $OA = OD = OB$ radii, and AB is double OD.

In triangle COD, given $CD = 10$ miles, $\angle C = 25°$, $\angle ODC = 90°$; find side OD.

By Natural Values

$$\frac{OD}{CD} = \tan OCD$$

$$\therefore\ OD = CD \tan OCD$$

$$OD = 10 \text{ nat tan } 25°$$

$$OD = 10 \times 0{\cdot}4663$$

$$OD = 4{\cdot}663$$

$$AB = \underline{2OD} = \underline{9{\cdot}326}$$

By Logarithms

$$OD = CD \tan OCD$$

$$\log OD = \log CD + \log \tan OCD$$

CD	10	$\log$ 1·00000
$\angle C$	25°	$\tan$ 9·66867
OD	4·66	$\log$ 0·66867

By Traverse Table

$\angle C$ 25° as course ($\angle C$)
CD 10 as D. Lat. (adj)
gives OD as 4·6 in Dep. col. (opp).

Answer Distance between A and B is 9·326 miles.

Example 27

A vessel A is 10 miles due South of another vessel B. A steams 027° T at 11 knots and B steams 117° T at 10 knots. Find the distance one will pass ahead of the other.

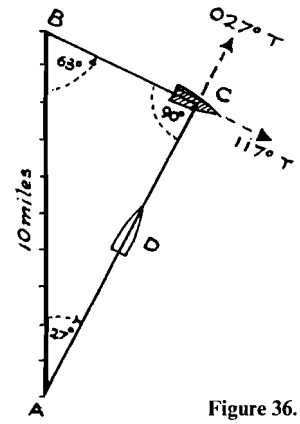


Figure 36.

Construction Draw AB a North-South line and make it 10 units long. Make $\angle BAC = 27°$ and $\angle ABC = 63°$. C is the crossing point of the two tracks. $\angle C = 90°$, BC is the distance ship B has to go to reach the crossing point C, and AC is the distance ship A has to go; it is required to find those distances.

Calculation

To find BC	*To find AC*
$\frac{BC}{AB} = \sin A$	$\frac{AC}{AB} = \cos A$
$\therefore BC = AB \sin A$	$\therefore AC = AB \cos A$
$BC = 10 \times \text{nat sin } 27°$	$AC = 10 \times \text{nat cos } 27°$
$BC = 10 \times 0{\cdot}454$	$AC = 10 \times 0{\cdot}891$
$BC = 4{\cdot}54$ miles	$AC = 8{\cdot}91$ miles

The student may work this out by logarithms if he prefers to, but we have used the natural values as the quantities are small and easily handled.

Check by Inspection

$\angle A = 27°$ at top of page
$AB = 100$ (hyp) in Dist. col.
gives $AC = 89{\cdot}1$ (adj) in D. Lat. col.
$BC = 45{\cdot}4$ (opp) in Dep. col.

Shift the decimal back one place and get 8·91 and 4·54.

It is obvious from the figure that ship B will reach the crossing point before ship A. We must, therefore, find how far ship A will have steamed along the line AC at 11 knots during the time ship B, at 10 knots, has steamed 4·54 miles to reach C. It is a case of simple proportion.

$$\frac{A\text{'s distance}}{B\text{'s distance}} = \frac{A\text{'s speed}}{B\text{'s speed}}; \qquad A\text{'s distance} = \frac{4{\cdot}54 \times 11}{10}$$

$$= 4{\cdot}99 \text{ miles}$$

Ship A would have to go along AC, 8·91 miles to reach C
but she has only gone to AD, i.e. 4·99 miles towards C

the distance apart is DC = 3·92 miles

Answer 3·92 miles.

The final proportion may be reasoned out as follows although it is a more indirect method:

Find the time B will take to go 4·54 miles at 10 knots.

$$\frac{\text{time}}{1 \text{ hour}} = \frac{\text{distance}}{\text{speed}}$$

$$\therefore \text{ time} = \frac{60 \text{ min.} \times 4{\cdot}54 \text{ mls.}}{10 \text{ knots}} = 27{\cdot}24 \text{ minutes}$$

Find how far A will go in 27·24 minutes at 11 knots.

$$\frac{\text{distance}}{\text{speed}} = \frac{\text{time}}{1 \text{ hour}}$$

$$\therefore \text{ distance} = \frac{11 \times 27{\cdot}24}{60} = 4{\cdot}994 \text{ miles.}$$

Total distance to go 8·91

Answer Distance still to go to reach C 3·92 miles

Example 28

Two vessels A and B are steaming North at 10 knots. Ship B, which is 5 miles on A's port beam, is ordered to increase speed to 12 knots and close to 1 mile on A's port beam. Find B's new course and the time she would take to get into position.

Construction Draw AA' a North-South line along which ship A sails at 10 knots. Draw AX due West of A. Draw a line CD parallel to AA' a convenient distance on A's port beam, to represent 1 mile but not to scale. The two vessels are 5 miles apart and one of them has to close in 4 miles on the other, call this distance x because we are not interested in actual distances at the moment as the preliminary work of solution depends upon relative speeds, and not on distances, the principle being the same whatever distance apart the vessels may be.

Make CD equal to 10 knots from any convenient scale. With centre D and radius 12 knots from the same scale describe an arc cutting AX at B. Join DB. BCD is a triangle of velocities, not of distance, and BC represents the speed at which B closes in on A to enable both ships to maintain the same East-West bearing from each other. Ship B sails along BD at 12 knots and reaches position D at the same time as ship A reaches A'. $\angle NBD$ is the alteration of B's course, $\angle NBD = \angle D$ and this angle, which is included between the lines representing the velocities of the two ships, gives the angle between their courses, and the third side, BC in figure, represents the closing speed.

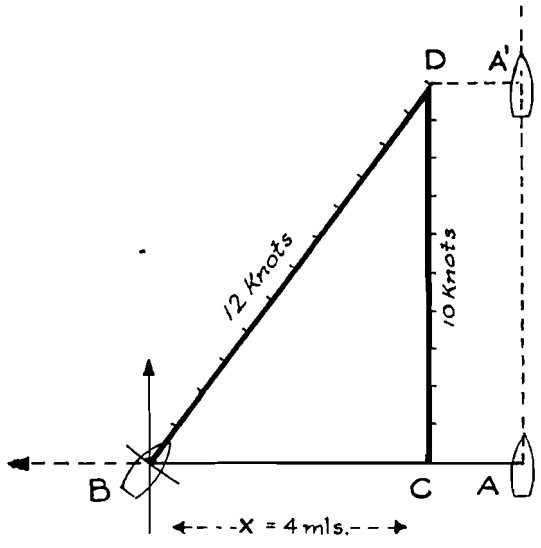


Figure 37.

Calculation In triangle BCD, given $\angle C = 90°$, $CD = 10$ knots, $BD = 12$ knots, find (1) $\angle D$, (2) side BC.

(1) $\sec D = \dfrac{DB}{DC}$

$\text{nat sec } D = \frac{12}{10} = 1{\cdot}20000$

$\therefore\ D = 33° 33\frac{1}{2}'$

Course $033° 33\frac{1}{2}'$

(2) $\dfrac{BC}{DC} = \tan D$

$\therefore\ BC = DC \text{ nat tan } D$

$BC = 10 \text{ nat tan } 33° 33\frac{1}{2}'$

$BC = 10 \times 0{\cdot}6633$

$BC = 6{\cdot}633$ knots

Check by Traverse Table

$DB = 12$ knots (hyp) in Dist. column
$DC = 10$ knots (adj) in D. Lat. column

gives an angle of approximately 33° at the top of the page and 6·5 in the Dep. column.

Time required to Close in The distance to close in is 4 miles, the closing speed is 6·633 knots; find the time required to get into position.

$$\frac{\text{time}}{1 \text{ hour}} = \frac{\text{distance}}{\text{speed}}$$

$$\text{time} = \frac{4 \text{ miles} \times 60 \text{ mins.}}{6{\cdot}633 \text{ knots}} = 36{\cdot}18 \text{ minutes}$$

Answer Course 033° 33·5′ T. Time 36·18 minutes.

In examples involving speed and distance care has to be taken not to mix units of speed with units of distance, hence the reason why it is better in examples such as this to leave the question of time and distance to the end of the working. **A knot** is a unit of speed and is 1 nautical mile per hour. A *nautical* mile is 1852 m or 6076·12 feet (6080 ft approx.).

Example 29

A vessel steering 000° T sees two beacons A and B of equal height. A bears 315° T and subtends a vertical angle of 1° 54′; B bears 045° T and subtends a vertical angle of 1° 25′. Find the alteration of the course so that the ship may pass midway between the two beacons.

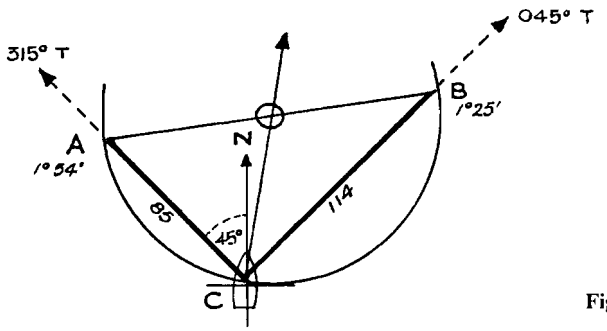


Figure 38.

Construction Mark a spot C to represent the position of the ship when steering North. Lay off $\angle NCA$ 45° and $\angle NCB$ 45°. $\angle ACB = 90°$.

When vertical angles are small the distances of the observer from the upright object vary inversely as the vertical angles. The bigger the vertical angle the nearer will the observer be to the object.

The beacons A and B are equal in height and B is further away from the ship than A because its vertical angle is smaller than A's vertical angle. Reduce the vertical angle to minutes and make $CA = 85$ units and $CB = 114$ similar units. Join AB. Bisect AB at O. The ship has to steer from C to O and $\angle NCO$ is the alteration of the course. The point O is the centre of a circle passing through ACB, because $\angle C = 90°$.

Calculation Triangle ABC is right angled at C, and the ratio of CA to CB as given in figure gives correct **relative** values of the distance of A and B from the ship but not their actual distances.

$$\frac{\text{distance from } A}{\text{distance from } B} = \frac{\text{vertical angle of } B}{\text{vertical angle of } A} = \frac{85'}{114'}$$

Find angle A.

$$\tan A = \frac{BC}{CA} = \frac{114}{85} \quad \therefore \log \tan A = \log 114 - \log 85$$

114	log	2·056905
85	log	1·929419
A 53° 17½′	tan	10·127486

Triangle OAC is ososceles, $OA = OC$, radii of circle

$$\therefore \angle OAC = \angle ACO = 53° 17\tfrac{1}{2}' \text{ as above}$$
$$\angle ACN = 45\ 00 \text{ given}$$
$$\angle NCO = 8\ 17\tfrac{1}{2}$$

Answer Alter course 8° 17½′ to starboard.

Example 30

From a vessel two towers A and B of equal height and 4 miles apart are observed to bear 342°T and 072° T respectively. The vertical angles subtended being 1° 24′ by tower A and 1° 36′ by tower B; find the distance of the nearer tower from the ship.

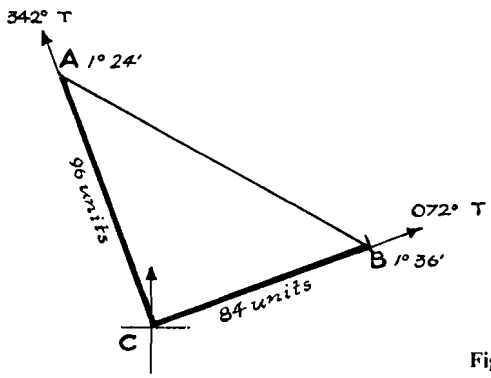


Figure 39.

Construction Make a spot C. Draw CA, 342° T, and CB, 072° T. $\angle C = 90°$.

vertical angle of $A = 1° 24' = 84'$
vertical angle of $B = 1° 36' = 96'$

The towers are of equal height, therefore their distances from C vary inversely as their vertical angles. Make $CB = 84$ units and $CA = 96$ units. Join AB. B is the nearer tower because it subtends the greater vertical angle. The triangle ABC is relatively correct.

Given $\angle C = 90°$, $CA = 96$ units, $CB = 84$ units, find $\angle A$.

$$\text{nat cot } A = \frac{AC}{CB} = \frac{96}{84} = \frac{8}{7} = 1{\cdot}14286$$

$$\therefore \angle A = 41° 11'$$

Assume now that the side AB is 4 miles in length as given in the question, and we have in triangle ABC, $\angle C = 90°$, $\angle A = 41° 11'$, side $AB = 4$ miles, find side CB.

$$\frac{CB}{AB} = \sin A \quad \therefore CB = AB \text{ nat sin } A$$

$$CB = 4 \text{ nat sin } 41° 11'$$
$$CB = 4 \times 0{\cdot}6585$$
$$CB = 2{\cdot}634.$$

Answer Distance from nearer tower 2·634 miles.

Example 31

At 0100 a ship sees a light bearing North; at 0140 it was abeam, and at 0200 it was bearing East. If the vessel's speed was 12 knots; find the course she made good and her distance from the light when abeam.

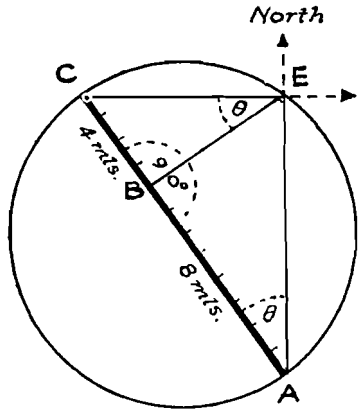


Figure 40.

Construction The total distance sailed is 12 miles. Take a radius of 6 units on the compasses and describe a circle. Lay off AC in a North-Westerly direction and divide it at B so that $AB = 8$ units and $BC = 4$ units. From B draw BE perpendicular to AC and meeting circumference at E, the position of the light. Join CE and AE. Then $\angle CEA = 90°$; the direction of AE is North, and of CE East.

The ship was at A at 0100. At B at 0140 and at C at 1400. Required BE the beam distance, and $\angle A$ the true course.

To find BE.

Triangles CBE and ABE are similar, $\angle CEB = \angle EAB$, let each $= \theta$.

In triangle CEB, $\dfrac{4}{BE} = \tan\theta$. In triangle ABE, $\dfrac{BE}{8} = \tan\theta$.

$$\therefore \frac{4}{BE} = \frac{BE}{8}, \quad BE^2 = 4 \times 8 = 32 \quad BE = \sqrt{32}$$

$$\log BE = \tfrac{1}{2}\log 32 = \tfrac{1}{2}(1{\cdot}50515) = 0{\cdot}75257 \quad \therefore\ BE = 5{\cdot}657.$$

To find $\angle A$.

In triangle ABE given $\angle B = 90°$, $AB = 8$, $BE = 5{\cdot}657$. Find $\angle A$.

$$\frac{BE}{AB} = \tan A \quad \therefore \log BE - \log AB = \log \tan A.$$

BE	5·657	log 0·75259
AB	8·000	log 0·90309
A	35° 16′	tan 9·84950

Answer Course made good 324° 44′ T. Distance when abeam 5·657 miles.

Alternative Solution

Construct the figure as already described and then join OE, O being the centre of the circle. Then $OE = 6$ miles (radius), $OB = 2$ miles. In triangle OBE, find (1) $\angle EOB$, (2) side EB.

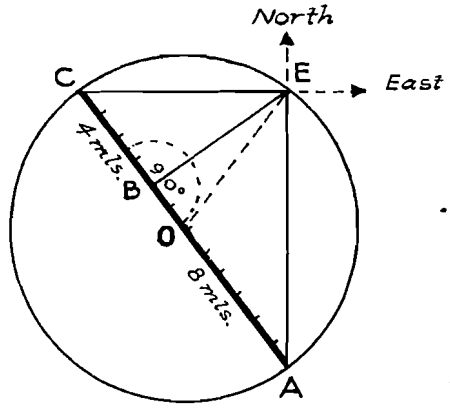


Figure 41.

To find $\angle EOB$.

$$\sec \angle O = \frac{OE}{OB}$$

$$\text{nat sec } \angle O = \tfrac{6}{2} = 3$$

$$\therefore \angle 0 = 70° 32'$$

$$\text{But } \angle EAC = \tfrac{1}{2} \angle EOC$$

$$= \tfrac{1}{2}\, 70° 32'$$

$$35° 16'$$

To find EB.

$$\frac{EB}{OB} = \tan \angle O$$

$$\therefore EB = OB \tan O$$

$$\log EB = \log 2 + \log \tan 70° 32'.$$

OB	2	log	0·30103
$\angle O$	70° 32′	tan	10·45166
EB	5·657	log	0·75269

Answer Course 324° 44′ T. Distance 5·657 miles.

Miscellaneous Examples—Right-Angled Plane Triangles

1. A vessel steaming 078° T sights a light bearing 040° T and after steaming 5 miles it was abeam. Find the beam distance.
2. A point bore 056° T from a ship which then steams 146° T 7 miles, and it then bore North. Find the distance off at 2nd bearing.
3. A ship steaming North observes two buoys abeam bearing East. She steams 3 miles and the nearer buoy bears 135° T and the horizontal angle between them is 18°. Find the distance between the buoys.
4. Steering South, 10 knots, a lighthouse bore 126° T and after steaming 36 minutes it was abeam. Find ship's distance off when it was 4 points abaft the beam.
5. Ship moored within a triangle formed by three buoys *A*, *B* and *C*. Each buoy is 2 miles distant from the other and the ship is in such a position that the horizontal angles between each pair of buoys is the same. Find distance of ship from *C*.
6. Two measured mileposts in line on the port quarter bearing 310° T, and after steaming 1·7 miles the other pair of mileposts are on the same bearing. The course on measured mile is 040° T. Find course ship has steered.
7. A ship has to make fast to a buoy 8 miles due North of her. Find the course to steer and the distance to steam in order to counteract a tide setting East, 2 knots, ship's speed 10 knots.
8. A ship steaming 050° T sights a lighthouse bearing 020° T, and after running 4 miles by patent log the lighthouse was abeam distant 1·8 miles. If a current set 320° T, find its strength, ship steaming 12 knots.

9. The height of the foremost of two leading lighthouses is 82 feet and the rear lighthouse is 60 feet directly behind the fore one. An observer 120 feet from the fore lighthouse sees the tops of both in line. Find the height of the rear lighthouse.
10. The angular height of a lighthouse 210 feet high is 0° 18′ 30″. Find its distance off in nautical miles. (6076·12 ft = 1 nautical mile.)
11. Required the vertical angle to set on a sextant for a lighthouse 208 feet high to pass 5 cables clear of a submerged rock 6 cables from the base of the lighthouse.
12. A lighthouse bore 040° T distant 6 miles by vertical angle. After steaming 1 hour at 9 knots on same course the vertical angle was the same. Find course made good and distance off on starboard beam.
13. Two towers 120 feet high subtend a vertical angle of 0° 40′ and a horizontal angle of 42°. Find the distance between them. (6076·12 ft = 1 nautical mile.)
14. A lighthouse 182 feet high bore North, distant 4 miles. A vessel steamed East 6 miles. Find the vertical angle subtended by the lighthouse at second bearing.
15. A vessel steaming 159° T at 10 knots observed a lighthouse bearing 123° T and after 45 minutes the lighthouse was abeam. Find the distance off when abeam, and supposing it was 246 feet high, find the vertical angle subtended by the lighthouse.
16. A ship steaming South observes a lighthouse bearing 126° T, and after running 40 minutes at 9 knots it was abeam and its vertical angle was 0° 24′. Find the height of the lighthouse.
17. Two beacons *A* and *B* of equal height. *A* subtends a vertical angle of 0° 54′ and *B* 1° 12′ from the ship. *B* bears 010° T from the ship and 100° T from *A*. Find the course to steer to reach *A*.
18. From a ship steaming North two beacons of equal height were observed, one bearing North and the other East, their vertical angles being 1° 40′ and 1° 19′ respectively. Find the alteration of course necessary to pass midway between them.
19. A lighthouse bore 036° T, its vertical angle being 0° 24′. Ship then steamed 4 miles and it was then abeam and subtended a vertical angle of 0° 32′. Find course steered and distance off on port beam.
20. A ship observes two towers of equal height and 3·7 miles apart. The vertical angles subtended by them are equal and the horizontal angle between them is 40°. Find the distance of the ship from tower *A*.
21. Two ships approach end on at 12 knots both alter course simultaneously 2 points to starboard; after 4 minutes each has the other 4 points on the port bow and each alters back to the original course. Find their distance apart when they come abeam of each other.
22. A ship steaming North sights another ship on her starboard beam distant 4 miles. She steams 48 minutes at 10 knots and then the other vessel is still abeam distant 1 mile. Find her course and speed.
23. A ship *A* steaming 020° T at 12 knots sights another ship *B* 24° on her starboard bow steaming in the opposite direction. In 30 minutes *B* is 4 miles abeam of *A*. Find the speed of ship *B*.

Answers

1. 3·9 miles.
2. 8·44 miles.
3. 2·89 miles.
4. 8·25 miles abeam. 11·7 miles on the quarter.
5. 1·155 miles.

6. Angle 53° 58′. Co. 093° 58′ T.
7. Co. 348° 27·8 T. Dist. 8·17 miles.
8. 1·53 knots.
9. 123 feet.
10. 39022·7 feet or 6·42 miles.
11. Angle 1° 48′ 18″.
12. Co. 358° 35·5′ T. Dist. 3·97 miles.
13. Dist. 7392 feet or 1·22 miles.
14. Angle 0° 14′ 15″.
15. Dist. 5·45 miles. Angle 0° 25′ 30″.
16. Height 350·5 feet.
17. Co. 328° 36′ T.
18. 51° 41′ to starboard.
19. Co. 084° 35·5′ T. Dist. 4·53 miles.
20. Dist. 5·41 miles.
21. Dist. 0·612 miles.
22. Co. 339° 26·5′ T. Spd. 10·62 knots.
23. Spd. 5·968 knots.

Note The student may now, if he so desires, pass on to Chapter 7 and work questions on Parallel Sailing and Mercator Sailing, and also to Chapter 9 which deals with the Day's Work problems. The solution of these problems depends upon the principles of Right-angled Plane Triangles.

OBLIQUE PLANE TRIANGLES

The solution of oblique plane triangles is confined mostly to coastal navigation. The various bearings and distances can be laid off on a chart and the triangle solved geometrically with the aid of parallel rules and a pair of compasses as explained later in the chapter dealing with Chartwork. Solution by chartwork is generally quicker than using trigonometry.

SOLUTION OF OBLIQUE-ANGLED PLANE TRIANGLES

Any plane triangle which does not contain a right angle is called an oblique-angled plane triangle. To find any part of such a triangle, three other parts must be given and of these three parts at least one must be a side. Four parts must, therefore, be under consideration, i.e. the required part and the three given parts. The following relationships exist in plane triangles.

1. The sum of the three angles is always 180°.
2. If two angles be known the third angle is the sum of the other two subtracted from 180°.
3. The greater angle is opposite to the greater side.
4. The smaller angle is opposite to the smaller side.

Three different cases present themselves in the solution of oblique plane triangles, each case requiring its particular formula depending upon the given information. We shall record here and then discuss each case separately. Refer to Figure 42.

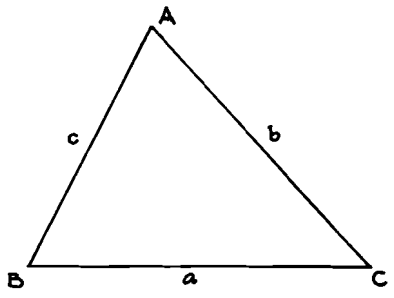


Figure 42.

Given three sides to find an angle

Formula 1

$$\text{hav}\, A = \frac{(s-b)(s-c)}{b \times c}$$

where $s = \frac{1}{2}(a+b+c)$

Of two angles and two sides opposite to each other, given any three to find the fourth

Formula 2

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Given two sides and the angle included between them, to find the remaining angles

Formula 3

$$\frac{\tan \frac{1}{2}(A \sim B)}{\tan \frac{1}{2}(A+B)} = \frac{a \sim b}{a+b}$$

It is convenient to refer to these three established formulae as the haversine formula, the sine formula and the tangent formula respectively.

HAVERSINE FORMULA

When three sides of a triangle are given and an angle is required the procedure is as follows. In triangle ABC, given the three sides a, b and c. Find the angles.

(a) To find $\angle A$, $\text{hav}\, A = \dfrac{(s-b)(s-c)}{b.c}$

(b) To find $\angle B$, $\text{hav}\, B = \dfrac{(s-a)(s-c)}{a.c}$

(c) To find $\angle C$, $\text{hav}\, C = \dfrac{(s-a)(s-b)}{a.b}$

s is the semi-perimeter $= \frac{1}{2}(a+b+c)$.

Note the symmetry of the above formulae.

(a) When finding $\angle A$ the side a is used only to get the value of s.

(b) When finding $\angle B$ the side b is used only to get the value of s.

(c) When finding $\angle C$ the side c is used only to get the value of s.

In each case the sides used in the formula, apart from determining s, are the two sides which bound the required angle; sides b and c are used to find $\angle A$, sides a and c to find $\angle B$ and sides a and b to find $\angle C$.

Natural values can be employed with advantage when the arithmetic involved is simple; in other cases the work is made easier by using logarithms.

Example 32

In triangle ABC given, side $a = 42$ feet, side $b = 36$ feet, side $c = 30$ feet. Find angles A, B and C.

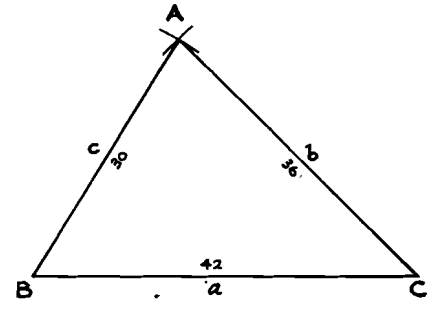


Figure 43.

Construction Draw BC to represent 42 feet. With C as centre and 36 similar units as radius describe an arc. With B as centre and 30 units as radius describe another arc cutting the first one at A. Join CA and BA. ABC is the required triangle and angles A, B and C may be lifted off approximately correct with a protractor.

Calculation First find the value of s.

a	42	$(s-a) = 12$
b	36	$(s-b) = 18$
c	30	$(s-c) = 24$
2)	108	
Semi-perimeter s	54	

$$\text{hav } A = \frac{(s-b)(s-c)}{b \cdot c}$$

$$\text{nat hav } A = \frac{(54-36)(54-30)}{36 \times 30} = \frac{\cancel{18} \times \cancel{24}^{2}}{\cancel{36} \times \cancel{30}_{5}} = \frac{2}{5} = 0{\cdot}4$$

$\therefore \angle A = 78° 27\frac{3}{4}'$ from the Nat Haversine Table.

$$\text{hav } B = \frac{(s-a)(s-c)}{a \times c}$$

$$\text{nat hav } B = \frac{(54-42)(54-30)}{42\times 30} = \frac{12\times 24}{42\times 30} = \frac{8}{35} = 0{\cdot}22857$$

$\therefore\ \angle B = 57^\circ\ 7\frac{1}{4}'$ from Nat Hav Table.

$$\text{hav } C = \frac{(s-a)(s-b)}{a\times b}$$

$$\text{nat hav } C = \frac{(54-42)(54-36)}{42\times 36} = \frac{12\times 18}{42\times 36} = \frac{1}{7} = 0{\cdot}14286$$

$\therefore\ \angle C = 44^\circ\ 25'$ from Nat Hav Table.

Angle C could have been found as follows: $C = 180^\circ - (A+B)$

$\angle A$	$78^\circ\ 27\frac{3}{4}'$
$\angle B$	$57\ \ 07\frac{1}{4}$
$A+B$	$135\ \ 35$
subtract from	$180\ \ 00$
$\angle C$	$44\ \ 25$

The same example worked out by logarithms:

$$\text{hav } A = \frac{(s-b)(s-c)}{b\times c}$$

$$\log \text{hav } A = [\log(s-b)+\log(s-c)]-[\log b+\log c]$$

$(s-b)$	18	log	1·25527	b 36	log	1·55630
$(s-c)$	24	log	1·38021	c 30	log	1·47712
		log	2·63548		log	3·03342
bc		log	3·03342	—		
$\angle A$	$78^\circ\ 27\frac{3}{4}'$	log hav	9·60206			

$$\text{hav } B = \frac{(s-a)(s-c)}{a\times c}$$

$$\log \text{hav } B = [\log(s-a)+\log(s-c)]-[\log a+\log c]$$

$(s-a)$	12	log	1·07918	a 42	log	1·62325
$(s-c)$	24	log	1·38021	c 30	log	1·47712
		log	2·45939		log	3·10037
ac		log	3·10037	—		
$\angle B$	$57^\circ\ 7\frac{1}{4}'$	log hav	9·35902			

$$\text{hav } C = \frac{(s-a)(s-b)}{a\times b}$$

$$\log \text{hav } C = [\log(s-a)+\log(s-b)]-[\log a+\log b]$$

$(s-a)$	12	log	1·07918	a	42	log	1·62325
$(s-b)$	18	log	1·25527	b	36	log	1·55630
		log	2·33445			log	3·17955
ab		log	3·17955 —				
$\angle C$	44° 25′	log hav	9·15490				

Example 33

A lighthouse bears 348° T 5 miles away from a vessel which then steams 8 miles to the Westward, the lighthouse is then 7·2 miles distant. Find the course steered by the ship and the bearing of the lighthouse.

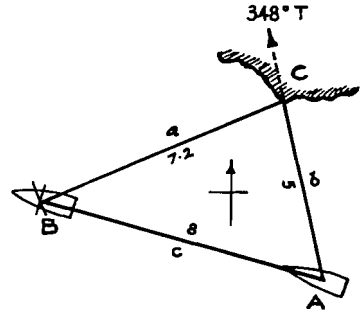


Figure 44.

Construction Let C represent the lighthouse. Lay off CA the reversed bearing 168° T from C, and distance 5 miles. With centre A and radius 8 miles describe an arc. With centre C and radius 7·2 miles describe an arc cutting the first arc at B. Join AB and BC, then ABC is the triangle required, of which the three sides are given to find (1) $\angle A$, to be applied to the left of 348° T to give the ship's course from A to B; (2) $\angle C$, to be applied to the right of 348° T to give the bearing of the lighthouse C from the ship at B.

a	7·2
b	5·0
c	8·0
	2)20·2
s	10·1
$(s-a)$	2·9
$(s-b)$	5·1
$(s-c)$	2·1

(1) $$\text{hav } A = \frac{(s-b)(s-c)}{b \times c}$$

$$\text{nat hav } A = \frac{5{\cdot}1 \times 2{\cdot}1}{5 \times 8} = \frac{10{\cdot}71}{40} = 0{\cdot}26775$$

$\therefore \angle A = 62° 19\frac{1}{2}'$ (apply to left of AC)

A to C is 348 00 T

A to B is 285 $40\frac{1}{2}$ T

(2) $$\text{hav } C = \frac{(s-a)(s-b)}{a \times b}$$

$$\text{nat hav } C = \frac{2{\cdot}9 \times 5{\cdot}1}{7{\cdot}2 \times 5} = \frac{14{\cdot}79}{36} = 0{\cdot}41083$$

$\therefore \angle C = 79° 43\frac{1}{2}'$ (apply to right of 348° T)

A to C produced is 348° 00′ T

B to C produced is 067° $43\frac{1}{2}'$ T

Answer Course 285° $40\frac{1}{2}'$ T. Bearing 067° $43\frac{1}{2}'$ T.

By Logarithms

$$\text{hav}\, A = \frac{(s-b)(s-c)}{b \times c}$$

$$\log \text{hav}\, A = [\log(s-b) + \log(s-c)] - [\log b + \log c]$$

$(s-b)$	5·1	log	0·70757	b	5	log	0·69897
$(s-c)$	2·1	log	0·32222	c	8	log	0·90309
		log	1·02979			log	1·60206
bc		log	1·60206				
$\angle A$	$62° 19\frac{1}{4}'$	log hav	9·42773				

The student may compute $\angle C$ by logarithms in the same way, and when the given quantities are clumsy it is always easier to solve the triangles by logs.

Exercise 7

1. In triangle ABC, side $a = 49$ miles, side $b = 38$ miles, side $c = 35$ miles. Find angles A, B and C.
2. In triangle ABC, $BC = 198$ metres, $AC = 382$ metres, $AB = 410$ metres. Find angles A, B and C.
3. A vessel 6 miles 196° T from a buoy steams 7 miles in a North Easterly direction. Find the course she must steer to reach a position 3 miles from the buoy.
4. A ship is 191° T 3 miles, from a lighthouse. She steams 3 miles in an Easterly direction and is then 4 miles from the lighthouse. What course did she steer?

Answers

1. $A = 84° 13'$. $B = 50° 30'$. $C = 45° 17'$.
2. $A = 28° 41'$. $B = 67° 47'$. $C = 83° 32'$.
3. Course $041° 12\frac{1}{2}'$ T.
4. Course $094° 52\frac{1}{4}'$ T.

THE SINE FORMULA

In any plane triangle the sides are always proportional to the sines of their opposite angles.

In the general triangle ABC

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

This formula can be used either to find a side or an angle in cases which deal with sides and angles opposite to each other.

To find side a the formula is written $\frac{a}{\sin A} = \frac{b}{\sin B}$, which by transposing becomes $a = \frac{b \,.\, \sin A}{\sin B} = b \sin A \operatorname{cosec} B$. (Dividing by $\sin B$ is equivalent to multiplying by its reciprocal $\operatorname{cosec} B$). Here side a is the required part, the other parts being given.

To find angle A we must invert the formula and write, $\frac{\sin A}{a} = \frac{\sin B}{b}$, and by transposing we have, $\sin A = \frac{a \cdot \sin B}{b}$. Here angle A is required, the other parts being known.

The conditions then are:

(a) Given two angles and a side opposite one of them, to find the other opposite side.
(b) Given two sides and the angle opposite one of them, to find the other opposite angle.

Example 34

In triangle ABC, given $\angle A = 64° 27'$, $\angle C = 46° 36'$, side $b = 1735$ feet. Find sides a and c.

$$\angle B = 180° - (A + C) = (180° - 111° 3') = 68° 57'$$

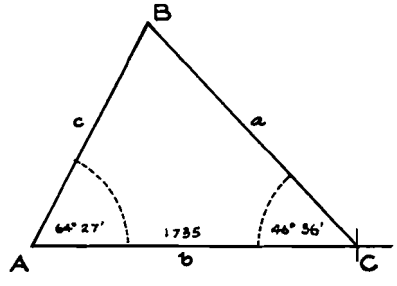


Figure 45.

To find side a

$$\frac{a}{\sin A} = \frac{b}{\sin B} \quad \therefore a = \frac{b \sin A}{\sin B} = b \sin A \operatorname{cosec} B$$

$$\log a = \log b + \log \sin A + \log \operatorname{cosec} B$$

b	1735	log	3·23930
A	64° 27′	sin	9·95531
B	68 57	cosec	10·02999
a	1677	log	3·22460

To find side c

$$\frac{c}{\sin C} = \frac{b}{\sin B} \quad \therefore c = \frac{b \sin C}{\sin B} = b \sin C \operatorname{cosec} B$$

$$\log c = \log b + \log \sin C + \log \operatorname{cosec} B$$

a	1735	log	3·23930
C	46° 36′	sin	9·86128
B	68 57	cosec	10·02999
c	1351	log	3·13057

Answer Side $a = 1677$ feet. Side $c = 1351$ feet.

Example 35

In triangle ABC, given side $a = 225$ feet, side $b = 180$ feet, $\angle A = 71° 15'$. Find side c.

To find side c

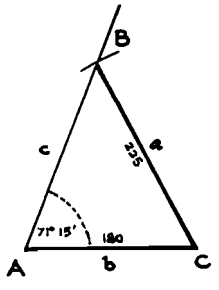


Figure 46.

$$\frac{c}{\sin C} = \frac{a}{\sin A}$$

The formula contains two unknown values, side c and $\angle C$, and therefore side c cannot be found directly. We must first find $\angle B$, thence $\angle C$ and then side c.

To find $\angle B$.

$$\frac{\sin B}{b} = \frac{\sin A}{a} \quad \therefore \sin B = \frac{b \sin A}{a}$$

$$\log \sin B = \log b + \log \sin A - \log a$$

b	180	log	2·25527		$\angle A$	71° 15′
A	71° 15′	sin	9·97632		$\angle B$	49 15
		log	2·23159		$(A+B)$	120 30
a	225	log	2·35218	—		180 00
B	49° 15′	sin	9·87941		$\angle C$	59 30

To find side c.

$$\frac{c}{\sin C} = \frac{a}{\sin A} \quad \therefore c = a \sin C \operatorname{cosec} A$$

a	225	log	2·35218
C	59° 30′	sin	9·93532
A	71 15	cosec	10·02368
c	204·7	log	2·31118

Answer Side $c = 204·7$ feet.

Example 36

A point of land bore 050° T distant 6·5 miles from a vessel steering 090° T. After $1\frac{1}{4}$ hours the point was distant 8 miles. Find the vessel's speed and the bearing of the point at the second position.

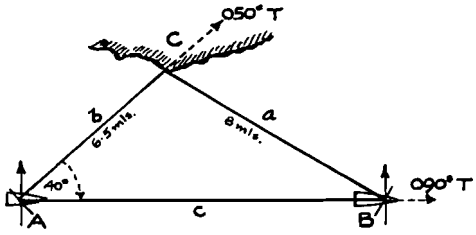


Figure 47.

Construction Mark a spot C to represent the point. Draw CA 230° T from C and make it 6·5 miles long from any convenient scale. Draw AB due East from A. With centre C and radius 8 miles describe an arc cutting AB at B. Join CB. ABC is the required triangle, A and B are the 1st and 2nd positions of the vessel. Given $b = 6{\cdot}5$, $a = 8$, $\angle A = 40°$. Find (1) $\angle B$ and thence the bearing of C; (2) side c which is the distance sailed by the vessel in $1\frac{1}{4}$ hours.

To find $\angle B$.

$$\frac{\sin B}{b} = \frac{\sin A}{a} \quad \therefore \sin B = \frac{b \sin A}{a}$$

$$\log \sin B = \log b + \log \sin A - \log a$$

b	6·5	log	0·81291	
A	40°	sin	9·80807	
		log	0·62098	
a	8	log	0·90309	—
B	31° 29′	sin	9·71789	

$\angle ABC$ is 31° 29′ and B to C is 270° + 31° 29′ = 301° 29′ T.

Answer Bearing of the point 301° 29′ T.

To find side c.

$\angle A =$	40° 00′
$\angle B =$	31 29
$(A+B)$	71 29
	180 00
$\angle C$	108 31

$$\frac{c}{\sin C} = \frac{c}{\sin A} \quad \therefore c = a \sin C \operatorname{cosec} A$$

$$\log c = \log a + \log \sin C + \log \operatorname{cosec} A$$

a	8	log	0·90309	
C	108° 31	sin	9·97691	*
A	40 00	cosec	10·19193	
c	11·8	log	1·07193	

The ship sailed 11·8 miles from A to B in $1\frac{1}{4}$ hours. If she steamed 11·8 miles in $\frac{5}{4}$ hours, she would steam $(\frac{4}{5} \times 11{\cdot}8)$ miles in one hour.

Answer Speed $= \frac{4}{5} \times 11{\cdot}8 = 9{\cdot}44$ knots.

* sine 108° 31′ = cos (108° 31′ − 90°) = cos 18° 31′.

Example 37

A and B are two ships. A steering East sights B ahead crossing her bow and steering 204° T.

Ten minutes later B is bearing 140° T, both ships steaming at 12 knots. Find the distance between the ships at the second bearing.

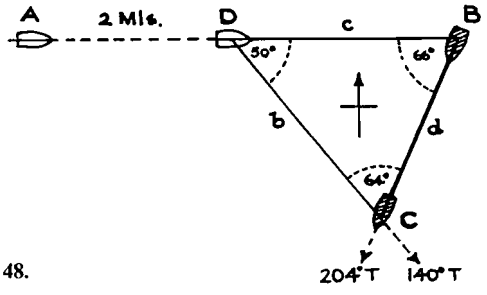


Figure 48.

Construction Draw a line DB due East. From B lay off BC to represent B's course, 204° T, and distance 2 miles. From C lay off CD 320° T which is the second bearing reversed.

Then D is the position of ship A when ship B was at C, bearing 140° T and A is the position of ship A, 10 minutes earlier when she was 2 miles astern of her second position and ship B was dead ahead. DC is the distance the two ships are apart after 10 minutes' steaming from positions A and B respectively.

In triangle BCD, given side $d = 2$ miles, $\angle D = 50°$, $\angle B = 66°$. Find side b.

$$\frac{b}{\sin B} = \frac{d}{\sin D} \quad \therefore\ b = d \sin B \operatorname{cosec} D$$

$$\log b = \log d + \log \sin B + \log \operatorname{cosec} D$$

d	2	log	0·30103
B	66°	sin	9·96073
D	50°	cosec	10·11575
b	2·385	log	0·37751

Answer Distance 2·385 miles.

Exercise 8

1. In triangle ABC, angle $A = 37° 45'$, $\angle B = 54°$, side $c = 40$ miles. Find the other parts.
2. In triangle ABC, $\angle C = 30° 55'$, side $c = 981$ feet, side $a = 252$ feet. Find the remaining parts.
3. A point of land bore 020° T from a ship which then sailed 310° T distance 5 miles, and the point then bore 050° T. Find the distance off at the time of taking the second bearing.
4. A and B are two buoys on the same meridian 5 miles apart, A bears 327° T and B bears 225° T from a ship at anchor. Find the distance of the ship from A.
5. A vessel A steaming North at 10 knots sees another vessel B 20° on her port bow steering 180° T. After 20 minutes B bore 275° T distant 2 miles. Find B's speed.
6. A ship steaming along a coast line at 12 knots sights a light bearing 344° T distant 3 miles; after steaming 40 minutes the light bore 060° T. Find the ship's course.

Answers

1. $\angle C = 88° 15'$. Side $a = 24{\cdot}5$ miles. Side $b = 32{\cdot}38$ miles.
2. $\angle A = 7° 35'$. $\angle B = 141° 30'$. Side $b = 1189$ feet.
3. Distance 9·397 miles.
4. Distance from A 3·614 miles.
5. B's speed 2 miles in 20 minutes or 6 knots.
6. Course 261° 20′ T.

TANGENT FORMULA

This formula is applied when two sides and their included angle are given and it is required to find one or both of the remaining angles. An example described in detail may serve to illustrate its application.

Example 38

In triangle ABC, given $\angle C = 74° 40'$, side $a = 46$ miles, side $b = 30$ miles. Find angles A and B.

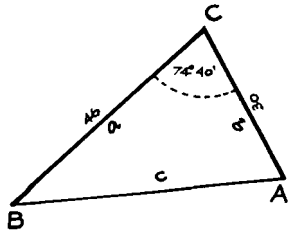


Figure 49.

Construction Draw $BC = 46$ miles. At C lay off an angle of 74° 40′. Make $CA = 30$ miles. Join AB. We are now given the two sides a and b and the included angle C, to find angles A and B. Formula:

$$\frac{\tan \tfrac{1}{2}(A \sim B)}{\tan \tfrac{1}{2}(A+B)} = \frac{a \sim b}{a+b}$$

By transposing we get

$$\tan \tfrac{1}{2}(A \sim B) = \frac{\tan \tfrac{1}{2}(A+B) \times (a \sim b)}{(a+b)}$$

$\frac{1}{2}(A+B)$ is known because $A+B = 180° - C$

$$\therefore \tfrac{1}{2}(A+B) = \tfrac{1}{2}(180° - C)$$

$$\begin{array}{rl} & 180°\ 00' \\ C & 74\ 40 \\ \hline 2\,) & 105\ 20 \\ \hline \tfrac{1}{2}(A+B) = & 52\ 40 \end{array}$$

$a \sim b = 46 \sim 30 = 16$

$a+b = 46+30 = 76$

By substituting these values the formula now reads

$$\tan \tfrac{1}{2}(A \sim B) = \frac{\tan 52° 40' \times 16}{76}$$

By Logarithms

$$\log \tan \tfrac{1}{2}(A \sim B) = \log \tan 52° 40' + \log 16 - \log 76$$

$\frac{1}{2}(A+B)$	52° 40′	tan	10·11764
$a \sim b$	16	log	1·20412
			1·32176
$a+b$	76	log	1·88081
$\frac{1}{2}(A \sim B)$	15° 26′	tan	9·44095
$\frac{1}{2}(A+B)$	52 40		
Sum A	68 06		
Diff B	37 14		

The angles are named A or B from the rule "that the greater angle is opposite to the greater side". If side c were required it could now be found by the sine formula. Note

$$\tfrac{1}{2}(A+B)+\tfrac{1}{2}(A \sim B) = \text{greater angle required}$$
$$\tfrac{1}{2}(A+B)-\tfrac{1}{2}(A \sim B) = \text{lesser angle required}$$

Let us assume A to be the greater angle and B to be the lesser angle. Then

$$\left.\begin{aligned}\tfrac{1}{2}(A+B) &= \tfrac{1}{2}A+\tfrac{1}{2}B\\ \tfrac{1}{2}(A-B) &= \tfrac{1}{2}A-\tfrac{1}{2}B\end{aligned}\right\}\text{add} \qquad \text{Sum} = A$$

$$\text{Again } \left.\begin{aligned}\tfrac{1}{2}(A+B) &= \tfrac{1}{2}A+\tfrac{1}{2}B\\ \tfrac{1}{2}(A-B) &= \tfrac{1}{2}A-\tfrac{1}{2}B\end{aligned}\right\}\text{subtract} \qquad \text{Difference} = B$$

When the symbol $\sim$ is used it matters not whether A or B is written first. If the minus sign be used the greater angle must be known and must be the first written. For example $12 \sim 8 = 4$, and $8 \sim 12 = 4$ but $12-8 = 4$, and $8-12 = -4$.

Example 39

A vessel sights a light bearing 036° T distant 25 miles. She steams 350° T for $2\frac{1}{2}$ hours at 12 knots. Find the bearing of the light and her distance from it at the end of that time.

Construction Let C be the initial position of the ship and A the light. CA represents the line of bearing 036° T 25 miles. Make $\angle C = 46°$, then CB represents the ship's track 350° T 30 miles in $2\frac{1}{2}$ hours. Join BA. Given sides a and b and $\angle C$, find angle A or B from whence the bearing of the light from B may be found, and side c her distance off.

$$\tfrac{1}{2}(A+B) = \tfrac{1}{2}(180° - 46°) = 67°$$

$$a \sim b = 30 \sim 25 = 5$$
$$a+b = 30+25 = 55$$

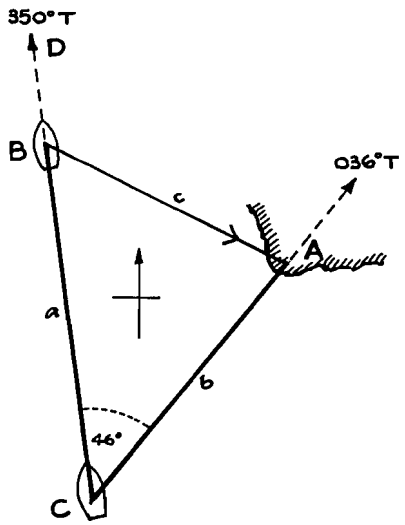


Figure 50.

To find $\angle B$.

$$\frac{\tan\frac{1}{2}(A\sim B)}{\tan\frac{1}{2}(A+B)}=\frac{a\sim b}{a+b}\qquad\frac{\tan\frac{1}{2}(A\sim B)}{\tan 67^\circ}=\frac{5}{55}=\frac{1}{11}$$

$$\therefore\ \text{nat}\tan\tfrac{1}{2}(A\sim B)=\frac{\text{nat}\tan 67^\circ}{11}=\frac{2{\cdot}35585}{11}=0{\cdot}21417$$

$$\therefore\ \tfrac{1}{2}(A\sim B)=12^\circ\,05'$$
$$\tfrac{1}{2}(A+B)=67\ \ 00$$
$$B\quad 54\ \ 55$$

Note $\angle B$ is the difference between the two values as it is opposite to the smaller side. This example lends itself to a simple solution by the method of natural values owing to the disappearance of one of the terms by cancellation, viz., $\frac{5}{55}=\frac{1}{11}$.

Using Logarithms

$$\log\tan\tfrac{1}{2}(A\sim B)=\log\tan 67^\circ-\log 11$$

$\frac{1}{2}(A+B)$	67	tan	10·37215
	11	log	1·04139
$\frac{1}{2}(A\sim B)$	12° 05′	tan	9·33076
$\frac{1}{2}(A+B)$	67 00		
$\angle B$	54 55	(apply to the left of BC)	

From B to C is 170° T.
From B to A is 115° 05′ T, the bearing of the light from the vessel.

To find side c.

$$\frac{c}{\sin C} = \frac{b}{\sin B} \quad \therefore\ c = b \sin C \operatorname{cosec} B$$

$$\log c = \log b + \log \sin C + \log \operatorname{cosec} B$$

b	25	log	1·39794
C	46° 00′	sin	9·85693
B	54 55	cosec	10·08708
c	21·98	log	1·34195

Answer Bearing 115° 05′ T. Distance 21·98 miles.

Example 40

A vessel sights a headland bearing 060° T and subtending a vertical sextant angle of 1° 56′. After steaming 4 miles the headland bore 359° T and subtended a vertical angle of 1° 34′. Find the course steered by the vessel.

The vertical angles being small it may be assumed that "the distances from the object vary inversely as the vertical angles"; that is to say

$$\frac{\text{distance on 1st bearing}}{\text{distance on 2nd bearing}} = \frac{\text{vertical angle on 2nd bearing}}{\text{vertical angle on 1st bearing}}$$

In this example this would be

$$\frac{\text{distance on 060° T}}{\text{distance on 359° T}} = \frac{\text{vertical angle on 359° T}}{\text{vertical angle on 060° T}} = \frac{94'}{116'}$$

These values merely express the ratio between the distances, they convey no idea of the actual distances themselves.

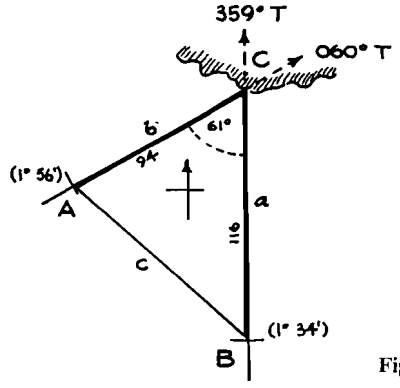


Figure 51.

Construction From C, the headland lay off CA, 240° T, and CB, 179° T (reversed bearings). Make $CB = 116$ units from any convenient scale, and $CA = 94$ units from the same scale. Join AB. The direction of AB is the required course. Find $\angle A$.

Note The side AB is 4 miles, but this value has not been used in the construction of the figure and will not be used in the solution of the triangle.

$$\tan \tfrac{1}{2}(A \sim B) = \frac{\tan \tfrac{1}{2}(A+B)\,(a \sim b)}{(a+b)}$$

	180°	a	116
C	61	b	94
2)	119	$a \sim b$	22
$\tfrac{1}{2}(A+B)$	59° 30′	$a+b$	210

$$\tan \tfrac{1}{2}(A \sim B) = \frac{\tan 59° 30' \times 22}{210}$$

$$\log \tan \tfrac{1}{2}(A \sim B) = \log \tan 59° 30' + \log 22 - \log 210$$

$\tfrac{1}{2}(A+B)$	59°	30′	tan	10·22985
$a \sim b$		22	log	1·34242
			log	1·57227
$a+b$		210	log	2·32222
$\tfrac{1}{2}(A \sim B)$	10°	5′	tan	9·25005
$\tfrac{1}{2}(A+B)$	59	30		
$\angle A$	69	35	add because $\angle A$ is opposite the greater side	
A to C is	060	00 T		
A to B is	129	35 T		

Answer Course 129° 35′ T.

Exercise 9

1. In triangle ABC, $\angle B = 72°$, side $a = 228$ feet, side $c = 148$ feet. Find angles A and C.
2. In triangle ABC, $\angle A = 66° 26'$, side $b = 31$ miles, side $c = 97$ miles. Find side a.
3. An observer on shore sights a ship bearing 040° T, her masthead subtending a vertical sextant angle of 1°. After an interval the ship is bearing 160° T, her masthead vertical angle being now 1° 30′. Find the vessel's course during the interval.
4. From a ship at anchor a lighthouse bore 296° T, distant 2·4 miles. At the same time a church bore 003° T, distant 3·2 miles. Find the distance between the lighthouse and the church.

Answers

1. $\angle A = 70° 19\frac{1}{2}'$. $\angle C = 37° 40\frac{1}{2}'$.
2. $\angle B = 18° 34'$. $\angle C = 95°$. Side $a = 89{\cdot}24$ miles.
3. Course 196° $35\frac{1}{2}'$ T.
4. Distance 3·162 miles.

Miscellaneous Examples—Oblique Plane Triangles

HAVERSINE FORMULA

1. A beacon B bears 300° T 4 miles, from a beacon A. A vessel situated to the Eastward finds

herself by sextant angles to be 6 miles from *A* and 7 miles from *B*. Find the bearing of the ship from beacon *B*.

2. A ship steaming 090° T 10 knots sights a lighthouse distant 4·5 miles, and after half an hour's steaming the same lighthouse was 6 miles off. Find the bearing of the lighthouse at the 2nd bearing, the ship being to the Southward of it.
3. Three buoys mark a triangular course. *B* is 8 miles from *A* and 9 miles from *C*, and *C* is 7 miles to the Eastward of *A*. If *B* bears 010° T from *A*, find the bearing of *C* from *A*.
4. The perimeter of a triangular yacht race course is 33 miles. The sides are 14, 10 and 9 miles. The longest side is in a NW and SE direction. What course would have to be steered to go round it right-handed?
5. A ship is to be moored in a position equidistant from three buoys *A*, *B* and *C*. Find the course and distance she would have to steam from *A* to take up this position, supposing *A* to be due East distant 6 miles from *B*, and *C* to be 7 miles from *B* and 8 miles from *A*.
6. The distances between three buoys are *A* to *B* 1·6 miles, *A* to *C* 1·1 miles, *C* to *B* 1·2 miles. *B* bears 315° T from *A*. Give the bearings of *A* and *B* from *C*.

SINE FORMULA

7. A lighthouse bears 059° T, and after steaming 340° T miles it bore 114° T. Find the distance off at the 2nd bearing.
8. A point bore 015° T, ship steamed 300° T 5 miles, and it then bore 028° T. Find distance of ship from the point at 2nd bearing.
9. When heading 140° T a point bore 060° T, and after steaming on the same course for 8 miles it bore 350° T. Find the ship's distance from the point at 2nd bearing.
10. A ship steaming 123° T sights a point bearing 069° T. After steaming 9 miles it bore 352° T. Find her distance from the point on the 2nd bearing.
11. A beacon bears 342° T from a vessel which sailed 264° T 6 miles, and it then bore 034° T. Find the distance from the beacon on the 2nd bearing.
12. A ship steaming along a coastline at 12 knots sights a light bearing 344° T. Distant 3 miles; after steaming 40 minutes the light bore 060° T. Find the course sailed between the bearings.
13. Two beacons on a measured mile bear 310° T when in transit, and after steaming 10 minutes on 090° T the other two beacons came into line on the same bearing. If the course to steer on the measured mile was 036° T find the speed of the ship.
14. Two stations *A* and *B*, 6000 feet apart, observe a balloon right over their line. Its altitude at *A* is 36° 20′ and at *B* it is 45° 18′. Find the height of the balloon.
15. Two ships are on the same meridian. *B* is 10 miles North of *A*. *B* steams 148° T at 15 knots. *A* steams 018° T at 13 knots. Required the distance apart when one crosses ahead of the other.
16. A ship sails due East along a coastline and observes a rock to bear 046° T. After steaming 7 miles the same rock bore 342° T. Find the distance off the rock at the time of taking the 2nd bearing.
17. A vessel is moored inside three buoys, *A*, *B* and *C*, which are all 2 miles apart. *A* and *B* subtend an angle of 90° from the ship's position. *B* and *C*, also *A* and *C*, subtend equal angles. Find the distance between the ship and the buoy *C*.
18. A vessel on the port tack, wind N by E, has a point of land bearing 000° T. She sails 6 miles on this course when she goes about and sails on the other tack until the point bears

000° T again. Compare the distance sailed with the distance made good, assuming her to be sailing 6 points from the wind.

TANGENT FORMULA, ETC.

19. Two vessels *A* and *B* are at anchor, 7 and 5 miles apart respectively, from a point which bears 010° T and 081° T from them. Find the bearing and distance of *B* from *A*.
20. A ship at anchor 250° T from a lighthouse distant 2·5 miles proceeds to another anchorage 1 mile 168° T from the lighthouse. Find the course steamed.
21. A ship steaming to the Eastward sights a lighthouse bearing 030° T 9 miles off. Find the course to steer to pass the lighthouse 6 miles off when bearing 330° T.
22. A seine net fishing vessel steams with her warp from a can buoy 080° T cables, and drops her net which lies in a 010° T and 190° T direction and is 6 cables long; she steams from the SW end of the net back to the buoy. Find the distance steamed to complete the operation.
23. Two ships start from the same position, *A* steams 080° T at 9 knots and *B* steams 140° T at 10 knots. Find their distance apart at the end of 1 hour and the bearing of *A* from *B*.
24. A ship steaming 340° T at 9 knots encounters a current setting 220° T at 2 knots. Find the distance made good over the ground in 1 hour.
25. Two ships *A* and *B* bear from a headland *C* 5 miles and 7 miles, 017° T and 150° T respectively. Find the bearing and distance of *B* from *A*.
26. Two vessels starting from the same position proceed on different courses. One steers 311° M at 12 knots, the other steers 191° M at 14 knots. Required their distance apart at the end of 3 hours, also the bearing of the northernmost ship from the other.
27. A ship is 190° T off a point of land distant 25 miles, and steams 341° T for 3 hours at 11 knots. Required the bearing of the point of land at the end of this time, also the distance from it.
28. A vessel steering North observes two buoys of equal height, one bearing 315° T and the other 045° T. The angle subtended by the first buoy was 1° 54′, and the angle subtended by the other was 1° 25′. Find the alteration of course required for the ship to pass midway between the buoys.
29. Two points of land of equal height and 4·6 miles apart subtend angles of elevation of *A* 2° 20′ and *B* 3° 15′. *A* bears 345° T, *B* bears 021° T. Required the distance you are from *B*.
30. The bearing of a lighthouse is observed to be 050° T with an angular height of 1° 39′. After steaming for 3 miles it bore 340° T with an angular height of 1° 22′. Find the height of the lighthouse.

Answers

1. Bearing 061° 12′ T.
2. Bearing 317° 13·3′ T.
3. Angle 73° 24′, bearing 083° 24′ T.
4. The courses are 315° T, 14 miles; 095° 10′ T, 10 miles; 180° 23′ T, 9 miles, or 135° T, 14 miles; 275° 10′ T, 10 miles; 000° 23′ T, 9 miles according to which way the course was laid out.
5. Course 226° 34′ T. Distance to steam 4·13 miles.
6. If buoy *C* is placed to the Northward of the *AB* line the bearing of *A* from *C* will be 183° 33′ T, and the bearing of *B* from *C* will be 271° 36′ T.

If buoy C is placed to the Southward of the AB line the bearing of A from C will be 086° 27′ T, and the bearing of B from C will be 358° 24′ T.

7. Distance 5·99 miles.
8. Distance 21·47 miles.
9. Distance 8·384 miles.
10. Distance 7·473 miles.
11. Distance 7·448 miles.
12. Angle 21° 20′. Course 261° 20′ T.
13. Speed 9·312 knots.
14. Height of balloon 2554 feet.
15. Distance apart 3·422 miles.
16. Distance from the rock 5·41 miles.
17. Distance between ship and buoy 0·732 miles or 7·32 cables.
18. Distance sailed on port tack 6 miles. Distance sailed on starboard tack 7·077 miles. Total distance sailed 13·077 miles. Distance made good 5·103 miles.
19. Bearing 328° 39′ T. Distance 7·15 miles.
20. Course 092° 45′ T, 2·56 miles.
21. Course 070° 58½′ T.
22. Distance 15·05 cables.
23. Bearing 014° 47′ T. Distance 9·54 miles.
24. Course 328° 47′ T. Distance 8·185 miles.
25. Bearing 169° 21½′ T. Distance 11 miles.
26. Distance apart 67·62 miles. Bearing of Northernmost ship 343° 32·6′ T.
27. Bearing 113° 34′ T. Distance 16·46 miles.
28. Course must be altered 8° 17′ 49″ to starboard.
29. Distance from B is 5·549 miles.
30. Height of lighthouse 411·3 feet.

TO CONSTRUCT AN ANGLE WITHOUT A PROTRACTOR

A given angle can be constructed with the aid of a pair of compasses and a scale of equal parts as follows.

Example 41

Construct an angle of 50°.

1. Draw a line AB, then from scale on figure:
2. Take any nine equal parts as radius and with centre A describe dotted arc CD.
3. Add to the angle half as much again as itself, i.e. $50° + 25° = 75°$ and take 7·5 equal parts from the same scale on the compasses and lay off the chord CD.
4. Join AD and produce; angle $DAC = 50°$. Any other angle can be constructed in the same way by simply making the chord CD equal to half as much again as the required angle.

If now ten equal parts, not necessarily from the same scale as used to construct the angle, say $AH = 10$ on the compasses, describe the quadrant HK and from E drop EF perpendicular

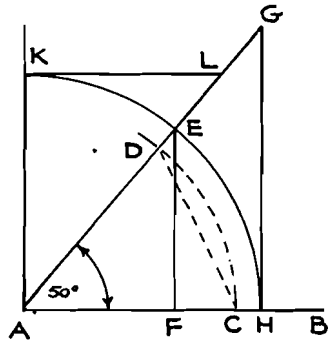


Figure 52.

EF = Nat sine 50° = 0·76 approximately

and AF = Nat cos 50° = 0·64 approximately

Erect HG perpendicular to AB meeting AE produced at G, then HG is a tangent to the quarter circle KH, because $\angle AHG$ is 90° and by measurement from the scale we find that

GH = Nat tan 50° = 1·20 approximately

and AG = Nat sec 50° = 1·56 approximately

From K draw KL parallel to AB then

KL = Nat cot 50° = 0·82 approximately

and AL = Nat cosec 50° = 1·30 approximately

THE OBLIQUE SPHERICAL TRIANGLE

This section should be understood before proceeding with the chapter dealing with Longitude Sights and Position Lines.

Position finding at sea by astro navigation depends upon the solution of an oblique spherical triangle.

In the Figure 53, triangle ABC is a spherical triangle. It is the area on the surface of a globe

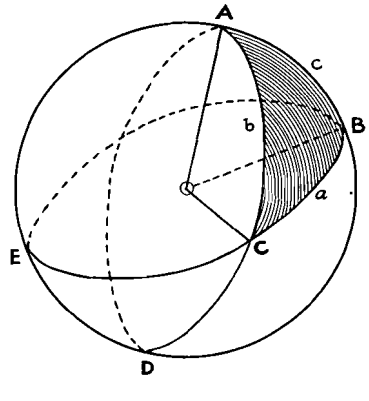


Figure 53.

enclosed by the intersection of three great circles. Great circles are those whose planes pass through the centre of the sphere.

ABD, *ACD* and *BCE* are three great circles, and triangles *ABC* and *DCB* are two of the spherical triangles formed by their intersection. All the angles at *A*, *B* and *C* are spherical angles.

Spherical triangles differ considerably from plane triangles. The sides, for example, are expressed in ° ′ ″, and on the earth's surface the minutes of arc of a great circle are also miles of distance, because the actual length of one minute of arc on the earth's surface has been carefully measured and called a nautical mile, the mean working value of it being 6080 feet. A land mile is 5280 feet; it is purely an arbitrary measurement and has nothing to do with the shape or size of the earth.

Referring again to the previous figure, the arc *AB* subtends $\angle AOB$ at the centre of the sphere and both arc and angle are expressed by the same number of ° ′ ″. Arc *BC* has the same angular measure as $\angle BOC$, and arc *AC* as $\angle AOC$. This is the principle adopted in the spherical triangulations of navigation and nautical astronomy, in which the observer is conceived to be at the centre of the earth looking outwards from *O* and measuring angles between points on the surface of the earth, or in the celestial sphere, such as $\angle AOB$ between the points *A* and *B*, $\angle AOC$ between *A* and *C*, and $\angle BOC$ between the points *B* and *C*. But we cannot get to the centre of the earth and so must measure along the arcs on its circumference.

The lineal length of an arc on the surface of a sphere depends upon the length of its radius, the bigger the sphere the longer will the actual length of an arc of 1 degree, or of 1 minute, on its surface be, hence the reason why it is to desirable to know with accuracy the length of the earth's radius for the purposes of navigation.

The chief properties of a spherical triangle are as follows:

1. The sides are expressed in ° ′ ″. (Degrees, minutes and seconds.)
2. The sum of the three angles must be greater than 180° and less than 540°; that is to say, their sum may be anything between two right angles and six right angles.
3. The sum of the three sides must be less than 360°.
4. The greater side is opposite to the greater angle as in plane triangles.
5. Where two great circles cut each other the vertically opposite angles are equal: $\angle ACB = \angle ECD$ and $\angle ACE = \angle BCD$.

Three sides given, to find the angles

In the spherical triangle *ABC*, given the three sides *a*, *b* and *c*; we shall write down the formula for finding each of the angles.

$$\text{hav}\, A = \frac{\text{hav}\, a - \text{hav}(b \sim c)}{\sin b \sin c}$$

$$\text{hav}\, B = \frac{\text{hav}\, b - \text{hav}(a \sim c)}{\sin a \sin c}$$

$$\text{hav}\, C = \frac{\text{hav}\, c - \text{hav}(a \sim b)}{\sin a \sin b}$$

It is the same formula applied to each angle in turn.

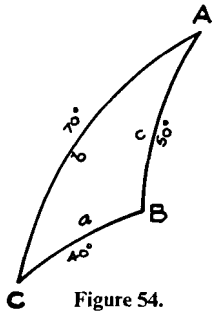


Figure 54.

Note the similarity. When angle A is asked for, the top line of the right hand side begins with hav "a", the side opposite to the angle, then minus the haversine of the difference between the two adjacent sides, b and c, the lower line being $\sin b \sin c$. The formula for B may be written from symmetry as the right hand side begins with haversine b the side opposite to the angle, minus haversine of the difference of a and c the two sides adjacent to it, divided by the sine of one into the sine of the other.

Example 42

In triangle ABC, given side $a = 40°$, $b = 70°$, $c = 50°$. Find angle A.

$$\text{hav}\, A = \frac{\text{hav}\, a - \text{hav}(b \sim c)}{\sin b \sin c}$$

$$\text{hav}\, A = \frac{\text{hav}\, 40° - \text{hav}\, 20°}{\sin 70° \sin 50°}$$

a	40°	nat hav	0·11698
$(b \sim c)$	20	nat hav	0·03015
		nat hav	0·08683
		log hav	8·93866
b	70	log cosec	0·02701
c	50	log cosec	0·11575
$\angle A$	40° 38′ 45″	log hav	9·08142

Note Dividing by the sine of an angle is the same as multiplying by its reciprocal the cosec, and this is done to simplify the working.

Answer $\angle A = 40° 38′ 45″$.

The **natural** haversines of "a" and $(b \sim c)$ are taken out of the Table because the quantities have to be subtracted and this cannot be done by logarithms. The nat haversine of their difference is changed into the corresponding log haversine by simply copying down the log hav 8·93866 given alongside nat hav 0·08683. The log cosecants are then added on to get the log haversine of the answer.

To find the angle from the Table, look for log hav 9·08142, the nearest is 9·08144, and at top of column in small type is given 40° 30′, and in the left hand column in a line with the log will be found 8′ 45″ to be added to 40° 30′ making 40° 38′ 45″.

Example 43

In triangle XYZ, given side $x = 40°$, side $y = 50°$, side $z = 70$, find angle Z.

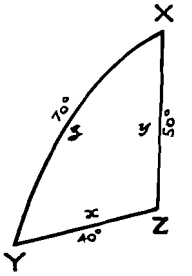


Figure 55.

$$\text{hav } Z = \frac{\text{hav } z - \text{hav}(x \sim y)}{\sin x \sin y} = \frac{\text{hav } 70° - \text{hav}(10°)}{\sin 40° \sin 50°}$$

z	70°	nat hav	0·32899
$(x \sim y)$	10	nat hav	0·00760
		nat hav	0·32139
		log hav	9·50704
x	40	log cosec	0·19193
y	50	log cosec	0·11575
$\angle Z$	107° 47′	log hav	9·81472

Answer $\angle Z = 107° 47'$.

Note Spherical triangles take on peculiar shapes and no attempt is made here to draw these figures accurately; the triangle merely shows the relative sizes of the sides and angles, that the greater side is opposite to the greater angle, etc.

Example 44

In triangle PZX, given side p 65° 06′, side z 109° 34′, side x 70° 18′, find $\angle P$.

$$\text{hav } P = \frac{\text{hav } p - \text{hav}(x \sim z)}{\sin x \sin z} = \frac{\text{hav } 65° 06' - \text{hav } 39° 16'}{\sin 70° 18' \sin 109° 34'}$$

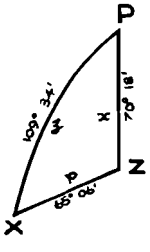


Figure 56.

p	65° 06′	nat hav	0·28948
$(x \sim z)$	39 16	nat hav	0·11290
		nat hav	0·17658
		log hav	9·24694
x	70 18	log cosec	0·02619
z	109 34	log cosec	0·02583
P	52° 59′ 30″	log hav	9·29896

Answer $\angle P = 52° 59' 30''$.

The same formula with a little manipulation is applicable to a triangle in which are given two sides and the angle included between them, to find the remaining side.

Example 45

In spherical triangle ABC, given $\angle A = 48°$, side $b = 103°$, side $c = 54°$, find side a.

We have already written the formula as follows:

$$\text{hav } A = \frac{\text{hav } a - \text{hav}(b \sim c)}{\sin b \sin c}$$

The only unknown quantity is hav a which we want to get by itself on the left hand side of the equation. Cross multiply the equation and we get

$$\text{hav } a - \text{hav}(b \sim c) = \text{hav } A \sin b \sin c$$

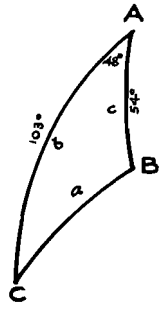


Figure 57.

and by shifting $-\text{hav}(b \sim c)$ over to the right hand side it becomes

$$\text{hav}\, a = \text{hav}\, A \sin b \sin c + \text{hav}(b \sim c)$$

which is the form we want it to take.

A	48°	log hav 9·21863
b	103	log sin 9·98872
c	54	log sin 9·90796
		log hav 9·11531
		nat hav 0·13041
$(b \sim c)$	49	nat hav 0·17197
a	66° 43′ 15″	nat hav 0·30238

Answer Side $a = 66°\ 43'\ 15''$.

The application of the formula is as follows. Add together the log hav A sin b sin c and this gives the log haversine of the product. Now substitute its nat haversine as given in the Table on the same line and in column alongside of it, then add the nat hav$(b \sim c)$ and this gives the nat haversine of the answer.

Example 46

In spherical triangle PZX, given $\angle P = 29°\ 08'$, side $PZ = 40°\ 14'$, side PX 98° 54′, find side ZX.

$$\text{hav}\, ZX = \text{hav}\, P \sin PZ \sin PX + \text{hav}(PZ \sim PX)$$

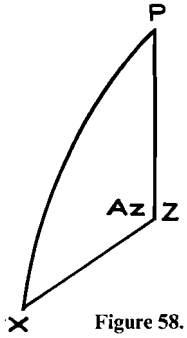


Figure 58.

P	29° 08′	log hav 8·80110
PZ	40 14	log sin 9·81017
PX	98 54	log sin 9·99474
		log hav 8·60601
		nat hav 0·04037
$(PZ \sim PX)$	58 40	nat hav 0·23999
ZX	63° 56′ 30″	nat hav 0·28036

All the useful problems in nautical astronomy can be solved by this formula in one form or another, as the questions usually give either the three sides of the spherical triangle or the two sides and the angle included between them. Even in a case where the two sides and included angle are given to find an angle, the required angle could be found indirectly by first calculating the third side and then using it with the two given sides to find the angle asked for.

OBLIQUE SPHERICAL TRIANGLES

Exercise 10

1. In triangle ABC, given $a = 57°, b = 83°, c = 71°$. Find angles A, B and C.
2. In triangle ABC, given $a = 64°, b = 85°, c = 91°$. Find angles A, B and C.
3. In triangle PZX, given $PZ = 70° 18', PX = 109° 33', ZX = 65° 6'$. Find angles P and Z.
4. In triangle ABC, given $b = 103° 42', c = 54° 38', \angle A = 48° 35'$. Find side a.
5. In triangle ABC, given $a = 23° 20', c = 51° 22', \angle B = 90°$. Find side b.
6. In triangle PZX, given $PZ = 40° 34', PX = 66° 48', \angle P = 27° 35'$. Find side ZX.

Answers

1. $\angle A = 57° 26' 45''$, $\angle B = 94° 00' 45''$, $\angle C = 71° 51' 30''$.
2. $\angle A = 63° 47' 30''$, $\angle B = 83° 56' 30''$, $\angle C = 93° 34' 00''$.
3. $\angle P = 53° 00' 30''$, $\angle Z = 123° 55' 30''$.
4. Side $a = 67° 13' 45''$.
5. Side $b = 55° 01' 15''$.
6. Side $ZX = 33° 59' 45''$.

SOLUTION OF RIGHT-ANGLED SPHERICAL TRIANGLES

Right-angled spherical triangles are of rare occurrence in practical navigation as an observer on board ship can seldom arrange his time of observation to fit in with selected heavenly bodies so that the triangle formed by the intersection of three great circles shall form an exact angle of 90° at one of the corners.

When one of the parts in a navigational spherical triangle happens to be 90° (and the parts are arranged in the order discussed earlier) it can be solved either by the haversine formula or, more quickly, by Napier's Rules for Circular Parts.

NAPIER'S RULES FOR CIRCULAR PARTS

The rules are briefly as follows:

1. Let the triangle consist of five parts, viz., the three sides and two angles, the 90° being always **omitted**.
2. The **complements** of the hypotenuse and the two angles are used.
3. Adjacent part means the one next. Opposite part means the one past adjacent.
4. By selecting **any** one of three parts as a middle part the other two must form either two adjacent parts or two opposite parts when one of the following formulae will apply:

$$\textbf{sine of middle part} = \begin{cases} \text{product of } \textbf{tangents} \text{ of } \textbf{adjacent parts} \\ \text{product of } \textbf{cosines} \text{ of } \textbf{opposite parts} \end{cases}$$

which may be abbreviated to

1. sine mid part = tan adj × tan adj
2. sine mid part = cos opp × cos opp

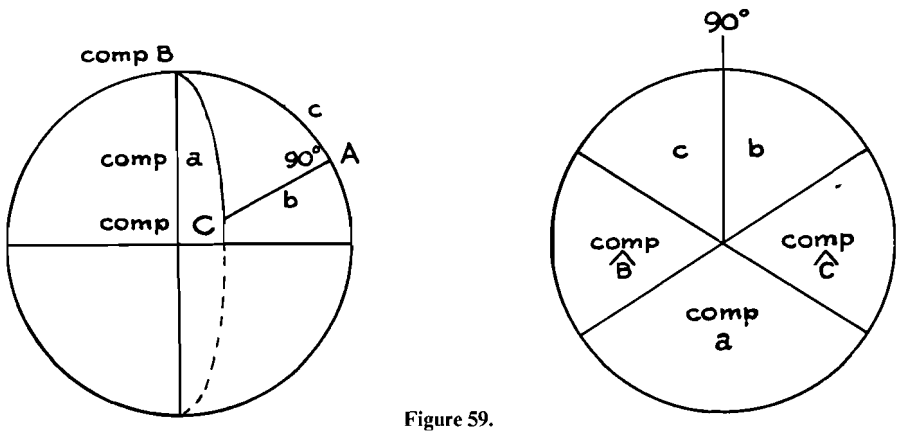


Figure 59.

1. In figure, the five parts of the triangle ABC starting at B and named in rotation are angle B, side c, side b, angle C and side a, the 90° part may be indicated as shown.

Some beginners draw a circle and divide it off into five sectors as shown above, then by writing in successive sectors the names of the parts in the order just given they are able to spot more readily the relative position of the adjacent, the opposite and the middle parts.

2. Write in front of the hypotenuse and the two angles the word complement, or, for it, the abbreviation "comp" or "co" as a reminder that we have to substitute the complements of any of those parts should they appear in the formula.

Instead of subtracting the angle from 90° to get its complement the cosine is substituted for sine, the tangent for cotangent, etc.

3. Adjacent part means the one next. Opposite part is the one past adjacent. Refer to triangle ABC.

"*Consider part B*"

Assuming complement B to be the middle part, then complement a and part c are its two adjacent parts, one on each side of it, and complement C and part b are its two opposite parts because the opposite part is one past adjacent. Omit the 90° always.

"*Consider part a*"

Complement a being the middle part, then, complement B and complement C are its two adjacent parts and parts b and c are its two opposite parts.

"*Consider part C*"

Then complement C being the middle part, complement a and part b are its two adjacent parts and complement B and part c are its two opposite parts.

"*Consider part b*"

Part b being the middle part, then comp C and part c are its adjacents and comp a and comp B its opposites.

"*Consider part c*"

Part c being the middle part, then comp B and part b are its adjacents and comp a and comp C its opposites.

These relationships will perhaps be more noticeable if the student will place his finger on sector B in the circular parts figure when a and c are, obviously, adjacent to $\angle B$ and side b and $\angle C$ are opposite to it. Do the same for side a when $\angle B$ and $\angle C$ are seen to be adjacent parts, side c and side b opposite parts.

4. The application of the formula may be better explained by means of an example.

In spherical triangle ABC, given $\angle A = 90°$, side $a = 80°$, side $c = 60°$. Find (a) $\angle B$, (b) $\angle C$, (c) side b.

(a) *To find* $\angle B$.

Refer to the figure. The three parts under consideration are a, $\angle B$ and c. Cover up the rest of the triangle with your finger, then, obviously, from the triangle, or from the circular parts figure, $\angle B$ is the middle part and parts a and c form its two adjacent parts when formula 1 will apply.

B is mid part, a and c are adjacents

$$\begin{aligned}
\sin \text{mid} &= \tan \text{adj} \tan \text{adj} \\
\sin \textit{comp}\, B &= \tan \textit{comp}\, a \tan c \\
\cos B &= \cot a \tan c \\
\cos B &= \cot 80° \tan 60°
\end{aligned}$$

a	$80°$	log cot	9·24632
c	60	tan	10·23856
$\angle B$	$72° 13'$	cos	9·48488

(b) *To find* $\angle C$.

The three parts under consideration now are side a, side c, and $\angle C$. Never mind for the moment which parts are given and what is wanted, but concentrate on those three parts and select *any* one of them so that the other two will form either two adjacent or two opposite parts.

Let us try side a, then angle C is adjacent to it and side c is opposite; this won't do.

Let us try $\angle C$, then side a is adjacent to it and side c is opposite; this won't do either.

Let us try side c, then side a is opposite to it and so is $\angle C$ and now formula 2 will apply because c is mid part, a and C are opposites.

$$\begin{aligned}
\sin \text{mid} &= \cos \text{opp} \cos \text{opp} \\
\sin c &= \cos \textit{comp}\, a \cos \textit{comp}\, C \\
\sin c &= \sin a \sin C \\
\frac{\sin c}{\sin a} &= \sin C \qquad \text{because } \angle C \text{ is wanted}
\end{aligned}$$

or $\sin c \operatorname{cosec} a = \sin C$

$\sin 60° \operatorname{cosec} 80° = \sin C$

By introducing the reciprocal of sine a, which is cosec a, we convert division into multiplication and this means adding the logs which is an easier operation than subtracting. It may be noted here that when a factor of the equation is shifted to the other side it is changed into its reciprocal, thus, in transposing $\sin a$ from the right hand side to the left hand side we could have written cosec a at once without introducing the step of dividing by $\sin a$.

a	$80°$	log cosec	0·00665
c	60	sin	9·93753
C	$61° 34'$	sin	9·94418

(c) *To find side b.*

The three parts under consideration are sides *a*, *c* and *b*. Never mind just now what is given and what is wanted, but select any one of the three as a middle part so that the other two are either adjacent to it or opposite to it. Cover up angles *B* and *C* with the index fingers of each hand as we are not interested in those angles at the moment. It will then be apparent that side *a* is the middle part and that sides *b* and *c* form its two opposite parts. No other arrangement can possibly fit in with the rules as to adjacent and opposite sides; indeed, when the three sides of the triangle are involved the hypotenuse is always the middle part. We have then *comp a* as mid part, *c* and *b* are opposites

$$\begin{aligned} \sin \text{mid} &= \cos \text{opp} \cos \text{opp} \\ \sin \textit{comp}\, a &= \cos c \cos b \\ \cos a &= \cos \underline{c \cos b} \\ \cos a \sec c &= \cos b \end{aligned}$$

a	$80°$	′log cos	9·23967
c	60	sec	0·30103
b	$69° 40\frac{1}{2}$	cos	9·54070

It is good practice to write out in logical sequence each step of the investigation as given above and not attempt to do too much of it mentally.

TRIGONOMETRICAL AXIOMS

When sides or angles are all under, or over, 90° they are said to be of **Like Affection**, but when some are under 90° and some over 90° they are said to be of **Unlike Affection**.

1. When two sides are of the same affection the third side is less than 90°, but when two sides are of unlike affection the third side is greater than 90°.
2. A side and its opposite angle are always of the same affection; that is, both are either less than, or greater than, 90°.
3. When the angle included between the hypotenuse and the side next to it is less than 90° then these two sides are of the same affection, either both greater than, or both less than, 90°, but when the angle included between them is greater than 90°, these two sides are then of unlike affection.

These facts, however, settle themselves algebraically by introducing the "Rule of Signs" given previously. Keeping in mind that when two quantities are multiplied together and both are plus or both minus their product is a plus sign (+), but when the quantities have different signs their product is a negative sign (−).

$$\begin{aligned} 6 \times 4 &= 24, & -6 \times -4 &= 24 \\ -6 \times 4 &= -24, & 6 \times -4 &= -24 \end{aligned}$$

Example 47

In triangle *ABC*, given $\angle C = 90°$, side $a = 110° 19'$, $\angle B = 112° 18'$. Find (a) side *c*, (b) $\angle A$, (c) side *b*.

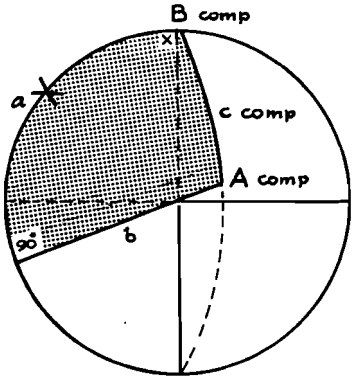


Figure 60.

In figure, $\angle C = 90°$, we have purposely dropped out the letter C as it does not enter into our discussion. The given parts are $\angle B$ and side a which we have marked with a cross.

(a) *To find side c.*

Of the three parts a, B and c, B is mid part, a and c are adjacents

$$\begin{aligned}
\sin \text{mid} &= \tan \text{adj} \tan \text{adj} \\
\sin \textit{comp}\, B &= \tan a \tan \textit{comp}\, c \\
\cos B &= \tan a \cot c \\
\cos B \cot a &= \cot c
\end{aligned}$$

B	112° 18′	cos	9·57916	− Note 1
a	110 19	cot	9·56849	− Note 2
c	82 00	cot	9·14765	+ Note 3

Notes

1. Angle B is in the 2nd quadrant and its cosine is negative (−).
2. Side a is in the 2nd quadrant and its cotangent is negative (−).
3. A minus multiplied by a minus gives (+), therefore side c is in the 1st quadrant and is less than 90°.

(b) *To find angle A.*

Of the three parts a, B and A, A is mid part, a and B are opposites

$$\begin{aligned}
\sin \text{mid} &= \cos \text{opp} \cos \text{opp} \\
\sin \textit{comp}\, A &= \cos a \cos \textit{comp}\, B \\
\cos A &= \cos a \sin B
\end{aligned}$$

B	112° 18′	log sin	9·966240	(+) Note 3
a	110 19	cos	9·540590	(−) Note 4
	71 16	cos	9·506830	(−) Note 5
	180 00			
$\angle A$	108 44			

Notes

3. The sine of an angle in the 2nd quadrant is (+).
4. The cosine of an angle in the 2nd quadrant is (−).

5. A plus and a minus gives a negative (−) sign so that cos A is minus and must therefore be in the 2nd quadrant. The calculated value got from the Tables must be subtracted from 180° to get the value of A which, from the figure, is obviously greater than 90°. $\angle A = (180° - 71° 16') = 108° 44'$.

(c) *To find side b.*

Of the three parts a, B and b, a is mid part, B and b are adjacents

$$\begin{aligned} \sin \text{mid} &= \tan \text{adj} \tan \text{adj} \\ \sin a &= \tan \textit{comp}\, B \tan b \\ \sin a &= \cot B \tan b \end{aligned}$$

sin a tan B = tan b				
B	112° 18′	log tan	10·38708	(−) Note 6
a	110 19	sin	9·97210	(+) Note 7
	66 23	tan	10·35918	(−) Note 8
	180 00			
b	113 37			

Notes

6. The tan of $\angle B$ is (−).

7. The sine of side a is (+).

8. A minus and a plus gives a minus therefore tan b is minus and side b must be over 90°. Subtract the calculated value from 180°.

AMBIGUOUS CASE

This arises when an angle and the side opposite to it are given, and when this is the case each of the remaining three parts has two values which are supplementary to each other.

Example 48

In triangle ABC, given $\angle C = 90°$, $\angle A = 40° 30'$, side $a = 35° 15'$. Find sides b and c.

To find side b.

Of the three parts A, b and a, b is mid part, A and a are adjacents

$$\begin{aligned} \sin \text{mid} &= \tan \text{adj} \tan \text{adj} \\ \sin b &= \tan \textit{comp}\, A \tan a \\ \sin b &= \cot A \tan a \end{aligned}$$

A	40° 30′	log cot	10·068501
a	35 15	tan	9·849254
b	55 50	sin	9·917755

This value of side b is the arc AC. But two triangles can be formed from the given values of $\angle A$ and side a, viz., triangle ABC and its supplementary triangle $A'BC$ because $\angle A = \angle A'$, side a is common to both triangles, and $\angle ACB = \angle A'CB = 90°$. The question as stated does not distinguish between the triangles so that side b has two values, the arc AC or $(b) = 55° 50'$ and the arc $A'C$ or $(b') = (180° - 55° 50') = 124° 10'$.

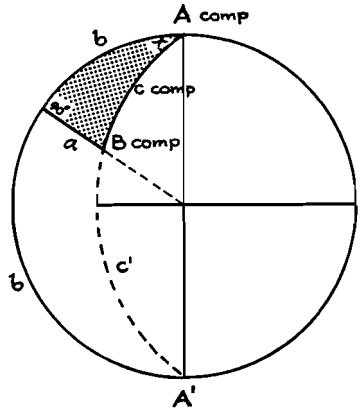


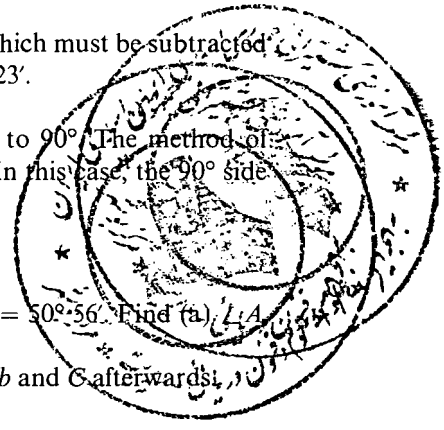
Figure 61.

Similarly, if the student calculates the value of side c he will obtain 62° 42′, but this is the arc AB and it has to be subtracted from 180° to yield the arc BA' or (c')

$$\text{side } c = 62° 42' \text{ or } 117° 18'$$

And again, the calculated value of $\angle B$ is 68° 37′. This is $\angle ABC$ which must be subtracted from 180° to get its supplementary value CBA'. $\angle B = 68° 37'$ or $111° 23'$.

A **Quadrantal Spherical Triangle** is one which has a side equal to 90°. The method of solution is the same as though an angle in the triangle were 90° but, in this case, the 90° side is left out when investigating the formula.



Example 49

In quadrantal triangle ABC, given side $a = 90°$, $\angle B = 70° 20'$, side $c = 50° 56'$. Find (a) $\angle A$, (b) side b, (c) $\angle C$.

Let us investigate the formulae first and compute the values of A, b and C afterwards.

(a) *To find angle A.*

Of B, c and A, c is mid part, B and A are adjacent

$$\begin{aligned} \sin \text{mid} &= \tan \text{adj} \tan \text{adj} \\ \sin \textit{comp}\, c &= \tan B \tan \textit{comp}\, A \\ \cos c &= \tan B \cot A \\ \cos c \cot B &= \cot A \end{aligned}$$

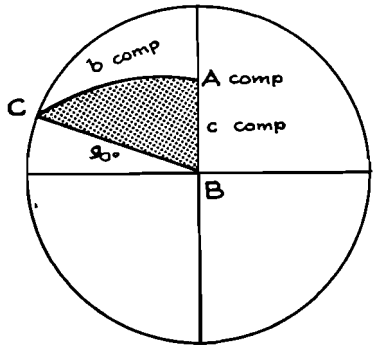


Figure 62.

(b) *To find side b.*
Consider *B*, *c* and *b*. *b* is mid part, *B* and *c* are opposites

$$\sin \text{mid} = \cos \text{opp} \cos \text{opp}$$
$$\sin \textit{comp}\, b = \cos B \cos \textit{comp}\, c$$
$$\underline{\cos b = \cos B \sin c}$$

(c) *To find* $\angle C$.
Consider *B*, *c* and $\angle C$. *B* is mid part, *c* and *C* are adjacents

$$\sin B = \tan \textit{comp}\, c \tan C$$
$$\sin B = \cot c \underline{\tan C}$$
$$\sin B \tan c = \tan C$$

		(a) $\angle A$	(b) side *b*	(c) $\angle C$
B	70° 20′	log cot 9·55315	log cos 9·52705	log sin 9·97390
c	50 56	cos 9·79950	sin 9·89009	tan 10·09060
	77° 18′ 24″	cot 9·35265	cos 9·41714	tan 10·06450

Answers $\angle A$ 102° 41′ 36″; *b* 74° 51′ 08″; $\angle C$ 49° 14′ 20″.

Note The angles and their opposite sides are always of like affection, but the angle opposite to the 90° side is more than 90° when its two adjacent sides are of the same affection, but less than 90° when the sides are of unlike affection.

"The Extra Minus Rule": If, in the original formula (before any transposition) both adjacent parts or both opposite parts are both angles or both sides, an extra minus sign must be inserted. The algebraic result of all the signs in the formula will indicate whether the answer is in the 1st or 2nd quadrant. NB: This rule applies to Quadrantal Triangles ONLY.

Exercise 11

In the following examples select any two parts and calculate any or all of the remaining three parts. They have been worked out to the nearest half minute:

	A	*B*	*C*	*a*	*b*	*c*
1.	32° 30′	106° 24′	90° 00′	28° 27½′	121° 42′	117° 31′
2.	161 47	86 47	90 00	162 03½	79 40	99 49½
3.	44 19½	60 20½	90 00	34 35	44 54½	54 20
4.	31 52	66 30½	90 00	22 10½	40 58	45 38
5.	17 54½	80 25½	90 00	15 12	57 15	58 32
6.	37 22	81 20½	90 00	87 20	81 20	89 36

7. In triangle *ABC*, given $\angle C = 90°$, $\angle B = 77° 02′$, side $b = 71° 01′$. Find sides *a* and *c* and $\angle A$.
8. In triangle *ABC*, given side $c = 90°$, side $a = 110° 22′$, $\angle B = 125° 30′$. Find side *b*, angles *C* and *A*.
9. In triangle *NPX*, given $\angle N = 90°$, side $NP = 33° 48′$, side $PX = 112° 06′$. Find side *NX*.
10. In triangle *PZX*, given side $ZX = 90°$, side $PZ = 40° 00′$, side $PX = 66° 37½′$. Find $\angle PZX$.
11. Given Lat. 44°N, Sun's Decl. 22°S. Find time of Sunset.

12. In Lat. 40° 30′S, Sun's Decl. 15° 27′S. Find Hour Angle of the Sun when on the Prime Vertical.
13. The Sun's altitude at 1800 was 18° 45′, Decl. 20° 04′N. Find the latitude of the observer.
14. The Obliquity of the Ecliptic being 23° 27′, Sun's Decl. 18° 30′N. Required the Right Ascension of the True Sun.
15. In Lat. 50° 48′N two stars, X and Y, both bearing East have altitudes 20° and 40° respectively. Find the difference of their Hour Angles.

Answers

1–6. Included with questions.
7. Side $c = 76° 01'$ or $103° 59'$, $\angle A = 43° 37'$ or $136° 23'$, side $a = 42° 01'$ or $137° 59'$.
8. $\angle C = 103° 56\frac{1}{2}'$, $\angle A = 114° 30\frac{1}{2}'$, side $b = 122° 59'$.
9. Side $NX = 116° 55'$.
10. $\angle PZX = 51° 53'$.
11. Sunset 16h 28m 08s.
12. Hour Angle 71° 07′.
13. Lat. 69° $31\frac{1}{2}'$N.
14. R. A. 50° 28·5′.
15. 14° 59·75′.

Chapter 7

The Sphere and Sailings

The course and distance between two positions can be accurately measured on large scale coastal charts but on small scale charts, such as those used for ocean navigation, accurate measurement is not possible. However, the course and distance between two positions can be found by calculation using one, or other, of the "sailings".

Before proceeding to an explanation of the sailings, the following definitions should be fully understood.

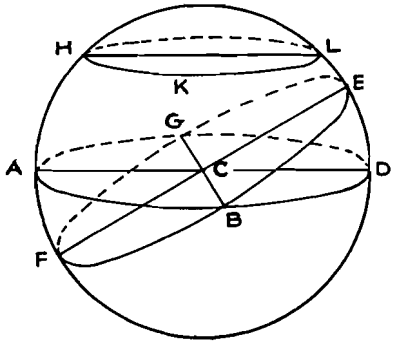


Figure 1.

Small Circle

A circle on a sphere whose plane does not pass through the centre of the sphere. HKL is a small circle and HL is the diameter of its plane surface.

Great Circle

A circle on a sphere whose plane passes through the centre of the sphere. ABD and EBF are great circles, C being the centre of the sphere. ACD is a diameter on the plane of the great circle $ABDG$, and ECF is a diameter on the plane of the great circle $EBFG$. The radii of all the great circles on a sphere are equal, thus $CA = CF = CB = CD$, etc.

Spherical Angles

Spherical angles are formed by the intersection of two great circles. In Fig. 1 the four angles at B are spherical angles, and the alternate angles are equal.

$$\angle EBD = \angle ABF \text{ and } \angle ABE = \angle FBD.$$

The spherical angle is also equal to the plane angle between the tangents to the great circles at their point of intersection as in Fig. 2, where AB is a tangent to the great circle OF

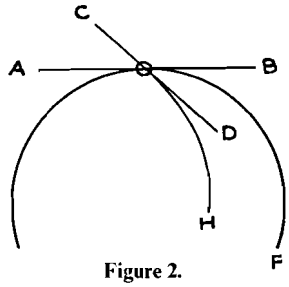


Figure 2.

and *CD* a tangent to the other great circle *OH*; the plane angle *BOD* measures the spherical angle *FOH*.

Spherical Triangles

Spherical triangles are formed on the surface of a sphere by the intersection of three great circles. The areas *BDE* and *ABF* in Fig. 1 are spherical triangles.

The arc of a great circle is expressed in degrees, minutes and seconds of angular measure, and this arc contains the same number of degrees, minutes and seconds as the angle it subtends at the centre of the sphere. In Fig. 1:

arc *BD* = angle *BCD*
arc *ED* = angle *ECD*
arc *EB* = angle *ECB*.

In a spherical triangle the greatest side is opposite the greatest angle, and the sides are expressed in degrees, minutes and seconds.

The sum of the three angles may be anything between two and six right angles, that is between 180° and 540°.

THE EARTH, ITS SHAPE AND SIZE

The earth is not quite a true sphere, being slightly flattened at the poles; the polar diameter is 27 miles shorter than the equatorial diameter, the respective diameters being 7899 and 7926 statute miles.

The **Statute** or **Land Mile** is an arbitrary measure of distance and has been legally fixed at 5280 feet.

The **Nautical Mile** is the arc of the earth's circumference subtended by an angle of one minute at the centre of curvature. The varying curvature of the earth makes the length of a minute of arc at the surface vary slightly with the Latitude so that the nautical mile measures 6108 feet at the poles where the curvature is flatter, and 6046 feet at the equator where the earth's curvature is sharper. A mean length of 6080 feet is universally adopted in navigation.

A **Geographical Mile** is constant and measures 6087 feet.

A **Cable** is the tenth part of a sea mile, the mean value being 203 yards. But it is customary

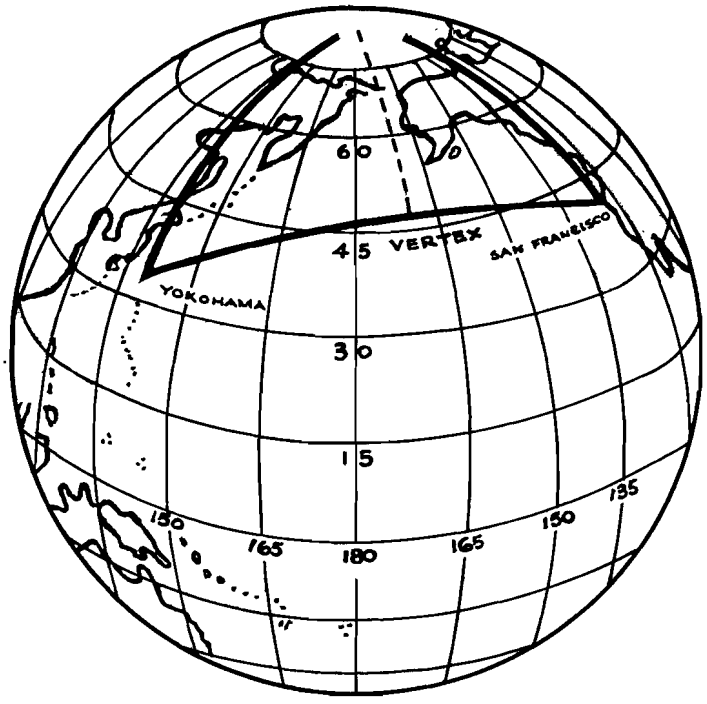


Figure 3.

to regard a cable as 200 yards = 600 feet = 100 fathoms in length and this is always used for navigational purposes irrespective of the Latitude.

A **Knot** is a unit of velocity and represents a speed of one nautical mile per hour.

Table of Measurements

6 feet	= 1 fathom
100 fathoms	= 1 cable
10 cables	= 1 sea mile
1 knot	= 6080 feet per hour
1 nautical mile	= 6080 feet = 1·152 statute miles
1 statute mile	= 5280 feet
1 international mile	= 6076·12 feet = 1852 metres (sea mile Lat. 45°)

Figure 3 is a sketch of a terrestrial globe, and Figure 4 a diagrammatic sketch to illustrate the terms Latitude and Longitude used in defining the positions of places on the earth's surface relatively to each other.

Latitude is the angular distance of a parallel of Latitude measured along a meridian to the North or South of the Equator. Latitude is reckoned from 0° to 90° N and from 0° to 90° S. Every place on the same parallel has the same Latitude, thus *A* and *B* in Fig. 4 are both in Latitude 10° N, and *F* is in Latitude 30° S.

The **Equator** is the zero circle of Latitude, and the small circles drawn parallel to it are called parallels of Latitude. Every place on the equator is in Latitude 0°.

Meridians are great circles drawn through the poles. The zero or **Prime Meridian** is the meridian passing through the Greenwich Observatory. Every place on the prime meridian is in Longitude 0°.

Longitude is the angular distance East or West of the Greenwich meridian measured along the equator to the meridian passing through the place. It is measured from 0° to 180° E and from 0° to 180° W so that Longitude 180° E is the same meridian as Longitude 180° W.

It will be observed from Fig. 4 that Lat. 10° N is the length of an arc of 10° on a meridian and that this arc subtends an angle of 10° at the centre of the earth.

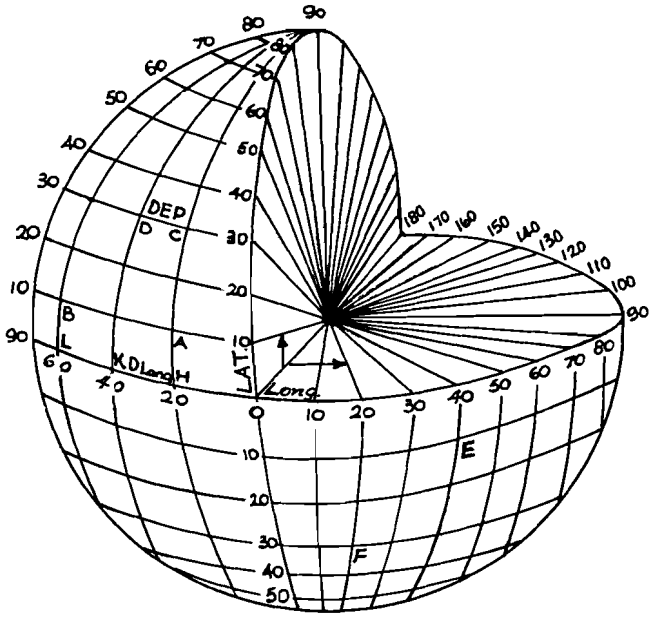


Figure 4.

Difference of Latitude (D. Lat.)

The geographical position of a place is at the intersection of the meridian and the parallel which passes through it. There is only one such condition for each place.

Refer to Figure 4 and note that the position of

A is Lat. 10° N	Long. 20° W	D is Lat. 30° N	Long. 40° W
B is Lat. 10° N	Long. 60° W	E is Lat. 10° S	Long. 40° E
C is Lat. 30° N	Long. 20° W	F is Lat. 30° S	Long. 20° E

Note also that the D. Lat. between *A* and *C* is 20°, or $20° \times 60' = 1200'$ nautical miles. Between *A* and *F* the D. Lat. is 40°, or $40° \times 60' = 2400$ nautical miles.

Difference of Longitude and Departure.

The **Difference of Longitude** (D. Long.) between A and B is 40°, or $40° \times 60' = 2400'$. Between A and F the D. Long. is 40°, or $40° \times 60' = 2400'$.

It can be seen that all the meridians converge and intersect at the poles so that the East-West distance between any two meridians becomes smaller as the Latitude gets higher. This distance is called **Departure** (Dep.) and it must not be confused with Difference of Longitude which is always the same between two given meridians. D. Long. is expressed in degrees of arc. The distance or departure between the two meridians depends upon the Latitude and is always expressed in nautical miles and never in degrees of arc.

For example, the distance between the meridians passing through D and C is 20° when measured on the equator. This is their **D. Long.** and is $20° \times 60' = 1200$ minutes of arc, which is 1200 nautical miles, on the equator.

In Lat. 30° the East-West distance between the same two meridians is reduced to 1040 miles represented by Dep., DC in figure, and in Lat. 60° it is still further reduced to 600 miles.

The relationship between **D. Long.** and **Dep.** should be clearly understood as the conversion of one factor into the other is incidental to, and a frequent operation in, navigation.

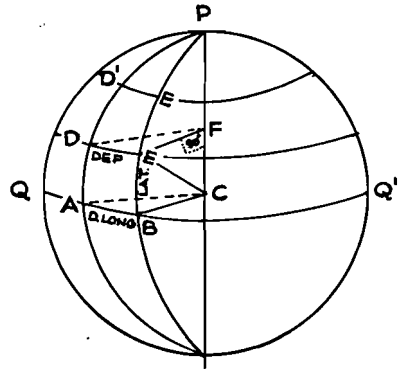


Figure 5.

The three arguments involved in the conversion are Lat., Dep., D. Long., and the question that crops up is, given any two of them to find the third.

The trigonometrical relationship between the factors may be proved from Figure 5.

P	Pole.
PC	Earth's axis.
C	Centre of the earth.
QQ'	Equator.
AB	D. Long. (an arc of the equator).
DE	Dep. (an arc of a parallel of Latitude).
BE	Lat. of that parallel which is also measured by the angle BCE
F	Centre of the circle DE.
FE	Radius of that circle. Note that $\angle PFE = \angle CFE = 90°$.
CB	Radius of the equator, which is also a radius of the earth and is equal to radius CE and also to the radius CP.

AB and DE are arcs of concentric circles, if viewed from the poles, their centres F and C being on the earth's axis, and as arcs of circles are proportional to their radii we have:

$$\frac{\text{Dep.}}{\text{D. Long.}} = \frac{\text{arc } DE}{\text{arc } AB} = \frac{\text{radius } FE}{\text{radius } CB} = \frac{FE}{CE} = \sin FCE = \cos BCE, \text{ so}$$

(a) $\dfrac{\text{Dep.}}{\text{D. Long.}} = \cos \text{Lat.}$ ($\angle BCE = \text{Lat.}$)

By transposing the terms the equation becomes

(b) Dep. = D. Long. × cos Lat.

(c) $\text{D. Long.} = \dfrac{\text{Dep.}}{\cos \text{Lat.}}$

or D. Long. = Dep. × sec. Lat. because the secant of an angle is the reciprocal of its cosine.

The relationship between the factors may be illustrated, but not proved, by a simple right-angled plane triangle in which an angle is made equal to the Latitude. The side **adjacent** to the angle is made equal to the Departure. The **hypotenuse** is made equal to the D. Long. as shown by the bracketed names in Fig. 6.

The operation of converting Departure into D. Long. and *vice versa* occurs frequently in navigation and is carried out by inspection of the Traverse Table. An explanation of the use of Traverse Tables is included in Norie's and Burton's Nautical Tables and in the following pages Traverse Tables can be used for (a) Plane Sailings using arguments Course, Distance, D. Lat. and Departure and (b) Parallel Sailing using Latitude, D. Long. and Departure.

It is unfortunate that the Departure in plane sailing does not bear the same trigonometrical relation to the angle at the top or bottom of the page as the Departure in parallel sailing, but the use of different type and the bracketing together of D. Long and Dep. in the Table helps to avoid confusion and a little practice gets over the difficulty.

Look up the Traverse Table and check the following figures by noting the degree of Lat. at the top, or bottom, of the page and the D. Long. and the Dep. in their respective columns.

Lat.	D. Long. (Dep. × sec. Lat.)	Dep. (D. Long. × cos Lat.)
40°	20′	15·3 miles
50	140	90·0
25	70	63·4
65	100	42·3
$36\frac{1}{2}$	18·4	14·79
$49\frac{1}{2}$	27·3	17·73
$63\frac{1}{2}$	12·7	5·67

The last three examples required interpolation, the first of them being figured out as follows.

Look up 36°, D. Long. 184 and obtain 148·9 in Dep. column.

Look up 37°, D. Long. 184 and obtain 146·9 in Dep. column.

The mean of 148·9 and 146·9 is 147·9, but the decimal point has to be shifted back one place to the left so the Dep. is 14·79.

Be careful to get into the proper Dep. column when the angle is at the bottom of the page.

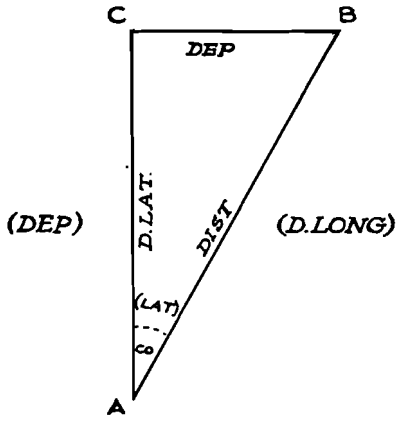


Figure 6.

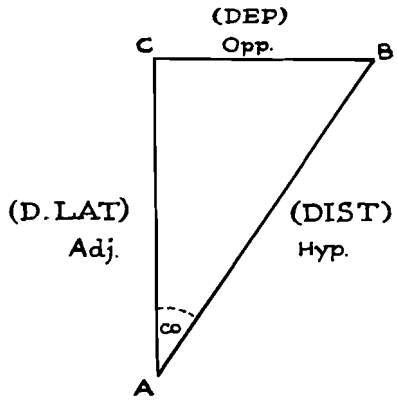


Figure 7.

TRAVERSE TABLES

These Tables give the solution of successive right-angled plane triangles for every even degree of angle and every even unit length of hypotenuse up to 600. It is a ready reckoner, or multiplication table, and it does not matter what name is given to the sides of the triangles so long as their correct relationship to each other is maintained.

In plane sailing, for example, if a ship sails from A to B, say 030° T, 100 miles, then $\angle A$ is the course (30°). AB is the Dist. or hypotenuse (100 miles). AC is the D. Lat., or adjacent side, and CB is the Dep. or opposite side. But

$$
\begin{aligned}
AC &= AB \times \cos A \\
\text{or adj.} &= \text{hyp} \times \cos A \\
\text{that is D. Lat.} &= \text{dist} \times \cos \text{co} \\
&= 100 \times \text{nat cos } 30° \\
&= 100 \times 0{\cdot}866 \\
&= 86{\cdot}6 \text{ miles} \\
\text{and } CB &= AB \times \sin A \\
\text{or opp} &= \text{hyp} \times \sin A \\
\text{that is Dep.} &= \text{dist} \times \sin \text{co} \\
&= 100 \times \text{nat sin } 30° \\
&= 100 \times 0{\cdot}5 \\
&= 50 \text{ miles}
\end{aligned}
$$

Refer to the Table and note that this information is arranged as follows:

30°

Dist.	D. Lat.	Dep.
100	86·6	50·0
Hyp	Adj	Opp

So that the values as calculated above could have been lifted at sight from the Traverse Table. But the columns might equally well have been headed Hyp, Adj, Opp, in so far as the solving of plane triangles by inspection is concerned.

It is well to remember in this respect that Dep. is always the side *opposite* to the angle being used to solve the triangle.

DEFINITIONS

QQ'	Equator.
PP	Poles.
PAP	Prime Meridian.
PBP	A meridian.
PCP	A meridian.
FG	A parallel of Latitude.
JK	A parallel of Latitude.
AB	Longitude of PBP (Long.).
AC	Longitude of PCP.
BC	Difference of Longitude (D. Long.).
DE	Departure (Dep.).
BE	Latitude of E (Lat.).
BE'	Latitude of E'.
EE'	Difference of Latitude (D. Lat.).
XY	Rhumb line.
FG	Tropic of Cancer.
$F'G'$	Tropic of Capricorn.
JK	Arctic Circle.
$J'K'$	Antarctic Circle.

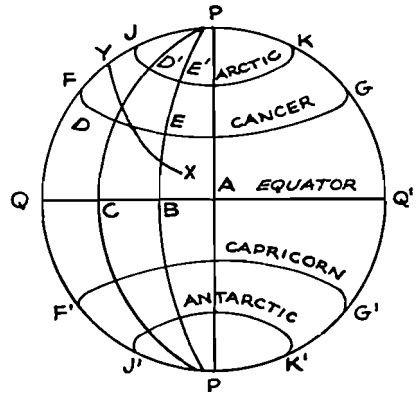


Figure 8.

Referring to Fig. 8 we shall give precise definitions of the above navigational terms.

Poles (P and P) Points where the earth's axis meets the surface.

Equator A great circle round the earth mid-way between the poles.

Meridians (PBP and PCP) Great Circles passing through the poles. **Prime Meridian** (PAP) The Great Circle which passes through Greenwich Observatory and from which Longitude is measured. All places situated on the same meridian are in the same Longitude.

Parallels of Latitude (FG and JK) Small Circles parallel to the equator. All places on the same parallel are in the same Latitude.

Longitude (AB and AC) The arc of the equator contained between the Prime Meridian and the meridian of the place expressed in degrees of arc.

Difference of Longitude (BC) The arc of the equator contained between the meridians passing through two places.

BC measures the D. Long. between any place on the meridian *PBP* and any place on the meridian *PCP*.

Departure The distance in nautical miles measured along a parallel due East or West between two meridians.

DE is the Dep. between the meridians *PCP* and *PBP* along the parallel *FG*, and *D'E'* is the Dep. between the same meridians along the parallel *JK*. Note how departure gets smaller as the poles are approached, and vanishes at the poles because all the meridians then intersect.

There is no Easting or Westing at the poles, only one theoretical direction to go, and that is South from the North Pole and North from the South Pole, but, physically of course, a person could go backwards, forwards or sideways.

Latitude (*BE* and *BE'*) The arc of the meridian contained between the equator and the parallel passing through the place expressed in degrees of arc.

BE measures the Latitude of every place on the parallel *FG*, and *BE'* the Latitude of every place on the parallel *JK*. The arcs *QF*, *CD*, *BE* and *Q'G* are all equal and express the same Latitude.

The Tropics (*FG* and *F'G'*) The parallels of Latitude $23\frac{1}{2}°$ N and $23\frac{1}{2}°$ S.

The Tropic of Cancer in the Northern hemisphere and the **Tropic of Capricorn** in the Southern hemisphere represent the extreme Northerly and Southerly excursion of the sun in a year, the sun being vertically over places on the parallel of Cancer on 21st June and vertically over places on the parallel of Capricorn on 22nd December, the area of the earth between Cancer and Capricorn being called the Torrid Zone.

Arctic Circle (*JK*) The parallel of Latitude $66\frac{1}{2}°$ N or $23\frac{1}{2}°$ from the pole. The area between the Arctic Circle and the pole is called the North Frigid Zone, and for a period of time during the year the sun never rises or never sets at places within this zone.

Antarctic Circle (*J'K'*) The parallel of Latitude $66\frac{1}{2}°$ S or $23\frac{1}{2}°$ from the South Pole. The area between the Antarctic Circle and the South Pole is called the South Frigid Zone, and for a period of time during the year the sun never rises or never sets at places within this zone.

The areas of the earth situated between Cancer and the Arctic Circle and between Capricorn and the Antarctic Circle are called the Temperate Zones, North and South respectively.

Rhumb Line (*XY*) A curve on the earth's surface which cuts all meridians at the same angle. When a ship is steered on the same true course she sails on a rhumb track. On a mercator chart a Rhumb Line, such as a course, is a straight line.

TO FIND DIFFERENCE OF LATITUDE (D. LAT.) AND DIFFERENCE OF LONGITUDE (D. LONG.)

Students should first study the sections on right angled triangles (Chapter 6) before proceeding with the calculations contained in this section.

D. Lat.

Write down the Latitude of one position and under it the Latitude of the other position; add them together if they are of different names, but subtract the lesser from the greater if they are of the same name. The result is the **D. Lat.** to be reduced to minutes by multiplying the number of degrees by 60, adding in the odd minutes, if any. The **D. Lat.** is named according to the direction from one place to the other: North if more Northerly, South if more Southerly.

D. Long.

Write down the Longitude of one position and under it the Longitude of the other position; add them together if they are of contrary names, but subtract the lesser from the greater if they are of the same name. The result is the **D. Long.** to be reduced to minutes by multiplying the number of degrees by 60 and adding the odd minutes, if any. The **D. Long.** is named according to the direction from one position to the other, East if more Easterly, West if more Westerly. Should the sum of an East Longitude and a West Longitude exceed 180°, then this **D. Long.** is subtracted from 360° before turning it into minutes, and the direction is altered from East to West, or *vice versa.*

Example 1

Required the D. Lat. and D. Long. from *A*, Lat. 20° 35′ N, Long. 165° 30′ W, to *B*, Lat. 10° 18′ S, Long. 172° 36′ E.

	Lat.	Long.
A	20° 35′ N	165° 30′ W
B	10 18 S	172 36 E
	30 53 S	338 06 E
	× 60	360 00
D. Lat.	1853′ S	21 54 W
		× 60
		D. Long. 1314′ W

Exercise 1

Find the difference of Latitude and difference of Longitude between *A* and *B* in each of the following examples:

1. *A* Lat. 49° 30′ N, Long. 27° 20′ W.
   B Lat. 56° 20′ N, Long. 38° 12′ W.
2. *A* Lat. 10° 35′ N, Long. 25° 12′ E.
   B Lat. 5° 12′ S, Long. 10° 20′ E.
3. *A* Lat. 30° 30′ N, Long. 173° 30′ E.
   B Lat. 35° 40′ N, Long. 165° 20′ W.
4. *A* Lat. 5° 30′ N, Long. 5° 30′ W.
   B Lat. 5° 30′ S, Long. 5° 30′ E.

Answers 1. 410′ N, 652′ W. 2. 947′ S, 892′ W.
3. 310′ N, 1270′ E. 4. 660′ S, 660′ E.

PARALLEL SAILING

Parallel Sailing has been handed down from the days when navigators had no means of finding

Longitude at sea. They sailed North or South until the desired Latitude was reached, then sailed due East or West until a landfall was made and finally coasted to their destination. Nowadays, of course, ships are sailed obliquely across the meridians but the Parallel Sailing formula is still used as part of the calculation in Mean Latitude Sailings and also in Great Circle Sailings.

This question resolves itself into three arguments Lat., Dep., D. Long. Given any two, find the third part.

Example 2

In what Lat. will 120 miles Dep. be equal to 145′ D. Long.? Given Dep. and D. Long., find the Lat. Draw a figure as indicated just to keep the three factors in view.

$$\frac{\text{Dep.}}{\text{D. Long.}} = \cos \text{Lat.}$$

Dep.	120	log	2·07918
D. Long.	145	log	2·16137
Lat.	34° 09′	cos	9·91781

Answer Lat. 34° 9′ N or S.

Check this answer by Traverse Tables.

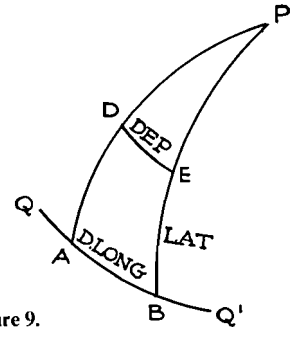


Figure 9.

Example 3

A ship in Lat. 51° 36′ N Long. 5° 30′ W wishes to make the Old Head of Kinsale on the same parallel but in Long. 8° 32′ W. Find the distance between the ship and its destination.

Given Lat. and D. Long., find the Dep.

By construction An approximate answer can be found by means of a right-angled plane triangle which, at the same time, affords an assistance in remembering the formula.

1. Make $\angle A$ = **Lat.** = 51° 36′.
2. Make AD = **D. Long.** = 182′ from any convenient scale of equal parts.
3. From D, drop DB perpendicular to AB.

The **Dep.** = AB as measured from the same scale of equal parts.

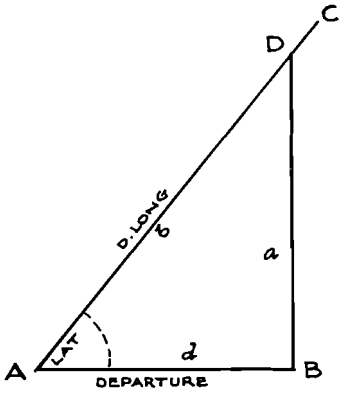


Figure 10.

By calculation

	D. Long.
Long. of ship	5° 30′ W
Long. of Kinsale	8 32 W
	3 2
	× 60
	182′ W

	Dep. = D. Long. × cos Lat.	
Lat.	51° 36′	log 9·79320
D. Long.	182	log 2·26007
Dep.	113	log 2·05327
Dist.	113 miles.	*Answer*

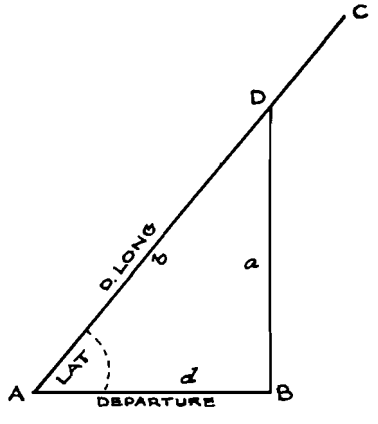


Figure 11.

Example 4

A ship bears due West distant 200 miles from Fastnet Rock (51° 23′ N 9° 36′ W). What is the ship's Longitude?

Given Lat. and Dep., find D. Long., thence the Long. of ship.

By construction

1. Make $\angle A$ = Lat. 51° 23′.
2. Make AB = Dep. = 200 miles from any convenient scale of equal parts.
3. Erect BD perpendicular to AB.

The D. Long. = AD as measured from the same scale of equal parts.

	D. Long. = Dep. sec Lat.		Long. of Fastnet	9° 36′ W
Lat.	51° 23′ sec	10·20474	D. Long. $\frac{320·5′}{60}$ =	5 20·5 W
Dep.	200 log	2·30103		
D. Long.	320·5 log	2·50577	Long. of ship	14 56·5 W

Exercise 2

1. In Lat. 49° 58′ the Departure made good was 226 miles. Required the corresponding Difference of Longitude.
2. In Lat. 42° 36′ a ship sails due East from Long. 26° 30′ W to Long. 21° 12′ W. What Departure has the ship made?

3. By sailing due East, distance 238 miles, a ship altered her Longitude 5° 26′. Find the ship's Latitude.
4. In Lat. 41° 14′ Long. 64° 36′ E a ship sails 090° T for 294 miles. Find the arrival Longitude.
5. A ship in Lat. 48° 31′ N sails 270° T from Long. 20° 14′ W to Long. 28° 42′ W. Find the distance made good.
6. A ship in Long. 22° W sails 270° T for 213 miles, and is then in Long. 27° 12′ W. What was the ship's Latitude?
7. At what rate per hour is Greenwich Observatory in Lat. 51° 28½′ N being carried round the earth's axis?[1]
8. In what Latitude will the number of minutes of Longitude be double the corresponding miles of Departure?
9. In what Latitude will the number of miles of Departure be one-third the number of minutes of the corresponding Difference of Longitude?
10. How many miles are there in 1° of Longitude in Lat. 50°?
11. A vessel steams 090° T for two hours at 20 knots and alters her Longitude 1° in the same interval of time. What was her Latitude?
12. What is the distance between the meridians of 120° E and 130° E on the parallel of 38° S?

Note 1 The earth rotates through 360° in 24 hours, or 15° of Long. per hour, which is at the rate of 15° × 60′ = 900′ per hour at the equator. This is equivalent to D. Long. per hour; the corresponding Dep. per hour will be the rate of rotation per hour in any other Latitude.

Example 5

A vessel sails from *D*, 38° 30′ N, 53° 18′ W, to *E*, 42° 12′ N, 51° 10′ W. Find the departure, also the course and distance the ship makes good.

Draw a figure to show the relative positions *D* and *E*. The figure demonstrates that the ship sailed directly from *D* to *E*, not due East to E′ and then due North to E, but along the rhumb line *DE*.

	D. Lat.	D. Long.	Mean Lat.
D	38° 30′ N	53° 18′ W	38° 30
E	42 12 N	51 10 W	½D. Lat.+ 1 51
	3 42	2 8	40 21
	60	60	
	222′ N	128′ E	

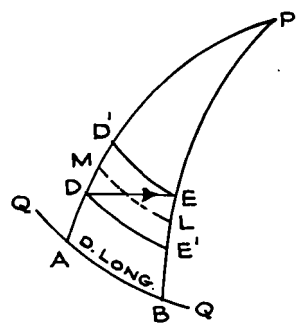


Figure 12.

We wish now to convert 128′ D. Long. into its corresponding Dep. If we used Lat. D. 38° 30′ we would get Dep. (*DE′*), 100·2 miles, which is obviously too big. If we used Lat. E 42° 12′ we would get Dep. (*D′E*), 94·8 miles, which is too small. The mean of these Deps., ½(100·2 + 94·8) = 97·5 and this would be a very close approximation to the Dep. (*ML*) in 40° 21′ which is the Mean Lat. between *D* and *E*. It is easier, however, to use the Mean Lat. and convert D. Long. into Dep. right away by the parallel sailing formula.

This method is adopted in practice so long as the distance does not exceed 600 miles and the Lat. is under 60°.

Dep. = D. Long. × cos Mean Lat.

Dep. = 128 cos 40° 21′

D. Long.	128	log	2·10721
M. Lat.	40° 21′	cos	9·88201
Dep.	97·55	log	1·98922

The **Traverse Tables** might have been used to convert D. Long. into Dep. by interpolation as follows:

	Mean Lat. 40° 21′		
40°	D. Long. 128′ gives	Dep. 98·1	
41	128	96·6	
40° 20′	128	97·6	The same Dep. as above.

The course and distance from *D* to *E* is now found by inspection.

Enter Traverse Tables with D. Lat. 222, Dep. 97·6, in their respective columns and find 23½°, Dist. 242, Co. N 23½ E, N 23½° E → 023½° T, Dist. 242½ miles.

When interpolating in the Traverse Table get the bigger factor as close as possible in its column, and if the smaller factor alongside of it is not exactly the same as wanted, but just a little bigger or a little smaller, then interpolate mentally between the next less and the next greater quantities on two successive pages, and get the course to the nearest half degree and the distance to the nearest half mile.

In this example:

	Dist.	D. Lat.	Dep.
23° gave	241	221·8	94·2
24	243	222·0	98·8

Our D. Lat. 222 and Dep. 97.5 fit in between the numbers given in the Table, i.e. 23½° and 242½ miles.

Example 6

Find the course and distance from *D*, 35° 15′ S, 17° 10′ E, to *E*, 36° 50′ S, 19° 56′ E. Draw a figure to indicate the relative positions of *D* and *E*.

	D. Lat.	D. Long.	Mean Lat.
D	35° 15′ S	17° 10′ E	35° 15′
E	36 50 S	19 56 E	½D. Lat. + 47
	1 35	2 46	36 02
	× 60	× 60	
	95′ S	166′ E	

Dep. = D. Long. × cos Mn. Lat. = 166 cos 36° 2′

D. Long.	166	log	2·22011
M. Lat.	36° 2′	cos	9·90777
Dep.	134·2	log	2·12788

Enter Traverse Tables with D. Lat. 95, Dep. 134·2, and find where they are in closest agreement when the course will be found at the bottom of the page, and the distance in the left-hand column, i.e. Co. S 55 E → 125° T and Dist. 164 miles.

Answer Co. 125° T, Dist. 164 miles.

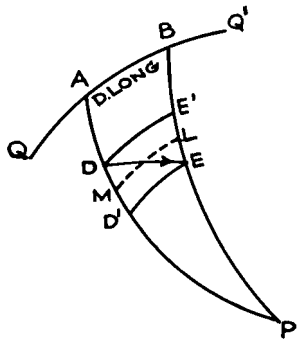


Figure 13.

In the preceding example the arithmetic mean of the two latitudes has been used. Ideally, and for very accurate results, corrections should be applied to make allowance for the compression of the earth and to convert the Mean Latitude applicable to a plane triangle to the latitude applicable to a sphere. Mean Latitude so corrected is referred to as the Middle Latitude.

Until recently many volumes of nautical tables included corrections for converting Mean to Middle Latitude. Unfortunately none of these correction tables has proved entirely satisfactory and recent editions of volumes, such as *Norie's Nautical Tables*, no longer include them. In addition, it is no longer required to apply the Mean to Middle Latitude correction in D.Tp. Examinations. It follows that you should always **use the Mean Latitude when working Plane Sailing problems**.

Despite the lack of suitable Mean to Middle Latitude correction tables, the Plane Sailing (and Traverse Tables) gives acceptable results over short distances. Under certain conditions the Plane (Mean Latitude) Sailing can give better results than the Mercator Sailing but, in the majority of cases, the Mercator Sailing is the more accurate one to use. In summary, **use the Mercator Sailing where Accurate Results are required**.

It must be added, however, that recent research indicates that, even when using the most suitable method, the calculated distance is liable to be in error by up to $\frac{1}{2}\%$.

Refer to Figure 20 and note that the factors connecting the sailings are as follows:

D. Long. connects Mercator with Plane Sailing,
Dep. connects Plane with Parallel Sailing,
Course connects Mercator with Plane Sailing.

Example 7

Find the course and distance from *E*, 56° 46′ N, 176° 15′ W, to *D*, 38° 10′ N, 170° 15′ E, by Plane Sailing.

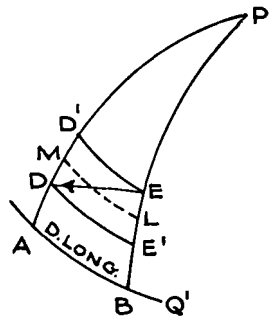


Figure 14.

E	56° 46′ N	176° 15′ W	Lat.	56° 46′ N	
D	38 10 N	170 15 E	½D. Lat.	−9 18	
	18 36 S	346 30 E	Mn. Lat.	47 28 N	
	60	360 00			
D. Lat.	1116′ S	13 30	Mn. Lat.	47° 28′	cos 9·82996
		60	D. Long.	810	log 2·90849
	D. Long.	810′ W	Dep.	547·6	2·73845

The quantities are too big to give the course and distance near enough by inspection from the Tables, although on entering with 111·6 and 54·7 we find 111·5 and 54·4 alongside of each other under course 26° and distance 124, so the approximate course and distance is 206° T (S 26° W), 1240 miles.

But for such a long stretch, we would need to calculate the course and distance to get an accurate result.

$$\text{Tan Co} = \frac{\text{Dep}}{\text{D. Lat.}} = \frac{547{\cdot}6 \text{ log } 2{\cdot}73846}{1116 \text{ log } 3{\cdot}04766}$$

Co 206° 08·2′ T (S 26° 08·2′ W) tan 9·69080

Dist. = D. Lat. sec co = 1116 sec 26° 08·2′

1116 log 3·04766

26° 08·2′ sec 0·04684

Distance 1243·1 miles log 3·09450

The ship would, in this example, cross the 180th meridian, and by adding together the West and East Longitudes we get the longer way round the world. There are two ways round,

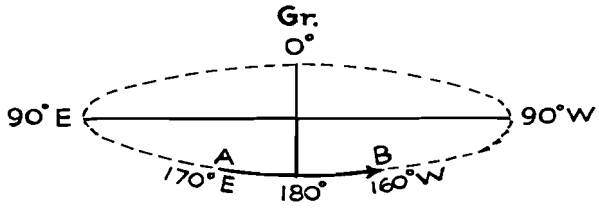


Figure 15.

one by going East and the other by going West, a complete round turn being 360°. We would obviously take the shorter way, so subtract the D. Long. from 360°, and don't forget to note that the direction is reversed.

If we were proceeding from *A* 170° E to *B* 160° W we would get the longer or dotted way round, which is 330° W by adding the longitudes, but by subtracting it from 360° we get the shorter way round, 30° E.

THE SET AND DRIFT OF A CURRENT

The position of a ship as determined from the courses steered and distances run only is known as the Dead Reckoning (D.R.) Position.

The ship's position as determined from visual bearings of shore objects, D.F. bearings, hyperbolic navigation systems or sights, is known as the Observed Position (Obs. Pos.).

Assuming leeway is not being experienced, the course and distance from D.R. to the Obs. Pos. is the set and drift of the current and it is found by inspection from the Traverse Table in the same way as the course and distance from one position to another, the order of work being as follows.

1. Find the **D. Lat.** and **D. Long.**
2. Convert the **D. Long.** into its corresponding **Dep.** using the **Mean Lat.**
3. Look up the Traverse Table and find the course and distance indicated by the **D. Lat.** and **Dep.**

Example 8

The ship's position by D.R. was 50° 20′ N, 115° 37′ E and by Obs. 50° 40′ N, 115° 20′ E. Required the set and drift of the current. Draw a figure to show the relative positions of D.R. and Obs.

D.R.	50° 20′ N	"Traverse Table"		
Obs.	50 40 N	M. Lat.	50° 30′	Gives Dep. 10·8
D. Lat. due to current	20′ N	D. Long.	17′	
D.R.	115° 37′ E	D. Lat.	20′ N	Gives Co. N 28° W
Obs.	115 20 E	Dep.	10·8 W	Dist. 23
D. Long. due to current	17 W	*Answer*	Set. 332° T Drift 23 miles.	

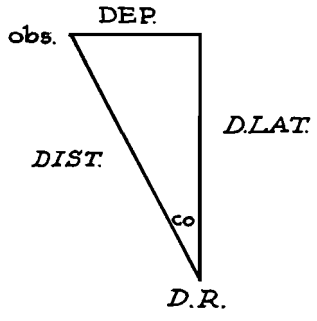


Figure 16.

Exercise 3

In the following exercises find the course and distance by inspection:

	Lat.	Long.
1. From	52° 12′ N	6° 12′ W
To	53° 18′ N	4° 42′ W
2. From	38° 30′ N	28° 12′ W
To	40° 20′ N	30° 18′ W
3. From	40° 12′ S	40° 12′ E
To	41° 13′ S	42° 40′ E
4. From	1° 18′ N	71° 12′ E
To	0° 20′ S	74° 30′ E
5. From	30° 43′ N	178° 10′ W
To	29° 12′ N	179° 18′ E
6. From	0° 30′ N	178° 12′ E
To	0° 30′ S	178° 12′ W
7. From	56° 37′ N	36° 12′ W
To	52° 13′ N	40° 36′ W

Answers at the end of the book.

PROJECTION OF THE SPHERE

It is impossible to project a sphere on a plane surface without considerable distortion. When looking at a globe only the surface area in the line of vision between the eye and the centre of the globe is accurately seen, and distortion becomes ludicrous at the circumference. (See Figure 3 and 4.) Various methods are adopted to try to reduce the errors that result from representing the curved surface of the earth on a flat sheet, each system possessing some special property of delineation for particular purposes, but all of them having disadvantages and limitations.

When only a small area is mapped out the curvature of the earth need not be taken into account. The plans of towns and the districts surrounding them are constructed on this assumption, also *plan charts* of the approaches to harbours; a convenient scale to represent the nautical mile on the chart is agreed upon and this scale of measurement is uniform throughout the comparatively small area covered by the chart.

Natural Scale The scale on which a chart is drawn is usually expressed as a fraction, viz., natural scale $\frac{1}{120,000}$ means that an actual mile is 120,000 times longer than the mile on the chart.

The **Mercator Projection** possesses many navigational advantages. In particular, it has the important feature of preserving shape—this means that the navigator can lay off courses and bearings at their true angles to the meridian. In consequence, the Rhumb Track from one position to another is a straight line. For this reason the Mercator Projection is used for all navigational charts other than large scale plans used for rivers and harbours etc. It should also be noted that on a Mercator projection a Great Circle Track will appear as a curve.

As explained later, the Mercator Projection is a mathematical projection in which the Latitude Scale = Longitude Scale × secant Latitude. Nevertheless, a general idea of the underlying principle of its construction may be conveyed by conceiving a cylinder to fit over the sphere and in contact with it along the equator, as in Fig. 17, then imagine all the meridians to be cut at the pole and transferred from the sphere to the interior surface of the cylinder by keeping them fixed at the equator and bending each one backwards until it forms a straight line up and down the inner wall of the cylinder. The meridians will then be all parallel to each other instead of converging as they do on the sphere. This means that all over the chart a degree of Longitude is of the same length as along the equator, whereas, on the globe, a degree of Longitude decreases from 60 nautical miles at the equator to 0 at the poles.

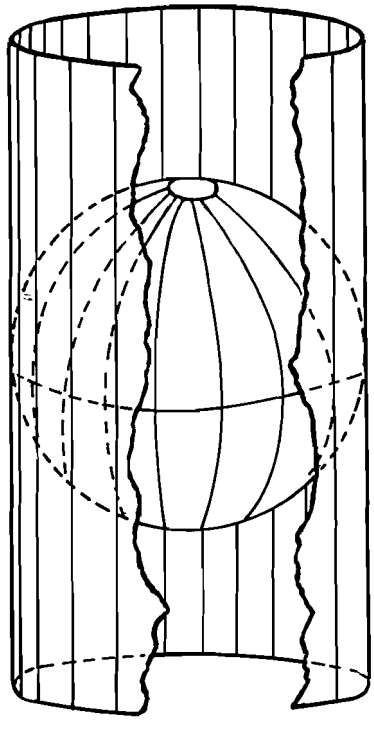


Figure 17.

If the cylinder be now unrolled and spread out flat the East-West distance on the chart will be truly represented at and near the equator, but the East-West distance will be increased as the Latitude increases until the exaggeration becomes so great that localities near the poles cannot be shown.

With the object of preserving the uniformity of the figure and keeping all the angles relatively correct, the successive parallels of Latitude are drawn at a steadily increasing distance apart in the same proportion as the East-West distance is increased, so that a degree of Latitude on the chart is increased in exactly the same ratio as a degree of Longitude is increased at each respective parallel. Thus small areas away from the equator are exaggerated equally East and West, North and South, and an island in a high Latitude has its form shown just as accurately as one near the equator, but on a larger scale.

As previously mentioned, the latitude and distance scale of a Mercator Chart is proportional to the secant Latitude. This scale increases when moving from the equator towards the poles. At the poles, where Latitude = 90°, the value of secant Lat. (90°) is Infinity. It is for this reason that the polar Regions cannot be shown on the Mercator Projection.

The Fig. 18 attempts to illustrate more definitely, but not to scale, the principle underlying the construction of a Mercator chart, and also its relationship to the sphere. *APa* is a section on a globe and *AGG'a* the corresponding section of a chart. The meridian *AP* would appear as *AG* on the chart and *aP* as *aG'*; the parallels on the globe *b*, *c*, *d*, *e*, *f*, and *g*, etc., would appear in the respective positions *B*, *C*, *D*, *E*, *F*, and *G*, etc., on the chart. The distance between successive parallels is seen to steadily increase with the Latitude and their increased distances

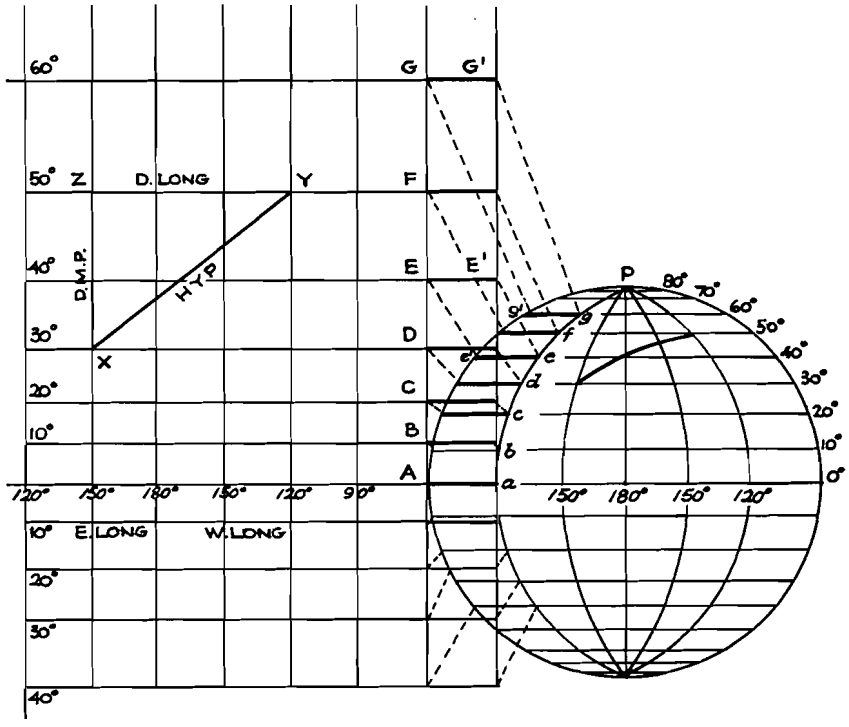


Figure 18.

apart is named *Difference of Meridional Parts* (*D.M.P.*) to distinguish it from the D. Lat. on the globe.

In Fig. 18 it will be noted that gg' (on the sphere) has been increased to GG' (on the projection)

$$\frac{GG'}{gg'} = \frac{\text{Diff. of Longitude}}{\text{Departure}} = \text{Secant Latitude.}$$

Difference of Latitude must be increased in the same proportion but, since secant Latitude varies, Integral Calculus is needed to find the value of Meridional Parts.

The **Meridional Parts** (Mer. Parts) for any Latitude is the increased length of the meridians on a Mercator chart measured from the equator to the parallel and expressed in minutes of the Longitude scale.

For example, the length of the meridian A to D when measured along the equator represents the number of meridional parts corresponding to ad; and AE to ae; AF to af and so on.

If position d is in Lat. 30° N then the lineal distance on the earth's surface of ad is $30° \times 60' = 1800$ nautical miles, but on referring to the Meridional Parts Table the parts for $30° = 1876{\cdot}67$, so that the meridional distance AD on the chart is 77 equatorial minutes longer than on the globe. Again, if position e is in Lat. 40° N, the lineal distance of the arc ae on the earth is $40° \times 60' = 2400$ nautical miles, but the meridional parts corresponding to $40° = 2607{\cdot}64$ equatorial minutes, so that AE on the chart is represented as being 208 miles longer than it would appear on an actual globe.

Differences of Meridional Parts (D.M.P.) is the difference between the meridional parts of two Latitudes. The Meridional Parts for the terrestrial spheroid are used.

Mer. Parts for Lat. D in 30° N =	1876·67
E in 40° N =	2607·64
D.M.P. between D and E is	730·97

This is represented by DE on our chart and thus corresponds to de on the globe, which is the D. Lat. and measures $10° \times 60' = 600$ miles.

The factor Dep. on the globe disappears on the chart and D. Long. takes its place; D. Lat. also disappears as such on the chart and D.M.P. takes its place, so that on the chart $\frac{\text{D. Long.}}{\text{D.M.P.}} = \frac{\text{Dep.}}{\text{D. Lat.}}$ on the globe, or, as named in the figure $\frac{EE'}{DE} = \frac{e'e}{de}$, thus maintaining correctly the relative proportion between the mercatorial section DEE' and the corresponding globe section dee'.

Similarly, FG on the chart corresponds to fg on the globe, and the plane area FGG' corresponds to the spherical area fgg'.

The skeleton chart may be completed by extending the equatorial line, then drawing the meridians perpendicular to it and equidistant from each other according to the scale of Longitude agreed upon; finally, the parallels are drawn in at their respective distances apart by an amount equal to the number of meridional parts which separate them. The navigational features of a Mercator Chart are:

1. The world, with the exception of the higher polar regions, can be seen at a glance.
2. The rhumb track from one position to another is a straight line, the great circle track, however, is a curve.
3. The course from one position to another is found by simply laying a parallel rule over them and reading off this direction from the compass rose engraved on the chart.
4. The scale of Latitude at the side is also the scale of nautical miles, but owing to the expanding nature of this scale the distances must be measured in the Latitude of the position, or, when two positions are separated considerably in Latitude the distance between them should be measured in the vicinity of their mean Latitude.
5. Calculating the course and distance between two places is reduced to the solution of a right-angled plane triangle as illustrated in the figure where XZ is the difference of meridional parts, ZY the difference of Longitude and $\angle ZXY$ the mercatorial or rhumb course to steer from position X in 30° N, 150° E to position Y in 50° N, 120° W.

The **Great Circle Track** is the shortest distance between two places; it is the direction an aviator would follow in his aircraft if he steered straight for his objective as if it were in sight.

In Figure 3 the great circle track is shown as if it had been drawn on a teaching globe from Yokohama to San Francisco. It will be noted that, in order to keep to the great circle, a vessel's course would need to be frequently altered, because the track crosses successive meridians at a different angle. The circle bends towards the pole of the hemisphere so that the course when going from Yokohama to San Francisco would first be to the North and East, then gradually becoming more Easterly until a point V, called the vertex, or turning point, is reached where the course becomes due East and, afterwards, a course gradually bending more and more to the Southward of East must be steered to reach San Francisco. This continued changing of the ship's course is a disadvantage in navigation and does not always make up for the saving of distance unless a decided advantage is to be gained by following the great circle.

The great circle track is a straight line when drawn on a gnomonic chart. A succession of points conveniently close to each other along this line are selected and the Latitude and Longitude of these points are laid off on a Mercator chart. The successive rhumb courses between the points are then steered so that the vessel follows approximately the great circle track and the distance sailed will not differ greatly from the shortest possible distance between the places.

MERCATOR SAILING

When the distance between two places is outside the limit of 600 miles, the course cannot be found accurately enough by plane sailing methods, and the course and distance is then calculated on the Mercator principle.

General Instructions

The Latitude and Longitude of two places being given, it is required to find the true course and distance from one to the other.

To find the Difference of Latitude (D. Lat.) Write down the Latitude of the place from which the ship departs, and underneath it put the Latitude of the place for which she is bound. If they have the same names subtract one from the other, if they have different names add them together. The result is the D. Lat. Reduce it to miles by multiplying the number of degrees by 60, adding in the odd minutes if there are any. Name it N if the ship is bound to the Northward, but S if she is bound to the Southward.

To find the Difference of Meridional Parts (D.M.P.) Take out from the Table of Meridional Parts in Norie's, or other Tables, the number of meridional parts corresponding to each Latitude. Do the same with these—that is, add or subtract them—as you have already done with the two Latitudes. The result is the D.M.P.

To find the Difference of Longitude (D. Long.) Write down the Longitude of the place from which the ship departs, and underneath it the Longitude of the place for which she is bound. If they have the same names subtract one from the other, if they have different names add them together. The result is the D. Long. Reduce it to minutes by multiplying the number of degrees by 60, adding in the odd minutes if there are any. If the D. Long. comes to more than 180° subtract it from 360° before turning it into minutes. Name it E if the ship is bound to the Eastward, but W if she is bound to the Westward. Note that when you subtract from 360° the course will **always have the same name as the first Longitude.**

To find the True Course This is done by right-angled plane trigonometry as follows hereafter, and is given the same names as the D. Lat. and the D. Long.

Example 9

Find the true course and distance from the Lizard Light in Lat. 49° 58′ N, Long. 5° 12′ W to St. Michael's (Western Islands) in Lat. 37° 49′ N, Long. 25° 8′ W.

Lat. Lizard	49° 58′ N	Mer. parts	3453·43	Long. Lizard	5° 12′ W
Lat. St. Michael's	37 49 N	Mer. parts	2439·97	Long. St. Michael's	25 08 W
	12 09	D.M.P.	1013·46		19 56
	60				60
D. Lat.	729 S			D. Long.	1196 W

The chartlet indicates what we have to do. A represents the Lizard, C St. Michael's.

In the triangle ABC, given $\angle B = 90°$, side AB = D.M.P. (1013), side BC = D. Long. (1196); to find $\angle A$ the course.

$$\frac{\text{D. Long.}}{\text{D.M.P.}} = \tan \text{course}$$

D. Long.	1196	log	3·07773
D.M.P.	1013·5	log	3·00582
229°43·3′ T ← S 49° 43·3′ W ←		tan	10·07191

Having now got $\angle A$, 49° 43·3′, and given D. Lat. 729 miles, we find the distance by plane sailing, where

AD = D. Lat. (729)
$\angle A = 49° 43·3′$
$\angle D = 90°$

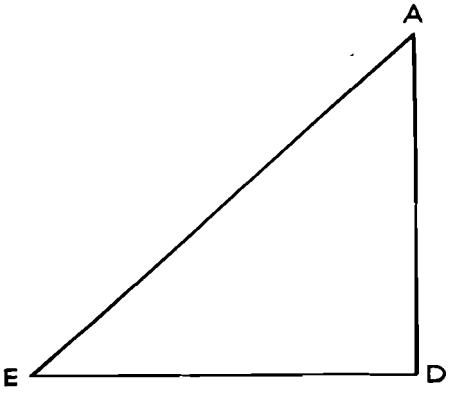


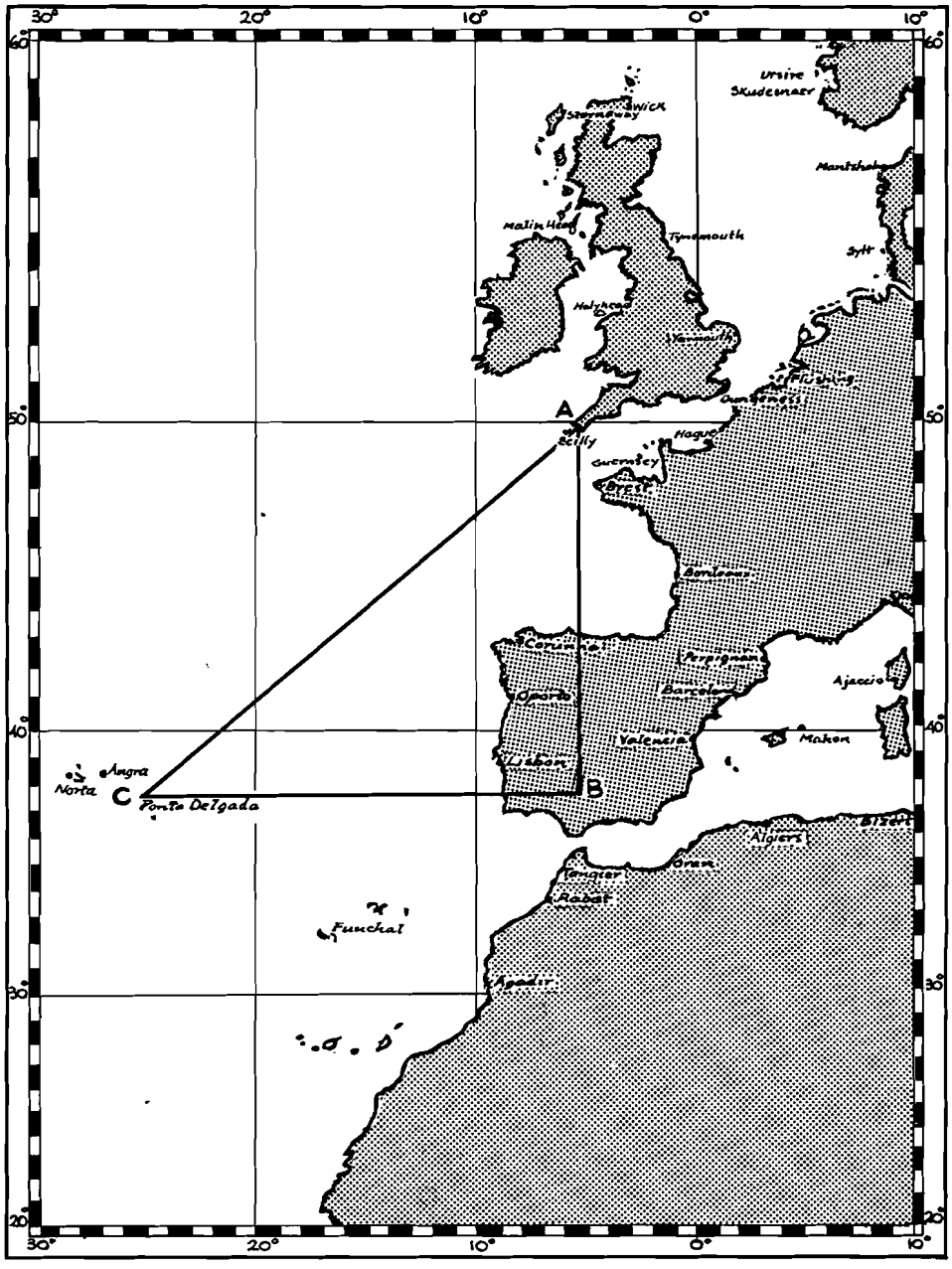
Figure 19.

Find AE the distance.

$$AE = AD \sec A$$

Dist. = D. Lat. sec course			
Co.	49° 43·3′	sec	10·18944
D. Lat.	729	log	2·86273
Dist.	1128 ←	log	3·05217

Answer Distance 1128 miles.
Course 229° 43·3′ T.



Mercator Projection The scale of Longitude is constant and the scale of Latitude is variable. Scale of 1′ Lat. = scale of 1′ Long. × Sec Lat.

On laying a protractor on the chartlet and measuring the angle A, at the Lizard, it will be found to approximate 50°. If the length of AC be measured with a pair of dividers and then applied to the Latitude scale of the chart, it will be found to fall short of 18° and to measure about 17° 40′ or 1060 miles, as near as one can estimate on such a small chart.

We must warn the student that AC is not the distance from Lizard to St. Michael's but simply a rhumb line to complete the triangle; also that the Lat. scale on the chart is not equal throughout its length and should only be used for comparatively short distances even on a large scale chart, and that for long distances it will only give an approximate answer. But $\frac{\text{D. Long.}}{\text{D.M.P.}} = \frac{BC}{AB} = \tan co$ is strictly accurate and then by combining this course with the actual D. Lat. the correct distance is found by the plane sailing methods previously described.

It may sometimes be required to draw a figure to illustrate a particular example, more as a test in geometry than of navigational practice. The foregoing example would be illustrated as follows.

Given D.M.P. (1013), D. Long. (1196), D. Lat. (729), construct a figure to scale and from it measure the course and distance from Lizard Light to St. Michaels.

From any convenient scale take a length in the compasses corresponding to the D.M.P. (1013), and draw the vertical line AB, which represents an arc of the meridian of the Lizard Light.

Take from the same scale a length corresponding to the D. Long. (1196), and as the course we have to find is a Southerly and Westerly one, lay it off from the **South** (bottom) end of the line AB in a due **West** direction, forming the line BC. Join A and C.

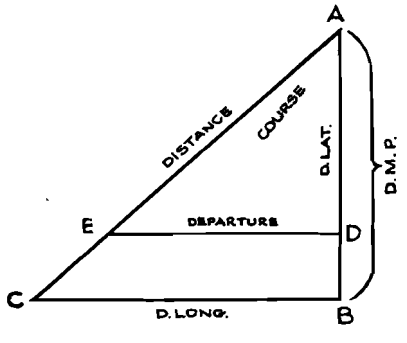


Figure 20.

This forms the right-angled triangle ABC, in which AB represents the D.M.P., BC the D. Long., and angle A the true course.

Again, from the same scale take a length corresponding to the D. Lat. (729), and lay it off from A along the line AB, reaching the mark D.

Draw the line DE parallel to BC.

We now have another right-angled triangle (ADE) in which angle A (common to both triangles) represents the true course, AD the D. Lat., DE the departure (not used in this problem), and AE the distance. Note that the line AE represents the actual track on which the ship is sailing.

Measure angle A with a protractor; it is approximately 50°, the course is therefore 230° T. The length of AE, the distance, is about 1100 miles, but the larger the scale the more accurately the distance may be found. In a well conditioned triangle the course can be found to the nearest degree, but the measured distance is not usually so satisfactory.

Example 10

Find the true course and distance, from Tuskar Rock 52° 12′ N, 6° 12′ W, to the South Stack Light 53° 18′ N, 4° 42′ W.

Lat. Tuskar	52° 12′ N	Mer. parts	3666·22	Long. Tuskar	6° 12′ W
Lat. South Stack	53 18 N	Mer. parts	3774·99	Long. South Stack	4 42 W
	1 06	D.M.P.	108·77		1 30
	× 60				× 60
D. Lat.	66 N			D. Long.	90 E

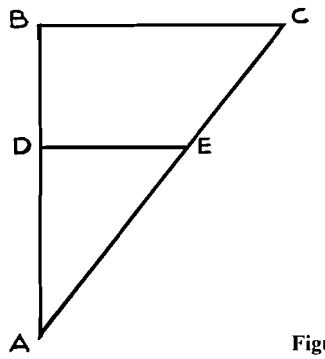


Figure 21.

In figure

$$BC = \text{D. Long. (90)}$$
$$AB = \text{D.M.P. (108·8)}$$
$$\angle B = 90°$$

Find $\angle A$ the course.

$$AD = \text{D. Lat. (66)}$$
$$\angle D = 90°$$

Find AE the Distance.

$$\frac{\text{D. Long.}}{\text{D.M.P.}} = \tan \text{course.} \quad \text{Distance} = \text{D. Lat. sec. co.}$$

D. Long.	90	log 1·95424	Co.	39° 36′	sec 0·11322
D.M.P.	108·8	log 2·03663	D. Lat.	66	log 1·81954
Co	N 39° 36′ E ←	tan 9·91761	Dist.	85·65	log 1·93276

Answer Course 039° 36′ T.
Distance 85·7 miles.

Example 11

A vessel sailed from Lat. 36° 20′ S, course 236° T, and changed her longitude 20°. Find the latitude reached and the distance sailed.

D.M.P. = D. Long. × cot co = 1200 cot 56°

(*BC*)	D. Long.	1200	log 3·07918
(∠*A*)	Course	56°	cot 9·82899
(*AB*)	D.M.P.	809·4	log 2·90817

From Table, Lat. 36° 20′ → M.P. 2328·9

From Table, Lat. 46 $27\frac{1}{2}$ ← M.P. 3138·3

D. Lat. 10 $07\frac{1}{2}$ = 607·5′ (*AD*)

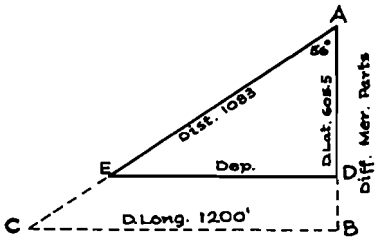


Figure 22.

Dist. = D. Lat. sec co = 607·5 sec 56°

(∠*A*)	Course	56°	sec 0·25244
(*AD*)	D. Lat.	607·5	log 2·78355
(*AE*)	Dist.	1086	log 3·03599

Answer Lat. 46° 27.5′ S. Distance 1086 miles.

Exercise 4

1. Required the true course and distance

From	33° 58′ S	18° 20′ E
To	8° 30′ N	13° 18′ W

2. Find by Mercator Sailing, the true course and distance

From	38° 41′ N	32° 54′ W
To	49° 50′ N	5° 14′ W

3. Required the true course and distance from *A* to *B* by Mercator Sailing

From	*A*	8° 20′ N	19° 40′ W
To	*B*	5° 12′ S	5° 50′ E

4. Required the true course and distance:

From	Cape Palliser	41° 37′ S	175° 19′ E
To	Chatham Islands	43° 51′ S	176° 50′ W

5. Find the true course and distance by Mercator Sailing

From	34° 40′ S	15° 20′ E
To	11° 46′ N	24° 39′ W

6. A vessel in Lat. 47° 30′ N sailed 315° T and her D. Long. was 27°, required the latitude reached and distance sailed.
7. Given Lat. 30° N, course 150° T, D. Long. 15°, find latitude reached and distance sailed.
8. A vessel sailed 1000 miles from position 38° 30′ S, 25° 30′ W, on course 210° T. Find the longitude reached.

   Note: Find D. Lat. and get latitude reached, then, with D.M.P. between the two latitudes and the course find the D. Long.

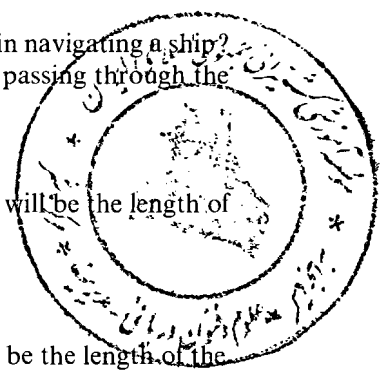
Questions

1. Explain the following terms: (a) Small circle, (b) great circle, (c) spherical angle, (d) spherical triangle.
2. How is a spherical angle measured?
3. In what terms is the length of the side of a spherical triangle expressed? Is the sum of the three angles in all spherical triangles the same?
4. What is the difference between a statute mile and a nautical mile? Why is the nautical mile not strictly the same length in all Latitudes?
5. What is the difference between a knot and a nautical mile? A ship goes from *A* to *B*, 27 miles, in three hours, what is her speed?
6. How many feet are in a fathom, a cable, a statute mile and a nautical mile?
7. Define: (a) Latitude, (b) Difference of Latitude, (c) Longitude, (d) Departure.
8. What is the distinction between the angular Latitude and the lineal Latitude of a place?
9. Write down the D. Lat. and D. Long. between *A* (12° N, 176° E) and *B* (13° S, 169° W).
10. Distinguish clearly between D. Long. and Departure.
11. Prove that $\cos \text{Lat.} = \dfrac{\text{Dep.}}{\text{D. Long.}}$.
12. Describe the Traverse Table. Draw a triangle and show the relationship between Course, Distance, D. Lat. and Dep.
13. How may a right-angled triangle be utilised to show the ratio between D. Long. and Dep.?
14. Explain the difference between plane sailing and parallel sailing.
15. A ship sails due East 90 miles in Lat. 50° 30′N, find the D. Long. by inspection.
16. The top of a tower subtends a vertical sextant angle of 32° at a point on a level with, and 50 feet from, its base. Find height of the tower by inspection.
17. Name the circles which separate the Frigid, Temperature and Torrid Zones and give their Latitudes.
18. What is a rhumb line? How would the rhumb line between two places differing both in Latitude and Longitude appear on a Mercator chart and on a globe?
19. How many miles per day through space is a place on the equator carried by the earth's rotation?
20. In what Latitude is the speed of rotation on the earth's surface exactly half the equatorial speed?
21. Fill in the missing quantities by inspection of the Traverse Table.

	Lat.	Dep.	D. Long.
(a)	40° N	—	180′
(b)	56° N	100 miles	—
(c)	—	40 miles	1° 30′
(d)	$38\frac{1}{2}$° S	36 miles	—

22. A ship sails 1530 miles due North from the equator, what Latitude does she reach?
23. Why is it necessary to use the Mean Latitude when finding the Departure between two places in plane sailing?
24. Find by inspection the course and distance from *A* (38° N, 47° W) to *B* (40° N, 40° W).
25. A ship sails from *A* (35° S, 18° 20′ E) to *B* (37° S, 21° 10′ E), find by inspection the course and distance made good.
26. Explain the terms (a) D.R. position, (b) Obs. Pos., (c) Set and Drift of current.

27. Why is a globe of the world not used in navigating a ship?
28. Two maps of a part of the world are placed before you, one a gnomonic projection, the other a Mercator projection. What special differences would distinguish one from the other?
29. What renders the Mercator chart very convenient for use in navigation?
30. Where would you look for the following scales on a Mercator chart; (a) Latitude, (b) Longitude, (c) Distance?
31. Define Meridional Parts and Difference of Meridional Parts.
32. Why is $\frac{\text{D. Long}}{\text{D.M.P.}} = \frac{\text{Dep.}}{\text{D. Lat.}}$?
    Draw a figure to show the equality of these ratios.
33. How and where should the distance between two places in different Latitudes be measured on the Mercator chart to ensure accuracy?
34. What is the difference between the rhumb track and the great circle track joining two places?
35. A ship is heading directly for her destination which lies 1200 miles dead ahead of her, what track is she on?
36. What great advantage has the rhumb track over the great circle track in navigating a ship?
37. Where is the vertex of a great circle? What is the ship's course when passing through the vertex along a great circle track?
38. How does the sweep of a great circle track appear on a chart?
39. Why cannot the polar regions be shown on a Mercator chart?
40. If 1′ of Longitude on a Mercator chart measures 0·5 of an inch, what will be the length of 1′ of Latitude in 40° N?



$$\text{Lat. scale} = \text{Long. scale} \times \text{sec. Lat.}$$

41. If 1° of Longitude on a Mercator chart is equal to 6 inches, what will be the length of the degree between (a) the parallels of 30° N and 31° N, and (b) between the parallels of 63° S and 54° S?
42. On a Mercator chart one mile of distance measures 1·2 inches in Lat. 60° N, what will 1′ of Longitude measure?
43. On the equator a small circle of radius 20° is drawn, how would it appear when drawn on a Mercator chart?
44. You are in Lat. 60° N and there is a vessel 100 miles East of you and another 100 miles West of you; would their bearings be reciprocal of each other?
45. When is the initial course of a great circle the same name as the final course, and when is it not the same name?
46. A steamer in a high N Lat. continues to steer 045°, unaffected by wind or current. How will her track appear if plotted on a Mercator chart and on a gnomonic chart?
47. If D.M.P. = D. Lat. × sec lat. calculate without reference to the table of meridional parts the D.M.P. between Lats. 45° and 60°.
48. Write out the factors of each of the sailings and give the relationship between plane, parallel and Mercator sailings.
49. Define mean latitude.
50. Explain why it is generally preferable to use the Mercator Sailing rather than the Mean Latitude Sailing.

Correcting Distances Obtained by Mercator or Mean Latitude Sailings

No method of distance calculation gives entirely perfect results. The following distance correction factor tables, devised by Capt. P. R. Lewis, R.D., R.N.R. (Retd.), provide a most helpful method for obtaining more satisfactory results.

Distance Correction Factor Tables

Table 1 Mercatorial Distance Factor

Mean Lat.	Difference of Latitude					
	1°	10°	20°	30°	40°	50°
0°	0·9950	51	52	53	56	59
5°	51	51	52	54	56	59
10°	53	54	55	56	58	61
15°	0·9957	57	58	60	62	64
20°	62	62	63	64	66	69
25°	69	69	69	71	72	74
30°	0·9976	76	77	77	79	80
35°	84	84	84	85	86	87
40°	93	93	93	93	94	94
45°	1·0001	01	01	01	01	01
50°	10	10	10	10	09	—
55°	19	19	18	18	—	—
60°	1·0027	27	26	—	—	—

Table 2 Mean Latitude Factor

Mean Lat.	Difference of Latitude			
	0°	2°	4°	6°
0°	1·0018	18	16	14
5°	19	18	17	14
10°	19	19	17	15
15°	1·0021	20	18	15
20°	22	22	20	17
25°	25	24	22	18
30°	1·0027	26	24	19
35°	30	29	26	21
40°	33	31	28	21
45°	1·0035	34	29	22
50°	38	36	31	21
55°	41	39	31	18
60°	1·0044	40	30	12

If the distance obtained by standard methods of calculation be multiplied by the appropriate factor the result will be given in international nautical miles of 1852 m (6076·12 ft).

Table 1 for Mercator's sailings.
Table 2 for Mean Latitude sailings.
The first column gives the factor in full; other columns have only the last two figures.
The following values have been used in compiling the tables:

$$\text{Earth's equatorial radius} = 6\,378{\cdot}39 \text{ km}$$

$$\text{Earth's compression} = \frac{1}{293{\cdot}465}$$

TEST PAPERS

Paper 1

Parallel Sailing

1. In latitude 54° 20′ S, departure 193 miles, course 090° T. Find the D. Long.
2. Latitude 47° 13′ N, D. Long. 5° 43·5′ E. Find the departure.
3. D. Long. 6° 24′ and corresponding departure 219 miles. Find the latitude.
4. From Latitude 60° N, Long. 30° W a vessel steams 090° T for a distance of 74 miles. In what longitude did she arrive.
5. From Latitude 65° 33′ S, Longitude 10° W, a vessel steams 270° T until she reaches Longitude 11° 38′ W. Find the distance steamed.
6. A vessel sails along a parallel of latitude for a distance of 492 miles altering her longitude by 11° 24′. Find the latitude.
7. At what speed does the earth rotate at Greenwich in Latitude 51° 28½′ N.
8. Two vessels are 200 miles apart at the Equator and both steam 000° T until they reach the parallel of 40° N. What is their distance apart, and how far did each steam?
9. Two vessels are 100 miles apart in latitude 28° 10′ N and both steam 180° T until they are 60 miles apart on the same parallel. How far did each steam?
10. The departure position being 55° N, 40° W a vessel makes the following courses: 090° T for 500 miles; 000° T for 400′; 270°T for 500 miles; 180° T for 400 miles. Find the final position.

Paper 2

Mean Latitude Sailing

1. Find the true course and distance

From	14° 28′ N	65° 15′ E
To	18° 20′ N	72° 17′ E

2. Find the true course and distance

From	12° 48′ S	172° 50′ W
To	16° 05′ S	179° 07′ W

3. A vessel steams on a course of 353° T for 175 miles from Lat. 37° 35′ N, Long. 09° 15′ W. Find the arrival position.

4. A vessel steams on a course of 207° T for 390 miles from Lat. 15° 55′ S, Long. 57° 50′ E. Find the arrival position.

Paper 3

Use of Traverse Tables

In the following examples find the D. Lat. and Departure.

1. Co. 330° T distance 250 miles.
2. 247° T 63 miles.
3. 075° T 375 miles.
4. 158° T 15 miles.

In the following examples find the True Course and Distance made good.

5. D. Lat. 257′ N Dep. 173·3 W.
6. 13·5′ S 110·2 E.
7. 190·3′ N 52·8 E.
8. 53·7′ S 264·1 W.

Convert Departure into D. Long. and vice versa.

9. Mean Lat. 45° S D. Long. 203′ W.
10. 51° N Dep. 163·3 E.
11. $21\frac{1}{2}$° N Dep. 301·5 W.
12. 50° N D. Long. 85′ W.

Paper 4

Set and Drift from Traverse Tables

1. DR 33° 41′ N, 25° 02′ E. Obs. Pos. 33° 43′ N, 25° 17′ E. Find the set and drift of the current.
2. DR 15° 14′ S, 90° 37′ E. Obs. Pos. 15° 08′ S, 90° 25′ E. Find the set and drift of the current.
3. From an observed position 00° 33′ S, 8° 25′ W a vessel steers 137° T for 328 miles when she obtains a fix in position 4° 38′ S, 05° 40′ W. Find the set and drift experienced.
4. From a fix in Lat. 9° 47′ N, Long. 86° 21′ E a vessel steers 202° T for 153 miles. It is estimated that a SW'ly wind is causing 5° leeway. At the end of this run she obtains a fix in position 7° 51′ N, 85° 42′ E. Find the set and drift experienced.

Paper 5

Mercator Sailings (NB: Use Meridional parts for the Spheroid)

Find the True and Compass courses and the distance by Mercator sailing in each of the following.

1. From 49° 53′ N To 48° 28′ N
   06° 19′ W 05° 03′ W
   Variation 15° W, Deviation 17° W.
2. From 35° 51′ S To 21° 15′ N
   158° 54′ E 157° 58′ W
   Variation 13° E, Deviation 17° W.

3. From 34° 22′ S To 15° 55′ S
   18° 29′ E 05° 43′ W
   Variation 24° W, Deviation 12° E.
4. From Latitude 50° S a vessel steers 140° T until she changes her longitude by 15°. In what latitude will she arrive and what distance has she made good?
5. A ship steams 650 miles on a course between South and East, and makes a D.M.P. of 400. If the departure position was on the Greenwich meridian in latitude 45° S, find the arrival position.
6. A vessel in latitude 48° 15′ S, longitude 178° W steers a course between South and West for a distance of 902 miles when she finds herself in latitude 58° 35′ S. Find the course steered and the longitude reached.
7. Calculate the DR position after steering 071° T for 577 miles from 32° 49′ N, 155° 27′ W. Also calculate the set and drift experienced if the Obs. Pos. at the end of the run is 35° 49′ N, 144° 17′ W.
8. A vessel steers 040° T for 2300 miles from 39° 37′ S, 47° 28′ N. Find the arrival position.
9. Calculate the course and distance

From	50° 00′ N	45° 00′ W
To	50° 31′ N	13° 49′ W

10. Calculate the course and distance

From	12° 35′ N	54° 30′ E
To	18° 53′ N	72° 48′ E

11. Calculate the course and distance

From	2° 53′ S	23° 20′ W
To	0° 54′ N	29° 26′ W

12. Calculate the course and distance

From	33° 03′ S	71° 42′ W
To	36° 53′ S	174° 51′ E

Answers in rear *Answer Section.*

Chapter 8

The Compass

To the navigator putting to sea from the end of a buoyed channel the horizon appears as an unbroken line separating sea from sky. There are no identifying marks which enable him to head his ship in a particular direction and, in consequence, he requires a datum direction as a reference. The datum most easily used is the direction of the True Meridian which lies North–South at the navigator's position. An instrument which indicates the direction of True North (or nearly so), and which can be used to head a ship in any desired direction, is the Gyro Compass.

Gyro Compass

A gyro compass consists of a small electrically driven gyroscope which has three degrees of freedom. These are, freedom to spin about the spin axis, freedom to tilt about an horizontal

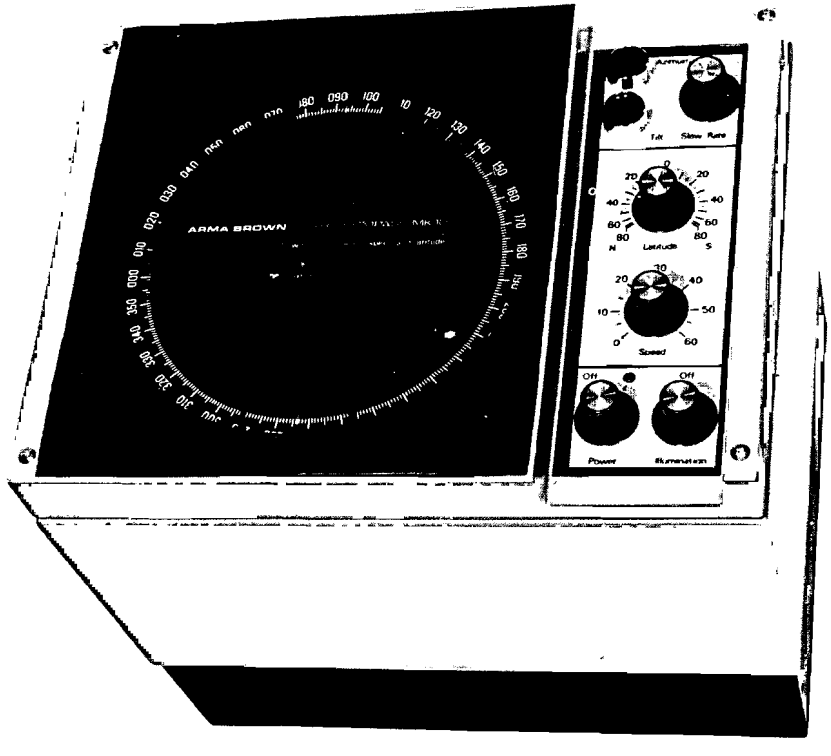


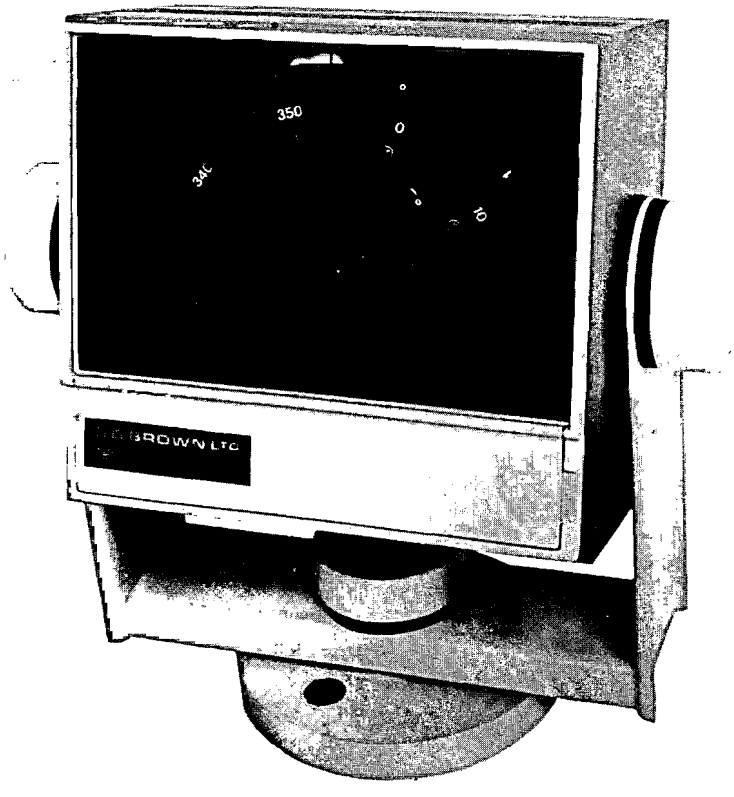
Figure 1. Master Gyro Compass (*by S. G. Brown, Watford*)

axis and freedom to drift and turn in azimuth about a vertical axis. If such a gyroscope is supported with its spin axis approximately North–South and horizontal, its spin axis will remain fixed in space due to gyroscopic inertia. To an observer and due to the earth's rotation, the spin axis will appear to tilt, or tilt and drift, as if following the path traced out by a heavenly body. By applying the force due to gravity the spin axis can be made to precess towards the true meridian and by suitable damping settle in (or close to) the meridian. The gyroscope has now become a compass whose spin axis continuously seeks and settles in, or close to, the true meridian.

In some gyro-compasses, due to the method of damping, it is necessary to apply a correction based on the ship's latitude and in all gyro-compasses a correction must be made for an error which depends on the ship's course, speed and latitude. These errors are either allowed for electrically or by entering a graph or table to obtain the correction to apply.

Follow-Up Unit

A Master Gyro-Compass can be placed on the bridge and its Follow-Up Unit made to drive a Steering Repeater (Fig. 2), a Bearing Repeater (Fig. 3) and to supply gyro stabilisation to the Radio Direction Finder and Radar and heading information to a Satellite Navigation System. It can also drive a Course-recorder (Fig. 4) and acts as the heart of an Automatic Pilot for steering the ship.



The Steering Repeater provides an easily read, accurate datum of ship's head for the helmsman to steer by.

The instrument is driven from a compass retransmission system by a Stepper Motor. It can also be driven by a transmitting magnetic compass having compatible retransmission facilities.

Figure 2. Steering Repeater

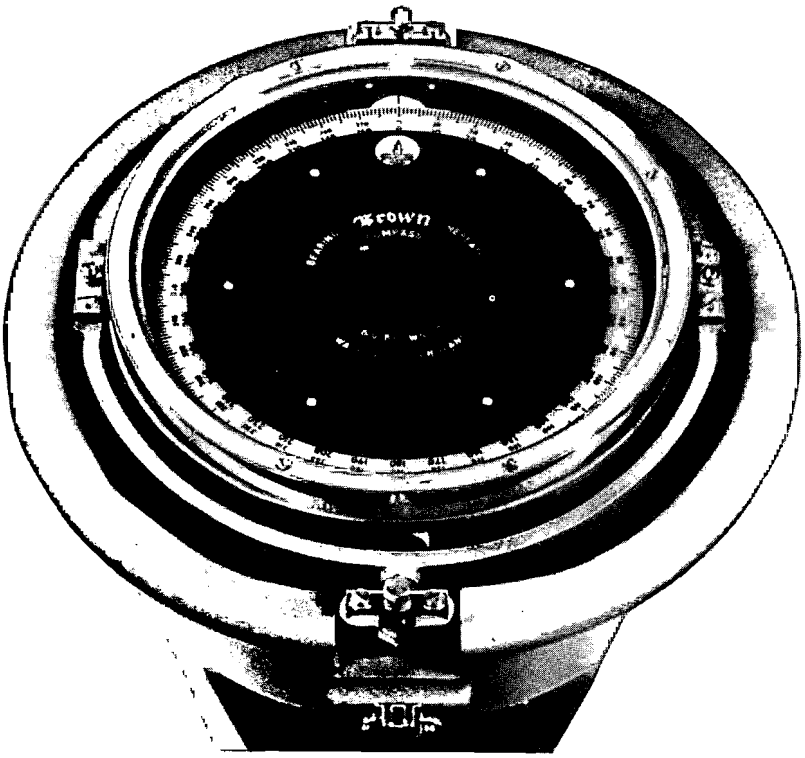
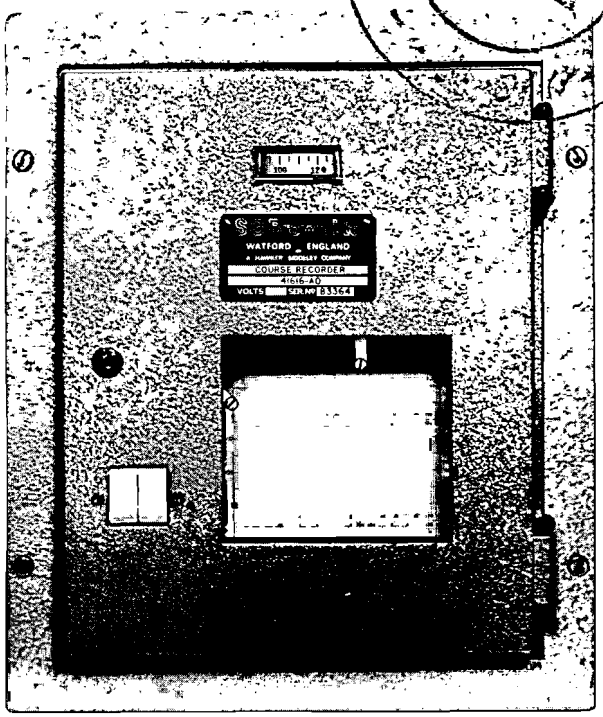


Figure 3. Bearing Repeater

Gimbal mounted, this instrument is specially constructed to enable accurate bearings to be taken. It can be fitted on the bridge wings, or within a covered area. The card is fully visible and the bezel locates an azimuth mirror or alidade bar sight.

This bearing repeater is driven from a compass retransmission system by an 'S' type Stepper Motor.



Driven from the Master Gyro Compass via 'S' Type step-by-step transmission, the Course Recorder provides an accurate record of the courses steered. A clockwork mechanism drives the paper chart on which these details are recorded.

Figure 4. Course Recorder

Magnetic Compass

A Magnetic Compass is fitted on all ships for setting the ship's course when starting the Gyro-Compass and for use as a reliable reserve compass in case the gyro-compass fails. The compass bowl (Fig. 5) is mounted in gimbals in a binnacle (Fig. 6) and sited on the ship's fore and aft centre line above the Wheel House. This compass is referred to as the Standard Compass and

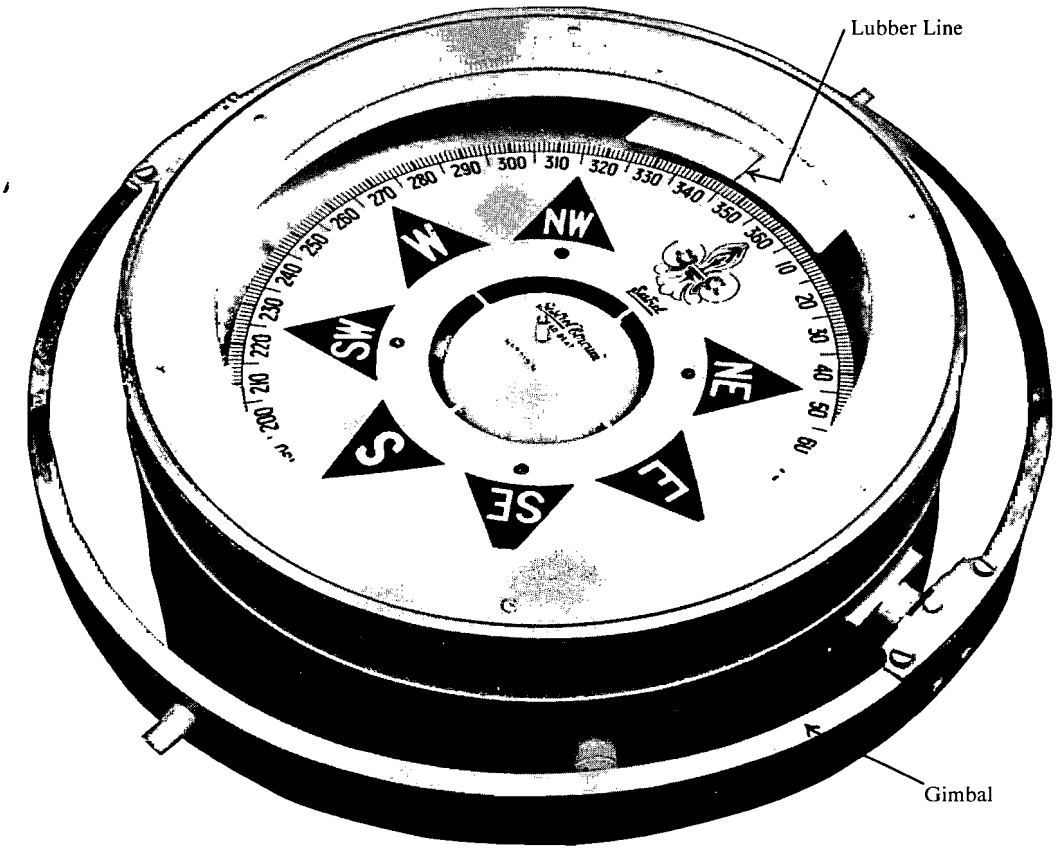


Figure 5. Reflector Compass Bowl (*by Henry Browne & Son Ltd., England*)

can be used to take compass bearings. A second magnetic compass, the Steering Compass, is provided for the helmsman at the Steering Position.

A cost effective and space saving alternative is to fit a magnetic Reflector Compass with a Reflector Unit which projects down into the Wheel House in way of the Steering Position. This arrangement removes the need for a duplicate steering compass.

The reflector unit consists of a telescopic Reflector Tube which is fitted with a focussing lens, an adjustable moisture sealed mirror and a detachable Anti-Glare Shield. A "D" shaped lens (located below the compass) magnifies the forward part of the compass card which lies 30–40° either side of the lubber line. The image is then focussed by the focussing lens and reflected via the mirror to the helmsman. When not required (as sometimes occurs in pilotage

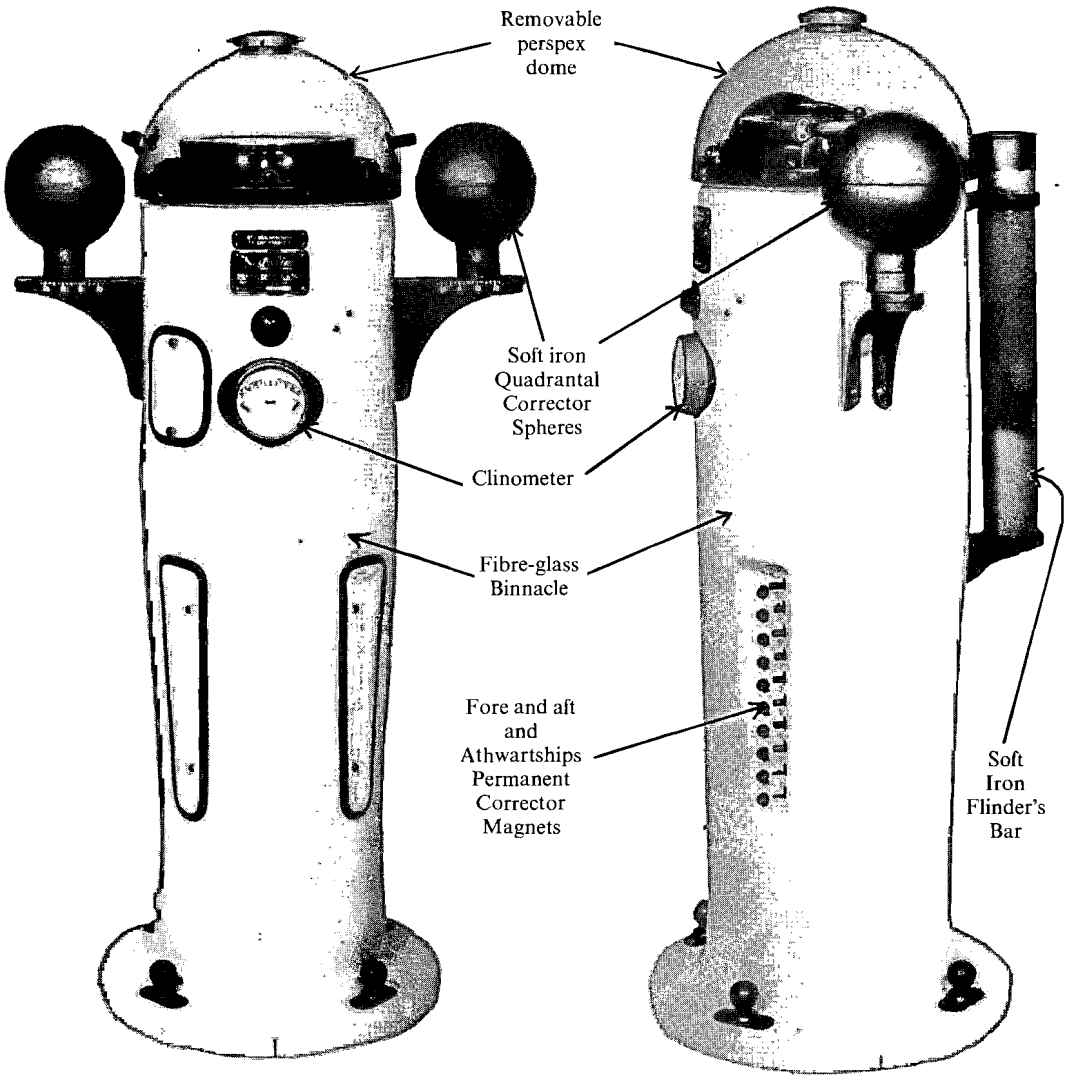


Figure 6. Magnetic Reflector Compass Binnacle (Fibre Glass) (*by Henry Browne & Son Ltd., England*)

waters) the reflector tube telescopes up into the binnacle and provides the helmsman with an uninterrupted view ahead.

The Reflector Compass and Reflector Unit are shown in Fig. 7.

A third magnetic compass, mounted on a pedestal, may be fitted at the Emergency Steering Position aft.

The sensitive part of a compass is the glass melamine card graduated 0° to 360°, fitted with a circular ring magnet and mounted on a pivot in the liquid filled bowl. The card is designed to remain horizontal and the direction of the ship's fore and aft line, the Lubber Line, is indicated by a mark or wire within the bowl as shown in Fig. 5.

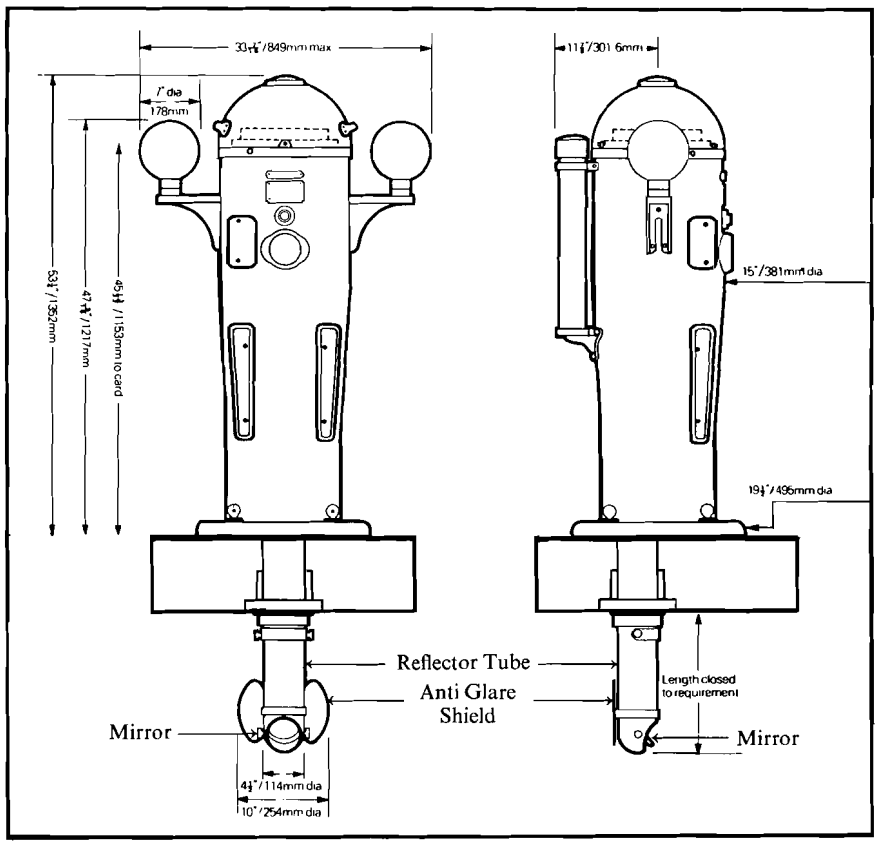


Figure 7. Reflector Compass and Reflector Unit (*Sestreline Series 2*)

Binnacle, Azimuth Circle and Correctors

The hardwood or fibreglass binnacle shown in Fig. 6 supports the compass about one metre above the deck and a removable brass or perspex hood is fitted to protect it from the weather. An Azimuth Circle is fitted on the top of the bowl to enable bearings to be taken. The North–South line of the card takes up the direction of the resultant of the Earth's magnetic field at the ship's position and the magnetic field of the ship's structure for the ship's heading. Correctors required to reduce the magnetic effect of the ship's structure at the compass position are attached to the binnacle. Provision is made for a 610 mm by 76 mm diameter soft iron Flinders Bar to be fitted on the fore side with a bracket each side to support the soft iron Quadrantal Corrector Spheres. Doors can be opened on the after side to allow access to the row of parallel holes which lie fore and aft and athwartships to take the horizontal permanent corrector magnets and also to the vertical heeling error corrector magnets in their movable "bucket".

Use of the Azimuth Circle (Bearing Circle)

The Azimuth Circle is fitted with an Azimuth Mirror which is a total internal reflecting prism

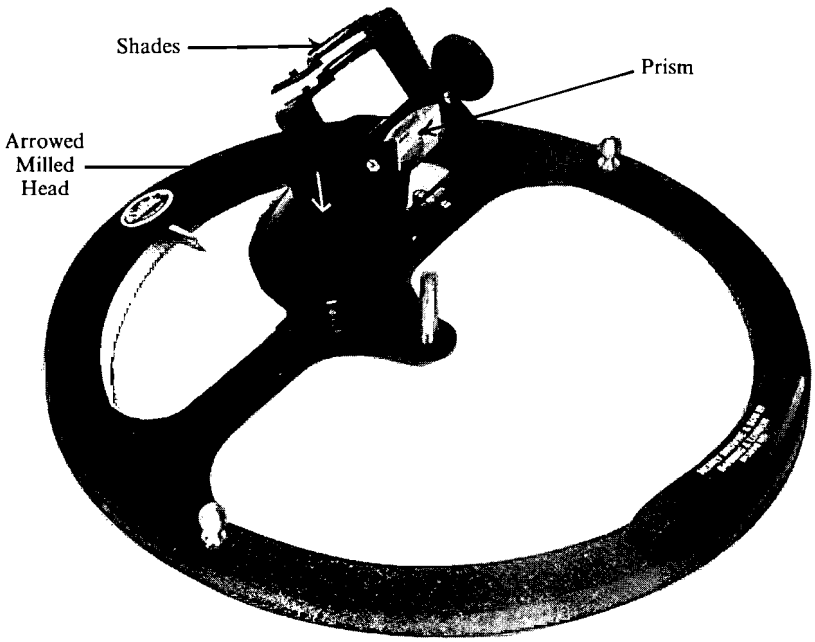


Figure 8. Azimuth or Bearing Circle (*by Henry Browne & Son Ltd., England*)

and which can be rotated on its horizontal axis by means of the milled head marked with an arrow. By directing the mirror towards a celestial body, looking down the tube at the compass card and turning the prism in the arrow up position until the reflected image of the body is brought down to the card, the bearing can be read off. In order to read the compass card a magnifying lens is fitted at the bottom of the tube. Shades, for use when taking a bearing of the sun, are also fitted. The bearing of an object on the horizon is taken by looking directly at the object across the top of the prism when in the arrow down position and reading the bearing where the reflected image of the compass card in the prism is seen in line with the object. The Azimuth Circle is shown in Fig. 8.

Transmitting Magnetic Compass (T.M.C.)

By fitting and accurately positioning a flux detector unit beneath the magnetic compass bowl information about the angular displacement between the North–South axis of the compass card and the ship's fore and aft line, i.e. the ship's heading, can be supplied to a Magnetic Compass Repeater at the steering position. Heading information can also be supplied to stabilise the radar and radio direction finder and provide a reference for the auto-pilot. By means of a suitable distribution box a T.M.C. can be connected (as shown in Fig. 9) as a Gyro Back-Up System to provide the ship's heading to gyro repeaters in the event of gyro failure.

The Pelorus is a portable instrument auxiliary to the compass. It is a circular plate, graduated like a compass card and mounted on a vertical axis so that it can be rotated freely by hand. It is fitted with a lubber line and sight vanes, and at first glance seems almost the same as a compass. When the plate is turned by hand so that the lubber line of the pelorus indicates the same direction as the ship's compass, then, for the time being, bearings read from the

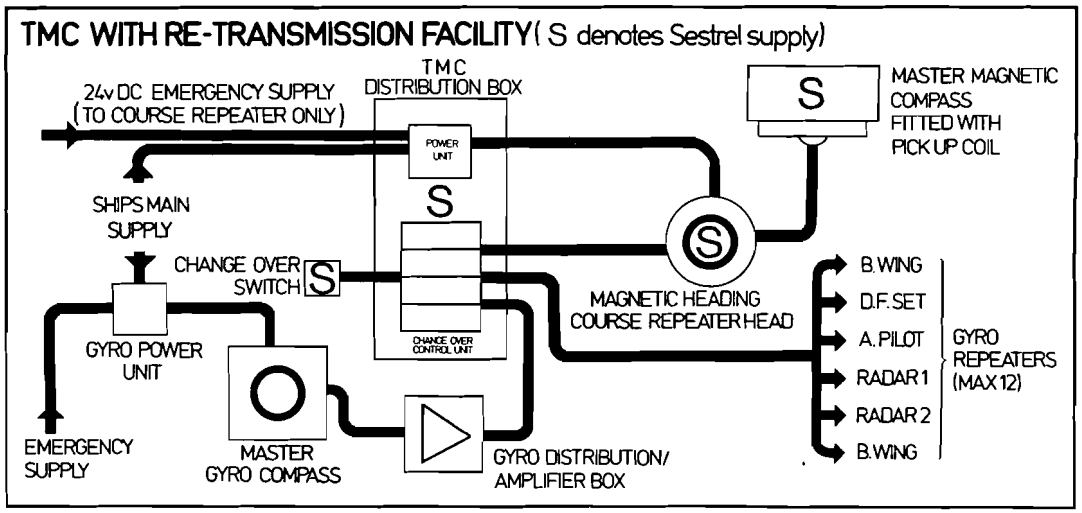


Figure 9. Wiring diagram for Transmitting Magnetic Compass connected for back-up to Gyro Compass.

pelorus will be the same as if read from the compass. When the direction of the ship's head changes, the plate of the pelorus is turned the same amount by hand, so that it may indicate the same direction as the compass. It is used to obtain bearings of an object that may be shut out from view at the compass position by the funnel and deck erections. It is especially useful when "swinging" ship to adjust compasses. (See page 334.)

The Compass Needle as a Magnet

In Fig. 11, the arrow head indicates the North or red end of the compass needle. Place a magnet on a table and pass a freely suspended needle over it from end to end. The North or red end of the needle is attracted by the South or blue pole of the magnet, and the South end of the needle is equally attracted by the red pole of the magnet. When held midway between the poles the needle lies horizontal, but on approaching the ends of the magnet the needle points more and more downwards until eventually it stands vertical when held over the poles. At any position in the field of the magnet, a freely suspended needle will always come to rest when pointing towards the pole of the magnet.

Analogy Between a Magnet and the Earth

Practically the same features appear on the earth's surface when a freely suspended needle is passed from pole to pole. The phenomena are similar to what would be expected if a huge magnet were situated inside the earth, nearly coincident with its axis of rotation, and flooding the North hemisphere with blue or South polarity and the South hemisphere with red or North polarity. Near the geographical equator the needle takes up a position parallel to the earth's surface. On approaching the poles, the North or red end of the needle dips downwards in the Northern hemisphere, but points upwards in the South hemisphere, making an ever-increasing angle with the plane of the horizon until eventually the needle stands upright over an area covering some 50 miles or more of the earth's surface. This region is called the magnetic pole, the accepted positions being: North pole about Lat. 70° N, Long. 97° W; South pole about Lat. 72° S, Long. 154° E.

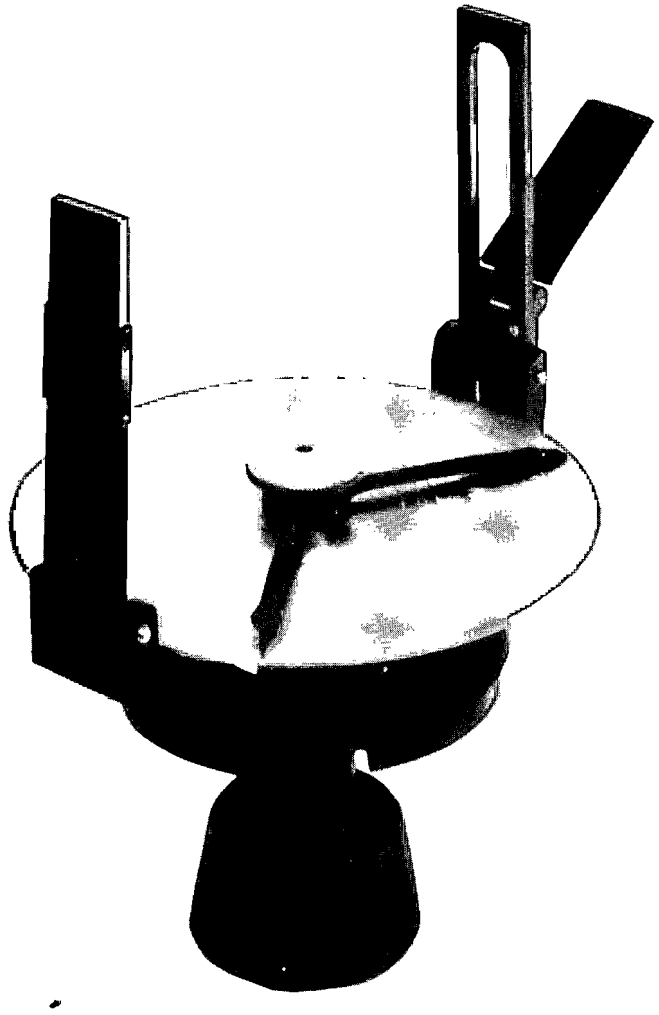


Figure 10. Pelorus (*by Henry Browne & Son Ltd., England*)

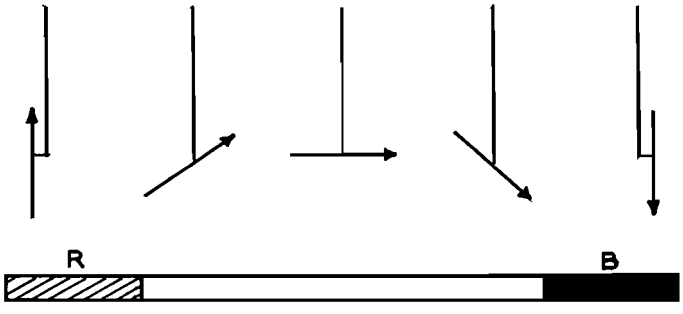


Figure 11.

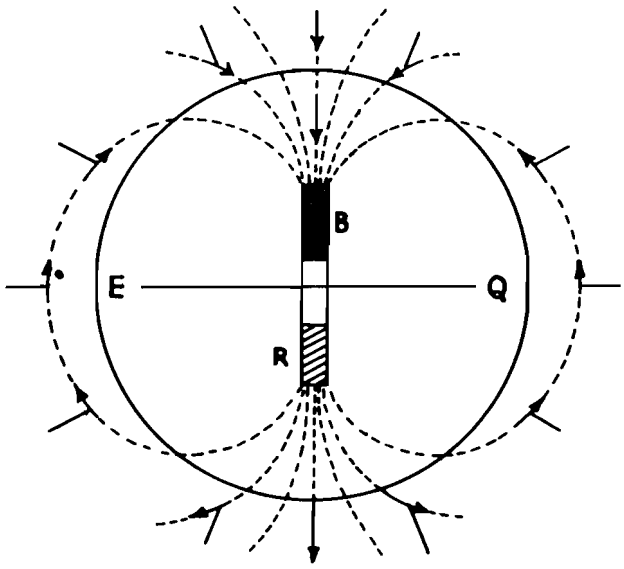


Figure 12.

The Magnetic Equator

A curve passing through places where there is no dip or inclination of the needle is called the magnetic equator. It is the dividing line between red and blue polarities of the earth. The magnetic equator crosses the geographical equator from South to North in about 12° West Longitude, and tracing it to the Eastward, it reaches as far as 10° North Latitude passing near Cape Guardafui. It then converges slowly with the geographical equator, which it re-crosses in about 170° West Longitude, and attains its maximum South Latitude, 14° in Brazil, when it again bends northward and rejoins the equator in 12° West. *See* Chart I.

VARIATION AND DEVIATION

(Refer also to Chapter 12, Chartwork, pages 324–343.)

The direction from any position on the earth's surface to the geographical pole is represented by a true meridian.

The direction taken up by the longitudinal axis of a compass needle when under the influence of the earth's normal force only is called the magnetic meridian.

Variation

At any place the angle contained between the true and magnetic meridians is the variation at that place. It is caused by the geographical and magnetic poles not coinciding.

The amount of variation depends on the parallactic angle subtended by the magnetic and geographical poles and varies in navigable Latitudes from 90° E to 90° W, being named East or West according to whether the needle points respectively to the right or left of the true meridian.

In Fig. 13, the variation at place *A* is 0°, at *B* it is Easterly, at *C* Westerly, at *D*, a position

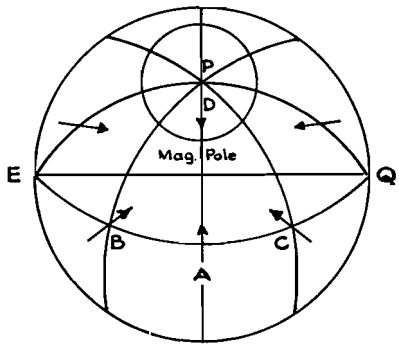


Figure 13.

between the two poles, the variation is 180°, the needle being turned end for end, so that when making Southing the ship's head would appear to be Northerly by the compass.

Variation Changes

The variation in addition to being different at different places is subject to a gradual change, the amount in Great Britain being at the rate of 8′ annually. This secular change is probably due to the magnetic poles changing their position relatively to the geographical poles, e.g. the South point of Africa, L'Agulhas ("The Needle"), was so named by the Portuguese who discovered it from the fact that, at this position, the compass needle pointed true North. At present, in the same position, the variation is 28° W. Refer also to page 337.

On the Clyde, 260 years ago, the variation was 0°, today it is 9° W.

The Variation Chart

The Admiralty issues a special chart which shows curves drawn through places having the same variation. These irregular curves are named isogonic lines, from the Greek word *isos* meaning equal, and *gonia* an angle. Refer to Chart 1, page 216 and Page 339.

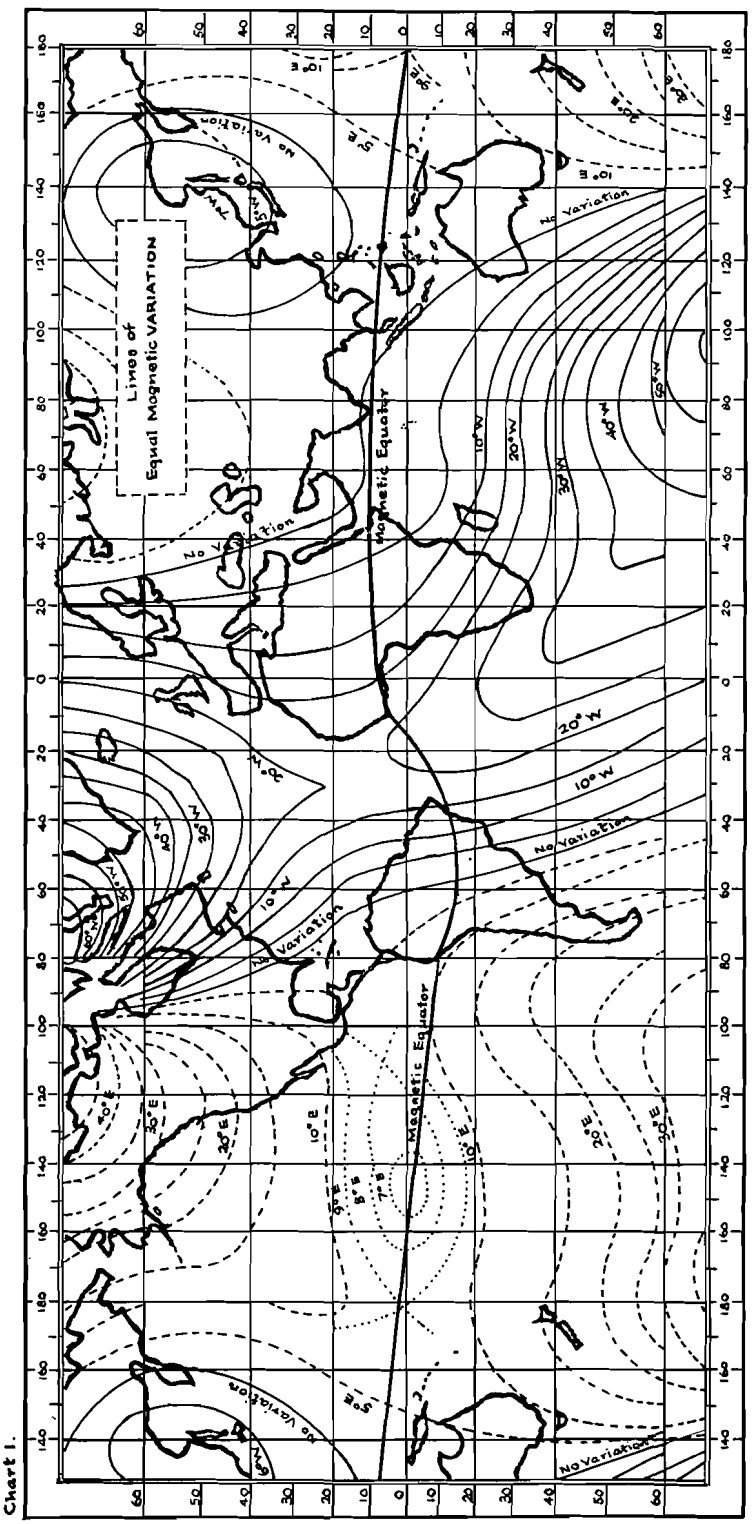
This chart is specially useful in the practice of navigation because the variation may change rapidly when the ship is sailing across the lines, especially when the course lies at right angles to them, and, as prospective changes in the variation are readily got from the chart, the compass course can be altered correspondingly from time to time.

It will be noted on examining the chart that the variation changes rapidly on the trans-Atlantic tracks, particularly in the English Channel and its approaches, also on the East Coast of the United States, the Brazilian Coast, and the West Coast of Australia.

Deviation

Deviation is due to the magnetism in the ship **and its value changes with every new direction given to the ship's head.** It is the angular deflection of the compass needle to one side or the other of the magnetic meridian. The deviation can only be ascertained by practical experiment, and a **Table of Deviations** is compiled by steadying the ship's head on each point, or on every alternate point of the compass, the operation being known as "swinging" ship, and noting the difference between the bearing of a distant object by the compass and its magnetic bearing which, of course, must be determined independently. The amount of

CHART I—LINES OF VARIATION



deviation for each heading is recorded in the form of a Table, the deviations for intermediate headings being found by interpolation. Refer to pages 327 and 330.

A compass adjuster when "swinging" ship reduces the deviations as much as possible but he cannot eliminate them entirely, nor can he guarantee that his adjustments will remain effective for any length of time, hence the reason for constant vigilance with regard to the errors of the compass.

The deviation is subject to change when the course is altered; when the ship heels over: with a change of cargo if containing iron; after repairs or when the ship is subjected to severe concussion. The magnetic condition of a new ship alters considerably at first and consequently the deviation changes, as it does also with lapse of time and when the ship changes her Latitude. Deviation is also dealt with on pages 325, 333 and 342.

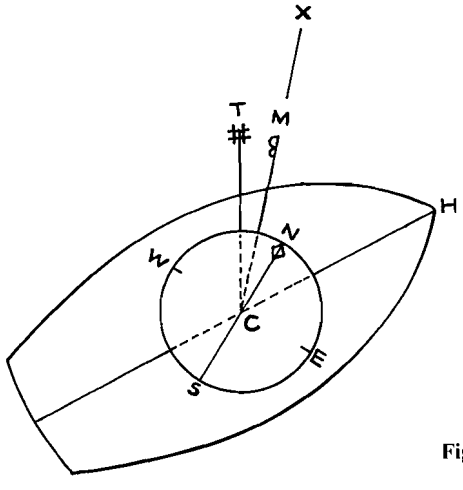


Figure 14.

Definitions In Fig. 14.

T	represents the True Meridian
M	the Magnetic Meridian
N	the Compass North
H	the Ship's Head
C	the compass
NESW	the compass card.

Variation, is the angle contained between the true and magnetic meridians (angle *TCM*).

Var. = 10° E.

Deviation, is the angle between the magnetic meridian and the compass needle (angle *MCN*).

Dev. = 20° E.

Compass Error, is the combined effect of **Var.** and **Dev.** It is the angle between the true meridian and the compass needle (angle *TCN*).

Error = 30° E.

Compass Course, is the angle between the compass North and ship's head (angle *NCH*).

030° C in fig.

Magnetic Course, is the angle between the magnetic North and ship's head (angle MCH).

050° M.

True Course, is the angle between the true North and ship's head (angle TCH).

060° T.

Given	Compass course	030° C	$\angle NCH$
	Deviation	20° E	$\angle MCN$
	Magnetic course	050° M	$\angle MCH$
	Variation	10° E	$\angle TCM$
	True course	060° T	$\angle TCH$

Rules for Naming Deviation

Deviation is caused by the magnetic condition of the ship, her equipment and cargo.

Deviation is named East when the compass North is deflected to the right of the magnetic North, and West when deflected to the left.

The deviation alters with every new direction given to the ship's head, it is necessary, to find the amount on each course by steadying the ship's head on successive points and noting the angle between the known magnetic bearing of a distant object and its bearing by compass.

The deviation is named East when the magnetic bearing lies to the right of the compass bearing, and West when to the left.

In Fig. 14, the compass North is deflected 20° to the right of magnetic North, hence the deviation is East. If X be the direction of a distant object then its magnetic bearing is N, and its compass bearing 340° C, the deviation is East, because the magnetic bearing of the object lies to the right of its bearing indicated by compass, ie 360° lies to the right of 340°.

Construct a figure showing course 200° C, Dev. 25° E, Var. 15° W.

Draw in a true meridian TT'. Lay off MM', the magnetic meridian, so that $\angle TCM$, the variation, is 15° W of true North. Lay off NCS, the compass needle, so that $\angle MCN$, the deviation, is 25° E of magnetic North. Draw in a compass and a deck plan to make the illustration more realistic.

Compass Co.	200° C	$\angle NCH$
Deviation	25° E	$\angle MCN$
Magnetic Co.	225° M	$\angle MCH$
Variation	15° W	$\angle TCM = T'CM'$
True Co.	210° T	$\angle TCH$

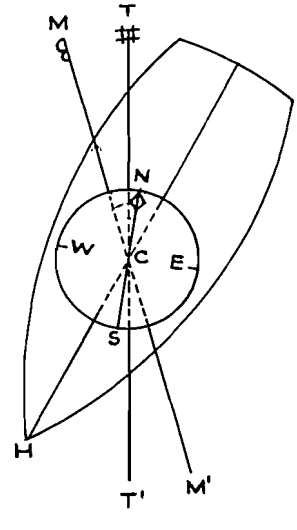


Figure 15.

Exercise 1

Draw figures illustrating the following information.

1. Var. 10° W, Dev. 15° W, Ship's Head 315° *C.*
2. Var. 30° E, Dev. 10° W, Ship's Head 040° *C.*
3. Var. 15° E, Dev. 30° W, Ship's Head 180° *C.*
4. Var. 10° W, Dev. 25° E, Ship's Head 210° *C.*

CORRECTION OF COURSES

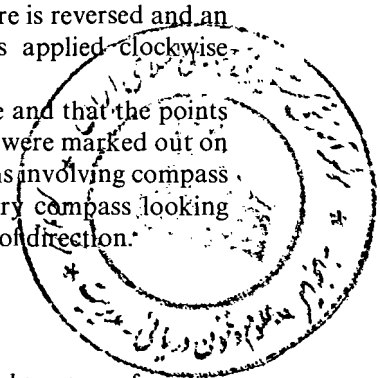
(Refer also to pages 324–326.)

The rules for converting Compass Courses to True Courses are exactly the same as those for converting Compass Bearings to True Bearings.

It should be made quite clear that naming deviation and variation East or West does not mean going East or going West, but simply that a compass course, or bearing, is converted into its equivalent true course, or bearing, by applying the given error clockwise (additive), that is, right handed round the compass when it is named East, and anti-clockwise (subtractive), or left handed, when it is named West.

When obtaining a True Course from a Compass Course the procedure is reversed and an E'ly error is applied anti-clockwise (subtractive) and a W'ly error is applied clockwise (additive).

The student should imagine himself to be standing on a ship's bridge and that the points of the compass radiate outwards to the horizon, just as if a huge compass were marked out on the surface of the sea its circumference being the horizon. In all calculations involving compass corrections he must assume himself to be in the centre of this imaginary compass looking outwards in the direction indicated and, in short, he must develop a sense of direction.



How to Apply Variation, Deviation and Compass Error

If Variation and Deviation have the *same name add* them together, but *subtract* one from the other if they have *different names*. The result is Compass Error, which **always** has the same name as the greater of the two quantities (Variation and Deviation).

Apply Compass Error to the Compass Course, to find the True Course, by allowing:

Easterly error to the right
Westerly error to the left

when looking from the centre of the compass. (NB. Leeway (if present) is then applied to the True Course in order to find the water track.)

Mark the variation Plus (+) if it is named East and Minus (−) if it is named West; similarly mark the deviation (+) for Easterly and (−) for Westerly then the algebraic sum of the two gives the error of the compass as before and the sign of the error indicates whether it must be added to or subtracted from the compass course to find the true course.

When converting from Compass to True an E'ly error is always Plus and W'ly error is always Minus. When converting from True to Compass an E'ly error is always Minus and a W'ly error is always Plus. This is demonstrated in the following diagrams.

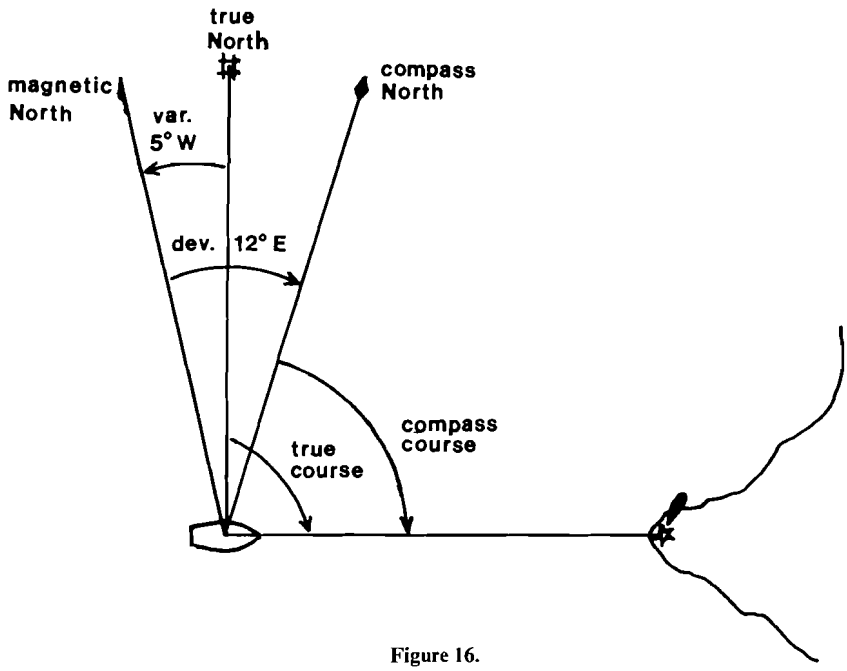


Figure 16.

True Course	090° T	Alternatively:	Variation	5° W
Variation (+)	5° W		Deviation	12° E
Magnetic Course	095° M		Compass Error	7° E
Deviation (−)	12° E			
Compass Course	083° C		True Course	090° T
			Compass Error (−)	7° E
			Compass Course	083° C

Compass Course	083° C
Compass Error (+)	7° E
True Course	090° T

It should be noted that neither True North nor the Point of Land change position or direction. What does change is the direction of Magnetic North (which changes with Variation) and Compass North (which changes with Deviation).

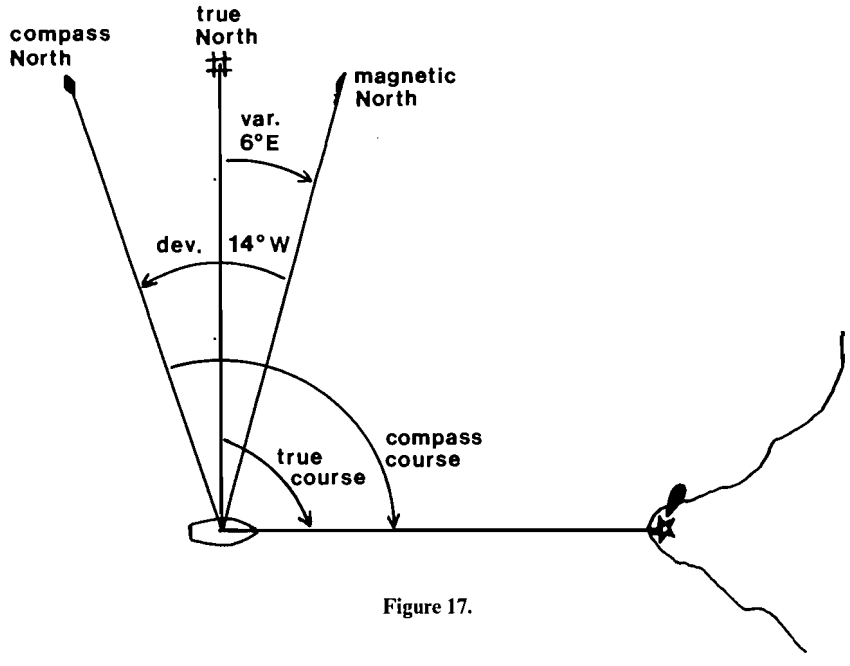


Figure 17.

True Course	090° T	Alternatively:	Variation	6° E
Variation (−)	6° E		Deviation	14° W
Magnetic Course	084° M		Compass Error	8° W
Deviation (+)	14° W			
Compass Course	098° C		True Course	090° T
			Compass Error (+)	8° W
			Compass Course	098° C

Compass Course	098° C
Compass Error (−)	8° W
True Course	090° T

Once again, note that the position of the Point of Land, to which the ship is headed does not change. Similarly, the direction of True North does not change. What does change is the direction of Magnetic North (which changes with Variation) and Compass North (which changes with Deviation).

It should also be noted that individual corrections for Variation and Deviation are always applied in the stated order as also shown on page 326 and summarised below:

True to Compass—True Co. ± Variation → Magnetic Co. ± Deviation → Compass Co.
Compass to True—Compass Co. ± Deviation → Magnetic Co. ± Variation → True Co.

Example 1

Correct the following Compass Courses for Variation and Deviation.

	Comp. Co.	Dev.	Var.	Comp. Error
1.	035° C	5° E	10° E	15° E
2.	140°	10° W	12° W	22° W
3.	198°	15° E	20° W	5° W
4.	300°	6° W	12° E	6° E

Compass Co.	035° C	140° C	198° C	300° C
Compass Error	(+)15° E	(−)22° W	(−)5° W	(+)6° E
True Co.	050° T	118° T	193° T	306° T

Leeway

In the following explanation it should be recalled that: Track is the path followed or to be followed between one position and another. This path may be that "over the ground" (Ground Track) or "through the water" (Water Track).

Leeway is the effect of wind in moving a ship bodily to leeward.

Leeway Angle is the angular difference between the Water Track and the ship's heading.

From the above, it can be seen that Leeway Angle is the amount which the ship makes to Leeward of the Intended Heading (course). To find the water track, the estimated Leeway Angle is always allowed *away* from the wind direction.

Sailing vessels make more leeway when close hauled than when on "a reach" and all vessels make more leeway when "light" than when loaded.

Leeway is clearly another factor which must be taken into account when trying to determine the ship's Water Track or Ground Track.

The allowance for leeway (the leeway angle) can seldom be more than an approximation. It is found by looking astern and estimating the angle between the ships fore and aft line and the wake. It is for this reason that yachtsmen often refer to the water track as the *Wake Course.*

In D.Tp. examinations, candidates are normally given the leeway angle. It is good practice to apply this quantity as a further (written) correction on the ship's course.

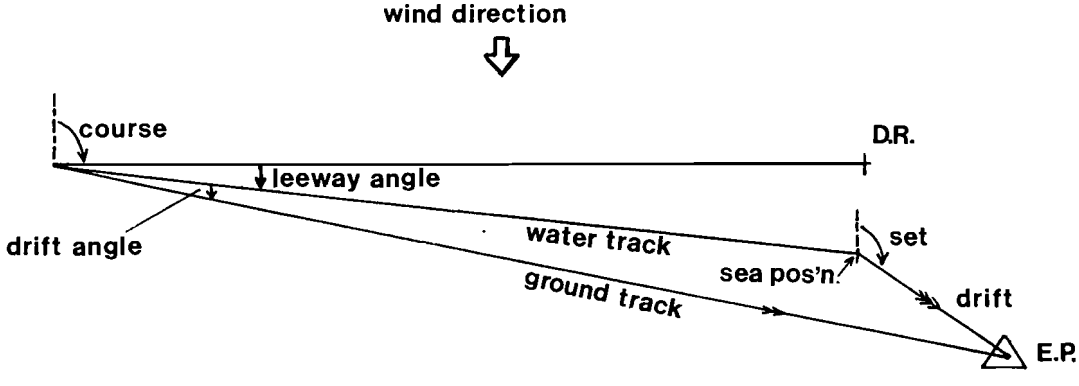


Figure 18.

How to Apply Leeway

A sketch is always the best way to positively decide which way to apply the allowance for leeway (Leeway Angle).

Face the direction of the ship's head, and if the wind is on your right hand side allow the given leeway to the left, and *vice versa.* Assume a course of 214° T, the wind SE and a leeway angle of 12°. Facing 214° T, the wind if SE would be on your **left** hand side, and the leeway must be allowed to the **right.** 12° to the right of 214° T is 226° T, which would be the true course corrected for leeway.

The correction for leeway is always **plus** when the wind is on the **port** side of the ship and **minus** when it is on the **starboard** side. In the above example, the wind is on the port side therefore the leeway is + 12° to 214° T giving 226° T.

Example 2

Convert the following True Courses into Compass Courses.

	True Co.	Variation	Deviation	Compass Error
1.	152° T	22° E	7° W	15° E
2.	327° T	18° W	2° E	16° W
3.	207° T	15° W	5° W	20° W
4.	341° T	28° W	6° E	22° W

True Co.	152° T	327° T	207° T	341° T
Compass Error	(−)15° E	(+)16° W	(+)20° W	(+)22° W
Compass Co.	137° C	343° C	227° C	003° C

Remember that when turning a Compass Course into a True Course the (+) and (−) signs are reversed according to the rule:

Error East—Compass Least
Error West—Compass Best

meaning that in the 360° notation the compass course is less than the true course when the error is easterly and *vice versa.*

Example 3

Find the true course made good, given a course 304° C, Variation 16° W, Deviation 7° E, wind NNE, and Leeway Angle 5°.

Course steered	304° C
Compass Error	(−)9° W
Course steered	295° T
Leeway	(−)5° T
Water Track	290° T

The variation being 16° W, and the deviation 7° E, we subtract one from the other giving us a Compass Error of 9° W. This error must be subtracted from the compass course and the result is the true direction of the ship's head. Facing the direction of the true course, 295° T, the wind would be on the right, the leeway (5°) must therefore be applied to the left or subtractive.

Example 4

Given a course 222° C, variation 18° E, deviation 9° E, wind NW, leeway angle 12°, find the true course.

Course	222° C
Compass Error	(+)27° E
Course	249° T
Leeway Angle	(−)12°
Water Track	237° T

The variation and the deviation having the same name are added giving us an error of 27° E. Easterly error is always added to the compass course to find the true course using the three figure notation. Looking in the direction of the true course, the NW wind is on the right-hand side, for which reason the leeway must be applied to the left or minus direction.

Example 5

Given a course of 096° C, variation 22° W, deviation 6° W, wind N by E, leeway angle 10°, find the true course made good.

Course	096° C
Compass Error	(−)28° W
Course steered	068° T
Leeway Angle	(+)10°
Water Track	078° T

The error is 28° W, and is therefore marked minus, and applied to the compass course to give the true direction of the ship's head. As the ship is steaming 068° T, the wind at N by E is on her port side, the leeway must therefore be applied to starboard of her course.

Example 6

Given a course of 020° C, variation 2° E, deviation 16° W, wind East, leeway angle 11°, find the true course.

Course steered	020° C
Compass Error	(−)14° W
Course steered	006° T
	360°
	366°
Leeway Angle	(−)11°
Water Track	355° T

The variation and deviation gives an error of 14° W, which must be subtracted from the compass course 020°. The ship will have the easterly wind on her starboard side consequently the 11° leeway must be subtracted from the true heading of 006°, and this is done after adding 360° as shown.

Example 7

Given a course of 164° C, variation 10° E, deviation 12° E, wind East, leeway 6°, find the true course.

Course steered	164° C
Compass Error	(+)22° E
Course steered	186° T
Leeway Angle	(+)6°
Water Track	192° T

The error of 22° is placed below the compass course 164° and being an easterly error it is marked + because the true course is required. Looking in the direction in which the ship is heading, it is seen that she has the wind on her port side and therefore the leeway is allowed to starboard or plus direction to find the course made good.

Exercise 2

Correct the following compass courses for leeway, variation and deviation:

No.	Compass Course	Wind	Leeway	Deviation	Variation
1	050° C	SE	10°	8° W	26° E
2	104°	NNE	12°	10° E	20° W
3	155°	SW	14°	6° E	11° E
4	202°	ESE	6°	11° W	23° W
5	245°	NW	10°	7° E	4° W
6	293°	NNE	5°	4° E	26° W
7	349°	W	11°	10° W	13° W
8	010°	E	12°	7° W	24° E
9	108°	SSW	8°	3° E	20° W

Questions

1. In what direction does the spin axis of a gyro compass point?
2. What are the factors which must be known in order to apply the required correction to a gyro compass in order to take account of the ship's motion on the earth's surface?
3. Describe the card, bowl and binnacle of a ship's Standard Compass.
4. Where is the ship's Standard Compass sited? After installation, what must be checked before it can be used?
5. What is an "azimuth mirror," and how is it used?
6. What is the distinction between the Standard Compass and Steering Compass? Describe an alternative arrangement.
7. In what direction would the compass needle point if under the influence of the earth alone?
8. What is meant by the "magnetic equator" and the "magnetic poles?"
9. Give definitions of "Variation," "Deviation" and "Compass Error".
10. What is the cause of variation? Where is its value recorded and why is it different at different places?
11. Refer to the Variation Chart in this chapter and write down the approximate variation at Gibraltar, Buenos Aires, Cape Town, Melbourne, Colombo, Port Said.
12. What is deviation and how is it caused? What conditions may cause deviation to change in name and amount?
13. When is deviation named East and when West?
14. Name the rules for applying Variation and Deviation to a compass course in order to obtain the true course.
15. Draw a figure illustrating Compass Course, Magnetic Course and True Course.
16. What is Leeway? How is the Leeway Angle estimated and applied?
17. Given a course of 162° C, Variation 20° W, Deviation 5° E, Leeway Angle 5° and the wind East. Required the Magnetic and True courses.
18. Define and illustrate Compass Course, Magnetic Course and True Course.
19. Why are the iron spheres placed on each side of the Standard Compass?
20. What is inside the brass container on the foreside of the binnacle? What is inside the lockers of the binnacle. Why are the doors so securely locked?
21. How is the error of an azimuth mirror detected and adjusted? What is a "shadow pin"?
22. Describe a Pelorus and explain how it is used.

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Chapter 9

Dead Reckoning and Use of Traverse Tables

Dead Reckoning is the process of maintaining or predicting an approximate record of progress by projecting course and distance from the last known accurate position. A quick and accurate method of carrying out this process is by use of Traverse Tables.

TRAVERSE TABLES AND THE DAY'S WORK PROBLEM

When several courses and distances have been run in a given period of time a ship is said to have steered a Traverse.

In the early days of sailing ships it was standard practice to record the courses and distances sailed by placing small pegs into holes made in a circular board engraved with the compass rose. This board was called the Travers. Later, the same record of course and distance was kept on a chalk board called the Log.

In both cases it was standard practice to use the recorded courses and distances to work out the ship's position at the end of a day's run from the previous noon ie from noon to noon.

This practice of "reckoning" the position from noon to noon became known as "The Day's Work."

Today, the term "*Day's Work*" is taken to mean estimating the position of a ship after running one or more courses and distances over any stated period of time which may be greater, or less than 24 hours.

As explained later and as shown in the first Figure, each course and distance run can be resolved into a right angled triangle in which two of the sides correspond to the Difference of Latitude (D.Lat.) and Departure (Dep.) made good on that particular course. Traverse Tables, which are entered with the arguments Course and Distance, provide a convenient way of finding the D.Lat. and Dep. by inspection (i.e. without calculation). They can also be used to convert Departure into Difference of Longitude (D.Long.) using the Mean Latitude (Mn.Lat.).

Before proceeding to an explanation of the use of these tables it is first necessary to understand what is meant by the term "Position", and also to be conversant with other terms and definitions which are related to it.

POSITION

A ship can only be in one position at any one time. The purpose of navigation is to determine this position as accurately as possible. A ship's position can be fixed, by taking sights of celestial bodies, cross bearings of terrestrial objects or by use of electronic navigational aids. Having fixed the position the ship will continue on its course towards some destination. Quite

clearly, it will seldom be convenient (and not always possible) to continuously fix the ship's position. In consequence it becomes necessary to update the last known accurate position. In order to do this it is necessary to know, or to estimate as accurately as possible, all the factors which influence the ship's progress. These factors will include the Course steered, Speed, the Time Interval since the last accurate position, the Effect of Current or Tidal Stream and the Effect of Wind.

At best, some of these factors can only be an intelligent estimate—the effect of wind, for example, is particularly difficult to estimate.

It should also be borne in mind that the navigator also has to take into account other factors such as bad steering, the heave of the sea, and doubtful currents.

Although a ship can only be in one position at any one time it is normal practice for a ship under way to be assigned several positions depending on the method used either to fix or to estimate such position. These positions are as follows:

Observed Position (Obs.Pos.)

The Observed Position is a position obtained from visual bearings of terrestrial objects, simultaneous star sights or some combination of sun, moon, planet and star sights, or reliable positions obtained from electronic navigational aids.

Dead Reckoning Position (D.R.)

A position obtained using ONLY the Courses steered and the Distances run. Such distances are derived from the Log or from Engine Revolutions.

Estimated Position (E.P.)

A position based on Course and Distance since the last known position with an estimation made for Leeway, Set and Drift of Current or Tidal Stream.

It can also be an extrapolation of earlier fixes.

Sea Position

The point at termination of the Water Track (see later).

N.B. Other positions include the Chosen Position, the Most Probable Position. These are dealt with at the page dealing with Navigational Terms, Definitions and Symbols.

DEFINITIONS

Definitions which have relevance to positions are as follows:

Wind Direction

The Direction FROM which the wind blows.

Leeway

The effect of wind in moving a vessel bodily to leeward (i.e. the side of the ship opposite to the wind).

Leeway Angle

The angular difference between the WATER TRACK (see later) and the SHIP'S HEADING.

Set

The Direction TOWARDS which the Current and/or Tidal Stream flows.

Rate

The speed of the Current or Tidal Stream expressed in Knots.

Drift

The distance covered in a given time and due solely to the movement of a current and/or Tidal Stream.

Heading (Ship's Head)

The horizontal direction of the ship's head at a given moment. (This term does not necessarily require movement of the vessel which could, for example, be at anchor.)

Course (Co.)

The intended heading of the ship.

Course to Steer

The course related to the compass used by the helmsman.

Distance Run

The distance derived from Log readings or Engine Revolutions.

Track

The path followed or to be followed between one position and another.

Track Angle

The direction of a track.

Ground Track

The path OVER THE GROUND between one position and another.

Track Made Good

The mean GROUND TRACK actually achieved over a given period. (This is sometimes referred to as Course Made Good Over the Ground.)

Water Track

The path THROUGH THE WATER between one position and another. (This is sometimes referred to as Course Made Good Through the Water.)

N.B. The student should appreciate that if an entire body of water is moving the ship's path in relation to fixed objects on land will be different to its path in relation to the water through which it is moving.

SOLUTION OF DAY'S WORK PROBLEMS BY TRAVERSE TABLES

In the following examples we are given what amounts to an incomplete page from the ship's Log Book and are asked to find the ship's position having run a series of courses. In cases where a final Observed Position is given, we can also find the ACTUAL set and drift of current experienced by finding the course and distance from the D.R. position (or Sea Position) to the Obs.Pos.

The courses and distances run are given in each case. Compass courses must be first converted into their corresponding True Courses by applying Deviation for the ship's head, Variation for the geographical location and finally by applying Leeway to find the Track.

N.B. In some examples Leeway has been applied first in order to save space but the student should always apply leeway last.

When using large scale charts (as in Coastal Navigation) the corrected courses can be laid off on the chart and positions plotted accurately. But when using small scale charts (particularly Ocean Charts) it is not possible to accurately plot courses and distances. In these circumstances the navigator could calculate the D.Lat. and Dep. resulting from each course and distance run: D.Lat. = Dist. × cos Co. and Dep. = Dist. × sin Co. But providing distances are not too great it is more convenient and normal practice to find the D.Lat. and Dep. for each course by Inspection of the Traverse Tables.

The procedure is reduce each course and distance into its corresponding components of D.Lat. and Dep. The summation of all the D.Lats. and all the Deps. will produce a resultant Total D.Lat. (North or South) and a resultant Total Dep. (East or West).

This is demonstrated in the following example.

Example

A ship is in position "A" 39° 40′ N 40° 30′ W.

The ship then runs the following True Courses:

130° T	31 miles
202° T	29
113° T	36
345° T	82 miles

Find the D.R. position at the end of the run and the course and distance from the Initial Position "A" to the Final Position "B".

Each course and distance is split up into its corresponding **D.Lat.** and **Dep.**

The resultant of the Norths and Souths gives the **D.Lat.** for the whole traverse. The resultant of the Easts and Wests gives the **Dep.** for the whole traverse, and the **Co.** and **Dist.** agreeing with this **D.Lat.** and **Dep.** gives the direction and the distance from the position left to the position reached, just as if the ship had sailed on a single direct course between the initial and terminal points instead of traversing.

The Latitude and Longitude of the position reached is found by calculation as follows:

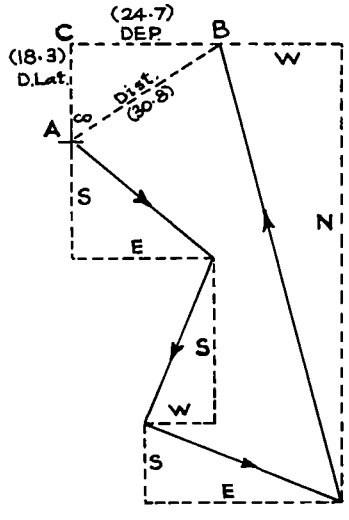


Figure 1.

To Find the Co. and Dist.

True 360°	Courses Quadrantal	Dist.	D. Lat.		Dep.	
			N.	S.	E.	W.
130°	S. 50° E.	31	—	19·9	23·7	—
202°	S. 22 W.	29	—	26·9	—	10·9
113°	S. 67 E.	36	—	14·1	33·1	—
345°	N. 15 W.	82	79·2	—	—	21·2
			79·2	60·9	56·8	32·1
			60·9		32·1	
		D. Lat.	18·3 N.		Dep. 24·7 E.	

D. Lat. 18·3 N., Dep. 24·7 E., gives Course N. $53\frac{1}{2}$ E. which is $053\frac{1}{2}$ T, Dist. 30·7 miles.
(*Note.*—Enter Traverse Table with 183 and 247 and get 307—call it 30·7.)

To Find the D.R. Position

Left	*A* Lat.	39° 40′ N.		Long.	40° 30′ W.
	D. Lat.	18·3 N.		D. Long.	32·2 E.
	B Lat.	39 58·3 N.		Long.	39 57·8 W.
	$\frac{1}{2}$ D. Lat.	— 9			
	Mean Lat.	39 49			

To find D. Long.: Enter Traverse Table in the **Parallel Sailing** columns with Mean Lat. 40°, Dep. 247 (instead of 24·7), and find in D. Long. column 322 (call it 32·2)

Answer	Course	$053\frac{1}{2}°$ T	Lat.	39° 58·3′ N.
	Distance	30·7 miles	Long.	39° 57·8′ W.

Order of Work

1. Decide precisely what is required in the question. Is the starting position required? Is the set and drift required? The type of question will determine the manner in which the work is laid out.
2. Apply Variation and Deviation (or Compass Error) and convert courses to True quadrantal notation. Apply leeway as necessary.
3. Obtain distances on each course.
4. List current set and drift.
5. Obtain reversed bearing and distance of starting position if applicable.
6. Draw up Day's Work Grid.
7. Fill in the appropriate spaces on the Grid—items 2–5 above.
8. Inspect Traverse Tables. Extract D.Lat. and Dep. for each course and enter in Grid.
9. Total up D.Lats. and name North or South.
10. Total up Deps. and name East or West.
11. Apply total D.Lat. to Initial Lat. in order to obtain the Final Latitude.
12. Calculate Mean Latitude: $\dfrac{\text{(Initial + Final Lat.)}}{2}$ $\left(\text{or Initial Lat.} \pm \dfrac{\text{D.Lat.}}{2}\right)$.
13. Convert total Dep. into D.Long. using Mn.Lat. either by Inspection or by formula:
$$\text{Dep.} \times \text{Sec.Lat.} = \text{D.Long.}$$
14. Apply D.Long. to Initial Long. to find Final Long.
15. Using Dep. and D.Lat. find Co. and Dist. by inspection of Traverse Tables or by formula:

$\text{Dep.} = \text{D.Long.} \times \cos \text{Mn.Lat.}$

$\dfrac{\text{Dep.}}{\text{D.Lat.}} = \tan \text{Co.}$

$\text{Dist.} = \text{D.Lat.} \times \text{Sec.Co.}$

D.Long.	log	
Mn.Lat.	log cos	_____
Dep.	log	
D.Lat.	log	_____
Co.	log tan	_____
Co.	log sec	
D.Lat.	log	_____
Dist.	log	_____

Exercise 1

1. A ship left position 43° 12′ N., 167° 20′ W., and sailed the following true courses and distances. Required the course, distance, and D.R. position.

080° T. 30 miles	155° T. 40 miles
194° T. 50 „	250° T. 60 „
280° T. 70 „	

2. A ship sailed from Lat. 37° 20′ S., Long. 97° 12′ E., on the following true courses by gyro compass, distances as per log.

330° T. 40 miles	280° T. 35 miles
240° T. 30 „	194° T. 25 „
150° T. 50 „	

Required the course and distance, and D.R. position.

3. A ship left position 49° 10′ N., 8° 25′ W., and sailed the following courses (1) 278° T. 7 miles, (2) 326° T. 18 miles, (3) 188° T. 12·7 miles. Find the track and distance made good and the position arrived at.

4. At noon a ship's position was 49° 30′ S., 69° 00′ E., the ship then steamed the following courses at 10 knots:

Time[1]	Compass Co.	Dev.	Var.
1200 to 1400	072° C.	13° E.	33° W.
1400 to 1730	172° C.	4 E.	32 W.
1730 to 1906	004° C.	10 W.	32 W.

Required ship's position at 1906 and the true course and distance.

5. A ship left a position in 51° 10′ N., 7° 30′ W., and sailed the following courses by gyro compass and distances by log. Gyro error nil.
(1) 067° G. 6 miles; (2) 087° G. 37 miles; (3) 237° G. 10 miles. Required the course and distance and the position at the end of the traverse.

6. A point in position 12° 00′ S., 135° 00′ W., bore 251° T. distance 2·2 miles. Ship then sailed by compass (1) 236° C., distance 24 miles, Dev. 4° E., Var. 5° E.; (2) 339° C., distance 7 miles, Dev. 2° W., Var. 5° E. Required the track and distance made good by the ship, also the position arrived at.

Note 1 The four figure notation of recording time is used in navigation.
The day is reckoned from midnight which is registered as 2400, and noon as 1200, the intermediate times being recorded as follows:

8h 12 A.M. is 0812	11h 37 P.M. is 2337
11 37 A.M. 1137	12 00 P.M. 2400
2 45 P.M. 1445	00 05 A.M. 0005
7 18 P.M. 1918	03 36 A.M. 0336

Example 1

April 6th, at noon, Cape Palliser in Lat. 41° 37′ S., Long. 175° 19′ E., bore 254° C., distant 12 miles. Ship's head on her first course of 150° C. Var. and Dev. as per log below.

S.M.T.	Compass Course	Log	Wind	Leeway	Dev.	Remarks
1200	150° C.	0	S.W.	3°	4° E.	Variation 10° E.
1700	144°	28	S.W. by S.	5°	3° E.	A current set 346° T. at
2100	137°	54	S.W. by S.	2°	2° E.	1 knot throughout.
2400	137°	—				
0100	128°	80	S.S.W.	3°	0°	
0500	120°	108	S. by W.	0°	2° W.	
0900	112°	135	S.	2°	3° W.	
1200	112°	162				

Correct the above Courses for Var., Dev., and Leeway, find the Course and Distance from the given point, and the Lat. and Long. in at noon on April 7th.

CORRECTIONS

Reversed bearing	074° C.
Compass error	+14
	088° T.
1st Co.	147° C.
Compass error	+14
	161° T.
2nd Co.	139° C.
Compass error	+13
	152° T.
3rd Co.	135° C.
Compass error	+12
	147° T.
4th Co.	125° C.
Compass error	+10
	135° T.
5th Co.	120° C.
Compass error	+ 8
	128° T.
6th Co.	110° C.
Compass error	+ 7
	117° T.

Mean Lat. sec 0·131791
Dep. log 2·028978
144·8 log 2·160679

D. Long. 2° 24·8′

Corrected Courses	Distance	N.	S.	E.	W.
088° T. N. 88° E.	12	0·4		12·0	
161° T. S. 19° E.	28		26·5	9·1	
152° T. S. 28° E.	26		23·0	12·2	
147° T. S. 33° E.	26		21·8	14·2	
135° T. S. 45° E.	28		19·8	19·8	
128° T. S. 52° E.	27		16·6	21·3	
117° T. S. 63° E.	27		12·3	24·1	
346° T. N. 14° W.	24	23·3			5·8
		23·7	120·0	112·7	5·8
			23·7	5·8	
			D. Lat. 96·3 S.	106·9 E. Dep.	

Course S. 48° E. Distance, 144 miles.

Lat. Cape Palliser	41° 37′ S.	Long. Cape Palliser	175° 19′ E.
D. Lat.	1 36·3 S.	D. Long.	2 24·8 E.
Lat. in	43 13·3 S.	Long. in	177 43·8 E.
½ D. Lat.	0 48		
Mean Lat.	42 25		

Ans.—Course S. 48° E. or 132° T. Dist. 144 miles.
Lat. 43° 13·3′ S., Long. 177° 43·8 E.

Important Note: In these examples and because of limited available space, the leeway angle has been applied first. As previously explained, the leeway angle should be applied last.

Order of Work

Example 1

1. Reverse the compass bearing of Cape Palliser, then treat it as a course and correct it for the Var. and Dev. as given for ship's head 150° C.
2. Correct each of the other courses in turn for Dev. and Var. and leeway (if any).
3. Note that the current course is given 346° T. or N. 14° W.
4. Line out a Traverse Table as indicated and write in each course and distance.
5. Refer to *Traverse Table* and fill in the respective *D. Lat.* and *Dep.* columns. Be careful when the angle is at the bottom of the page that the proper *D. Lat.* and *Dep.* columns are entered; and note, also, that when the course exceeds 45° the *Dep.* is greater than the *D. Lat.*
6. Add up the respective *N.S.E.W.* columns. The difference between the Northing and the Southing is the *D. Lat.*, to be named the same as the greater. The difference between the Easting and Westing is the *Dep.*, to be named the same as the greater.

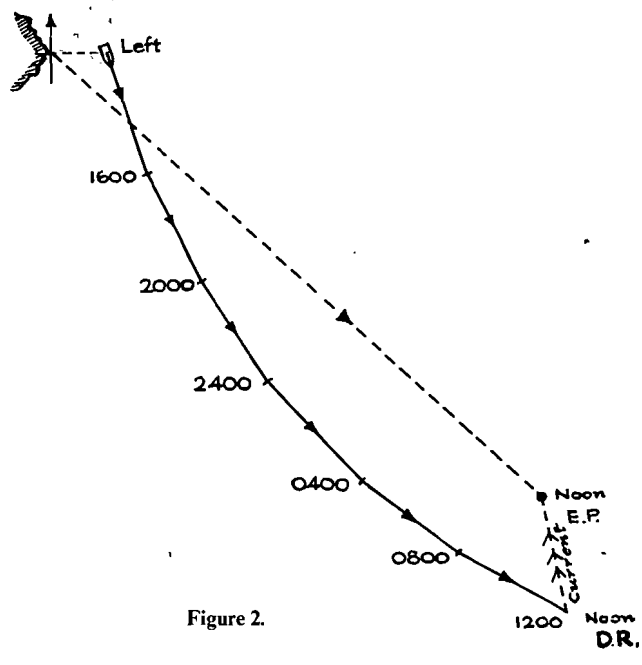


Figure 2.

7. Look up the *Traverse Table* with D. Lat. (96·3′ S.), Dep. (106·9′ E.) and pick out the corresponding *Co.* and *Dist.* by inspection 132° T. 144 miles.
8. Write down the Latitude of Cape Palliser and apply to it the *D. Lat.* expressed in degrees and minutes—adding the *D. Lat.* if it is the same name as Latitude and subtracting if it is named opposite to the Lat. Better to think this out than to apply the rule blindly, by noting if the ship is in N. or S. Latitude and whether she is sailing away from the equator (add) or towards the equator (subtract). This gives the estimated Latitude.
9. Get the mean of the two Latitudes and use it to turn the Dep. (106·9) into D. Long (145′), either by inspection of the Traverse table, or by calculation as a parallel sailing. The latter method is the safer one for accurate results and should be used when the Departure exceeds 100 miles and the latitude is greater than 45°.
10. Write down the Longitude of Cape Palliser and apply to it the D. Long. expressed in degrees and minutes—adding the D. Long. if it is the same name as the Longitude and subtracting if it is named opposite to the Longitude. Reason this out when applying the rule. If the ship is East or West of Greenwich and sailing away from the prime meridian she is, obviously, increasing her Longitude, so add the D. Long.; but if sailing towards Greenwich meridian the ship's Longitude must be getting less and the *D. Long.* is then subtracted. The result is the estimated Longitude.

Example 2

January 11th, at noon. Departure was taken from a point with the Lizard in position 49° 58′ N., 5° 12′ W., bearing 034° C. distant 15 miles. Var and Dev. as per log. Ship's head on her first course of 214° C.

S.M.T.	Compass Course	Log	Wind	Leeway	Dev.	Remarks
1200	214° C.	0	S.E.	3°	8° E.	Variation 21° W.
1700	219°	38	S.E. by S.	2°	7° E.	A current set the ship
2100	299°	73	S.W.	2°	1° W.	294° T. 26 miles during
2400	299°		S.W.	2°	1° W.	the day.
0100	290°	104	S.W. by S.	4°	3° W.	
0500	184°	132	W. by S.	0°	6° E.	
0900	198°	158	W.	3°	6° E.	
1200	198°	190	W.	3°	6° E.	

Correct the above Courses for Var., Dev., and Leeway, find the Course and Distance from noon to noon and the position of the ship at noon on January 12th.

CORRECTIONS

Reversed compass bearing off Lizard 214° C.
Compass error −13
201° T.

D. Lat. 14·0 S.
Dep. 5·4 W.

1st Co. 217° C.
Compass error
204° T.

2nd Co. 221° C.
Compass error −14
207° T.

3rd Co. 301° C.
Compass error −22
279° T.

4th Co. 294° C.
Compass error −24
270° T.

5th Co. 184° C.
Compass error −15
169° T.

6th Co. 195° C.
Compass error −15
180° T.

Lat. of Lizard 49° 58′ N. Long. of Lizard 5° 12′ W.
D. Lat. 14 S. D. Long. 8·4 W.
Lat. of ship 49 44 N. Long. of ship 5 20·4 W.

Corrected Courses	Distance	N.	S.	E.	W.
204° T. S. 24° W.	38		34·7		15·5
207° T. S. 27° W.	35		31·2		15·9
279° T. N. 81° W.	31	4·8			30·6
270° T. West	28				28·0
169° T. S. 11° E	26		25·5	5·0	
180° T. South	32		32·0		
294° T. N. 66° W.	26	10·6			23·8
		15·4	123·4	5·0	113·8
			15·4		5·0
			D. Lat. 108·0 S.	Dep.	108·8 W.

Course S. 45° W. Distance 153½ miles

Lat. Left 49° 44′ N. Long. left 5° 20·4′ W.
D. Lat. 1 48 S. D. Long. 2 45·3 W.
Lat. in 47 56 N. Long. in 8 5·7 W.

½ D. Lat. 0 54
Mean Lat. 48 50 sec 0·181608
Dep. 108·8 log 2·036629
D. Long. 165·3 log 2·218237

Ans.—Co. S. 45° W. or 225° T. Distance 153½ miles
E.P. 47° 56′ N., 8° 05·7′ W.

Order of Work

Example 2

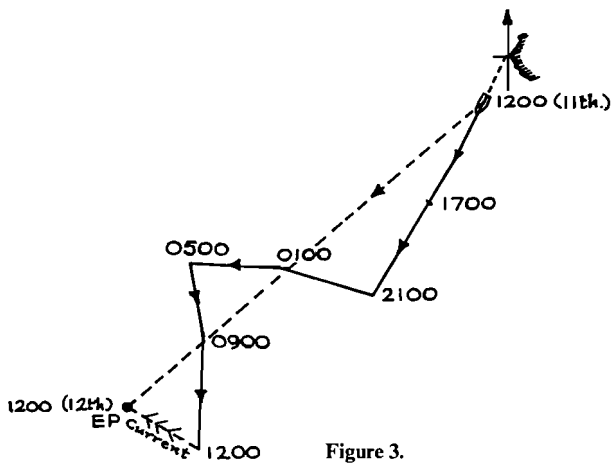


Figure 3.

1. Reverse the Compass bearing of Lizard and apply the Dev. and Var. to obtain the true bearing. Use this reversed bearing as an Initial Course and Distance from the Lizard to the ship's position at 1200 on the 11th. Find the D. Lat., Dep., and D. Long corresponding to this initial course.
2. Write down the Latitude and Longitude of Lizard, apply the D. Lat. and D. Long respectively, to obtain the ship's position at 1200.
3. Correct each course in turn. Arrange the work in a traverse form as shown.
4. Obtain the resultant *D. Lat.* and *Dep.*, then find the *track* and *distance* made good by the ship. This course and distance are reckoned from where the ship left, not from the point of land.
5. Turn the *Dep.* into *D. Long.* and apply the resultant *D. Lat.* and *D. Long.* to the position left. The result is the estimated position.

Example 3

S.M.T.	Compass Course	Log	Wind	Leeway	Dev.	Remarks
1200	316° C.	0	E.N.E.	0°	5° E	Obs Pos. Noon 42° 26′ N. 54° 34′ W. 1200–0100 Variation 22° W.
2400	316°		E.N.E.	0°	5° E.	0100–1200
0100	321°	196	E.	0°	5° E.	Variation 25° W.
1200	321°	402	E.N.E.	0°	5° E.	Obs Pos. Noon 46° 06′ N. 62° 24′ W.

August 5th, at noon, the ship was in the given position. Correct the above Courses for Var. and Dev., find the Course and Distance by Dead Reckoning and the Position in at noon on August 6th. The ship's Obs. Pos. at noon was 46° 6′ N., 62° 24′ W. Find the set and drift of the current.

1st Co.	316° C.
Compass error	−17
	299° T.
2nd Co.	321° C.
Compass error	−20
	301° T.

Mean Lat. Sec 0·143860
Dep. 348 log 2·541579
D. Long. log 2·685439

484·7′ = 8° 4·7′

Corrected Courses	Distance	N.	S.	E.	W.
N. 61° W.	196	95·0			171·4
N. 59° W.	206	106·1			176·6

D. Lat. 201·1 N. Dep. 348·0 W.

Course N. 60° W. or 300° T. Distance 402 miles.

Lat. noon, 5th	42° 26′ N.	Long. noon, 5th	54° 34′ W.
D. Lat.	3 21·1 N.	D. Long.	8 4·7 W.
Lat. noon, 6th	45 47·1 N.	Long. noon, 6th	62 38·7 W.
	2) 88 13		
Mean Latitude	44 6½		
Lat. noon by D.R.	45° 47·1′ N.	Long. noon by D.R.	62° 38·7 W.
Lat. noon by Obs.	46 06 N.	Long. noon by Obs.	62 24 W.
D. Lat. due to current	18·9 N.	D. Long. due to current	14·7 E.

or Dep. 10·2 miles.

Set and drift of current, N. 28° E. or 028° T., 21·4 miles.

Ans.—Course 300° T. Distance 402 miles.
Lat. 45° 47·1′ N., Long. 62° 38·7′ W.
Set 028° T. Drift 21·4 miles.

Order of Work

Example 3

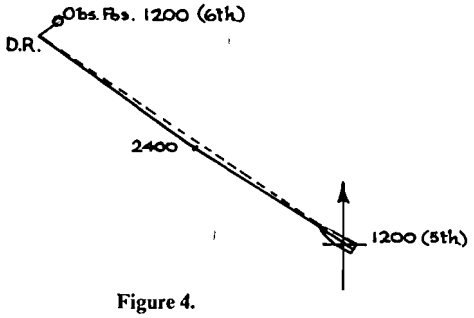


Figure 4.

We are asked to *find the set and drift of the current in this example.*

1. Correct the courses; resolve the traverse; obtain the course and distance the ship has made *through the water,* (water track) also the position by D.R. at the end of the day.

   The Course and distance from D.R. position to Obs. Pos. is assumed to be due to a current. The *direction of the current is the set,* and the *distance* its *drift.*

2. Write down the D.R. position and under it the Obs. position. Find the *D. Lat.* and *D. Long* due to the current, convert the *D. Long.* into its corresponding *Dep.* by inspection in the Traverse Table, and then find the *course* and *distance* agreeing with this *D. Lat.* and *Dep.* This will be the estimated set and drift of the current.

   It will be realised by now that positions found by traverse methods must always be approximate and that the ship's position should be ascertained whenever possible by visual bearings, D.F. bearings, or astronomical sights.

   The discrepancy between the D.R. and Obs. Pos is assumed to be due to current.

   If Leeway exists, set and drift of current will be from the Sea position to the Observed Position.

Example 4

At noon, on September 1st, Cape Recife (Lat. 34° 2′ S., Long. 25° 42′ E.) bearing 337° T. distant 12 miles. Course 183° C. (Dev. 2° W., Var. 27° W.).

S.M.T.	Compass Course	Log Reading	Wind	Leeway	Dev.	Remarks
1200	181° C.	0	E.	2°	2° W.	Variation 27° W. throughout day.
1300						
1700	170°	22	E.	2°	4° W.	a/c 170° C
2100	166°	44	E.	2°	5° W.	a/c 166° C.
2400	166°	62	E.	2°	5° W.	
0100	138°	72	E.N.E.	5°	7° W.	a/c 138° C.
0500	129°	104	E.N.E.	5°	8° W.	
1200	129°	172	E.N.E.	5°	8° W.	Obs. Pos. Noon 35° 53′ S. 28° 05′ E.

Find the D.R. position at noon on September 2nd. If the ship's Obs. Pos. on the 2nd is 35° 53′ S., 28° 5′ E., find the set and drift of the current and the track and distance made good during the 24 hours.

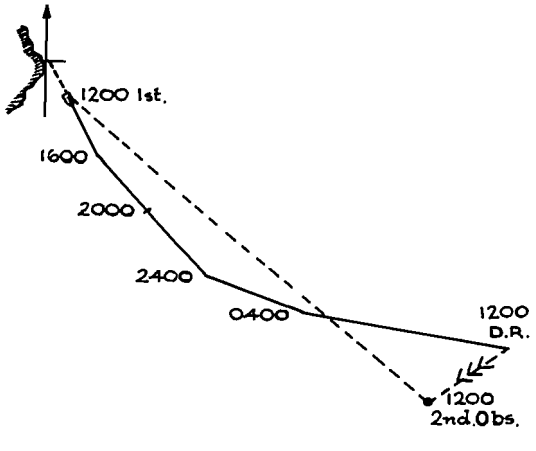


Figure 5.

The order of work is similar to that of the previous examples except that the course and distance made good from the position which the ship left at noon of the 1st to the position by observation at noon on the 2nd is asked for. The work is shown as follows and is arranged in four sections.

Reversed Bearing 157° T.	
or S. 23° E.	12 mls.
D. Lat.	11·0
Dep.	4·7
D. Long.	5·7
1st Co.	183° C.
Compass error	−29
	154° T.
2nd Co.	172° C.
Compass error	−31
	141° T.
3rd Co.	168° C.
Compass error	−32
	136° T.
4th Co.	143° C.
Compass error	−34
	109° T.
5th Co.	134° C.
Compass error	−35
	099° T.

To Find Position of Ship at Noon on September 1st.

Lat. of Cape Recife	34° 2′ S.	Long. of Cape Recife	25° 42·0′ E.
D. Lat.	11 S.	D. Long.	5·7 E.
Lat. of ship	34 13 S.	Long. of ship	25 47·7 E.

To Find Position at Noon on September 2nd D.R.

Corrected Courses	Distance	N.	S.	E.	W.
154° T. S. 26° E.	22		19·8	9·6	
141° T. S. 39° E.	22		17·1	13·8	
136° T. S. 44° E.	28		20·1	19·5	
109° T. S. 71° E.	32		10·4	30·3	
099° T. S. 81° E.	68		10·6	67·2	
			78·0 D. Lat.	140·4 Dep.	

Lat. noon, 1st	34° 13′S.	Long. noon, 1st	25° 47·7′ E.
D. Lat.	1 18 S.	D. Long.	2 51·1 E.
Lat. noon, 2nd	35 31 S.	Long. noon, 2nd	28 38·8 E.
½ D. Lat.	0 39		
Mean Lat.	34 52	sec 0·085930	
Dep.	140 ·4	log 2·147367	
D. Long.	171 ·1	log 2·233297	

To Find Set and Drift of Current.

Lat. noon, 2nd, by D.R.	35° 31′ S.	Long. noon, 2nd, by D.R.	28° 38·8′ E.
Lat. noon, 2nd, by obs.	35 53 S.	Long. noon, 2nd, by obs.	28 05·0 E.
D. Lat.	22 S.	D. Long.	33·8 W.

or Dep. 27·4 miles.

Set of current S. 51½° W. 231½ T. Drift 35 miles.
Mean Lat. is 35° 42′ S.

To Find the Course and Distance Made Good.

Lat. left noon on 1st	34° 13′ S.	Long. left noon on 1st	25° 47·7′ E.
Lat. by obs. on 2nd	35 53 S.	Long. by obs. on 2nd	28 05·0 E.
D. Lat.	1 40 S.	D. Long.	2 17·3
	60 S.		60
D. Lat.	100 S.	D. Long.	137·3 E.

Course S. 8° E. (Dep. 112·4 miles.)

Mean Lat.	35° 03′	cos 9·913099
D. Long.	137·3	log 2·137670
Dep.	112·4	log 2·050769

Track and distance made good during 24 hours 172° T 151 miles.

Example 5

May 7th, at 1800, Muckle Flugga in position 60° 51′ N., 0° 53′ W., bore 4 points on the starboard bow, and at 1900 it was abeam. Variation and Deviation as per log.

S.M.T.	Compass Course	Log	Wind	Leeway	Dev.	Remarks
1200	076° C.	0	S.E.	Nil	1° W.	
1700	062°	48	N.W.	Nil	3° W.	a/c 062° C.
1800	062°	55	N.W.	Nil	3° W.	
1900	062°	62	N.W.	Nil	3° W.	Variation 18° W. throughout.
2400	062°	—	N.W.	Nil	3° W.	
0200	108°	131	N.W.	Nil	2° E.	a/c 108° C
1200	108°	245	N.W.	Nil	2° E.	

Correct the above Courses for Var. and Dev., find the Course and Distance from noon to noon and the D.R. at noon on May 8th.

1st Co.	076° C.
Compass error	−19
	057° T.
2nd Co.	062° C.
Compass error	−21
	041° T.
3rd Co.	108° C.
Compass error	−16
	092° T.
Co. at 1900	041° T.
Abeam to Stbd.	90°
Beam Bearing	131° T.
	180°
Reversed Brg. Muckle Flugga	311° T.
	N. 49° W.

Dist. run between 4 point and Beam Bearing = 7 miles = Dist. Off.

TO FIND THE COURSE AND DISTANCE

Time	Courses	Dist.	N.	S.	E.	W.
Noon to 1700	N. 57° E.	48	26·1		40·3	
1700 to 0200	N. 41° E.	83	62·6		54·5	
0200 to 1200	S. 88° E.	114		4·0	113·9	
			88·7	4·0	208·7	E.
			4·0			
		D. Lat.	84·7	N. Dep.	208·7	E.

Course N. 68° E. Distance 225 miles.

TO FIND THE D.R.

Time	Courses	Dist.	N.	S.	E.	W.
Rev. Bearing	N. 49° W.	7	4·6			5·3
1900 to 0200	N. 41° W.	69	52·1		45·3	
0200 to 1200	S. 88° E.	114		4·0	113·9	
			56·7	4·0	159·2	5.3
			4·0		5·3	
		D. Lat.	52·7	N. Dep.	153·9	E.

Mn. Lat. sec 0·318418
Dep. 153·9 log 2·187239
320·4′ log 2·505657
D. Long. = 5°20·4′

Muckle Flugga	60° 51′ N.	Muckle Flugga	0° 53′ W.
D. Lat.	0° 52·7′ N.	D. Long.	5 20·4 E.
D.R.	61° 43·7′ N.		4° 27·4 E.
½ D. Lat.	0 26·3		
Mean Lat.	61° 17·4′		

D.R. 1200 May 8 61° 43·7′ N 4° 27·4′ E

Explanation of Worked Example 5

The best way to work this question will be by means of two separate Day's Worked. One for finding the Course and Distance and another for finding the D.R. position.

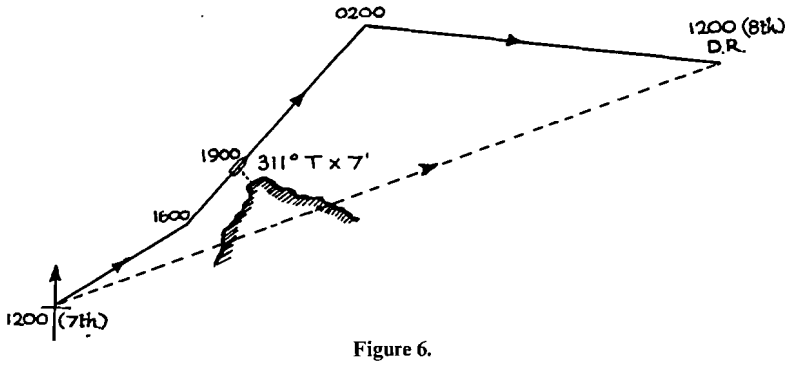


Figure 6.

As the question asks for the course and distance during *the* 24 *hours*, all we want in the first one are the courses and distances actually done during that time. These will give us the D. Lat. and Dep. corresponding to them, by means of which we take out the course and distance by inspection.

The fact that we took a 4 point bearing of Muckle Flugga when passing it has nothing whatever to do with the course and distance during the 24 hours. We shall use the 4 point bearing for a Departure course in the second Day's Work when finding the D.R. position, but have no other use for it.

At 1800 on May 7th, Muckle Flugga bore 4 points on the starboard bow, and at 1900 it was abeam. This is an example of the "4 point bearing." As the bearing was doubled, we know that the distance covered between the time of taking the two bearings is the distance off when the second bearing was taken (in this case when abeam).

It will be seen from the question that between 1800 and 1900 the ship covered 7 miles by log and was, therefore, 7 miles off Muckle Flugga when it was on the starboard beam at 1900.

The ship was then on the second course heading 041° T., so Muckle Flugga must have been bearing 131° T. Reverse this bearing and use it as a course, viz., 311° T., 7 miles, together with the ship's course from 1900 to 0200, and from 0200 to 1200, and find the position at noon on the 8th in the usual way as shown opposite in the second Day's Work.

Example 6

The following courses were steered by Gyro compass, Gyro error nil, Speed as per engine revolutions:—

At 1200 steaming 236° T., 15 knots At 2000 altered course 262° T., 15 knots
At 1700 altered course 284° T., 16 knots At 0400 altered course 198° T., 14·5 knots

At 1800, a point in position 48° 28½′ N., 67° 05′ E., bore 4 points on starboard bow and at 1845 it was abeam. Required the D.R. position at the following noon, also the course and distance from noon to noon.

TO FIND THE COURSE AND DISTANCE

Time	Interval Hrs.	Speed Knots	True Course	Dist.	N.	S.	E.	W.
1200–1700	5	15	S. 56° W.	75	—	41·9	—	62·2
1700–2000	3	16	N. 76 W.	48	11·6	—	—	46·6
2000–0400	8	15	S. 82 W.	120	—	16·7	—	118·8
0400–1200	8	14·5	S. 18 W.	116	—	110·3	—	35·8
					11·6	168·9	—	263·4
						11·6		—
						D. Lat. 157·3 S.		Dep. 263·4 W.

Ans.—Course S. 59° W. 239° T. Dist. 307 miles.

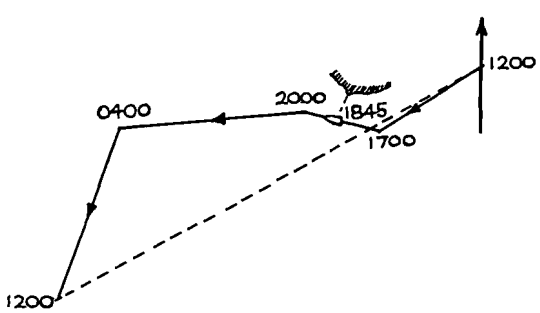


Figure 7.

TO FIND POSITION OF SHIP AT 1845.

N. 76° W.
Co. 284° T.
90
Beam Brg. 374°
014°
180
Rev. Brg. 194° T.
S. 14° W.

Beam bearing reversed
S. 14° W. D. Lat. 11·6 S.
12 miles Dep. 2·9 W.
D. Long. 4·3 W.

Point in Lat.	48° 28·5′ N.	Long.	67° 05′ E.
D. Lat.	11·6	D. Long.	04·3 W.
Ship's position at 1845	48 16·9 N.		67 00·7 E.

To Find Position at Following Noon

Time	Interval Hrs.	Speed Knots.	True Course	Dist.	N.	S.	E.	W.
1845–2000	1¼	16	N. 76° W.	20	4·8	—	—	19·4
2000–0400	8	15	S. 82 W.	120	—	16·7	—	118·8
0400–1200	8	14·5	S. 18 W.	116	—	110·3	—	35·8
					4·8	127·0	—	174·0
						4·8		—

D. Lat. 122·2 S. Dep. 174·0 W.

D. Long. 256·4

Mean Lat.	47° 16′	sec	0·168394	1845 Ship in Lat.	48° 16·9′ N.	Long.	67° 00·7′ E.
Dep.	174	log	2·240549	D. Lat.	2 02·2 S.	D. Long.	4 16·4 W.
D. Long.	256·4	log	2·408943	1200 Ship in Lat.	46 14·7 N.	Long.	62 44·3 E.

There is a good deal of repetition in this example and the student will probably find a neater way of arriving at the answers. But resolving a traverse by calculation is just a laborious way of doing what can be much easier accomplished by laying off the courses, distances and bearings on a chart of suitable scale. This example, and also the two following exercises, may be plotted on the blank Sumner chart extending from Lat. 46° N. to Lat. 49° N., published by Messrs. Brown, Son & Ferguson, Ltd., Glasgow.

Exercise 2

1. At noon a point of land in position 47° 00′ N., 178° 35′ W., bore 115° C., distant 12 miles. Dev. 6° W. Var. 19° Var. 19° W. The ship then steered the following courses:—

Course	Dist.	Dev.	Var.
273° C.	70 miles	2° W.	19° W.
317°	45 miles	5 E.	19 W.
286°	20 miles	9 E.	19 W.
335°	82 miles	4 E.	19 W.

A current set 025°, 1·5 knots during the day. Find by calculation the course and distance made good in the 24 hours and the ship's Lat. and Long. at the end of the day.

(When laying off on the blank chart begin at the lower right hand corner.)

Exercise 3

At 1200 on January 12th a ship was in position 47° 00′ N., Long. 4° 00′ W. The ship then steered the following courses:—

Course	Dist.	Dev.	Var.
357° C.	72 miles	7° E.	30° E.
020°	50 miles	15 E.	30 E.
110°	90 miles	5 W.	30 E.
133°	35 miles	17 W.	30 E.
119°	55 miles	7 W.	30 E.

The ship's position by observation at 1200 on January 13 was 46° 33′ N., 00° 39′ E. Find by calculation the set and drift of the current, the D.R. position, the course and distance made good during the day from noon to noon, also the course and distance by D.R.

(If laying off on the blank chart begin at the left hand side.)

Exercise 4

1. July 6th, at noon, ship bound for New York, departure was taken from a point with the Fastnet Rock (51° 23′ N., 9° 36′ W.) bearing 112° C., distant 7 miles. Ship's head 236° C., Var. and Dev. as per log.

S.M.T.	Compass Course	Log	Wind	Leeway	Dev.	Remarks
1200	236° C.	0	N.W.	5°	6° E.	
2100	252°	54	N.W. by N.	10°	5° E.	a/c 252° C.
2400	252°	—	N.W. by N.	10°	5° E.	Variation 22° W. throughout.
0500	258°	102	N.N.W.	5°	5° E.	a/c 258° C.
1200	258°	158	N.N.W.	5°	5° E.	A current set 038° T. 23 miles during the day.

Correct the above Courses for Var., Dev., and Leeway, find the Course and Distance from Fastnet Rock, and the Lat. and Long. in at noon on July 7th.

2. August 8th, at noon, Cape Sorell (42° 11′ S., 145° 10′ E.) bore 070° C., distant 10 miles. Ship's head, 292° C., Var. and Dev. as per log.

S.M.T.	Compass Course	Log Reading	Wind	Leeway	Dev.	Remarks
1200	292° C.	0	S.W.	3°	3° E.	1200–0100 variation 8° E.
1700	290°	32	S.W. by S.	2°	3° E.	
2100	287°	62	S.S.W.	2°	2° E.	
2400	—	—	S.S.W.	2°	—	0100–1200 variation 6° E.
0100	285°	90	S.S.W.	0°	1° E.	
0500	282°	116	S.S.W.	2°	0°	
0900	279°	138	S.S.W.	3°	1° W.	
1200	279°	158	S.S.W.	3°		A current set 178° T. throughout. Drift 10 miles.

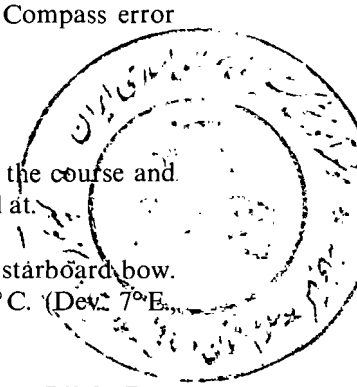
Correct the above Courses for Var., Dev., and Leeway, find the Course and Distance from noon to noon and her position by dead-reckoning at noon on August 9th.

3. October 22nd, at noon, being in a position with the Lizard Lighthouse (49° 58′ N., Long. 5° 12′ W.) bearing 026° C., distant 12 miles. Variation and Deviation as per log, ship steering on her first course of 281° C.

S.M.T.	Compass Course	Log	Wind	Leeway	Dev.	Remarks
1200	281° C.	0	N.	8°	11° W.	
1700	248°	25	N.N.W.	3°	9° W.	Variation 17° W. throughout.
2100	292°	47	S.W.	6°	12° W.	
2400	292°	—	S.W.	6°	12° W.	
0100	225°	66	W.N.W.	17°	6° W.	
0500	236°	82	N.W.	28°	7° W.	A current set the ship
0900	180°	96	W.S.W.	28°	0°	298° T. during the day.
1200	180°	109	W.S.W.	28°	0°	Drift 6 miles.

Correct the above Courses for Variation and Deviation, and Leeway and find the Course and Distance since the preceding noon, also the position at noon on October 23rd.

4. May 12, on passage London to Australia, at noon, ship in position 43° 26′ S., 104° 53′ E. Log set at 0. Course 096° C., Dev. 8° E. Var. 20° W.
   At 2000, course 096° C., Dev. 8° E. Var. 18° W. Log 138.
   At noon. Observed Position 42° 39′ S., 114° 18′ E. Log 416. Find the ship's D.R. position and the set and drift of the current experienced during the day.
5. At 1200, June 12, bound from Gibraltar to Trinidad, Madeira 32° 43′ N., 16° 40′ W. bore 000° C., distant 8 miles. Course 248° C. Dev. 7° E. Var. 18° W. Log 0.
   2400, course 248° C. Dev. 7° E. Var. 22° W. Log 218.
   At 1200 on the 13th the Observed Position was 28° 38′ N., 23° 15′ W. Log 428. Required the D.R. position and the set and drift of current experienced.
6. 1200, bound from Cape Town to Durban, Cape Agulhas (34° 50′ S., 20° 01′ E.) bore 060° T., distant 8 miles. Course 114° C. Dev. 6° E. Var. 27° W. Log 0.
   1800, a/c 111° C. Dev. 6° E. Var. 27° W. Log 42.
   2400, a/c 105° C. Dev. 5° E. Var. 27° W. Log 82.
   0600, a/c 103° C. Dev. 5° E. Var. 27° W. Log 122.
   1200, Obs. Pos. 34° 59′ S., 22° 20′ E. Log 164. Find the D.R. position and the set and drift of current experienced.
7. 1200, Dondra Head (5° 56′ N., 80° 36′ E.) bore 000° C. distant 10 miles. Compass error 4° W.
   Set Course 137° C. Dev. 1° E. Var. 2° W. Log 0.
   2000, a/c 134° C. Dev. 0°. Var. 2° W. Log 82.
   0400, a/c 122° C. Dev. 2° W. Var. 2° W. Log 168.
   1200, Log 252. Estimated current 000° T., 14 miles during the day. Find the course and distance made good since the preceding noon and the position arrived at.
8. 1200, Course 268° C. Dev. 7° E. Var. 17° W. Log 0.
   At 1800, St. Catherine's Point (50° 34′ N. 1° 18′ W.) bore 4 points on the starboard bow. Log 64. At 1900 it was abeam. Log 76. No current. Course 268° C. (Dev. 7° E., Var. 17° W.)
   2400. Log 136. Required the ship's position.
9. At noon the ship's position was 47° 30′ N., 179° 25′ W. Log. 0. Course 176° C. Dev. 3° E. Var. 5° E.
   At 2200, Obs. Pos. by star sights 44° 55′ N., 180° E. Log 166. Find the set and drift experienced since noon and the course and distance made good.
10. At 1200 in position 36° 20′ S., 20° 30′ W. a ship steered the following courses:
    Course 150° C. Dev. 5° E., Var. 20° W. 90 miles.
    Course 190° C. Dev. 1° W., Var. 20° W. 30 miles.
    Course 175° C. Dev. 2° E., Var. 20° W. 120 miles
    Having steered these courses the ship's Obs. Pos. was found to be 40° 05′ S., 18° 18·8′ W. Find the D.R. position and the set and drift of the current.
11. At noon, Cape Sorell (42° 11′ S., 146° 10′ E.) bore 070° C. distant 10 miles. Ship's head, 240° C. Dev. 10° W.; Var. 8° E.
    The ship then steered the following courses to noon the following day.
    240° C. Dev. 10° W. Var. 8° E., 50 miles.
    260° C. Dev. 8° W. Var. 8° E., 65 miles.
    275° C. Dev. 6° W. Var. 8° E., 70 miles.
    260° C. Dev. 6° W. Var. 8° E., 90 miles.
    At noon on the following day the ship was in Obs. Pos. 42° 01′ S., 140° 40′ E.



Find the D.R. position, the set and drift experienced and the course and distance made good from noon to noon.

12.

December 24	1200	Co.	100° C.	Dev. 5° W.	Log 0.
December 24	1800	a/c	095° C.	Dev. 6° W.	Log 96.
December 24	2400		082° C.	Dev. 6° W.	Log 186.
December 25	0400		075° C.	Dev. 7° W.	Log 250.
December 25	1200				Log 370.

Dec. 24 at 1830 hrs. East Cape Lt. Ho. (37° 40′ S. Long. 178° 36′ E.) was on the starboard beam, distant 15 miles. Log 103. Variation throughout the day was 13° E.

Find the ship's position at Noon Dec. 25, and the course and distance made good during the 24 hours.

13. At 1500, Godley Head Lt. Ho. (43° 36′ S., 172° 50′ E.) bore 230° C. Distant 15 miles. Ship heading on her first course 095° C. Variation 10° E. Deviation 3° W. Log 39.

At 2000 a/c 085° C. Var. 10° E. Dev. 5° W. Log 104.

At 0400 a/c 070° C. Var. 11° E. Dev. 7° W. Log 216.

At noon the vessel's position was found by observation to be 43° 15′ S., 179° 57′ W. Log 328.

Find the D.R. position at noon, the set and drift of the current and the course and distance made good.

14. At noon Cape Palliser (41° 37′ S., 175° 19′ E.) bore 250° C., distant 10 miles. Ship's head on the first course 138° C. Var. 10° E. Dev. 2° W. Log set to 0.

1600 a/c 145° C. Dev. 4° W. Var. 10° E. Log 56.

2000 a/c 151° C. Dev. 5° W. Var. 10° E. Log 112.

2400 log 162.

A current set 325° T. at 2 knots throughout.

Find the ship's position at 2400 and the course and distance made good.

Chapter 10

Radar Plotting

RADAR AS AN AID TO NAVIGATION

Radar, as the name implies, is a radio direction and range finder. The principle upon which it depends is similar to that of ranging by sound wave echoes, because radio waves are also reflected from solid objects. The equipment consists of the motor generator, the transmitter and receiver, the directional aerial with turning mechanism and the plan position indicator (PPI). The set generates ultra short radio waves which are transmitted in short pulses and directed from the aerial in a narrow beam. When the beam strikes an object some of the radio waves are reflected back to the set and an echo is received. The time interval from transmission to reception of a pulse is measured electronically and half of this interval multiplied by the speed of radio waves gives the range of the target. The range is indicated to scale as the distance from the centre of the PPI to the bright spot of light produced by the echo. The echo displayed persists for a few seconds so that all targets appear continuously as the beam scans the horizon at a rate of 20 revolutions per minute.

A radar set should be capable of accurately indicating ranges from 50 yards for a small object to 20 miles for a coastline target where the ground rises to a height of 200 feet, and a cargo steamer of 5000 g.r.t. should be detected at 7 miles

The bearing of a target can be read off to an accuracy of one degree from the azimuth scale at the rim of the PPI and expressed from the fore and aft line of an unstabilised display as 0°–360°. If the display is stabilised then the bearings may be read off as 0°–360° True.

The ship's position can be plotted on the chart from the radar bearing and range of a prominent shore target which is also conspicuous on the radar picture, but it is preferable to use ranges only, from three suitable objects. Special reflectors are fitted on certain lighthouses and buoys to increase their efficiency as radar targets. As this is standard practice for modern buoys of GRP construction, the chart abbreviation, "Ra. Refl." is now obsolescent and is found only on the older style Fathom Charts. On Metric Charts only the symbol  for a radar reflector is charted. Radar reflectors are not charted for IALA System A buoys. The chart abbreviation, "Ra. conspic", is now obsolescent and the symbol  is used to indicate radar conspicuous targets.

Further information regarding radar symbols and abbreviations may be found at sections M and L70 of the latest Book Edition of Admiralty Chart No. 5011, *Symbols and Abbreviations*.

RADAR PLOTTING

On the Plan Position Indicator (PPI) radar display, the range and bearing of a ship's echo can be obtained from a single observation but correct action to avoid a close quarters situation

cannot be determined from a single observation alone. To avoid a close quarters situation it is necessary to make a plot consisting of several observations. These observations of range and bearing should be taken at suitable intervals.

Two methods of plotting can be used. The first method is a Relative Motion Plot in which the observing ship remains at the centre of the PPI. The second method is the True Motion Plot in which the observing ship moves along her course line on the PPI.

In the Relative Motion Plot, the target's relative track is immediately obtained after plotting the first set of observations. When produced, the relative track gives the target's Closest Point of Approach (CPA) to the observing ship. But the Relative Plot does not give the target's true course and speed without further plotting—this is demonstrated in Example 1.

In the True Motion Plot, the target's true course and speed are immediately obtained after plotting the first set of observations but the True Plot does not give the CPA without further plotting—this is demonstrated in Example 2.

As will be appreciated, both methods have certain advantages.

CPA and Risk of Collision by Relative Plot

Example 1
(Refer to Radar Plot 1)

The following radar bearings and ranges were obtained when steering 080°T at 12 knots.

	Target X		Target Y		Target Z	
	Bearing	*Range*	*Bearing*	*Range*	*Bearing*	*Range*
0900	143°T	10 miles	023°T	10 miles	310°T	9 miles
0906	140°T	8 miles	023°T	8 miles	310°T	8 miles

Relative Motion Plot:

1. The observing ship remains at the centre of the plot.
2. Plot the target's positions as shown, the first position of each target being labelled '*O*' and the last '*A*'.
3. *OA* is the relative track of each target.
4. Produce each track (*OA*) towards the centre. The perpendicular from the centre of the plot to each track gives the target's CPA.
5. The time interval to CPA is found by:

$$\frac{\text{Distance to CPA}}{OA} \times \text{Plotting Interval in minutes}$$

Target '*X*' will have a CPA of 2·0 miles
CPA will occur in:

$$\frac{7{\cdot}7}{2} \times 6 = 23{\cdot}1 \text{ minutes}$$

Target '*Y*' is on a steady bearing and CPA is a collision which will occur in:

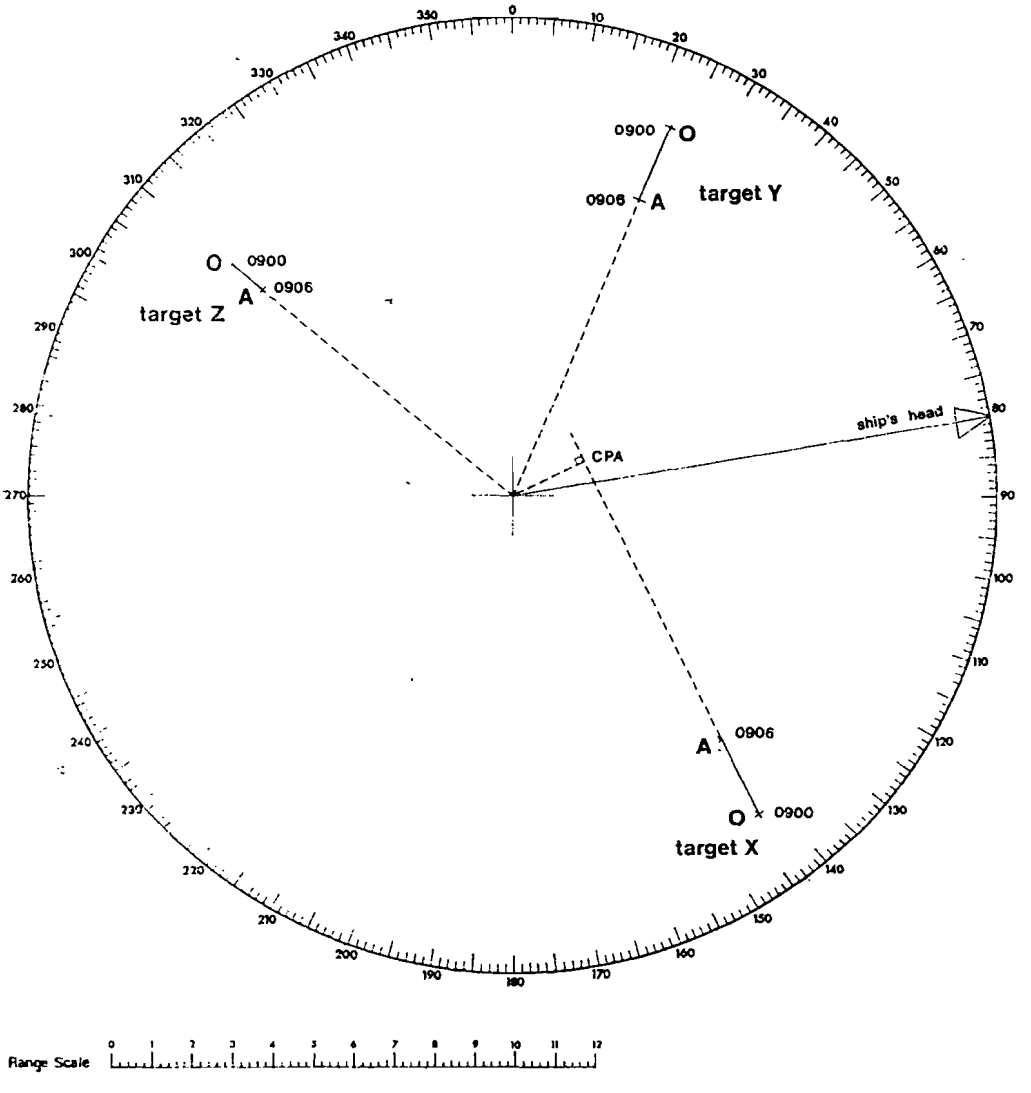
$$\frac{8}{2} \times 6 = 24 \text{ minutes}$$

Target '*Z*' is on a steady bearing and CPA is a collision which will occur in:

$$\frac{8}{1} \times 6 = 48 \text{ minutes}$$

Radar Plot 1

(Relative Motion)



If the same information is used in a True Motion Plot the true course and speed of the target are obtained immediately but the CPA and collision threat priority cannot be obtained without further plotting. This is demonstrated in Radar Plot 2.

Target's True Course and Speed by True Motion Plot

To aid comparison, Example 2 is worked using the same data as used for the Relative Plot in Example 1.

Example 2
(Refer to Radar Plot 2)
The following radar bearing and ranges were obtained when steering 080°T at 12 knots.

	Target X		Target Y		Target Z	
	Bearing	*Range*	*Bearing*	*Range*	*Bearing*	*Range*
0900	143°T	10 miles	023°T	10 miles	310°T	9 miles
0906	140°T	8 miles	023°T	8 miles	310°T	8 miles

True Motion Plot:
1. The observing ship moves along its course line of 080°T at a speed of 12 knots, i.e. 1·2 miles in 6 minutes. The observing ship's position is '*B*' at 0900 hrs. and '*C*' at 0906 hrs.
2. Using the bearings and ranges of the targets at 0900, lay off the positions of the 3 targets from '*B*'. Label these positions '*W*'.
3. Using the bearings and ranges of the targets at 0906, lay off the positions of the 3 targets from '*C*'. Label these positions '*A*'.
4. *WA* is the true course and distance made good in 6 minutes.
   Target '*X*' is steering 010°T at 21·5 knots.
   Target '*Y*' „ 168°T at 16·0 knots.
   Target '*Z*' „ 101°T at 20·0 knots.

Radar as an Anti-Collision Aid—Information Required

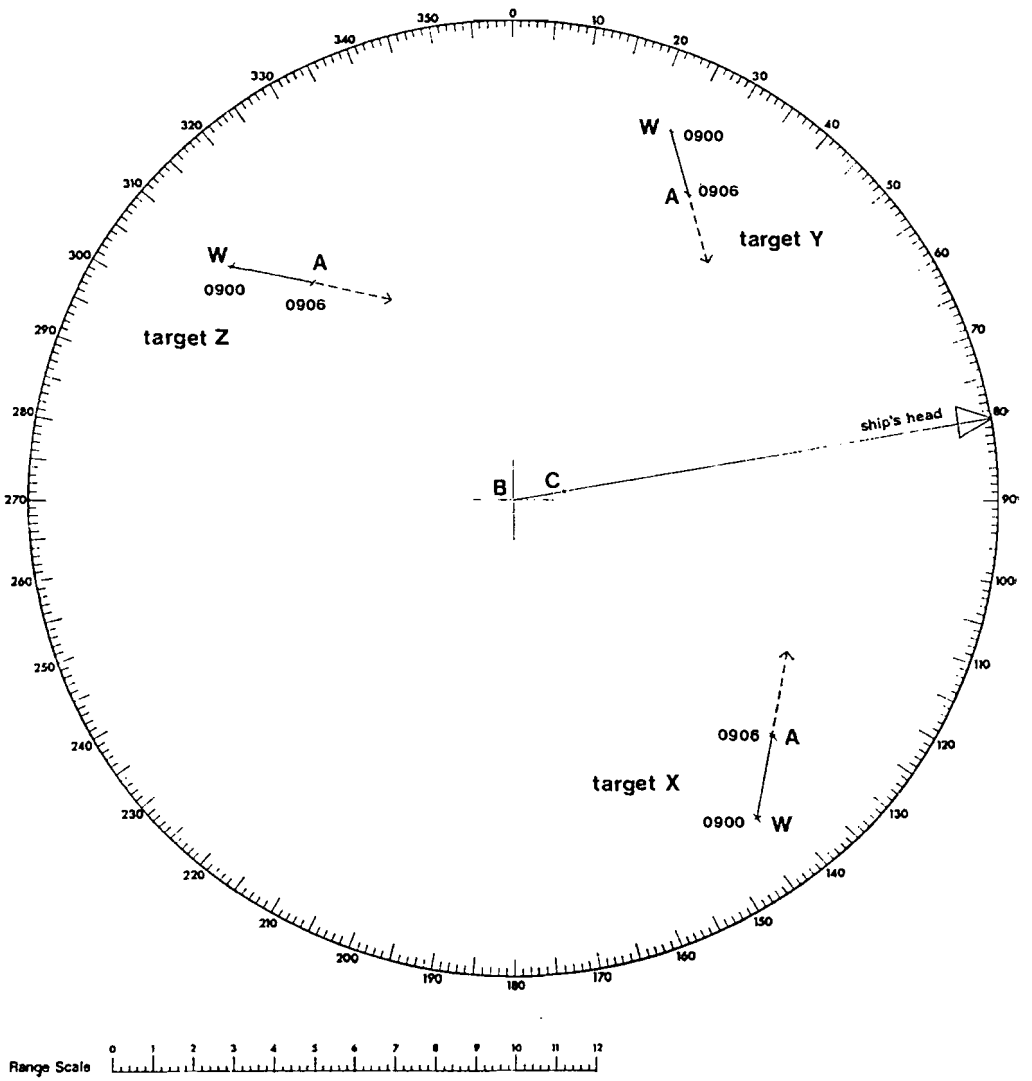
A minimum of 3 radar bearings and ranges, with suitable intervals between them, are necessary before reliable information can be obtained from a radar plot.

When radar is being used as an anti-collision aid the following information will be required from the plot:
1. True Course and Speed of the Target,
2. Aspect (which is the target ship's relative bearing of the observing ship),
3. Closest Point of Approach of the Target (CPA),
4. Time of CPA, and
5. Observer's Relative Bearing of the Target at CPA.

How to obtain this information is explained in Example 3.

Radar Plot 2

(True Motion)



Target's True Course, Speed, Aspect, CPA and the Observer's Relative Bearing of the Target at CPA

Example 3

The following radar information was obtained when steering 080°T at 10 knots:

	Relative Bearing	Range
0900	050°	7·0 miles
0906	046°	5·6 miles
0912	038°	4·2 miles

Find: (a) The true course, speed and aspect of the target at 0912.
(b) The time and range of the target at CPA.
(c) The relative bearing of the target at CPA.

To obtain the required information the plot can be either:
Method (1) Relative Plot, Ship's Head Up.
„ (2) Relative Plot, North Up.
„ (3) True Plot, North Up.

To aid comparison, these three methods are demonstrated (using identical radar information) in Examples 3, 4 and 5.

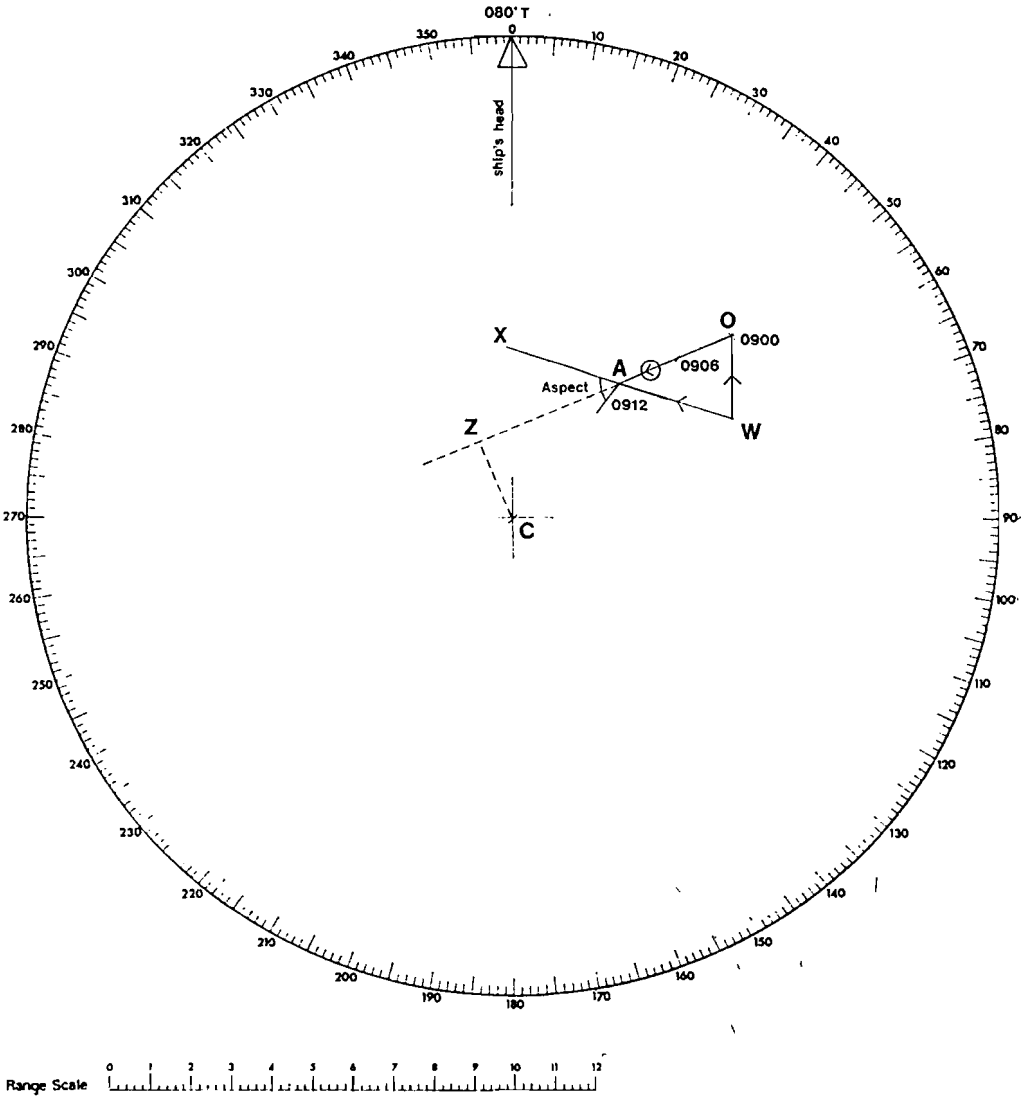
Relative Plot, Ship's Head Up (Method 1)

(Refer to Radar Plot 3)

1. The observing ship remains at the centre of the plot.
2. Plot the positions of the target as shown in Radar Plot 3.
3. The position of the target at 0900 is labelled '*O*' and at 0912 it is labelled '*A*'.
4. *OA*, the relative track of the target, is identified by an encircled arrow always from '*O*' to '*A*' as shown. If the target has not altered course or speed its 0906 position should lie on *OA*.
5. *CZ*, the perpendicular from the centre of the plot to *OA* produced, is the range of the target at CPA, i.e. 2·0 miles.
6. The time to CPA is :
$$\frac{AZ}{OA} \times 12 \text{ minutes}$$
$$\frac{3{\cdot}7}{3{\cdot}0} \times 12 = 15 \text{ minutes (approx)}$$
CPA will occur at 0927 hrs. (i.e. 0912 + 15).
7. The relative bearing at CPA is the angle between the ship's course line and *ZC*, i.e. 337° Relative.
8. From '*O*' lay off *OW* equal to the reciprocal of the observing ship's course (080°T) and the distance it steams in 12 minutes (2 miles), i.e. *WO*, arrowed as shown, is the observing ship's course and distance between 0900 and 0912.
9. *WA*, arrowed as shown, is the target's course and distance between 0900 and 0912. *WA* is at an angle of 72° to the observing ship's course so the target's course is 008°T, (i.e. 080°–72°). *WA* is 2·8 miles long so the target has steamed 2·8 miles in 12 minutes which gives a speed of 14·0 knots.
10. Angle *XAC*, the aspect, is the target's relative bearing of the observing ship, Red 68°.

Radar Plot 3

(Relative—Ship's head up)



Relative Plot, North Up (Method 2)

Example 4

(Refer to Radar Plot 4)

The following radar information was obtained when steering 080°T at 10 knots:

	Relative Bearing	Range
0900	050°	7·0 miles
0906	046°	5·6 miles
0912	038°	4·2 miles

Find: (a) The true course, speed and aspect of the target at 0912.
(b) The time and range of the target at CPA.
(c) The relative bearing of the target at CPA.

1. By applying the observing ship's course, 080°T, to the relative bearings, the true bearings can be obtained:

	Relative Bearing*	Course	Bearing	Range
0900	050°	080°T	130°T	7·0 miles
0906	046°	„	126°T	5·6 miles
0912	038°	„	118°T	4·2 miles

*N.B.—If the Radar Display is compass stabilised, any bearings obtained will be compass bearings. To obtain true bearings, compass error, if present, should be applied.

2. The observer's ship is at the centre of the plot, heading 080°T.
3. Plot the positions of the target as shown in Radar Plot 4.
4. The position of the target at 0900 is labelled '*O*' and at 0912 it is labelled '*A*'.
5. *OA*, the relative track of the target, is identified with an encircled arrow, always from '*O*' to '*A*' as shown. If the target has not altered course or speed its 0906 position should lie on *OA*.
6. *CZ*, the perpendicular from the centre of the plot to *OA* produced, is the range of the target at CPA, i.e. 2·0 miles.
7. The time to CPA is:

$$\frac{AZ}{OA} \times 12 \text{ minutes}$$

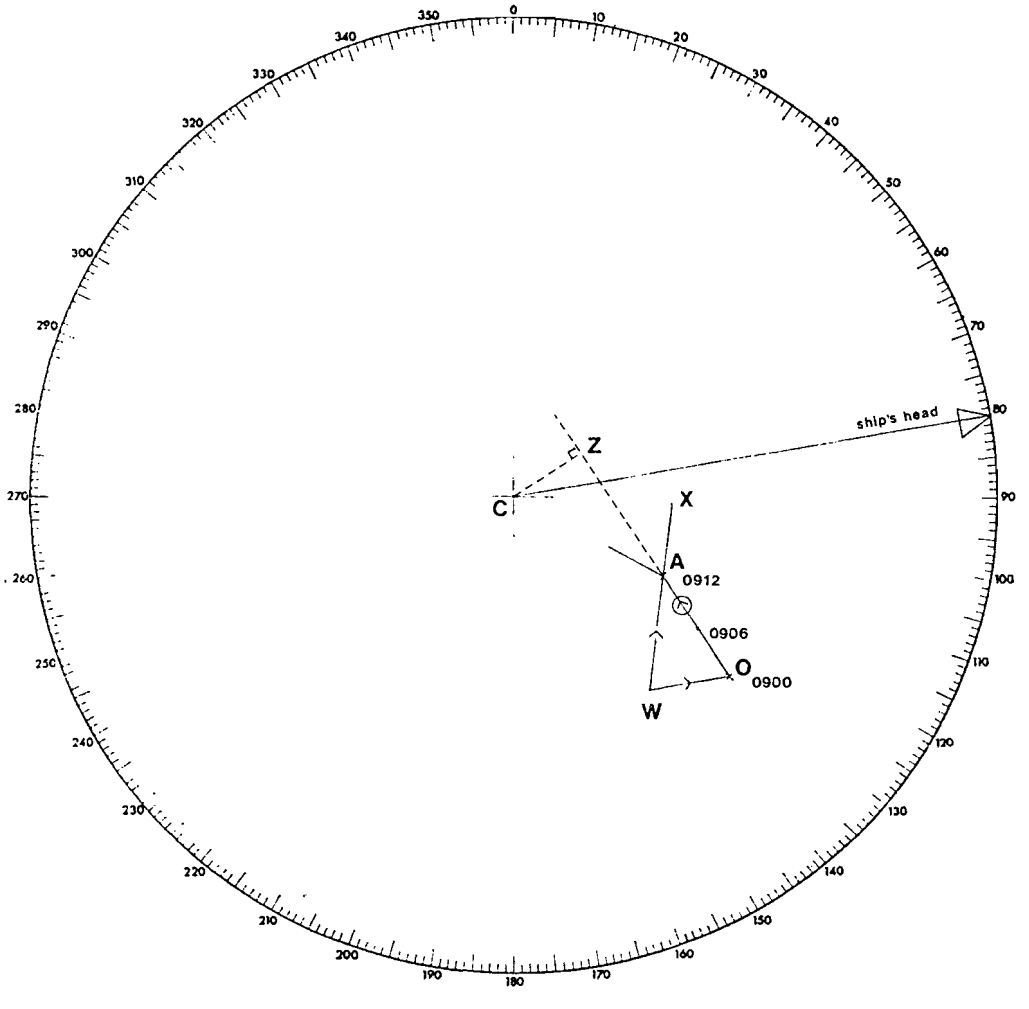
$$\frac{3{\cdot}7}{3{\cdot}0} \times 12 = 15 \text{ minutes (approx)}$$

CPA will occur at 0927 hrs. (i.e. 0912 + 15).

8. The relative bearing at CPA is the angle between the ship's course line and *ZC*, i.e. 337° Relative.
9. From '*O*' lay off *OW* equal to the reciprocal of the observing ship's course (080°T) and the distance it steams in 12 minutes (2 miles), i.e. *WO*, arrowed as shown, is the observing ship's course and distance between 0900 and 0912.
10. *WA*, arrowed as shown, is the target's course and distance between 0900 and 0912. The course of 006°T is obtained directly from the azimuth scale on the outer edge of the plotting sheet, i.e. the direction *WA* does not have to be first applied to the observing ship's course as was the case for a ship's head up plot—see Example 3. *WA* is 2·8 miles long so the target has steamed 2·8 miles in 12 minutes which gives a speed of 14·0 knots.
11. Angle *XAC*, the aspect, is the target's relative bearing of the observing ship, i.e. Red 68°.

Radar Plot 4

(Relative—North up)



True Motion Plot, North Up (Method 3)

Example 5
(Refer to Radar Plot 5)

The following radar information was obtained when steering 080°T at 10 knots:

	Relative Bearing	Range
0900	050°	7·0 miles
0906	046°	5·6 miles
0912	038°	4·2 miles

Find: (a) The true course, speed and aspect of the target at 0912.
(b) The time and range of the target at CPA.
(c) The relative bearing of the target at CPA.

1. With speed 10 knots, plot the observing ship's position at 0900, 0906 and 0912 along her course line, 080°T. Label these positions '*E*', '*D*' and '*C*' respectively, as shown in Radar Plot 5.
2. From these points lay off target's positions at 0900 and 0912.
3. The position of the target at 0900 is labelled '*W*' and at 0912 it is labelled '*A*'.
4. *WA*, arrowed as shown, is the true course (006°T) of the target and its length (2·8 miles) is the distance steamed in 12 minutes which gives a speed of 14 knots.
5. To obtain the CPA draw *WO* equal to *EC* in magnitude and direction. *OA* is the target's relative track and *CZ*, the perpendicular to *OA* produced, is the CPA which is 2 miles. CPA will occur in

$$\frac{AZ}{AO} \times 12 \text{ minutes}$$

$$\frac{3{\cdot}7}{3{\cdot}0} \times 12 = 15 \text{ minutes (approx)}$$

CPA will occur at 0927 hrs.

6. The Aspect, which is the target's relative bearing of the observing ship, is the angle between *AC* and *WA* produced, Red 68°.

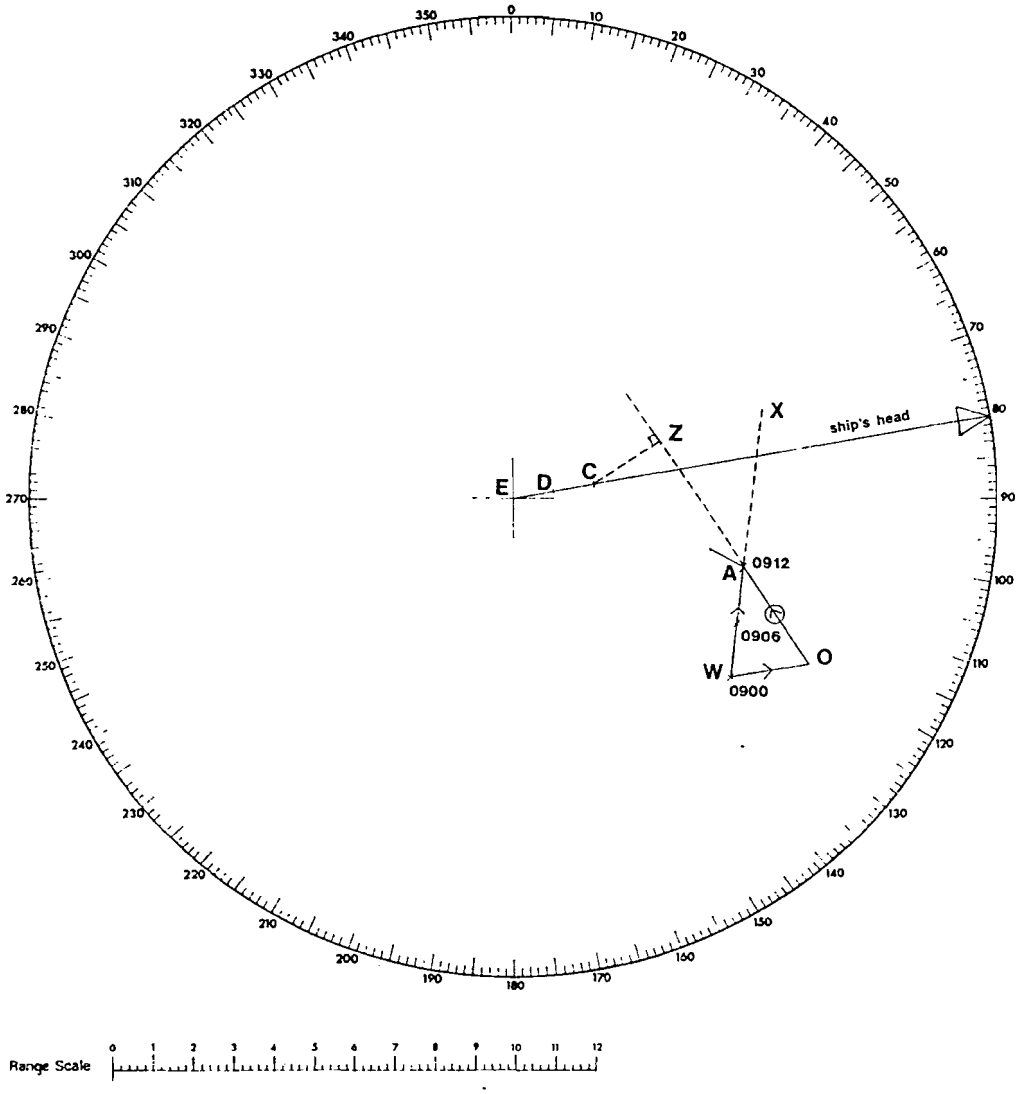
Avoiding a Close Quarters Situation—the Forecast Plot

Having determined the course and speed of the target, action to avoid a close quarters situation can be decided by means of a forecast plot. Such action will consist of either an alteration of course or an alteration of speed. Any alteration of course or speed, which has been obtained from a forecast plot, is assumed to be instantaneous. This assumption will result in a difference between the observed and estimated CPA.

The following example illustrates the construction and use of a forecast plot.

Radar Plot 5

(True—North up)



Course or Speed Alteration Necessary to Increase the Distance Off at CPA

Example 6
(Refer to Radar Plot 6)

The following radar information was obtained when steering 340°T at 10 knots.

	Bearing	Range
0400	035°T	7·0 miles
0406	035°T	6·0 miles
0412	035°T	5·0 miles

Required: (a) A complete assessment of the situation at 0412.
(b) The single alteration of course or speed necessary at 0415 so that the target's CPA will be 2 miles to Port, assuming an instantaneous alteration.

Assessment

By Relative Motion, North Up Plot, as in Radar Plot 6, the assessment† of the situation is as follows:

1. The target is on a steady bearing, 55° on the starboard bow.
2. CPA will be a collision in

   $\frac{5}{2} \times 12$ minutes $= 30$ minutes

   and will occur at 0442 hrs. (0412 + 30).
3. The target's course is 280°T at 9·5 knots.
4. Aspect is Red 65°.

†Students should verify this assessment by working through all stages of Radar Plot 6, as previously explained at Example 4.

Achieving a New CPA by a Single Alteration of Course

(Refer to Radar Plot 6)

1. Plot the target's 0415 position, on OA produced. Label this position 'A^1'. AA^1 is the distance made good along the relative track in 3 minutes.
2. From A^1 draw a tangent to the 2 mile circle and transfer this tangent back through 'A'.
3. With centre 'W' and radius WO draw an arc to cut the transferred tangent at O^1. WO^1 is the new course to steer, 027°T.
4. The new CPA will occur in

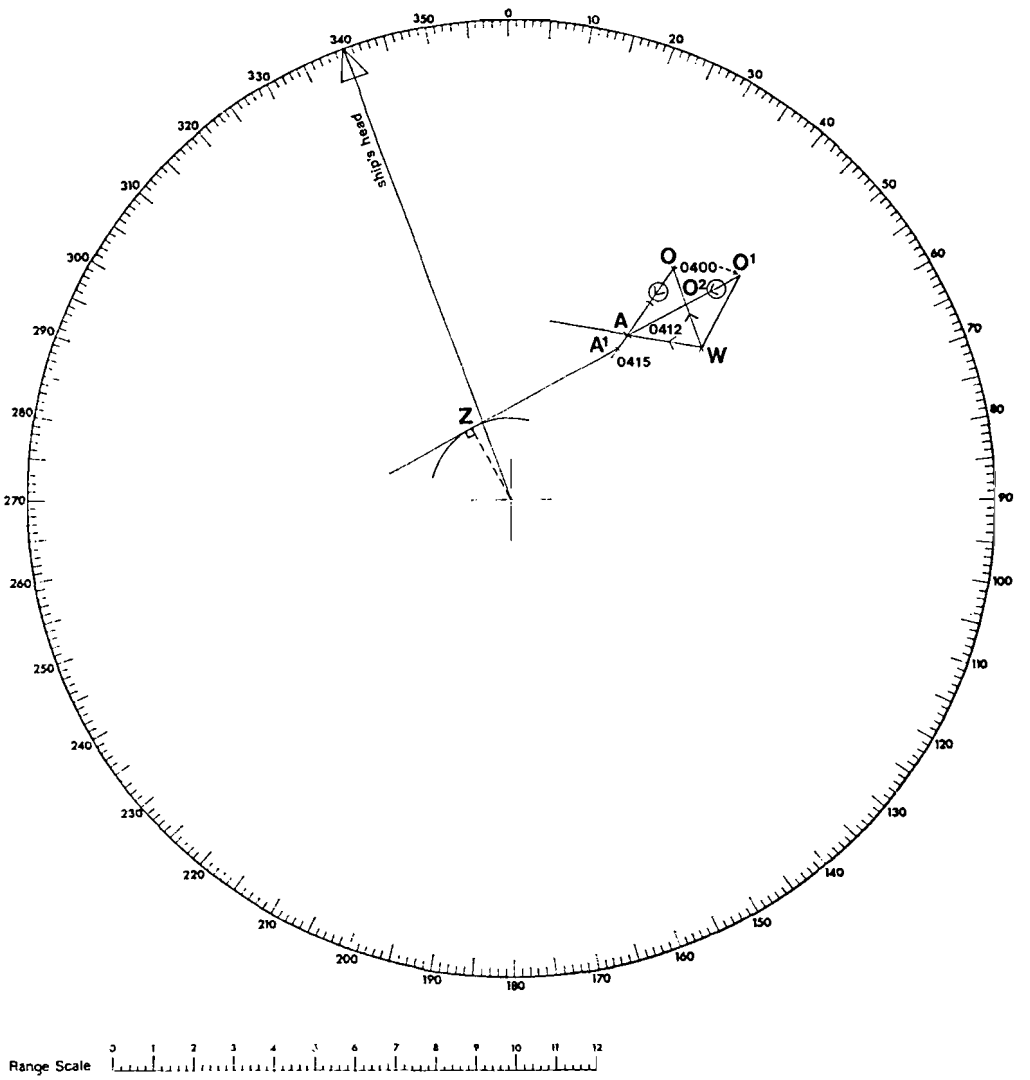
   $\frac{A^1Z}{O^1A} \times 12$ minutes

   $\frac{4}{3} \times 12$ minutes $= 16$ minutes

   CPA will occur at 0431 hrs.

Radar Plot 6

(Relative—North up)



Achieving a New CPA by Speed Reduction Only

(Refer to Radar Plot 6)

1. The single alteration of speed is found from WO^2, where O^2 is the point of intersection of WO and O^1A. WO^2 is 1·2 miles long which, over the 12 minute period, represents a speed of 6 knots. The required speed reduction is 4 knots.
2. The new CPA will occur in

$$\frac{A^1Z}{O^2A} \times 12 \text{ minutes}$$

$$\frac{4{\cdot}1}{1{\cdot}6} \times 12 = 31 \text{ minutes (approx)}$$

CPA will occur at 0446 hrs.

Because course alterations of 47° and speed reductions of 4 knots cannot be carried out instantaneously, the actual CPA's in this example will be less than 2 miles.

It should be noted that, though a CPA of approximately 2 miles was achieved by both methods, the time of CPA was different in each case. At the reduced speed the time of CPA was later.

The Effect of Tide

When using radar in the anti-collision mode, tidal effects are ignored and it is assumed that both the observing ship and the target are subjected to the same set. When a radar plot is made of a stationary target, such as a light vessel which is known to be anchored, the set and drift of the current can be obtained.

Set and Rate of Current from a Stationary Target

Example 7

(Refer to Radar Plot 7)

Whilst steering 000°T at 12 knots the following information was obtained from radar observations of a light vessel.:

	Bearing	Range
0600	030°T	4·0 miles
0615	070°T	2·8 miles

At 0615, a second light vessel was observed right ahead at a range of 5 miles.

Find: (a) The set and rate of the current at 0615.

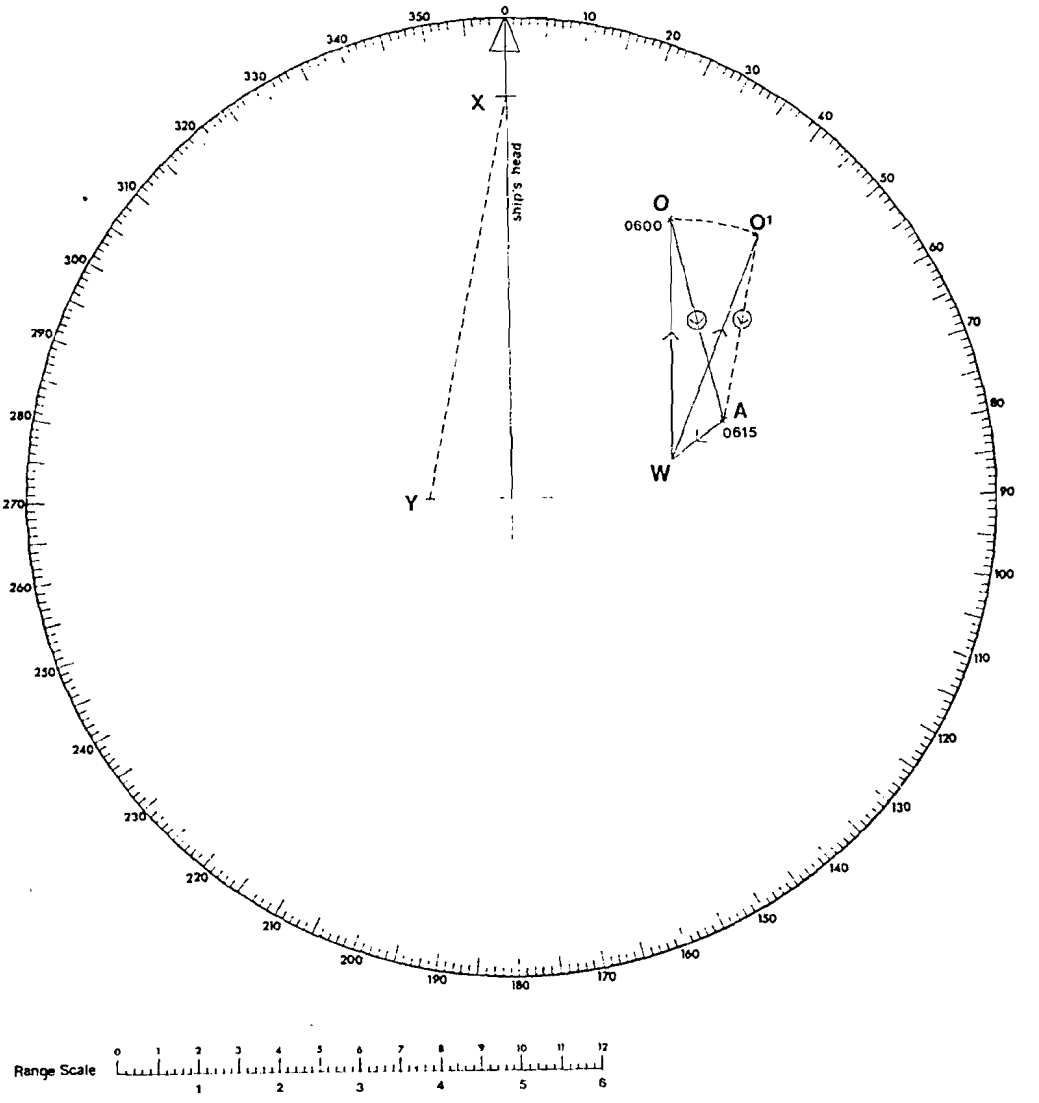
(b) The course to steer so that the second lighthouse will be passed bearing 270°T distant 1 mile.

1. By Relative Motion, North Up Plot, as in Radar Plot 7, the set is in the direction AW, 233°T.

   Because the target is known to be a stationary light vessel, its apparent motion (WA) must be due to the current setting the observer in the opposite direction (AW). The drift is 0·8 miles in 15 minutes which gives a rate of 3·2 knots.
2. Plot the position of the 2nd light vessel at 0615 and its required position when bearing 270°T. Label these positions 'X' and 'Y', as shown in Radar Plot 7.

Radar Plot 7

(Relative—North up)



3. Draw a line through 'A' parallel to XY and with centre 'W' and radius WO draw an arc to cut this parallel line at O^1. WO^1 is the course to steer, 021°T, to bring the light vessel to the chosen beam position.
4. The time to CPA is

$$\frac{XY}{O^1A} \times 15 \text{ minutes}$$

$$\frac{5{\cdot}1}{2{\cdot}3} \times 15 = 33 \text{ minutes}$$

CPA will occur at 0648 hrs.

Relative Motion and True Motion Radar Plots—Comparison

Assuming the previous examples have been carefully studied, it should now be apparent that, having plotted the first set of radar observations, the Relative Motion Plot does not give the target's true course and speed without further plotting. The Relative Plot also requires the construction of a new triangle whenever the observing ship, or the target, alters course—this can be a disadvantage when several targets are involved. What the Relative Plot does give is an immediate indication of the Target's Closest Point of Approach (CPA) which is a vital piece of information.

In the True Motion Plot, further plotting is required to obtain the target's CPA. In the True Plot, however, both the observing ship's and the target's course lines are continuously produced with each plotted observation. Thus, as soon as a target ship alters course the alteration is immediately apparent by a change in direction of the plotted course line. Similarly, any change of speed is immediately apparent by a change in the target's rate of progress along the course line.

From the foregoing it will be seen that the True Plot tends to give a better overall understanding of the developing situation and is generally better suited to handling several targets at the same time. But it must be again stressed that the True Plot does not give the target ship's CPA without further plotting. If the True Plot is used the CPA should be obtained either by "on plotting" both own ship and target ship's positions along their course lines and, preferably, by making use of relative plotting to construct a course-speed triangle (OAW) as previously explained.

Many serving Officers and Masters prefer the True Plot which they consider gives them a better understanding of the developing situation than can be obtained from the Relative Plot. Others prefer the Relative Plot because it gives an immediate indication of risk of collision and the target's closest point of approach. A thorough knowledge of both methods is clearly essential and the student should become familiar with both before forming any personal opinion regarding their relative merits.

Radar Plotting Terms

True Bearing

The direction of one object from another expressed in degrees clockwise from True North.

Sea Speed

The speed of own ship through the water track expressed in knots.

Ground Speed

The speed of own ship over the ground track expressed in knots.

Relative Track of Target

The direction of motion of a target as observed on a relative motion display.

True Track of Target

The direction of motion of a target as observed on a true motion display.

Aspect Symbol ° Red or ° Green

The relative bearing of own ship from the target ship expressed in degrees 0 to 180 "RED" or "GREEN".

NOTE: When plotting a target ship on a radar the deduced aspect may not be the same as the visual aspect. Several factors can cause this variation. The effects of current and leeway which may be different on both own and target ship; the accuracy of speed input on a true motion display and the variation between the actual width or ground track of own ship and that displayed on the PPI.

Detection

The recognition of the presence of a target.

Acquisition

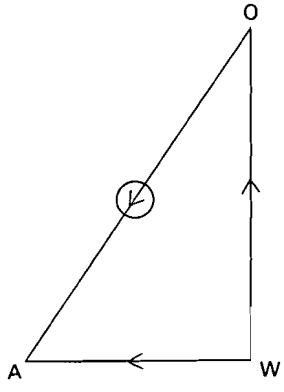
The selection of those targets requiring a tracking procedure and the initiation of their tracking

Tracking

The process of observing the sequential changes in the position of a target, to establish its motion.

Plotting Diagrams

Radar data obtained from a stabilized or unstabilized relative motion display, or true motion sea stabilized display.



RELATIVE PLOT		TRUE PLOT	
O	Initial position of target on plot at appropriate range and bearing from own ship.	W	Initial position of target on plot at appropriate range and bearing from own ship.
O ⟶ A	Target's relative track/ speed vector.	W ⟶ A	Target's true track/speed vector.
W ⟶ O	Own ship's course/speed vector over time increment *OA*.	W ⟶ O	Own ship's course/speed vector over time increment *WA*.
W ⟶ A	Target's true track/ speed vector over time increment *OA*.	O ⟶ A	Target's relative track/ speed vector.

NOTE: When the target is a fixed terrestrial point A ⟶ W is the vector representing the set and drift of a current or tidal stream.
When the radar data is taken from a true motion ground stabilized display a vector A ⟶ W for a fixed terrestrial point represents an error of speed input.

COLLISION AVOIDANCE RULES WHICH REFER TO THE USE OF RADAR

The following Rules from the *International Regulations for Preventing Collisions at Sea*, 1972, refer to the use of Radar:

RULE 6

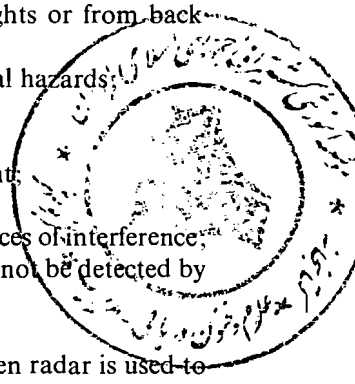
Safe Speed

Every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions.

In determining a safe speed the following factors shall be among those taken into account:

(a) By all vessels:
  (i) the state of visibility;
  (ii) the traffic density including concentrations of fishing vessels or any other vessels;
  (iii) the manoeuvrability of the vessel with special reference to stopping distance and turning ability in the prevailing conditions;
  (iv) at night the presence of background light such as from shore lights or from back-scatter of her own lights;
  (v) the state of wind, sea and current, and the proximity of navigational hazards;
  (vi) the draught in relation to the available depth of water.

(b) Additionally, by vessels with operational radar:
  (i) the characteristics, efficiency and limitations of the radar equipment;
  (ii) any constraints imposed by the radar range scale in use;
  (iii) the effect on radar detection of the sea state, weather and other sources of interference;
  (iv) the possibility that small vessels, ice and other floating objects may not be detected by radar at an adequate range;
  (v) the number, location and movement of vessels detected by radar;
  (vi) the more exact assessment of the visiblity that may be possible when radar is used to determine the range of vessels or other objects in the vicinity.



RULE 7

Risk of Collision

(a) Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist.

(b) Proper use shall be made of radar equipment if fitted and operational, including long-range scanning to obtain early warning of risk of collision and radar plotting or equivalent systematic observation of detected objects.

(c) Assumptions shall not be made on the basis of scanty information, especially scanty radar information.

(d) In determining if risk of collision exists the following considerations shall be among those taken into account:
  (i) such risk shall be deemed to exist if the compass bearing of an approaching vessel does not appreciably change;
  (ii) such risk may sometimes exist even when an appreciable bearing change is evident,

particularly when approaching a very large vessel or a tow or when approaching a vessel at close range.

RULE 8

Action to Avoid Collision

(a) Any action taken to avoid collision shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship.
(b) Any alteration of course and/or speed to avoid collision shall, if the circumstances of the case admit, be large enough to be readily apparent to another vessel observing visually or by radar; a succession of small alterations of course and/or speed should be avoided.
(c) If there is sufficient sea room, alteration of course alone may be the most effective action to avoid a close-quarters situation provided that it is made in good time, is substantial and does not result in another close-quarters situation
(d) Action taken to avoid collision with another vessel shall be such as to result in passing at a safe distance. The effectiveness of the action shall be carefully checked until the other vessel is finally past and clear.
(e) If necessary to avoid collision or allow more time to assess the situation, a vessel shall slacken her speed or take all way off by stopping or reversing her means of propulsion.

RULE 19

Conduct of Vessels in Restricted Visibility

(a) This Rule applies to vessels not in sight of one another when navigating in or near an area of restricted visibility.
(b) Every vessel shall proceed at a safe speed adapted to the prevailing circumstances and conditions of restricted visibility. A power-driven vessel shall have her engines ready for immediate manoeuvre.
(c) Every vessel shall have due regard to the prevailing circumstances and conditions of restricted visibility when complying with the Rules of Section I of this Part.
(d) A vessel which detects by radar alone the presence of another vessel shall determine if a close-quarters situation is developing and/or risk of collision exists. If so, she shall take avoiding action in ample time, provided that when such action consists of an alteration of course, so far as possible the following shall be avoided;
    (i) an alteration of course to port for a vessel forward of the beam, other than for a vessel being overtaken;
    (ii) an alteration of course towards a vessel abeam or abaft the beam.
(e) Except where it has been determined that a risk of collision does not exist, every vessel which hears apparently forward of her beam the fog signal of another vessel, or which cannot avoid a close-quarters situation with another vessel forward of her beam, shall reduce her speed to the minimum at which she can be kept on her course. She shall if necessary take all her way off and in any event navigate with extreme caution until danger of collision is over.

RADAR PLOTTING EXERCISE

1. Own course 090°T, speed 12 knots. Target bore 315° Relative, range 5 miles and 10 minutes, later it bore 320° Relative, 4 miles. Find the course and speed of the target vessel and the nearest approach assuming no alteration of course and speed.
2. Heading 235°T, at 10 knots, target bearing 010° Relative, range 7 miles. 15 minutes later it bears 012° Relative, range 3 miles. What is the course and speed of the target vessel and what alteration of course would you make to allow a nearest approach of 2 miles.
3. Describe a True Plot and a Relative Plot. From the following information make a True Plot: Own course 065°T, speed 6 knots. A target was observed bearing 080° Relative, range 5 miles, and after 30 minutes it bore 125° Relative, range 7 miles. Find the course and speed of the target vessel.
4. Heading 333°T, at 20 knots, a target which was known to be a light vessel bore 330° Relative, range 8 miles. After 18 minutes it bore 285° Relative, range 3 miles. Find the set and rate of the current in the vicinity.
5. Course 075°T, speed 10 knots, target bearing 045° Relative, range 8 miles. Three minutes later it bears 043° Relative, range 7 miles, and after a further 3 minutes it bears 041° Relative, range 6 miles. It is desired to let this vessel cross ahead of you, 3 miles distant, without altering own course. What should the speed be reduced to? Find also the course, speed and aspect of target vessel at last plotted point.
6. Course 300°T, speed 15 knots, targets were observed as follows:

	'X' Relative Brg.	*Range*	*'Y' Relative Brg.*	*Range*
0000	330°	5·0 miles	045°	7·0 miles
0004	331°	3·0 miles	046°	6·0 miles
0008	320°	2·0 miles	047°	5·0 miles
0012	293°	1·4 miles	058°	3·7 miles

Have the target vessels made any alteration of course or speed? If so, state what each has done.

What will be the nearest approach of each target vessel and would any avoiding action be necessary on your part?

7. Course 105°T, speed 6 knots the following plot was made:

	Relative	*Range*
1200 target bearing	020°	7·0 miles
1203	030°	6·5 miles
1206	030°	6·0 miles
1209	030°	5·5 miles

At 1212 course was altered 90° to starboard (turning time 4 minutes). What report should be made at 1200 and at 1209?

What will be the expected bearing and range of target at 1220, and what will be the nearest approach after the alteration of course? Is a further alteration of course necessary?

8. Course 090°T, speed 20 knots, the following plot was made:

Target 'X'	*Relative Brg.*	*Range*	*'Y'*	*Relative Brg.*	*Range*
1800	340°	8 miles		050°	7 miles
1803	331°	6 miles		050°	6 miles
1806	317°	4 miles		049°	5 miles

What report should be made to the O.O.W. at 1800 and at 1806? At 1809, what alteration of course will be necessary to allow '*Y*' to cross your course 2 miles ahead of you, and what will be his expected bearing and range at 1812? Make no allowance for turning time.

9. Course 180°T, speed 10 knots, the following observations of a target were made:

	Relative Brg.	*Range*
2200	310°	7·0 miles
2203	310°	6·3 miles
2206	310°	5·6 miles
2209	303°	4·7 miles
2212	294°	4·0 miles

Is any avoiding action necessary on your part? What will be the CPA of the target and when? State what action has been taken by the target vessel.

10. Course 260°T, speed 12 knots, the following observations of a target were made:

	Relative Brg.	*Range*
0000	290°	6·0 miles
0003	290°	5·0 miles
0006	290°	4·0 miles
0009	284°	3·4 miles
0012	277°	2·9 miles

Is avoiding action necessary? And if not why not? What is the course and speed of the target at 0006 hrs. and what is her speed at 0012 hrs.? Has the target vessel made any alteration of course? What will be its CPA?

11. Course 333°T, speed 15 knots.

Target 'X'	*Relative Brg.*	*Range*	*'Y'*	*Relative Brg.*	*Range*
0100	315°	5·0 miles		045°	8·0 miles
0103	316°	4·4 miles		045°	7·2 miles
0106	317°	4·0 miles		046°	6·6 miles
0109	318°	3·4 miles		046°	5·9 miles

What report should be made to the O.O.W. at 0109? What are the course and speeds of target vessels '*X*' and '*Y*'? At 0112 speed was reduce to 5 knots. How far ahead of you will '*X*' and '*Y*' be when they cross your course?

12. The following radar observations were made whilst steering 225°T at 10 knots.

	Target Bearing	*Range*
1515	220°T	8 miles
1518	221°T	7 miles
1521	221°T	6 miles
1524	220°T	5 miles

At 1524 the observing ship altered course to 285°T and made the following observation:

1530	198°T	4 miles

At 1530 the observing ship altered course back to 225°T and made a further observation:

1536	170°T	2·9 miles

Make no allowance for swinging time
What will be the target's CPA?

Has target altered course since first observed, and if so, give the alteration to her original course and speed and last course and speed.

13. During fog patches, ship steering 045°T, at 6 knots, targets were observed at 3 minute intervals as follows:

Target 'X'		*Target 'Y'*		*Target 'Z'*	
Bearing	Range	Bearing	Range	Bearing	Range
020°T	5·0 miles	085°T	5·5 miles	145°T	7·0 miles
022°T	4·2 miles	091°T	4·3 miles	145°T	6·4 miles
024°T	3·4 miles	101°T	3·3 miles	145°T	5·8 miles
023°T	2·9 miles	120°T	2·4 miles	141°T	6·1 miles
020°T	2·6 miles	152°T	2·0 miles	137°T	6·4 miles

Give the courses and speed of the targets and state what action you would take if any. What action has been taken by the targets?

14. While steering 045°T, at 10 knots a Ramark beacon is observed 035°T, range 9 miles. Twelve minutes later the same beacon bore 034°T, range 7 miles and again 12 minutes later it bore 032°T, range 5 miles. Find the set and drift of the current and also the alteration of course necessary to pass the beacon 2 miles off on your port hand.

15. Steaming at 12 knots on a course of 225°T, targets '*X*' and '*Y*' were observed as follows:

	Target 'X'		*Target 'Y'*	
0000	205°T	8·5 miles	270°T	8·0 miles
0005	204°T	7·3 miles	270°T	6·8 miles
0010	204°T	6·2 miles	270°T	5·6 miles
0015	203°T	5·1 miles	270°T	4·4 miles

'*X*' is known to be a Light Vessel and you wish to pass 3 miles off leaving it to port.

Find (*a*) the alteration of course necessary at 0015 to pass 3 miles off. (*b*) The set and drift of the current. (*c*) The course and speed of '*Y*' and how far she will cross ahead of you, also will she cross your course before or after you pass the Lt. V.

Answers

1. Course 122°T, Speed 11 knots. CPA 1·7 miles. 025° Relative.
2. Course 080°T, Speed 6·4 knots. A/C 62° to Port.
3. Course 222°T, Speed 4·2 knots.
4. Set 252°T, Rate 3·8 knots.
5. Reduce speed to 5·5 knots. Co. 347°T, Speed 17·5 knots. Aspect Red 46° or 314° Relative.
6. '*X*' has stopped, CPA 1·2 miles. '*Y*' has altered course 5 points to Port, CPA 1·2 miles.
7. 1200, Target bears 030° Relative, Range 7 miles.
   1209, Target bears 030° Relative, Range 5·5 miles. Collision in 33 minutes.
   Co. 345°T, Speed 6 knots.
   1220 Target bears 287° Relative, Range 3·3 miles. CPA 105° × 3·3 miles.
8. 1800, '*X*' bears 340° Relative at 8 miles.
   1800, '*Y*' bears 050° Relative at 7 miles.
   1806, '*X*' bears 317° Relative at 4 miles (decreasing). CPA 2·7 miles, 270° Relative in 4 minutes.
   Co. 270°T, Speed 26·5 knots.
   1806, '*Y*' bears 049° Relative (drawing forward), Range 5 miles decreasing. CPA 0·3 miles.
   322° Relative in 15 minutes. Target altered course 46° to starboard.
   Expected bearing at 1812, 345° Relative at 2·7 miles.

9. No action required: CPA 3 miles, 250° Relative. Target has altered course 61° to starboard.
10. No, Target has reduced speed from 19 knots to 8·5 knots. CPA 2 miles, 230° Relative. Co. 335°T.
11. '*X*' Course 018°T, Speed 12 knots, crosses 2·9 miles ahead.
    '*Y*' Course 268°T, Speed 10 knots, crosses 3·5 miles ahead.
12. CPA 153°T, 2·8 miles, about 3 minutes after last plot. Target has altered course 37° to starboard.
    Original course and speed 045°T, 10 knots. Final course 072°T, speed 10 knots.
13. '*X*' Course 172°T, Speed 10 knots, has stopped in the interval between 3rd and 4th observations.
    '*Y*' Course 250°T, Speed 20 knots, has made no alteration.
    'Z' Course 352°T, Speed 15 knots, has altered course approx. 80° to starboard presumably to avoid collision with '*Y*'.
    No action necessary by own ship.
14. Set 314°T, drift 1 mile. Alter course 16° to starboard.
15. (*a*) Alter course 34° to starboard.
    (*b*) Set 150°T, Speed 4 knots.
    (*c*) Course 146°T, Speed 10 knots, she will cross 1·6 miles ahead before I pass the Lt. Vessel.

Chapter 11

Admiralty and Other Publications used in Navigation

British Admiralty publications include:

The Admiralty Catalogue
Which lists all British Admiralty publications.

The Mariner's Handbook
Which gives general information relating to Admiralty Publications, navigation, navigational aids, the sea, ice and meteorology.

Charts
For both navigational and other purposes.

Books, Diagrams and Other Publications
Which provide more detailed information than that found on charts, or relate to navigation, or which deal with meteorology, oceanography or hydrographic practice.

Notices to Mariners
Which provide the latest information necessary to correct charts, books and other publications, which reprint the latest Navigational Warnings, and which are published in weekly and annual editions.

Supplements
Which list more detailed corrections to specific Admiralty Publications and which are published approximately every 18 months.

The Nautical Almanac (HMSO)
Which tabulates all data required to practice astronomical navigation at sea.

ADMIRALTY CHART CATALOGUE

The *Catalogue of Admiralty Charts and Hydrographic Publications* is divided into 39 sections:

Section	
XA and 1–3	Chart Index Limits and General Information regarding countries which publish Charts and Lists of Chart Agents.
4	Navigational Charts.
5–25	Other Charts.

26–37 Publications.
38–39 Index.

In alphabetical order, the twelve sections included under the general heading of Publications are as follows:

1. Astronomical.
2. Catalogues.
3. Distance Tables.
4. Hydrographic Practice and Symbols.
5. Light Lists and Fog Signals.
6. Marine Science.
7. Meteorology.
8. Miscellaneous.
9. Oceanographic.
10. Radio.
11. Sailing Directions.
12. Tidal.

The following list is an approximate guide to the contents of the 12 sections.

Astronomical	*Section* 28	
	Sight Reduction Tables and Forms	NP 401
	Star Finder and Identifier	NP 323
	Rising and Setting Diagrams	NP 301
Catalogues	*Section* 29	
	Catalogue of Admiralty Charts and Hydrographic Publications: Home Edition	NP 109
	World Edition	NP 131
Distance Tables	*Section* 30	
	North and South Atlantic Oceans and Europe Mediterranean, Caribbean and Gulf of Mexico, Vol. I	NP 350/1
	Indian and Southern Oceans, Red Sea, Persian Gulf and Eastern Archipelago, Vol. II	NP 350/2
	Pacific Ocean, Vol. V	NP 355
Hydrographic Practice and Symbols	*Section* 31	
	Admiralty Manual of Hydrographic Surveying, Vols. I and II	NP 134a & b
	General Instructions to Hydrographic Surveyors	NP 135
	Table of Meridional Parts, Spheroidal Tables and Metric Conversion Tables for fathoms and feet.	
	N.B.—The Symbols and Abbreviations booklet, Chart No. 5011, is listed under the heading "Charts and Other Diagrams" at Section 20 (For further information see Chapter 12)	
Light Lists	*Section* 27	
	Admiralty List of Lights and Fog Signals Covering the World in 12 volumes A–M (For further information see Chapter 12)	

Marine Science	*Section* 35	
	Bathymetric, Magnetic and Gravity Surveys (Indian Ocean and UK)	
	Equatorial Current Investigations (Gilbert Islands)	
	Oceanographic Cruises and Observations (North and South Atlantic, Indian Ocean and Carribbean Sea)	
	Seismic Investigations, Mean Sea Levels and Hydrographic Analysis of Sandbanks (UK)	
	Surface Temperature and Salinity Observations (Indian Ocean)	
Meteorology	*Section* 37	
	Weather in Home Fleet Waters, Vol. I, Northern Seas; Vol. II, British Isles and Baltic	NP 447c & d
	Weather in the Mediterranean, Vol. I, General: Vol. II, Local Information	NP 428a & b
Miscellaneous	*Section* 32	
	Guide to Publications and Information Services	NP 95
	The Mariner's Handbook	NP 100
	Ocean Passages for the World	NP 136
	Index to Notices to Mariners for preceding year	
	Admiralty Notices to Mariners—small craft editions	
	Chart Correction Log	NP 133a
	Ships, Boats, Charts, and Folio Cover for Charts	
Oceanographic	*Section* 33	
	Echo Sounding correction tables	NP 139
	Echo Sounding velocities (UK & North Sea)	NP 642
	Oceanography of seas around Japan	NP 637
	Sea Ice North of USSR, Parts I and II	NP 700a & b
	Sea Ice Distribution (Antarctic)	NP 701
	Surface Water Density Charts (Mediterranean)	NP 607
	Surface and Sub-surface Water Movements (Straits of Gibraltar)	NP 629
	Temperature and Salinity Charts (Mediterranean)	NP 644
	Underwater Handbook (Western Approaches)	NP 625
	Underwater Handbook (South China and Java Seas)	NP 623
Radio	*Section* 34	
	The Admiralty List of Radio Signals in 6 volumes (1–6) covering the World and with accompanying diagrams (For further information see Chapter 13)	NP 281 (1)–NP 286 (2)
Sailing Directions	*Section* 26	
	Admiralty Sailing Directions (Pilots) in over 70 volumes covering the World and with accompanying Supplements (For further information see Chapter 12)	NP 1–73

Tidal	*Section* 36	
	Admiralty Tide Tables:	
	European Waters, inc. Mediterranean, Vol. 1	NP 201
	Atlantic and Indian Oceans, Vol. 11	NP 202
	Pacific Ocean and Adjacent Seas, Vol. 111	NP 203
	(Vols. 11 and 111 include Tidal Stream Tables)	
	Admiralty Manual of Tides	NP 120
	Admiralty Tidal Handbooks, Nos. 1–3	NP 122 (1–3)
	Admiralty Method Tidal Prediction Forms	NP 159
	Harmonic Tidal Analysis Forms	NP 171 & 112
	Admiralty Tidal Stream Atlases in 16 volumes:	
	Hong Kong	NP 217
	North-West Europe	NP 209–337*
	Co-Tidal Atlas (South East Asia)	NP 215
	(For further information see Chapter 14)	

* Not consecutively numbered.

Important Note

Section numbers may change and reference should always be made to the most recent edition of the *Catalogue of Admiralty Charts and Hydrographic Publications*. Section numbers quoted above refer to the 1986 Edition.

Chapter 12

Chartwork

Navigating a ship between two ports involves the three main branches of navigation:

Pilotage	when entering or leaving port,
Coastal Navigation	when in sight of land, and
Ocean Navigation	when out of sight of land.

In this chapter we examine the various methods and techniques which assist the navigator to make safe passage along a coast. These include various methods for laying off courses to steer, for avoiding charted dangers and for fixing the ship's position on the chart. Such methods include use of Admiralty Publications, the Gyro and Magnetic Compasses, the Sextant, Electronic Navigational Aids and other means. Coastal Navigation involves a considerable amount of plotting on the chart (Chartwork). Pilotage, on the other hand, involves specialised Local Knowledge which enables the navigator (or Pilot) to navigate by eye and generally without reference to the chart.

THE CHART

The chart is a specialised map used by the navigator. On the chart is depicted all the necessary information which the navigator requires in order to safely navigate the ship. Quite clearly, a chart can only be of limited size and in order to depict all the required information it is necessary to use various symbols and abbreviations. Those used by the Admiralty are included in the booklet edition of the Admiralty Publication 5011, *Symbols and Abbreviations*, a copy of which is included in the rear pocket of this book.

Symbols and Abbreviations NP5011

The 5th Edition of NP5011 was published in 1984. It includes a Correction System for recording serially numbered illustrative supplements which are published as block corrections in *Notices to Mariners*. Each major group of features is assigned a letter in accordance with the system published by the International Hydrographic Organisation (IHO), e.g. [A] The Coastline; [K], Lights; [O] Dangers etc. The contents page lists the IHO letter, group of features and page number on which they may be found. An additional item, "Small Craft Facilities", which does not have an IHO system number, is also included.

Symbols and abbreviations are depicted (side by side or on facing pages) first for Metric Charts and second for Fathom Charts. Alternatively, Metric and Fathom Chart symbols are shown combined. Abbreviations of principal Foreign and English Terms are included at the rear together with the Index to Symbols and Abbreviations. When using charts: **A Fully Corrected Copy of the Latest Edition of NP5011 should ALWAYS be At Hand.**

Natural Scale of a Chart

The natural Scale of a chart is the ratio between a unit of length on the chart and the number of such units which it represents on the earth's surface, e.g. taking an approximate value of 6000 ft for 1 nautical mile and a chart of Natural Scale 1 : 72,000 we would expect 1 inch on the chart to represent 1 nautical mile ($6000 \times 12 = 72{,}000$)

Types of Chart

Broadly speaking, charts can be divided into five main categories:

1. Ocean Charts	(Small scale)	which include little detail and which are used for Ocean Navigation.
2. Coastal Charts	(Large scale)	which include detailed information required for Coastal Navigation.
3. Plan Charts	(Very Large scale)	which include very detailed information of small areas, e.g. ports, rivers and estuaries.
4. Ocean, Coastal or Plan Charts overprinted with some form of Lattice		which are used to plot positions obtained by Electronic Navigational Aids, e.g. Decca, Omega and Loran.
5. Special Purpose Charts		not used to plot position but which provide navigational information, e.g. Regions of Ice, Routes, Magnetic Variation etc.

The amount of information included on a chart depends not only on the physical size of the chart but also on the area covered by the chart. The larger the area covered, the smaller the amount of navigational information which can be included. The smaller the area covered by the chart, the greater the amount of navigational information. Put another way, the larger the scale of the chart the greater the amount of information which can be included.

Chart Projections

The most useful chart for a navigator is one on which it is possible to show the ship's intended track by drawing a straight line between the departure point and the destination and then measure the True Course which must be steered to arrive at the required destination. The chart which allows the navigator to do this is one which is drawn on the Mercator Projection.

Mercator Projection

The main features of a Mercator Chart are Parallels of Latitude which appear as straight lines parallel to the Equator and Meridans of Longitude which appear as straight lines parallel to each other but at right angles to the Parallels of Latitude. It follows that a straight line drawn on a Mercator Chart (a Rhumb Line) will cut successive meridians at a constant angle and provide the navigator with a single course between the ship's departure point and destination.

The Mercator Projection is used for all Admiralty Charts which have a Natural Scale which is less than 1 : 50,000.

A disadvantage of the Mercator Projection is that the Rhumb Line Course between two positions does not represent the shortest distance between them but this feature is of little

importance where we are concerned with relatively short coastal distances. An advantage of the Mercator Projection is that the Latitude Scale is also the scale used for measuring distance.

Gnomonic Projection and Plan Charts

To show the track which represents the shortest distance between two positions it is necessary to use a chart drawn on the Gnomonic Projection. The main features of a Gnomonic Chart are Meridians of Longitude which are shown as straight lines converging at the Poles, and Parallels of Latitude which are shown as curves. The disadvantage of the Gnomonic Projection is that when covering large areas such as the North Atlantic, it is not possible to measure distance or course—these have to be calculated. But when covering very small areas, such as a harbour, a special form of Gnomonic Chart is used and is referred to as a Plan Chart. The Plan Chart includes scales of Latitude and Longitude which are used in much the same way as those on a Mercator Chart.

The Gnomonic Projection is used for all Admiralty Charts having a Natural Scale which is greater than 1: 50,000. A straight line joining two positions on a Gnomonic Chart is a Great Circle which, as previously mentioned, is the shortest distance between the two positions.

Production (and Distortion) of Charts

The original work of the Hydrographic Surveyor is passed to the Draughtsman and engraved on a copper plate or drawn in ink on an enamelled plate. It is then transferred to a zinc plate which is used to print the chart by the lithographic process. All charts are liable to slight distortion during the process of reproduction. Charts printed direct from the copper plate have to be thoroughly dampened for the ink to "take". These charts are particularly prone to distortion. Longer print runs are made using the zinc plate and these charts are less prone to distortion. The prudent navigator will note the information (printed on the chart) which relates to the type of plate used. The dimensions can then be checked against those measured directly from the chart and any distortion noted.

The effect of the distortion decreases as the scale of the chart increases and for this and other reasons THE LARGEST SCALE CHART SHOULD ALWAYS BE USED.

Obtaining Charts

Agents dealing in the sale of Admiralty Charts and Hydrographic Publications are listed in Notice No. 2 of the *Annual Summary of Admiralty Notices to Mariners.*

Admiralty Chart Catalogue

When planning a voyage or series of voyages, the navigator will consult the *Catalogue of Admiralty Charts and Hydrographic Publications*, NP131. A special *Home Edition*, NP109 is also available and is popular with Yachtmasters. These catalogues show, in diagrammatic form, the areas covered by each chart and also include a full list of all Admiralty Charts. The navigator selects the most suitable combination of Ocean, Coastal, Plan, Lattice and Special Purpose Charts which are then collated into geographical areas and placed in linen folders known as Folios.

More detailed information regarding the Admiralty Chart Catalogue is contained in the Chapter dealing with Admiralty Publications and Sources of Information.

Chart Correction

Without a chart the ship cannot be navigated. Without an up to date chart the ship cannot be navigated safely. In consequence, it is of vital importance to keep all charts required for the voyage properly corrected and up to date. Chart corrections are promulgated in the *Weekly Editions of Admiralty Notices to Mariners* (obtainable free of charge at Admiralty Chart Agents and available for consultation at locations listed in Notice 14 of the *Annual Summary of Notices to Mariners*). Radio Navigational Warnings are also broadcast and these are designed to give early information of incidents which may constitute a danger to navigation—see Annual Notice No. 13.

The following is an example of a Notice to Mariners contained in Weekly Edition No. 3 of 1984:

***150. AFRICA, West Coast — Ivory Coast — Yobua Rocks — Stranded wreck.**
A stranded wreck, ⊀ *PA*, is to be inserted in position 4° 21′·0 N., 7° 28′·7 W.
Note: This is the wreck of the M.V. *Med Explorer* (9826 GRT).

Charts [*Last correction*].—**1980** [*2845/81*]—**1365** [*New Edition, 2/12/83*].
Lloyds List. (H. *3332/76.*)

Note that the Notice has been marked with a star which indicates that the notice is based on original information. Also note, at the bottom of the notice, that we are given the number of the affected chart (No. 1980) and the number of the last correction made to that chart (Notice No. 2845 promulgated in 1981). Assuming we are navigating in the vicinity of Yobua Rocks, we would immediately get out Chart No. 1980, insert the stranded wreck in the position indicated and also insert the number of the correction (150/84) in the chart's bottom left hand border. We would next examine the numbers of previous "Hand Corrections" which have been made to the chart. We should find that the last correction (2845/81) has also been entered in the bottom left hand border. If not, we should check back through the weekly editions of Notices to Mariners for 1981, find the last correction, make the correction and then check that earlier corrections have been made. In this manner it is possible to check that all corrections have been made since the chart's publication.

Though most Admiralty Chart Agents offer a Chart Correction Service it is important that the navigator keeps all charts required for the current voyage fully corrected.

Further information on chart correction is contained in *The Mariner's Handbook*, NP100.

Information included on Charts

(Refer to Chart 5053 and NP5011 in Rear Pocket and Plate 1)

A very considerable amount of information is included on a chart. Refer to Chart 5053, *Symbols and Abbreviations* NP5011 (included in the Rear Pocket) and the following list which includes some of the more important items. Identify the location of each item and then make up a second list of other items.

Number of Chart	Left hand Top Corner and Right hand Bottom Corner.	
Title	Shown in the most convenient position so as not to obscure essential navigational information.	
Units of Depth	Beneath Title	also Top and Bottom of chart. (Metres or Fathoms).
Scale	„ „	at a stated Latitude.
Depths	„ „	level from which measured.
Projection	„ „	e.g. Mercator or Gnomonic.
Authorities	„ „	e.g. Admiralty surveys and French Govt. Charts.
Cautions	„ „	also found elsewhere.
Magnetic Variation	„ „	and on the Compass Rose or "curves".
Submarine Exercise Areas	„ „	and on the chart.
Wreck Information	„ „	not always included in Title Area.
Compass Rose	Various Positions	
Isogonals	„ „	(Lines of Equal Magnetic Variation) or "curves".
Lights and Buoys	„ „	e.g. Fixed, Flashing, Group Flashing, High Focal Plane buoy etc.
Wrecks and Dangers	„ „	e.g. Dangerous Wreck and a Rock which covers and uncovers.
Natural Features	„ „	e.g. Hills, rivers and trees.
Buildings	„ „	
Traffic Separation Schemes	„ „	e.g. Off Beachy Head.
Soundings	On Charted Sea Areas	e.g. *33* and 10_4 (metres)
Depth Contour Lines	„ „	e.g. *30* metre contour line edged in blue.
	„ „	e.g. *20* metre contour line solid blue.
Quality of the Bottom	„ „	e.g. *MS* (Mud and Sand).
Areas which Cover and Uncover	„ „	Solid green on metric charts.
Tidal Stream Diamonds	On Chart Sea Area, e.g. Ⓐ, Ⓑ and Ⓒ.	
„ „ Data	Shown in the most convenient position so as not to obscure essential navigational information.	

Charts published by the Hydrographic Department give a considerable amount of information regarding the navigation of coasts and of pilotage waters, anchorages, inland waters and harbours, topographical features, depths of water, shoals and hidden dangers, clearing marks, tidal streams, the winds and currents to be expected, port facilities, trade and administration and indeed all the available information that might be of value or of interest to mariners navigating the areas described. The *Merchant Shipping (Carriage of Nautical Publications) Rules* 1975, which are based on Regulation 20 of the 1974 SOLAS Convention, require U.K. registered ships to carry suitably detailed charts, Sailing Directions and other publications appropriate to the voyage—see Annual Notice to Mariners No. 18 for further details. Navigation students should make a careful study of the remarks contained in these publications and which relate to practical navigation, pilotage and the use of charts.

Reliance on a chart depends upon the date and accuracy of the survey on which it is based

and on whether, or not, it has been corrected up to date from information given in *Notices to Mariners* issued by the Hydrographic Department, Taunton. The degree of reliance to be placed on a chart is also influenced by the scale and the amount of detail shown along the coast. Large scale charts should be used when coasting as corrections cannot always be inserted satisfactorily on charts drawn on a small scale, nor can positions be laid off so accurately on them.

The closeness of the soundings is an indication of the reliability of a chart and as depths of water have hitherto been obtained solely by the laborious use of the lead and that the lead only covers about 5 cms. (2 inches) of the bottom, it follows that inequalities situated between two lines of soundings may have escaped notice. Blank spaces among soundings mean that no soundings have been obtained at these spots. When the sounded depths are deep it may be assumed that in the blanks the water is also deep; but when the sounded depths are shallow such blanks should be regarded with suspicion, especially in coral regions and off rocky coasts. In consequence a wide berth should be given to every rocky shore or patch and the rule should be that instead of considering a coast to be clear, unless shown to be foul, the contrary should be assumed.

The twenty metre contour line is a caution against unnecessarily approaching the shore or bank within that line on account of the possibility of the existence of undiscovered inequalities of the bottom which nothing but an elaborate detailed survey could reveal.

It has been pointed out by the Hydrographic Department that when transferring the ship's position from one chart to another it should be done whenever possible by taking the bearing and distance from a distinguishing feature common to both, such as a light or a point of land. Chart graduations may differ slightly due to one being constructed on later and more complete geographical data than the other.

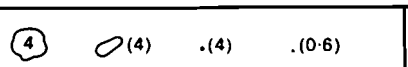
Hints on the Use of Charts

1. ALWAYS use the largest scale chart available.
2. ALWAYS use a soft (2B) pencil for plotting on the chart.
3. ALWAYS use a soft eraser to remove plotting.
4. ALWAYS use a Bearing and Distance of some common point when transferring a position from one chart to another.
5. ALWAYS obtain a fix as soon as possible after transferring a position from one chart to another.
6. ALWAYS check the Variation (particularly after changing charts).
7. ALWAYS check the units used for Depth, i.e. Fathoms, Feet or Metres.
8. ALWAYS check Warnings and other Information printed in the Title Area.
9. ALWAYS use the Latitude Scale in the vicinity of the position in which you wish to measure distance.
10. NEVER have two charts on the chart table at the same time—you may use the latitude scale of one to measure distance on the other.

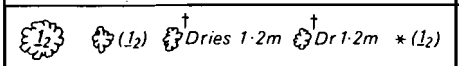
Before attempting the worked examples the following instructions should be carefully read and noted.

O Dangers

Metric Charts



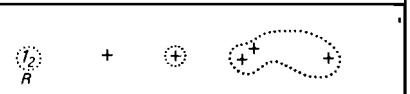
1 Rock which does not cover (with elevation above MHWS or MHHW, or where there is no tide, above MSL)



2 Rock which covers and uncovers (with elevation above chart datum)



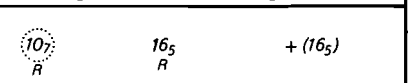
3 Rock awash at the level of chart datum



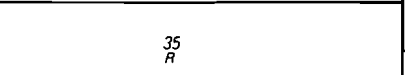
4 Underwater rock with 2 metres or less water over it at chart datum, or

rock ledge on which depths are known to be 2 metres or less, or

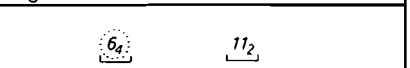
a rock or rock ledge over which the exact depth is unknown but which is considered to be dangerous to surface navigation



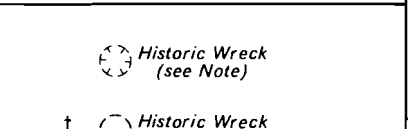
5 Shoal sounding on isolated rock



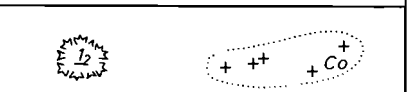
6 Underwater rock not dangerous to surface navigation



6a Underwater danger with depth cleared by wire drag sweep



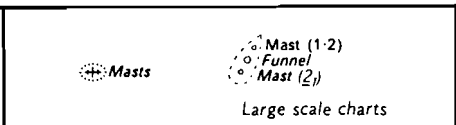
(Oc) Restricted area round the site of a wreck of historical and archaeological importance.



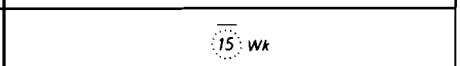
10 Coral reef



11 Wreck showing any portion of hull or superstructure at the level of chart datum



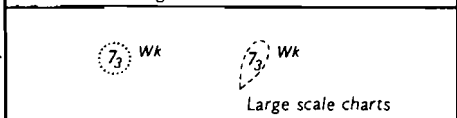
12 Wreck of which the masts only are visible



(Oa) Unsurveyed wreck over which the exact depth is unknown but which is considered to have a safe clearance at the depth shown



14 Wreck over which the exact depth of water is unknown but is thought to be 28 metres or less, and which is considered dangerous to surface navigation



15 Wreck over which the depth has been obtained by sounding, but not by wire sweep

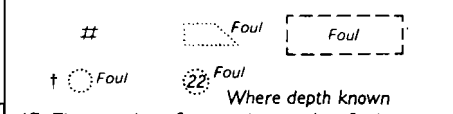


15a Wreck which has been swept by wire to the depth shown

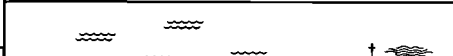


16 Wreck over which the exact depth is unknown but thought to be more than 28 metres, or

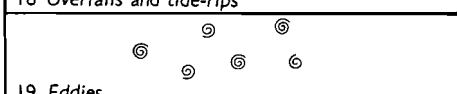
a wreck over which the depth is thought to be 28 metres or less, but which is not considered dangerous to surface vessels capable of navigating in the vicinity.



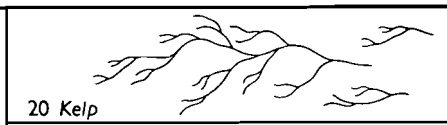
17 The remains of a wreck, or other foul area, no longer dangerous to surface navigation, but to be avoided by vessels anchoring, trawling, etc.



18 Overfalls and tide-rips



19 Eddies



20 Kelp

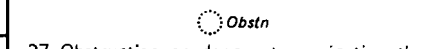
21	Bk.	Bank
22	Sh.	Shoal
23	Rf.	Reef
24	Le.	Ledge



25 Breakers



(Od) Submerged wellhead (with least depth where known)

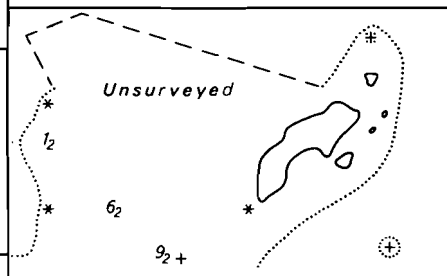


27 Obstruction or danger to navigation the exact nature of which is not specified or has not been determined.



(Oe) Fish haven
(with least depth where known)

28	Wk	Wreck
29	See 17	Wreckage
29a	See 17	Wreck remains
30	See 17	Submerged piling
30a		Snags, submerged stumps
	See also 17	
32	dr	Dries
33	cov	Covers
34	uncov	Uncovers
35	Rep † Repd	Reported



38 Danger line (see Note)



(Ob) Areas of mobile bottom
(including sand waves)

41	PA	† (PA)	Position approximate
42	PD	† (PD)	Position doubtful
43	ED	† (ED)	Existence doubtful
	See Q1		Sounding of doubtful depth
44	pos	† posn	Position
46	unexam	† unexamd	Unexamined

Drying heights: See note in the Introduction.

Non-dangerous wrecks: Where the depth of a wreck exceeds 28 metres, or it is otherwise considered non-dangerous, the appropriate symbol is generally shown on the largest scale chart only.

Danger line: A danger line draws attention to a danger which would not stand out clearly enough if represented solely by its symbol (eg. isolated rock), or delimits an area containing numerous dangers, through which it is unsafe to navigate. A bold pecked line with explanatory legend may be used to delimit an area where there is inadequate information.

INSTRUCTIONS FOR USING WORKED EXAMPLES

(To be read Before attempting the Worked Examples)

1. Worked Examples have been designed both for the beginner and the advanced student.
2. Earlier examples include fairly detailed instructions which should enable the beginner to get started and to progress steadily.

   More advanced students may find it sufficient to read the earlier Example Questions and to study the corresponding Figures.
3. The Examples are progressive and should be tackled in sequence. (Explanations and calculations are more detailed in earlier examples, less detailed in the later ones).
4. Beginners should note that the examples cover the full range of chartwork constructions and possibly extend beyond the normal requirements of Dept. of Transport Examinations. Students should consult the appropriate syllabus included in this volume to determine their precise requirements.
5. All Example Questions can be worked on Admiralty Practice Chart 5053 "English Channel Western and Central Portions". (A reduced copy of this chart is included in the Rear Pocket). Ideally, the serious student should obtain a full size (full colour) copy of this chart.
6. All necessary extracts from Admiralty and other publications have been included in the text.
7. All Example Questions include a detailed plot carefully drawn to scale. These Figures include the appropriate Latitude Scale which will enable the student to measure distances and to check each stage of construction.
8. Due to chart distortion, which can occur in the printing process, plots made on different copies of the same chart may differ slightly. Such differences may result in slightly different answers to those given in the text. Beginners should be aware of these slight differences and concentrate on correct principles rather than minor differences.
9. The suggested study plan is as follows:
   (a) Read through the initial notes on each construction and refer to the accompanying Figure.
   (b) Study the Example Question.
   (c) Go through the explanation or numbered instructions and check each step on the accompanying Figure (you will need dividers, 2B pencil, soft rubber eraser, a note book and the copy of Chart 5053. A Douglas protractor, if available, will be of added assistance).
   (d) When thoroughly conversant with the construction, get out your full set of chartwork instruments and attempt the Example Question without further reference to this volume.
   (e) Check your answer before proceeding to the next example.
   (f) Tackle the appropriate Exercises (at the end of this chapter) at regular intervals to assess your progress.
10. Finally, a word of warning and some encouragement:

    Chartwork is not difficult but it does require scrupulous attention to detail and a thorough knowledge of the principles involved. Quite rightly, the Department of Transport always examine Chartwork on the First Day of every professional examination. Failure in your Chartwork paper (or your Coastal Navigation paper which includes Chartwork) will mean failure in the entire examination. Many certificated Junior Officers

fail their Class 2 Examination for this reason. In these modern times ships are very expensive and examination courses very costly. Safeguard your ship and your bank balance now—learn Chartwork, it isn't difficult. Good luck.

PLOTTING

Summary

The **Parallel Ruler** is used to lay off courses and bearings on the chart. It can be used in conjunction with either:

(a) The Compass Rose, as shown in Figure 3, or
(b) Any convenient Meridian, as shown in Figure 4.

When adopting method (b) the parallel ruler is used much as a protractor. The parallel ruler (which must be fully closed) is aligned with the meridian such that the South point marked S (bottom edge) and the required three figure notation engraving (top edge) and the meridian form a continuous line.

Compasses, which are fitted with one metal tip and one soft lead or pencil tip, are used to draw arcs of D.Long or Distance.

Dividers, which have two metal tips, are used to measure distance.

To Plot Latitude and Longitude

1. Draw in the required Latitude with the Parallel Ruler (Figure 1).
2. Mark off the required D.Long. with Compasses (Figure 2).

To Plot Bearing and Range

1. Draw in the bearing using Parallel Rulers and either the Compass Rose or any convenient Meridian.
2. Use Compasses to measure the distance off (range) on the Latitude Scale in the vicinity of the position.
3. Plot the range along the line of bearing.

To Measure Distance

1. Select a convenient distance on the Latitude scale which lies in the vicinity of the two positions.
2. Adjust the dividers to this distance.
3. "Step" this distance along the course line and adjust the dividers for any "remainder".
4. Measure the remainder (on the same part of the Latitude scale as before) and total up the distance.

More Detailed Explanations (for the beginner) are included in the Examples 1–4.

To Plot a Position

Example 1

(Refer to Figures 1 and 2 and the English Channel Chart insert at Page 288)

Lay off position X in 50° 30′ N 00° 00′
Y in 49° 55′ N 2° 45′ W, and
Z with Les Hanois bearing 090°T. Distance 10 miles.

First study the vertical scale on the right hand side of the Chart—this is the Scale of Latitude which is also the scale of distance.

To Plot Position X

1. Place the point of the compasses on Latitude 50° N. and open the compasses to 50° 30′ N. Draw a small arc to make sure that you have the precise latitude.
2. Transfer the point of the compasses to the position in which the 50th parallel of latitude cuts the Greenwich meridian (Long. 00° 00′).
3. Describe a small arc to cut the Greenwich meridian.
4. The point of intersection of the arc and the Greenwich meridian is the required position (50° 30′ N. 00° 00′).

To Plot Position Y

1. Take the parallel rulers and carefully align the top edge with the parallel of 50° N.
2. "Walk" the parallel ruler down the chart until the top edge is about the thickness of a pencil line below latitude 49° 55′.
3. Draw a trial pencil line to check that it passes exactly through 49° 55′ N. (adjust if necessary).
4. Draw a fine pencil line commencing at Longitude 2° 00′ W. and extending a short distance beyond 2° 45′ W.
5. Place the Compass point on the meridian of 2° 00′ W. (on the top horizontal scale).
6. Open the compasses so that the lead passes precisely through Longitude 2° 45′ W, i.e. Measure the Difference of Longitude (D.Long.) between the printed meridian and the required meridian.
7. Transfer the compasses to the newly drawn parallel of 49° 55′ N.
8. With centre Longitude 2° 00′ W. describe a small arc to cut the parallel.
9. The point of intersection of the arc and the parallel is the required position (49° 55′ N. 2° 45′ W.).

To Plot Position Z

1. Carefully align the top edge of the parallel ruler with the parallel of 50° 00′ N. (All parallels run 090°–270°T. Check this by "walking" the parallel ruler to the Compass Rose and noting the compass direction.)
2. "Walk" the parallel ruler down the chart until the top edge is just below the starred circle which indicates the position of Les Hanois Gp.Fl. (Group Flashing) Lt.
3. Draw a trial pencil line to check that it just passes through the light (adjust if necessary).
4. Continue the line for a short distance in a 270°T (Westerly) direction.
5. Using the compasses, measure a distance of 10 miles on the latitude scale which lies in the vicinity of the latitude of Les Hanois (49° 26′ N.).
6. With centre Les Hanois and radius 10 miles measured above, described a small arc to cut the 270°T line drawn at (4).
7. The point of intersection of the arc and the 270°T line is the required position (Les Hanois bearing 090°T distant 10 miles).

Answer: See Plot.

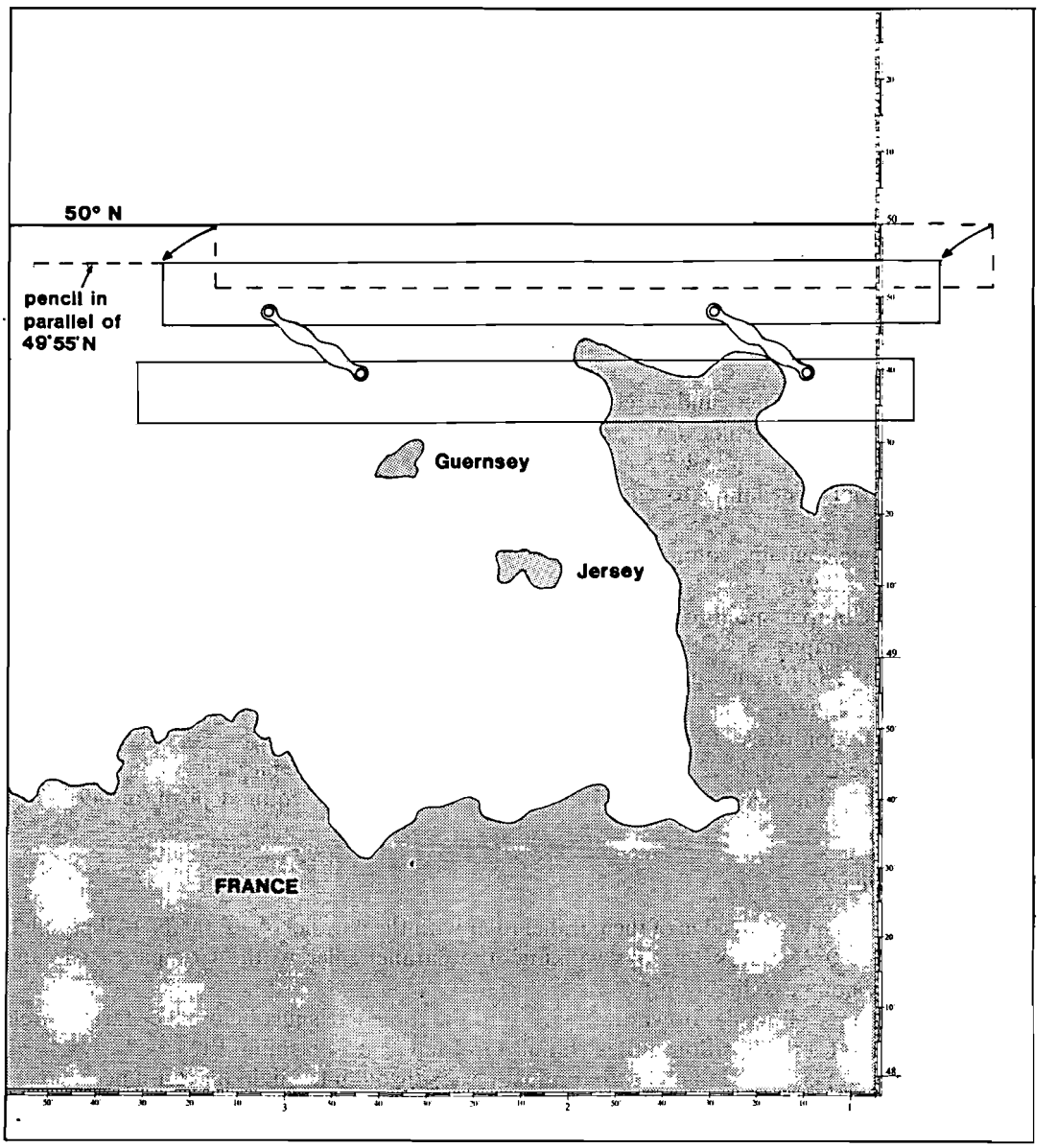


Figure 1. Plotting Latitude.

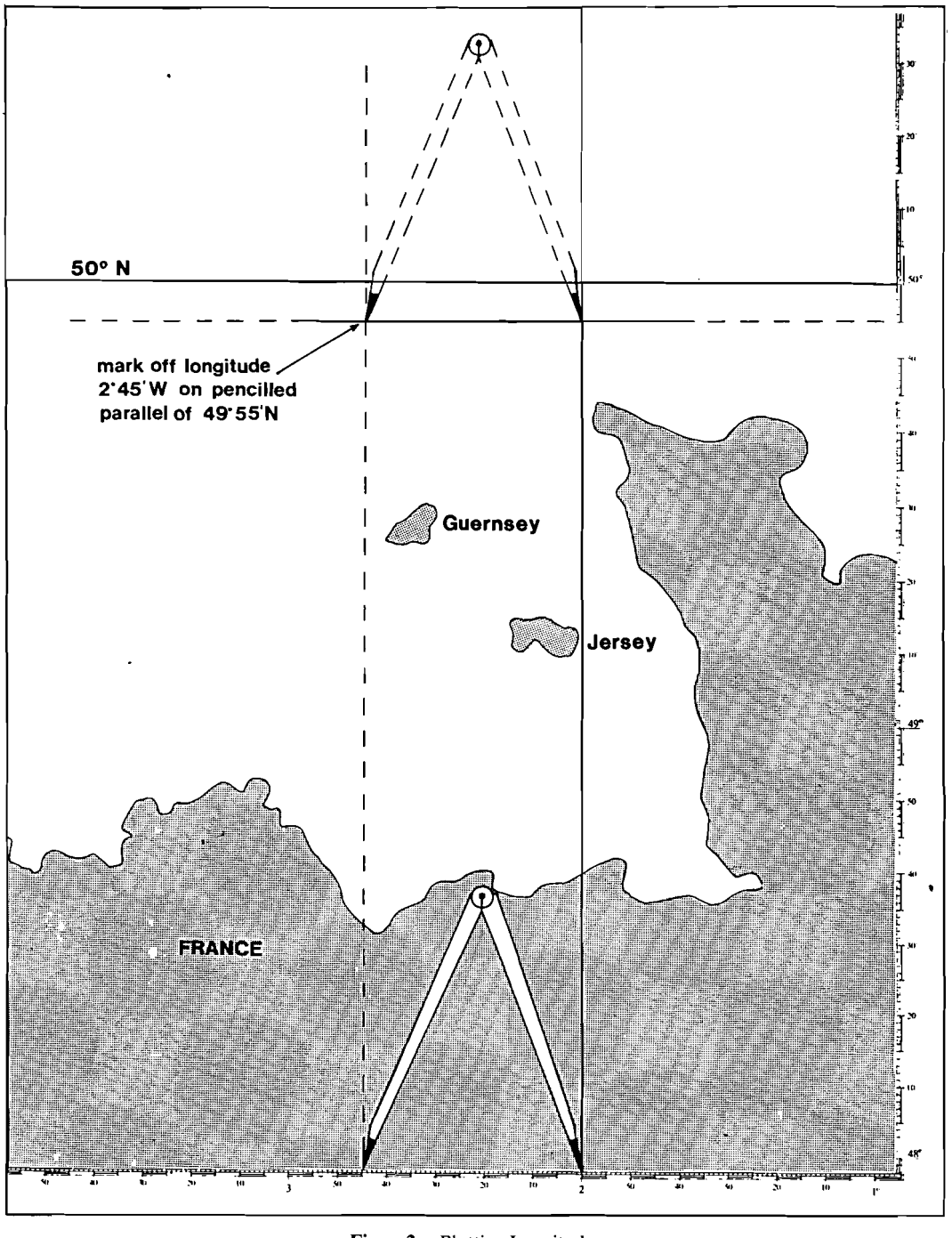


Figure 2. Plotting Longitude.

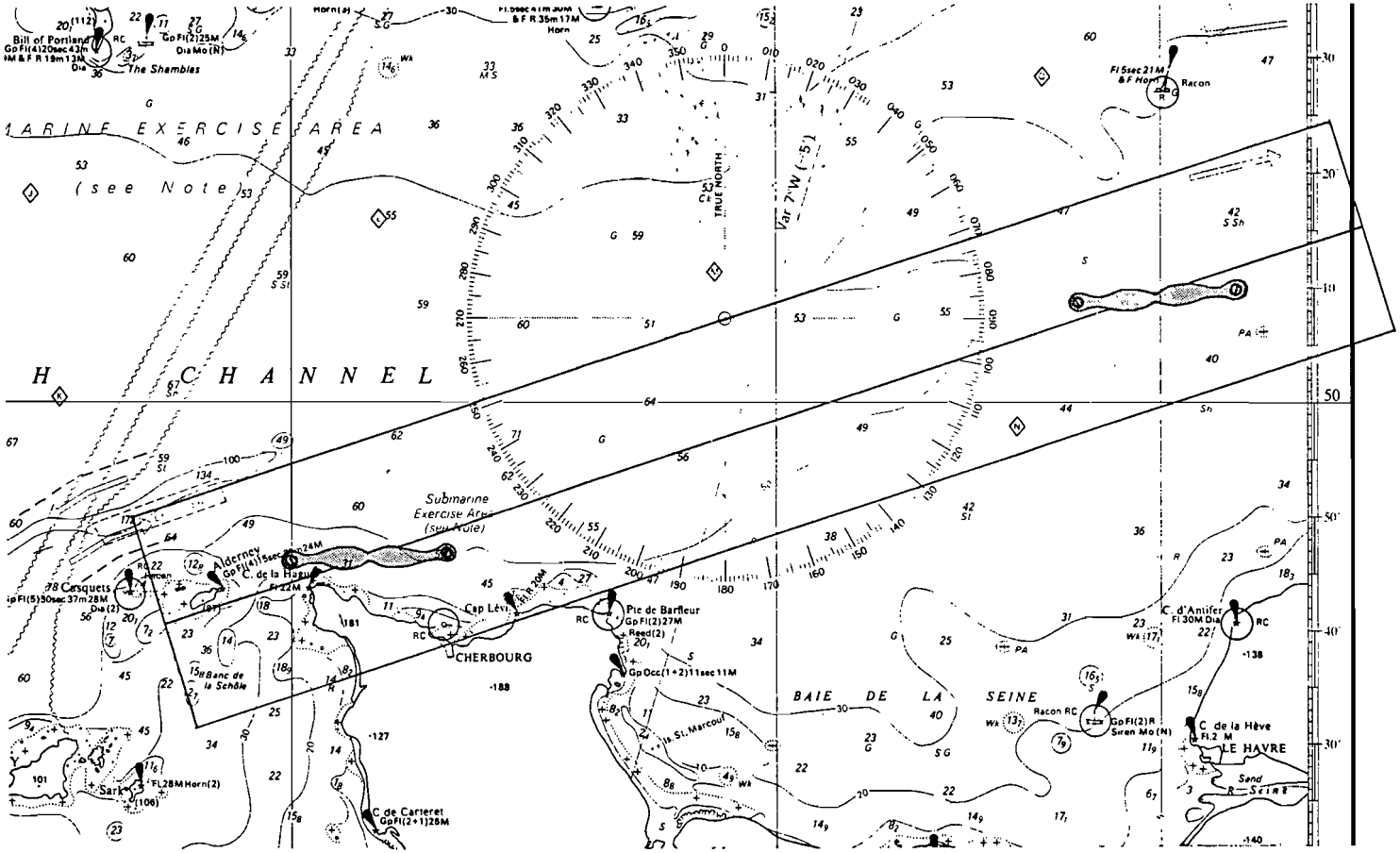


Figure 3. Using the Compass Rose and Parallel Ruler to lay off Course 252°T.

To Find the True Course.

Example 2

Find the True Course from position X 50° 30′ N. 00° 00′
to position Y 49° 55′ N. 2° 45′ W, and
from Y to Z Les Hanois bearing 090°T × 10 miles.

Note that the parallel rulers are graduated in 360 degree notation on the top edge and in quadrantal notation on the bottom edge. Also note that, when tightly closed, the South point on the bottom edge aligns with the 090° mark on the top edge. Always use parallel rulers right way up, i.e. with 360° notation at the top.

To Find the Course from X to Y (using the Compass Rose)

1. Align the parallel rulers so that the top edge passes exactly through the two positions X and Y.
2. Adjust the parallel ruler down (very slightly) so that a pencil line drawn along the ruler's top edge passes precisely through the two positions.
3. Draw in the course line from X to Y.
   (Make a mental note that the course is, very roughly, in a WSW'ly direction.)
4. Carefully "walk" the parallel ruler to the nearest Compass Rose.
5. Adjust the parallel ruler until the top edge passes precisely through the encircled centre point of the Compass Rose.
6. Adjust (very slightly) down so that a pencil line will pass precisely through the centre point.
7. Draw a fine line through the centre point and the graduated outside edge of the Compass Rose. Note that the line is drawn in the general direction previously noted at (3), i.e. it is in a WSW'ly rather than ENE'ly direction.
8. Read off the True Course from the graduated outside edge of the Compass Rose.
9. The True Course is 252°T from X to Y.
10. If you have obtained an answer of 072°T it indicates that you have not noted the general direction of the course line (WSW) and have read off the reverse Course. A reverse course is known as a Reciprocal Course, it differs from the course by 180 degrees, i.e. 072° is the reciprocal of 252°.

Alternative Method (using Parallel Rulers and the Meridian)

1. Proceed as for steps 1, 2 and 3 above.
2. Carefully "walk" the parallel ruler to the nearest meridian of longitude which is printed on the chart (2° W.).
3. Adjust the parallel ruler until the South point on the BOTTOM edge of the ruler is directly over the chosen meridian (2° W.).
4. Tightly close the parallel ruler (taking great care not to shift the South point away from the meridian).
5. Study the top edge of the closed parallel ruler. Note that the printed meridian passes between the 250° and 260° marks.
6. Read off the True Course, 252°T, on the degree graduations.
7. Note that, once again, a reciprocal course could have been read off, i.e. 072°T instead of 252°T.

U

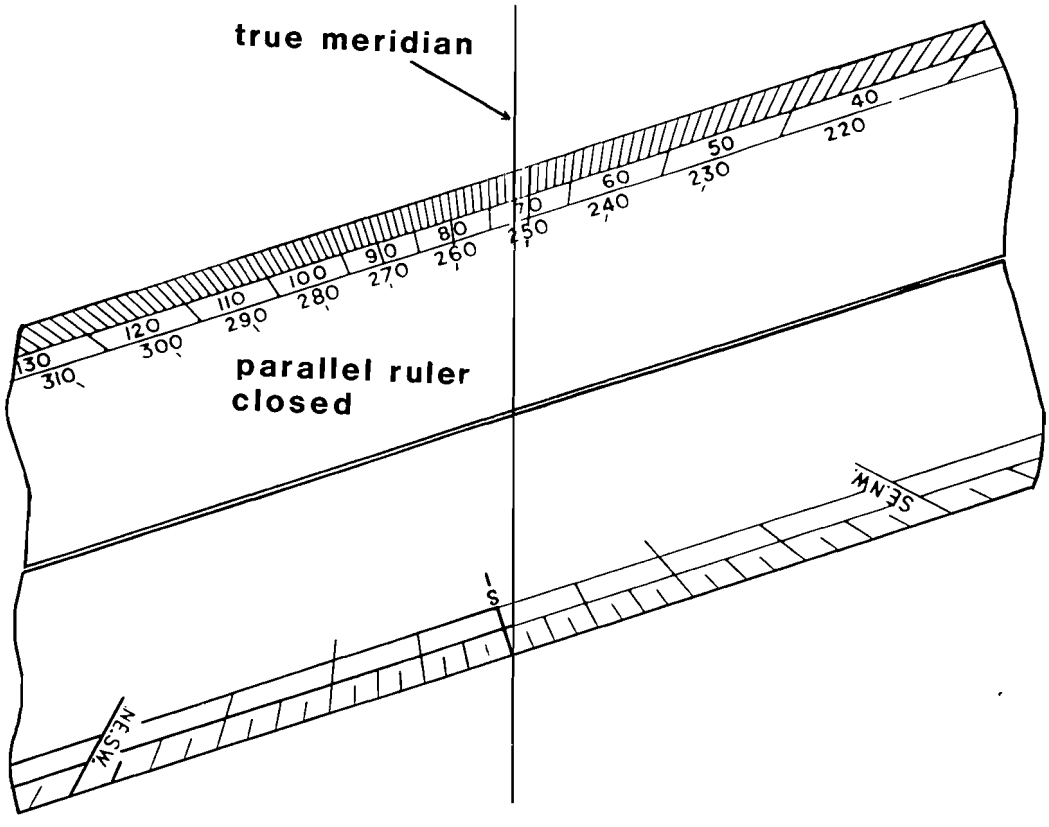


Figure 4. Using the Meridian and Parallel Ruler to lay off Course 252°T.

8. Note also, that it is very easy to make a mistake when reading off the parallel ruler, e.g. 248° can be mistaken for 252° and 258° mistaken for 262°.
   N.B.—Always note the direction in which the 360° graduations are increasing, i.e. they increase from right to left.
9. When comparing the two methods to read off course, note that whilst it is very convenient to use the parallel ruler graduations for reading off E'ly and W'ly courses they are not so convenient for reading off more N'ly and S'ly courses.
10. Practice both methods until thoroughly conversant (and reliable) with both.

Answer: Course from Position 'X' to Position 'Y' 252°T.
Position 'Y' to Position 'Z' 195°T.

To Find the Distance

Example 3
(Refer to Chart 1)
Find the Distance from X to Y; and
Y to Z.
(The Positions plotted previously.)

First note that the Scale of Latitude (the vertical scale) is also the scale of distance.

There are 60 minutes in each degree and each minute represents one sea mile.

The scale on which latitude is drawn increases as the latitude increases. Take the dividers and measure 10 minutes between 48° 00′ N. and 48° 10′ N.

Without altering the dividers, transfer them to latitude 51° 00′ N. Note that the same measurement represents only about $9\frac{1}{2}$ minutes in latitude 51°.

It follows, that distances between two positions should ALWAYS be measured using the latitude scale which lies in the vicinity of the two positions.

To Find the Distance between X and Y

1. Note the latitudes of the two positions (49° 55′ N. and 50° 30′ N.).
2. Decide a convenient distance on the latitude scale which lies between the two positions—say 20 miles lying between 50° 00′ N. and 50° 20′ N.
3. Take the dividers and carefully adjust to the 20 mile distance lying between the two latitudes selected.
4. Place one point of the dividers on Position X and carefully "walk" the dividers along the course line towards Position Y and at the same time count out the distance which measures:

$$5 \times 20 \text{ miles plus a remainder}$$

5. Adjust the dividers to the remaining distance.
6. Transfer the dividers to Latitude 50° N. on the latitude scale and measure the remaining distance (once again using the same scale).

$$\text{Remainder} = 12 \text{ miles}$$

7. Total Distance = 5×20 miles + 12 miles = 112 miles.
8. Repeat the above once more in order to check the accuracy of your result.

Answer: Distance 'X' to 'Y' 112 miles.

To Find the Distance between Y and Z

First note that the distance between Y and Z is relatively small. In consequence, distance can be measured in one step.

1. Note that the two positions are close together and that position Y lies close to latitude 50° N.
2. Take the dividers and carefully adjust to the distance between Y and Z.
3. Transfer the dividers to the latitude scale and place one leg on Latitude 50° N.
4. Count out the number of minutes between latitude 50° N. and the other point of the divider. (Count in tens first plus a remainder.)

$$\text{Distance is } 3 \times 10 \text{ miles (no remainder)} = 30 \text{ miles}$$

5. Repeat once more to check your result.

Answer: Distance = 30 miles.

TO FIX POSITION BY CROSS BEARINGS

A bearing, or line of bearing, tells the navigator that the vessel's position lies somewhere along that line. For this reason the line is generally referred to as a Position Line (P/L). Symbol: a single arrow head at the end of the position line.

Now two bearings provide two position lines so the vessel's position must lie somewhere along both lines. The point of intersection of the two lines is clearly the vessel's position which is referred to as the Observed Position (Obs.Pos.). Symbol: a circle.

Quite clearly, two bearings will always cross somewhere and, in consequence, a fix by two bearings gives no indication of the accuracy of the fix. To ensure accuracy a third bearing should always be taken.

Any error in observation, or an unapplied gyro or compass error, will obviously affect the accuracy of the fix. Such error is minimum at an angle of cut of 90° and will increase as the angle of cut decreases. For this reason a prudent navigator always tries to select shore objects which give a good angle of cut—say 30° as a minimum

If three objects are carelessly chosen such that they lie on a common circle an error known as Circular Error will result. In such cases (and no matter what fixed error is applied to the bearings) three bearings will always intersect at a single point (as shown on Page 359).

Example 4

(Refer to Figure 5)

From the following information find the vessel's position and the course to steer to pass 12 miles off Eddystone Light House

GMT 1100 Log 78		
Bill of Portland	bearing	055°T
Berry Head		325°T
Start Point		282°T

First note that three bearings have been taken and that the "angle of cut" between the first and second bearing is exactly 90°. A good reliable fix should be obtained from these bearings.

To Fix Position

1. Align the parallel ruler with the centre of the Compass Rose and the outer graduation which corresponds to the first bearing (055°T).
2. Walk the parallel ruler to the first object (Portland Bill) and align with the small circle at the bottom of the light symbol.
3. Pencil in the Position Line and mark the end with a small arrow head.
4. Repeat 1–3 above for the remaining two bearings.
5. The point of intersection of the three position lines is the vessel's position—that is an Observed Position which should be marked with a circle.
6. Add the time of the observation and the Log reading (1100 Log 78).
7. Using Dividers, measure the distance off the nearest light and write down its bearing and distance from the fix.

Answer: Start Point Light House bearing 282°T at 16·5 miles

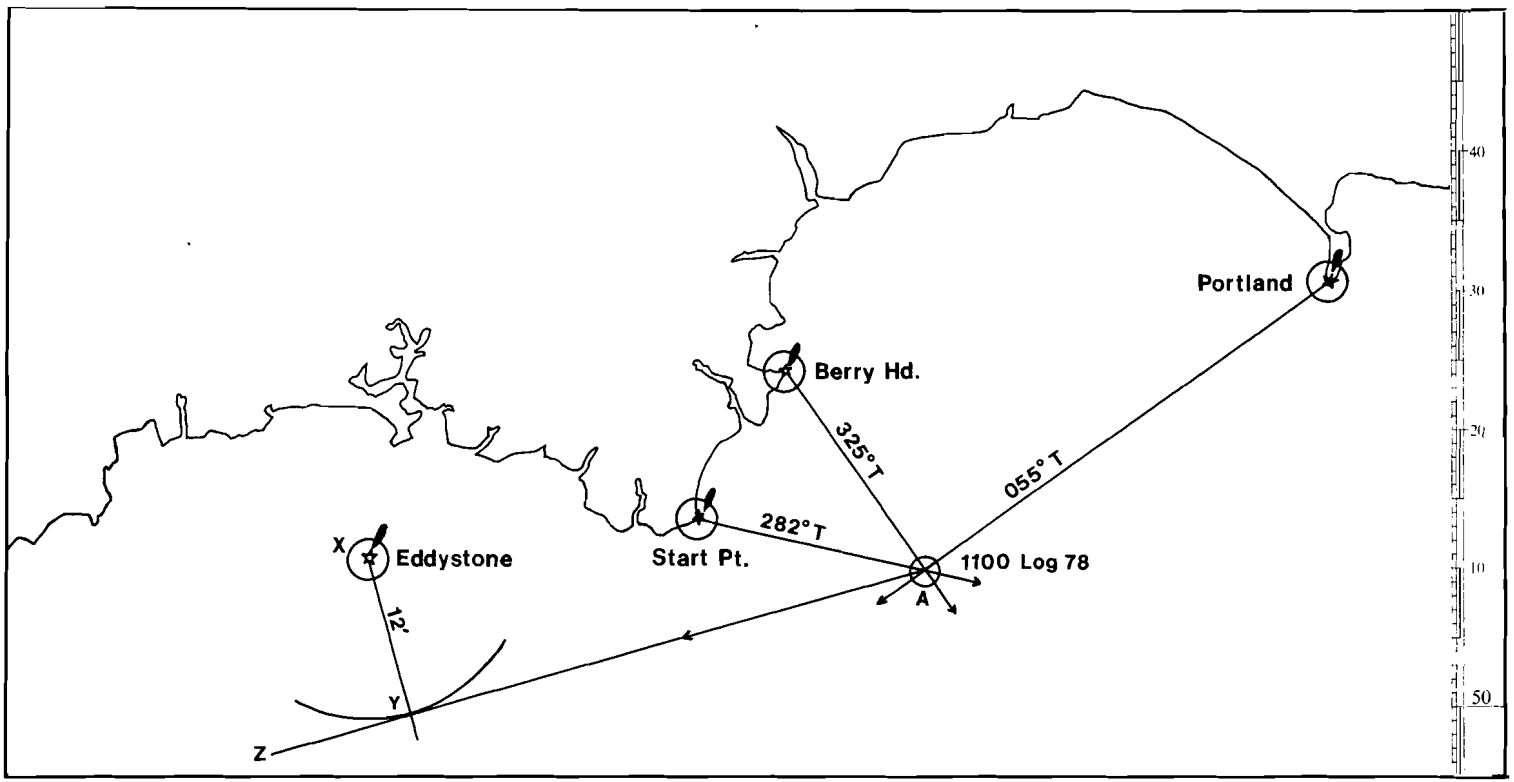


Figure 5. Fixing position by Cross Bearings and laying off a course to pass a chosen distance off a selected point.

To Find the Course to Steer to Pass 12 mile off Eddystone Light House

1. Using compasses, measure 12 miles on the latitude scale.
2. With centre Eddystone Light House and radius 12 miles describe an arc.
3. Using the parallel ruler, draw a line passing through the 1100 position which is tangential (just grazing) the 12 mile arc—this is the course to steer.
   N.B.—Note that it is in a SW'ly direction.
4. Transfer the parallel ruler to the compass rose or meridian and read off the course—255°T.

Answer: 255°T is the Course to Steer to Pass 12 miles off Eddystone Light House.

The Cocked Hat

In Example 4 three bearings were used to fix the vessel's position. The three position lines intersected at a single point and a good fix was obtained. In practice such perfect results are unlikely. It simply is not possible to take three bearings at the same instant in time. If the vessel's speed is great, or the chosen shore objects close to the ship, or some combination of these factors, the bearings will change quickly. The longer the interval between taking each bearing the greater the change in bearing. In consequence, it is not uncommon to find that the three bearings do not intersect at a single point but, instead, form a small triangle known as a Cocked Hat. Providing the Cocked Hat has resulted solely from some slight change of bearing caused by some combination of speed, proximity and a time interval between bearings, the triangle will be small. But if the Cocked Hat has resulted from a wrongly applied compass error, an error of observation or some other cause, the triangle formed may be quite large.

Providing the Cocked Hat has resulted solely from some constant (though unknown) error, the vessel's position can be found by plotting the horizontal angles contained between the compass or gyro bearings obtained. The method is explained later in this chapter. Where a "cocked hat" results it is normal practice to assume that the vessel is at the most dangerous point of the triangle. The most dangerous point will normally be that closest to land or the nearest danger. Having assumed the vessel is at the most dangerous position, the navigator will take immediate action, as necessary, to remedy the situation. First, an alteration of course is made to avoid the danger. Second, another set of bearings is taken as soon as possible in order to check the vessel's position and the accuracy of the previous fix. If the earlier fix is proved inaccurate through some careless error no harm will have resulted from altering onto a safer course. But if the earlier fix is proved reliable the vessel will already be on a safe course. The prudent navigator does not take chances, the worst is assumed and immediate action is taken to bring the vessel out of danger. Failure to "believe what you get" and to take quick, safe, decisive action has resulted in many serious accidents and strandings at sea.

In the following example a large Cocked Hat has resulted. A dangerous wreck lies North of the intended track. What action would you take?

Example 5

(Refer to Figure 6)

A vessel is steering 255°T in order to pass 12 miles off Eddystone Light House. At 1100 the navigator obtains the following bearings:

Bill of Portland	bearing	055°T
Berry Head		325°T
Start Point		272°T

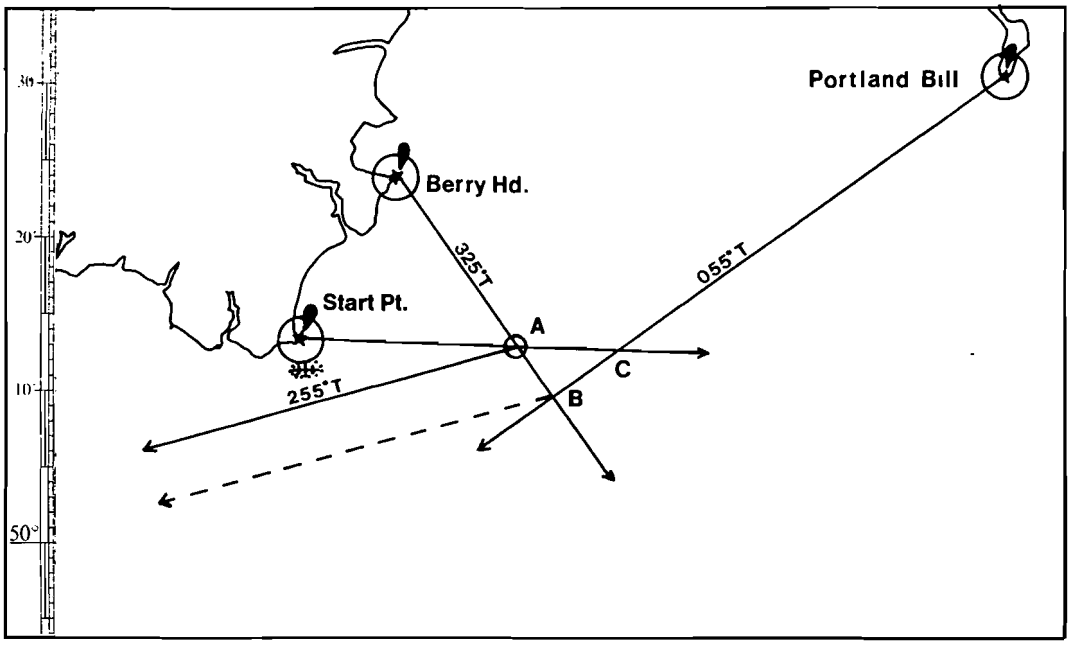


Figure 6. The Cocked Hat (triangle ABC).

The navigator plots the three position lines and notes that a Cocked Hat has resulted. A dangerous wreck, South of Start Point, is also noted

State (a) The position which should be assumed;
(b) The action which should be taken; and
(c) The likely reason for the Cocked Hat which has resulted.

1. Plot the three bearings as previously explained.
2. Note that a Cocked Hat (ABC) has been formed by the intersection of the three position lines
3. The vessel could be at position A, B or C.
4. Assuming the vessel is at position B, the intended track (shown by the pecked line) clears the dangerous wreck by some 7 miles.
5. Assuming the vessel is at position A, the intended track clears the dangerous wreck by only 2 miles.
6. Obviously there is some error in the bearings and it is also possible that the vessel is not at position A, B or C but even closer to the dangerous wreck.
7. The navigator assumes the vessel to be at the most dangerous position (A) and orders an immediate course alteration to the South and steadies up on a safe course of, say, 235°T.
8. Immediately the vessel has steadied on the new course, the navigator takes a second set of bearings.
9. Plotting the second set of bearings, the navigator finds that the three position lines intersect well, that no Cocked Hat has been formed. The vessel's position is now South of the intended track shown by the pecked line.
10. Checking back on the original three bearings, the navigator finds that bearing of Start

Point had been carelessly written down and read as 272°T instead of 282°T (see Example 4). The navigator resolves to be more careful in future and alters course back onto 255°T.

Answer: (a) Position A, the most dangerous position, is assumed.
(b) Alter course (A/C) onto a more S'ly course immediately and take another set of bearings to check the vessel's (V/L's) position.
(c) The bearing of Start Point was 282°T not 272°T as plotted—but prompt action in altering course away from the danger is to be commended—positive action such as this may prevent a stranding on another occasion.

TO FIX POSITION BY RADAR

Radar information can be used to fix position either alone or combined with other information as follows:

1. Radar Range and Visual Bearing
2. Radar Range and Radar Bearing
3. Radar Ranges as Position Arcs

Because of the inaccuracy caused by the beam-width of the radar lobe, a visual bearing should be used in preference to a radar bearing. Similarly, a radar range is less liable to error than a radar bearing. In general, avoid the use of radar bearings whenever possible.

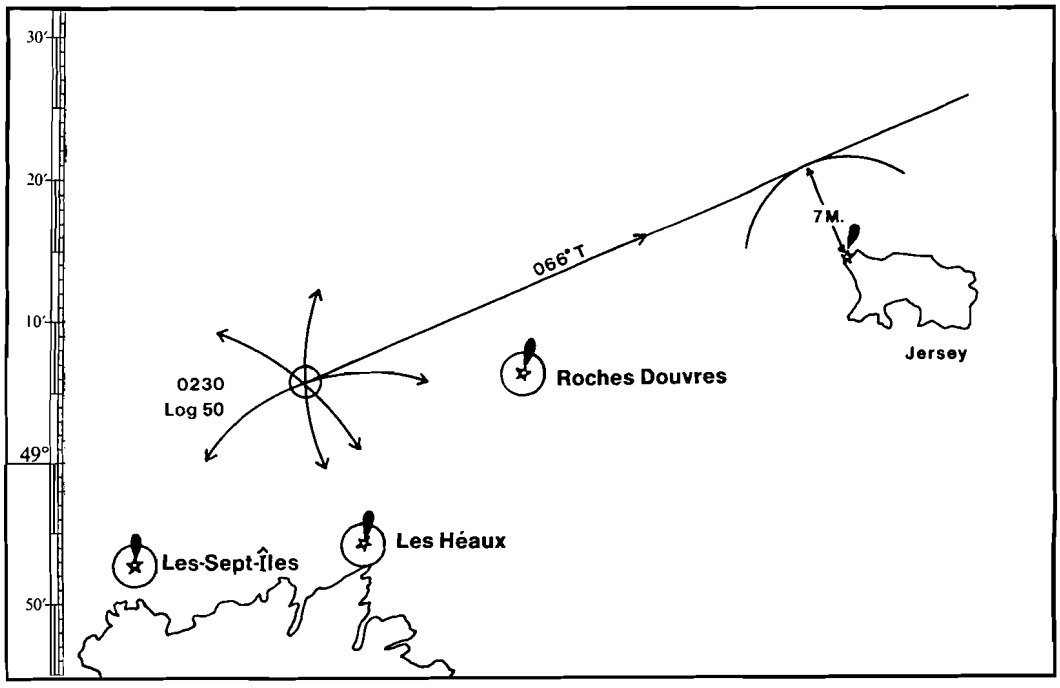


Figure 7. Fix by Radar Ranges.

The use of radar ranges as position arcs is normally the most accurate method of fixing position when using radar information alone.

Example 6
(Refer to Figure 7)

From the following information obtained by radar find the vessel's position and the course to steer to pass 7 miles off Jersey Gp. Fl. Lt.

GMT 0230	Log 50	Plateau des Roches Douvres Lt. Ho.	Radar Range 15·0
		Les Heaux Lt. Ho.	12·0
		Les-Sept-Iles Lt. Ho.	17·4

To Fix Position

1. Using compasses, measure off the first radar range (15 miles) on the latitude scale.
2. With centre the first radar object (Plateau des Roches Douvres) and radius 15 miles, describe an arc.
3. Repeat as above for the remaining two radar ranges.
4. The point of intersection of the three arcs (position circles) is the vessel's position—that is an Observed Position which should be marked with a circle.
5. Write the time and log reading (0230, Log 50) next to the position on the chart.
6. Using the parallel ruler, read off the True Bearing of the nearest radar object and write down its bearing and distance from the 0230 position.

Answer: Les Heaux Lt. Ho. Bearing 160°T at 12 miles (49° 06′ N., 3° 11·2′ W.).

To Find the Course

1. Using the parallel ruler, draw a line passing through the 0230 position which is tangential to the 7·0 mile arc—this is the course to steer.
   N.B.—Note that it is in a ENE'ly direction.
2. Transfer the parallel ruler to the compass rose or meridian and read off the course—066°T.

Answer: 066°T is the Course to Steer to Pass 7 miles off Jersey Gp. Fl. Lt.

OBSERVED POSITION (Obs Pos)

In Example 4 the vessel's position was found by visual bearings (cross bearings) and in Example 6 by radar ranges. In both cases the position was an Observed Position.

Definition

The Observed Position is a position obtained from visual bearings of terrestrial objects or reliable positions obtained from electronic navigational aids.

An Observed Position can also be found from simultaneous star sights or some combination of sun, moon, planet and star sights.

To obtain an observed position, it is sometimes convenient to combine a visual bearing with a radar range or distance off found by vertical sextant angle. Compass error, if present, is always applied to visual bearings which are always plotted as true bearings on the chart.

DEAD RECKONING POSITION (DR) AND ESTIMATED POSITION (EP)

A ship can only be in one position at any one time. The purpose of navigation is to determine this position as accurately as possible. Having fixed position the ship will continue on its course towards some destination. It is seldom convenient (and not always possible) to continuously fix the ship's position. In consequence, it becomes necessary to update the last known accurate position. In order to do this it is necessary to know, or to estimate as accurately as possible, all the factors which influence the ship's progress.

Such factors will include:

Courses steered,
Speed,
Time interval since the last observed position,
Current or Tidal Stream which has been experienced,
Wind effect.

At best, some of these factors can only be an intelligent estimate—the effect of wind, for example, is particularly difficult to estimate. It should also be borne in mind that the navigator also has to take into account other factors such as bad steering, the heave of the sea, and doubtful currents.

Although a ship can only be in one position at any one time it is normal practice for a ship under way to be assigned several positions depending on the method used either to fix or to estimate such position. One of these, the Observed Position, has already been dealt with, other positions [defined by the Nautical Institute in 1981] are as follows:

Dead Reckoning Position (DR)

A position obtained using ONLY the Courses steered and the Distances run. Such distances are derived from the Log or from Engine Revolutions.

Sea Position

A position obtained using the Courses steered, with an adjustment made for the estimated effect of Leeway, and the Distances run. Such distances are derived from the Log or from Engine Revolutions. The Sea Position is the point at the termination of the Water Track (see later).

Estimated Position (EP)

A position based on Course and Distance since the last known position with an adjustment made for the estimated effect of Leeway and the Set and Drift of Current or Tidal Stream. It can also be an extrapolation of earlier fixes.

N.B.—Other positions include the Chosen Position and the Most Probable Position. These are dealt with on the pages dealing with Ocean Navigation.

Terms and Definitions

(Refer to Figure 8)

In order to plot the DR and EP the following terms should be understood:

1. Course
2. Heading
3. Course to Steer
4. Distance Run
5. Wind Direction
6. Leeway
7. Leeway Angle
8. Set
9. Rate
10. Drift
11. Track
12. Track Angle
13. Water Track
14. Ground Track
15. Track Made Good

Course

The intended heading of the ship.
(The vessel's helmsman is steering 279°T in Figure 8.)

Heading

The horizontal direction of the ship's head at a given moment. This term does not necessarily require movement of the vessel which could, for example, be at anchor.
(Though steering 279°T the helmsman may be off course at any given moment of time e.g. the heading may vary between 277°T and 281°T.)

Course to Steer

The course related to the compass used by the helmsman.
(The Magnetic Compass may have an error of 1° West or the Gyro Compass an error of 1° High in which case the course to steer will be 280°C or 280°G in order to make good 279°T in Figure 8.)

Distance Run

The distance derived from Log readings or Engine Revolutions.
(At 1500 the Log read 70 and at 1600 it read 86—the distance run was 16 miles between the Obs Pos (A) and DR (B) in Figure 8.)

Wind Direction

The Direction FROM which the wind blows.
(The wind is blowing from the North in Figure 8.)

Leeway

The effect of wind in moving a vessel bodily to leeward i.e. the side of the ship opposite to the wind.
(The vessel is being blown to the South in Figure 8.)

Leeway Angle

The angular difference between the ship's Course and the Water Track (see later).
(The vessel is on course 279°T. The wind is North and the leeway angle is 5°. The water track is 5° to the South—274°T in Figure 8.)

Set

The Direction TOWARDS which a Current or Tidal Stream flows.
(The tidal stream is setting 250°T from C to D in Figure 8. Note that the tidal stream vector is marked with three arrows.)

Rate

The speed of the Current or Tidal Stream expressed in Knots.
(e.g. 3·5 knots.)

Drift

The distance covered in a given time and due solely to the movement of a current and/or Tidal Stream.
(Assuming a rate of 3·5 knots the drift in 2 hours would be 7·0 miles. Between 1500 and 1600, 1 hr at 3·5 knots, the drift would be 3·5 miles as in Figure 8.)

Track

The path followed or to be followed between one position and another.

Track Angle

The direction of a track expressed in degrees.

Water Track

The path THROUGH THE WATER between one position and another. This is sometimes referred to as Course Made Good Through the Water and by yachtmasters as the Wake Course.
(The helmsman is steering a course of 279°T but because of the effect of leeway the Water Track A to C is 274°T in Figure 8. Note that the water track is marked with a single arrow.)

Ground Track

The path OVER THE GROUND between one position and another.
(The combined effect of leeway, set and drift result in a Ground Track A to D of 270°T—this is really an Estimated Ground Track because leeway has been estimated and the tidal stream data taken from the chart. The actual leeway, set and drift experienced may differ from predictions. Note that the Ground Track is marked with a double arrow.)

Track Made Good

The mean GROUND TRACK actually achieved over a given period. This is sometimes referred to as Course Made Good Over the Ground.
(In Figure 8 the Estimated Ground Track is 270°T. To find the Track Made Good i.e. the Ground Track actually achieved, it would be necessary to have an Observed Position at both 1500 and 1600.)

N.B.—The student should appreciate that if an entire body of water is moving, the ship's path in relation to fixed objects on land will be different to its path in relation to the water through which the ship is steaming.

Plotting the DR, Sea Position and EP—Summary

(Refer to Figure 8)

The Dead Reckoning (DR), Sea Position and the Estimated Position (EP) have been earlier defined. To plot these positions proceed as follows:

To Plot the DR

1. Plot the last observed position (A).
2. Lay off the true course line (AZ) from the last observed position.
3. Find the distance run (or to be run) in the time interval between the last observed position and the required DR.
4. With radius the distance run and centre the last observed position describe an arc to intersect the course line (AZ) at 'B'.
5. Position 'B' is the vessel's DR for the required time.

To Plot the Sea Position

1. Plot the last observed position (A).
2. Make a sketch to decide which way to apply leeway.
3. Apply the estimated leeway angle to the true course steered and find the water track.
4. Lay off the water track from the last observed position.
5. Find the distance run (or to be run) in the time interval between the last observed position and the required Sea Position.
6. With radius the distance run and centre the last observed position, describe an arc to intersect the water track at 'C'.
7. 'C' is the vessel's Sea Position for the required time.

To Plot the EP

1. Find the DR (B) or, if leeway is being experienced, the Sea Position (C) as described above.
2. Note the set and rate of tidal stream or current.
3. Find the set and drift for the time interval between the last observed position and the required EP.
4. Lay off the set and drift (tidal stream vector 'CD') from the DR (B) or, if leeway is being experienced, from the Sea Position (C).
5. 'D' is the vessel's estimated position.
6. Direction 'AD', the line joining the last observed position and the EP, is the vessel's estimated ground track.

Example 7

(Refer to Figure 8)

A vessel is steering 279°T to pass 10 miles off Portland Bill Lt. Ho.

1500 V/L in position 50° 10′ N 0° 45′ W Co 279°T Log Speed 16 knots
Wind N'ly Tidal Stream ◇M◇ 4 hrs After HW Dover (near Springs)
Leeway Angle 5° Dir (Set) 250°T Rate 3·5 kn.

Plot the vessel's DR and EP at 1600 and find:
(a) The Water Track
(b) The Ground Track
(c) The Ground Speed

To Plot the 1600 DR

1. Plot the last Obs Pos, as previously explained, and mark the position with a circle, as shown. Label the position 'A' and note the time, 1500, on the chart.
   In this case the Lat and Long of the 1500 position have been given but the position could have been stated by bearing and radar range, cross bearings, Decca co-ordinates or some other method.
2. Lay off the course line (AZ) 279°T from the 1500 Obs Pos 'A'. Note the course on the chart.
3. At 16 knots the vessel will cover 16 miles between 1500 and 1600. Using compasses, measure off 16 miles from the latitude scale in the vicinity of the 1500 position.
4. With centre 'A' and radius 16 miles describe a small arc to cut the course line (AZ) at 'B'.
5. Position 'B' is the DR position at 1600.

To Plot the 1600 EP

1. Make a simple sketch of the course line and wind direction. Decide which way to apply leeway. The wind is blowing from the North and the vessel will be blown bodily to the South.
2. To find the water track, write down the course and apply the leeway angle:

Co	279°T
Leeway	5°
Water Track	274°T

3. Lay off the water track, 274°T, from 'A' the 1500 Obs Pos. Mark the water track with a single arrow, as shown.
4. At 16 knots the distance logged between 1500 and 1600 will be 16 miles.
   Using compasses, measure off 16 miles from the latitude scale in the vicinity of the 1500 position.
5. With centre 'A' and radius 16 miles describe a small arc to cut the water track at 'C'.
6. Position 'C' is the Sea Position.
7. The navigator has already provided us with Tidal Stream information from the chart:
   Tidal Stream ◇M 4 hrs After HW Dover (near Springs)
   Dir (Set) 250°T Rate 3·5 kn.
   Refer to the chart and check this information.
8. Lay off the Tidal Stream direction, 250°T, from the Sea Position 'C'. Call this the Set Line.
9. With a Tidal Stream Rate of 3·5 knots the Drift between 1500 and 1600 will be 3·5 miles. With centre 'C' and radius 3·5 miles describe a small arc to cut the Set Line at 'D'.
   CD is the Tidal Stream Vector which is marked with three arrows, as shown.
10. Position 'D' is the EP position at 1600.

To Find the Ground Track and Ground Speed

1. Using the parallel ruler, draw a straight line (AD) through the 1500 Obs Pos 'A' and the 1600 EP 'D'. AD is the ground track marked with a double arrow as shown.

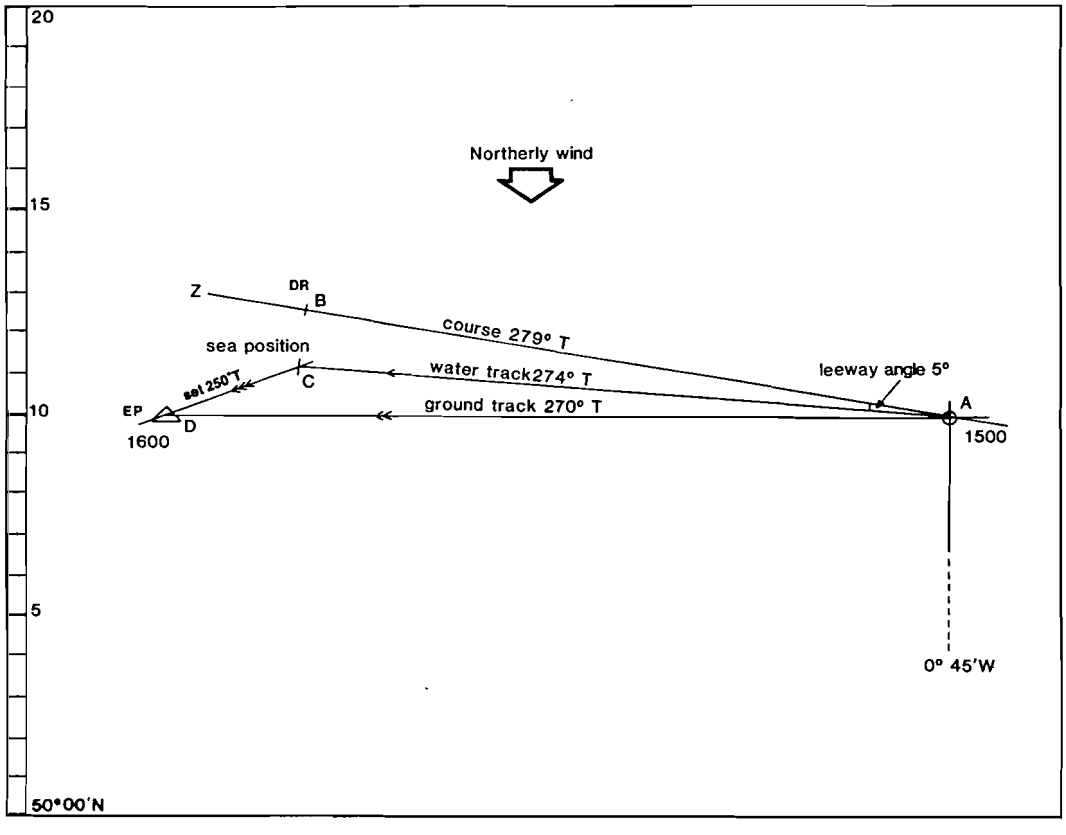


Figure 8. Plotting the DR and EP.

2. Carefully transfer the parallel ruler to the meridian or compass rose and read off the direction, 270°T, which is the Ground Track.
   Mark the ground track with two arrows, as shown.
3. Using dividers or compasses and the latitude scale, measure off the distance (AD) between the 1500 Obs Pos 'A' and the 1600 EP 'D'. The distance is 19·2 miles.
4. The Time Interval between 1500 and 1600 is 1 hour so:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time (hrs)}} = \frac{19.2}{1} = 19{\cdot}2 \text{ knots}$$

5. Distance has been measured along the Ground Track so the speed found is the Ground Speed.
   (Note that it is really the Estimated Ground Speed because it was found from information derived from an Estimated Position.)

Answer: (a) Water Track 274°T
(b) Ground Track 270°T
(c) Ground Speed 19·2 knots

DR and EP by Traverse Tables

DR and EP positions can also be found using Traverse Tables as explained earlier in this volume.

The use of Traverse Tables is convenient when several courses are involved or where the scale of the chart is too small to make accurate plotting possible. The term "Day's Work" is taken to mean estimating the position of a ship after running one or more courses and distances over any stated period of time.

RELATIVE BEARINGS

So far we have dealt with true bearings i.e. bearings which have been stated with reference to True North. Later we will deal with bearings which are stated with reference to Magnetic North, Compass North and Gyro North.

Another way of stating bearings is with reference to the fore and aft line of the ship—such bearings are known as Relative Bearings.

Relative bearings can be measured or estimated from right ahead e.g. 30° on the Port bow, 50° on the Starboard bow. They can also be measured or estimated from right astern e.g. 15° on the Port quarter, 35° on the Starboard quarter.

Another method is to measure or estimate relative bearings from the Beam Position i.e. from the athwartships line which lies at right angles to the fore and aft line of the ship. For example, 10° before (in front of) the Port beam, 20° abaft (behind) the Starboard beam.

An important relative bearing is the Beam Bearing.

NOTE: Relative bearings can also be stated in 360° notation as Red (Port) 0°–180° and Green (Starboard) 0°–180° or 0°–360°. These methods are dealt with in the text on DF bearings which accompanies Examples 43–45.

BEAM BEARING

The Beam Bearing is that bearing which lies at right angles to the course (intended heading) of the ship i.e. at right angles to the course steered.

Co	080°T			080°T	
(−)	90°			(+)	90°
Beam Bearing to Port	350°T		Beam Bearing to Starboard		170°T

The person at the helm may be steering badly and the ship may be "off course" i.e. not heading 080°T, but the Beam Bearing will remain the same—350°T to Port and 170°T to Starboard.

A frequent source of error in professional examinations is to calculate the beam bearing by applying 90° to a course other than that actually being steered—**Always calculate Beam Bearings from the Course steered.**

Refer to Figure 9 and note that the beam bearing is at right angles to the course steered (AZ) 255°T not the ground track (AD) 252°T.

BEAM DISTANCE OFF

The Beam Distance Off (or Distance Off Abeam) is the distance measured from the object to the ship's observed or estimated position. Beam distance off is measured along the beam bearing.

Refer to Figure 9 and note that although the ship intended to pass 12 miles off the light house, the Beam Distance Off (measured along the beam bearing) will be considerably greater.

Example 8
(Refer to Figure 9)

At 1100 a vessel fixes position by bearings and steers 255°T to pass 12 miles off Eddystone Lt. Ho.
From the following information:
(a) Plot the DR and EP at 1300
(b) Find the Ground Speed and Ground Track
(c) Find the Bearing and Distance Off Eddystone Lt. Ho. when abeam.

1100	Log 78	Bill of Portland	bearing	055°T
		Berry Head		325°T
		Start Point		282°T
1300	Log 109·5			

Tidal Stream ⟨G⟩ 2–3 hrs after HW Dover (Near Springs)
Dir. 223°T Rate 1·5 kn.

To Plot the Course and Find the Beam Bearing

1. Lay off the bearings and plot the 1100 Obs Pos (A), as shown.
2. Lay off the course line (AZ) 255°T from the 1100 position.
   N.B.—There is no leeway so 'AZ' is the water track.
3. Find the beam bearing:

Co	255°T
(+)	90°
Beam Bearing to Starboard	345°T

4. Lay off the beam bearing through Eddystone Lt. Ho., as shown.

To Plot the DR and EP

1. Find the log distance:

1300	log	109·5
1100	,,	78·0
Log Distance 1100 – 1300		31·5 miles

2. Plot the 1300 DR (B) along the water track (AZ) using log distance 31·5 miles from the 1100 Obs Pos (A), as shown.
3. Find the set and drift

Set	223°T from chart and given in question
Rate	1·5 kn ,, ,, ,, ,,
Drift	1100 – 1300 (2 hrs) = 2 × 1·5 = 3·0 miles

v

4. Lay off the tidal stream (or current) direction from the DR (B) and plot the vector (BC) 223°T × 3 miles.
5. The EP (C) lies at the end of the tidal stream vector, as shown.

To Find the Ground Track and Ground Speed

1. Join the Obs Pos (A) and EP (C). 'AC' is the ground track.
2. Transfer the parallel ruler to the compass rose or meridian and read off the estimated ground track, 252°T.
3. Measure the distance (AC) along the ground track between the 1100 Obs Pos and 1300 EP. The distance is 34 miles.
4. Find the ground speed

$$\frac{\text{Dist}}{\text{Time (hrs)}} = \frac{34}{2} = 17{\cdot}0 \text{ knots}$$

To Find the Beam Distance Off

1. Produce the ground track (AC) to meet the extended beam bearing (XY) at 'D'.
2. Measure the distance off (XD) at the beam bearing

Beam Dist Off = 13·5 miles

Note that the intended distance off was 12 miles. Distance off has been increased because the tidal stream carried the vessel bodily to the SW.

Answer: (a) DR 1300 see plot.
EP ,, ,, ,,
(b) Ground Speed 17 knots Ground Track 252°T.
(c) Beam Bearing 345°T.
Beam Distance Off 13·5 miles.

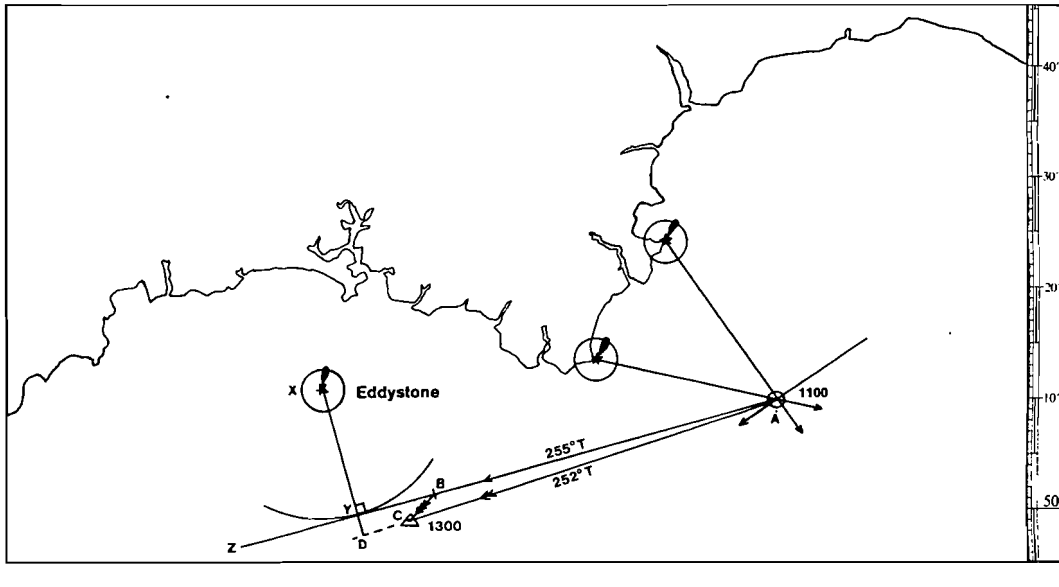


Figure 9. Beam Bearing (∠ AYX) and Beam Distance Off (XD).

TIDAL STREAMS, CURRENT AND SURFACE MOVEMENT

In the two preceding examples we found the vessel's estimated position (EP) by applying the set and drift of the tidal stream to the dead reckoning (DR) position or, if leeway was being experienced, to the sea position. In many cases (particularly ocean navigation) the navigator is concerned with the effect of current. To find the EP, set and drift of current is applied in exactly the same way.

Tidal Stream—Definition

A tidal stream is a periodic, horizontal movement of water caused by the tide raising forces of the sun and moon.

The important feature of a tidal stream is that its direction and rate are not constant. Tidal streams can be "rotary", and change direction clockwise or anti-clockwise through 360°, or "rectilinear", and flow in approximately reciprocal (opposite) directions.

Current—Definition

A current is the horizontal movement of water caused by meteorological or oceanographical factors—drift currents, for example, are caused by the effect of prevailing winds.

The important feature of a current is that, seasonal variations apart, its direction and rate are usually constant.

Other Forms of Surface Movement

Other forms of surface movement result from water turbulence caused by abruptly changing sea bed topography, coastline configuration, constricted channels and sudden changes in tidal and tidal stream characteristics.

Overfall An area of turbulent water caused by tidal streams being deflected upwards by underwater obstructions or an uneven bottom. Also known as a "tide-rip".

Eddy A circular movement of water caused by deflection of the tidal stream by some obstruction such as an island, jetty or headland. There is a permanent eddy to the East of Portland.

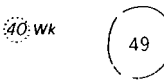
Race An exceptionally strong stream which is usually caused by water flowing through a constricted channel or by convergent tidal streams.

Chart Symbols

Chart symbols and abbreviations for tidal stream and current information are included in BA 5011 as follows:

Tidal Streams and Current	Section T	Tides and Currents
Overfalls and Eddies	Section O	Dangers.

Refer now to the copy of BA 5011 in the rear pocket, to practice chart BA 5053 and to Figure 39 on page 400. Study the type of current and tidal stream information provided.



Tidal Streams referred to HW at AVONMOUTH

Hours		(A) 51°22·0N 4 43·1W		(B) 51°21·5N 4 19·3W		(C) 51°11·8N 4 16·0W		(D) 51°04·8N 4 15·9W		(E) 51°03·1N 4 33·9W		(F) 51°10·0N 5 00·0W	
		Dir	Rate(kn) Sp Np	Dir	Rate(kn) Sp Np	Dir	Rate(kn) Sp Np	Dir	Rate(kn) Sp Np	Dir	Rate(kn) Sp Np	Dir	Rate(kn) Sp Np
Before HW	6	095	0·9 0·4	034	1·1 0·5	055	1·5 0·7	359	0·6 0·3	066	1·6 0·7	134	0·3 0·1
	5	075	1·4 0·6	067	2·2 1·1	045	2·9 1·4	038	0·3 0·1	059	2·6 1·2	080	0·8 0·4
	4	076	1·7 0·8	085	2·5 1·2	042	2·9 1·4	060	0·7 0·3	060	2·6 1·2	063	1·4 0·7
	3	072	1·6 0·7	096	2·4 1·1	051	2·5 1·2	060	1·0 0·5	057	2·5 1·2	055	1·3 0·6
	2	064	0·9 0·4	100	1·6 0·7	052	1·8 0·8	065	0·8 0·4	061	1·7 0·8	048	1·0 0·5
	1	128	0·1 0·0	106	0·4 0·2	078	0·3 0·1	083	0·4 0·2	050	0·6 0·3	030	0·5 0·2
HW		247	0·6 0·3	225	1·0 0·5	226	1·3 0·6	184	0·8 0·4	257	1·4 0·7	302	0·3 0·1
After HW	1	262	1·4 0·7	237	1·8 0·8	225	2·9 1·3	198	0·9 0·4	240	2·8 1·3	257	0·9 0·4
	2	265	1·8 0·8	250	2·8 1·3	231	3·2 1·5	212	0·9 0·4	228	3·0 1·4	249	1·3 0·6
	3	267	1·5 0·7	260	1·9 0·9	233	2·3 1·1	225	0·8 0·4	233	2·7 1·3	237	1·2 0·6
	4	245	1·1 0·5	276	1·7 0·8	237	1·2 0·6	290	0·6 0·3	239	1·8 0·8	229	1·0 0·5
	5	191	0·4 0·2	302	1·2 0·6	218	0·4 0·2	313	0·7 0·3	264	0·6 0·3	219	0·6 0·3
	6	105	0·7 0·3	007	0·9 0·4	062	1·5 0·7	340	0·7 0·3	058	1·1 0·5	173	0·3 0·1

Tidal Levels referred to Datum of Soundings

Place	Lat N	Long W	Heights in metres above datum MHWS	MHWN	MLWN	MLWS	Datum and remarks
Ilfracombe	51° 13′	4° 07′	9·2	6·9	3·0	0·7	4·80m below Ordnance Datum (Newlyn)
Appledore	51 03	4 12	7·5	5·2	1·6	0·2	3·18m below Ordnance Datum (Newlyn)
Clovelly	51 00	4 24	8·3	6·3	2·7	0·9	4·40m below Ordnance Datum (Newlyn)
Lundy	51 10	4 40	8·0	5·9	2·7	0·8	4·20m below Ordnance Datum (local)

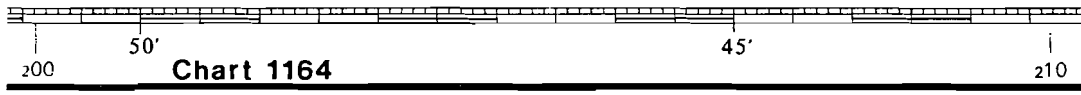


Plate 2. Tide and Tidal Stream Information on Chart 1164.

Sources and Use of Tidal Stream Information

The British Admiralty provide two main sources of tidal stream information:

1. Tidal Stream Data included on the Chart
2. Tidal Stream Atlases.

On charts, tidal stream data is provided for positions marked by a tidal diamond, thus ⟨A⟩. Reference is then made to the tabulated tidal stream data provided elsewhere on the chart. This data is based on high water at a Standard Port, e.g. on BA 5053 it states, "Tidal Stream referred to HW Dover", and on the accompanying plate taken from BA 1164, "Tidal Streams referred to HW at Avonmouth".

The direction and rate of tidal stream for each position are listed against the number of hours before or after HW at the standard port. Rates are given for Spring tides (when the tidal stream is strongest) and for Neap tides (when tidal stream is weakest). Refer to the chapter on Tides and Tidal Streams for further information.

Choice of Method and Interpolation

On charts, tidal stream data can be provided for only a limited number of positions—space simply does not permit full coverage.

In Tidal Stream Atlases very detailed information is provided for a large number of positions—see specimen pages in the Appendix to this volume.

Whenever possible, use tidal stream information from the appropriate tidal stream atlas.

Particularly in low speed vessels (where tidal stream or current has the greatest effect on the track made good) it is most important to interpolate (insert intermediate values) between the tabulated rates, and sometimes direction, of tidal stream. To aid interpolation, a "Computation of Rates" diagram is provided in the tidal stream atlas.

Reliability of Tidal Stream Information

Whilst great care is exercised in the preparation of tide and tidal stream information, it must be stressed that such information consists only of "predictions". A substantial change in meteorological conditions, e.g. high winds from a constant direction over a number of days or a substantial change in barometric pressure are likely to produce a corresponding change in the times of high water (HW) and low water (LW) and the range of tide. Such changes are likely to produce changes in tidal stream direction and rate.

FINDING THE ACTUAL SET, DRIFT, AND RATE OF CURRENT FROM TWO FIXES

So far we have used the predicted tidal stream rate and direction (and other information) to plot the vessel's estimated position. When steaming in reducing visibility it would obviously be helpful to find the actual set and rate of tidal stream (or current) being experienced and to compare this with the predicted set and rate. Allowance could then be made for any difference and more accurate EP's plotted in the event of the navigator being unable to obtain observed positions when visibility finally closes down.

To find the set, drift and rate of current actually experienced two observed positions are required. If leeway is being experienced, an accurate estimate of the leeway angle is also required.

Example 9

(Refer to Figure 10)

A vessel steering 095°T at 16 knots obtains fixes at 0100 and 0300. From the following information find:

(a) The position at 0300
(b) The Set, Drift and Rate of Current experienced, assuming no Leeway.
(c) The Set Drift and Rate of Current assuming the vessel experienced 5° Leeway due to a N'ly Wind.

	Portland Bill	Anvil Point	St Catherines Point	Nab Tr
0100	330°T	031°T	065°T	—
0300	—	313°T	000°T	025°T

To Find Set and Drift when No Leeway is being Experienced

1. Lay off the true bearings and plot the 0100 Obs Pos (A).
2. Lay off the true bearings and plot the 0300 Obs Pos (D).

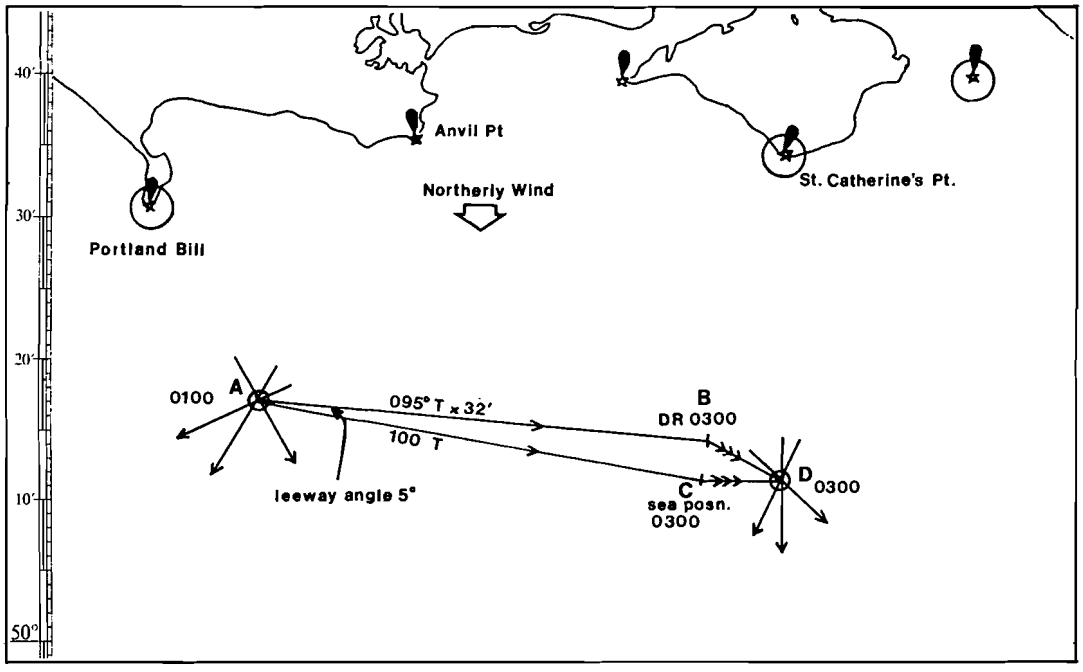


Figure 10. Set and Drift from Two Fixes.

3. Distance steamed 0100–0300 = Speed × Time (hrs) = 16·0 × 2 = 32 miles.
4. Co 095°T, Leeway Nil, Water Track 095°T.
5. Plot the 0300 DR (B) 095°T, 32 miles from the 0100 Obs Pos (A).
6. Set and Drift, 0100 – 0300, is represented by vector 'BD', i.e. from the DR to Obs Pos. No leeway is being experienced so, having steamed 095°T for 32 miles from position 'A', the vessel should be at position 'B'. In fact, the vessel is at position 'D'. The "difference" (BD) must be the result of current or tidal stream.
7. Measure the length and direction of tidal stream vector 'BD'. 'BD' runs 118°T, 6 miles, from DR to Obs Pos, i.e., Set 118°T, Drift 6 miles.
8. $\text{Rate} = \dfrac{\text{Drift}}{\text{Time (hrs)}} = \dfrac{6}{2} = 3$ knots

To Find Set and Drift when Leeway is being Experienced

1. Lay off the true bearings and plot the two observed positions at 0100 and 0300 (A and D).
2. Distance steamed 0100–0300 = 16·0 × 2 = 32 miles.
3. Make a sketch to decide which way to apply leeway:

Course	095°T	
Leeway (+)	5°	(N'ly wind pushes the vessel South)
Water Track	100°T	

4. Plot the 0300 Sea Position (C) on the water track 100°T, 32 miles from the 0100 Obs Pos (A).
5. Set and Drift, 0100 – 0300, is represented by vector 'CD', i.e. from the Sea Position to Obs Pos.

The vessel has steered 095°T but 5° leeway has been experienced so the water track is 100°T. Having steamed for 32 miles along water track 100°T from position 'A', the vessel should be at position 'C'. In fact, the vessel is at position 'D'. The "difference" (CD) must be the result of current and/or tidal stream.

6. Measure the length and direction of tidal stream vector 'CD'. 'CD' runs 090°T, 5·5 miles, from Sea Position to Obs Pos, i.e. Set 090°T, Drift 5·5 miles.
7. $\text{Rate} = \frac{\text{Drift}}{\text{Time (hrs)}} = \frac{5{\cdot}5}{2} = 2{\cdot}75$ knots

To Find the Vessel's Position at the Second Fix

Measure the bearing and distance off the nearest point of land.

Answer: (a) St Catherines Point bearing 000°T at 23 miles.
(b) Set 118°T Drift 6 miles Rate 3 knots (No leeway).
(c) Set 090°T Drift 5·5 miles Rate 2·75 knots (Leeway).

COUNTERACTING THE EFFECT OF CURRENT (OR TIDAL STREAM) AND LEEWAY

Knowing the set and rate of a current or tidal stream it is possible to find a vessel's estimated position after steering a course at some known speed—this was demonstrated in Example 7. But if current or a tidal stream is known to be present, the prudent navigator will generally prefer to counteract the effect of set and drift.

By counteracting the current the navigator can ensure, with a fair degree of accuracy, that his vessel makes good a required ground track. For example, it may be necessary to follow a track which will ensure that the vessel passes a point of land at some particular distance off or that it will "fetch up", more or less exactly, at the opening to a narrow channel or harbour.

The procedure for finding the course to steer to counteract a current is quite straightforward. Nevertheless, it does cause some confusion and, in DTp examinations, is a frequent cause of failure. To avoid such confusion it is important to master this technique by careful study of the underlying principles and, in the early stages, by use of helpful aids to memory.

Problems Commonly Experienced when Carrying Out the Plot to Counteract a Current

(Refer to Figures 8 and 11)

When attempting to find the course to counteract a current, one of the problems sometimes experienced is confusion between the method used for plotting the EP and that used for counteracting the current. To overcome this problem, carefully consider the purpose of each method.

The purpose of plotting an EP is to find the vessel's position **at the end of the "run"**, so set and drift of current are plotted—**at the end of the run.** (Refer to Figure 8.)

The purpose of counteracting the current is to find the course to steer **at the beginning of the run** so set and drift of current are plotted—**at the beginning of the run.** (Refer to Figure 11).

A second problem is deciding the point from which the distance run is measured. When finding the course to steer to counteract a current, distance run is **always** measured from the

end of the tidal stream vector—**never** from the vessel's initial or starting position. It may prove helpful to imagine that the vessel experiences the total effect of set and drift in a single instant of time at the start of the run (and moves from 'A' to 'B' in Figure 11). The vessel would then be at position 'B' so it must be from this point that the distance run is measured.

A third problem is deciding at which stage to apply leeway. When finding the course to steer to counteract current and leeway, **leeway is always applied last.** This should be quite obvious if one considers a situation in which the wind direction is directly from ahead of the required track. With the wind directly ahead, it will not be possible to determine whether the wind will be on the port or starboard side until **after** carrying out the plot and finding the course to counteract the current.

A fourth and, perhaps, final problem is the wording of examination questions which invariably include the phrase "make allowance for the current". This phrase is simply inserted to remind the candidate that current details have been provided and that the examiner requires either an EP (not a DR position) or a course to counteract the current (not the rhumb line course between two stated positions). But the phrase is often wrongly interpreted as meaning, "counteract the current".

It must be stressed that the prudent navigator **always** "makes allowance for a known current" i.e. when finding an EP he "makes allowance" and, when counteracting the current, he also "makes allowance".

At sea, the navigator will obviously know what he wants to do i.e. whether he wants to find the EP or the course to counteract the current. But, when tackling examination questions, some candidates are not quite so certain. In order to decide if the examiner is asking for an EP or the course to counteract the current, the following questions should be asked:

1. Has a course been given?
   If the answer is yes, apply leeway (if present), and current to the course and find the vessel's EP.
2. Has it been stated that the vessel must make good a particular course or track?
   If the answer is yes, counteract the current.
3. Has a starting and final position (or distance off some point) been given, but no course?
   If the answer is yes, then a required track has been defined and it will be necessary to counteract the current to make good that track.

Making the Plot to Find the Course to Steer to Counteract the Current—Summary

(Refer to Figure 11)

1. Plot the initial position (A) and final position.
2. Lay off the required ground track between the two positions.
3. Note the vessel's speed and the set and rate of current.
4. Decide a suitable time interval which will result in a good sized current triangle.
5. Find the set and drift for the chosen time interval.
6. Find the distance run for the same time interval.
7. Plot the set and drift (current vector 'AB') from the initial position.
8. With radius the distance run and centre the end of the current vector (B) describe an arc to intersect the required ground track (at 'C').
9. Draw a straight line (BC) from the end of the current vector to the point of intersection with the ground track.

10. Direction 'BC' is the course to counteract the current.
11. Apply leeway (if present) to the above course to find the course to steer.

Example 10
(Refer to Figure 11)

At 1500 a vessel is in position 50° 10′ N 0° 45′ W and wishes to make good a track of 279°T in order to pass 10 miles off Portland Bill Lt.

From the following information find:

(a) The course to steer to make good a track of 279°T.
(b) The Ground Speed.

Log Speed	16 knots	
Tidal Stream	Dir. 250°T	Rate 3·5 knots
Wind	S'ly	Leeway Angle 5°

To Find the Course to Steer to Counteract the Tidal Stream

1. Note that the course has **not** been given, the vessel must make good a track of 279°T. To do this we must first know the set and rate of tidal stream (or current) which has been, or is likely to be, experienced.

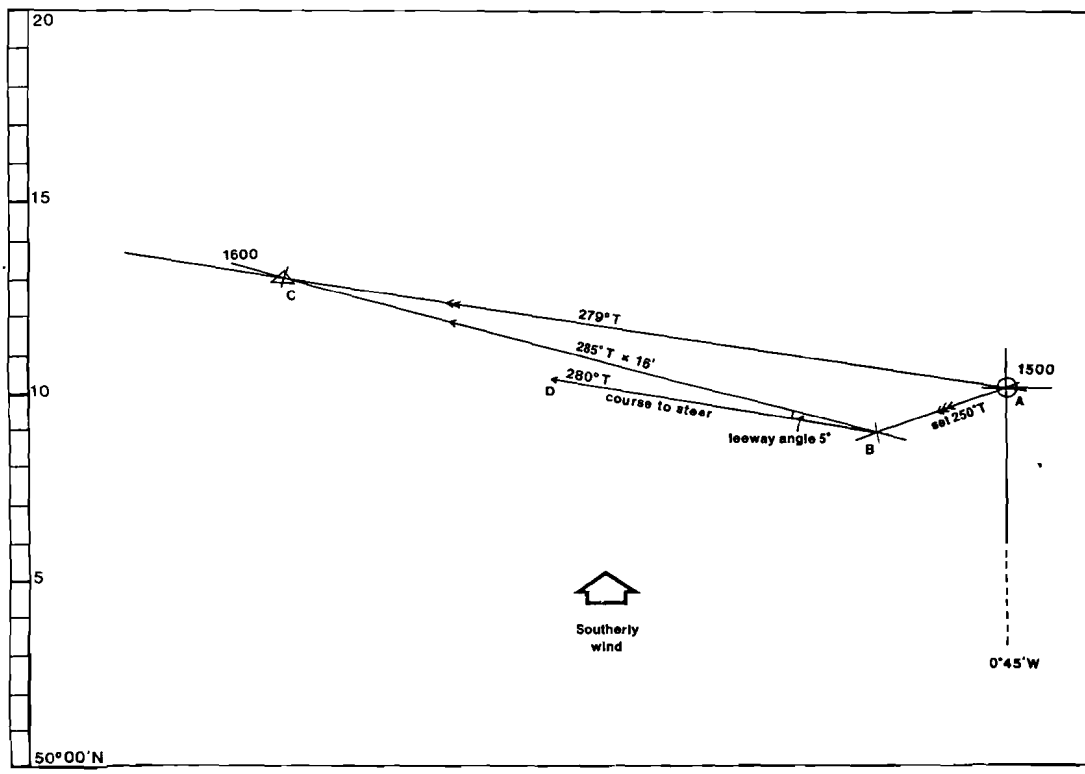


Figure 11. Counteracting the Current (or Tidal Stream) and Leeway.

2. Plot the vessel's 1500 Obs Pos (A), as shown.

   In this example, latitude and longitude have been given but position could be described by bearing and radar distance, cross bearings, Decca co-ordinates or some other method. The position is an observed position but the same procedure is followed if the last known position is an EP.
3. Lay off the required ground track, 279°T, from the last position (A), as shown.
4. Note the vessel's speed, the rate of tidal stream (or current) and the scale of the chart. Decide a suitable time interval which will result in a good sized, accurate current triangle.
5. Lay off the set and drift (tidal stream vector) 'AB', (for the chosen time interval) from the last position (A), as shown.

   1 hr triangle: Set 250°T. Rate 3·5 knots. Drift 3·5 miles.
6. Calculate the distance which will be logged in the same time interval,

   1 hr triangle: Log Speed 16 knots. Log Distance in 1 hr, 16 miles.
7. With centre (B) at the end of the tidal stream vector (AB) and radius 16 miles (the distance for same time interval), describe an arc to cut the required ground track at 'C'.
8. Direction 'BC' is the required water track, 285°T.
9. Leeway, if present, **must** be applied to the required water track in order to find the course to steer:

Water Track		285°T	(To counteract tidal stream)
Leeway	(−)	5°	
Course to Steer		280°T	(To counteract leeway and tidal stream)

Note that the WSW'ly tidal stream will carry the vessel to the WSW—the vessel must steer "up" to counteract its effect.

Note that the S'ly wind will push the vessel bodily to the North—the vessel must steer "down" to counteract its effect.

To Find the Ground Speed

1. First note that the distance actually covered by the vessel will be along the ground track from position 'A' at 1500 to position 'C' at 1600.
   (Distance 'BC' is the log distance steamed.)
2. Measure the distance along the ground track (AC) and calculate the ground speed:

$$\frac{\text{Distance along Ground Track}}{\text{Time (hrs)}} = \text{Ground Speed} = \frac{19}{1} = 19 \text{ knots}$$

Answer: (a) Course to Counteract Tidal Stream 285°T (Water Track).
Course to Steer to Counteract Leeway and Tidal Stream 280°T.
(b) Ground Speed 19 knots.

RUNNING FIX

In reduced visibility or in sea areas having few conspicuous features on the adjacent coastline, occasions may arise when only one charted shore object is visible. In consequence, it is not possible to fix position by cross bearings.

One technique for fixing position from a single object is known as "The Running Fix". The running fix makes use of "Transferred Position Lines".

Transferred Position Lines

Using an accurate knowledge of the course steered and distance steamed, we have already "run up" a DR position. Using additional information acquired from observations or an accurate estimate of current and leeway we have also "run up" an EP.

Position lines can be "run up" in much the same way as a DR or EP. When a position line is "run up" it is referred to as a Transferred Position Line and is always marked with a double arrow, as shown in Figure 12.

To Transfer a Position Line

(Refer to Figure 12)

1. Lay off the bearing and mark with a single arrow, as shown, to indicate it is a position line (P/L).
2. Select any position on the P/L—position 'A' selected.
3. Decide the required time interval and distance, for transferring the P/L, e.g. 2 hours at 9 knots = 18 miles.
4. Lay off the course steered from 'A' which may be regarded as an "assumed starting position" and plot the vessel's resulting DR for the required time interval. In Figure 12, 'XY' is the first P/L, Course 255°T. 'A' the assumed starting position at 2000, and 'B' the resulting DR at 2200 for a time interval of 2 hours at 9 knots or log distance (AB) of 18 miles.
5. Align the parallel ruler with the first P/L (XY) and transfer through the resulting DR (B) which was previously plotted.
6. Mark the transferred P/L with a double arrow at each end, as shown.

Note that the vessel was somewhere along P/L 'XY' at 2000. Assuming the vessel has made good a course of 255°T for a distance of 18 miles, the vessel will be somewhere along the transferred P/L which runs through 'B' at 2200, i.e. the position line has been transferred for a two hour time interval.

Tidal Stream and Current—Note

In subsequent pages and to avoid constant repetition, the term current will be used generally to describe both tidal streams and current.

Types of Running Fix

There are two types of running fix:

1. Running Fix without Current or Leeway.
2. Running Fix with Current and/or Leeway.

Both types are dealt with in the following examples. These examples ask for the vessel's position both at the time of obtaining the second position line (the most recent position) and also at the time of obtaining the first position line (the earlier position). In this particular case, there is little practical value in the navigator knowing where his ship was an hour or two earlier—but finding the earlier position does help to emphasise the principles involved and is included for this reason.

It must be stressed that the accuracy of a position obtained by running fix is entirely dependent on an accurate knowledge of course, distance, leeway and current.

Example 11
(Refer to Figure 12)

A vessel steering 255°T off the South Coast obtains two bearings of the same light.
From the following information find:

(a) Position at 2200 and thence,
(b) Position at 2000.

2000	Log 10	Anvil Point Light bearing 310°T
2200	Log 28	Anvil Point Light bearing 024°T

To Find Position at the Time of the 2nd Bearing

1. Note if leeway or current are present.
2. Find the water track:

Course	255°T
Leeway	—
Water Track	255°T

3. Find the distance between 1st and 2nd bearings:

2200	Log 28
2000	Log 10
Log Distance Run	18

4. Lay off the 1st bearing as the 2000 P/L (XY)
5. Lay off the 2nd bearing as the 2200 P/L (XZ)
6. Select any position on the 1st P/L: Position 'A' selected.
7. Using the selected position 'A' as the assumed starting position plot the resulting DR at 2200.
   Water Track 255°T. Log Distance (A–B) 18 miles. DR at 'B'.
8. Transfer the 1st P/L (XY) through the DR position 'B'.
9. The transferred P/L intersects the 2nd P/L (XZ) at position 'C'.
10. 'C' is the vessel's position at the time of the 2nd bearing (2200).

To Find Position at the Time of the 1st Bearing

1. Transfer the water track (AB) backwards through 'C' to intersect the 1st P/L at position 'D'.
2. 'D' was the vessel's position at the time of the 1st bearing (2000).

To Describe the Two Positions

Use the bearings already obtained and measure off the distances of the two positions from the same point.

2200	Anvil Point	15·0 miles (distance 'XC')	2nd bearing 024°T
2000	Anvil Point	14·2 miles (distance 'XD')	1st bearing 310°T

Answer: (a) 2200 Anvil Point bore 024°T at 15·0 miles.
(b) 2000 Anvil Point bore 310°T at 14·2 miles.

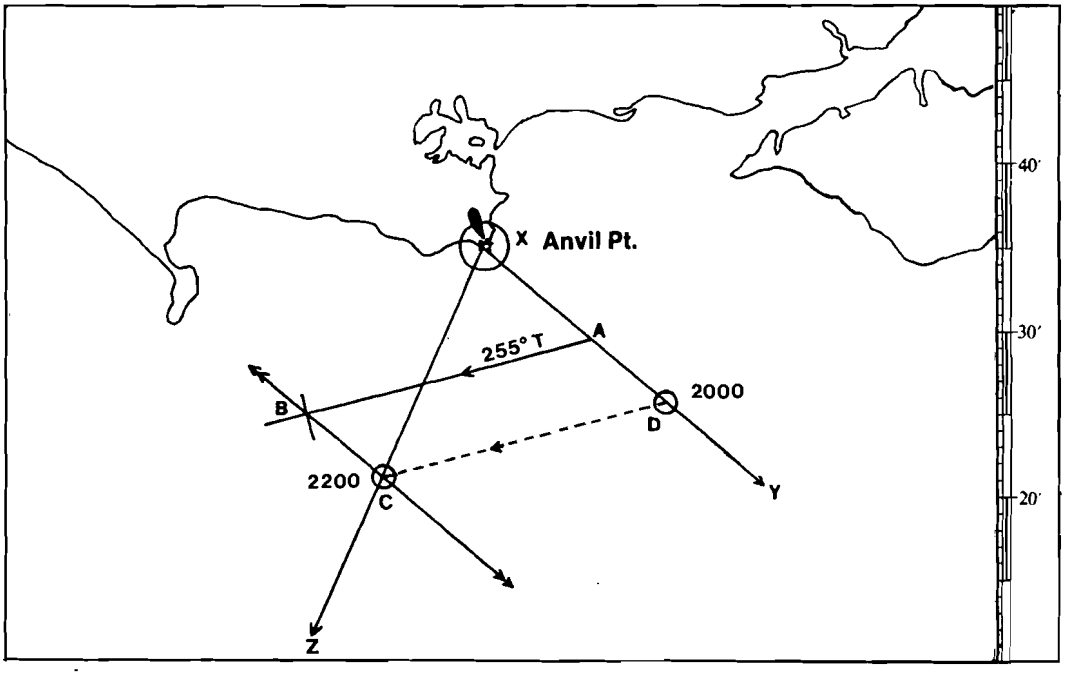


Figure 12. Running Fix without Leeway or Current.

RUNNING FIX WITH LEEWAY AND CURRENT

The procedure for plotting position by running fix *with* current and/or leeway is, with certain exceptions, identical to that followed when plotting position by a running fix *without* current or leeway.

The main exceptions are as follows:

1. If leeway is being experienced the 1st P/L is transferred through an assumed Sea Position.
2. If current or current and leeway is being experienced the 1st P/L is transferred through an assumed EP.

In the following example current and leeway are being experienced.

Example 12

(Refer to Figure 13)

A vessel steering 255°T off the South Coast obtains two bearings of the same light.

From the following information find:

(a) Position at 2200 and thence,
(b) Position at 2000.
(c) Ground Track and Ground Speed.

2000 Log 10 Anvil Point Light bearing 310°T
2200 Log 28 Anvil Point Light bearing 024°T

Wind N'ly Leeway Angle 10° Tidal Stream Dir. 270°T Rate 1·7 knots
◁L▷ 2 hours After HW Dover (Neaps)

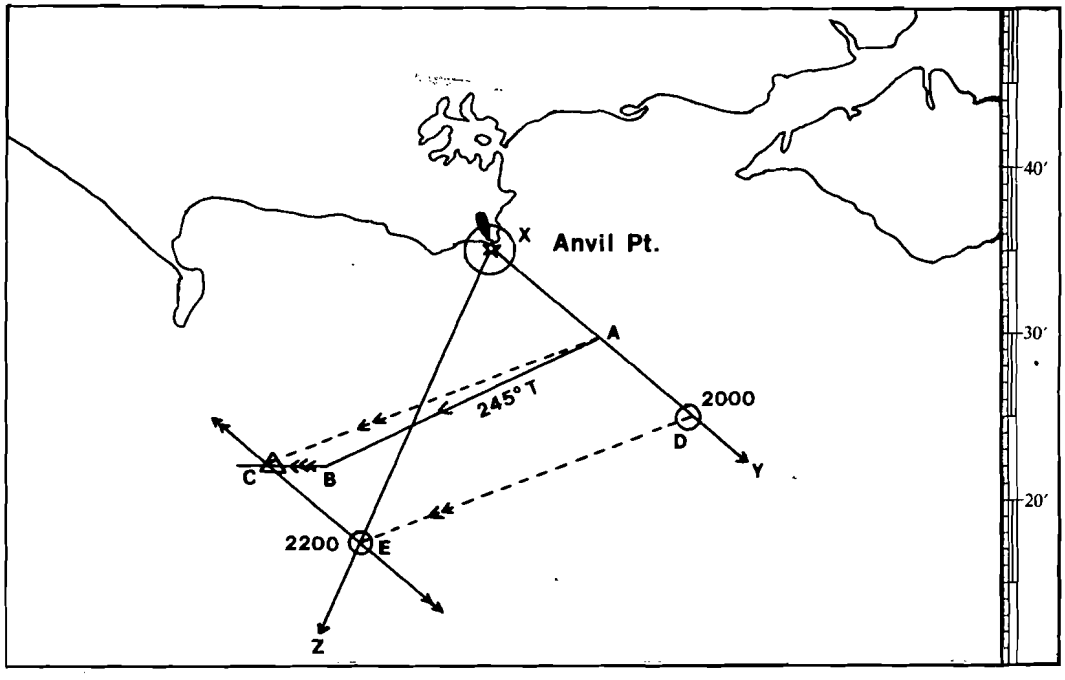


Figure 13. Running Fix with Leeway and Current.

To Find Position at the Time of the 2nd Bearing

1. Note if leeway or current are present.
2. Find the water track:

Course	255°T
Leeway	10°
Water Track	245°T

3. Find the distance between 1st and 2nd bearings:

2200 Log 28
2000 Log 10

Log Distance Run 18 miles

4. Lay off the 1st bearing as the 2000 P/L (XY)
5. Lay off the 2nd bearing as the 2200 P/L (XZ)
6. Select any position on the 1st P/L: Position 'A' selected.
7. Using the selected position 'A' as the assumed starting position plot the resulting EP at 2200.

   Water Track 245°T Log Distance (A–B) 18 miles
   Tidal Stream 270°T Rate 1·7 knots Drift (in 2 hours) 3·4 miles
   Sea Position at 'B'. EP at 'C'.

8. Transfer the 1st P/L (XY) through the EP 'C'.

9. The transferred P/L intersects the 2nd P/L (XZ) at position 'E'.
10. 'E' is the vessel's position at the time of the 2nd bearing (2200).

To Find Position at the Time of the 1st Bearing

1. Transfer the ground track (AC) backwards through 'E' to intersect the 1st P/L at position 'D'.
2. 'D' was the vessel's observed position at the time of the 1st bearing (2000).

To Find the Ground Track and Ground Speed

1. The ground track was from the 2000 starting position 'D' to the 2200 final position 'E'. (The same direction as 'AC'.)
   Read off the ground track (DE) with the parallel ruler—249°T.
2. The distance actually covered by the vessel will be along the ground track from position 'D' at 2000 to position 'E' at 2200.
   (Distance 'AB' is the log distance steamed.)
3. Measure the distance along the ground track (DE) and calculate the ground speed:

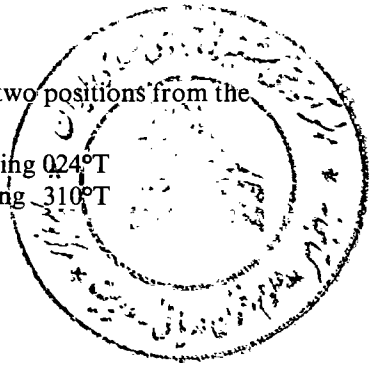
$$\frac{\text{Distance along Ground Track}}{\text{Time (hrs)}} = \text{Ground Speed} = \frac{21}{2} = 10{\cdot}5 \text{ knots}$$

To Describe the Two positions

Use the bearings already obtained and measure off the distances of the two positions from the same point.

2200 Anvil Point 19·3 miles (distance 'XE') 2nd bearing 024°T
2000 Anvil Point 15·5 miles (distance 'XD') 1st bearing 310°T

Answer: (a) 2200 Anvil Point bore 024°T at 19·3 miles.
(b) 2000 Anvil Point bore 310°T at 15·5 miles.
(c) Ground Track 249°T Ground Speed 10·5 knots.



DOUBLING THE ANGLE ON THE BOW

An approximate offshore distance can be found (without consulting the chart or leaving the bridge) by a technique known as "Doubling the Angle on the Bow". This technique is based on the properties of an isosceles triangle in which the vessel's track forms one of the equal sides.

The angle between the ship's head and the bearing of a selected shore object is noted—this is referred to as the "Angle on the Bow". The log reading and time of taking the bearing are also noted. The vessel continues on course until the angle on the bow broadens to exactly double the first angle, e.g. from say 20° to 40° or 32° to 64°.

Providing the course made good is known, the distance off at the time of the second bearing is equal to the distance run between the first and second bearings.

It must be stressed that to obtain an accurate distance off it is essential to have an accurate knowledge of the vessel's track. If leeway and/or current are being experienced, position should be obtained by the running fix method previously described.

When obtaining distance off by this method it is first necessary to find the angle on the bow.

Finding the Angle on the Bow

The angle on the bow (which is a Relative Bearing) is found as follows:

Course	090°T		090°T
1st Bearing	125°T		
Angle on the Bow	35°	next angle required	70°
		2nd Bearing required	160°T

Example 13

A vessel steering 230°T obtains a bearing of a shore object on the port side and wishes to find the distance off by doubling the angle on the bow.

From the following information find the second bearing which will result in an angle on the bow which is double the first angle:

Course 230°T 1st Bearing 189°T

Course	230°T		230°T
1st Bearing	189°T		
Angle on the Bow	41°T	next angle required	82°
		2nd Bearing required	148°T

Answer: 2nd bearing 148°T

Exercise

Study Figure 14 and measure and write down the lengths of all sides of the triangles. Refer to these measurements as you complete Examples 14, 15 and 16.

Example 14

(Refer to Figure 14)

A vessel steering 090°T to pass South of Guernsey notes the log reading when Les Hanois Light is 30° on the bow and again notes the log reading when the light is 60° on the bow.

From the following information find the bearing and distance off the light at the time of the 2nd bearing:

Log reading 81 miles Les Hanois 30° on the bow
Log reading 96 miles Les Hanois 60° on the bow

1. Find the angle on the bow—30° given.
2. Double the angle on the bow and find the corresponding bearing:

Course	090°T		090°T
Angle on the Bow	30°	next angle required	60°
1st Bearing	060°T	2nd Bearing	030°T

3. Find the log distance run between the 1st and 2nd bearings:

30° on bow	log 81 miles
60° on bow	log 96 miles
Log Distance	15 miles (A–B)

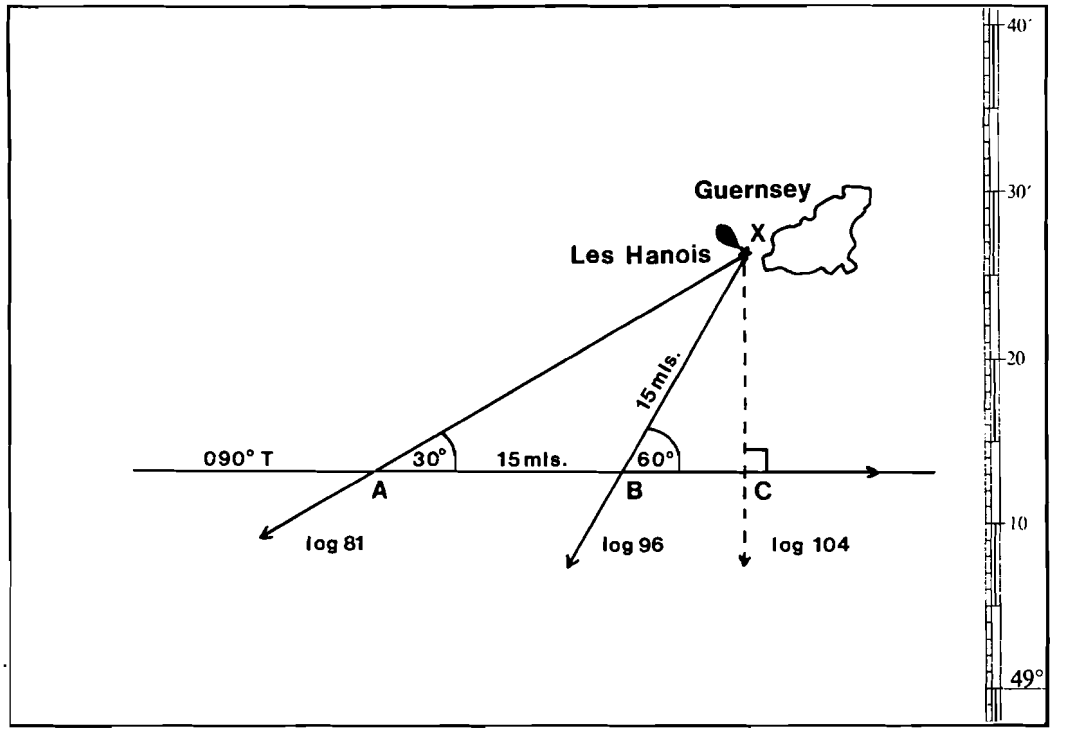


Figure 14. Doubling the Angle on the Bow.

4. Plot the 2nd bearing as a P/L (XB) 030°T.
5. Plot the distance off equal to the log distance run (15 miles) between bearings. The vessel is at position 'B'.

Answer: Les Hanois Light should be 15 miles off at the 2nd bearing 030°T.

THE FOUR POINT BEARING

When doubling the angle on the bow, the best results are obtained when the angles are as broad as possible. An angle of 45° (four points of the compass) on the bow, when doubled, results in an angle of 90° to the fore and aft line of the ship. Such an angle corresponds to the beam bearing.

The four point bearing, which is simply a special case of doubling the angle on the bow, is favoured because:

1. It is the "broadest" possible angle which can be used "before the beam".
2. The distance run between the 1st and 2nd bearing is equal to the distance off abeam.
3. It is easy to judge (by eye) when to take the four point and beam bearings.

But, as before, the running fix (with current) technique should be used if leeway and/or current are being experienced.

w

Example 15

(Refer to Figure 15)

A vessel steering 090°T to pass South of Guernsey notes the log reading when Les Hanois Light is Four Points (45°) on the port bow and again notes the log reading when the light is abeam to port (90° on the bow).

From the following information find the distance off the light at the time of the beam bearing:

Log reading 91 miles Les Hanois 4 Points (45°) on the bow
Log reading 104 miles Les Hanois Abeam (90°) on the bow

1. Find the angle on the bow—45° given.
2. Double the angle on the bow and find the corresponding bearing:

Course	090°T		090°T
Angle on the Bow	45°T	next angle required	90°
1st Bearing	045°T	2nd Bearing	000°T

3. Find the log distance run between the 1st and 2nd bearings:

45° (4 points) on bow log 91 miles
90° (abeam) on bow log 104 miles
Log distance 13 miles (B–C)

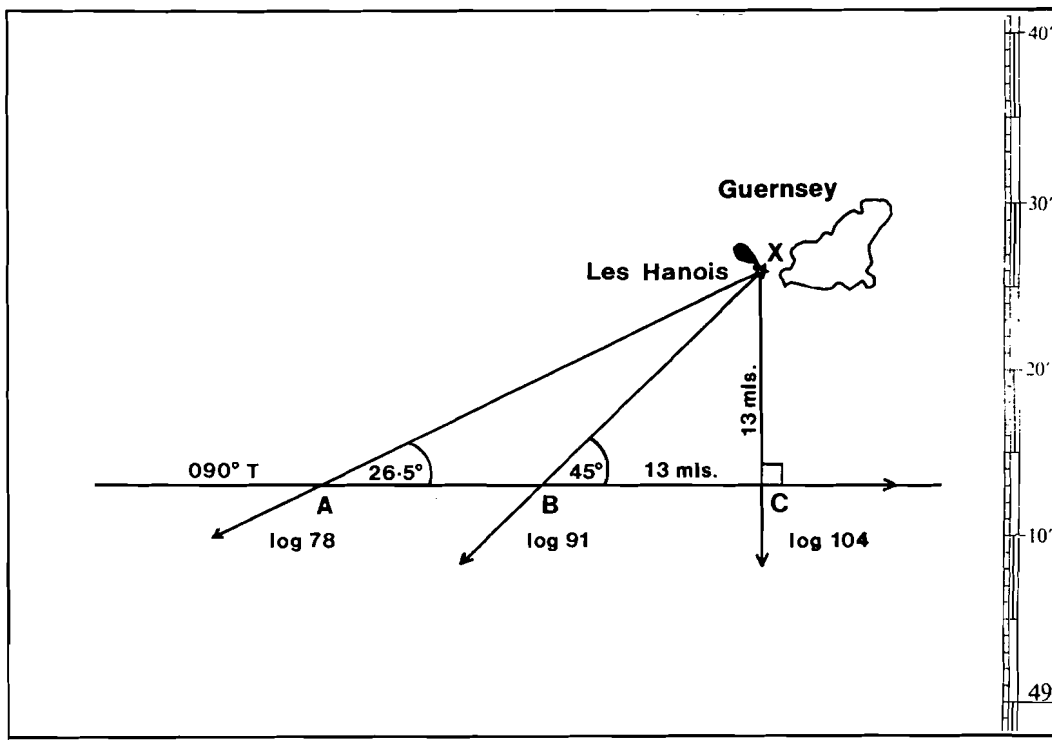


Figure 15. The Four Point Bearing and "Special" Angles.

4. Plot the 2nd bearing as a P/L (XC) 000°T.
5. Plot the distance off equal to the log distance run (13 miles) between bearings. The vessel is at position 'C'.

Answer: Les Hanois Light should be 13 miles off at the beam bearing 000°T.

SPECIAL ANGLES

A weakness of the Four Point Bearing is that the object is abeam before the beam distance can be found. Refer to Figure 15 and imagine a submerged danger exactly 13 miles due South of Les Hanois. The navigator has laid the course to pass 2 miles South of the danger, i.e. 15 miles South of Les Hanois. The beam position is checked by a four point bearing. The vessel will strike the hidden danger at exactly the time it is discovered that the vessel is 2 miles North of the intended track.

To overcome this disadvantage it is possible to use the technique of "special" angles. Using this technique the log distance run between special angle 26·5° and 45° on the bow will give the distance off when abeam, i.e. beam distance off is known at the time of the four point bearing and any necessary change of course made in advance to increase the beam distance off.

It is important to note that when using special angles we are, clearly, **not** doubling the angle on the bow. For the reasons given, an angle on the bow of (almost) 26·5° is very helpful. But 26·5° is just one of several "special" angles which can be calculated and used to some advantage. To find other special angles we must work from first principles and a proof.

Special Angles—Proof

In order to calculate a special angle we first make an assumption:

Let the distance between the 1st (special) angle and the 2nd angle on the bow be equal to the beam distance off, e.g. in Figure 15

Let Distance AB = Beam Distance Off XC = 'd'

Now $$\text{cotan A} = \frac{AC}{XC} = \frac{d+BC}{d} = 1+\frac{BC}{d}$$

But $$\text{cotan B} = \frac{BC}{d}$$

Therefore $$\text{cotan A} = 1+\text{cotan B}$$

Or $$\text{cotan B} = \text{cotan A}-1$$

To Test if Angle 45° corresponds to Special Angle 26·5°

A 26·5° → nat cotan 2·0000 (very nearly)

(−) 1·0000

B 45·0° ← nat cotan 1·0000 (exactly)

Other Useful Angles

Attempt to find other special angles by applying the formulae. In each case assume that the

distance run between the first and second angle on the bow is equal to the distance off abeam.

Other useful "special" angles include, 35° and 67°, and 37° and 72°. Should the angle on the bow exceed 45° on first sighting, angles of 26·5° before the beam (90° − 26·5°) and 26·5° abaft the beam (90° + 26·5°) can be used to find the distance off at the intervening beam bearing. But if advanced warning of the expected beam distance off is required, these particular angles are clearly of no value and should not be used in areas which have offlying dangers.

Example 16
(Refer to Figure 15)

A vessel steering 090°T to pass South of Guernsey notes the log reading when Les Hanois Light is 26·5° on the port bow and again notes the log reading when the light is four points on the bow.

From the following information find the distance off the light house at the time of the beam bearing:

Log reading 78 miles	Les Hanois 26·5° on the bow
Log reading 91 miles	Les Hanois 45° (four points) on the bow

1. Special angles 26·5° and 45° given.
2. Find the corresponding bearings:

Course	090°		090°T		090°T
Angle on the Bow	26·5°		45°		90°
1st Bearing	063·5°T	2nd Bearing	045°T	Beam Bearing	000°T

3. Find the log distance steamed between the special angles:

26·5° on bow	log 78 miles
45° on bow	log 91 miles
Log Distance	13 miles (A–B)

4. Plot the beam bearing (XC) 000°T.
5. Plot the distance off (along the beam bearing) equal to the log distance steamed (13 miles) between the special angles. The vessel should be at position 'C' when the light house is abeam.

Answer: Les Hanois Light should be 13 miles off at the beam bearing.

CONVERTING A TRUE COURSE (OR BEARING) TO A COMPASS COURSE (OR BEARING)

So far, we have assumed that the navigator is working with true bearings and that true courses are being steered. But when steering by magnetic compass it becomes necessary to convert the true course to steer into a compass course to steer. To convert a true course into its equivalent compass course variation and deviation (for the ship's head) are applied.

The application of variation and deviation has been dealt with in Chapter 8 but, for convenience, a brief summary is included here. (Refer back to Pages 219–221; if necessary.)

Variation and Magnetic Course

Variation is the horizontal angle between True North and Magnetic North. It results from the fact that the true and magnetic poles do not coincide. Variation changes with change of position.

Variation is named West if Magnetic North lies to the left of True North and East if Magnetic North lies to the right.

Having applied variation, a true course is converted into a magnetic course.

Deviation and Compass Course

Deviation is the horizontal angle between Magnetic North and Compass North. It results from the magnetic influence of the ship's structure which attracts (or deviates) the compass needle away from Magnetic North. Deviation changes with change of course (the ship's head).

Deviation is named West if Compass North lies to the left of Magnetic North and East if it lies to the right.

Having applied deviation, a magnetic course is converted into a compass course.

Compass Error

When combined, variation and deviation make up compass error.

Compass error is the horizontal angle between True North and Compass North. Compass error is named West if Compass North lies to left of True North and East if it lies to the right.

Compass error can be found directly by the azimuth and amplitude methods in astronavigation and by use of transit bearings (see Example 20) in coastal navigation.

Having applied compass error, a true course is converted into a compass course.

Converting True Bearings to Compass Bearings

True bearings are converted to their equivalent compass bearings in exactly the same way as when converting courses. But great caution should be exercised when applying deviation.

The deviation applied is **always** for the ship's head (that is the course steered) **not** the observed bearing. A general rule is to double check whenever it seems necessary to find a large number of deviations—this invariably indicates that deviations are being found for the observed bearings as opposed to the **single deviation for the course steered.**

A single deviation (for the course steered) is found and **applied** to all bearings observed when steering that course—to do otherwise is a most serious error of principle and one which the DTp, quite correctly, will carefully take into account when deciding on a candidate's success or failure in examinations involving chartwork. In fact, this error is a very frequent cause of examination failure and, at sea, could lead to the vessel being put at risk.

Order of Applying Variation and Deviation

True to Compass

When applying separate corrections to convert a true course (or bearing) to a compass course (or bearing), variation is **always** applied first and deviation applied second, as follows:

True Course (or Bearing)	°T
Variation	°E or W
Magnetic Course (or Bearing)	°M
Deviation (for the Magnetic Course)	°E or W
Compass Course (or Bearing)	°C

Alternatively, when applying compass error:

True Course (or Bearing)	°T
Compass Error	°E or W
Compass Course (or Bearing)	°C

Compass to True

When applying separate corrections to convert a compass course (or bearing) to a true course (or bearing), deviation is **always** applied first and variation applied second as follows:

Compass Course (or Bearing)	°C
Deviation (for the Compass Course)	°E or W
Magnetic Course (or Bearing)	°M
Variation	°E or W
True Course (or Bearing)	°T

Alternatively, when applying compass error:

Compass Course (or Bearing)	°C
Compass Error	°E or W
True Course (or Bearing)	°T

Sources of Information—the Deviation Card and Chart

Unless the compass error has been found directly (either by azimuth, amplitude, transit bearing or some other method) deviation, for the ship's head, will be taken from the deviation card (and sometimes the compass error book) and variation taken from the chart.

DEVIATION CARDS

Deviation for the ship's head can be presented either in tabular form on a Deviation Card, or in graphical form on a Deviation Curve. In both cases the ship's head by compass is normally shown at intervals of ten degrees.

Use of Deviation Cards

(Refer to Deviation Card 1)

On a deviation card tabulated at ten degree intervals, the deviation for a heading of, say, 010°C or 020°C, can be read directly from the card. But for an intermediate heading of, say, 024°C it is

necessary to interpolate between the two deviations tabulated for the compass headings which lie either side of 024°C. Interpolation is carried out by linear ratio.

Use of Deviation Curves

(Refer to the Deviation Curve for Deviation Card 1)

On a deviation curve, the deviation for a particular compass heading, such as 024°C can be read directly from the curve and no interpolation is required. Providing the curve has been carefully drawn and the deviation "picked off" with equal care, the deviation curve is likely to give the best results—but in practice (and DTp examinations) deviation cards are more commonly used.

Important Note on Deviation Cards Included in this Volume

A well adjusted compass will normally have relatively small deviations and a symmetrical curve. The deviation cards used for examination and instruction (such as those included in this section) generally have fairly large deviations and their curves are not necessarily symmetrical.

Interpolation—Compass to True

Example 17

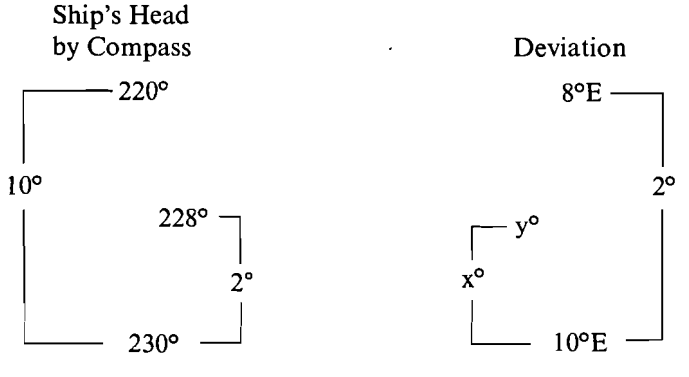
(Use Deviation Card 1)

A vessel is steering 228°C. Variation is 7½°W. Find the True Course.

Let y° = Required Deviation.

Let x° = Difference between the Required Deviation and the Nearest Tabulated Deviation.

Then from Deviation Card 1:



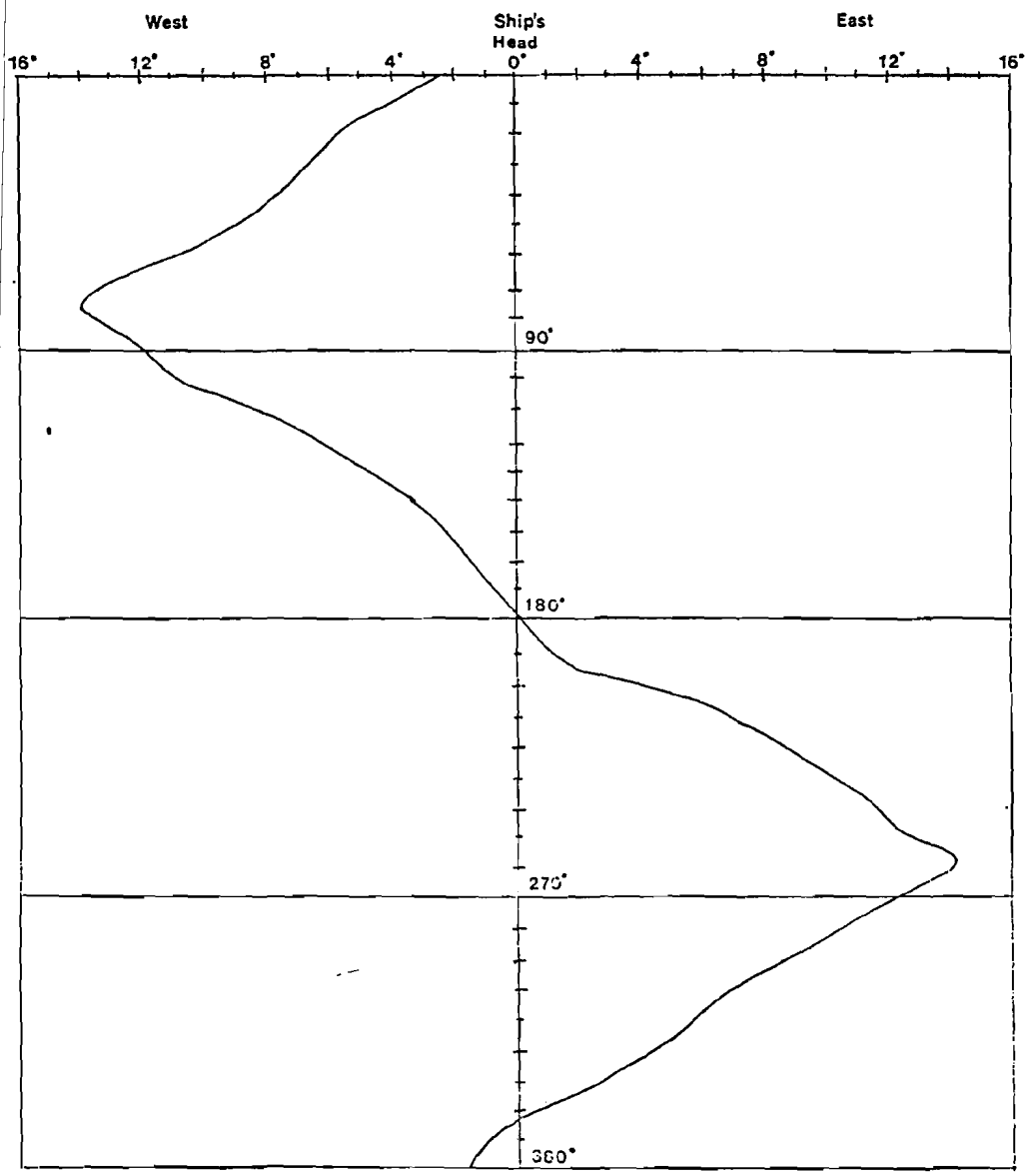
Now:

$$\frac{x^\circ}{2^\circ} = \frac{2^\circ}{10^\circ} \quad \text{so} \quad \text{'x'} = \frac{4}{10} = 0{\cdot}4^\circ \simeq \tfrac{1}{2}^\circ$$

Nearest Deviation (for 230°C)	10 °E	Compass Course	228 °C
Change 'x'	(−) ½°	Deviation	9½°E
New Deviation 'y' (for 228°C)	9½°E	Magnetic Course	237½°M
		Variation	7½°W
		True Course	230 °T

DEVIATION CARD No. 1	
Ship's Head by Compass	Deviation
000°	2° W
010°	3½°W
020°	5½°W
030°	6½°W
040°	7½°W
050°	8½°W
060°	11° W
070°	13½°W
080°	13½°W
090°	12° W
100°	11° W
110°	8½°W
120°	6¼°W
130°	5° W
140°	3½°W
150°	2½°W
160°	1¾°W
170°	1° W
180°	0°
190°	1° E
200°	4° E
210°	6½°E
220°	8° E
230°	10° E
240°	11½°E
250°	12½°E
260°	14° E
270°	12° E
280°	10¼°E
290°	8½°E
300°	6¾°E
310°	5½°E
320°	4° E
330°	2½°E
340°	½°E
350°	1° W
360°	2° W

Deviation Card No. 1



Note that the change ('x') in deviation was subtracted because the deviation for 220°C (8°E) is less than the deviation for 230°C (10°E). Had it been greater, the change would have been additive (+).

Alternatively:

Deviation	9½°E	Compass Course	228°C
Variation	7½°W	Compass Error	2°E
Compass Error	2 °E	True Course	230°T

Answer: True Course 230°T
Deviation for 228°C is 9½°E

Interpolation—True to Compass

The deviation card tabulates deviation against compass course and, in consequence, when converting a True Course into a Compass Course it is not possible to extract, directly, the required deviation from the deviation card.

To convert a True Course, variation is first applied in order to find the required Magnetic Course. Deviation is then applied to the Compass Course of similar value and the corresponding Magnetic Courses found. The exercise is repeated until two magnetic courses are found which lie either side of the required Magnetic Course. Interpolation is then carried out between the two deviations which correspond to the adjacent magnetic courses, as demonstrated in the following example.

Example 18
(Use Deviation Card 1)

A vessel is steering 230°T. Variation is 7½°W. Find the Compass Course.

Find the required Magnetic Course:

True Course	230 °T
Variation	7½°W
Magnetic Course	237½°M

Refer to Deviation Card 1 and apply tabulated Deviations to tabulated Compass Courses to find the adjacent Magnetic Courses:

Ship's Head by Compass	Deviation	Corresponding Magnetic Heading
210°C	6½°E	216½°M
220°C	8 °E	228 °M
230°C	10 °E	240 °M
240°C	11½°E	251½°M

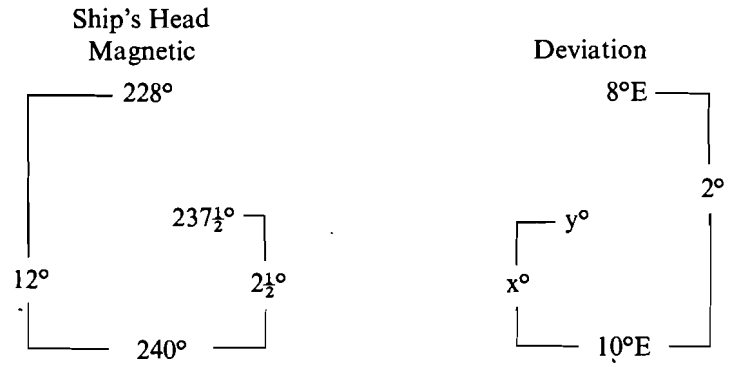
Note that Magnetic Courses 228°M and 240°M lie either side of the required Magnetic Course 237½°M.

Now proceed as before:

Let y° = Required Deviation.

Let x° = Difference between the Required Deviation and the Nearest Tabulated Deviation.

Then from our newly constructed table of deviations:



Now:

$$\frac{x^\circ}{2^\circ} = \frac{2\frac{1}{2}^\circ}{12^\circ} \quad \text{so} \quad \text{'x'} = \frac{5}{12} = 0{\cdot}4^\circ \simeq \tfrac{1}{2}^\circ$$

Nearest Deviation (for 240°M)	10 °E	Magnetic Course	237½°M
Change 'x'	(−) ½°	Deviation	9½°E
New Deviation 'y' (for 228°C)	9½°E	Compass Course	228 °C

Note that the change ('x') in deviation was subtracted because the deviation for 228°M (8°E) is less than the deviation for 240°M (10°E). Had it been greater, the change would have been additive (+).

Alternatively:

Deviation	9½°E	True Course	230°T
Variation	7½°W	Compass Error	2°E
Compass Error	2 °E	Compass Course	228°C

Compare this and the previous example. Note that the deviation obtained for an intermediate heading is identical when working from Compass to True and from True to Compass.

Answer: Compass Course 228°C
Deviation for 237½°M is 9½°E

CONSTRUCTING A DEVIATION CARD FOR MAGNETIC HEADINGS

When converting courses from True to Compass (as in the previous example) it is necessary to first apply variation in order to find the required magnetic course. Tabulated deviations are then applied to tabulated compass courses in order to find the two magnetic courses which lie either

side of the required magnetic course. Interpolation, if necessary, is then carried out between the corresponding deviations tabulated on the deviation card. This method is satisfactory where only a small number of true courses are involved. But when it is necessary to convert several true courses it is generally quicker to draw up a deviation card which includes both Compass and Magnetic headings as shown at Deviation Card No. 3. Note that this results in irregular intervals between the magnetic headings.

Using the same information, it is also possible to draw up a new deviation card which tabulates magnetic headings at ten degree intervals as shown at Deviation Card No. 4. This type of deviation card further simplifies the conversion of true courses to compass courses. Due to "rounding off" the deviations, slightly different results can be expected when using these two types of deviation card.

DEVIATION CARD No. 3			DEVIATION CARD No. 4		
Ship's Head by Compass	Deviation	Ship's Head Magnetic	Ship's Head Magnetic	Deviation	Ship's Head by Compass
000°C	2·0°W	358·0°M	000°M	2·4°W	002·4°C
010	3·5 W	006·5	010	4·4 W	014·4
020	5·5 W	014·5	020	6·4 W	026·4
030	7·0 W	023·0	030	8·8 W	038·8
040	9·0 W	031·0	040	10·3 W	050·3
050	10·3 W	039·7	050	11·4 W	061·4
060	11·5 W	048·5	060	12·3 W	072·3
070	12·2 W	057·8	070	12·6 W	082·6
080	12·6 W	067·4	080	12·3 W	092·3
090	12·5 W	077·5	090	11·4 W	101·4
100	11·6 W	088·4	100	10·5 W	110·5
110	10·5 W	099·5	110	9·0 W	119·0
120	9·0 W	111·0	120	7·5 W	127·5
130	7·0 W	123·0	130	6·0 W	136·0
140	5·0 W	135·0	140	4·2 W	144·2
150	3·0 W	147·0	150	2·5 W	152·5
160	1·0 W	159·0	160	0·9 W	160·9
170	0·5 E	170·5	170	0·5 E	169·5
180	2·0 E	182·0	180	1·7 E	178·3
190	3·5 E	193·5	190	3·1 E	186·9
200	5·1 E	205·1	200	4·5 E	195·5
210	6·8 E	216·8	210	5·8 E	204·2
220	8·5 E	228·5	220	7·2 E	212·8
230	10·0 E	240·0	230	8·7 E	221·3
240	11·0 E	251·0	240	10·0 E	230·0
250	12·0 E	262·0	250	10·9 E	239·1
260	12·8 E	272·8	260	11·8 E	248·2
270	12·5 E	282·5	270	12·6 E	257·4
280	11·5 E	291·5	280	12·4 E	267·6
290	10·0 E	300·0	290	11·7 E	278·3
300	8·2 E	308·2	300	10.0 E	290·0
310	6·5 E	316·5	310	7·9 E	302·1
320	4·5 E	324·5	320	5·7 E	314·3
330	2·5 E	332·5	330	3·3 E	326·7
340	1·0 E	341·0	340	1·2 E	338·8
350	0·5 W	349·5	350	0·5 W	350·5
360	2·0 W	358·0	360	2·4 W	002·4

Deviation Applied to Bearings is for the Ships Head Only

It is **most important** to note that **Deviation is for the Ship's Head.**

When converting Compass Bearings to True Bearings, **find the Deviation for the Ship's Head** and **apply it to all Compass Bearings taken whilst on that heading.**

Simplified and put another way, **find the Deviation for the course steered** and **apply it to all Compass Bearings taken on that course.**

Failure to understand this principle is a most frequent source of failure in examinations and a source of potential danger at sea. All bearings taken on the same course will have a single deviation applied. The student who finds himself working out a large number of deviations should first stop and then carefully consider what he is doing. If he is working out, say, three deviations for three cross bearings used to fix position, he is guilty of a most serious error of principle. Deviation is for the ship's head **not** the bearing.

Deviation Cards used in DTp Examinations

Deviation cards used in DTp Examinations are of the type shown at Deviation Cards Nos. 6 and 7. Note that Deviations are tabulated for Compass Headings at twenty degree intervals.

DEVIATION CARD

No. 6

Ship's head by Compass	Deviation
000°	2·5° E
010°	
020°	1·5° E
030°	
040°	0·5° E
050°	
060°	0·5° W
070°	
080°	2·0° W
090°	
100°	3·0° W
110°	
120°	4·0° W
130°	
140°	4·5° W
150°	
160°	5·0° W
170°	
180°	5·0° W
190°	
200°	4·0° W
210°	
220°	3·0° W
230°	
240°	1·5° W
250°	
260°	0·0.
270°	
280°	2·0° E
290°	
300°	4·0° E
310°	
320°	5·0° E
330°	
340°	4·0° E
350°	

763+ 337L D 894879 280 8/71 T P. Gp 666

DEVIATION CARD

No. 7

Ship's Head by Compass	Deviation
000°	3°0 E
010°	
020°	1°.5 W
030°	
040°	4°.5 W
050°	
060°	3°.5 W
070°	
080°	0°.5 E
090°	
100°	5°.5 E
110°	
120°	9°.0 E
130°	
140°	8°.5 E
150°	
160°	4°.0 E
170°	
180°	1°.0 W
190°	
200°	7°.0 W
210°	
220°	9°.5 W
230°	
240°	9°.0 W
250°	
260°	4°.0 W
270°	
280°	2°.0 E
290°	
300°	7°.5 E
310°	
320°	9°.0 E
330°	
340°	7°.5 E
350°	

2292/1397L D527507 360 10/76 TP Gp 3628/2

Degree of Accuracy Required by DTp

In all cases, very careful interpolation, preferably to the nearest $\frac{1}{4}°$ or 0·2°, is essential. The final

result may then be rounded up or down to the nearest $\frac{1}{2}°$ which is the degree of accuracy required in DTp Examinations.

Swinging Ship to find Deviation

The compasses are normally swung approximately once a year by a professional compass adjuster. The deviations are recorded on a card usually for every 10° of compass course. The watchkeeping officers should, when possible, check the deviation at each course alteration and at least once every watch when on a steady course. Each observation together with the date, ship's head and deviation should then be recorded in the Compass Record Book and compared with the card prepared by the adjuster. Whenever a significant difference is noted, the record of observations should be analysed and it may be considered necessary to swing the ship during the passage.

In coastal waters the best method is to select a transit (see Figure 19) of fixed objects about 7 to 8 miles away. At this distance the objects should remain in transit whilst the ship is being swung. The compass bearing of the transit must be taken at equidistant headings, preferably every 10 degrees. The magnetic bearing of the transit is then compared with compass bearing on each heading. In the open ocean, azimuths of a heavenly body are substituted for the transits.

When in coastal waters, where a suitable transit is not available, the compass can be swung using a single fixed object, again 7 to 8 miles away. This method assumes that the magnetic field of the ship is symmetrical and that on reciprocal headings the deviations will be equal and opposite. In the majority of cases this is nearly true for merchant ships. The bearings are taken on equidistant headings as for the transits but in this case the compass bearings are summed up and then divided by the number of observations to obtain an average bearing. This average bearing is then taken as the magnetic bearing and used for determining the deviation on individual compass headings.

To find the Magnetic Bearing and Construct a Deviation Card

To find the Magnetic Bearing of a distant object and thence to construct a deviation card:

1. "Swing" the ship and take compass bearings at 10°C (ship's head) intervals.
   i.e. Take 36 bearings on 36 compass headings
2. Add together all the compass bearings and find their sum.
   e.g. The sum of all compass bearings shown below is 4968°
3. Divide the sum of all compass bearings by the number of bearings taken in order to find the Magnetic Bearing of the distant object.

$$\text{e.g. Magnetic Bearing} = \frac{\text{Sum of all Bearings}}{\text{Number of Bearings}} = \frac{4968}{36} = 138°\text{M}$$

4. Take the difference between **each** Compass Bearing and the Magnetic Bearing to find the deviation on each heading.
   Name each deviation according to the rule:
   Error East —Compass Least
   Error West—Compass Best.

e.g.

Ship's Head by Compass	Compass Bearing	Magnetic Bearing	Deviation for Ship's Head
000°C	128°C	138°M	10°E
050°C	140°C	138°M	2°W

5. Tabulate the results as shown:

Ship's Head by Standard Compass	Bearing of object by Standard Compass	Magnetic Bearing	Deviation	Ship's Head by Standard Compass	Bearing of object by Standard Compass	Magnetic Bearing	Deviation
000°	128° C	138°M	10° E	180°	146° C	138°M	8° W
010°	130°	,,	8° E	190°	144½°	,,	6½°W
020°	132°	,,	6° E	200°	143°	,,	5° W
030°	134½E	,,	3½°E	210°	141°	,,	3° W
040°	137½°	,,	½°E	220°	139°	,,	1° W
050°	140°	,,	2° W	230°	137°	,,	1° E
060°	142½°	,,	4½°W	240°	135°	,,	3° E
070°	145°	,,	7° W	250°	132½°	,,	5½°E
080°	147°	,,	9° W	260°	130½°	,,	7½°E
090°	148°	,,	10° W	270°	128½°	,,	9½°E
100°	149½°	,,	11½°W	280°	127°	,,	11° E
110°	151°	,,	13° W	290°	125°	,,	13° E
120°	152°	,,	14° W	300°	124°	,,	14° E
130°	153°	,,	15° W	310°	123°	,,	15° E
140°	152½°	,,	14½°W	320°	124°	,,	14° E
150°	151°	,,	13° W	330°	124½°	,,	13½°E
160°	149½°	,,	11½°W	340°	125½°	,,	12½°E
170°	148°	,,	10° W	350°	127°	,,	11° E

Using Sun Azimuths to Construct a Deviation Card

When a vessel is "swung" using sun azimuths to find the deviation, the procedure is much the same as when using a distant object. But in this case it will be necessary to note the G.M.T. of each azimuth which is then worked out using ABC tables.

The ABC tables, when entered with latitude, hour angle and declination of the sun, give the true azimuth. The angle between the compass bearing and the true azimuth of the sun gives compass error, and the difference between compass error and the variation is the deviation for the direction of the ship's head at the time, as shown below.

On 8th May in Obs Pos 49°N, 5°W, the variation was 16°W. The vessel's head was steadied on various compass headings in order to find the deviations. The compass bearings of the sun were taken at the times indicated below.

Latitude 49°N, Sun Declination 17°N. Refer to ABC Tables.

Ship's Head by Compass	8th May G.M.T.	Compass Bearing	True Azimuth from Tables	Compass Error	Variation	Deviation
000°C	0920 hrs	128°C	116·2°T	11·8°W	16°W	4·2°E
045°	0928	125°	118·3°	6·7°W	,,	9·3°E
090°	0936	122°	120·3°	1·7°W	,,	14·3°E
135°	0944	132°	122·5°	9·5°W	,,	6·5°E
180°	0952	141°	124·8°	16·2°W	,,	0·2°W
225°	1000	150°	127·0°	22·7°W	,,	6·7°W
270°	1008	159°	129·6°	29·4°W	,,	13·4°W
315°	1012	154°	130·9°	23·1°W	,,	7·1°W

VARIATION FROM THE CHART

As previously mentioned, the Earth's magnetic field is irregular and in most locations the meridians passing through the True and Magnetic Poles do not coincide. In consequence, variation has different values for different positions. Thus, as a ship proceeds along its track it will usually experience a slow but steady alteration in compass error.

Variation also changes with change in time. Daily fluctuations (diurnal change) increase with latitude and in UK waters can produce changes of up to 25′. Seasonal fluctuations also occur. Such changes can sometimes be detected by taking a compass error but they cannot be calculated by the navigator and are ignored in day to day navigation. The most important change in variation is known as Secular Change.

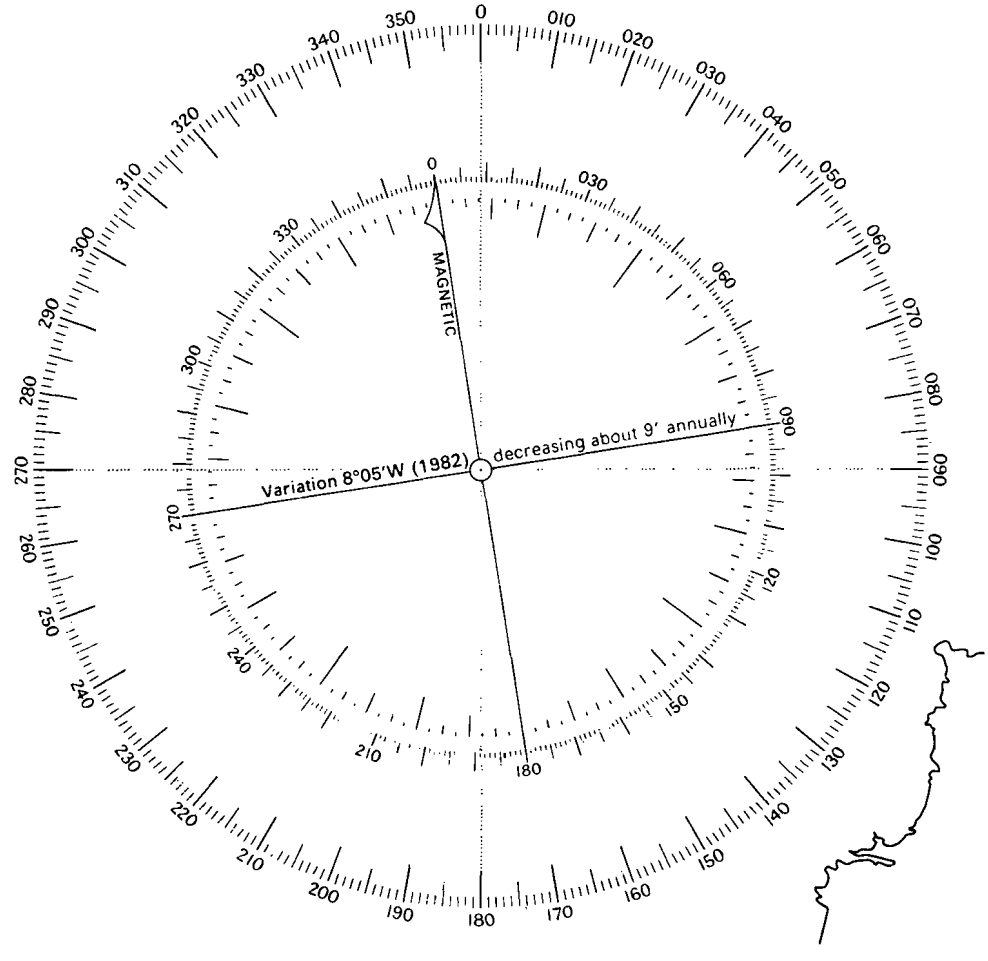


Figure 16. Details of Magnetic Variation included on a Compass Rose from the 1982 edition of English Channel Chart BA. 2675.

Secular Change (Annual Change)

The magnetic poles move and this results in a continuous alteration in the value of variation and which is known as secular change. When finding the variation for a position allowance must be made for this change which, on modern charts, is referred to as Annual Change.

Variation Information on Charts

(Refer to Figures 16, 17 and 18)

Variation and annual change in variation is given on:

1. The Compass Rose (larger scale charts) or
2. Isogonic lines printed on the chart (smaller scale charts).

Isogonic lines (isogonals) are "curves" drawn through positions and places which have the same variation. When isogonals are used, information relating to variation is also included in:

3. The Title Area of the chart.

Finding Variation from the Chart

On some charts the True and Magnetic Compass Rose are combined and include details of Magnetic Variation. For example:

"Variation 10° 00′ W (1983) decrg about 6′ annly" or on charts printed after 1984 as **"10° 00′ W 1983 (6′E)".**

On charts which show only the True Compass Rose this information would be given as follows:

"Decreasing about 6′ annually Magnetic Variation 10° 00′ W (1983)", or on charts printed after 1984 as **"10° 00′ W 1983 (6′E).**

On charts which include isogonals the same information would be given in the Title Area as follows:

"Magnetic Variation curves are for 1983.

The annual change in Magnetic Variation is shown at certain positions on the curve. A positive (+) prefix denotes an annual increase and negative (−) prefix an annual decrease." On charts printed after 1984 the annual change is given as E or W.

And on the "Curve" (Isogonic Line) as:

"Variation 10°W (−6′)" or on charts printed after 1984 as **"10°W (6′E).**

Finding Magnetic Variation for the Current Year

1. Note the Magnetic Variation and annual change printed on the isogonal or compass rose which lies nearest to the required position.
2. If the required position lies between two isogonals it may be necessary to **interpolate** between the two values.
3. Note the year for which Magnetic Variation is given.
4. Find the interval between "charted" year and present year.
5. To find total change, multiply the interval in years by the annual change in minutes—divide by 60 to convert to degrees.

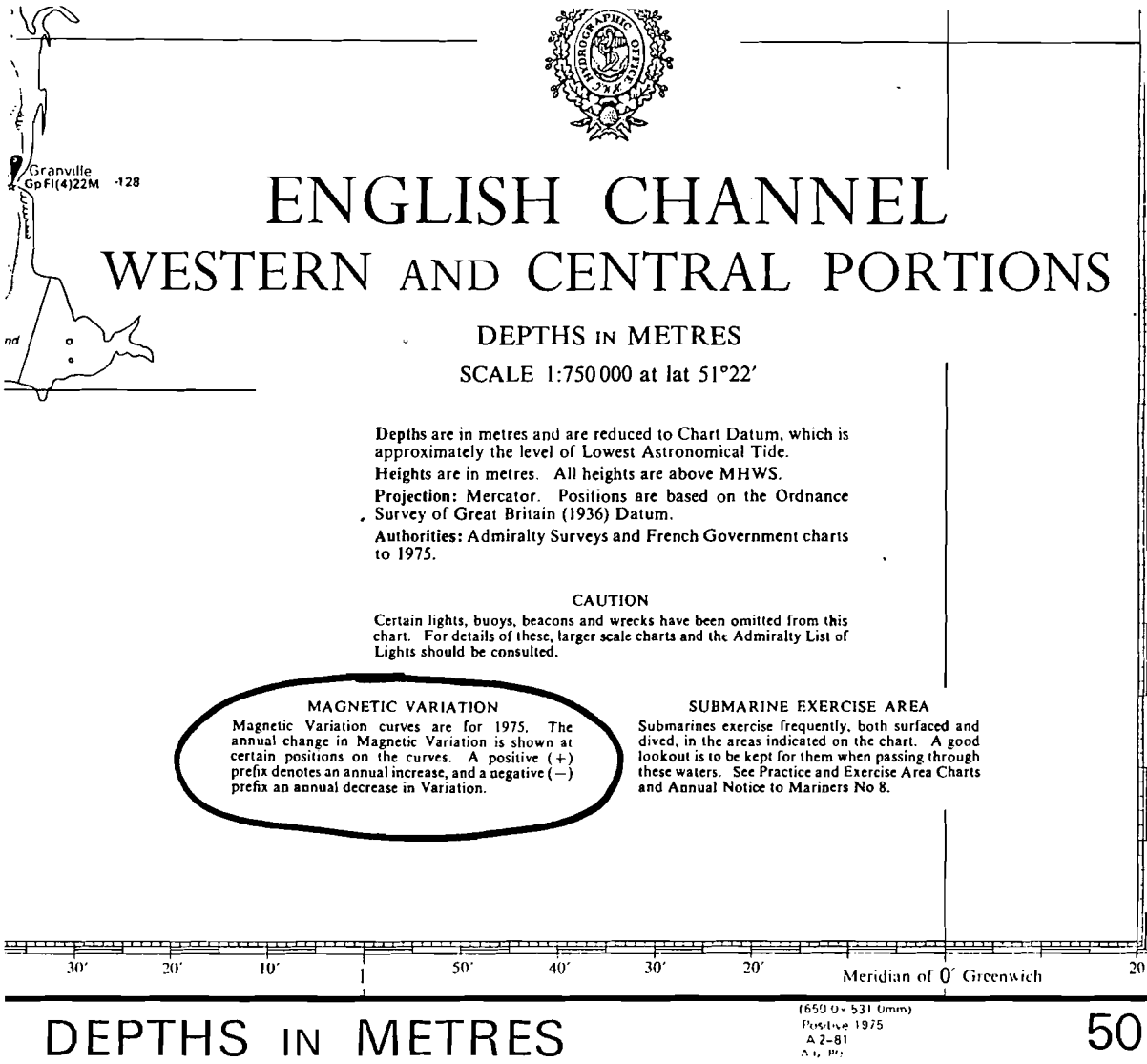


Figure 17. The Title Area of Practice Chart 5053—Information relating to Magnetic Variation.

6. To find present value, apply total change (+) or (−) i.e. E or W, to Magnetic Variation for "charted" year.

Using the values given above:

In 1983 Magnetic Variation was 10°W.
Time Interval 1983–1993 10 years.
Annual change (−) 6′ or 6′E.
Total change 10 years × (−) 6′ = (−) 60′ = (−) 1°

In 1993 Magnetic Variation will be 10°W − 1° = 9°W.

The method is demonstrated in the following example.

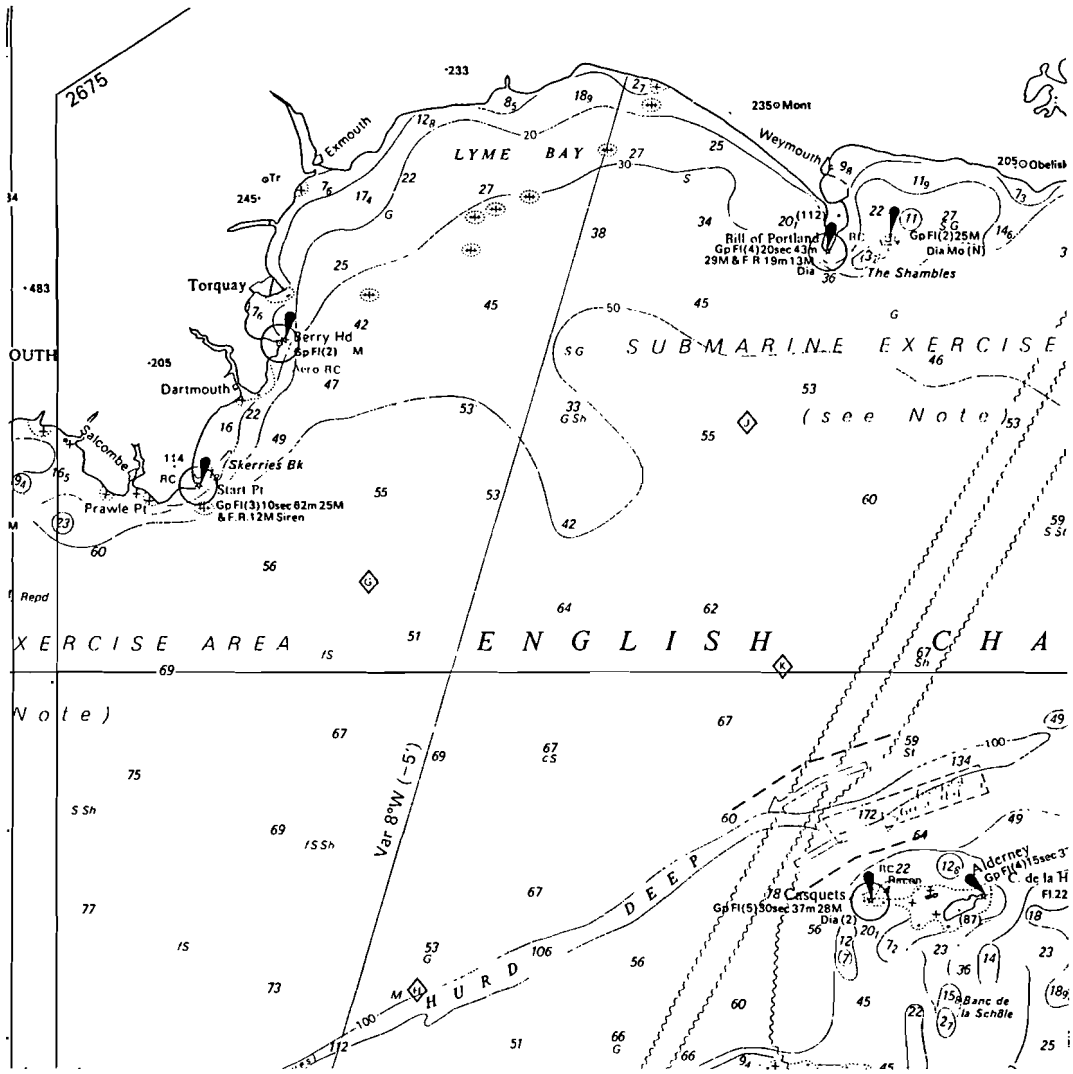


Figure 18. Magnetic Variation "Curve" printed on Practice Chart 5053.

Example 19

(Refer to Figures 17, 18 and Chart 5053 in Rear Pocket)

What will be the Variation in Lyme Bay in the year 1999?

1. Note that the isogonal passing through Lyme Bay gives Variation 8°W and that the Annual Change in Variation for this position is given as (−5′).
2. There is no need for interpolation—in this case.
3. Refer to the Title Area of the Chart and the Note headed "Magnetic Variation". As stated in the note, Variation curves are for the year 1975 and the Annual Change is given in minutes of arc and shown as a bracketed figure (+) if the variation is increasing and (−) if decreasing.

   In this case we note that the annual change is (−5′) so the variation is decreasing.

4.

Required Year	1999
Variation on Chart	1975
Interval in Years	24

5. Interval in years × Annual Change = Total Change

24 × (−) 5′ = (−) 120′ = (−) 2° 00′

6.

Variation for 1975	8°W
Change for 24 years	(−) 2°
Variation for 1999	6°W

Answer: Variation 6°W in 1999. N.B. This example demonstrates the principle. In practice, such a large interval of years is avoided by purchase of a new chart.

TRANSIT BEARINGS

(Refer to Figure 19)

When two conspicuous (charted) objects are seen exactly in line with one another they are said to be "in transit".

Refer to Figure 19 and note that, to an observer on the Shambles light vessel, Eastward of Portland Bill, Anvil Point and the Needles are in transit bearing 074°T.

It should be noted that the accuracy of position lines obtained from compass bearings depends on an accurate knowledge of compass error, if present, which must be applied to compass bearings to obtain true bearings. In the case of transit bearings, this does not apply. The transit bearing is observed by eye and so does not depend on the accuracy of the compass—this is a considerable advantage. Providing the two objects are carefully chosen, transit bearings provide very reliable position lines.

When two objects are very close together it is difficult to judge if they are exactly in line. In general, the greater the horizontal distance between the two objects the greater is the accuracy of the position line they give. But if the distance off the nearer object is too great reliability will be affected.

In consequence, and as a general rule:

1. Select objects with a good horizontal separation, and
2. Ensure that the distance between observer and nearer object is **not** more than three times the distance between the two objects.

Also note that, at different times, a charted light house, for example, can often be lined up (seen in transit) with several other conspicuous charted objects, e.g. a headland, tree, building, jetty head, etc. In other words, transits are often readily available.

The competent navigator is always on the look out for good transit bearings to include in a fix—by so doing the accuracy of all other compass bearings can be checked at the same time. This technique is demonstrated in Example 20.

After a long sea passage on the same heading, or after a long period alongside a berth, the permanent magnetism of the ship may become modified and so affect deviation—transit bearings are particularly useful for checking the compass error as soon as possible after making landfall or leaving port.

The symbol for a transit bearing is ∅.

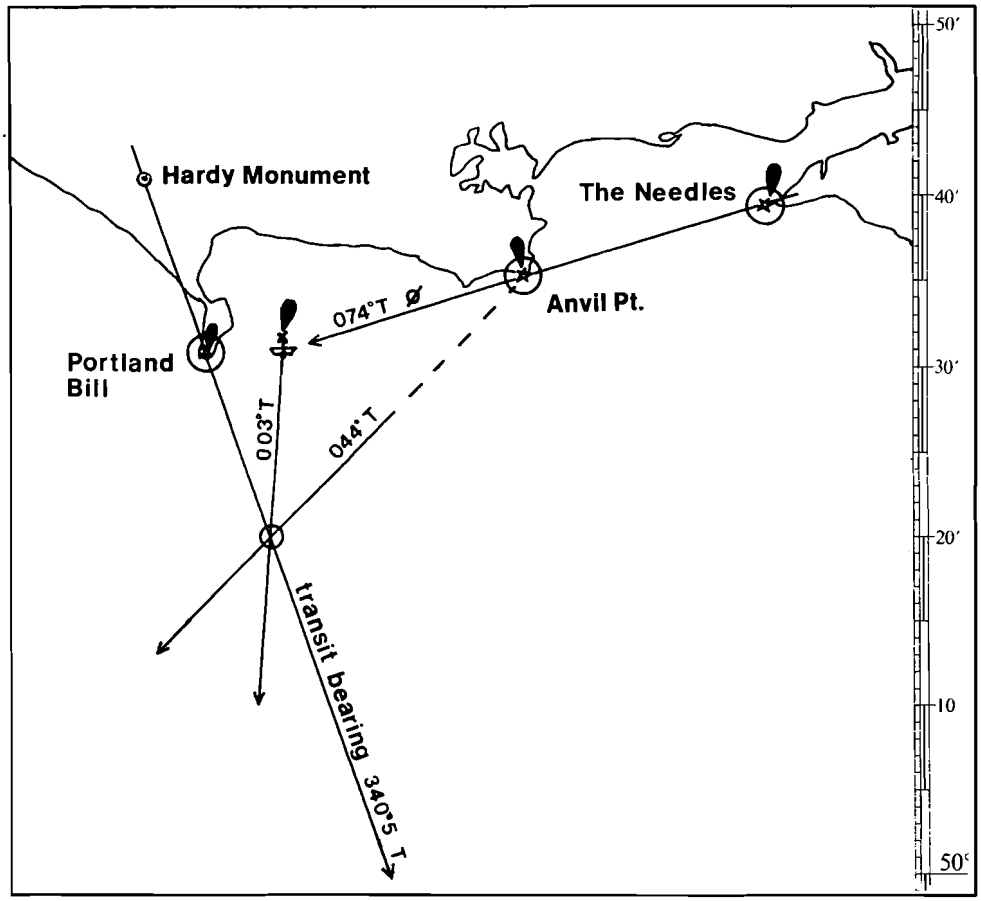


Figure 19. Transit bearings.

To Check Compass Error by Transit Bearing

To check compass error by transit bearing:

1. Select suitable charted objects.
2. At the moment the two objects are in transit, take Compass (and Gyro) bearings of the transit objects.
3. Using the parallel ruler, read the True transit bearing from the chart.
4. Compare the Compass (and Gyro) bearings with the True bearing and find Compass Error (and Gyro Error) and the deviation for the ship's head.

GYRO ERROR

In addition to the magnetic compass, most modern ships are fitted with a gyroscopic compass which is referred to as the "Gyro". Like the magnetic compass, the Gyro is likely to have an error. Such error is normally small.

Gyro error is the horizontal angle between True North and Gyro North. It results from the fact that although the gyroscopic compass can be extremely accurate, it seldom points exactly True North.

Gyro errors are normally referred to as being either High (of True) or Low (of True) as shown below.

True bearing of object	090°T	090°T
Gyro bearing of object	091°G	089°G
Gyro Error	1° High	1° Low

In some countries, notably the United States, gyro error is sometimes referred to as being West (High) or East (Low).

GYRO ERROR, COMPASS ERROR AND DEVIATION FROM TRANSIT BEARING

Example 20

(Refer to Figure 19)

From a vessel off the South Coast, Portland Bill Lt. Ho. and the Hardy Monument (235) are seen in Transit. Gyro and Compass bearings are taken.

From the following information find:

(a) Gyro Error,
(b) Compass Error,
(c) Deviation for the Ship's Head.

Portland Bill Lt. Ho. ∅ Hardy Monument bearing 342°G and 338°C. Use Variation 8°W.

Portland Bill ∅ Monument	340·5°T	from the Chart
Gyro Transit Bearing	342 °G	
Gyro Error	1·5° High	
Portland Bill ∅ Monument	340·5°T	from the Chart
Compass Transit Bearing	338 °C	
Compass Error	2·5°E	
Variation	8 °W	
Deviation for Ship's Head	10·5°E	

Answer: Gyro Error 1·5° High. Compass Error 2·5°E. Deviation 10·5°E.

Example 21

(Refer to Figure 19)

From a vessel East of Portland Bill, Anvil Point Lt. Ho. and the Needles Lt. Ho. are seen in transit. Gyro and Compass bearings are taken. From the following information find:

(a) Gyro Error
(b) Compass Error
(c) Deviation for the Ship's Head.

Anvil Point Lt. Ho. ∅ Needles Lt. Ho. bearing 072°G and 085°C. Use Variation 8°W corrected for 1987.

Required Year	1987
Variation on Chart	1975
Interval in Year	12 × Annual Change (−) 5′ = (−) 60′ = (−) 1°

Variation for 1975	8°W
Change for 12 years	(−) 1°
Variation for 1987	7°W

Anvil Point ∅ Needles	074°T	from the Chart
Gyro Transit Bearing	072°G	
Gyro Error	2° Low	

Anvil Point ∅ Needles	074°T	from the Chart
Compass Transit Bearing	085°C	
Compass Error	11°W	
Variation for 1987	7°W	
Deviation for Ship's Head	4°W	

Answer: Gyro Error 2° Low. Compass Error 11°W. Deviation 4°W.

Example 22

(Refer to Figure 19)

A vessel off the South Coast fixes position from the following Compass bearings:

Portland Bill ∅ Monument (235)	Shambles Light Vessel	Anvil Point Light House
345·5°C	008°C	049°C

Use Variation 8°W.

Find: (a) Compass Error,
(b) Deviation,
(c) Latitude and Longitude of the position.

Portland Bill ∅ Monument	340·5°T	from the Chart.
Compass Transit Bearing	345·5°C	
Compass Error	5°W	
Variation	8°W	
Deviation for Ship's Head	3°E	

	Portland Bill ∅ Monument (235)	Shambles Light Vessel	Anvil Point Light House
Bearings	345·5°C	008°C	049°C
Compass Error	5 °W	5°W	5°W
True Bearings	340·5°T	003°T	044°T

Answer: (a) Compass Error 5°W.
(b) Deviation 3°E.
(c) Position 50° 20′ N 2° 20·5′ W.

ALTERING COURSE ONTO A TRANSFERRED POSITION LINE

Situations may arise when it becomes necessary to make an important course alteration without the benefit of a suitable alter course (A/C) position.

Circumstances which give rise to this type of situation can include absence of radar or other electronic navigational aid (or breakdown of such equipment) coupled with a need, for example, to:

(a) Round an unlit headland at night.
(b) Avoid a submerged danger.
(c) Enter a narrow channel, or
(d) Make the final approach course to a port or anchorage in reduced visibility.

In such circumstances use can be made of a transferred position line obtained earlier from a single charted object.

A previously obtained, reliable, position line is transferred through the required position or destination. Any suitable position on the original P/L is selected and the vessel's track laid off from this position and produced to intersect the transferred P/L. The point of intersection is the position at which course should be altered onto the P/L, i.e. the A/C position.

Distance between the assumed starting position and the A/C position is measured and the Estimated Time of Arrival (ETA) at this position is calculated using log speed or ground speed as appropriate.

In the Running Fix we took two bearings, with a known time interval between them, of the same object and crossed the second P/L with the transferred P/L. In the technique described here, we take only one bearing, transfer it for an unknown time interval and then calculate the time interval between the P/L and transferred P/L.

The use of transferred position lines is fundamental to both coastal and ocean navigation and the principles involved must be thoroughly understood.

Accuracy, as with the Running Fix, depends on an accurate knowledge of speed, the course steered, leeway angle and tidal stream and/or current (if present).

Though extremely useful, this technique does have its limitations and, for the reasons given above, must be used with intelligence and discretion. It must be stressed that, on any final approach course the navigator should make full use of all available navigational information derived from, in particular, the echo sounder, the look-out, sight and sound.

Example 23
(Refer to Figure 20)

A vessel bound for Plymouth enters an area of restricted visibility immediately after obtaining a single bearing of Lizard Point light. From the following information find:

(a) The track to make good in order to enter Plymouth Sound passing 5 miles Eastward of Eddystone Rocks on the approach course.
(b) The course to steer to make good the intended track.
(c) The time to alter course onto the intended track.

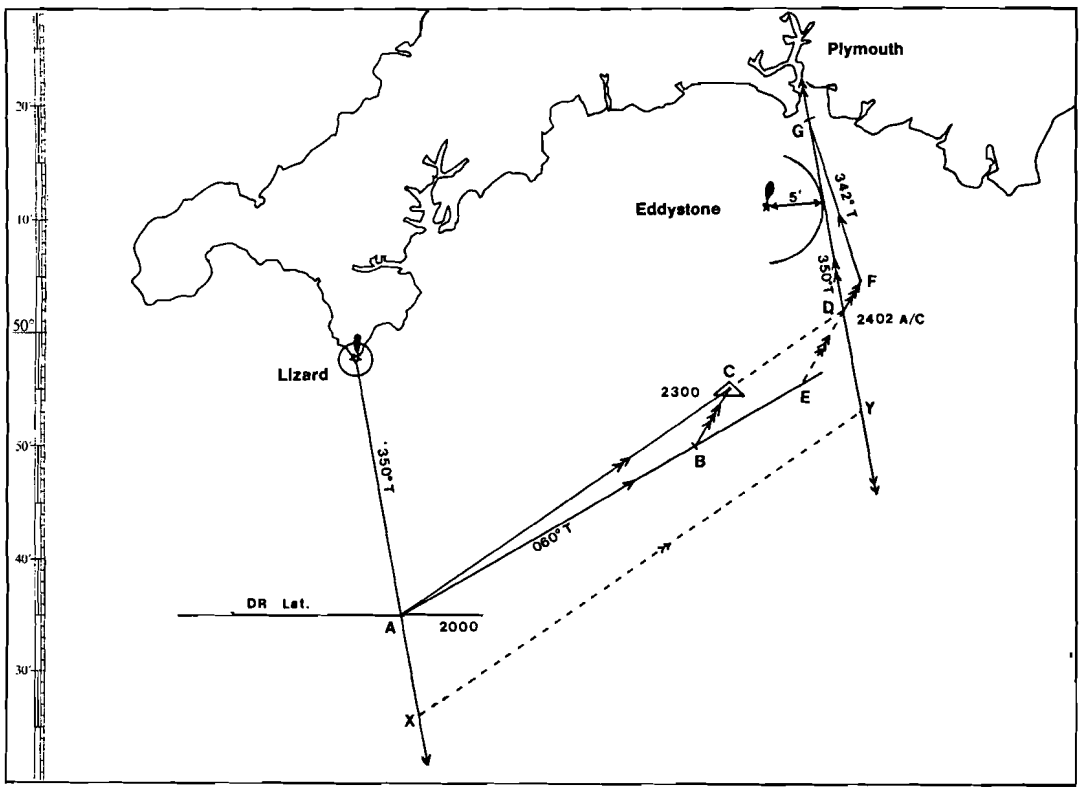


Figure 20. Altering Course onto a Transferred Position Line.

(d) The ground track and speed made good from 2000 to the A/C position.

2000 DR 49° 35′ N 5° 00′ W Lizard Point Light bearing 352°G
Course 062°G at 10 knots Gyro Error 2° High
Current 030°T at 2 knots (Throughout)

To Find the Time to Alter Course

1. Find the True Course and bearing.

Course	062°G	Bearing	352°G
Gyro Error	2° High		2° High
	060°T		350°T

2. Using compasses and centre Eddystone Light, describe a 5 mile arc Eastwards of the light (this is the required distance off).
3. Using the parallel ruler, lay off the bearing as the 2000 P/L (350°T) through The Lizard Light.
4. Transfer the 2000 P/L through the entrance to Plymouth Sound and tangential to the 5 mile arc off Eddystone (GY). (This is the required track to make the entrance safely.)
5. Select any suitable position on the 2000 P/L—Position 'A' selected. (This position coincides with the DR latitude.)

6. Using position 'A' as the assumed starting position, lay off the course as the track angle 060°T.
7. Select a suitable time interval, say 3 hours, and plot the 2300 DR (B) and EP (C).

Log Distance	2000–2300	3 hours at 10 knots	30 miles (A–B)
Set	2000–2300		030°T
Drift	2000–2300	3 hours at 2 knots	6 miles (B–C)

(Any time interval which will provide a good sized current triangle may be chosen.)

8. Plot the Ground Track (AC) between the assumed starting position (A) and the EP (C) and produce to intersect the transferred P/L (GY) at 'D'.
(Position 'D' is the required Alter Course (A/C) position.)
9. Measure the 2000–2300 distance (AC) along the ground track—35·25 miles.
10. Find the Ground Speed.

$$\frac{\text{Distance along Ground Track}}{\text{Time (hrs)}} = \text{Ground Speed} = \frac{35{\cdot}25}{3} = 11{\cdot}75 \text{ knots}$$

11. Measure the distance (AD) between the Assumed Starting position 'A' and 'D' the A/C position. Distance 'AD' is 47·4 miles which is the distance over the ground to the A/C position.
12. Find the time at which to A/C onto the transferred P/L 350°T.

$$\frac{\text{Distance along Ground Track}}{\text{Ground Speed}} = \text{Time (hrs)} = \frac{47{\cdot}4}{11{\cdot}75} = 4{\cdot}033 \text{ hours}$$

Time of P/L off Lizard	2000
Steaming Time to transferred P/L off Plymouth	402
Alter Course (A/C) onto 350°T at	2402

To Find the Approach Course to Steer to Make Good the Intended Track

1. The required ground track for the approach to Plymouth is 350°T.
2. To make good the intended track counteract the current as previously described in Example 10 and summarised below.

Construct a good, accurate current triangle—say 1½ hour triangle:

Current	Set 030°T	Rate	2 knots	Drift	3 miles
		Speed	10 knots	Log distance	15 miles

Lay off the current vector (DF) 030°T 3 miles. With centre 'F' and radius Log Distance 15 miles describe an arc to cut the intended track at 'G'.

Direction 'FG' is the required course (342°T) and the distance over the ground in 1·5 hours (DG) will be 17 miles.

Required Course	342°T
Gyro Error	2° High
Course to Steer	344°G

$$\text{Ground Speed} = \frac{17}{1{\cdot}5} = 11{\cdot}33 \text{ knots}$$

3. Note that in this example (and for ease of explanation) current has been assumed constant throughout. In fact, tidal streams operating in this area would not be constant.

Answer: (a) Required Track 350°T
(b) Course to Steer 344°G
(c) A/C at 0002
(d) Ground Track 2000 – 0002 055°T at 11·75 knots.

LOG DISTANCE TO STEAM

(Refer to Figure 20)

In Example 23 it was necessary to find the time at which to alter course onto the transferred position line. To do this we found the time interval in hours by measuring the distance along the ground track (AD) and dividing by the ground speed of 11·75 knots (which had previously been obtained from the 3 hour current triangle ABC and which represented the Assumed Starting Position to EP).

We proceeded as follows:

$$\frac{\text{Distance along Ground Track}}{\text{Ground Speed}} = \text{Time (hrs)} = \frac{47{\cdot}4}{11{\cdot}75} = 4{\cdot}033 \text{ hours}$$

An alternative method is to divide the Log Speed into the Log Distance to Steam.

Using the parallel ruler, transfer the direction of the tidal stream vector (BC) through the alter course position 'D' and produce back to intersect the 060°T course line at 'E'.

Consider triangle AED:

Direction 'AE' is the course steered.
Distance 'AE' „ „ total distance recorded by the Log or (Log Distance to Steam).
Direction 'ED' „ „ set of current.
Distance 'ED' „ „ total drift.
Direction 'AD' „ „ ground track.
Distance 'AD' „ „ total distance over the ground.

Log speed was 10 knots. Log Distance to Steam (AE) = 40·33 miles (Measured from chart).

$$\frac{\text{Log Distance to Steam (AE)}}{\text{Log Speed}} = \text{Time} = \frac{40{\cdot}33}{10} = 4{\cdot}033 \text{ hours}$$

Note that exactly the same answer is achieved as with the other method. Note also that, by using the log speed, awkward decimal places included in the ground speed are avoided and the calculation is simplified.

CALCULATING ESTIMATED TIME OF ARRIVAL (ETA)

A simple example of calculating ETA is included in Example 23 at Stage 12. On long passages it is good practice to calculate steaming time in hours and convert to days and hours.

The time passage commences should be recorded in GMT to which is added the "Day of the Year" taken from the "Day of the Year Calendar", contained in the Nautical Almanac.

Steaming time in days and hours is then added to the starting day of the year and GMT time to find the Estimated Time of Arrival "Day of the Year" and GMT.

GMT is then adjusted for Standard Time at the destination and the day of the year

converted to calendar date. This method avoids many "pitfalls" which can occur when a passage starts in one month and ends in another, when the port of departure and destination have different standard times and, in ocean navigation, when crossing the date line.

A simple example is as follows:

Voyage commences March 30 at 1000 LMT 0900 GMT (Standard Time + 1 hr).
Steaming time 2 days 15 hours
Destination Port Standard Time + 2 hours

March 30 (Day of Year from Almanac)		89d	09	00	GMT
Steaming time		2	15	00	
ETA		92	00	00	GMT
Standard Time	(+)		2	00	
ETA (Day of Month from Almanac)		92	02	00	LMT
	April	2	02	00	LMT

Refer to the Nautical Almanac for further information on the use of the "Days of the Week and Days of the Year Calendar" and "Standard Time", tables.

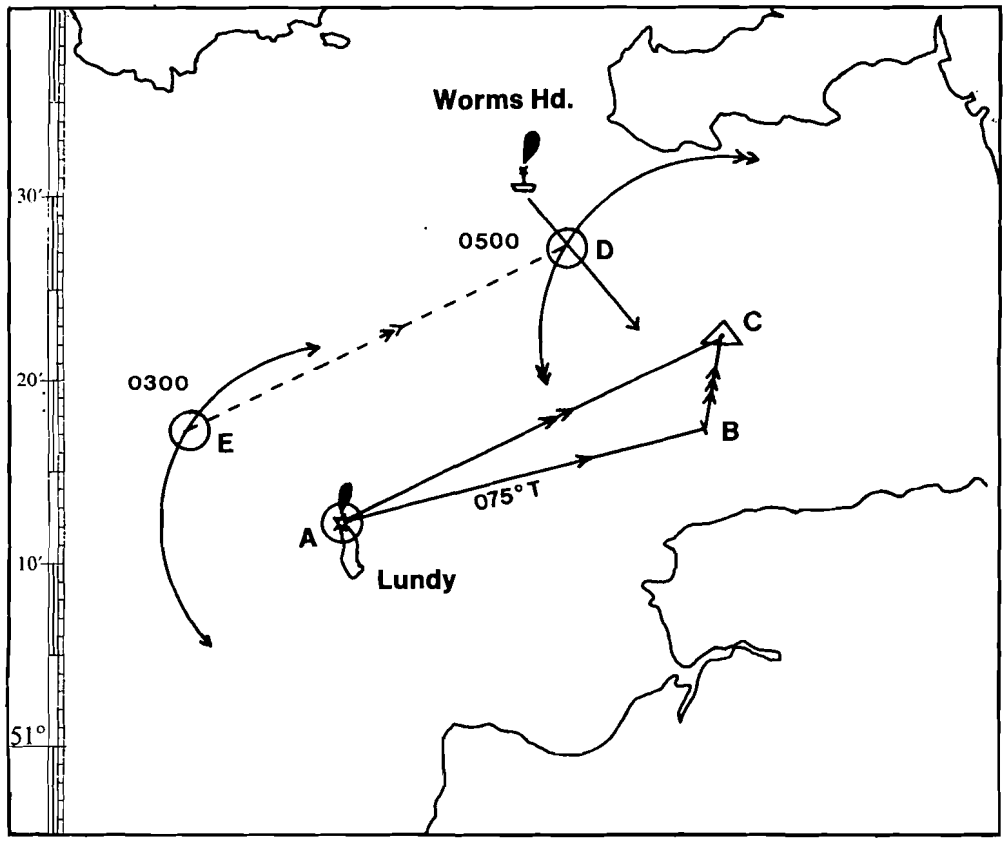


Figure 21. Transferring a position circle.

TRANSFERRING A POSITION CIRCLE

Position circles can be obtained by horizontal or vertical sextant angles or, more frequently, by radar range as demonstrated in Example 6.

When transferring a position circle, the object (from which the range is taken) is "run up" to an imaginary DR, Sea Position or EP. The transferred range is then plotted from this position. Refer to Figure 21 and the following instructions:

1. Obtain and write down the distance off (range) of the charted object.
2. With compasses, describe an arc (AE) equal to the range obtained from the chosen object (A). Mark the arc with a single arrow at each end.
3. Lay off the vessel's course from the chosen object (A) used to obtain the range.
4. Using the vessel's speed and the required time interval, transfer the object's position (A), along the course line, to DR (B) **or** if leeway and/or set and drift are being experienced, transfer to a Sea Position or EP (C).
5. With centre the DR, Sea Position or EP (as appropriate) describe an arc (CD) equal to the range previously obtained (AE). Mark the arc with a double arrow, at each end, to indicate it is an arc of a transferred position circle.
6. The relevant arc of the position circle has now been transferred for the time interval selected and may be crossed with a position line obtained at the corresponding time.

The following example demonstrates the method.

Example 24
(Refer to Figure 21)

A vessel bound for Swansea obtains a radar distance off Lundy Island. Shortly afterwards the radar breaks down and the vessel proceeds in reduced visibility until obtaining a single Gyro bearing of Worms Head Light Vessel.

From the following information find:

(a) Bearing and distance off the Light Vessel at 0500.
(b) Ground track and ground speed.

0300 Lundy Island Gp. Fl. Light House Radar Range 10 miles
V/L in a position approximately NW of the Island.
0500 Worms Head Light Vessel bearing 319°G
Echo Sounder indicates V/L has crossed 30 m contour line.
Course 074°G at 10·0 knots Gyro Error 1° Low
Current 010°T at 2·5 knots (throughout)

1. 0300 Lundy Island Light House range 10·0 miles.
2. Radius 10 miles, centre Light House, describe 0300 position circle (arc).
3. Course 074°G — Bearing Worms Head Light Vessel 319°G
   Gyro Error 1° Low — (0500) — 1° Low
   075°T — 320°T
   Lay off course line 075°T from Lundy Island Light House.
4. 0300–0500 Course 075°T Log Speed 10·0 knots Log Distance 20·0 miles
   Set 010°T Rate 2·5 knots Drift 5·0 miles
   Plot EP (C) using course line drawn from Lundy Island at (3).

5. Radius 10 miles, centre EP (C), describe 0500 transferred position circle (arc). Mark with double arrow.
6. Lay off 0500 bearing of Worms Head Light Vessel 320°T as P/L to intersect the transferred position circle arc at 'D'.
7. 'D' is the vessel's position at 0500 with Light Vessel bearing 320°T at 3·5 miles.
8. Read off ground track 063°T (AC).
9. Measure off distance over the ground 0300–0500 (AC) 22·5 miles. Ground speed 11·25 knots.
10. If desired, produce ground track backwards from 0500 position 'D' to intersect 0300 position circle at 'E'. 'E' was the vessel's position at 0300.

Answer: (a) 0500 Worms Head Light Vessel bearing 320°T at 3·5 miles
(b) Ground Track 063°T Ground Speed 11·25 knots.

HORIZONTAL ANGLES

In the same segment of a circle, all angles subtended by a chord are equal. It follows that if the horizontal angle between two fixed objects is measured from a ship, the ship's position must lie somewhere on the arc of a circle which passes through the two objects and which contains the horizontal angle observed.

Using two objects a position circle is thus obtained. If three objects are used, and two horizontal angles obtained at the same time, two position circles are obtained.

The point of intersection of the two position circles is the vessel's observed position.

Horizontal angles can be obtained from:

1. Sextant angles,
2. Magnetic Compass bearings, and
3. Gyro Compass bearings.

Horizontal sextant angles (on the arc) are obtained directly after applying any Index Error.

Horizontal angles obtained from Magnetic or Gyro Compass bearings are found by taking the angular difference between the bearings.

Any Compass or Gyro Error which is present will affect all bearings equally. In consequence, it is not necessary to apply any Compass or Gyro error which may be present.

Finding Compass Error from Horizontal Angles

Having fixed the vessel's position by horizontal angles, true bearings (from the resulting position to each of the objects observed) can be taken off the chart, compared with compass or gyro bearings and the compass or gyro error found.

Plotting Position Circles Obtained from Horizontal Angles

There are three cases:

1. Angles greater than 90°,
2. Angles of exactly 90°, and
3. Angles less than 90°.

Angles Greater than 90°, i.e. (90° + θ°)

(Refer to Figure 22)

An observed horizontal angle which is greater than 90° indicates that the observer lies on the minor arc of a position circle which passes through the two points, i.e. in the figure, the observer lies somewhere on the minor arc AFB.

To plot the position circle:

1. Subtract 90° from the observed angle to obtain the "base angle",
   e.g. HA 116° − 90° = 26°.
2. Join the two points to form a base line.
   AB in the figure.
3. Lay off the "base angle" at each end of the base line on the side facing the major arc.
   Angles EAB and EBA in the figure.
4. Produce the two angles to intersect at 'E' the centre of a position circle passing through 'A' and 'B'.
5. With centre 'E' and radius either 'EA' or 'EB' describe a circle passing through the two points 'A' and 'B'.
   Circle ABF in the figure.
6. Position lies somewhere along the minor arc of the circle passing through the two points.
   Somewhere on arc AFB.

Angles of Exactly 90°

An observed horizontal angle of exactly 90° indicates that the observer lies on one of the semicircles which make up the position circle passing through the two points.

1. In the figure, draw any diameter 'LDM' through the centre of circle 'CFB'.
2. Choose any position on the circumference.
3. Measure the horizontal angle at the chosen position between points 'L' and 'M'.
4. The measured angle will be 90°.

Angles Less than 90°, i.e. (90° − θ°)

(Refer to Figure 22)

An observed horizontal angle of less than 90° indicates that the observer lies on the major arc of a position circle which passes through the two points, i.e. in the figure, the observer lies somewhere on arc 'BFC'.

To plot the position circle:

1. Subtract the observed angle from 90° to obtain the "base angle",
   e.g. 90° − HA 25° = 65°.
2. Join the two points to form a base line.
   BC in the figure.
3. Lay off the "base angle" at each end of the base line on the side facing the major arc.
   Angles CBD and BCD in the figure.
4. Produce the two angles to intersect at 'D' the centre of a position circle passing through 'B' and 'C'.

5. With centre 'D' and radius either 'DB' or 'DC' describe a circle passing through the two points 'B' and 'C'.
   Circle BCF in the figure.
6. Position lies somewhere along the major arc of the circle passing through the two points.
   Somewhere on the major arc BFC.

Fixing Position by Horizontal Angles

The two position circles intersect at position 'F' which is the vessel's observed position obtained from horizontal angles.

The following example demonstrates the method.

Example 25
(Refer to Figure 22)

Cross bearings are obtained using a compass of unknown error. From the following information find:

(a) Vessel's position and
(b) Deviation for the Ship's Head.

	Portland Bill	Anvil Point	The Needles
0800	287°C	043°C	068°C

Use Variation from the Chart corrected for 1999.

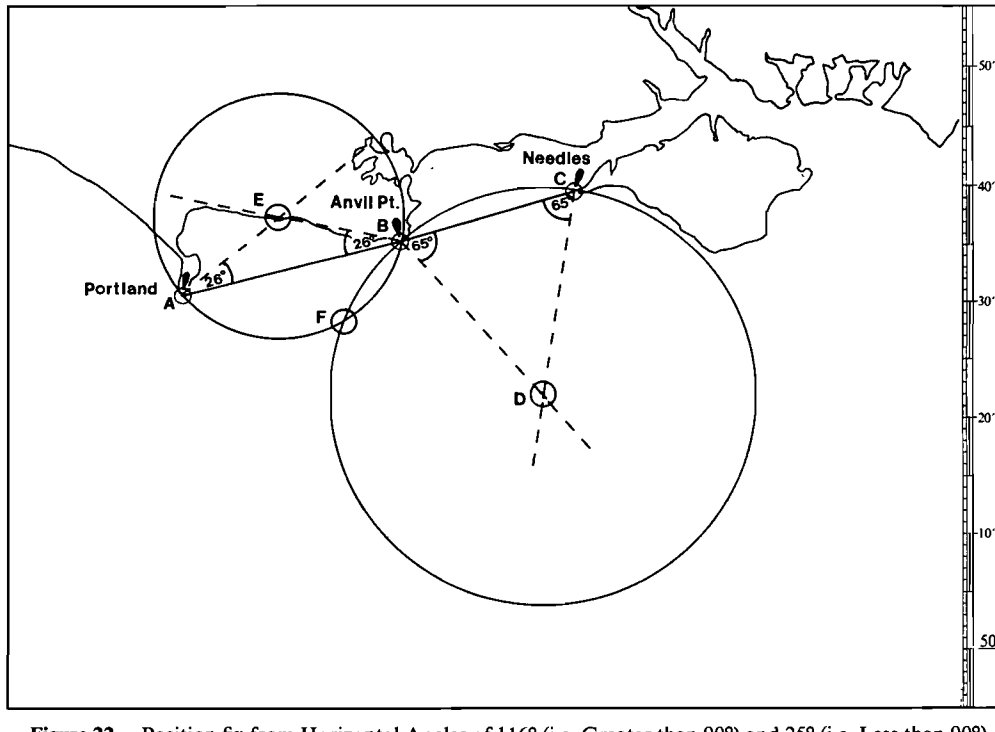


Figure 22. Position fix from Horizontal Angles of 116° (i.e. Greater than 90°) and 25° (i.e. Less than 90°).

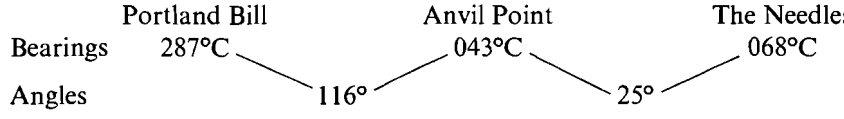
To Find Variation

The approximate position lies midway between the 7° and 8° isogonals. Variation in 1975 was therefore 7·5°W.

Annual Change (−) 5′W × (1999 − 1975) gives
(−) 5′W × 24 = Total Change (−) 2°W

Variation for 1999 = 7·5°W (−) 2°W = 5·5°W.

To Find Horizontal Angle



N.B.—When two of the bearings are in the 4th and 1st quadrants (as above) proceed as follows:

043°
(+) 360°
403°
(−) 287°
116°

To Plot Position Circle Derived from Horizontal Angle Greater than 90°

1. Observed HA 116°
(−) 90°
Base angle 26°

Horizontal angle greater than 90°—position must be on minor arc of position circle.

2. Join the two points observed (A and B) Portland Bill and Anvil Point by straight line (AB) which is the base line.
3. Lay off base angle (26°), facing major arc, on base line at 'A' and 'B'.
4. Produce two base angles to intersect at 'E' which is the centre of the position circle.
5. Centre 'E' and radius 'EA' or 'EB' describe the circle passing through the two points.
6. The vessel lies somewhere on the minor arc of position circle AFB.

Note that at any position on this arc the horizontal angle between Portland Bill (A) and Anvil Point (B) will be exactly 116°. (Check this out by selecting any three points on the minor arc, say, 'X', 'Y' and 'Z', and measuring angles 'AXB', 'AYB' and 'AZB'.)

To Plot Position Circle Derived from Horizontal Angle Less than 90°

1. 90°
Observed HA (−) 25°
Base angle 65°

Horizontal angle less than 90°—position must be on major arc of position circle.

2. Join the two points observed (B and C) Anvil Point and The Needles by straight line (BC) which is the base line.
3. Lay off base angle (65°), facing major arc, on base line at 'B' and 'C'.
4. Produce two base angles to intersect at 'D' which is the centre of the position circle.

5. Centre 'D' and radius 'DB' or 'DC' describe the circle passing through the two points.
6. The vessel lies somewhere on the major arc of position circle 'BFC'.

Note that at any position on this arc the horizontal angle between Anvil Point (B) and The Needles (C) will be exactly 25°. (Check this out by selecting any three points on the major arc, say, 'P', 'Q' and 'R', and measuring angles 'BPC', 'BQC' and 'BRC'.)

Fixing Position

The two position circles intersect at position 'F' with Anvil Point bearing 035°T at 8·5 miles.

Finding Deviation for the Ship's Head

	Anvil Point
Observed Bearing	043·0°C
Bearing from Chart	035·0°T
Compass Error	8·0°W
Variation for 1999	5·5°W
Deviation	2·5°W

Repeat the above calculation for the remaining two compass bearings and compare the resulting deviations—they should have approximately the same value. Average out any slight differences found. Repeat the entire operation (i.e. take new bearings) if large differences are found.

Answer: (a) 0800 Anvil Point bearing 035°T at 8·5 miles.
(b) Deviation 2·5°W.

STATION POINTER AND OTHER MEANS OF PLOTTING HORIZONTAL ANGLES

In the preceding example horizontal angles were plotted by construction. Other means of plotting horizontal angles include:

1. Station Pointer,
2. Douglas Protractor, and
3. Tracing Paper or Transparent Plotting Sheet.

The Station Pointer is a hydrographic surveyor's instrument which, as can be seen in Figure 23, consists of a circular protractor with three arms attached. The centre arm is fixed and the outer arms movable. The outer arms are adjusted to the observed horizontal angles in relation to the centre arm and then clamped into position.

Having clamped the movable arms at the observed angles, the station pointer is moved about the chart until the bevelled edges of the three arms align with the observed objects. Position is then plotted by inserting the chartwork pencil through the small hole at the centre of the instrument. Use of the station pointer requires some practice.

The Douglas Protractor is a combined protractor and parallel ruler. Square in shape, it has a North point, an inner and outer 360° scale, parallel lines running North–South and East–West and a small hole at its centre. It is an instrument much favoured by Yachtmasters and comes in various sizes. It can be used for laying off courses and bearings and, in the context

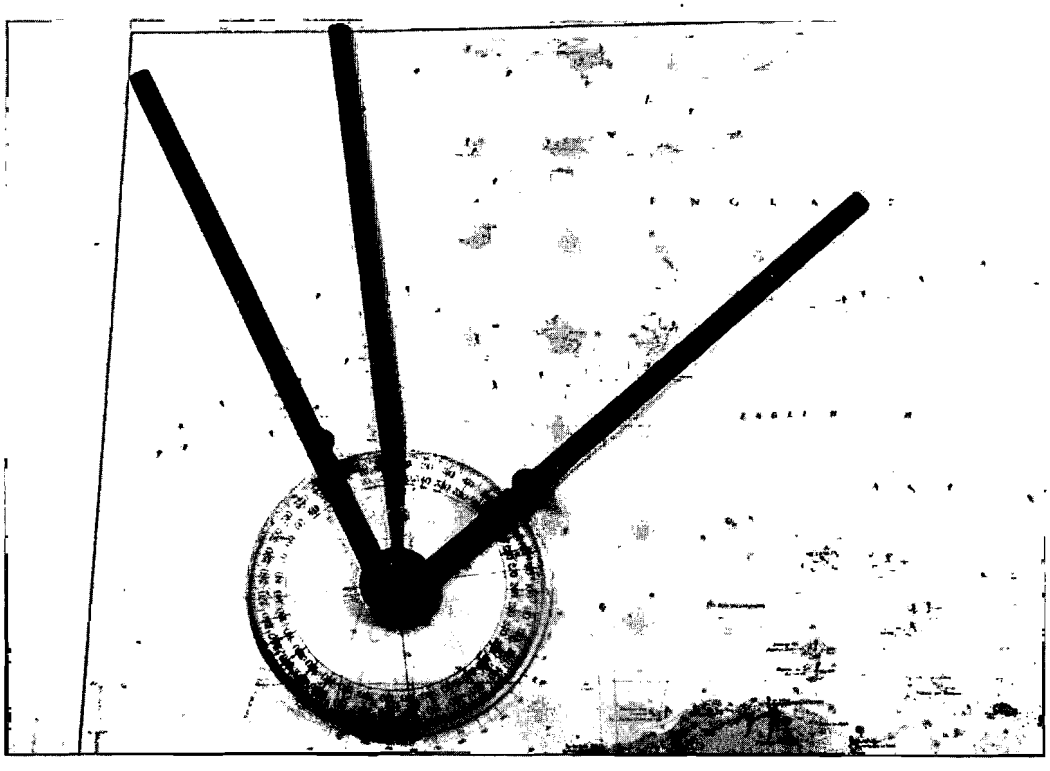


Figure 23. The Station Pointer used for plotting horizontal angles.

of this section can be used in much the same way as a Station Pointer. For this latter purpose, a large size Douglas Protractor is advised. This protractor is supplied with full instructions for its use.

Tracing Paper or a Transparent Plotting Sheet can also be used. Observed horizontal angles are plotted on the tracing paper which is then used much as the station pointer.

Relevant Geometric Properties of Circles

The angle (on a chord) at the centre of a circle is twice the angle (on the same chord) at the circumference. Refer to Figure 22:

A triangle contains	180°
Base angles on chord 'BC' $65° \times 2 = (-)$	130°
Angle BDC at centre of circle	050°
Angle at circumference (on chord 'BC')	025°

1. Select any three positions on the major arc of position circle 'BFC'.
2. Measure the horizontal angle (between points 'B' and 'C') at each of the chosen three positions.
3. Note that the horizontal angle is the same for each case (25°).

The geometric property described above can be used to advantage when a navigator wishes to avoid an offshore danger.

Horizontal Danger Angle

Horizontal angles can be used for avoiding offshore dangers.

If a submerged rock or other offshore danger lies in the vicinity of two conspicuous, charted, objects the danger may be avoided by steering courses such that the vessel never comes closer than some chosen "safe distance off".

A position at the required "safe distance" off the danger is plotted on the chart. The horizontal angle (between the two conspicuous objects) at this position is then measured from the chart and the sextant set to this angle.

As the vessel approaches the vicinity of the danger, the horizontal angle between the two objects is checked at short time intervals. If this "Danger Angle" is exceeded it indicates that the vessel is approaching closer than the chosen "safe distance off" and course is immediately altered away from the danger.

By steering courses such that the horizontal danger angle is exactly maintained, the vessel will exactly follow the circumference of the position circle which clears the danger by the required safe distance off.

The technique is demonstrated in the following example.

Example 26

(Refer to Figure 24)

Following a collision a VLCC sinks in position 50° 05′ N 4° 00′ W.

The same day, a vessel proceeding to Falmouth receives a Radio Navigation Warning which states that the wreck is considered dangerous to surface navigation.

It is decided to proceed on Course 280°T and to maintain a minimum distance 3 miles South of the wreck. The radar having broken down, it is decided to use the sextant for a Horizontal Danger Angle between Eddystone Rocks Light House and Start Point Light House.

From the following information find:

(a) The Horizontal Danger Angle for maintaining the required 3 mile minimum distance off the danger, and

(b) State what action should be taken if the Danger Angle is exceeded.

Vessel in DR 49° 56′ N 3° 10′ W. Course 280°T.

To Find the Required Horizontal Danger Angle

1. Plot the vessel's DR, as shown.
2. Plot the position of the danger (W), as shown.
3. Plot the required distance off the danger (3 miles South) to find the point of nearest approach (C).
4. At the point of nearest approach (C), measure the Horizontal Angle (98°) between two conspicuous points (Eddystone and Start Point Light House).
5. Construct the position circle passing through the two points and which gives the required horizontal angle (98°) at position 'C'. (Minor arc. Base angles $98° - 90° = 8°$.)
6. If the vessel is actually at the DR position and the track made good is 280°T the point of nearest approach will be at position 'C'. As the vessel approaches 'C' the Horizontal Angle will increase, reach a maximum of 98° at 'C', and then decrease.
7. If the vessel is North of the DR, as shown by the N'ly pecked line, the Horizontal Angle will steadily increase until reaching a value of 98° at, say, position 'E' and then **continue to increase**.

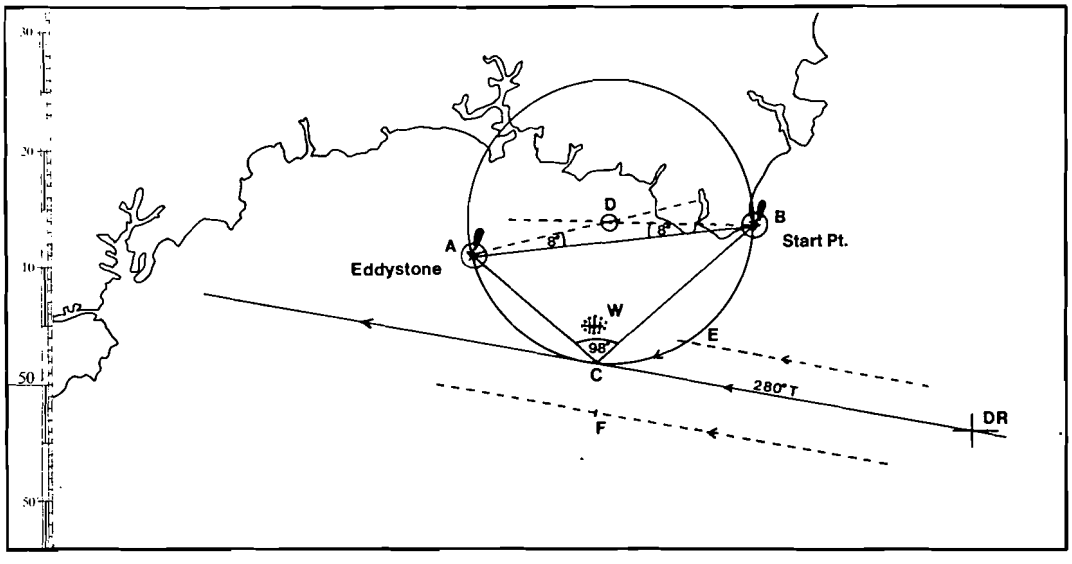


Figure 24. 'Horizontal Danger Angle 98°. At Position 'E' the horizontal angle will start to increase above the value of the horizontal danger angle—order immediate course alteration to the South.

If this occurs the vessel should immediately alter course to the South and steer courses such that the Horizontal Danger Angle is **never** exceeded. Once the angle continues to steadily decrease course can be resumed.

8. If the vessel is South of DR (as shown by the S'ly pecked line) the Horizontal Angle will still increase but will never reach the maximum safe value of 98°.

At point 'F' a maximum value (under 98°) will be reached and then start to decrease.

Answer: (a) Horizontal Danger Angle 98°.
(b) Immediately A/C onto a S'ly or SW'ly course to regain a Horizontal Angle of just under 98°.

Observing Horizontal Sextant Angles

When observing horizontal sextant angles, take the angles from right to left—this avoids the need to use the sextant face downwards which requires some skill.

When observing horizontal angles between a fixed and flashing light, take the fixed light to the flashing light—this helps to remove the possibility of "losing" the flashing light mid-way. If the flashing light lies to the right of the fixed light the need to use the sextant face downwards cannot be easily avoided.

Choice of Objects When Fixing Positions by Horizontal Angles—Rules

When fixing position by horizontal angles one or other of the following rules should apply to the objects selected:

1. Three objects in a straight line, or nearly so (as shown in Figure 22) **or,**
2. Middle object to be closest to the ship **or,**
3. Ship lies inside a triangle formed by the three objects.

Failure to select objects in accordance with these rules may result in Circular Error.

CIRCULAR ERROR

As mentioned earlier, the reliability of a three bearing fix can generally be checked by the size of the "Cocked Hat" which results. However, a special case can occur in which the three charted objects (used for bearings) and the ship, all lie on a common circle. Under these conditions, and regardless of the value of the compass error applied, the three bearings will always intersect at a single point and appear to give a perfect fix, i.e. no "cocked hat".

Example 27
(Refer to Figure 25)

A vessel is returning from the United States with a bulk cargo of scrap metal. The passage has been made in overcast conditions and it has not proved possible to obtain a compass error for the past 7 days. The last azimuth, shortly after departure, gave a Deviation of 9°E. Course has been maintained since that time.

Making landfall off Lands End, an inexperienced 3rd Officer takes the following bearings:

Wolf Rock Light	Lands End Light	Lizard Point Light
350°C	012°C	044°C

Variation 9°W. Comment on the reliability of the fix obtained

Compass error is assumed to be Nil (Variation 9°W Deviation 9°E) and the bearings are plotted as true bearings fixing the vessel's position at 'X'. There is no "cocked hat".

If the compass error had been assumed to be, say, 30°W giving bearings of 320°T, 342°T and 014°T the vessel's position would have been at 'Y' and once again there would have been no "cocked hat".

Whatever compass error is applied to the three bearings, the resulting position will lie on arc 'AXYC', produce no "cocked hat" and **appear** to give a "perfect" fix.

Answer: The position is quite unreliable.

Points of land used for bearings have been badly chosen such that they lie on a common circle.

Deviation is likely to be seriously in error due to the nature of the cargo and its effect on the ship's magnetism. Compass Error applied Nil (Variation 9°W Deviation 9°E).

Regardless of what Compass Error is applied the bearings will always **appear** to give a "perfect" fix, i.e. no "cocked hat".

Under these circumstances the navigator should have first obtained a reliable compass error before taking and plotting bearings **or** if this was not possible, three more suitable objects chosen and position plotted by horizontal angles.

VERTICAL SEXTANT ANGLES

A vertical sextant angle of a well charted object, such as a light house, can provide the navigator with a very accurate distance off (range). This can be of use in fixing position by combining range and bearing or by one of the other methods previously described. It can also be of considerable use in confined waters where frequent course alterations are required at pre-selected positions. Given appropriate pre-planning, this technique can be extremely fast and

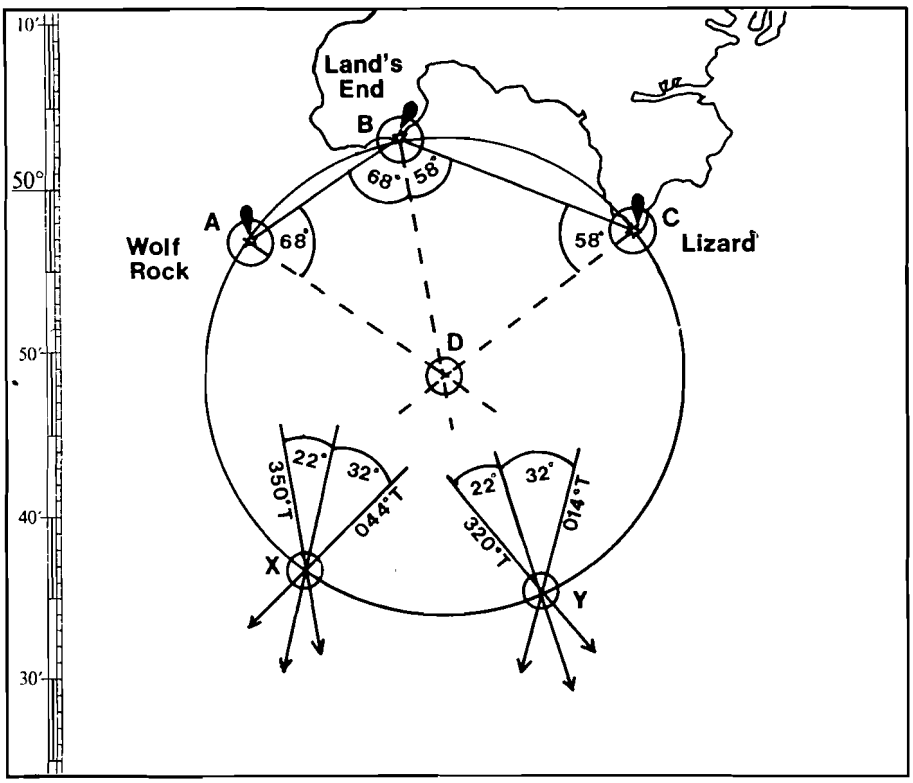


Figure 25. Circular Error.

accurate and enables the vessel to be navigated from the bridge wing. Range by vertical sextant angle can be extremely helpful in the event of radar breakdown.

The range of the object, which must be of known height, is found from its vertical sextant angle, corrected for any index error, and use of either:

Plane right angles trigonometry, or
Distance by Vertical Angle Tables (and similar).

Distance by Vertical Angle Tables are probably the most convenient method. Those contained in *Nories Nautical Tables* are calculated for distances of up to 7 miles and heights of up to 600 metres (1969 ft). At the tabulated maximum distance of 7 miles, the whole object, from top to base, will be visible to an observer with a height of eye greater than 12 metres (39 ft). A correction for dip is necessary when height of eye is less than 12 metres.

Another example of vertical angle tables is Captain Lecky's, *The Danger Angle and Offshore Distance Tables*. These tables are divided into two parts:

Part 1 Object between observer and horizon.
(Distances up to 7·5 miles, heights up to 1,100 ft)

Part 2 Object beyond the horizon.
(Distances 5–110 miles, heights up to 18,000 ft)

When finding the range of objects beyond the horizon, i.e. when using Part 2, a correction for refraction must be made in addition to the correction for dip—full instructions are included with the tables.

Charted Height (Elevation)

The charted height (Elevation) of an object is given above MHWS or MHHW or, where there is no tide, above MSL.

In the case of a light house, charted height is measured from the chosen level (e.g. MHWS) to the centre of the focal plane of the light (centre of the lens).

Charted heights of lights are listed in the "elevation" column of Admiralty Light Lists and are also included on larger scale charts, e.g. 13 m (13 metres above MHWS).

In addition to elevation, Admiralty light lists also include the "Height" of a light—in this context "Height" refers to the height of the structure measured from the top of the structure to the ground. The listed height **must not** be confused with elevation (charted height).

Tidal levels of MHWS, MHHW and MSL (above Chart Datum) are listed in Table V of the *Admiralty Tide Tables.*

In the examples which follow, the term "height" refers to the charted height or elevation of the object.

Correction for Height of Tide

As charted heights are given above a stated tidal level (e.g. MHWS) any change in tide will produce a corresponding change in the object's actual height above the water level. In consequence, and for very accurate results, it is necessary to make allowance for any increase (or decrease) in the object's height which results from the water plane being at a level which is lower (or higher) than that of the stated tidal level (e.g. below MHWS)—refer to the chapter on tides for examples and further information.

In the case of a light vessel, the water plane always remains at the same distance from any part of the vessel and no such allowance is necessary.

On near objects the high water mark can sometimes be seen quite clearly as darker "tide mark" or line of seaweed. In such cases the angle measured should be between this mark and the top of the object.

In the majority of cases the water plane will be below MHWS and actual height will be greater than charted height. In consequence, the actual distance off will be greater than that calculated when no allowance is made for the height of tide—in most cases this acts as a safety margin.

Assumptions Made

(Refer to Figure 26)

Certain assumptions are made when using right angled plane trigonometry to find the range of an object lying between the observer and horizon. The more important of these are:

1. The triangle is assumed to be right angled, and
2. The base point at which the vertical angle is measured is vertically under the top of the object.

Referring to the figure it will be clear that because of the observer's height of eye, the triangle 'ABC' is not a perfect right angled triangle, but the resulting effect on accuracy is insignificant.

It will also be clear that the foreshore point (C), at which the angle is measured, is not vertically under the object. In consequence, the distance found is that measured from the object and **not** from the foreshore. Where the difference between these two points is appreciable due allowance must be made.

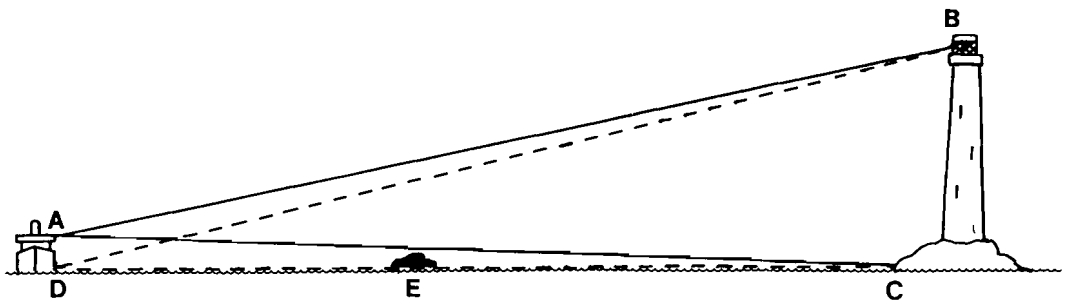


Figure 26. Vertical Sextant Angle.

Applying Index Error to the Vertical Sextant Angle

In all circumstances, allowance **must** be made for any index error present in the sextant. For near objects, allowance can be made in two ways. The index error can be applied to the Sextant Angle to find the corrected or Observed Angle. Alternatively, readings can be taken "on" and "off" the arc. The mean of these two angles will be free of index error. The latter method is distinctly preferable when observing very small angles.

Sextant index error results from the fact that the instrument's true zero lies to the left or right of the engraved zero. If to the left, index error is said to be "on" the arc and must be subtracted from the sextant angle. If to the right, index error is said to be "off" the arc and must be added.

The following examples demonstrate the method.

Sextant Angle and Observed Angle—Definitions

The "Sextant Angle" is the angle actually read from the sextant (which may have index error) and "Observed Angle" is the "Sextant Angle" corrected for index error, if present.

Example 28 (Sextant Angle to Observed Angle)

The vertical sextant angle of a light house is 1° 22′. The sextant has an Index Error of 2′ on the arc. What angle should be used to enter the "Distance by Vertical Angle" tables?

Sextant Angle	1° 22′	
Index Error (−)	2′	On the arc
Observed Angle	1° 20′	with which to enter the tables.

Example 29

The vertical sextant angle of a light house is 2° 10′. The sextant has an Index Error of 1′ off the Arc. What angle should be used to enter the "Distance by Vertical Angle" tables?

Sextant Angle	2° 10′	
Index Error (+)	1′	Off the arc
Observed Angle	2° 11′	with which to enter the tables.

Finding the Vertical Angle to Set on the Sextant

So far we have assumed that the vertical sextant angle is measured first and the distance off (range) found second. Sometimes the navigator will decide, in advance, at what range the vessel should pass a particular object—this is a common requirement in confined waters or when making a harbour approach. In such cases, the tables are first entered with the required range and the vertical angle is found second.

The angle taken from the tables is the corrected or Observed Angle which does not include any index error. Index error must now be applied to the tabulated angle in order to find the angle to set on the sextant (i.e. the Sextant Angle).

In consequence, when working from an Observed (corrected) Angle to a Sextant (uncorrected) Angle, the Index Error sign (+) or (−) must be reversed. This is demonstrated in the following examples.

Table 1.

DISTANCE BY VERTICAL ANGLE

Height of Object

Beachy Head Elev. 31m — Bill of Portland Lt. Ho. Elev. 43m

Distance mls	m 26.5 / ft 87	28 / 92	29.5 / 97	(31) / 102	32.5 / 107	34 / 112	35.5 / 116	37 / 121	38.5 / 126	40 / 131	41.5 / 136	(43) / 141	44.5 / 146	46 / 151
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0.1	8 09	8 36	9 03	9 30	9 57	10 24	10 51	11 18	11 45	12 11	12 38	13 04	13 31	13 57
.2	4 06	4 19	4 33	4 47	5 09	5 15	5 28	5 42	5 56	6 10	6 24	6 37	6 51	7 05
.3	2 44	2 53	3 02	3 12	3 21	3 30	3 39	3 49	3 58	4 07	4 16	4 26	4 35	4 44
.4	2 03	2 10	2 17	2 24	2 31	2 38	2 45	2 52	2 59	3 05	3 12	3 19	3 26	3 33
(0.5) distance off found	1 38	1 44	1 49	1 55	2 01	2 06	2 12	2 17	2 23	2 28	2 34	2 40	2 45	2 51
.6	1 22	1 27	1 31	1 36	1 41	1 45	1 50	1 54	1 59	2 04	2 08	2 13	2 18	2 22
.7	1 10	1 14	1 18	1 22	1 26	1 30	1 34	1 38	1 42	1 46	1 50	1 54	1 58	2 02
.8	1 01	1 05	1 08	1 12	1 15	1 19	1 22	1 26	1 29	1 33	1 36	1 40	1 43	1 47
.9	0 55	0 58	1 01	1 04	1 07	1 10	1 13	1 16	1 19	1 22	1 26	1 29	1 32	1 35
1.0	0 49	0 52	0 55	0 58	1 00	1 03	1 06	1 09	1 11	1 14	1 17	1 20	1 23	1 25
.1	0 45	0 47	0 50	0 52	0 55	0 57	1 00	1 02	1 05	1 07	1 10	1 13	1 15	1 18
.2	0 41	0 43	0 46	0 48	0 50	0 53	0 55	0 57	1 00	1 02	1 04	1 07	1 09	1 11
.3	0 38	0 40	0 42	0 44	0 46	0 49	0 51	0 53	0 55	0 57	0 59	1 01	1 04	1 06
.4	0 35	0 37	0 39	0 41	0 43	0 45	0 47	0 49	0 51	0 53	0 55	0 57	0 59	1 01
1.5	0 33	0 35	0 37	0 38	0 40	0 42	0 44	0 46	0 48	0 49	0 51	0 53	0 55	0 57
.6	0 31	0 33	0 34	0 36	0 38	0 39	0 41	0 43	0 45	0 46	0 48	0 50	0 52	0 53
.7	0 29	0 31	0 32	0 34	0 35	0 37	0 39	0 40	0 40	0 44	0 45	0 47	0 49	0 50
.8	0 27	0 29	0 30	0 32	0 34	0 35	0 37	0 38	0 40	0 41	0 43	0 44	0 46	0 47
.9	0 26	0 27	0 29	0 30	0 32	0 33	0 35	0 36	0 38	0 39	0 41	0 42	0 43	0 45
2.0	0 25	0 26	0 27	0 29	0 30	0 32	0 33	0 34	0 36	0 37	0 39	0 40	0 41	0 43
.1	0 23	0 25	0 26	0 27	0 29	0 30	0 31	0 33	0 34	0 35	0 37	0 38	0 39	0 41
.2	0 22	0 24	0 25	0 26	0 27	0 29	0 30	0 31	0 32	0 34	0 35	0 36	0 38	0 39
.3	0 21	0 23	0 24	0 25	0 26	0 27	0 29	0 30	0 31	0 32	0 33	0 35	0 36	0 37
.4	0 20	0 22	0 23	0 24	0 25	0 26	0 27	0 29	0 30	0 31	0 32	0 33	0 34	0 36
2.5	0 20	0 21	0 22	0 23	0 24	0 25	0 26	0 27	0 29	0 30	0 31	0 32	0 33	0 34
.6	0 19	0 20	0 21	0 22	0 23	0 24	0 25	0 26	0 27	0 29	0 30	0 31	0 32	0 33
.7	0 18	0 19	0 20	0 21	0 22	0 23	0 24	0 25	0 26	0 27	0 29	0 30	0 31	0 32
.8	0 18	0 19	0 20	0 21	0 22	0 23	0 24	0 25	0 26	0 27	0 28	0 29	0 30	0 30
.9	0 17	0 18	0 19	0 20	0 21	0 22	0 23	0 24	0 25	0 26	0 27	0 28	0 28	0 29
(3.0) required distance off	0 16	0 17	0 18	0 19	0 20	0 21	0 22	0 23	0 24	0 25	0 26	(0 27) observed angle found	0 28	0 28
.2	0 15	0 16	0 17	0 18	0 19	0 20	0 21	0 21	0 22	0 23	0 24	0 26	0 26	0 27
.4	0 14	0 15	0 16	0 17	0 18	0 19	0 19	0 20	0 21	0 22	0 23	0 23	0 24	0 25
.6	0 14	0 14	0 15	0 16	0 17	0 18	0 18	0 19	0 20	0 21	0 21	0 22	0 23	0 24
.8	0 13	0 14	0 14	0 15	0 16	0 17	0 17	0 18	0 19	0 20	0 20	0 21	0 22	0 22
4.0	0 12	0 13	0 14	0 14	0 15	0 16	0 16	0 17	0 18	0 19	0 19	0 20	0 21	0 21
.2	0 12	0 12	0 13	0 14	0 14	0 15	0 16	0 16	0 17	0 18	0 18	0 19	0 20	0 20
.4	0 11	0 12	0 12	0 13	0 14	0 14	0 15	0 16	0 16	0 17	0 18	0 18	0 19	0 19
.6	0 11	0 11	0 12	0 13	0 13	0 14	0 14	0 15	0 16	0 16	0 17	0 17	0 18	0 19
.8	0 10	0 11	0 11	0 12	0 13	0 13	0 14	0 14	0 15	0 15	0 16	0 17	0 17	0 18
5.0	0 10	0 10	0 11	0 12	0 12	0 13	0 13	0 14	0 14	0 15	0 15	0 16	0 17	0 17

Tan. $\theta = \frac{h}{d}$. Where θ = vertical angle, h = height of object, and d = distance.

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Example 30 (Observed Angle to Sextant Angle)

A vessel wishes to pass 1 mile off a light house of height 43 metres. On entering the "Distance by Vertical Angle" tables, an angle of 1° 20′ is obtained. Index Error is 2′ on the arc. What angle should be set on the sextant?

Angle found in tables (Observed Angle)		1° 20′	(Corrected Angle)
Index Error. On the Arc normally (−)	(+)	2′	(Reverse Sign)
Angle to set on Sextant (Sextant Angle)		1° 22′	(Uncorrected Angle)

Example 31

A vessel wishes to pass 0·5 miles off a rock of charted height 34 metres. On entering the "Distance by Vertical Angle" tables an angle of 2° 06′ is obtained. Index Error is 1′ off the arc. What angle should be set on the sextant?

Angle found in tables (Observed Angle)		2° 06′	(Corrected Angle)
Index Error. Off the Arc normally (+)	(−)	1′	(Reverse Sign)
Angle to set on Sextant (Sextant Angle)		2° 05′	(Uncorrected Angle)

To Find Distance Off (Range) Using Vertical Angle Tables

1. Refer to the chart or relevant volume of the Admiralty Light Lists and find the height (elevation) of the object or light house.
2. Correct the vertical sextant angle for Index Error (if present).
3. Refer to the "Distance by Vertical Angle" tables and turn to the appropriate page for the required height.
   N.B.—If there is no column for the exact height value it will be necessary to interpolate between two values.
4. Run vertically down the height column until the corrected angle is found.
5. Run horizontally to the left hand edge of the tables and read off the corresponding distance. Interpolate if necessary.

Example 32

(Refer to Chart 5053 and Table 1)

Beachy Head Light House subtends a vertical sextant angle of 1° 56′. The sextant has been checked recently and has an Index Error of 1′ on the arc. Find the distance off.

From the chart:	Beachy Head Light House Height		31 m		1.
	Sextant Angle		1° 56′		
	Index Error	(−)	1′	On the arc	
	Observed Angle		1° 55′		2.
From Vertical Angle Tables:	Height 31 m is tabulated—No interpolation.				3.
	Observed Angle 1° 55′ is tabulated—No interpolation.				4.
	Distance Off 0·5 miles found in LH scale opposite 1° 55′.				5.

Answer: Distance Off Beachy Head Light House is 0·5 miles.

To Find the Vertical Angle Corresponding to a Required Distance Off (Range)

1. Refer to the chart or relevant volume of the Admiralty Light Lists and find the height (elevation) of the object or light house.
2. Refer to the "Distance by Vertical Angle" tables and turn to the appropriate page for the required height.
3. Check if the required height and distance are tabulated values. If not, it will be necessary to interpolate.
4. Find the required distance off (range) on the LH scale and run horizontally across the page to find the corresponding vertical angle in the appropriate height column. Interpolate if necessary.
5. Correct the tabulated angle for Index Error (if present).

Example 33
(Refer to Chart 5053 and Table 1)

A vessel wishes to pass 3 miles off Bill of Portland Light House using a vertical sextant angle to maintain the required distance off. The sextant has been adjusted recently and no Index Error is present. Find the angle to be set on the sextant.

From the chart:	Bill of Portland Light House Height 43 m.	1.
From Vertical Angle Tables:	Distance 3 miles and Height 43 m are tabulated values — No interpolation required.	2. & 3.
	Opposite Distance (3 miles) Observed Angle (0° 27′) found beneath Height (43 m).	4.
	No Index Error to apply. Angle to set on sextant 0° 27′.	5.

Answer: Angle to set on sextant 0° 27′.

Interpolation

Whilst mental interpolation can be carried out, by some, without loss of accuracy it does require a sound knowledge of the principles involved **and** practice. Such practice is best obtained by carefully writing down the various values and carrying out any necessary calculation on paper—this is particularly important both at sea and in DTp examinations.

Example 34
(Refer to Figure 26, Chart 5053 and Table 2)

Start Point Light House subtends a vertical sextant angle of 2° 00′. The sextant has an Index Error of 1·5′ off the arc. Find the distance off.

From the chart:	Height Start Point Light House		62 m	1.
	Sextant Angle		2° 00·0′	
	Index Error	(+)	1·5′	
	Observed Angle		2° 01·5′	2.
From Vertical Angle Tables:	Tabulated Height Values 61 m and 62·5 m lie either side of the Required value 62 m—**interpolate**.			

Table 2.

DISTANCE BY VERTICAL ANGLE

Height of Object

Start Pt. Lt. Ho. Elev. 62m

Distance mls	m 46 / ft 151	47.5 / 156	49 / 161	50.5 / 166	52 / 171	53.5 / 176	55 / 180	56.5 / 185	58 / 190	59.5 / 195	61 / 200	62.5 / 205	64 / 210	65.5 / 215
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0.1	13 57	14 23	14 49	15 15	15 41	16 07	16 32	16 58	17 23	17 49	18 14	18 39	19 04	19 29
.2	7 05	7 18	7 32	7 45	7 59	8 13	8 27	8 40	8 54	9 08	9 21	9 35	9 48	10 02
.3	4 44	4 53	5 02	5 12	5 21	5 30	5 39	5 48	5 58	6 07	6 16	6 25	6 34	6 43
.4	3 33	3 40	3 47	3 54	4 01	4 08	4 15	4 22	4 29	4 36	4 42	4 49	5 49	5 03
0.5	2 51	2 56	3 02	3 07	3 13	3 18	3 24	3 29	3 35	3 41	3 46	3 52	3 57	4 03
.6	2 22	2 27	2 31	2 36	2 41	2 45	2 50	2 55	2 59	3 04	3 09	3 13	3 18	3 22
.7	2 02	2 06	2 10	2 14	2 18	2 22	2 26	2 30	2 34	2 38	2 42	2 46	2 50	2 54
.8	1 47	1 51	1 54	1 57	2 01	2 04	2 08	2 11	2 15	2 18	2 21	2 25	2 28	2 32
.9	1 35	1 38	1 41	1 44	1 47	1 50	1 53	1 56	2 00	2 03	2 06	2 09	2 12	2 15
1.0	1 25	1 28	1 31	1 34	1 36	1 39	1 42	1 45	1 48	1 50	1 53	1 56	1 59	2 02
.1	1 18	1 20	1 23	1 25	1 28	1 30	1 33	1 35	1 38	1 40	1 43	1 45	1 48	1 50
.2	1 11	1 13	1 16	1 18	1 20	1 23	1 25	1 27	1 30	1 32	1 34	1 37	1 39	1 41
.3	1 06	1 08	1 10	1 12	1 14	1 16	1 18	1 21	1 23	1 24	1 27	1 29	1 31	1 34
.4	1 01	1 03	1 05	1 07	1 09	1 11	1 13	1 15	1 17	1 19	1 21	1 23	1 25	1 27
1.5	0 57	0 59	1 01	1 02	1 04	1 06	1 08	1 10	1 12	1 14	1 15	1 17	1 19	1 21
.6	0 53	0 55	0 57	0 59	1 00	1 02	1 04	1 06	1 08	1 09	1 11	1 12	1 14	1 16
.7	0 50	0 52	0 53	0 55	0 57	0 58	1 00	1 02	1 03	1 05	1 07	1 08	1 10	1 12
.8	0 47	0 49	0 50	0 52	0 54	0 55	0 56	0 58	1 00	1 01	1 03	1 04	1 06	1 08
.9	0 45	0 46	0 48	0 49	0 51	0 52	0 54	0 55	0 57	0 58	1 00	1 01	1 03	1 04
2.0	0 43	0 44	0 45	0 47	0 48	0 50	0 51	0 52	0 54	0 55	0 57	0 58	0 59	1 01
.1	0 41	0 42	0 43	0 45	0 46	0 47	0 49	0 50	0 51	0 53	0 54	0 55	0 57	0 58
.2	0 39	0 40	0 41	0 43	0 44	0 45	0 46	0 48	0 49	0 50	0 51	0 53	0 54	0 55
.3	0 37	0 38	0 39	0 41	0 42	0 43	0 44	0 46	0 47	0 48	0 49	0 50	0 52	0 53
.4	0 36	0 37	0 38	0 39	0 40	0 41	0 43	0 44	0 45	0 46	0 47	0 48	0 49	0 51
2.5	0 34	0 35	0 36	0 37	0 39	0 40	0 41	0 42	0 43	0 44	0 45	0 46	0 48	0 49
.6	0 33	0 34	0 35	0 36	0 37	0 38	0 39	0 40	0 41	0 42	0 44	0 45	0 46	0 47
.7	0 32	0 33	0 34	0 35	0 36	0 37	0 38	0 39	0 40	0 41	0 42	0 43	0 44	0 45
.8	0 30	0 31	0 32	0 33	0 34	0 35	0 36	0 37	0 38	0 39	0 40	0 41	0 42	0 43
.9	0 29	0 30	0 31	0 32	0 33	0 34	0 35	0 36	0 37	0 38	0 39	0 40	0 41	0 42
3.0	0 28	0 29	0 30	0 31	0 32	0 33	0 34	0 35	0 36	0 37	0 38	0 39	0 40	0 41
.2	0 27	0 28	0 29	0 29	0 30	0 31	0 32	0 33	0 34	0 35	0 35	0 36	0 37	0 38
.4	0 25	0 26	0 27	0 28	0 28	0 29	0 30	0 31	0 32	0 32	0 33	0 34	0 35	0 36
.6	0 24	0 24	0 25	0 26	0 27	0 28	0 28	0 29	0 30	0 31	0 31	0 32	0 33	0 34
.8	0 22	0 23	0 24	0 25	0 25	0 26	0 27	0 28	0 28	0 29	0 30	0 31	0 31	0 32
4.0	0 21	0 22	0 23	0 23	0 24	0 25	0 26	0 26	0 27	0 28	0 28	0 29	0 30	0 30
.2	0 20	0 21	0 22	0 22	0 23	0 24	0 24	0 25	0 26	0 26	0 27	0 28	0 28	0 29
.4	0 19	0 20	0 21	0 21	0 22	0 23	0 23	0 24	0 24	0 25	0 26	0 26	0 27	0 28
.6	0 19	0 19	0 20	0 20	0 21	0 22	0 22	0 23	0 23	0 24	0 25	0 25	0 26	0 26
.8	0 18	0 18	0 19	0 20	0 20	0 21	0 21	0 22	0 22	0 23	0 24	0 24	0 25	0 25
5.0	0 17	0 18	0 18	0 19	0 19	0 20	0 20	0 21	0 22	0 22	0 23	0 23	0 24	0 24
.2	0 16	0 17	0 17	0 18	0 19	0 19	0 20	0 20	0 21	0 21	0 22	0 22	0 23	0 23
.4	0 16	0 16	0 17	0 17	0 18	0 18	0 19	0 19	0 20	0 20	0 21	0 21	0 22	0 23
.6	0 15	0 16	0 16	0 17	0 17	0 18	0 18	0 19	0 19	0 20	0 20	0 21	0 21	0 22
.8	0 15	0 15	0 16	0 16	0 17	0 17	0 18	0 18	0 19	0 19	0 20	0 20	0 20	0 21
6.0	0 14	0 15	0 15	0 16	0 16	0 17	0 17	0 17	0 18	0 18	0 19	0 19	0 20	0 20

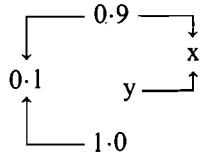
Interpolate Distance off

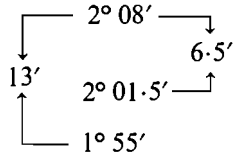
2° 01½′

Tan. $\theta = \frac{h}{d}$. Where θ = vertical angle, h = height of object, and d = distance.

Tab. Values → **Height** ↓ **Distance**	61 m	Mental Interpolation 62 m	62·5 m
0·9	2° 06′	2° 08′	2° 09′
1·0	1° 53′	1° 55′	1° 56′

Let 'y' = Distance Off and 'x' = Adjustment to the Tabulated Value:





Then $\frac{x}{0{\cdot}1} = \frac{6{\cdot}5}{13}$ so 'x' $= \frac{0{\cdot}1 \times 6{\cdot}5}{13} = 0{\cdot}05$ = Adjustment

Tabulated Value for	2° 08′	0·9 miles
Adjustment for	6·5′	0·05 miles
Distance Off for	2° 01·5′	0·95 miles

Answer: Distance Off Start Point Light House is 0·95 miles.

Vertical Danger Angle

Like the horizontal danger angle, the vertical danger angle can be used for avoiding offshore dangers.

If a submerged rock or other offshore danger lies in the vicinity of a conspicuous, charted object of known height (say a light house), the danger can be avoided by steering courses such that the vessel never comes closer than some chosen "safe distance off".

A position at the required "safe distance off" the danger is plotted on the chart. As shown in the figure, the distance between this position and the light house is then measured from the chart.

The "Distance by Vertical Angle" tables are then entered with the height of the light house (or other chosen object) and the previously obtained total distance off the light house (which includes the "safe distance off" the danger). The corresponding vertical angle is then taken from the tables, index error applied, and the sextant set to the resulting value.

As the vessel approaches the vicinity of the danger, the vertical sextant angle of the light house is checked at short time intervals. If this "Vertical Danger Angle" is exceeded it indicates that the vessel is approaching closer than the chosen "safe distance off" and course is immediately altered away from the danger.

By steering courses such that the vertical danger angle is exactly maintained, a vessel will exactly follow the circumference of the position circle which clears the danger by an amount never less than the required safe distance off.

The technique is demonstrated in the following example.

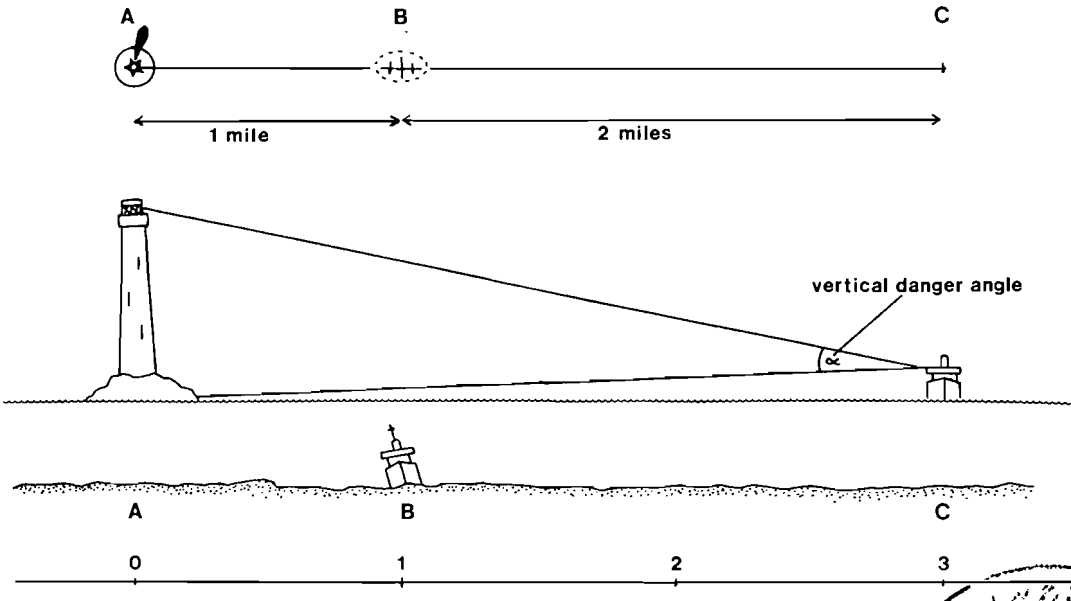


Figure 27. Vertical Danger Angle.

Example 35

(Refer to Figure 27, Chart 5053 and Table 1)

A dangerous wreck has been reported 1 mile due East of Eddystone Rocks Light House. What angle should be set on the sextant to ensure that a vessel heading for Plymouth (from the South East) does not approach the wreck closer than 2 miles?

Index Error 1·5′ on the Arc.

Distance from Wreck to Light House	1 mile	From Chart: Light House Height 41 m
Required Distance off Wreck	2 miles	
Required Distance off Light House	3 miles	

From Vertical Angle Tables:

Height 41 m and Distance 3 miles →	Observed Angle	0° 25·7′	
	Index Error (+)	1·5′	On the arc
Vertical Danger Angle to Set on Sextant		0° 27·2′	

Interpolate mentally between 40 m (0° 25′) and 41·5 m (0° 26′).

Note that the Index Error sign has been reversed. To make this procedure clear, apply the index error in the usual way to an Observed Angle of 0° 27·2′. The calculation would then be as follows:

Sextant Angle		0° 27·2′
Index Error	(−)	1·5′
Observed Angle		0° 25·7′

If the Vertical Danger Angle is exceeded the vessel is closer than 2 miles to the wreck.

If the Sextant Angle is less than the Vertical Danger Angle the vessel is more than 2 miles from the wreck.

Answer: Vertical Danger Angle to Set on the Sextant 0° 27·2′.

DISTRESS POSITIONS

On Charts and in *Admiralty Sailing Directions* ("Pilot Books") it is customary to give bearings **from Seaward** but for the purpose of reporting distress positions the format given below is adopted. It should be noted that the reciprocal bearing is used, i.e. the bearing is given **from Shore to Ship.**

	Bearing	Object	Distance
e.g.	090°T (from)	Lizard Point (at)	10 miles

The message would be sent as: 090°T Lizard Point 10 miles. It will be apparent that, looking from the ship towards the shore the bearing of Lizard Point would be 270°T, i.e. the reciprocal bearing. Plot this distress position on Chart 5053 and verify these statements.

Example 36

(Refer to Table 2 and plot the position on Chart 5053)

A vessel has suffered a main engines and auxiliaries breakdown off the Scilly Isles. Without radar, it is decided to fix position by sextant and magnetic compass.

The Vertical Sextant Angle of Round Island Light House is 1° 06′ and its corrected bearing 180°T. Index Error 2′ Off the Arc.

What position would be transmitted on the Emergency Radio?

Sextant Angle		1° 06′	
Index Error	(+)	2′	Off the arc
Observed Angle		1° 08′	

From the Chart: Round Island Light House Height 55 m

From Vertical Angle Tables: Height 55 m, Vertical Angle 1° 08′ → Distance 1·5 miles

Bearing of Light House from Ship (i.e. from **Seaward**) 180°T

Bearing of Ship from Light House (i.e. from **Shoreward**) 000°T

Answer: Distress Position transmitted as follows:

000°T Round Island Light House 1·5 miles.

USE OF SOUNDINGS

Depth of water can be measured using the hand lead line, or by use of the patent sounding machine, or by some form of echo sounding device usually referred to as the "Echo Sounder". A depth so obtained is referred to as a "Sounding".

In the case of the hand lead line the depth obtained is measured from the surface of the water whereas when obtained by use of the echo sounder the depth obtained is measured from a transducer fitted in the bottom of the vessel. In both cases it is necessary to apply a correction to

the measured depth in order to make comparison with the charted depth which is measured from chart datum. The level of chart datum is so fixed that the depth shown on a modern chart is normally the least depth which can be expected—refer to the chapter on tides and tidal streams for further information.

Reference to the chart and "*Symbols and Abbreviations*" BA 5011 will quickly show that, in addition to soundings at specific positions, "Depth Contour Lines" are also included.

Depth Contour Lines

Depth contour lines join positions having equal depth, e.g. 10, 20, 30, 50 and 100 metre depth contour lines. The modern echo sounder is generally extremely reliable and, simply by altering course, as necessary, to keep outside a chosen "safe" depth contour line, many vessels could have been saved from stranding.

A depth contour can also be used as a position line and is of particular value when it runs parallel, or nearly parallel, to the coast line. But the accuracy of such position lines is dependent on the definition of the sea bed contours. A gently shelving bottom will have ill defined contours and give unreliable position lines. A steeply shelving bottom will have well defined contours and can give very accurate position lines. Such position lines can be extremely useful when making port in "thick" weather and without the use of radar.

Line of Soundings

At any given moment in time, a depth contour line can only produce one position line but, under the right conditions, a series of soundings can give a good indication of position. In addition, where a vessel is on a regular run, the sounding graph (produced by the echo sounder) can be retained and used on subsequent runs to confirm that the vessel is making good the customary track.

To Fix Position by Line of Soundings

This technique involves noting the sounding, time and log reading at the more significant changes of depth. These are used to make up a "ruler" showing time and depth against a distance scale taken from the chart's latitude scale. "Ruler" depths are then compared with charted depths to obtain a "match".

1. Note the sounding, time and log reading at each significant change of depth.
2. Correct the soundings for draft and adjust for height of tide to reduce to chart datum.
3. Using the log readings (or time intervals and estimated speed) find the distance run between each significant change of depth.
4. Have ready a clean sheet of paper (tracing paper is preferable) and a straight edge.
5. Using the latitude scale (in the vicinity of the DR or EP) mark off the piece of paper with the distances run between each significant change of depth.
6. Against each mark write down the sounding obtained and record the corresponding time and log reading alongside, as shown. The piece of paper can now be used as a "sounding ruler".
7. Plot the DR or EP, at the time soundings commenced, on the chart.
8. Through the DR or EP, plot the ground track on the chart.

9. Align the "sounding ruler" to the track plotted.
10. Keeping the "sounding ruler' parallel to the ground track, adjust its position until "ruler" soundings match the soundings on the chart—mark two positions along this line of soundings.
11. Using parallel rulers, plot the intended track through the line of soundings on the chart, and alongside record the times and log readings against each significant sounding.
12. Note any difference between the positions so obtained and the corresponding DR's or EP's. Take safe, positive and appropriate action, as necessary.

Example 37
(Refer to Figure 28)

A vessel on passage from Le Havre to Portsmouth intends to make an arrival position due East of Nab Tower.

At 0100 in D.R. 50° 10′N, 0° 30′W the vessel enters an area of reduced visibility and reduces speed to 10 knots. Due to a radar breakdown it is decided to use the echo sounder to fix position.

Courses are steered to counteract the effect of tidal streams experienced and to make good a track of 335°T.

The following soundings (corrected for draft and reduced to chart datum) are obtained:

	Log	Sounding
0100	40	53 m
	45	48
	46	50
0200	50	55
	55	55
	58	50 (shoaling)
0300	60	23
	65	15
	66	22
	68	14
	69	22
0400	70	20 (shoaling)

Find the vessel's most probable arrival position off the Nab Tower and state if the 0100 D.R. was correct.

Last sounding	0400	Log reading	70 miles
First „	0100	„ „	40
Time interval	3 hrs	Log dist. run	30 miles

To Make the "Sounding Ruler"

On a sheet of paper, mark up a "ruler" of length 30′ on the appropriate part of the latitude scale—this represents a distance of 30 miles on the chart.

Mark the "ruler" at 10 mile intervals, and insert the time and log reading at hourly intervals, as shown.

On the "ruler" and using the chosen scale, pencil in the soundings at the beginning and end of the run, any significant soundings and one or two others as a check, as shown.

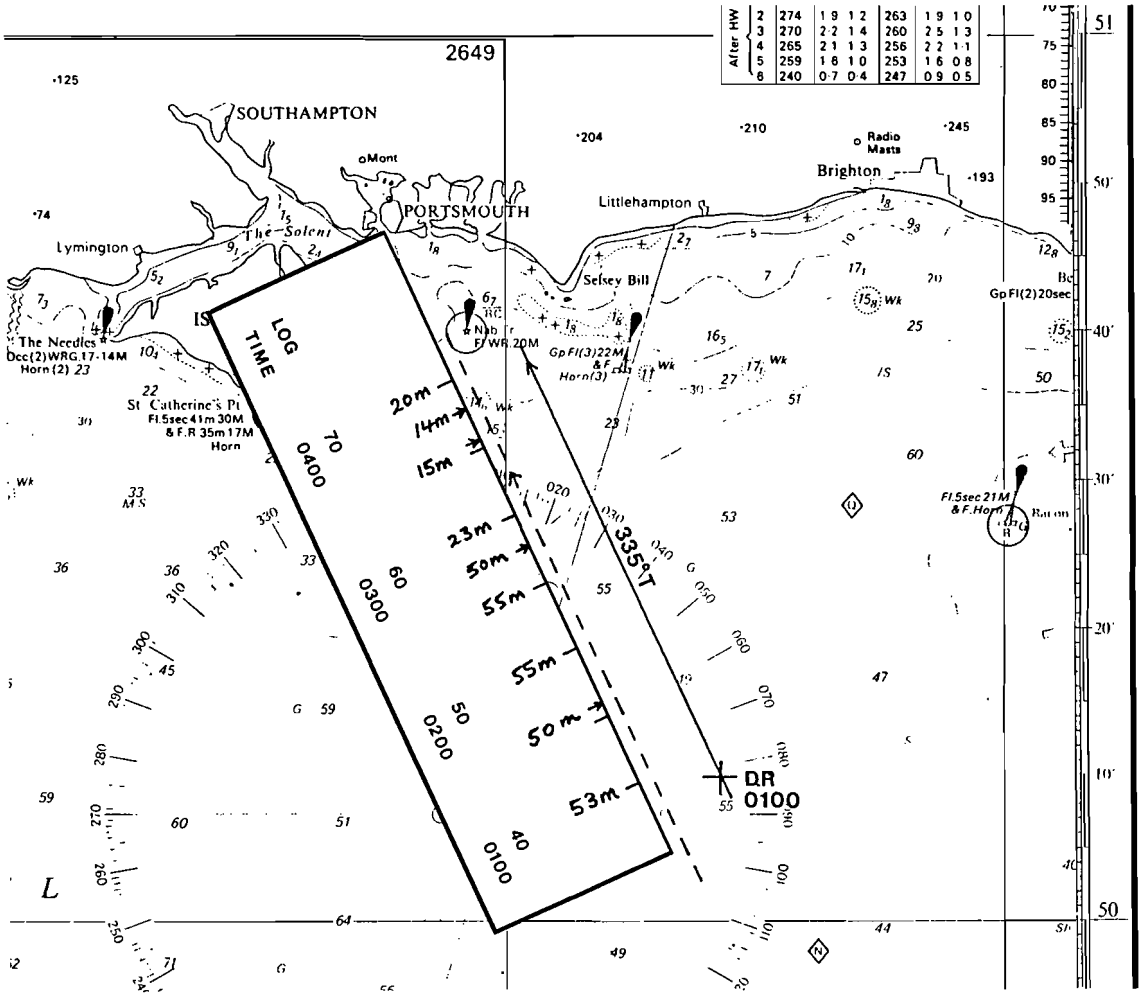


Figure 28. Fixing position by Line of Soundings.

To Find Position (Approximate)

Plot the DR (at the beginning of the run) on the chart, as shown.

Plot the ground track 335°T from DR towards the destination port, Portsmouth, as shown.

Position the "sounding ruler" on the chart and parallel to the ground track.

Keeping the "ruler" parallel to the ground track, adjust its position until "ruler" soundings match the charted soundings, as shown.

Plot the ground track through this "line of soundings", as shown by the pecked line.

The line of soundings indicates that the vessel was West of DR at 0100 and will pass approximately 1 mile WSW of Nab Tower if course is maintained. Measure these distances on the chart.

Answer: Beam position will be approximately 1 mile WSW of Nab Tower. At 0100 vessel was approximately 5 miles West of D.R.

THREE BEARING PROBLEM

The "Three Bearing Problem" is a method which can be used to find the vessel's ground track[1] but **not** its position. This method involves three bearings of a single object.

Insofar as only one object is used, the method is similar to the running fix, explained earlier.

Unlike the running fix, it is not necessary to know either the set or rate of current or even the vessel's speed. But if the speed is not known, it is essential to know, accurately, the time intervals between the three bearings.

Uses

From the foregoing it should be clear that, whilst the method is not frequently used, it has merit where:

1. Only one object is available

   and either

   Speed is not known and/or current set and rate is not known.
2. A knowledge of the vessel's ground track can be later combined with a bearing obtained from a second object likely to appear some short time later **or** combined with some other technique, e.g. a knowledge of the ground track is very helpful when finding position using, say, a "line of soundings", as previously explained.

Accuracy and Assumptions

The accuracy of results obtained by this method relies on three assumptions:

1. Current or tidal stream is constant throughout, and
2. Course and speed are constant throughout.
3. The ratio of time intervals between bearings **or** the ratio of distances between bearings (which amount to the same thing) are accurately known.

Note 1.—What is actually found is a track parallel to the ground track but, for convenience, it is referred to as the "ground track" throughout the following explanation.

Method

1. Note the time (or if a log is available, the log reading) of each of the three bearings.
2. Find the time interval (or, distance run) between the 1st and 2nd (Middle) bearing and the 2nd and 3rd bearing.
3. Lay off the three true bearings as position lines on the chart.
4. Using the parallel rulers, pencil in a "base ratio line" through the object observed (A) and at right angles to the middle (2nd) bearing.
5. Select **any** convenient scale.
6. Starting at the object (A) and measuring along the "base ratio line", mark off the time intervals (or distances) between the Middle and 1st bearing and the Middle and 3rd bearing. Mark these points 'B' and 'C', respectively.
7. Using parallel rulers, transfer the middle position line through points 'B' and 'C'.
8. The transferred middle position line will intersect the 1st position line at point 'D' and the 3rd position line at point 'E'.

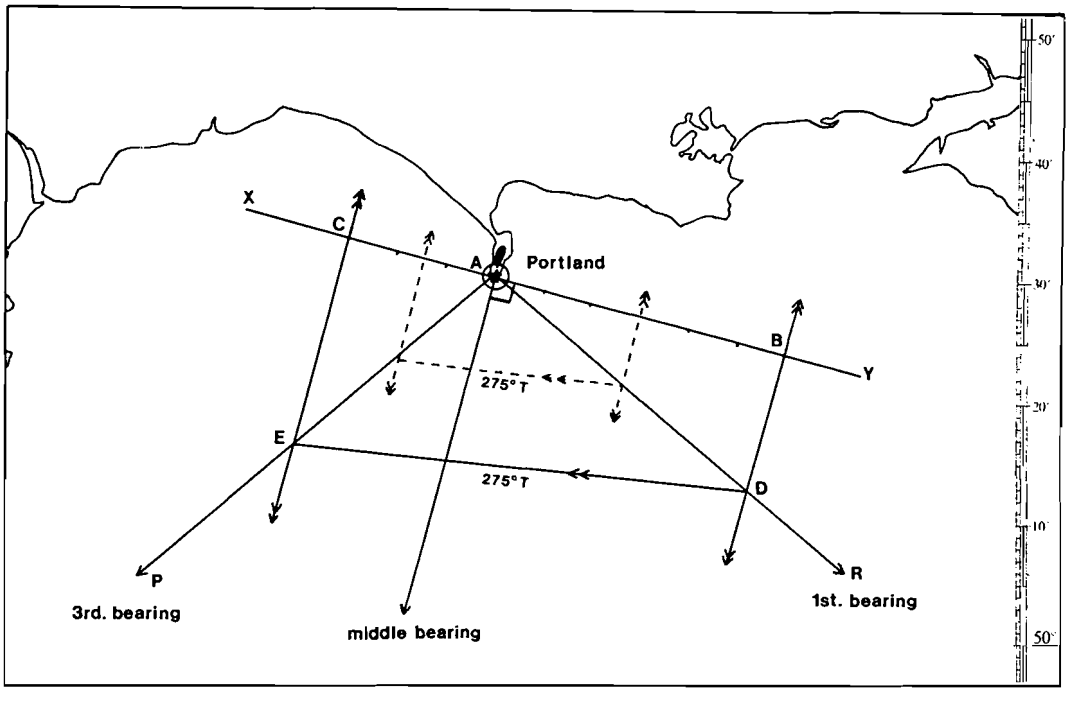


Figure 29. Three Bearing Problem.

9. Join points 'D' and 'E'.
10. 'DE' is the direction of the ground track—transfer the parallel rulers to the compass rose or meridian and read off its value.

Example 38

(Refer to Figure 29)

A vessel is steering 270°T at 15 knots along the South Coast off Portland Bill. No tidal stream information is available to the navigator who takes three bearings as follows:

1. 1000	Log 50	Portland Bill Light House	bearing 310°T
2. 1036	,, 59	,, ,, ,, ,,	,, 015°T
3. 1054	,, 63·5	,, ,, ,, ,,	,, 050°T

Find the ground track.

1. In this case log readings are available and can be used. Had log readings not been available we could have used time intervals.

1st Bearing	1000	Log	50
2nd Bearing	1036		59
Time interval	36 minutes	Log distance run	9 miles
2nd Bearing	1036	Log	59·0
3rd Bearing	1054		63·5
Time interval	18 minutes	Log distance run	4·5 miles

2. Ratio of time intervals 36 : 18 or 2 : 1
   Ratio of log distance intervals 9 : 4·5 or 2 : 1
3. Plot the 3 bearings, as shown.
4. Using parallel rulers, lay off the "ratio base line" (XY) through 'A' at right angles to the middle bearing, as shown.
5. To use the actual log distances would result in a very small triangle so we decide to use a centimetre scale.
6. Ratio is 2:1. Along the ratio base line (XY) measure:
   6 cms 'A'–'B' (Time/log interval, middle to 1st bearing) and
   3 cms 'A'–'C' („ „ „ , „ „ 3rd „), as shown.[2]

7/8. Using parallel rulers, transfer the middle position line (P/L) through point 'B' to intersect the 1st P/L at point 'D', as shown.
   Transfer the middle P/L through point 'C' to intersect the 3rd P/L at point 'E', as shown.[3]
9. Using parallel rulers, join points 'D' and 'E', as shown.
10. Transfer the parallel rulers to the meridian or compass rose and read off the ground track 'DE', 275°T.

Note 2.—The centimetre scale will be affected by the printing and reproduction process—it can be used on the original edition of Practice Chart 5053.
Note 3.—Had a different scale been selected, say ½ cm, the transferred middle P/L would have intersected the 1st and 3rd P/L's at different positions (as indicated by the pecked lines) but the resulting ground track (also shown by a pecked line) would have been the same.

Answer: Ground Track 275°T.

It is not possible to fix position by this method but, having found the Ground Track,[1] the information derived can be combined with other information, e.g. a reliable fix followed by three bearings of the same object would make it possible to obtain an EP at the 3rd bearing even though no current information was available.

To Find Current Set and Rate by Combining Additional Information with Three Bearings of the Same Object

In conditions of reduced visibility situations can arise where only the closest charted objects are visible and, hence, a fix by cross bearings is possible only rarely. In such conditions it is important to have accurate knowledge of the actual set and rate being experienced in order to plot good EP's when subsequent cross bearing fixes are not possible.

In the previous example we found the ground track by the "Three Bearing" method.

In the next example we find the set and rate of current by combining knowledge of the ground track (found by the "Three Bearing" method) with an observed position obtained at the time of taking the third bearing.

Example 39
(Refer to Figure 30)

In conditions of reduced visibility, a vessel steering 275°T obtains three bearings of the same object, as listed.

At the time of taking the 3rd bearing, a second charted object is sighted and a fix by cross bearings is thus possible.

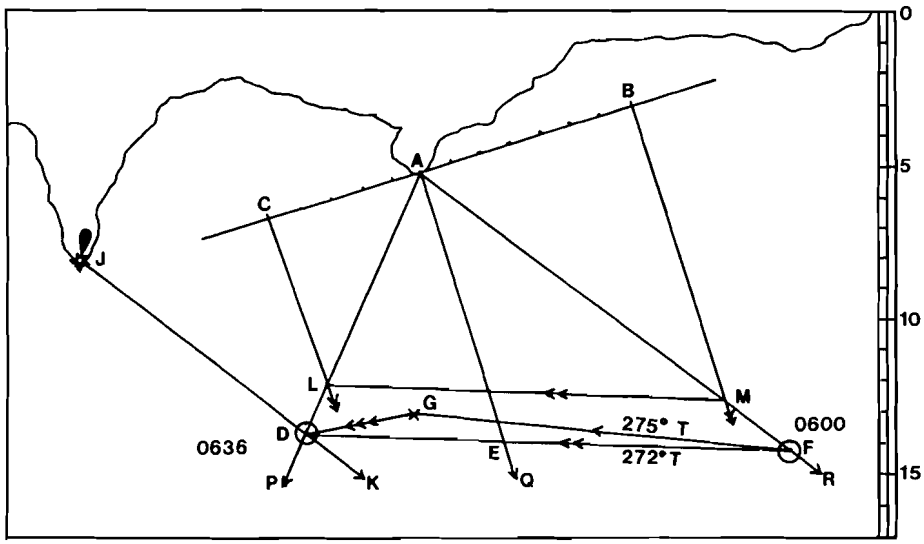


Figure 30. Combining additional information with the "Three Bearing" method to find Current Set and Rate.

It seems likely that visibility will deteriorate and the navigator wishes to find the set and rate of current for use in plotting subsequent EP's.

Bearings are as follows:

1. 0600	Log 83	Point A	bearing 307°T
2. 0621	„ 90	„	„ 342°T
3. 0636	„ 95	„	„ 023°T
4. 0636	„ 95	Point J	„ 308°T

Plot the vessel's position at 0636 and find current set and rate being experienced.

1. Note that there are three consecutive bearings of the first object and that the third bearing has been combined with another, of a different object, i.e. "Three Bearing Problem" combined with a Fix.
2. Using either time intervals or log distances between the first three bearings find the ground track (ML) as previously described.
3. Ground track is 272°T.
4. Lay off the 4th bearing (JK) to intersect the 3rd bearing at 'D'—this is the vessel's position at 0636.
5. Transfer the ground track (LM) backwards from the 0636 position (D) to intersect the 1st bearing (AR) at 'F'—this is the vessel's 0600 position.
6. Lay off the True course and log distance steamed from the 0600 position (F) to find the 0636 DR position (G).
7. No leeway having been experienced, vector (GD) from DR (G) to Observed Position (D) is the Set and Drift of Current.
8. Current Set is 259°T and the Drift in 1 hour 36 minutes is 3·5 miles.

$$\frac{\text{Drift}}{\text{Time (hrs)}} = \frac{3{\cdot}5}{1{\cdot}6} = 2{\cdot}2 \text{ knots} = \text{Rate}$$

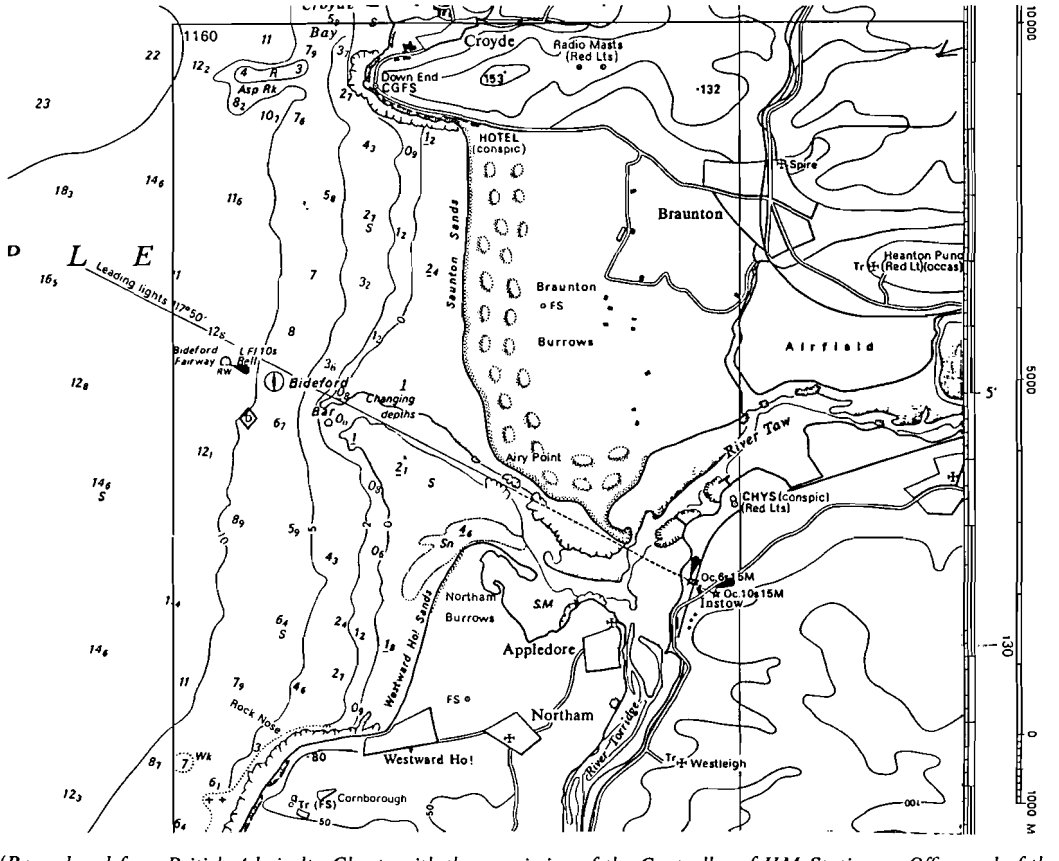
Answer: Set 259°T Rate 2·2 knots.

LEADING LINES AND LEADING MARKS

(Refer to Figure 31)

A Leading Line passes through two Leading Marks which, when kept in transit, lead the vessel through a safe channel and keep it clear of any dangers.

As can be seen in the figure, leading lines and leading marks (which often incorporate navigational lights) are shown on many charts of harbours and their approaches.



(Reproduced from British Admiralty Charts with the permission of the Controller of HM Stationery Office and of the Hydrographer of the Navy.)

Figure 31. Leading Line on BA Chart 1164.

CLEARING LINES AND CLEARING BEARINGS

A Clearing Line is a transit which runs through two charted Clearing Marks selected by the navigator. By keeping to the appropriate side of the clearing line the vessel will run clear of certain dangers.

When navigating near dangers it is essential not to go inside the transit line passing through the two clearing marks. So long as the clearing marks are kept "open" the vessel will be outside the clearing line which marks the limits of the danger.

If clearing marks are not available, draw a line on the chart which passes through some prominent object such that it passes clear of the danger. Such lines (which are lines of bearing) are referred to as Clearing Bearings. Providing the bearing is kept greater or less (as appropriate) than the Clearing Bearing, the vessel will clear the danger.

Procedure when Using Clearing Lines and Clearing Bearings

(Refer to Figure 32)

1. Plot the vessel's position—call this the Initial Position (A).
2. Select suitable clearing marks through which to draw a Clearing Line which clears local dangers.

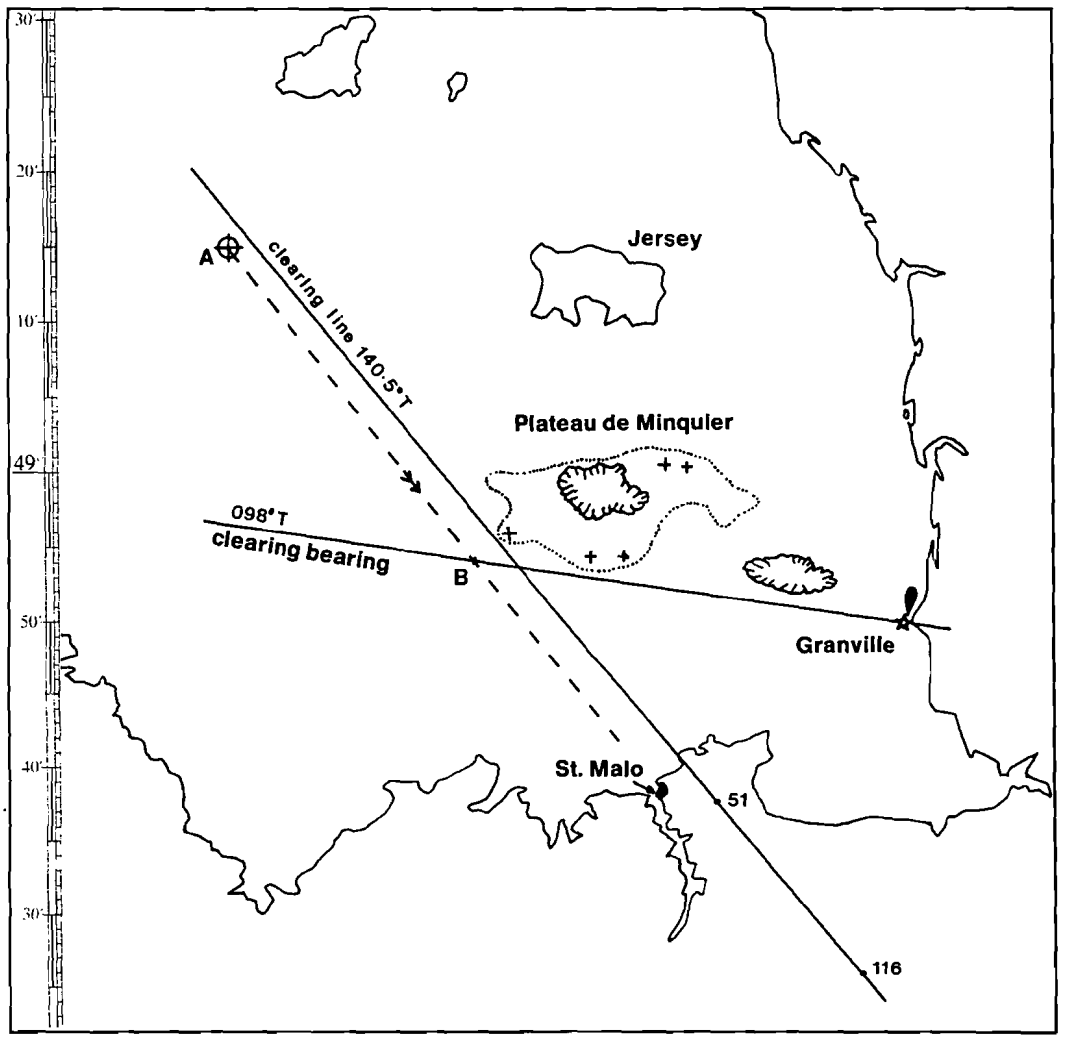


Figure 32. Clearing Lines and Clearing Bearings.

3. Select a suitable Clearing Bearing which indicates when such dangers have been safely passed.
4. From the Initial Position plot the vessel's intended track to intersect the Clearing Bearing at the "Safe Position" (B).
5. Measure the distance between the vessel's Initial Position and the "Safe" Position. Calculate the approximate steaming time from the Initial to "Safe Position".
6. Refer to Current or Tidal Stream information. Write down the set and rate likely to be experienced in the intervening time period, i.e. from the Initial to "Safe Position".
7. At the Initial Position measure the distance off the clearing line and, using the current or tidal stream information, decide if the vessel is likely to be set inside the clearing line.
8. Take appropriate action to ensure the vessel maintains the required track and does not set inside the clearing line (such action will include counteracting the effect of current or tidal stream, careful monitoring of position on the approach by careful sighting of the chosen transit, fixes and use of the echo sounder).

Example 40

(Refer to Figure 32)

A vessel approaching St Malo on Course 143°T fixes position in 49° 15′ N 2° 45′ W. The tidal stream is setting predominantly NE at Spring rate and the vessel wishes to have independent means for safely clearing Plateau des Minquiers and the offlying rocks.

Find:

(a) A suitable Clearing Line which could be used to safely clear Plateau des Minquiers.
(b) A suitable Clearing Bearing which will indicate when the offlying dangers have been safely passed.

N.B.—Support your choice by making any necessary calculations.

Co 143°T Speed 15 knots Tidal Stream ⟨H⟩ 5 hrs Before HW Dover Springs.

1. Plot the vessel's initial position (A), as shown.
2. A suitable clearing line runs 140·5°T through the 51 m and 116 m hills SE of St Malo. By keeping the transit well open to port the vessel will clear all offlying dangers.
3. When Granville Light House bears 098°T the vessel will be at least 1 mile south of the most W'ly danger.
4. Plot the "Safe Position" (B) at intersection of the intended track and the 098°T Clearing Bearing.
5. From Initial to "Safe Position" is approximately 27 miles which, at 15 knots, will take 1 hr 48 mins.
6. Tidal Streams for 2 hr period at ⟨H⟩:

5 hrs Before HW	064°T	1·5 knots
4 „ „ „	050°T	1·6 „

7. At position 'A' the V/L is only 1·2 miles (approx) SW of the clearing line. From the Tidal Stream information found it is quite clear the vessel will set into danger **unless** appropriate action is taken.
8. Steer courses to counteract the effect of the Tidal Stream in order to maintain a track parallel to the clearing line and a safe distance off. Keep the transit open to port until the 098°T clearing bearing is passed.

Answer:
(a) Clearing Line 140·5°T through the 51 m and 116 m hills.
(b) „ Bearing 098°T Granville Light House.

COURSE TO STEER TO BRING UP A POINT AT A PRECALCULATED ANGLE ON THE BOW

In order to find the course to steer in order to "bring up" some chosen point of land at some specified angle on the bow it is necessary to decide (or be given):

1. The required angle on the bow, and
2. Distance off (range) at the time the required angle is reached.

These two items provide data regarding two parts of a triangle and enable the navigator to calculate a third part, the beam distance off, which is necessary to find the required course to steer.

The problem is best tackled by making a simple sketch which assumes the problem is solved and which clearly shows the vessel's initial position, the range circle on bringing up the chosen object (at the required angle), the beam range circle and a track drawn tangential to the beam range circle. The required angle on the bow is represented by a line drawn from the chosen object to the point of intersection of the track and outer range circle.

As indicated in the figure, the unknown part of the triangle (the beam range) can be conveniently found by inspection of the Traverse Tables or by calculation.

Having found the resulting beam range, the navigator plots the initial position, the range circle on "bringing up" the object and the beam range circle. The line drawn from this initial position, tangential to the beam range circle represents the required track from which the course to steer can be found.

Example 41
(Refer to Figure 33)

A vessel is in Observed Position 49° 37′ N 3° 22′ W. The navigator wishes to "bring up" Casquets Light 30° on the starboard bow at a distance of 10 miles.
Find: (a) The Course to Steer.
(b) The Beam Distance Off.
(c) The Distance to Steam to bring up the light 30° on the bow.

To Find the Corresponding Beam Range

1. Make a simple sketch showing the Initial Position (A), Object (C), "Bringing Up" range circle (10 miles), Beam Range circle (unknown radius), Track drawn tangential to the beam range circle and the Chosen Angle on the Bow (30°), as shown, to form triangle CBD.
2. Mark in the known quantities as bracketed above.
3. In triangle BDC, angle 'D' is a right angle (the beam bearing); side BC, the hypotenuse, 10 miles (range); side DC (beam range) is unknown.
4. Enter Traverse Tables with Course 30° and Distance 10 miles.
5. Beam range (DC) 5 miles will be found in the Departure column.

To Find the Required Track

1. Plot the Observed Position (A) as the Initial Position on the chart.

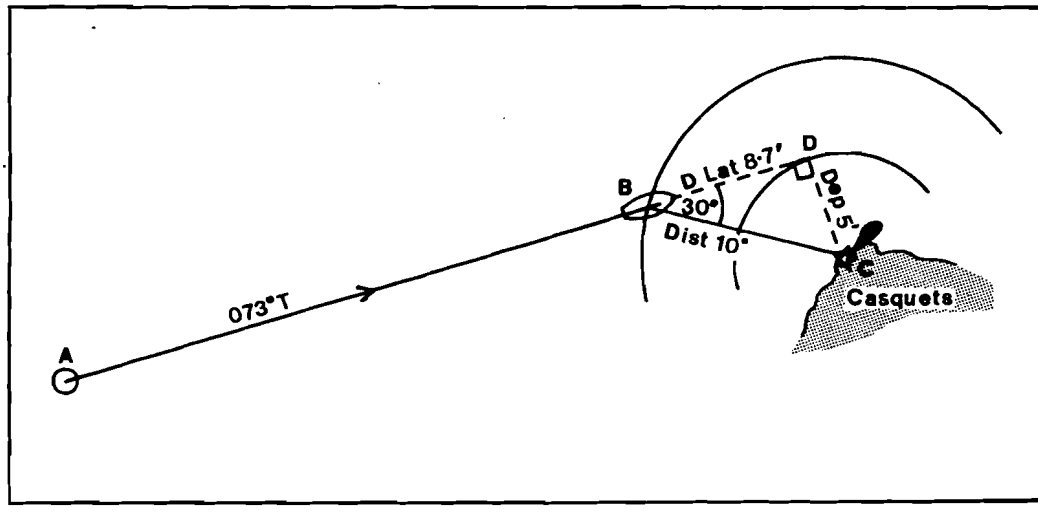


Figure 33. Bringing Up a Point at a Precalculated Angle on the Bow.

2. With centre (C) Casquets Light plot the required range circle (10 miles) **and** the beam range circle (5 miles).
3. Lay off the required track (AD) from the Initial Position tangential to the beam range circle.
4. Read off the required track, 073°T. In the absence of current, leeway and Gyro or Compass Error, this will be the course to steer.
5. Mark the position at which the track intersects the 10 mile range circle as 'B'.
6. Join Casquets Light and position 'B' by a straight line (BC).
7. Measure angle DBC and check that it is the required angle (30°) on the bow.
8. Measure the distance to steam (AB) 30 miles.

Answer: (a) Course 073°T.
(b) Beam Distance 5 miles.
(c) Distance to Steam 30 miles.

COURSE TO STEER TO BRING A POINT ABEAM USING THE SHIP'S RADIUS OF ACTION

In the following example it is required to find the track which will bring a chosen object abeam at a specified time after steering a straight course at a given speed.

The term "Radius of Action" refers to the maximum distance which a vessel can travel in any direction, at some specified speed and in some stated period of time, e.g. at 20 knots a vessel has a 5 hour radius of action of 100 miles.

Example 42
(Refer to Figure 34)
A vessel steaming at 14 knots is in position:

250°T Lizard Point Light 30 miles

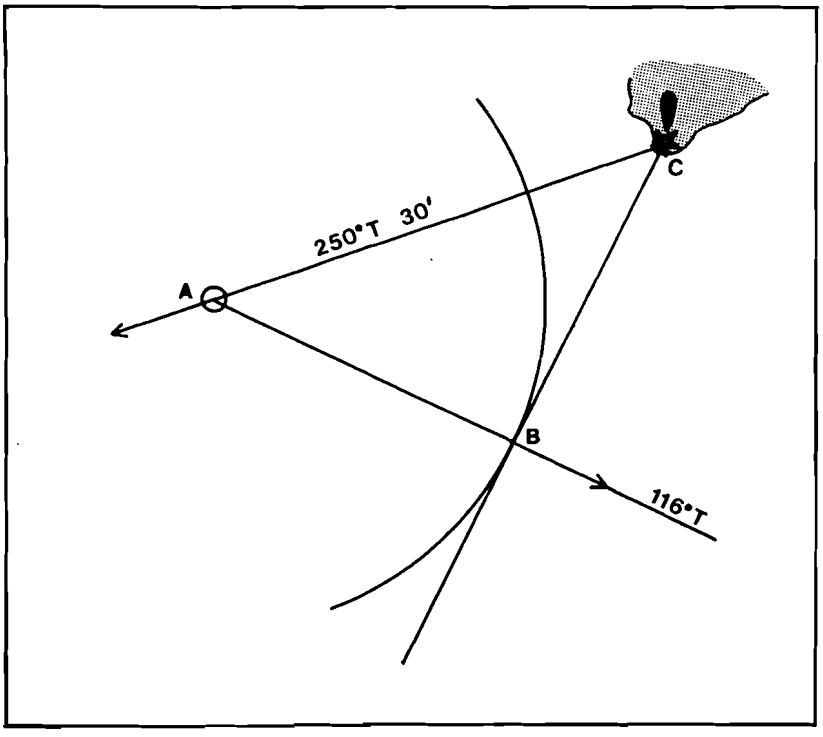


Figure 34. Course to Steer to Bring a Point Abeam.

Find the course to steer to bring the light abeam to Port in 1·5 hours.

Note that:

(a) the position is given in the Distress Format, i.e. 250°T from Lizard Point Light at a distance of 30 miles, and that
(b) the bearing of Lizard Point from the ship will be 070°T.

1. Plot the vessel's position (A) as shown.
2. In 1·5 hours at 14 knots the vessel will steam

$$1{\cdot}5 \times 14 = 21 \text{ miles}$$

and this is the vessel's Radius of Action for the chosen interval of time.
3. With centre 'A' and radius 21 miles describe a circle—this is the vessel's radius of action in 1·5 hours.
4. From Lizard Point Light (C) draw a line which is tangential to the radius of action at point 'B'.
5. Join 'A' and 'B'—this is the required track 116°T which will bring Lizard Point abeam in 1·5 hours and which, in the absence of current, leeway, Gyro or Compass Error is also the course to steer.

Answer: Course to steer 116°T.

DF BEARINGS

A vessel's position can be fixed by cross bearings of two, and preferably at least three, bearings of radiobeacons. These bearings are taken using radio Direction Finding (DF) equipment. The bearings are observed "relative" to the ship's head and referred to as "Relative Bearings".

Relative Bearings

In connection with DF, relative bearings are measured 0°–360° from right ahead. Many vessels are fitted with automatic DF with a Gyro compass input and facility for reading off, directly, the Gyro bearing of the radiobeacon. But whether automatic or non-automatic, the incoming signal is always measured relative to the ship's head, e.g.:

Ship's Head	091°G	268°G
Error	1° High	2° Low
True Heading	090°T	270°T
Relative Bearing	045°	135°
True Bearing	135°T	405°
		(−) 360°
	True Bearing	045°T

Relative bearings can also be measured from right ahead 0°–180° to port (Red) and 0°–180° to starboard (Green)—this method is used in radar plotting in connection with a target's "aspect".

Track Followed by Radio Waves

Radio waves follow a great circle (GC) track which is the shortest distance between the transmitter and receiver. On a Gnomonic chart the GC track appears as a straight line. On a Mercator chart (which is the type used for coastal navigation) the GC track appears as a curve unless it happens to coincide with the equator or one of the meridians (which are great circles). Refer to Figures 35–37 and study the diagramatic representation of the paths followed by the incoming signals.

It follows that, in most cases, the observed DF bearing, which is a GC bearing, cannot be used for plotting directly onto a Mercator chart. In order to plot a DF bearing it is first necessary to convert the observed GC bearing into a Mercator bearing. To convert a GC bearing into a Mercator bearing a correction is applied which amounts to half the "Convergency" between the position of the ship and radiobeacon.

Convergency and Half Convergency

When plotted on a Mercator chart, the GC joining the ship and radiobeacon appears as a curve. Tangents to this curve may be drawn at the ship position and at the radiobeacon position. Produced, the two tangents will intersect and make an angle which is the "convergence" between these two positions.

The rhumb track (Mercator bearing) between the same two positions makes a small angle

Table 3. Half Convergency Correction Table.

CORRECTION REQUIRED to CONVERT a RADIO GREAT CIRCLE BEARING to MERCATORIAL BEARING

Mean Lat.	DIFFERENCE OF LONGITUDE OF SHIP AND RADIO STATION															Mean Lat.
	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°	
°	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	°
84	1·0	2·0	3·0	4·0	5·0	6·0	7·0	8·0	9·0	9·9	10·9	11·9	12·9	13·9	14·9	84
81	1·0	2·0	2·9	4·0	4·9	5·9	6·9	7·9	8·9	9·9	10·9	11·9	12·8	13·8	14·8	81
78	1·0	2·0	2·9	3·9	4·9	5·9	6·8	7·8	8·8	9·8	10·8	11·7	12·7	13·7	14·7	78
75	1·0	1·9	2·9	3·9	4·8	5·8	6·8	7·7	8·7	9·7	10·7	11·6	12·6	13·5	14·4	75
72	1·0	1·9	2·9	3·8	4·8	5·7	6·7	7·6	8·6	9·5	10·5	11·4	12·4	13·3	14·3	72
69	0·9	1·9	2·8	3·7	4·7	5·6	6·5	7·5	8·4	9·3	10·3	11·2	12·1	13·1	14·0	69
66	0·9	1·8	2·8	3·7	4·6	5·5	6·4	7·3	8·2	9·1	10·0	11·0	11·9	12·8	13·7	66
63	0·9	1·8	2·7	3·6	4·5	5·4	6·3	7·1	8·0	8·9	9·8	10·7	11·6	12·5	13·3	63
60	0·9	1·7	2·6	3·5	4·3	5·2	6·1	6·9	7·8	8·6	9·5	10·4	11·2	12·1	12·9	60
57	0·8	1·7	2·5	3·4	4·2	5·0	5·9	6·7	7·5	8·4	9·2	10·0	10·9	11·7	12·5	57
54	0·8	1·6	2·4	3·3	4·1	4·9	5·7	6·5	7·3	8·1	8·9	9·7	10·5	11·3	12·1	54
51	0·8	1·6	2·3	3·1	3·9	4·7	5·5	6·2	7·0	7·8	8·5	9·3	10·1	10·8	11·6	51
48	0·8	1·5	2·2	3·0	3·7	4·5	5·2	5·9	6·7	7·4	8·2	8·9	9·6	10·4	11·1	48
45	0·7	1·4	2·1	2·8	3·5	4·2	4·9	5·6	6·3	7·1	7·8	8·5	9·2	9·9	10·6	45
42	0·7	1·4	2·0	2·7	3·4	4·0	4·7	5·4	6·0	6·7	7·4	8·0	8·7	9·4	10·0	42
39	0·6	1·3	1·9	2·5	3·2	3·8	4·4	5·0	5·7	6·3	6·9	7·5	8·1	8·8	9·4	39
36	0·6	1·2	1·8	2·4	3·0	3·5	4·1	4·7	5·3	5·9	6·4	7·0	7·6	8·2	8·7	36
33	0·5	1·1	1·6	2·2	2·7	3·3	3·8	4·4	4·9	5·4	6·0	6·5	7·1	7·6	8·1	33
30	0·5	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5	7·0	7·4	30
27	0·5	0·9	1·4	1·8	2·3	2·7	3·2	3·6	4·1	4·5	5·0	5·4	5·9	6·3	6·8	27
24	0·4	0·8	1·2	1·6	2·1	2·4	2·9	3·3	3·6	4·0	4·4	4·8	5·2	5·6	6·0	24
21	0·3	0·7	1·1	1·4	1·8	2·2	2·5	2·9	3·2	3·6	3·9	4·3	4·6	5·0	5·3	21
18	0·3	0·6	0·9	1·2	1·6	1·9	2·2	2·5	2·8	3·1	3·4	3·7	4·0	4·3	4·6	18
15	0·3	0·5	0·8	1·0	1·3	1·6	1·8	2·1	2·3	2·6	2·8	3·1	3·3	3·6	3·8	15
12	0·2	0·4	0·6	0·8	1·0	1·3	1·5	1·7	1·9	2·1	2·3	2·5	2·7	2·9	3·1	12
9	0·2	0·3	0·5	0·6	0·8	1·0	1·1	1·2	1·4	1·6	1·7	1·9	2·0	2·2	2·3	9
6	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·5	1·6	6
3	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·5	0·6	0·6	0·7	0·7	0·8	3
	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°	



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with the GC track at the ship position and at the radiobeacon position. Each of these angles is equal to half the convergency. Considering the ship position alone, this small angle represents the correction required to convert the incoming GC signal bearing into the corresponding Mercator bearing which can be plotted on the chart.

Finding the Value of Half Convergency

Half convergency may be calculated or found by inspection from tables such as the, "Correction Required to Convert a Radio Great Cirle Bearing to a Mercatorial Bearing", tables contained in *Norie's Nautical Tables.*

The formula for finding half convergency is as follows:

$$\text{Half Convergency (in minutes)} = \frac{\text{D Long (in minutes)} \times \sin \text{Mn Lat}}{2}$$

It should be noted that if the Difference of Longitude (D Long) between the ship and radiobeacon is 0° (i.e. when they are on the same meridian and bearing North or South of each other) the half convergency correction will also be 0°.

Similarly, when the Mean Latitude (Mn Lat) is 0° (i.e. when the ship and radiobeacon are on the equator and bearing East or West of each other) the half convergency correction will also be 0°.

N.B.—Meridians and the equator are, themselves, great circles, coincide with Mercator bearings and, hence, result in 0° corrections.

Naming Convergency (+) or (−)

(Refer to Figures 35, 36 and 37)

Common sense, a sound knowledge of the basic principles involved, a simple sketch and a ruler (or straight edge) are all that is required to correctly name the half convergency correction.

The curve of the **Great Circle Track** between the radiobeacon and the ship is **always towards the Pole**, e.g.

In **South Latitude** (Figure 35) the GC tracks 'A' to 'F' and 'C' to 'F' are drawn with the curve towards the South.

In **North Latitude** (Figures 36 and 37) the GC tracks are drawn with the curve towards the North.

In both **North and South Latitudes** the GC track coincides with the Rhumb track when the radiobeacon is either North or South of the ship in which case both appear as the same straight line.

In both **North and South Latitudes** corresponding Rhumb Tracks (Mercator Bearings) between the radiobeacons and the ship are drawn as straight lines.

Having found the correction, either by calculation or from tables:

1. Make a simple sketch showing the relative positions of the ship and each radiobeacon.
2. Draw in the GC and Rhumb tracks joining them.
3. At the ship position, lay a straight edge tangential to the incoming signal (GC track).
4. Compare the value (in 360° notation) of the incoming GC bearing (indicated by the direction of the straight edge) with the Mercator bearing as shown in your sketch.
5. If the Mercator bearing is **greater** than the GC bearing, **add** the half convergency correction.
6. If the Mercator bearing is **less** than the GC bearing, **subtract** the half convergency correction.

Radiobeacons, "Grouping" and Difference of Longitude (D Long)

Each radiobeacon has its own two letter morse code identification signal or call sign which is listed in *Admiralty List of Radio Signals* (ALRS) volume 2, together with radio frequency and other details.

"Non-directional" (RC) radiobeacons are those which transmit a signal in all directions whereas "Directional" (RD) radiobeacons transmit a directional signal which is shown on the chart and can be used as a "leading" line. Another type, the "Rotating pattern" (RW) radiobeacon is suitable for small craft without special equipment.

RC radiobeacons are often arranged in networks or groups. Each group has a common radio frequency and a common audible frequency. This enables the navigator to tune into a particular group and then to distinguish between each radiobeacon within that group. Time sharing is practiced and up to six radiobeacons transmit their call sign and directional signal at one minute intervals over a total period of six minutes.

Using radiobeacons from a position within one group helps to ensure that the D Long

between the ship and each radiobeacon is reasonably small and hence keeps the half convergency correction small.

Radiobeacon symbols and abbreviations are listed at [M] in BA 5011, *Symbols and Abbreviations*.

Procedure for Plotting DF Bearings

Note that the procedure outlined below applies to each DF bearing, i.e. each bearing has a separate correction.

Having noted the call signs and taken DF bearings of suitable transmitting radiobeacons:

1. Refer to the chart and *Admiralty List of Radio Signals* Vol. 2, and identify the radiobeacons used. Write down the latitude and longitude of each radiobeacon and of the vessel's DR or EP.
2. Find the Mean Latitude (Mn Lat) between the vessel and each radiobeacon.
3. Find the Difference of Longitude (D Long) between the vessel and each radiobeacon.
4. Using arguments Mn Lat and D Long, enter the Half Convergency Correction Tables and note the corrections for the tabulated intervals, e.g. for D Long 0°, 2°, 4°.
5. Interpolate, as necessary, between the tabulated corrections to find the half convergency correction to apply to each bearing.
   N.B.—If preferred, the half convergency correction can be calculated:
   $$\text{Half Convergency (in minutes)} = \frac{\text{D Long in minutes} \times \sin \text{Mn Lat}}{2}$$
   in which case interpolation is not necessary.
6. Decide whether the half convergency correction for each DF bearing is additive (+) or subtractive (−).
   N.B.—This is best decided by making a simple diagram of the relative positions of the ship and each radiobeacon and sketching in the corresponding rhumb lines (Mercator bearings) and Great Circle (GC) bearings—it will then be apparent if the Mercator bearing (in 360° notation) is greater or less than the received GC bearing.
7. Apply Gyro or Compass Error, as appropriate, to the ship's head in order to find the True Heading at the time of taking the DF bearing.
8. Apply any Calibration Curve Correction (see note) to the observed Relative Bearing and **add** the corrected Relative Bearings to the True Heading to find the True GC Bearing of each radiobeacon.
9. Apply the previously found Half Convergency Corrections to each True GC bearing to find the True Mercator Bearings of the radiobeacons.
10. Lay off the Mercator bearings and fix the vessel's position on the chart.

Note: Quadrantal (re-radiation) Error results from re-radiation (of the incoming signal) by the vessel's superstructure, masts and aerials. This re-radiation displaces the incoming signal.

The error, which varies with the relative bearing, is found by calibration. Errors are then tabulated on a calibration curve which should be referred to when correcting DF bearings.

Quadrantal error is greatest when the incoming signal is four points on the bow or quarter, i.e. at 045° Relative, 135° Relative, 225° Relative and 315° Relative. This error varies from ship to ship. When calibrating the ship, all cargo handling gear, etc, should be in the stowed position and the position of aerials noted. When taking DF bearings cargo handling gear, aerials, etc, should be in the same position as when calibration was carried out.

Fix by DF Bearings in South Latitude—Radiobeacons North, East and West

In the following example the vessel is in South Latitude and the radiobeacons are situated North, East and West of the vessel's EP. Note how this configuration results in half convergency corrections which are nil (0°), negative (−) and positive (+).

Also note the Great Circle Tracks which are towards the Pole, i.e. in South Latitude the GC curves are drawn towards the South Pole.

And finally, note that as the D Long increases the half convergency correction increases.

Example 43

(Refer to Figure 35 and Table 3)

A vessel in EP 39° 30′ S 145° 00′ E is steering 015°G. Using the DF equipment, the following relative bearings are taken of three nondirectional radiobeacons:

Radiobeacon	A	39° 15′ S	142° 00′ E	Relative bearing	262°	Ship's Head	015° G
„	B	38° 30′ S	145° 00′ E	„	„	346°	„	„	014° G
„	C	41° 00′ S	146° 40′ E	„	„	121·5°	„	„	015°G

Gyro Error: Nil.

Find the half convergency correction (if any) to apply to each of the three radio great circle bearings and,

(a) Calculate each half convergency correction by formula.
(b) Check each correction by inspection of correction tables.
(c) Find the corresponding Mercator bearings to plot on the chart.

To Find Mean Latitude and D Long

DF Bearing	A	B	C	
Latitude ship	39° 30′ S	39° 30′ S	39° 30′ S	1.
Latitude Radiobeacon	39 15 S	38 30 S	41 00 S	
	2)78 45	2)78 00	2)80 30	
Mean Lat	39° 22·5′ S	39° 00′ S	40° 15′ S	
	39·4°	39°	40·25°	2.
Longitude ship	145° 00′ E	145° 00′ E	145° 00′ E	
Longitude Radiobeacon	142 00′ E	145 00 E	146 40 E	
D Long	3° 00′ W	Nil	1° 40′ E	
For Calculation	180′	0′	100′	
Enter Tables with D Long	3°	0°	1·7°	3.

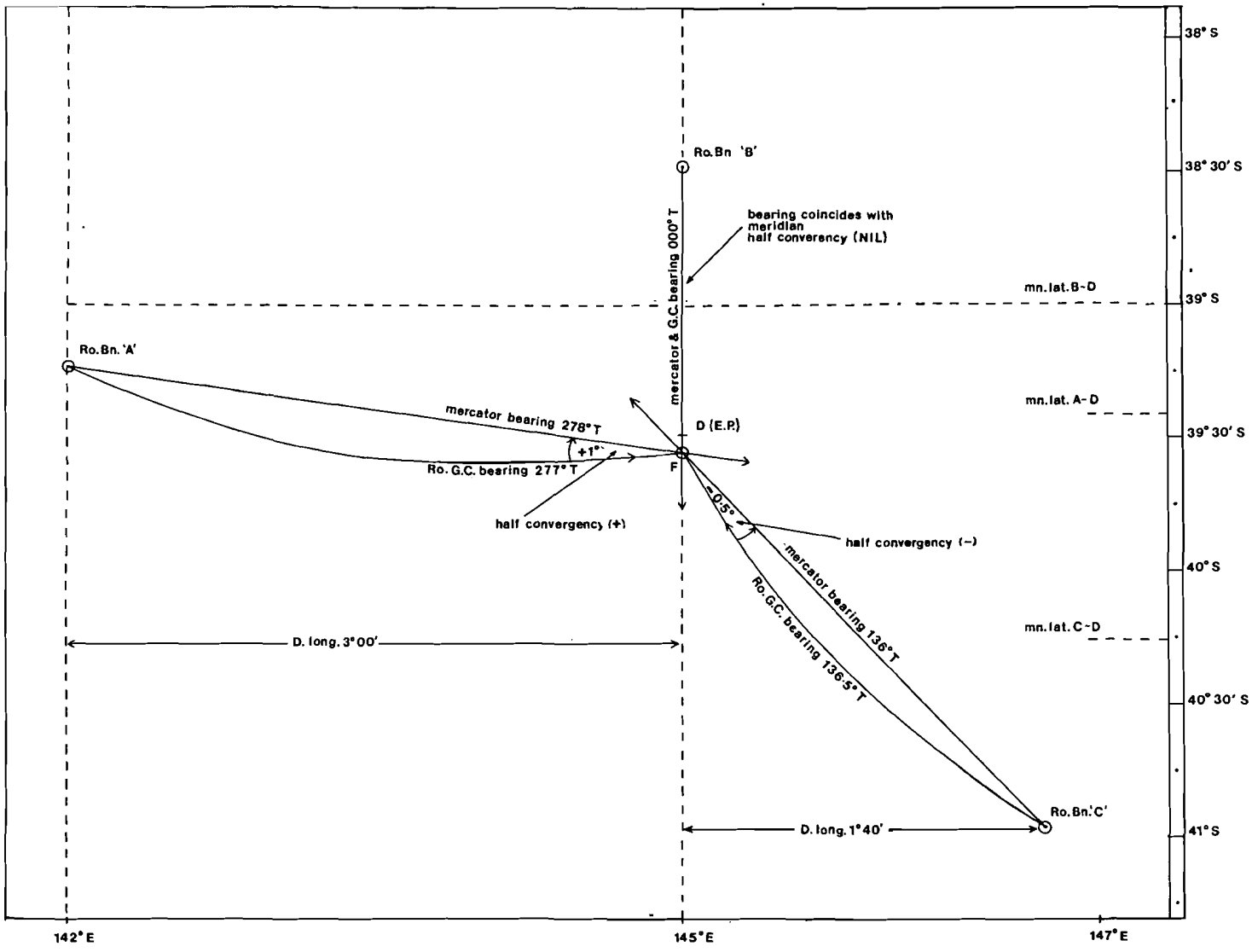


Figure 35. Fix by DF bearings. South Latitude. Radiobeacons North, East and West of Ship.

To Find Half Convergency

By Calculation

$$\text{Half Convergency} = \frac{\text{D Long} \times \sin \text{Mn Lat}}{2}$$

GC Bearing A	D Long A 180′		log	2·25527	
	Mn Lat 39° 22·5′		„ sin	9·80236	
	Convergency	2)114·1′	„ ←	2·05763	
	Half Convergency	57·05′			1° approx.
GC Bearing B	D Long B Nil				
	Half Convergency				Nil.
GC Bearing C	D Long C 100′		log	2·00000	
	Mn Lat 40° 15′		„ sin	9·81032	
	Convergency	2)64·61	„ ←	1·81032	
	Half Convergency	32·31′			0·5° approx.

By Correction Tables
(Refer to Table 3)

	D Long		
Mn Lat	0°	2°	4°
	Half Convergency Correction		
42°	0°	0·7°	1·4°
39°	0°	0·6°	1·3°

From the Tables:

In this example the interpolation is very straightforward and can be carried out mentally.

Ship to Ro Bn A–D Long 3° } → Half Convergency 0·95° (57·05′ by calculation)
Mean Latitude 39·4° }

(Interpolation carried out for 39° half way between 2° and 4°)

Ship to Ro Bn B–D Long 0° → Half Convergency Nil

Ship to Ro Bn C–D Long 1·7° } → Half Convergency 0·5° (32·31′ by calculation)
Mean Latitude 40·25° }

(Interpolation carried out for 39°, $\frac{17}{20}$ from 0° to 2°.)

Naming the Half Convergency Correction (+) or (−)

From sketch or Figure 35:

DF Bearing	'A'	Half Convergency Correction	(+)				
,, ,,	'B'	,, ,,	,,	Nil			
,, ,,	'C'	,, ,,	,,	(−)			6.

Applying Corrections and Converting the GC Bearings to Mercator Bearings

Ship's Head	015°G	014°G	015°G	
Gyro Error	—	—	—	
True Heading	015°T	014°T	015°T	7.
Relative Bearing (if present also apply calibration error)	262° Rel	346° Rel	121·5° Rel	
True GC Bearing	277°T	000°T	136·5°T	8.
Half Convergency Correction (+)	1°	Nil	(−) 0·5°	
Mercator Bearing	278°T	000°T	136°T	9.
Bearing to Plot	278°T	000°T	136°T	10.

Answer: Half Convergency Corrections

(a) A 57·05′ B Nil C 32·31′ by Calculation.

(b) 1° Nil 0·5° from Tables.

Mercator Bearings to plot

(c) A 278°T B 000°T C 136°T

Fix by DF Bearings in North Latitude—Radiobeacons North and East

In the next example the vessel is in North Latitude and the radiobeacons are situated North and East of the vessel's DR. Note how this configuration results in half convergency corrections which are Nil (0°) and positive (+).

Also note the Great Circle Tracks which are towards the Pole, i.e. in North Latitude the GC curves are drawn towards the North Pole.

And finally, note that as in the previous example, as the D Long increases the half convergency correction increases.

The following example also demonstrates the method for interpolating between tabulated values in the correction tables.

Example 44

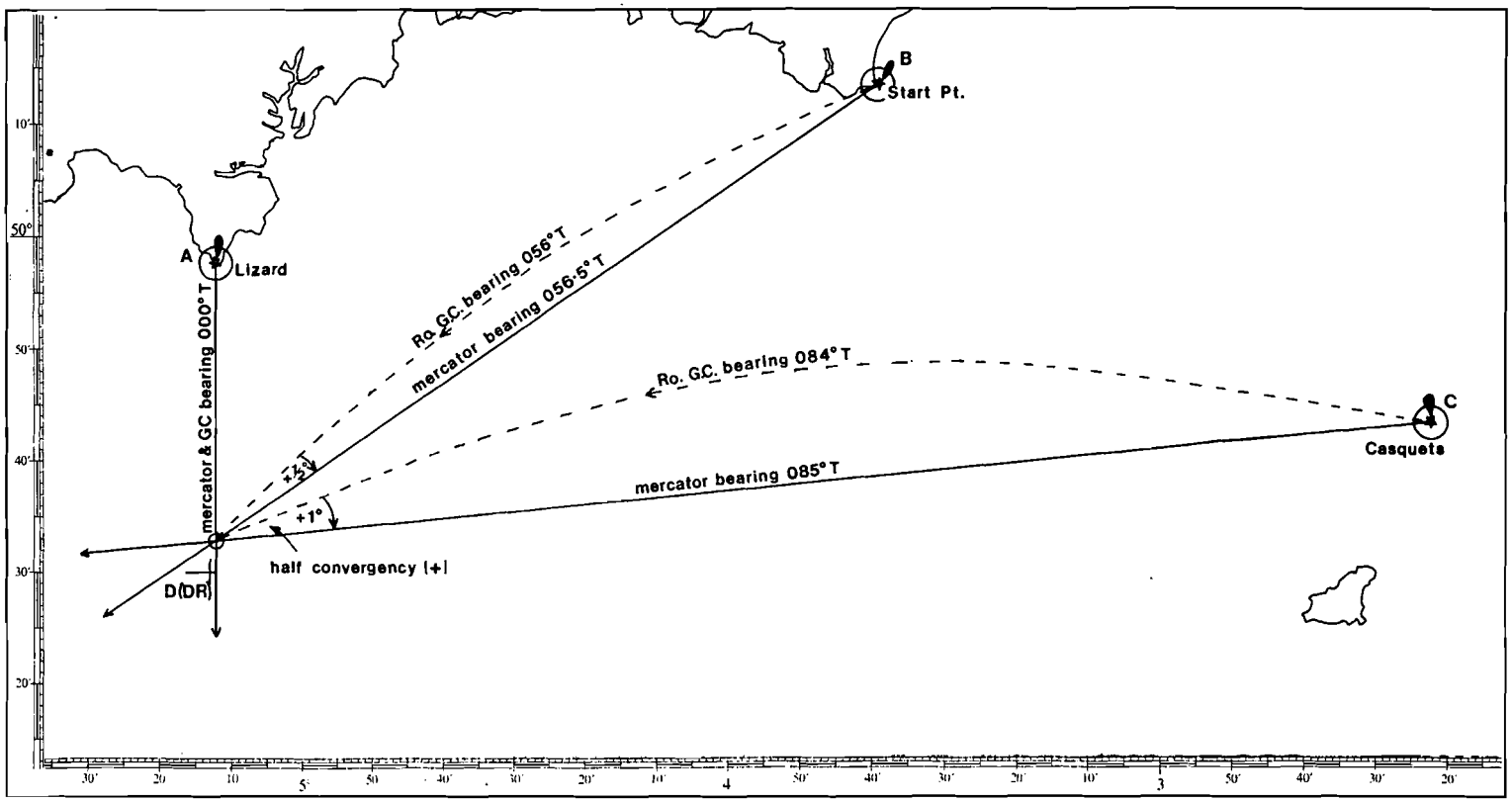
(Refer to Figure 36 and Table 3)

A vessel in DR 49° 30′ N 5° 13′ W is steering 078°G in reduced visibility. The following DF bearings are taken at 2000 on frequency 298·8 kHz.

Radiobeacon A	Call sign LZ	Relative bearing 285°	Ship's Head 077° G
B	SP	340°	078° G
C	QS	007°	079° G

Gyro Error: 2° High.

Identify the radiobeacons and find the vessel's position.



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Figure 36. Fix by DF bearings. North Latitude. Radiobeacons North and East of Ship.

To Identify the Radiobeacons
Refer to the chart and ALRS volume 2.

RADIOBEACONS AND RADIO DIRECTION-FINDING STATIONS

GREAT BRITAIN

RC **Start Pt Lt** 50°13′19″N 3°38′28″W 0013
SP—Grouped with 0014

RC **Penlee Point**[1] 50°19′07″N 4°11′16″W 0014
298·8 A2* (545 Hz)

No	Name	Ident	Range	Seq	Fog	Clear
0014	Penlee Pt	PE	50	1	Cont	Cont
0013	Start Pt	SP	70[3]	2	Cont	Cont
0159	Casquets	QS	50[3]	3	Cont	Cont
0854	Roches Douvres	RD[2]	70	4	Cont	Cont
0856	Ile Vierge	VG[2]	70	5	Cont	Cont
0015	Lizard	LZ	70[3]	6	Cont	Cont

1) Located 156° 40m from the Lt
2) A2
3) Reduced range ufn (Sept 1980)

RC **Lizard Lt** 49°57′35″N 5°12′04″W 0015
LZ—Grouped with 0014

36

CHANNEL ISLANDS

RC **Casquets Lt** 49°43′23″N 2°22′33″W 0159
QS—Grouped with 0014

RC Channel Lt V 49°54′25″N 2°53′40″W 0160
CR 287·3 A2 (395 Hz) 10 n miles H24

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(*Extract from* Admiralty List of Radio Signals *by kind permission of the Hydrographer of the Navy.*)

The radiobeacons are:

Radiobeacon	A	Lizard	LZ	49° 58′ N	5° 12′ W	Relative bearing 285°	
„	B	Start Point	SP	50° 13′ N	3° 38′ W	„ „ 340°	
„	C	Casquets	QS	49° 43′ N	2° 23′ W	„ „ 007°	1.
Ship DR				49° 30′ N	5° 13′ W		

To Find Mean Latitude and D Long

DF Bearing	A		C
Latitude ship	49° 30′ N	49° 30′ N	49° 30′ N
Latitude Radiobeacon	49 58 N	50 13 N	49 43 N
	2)99 28	2)99 43	2)99 13
Mean Lat	49° 44′ N	49° 51·5′ N	49° 36·5′ N
	49·7°	49·9°	
Longitude ship	5° 13′ W	5° 13′ W	5° 13′ W
Longitude Radiobeacon	5 12 W	3 38 W	2 23 W
D Long	1′E	1° 35′ E	2° 50′ E
Enter Tables with D Long	Nil	1·6°	2·8°

2.

3.

To Find the Half Convergency Correction from Tables
(Refer to Table 3)

	D Long		
Mn Lat	0°	2°	4°
	Half Convergency Correction		
51°	0°	0·8°	1·6°
48°	0°	0·8°	1·5°

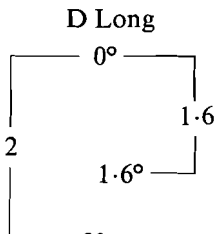
4.

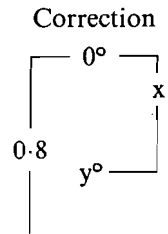
Interpolation

GC Bearing A
Lizard Mn Lat 49·7° D Long 0°
Half Convergency Correction 0°

5a.

GC Bearing B
Start Point Mn Lat 49·9° D Long 1·6°
Use Mn Lat 51°





Now $\frac{1{\cdot}6}{2} = \frac{\text{'x'}}{0{\cdot}8}$ so Adjustment $\text{'x'} = \frac{1{\cdot}6 \times 0{\cdot}8}{2} \simeq 0{\cdot}6°$

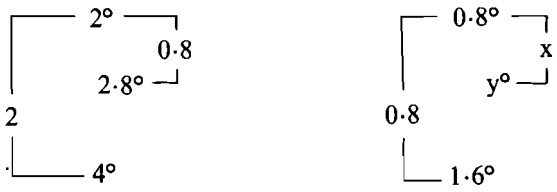
Correction for 0°	0·0°
Adjustment	0·6°
Half Convergency Correction 'y'	0·6°

5b.

GC Bearing C

Casquets Mn Lat 49·6° D Long 2·8°

Use Mn Lat 51° D Long Correction



Now $\frac{0{\cdot}8}{2} = \frac{\text{'x'}}{0{\cdot}8}$ so Adjustment $\text{'x'} = \frac{0{\cdot}8 \times 0{\cdot}8}{2} \simeq 0{\cdot}3°$

Correction for 2°	0·8°
Adjustment	0·3°
Half Convergency Correction 'y'	1·1°

5c.

Naming the Correction (+) or (—)

From sketch or Figure 36:

DF Bearing	'A'	Half Convergency Correction				Nil
,,	,, 'B'	,,	,,	,,		(+)
,,	,, 'C'	,,	,,	,,		(+)

6.

Applying Corrections and Converting the GC Bearings to Mercator Bearings.

Ship's Head	077°G		078°G		079°G	
Gyro Error	2° High		2° High		2° High	
True Heading	075°T		076°T		077°T	7.
Relative Bearing	285° Relative		340° Relative		007° Relative	
(if present also apply calibration error)	360°		416°		084°	
	(—) 360°	(—)	360°		—	
True GC Bearing	000°T		056·0°T		084·0°T	8.
Half Convergency Correction	Nil	(+)	0·6°	(+)	1·1°	
Mercator Bearing	000°T		056·6°T		085·1°T	9.
Bearing to Plot	000°T		056·5°T		085°T	10.

Answer: Radiobeacon 'A' Lizard Mercator Bearing 000°T

,, 'B' Start Point ,, ,, 056·5°T

,, 'C' Casquets ,, ,, 085°T

Position 49° 32·8′ N 5° 12′ W.

Fix by DF Bearings in North Latitude—Radiobeacons South and West

In the next example, the vessel is again in North Latitude but this time the radiobeacons are

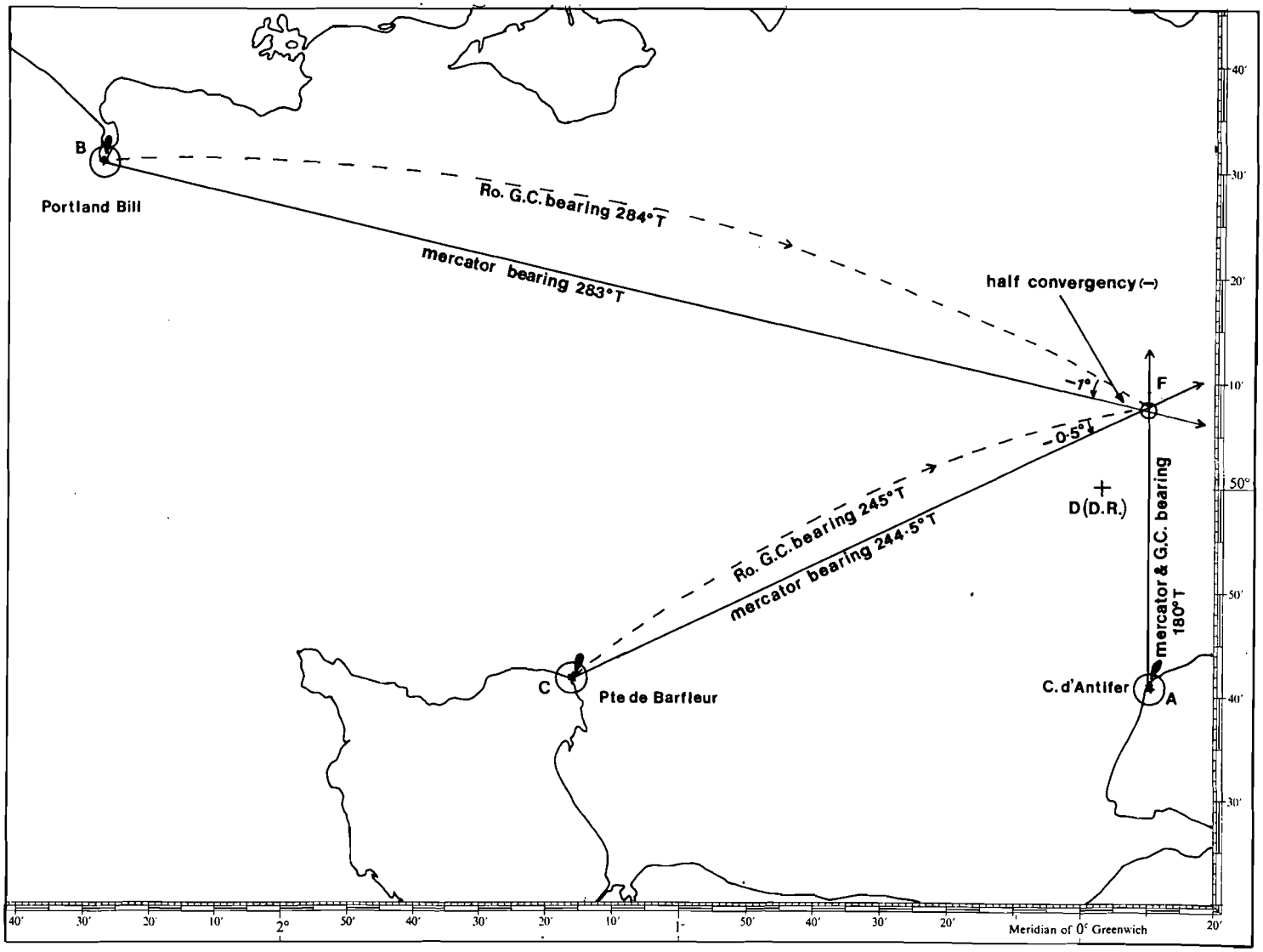


Figure 37. Fix by DF bearings. North Latitude. Radiobeacons South and West of Ship.

situated South and West of DR. Note how this configuration results in half convergency corrections which are Nil (0°) and negative (−).

Again note the curve of the GC track is "towards the Pole" and that half convergency increases as the D Long increases.

Example 45

(Refer to Figure 37)

A vessel in DR 50° 00′ N 00° 03′ E is steering 259°G in reduced visibility. The following DF bearings are taken at 0900 on frequency 291·9 kHz.

Radiobeacon 'A'	Call sign TI	Relative Bearing 280°	Ship's Head 259°G
'B'	PB	024°	259°G
'C'	FG	344°	260°G

Gyro Error: 1° Low.

Identify the Radiobeacons and find the vessel's position.

To Identify the Radiobeacons

Refer to the Chart and ALRS volume 2.

RADIOBEACONS AND RADIO DIRECTION-FINDING STATIONS

RC **Bill of Portland Lt** 50°30′49″N 2°27′19″W 0010
291·9 A2 (670 Hz)

No	Name	Ident	Range	Seq	Fog	Clear
0010	Portland Bill	PB[1]	50[2]	1	Cont	Cont
0004	St Catherine's Pt	CP[1]	50[2]	2	Cont	Cont
0839	C d'Antifer	TI	50	3	Cont	Cont
0841	Le Havre Lanby	LH	30	4	Cont	Cont
0843	P de Ver	ER	20	5	Cont	Cont
0846	P de Barfleur	FG	70	6	Cont	Cont

1) A2°
2) Reduced range ufn (Sept 1980)

35

Cap d'Antifer Lt[1] 49°41′04″N 0°10′00″E 0839
TI—Grouped with 0010
1)Located 40 m NNW from the Lt

81

Pointe de Barfleur Lt 49°41′52″N 1°15′52″W 0846
FG - Grouped with 0010

81

RC **Saint Catherine's Point Lt** 50°34′31″N 1°17′48″W 0004
CP—Grouped with 0010

33

(*Extract from* Admiralty List of Radio Signals, *volume 2, by kind permission of the Hydrographer of the Navy.*)

The Radiobeacons are:

Radiobeacon 'A'	C d'Antifer	TI	49° 41′ N	0° 10′ E	Relative bearing	280°
'B'	Portland Bill	PB	50° 31′ N	2° 27′ W		024°
'C'	Pt de Barfleur	FG	49° 42′ N	1° 16′ W		344°

1.

To Find Mean Latitude and D Long

DF Bearing	A	B	C
Latitude Ship	50° 00′ N	50° 00′ N	50° 00′ N
Latitude Radiobeacon	49 41 N	50 31 N	49 42 N
	2)99 41	2)100 31	2)99 42
Mean Lat	49° 50·5′ N	50° 15·5′ N	49° 51′ N
	49·8°	50·3°	49·8°

2.

Longitude Ship	0° 03′ E	0° 03′ E	0° 03′ E
Longitude Radiobeacon	0° 10′ E	2 27 W	1 16 W
D Long	7′ W	2° 30′ W	1° 19′ W
Enter Tables with D Long	Nil	2·5°	1·3°

3.

To Find the Half Convergency Correction from Tables
(Refer to Table 3)

	D Long		
Mn Lat	0°	2°	4°
	Half Convergency Correction		
51°	0°	0·8°	1·6°
48°	0°	0·8°	1·5°

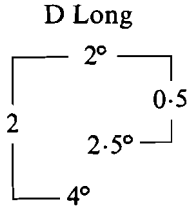
4.

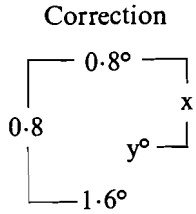
Interpolation

GC Bearing A Mn Lat 49·8° D Long Nil.
C d'Antifer Half Convergency Correction 0° 5a.

GC Bearing B Mn Lat 50·3°N D Long 2·5°
Portland Bill

Use Mn Lat 51°



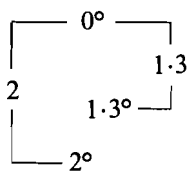


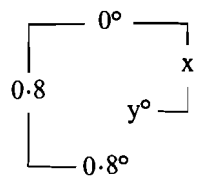
Now $\frac{0{\cdot}5}{2} = \frac{x}{0{\cdot}8}$ so Adjustment $x = \frac{0{\cdot}5 \times 0{\cdot}8}{2} = 0{\cdot}2°$

Correction for 2°	0·8°
Adjustment	0·2°
Half Convergency Correction 'y'	1·0°

5b.

GC Bearing C Mn Lat 49·8°N D Long 1·3°
Pte de Barfleur
Use Mn Lat 51° D Long Correction





Now $\frac{1{\cdot}3}{2} = \frac{x}{0{\cdot}8}$ so Adjustment $x = \frac{1{\cdot}3 \times 0{\cdot}8}{2} \simeq 0{\cdot}5°$

Correction for 0°	0·0°
Adjustment	0·5°
Half Convergency Correction 'y'	0·5°

5c.

Naming the Correction (+) or (—)
From sketch or Figure 37:

DF Bearing 'A' Half Convergency Correction Nil
'B' Half Convergency Correction (−)
'C' Half Convergency Correction (−) 6.

Ship's Head		259°G		259°G		260°G	
Gyro Error		1° Low		1° Low		1° Low	
True Heading		260°T		260°T		261°T	7.
Relative Bearing	(+)	280°	(+)	024°	(+)	344°	
(if present also apply calibration error)		540°		284°		605°	
	(−)	360°		—	(−)	360°	
True GC Bearing		180°T		284°T		245°T	8.
Half Convergency		Nil	(−)	1°	(−)	½°	
Mercator Bearing		180°T		283°T		244½°T	9.
Bearing to Plot		180°T		283°T		244½°T	

Answer: Ro Bn 'A' Mercator Bearing 180°T.
'B' Mercator Bearing 283°T.
'C' Mercator Bearing 244½°T.
Position 50° 07½′N 0° 10′E.

NAVIGATIONAL LIGHTS

The number of navigational lights which can be included on a particular chart is governed by the scale of that chart. Quite simply, a large scale chart can include more lights than a small scale chart. Of equal importance, a large scale chart can include more of the details relating to each light. For full information regarding a navigational light reference should always be made to the appropriate (corrected) volume of the Admiralty Light Lists.

Admiralty Light Lists

Details of all navigational lights are contained in the, *Admiralty List of Lights and Fog Signals* (Light Lists), and published in twelve volumes, A–M, covering the World.

Such details include the light's Characteristic, e.g. whether fixed, flashing etc; Colour, e.g. white, red, green etc; Period, the time taken to complete one cycle of the characteristic; Elevation, e.g. the focal plane height above MHWS, MHHW or MSL, which is important for working out light ranges; Description of Structure, which is important when making daytime identification; Height of Superstructure above ground level and other details.

The preliminary pages of the Admiralty Light Lists include much helpful information and explanations regarding their use—refer to a current volume for further details.

Corrections to Light Lists are promulgated in the weekly editions of, *Admiralty Notices to Mariners.*

Light Symbols and Abbreviations

Light symbols and abbreviations are included at K in the booklet edition of, *Symbols and Abbreviations,* BA 5011—refer to the latest edition or the copy contained in the rear pocket of this volume.

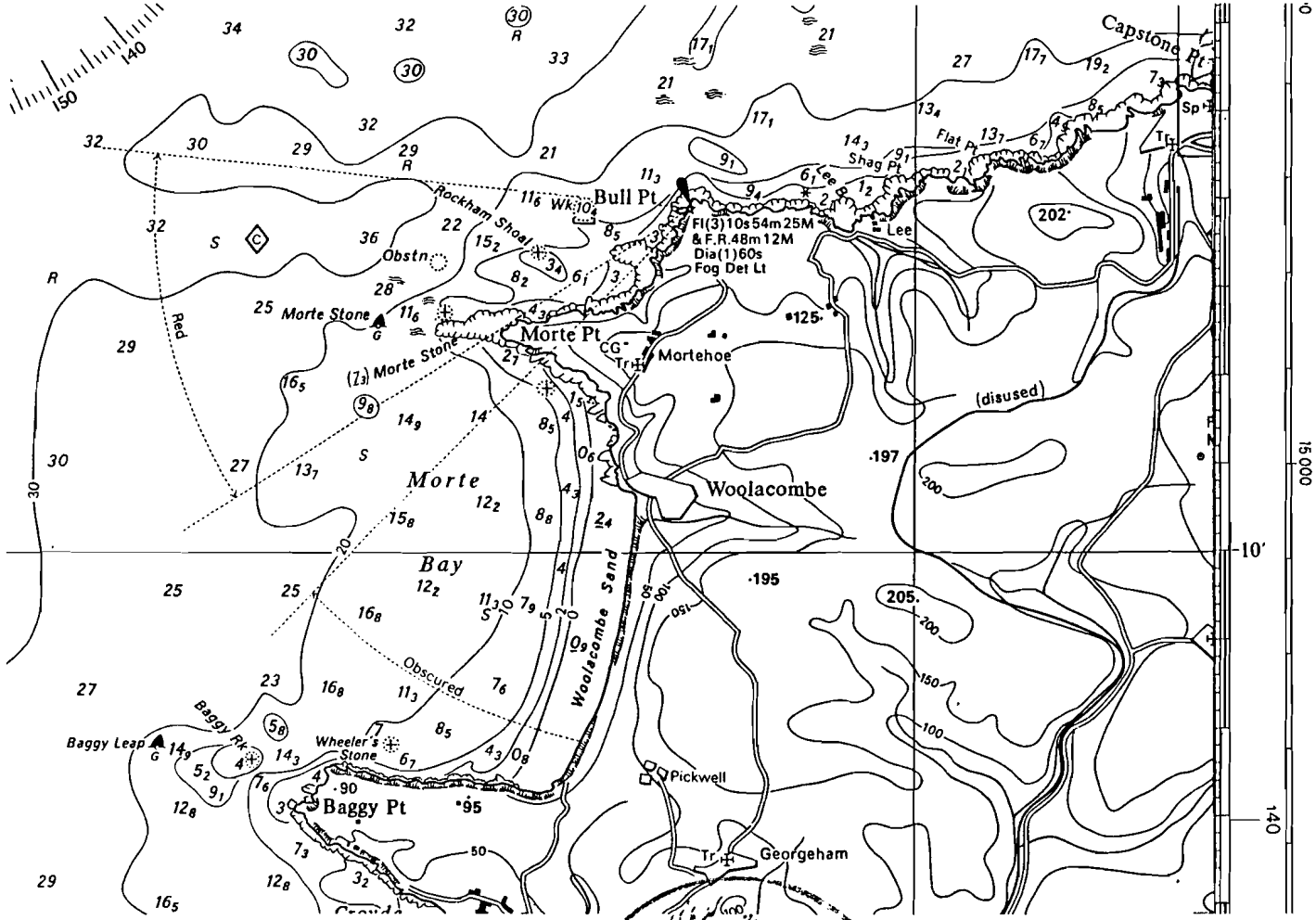
Comment on Lights contained in "The Mariner's Handbook"

General information on navigational lights is contained in the *Mariner's Handbook*, NP 100.

Such information includes remarks on Aero Lights, Obstruction Lights, and Range and comment on the effect of Abnormal Refraction, Haze, Cloud (on lights of high elevation) and Height of Eye—refer to NP 100 for further information.

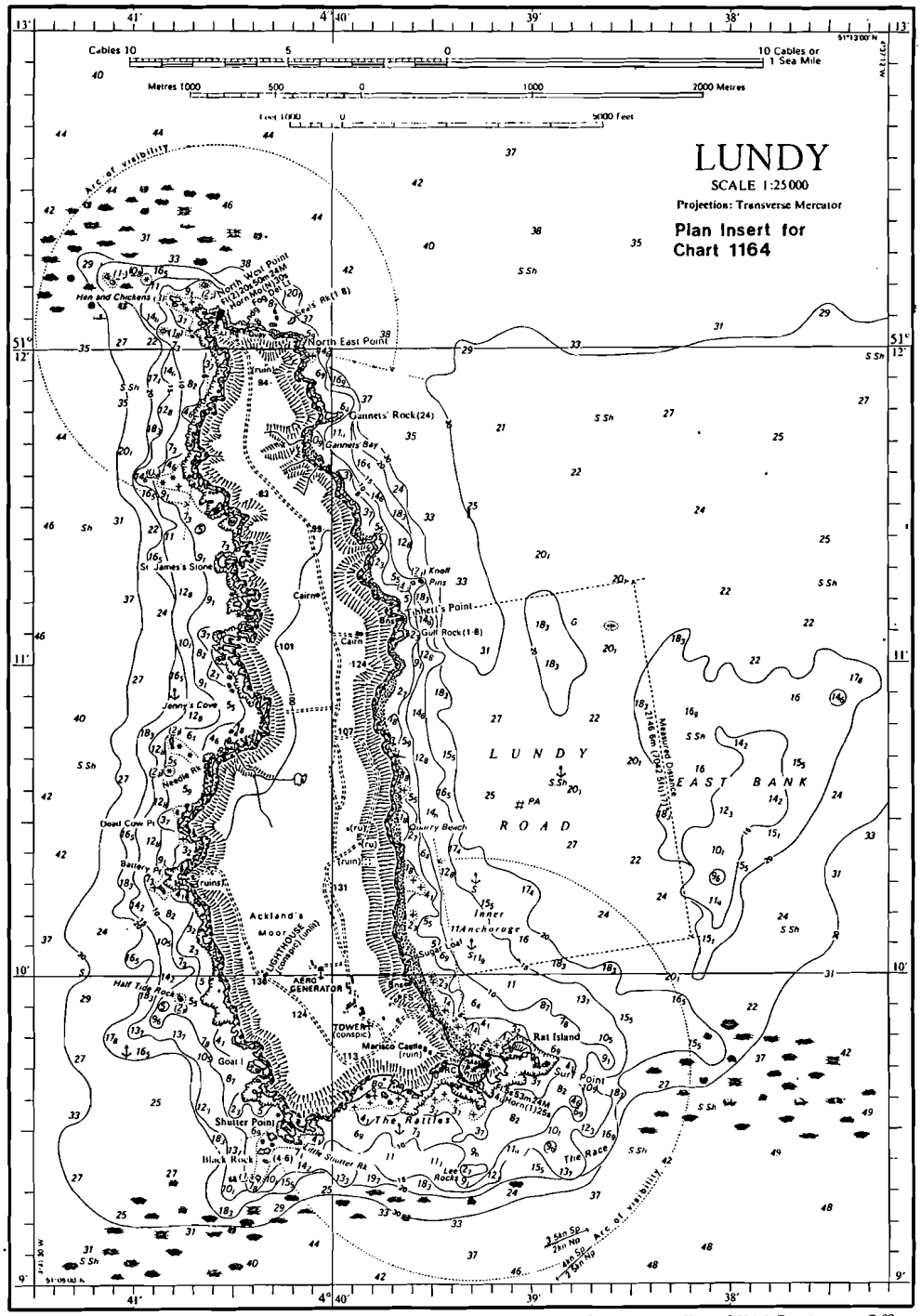
Light Arcs on Charts

The arcs drawn around lights are intended to give information regarding their arcs of visibility or, in the case of sectored lights (which show different colours in different sectors) the bearings between which differences occur. Arcs do not give information regarding the range at which a light can be sighted.



(Reproduced from British Admiralty Charts with the permission of the Controller of HM Stationery Office and of the Hydrographer of the Navy.)

Figure 38. Arcs of Visibility and Obscured Sectors of Navigational Lights. BA 1164.



(Reproduced from British Admiralty Charts with the permission of the Controller of HM Stationery Office and of the Hydrographer of the Navy.)

Figure 39. Arcs of visibility and other more detailed information included on a Plan Chart. BA 1164.

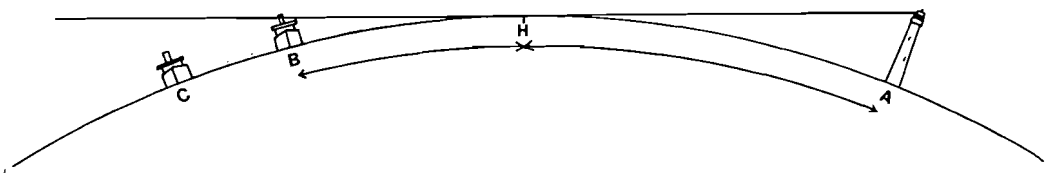


Figure 40. Geographical or Extreme Range.

LIGHT RANGES

In certain conditions a light can be seen when still below the horizon. As the vessel approaches the coast a light first appears as a diffuse glow in the sky. This diffuse glow is known as the "Loom" and which, in the case of a navigational light, often appears much as a searchlight sweeping across the horizon.

As the light comes closer to the observer's horizon, the swept arc becomes increasingly smaller until the light itself appears over the horizon. If, at this point, the observer's height of eye is lowered a foot, or two, the light will once more disappear or "dip" below the horizon. This point is known as the light's "Dipping Distance".

The dipping distance of a light can be calculated, or found from tables, and gives an approximate range or distance off. Combined with a true bearing, the dipping distance can provide the navigator with an approximate but useful "Landfall Position".

Dipping distance is also referred to as "Geographical Range" and "Extreme Range".

General Conditions for Sighting a Light

Certain conditions must be met if the navigator is to sight a particular light:

1. The light (A) must have sufficient elevation.
2. The navigator (B) must have sufficient height of eye.
3. The light must have sufficient power (intensity) to penetrate the existing atmosphere and travel the total distance (AB) between the light and the navigator's vessel.

If any one of these conditions is not met the light will not be seen, e.g. even though the light may have sufficient power to travel distance 'AC' it will not be seen at ship 'C' which has insufficient height of eye.

Conversely, if the light has insufficient power to travel distance 'AB' it will not be seen on ship 'B' even though it has sufficient height of eye.

Light Ranges—Summary

The following summary serves as an "overview" for beginners and may be sufficient, for revision purposes, for advanced students. More detailed explanations are given later.

Three ranges are referred to in the Light Lists:

1. Geographical Range (also referred to as Extreme Range and Dipping Distance).
2. Luminous Range.
3. Nominal Range.

Geographical Range is the maximum distance at which, in theory, a light will be visible to an observer.

It depends upon the observer's height of eye and the elevation of the light. Allowances for refraction and curvature are built into the formulae used. It takes **no account** of the light's intensity or the prevailing state of visibility.

Luminous Range is the maximum distance at which a light can be seen at a given moment in time.

It depends upon the intensity of the light and the meteorological visibility at that moment in time. It takes **no account** of the observer's height of eye or the light's elevation.

N.B.—A particular, "Clear Visibility", case of Luminous Range is adopted in some countries and is used as the range inserted on the chart (see Admiralty Light Lists for more detail). In Great Britain, "clear" is defined as 10 sea miles and the range referred to as Nominal Range.

Nominal Range is the luminous range when the meteorological visibility is 10 miles.

It is the range normally inserted on recent editions of modern charts (but see Admiralty Light Lists for full information).

Methods for Obtaining Light Ranges and Associated Information

Light ranges can be found by one, or other, of the following methods:

Nominal Range

1. From the chart.
2. From Admiralty Light Lists.

Geographical Range

1. By calculation.
2. From tables:
   (a) Distance of Sea Horizon Tables (Norie's or equivalent)
   (b) Extreme Range Tables (Norie's or equivalent)
   (c) Geographical Range Tables (Admiralty Light Lists)

Luminous Range

1. Luminous Range Diagram (Admiralty Light Lists)

N.B.—Given a known range at which a light is sighted the Luminous Range Diagram can also be used to find the prevailing Meteorological Visibility.

Given major or minor background lighting, the diagram can also be used to find the reduction to a light's Nominal Range.

Arguments Used to Enter Range Tables and Diagrams

Intensity (Power)	→	Nominal Range
Elevation and Height of Eye	→	Geographical Range
Nominal Range and Meteorological Visibility	→	Luminous Range

Luminous Range and Nominal Range	→	Meteorological Visibility
$\frac{\text{Intensity (candelas)}}{10}$	→	Nominal Range with Minor Background Lighting
$\frac{\text{Intensity (candelas)}}{100}$	→	Nominal Range with Major Background Lighting

Understanding the Terms

From the preceding paragraph it will be apparent that before proceeding with more detailed explanation it is important to define the term "meteorological visibility" and to understand the factors which influence it.

Meteorological Optical Range (MOR)

In 1957, the World Meteorological Organization (WMO) adopted a new measure for the optical state of the atmosphere which is referred to as the Meteorological Optical Range (MOR).

For all practical purposes MOR is the same as Meteorological Visibility which is defined as follows in the *Meteorological Office Handbook*.

Meteorological Visibility—Definition

Meteorological visibility is defined as the greatest distance at which a black object of suitable dimensions can be seen and recognized against the horizon sky, or, in the case of night observations, could be seen and recognized if the general illumination were raised to the normal daylight level. The criterion of recognizing an object must be used and not merely the seeing of an object without recognizing what it is. The lower visibilities are expressed in metres (m) and the higher visibilities in kilometres (km).

Briefly, visibility is the greatest horizontal distance at which suitable objects can be recognized for what they are in daylight, or at which lights of specified candle-power can be seen at night, by a person of normal sight.

Factors Affecting Daylight Visibility

Daylight visibility depends mainly on four factors:

1. Transparency of the atmosphere—which is mainly governed by the solid and liquid particles held in suspension.
2. Degree of contrast between an object and the background against which it is observed.
3. Position of the sun.
4. Physiological and physical factors relating to the observer, e.g. defective vision or acute vision.

In general, the assessment of daylight visibility for meteorological purposes is based on the observation of suitable objects at known distances.

Factors Affecting Visibility at Night

The distance at which a light can be seen at night depends mainly on five factors:

1. Brightness of the light.
2. Sensitivity of the observer's eyes.
3. Presence or absence of other bright lights in the field of view.
4. General level and illumination.
5. Transparency of the atmosphere.

For meteorological purposes, visibility reports at night should indicate the same degree of atmospheric transparency as they do by day, so, in determining visibility from observations of fixed lights, the effects of the first four factors should be reduced as far as is possible. Practical ways of doing this include the use of the Gold visibility meter and the use of lights of known candle-power at known distances.

The Gold Visibility Meter is a photometer fitted with a neutral filter which can be varied until the light is just visible.

Vertical Visibility

When the sky is obscured, that is when the clouds cannot be observed because of fog, sandstorm, duststorm, blowing snow or other obscuring phenomenon, or the cloud amount cannot be estimated, observers are required to measure or estimate the "vertical visibility" in place of cloud height.

The vertical visibility is defined by WMO as the vertical visual range into an obscuring medium. In the United Kingdom this definition is interpreted as the visual range of a dark object of moderate size viewed vertically upwards against a sky background in daylight.

The vertical visibility may be taken as the height above ground at which a pilot balloon, **if rising vertically**, would disappear from view in daylight.

Geographical Range

(Refer to Figure 40)

Geographical range is the maximum distance at which, in theory, a light can reach the observer.

It is limited only by:

1. Curvature of the earth.
2. Elevation of the light.
3. Height of eye of the observer.
4. Refraction of the atmosphere.

It follows that a light can only be seen at its geographical range if it has sufficient intensity (power) to penetrate the prevailing atmosphere and reach the observer.

The most convenient method for finding geographical range is to use one, or other, of the tables provided in either *Norie's Nautical Tables* (or equivalent) or the Admiralty Light Lists.

Different tables use slightly different formulae. In consequence, slightly different results may be obtained from different sets of tables.

Formula Used in Norie's Distance of the Sea Horizon Tables

In *Norie's Nautical Tables* the formula used to derive tabulated values for the distance of the sea

horizon is as follows:

$$\text{Distance of Sea Horizon} = 2{\cdot}095\sqrt{h}$$

where h = the observer's height of eye in metres.

Example 46

What is the distance of the sea horizon for an observer with height of eye 23 m?

$$\text{Distance of Sea Horizon} = 2{\cdot}095\sqrt{h}$$

H.E.	23	log	1·36173
	$\sqrt{23}$	,,	0·68086 (divide by 2)
	2·095	,,	0·32118
	10·05	,,	1·00204

Answer: Distance of sea horizon = 10·05 miles. (Check this answer by reference to Distance of Sea Horizon tables and note that the tabulated value is 10 miles.)

To Find Geographical Range by Inspection of Distance of Sea Horizon Tables

(Refer to Figure 40)

The method for finding geographical range by these tables is as follows:

Geographical Range (AB) = Distance of Sea Horizon from ship (BH)
+ Distance of Sea Horizon from light (AH)

This method often avoids the need for interpolation.

Example 47

(Refer to Figure 40 and Table 4)

At what distance would you expect to raise Start Point Gp. Fl. light from a vessel with Height of Eye 15 m? Use Distance of the Sea Horizon tables.

From the Chart or, preferably, Admiralty Light Lists:

Start Point Index No. 0228 Elevation 62 m
Nominal Range 25 miles

From Distance of Sea Horizon Tables:

H.E.	15 m	Distance of Sea Horizon	8·1 miles
Elevation	62 m	,, ,, ,, ,,	16·5 ,,
		Geographical Range	24·6 miles

Answer: Start Point Light would be raised at 24·6 miles.

To Find Geographical Range Using the Admiralty Light List (A.L.L.) Geographical Range Table or Extreme Range Tables

The Geographical Range Table contained in Admiralty Light Lists is similar to the Extreme Range Tables in *Norie's Nautical Tables*. It is a combined table which is entered with the observer's height of eye at the top of the table and the elevation of the light at the side.

Table 4.

DISTANCE OF THE SEA HORIZON

Height m	Height ft	Dist. mls	Height m	Height ft	Dist. Miles	Height m	Height ft	Dist Miles
			40	131	13.3	200	656	29.6
0.5	1.6	1.5	42	138	13.6	205	673	30.0
1.0	3	2.1	44	144	13.9	210	689	30.4
1.5	5	2.6	46	151	14.2	215	705	30.7
2.0	7	3.0	48	157	14.5	220	722	31.1
2.5	8	3.3	50	164	14.8	225	738	31.4
3.0	10	3.6	52	171	15.1	230	755	31.8
3.5	11	3.9	54	177	15.4	235	771	32.1
4.0	13	4.2	56	184	15.7	240	787	32.5
4.5	15	4.4	58	190	16.0	245	804	32.8
5.0	16	4.7	60	197	16.2	250	820	33.1
5.5	18	4.9	62	203	16.5	260	853	33.8
6.0	20	5.1	64	210	16.8	270	886	34.4
6.5	21	5.3	66	217	17.0	280	919	35.1
7.0	23	5.5	68	223	17.3	290	951	35.7
7.5	25	5.7	70	230	17.5	300	984	36.3
8.0	26	5.9	72	236	17.8	310	1017	36.9
8.5	28	6.1	74	243	18.0	320	1050	37.5
9.0	30	6.3	76	249	18.3	330	1083	38.1
9.5	31	6.5	78	256	18.5	340	1115	38.6
10.0	33	6.6	80	262	18.7	350	1148	39.2
11	36	6.9	82	269	19.0	360	1181	39.8
12	39	7.3	84	276	19.2	370	1214	40.3
13	43	7.6	86	282	19.4	380	1247	40.8
14	46	7.8	88	289	19.7	390	1280	41.4
15	49	8.1	90	295	19.9	400	1312	41.9
16	52	8.4	92	302	20.1	410	1345	42.4
17	56	8.6	94	308	20.3	420	1378	42.9
18	59	8.9	96	315	20.5	430	1411	43.4
19	62	9.1	98	322	20.7	440	1444	43.9
20	66	9.4	100	328	21.0	450	1476	44.4
21	69	9.6	105	344	21.5	460	1509	44.9
22	72	9.8	110	361	22.0	470	1542	45.4
23	75	10.0	115	377	22.5	480	1575	45.9
24	79	10.3	120	394	23.0	490	1608	46.4
25	82	10.5	125	410	23.4	500	1640	46.8
26	85	10.7	130	427	23.9	510	1673	47.3
27	89	10.9	135	443	24.3	520	1706	47.8
28	92	11.1	140	459	24.8	530	1739	48.2
29	95	11.3	145	476	25.2	540	1772	48.7
30	98	11.5	150	492	25.7	550	1804	49.1
31	102	11.7	155	509	26.1	560	1837	49.6
32	105	11.9	160	525	26.5	570	1870	50.0
33	108	12.0	165	541	26.9	580	1903	50.5
34	112	12.2	170	558	27.3	590	1936	50.9
35	115	12.4	175	574	27.7	600	1969	51.3
36	118	12.6	180	591	28.1	610	2001	51.7
37	121	12.7	185	607	28.5	620	2034	52.2
38	125	12.9	190	623	28.9	630	2067	52.6
39	128	13.1	195	640	29.3	640	2100	53.0
40	131	13.3	200	656	29.6	650	2133	53.4

eleration
start Pt.
Lt. Ho.
62m

observer's
Ht. of eye
15m

Where tabulated values do not exactly coincide with the required values, interpolation may be required. Where mental interpolation cannot be quickly carried out it is probably advisable to use Distance of the Sea Horizon Tables and avoid the need to interpolate, if possible.

Example 48
(Refer to Figure 40 and Table 5)

At what distance would you expect to raise Ile d'Ouessant (Ushant) Gp. Fl. light from a vessel with Height of Eye 12 m? Use the Geographical Range Table included in Admiralty Light Lists.

Ushant Index No. 1842 Elevation 70 m
Nominal Range 33 miles

From A.L.L. Geographical Range Table:

H.E. 12 m
Elevation 70 m } → 24 miles Geographical Range

Answer: Ushant would be raised at 24 miles.

Luminous Range

Luminous range is the maximum distance at which a light can be seen at a given moment in time.

It is determined by:

1. Intensity of the light.
2. Meteorological visibility prevailing at the time of observation.

In summary, meteorological visibility is defined as the greatest distance at which a black object of suitable size can be seen and recognised in normal daylight.

Luminous range takes no account of:

1. Elevation of the light.
2. Height of eye of the observer.
3. Curvature of the Earth.

Method for Finding Luminous Range

(Refer to Figure 41)

Luminous range is found from the Luminous Range Diagram, HD574, contained in the Admiralty Light Lists.

Refer to the figure and note:

1. Nominal Ranges on the upper, horizontal scale.
2. Intensity (in Candelas) on the lower, horizontal scale.
3. Luminous Ranges on the left hand, vertical scale.
4. Meteorological Visibility Curves for 0·2, 0·5, 1, 2, 5, 10, 20 miles and Perfect Visibility.

The diagram is entered with a known nominal range on the upper horizontal scale and the corresponding luminous range is found opposite the point of intersection of the vertical through nominal range and the appropriate visibility curve.

Table 5.

GEOGRAPHICAL RANGE TABLE

observers height of e 12m

Elevation in		Height of Eye of Observer in feet/metres																					
ft		3	7	10	13	16	20	23	26	30	33	39	46	52	59	66	72	79	85	92	98	115	131
	m	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30	35	40
		Range in Sea Miles																					
0	0	2·0	2·9	3·5	4·1	4·5	5·0	5·4	5·7	6·1	6·4	7·0	7·6	8·1	8·6	9·1	9·5	10·0	10·4	10·7	11·1	12·0	12·8
3	1	4·1	4·9	5·5	6·1	6·6	7·0	7·4	7·8	8·1	8·5	9·1	9·6	10·2	10·6	11·1	11·6	12·0	12·4	12·8	13·2	14·0	14·9
7	2	4·9	5·7	6·4	6·9	7·4	7·8	8·2	8·6	9·0	9·3	9·9	10·5	11·0	11·5	12·0	12·4	12·8	13·2	13·6	14·0	14·9	15·7
10	3	5·5	6·4	7·0	7·6	8·1	8·5	8·9	9·3	9·6	9·9	10·6	11·1	11·6	12·1	12·6	13·0	13·5	13·9	14·3	14·6	15·5	16·4
13	4	6·1	6·9	7·6	8·1	8·6	9·0	9·4	9·8	10·2	10·5	11·1	11·7	12·2	12·7	13·1	13·6	14·0	14·4	14·8	15·2	16·1	16·9
16	5	6·6	7·4	8·1	8·6	9·1	9·5	9·9	10·3	10·6	11·0	11·6	12·1	12·7	13·2	13·6	14·1	14·5	14·9	15·3	15·7	16·6	17·4
20	6	7·0	7·8	8·5	9·0	9·5	9·9	10·3	10·7	11·1	11·4	12·0	12·6	13·1	13·6	14·1	14·5	14·9	15·3	15·7	16·1	17·0	17·8
23	7	7·4	8·2	8·9	9·4	9·9	10·3	10·7	11·1	11·5	11·8	12·4	13·0	13·5	14·0	14·5	14·9	15·3	15·7	16·1	16·5	17·4	18·2
26	8	7·8	8·6	9·3	9·8	10·3	10·7	11·1	11·5	11·8	12·2	12·8	13·3	13·9	14·4	14·8	15·3	15·7	16·1	16·5	16·9	17·8	18·6
30	9	8·1	9·0	9·6	10·2	10·6	11·1	11·5	11·8	12·2	12·5	13·1	13·7	14·2	14·7	15·2	15·6	16·0	16·4	16·8	17·2	18·1	18·9
33	10	8·5	9·3	9·9	10·5	11·0	11·4	11·8	12·2	12·5	12·8	13·5	14·0	14·5	15·0	15·5	15·9	16·4	16·8	17·2	17·5	18·4	19·3
36	11	8·8	9·6	10·3	10·8	11·3	11·7	12·1	12·5	12·8	13·2	13·8	14·3	14·9	15·4	15·8	16·3	16·7	17·1	17·5	17·9	18·8	19·6
39	12	9·1	9·9	10·6	11·1	11·6	12·0	12·4	12·8	13·1	13·5	14·1	14·6	15·2	15·7	16·1	16·6	17·0	17·4	17·8	18·2	19·1	19·9
43	13	9·4	10·2	10·8	11·4	11·9	12·3	12·7	13·1	13·4	13·7	14·4	14·9	15·4	15·9	16·4	16·8	17·3	17·7	18·1	18·4	19·3	20·2
46	14	9·6	10·5	11·1	11·7	12·1	12·6	13·0	13·3	13·7	14·0	14·6	15·2	15·7	16·2	16·7	17·1	17·6	18·0	18·3	18·7	19·6	20·4
49	15	9·9	10·7	11·4	11·9	12·4	12·8	13·2	13·6	14·0	14·3	14·9	15·5	16·0	16·5	17·0	17·4	17·8	18·2	18·6	19·0	19·9	20·7
52	16	10·2	11·0	11·6	12·2	12·7	13·1	13·5	13·9	14·2	14·5	15·2	15·7	16·2	16·7	17·2	17·7	18·1	18·5	18·9	19·2	20·1	21·0
56	17	10·4	11·2	11·9	12·4	12·9	13·3	13·7	14·1	14·5	14·8	15·4	16·0	16·5	17·0	17·4	17·9	18·3	18·7	19·1	19·5	20·4	21·2
59	18	10·6	11·5	12·1	12·7	13·2	13·6	14·0	14·4	14·7	15·0	15·7	16·2	16·7	17·2	17·7	18·1	18·6	19·0	19·4	19·7	20·6	21·5
62	19	10·9	11·7	12·4	12·9	13·4	13·8	14·2	14·6	14·9	15·3	15·9	16·5	17·0	17·5	17·9	18·4	18·8	19·2	19·6	20·0	20·9	21·7
66	20	11·1	12·0	12·6	13·1	13·6	14·1	14·5	14·8	15·2	15·5	16·1	16·7	17·2	17·7	18·2	18·6	19·0	19·4	19·8	20·2	21·1	21·9
72	22	11·6	12·4	13·0	13·6	14·1	14·5	14·9	15·3	15·6	15·9	16·6	17·1	17·7	18·1	18·6	19·1	19·5	19·9	20·3	20·7	21·5	22·4
79	24	12·0	12·8	13·5	14·0	14·5	14·9	15·3	15·7	16·0	16·4	17·0	17·6	18·1	18·6	19·0	19·5	19·9	20·3	20·7	21·1	22·0	22·8
85	26	12·4	13·2	13·9	14·4	14·9	15·3	15·7	16·1	16·4	16·8	17·4	18·0	18·5	19·0	19·4	19·9	20·3	20·7	21·1	21·5	22·4	23·2
92	28	12·8	13·6	14·3	14·8	15·3	15·7	16·1	16·5	16·8	17·2	17·8	18·3	18·9	19·4	19·8	20·3	20·7	21·1	21·5	21·9	22·8	23·6
98	30	13·2	14·0	14·6	15·2	15·7	16·1	16·5	16·9	17·2	17·5	18·2	18·7	19·2	19·7	20·2	20·7	21·1	21·5	21·9	22·2	23·1	24·0
115	35	14·0	14·9	15·5	16·1	16·6	17·0	17·4	17·8	18·1	18·4	19·1	19·6	20·1	20·6	21·1	21·5	22·0	22·4	22·8	23·1	24·0	24·9
131	40	14·9	15·7	16·4	16·9	17·4	17·8	18·2	18·6	18·9	19·3	19·9	20·4	21·0	21·5	21·9	22·4	22·8	23·2	23·6	24·0	24·9	25·7
148	45	15·7	16·5	17·1	17·7	18·2	18·6	19·0	19·4	19·7	20·0	20·7	21·2	21·7	22·2	22·7	23·2	23·6	24·0	24·4	24·7	25·6	26·5
164	50	16·4	17·2	17·9	18·4	18·9	19·3	19·7	20·1	20·5	20·8	21·4	22·0	22·5	23·0	23·4	23·9	24·3	24·7	25·1	25·5	26·4	27·2
180	55	17·1	17·9	18·6	19·1	19·6	20·0	20·4	20·8	21·2	21·5	22·1	22·7	23·2	23·7	24·1	24·6	25·0	25·4	25·8	26·2	27·1	27·9
197	60	17·8	18·6	19·3	19·8	20·3	20·7	21·1	21·5	21·8	22·2	22·8	23·3	23·9	24·3	24·8	25·3	25·7	26·1	26·5	26·9	27·7	28·6
213	65	18·4	19·2	19·9	20·4	20·9	21·4	21·7	22·1	22·5	22·8	23·4	24·0	24·5	25·0	25·5	25·9	26·3	26·7	27·1	27·5	28·4	29·2
230	70	19·0	19·9	20·5	21·1	21·5	22·0	22·4	22·7	23·1	23·4	24·0	24·6	25·1	25·6	26·1	26·5	26·9	27·4	27·7	28·1	29·0	29·8
246	75	19·6	20·5	21·1	21·7	22·1	22·6	23·0	23·3	23·7	24·0	24·6	25·2	25·7	26·2	26·7	27·1	27·5	27·9	28·3	28·7	29·6	30·4
262	80	20·2	21·0	21·7	22·2	22·7	23·1	23·5	23·9	24·3	24·6	25·2	25·8	26·3	26·8	27·3	27·7	28·1	28·5	28·9	29·3	30·2	31·0
279	85	20·8	21·6	22·2	22·8	23·3	23·7	24·1	24·5	24·8	25·1	25·8	26·3	26·9	27·3	27·8	28·3	28·7	29·1	29·5	29·9	30·7	31·6
295	90	21·3	22·1	22·8	23·3	23·8	24·2	24·6	25·0	25·4	25·7	26·3	26·9	27·4	27·9	28·4	28·8	29·2	29·6	30·0	30·4	31·3	32·1
312	95	21·8	22·7	23·3	23·9	24·3	24·8	25·2	25·5	25·9	26·2	26·8	27·4	27·9	28·4	28·9	29·3	29·7	30·1	30·5	30·9	31·8	32·6
328	100	22·3	23·2	23·8	24·4	24·9	25·3	25·7	26·1	26·4	26·7	27·3	27·9	28·4	28·9	29·4	29·8	30·3	30·7	31·1	31·4	32·3	33·2
361	110	23·3	24·2	24·8	25·4	25·8	26·3	26·7	27·0	27·4	27·7	28·3	28·9	29·4	29·9	30·4	30·8	31·3	31·7	32·1	32·4	33·3	34·1
394	120	24·3	25·1	25·8	26·3	26·8	27·2	27·6	28·0	28·3	28·7	29·3	29·8	30·4	30·9	31·3	31·8	32·2	32·6	33·0	33·4	34·3	35·1
427	130	25·2	26·0	26·7	27·2	27·7	28·1	28·5	28·9	29·2	29·6	30·2	30·8	31·3	31·8	32·2	32·7	33·1	33·5	33·9	34·3	35·2	36·0
459	140	26·1	26·9	27·6	28·1	28·6	29·0	29·4	29·8	30·1	30·5	31·1	31·6	32·2	32·6	33·1	33·6	34·0	34·4	34·8	35·2	36·0	36·9
492	150	26·9	27·7	28·4	28·9	29·4	29·9	30·2	30·6	31·0	31·3	31·9	32·5	33·0	33·5	34·0	34·4	34·8	35·2	35·6	36·0	36·9	37·7
525	160	27·7	28·6	29·2	29·8	30·2	30·7	31·1	31·4	31·8	32·1	32·7	33·3	33·8	34·3	34·8	35·2	35·6	36·0	36·4	36·8	37·7	38·5
558	170	28·5	29·4	30·0	30·5	31·0	31·5	31·9	32·2	32·6	32·9	33·5	34·1	34·6	35·1	35·6	36·0	36·4	36·8	37·2	37·6	38·5	39·3
591	180	29·3	30·1	30·8	31·3	31·8	32·2	32·6	33·0	33·3	33·7	34·3	34·9	35·4	35·9	36·3	36·8	37·2	37·6	38·0	38·4	39·3	40·1
623	190	30·0	30·9	31·5	32·1	32·5	33·0	33·4	33·7	34·1	34·4	35·0	35·6	36·1	36·6	37·1	37·5	37·9	38·4	38·7	39·1	40·0	40·8
656	200	30·8	31·6	32·2	32·8	33·3	33·7	34·1	34·5	34·8	35·1	35·8	36·3	36·8	37·3	37·8	38·3	38·7	39·1	39·5	39·8	40·7	41·6
722	220	32·2	33·0	33·6	34·2	34·7	35·1	35·5	35·9	36·2	36·5	37·2	37·7	38·3	38·7	39·2	39·7	40·1	40·5	40·9	41·4	42·1	43·0
787	240	33·5	34·3	35·0	35·5	36·0	36·4	36·8	37·2	37·6	37·9	38·5	39·1	39·6	40·1	40·4	41·0	41·4	41·8	42·2	42·6	43·5	44·3
853	260	34·8	35·6	36·3	36·8	37·3	37·7	38·1	38·5	38·8	39·2	39·8	40·4	40·9	41·4	41·8	42·3	42·7	43·1	43·5	43·9	44·8	45·6
919	280	36·0	36·9	37·5	38·0	38·5	39·0	39·4	39·7	40·1	40·4	41·0	41·6	42·1	42·6	43·1	43·5	43·9	44·3	44·7	45·1	46·0	46·8
984	300	37·2	38·1	38·7	39·2	39·7	40·2	40·6	40·9	41·3	41·6	42·2	42·8	43·3	43·8	44·3	44·7	45·1	45·5	45·9	46·3	47·2	48·0
1050	320	38·4	39·2	39·9	40·4	40·9	41·3	41·7	42·1	42·4	42·8	43·4	43·9	44·5	45·0	45·4	45·9	46·3	46·7	47·1	47·5	48·3	49·2
1115	340	39·5	40·3	41·0	41·5	42·0	42·4	42·8	43·2	43·5	43·9	44·5	45·1	45·6	46·1	46·5	47·0	47·4	47·8	48·2	48·6	49·5	50·3
1181	360	40·6	41·4	42·1	42·6	43·1	43·5	43·9	44·3	44·6	45·0	45·6	46·1	46·7	47·2	47·6	48·1	48·5	48·9	49·3	49·7	50·6	51·4
1247	380	41·6	42·5	43·1	43·7	44·1	44·6	45·0	45·3	45·7	46·0	46·6	47·2	47·7	48·2	48·7	49·1	49·5	50·0	50·3	50·7	51·6	52·4
1312	400	42·7	43·5	44·1	44·7	45·2	45·6	46·0	46·4	46·7	47·0	47·7	48·2	48·7	49·2	49·7	50·1	50·6	51·0	51·4	51·7	52·6	53·5

elevation Ushant Lt. Ho. 70m

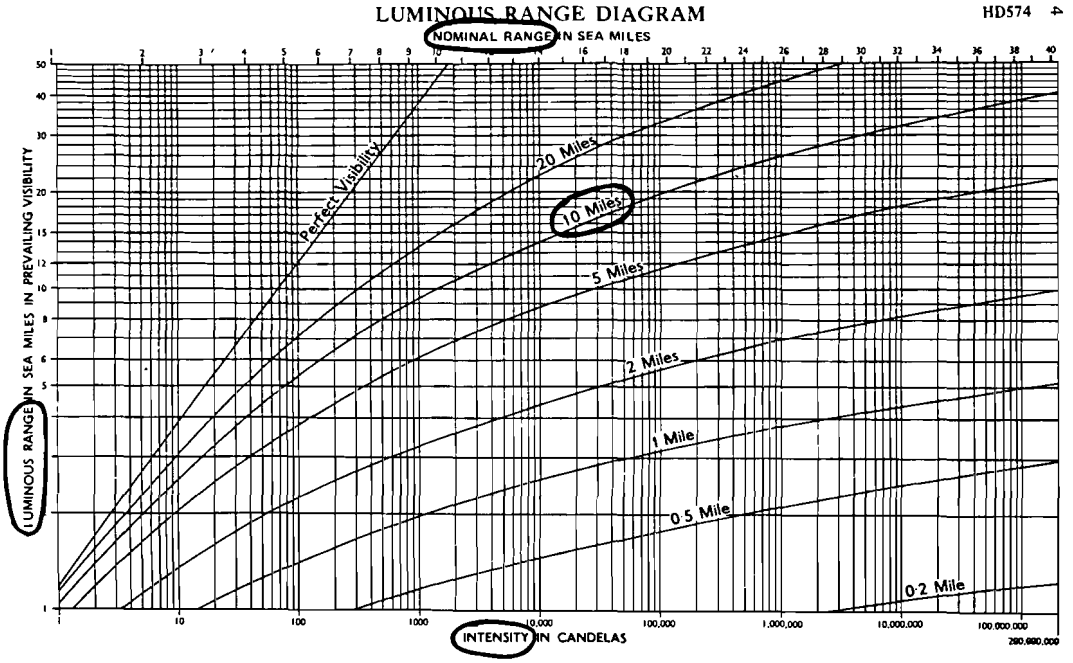


Figure 41. Luminous Range Diagram, HD574.

Nominal Range

(Refer to Figure 42)

Nominal range is the luminous range when meteorological visibility is 10 sea miles.

In other words, a light of nominal range 10 miles will be sighted at 10 miles when the meteorological visibility is 10 miles, and a light of nominal range 20 miles will be sighted at 20 miles.

A sea mile is the arc of the earth's surface subtended by an angle of 1′ at the centre of the earth in the vicinity of the chosen position—whereas a nautical mile is a precisely defined quantity.

Nominal range has now been adopted in many countries and is simply a special case of luminous range.

To Find the "Sighting" Range in Reduced Visibility

As previously explained, the Luminous Range is found by entering the Luminous Range Diagram with a known nominal range and meteorological visibility.

But the light will only be sighted if the observer's height of eye and the light's elevation are sufficient to ensure that the geographical range is at least equal to (and, preferably greater than) the luminous range.

We here introduce a fourth term, "Sighting Range", to define that range which has taken into account of both Luminous and Geographical Ranges. When working out the likely range at which a light will be sighted both Luminous and Geographical Ranges should be considered. A modern seagoing vessel will invariably have ample height of eye and the Luminous and Sighting Ranges be the same, nevertheless, consideration of the Geographical Range is an important point of principle.

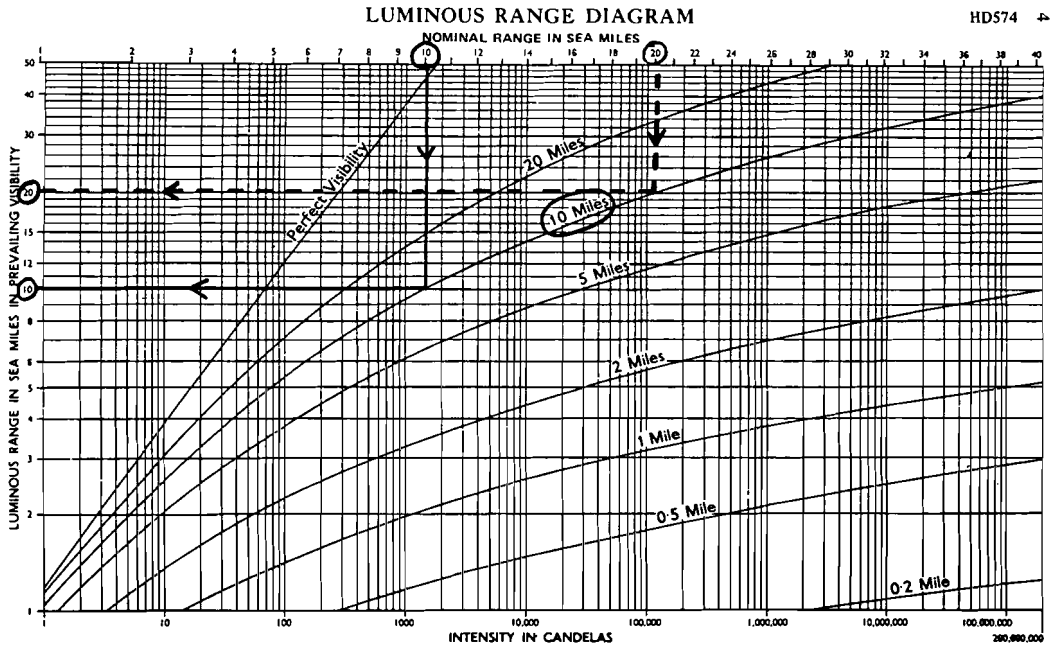


Figure 42. Nominal Range equals Luminous Range when Meteorological Visibility is 10 miles.

Example 49

(Refer to Figure 43)

At what distance would you first sight Start Point Gp. Fl. light in forecast Meteorological Visibility of 2 miles? H.E. 10 m.

From Chart or, preferably, Admiralty Light Lists:

Start Point Index No. 0228 Elevation 62 m
Nominal Range 25 miles

From Luminous Range Diagram:

Nominal Range 25 miles
Meteorological Visibility Curve 2 miles
→ Luminous Range 6·8 miles

From Geographical Range Table:

H.E. 10 m
Elevation 62 m
→ Geographical Range 22·5 miles (approximately)

Answer: Start Point Light would be sighted at approximately 6·8 miles in Meteorological Visibility of 2 miles.

Estimating Meteorological Visibility Using the Luminous Range Diagram

In the previous example we used nominal range and the estimated meteorological visibility to find the luminous or sighting range. In the next example we assume that a radar range is obtained at the time the light is sighted visually. Nominal range (from the chart) and radar range (which at first sighting corresponds to Luminous Range) are used to enter the Luminous Range Diagram in order to find the prevailing Meteorological Visibility.

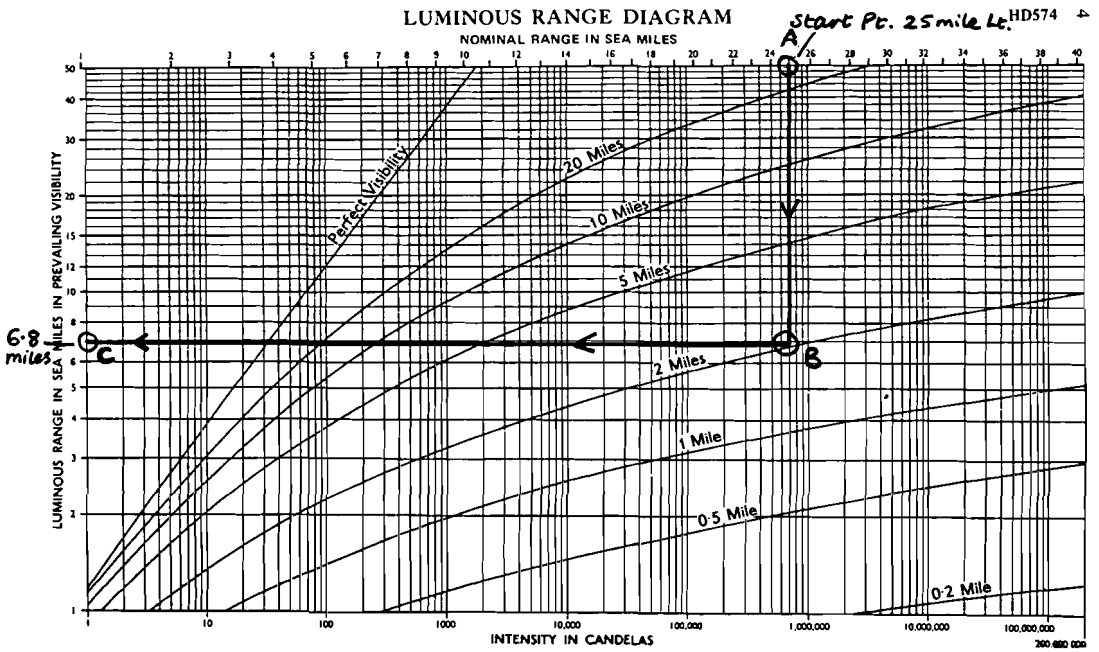


Figure 43. Finding Luminous Range for a Known Nominal Range.

Example 50

(Refer to Figure 44)

Casquets Gp. Fl. light is first sighted visually at a radar range of 16 miles. What is the estimated Meteorological Visibility?

From Chart or, preferably, Admiralty Light Lists:

Casquets Light Elevation 37 m
Nominal Range 28 miles

From Luminous Range Diagram:

Nominal Range 28 miles
Luminous Range 16 „ } → Meteorological Visibility 5 miles

Answer: Casquets Light sighted at 16 miles indicates that the Meteorological Visibility is approximately 5 miles.

Relationship Between Luminous Range and Meteorological Visibility

(Refer to Figure 45)

In the figure, line (AB) is drawn through co-ordinates of equal value of Luminous Range and Meteorological Visibility, parallel to the "Perfect Visibility" curve.

Intersections to the Left of Line 'AB':

Luminous Range < Estimated Meteorological Visibility

Intersections to the Right of Line 'AB':

Luminous Range > Estimated Meteorological Visibility

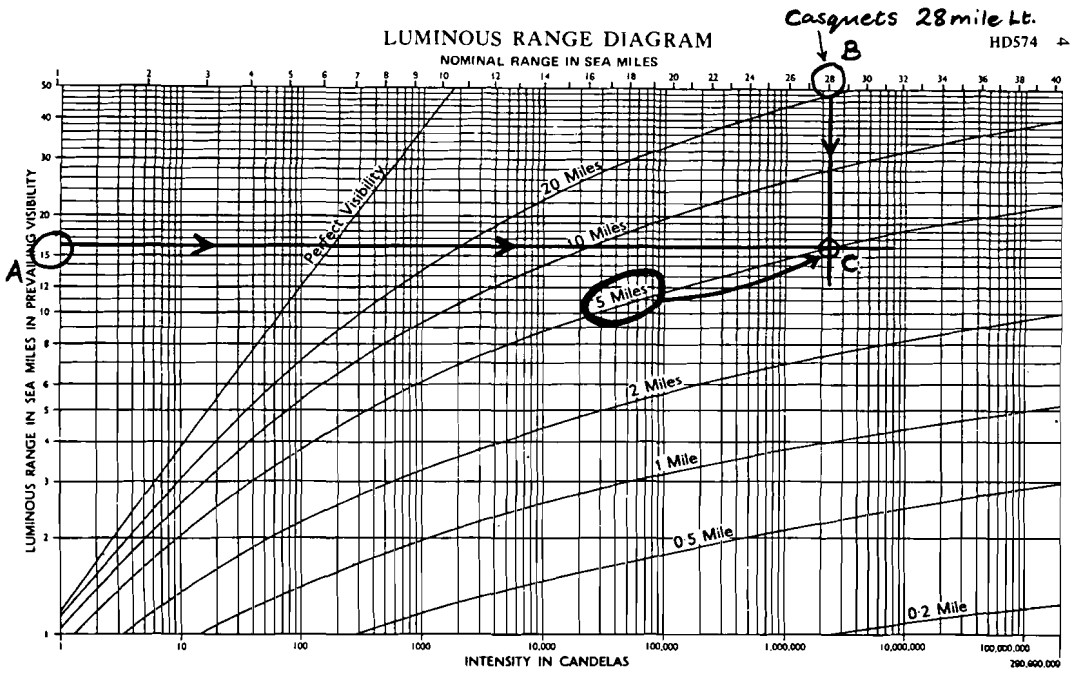


Figure 44. Finding the Estimated Meteorological Visibility after Visual Sighting of a Light at a Known Radar Range.

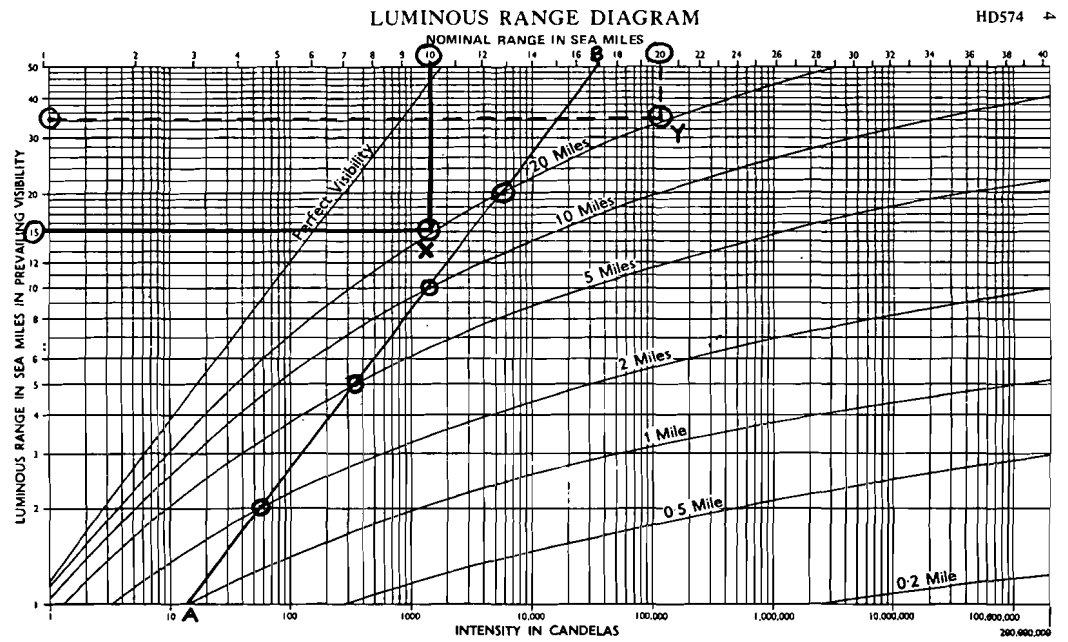


Figure 45. Relationship between Luminous Range and Meteorological Visibility.

Luminous Range Greater than, and Smaller than Geographical Range

Depending on the meteorological visibility prevailing, a light's luminous range can be greater than, or smaller than, its geographical range—this is demonstrated in the following example.

Example 51

(Use any Luminous Range Diagram)

La Corbiere Iso. W. Light has a charted range of 18 miles. Reference to the Admiralty Light List gives Elevation 36 m. Observer's Height of Eye 16 m.

Find

(a) Geographical Range.
(b) Luminous Range in Meteorological Visibility 20 miles.
(c) ,, ,, ,, ,, 1 mile.

(a) H.E. 16 m Distance of Sea Horizon 8·4 miles
Elevation 36 m ,, ,, ,, ,, 12·6 ,,
Geographical Range 21·0 miles

(b) From Luminous Range Diagram:

Nominal Range 18 miles
Meteorological Visibility Curve 20 ,, } → Luminous Range 30·0 miles

(c) From Luminous Range Diagram:

Nominal Range 18 miles
Meteorological Visibility Curve 1 ,, } → Luminous Range 3·0 miles

Answer: (a) Geographical Range 21 miles
(b) Luminous Range 30 ,,
(c) ,, ,, 3 ,,

Background Lighting and Reduction to Nominal Range

In previous examples we considered the effect of reduced visibility on the range at which a light is sighted. Another factor is background lighting.

Background lighting results in an effective reduction to a light's intensity and hence a reduction to its nominal range and sighting range.

Minor background lighting reduces intensity by approximately one tenth, and major background lighting by one hundredth.

Example 52

(Refer to Figure 46)

A vessel is steering 090°T heading towards the light vessel off Worms Head. At what distance would its light be first sighted:

(a) Assuming NO Background Lighting from Swansea
(c) ,, MINOR ,, ,, ,, ,,
(c) ,, MAJOR ,, ,, ,, ,,

Estimated Meteorological Visibility was 5 miles.

From the Chart or Admiralty Light Lists: Nominal Range 26 miles.

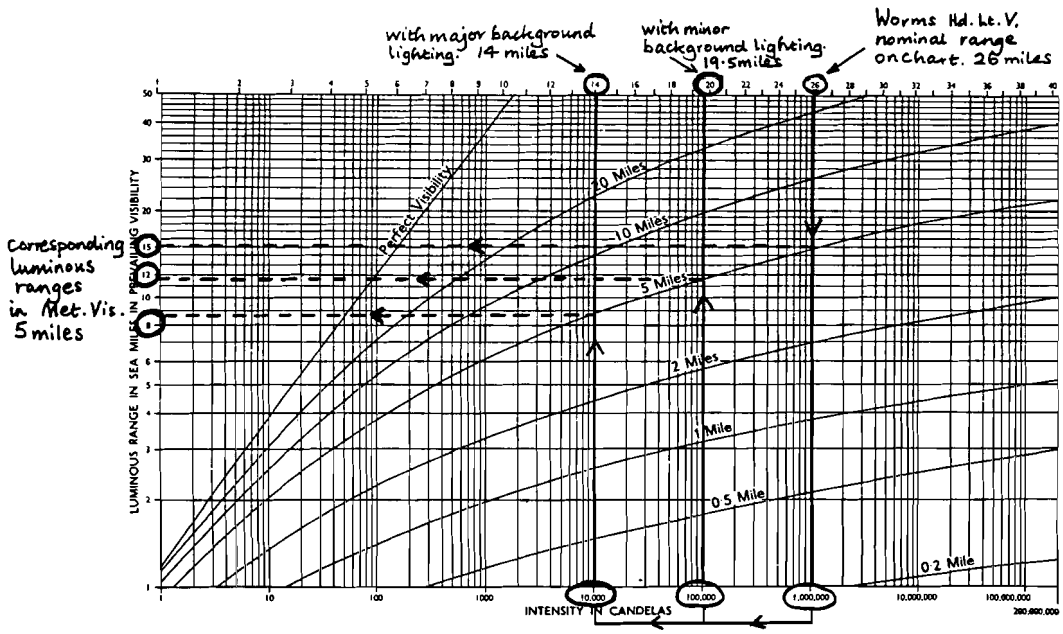


Figure 46. The Effect of Background Lighting on Range.

From Luminous Range Diagram:

Nominal Range 26 miles → Intensity 1,000,000 candelas

(a)

Nominal Range 26 miles
Meteorological Visibility 5 „ } → Luminous Range 15 miles

(b)

Minor Background Lighting divide intensity by 10. $\frac{1,000,000}{10} = 100,000$

Intensity 100,000 candelas
Meteorological Visibility 5 miles } → Luminous Range 11·5 miles

N.B.—Intensity 100,000 candelas corresponds to a Nominal Range of 19·5 miles and the Luminous Range Diagram could have been entered with Nominal Range 19·5 and Meteorological Visibility 5 miles to give the same result.

(c)

Major Background Lighting divide intensity by 100. $\frac{1,000,000}{100} = 10,000$

Intensity 10,000 candelas
Meteorological Visibility 5 miles } → Luminous Range 8·8 miles

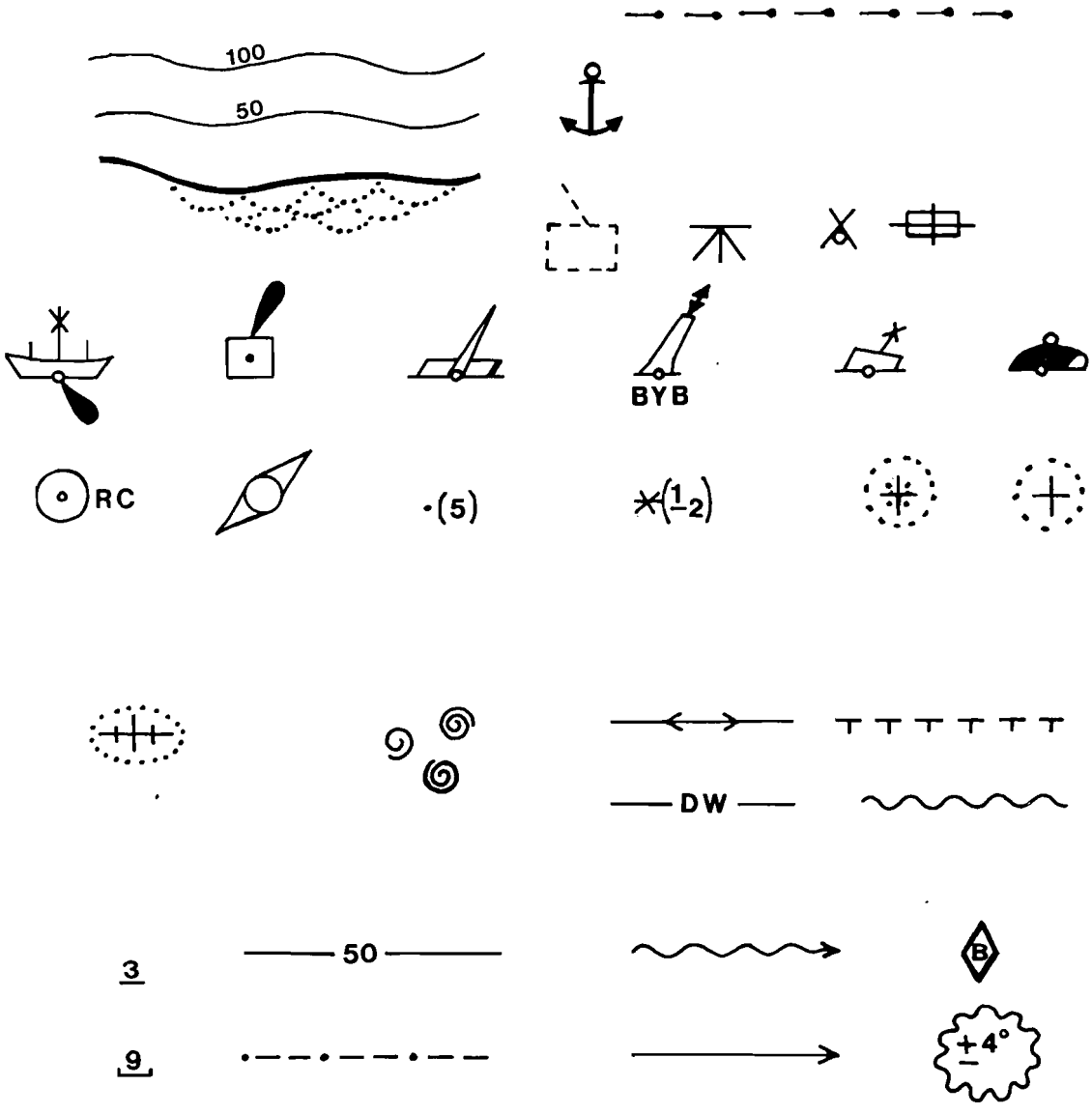
N.B.—Intensity 10,000 candelas corresponds to a Nominal Range of 14 miles and the Luminous Range Diagram could have been entered with Nominal Range 14 and Meteorological Visibility 5 miles to give the same result.

Answer: (a) Light sighted at 15 miles with NO Background Lighting
(b) „ „ 11·5 „ „ Minor „ „
(c) „ „ 8·8 „ „ Major „ „

Questions

The following chartwork questions can be answered by reference to the preceding text pages.

1. What is a chart?
2. In which publication would you find details of the symbols and abbreviations used on a chart? List the topic headings in this publication and identify the symbols and abbreviations in Figure 47.
3. A chart has a natural scale of 1:36,000—what is meant by this statement?
4. Charts can be divided into five main categories. What are these categories?
5. What are the features of a Mercator chart?
6. What are the features of a Gnomonic chart?
7. What is a Plan chart?
8. Why are charts liable to distortion? What practical steps can be taken to minimise this effect?
9. Discuss chart correction and list the publications used.
10. List ten examples of information included on a chart.
11. What specific points should be checked when taking out a new chart from the chart drawer?
12. It is never good policy to have two charts on the chart table at the same time—discuss this statement.
13. What instruments are used for plotting? State the purpose of each.
14. What precautions should be taken when measuring distance on a chart?
15. Parallel rulers can be used in conjunction with the meridian to lay off courses and bearings. Sketch the relative positions of the parallel ruler and meridian when laying off a course of (a) 090°T, (b) 180°T, (c) 225°T and (d) 045°T.
16. Discuss the use of cross bearings.
17. What is a "cocked hat"? What position should be assumed when plotted cross bearings result in a "cocked hat"?
18. What is the best method for fixing position by radar? Give reasons.
19. Define observed position, DR position, Sea position and EP.
20. Define course, heading and course to steer.
21. Define wind direction, leeway and leeway angle.
22. Define set, rate and drift.
23. Discuss the effect on a vessel of (a) a N'ly wind, and (b) a N'ly current.
24. Define track and track angle.
25. Define water track, ground track and track made good.
26. Give three examples of relative bearings.
27. Define "beam bearing" and "beam distance off".
28. Explain the difference between a current and tidal stream.
29. Explain the difference between an overfall, eddy and race.
30. Where would you find information relating to tidal streams?
31. What factors influence the reliability of tidal stream information?
32. What is a running fix? In what circumstances might it be used?
33. Discuss the principle of "doubling the angle on the bow" and make a scale drawing to illustrate your answer.
34. Why is the "four point bearing" sometimes used in preference to doubling some other angle on the bow?



PA, *PD*, *Wk*, MSL, MHHW, LAT, CG, FS, *f S*, *syCy*, *c Sn*, *bk Co*, *Si/P*, *S Cy*.

Describe the following lights:

(a) Oc, Iso, LFl, Gp Fl(3), Fl(2), VQkFl, IVQ.

(b) Fl(4) 20 sec 43 m 29M & FR 19 m 13M Dia.

(c) Gp Occ (1+2) WRG 15, 12, 11M Siren Mo (AE).

Figure 47.

35. What is a "special angle"? Give examples.
36. Define magnetic variation and deviation.
37. Define compass error.
38. In what order should variation and deviation be applied when working from a true course to a compass course?
39. In what order should variation and deviation be applied when working from a compass course to a true course?
40. State (a) how you would find the deviation for the ship's head and (b) where such information might be recorded.
41. Where can information relating to magnetic variation be found?
42. Comment on the statement that variation changes with change of time and location.
43. What is a transit bearing? How can it be of use?
44. What are the general rules for observing reliable transits?
45. What is gyro error? How is it named?
46. A navigator may sometimes alter course onto a transferred position line, why is this?
47. Define "log distance to steam".
48. Explain, with examples, what is meant by ETA.
49. Why is it sometimes necessary to transfer a position circle?
50. How can horizontal angles be of use? How are they obtained?
51. What is a station pointer? What other alternatives can be used?
52. Explain use of the horizontal danger angle.
53. What is circular error? How can it be avoided?
54. What use can be made of vertical sextant angles? What corrections should be applied?
55. What use can be made of a vertical danger angle?
56. In what format is a "distress position" transmitted? Give an example.
57. Discuss the use of soundings when attempting to fix position.
58. How would you find the vessel's ground track from three bearings of a single object?
59. What is (a) a leading line (b) a clearing line and (c) a clearing bearing.
60. How would you "bring up" a point of land 40° on the starboard bow at a distance of 12 miles? To aid explanation, make a sketch.
61. What is a ship's "radius of action"? Give two examples.
62. How are DF bearings measured? Give three examples.
63. What track is followed by an incoming DF signal?
64. Explain convergency and half convergency.
65. How would you find the value of half convergency? State one other method.
66. Make a sketch for (a) the Northern hemisphere and (b) the Southern hemisphere to show why half convergency corrections are named (+), (−) and nil.
67. What is the purpose of radiobeacon grouping?
68. On a chart, navigational lights sometimes have arcs drawn around them. What information is provided by such arcs?
69. Explain the terms "loom" and "dipping distance".
70. What are the general conditions necessary in order to sight a light?
71. List the three ranges referred to in Light Lists.
72. Define meteorological visibility.
73. What factors affect daylight visibility?
74. What factors affect visibility at night?
75. Define geographical range and state how it may be found.

76. Define luminous range and state how it may be found.
77. Define nominal range and state how it may be found.
78. List the arguments required to enter tables in order to find the three ranges.
79. How could you estimate meteorological visibility using the Luminous Range Diagram?
80. Explain the effect of background lighting on the nominal range of a light.

Exercises

Exercise 1

Subject: Laying off Courses, Beam Bearings and Nearest Approach.
Use: Chart No. 5053 English Channel Western & Central Portions.

1. What is the true course and distance from: The Nab Tr. to: Tidal Diamond ◇L.
2. What is the true course and distance from: Tidal Diamond ◇L to: The Shambles Light Vessel.
3. What is the true course and distance from: The Shambles Light Vessel to: Position 49° 00′ N 4° 00′ W.
4. What is the true course from: E.P. 49° 00′ N 4° 00′ W to pass 10 miles off Les Hanois Gp. Flashing Light (whilst en route for the Casquets).
   What is the Beam Bearing of Les Hanois?
5. On Course 050°T Casquets Gp. Flashing Light is observed abeam to starboard at a Radar Distance of 5 miles.
   Plot the beam position and lay off a course to pass 5 miles off the Traffic Separation Zone Buoy SW of Beachy Head.
   (a) What is the true course and distance to the buoy? (b) What is the nearest approach to Casquets Light?

Answers

1. Course 234°T 40·5 miles.
2. Course 306°T 25·5 miles.
3. Course 215°T 112 miles.
4. Course 053°T 57 miles, Beam Bearing 143°T.
5. (a) Course 070°T Distance 103 miles, (b) Nearest approach 4·9 miles.

Exercise 2

Subject: Plotting Positions and Courses and Measuring Distance.
Use: Chart No. 5053 English Channel Western and Central Portions.

1. At 1000 Start Point Light House bore 250°T and Berry Head Light House bore 320°T.
   What is the Latitude and Longitude of this position?
2. At 2000 Cape de la Hague Light House bore 230°T and Cape de la Barfleur Light House bore 120°T.
   What is the Latitude and Longitude of this position?
3. At 1800 Casquets Light bore 130°T at a radar range of 15 miles.
   What is the Latitude and Longitude of this position?
4. Find the true course and distance from: 50° 00′ N 4° 00′ W to: 49° 00′ N 3° 00′ W.
5. Find the true course and distance from: a position where Bishops Rock Light House bore 270°T at a Radar Range of 10 miles to: a position where Ile d'Ouessant Light House bore 116°T at a radar range of 13·8 miles.

Answers

1. 50° 18′ N 3° 20·5′ W.
2. 49° 51·3′ N 1° 42·8′ W.
3. 49° 52·8′ N 2° 40·5′ W.
4. 147°T 71·5 miles.
5. 159½°T 84·5 miles.

Exercise 3

Subject: Courses and distances.
Use: Variation for the current year and Chart 5053.

Plot the following positions and find the distances and courses (True and Magnetic).

1. *A* in 49° 50′ N 3° 30′ W, to *B* in 48° 34′ N 5° 52′ W.
2. *C* in 48° 41′ N 5° 41′ W, to *D* in 49° 57′ N 6° 03′ W thence to *E*, 10 miles 270°T from Lundy Island North Light.
3. *F* in 48° 29′ N 6° 35′ W, to *G* with Start Point bearing 000°T at 8 miles, thence to pass 7 miles off the Horn buoy off Selsey Bill.
4. *K* 13 miles 164°T from Eddystone Light to *L*, 10·5 miles 180°T from Wolf Rock Light, thence to *M* in 50° 15′ N 6° 00′ W, thence to *N* in 50° 55′ N 4° 52′ W. Find the Latitude and Longitude of the positions *K* and *L*.
5. *P* with Bishop Rock Light bearing 000°T on the 100 metre line to *Q*, with Les Hanois Light bearing 080°T in 62 metres.

Answers

	True Course	Distance (miles)
1.	231°T	120
2.	349°T	78
	031°T	93
3.	051°T	150
	077°T	118½
4.	259°T	65
	346°T	29½
	048°T	59

Position *K*, 49° 58½′ N 4° 11′ W; Position *L*, 49° 46½′ N 5° 49′ W.

5.	096°T	137½

Exercise 4

Subject: Cross Bearings.
Use: Variation 7°W, where appropriate, and Chart 5053.

Given the following cross bearings, find the Latitude and Longitude of the ship:

1. Ushant NW Light bore 177°T and Vierge Island Light bore 096°T.
2. Vierge Island Light bore 183°T and Ile de Bas Light bore 119°T.
3. Lizard Light bore 053°M and Wolf Rock Light bore 319°M.
4. Eddystone Light bore 303°T and Start Point Light bore 035°M.
5. Seven Stones Light bore 180°T and Trevose Head Light bore 090°T.
6. Bishop Rock Light bore 182°T, Round Island Light bore 150°T and Seven Stones Light vessel bore 101°T.

Answers

1. 48° 40½′ N 5° 08½′ W.
2. 48° 56′ N 4° 32½′ W.
3. 49° 45½′ N 5° 31′ W.
4. 50° 00′ N 3° 50′ W.
5. 50° 33′ N 6° 05½′ W.
6. 50° 06½′ N 6° 27′ W.

Exercise 5

Subject: Counteracting the Current and Radar Fix.
Use: Chart 5053.

In the following examples *A* indicates the initial position and *B* the final position.

1. Find the course to steer and the ground speed from *A*, with Lundy Island North Light bearing 136°T at 10 miles, to *B* with Round Island Light bearing 136°T at 10 miles. Current is setting 279°T at 3 knots. Log speed 16 knots.
2. Find the course to steer to counteract the current, the ground speed and the total distance to steam to reach *B*, from *A*, 12 miles 180°T from Beachy Head to *B* 15 miles 299°T from Casquets Light. Current setting 264°T at 2½ knots. Log speed 10½ knots.
3. From position *A* by station pointer Ushant NW Light, Gp. Fl. (2), 35° Pierres Noires Red Light 42° Ile de Sein Light, Gp. Fl. (4) to *B* with Wolf Rock bearing 016°T × 11·3. Current 221°T at 2 knots. Find the course to steer and the speed to steam to reach *B* in 9 hours.
4. From the following information find the course to steer to pass 10 miles off Anvil Pt.

0600	Selsey Bill radar range	14·7 miles	Speed 18 knots.
	Nab Tr	10·0 miles	Tidal Stream ◇M◇ 4 and 5 hrs after HW
	St Catherines Pt	14·0 miles	Gyro Error 1° Low.

5. A vessel steaming at reduced speed, in restricted visibility, to Le Havre obtains the following radar ranges:

1000	Alderney NE tip	Range 13·0 miles
	C. de la Hague Light House	10·0 ,,
	Cap Levi	22·0 ,,

From this position the vessel is to make good a course to a position 8 miles due North of Pte de Barfleur.

Speed 8 knots. Tidal Stream 060°T at 2 knots. Gyro error 3°H. Variation 7°W. Find:

(a) The course to steer Gyro and Magnetic.
(b) The track to make good.
(c) The ground speed.
(d) ETA at the position North of Barfleur.

Answers

1. Course to steer 211°T. Ground speed 17·1 knots.
2. Course to steer 246°T. Ground speed 12·9 knots. Distance to steam 99 miles.
3. Course to steer 357°T. Speed 11·5 knots.
4. Ground track 265°T. Course to steer 263°T 262°G. Ground speed 21·25 knots.
5. (a) 108°T 111°G 115°M.
   (b) 099°T.
   (c) 28·5/3 → Speed 9·5 knots.
   (d) 27/9·5 → ETA 1251.

Exercise 6

Subject: Tidal Stream Data on the Chart.
Use: Chart No. 5053 English Channel Western and Central Portions and ATT Extracts supplied in the rear Appendix.

1. Tidal Stream Data is given for selected positions on the Chart. How are these positions marked?
2. Tidal Streams predictions for a particular position are given every hour from 6 hours before High Water (HW) at a Standard Port to 6 hours after HW. To which Standard Port HW do the hourly intervals relate?
3. Refer to Tidal Diamond Ⓖ off Start Point and the Tidal Stream Data at the top of the Chart. What information is given for HW at Ⓖ?
4. What information is given for 2 hours after HW at Ⓖ?
5. What information is given for 4 hours after HW at Ⓜ in mid-Channel opposite the Isle of Wight?
6. What is Range of Tide?
7. Refer to the box included on the Tidal Curve for Dover (see ATT extracts at rear). What is the Mean Spring and Mean Neap Range at Dover?
8. What is the Predicted Range at Dover?
   (a) On the evening of 16th October. (b) PM on 24th December.
   (b) PM on 20th August. (d) In the forenoon of 28th August.
   (e) On the evening of 7th November.
9. What Tidal Stream Rate should be used for the ranges found at (a), (b), (c), (d) and (e) in Question 8?
10. What direction and Tidal Stream Rate should be used off the West Coast of Cornwall?
    (a) Shortly after AM HW on 13th May.
    (b) At 0920 on 20th November.
    Show all calculations.

N.B.—Find the Predicted Range for the day and compare with the Mean Spring and Neap Ranges.

Answers

1. By Tidal Diamonds, e.g. Ⓖ.
2. Dover.
3. Tidal Stream Direction 225°T
   Spring Rate 0·6 knots
   Neap Rate 0·3 knots
4. 224°T
   1·7 knots
   0·8 knots
5. Tidal Stream Direction 250°T
   Spring Rate 3·6 knots
   Neap Rate 1·8 knots
6. HW height − LW height = Predicted Range.
7. Mean Spring Range 5·9 m. Mean Neap Range 3·3 m.
8.

	16 Oct	24 Dec	20 Aug	28 Aug	7 Nov
HW	6·6	5·3	6·8	5·1	5·9
LW	0·7	2·0	0·5	2·5	7·1
Range	(a) 5·9	(b) 3·3	(c) 6·3	(d) 2·6	(e) 4·2

9. (a) Spring Rate (b) Neap Rate
   (c) Spring Rate (Range greater than Mean Spring Range—Use Spring Rate or Extrapolate).
   (d) Neap Rate (Range less than Mean Neap Range—Use Neap Rate or Extrapolate).
   (e) Interpolate (Range between Mean Neap and Spring Range).
10. (a) Use ◇B◇ 235°T, 0·75 knots.

13 May

0133	5·9	Mean Spring Range	5·9	Predicted	4·6
0905	1·3	Mean Neap Range	3·3		3·3
Range	4·6		~2·6		~1·3

Predicted range lies $\frac{1\cdot3}{2\cdot6}$ exactly half way between Mean Spring and Neap Ranges.

HW Direction 235°T. Rate 0·75 knots (Spring 1·0, Neap 0·5).

(b) 20 Nov, 279°T, 0·2 knots

1321	6·1	
0830	1·5	
Range	4·6	lies exactly half way between Mean Spring and Neap Ranges as in (a).
HW	1321	
Time	0920	
	4 hours Before HW	

At ◇B◇—4 hours Before HW. Tidal Stream Direction 279°T. Rate: Spring 0·3 knots; Neap 0·1 knots.

Exercise 7

Subject: Running Fix.
Use: Chart 5053.

1. Cape d'Antifer bore 185°T. Ship steamed 234°T 11 miles by Log and it then bore 131°T. Find the position of the ship at both bearings.
2. La Corbiere WR Light bore 032°T. Ship steamed 327°T for 2 hours at 7 knots, and it then bore 100°T. Find the position at both bearings.
3. Eddystone Light bore 318°T and after steaming for 2 hours at 9·5 knots on 254°T it bore 032°T. Find the position on the 2nd bearing.
4. St. Govens Shoal Light vessel bore 049°T, and 1 h 40 m later it bore 314°T. Ship steamed 099°T at 12 knots during the interval. Find the position on the 2nd bearing.
5. At 0115 St. Catherines Point Light bore 042°T, and at 0245 it bore 314°T. Course 074°T, speed 10 knots. Find the position at both bearings.

Answers

	1st Bearing	2nd Bearing
1.	49° 54′ N 00° 11½′ E	49° 47½′ N 00° 02′ W
2.	49° 01′ N 2° 24′ W	49° 13′ N 2° 35′ W
3.	Not required.	49° 56′ N 4° 30′ W
4.	Not required.	51° 20′ N 4° 42½′ W
5.	50° 26′ N 1° 31½′ W	50° 29′ N 1° 08½′ W

Exercise 8

Subject: Running Fix with Current.
Use: Chart 5053.

1. Ship steaming 227°T. Trevose Head Light bore 176°T. Log 47. Later it bore 098°T. Log 64. During the interval between the bearings a current set the ship 277°T, 6 miles. Find the position on both bearings.
2. At 0740 Start Point Light bore 306°T and at 0940 it bore 022°T. Course 250°T. Speed 11 knots. Current setting 232°T at 2 knots. Find the course made good between the bearings and the position on the 2nd bearing.
3. At 1810 Cape Barfleur bore 142°T and at 2040 it bore 213°T. Course 090°T. Speed 9 knots. Current setting 254°T at 3 knots. Find the ground track and ground speed between the bearings and the position on both bearings.
4. Les Hanois Light bore 074°T, and 3 hours later it bore 146°T. Ship steamed 042°T at 8 knots through a current setting 222°T at 2 knots. Find the position on both bearings.

Answers

	1st Bearing	2nd Bearing
1.	50° 46′ N 5° 03′ W	50° 35½′ N 5° 32′ W
2.	Not required.	49° 53′ N 3° 52′ W
	Course made good 247°T	
3.	49° 53½′ N 1° 29′ W	49° 51½′ N 1° 05′ W
	Ground track 097°T. Ground speed 6·2 knots.	
4.	49° 21′ N 3° 09′ W	49° 34′ N 2° 51′ W

Exercise 9

Subject: Magnetic Variation.
Use: Chart 5053 English Channel.

1. Where will you find details regarding the Magnetic Variation Curves (Isogonals) which are printed on the Chart?
2. For what year are the curves correct?
3. What is the Annual Change?
4. What is the Magnetic Variation in the following positions
   (a) 50° 00′ N 5° 15′ W in 1984
   (b) Off Littlehampton in 1984.
5. What Magnetic Variation would have been allowed in 1984 in the vicinity of Fowey? Show all working.
6. What Magnetic Variation would have been allowed off C. Cornwall in 1984?

Answers

1. Included in the notes beneath the Title.
2. 1975.
3. Annual Change (−) 5′.
4. (a) 8°W. 1984 − 1975 (9 years × 5′) = 45′. 9°W − 45′ = 8° 15′ W
   (b) 6°W. 7°W − 45′ = 6° 15′ W
5. 8°W. 8° 45′ W − 45′ = 8°W.
6. 8½°W. 9° 15′ W − 45′ = 8° 30′ W

Exercise 10

Subject: Compass Error.

Complete the statements in questions 1–4.

1. Compass Error is made up of two quantities ..... and .....
2. Variation varies with ..... and Deviation varies with the ....
3. Deviation is likely/unlikely in an inflatable Liferaft but it could be caused by .... and .....
4. (a) Error East Compass .....
   (b) Error West Compass .....
5. True Course 050°T. Variation 7°W. Find the Magnetic course.
6. True Course 251°T. Variation 3°E. Find the Magnetic course.
7. True Bearing 035°T. Variation 6°W. Find the Magnetic bearing.
8. Course 108°T. Variation 10°W. Deviation 2°W. Find the Compass Error and Compass Course.
9. Course 260°C. Variation 8°E. Deviation 2°E. Find the Compass Error and True Course.
10. Bearing 308°C. Variation 6°E. Deviation for ship's head (145°C) 4°W. Find the Compass Error and True Bearing.

Answers

1. Variation and Deviation.
2. ... Location ... Ship's Head.
3. ... Unlikely ... compressed air cylinders and other metal objects.
4. (a) Least (b) Best.
5. 057°M.
6. 248°M.
7. 041°M.
8. Compass Error 12°W. Compass Course 120°C.
9. Compass Error 10°E. True Course 270°T.
10. Compass Error 2°E. True Bearing 310°T.

Exercise 11

Subject: Transit Bearings.
Use: Chart No. 5053 English Channel.

In the following questions, find the Compass Error, Deviation for the ship's head and Gyro Error, as appropriate.

1. Bull Point Light House ∅ R radiostation bearing 123°C, 117°G. Variation 9°W.
2. Lizard Point Light ∅ Land's End Gp. Fl. Light bearing 301°C, 290°G. Variation 8°W.
3. RY buoy ∅ Eddystone Rocks Light House bearing 072°C, 067°G. Variation 7½°W.
4. Start Point Light House ∅ Hill (205) bearing 346°C, 336½°G. Variation 7°W.
5. Pte de Barfleur Light ∅ Cap Levi Light bearing 275°C, 270°G. Variation 6°W.
6. Jersey Gp. Fl. Light ∅ La Corbiere Light bearing 182°G.
7. Wolf Rock Light ∅ Longships Light bearing 018°G.

Answers

	True bearing	Compass Error	Deviation	Gyro Error
1.	116°T	7°W	2°E	1° High

2.	291°T	10°W	2°W	1° Low
3.	067°T	5°W	2½°E	Nil
4.	338°T	8°W	1°W	1½° Low
5.	270°T	5°W	1°E	Nil
6.	182½°T	—	—	½° Low
7.	017½°T	—	—	½° High

Exercise 12

Subject: Horizontal Sextant Angles.
Use: Chart 5053.

Find the Latitude and Longitude of the vessel's position obtained from the following horizontal sextant angles.

1. Lundy Island North Lt	25°	Hartland Point	68°	Trevose Head
2. Shambles Lt Ho.	60°	Needles Lt	33°	Nab Tower Lt
3. Bishop Rock Lt	52°	Wolf Rock Lt	32°	Lizard Lt
4. Cape Barfleur	37°	Cape La Hague	53°	Casquets
5. Vierge Island	40°	Ile de Bas	49°	Les Sept Iles
6. Pte de Ver	30°	Lt Vessel	102°	C. d'Antifer

Answers

1. 51° 04′ N 5° 17′ W
2. 50° 10½′ N 1° 46′ W
3. 49° 29½′ N 6° 01′ W
4. 50° 00′ N 2° 09′ W
5. 49° 09′ N 4° 07′ W
6. 49° 40′ N 0° 07½′ W

Exercise 13

Subject: Circular Error.
Use: Chart 5053.

1. The following bearings were taken at 0100:

St. Catherines Point Light	006°G
Nab Tower Light	028°G
Horn Buoy off Selsey	044°G

   Comment on the reliability of any fix obtained.
2. From the following information state if it will be possible to fix the vessel's position and find compass error.

Land's End Light	351°C
Hill (191)	030°C
Lizard Point Light	077°C

3. Horizontal Sextant Angles were taken as follows:

   Anvil Point 22° The Needles 24° St. Catherine's Point

   State if it is possible to fix the vessel's position and comment on the choice of objects.

Answers

1–3. The objects used lie on a common circle—it is not possible to fix position (or to find Gyro or Compass where appropriate).

Exercise 14

Subject: Vertical Sextant Angles.
Use: Chart 5053.

1. Portland Bill Light House subtends a vertical angle of 1° 30′. I.E. 1′ on the arc. Find the distance off.
2. Eddystone Rocks Light House subtends a vertical angle of 1° 16′. I.E. Nil. Find the distance off.
3. What angle should be set on the sextant to pass 2 miles off Round Island Light House? I.E. 2′ off the arc.
4. What angle should be set on the sextant to pass 0·5 miles off Eddystone Rocks Light House? I.E. 1′ on the arc.
5. What is the vertical danger angle to pass 0·5 miles clear of a wreck lying 0·7 miles off Beachy Head Light House? I.E. 1′ off the arc.

Answers

1.	0·9 miles	Elevation 43 m
2.	1·0 mile	41 m
3.	0° 49′	55 m
4.	1° 03·3′	41 m
5.	0° 47′	31 m

Exercise 15

Subject: Three Bearing Problem.
Use: Chart 5053.

1. Steaming up channel, current unknown, Start Point Light bore 030°T; after steaming 10 miles it bore 000°T, and after steaming a further 14 miles on the same course it bore 300°T. Find the ground track.
2. Lizard Head Light bore 308°T; after steaming 8 miles it bore 356°T, and after steaming a further 6 miles on the same course it bore 044°T. Find the ground track, the ship being under the influence of a current of unknown set and rate.
3. Hazy weather off Ushant. At 2100, Ushant Gp. Fl. (2) ev 10 Light bore 074°T. At 2215 the bearing was 110°T and at 2300 it was 140°T. Ship steaming 16 knots on the same course but current unknown. Find the ground track.
4. Steaming down channel, Casquets Light bore 217°C; after steaming 10 miles by log it bore 172°C, and after steaming another 5 miles it bore 144°C. Ship heading on the same course between the bearings. Variation 7°W. Deviation 0°. Current unknown. Find the ground track.

Answers

1. Course 070°T.
2. „ 272°T.
3. „ 030°T.
4. „ 254°T.

Exercise 16

Subject: Light Ranges.
Use: Chart 5053 and the Luminous Range Diagram.

Find the Luminous Range for the following criteria:

	Nominal Range of Light (from Chart or A.L.L.)	Meteorological Visibility
1.	5	10
2.	15	10
3.	25	10
4.	5	5
5.	20	10
6.	30	5
7.	28	20
8.	16	1
9.	26	2
10.	19	20

Refer to English Channel Chart 5053 (in rear pocket) and find the Nominal and Luminous Ranges for each of the following lights:

11. St. Catherine's Point Fl Light — Meteorological Visibility 10 miles
12. Bill of Portland Gp. Fl(4) Light — „ „ 5 „
13. Start Point Gp. Fl(3) Light — „ „ 0·5 „
14. Lundy Island Gp. Fl(2) Light — „ „ 2 „
15. La Corbiere (Jersey) Iso. W Light — „ „ 20 „

From the following information find the prevailing Meteorological Visibility:

16. Alderney Gp. Fl(4) Light — Sighted at range 13·7 miles
17. Eddystone Rocks Gp. Fl(2) Light — „ „ „ 24·0 „
18. Pte de Barfleur Gp. Fl(2) Light — „ „ „ 3·75 „
19. How would you find the intensity of a light?
20. Background lighting reduces the effective intensity of a light. A light has a charted nominal range of 12 miles—what would be its effective intensity and nominal range:
    (a) with Minor background lighting?
    (b) with Major background lighting?

Answers

1. 5 Luminous Range
2. 15 „ „
3. 25 „ „
4. 3·7 „ „
5. 20 „ „
6. 17 „ „
7. 48 „ „
8. 2·8 „ „
9. 7 „ „
10. 32 „ „

11. Nominal Range 30 Luminous Range 30
12. 29 16·8
13. 25 2·1
14. 24 6·5
15. 16 26
16. Nominal Range 24 Meteorological Visibility 5
17. 24 10
18. 27 1
19. Refer to the Luminous Range Diagram. A light's Intensity is found on bottom scale directly beneath Nominal Range on the top scale.
20. Use the Luminous Range Diagram.

Nominal Range (from Chart) 12 miles → Intensity 4,000 Candelas

(a) $\frac{4000}{10} \rightarrow$ 400 Candelas with Minor background lighting
(Nominal Range reduced to 7 miles)

(b) $\frac{4000}{100} \rightarrow$ 40 Candelas with Major background lighting
(Nominal Range reduced to 4·1 miles)

Chapter 13

Coastal Passage Planning

Research into shipping casualties has shown that the most important contributing factor is that of human error; the incidence has been estimated at 85%.

Among the recommendations for improving this situation is one for **Passage Planning**, by which is meant the preliminary assessment of all relevant information by the Master and Officers concerned. Reference to this subject is made in the following publications:

"*A Guide to the Planning and Conduct of Sea Passages*", Department of Transport.

M Notices Nos. 756 and 854, Department of Transport.

"*Bridge Procedures Guide*", International Chamber of Shipping.

These publications refer mainly to coastal passages, where the safety aspect is paramount.

References and International Requirements

Information relating to ocean passages may be found in the latest edition of British Admiralty publication, NP 136, *Ocean Passages for the World*, together with the current Supplement. When approaching land the mariner should adopt the procedure appropriate to Coastal Passage Planning with particular reference to Traffic Separation Schemes. Details of such schemes are shown in British Admiralty Charts, referred to in *Sailing Directions* and listed in Annual Notice No. 17 which is contained in the *Annual Summary of Admiralty Notices to Mariners*.

Details of traffic separation schemes adopted by IMO are set out in the IMO publication, *Ships' Routeing*, 4th Edition with Amendments, and in subsequent IMO Resolutions.

Compliance with Rule 10, of the, *International Regulations for the Prevention of Collisions at Sea*, is mandatory for all ships when operating in or near schemes which have been adopted by IMO. Rule 10 is included at the end of this chapter.

Further information about ships routeing is contained in Chapter 4 of *The Mariner's Handbook* and appropriate reference should also be made to the *Loadline Rules—Zones, Areas and Seasonal Periods* BA Chart, D 6083, and to Routeing Charts.

Check Lists

It is recommended that suitable reminders should be prepared for any procedure that has to be followed. In the case of passage planning, the lists given below would be useful:

1. Publications to be consulted.
2. Factors to be taken into account.
3. Information to be shown on the charts or in the bridge notebook.

Organisation of Passage Planning

The full procedure consists of four stages, but strictly speaking, the last stage is not part of the planning phase.

1. **Appraisal.**
   The Master, in consultation with his Deck Officers, will consider all the relevant information and make a general decision on the track to be followed. It could be useful to lay off the tracks on a small scale chart so that the overall situation may be assessed.
2. **Planning.**
   The Navigating Officer may now lay off the courses on charts of suitable scale and complete the details of the plan, which should be from "berth to berth". Those parts under pilotage should be prepared in such a manner that the Bridge Officer may check on the ship's safety independently of the Pilot.
3. **Execution.**
   When the time of departure is known, tactics may be considered. Conditions of light or darkness, the state of the tide etc. must be assessed, and, if necessary, the Master consulted with a view to adjusting speed or modifying the track so as to obtain more favourable circumstances.
4. **Monitoring.**
   At this stage the plan is in operation with the Officer of the Watch checking progress. He should, of course, call the Master in all cases of doubt, but also bear in mind the possible necessity for immediate action in cases of emergency.

PASSAGE PLANNING (COASTAL)—STAGE 1 (APPRAISAL)

List of Publications to which reference may need to be made.

(Check that the publications are corrected to date, or that the latest supplement is consulted.)

1. **Passage Record Book.**
   Advisable to retain past plans for future reference. Value is enhanced by comments on the success, or otherwise, of the plan used.
2. **Sailing Directions.**
   For routes, approaches, pilotage, hazards, port facilities, local weather, etc., etc.
3. **Distance Tables.**
   Admiralty, or other.
4. **Routeing Instructions.**
   IMO or local instructions. Details of Traffic Schemes.
5. **Catalogue of Charts and Publications.**
   To check on those available, especially for the largest scale charts for coastal navigation.
6. **Tide Tables.**
   Depths of water. Port entry.
7. **Tidal Atlas.**
   Tidal streams.
8. **List of Lights and Fog Signals.**
   Information is more detailed, and may be more recent than on the charts.
9. **Mariners' Handbook (NP 100)**
   General information on navigation and weather.

10. **Nautical Almanac.**
    Sunrise/set, moonrise/set.
11. **Admiralty List of Radio Signals.**
    Vol. I. Communications.
    II. Radio beacons.
    III. Weather reports.
    IV. Meteorological stations.
    V. Radio aids to navigation.
    VI. Port communications
12. **Ships' Manoeuvring Data.**
    Turning circle, Allowance for "squat".
13. **Bridge Procedures Guide.**
    Published by the International Chamber of Shipping. Gives check lists for various procedures while coasting and when under pilotage.
14. **Notices to Mariners.**
    For corrections to charts and publications.
15. **Radio Warnings.**
    To ensure that information is up to date.
16. **Weather Reports.**
    For the latest weather information.
17. **Special Publications.**
    As appropriate to some particular area,
    e.g. English Channel Passage Planning Guide—Chart 5500.
    Gulf of Mexico—*Shipping Safety Fairways.*



PASSAGE PLANNING (COASTAL)—STAGE 2 (PLANNING)

List of Information to be noted on the charts and in the bridge note book.

1. **Tracks.**
   Courses to be shown alongside in 360° notation.
2. **Areas of Danger.**
   Also indications of hazards on the next chart. Take care not to obscure information on the chart.
3. **Position Fixing.**
   Suitable notes to include ranges of lights, radar conscpicuous areas, etc. Indicate where special accuracy is required, giving alternative methods for independent checks.
4. **Transits.**
   Also clearing bearings and clearing ranges.
5. **Underkeel Clearance.**
   Especially where information is sparse or unreliable.
6. **Alterations of Course.**
   Indicate "wheel over" positions. Allow for the turning circle and any current.
7. **Speed.**
   Indicate where changes must be made to a "safe speed" or to make the ETA. Allow for squat.

8. **Tides.**
   Note times of HW and LW at reference ports and at destination, and if springs or neaps.
9. **Communication Points.**
   For reporting progress to navigation control centres.
10. **Nautical Almanac.**
    Times of sunrise/set, moonrise/set.
11. **Contingency Plans.**
    Alternative tracks around areas where there may be special hazards due to fog, possible engine failure, etc.

An Example of Passage Planning—Plymouth to Swansea

In this particular case the Master has decided to lay off his projected passage on a small scale chart (referring as necessary to the large scale charts). As well as giving an overall picture, it enables him to check distances along the routes selected. He will also be able to make notes, at appropriate places, for the guidance of the Navigating Officer and the Officers of the Watch.

Stage 1 (Appraisal)

Vessel General cargo carrier, 12,000 GT, speed 16 knots. Equipped with magnetic and gyro compasses, D/F, radar, and satellite navigation.

Publications As per standard list, plus: Chart 5500, *English Channel Passage Planning Guide.*

Factors to be considered

Probable time of sailing:	Evening of 17 April.
Distance (from tables):	199 miles at 16 knots, $12\frac{1}{2}$ hours approx.
Approximate ETA:	Forenoon, 18 April.
Probable Draft:	F 7·2 m, A 7·9 m.
Swansea Entrance:	Channel dredged to 3·0 m.
	LW 0351 0·8 m on 18th
	HW 1017 8·3

N.B. Full speed will be needed to make the tide.
Distances along the tracks = 225 or 217 miles.
Steaming time at 16 knots = 14 hours (allow time for slowing down).

Latest time at Pilot	1000	on 18th.
Steaming time	14	hours
Clear Breakwater	2000	17th.

N.B. Try to be ready for sailing at 1900.
Reconsider speed if there is a later finish.

Memo Contact Swansea Agents re: berth, draft, and latest time at the Pilot.

Master's Guidance Notes on the Passage Plan

Sunset 1955/17	Sunrise 0605/18.	
Devonport	HW 2129 on 17th	Springs.
Dover	HW 0244	18th
Swansea	LW 0351	HW 1017 on 18th.

Numbers Refer to Locations on the Chart

1. Take the Westerly track only if weather, traffic and tidal streams are favourable. Parallel Index on Eddystone Lt Ho.
2. If radar indicates heavy traffic, continue on the 260°T course, then alter course so as to enter the traffic stream at a fine angle.
3. Parallel Index on the Wolf Lt. Ho.
4. Master to consider progress and weather reports. Westerly track if there is any chance of fog. Ensure that Satnav is in operation.
5. Keep further East in bad weather, to avoid rough water on the shoal.
6. Send ETA to the Pilot. Make allowances for cross tides on the next track.

Stage 2

The Plan and Notes will now be given to the Navigating Officer who will select appropriate charts, lay off and check the courses.

When the sailing time is known, tidal streams can be assessed, and the ETA and speed considered.

The Plan and Notes, amended if necessary, will be placed on the chart table for the guidance of the Officers of the Watch.

Pilotage Plans for departure and arrival should also be prepared.

After completing the passage the Plan should be filed for future reference. Any "post mortem" comments that can be made will greatly enhance its value as a guide to planning on another occasion.

TRAFFIC SEPARATION SCHEMES

The following Rule from the *International Regulations for Preventing Collisions at Sea*, 1972 (Incorporating the 1981 Amendments), refers to the use of *Traffic Separation Schemes*.

RULE 10

Traffic Separation Schemes:

(a) This Rule applies to traffic separation schemes adopted by the Organisation.

(b) A vessel using a traffic separation scheme shall:
  (i) proceed in the appropriate traffic lane in the general direction of traffic flow for that lane;
  (ii) so far as practicable keep clear of a traffic separation line or separation zone;
  (iii) normally join or leave a traffic lane at the termination of the lane, but when joining or leaving from either side shall do so at as small an angle to the general direction of traffic flow as practicable.

(c) A vessel shall so far as practicable avoid crossing traffic lanes, but if obliged to do so shall cross as nearly as practicable at right angles to the general direction of traffic flow.

(d) Inshore traffic zones shall not normally be used by through traffic which can safely use the appropriate traffic lane within the adjacent traffic separation scheme. However, vessels of less than 20 metres in length and sailing vessels may in all circumstances use inshore traffic zones.

(e) A vessel, other than a crossing vessel or a vessel joining or leaving a lane shall not normally enter a separation zone or cross a separation line except:

(i) in cases of emergency to avoid immediate danger;
(ii) to engage in fishing within a separation zone.

(f) A vessel navigating in areas near the terminations of traffic separation schemes shall do so with particular caution.

(g) A vessel shall so far as practical avoid anchoring in a traffic separation scheme or in areas near its terminations.

(h) A vessel not using a traffic separation scheme shall avoid it by as wide a margin as is practicable.

(i) A vessel engaged in fishing shall not impede the passage of any vessel following a traffic lane.

(j) A vessel of less than 20 metres in length or a sailing vessel shall not impede the safe passage of a power-driven vessel following a traffic lane.

(k) A vessel restricted in her ability to manoeuvre when engaged in an operation for the maintenance of safety of navigation in a traffic separation scheme is exempted from complying with this Rule to the extent necessary to carry out the operation.

(l) A vessel restricted in her ability to manoeuvre when engaged in an operation for the laying, servicing or picking up of a submarine cable, within a traffic separation scheme, is exempted from complying with this Rule to the extent necessary to carry out the operation.

Questions

1. What is meant by Passage Planning?
2. What are the Four Stages of Passage Planning?
3. Summarise the first Three Stages of Passage Planning.
4. "Strictly speaking the last stage (Monitoring) is not part of Passage Planning." Discuss this statement.
5. List the publications to which you would refer when planning a Coastal Passage.
6. Discuss the importance of Traffic Separation Schemes when planning a Coastal Passage.
7. Summarize the requirements of Rule 10.
8. What check lists would you prepare when planning a Coastal Passage?
9. What attention should be paid to the use of Electronic Navigational Aids when planning a Coastal Passage.
10. You are navigator on a 16 knot, 10,000 GRT vessel equipped with magnetic and gyro compass, D.F., radar, and echo sounder. Fog is anticipated. Prepare a passage plan from Plymouth to Southampton stating the publications you would consult and the use which should be made of Navigational Aids.

Chapter 14

Tides and Tidal Streams

The sun and moon exert gravitational forces on all parts of the earth. One of the results of these attractive forces is the production of Tide Generating Forces.

As the differential attractive force due to the moon is approximately twice that of the sun it should be apparent that tides are more influenced by the moon. For this reason the interval between two successive high waters is approximately half a Lunar Day (12 h 25 m).

Spring Tides

In Figure 1, a simple case is shown in which the sun and moon are in line. This configuration occurs at New Moon when the two bodies are in Conjunction. A High Water (HW) is produced at that point on the earth's surface which is nearest to the sun and moon and also at the opposite point. Two Low Waters (LW) lie approximately mid-way between the two high waters.

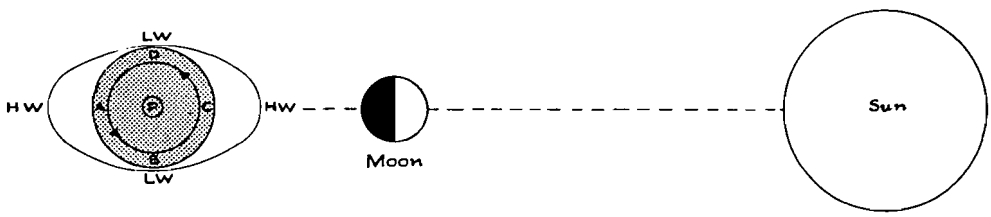


Figure 1. Sun and Moon in Conjunction (New Moon) Spring Tides.

When the sun and moon are in line, but on opposite sides of the earth, they are said to be in Opposition. This occurs at Full Moon and produces a similar situation to that which occurs at New Moon when the sun and moon are in Conjunction.

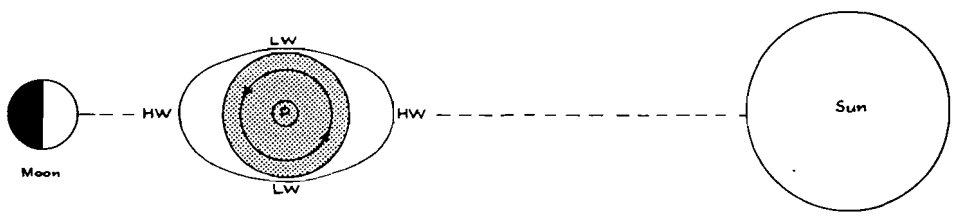


Figure 2. Sun and Moon in Opposition (Full Moon) Spring Tides.

When the sun and moon are in line either at New Moon or Full Moon, the maximum tide raising forces occur. These maximum forces produce the Highest High Waters and the Lowest Low Waters which are referred to as Spring Tides.

Neap Tides

When the sun and moon are at right angles to each other they are said to be in Quadrature.

In this configuration the smaller attractive forces of the sun oppose the larger attractive forces of the Moon. This results in Lower High Waters and Higher Low Waters which are referred to as Neap Tides.

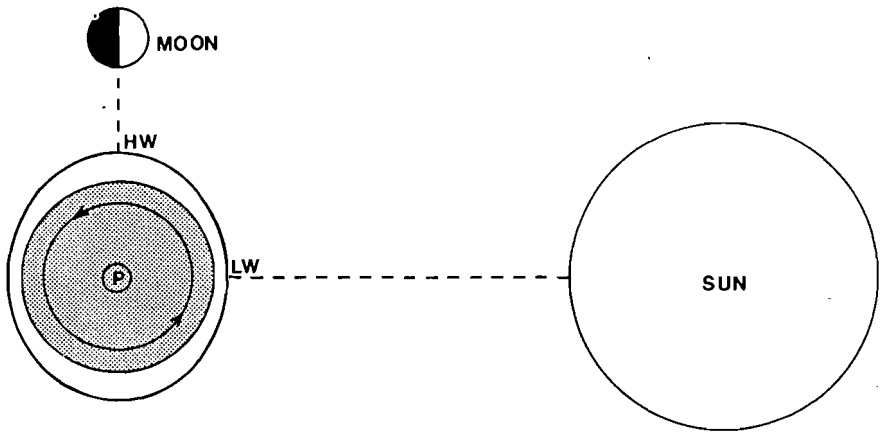


Figure 3. Sun and Moon in Quadrature (Half Moon) Neap Tides.

N.B.—A more detailed explanation of tides is included in Nicholls's Concise Guide, Volume 2.

Range of Tide and Duration of Tide

The Range of Tide is the height difference between a HW height and the preceding or following LW height at a particular place. The largest range occurs at Spring Tides and the smallest range at Neap Tides.

Duration of Tide is the time interval (time difference) between a HW time and the preceding or following LW time at a particular place.

DEPTH AND SOUNDINGS

It is frequently necessary to know the precise depth of water beneath the keel or over some charted danger.

Depth of water can be measured by hand using the Hand Lead Line, or by use of the Patent Sounding Machine, or by some type of Echo Sounding Device.

In the case of the hand lead line the depth so measured is from the surface water level whereas with an echo sounding device depth is measured from a transducer situated in the bottom of the vessel.

In both cases it is necessary to apply a correction to the measured depth in order that comparison can be made with the depth shown on the chart.

Charted Depth

The depth shown on a chart is measured from a level known as Chart Datum (CD). On a modern chart, Chart Datum is normally placed at the level of the Lowest Astronomical Tide

(LAT) which is the lowest level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions. It follows that the depth shown on a modern chart is the least depth which can be expected under normal conditions.

LW and HW Heights

LW and HW heights are always measured from Chart Datum. Unless preceded by a minus sign, LW heights are always additive to the charted depth. LW heights preceded by a minus sign indicate that LW falls below datum and that the charted depth is reduced at LW.

Example 1

(a) Charted Depth	10·0 m	(b) Charted Depth	10·0 m
LW from ATT	1·0 m	LW from ATT	−1·0
Predicted Depth at LW	11·0 m	Predicted Depth at LW	9·0 m

Rise of Tide

(Refer to Figure 4)

Note that Rise of Tide is the vertical distance measured from LW to the actual water level.

Height of Tide

(Refer to Figure 4)

Note that Height of Tide is the vertical distance measured from Chart Datum to the actual water level.

Height of Tide = LW Height + Rise of Tide.

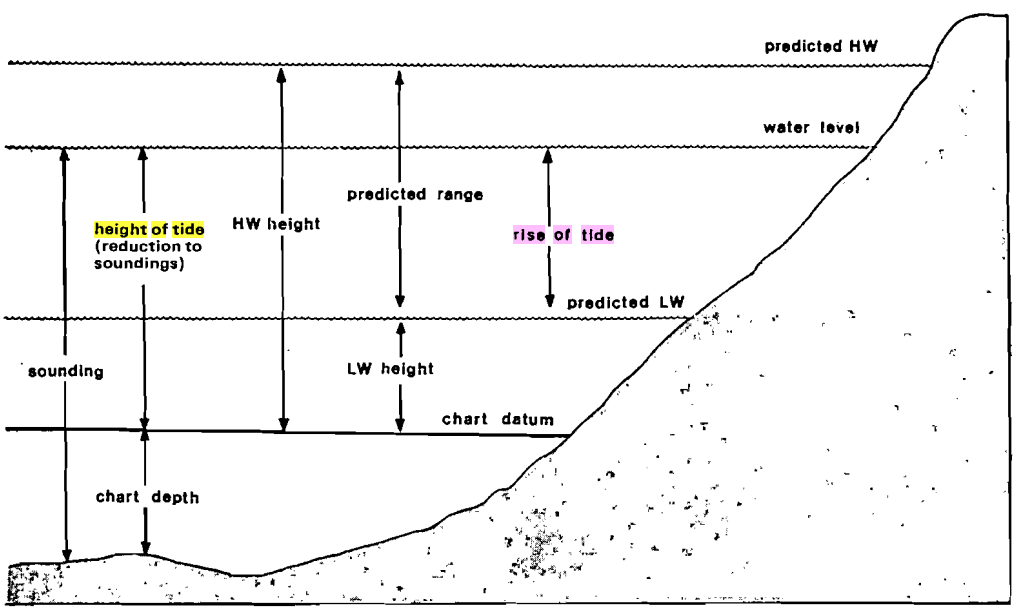


Figure 4. Rise of Tide and Height of Tide (Reduction to Soundings).

Example 2

(a)	LW from ATT	1·0 m	(b)	LW from ATT	−1·0 m
	Rise of Tide	4·0 m		Rise of Tide	4·0 m
	Height of Tide	5·0 m above CD.		Height of Tide	3·0 m above CD.

Height of Tide is also referred to as Correction to Leadline and Reduction to Soundings.

From the foregoing it should be clear that:

Predicted Depth = Charted Depth + LW Height + Rise of Tide

OR

Predicted Depth = Charted Depth + Height of Tide

Study Figure 4 and note that the actual depth of water has been increased by the Height of Tide above Chart Datum.

Reduction to Soundings

(Refer to Figure 4)

In order to compare a lead line sounding with that shown on the chart, the depth by sounding must be reduced by the Height of Tide.

Providing the water level is *above* Chart Datum:

Leadline Depth − Height of Tide = Charted Depth

Example 3

(a)	Sounding by hand lead line		15 m
	LW	2·0 m	
	Rise of Tide	3·0	
	Height of Tide		5
	Depth for comparison with chart		10 metres
(b)	Sounding by hand lead line		20 m
	LW	−1·0 m	
	Rise of Tide	4·0	
	Height of Tide		3
	Depth for comparison with chart		17 metres

In the case of a sounding obtained by an Echo Sounding Device the recorded depth must first be corrected for the distance between the transducer (at the bottom of the vessel) and the surface water level. The corrected depth is then reduced by the Height of Tide to obtain the depth for comparison with that shown on the chart.

Providing the water level is *above* Chart Datum:

(Depth by Echo Sounder + Draft) − Height of Tide = Charted Depth

Example 4

Depth obtained by Echo Sounder		25 m
Draft		5
Depth from surface Water Level		30
LW	2·5 m	
Rise of Tide	4·5	
Height of Tide		7
Depth for comparison with Chart		23 metres

Example 5

Depth obtained by Echo Sounder		25 m
Draft		5
		30
LW	−0·5 m	
Rise of Tide	4·5	
Height of Tide		4
Depth for comparison with Chart		26 metres

DRYING HEIGHTS AND CHARTED HEIGHTS

(Refer to Figure 5)

In addition to depths of water, the chart also shows the HEIGHT ABOVE CHART DATUM of rocks and sand banks which cover and uncover at different states of the tide. Such heights are referred to as DRYING HEIGHTS and are indicated by a figure with a line beneath, e.g. $\underline{3}$ indicates Drying Height 3 ft (Fathom Chart) and $\underline{1_3}$ would indicate a Drying Height of 1·3 metres (Metric Chart). In the latter case, the chart tells us that the rock projects 1·3 m vertically above Chart Datum and that a Height of Tide of 1·3 m will be required before the rock is just covered.

Example 6

Find the depth of water over a rock marked $\underline{6}$ near Avonmouth (p.m.) on September 29th. The calculated rise of tide was 5·5 m.

Drying Height (rock)		6 m
LW	3·5 m	
Rise of Tide	5·5	
Height of Tide		9
Depth of Water over rock		3 metres

Charted Height (Elevation) page 360 (407)
The charted height (Elevation) of an object is given above MHWS or MHHW or, where there is no tide, above MSL.

Tidal levels of MHWS, MHHW and MSL (above Chart Datum) are listed in Table V of the Admiralty Tide Tables.

For Secondary Ports, MHWS is obtained by applying the height difference in Part II to the Standard Port MHWS level given there. page 450 (497)

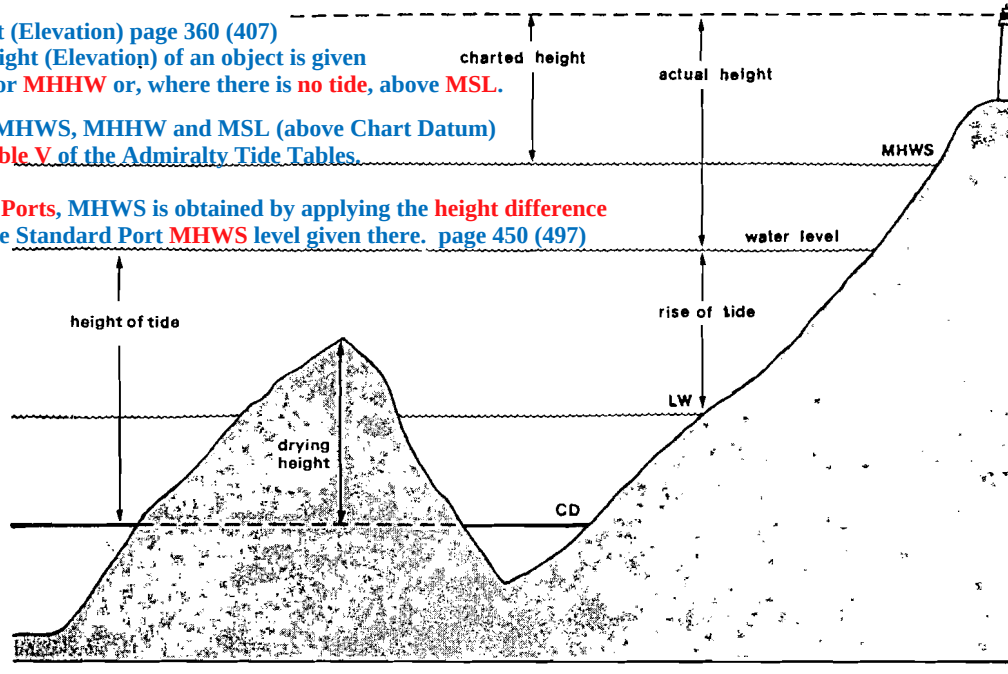


Figure 5. Charted Height and Drying Height.

Charted Heights

(Refer to Figure 5)

The charted height of lighthouses, hills and other high objects is given above the level of Mean HW Springs (MHWS).

In the case of a lighthouse the charted height is measured from MHWS to the centre of the focal plane of the light.

Example 7

A lighthouse near Portsmouth has a charted height of 19 m. Find the actual height of the lighthouse (p.m.) on July 29th. Rise of Tide for the required time was calculated as 2 m.

Charted Height of Lighthouse (above MHWS)			19 m
MHWS (from ATT Table V) Level above CD		4·7 m	
LW (from ATT)	1·7		
Rise of Tide	2·0		
Height of Tide		(−)3·7	
Water Level BELOW MHWS			1
Actual Height of Lighthouse (above water level)			20 metres

TIDAL LEVELS

(Refer to Figure 6)

Tidal levels for Standard Ports are listed in Table V of the *Admiralty Tide Tables* (see Appendix). They are given under abbreviated headings which are listed below and shown on the accompanying diagrams. As can be seen in the Appendix, these abbreviated headings are used to tabulate Secondary Port Time and Height Differences included in ATT Part II.

Study Figure 6 and note the various levels and ranges. Also note that the vertical distance between MHWS and MLWS is referred to as the Spring Range, between MHWN and MLWN as the Neap Range and between the Predicted HW and LW (for the day in question) as the Predicted Range. Refer to the ATT Extracts in the Appendix and note that the Mean Spring and Neap Ranges for a Standard Port are shown in the box included in the Tidal Curve for that port.

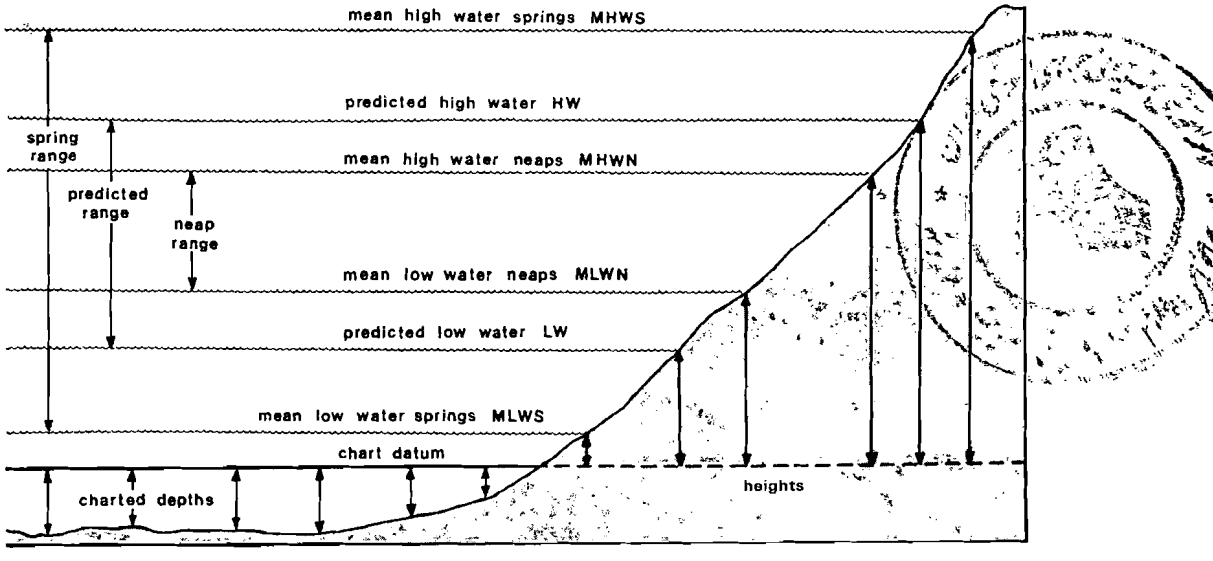


Figure 6. Tidal Levels.

MHWS (Mean High Water Springs) and **MLWS** (Mean Low Water Springs) are the average heights of two successive spring high and low waters in the same period when the range of tide is greatest.

MHWN (Mean High Water Neap) and **MLWN** (Mean Low Water Neap) are the average heights of two successive neap high and low waters in the same period when the range of tide is least.

MHHW (Mean Higher High Water) and **MLHW** (Mean Lower High Water) are the means of the higher and the lower of the two daily high waters taken over a long period of time.

MLLW (Mean Lower Low Water) and **MHLW** (Mean Higher Low Water) are the means of the lower and the higher of the two daily low waters.

HAT (Highest Astronomical Tide) and **LAT** (Lowest Astronomical Tide) are the highest and

lowest levels which can be predicted under normal meteorological conditions. These levels will not occur every year.

MSL (Mean Sea Level) is the average level of the sea surface over a long period, preferably 18·6 years, or the average level which would exist in the absence of tides.

STANDARD PORTS AND SECONDARY PORTS

There are two types of port—Standard Ports and Secondary Ports. Secondary Ports are based on Standard Ports which have a similar tidal curve.

The Admiralty Tide Tables include the Tidal Curve and full details of daily predictions for Standard Ports. They also list the Time and Height Differences of Secondary Ports from the chosen Standard Port. To give full daily predictions for each Secondary Port would clearly require a very large volume indeed and the above method makes for a more convenient size.

ADMIRALTY TIDE TABLES

Admiralty Tide Table (ATT) are published in three volumes:

Vol. 1. European Waters (including Mediterranean Sea).
Vol. 2 Atlantic and Indian Oceans (including tidal stream predictions).
Vol. 3. Pacific Ocean and Adjacent Seas (including tidal stream predictions).

Each of these volumes is divided into two parts:

Part I. Standard Ports.
Part II. Secondary Ports.

Standard Ports are listed in the Index to Standard Ports printed on the inside Front Cover of each volume.

Secondary Ports are listed in the Geographical Index at the rear of each volume and which also includes the Standard Ports.

Each port is assigned an Index Number.

TYPES OF TIDAL PROBLEM

Tidal problems fall into 4 main types in which it is necessary to find:

1. Time of HW and LW on a particular day.
2. Height of Tide at an Intermediate Time between HW and LW.
   OR
   Reduction to Soundings (Correction to Leadline) at an Intermediate Time.
3. Time at which a Required Height of Tide (or Depth of Water) is reached.
4. Correction to Apply to the Charted Height of a Lighthouse or other shore object.

Each type of problem is included in the following pages.

TIDE CALCULATIONS

Accuracy and Interpolation

It must be borne in mind that meteorological conditions which differ from average may cause differences between the predicted and actual tide. These effects are discussed in the Introduction to the tide tables. Despite these limitations, calculations should be worked as accurately as possible within the limits of the tables and, particularly in examinations, all interpolation shown.

Time Zones, Zone Time, Standard Time and Time Differences

The Time Zone for the port in question is clearly shown in the top, left hand corner of prediction pages in *Admiralty Tide Tables*. Daily predictions are given in the normal Standard Time of the port. Before attempting calculations, time zones, zone time and standard time should be understood.

The world is divided into 24 **Time Zones**. Each Time Zone is 15° of longitude in width. The "Zero Time Zone" extends from $7\frac{1}{2}$°W to $7\frac{1}{2}$°E—this zone keeps GMT. In each of the remaining 23 zones the time differs from GMT by a whole number of hours and is numbered, in sequence, 1–12: East of Greenwich with a Negative (−) prefix, West of Greenwich with a positive (+) prefix.

e.g. 60°E lies in the $52\frac{1}{2}$°E—$67\frac{1}{2}$°E Zone (Zone −4)
10°W „ „ „ $7\frac{1}{2}$°W—$22\frac{1}{2}$°W „ (Zone +1)

To obtain the **Zone Time** for a position or place, subtract the Zone number **algebraically** from GMT.

Example—Given GMT 1200, what is the correct Zone Time to keep in Longitude 60°E (Zone −4)?

GMT − (Zone) = Zone Time
1200 − (−4) = 1600 i.e. 4 hours ahead of GMT

conversely,

Zone Time + (Zone) = GMT
1600 + (−4) = 1200

For convenience on land, a **Standard Time** is adopted throughout a given country. In most cases Standard Time or Legal Time is that of the Zone in which the country mainly lies. Countries like USA and Australia, which extend over several Time Zones, generally adopt several Standard Times.

To prolong daylight hours, many countries also adopt (for part of the year) a form of Daylight Saving Time or **Summer Time**. For such periods, the time of the Eastward zone is usually adopted, e.g. BST (British Summer Time), which is kept in the UK from a date in March to a date in October, is the time for Zone −1, i.e. GMT −(−)1 = GMT +1 hour.

Time Differences for Secondary Ports, when applied to the printed times of HW and LW at Standard Ports will give the times of HW and LW at the Secondary Port in the Zone Time tabulated in the tables for the Secondary Port.

Zone Time exercises are included on page 570.

To Find the Times of HW and LW

Example 8

Find the Standard Times of HW and LW at SHEERNESS on January 7th.

1. Turn to "Index of Standard Ports" in ATT Volume 1 (see page 817). Find that Sheerness is a Standard Port for which daily predictions are given.
2. Turn to the daily predictions for Sheerness. (See page 827.)

TIME ZONE GMT

JANUARY

7	0325	1·2	22	0433	1·3
	0952	5·3		1059	4·9
TH	1609	0·9	F	1648	1·1
	2237	5·5		2316	5·1

Four times are given with the height of the tide at each instant. The High Waters are the higher figures, 5·3 metres (m) and 5·5 m. The Low Waters are the lower figures, 1·2 m and 0·9 m.

	LW	HW
Times	0325	0952
	1609	2237

Note that the times are Standard Times for the Time Zone indicated. In this case the Time Zone is GMT.

Example 9

Find the BST (British Summer Time) of HW and LW at Greenock on August 18th and also the Duration and Range of the AM rising tide.

1. Check that Greenock is a Standard Port. (See page 817.)
2. Turn to the daily predictions for Greenock. (See page 830.)
3. Note and apply the time difference: GMT + 1 hr = BST.
4. Subtract the AM LW times and heights from the following HW times and heights to obtain the Duration and Range of Tide.

TIME ZONE GMT

18	0442	0·3
	1145	3·1
W	1704	0·4
	2345	3·4

High Waters are 3·1 m and 3·4 m and Low Waters are 0·3 m and 0·4 m.

	LW	HW	LW	HW
GMT	0442	1145	1704	2345 Aug. 18th
Time Diff.	+01	+01	+01	+01
BST	0542 (18th)	1245	1804	0045 (19th)

HW	12	45	3·1m	
LW	05	42	0·3 m	
Duration	7 h	03 m	2·8 m	Range

Note the time difference has made the BST of the second High Water occur on the following day which is August 19th.

Admiralty Tidal Prediction Form—NP 204

In the following pages, tide calculations will be worked on *Admiralty Tidal Prediction Form,*

NP 204. Copies of this form, together with instructions, graph paper for interpolation and a selection of Standard Port Tidal Diagrams (with curves), are contained in the booklet edition of NP 204. The form is also included in the back pages of *Admiralty Tide Tables* (ATT).

Refer to the copies of NP 204 on page 855 and in Example 10. Note that the form contains boxes numbered 1–16. Boxes 1–5 are completed for Standard Ports. Boxes 1–16 are completed for Secondary Ports.

To Find the Height of Tide at an Intermediate Time between HW and LW

(European Standard Port—**Checklist 1**)

1. Check that the port is in the ATT "Index to Standard Ports". Turn to the appropriate page. Complete heading in NP 204. In boxes 1–4, write down the Times and Heights of HW and LW which lie either side of the required time. Subtract LW height from HW height to obtain Predicted Range—enter in box 5.
2. Turn to the Tidal Diagram for the port (first page of predictions for that port). Plot the heights of HW (top LH scale) and LW (bottom LH scale) which occur either side of the required time. Join by a sloping line.
3. Write down the HW time in the HW box below the curve. In adjacent boxes, enter other times (differing by one hour intervals from HW time) to "embrace" the required time. It may be helpful to write down the required Time Interval from HW (i.e. HW Time ~ Required Time).
4. Plot the required time on the time scale (note, 10 minute divisions). Through this point draw a vertical line to intersect the appropriate curve—see (5).
5. Note Spring and Neap Ranges shown in the box (top right).
   Predicted Range equal to or greater than Spring Range—Use Spring Curve only.
   Predicted Range equal to or less than Neap Range—Use Neap Curve only.
   Other Ranges—Interpolate (and draw in the appropriate part of the curve as explained below.)
6. From vertical intersection with curve, proceed horizontally to sloping line (2) then vertically to the Height Scale.
7. Read off the Height of Tide (also known as Reduction to Soundings or Correction to Leadline).

Interpolating between Spring and Neap Curves

To interpolate between curves (i.e. where the Predicted Range lies between the Spring and Neap Ranges):

$$\text{Express: } \frac{\text{Spring Range} - \text{Predicted Range}}{\text{Spring Range} - \text{Neap Range}} \text{ as a fraction.}$$

Using this fraction, sketch in an intermediate curve, parallel to the Spring curve this fractional distance away from the Spring curve towards the Neap curve, e.g. Fraction $\frac{1}{4}$; draw curve $\frac{1}{4}$ of the distance away from the Spring curve towards the Neap curve.

Where there is an appreciable change in duration between Spring and Neap tides, interpolating between curves may result in a slight error—the error is greatest near LW. **Do not extrapolate.**

Example 10

(European Standard Port)

Find the Height of Tide at Londonderry at 1300 Standard Time on August 22nd. (Predictions on page 832.)

Follow the instructions in **Checklist 1.** (Step 1)

TIME ZONE GMT

AUGUST

	TIME	M
22 SU	0424	0·4
	1012	2·6
	1614	0·3
	2228	2·8

STANDARD PORT LONDONDERRY TIME/ REQUIRED 1300

SECONDARY PORT ——— DATE Aug 22 TIME ZONE GMT

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	1 1012	2 1614	3 2·6	4 0·3	5 2·3
Seasonal change	Standard Port		6	6	
DIFFERENCES	7*	8*	9*	10*	
Seasonal change	Secondary port		11	11	
SECONDARY PORT	12	13	14	15	
Duration	16				

Interpolation (Step 5)

Predicted Range equals Spring Range—use Spring Curve.

NB At this port the Spring and Neap curves coincide throughout the tidal cycle—so interpolation "between curves" is, in any case, not possible.

Plotting (Steps 2, 3, 4, 6 and 7)

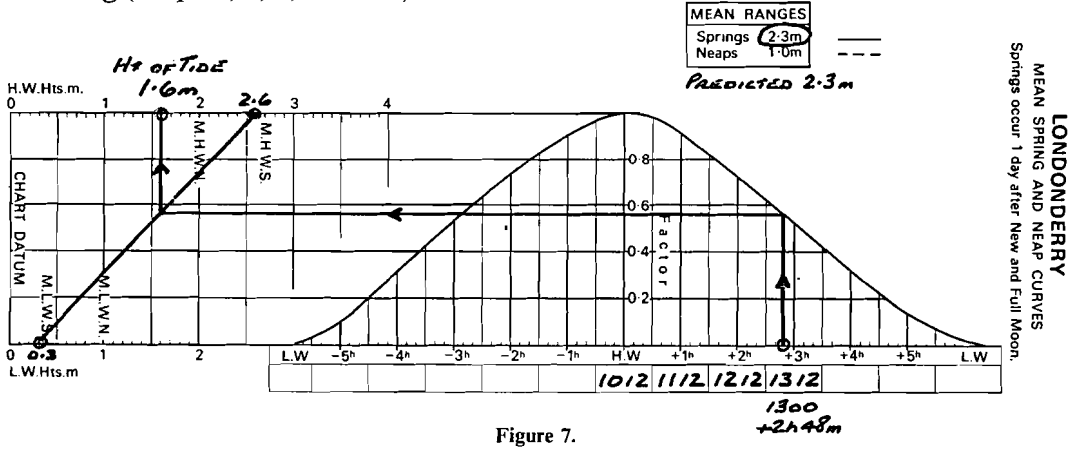


Figure 7.

Answer 1·6 metres is the Ht of Tide above Chart Datum.

Example 11

(European Standard Port)

Find the Height of Tide at Avonmouth at 1500 Standard Time on November 28th. (Predictions on page 831.)

Follow the instructions in **Checklist 1.** (Step 1)

TIME ZONE GMT

NOVEMBER

28 SU	0431	11·5
	1104	2·7
	1658	12·2
	2339	2·1

STANDARD PORT AVONMOUTH TIME [redacted] REQUIRED 1500

SECONDARY PORT — DATE Nov. 28 TIME ZONE GMT

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	[1] 1658	[2] 1104	[3] 12·2	[4] 2·7	[5] 9·5
Seasonal change	Standard Port		6	6	
DIFFERENCES	7*	8*	9*	10*	
Seasonal change	Secondary port		11	11	
SECONDARY PORT	12	13	14	15	
Duration	16				

Interpolation (Step 5)

Spring Range	12·3 m	Spring Range	12·3 m
Neap Range	6·5 m	Predicted Range	9·5 m
S − N	5·8 m	S − P	2·8 m

$$\frac{S-P}{S-N} = \frac{2{\cdot}8}{5{\cdot}8} = 0{\cdot}48 \simeq \tfrac{1}{2} \text{ (Fractional Distance from Spring Curve).}$$

Plotting (Steps 2, 3, 4, 6 and 7)

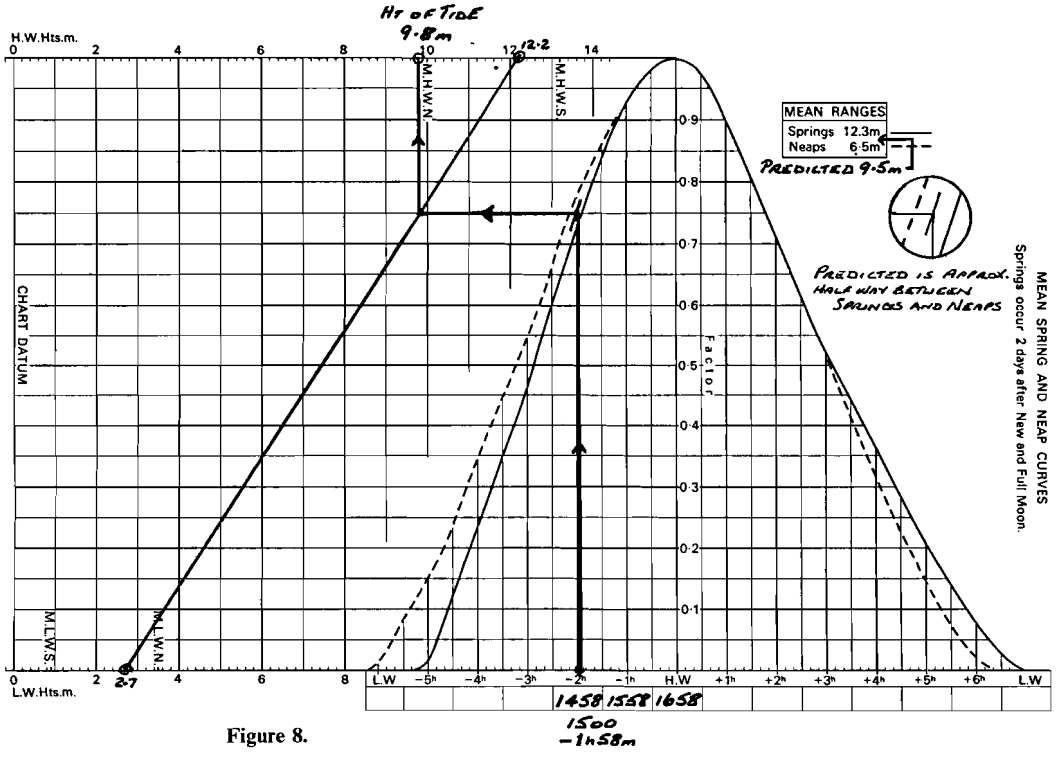


Figure 8.

Answer 9·8 metres is the Ht of Tide at 1500 GMT.

To Find the Time at which a Required Depth is Reached

(European Standard Port—**Checklist 2**)

1. Check that the port is in the ATT "Index to Standard Ports". Turn to the appropriate page. Complete heading in NP 204. In boxes 1–4, write down the Times and Heights of HW and LW which lie either side of the required time. Subtract LW height from HW height to obtain Predicted Range—enter in box 5.
2. Using a sketch to assist, find the Height of Tide necessary for the required depth.
3. Turn to the Tidal Diagram for the port. On the diagram, plot heights of HW (top LH scale) and LW (bottom LH scale) which occur either side of the required time. Join by a sloping line.
4. Write down the HW time in the HW box below the curve. In adjacent boxes, enter other times (differing by one hour intervals from HW time) to "embrace" the required time. If helpful, write down the required Time Interval from HW (i.e. HW time ~ Required Time).
5. From the required Height of Tide on the HW height scale, proceed vertically down to the sloping line, then horizontally to the appropriate curve—see (6).
6. Note Spring and Neap Ranges shown in the box, (top right).
   Predicted Range equal to or greater than Spring Range—Use Spring Curve only.
   Predicted Range equal to or less than Neap Range—Use Neap Curve only.
   Other Ranges—Interpolate—as previously explained, and draw in the appropriate part of the curve.
7. From the intersection at the appropriate curve, proceed vertically down to the time scale.
8. Read off the required time (or time interval) using the 10 minute divisions to assist.

Example 12

(European Standard Port)

Find the Standard Time when a ship of draft 5·5 m will have 2 m clearance under the keel over a 4·5 m shoal off Portsmouth on the a.m. ebb tide of June 29th.

Follow the instructions in **Checklist 2.** (Step 1)

TIME ZONE GMT

JUNE

	TIME	M
29	0530	4·0
	1058	1·5
TU	1820	4·2
	2337	1·7

STANDARD PORT Portsmouth HEIGHT REQUIRED 3·0m

SECONDARY PORT — DATE June 29 TIME ZONE GMT

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	1 0530	2 1058	3 4·0	4 1·5	5 2·5
Seasonal change	Standard Port		6	6	
DIFFERENCES	7*	8*	9*	10*	
Seasonal change	Secondary port		11	11	
SECONDARY PORT	12	13	14	15	
Duration	16				

Sketch and Preliminary Calculations (Step 2)

Draft	5·5 m
Clearance	2·0
Required Depth	7·5
Charted Depth	4·5
Required Height of Tide	3·0 m

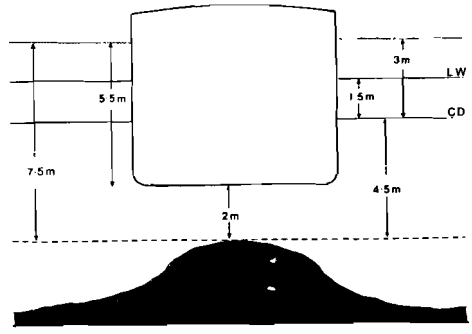


Figure 9.

Interpolation (Step 6)

Spring Range	4·1 m	Spring Range	4·1 m
Neap Range	2·0 m	Predicted Range	2·5 m
S – N	2·1 m	S – P	1·6 m

$$\frac{S-P}{S-N} = \frac{1{\cdot}6}{2{\cdot}1} = 0{\cdot}76 \simeq \tfrac{3}{4} \text{ (Fractional Distance from Spring Curve).}$$

Plotting (Steps 3, 4, 5, 7 and 8)

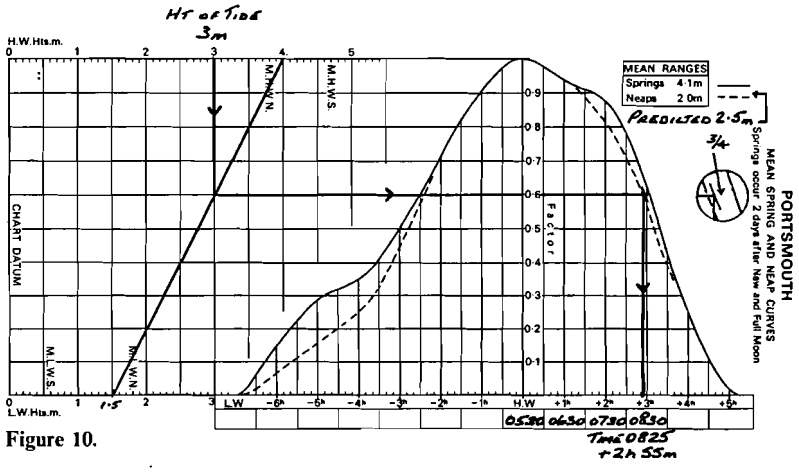


Figure 10.

Answer 0825 GMT (0925 BST).

To Find the Corrected Height of a Lighthouse

(European Standard Port)

Use earlier instructions (Checklist 1), "To Find the Height of Tide at an Intermediate Time between HW and LW". Note that the charted height of a lighthouse or other shore object, is

given above MHWS. This level can be found from the Table of Tidal Levels on the chart, if included, or, for Standard Ports, from ATT, Table V (see page 819). For Secondary Ports, MHWS is obtained by applying the height difference in Part II to the Standard Port MHWS level given there.

Example 13

A lighthouse off Sheerness has a charted height of 15 m. Find its height above water level at 0930 GMT on April 22nd for use with a vertical sextant angle. (Predictions page 826.)

Follow the instructions in **Checklist 1.** (Step 1)

TIME ZONE GMT
APRIL

22 TH	0523	0·6
	1140	5·7
	1740	0·8
	2353	5·6

STANDARD PORT SHEERNESS TIME/~~HEIGHT~~ REQUIRED 0930

SECONDARY PORT — DATE APR. 22 TIME ZONE GMT

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	[1] 1140	[2] 0523	[3] 5·7	[4] 0·6	[5] 5·1
Seasonal change	Standard Port		6	6	
DIFFERENCES	7*	8*	9*	10*	
Seasonal change	Secondary port		11	11	
SECONDARY PORT	12	13	14	15	
Duration	16				

Interpolation (Step 5)

Predicted Range is equal to Spring Range—use Spring Curve only.

Plotting (Steps 2, 3, 4, 6 and 7)

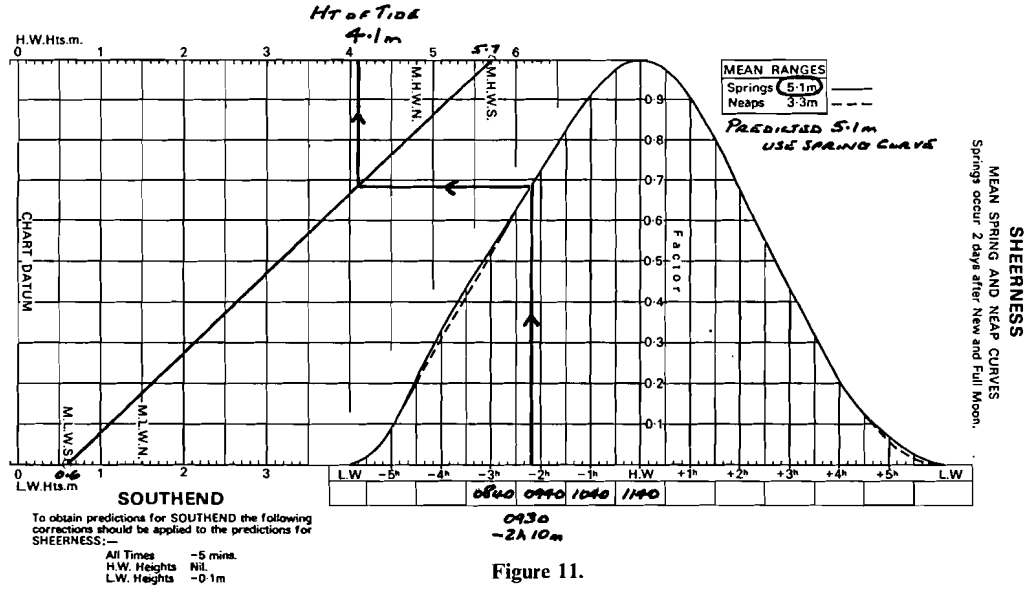


Figure 11.

Sketch and Final Calculations

Charted Height Lt.Ho.	15·0	
MHWS	5·7	(from Table V—page 819)
Height above CD	20·7	
Height of Tide	4·1	
Corrected Height Lt.Ho.	16·6 m	

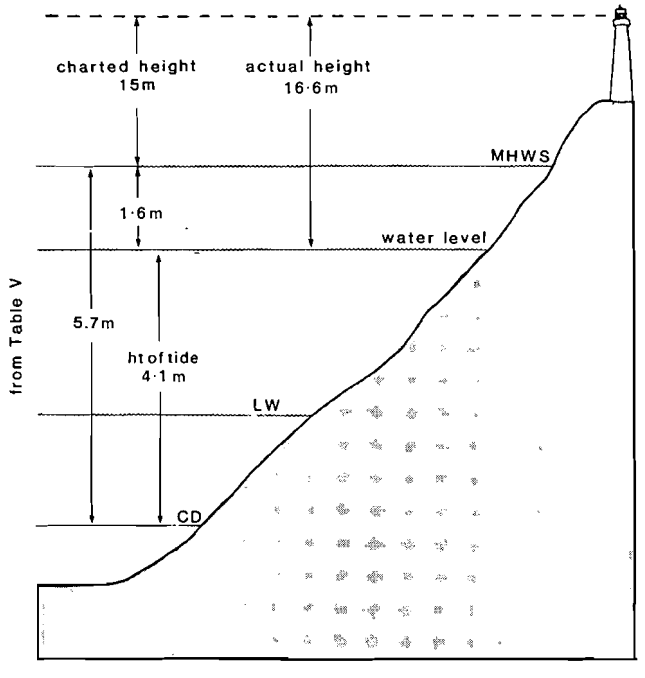


Figure 12.

Answer 16·6 metres is the corrected height.

Exercises on European Port tides are included at the end of the chapter.

SECONDARY PORT TIDE CALCULATIONS

European Secondary Ports—ATT Volume 1

The method of finding the time and heights of HW and LW at any Secondary Port given in the *Admiralty Tide Tables* is by means of simple differences in times and heights from predictions for the Standard Port indicated, which is the most suitable, not necessarily the closest, Standard Port.

To Find HW and LW Times and Heights

(European Secondary Ports—**Checklist 3**)

1. Find the Secondary Port in the Geographical Index at the back of ATT. Note its number.
2. Refer to ATT Part II with Secondary Port number and note the relevant Standard Port, its number and page number in Part I.
3. Refer to Part I. Find HW and LW times and heights at the Standard Port for the required day. Enter in NP 204, boxes 1–4, and complete box 5 with the predicted range.
4. Refer back to Part II, bottom RH page "Seasonal Change in Mean Level". Using its number to assist, locate the correct line and find the Standard Port's Seasonal Change (for the month). Enter this change in boxes 6, with its sign changed (see note).
5. Note the time and height differences for the Secondary Port and the related reference times and reference heights at the Standard Port.
6. Interpolate between Secondary Port time differences and height differences using graph paper (see Example 15) or by calculation. Suitable graph paper is included in ATT but any type can be used.
7. Enter the interpolated Secondary Port time and height differences in boxes 7–10.
8. Using its number to locate the right line, find and enter the Secondary Port's Seasonal Change for the month in boxes 11.
9. Apply differences to Standard Port times and heights to find times and heights at the Secondary Port (boxes 12–15).

Note The Standard Port height quoted in ATT already includes the Seasonal Change which must be subtracted algebraically so that subsequent interpolation is carried out on the unadjusted tidal heights.

Example 14

(European Secondary Port)

Find the times and heights of HW and LW at Brodick Bay for the AM rising tide on August 1st. (Refer to pages 839, 838, 830 and the table in Example 15.)

Follow the instructions in **Checklist 3**.

STANDARD PORT GREENOCK (404) ....TIME/HEIGHT REQUIRED AM RISING

SECONDARY PORT BRODICK BAY (408) DATE AUG 1ST TIME ZONE GMT

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	1 0939	2 0329	3 2·8	4 0·8	5 2·0
Seasonal change	Standard Port (404)		6 +0·1	6 +0·1	SIGN CHANGED
DIFFERENCES	7* 0000	8* +0005	9* −0·2	10* 0·0	
Seasonal change	Secondary port (408)		11 0·0	11 0·0	
SECONDARY PORT	12 0939	13 0334	14 2·7	15 0·9	
Duration	16 /				

Note that in this case (i.e. at Brodick Bay No. 408) the Secondary Port time and height differences at HW and LW remain constant for different Standard Port times and heights—compare these differences with those at Lamlash (409) where differences are not constant.

Answer HW 0939 GMT 2·7 m LW 0334 GMT 0·9 m at Brodick Bay.

Interpolating Secondary Port HW and LW Time and Height Differences using Graph Paper—Checklist 4.

1. Complete NP 204, heading and boxes 1–6, taking data from ATT Parts I and II.
2. In Part II, encircle and "arrow" the Standard Port HW and LW reference times and heights. Also encircle the Secondary Port time and height differences (as shown in Example 15).
3. Apply Standard Port Seasonal Change in Mean Level to HW and LW (boxes 3 and 4) to give the corrected Standard Port HW and LW—note the result required for later plotting—see (10).
4. Take a piece of graph paper. Mark up the RH side edge at hourly intervals with a scale of Standard Port HW reference times (previously encircled). Mark the top edge with a scale for the Secondary Port time differences (previously encircled)—see Example 15. The top scale may require negative (−), zero and positive (+) values.
5. Plot the Secondary Port HW time differences (using top scale) against their Standard Port HW reference times (RH side scale). Join plotted points by a sloping line.
6. Plot the predicted Standard Port HW time on the RH scale. From this point move horizontally to the sloping line—then vertically to the top scale and read off the corresponding Secondary Port HW time difference. Enter in box 7.
7. Repeat (5) and (6) but use LW reference times and LW time differences. Read off the Secondary Port LW time difference against the Standard Port LW time. Enter in box 8.
8. Mark up the LH side of the graph with a suitable scale for Standard Port heights from MLWS to MHWS (previously encircled values). Mark the bottom edge with a scale for Secondary Port height differences (previously encircled). It may be necessary to have negative (−), zero and positive (+) values.
9. Using the LH and bottom scales, plot Secondary Port HW height differences against the Standard Port MHWS and MHWN heights. Join by a sloping line—extend each way to allow possible extrapolation.
10. Plot the corrected Standard Port HW height on the LH scale. From this point move horizontally to the sloping line—then vertically down to the bottom scale and read off the corresponding Secondary Port height difference. Enter in box 9.
11. Repeat (9) and (10) but use Standard Port MLWS and MLWN heights and Secondary Port LW height differences. Read off the Secondary Port LW height difference corresponding to the Standard Port LW height. Enter in box 10.
12. Enter Secondary Port Seasonal Change in Mean Level (for the month) in boxes 11.
13. Add the columns and complete boxes 12–15 which give HW and LW times and heights at the Secondary Port.

Example 15

Find the predicted times and heights of HW and LW at Bowling (406) for the falling PM time on June 4th—predictions for Greenock were HW 1041 3·1 m, LW 1629 0·5 m. Time Zone GMT. The Predicted Seasonal Change in Mean Level for ports numbered 399–407, on June 1st, was −0·1 m. (Check this data by reference to the extracts.)

No.	PLACE	Lat. N.	Long. W.	TIME DIFFERENCES High Water (Zone G.M.T.)	TIME DIFFERENCES Low Water (Zone G.M.T.)	HEIGHT DIFFERENCES (IN METRES) MHWS	MHWN	MLWN	MLWS	M.L. Z_0 m.
404	GREENOCK . (see page 94)			0000 and 1200 / 0600 and 1800	0000 and 1200 / 0600 and 1800	3·4	2·9	1·0	0·4	2·00
	River Clyde									
405	Port Glasgow .	55 56	4 41	+0011	+0005 / +0010	+0018	+0·2	+0·1	0·0	0·0	⊙
406	Bowling .	55 56	4 29	+0032	+0016 / +0043	+0107	+0·6	+0·5	+0·3	+0·1	⊙
408	Brodick Bay .	55 35	5 08	0000	0000 / +0005	+0005	−0·2	−0·2	0·0	0·0	1·86
409	Lamlash .	55 32	5 07	−0016	−0036 / −0024	−0004	−0·2	−0·2	⊙	⊙	⊙
410	Ardrossan .	55 38	4 49	−0020	−0020 / −0030	−0010	−0·2	−0·2	−0·1	−0·1	⊙
411	Irvine .	55 36	4 41	−0020	−0020 / −0030	−0010	−0·3	−0·3	−0·1	0·0	⊙

Interpolation

pocket calculator may be preferred

Follow the instructions in **Checklist 4.**

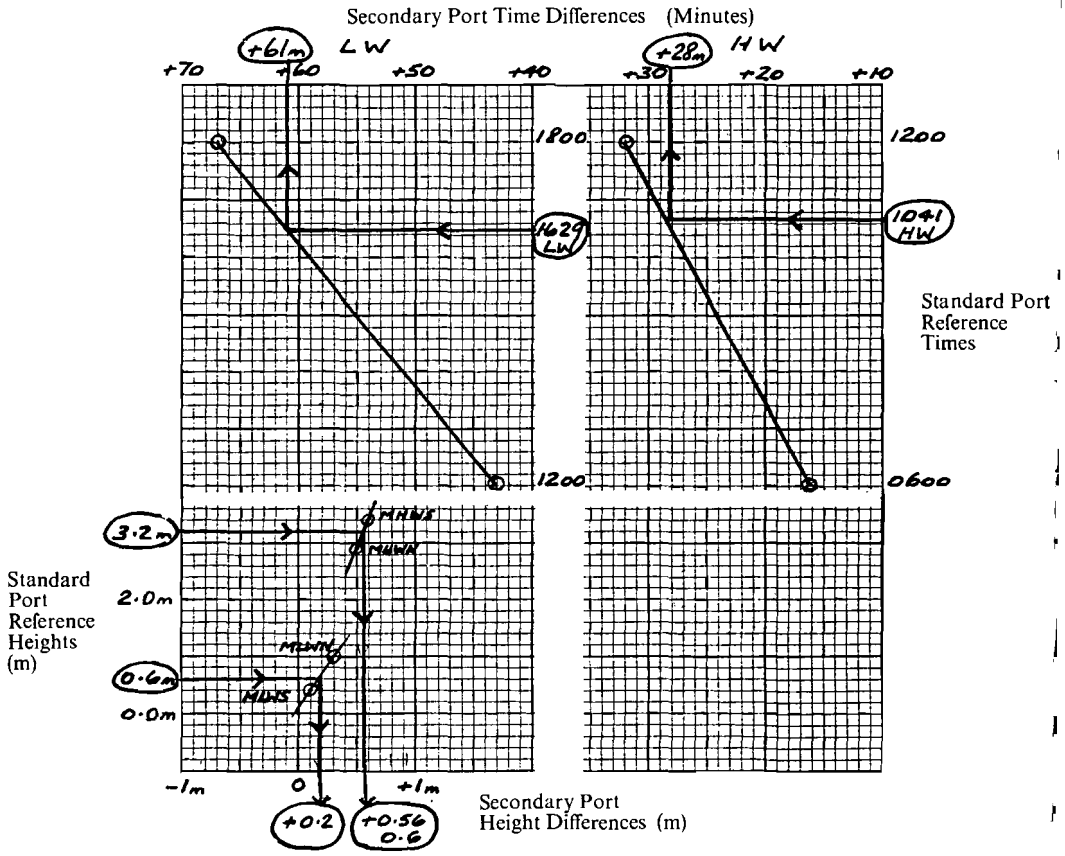


Figure 13.

STANDARD PORT GREENOCK (404) TIMES HEIGHTS REQUIRED PM FALLING

SECONDARY PORT BOWLING (406) DATE JUNE 4 TIME ZONE GMT

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	1 1041	2 1629	3 3.1	4 0.5	5 2.6
Seasonal change	Standard Port		6 +0.1	6 +0.1	SIGN CHANGED
DIFFERENCES	7* +0028	8* +0101	9* +0.6	10* +0.2	NB PLOT 3.2 + 0.6
Seasonal change	Secondary port		11 −0.1	11 −0.1	
SECONDARY PORT	12 1109	13 1730	14 3.7	15 0.7	
Duration	16 —				

Answer HW 1109 3·7 m LW 1730 0·7 m at Bowling.

Height of Tide at Intermediate Times—European Secondary Ports

At European Secondary Ports, the Height of Tide at an intermediate time (between HW and LW) is found by plotting Secondary Port data on the relevant Standard Port Tidal Diagram. Interpolating the curve for the day, if necessary, is carried out by comparing the Standard Port Range, for the time and date in question, with the Standard Port Spring and Neap Ranges, i.e. when interpolating, the procedure is identical for Standard and Secondary Ports. This gives acceptable accuracy because Secondary Ports are "paired" with Standard Ports because of the similarity of their tidal curves.

This method is only to be used when:

1. Adjacent Standard Port tidal curves are similar, and
2. Secondary Port HW and LW time differences are nearly the same.

In other cases, indicated in Part II by the letter "*c*", use the *Admiralty Method of Tidal Prediction*, NP 259.

Swanage to Selsey Secondary Ports—Special Instructions

Special instructions apply to places between Swanage and Selsey. In this area there is a rapid change of tidal characteristics and distortion of the tidal curve. Tidal curves for these places have either a Spring and Neap curve or a Spring, Neap and Critical curve—see page 866. On these curves times are related to LW not HW. Where three curves are shown, interpolation is carried out between either, the Critical and Spring curve, or the Critical and Neap curve. This type of calculation is demonstrated in ATT Volume 1 and Example 18.

Use of the Admiralty Method of Tidal Prediction (NP 159)

For Secondary Ports on stretches of coast where there is little change of shape between adjacent Standard Port curves and where the duration of rise or fall at the Secondary Port is not markedly different from the duration of rise or fall at the relevant Standard Port (i.e. where HW and LW time differences in Part II are nearly the same) intermediate times and heights

may be obtained by using the Spring and Neap Curves for the Standard Port. In other cases, where use of the *Admiralty Method of Tidal Prediction* (NP 159) is recommended and where intermediate heights are important, these are indicated by the letter "*c*" in the final column of the Secondary Port entry in Part II. For those wishing to use a pocket calculator rather than the graphical method (shown later) a calculator "box diagram" (see page 865) and detailed instructions are included at the front of ATT. The "box diagram" is also helpful when programming a programmable calculator.

Offshore Areas and Places Between Secondary Ports

Tidal predictions for certain offshore areas and stretches of coast between Secondary Ports should be obtained by use of Co-Tidal Charts. Full instructions for their use are included on the body of these charts which are listed in the *Catalogue of Admiralty Charts and Hydrographic Publications.*

To Find the Height of Tide at an Intermediate Time Between HW and LW

(European Secondary Port)

Refer to earlier comment on restrictions in the use of this method and use of NP 159.

Instructions for Secondary Ports are similar to those given earlier in **Checklist 1**, "To Find the Height of Tide at an Intermediate Time", for a Standard Port—see page 445. But, in step (2), use the Secondary Port HW and LW heights to plot the sloping line on the relevant Standard Port tidal diagram. And, in step (3), the Secondary Port HW time and time interval are entered below the curve.

Interpolating the predicted curve, step (5), is carried out using Standard Port Predicted, Spring and Neap Ranges—exactly as before. Steps (6) and (7) are also unchanged.

Example 16

(Refer to Figure 14)

Find the height of tide at 1400 GMT at Bowling (406) on the PM falling tide on June 4th. Use the times and heights given in Example 15.

Bowling Predictions:	HW 1109 3·7 m LW 1730 0·7 m
Standard Port (Greenock):	Range 2·6 m

Interpolating between Curves for Standard Port, Greenock

Spring Range	3·0 m	Spring Range	3·0 m
Neap Range	1·9 m	Predicted Range	2·6 m
S − N	1·1 m	S − P	0·4 m

$$\frac{S-P}{S-N} = \frac{0{\cdot}4}{1{\cdot}1} = 0{\cdot}36 \simeq \frac{1}{3} \text{ (Fractional Distance from Spring Curve)}$$

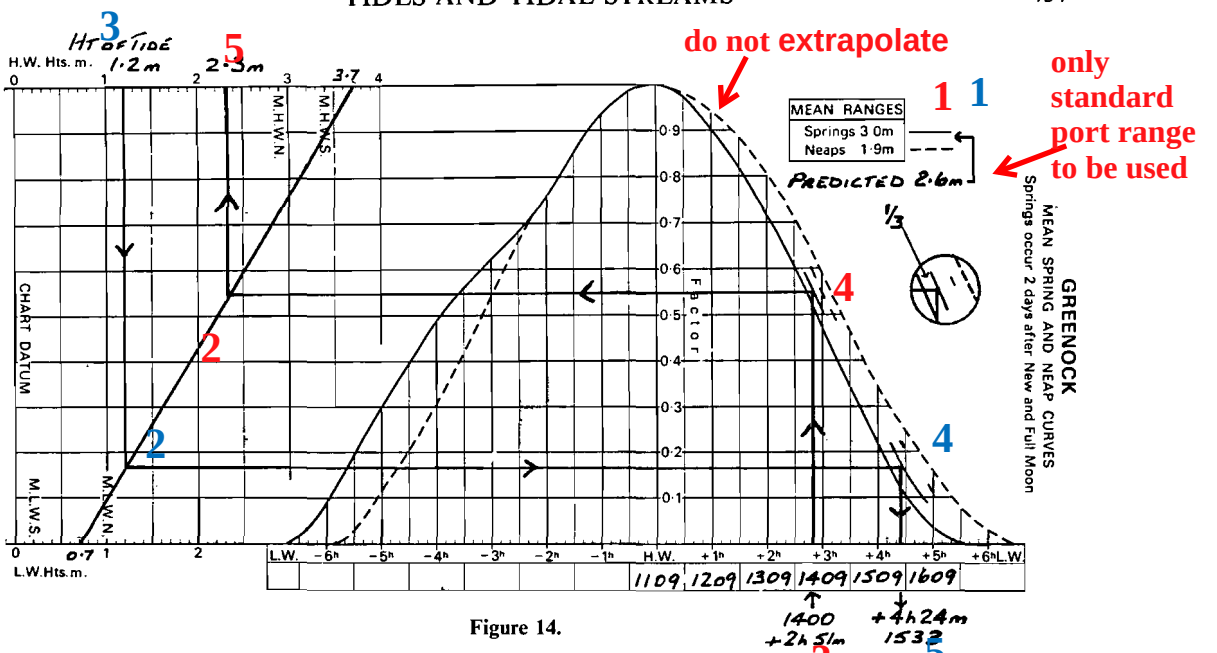


Figure 14.

Answer 2·3 metres Ht of Tide at 1400 GMT.

To Find the Time when the Tide Reaches a Required Height or Gives a Required Depth

(European Secondary Port)

Instructions for Secondary Ports are similar to those given previously in **Checklist 2**, "To Find the Time at which a Required Depth is Reached", for a Standard Port—see page 448. But, in step (3), use the Secondary Port HW and LW heights to plot the sloping line on the relevant Standard Port tidal diagram. And, in step (4), the Secondary Port HW time and time interval are entered below the Standard Port curve.

Interpolating the predicted curve, step (6), is carried out using Standard Port Predicted, Spring and Neap Ranges—exactly as before. Steps (7) and (8) are also unchanged.

Example 17

(Refer to Figure 14)

Find the time when the PM tide will have fallen to 1·2 metres above Chart Datum at Bowling (406) on June 4th. Use the times and heights given in Example 15.

Interpolating between Curves for Standard Port, Greenock

Spring Range	3·0 m	Spring Range	3·0 m
Neap Range	1·9 m	Predicted Range	2·6 m
S − N	1·1 m	S − P	0·4 m

$$\frac{S-P}{S-N} = \frac{0{\cdot}4}{1{\cdot}1} = 0{\cdot}36 \simeq \frac{1}{3} \text{ (Fractional Distance from Spring Curve)}$$

Answer 1533 GMT Ht of Tide 1·2 metres.

Example 18

(Swanage to Selsey Port)

Given the following data, find height of tide at 1500 GMT at Swanage (35) and thence the depth of water over a wreck of charted depth 29 metres.

65	**PORTSMOUTH** . . . (see page 14)				0000 and 1200	0600 and 1800	0500 and 1700	1100 and 2300	4·7	3·8	1·8	0·6	
35	Swanage	50	37	1 57	−0250	+0105	−0105	−0105	−2·7	−2·2	−0·7	−0·3	1·49	*j

TIME ZONE GMT

0111 4·4
0637 1·1
1339 4·5
1905 1·0

(65)

STANDARD PORT PORTSMOUTH TIME/HEIGHT REQUIRED 1500

SECONDARY PORT SWANAGE (35) DATE EXAMPLE TIME ZONE GMT

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	1 —	2 1905	3 4·5	4 1·0	5 3·5
Seasonal change	Standard Port		6 0·0	6 0·0	
DIFFERENCES	7* —	8* −0105	9* −2·6	10* −0·4	
Seasonal change	Secondary port		11 0·0	11 0·0	
SECONDARY PORT	12 —	13 1800	14 1·9	15 0·6	
Duration	16 —				

Note that Swanage is a European Secondary Port for which there are special instructions and three tidal curves which are related to the time of LW (not HW as with other Secondary Ports)—refer to earlier comment.

Interpolating between Curves for Swanage

Interpolate between the Critical Range at Portsmouth and either the Spring or Neap Range at Portsmouth as appropriate—in this case Predicted Range (at Portsmouth) lies between the Critical and Spring Ranges.

Ranges at Portsmouth

Spring Range	4·1 m	Predicted Range	3·5 m
Critical Range	2·9 m	Critical Range	2·9 m
S−C	1·2 m	P−C	0·6 m

$$\frac{P-C}{S-C} = \frac{0{\cdot}6}{1{\cdot}2} = \frac{1}{2} \text{(Fractional Distance from Critical Curve towards Spring Curve)}$$

Some of the ports refer to three tidal curves which are related to the time of LW not HW where normally Interpolate tide range would be the Critical.

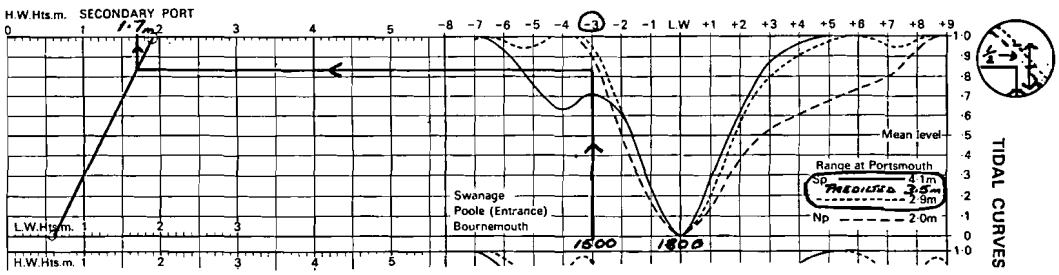


Figure 15.

Plotting

1. Plot the Secondary Port HW and LW heights and join by a sloping line.
2. Plot the Time Interval (Required Time − LW Time) on the scale beneath the curves, i.e. 1500—1800 = (−) 3 hrs (before LW).
3. From this point, draw a vertical line terminating at a point the correct fractional distance between the Critical and Spring Curves—as shown.
4. From the above point, draw a horizontal to intersect the sloping line and then a vertical to intersect the Height Scale.
5. Read off the height of tide above chart datum and apply to the charted depth of the wreck, i.e. 29 m + 1·7 = 30·7 metres.

Answer 30·7 metres is the actual depth over the wreck.

The coverage of ADMIRALTY Tide Tables 2015 Edition for six 6 volume will have to be seen later

ATLANTIC and INDIAN OCEAN PORTS (ATT Volume 2), and PACIFIC OCEAN and ADJACENT SEAS (ATT Volume 3) & Volume 4

HW and LW Times and Heights at Standard Ports

Times and heights of HW and LW at Standard Ports are found directly from the daily predictions in ATT Volumes 2 and 3. The Zone Time used for the predicted times is usually the Standard Time for the area and is given at the top of each page. Care should be taken to check that this time is the actual Time Zone in use on the date in question—if not, correct as necessary.

HW and LW Times and Heights at Secondary Ports

Times and heights of HW and LW at Secondary Ports are found by applying simple differences in times and heights to the predictions at the most suitable (not necessarily the closest) Standard Port.

In many Pacific Ports, the heights of HW and LW show irregularities due to the predominantly diurnal effect. In extreme cases this can produce only one HW and one LW each day. Where the effect is less, it may cause two high waters at different levels and two low waters at different levels. These are usually termed Higher HW (HHW) and Lower HW (LHW); Higher LW (HLW) and Lower LW (LLW)—in calculations, these should be taken into account according to ATT footnotes for the ports affected.

For certain ports, indicated by the letter "*p*", no time differences are listed in ATT Part II. Predictions for these ports can only be made by using the *Admiralty Method of Tidal Prediction*, NP 159.

To Find HW and LW Times and Heights

(Secondary Ports—Atlantic, Indian and Pacific Oceans—**Checklist 5**)

1. Use NP 204 to record the date, required time or height and the Secondary Port name, i.e. complete NP 204 heading, as far as possible and then use the form to record, and total, data extracted from the tide tables.
2. Find the Secondary Port in the Geographical Index of ATT Volume 2 or 3. Note its number.
3. Refer to ATT Part II with Secondary Port number and note the relevant Standard Port, its number and page number in Part I.
4. Refer to Part I and find HW and LW times and heights at the Standard Port for the required day.
5. Refer back to Part II. Find the Standard Port Seasonal Change in Mean Level, change its sign and add it to the Standard Port heights. (NB. Standard Port heights quoted in ATT already include this Seasonal Correction which must be subtracted algebraically so that subsequent interpolation is carried out on the unadjusted tidal heights—this is achieved by changing the sign and adding.)
6. Note the time and height differences for the Secondary Port (interpolate using graph paper, if necessary).
7. To find the Secondary Port HW's and LW's, apply interpolated Secondary Port time and height differences to the Standard Port HW and LW times and heights and add, algebraically, the Secondary Port Seasonal Change in Mean Level.
8. Complete NP 204, box 16, by finding the Duration of Tide (time intervals between each HW and the preceding or following LW)—which will be required for any subsequent intermediate time or height calculations.

Example 19

(Indian Ocean Secondary Port)

Find the time and heights of HW and LW at Akyab (4520) on September 28th.

Form NP 204 is somewhat cramped for entering two HW's and two LW's—make up a new grid or use two forms, if desired. (Predictions page 847–8.)

STANDARD PORT Bassein River Entrance (4539) TIME/HEIGHT REQUIRED HW & LW

SECONDARY PORT Akyab (4520) DATE Sept 28 TIME ZONE −0630

Volume 2

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	1 0655 1928	2 0008 1337	3 2.0 1.8	4 1.3 1.2	5 0.7 0.6
Seasonal change	Standard Port		6 −0.1	6 −0.1	Sign Changed
DIFFERENCES	7* +0004	8* +0001	9* −0.1	10* −0.3	
Seasonal change	Secondary port		11 +0.1	11 +0.1	
SECONDARY PORT	12 0659 1932	13 0009 1338	14 1.9 1.7	15 1.0 0.9	
Duration	16 6h 50m 6h 39m 5h 54m				

N.B. In this particular example the Seasonal Change in Mean Level at the Standard and Secondary Ports are the same and hence cancel out—this is *not* always the case.

Standard Curves Diagram—ATT Volumes 2 and 3

(Refer to Figure 17 and page 867)

Curves for individual Standard Ports are not included in ATT Volumes 2 and 3. Instead, a single "Standard Curves Diagram", (identical in both volumes), is included. This diagram shows the height of tide attained at a given time or time interval from HW. Subject to certain restrictions, this diagram is used for all Atlantic, Indian and Pacific Ocean Ports.

The Diagram includes three Standard Curves which correspond to Durations of Tide of 5, 6 and 7 hours. It assumes that the tidal curve of the place under consideration closely resembles a cosine curve. Where the Duration of Tide has an intermediate value (say $6\frac{1}{4}$ hours), for which there is no curve, it becomes necessary to interpolate between adjacent curves (i.e. for $6\frac{1}{4}$ hrs, draw in part of a new curve $\frac{1}{4}$ of the way from the 6 hour curve towards the 7 hour curve).

Intermediate Times and Heights between HW and LW

The Standard Curves Diagram can be used to find either a height of tide at a particular place or the time at which a tide reaches a required height. It is used in much the same way as a European Standard Port Tidal Diagram. After any necessary interpolation, the Standard Curves give acceptable results for intermediate times and heights providing that:

1. Duration of Tide is between 5 and 7 hours, and
2. There is no Shallow Water Correction shown in Part III.

If either of these conditions is not met, intermediate times and heights at places listed in ATT Volumes 2 and 3 must be predicted using the *Admiralty Method of Tidal Prediction*, NP 159, which is explained later.

To Find the Height of Tide at an Intermediate Time between HW and LW using Standard Curves

(Secondary Ports—Atlantic, Indian and Pacific Oceans—**Checklist 6**)

1. Complete NP 204 to box 15 for the tide concerned—see Checklist 5.
2. Subtract earlier Secondary Port tide time from later time to obtain Duration of Tide (box 16).
3. On the Standard Curves Diagram, plot the heights of HW and LW and join by a sloping line.
4. Write down the HW time and sufficient others to "embrace" the required time in the boxes below the curves. If helpful, also write down the Time Interval from HW.
5. Plot the required time on the Time Scale and proceed vertically to the curve for the predicted Duration of Tide (interpolate, as necessary, between curves).
6. Proceed horizontally to the sloping line then vertically to the Height Scale. Read off the height of tide.

Example 20

(Pacific Ocean Secondary Port—refer to Figure 17)

Find the height of tide at Port Hardy (9020, Volume 3) at 1755 Standard Time on May 1st. (Predictions page 853.)

Interpolation

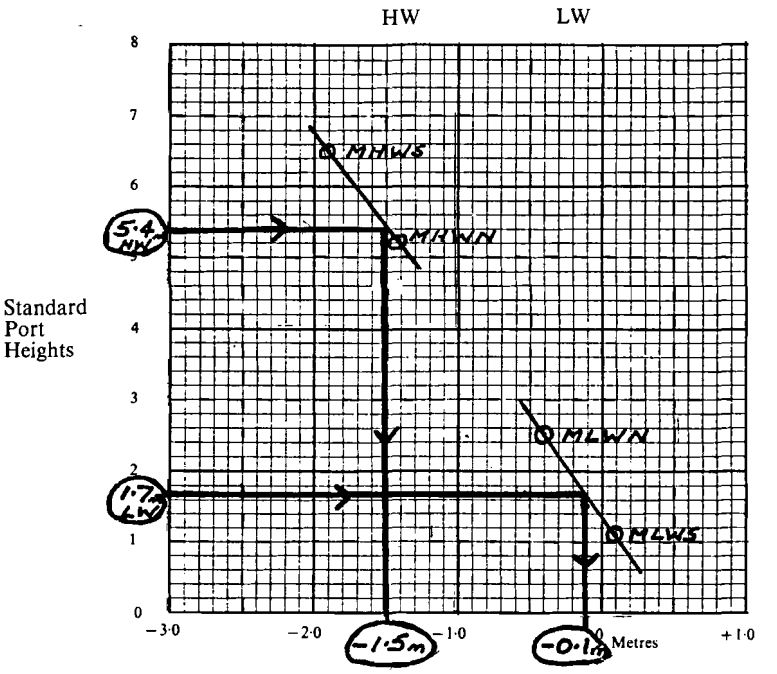


Figure 16. Secondary Port Height Differences.

NP 204

STANDARD PORT PRINCE RUPERT (8850) TIME/[redacted] REQUIRED 1755

SECONDARY PORT PORT HARDY (9020) DATE MAY 1st TIME ZONE +0800 VOLUME 3

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	1 2110	2 1430	3 5·4	4 1·7	5 3·7
Seasonal change	Standard Port		6 0·0	6 0·0	
DIFFERENCES	7* −0025	8* −0030	9* −1·5	10* −0·1	
Seasonal change	Secondary port		11 −0·1	11 −0·1	
SECONDARY PORT	12 2045	13 1400	14 3·8	15 1·5	
Duration	16 6h 45m				

Secondary port Duration to be used in curve

NB DRAW IN 6¾ hr CURVE

Answer 2·9 metres Ht of Tide at 1755 Standard Time.

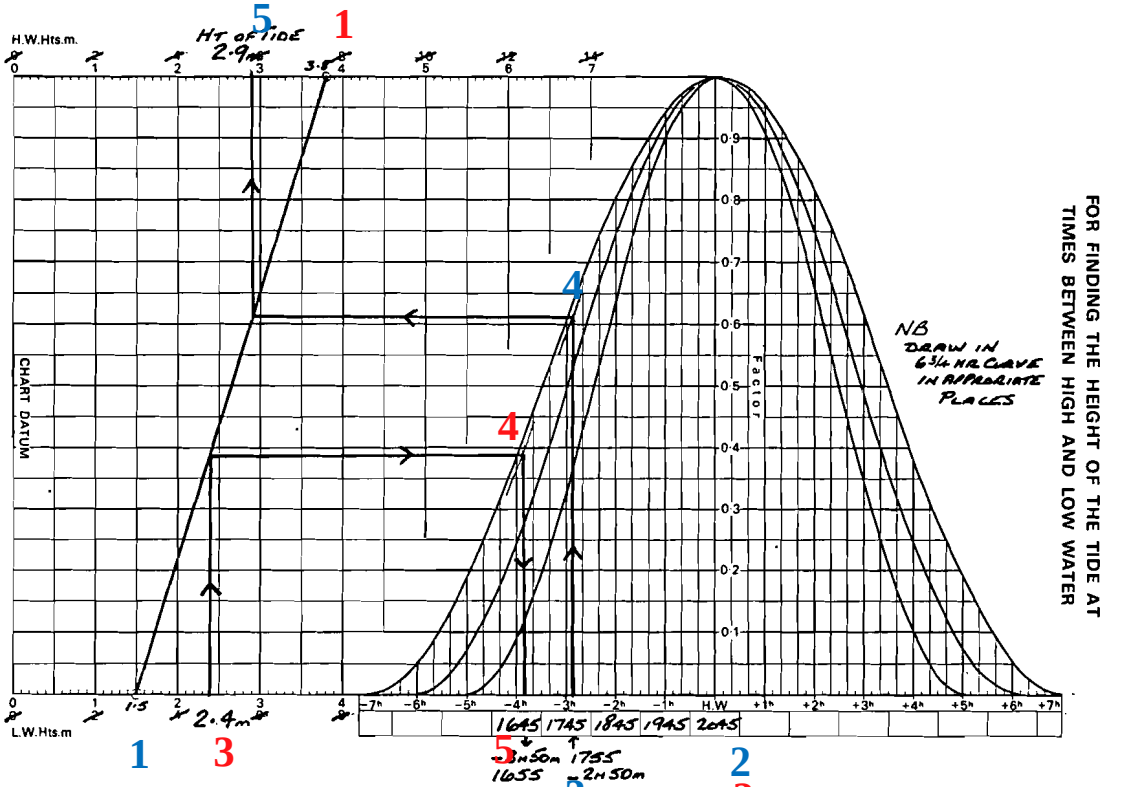


Figure 17.

To Find the Time at which a Tide Reaches a Required Intermediate Height using Standard Curves

(Secondary Ports—Atlantic, Indian and Pacific Oceans—**Checklist 7**)

1. Complete NP 204 to box 16. Plot HW and LW heights and join by a sloping line.
2. In the boxes beneath the curves, write in the HW time and sufficient others to "embrace" the likely time.
3. Plot the required Height of Tide, proceed vertically to the sloping line, then horizontally to the appropriate curve for the predicted Duration of Tide. From this point proceed vertically down to the Time Scale and read off the time.

Example 21

(Pacific Ocean Secondary Port—refer to Figure 17)

Find the time when the rising PM tide reaches a height of 2·4 metres at Port Hardy (9020, Volume 3) on May 1st. Use HW and LW predictions found in Example 20.

Secondary Port HW and LW predictions found in the previous example.

Plotting for this example is shown in Figure 17.

Answer 1655 Standard Time.

NP 159—Calculator Method. For those wishing to use a pocket calculator rather than the graphical method (demonstrated on subsequent pages) a calculator "box diagram" is included on page 865.

Detailed instructions for the completion of the NP 159 "box diagram", and notes relating to the use of this method with calculators and programmable calculators, are included in: *Admiralty Tide Tables* Volume 1, pages xxvi–xxviii and in Volumes 2 and 3, on pages xviii–xx.

THE ADMIRALTY METHOD OF TIDAL PREDICTION—NP 159

A harmonic curve is a symmetrical curve which recurs periodically. The forces which raise the tides are periodic and they can be represented by harmonic curves.

If each force was represented by its harmonic curve then the predicted tidal curve would be the sum of these harmonic curves. Lord Kelvin proposed the harmonic system of tidal prediction. Previously this method required a complex mechanical tide predicting machine. The Admiralty Method has been developed so that the navigator can improve on the accuracy of the tidal curve. This is particularly necessary in those places where there is an appreciable Shallow Water effect.

Harmonic Constants for the port are given in Part II of the Tide Tables and in Table VII data is given to adjust them for the day and year. Detailed instructions are given in NP 159.

Four constituents are used, namely:

M_2 the lunar semidiurnal tractive force and the part of tide due to it.
S_2 the solar semidiurnal tractive force and the part of the tide due to it.
K_1 the combined lunar and solar diurnal force and tide due to it.
O_1 the principal variation in lunar diurnal force and tide due to it.

NP 159 consists of three forms:

Form A includes a Table of data for M_2, S_2, K_1, O_1 and the Mean Level and a plotting circle to produce the various parts of the tide height due to these Harmonic Constants.

Form B which is used to plot the predicted tide heights and on which a tidal curve may be drawn.

Form C which consists of a Table and Plotting Circle to produce the tide heights due to Shallow Water Effect.

A knowledge of the method is required in Class 1 examinations but not the full calculation and the plot of the tidal prediction. This method can also be used with a calculator—see NP 159 Box Diagram on page 865.

Admiralty Method of Tidal Prediction

1. In those places where the Shallow Water effect is known and is appreciable, the predicted tidal curve can be improved by the addition of corrections based on the quarter and sixth diurnal constituents, using Form C. In these cases, the appropriate angles f_4 and f_6 and factors F_4 and F_6 are tabulated for the place concerned in Admiralty Tide Tables, Part II. If no data is tabulated for these angles and factors, Form C is not required.
2. On Forms A and B, all working and plotting should be done to 2 decimal places, to provide predictions correct to 1 decimal place. If the range of the tide to be predicted is either very large or very small, it may be desirable either to double or to halve the height scale of the Graph Sheet (Form B). If this is done, the same factor MUST be applied to the scale of the Plotting Circle on Form A.
3. On Form C, the working and plotting should be done to 3 decimal places, to provide Shallow Water Corrections correct to 2 decimal places for entering on Form B. The scale of the Plotting Circle on this form is considerably greater than that on Forms A and B; like the latter, it may be amended, if desired, for ease of plotting. When transferring the total Shallow Water Corrections at the foot of Form C to the Graph Sheet, the scale of Form B MUST be used.

4. The multiplications required on Forms A and C may be done long-hand, by slide-rule or by logarithms. A table of logarithms to a sufficient degree of accuracy is included inside the front and back covers of this book.
5. The data used in the Example does not refer to any particular port.
6. The Admiralty Method of Tidal Prediction is also suitable for use on an electronic calculator. Details are published in the Instructions section of each volume of Admiralty Tide Tables.

FORM A—Instructions (refer to example Form A across).

Enter PLACE, DATE and ZONE TIME (from Admiralty Tide Tables, Part II).

TABLE—Row 3 From ATT, Part II and Tables VI and VIa where appropriate, for the place enter g and H of M_2, S_2, K_1 and O_1 and Mean Level (Z_0).

Row 4 From ATT, Table VII, for the date, enter Tidal Angle (A) and Factor (F) for M_2, S_2, K_1 and O_1.
From ATT, Part II, enter Seasonal Correction to ML.

Row 5 Add $\alpha°$, g° and A° (subtracting 360° or 720° if necessary), to get m°, s°, k° and o°.
Multiply H and F, to get M, S, K and O.
Add Z_0 and Seasonal Correction, to get A_0.

Plotting Circle

1. From centre C, lay off length M in direction m°, to get point M_2.
   From point M_2, lay off length S in direction s°, to get point H_2.
   Draw line ②——② through centre C and perpendicular to CH_2.
   With centre C and radius CH_2, describe a circle (Semi-Diurnal circle).
2. From centre C, lay off length K in direction k°, to get point K_1.
   From point K_1, lay off length O in direction o°, to get point H_1.
   Draw line ①——① through centre C and perpendicular to CH_1.
   With centre C and radius CH_1, describe a semi-circle to cut all the short (pecked) radii from 06 to 18 (Diurnal semi-circle).
3. Take off the angle h_2 (= direction of H_2 from C) and length H_2 (= CH_2) and enter them in the appropriate spaces in the small panel to the right of the Circle. These are required later, for use with Shallow Water Corrections (Form C), if these are appreciable.

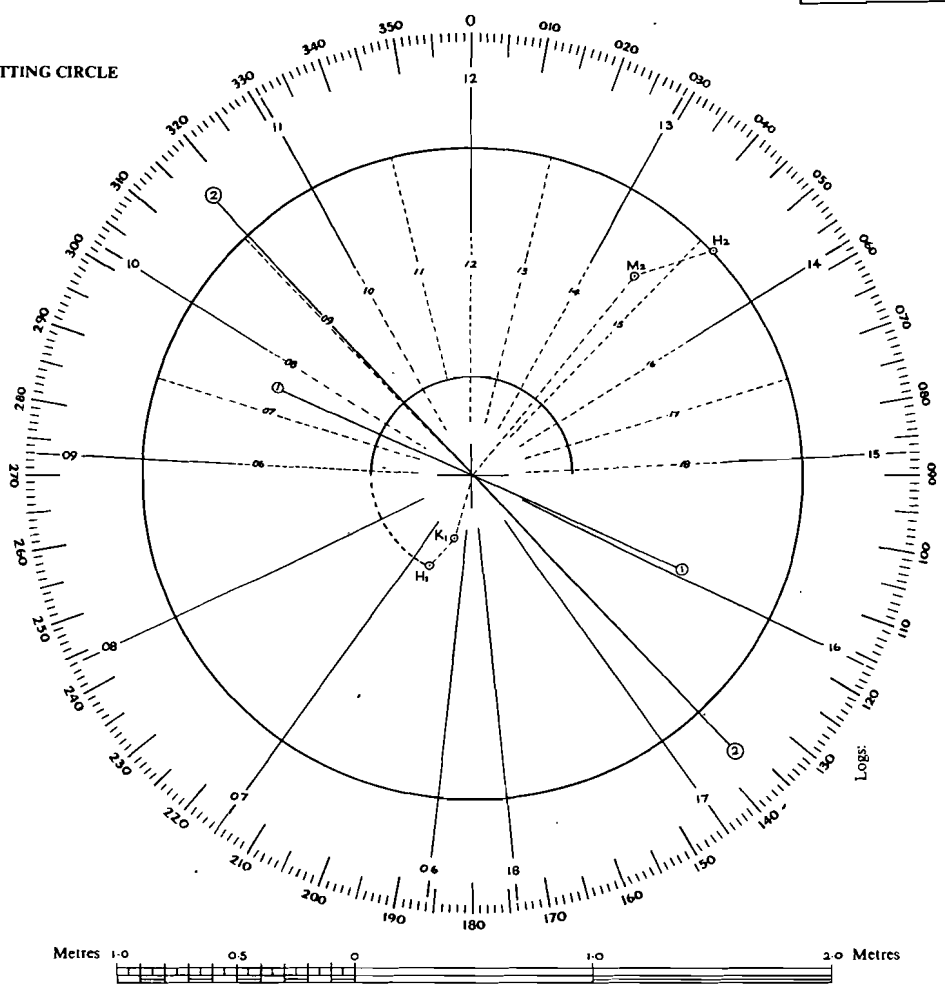
Place EXAMPLE PORT Date 10 JULY 1975 **FORM A** [Example]

Lat 31° 24′ N Long 121° 30′ E Zone Time −0800

TABLE			M_2		S_2		K_1		O_1		M.L.	
	$\alpha°$		012		000		180		192			
from ATT, Part II	$g°$	H	008	0·94	060	0·42	215	0·23	162	0·14	2·55	Mean level (Z_0)
from ATT, Table VII	$A°$	F	019	1·17	012	0·82	161	1·28	229	1·05	+0·2	Seasonal Correction
	$\alpha+g+A$	H x F	039	1·100	072	0·344	196	0·294	223	0·147	2·55	ADD
			−m°	−M	−s°	−S	−k°	−K	−o°	−O	−A_0	
	logs:		T·9731		T·6232		T·3617		T·1461			
			0·0682		T·9138		0·1072		0·0212			
			0·0413		T·5370		T·4689		T·1673			

h_2 =	0·47
H_2 =	1·40

PLOTTING CIRCLE



Metres 1·0 0·5 0 1·0 2·0 Metres

Admiralty Method of Tidal Prediction

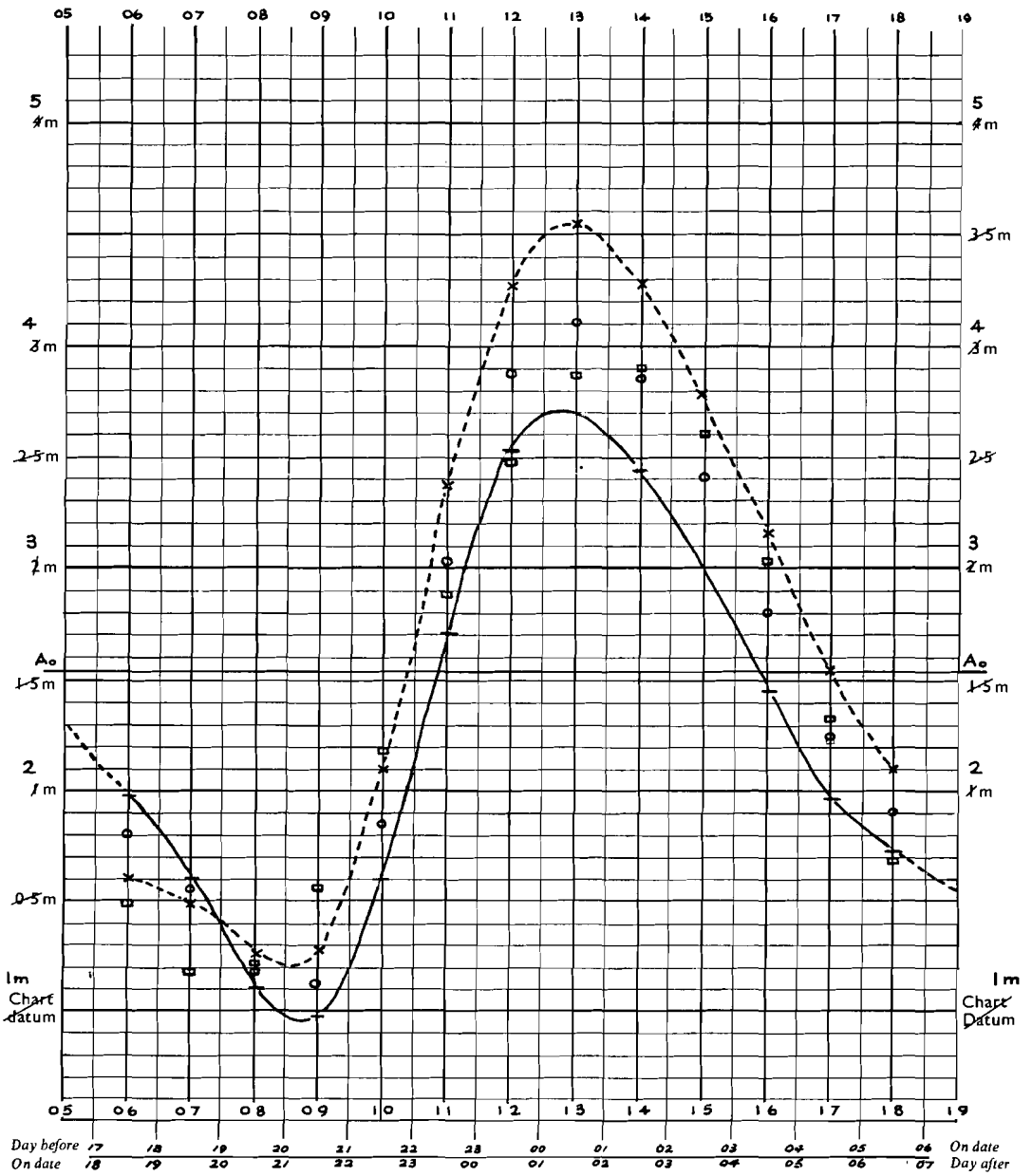
FORM B—Instructions (refer to example Form B across).

1. Enter PLACE, DATE and ZONE TIME (from Admiralty Tide Tables, Part II).
2. Draw a line across the sheet at height A_0.
3. From Form A take off, with dividers, the shortest (perpendicular) distance from the intersection of the Semi-Diurnal circle with the long (firm line) radius 06 to the line ②——②. Transfer this length to Form B, laying it off from the line A_0 along the vertical marked 06 at the top, upwards ($+^{ve}$) if the intersection and H_2 are on the same side of ②——② and downwards ($-^{ve}$) if they are on opposite sides of ②——②.
4. Repeat this process of each of the intersections of the S.D. circle with the long (firm line) radii 07 to 18, laying off the distances, with appropriate signs, from the line A_0 along the verticals marked 07 to 18 at the top. Mark these points ⊡ if there are Shallow Water Corrections, otherwise ⊙.
5. At this stage, the Shallow Water Corrections (if any) should be applied. For the method of doing this, see the instructions for Form C on page 6.
6. After applying the Shallow Water Corrections, return to Form A. Take off, with dividers, the shortest (perpendicular) distance from the intersection of the Diurnal semi-circle with the short (pecked line) radius 06 to the line ①——①. Transfer this length to Form B, laying it off from the point ⊙ on the vertical marked 06 at the top, upwards ($+^{ve}$) if the intersection and H_1 are on the same side of ①——① and downwards ($-^{ve}$) if they are on opposite sides of ①——①.
7. Repeat this process for each of the intersections of the D. semi-circle with the short (pecked line) radii 07 to 18, laying off the distances, with appropriate signs, from the points ⊙ already plotted on the appropriate verticals 07 to 18 on Form B, marking these points +.
8. The result is a series of 13 points +. These points are joined by a smooth curve, which is the predicted tide curve from 0600 to 1800 on the date at the head of the form
9. To obtain predictions for further periods of 12 hours on either side of these times, see instructions for extending the predictions on page 468.

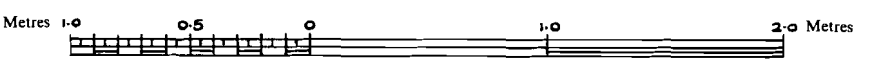
FORM B
[Example]

Place EXAMPLE PORT Date 10 JULY 1975

Lat 31° 24' N Long 121° 30' E Zone Time - 0800



Times at top and bottom of main framework relate to continuous curve (drawn first)
Lower set of times (in italics) relate to pecked curve (drawn second).



Admiralty Method of Tidal Prediction

FORM C—(Shallow Water Corrections) **instructions** (refer to example Form C across).

1. Enter PLACE, DATE and ZONE TIME (from Admiralty Tide Tables, Part II).
2. Transfer the values of h_2 and H_2 from the small panel on Form A to the appropriate spaces in the Table at the top of the form. Hence evaluate, and enter in the appropriate spaces, $2h_2$ and $3h_2$ (subtracting 360° or 720° if necessary), H_2^2 and H_2^3.
3. From ATT, Part II, for the place, obtain the angles f_4 and f_6 and factors F_4 and F_6 and enter them in the appropriate spaces in the Table.
4. Evaluate, and enter in the appropriate spaces in the Table, h_4 $(= f_4 + 2h_2)$, h_6 $(= f_6 + 3h_2)$ (subtracting 360° if necessary), H_4 $(= F_4 \times H_2^2)$ and H_6 $(= F_6 \times H_2^3)$. If no data is given for F_6, then H_6 is assumed to be zero.
5. On the Plotting Circle, lay off distance H_4 in direction h_4 from the centre C to get point H_4. Draw the line ④——④ through centre C and perpendicular to CH_4. With centre C and radius CH_4, describe the Quarter-Diurnal semi-circle to cut the continuous radii A and P to U.
6. Take off the shortest (perpendicular) distance from the intersection of the Q.D. semi-circle with the radius A to the line ④——④ and enter it in the Q.D. row of the 1200 column of the Table at the foot of the Form, calling it positive $(+^{ve})$ if the intersection and H_4 are on the same side of ④——④ and negative $(-^{ve})$ if they are on opposite sides.
7. Repeat this process for the intersections of the Q.D. semi-circle with the radii P, Q, R, S, T and U, entering the values, with appropriate signs, in the 06, 07, 08, 13, 14 and 1500 columns of the Table respectively, as indicated therein.
8. Complete the Q.D. row of the Table by entering P, Q, R, S, T and U, with OPPOSITE signs, in the 09, 10, 11, 16, 17 and 1800 columns respectively, again as indicated therein.
9. Repeat step 5, with H_6 and h_6 replacing H_4 and h_4, to get point H_6, the line ⑥——⑥ and the Sixth-Diurnal semi-circle cutting the continuous radius A and the pecked radii V to Z.
10. Take off the shortest (perpendicular) distance from the intersection of the 6-D. semi-circle with the continuous radius A to the line ⑥——⑥ and enter it, with appropriate sign, in the 6-D. row of the 1200 column of the Table.
11. Repeat this process for the intersections of the 6-D. semi-circle with the pecked radii V, W, X, Y and Z, entering the values, with appropriate signs, in the 06, 07, 11, 15 and 1600 columns of the Table respectively, as indicated therein.
12. Complete the 6-D. row of the Table by entering V, W, A, X, A, Y and Z, with OPPOSITE signs, in the 08, 09, 10, 13, 14, 17 and 1800 columns respectively, again as indicated therein.
13. Sum, algebraically, the Q.D. and 6-D. values in each of the 13 columns and enter the results in the bottom line of the Table, to obtain the total Shallow Water Correction for each hour.
14. Using the scale on the Graph Sheet (Form B), apply the total S.W.C. for each hour to the appropriate S.D. points ⊡ already plotted on the Graph Sheet, applying them upwards if the correction is positive $(+^{ve})$ and downwards if it is negative $(-^{ve})$. Mark these points ⊙.

Place EXAMPLE PORT Date 10 JULY 1975 **FORM C** [Example]

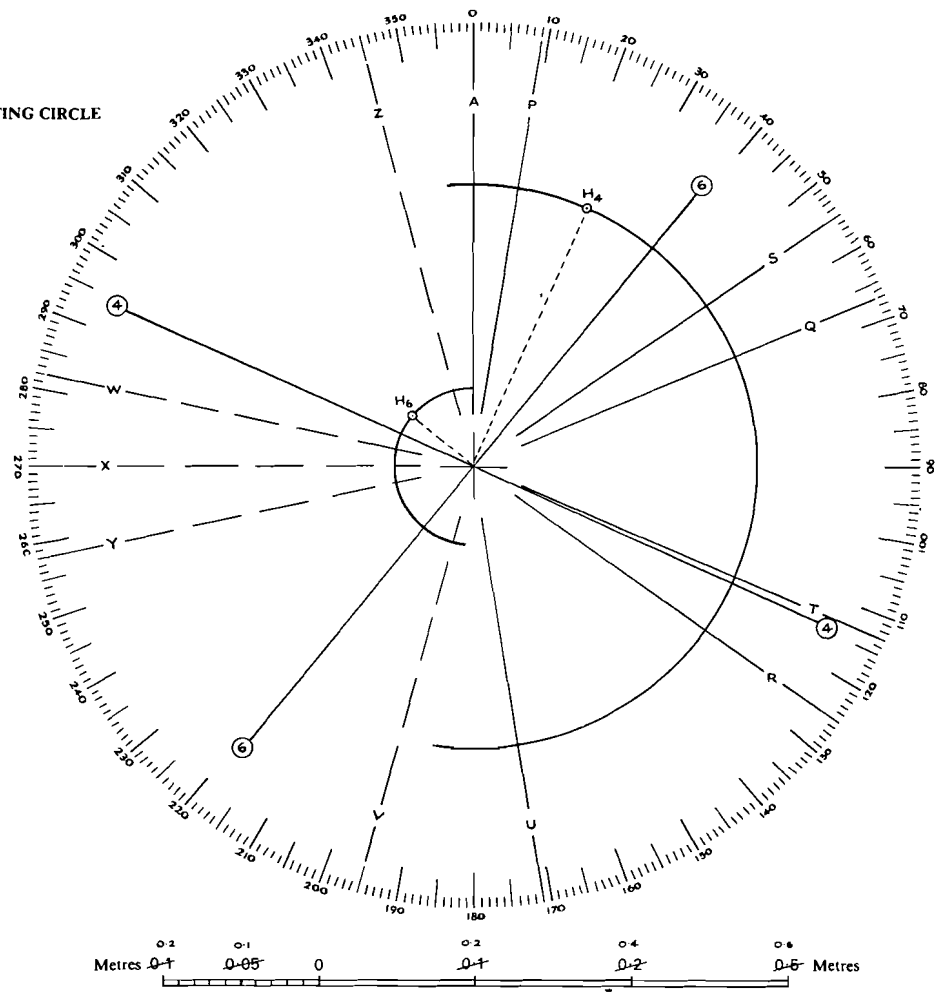
Lat 31° 24′ N Long 121° 30′ E Zone Time −0800

TABLE

$h_2 - 047$	$2h_2 - 094$	$f_4 - 290$	$h_4 - f_4 + 2h_2 - 024$	$3h_2 - 141$	$f_4 - 168$	$h_6 - f_6 + 3h_2 - 309$
$H_2 - 1{\cdot}40$	$H_2^2 - 1{\cdot}960$	$F_4 - 0{\cdot}185$	$H_4 - F_4 \times H_2^2 - 0{\cdot}363$	$H_2^3 - 2{\cdot}744$	$F_4 - 0{\cdot}038$	$H_6 - F_6 \times H_2^3 - 0{\cdot}104$

logs: 0·1461 0·2922 $\bar{1}$·2672 $\bar{1}$·5594 0·4383 $\bar{2}$·5798 $\bar{1}$·0181

PLOTTING CIRCLE



TABLE

Time	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800
QD	P^{+} ·350	Q^{+} ·266	R^{-} ·068	$-P^{-}$ ·350	$-Q^{-}$ ·266	$-R^{+}$ ·068	A^{+} ·336	S^{+} ·314	T^{+} ·010	U^{-} ·304	$-S^{-}$ ·314	$-T^{-}$ ·010	$-U^{+}$ ·304
6-D	V^{-} ·042	W^{+} ·088	$-V^{+}$ ·042	$-W^{-}$ ·088	$-A^{-}$ ·062	X^{+} ·080	A^{+} ·062	$-X^{-}$ ·080	$-A^{-}$ ·062	Y^{+} ·062	Z^{+} ·082	$-Y^{-}$ ·062	$-Z^{-}$ ·082
Sum	+ ·308	+ ·354	− ·026	− ·438	− ·328	+ ·148	+ ·398	+ ·234	− ·052	− ·242	− ·232	− ·072	+ ·222

Admiralty Method of Tidal Prediction

Extending the predictions

The preceding instructions enable the predicted tide curve from 0600 to 1800 on the date to be drawn, using the time scale at the top and bottom of the main framework of Form B. This tide curve can be simply extended for a further 12 hours in both directions, giving predictions from about 1800 on the day before to about 0600 on the day after the date at the head of the form. These extended predictions are not as accurate as those for the central 12 hours, but are adequate for most purposes.

Previously, the diurnal tide at, say, hour 06 has been taken from the Plotting Circle on Form A with dividers and laid off in the appropriate direction along the 06 hour vertical from the already plotted point ⊙ (the combined S.D. and S.W.C. point, or, if there is no S.W.C., the S.D. point). This gives the height of the whole tide at 0600 on the date. Now lay off the same length from the same point ⊙ in the OPPOSITE direction along the 06 hour vertical, marking it ×. This point gives the approximate height of the whole tide $12\frac{1}{2}$ hours both before and after 0600 on the date—i.e. at 1730 on the day before and at 1830 on the date, as indicated on the lower time scales.

Repeat this process for the hours 07 to 18; the result will be 13 points ×. Join these points by a smooth curve—a pecked line to distinguish it from the continuous line curve already drawn. This pecked curve, read in conjunction with the appropriate lower time scale, extends the original continuous tide curve for a further 12 hours in both directions.

If H_1, the diurnal tide, is negligibly small, then the curve obtained by joining the points ⊙ is the predicted tide curve from 0600 to 1800 on the date at the head of the form, using the time scale at the top and bottom of the main framework of Form B. It is also the predicted tide curve for the 12 preceding and the 12 subsequent hours, using the appropriate one of the two time scales beneath the graph.

It may sometimes be desirable to extend the continuous curve to the edges of the Graph Sheet, at 0500 and 1900 on the date (e.g. when high or low waters occur near 0600 and 1800). The height of the tide at 0500 on the date appears on the pecked curve $1\frac{1}{2}$ hours from the right-hand edge of the Graph Sheet; this height is transferred to the 05 hour vertical on the left-hand edge, to give another point on the continuous curve. Similarly, a further point can be obtained at 1900 on the right-hand edge, enabling the continuous curve to be drawn from 0500 to 1900 on the date.

Additional uses

When the tidal curve for the day is drawn, the times and heights of HW and LW can be read off. Additional information is available from the curve, such as:

(a) When will the height of the tide be greater than 3 metres above datum?
(b) If the ship grounds at 0600 when will she refloat?

Answers:

HW 1250 3·7 m. LW 0845 0·95 m, 2200 1·2 m.
(a) Periods between 1118 to 1500 hours
(b) 1020.

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Tides Around the United Kingdom

The main undulation from the Atlantic Ocean approaches the English Channel and Ireland from a SW'ly direction, the line of the crest of the progressing wave being NW and SE, so that it reaches the SW point of Ireland at almost the same time as it arrives at Ushant.

The tidal wave, on striking the SW point of Ireland, is split into two parts, one running northerly, causing high water successively on the West coast of Ireland and Scotland, the other running to the SE, causing high water successively along the South coast of Ireland and the North coast of France. When the tide wave reaches shallow water it generates tidal streams which have the same period as the wave, flowing in the direction of the rapidly moving crest and then ebbing in the opposite direction at the trough. The velocity of the stream is maximum at HW and LW.

In the Irish Sea, tides are raised by the tidal streams entering both North and South channels at the same time, and the resulting movement is similar to that observed when a basin of water is tilted. The level rises at one end of the basin and falls at the other while at a nodal point in between, there is no change in level. This is called a standing oscillation. The tidal streams set towards Liverpool when the water is rising at that port, and away from Liverpool as the water falls there.

In the North Sea the tide wave from the Atlantic sets up a standing oscillation type of tide having more than one high water area at the same time.

The high water crest proceeds S'ly from the vicinity of 60° N. to about 56° N. and a crest then continues from the next tidal system to meet a third system about latitude 53° N. The average rate of the tidal streams are moderate, not exceeding a knot and a half but that part of the stream that enters from the Pentland Firth acquires great rapidity, amounting in spring tides to 8 knots.

In the English Channel the tide waves are of the standing oscillation type and the crest of high water due to constituent M_2 runs transversely across the channel as shown by the co-tidal lines on Admiralty Chart No. 5058. Over a considerable length of the coast between Portland and Selsey Bill a double tide is experienced due to large tide waves from quarter diurnal and other constituents. In the Solent two distinct high waters are experienced with an interval of from one to two hours. At Portland a double low water is experienced from similar causes.

ADMIRALTY TIDAL STREAM ATLASES (NW EUROPE AND HONG KING)

Tidal Stream Atlases (ATSA) published by the Admiralty include some 13 volumes in respect of NW Europe and one volume in respect of Hong Kong

These Atlases give detailed tidal stream information for the areas covered and include full instructions for the prediction of tidal stream rates. A "Computation of Rates Diagram" is included to aid accurate interpolation. Refer to the diagram on page 878.

Each atlas contains 13 charts (A4 size) which show, in pictorial form, the tidal streams operating at hourly intervals from High Water (HW) at a selected Standard Port.

The 13 charts included correspond to time intervals of 6 hrs–1 hr *Before* HW, HW, and 1 hr–6 hrs *After* HW. Specimen charts are shown on pages 871–877.

Direction of Tidal Stream

The Direction of Tidal Streams is indicated by arrows. No compass rose is included on the charts. If a precise indication of direction is required it is necessary to use the parallel ruler. (The side of the chart may be used as the meridian.) A "Douglas" protractor is a convenient alternative.

Rate

The Rate of a Tidal Stream is indicated in two ways—numerically and pictorially. In the numerical presentation the Neap and Spring rates are given in tenths of a knot. The two rates are separated by a comma which indicates the approximate position at which observations were obtained, e.g. 14,22 indicates 1·4 knots at Neaps and 2·2 knots at Springs at the position (,).

In the pictorial presentation the strength (rate) of the tidal stream is indicated by the length and thickness of the arrow, e.g. a short thin arrow represents a weak tidal stream.

Plotting Positions

If accurate data is required it is essential to accurately plot the position required. A latitude and longitude scale is provided.

Interpolation

Interpolation between Neap and Spring rates can be carried out in the usual way or by use of the "Computation of Rates" diagram which is printed on the inside front cover of each atlas. This diagram is a "purpose built" graph designed to be used for interpolating rates quoted in (and only in) the particular atlas in which it is contained, i.e. it should not be used for interpolating rates from areas covered by other atlases.

Use of the "Computation of Rates" Diagram

(Refer to page 878)

1. Select the Tidal Stream Atlas for the required area. (The Area Coverage of Admiralty Tidal Stream Atlases is shown on the last page of each atlas.)
2. Select the appropriate volume of the Admiralty Tide Tables (ATT Vol. 1 for European Waters).
3. Write down the required Position, Date, Time and the Standard Port (as stated at the top of each page) on which the Tidal Stream Atlas predictions are based.
4. Refer to ATT and write down the HW and LW times and heights for the day.
5. Find the interval between the Required Time and the nearest HW. Label Before HW or After HW, as appropriate.
6. Find the ranges between successive HW and LW heights for the day and calculate the Mean Range for the day.
7. Compare the Mean Range (found above) with the Mean Spring and Neap Ranges at the Standard Port.

N.B.—Mean Spring and Neap ranges are shown in the box included on the tidal curve.
If equal to Springs use Spring Rate.
If equal to Neaps use Springs Rate.
In other cases use the Computation of Rates Diagram.

8. Find the tidal stream chart which corresponds to the Time Interval found at (5).
9. Plot the required position on the chart.
   N.B.—Having regard for the small scale, **accurate plotting** is **essential.**
10. Read off the Neap and Spring rates from the chart and write them down.
11. Using the parallel ruler (or a Douglas protractor) find the direction of tidal stream
12. Turn to the Computation of Rates Diagram on the inside front cover.
13. Plot the Neap Rate on the dotted line marked Neaps.
    N.B.—Each dot represents 0·1 knots.
14. Plot the Spring Rate on the dotted line marked Springs.
15. Joint the Neap and Spring rates by a straight line.
16. Draw a horizontal line from the point on the vertical scale which corresponds to the Mean Range for the day, found at (6), to intersect the Neap/Spring rates line at "×".
17. The predicted rate for the day will be found on the horizontal scale vertically below "×".

Admiralty Tidal Publications

Other publications include the Admiralty Manual of Tides, NP 120; Tidal Handbooks 1–3, NP 122; and the 3 volumes of Tide Tables already mentioned. The full list is included below and reference should be made to these publications for further information.

NP No.	
	ADMIRALTY TIDE TABLES (published annually in three volumes)
201	Volume **1:** European Waters (including Mediterranean Sea)
202	Volume **2:** Atlantic and Indian Oceans (including Tidal Stream Tables)
203	Volume **3:** Pacific Ocean and Adjacent Seas (including Tidal Stream Tables)
	ADMIRALTY TIDAL HANDBOOK SERIES
122(1)	No. 1 The Admiralty Semi-graphic Method of Harmonic Tidal Analysis
122(2)	No. 2 Datums for Hydrographic Surveys
122(3)	No. 3 Harmonic Tidal Analysis (short periods)
	TIDAL STREAM ATLASES
250	English and Bristol Channels
257	Approaches to Portland
337	The Solent and adjacent waters
219	Portsmouth Harbour and Approaches
233	Dover Strait
249	Thames Estuary (with co-tidal charts)
251	North Sea, Southern Part
252	North Sea, Northern Part
253	North Sea, Eastern Part
220	Rosyth Harbour and Approaches
209	Orkney and Shetland Islands
218	North Coast of Ireland and West Coast of Scotland
256	Irish Sea
264	The Channel Islands and adjacent coasts of France
265	France, West Coast
217	Hong Kong

MISCELLANEOUS PUBLICATIONS

120 Admiralty Manual of Tides
159 Admiralty Method of Tidal Prediction, using Harmonic Constants, book of forms with instructions and example
204 Admiralty Tidal Prediction Form, with instructions
112 Harmonic Analysis Form (H.206) for one month
171 Harmonic Analysis (H.224) for short period observations
164 Dover, Times of high water and mean ranges (published annually)
215 Tides in the South China Seas

MISCELLANEOUS ATLASES AND CHARTS

Chart 5057, Dungeness to Hoek van Holland, co-tidal and co-range chart
Chart 5058, British Isles and adjacent waters, co-tidal and co-range lines
Chart 5059, Southern North Sea, co-tidal and co-range chart
Chart 5084, Malacca Strait, co-tidal and co-range chart
Chart 5081, Persian Gulf, co-tidal atlas

The above publications are obtainable from the Agents for the sale of Admiralty Charts, a list of whom is published annually in Admiralty Notice to Mariners No. 2, or from the Hydrographic Department, Ministry of Defence, Taunton, Somerset.

Standard Port Tide Calculations

Exercise 1 (European Waters)

Find the times (as indicated) of HW and LW at:

1. Portsmouth GMT on May 29th.
2. Greenock GMT August 18th.
3. Londonderry BST July 9th.
4. Wilhelmshaven ZT January 17th.
5. Avonmouth GMT September 11th.

Find the Height of Tide (Reduction to Sounding) for the given times:

6. Sheerness at 0830 GMT on March 8th.
6. Londonderry 1600 August 26th.
8. Greenock 0600 May 5th
9. Avonmouth 0900 December 28th.
10. Find the time when the height of tide above Chart Datum (CD) will be 3·0 m on the a.m. flood tide of January 18th at Wilhelmshaven.
11. Find the time when a ship drawing 4·7 m will have 1·5 m clearance under the keel over a charted depth of 2·5 m on the p.m. ebb tide at Portsmouth on June 14th.
12. A lighthouse off Greenock has a charted height of 21 m. Find its height above the water line at 0630 BST on May 18th. (From Table V—Greenock—MHWS +3·4 m.)
13. Between what Standard Times can a ship drawing 11·5 m cross a bar of charted depth 3 m with a clearance of one metre under the keel on the a.m. tide at Avonmouth on November 13th.
14. Off Wilhelmshaven, a sandbank is charted with a symbol $\underline{Q}_5$. Find the distance that the sandbank is above the water at 1000 ZT on February 11th.

Secondary Port Tide Calculations

Exercise 2 (European Waters, Atlantic and Indian Oceans)

Find the times of high and lower water at:

1. Sandown on June 15th.
2. Moville July 24th.
3. Tilbury March 10th.
4. Bowling May 1st.
5. Barry November 27th
6. Akyab September 9th
7. Lubec (U.S.A.) February 8th

(Standard Tidal Curves are included in the Appendix.)

Exercise 3 (European Waters)

From the predictions found in the first five examples of Exercise 2 find the height of tide:

1. At Sandown on June 15th, at 2000 hours GMT
2. At Moville on July 24th, at 1400 hours GMT.
3. At Tilbury on March 10th, at 0600 hours GMT
4. When will the tide be 2·5 m above datum at Bowling on May 1st?
5. When will the tide be 6·0 m above datum at Barry on November 27th?

Exercise 4 (Pacific Ocean and Adjacent Seas)

1. Find the times and heights of HW and LW at Kildala (No. 8947) on May 1st, 1982. (Standard Port Prince Rupert, No. 8850.)
2. Find the time and heights of HW and LW at Namu (No. 8943) on May 1st, 1982. (Standard Port Prince Rupert, No. 8850.)

Exercise 5 (Atlantic, India Ocean and Pacific Ocean)

(HARMONIC CONSTANTS)

NP 159, Forms A, B & C, are included in the Appendix

1. Find the times of HW and LW at Welshpool in February 8th. The ship grounded at 0815, when will she refloat?
2. Find the times and heights of HW and LW at Elephant Point on March 13th.
3. Find the times and heights of HW and LW at Quebec on May 16th.
4. Find the times and heights of HW and LW at Port Hedland on July 25th.
5. Find the times and heights of HW and LW and the period when the tide will be 3 metres and more above chart datum at Daly River on April 24th.

Answers on Page 475

ATT extracts included in the Appendix on Page 815

Tidal Steam Rate Calculations

Exercise 1

Use extracts from Admiralty Tidal Stream Atlas, NP 249, Thames Estuary and ATT Vol. I, Predictions for Sheerness. All times are in GMT.

1. Predict the rate of Tidal Stream off Walton-on-the-Naze at approximately 0600 on February 8th.

2. Predict the rate of Tidal Stream east of Maplin Sands at approximately 0900 on March 18th
3. Predict the set and rate of Tidal Stream for a position off Margate (51° 20′ N. 1° 34′ E.) at 0952 on January 7th.
4. Predict the set and rate of Tidal Stream in position east of Gunfleet Sands (51° 47′ N. 1° 25′ E.) at 0748 on March 22nd.
5. Predict the set and rate of Tidal Stream in a position SE of Orfordness (52° 04′ N. 1° 37′ E.) at 1703 on April 12th.

Tide Questions

1. How many high waters and low waters are usually experienced each day? Where are Standard Port HW and LW times found?
2. What is meant by the term Standard Time? Why is a correction for Longitude required when LMT is required?
3. State a rule for the converting Standard Time into GMT
4. What is meant by the term Drying Height.
5. What effect has the solar tide on the lunar tide?
6. What influence has the rise and fall of the tide on: (a) The sighting of guns mounted ashore when firing at a floating target; (b) The range of visibility of a light vessel's lights from a ship and from the shore?
7. How is the Duration of Tide ascertained?
8. Define the terms (a) Chart Datum; (b) Mean Level; (c) Height of Tide; and (d) Rise of Tide.
9. How is the mean tide level obtained?
10. What is meant by the term "Range of Tide"?
11. Define the terms (a) Neap Rise; (b) Mean Rise; (c) Spring Rise. How often do spring tides and neap tides occur?
12. When is the greatest depth of water to be found, at Spring LW or at Neap LW?
13. Explain the terms (a) Conjunction; (b) Opposition; and (c) Quadrature. Make a sketch to aid explanation.
14. What information is required in the process of reducing the actual depth of water to the soundings given on the chart?
15. To what level are chart soundings referred?
16. What correction should be made to a depth obtained by Echo Sounder?
17. How is the factor found?
18. A lighthouse is given on the chart as 40 m. Suppose the spring rise to be 10 m and the height of tide at a given time to be 3 m, what will be the height of the lighthouse above sea level at that time? If the charted sounding at the place is 6 m, what will be the depth of water?
19. What is meant by the term Charted Height?
20. Explain the difference between a Standard Port and a Secondary Port.

ANSWERS

Tides

Exercise 1 (European Standard Port Tides)

			HW	HW	LW	LW
1. Portsmouth	May 29th	GMT	0345	1640	0910	2148
2. Greenock	August 18th	GMT	1145	2345	0442	1704
3. Londonderry	July 9th	BST	1050	2309	0500	1712
4. Wilhelmshaven	January 17th	ZT	0559	1830	1209	—
5. Avonmouth	September 11th	GMT	—	1210	0608	1834
6. Sheerness	March 8th	0830 GMT, 3·1 m				
7. Londonderry	August 26th	1600 GMT, 1·6 m				
8. Greenock	May 5th	0600 GMT, 1·6 m				
9. Avonmouth	December 28th	0900 GMT, 5·4 m				
10. Wilhelmshaven	January 18th	0405 ZT				
11. Portsmouth	June 14th	1850 GMT				
12. Greenock	May 18th	21·8 m				
13. Avonmouth	November 13th	0325 to 0723 GMT				
14. Wilhelmshaven	February 11th	0·3 m				

Secondary Port Tide Calculations

Exercise 2

	HW		LW	
	Time	Ht (m)	Time	Ht (m)
1. Sandown	0453	3·3	1037	1·3
	1744	3·5	2320	1·5
2. Moville	0944	2·2	0342	0·3
	2202	2·3	1532	0·3
3. Tilbury	0112	6·6	0751	0·1
	1336	6·8	1958	0·5
4. Bowling	0542	3·8	0029	1·2
	1912	3·3	1259	0·9
5. Barry	0309	9·0	0906	3·6
	1538	9·7	2138	2·8
6. Akyab	0057	2·6	0705	0·6
	1304	2·4	1921	0·5
7. Lubec (USA)	1140	6·9	0545	0·7
	—	—	1815	0·3

Exercise 3

1. 3·1 m	2. 0·8 m	3. 0·6 m	
4. 0235	0833	1641	2200
5. 0633	1154	1857	

Exercise 4

1. Kildala	HW	0708	3·6 m	HW	2023	3·5 m
	LW	0109	2·0 m	LW	1349	1·2 m
2. Mamu Harbour	HW	0719	3·6 m	HW	2034	3·5 m
	LW	0114	1·9 m	LW	1354	1·1 m

Exercise 5 (Harmonic Constants)

1. HW	1145	6·5 m	LW	0600	0·5 m
HW	—	—	LW	1800	0·1 m
Ship refloats about 1520						
2. HW	0515	5·6 m	LW	0000	0·9 m
HW	1730	5·6 m	LW	1230	0·9 m
3. HW	1200	3·9 m	LW	0636	1·3 m
HW	—	—	LW	2000	1·3 m
4. HW	0130	6·6 m	LW	0730	1·7 m
HW	1345	6·5 m	LW	2000	1·6 m
5. HE	0600	6·8 m	LW	0000	0·4 m
HW	1800	6·8 m	LW	1200	1·0 m
Periods 0210 to 0915 and 1405 to 2105.						

Tidal Stream Rate Calculations

Exercise 1

1. Predicted Range 5·3 m (Springs) Rate 0·8 knots (6 hrs after HW).
2. Predicted Range 3·2/3·1 (Neaps) Rate 1·7 knots (3 hrs after HW).
3. Predicted Range 4·4, Set 010°T (approx), Rate 2·5 knots (HW).
4. Predicted Range 3·8, Set 220°T (approx), Rate 1·65 knots (3 hrs before HW).
5. Predicted Range 4·9, Set 030°T (approx), Rate 2·7 knots (2 hrs after HW).

Chapter 15

Navigation in Ice

Ice is an obstacle to any ship—even an "Ice Breaker". Those who have no experience of navigation in ice are advised to develop a healthy respect for its strength and latent power. Nevertheless, in capable hands, a well found ship can operate successfully in ice covered waters.

The importance of a sound knowledge of the techniques used when navigating in ice, together with associated procedures and an appreciation of the limitations of Radar, has been stressed in the Department of Transport's Merchant Shipping Notice No. M1058, *Navigation in Ice*. This topic is also included in the Department's Examination Syllabus for Class 1 Master Mariner and for the Command Endorsements.

Merchant Shipping Notice 1058, which is included at the end of this chapter, draws attention to the more important sections of *The Mariner's Handbook* which deals with this subject and which are included here under the following headings:

1. Polar Navigation.
2. Operating in Ice.
3. Detection of Ice by Radar.
4. Detection of Icebergs.
5. Working through Ice.
6. Ice Accumulation on Ships.
7. Master's Duty on Meeting Dangerous Ice.
8. International Ice Patrol.

POLAR NAVIGATION

High Latitudes

In high latitudes, directions change fast with movement of the observer, meridians converge, and excessive longitudinal curvature renders the meridians and parallels impracticable for use as navigational references. All time zones meet at the poles, and local time has little significance. Sunrise and sunset, night and day, as they are known in the temperate regions, are quite different in polar regions.

At the poles the sun rises and sets once a year, slowly spiralling to a maximum altitude of 23° 27′ and then decreasing in altitude until it sets three months later. The moon rises once each month and provides illumination when full, though sometimes the aurora gives even more light; and the planets rise and set once each sidereal period (12 years for Jupiter, 30 years for Saturn).

Polar Charts

Polar charts are largely based on air photography without adequate geodetic control or triangulation, so that the geographical positions of features are unreliable, and even if the features are correctly placed locally in relation to one another, considerable errors may accumulate when they are separated by appreciable distances. Soundings, topography, and all navigational information is scarce in most parts of the polar regions.

Fog

Fog, which is most frequent when the water is partly clear of ice, low cloud ceilings, and the ice itself all add to the difficulties of navigation.

Celestial Observations

The Mariner cannot rely on obtaining accurate celestial observations. For much of the navigation season clouds hide the sun, and long days and short nights in summer preclude the use of stars for observations. In summer when, apart from the moon at times, only the sun can be used for observations, transferred position lines must be used, and as accurate dead reckoning in ice is impossible, the accuracy of the resulting positions must always be questioned.

Use of Satellite and Inertial Navigation Systems

Satellite and Inertial Navigational systems, if available, may, however, both be used for position finding as satisfactorily in polar regions as any other part of the world.

Use of Magnetic and Gyro Compass

The magnetic compass is of little value for navigation near the magnetic poles, but in other parts of the polar regions it can be used, provided that the ship has been swung and the compass adjusted in low latitudes, and again on entering high ones.

The gyro compass, which loses all directive force at the geographical poles, is also subject to errors, but not in the same degree as the magnetic compass provided that the appropriate settings and corrections are used. It should be checked several times a day by azimuth bearings.

Sights and The Horizon

Sights must be taken with great care, for in pack ice false horizons are frequently observed. If the horizon is covered with ice, it may still be used for celestial observations by substracting the height of the ice on the horizon above the water from the height of eye of the observer: the maximum error this may cause is 4 minutes. A bubble sextant, or a sextant used with an artificial horizon set up on the ice, will be found, however, to give better results. It should be remembered, however, that refraction elevates both the celestial body and the visible horizon, so that the error due to abnormal refraction is minimized if the visible horizon is used for observations.

In polar regions the only celestial body available for observations may not exceed the altitude of 10° for several weeks on end, so that, contrary to the usual practice, observations at low altitudes must be accepted. Because of the low temperature, the refraction correction for sextant altitudes may require to be taken from Table 8 of the *Mariner's Handbook*, if outside the limits of Table A4 in the Nautical Almanac.

Use of Radio Aids and Radar

Whenever possible use should be made of radio aids to navigation, and radar will be found a most valuable instrument for safe navigation if used judiciously. Radar should not, however, be relied upon so completely that the rules of good seamanship are relaxed.

Estimating Position

A careful record should be kept of all alterations of course and speed together with the times at which they were made, so that a large scale plot of the ship's track can be maintained. The lack of information on tides and other factors usually prevents the most accurate reckoning from giving the exact position of the ship, but a carefully kept reckoning will considerably help to avoid errors.

In keeping the reckoning, the fundamental factors, speed and course, change continually and do not lend themselves to accurate calculation. Even if a gyro-compass and automatic plot are fitted, the speed relative to the ice is required, and this can rarely be measured continuously with accuracy. To check the resultant of the ship's course and speed through the ice, and the drift of the ice, every opportunity should be seized to obtain fixes or observed positions. The speed at any moment through the ice can be measured by the Dutchman's log (see *Admiralty Manual of Navigation*, Vol. I), or by measuring the time taken to pay out on the ice a line of a given length secured to a weight. The speed through the ice should be obtained as often as possible, or at least twice an hour.

Use of Echo Sounder

The echo sounder should run continuously to detect signs of approaching shoal water, though in many parts of the polar regions depths change too abruptly to rely solely on the sounder for warning. In some better sounded areas, the depths may give an indication of the ship's position, or of the drift of the ice, and in these areas ships without echo sounders should make use of all enforced stops to obtain a sounding with the deep-sea lead through a hole cut in the ice.

OPERATING IN ICE

Ice is an obstacle to any ship, even an ice-breaker, and the inexperienced ice navigator is advised to develop a healthy respect for the latent power and strength of ice in all its forms. However, well-found ships in capable hands can operate successfully in ice-covered waters.

The first principle of successful passage through ice is to maintain freedom of manoeuvre. Once a ship becomes trapped, she goes wherever the ice goes. Operating in ice requires great

patience and can be a tiring business with or without ice-breaker escort. The long way round a difficult area whose limits are known, is often the quickest and the safest way.

Experience has proved that in ice concentrations three basic ship handling rules apply:

1. Keep moving, even if only very slowly.
2. Try to work with the ice movement and not against it.
3. Excessive speed leads to ice damage.

Requirements for Ships Operating in Ice.

Experience has shown that ships that are not ice-strengthened and with a speed in open water of about 12 knots often become firmly beset in light ice conditions, whereas an adequately powered ice-strengthened ship should be able to make progress through 6/10 to 7/10 first year ice.

The engines and steering gear of any ship intending to operate in ice must be reliable and capable of quick response to manoeuvring orders. The navigational and communications equipment must be equally reliable and particular attention should be paid to maintaining radar at peak performance.

Light and partly-loaded ships should be ballasted as deeply as possible, but without excessive stern trim which reduces manoeuvrability. Suction strainers should be easy to remove and clear of ice and snow. Good searchlights should be available for night navigation with or without ice-breaker escort.

Signs of Pack Ice

There are two reliable signs of pack ice. One is ice blink whose characteristic light effects in the sky once seen, can never be mistaken. It may sometimes be seen at night. Ice blink is observed some time before the ice itself appears over the horizon. It is rarely, if ever, produced by icebergs, but is always distinct over consolidated and extensive pack.

On clear days, with the sky mostly blue, ice blink appears as a luminous yellow haze on the horizon in the direction of the ice. It is brighter below, and shades off upward, its height depending on the proximity of the ice field. On days with overcast sky, or low clouds, the yellow colour is mostly absent, the ice blink appearing as a whitish glare on the clouds. Under certain conditions of sun and sky, both the yellowish and whitish glares may be seen simultaneously. In fog, white patches indicate the presence of ice at a short distance.

The second reliable sign of pack ice is the abrupt smoothing of the sea and the gradual lessening of the ordinary ocean swell. These are sure indications of pack ice to windward.

There is frequently a thick band of fog over the edge of pack ice.

In the Arctic, if far from land, the appearance of walruses, seals and birds may indicate the proximity of ice. In the Antarctic, the Antarctic Petrel and Snow Petrel are said to indicate the proximity of ice—the former being found only within 400 miles of the ice edge, and the latter within only a few hours steaming of it.

The appearance of isolated fragments of ice often points to the proximity of larger quantities.

The sea surface temperatures give some indication of the vicinity of pack ice, providing that the ship is not at the time within the flow of one of the main cold currents. If the surface temperature is $-1°C$, the ice edge should for safety be considered as not more than 150 miles

distant, or 100 miles if there is a persistent wind blowing off the ice, since this will cause the ice temporarily to extend and become more open. A surface temperature of −0·5°C should generally be assumed to indicate that the nearest ice is not more than 50 miles away.

Signs of Open Water

Water sky[1] indicates the direction of leads or patches of open water. Dark spots in fog give a similar indication, but are only visible as shorter distances than reflections on clouds. A dark band on the cloud at a high altitude indicates the existence along this line of small patches of open water which may connect with a larger distant area of open water. If low on the horizon, water sky may possible indicate the presence of open water up to about 40 miles beyond the visible horizon.

The sound of a surge in the ice indicates the presence of large expanses of open water in the close vicinity.

Effect of Mirage

Ice or open water in the distance may often be detected by mirage raising the horizon. The image of the ice or areas of open water, or a mixture of the two, may be seen as an erect or inverted image, or both images may be seen at once, one above the other. In this case the erect image is the higher of the two, which are usually in contact. Allowance must be made for the fact that the refraction causing the mirage will increase the apparent dimensions of small ice, sometimes so greatly as to make small pieces appear like icebergs. The areas of open water are dark relatively to the ice.

Detection of Ice by Radar

Radar is an invaluable aid in detecting ice, but its limitations must always be borne in mind. Absence of an indication of ice on the radar screen does not necessarily mean that there is no dangerous ice near the ship.

It is important that the operators are aware of the limitations given below and that less than full operating efficiency will greatly reduce the chance of detecting ice.

The following conclusions have been reached from recent experience, but abnormal weather conditions may substantially reduce detection ranges.

1. In a calm sea, ice formations of all sorts should be detected; from large icebergs at ranges of from 15 to 20 miles down to small growlers at a range of possibly 2 miles. However, bergy bits weighing several tons, and protruding up to 3 m out of the water, are unlikely to be detected at a range of more than 3 miles. As warning of ice may therefore be short, radar should be operated continuously in low visibility where ice is expected.
2. In rough weather, it is unsafe to rely on radar when sea clutter extends beyond 1 mile, as insufficient warning will be given of the presence of growlers large enough to damage the ship, or of pack ice.
3. Fields of concentrated hummocked pack ice should be detected in all sea conditions at a range of at least 3 miles.

[1] Dark streaks on the underside of low cloud.

4. A lead through static ice will not show on radar unless the lead is at least $\frac{1}{4}$ mile wide and completely free from brash ice. Radar will usually show large floes in the midst of brash ice. Areas of open water and smooth floes appear very similar, but in an ice field the edge of a smooth floe is prominent, while the edge of open water is not.

   Ridges show clearly, but shadow areas behind ridges are liable to be mistaken for the leads or the closed tracks of ships, and the large area of weak echoes given by a flat floe may be mistaken for a polynya. It is difficult to distinguish between 10/10 hummocked or rafted ice and 3/10 small floes and ice cakes.
5. Radar can sometimes detect snow, sleet and rain squalls, and so enable lookouts to be increased, or speed or course altered to avoid the squalls.
6. The strength of the echo received from an iceberg depends as much on the inclination of its reflecting surfaces as on its size and range.

Detection of Icebergs

There are no infallible signs of the proximity of a berg. The only sure way is to see it, so that too much reliance on radar or any of the possible signs is dangerous. As previously explained, radar may give warning of large icebergs in time to take avoiding action, but it cannot be relied upon to detect bergy bits and growlers, which can rip open even ice-strengthened ships, especially if there is any sea running.

Despite their size, icebergs can be very difficult to see under certain circumstances, and the Mariner should invariably navigate with caution in waters in which they may be expected.

In fog with sun shining a berg appears as a luminous white mass, but with no sun it appears close aboard as a dark mass, and the first signs may well be the wash of the sea breaking on its base.

On a clear night with no moon bergs may be sighted at a distance of 1 or 2 miles, appearing as black or white objects, but the ship may then be among the bergy bits and growlers often found in the vicinity of a berg. On a clear night, therefore, lookouts and radar operators should be particularly alert, and there should be no hesitation in reducing speed if a berg is sighted without warning.

On moonlit nights bergs are more easily seen provided the moon is behind the observer, particularly if it is high and full.

At night with a cloudy sky and intermittent moonlight, bergs are more difficult to see and to keep in sight. Cumulus or cumulo-nimbus clouds at night can produce a false impression of icebergs.

No reliance can be placed on changes of air or sea temperature in the vicinity of a berg, though the sea temperature in the North Atlantic, if carefully watched, will indicate when the cold ice-bearing current is entered. Neither can reliance be attached to echoes from a steam whistle or siren, because the shape of the berg may be such as to prevent any echo, and also because echoes are often obtained from fog-banks. Bergs have been located by means of sonar, but the method is unreliable since the distribution of water temperature and salinity, particularly near the boundary of a current, may produce such excessive refraction as to prevent a sonar signal from reaching the vessel or berg.

The following signs are useful when they occur, but reliability cannot be placed on their occurrence. In the case of large Antarctic bergs, the absence of sea in a fresh breeze indicates the presence of ice to windward if far from land. When a growler is calved, or ice otherwise

cracks and falls into the sea, it produces a thunderous roar, or sounds like the distant discharge of guns. The observation of growlers or smaller pieces of detached ice is an indication that a berg is in the vicinity, and probably to windward; a berg may be detected in thick fog by this means. When proceeding at slow speed on a quiet night, the sound of breakers may be heard if an iceberg is near and should be constantly listened for. The appearance of isolated fragments of ice often points to the proximity of larger quantities.

Working through Ice

When entering pack ice and working through it, the following points should be borne in mind:

1. Ice should not be entered if an alternative, although longer, route is available.
2. It is very easy and extremely dangerous to under-estimate the hardness of ice.
3. If a flow cannot be avoided, it should be hit squarely with the stern. A glancing blow may damage the bow plating, and by throwing the ship off course cause another glancing blow from a nearby flow, or her stern to be swung into the ice damaging her rudder and propellers.
4. Ice should be entered at low speed to receive the initial impact, and once into the pack speed should be increased to maintain headway and control of the ship.
5. Engines must be prepared to go full astern at any time.
6. All forms of glacial ice in the pack should be given a wide berth. Icebergs are current-driven while the pack is wind-driven.
7. Navigation in pack ice after dark should not be attempted without good searchlights, and if visibility precludes progress a ship should heave to, keeping her propeller turning slowly as it is less susceptible to ice damage than if stopped.
8. A ship stopped in ice close inshore should always be pointed to seaward unless it is intended to anchor.
9. Anchoring in a heavy concentration of ice should be avoided. If ice is moving, its tremendous force may break the cable. When conditions permit anchoring, such as in light brash ice, rotten ice, or among widely scattered floes, the windlass and main engines should be kept at immediate notice, and the anchor weighed as soon as wind threatens to move ice onto the ship.
10. Propellers are the most vulnerable part of a ship and ships should go astern in ice with extreme care, and always with the rudder amidships. If ice goes under a ship, speed should immediately be reduced to dead slow.
11. Full rudder should only be used in emergency. Violent rudder movements may swing the stern into the ice.
12. Wherever possible, pressure ridges should be avoided and a passage through pack ice under pressure should not be attempted.
13. Leads through ice should be used to best advantage. If a large floe blocks the ship's intended course, no attempt should be made to break it unless it is very rotten, but the stem should be put against it, power increased until the floe is forced ahead and begins to swing to one side, when power should be reduced to allow it to pass clear.
14. If a ship is stopped by a heavy concentration of ice, the rudder should be put amidships and the engines kept turning slowly ahead. This will wash the ice astern clear, and enable the ship to come astern, after making certain that the propellers are clear of ice.
15. When not accompanied by an ice-breaker, it is unwise to follow a shore lead with an onshore wind blowing.

16. When a ship proceeding independently becomes beset it usually requires ice-breaker assistance to free her. However, ships in ballast can sometimes free themselves by pumping and transferring ballast from side to side, and it may need very little change in trim or list to release the ship.

ICE ACCUMULATION ON SHIPS

In certain weather conditions ice, formed of sea water or fresh water, accumulating on the hulls and superstructures of ships can be a serious danger.

Ice accumulation may occur from three causes:

1. Fog, including fog formed by evaporation from a relatively warm sea surface, combined with freezing conditions.
2. Freezing drizzle, rain or wet snow.
3. Sea spray or sea water breaking over the ship when the air temperature is below the freezing point of sea water (about $-2°C$).

The weight of ice which can accumulate from causes (1.) and (2.) may increase on the rigging to such an extent that it is liable to fall and endanger those on deck. It is, however, small in comparison with the weight of ice accumulating in rough weather with low temperatures, when large amounts of spray, and often heavy seas, break over a vessel. Radio and radar failures due to ice on aerials or insulators may be experienced soon after ice starts to accumulate.

When the air temperature is below the freezing point of sea water and the ship is in heavy seas, considerable amounts of water will freeze on to the superstructure and those parts of the hull which are sufficiently above the waterline to escape being frequently washed by the sea. The amounts so frozen to surfaces exposed to the air will rapidly increase with falling air and sea temperatures, and might in extreme cases lead to the capsizing of the vessel. The trawlers *Lorella* and *Roderigo* were lost from this cause, about 90 miles north-north-east of Horn, Iceland, on 26th January, 1955, in an E to NE gale.

The dangerous conditions are those in which strong winds are experienced in combination with air temperatures of about $-2°C$ or below; freezing rain or snowfall increases the hazard. The rapidity with which ice accumulates increases progressively as the wind increases above force 6 and as the air temperature falls further below about $-2°C$. It also increases with decreasing sea temperatures. The rate of accumulation also depends on other factors such as the ship's speed and course relative to wind and waves, as these affect the amount of spray produced.

Dr. H. O. Mertins of the German *Seewetteramt* collected some 400 observations of icing due to spray, mostly from the seas around Iceland, Greenland and Labrador, and from the Barents Sea; covering the period of about 1958 to 1967. From these observations he produced diagrams shown in *The Mariner's Handbook* which indicate the rate of ice accumulation to be expected on a slow moving trawler with different values of wind force, air temperature and sea temperature.

It will be appreciated that it is very difficult to forecast accurately the three variables involved. Accordingly the mariner is advised to exercise all possible caution whenever gales are expected in combination with temperatures of $-2°C$ or below. These conditions are most likely to occur with winds from polar regions, but the direction may be any that will transport

sufficient cold air. If these conditions are expected, the prudent course is to steer towards warmer conditions, or to seek shelter, as soon as possible.

Gale Force Winds and Air Temperatures below Freezing—Obligatory Reports

Obligatory reports are required from the Masters of ships encountering air temperatures below freezing associated with gale force winds causing severe ice accumulation on ships. Reports should contain the following information:

1. The date, GMT and ship's position when the conditions were encountered.
2. The air and sea temperatures.
3. The force and direction of the wind.

THE MASTER'S DUTY ON MEETING DANGEROUS ICE

Obligatory reports are required from the Masters of ships meeting dangerous ice.

The message should contain the following information:

1. Type of ice.
2. The position of the ice.
3. GMT and date of observation.

The International Convention on Safety of Life at Sea, 1960, also requires the Master of every ship, when ice is reported on or near his course, to proceed at a moderate speed at night or to alter his course to pass well clear of the danger zone.

INTERNATIONAL ICE PATROL

The International Ice Patrol is operated by the United States Coast Guard, the cost being met by Signatory Nations to the Convention mentioned above, its prime object is to warn ships of the extent and limits of icebergs and sea ice in the North Atlantic tracks near the Grand Banks of Newfoundland.

The service operates during the ice season, beginning in late February or early March and ending about the end of June

Broadcasts

During the ice season, ice broadcasts are made twice daily, and a facsimile chart of ice conditions in the vicinity of the Grand Banks is also transmitted daily from stations listed in *Admiralty List of Radio Signals*; when necessary, additional Special Ice broadcasts are made.

Reports from Shipping

Ship reports of ice and weather from the Grand Banks area are an indispensible source of ice, oceanographic and meteorological data. They materially assist the International Ice Patrol in determining ice conditions and in disseminating ice information to shipping. When reporting icebergs, ships should describe the shape and estimate the size of the berg; the description is

required to aid in berg identification, while the size assists in determining its eventual deterioration. The dimensions used in iceberg nomenclature by the Ice Patrol are as follows:

	Height (m)	*Length* (m)
Growler	Under 1	Less than 6
Small berg	1–15	6–60
Medium berg	16–45	61–122
Large berg	46–75	123–213
Very large berg	Over 75	Over 213

Whenever any dimension falls into a larger size, that sized is used.
The shape of an iceberg is described by the Ice Patrol as follows:

Blocky. Steep-sided with flat top. Very solid. Length-height ratio is less than 5:1.
Drydock. Eroded so that a large U-shaped valley is formed between twin columns and extendeds to, or nearly to, the waterline.
Dome. Large smooth round-topped solid iceberg.
Pinnacled. One or more large central spires or pyramids predominate.
Tabular. Flat-topped berg. Length-height ratio greater than 5:1.
Tilted blocky. Blocky berg which has tilted to present a triangular elevation on certain bearings.

Ice reports should include the following information:

1. Position of ice.
2. Size and shape of ice (for bergs).
3. Concentration of ice (for sea ice, in eighths).
4. Thickness of ice (for sea ice, in feet).
5. Sea surface temperature (Celsius).

In addition to ice sighting reports, ships are urged to make weather reports at six-hourly intervals to the Ice Patrol when within latitudes 40° N. and 50° N. and longitudes 42° W. and 60° W. The following information should be included in the reports:

1. Ship's position, course and speed.
2. Visibility in miles.
3. Air temperature (Celsius).
4. Sea surface temperature (Celsius).
5. Wind direction and speed in knots.

Visibility reports are especially valuable in planning ice observation flights. Sea temperatures are used to estimate ice deterioration and to assist in detecting shifts in branches of the Labrador current. Wind data is useful in estimating set and drift of ice and in forecasting weather for the purpose of planning ice observation flights. It is realized that ships with only one radio operator may find it impracticable to report every 6 hours. It is therefore suggested that the reports be prepared and held until the radio operator is on watch.

Full details of the Ice Patrol service are given in *Admiralty List of Radio Signals*.

Further Information on Navigation in Ice

For further information, definitions, diagrams and photographs relating to Navigation in Ice, refer to *The Mariner's Handbook*.

DEPARTMENT OF TRANSPORT MERCHANT SHIPPING NOTICE NO. M.1058

NAVIGATION IN ICE

Notice to Shipowners, Masters and Officers

1. The Report of Court of the Formal Investigation into a casualty involving a United Kingdom registered tanker, whilst navigating in ice, has drawn attention to the need for Masters and Officers to comply with the relevant guidance available for operating in ice
2. Ice should be regarded as a considerable obstacle to a vessel's progress and great care must be exercised. Before encountering ice in any form, careful voyage planning must be observed. This should include the Master discussing with all the Navigating Officers the procedures to be followed when the vessel first encounters the ice edge. Additionally the draught and trim of the vessel, the immersion of the propeller and the rudder need to be taken into consideration. All Navigating Officers should be instructed to make themselves familiar with Chapter 8 of The Mariners Handbook* with special reference to Sections 1, 2, 3, 8 and 9.[1]
3. Masters should obtain the latest ice information available by all means at their disposal, including an assessment of the density and thickness of the ice and plot on the chart the location of the ice edge together with changes in the strength and direction of the wind since the receipt of the latest report. The importance of keeping a continuous lookout when approaching the ice edge cannot be too strongly emphasised. This visual lookout together with a radar lookout is recommended but the limitations of radar in detecting ice must be recognised.
4. When nearing the proximity of the ice edge, the main engines should be placed on standby and be available for manoeuvring. In conditions of impaired visibility this should be done at an early stage. The Master should ensure he is on the bridge when entering the ice or has given clear instructions to the Officer on watch on how to enter the ice.
5. In general, Masters should be aware of the ice classification of their ships and, when entering ice, do so at right angles and at reduced speed. Ice conditions differ widely, but it should be noted that in conditions other than light ice, the practice of forcing entry in a non-ice-strengthened ship is not recommended, and when in ice such ships should only attempt to force ice if their passage is completely blocked. The principle of maintaining the freedom to manoeuvre in ice is of the utmost importance.
6. In an ice-strengthened ship it is sometimes beneficial to enter at a moderate speed rather than low; the reason being that at a low speed with only moderate power the vessel may quickly become beset. In vessels with controllable pitch propellers, however, entry can be at low speed and subsequently worked up to full power once the vessel has entered the ice.

*This publication is required to be carried by the Merchant Shipping (Carriage of Nautical Publications) Rules 1975 (SI 1975, No. 700).

London, April 1983

Note 1. These sections are included in the preceding pages of this chapter.

Questions

1. Why do Polar Charts tend to be unreliable?
2. Discuss Polar Navigation and comment on any three of the following:
   (a) Celestial Observations.

(b) Use of Satellite Navigation Systems.
(c) Use of Magnetic and Gyro Compasses.
(d) Use of Radar and Radio Navigational Aids.
(e) Use of the Echo Sounder.
(f) DR's and EP's.

3. List the important points relating to the Detection of Ice by Radar.
4. List the important points to consider when working through pack ice.
5. Summarise *Merchant Shipping Notice*, M1058 and state the master's duties on meeting dangerous ice.

Chapter 16

Search and Rescue

Search and Rescue operations may involve ships, rescue craft, aircraft, helicopters and any form of rescue equipment.

There are 3 main objectives:

1. To reach the distress area with minimum delay.
2. To locate those in distress.
3. To rescue and care for the survivors.

A sound knowledge of Search and Rescue procedure (and good communication between involved parties) will help to achieve these objectives. Nevertheless, it should be borne in mind that there is no obligation for the rescuer to risk "own" ship or "own" crew.

Reference should be made to the following publications:

1. Annual Summary of Admiralty Notices to Mariners.
2. Merchant Ship Search and Rescue Manual (MERSAR) I.M.O.
3. U.K. Search and Rescue Organisation, D.Tp.
4. International Code of Signals.
5. Admiralty List of Radio Signals (Vol. I).
6. Admiralty Manual of Seamanship (Vol. II).

The Annual Summary of Admiralty Notices to Mariners

Annual Notices contained in the Summary are as follows:

1. Distress and Rescue at Sea—which gives relevant details regarding communications and describes the co-operation to be expected from H.M. Coastguard, aircraft and helicopters.
2. AMVER (Automated Mutual-assistance VEssel Rescue) System—which explains this system.
3. Distress and Rescue in the Indian Ocean and SW Pacific—which gives details regarding ships' positions.

MERSAR (Merchant Ship Search and Rescue) Manual

This manual gives advice on rescuing survivors and includes the organisation of search patterns appropriate to the number of ships available. Preparations for receiving survivors on board are also explained.

N.B.—A similar, but more extensive, publication is entitled "IMCOSAR". It is intended as a guide to governments which are establishing search and rescue organisations.

U.K. Search and Rescue Organisation

This publication contains detailed descriptions of all services connected with search and rescue and of the craft and equipment in use.

The International Code of Signals

This publication lists International Rescue signals. Certain signals are also contained in *The Mariner's Handbook.*

The Admiralty List of Radio Signals (Vol. I)

This publication details the communication arrangements for Search and Rescue organisations of certain British Commonwealth and foreign countries.

Admiralty Manual of Seamanship (Vol. II)

This publication gives details of rescue methods and the treatment of survivors.

Other Publications

Other publications which have relevance include:

The Standard Marine Vocabulary, (I.M.O.), which could be of value when communicating with those not fluent in English.

Peril at Sea and Salvage, which is published for the International Chamber of Shipping and the Oil Companies International Forum. This publication, which contains advice for shipmasters involved in various emergencies and chapters dealing with communications and on the behaviour of disabled ships, could be of value in Search and Rescue operations.

The *Ship Captain's Medical Guide*, which gives details regarding the medical treatment of survivors.

The *International Regulations for Preventing Collisions at Sea*, (I.M.O.), which list Distress Signals at Annex IV. (Annex IV is included at the end of this chapter.)

The Rendezvous

A rendezvous is a convenient position where one ship may meet another, or perhaps a helicopter, for some reason such as taking on stores or to receive medical assistance.

In the latter case there is frequently an urgency and the two craft would proceed directly towards each other at their best speeds—thus establishing rendezvous at the earliest possible time.

$$\text{Time to Rendezvous} = \frac{\text{Distance between Ships}}{\text{Sum of Speeds}} \text{ Hrs}$$

A ship which requests assistance from another may be required to defray expenses and, for this reason, should endeavour to reduce the inconvenience to the other ship. One method of achieving this is by INTERCEPTION, providing one ship is not too slow or too far abaft the beam of the other ship.

The construction to find the course to steer to intercept another vessel is similar to the

radar plotting technique to find the course to steer so that the closest approach will be "x" miles. In the case of interception, however, "x" will be zero; i.e. the targets relative track will be directly towards "own ship".

Example of Interception

A helicopter has to deliver stores to a vessel steaming 130°T at 20 knots. The helicopter, speed 50 knots, is in position 015°T, 80 miles from the vessel at 1000 hours. Required the time of rendezvous

Caution. Note that it is the helicopter which has to intercept the vessel. In the standard terms of radar plotting the helicopter is thus "own ship" and the vessel is the "target".

Scales

Distance: 1 cm = 10 miles
Speed: 1 cm = 10 knots

H is the position of the helicopter
A „ „ „ vessel
R „ „ „ rendezvous

Construction

Draw WA to represent the vessel's course and speed (130°T at 20 knots).

With centre W and radius equal to the helicopter's speed (50 knots) cut HA produced at O.

OA represents the vessel's relative course and speed along AH

Relative speed = 38·5 knots (by measurement).

$$\text{Time Interval} = \frac{AH}{OA} = \frac{80}{38{\cdot}5} = 2{\cdot}08 \text{ hours}$$

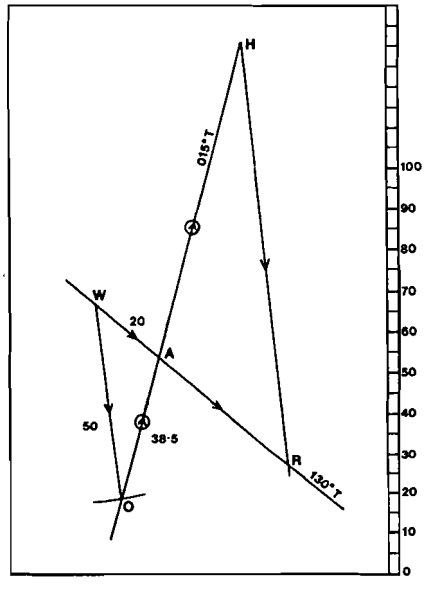
$$= 2 \text{ hrs } 5 \text{ mins}$$

Draw HR parallel to WO to cut WA produced at R. HR is the helicopter's true track. The time interval may also be found by allowing the helicopter's true speed along HR.

$$\text{Time Interval} = \frac{HR}{WO} = \frac{104}{50} = 2{\cdot}08 \text{ hours}$$

$$= 2 \text{ hrs } 5 \text{ mins}$$

	10	00
Time of RV	12	05



Distress Signals—Collision Regulations Annex IV

The following annex is included at Annex IV of the *The International Regulations for Preventing Collisions at Sea.*

Annex IV Distress Signals

1. The following signals, used or exhibited either together or separately, indicate distress and need for assistance:
   (a) a gun or other explosive signal fired at intervals of about a minute;
   (b) a continuous sounding with any fog-signalling apparatus;
   (c) rockets or shells, throwing red stars fired one at a time at short intervals;
   (d) a signal made by radiotelegraphy or by any other signalling method consisting of the group ...---... (SOS) in the Morse Code;
   (e) a signal sent by radiotelephony consisting of the spoken word "Mayday";
   (f) the International Code Signal of distress indicated by N.C.;
   (g) a signal consisting of a square flag having above or below it a ball or anything resembling a ball;
   (h) flames on the vessel (as from a burning tar barrel, oil barrel, etc.);
   (i) a rocket parachute flare or a hand flare showing a red light;
   (j) a smoke signal giving off orange-coloured smoke;
   (k) slowly and repeatedly raising and lowering arms outstretched to each side;
   (l) the radiotelegraph alarm signal;
   (m) the radio telephone alarm signal;
   (n) signals transmitted by emergency position-indicating radio beacons.
2. The use or exhibition of any of the foregoing signals except for the purpose of indicating distress and need of assistance and the use of other signals which may be confused with any of the above signals is prohibited.
3. Attention is drawn to relevant sections of the International Code of Signals, the Merchant Ship Search and Rescue Manual and the following signals:
   (a) a piece of orange-coloured canvas with either a black square and circle or other appropriate symbol (for identification from the air);
   (b) a dye marker.

Questions

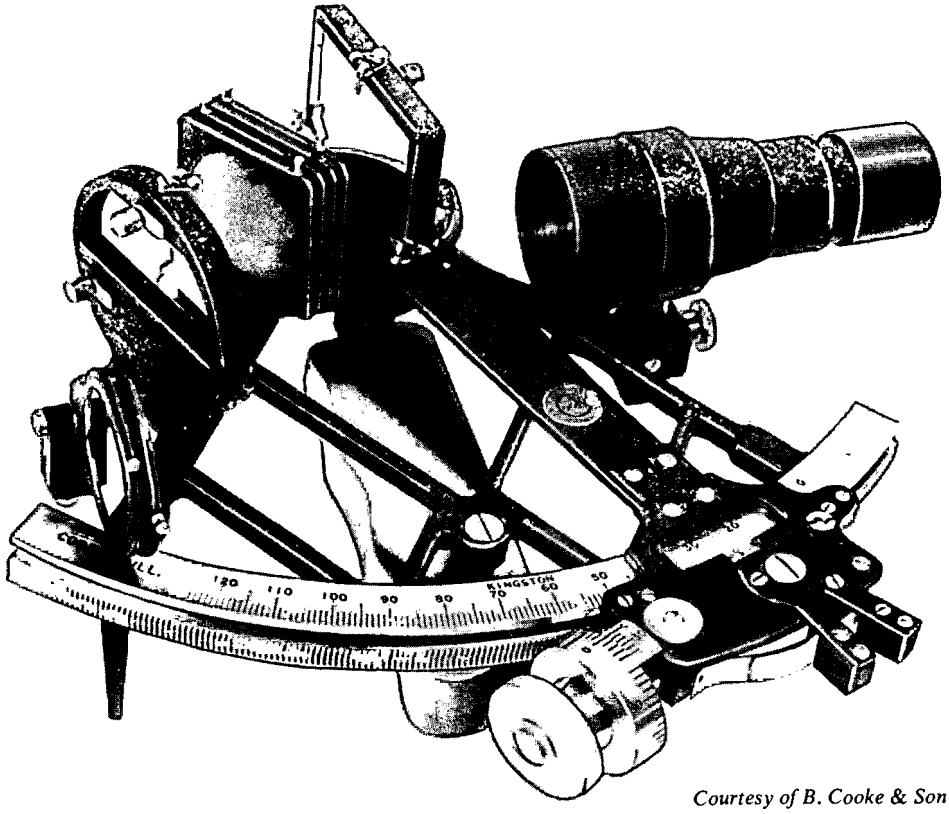
1. What are the objectives of Search and Rescue operations?
2. List the publications which contain information relating to search and rescue.
3. Refer to the relevant publication and make notes on one or other of the following:
   (a) Distress and rescue at sea, generally.
   (b) The AMVER system.
   (c) Distress and rescue in the Indian Ocean and SW Pacific.
4. What is meant by MERSAR and IMCOSAR? What details are indicated in these publications?
5. What is meant by the terms, "Rendezvous" and "Interception"? Give an example of interception.

Chapter 17

The Marine Sextant

The marine sextant is a precision built optical instrument which is used for measuring altitudes and angles. It is an essential part of a ship's navigational equipment.

The sextant is so named because the length of its graduated arc is approximately one sixth of a circle. One of the optical laws upon which the operation of the sextant depends states that, when a ray of light is twice reflected by two mirrors in the same plane, the angle between the first and last rays is twice the angle between the two mirrors. As the sextant's arc is one sixth of a circle or 60° of arc, it follows that the sextant can measure angles of twice this amount or 120°. In actual fact, most manufacturers increase the length of arc to slightly more than one sixth of a circle and the modern sextant is usually graduated from 0° to 125° "On" the arc. The graduations are also continued over a 5° arc on the opposite side of the zero. This is known as the "Arc of Excess" and angles read on this part are said to be "Off" the arc.



Courtesy of B. Cooke & Son of Hull

Figure 1. A Modern British Sextant fitted with Erect Star Telescope.

Types of Sextant

Two types of marine sextant are in use:

1. Micrometer Sextant.
2. Vernier Sextant.

The difference between the two types lies mainly in the method of graduating and reading the arc.

Micrometer Sextant

On the micrometer sextant degrees are read directly from the arc. Minutes of arc are read on a Micrometer Drum and tenths of minutes of arc or, in some cases, ten seconds of arc, are read on the Micrometer Vernier. The sextant illustrated reads to 10 seconds of arc which is 1/360 of a degree. Reading the micrometer drum is extremely easy and is quickly learnt. Nowadays manufacturers produce only the micrometer sextant which, for this reason, now incorporates many other improvements not found in the vernier sextant.

Vernier Sextant

On the arc of the vernier sextant, each degree is divided into six divisions of 10 minutes of arc. A moving vernier is provided which is divided into ten division each of 1 minute of arc. These 1 minute divisions are further subdivided into six smaller divisions each of 10 seconds of arc.

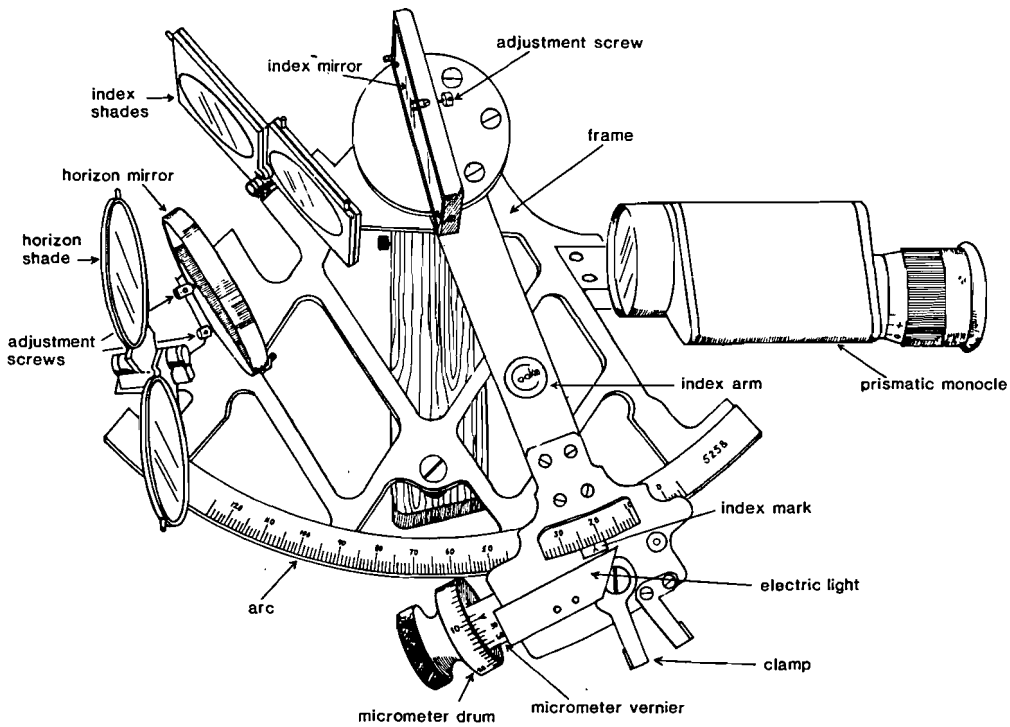


Figure 2. Parts of the Micrometer Sextant. The sextant is reading 22° 10′ exactly. (Shown, to a larger scale, on page 524.)

The divisions are extremely small and a microscope, which is always fitted to the vernier sextant, is required to read them. Reading the vernier sextant requires some skill and considerable practice. Nevertheless, this type of sextant is perfectly acceptable for modern navigational requirements and, providing it is well adjusted and in a good state of repair, will give results of comparable accuracy to those achieved with the micrometer sextant. Nevertheless the modern micrometer sextant does have considerably improved optics and many other refinements which make it easier to use.

Uses

As previously mentioned, the sextant's main navigational use is for measuring the altitudes of celestial bodies. It also has several other uses. A full list would include:

1. Altitudes of the Sun, Stars, Moon and Planets (Ocean Navigation).
2. Horizontal Angles between prominent Terrestrial Objects to fix position (Coastal Navigation).
3. Vertical Angles of suitably high Terrestrial Objects to obtain Distance Off (Coastal Navigation and Pilotage).
4. Vertical Angles of Masts to obtain Distance Off other Ships when Steaming in Convoy (In times of Hostility).
5. Hydrographic Surveying.

Parts of the Sextant

(Refer to Figure 2)

1. Frame
2. Handle
3. Telescope or Monocle
4. Rising Piece
5. Arc
6. Index Arm
7. Clamp
8. Worm and Rack
9. Micrometer Drum
10. Micrometer Vernier
11. Electric Light
12. Index Mirror
13. „ „ Clips
14. „ „ (First) Adjustment Screw
15. „ „ Shades
16. Horizon Mirror
17. „ „ Clips
18. „ „ (Second) Adjustment Screw
19. „ „ (Third) Adjustment Screw
20. „ „ Shades

1. **Frame**
   The frame is of rigid metal construction and incorporates three legs upon which the sextant rests when in the horizontal position. The upper side of the frame is referred to as the Plane of the Instrument. The curved, lower, part of the frame is referred to as the Lower Limb of the Sextant.
2. **Handle**
   The handle is fitted with a button switch and contains the battery which supplies power to the electric light on the Index Arm.
3. **Telescope or Prismatic Monocle**
   The Telescope or Monocle is used to enlarge the observed object and to make accurate observation easier.

   Figure 1 shows the sextant fitted with an Erect Star Telescope having a magnification

of 4 × and a 5° field of view. Figure 2 shows the same sextant fitted with a Prismatic Star Monocle having a magnification of 6 × and an 8·5° field of view.

Higher magnification is desirable when observing vertical sextant angles of distant shore objects such as a lighthouse and to obtain a clearer view of the sun's lower limb when taking sights.

A wide field of view is important when trying to locate stars which, because of their apparent size, are not easily found.

The Prismatic Star Monocle overcomes these conflicting requirements which, in the past, required two different telescopes—an Inverting Telescope of higher magnification and an Erect Star Telescope of lower magnification.

4. **Rising Piece**
The Telescope or Monocle is attached to the Frame by an adjustable slide or Rising Piece which is fitted with a milled head quick release screw. By adjusting the Rising Piece the Telescope is brought closer to, or further from, the Frame. This adjustment alters the area of the Horizon Mirror viewed through the Telescope and hence alters the brilliance of the reflected image.

5. **Arc**
The Arc is constructed of a thin strip of metal which has a low co-efficient of expansion. It is "let in" flush with the "lower limb" of the sextant and is graduated from 0°–125° "On" the Arc and from 0°–5° "Off" the arc.

6. **Index Arm**
Mounted on a circular base plate, the Index Arm is free to rotate on a central axis beneath the Index Mirror. The arrow or zero of the Index Arm is known as the Index Mark

7. **Clamp**
By exerting finger pressure, the clamp disengages or unclamps the Index Arm from the gearing cut into the lower limb of the sextant. The Index Arm can then be moved to the required angle. On releasing pressure, the Index Arm is automatically clamped in position.

8. **Worm and Rack**
The Worm is an endless tangent screw which engages with the Rack or gearing which is cut into the lower limb of the sextant. Exerting pressure on the quick release Clamp disengages the Worm from the Rack and allows the Index Arm to move.

The Rack is visible in Figure 1. The Worm is not visible.

9. **Micrometer Drum**
Whereas whole degrees are read directly from the arc, minutes of arc are read off the Micrometer Drum. Turning the Micrometer Drum screws the Worm along the Rack and permits fine adjustment of an observed angle or altitude. In Figure 2, the Micrometer reads 10′ (opposite the Vernier Index Mark or arrow).

10. **Micrometer Vernier**
The Micrometer Vernier has either 5 or 6 graduations which correspond to 0·2′ or 10″ of arc respectively. Minutes of arc are read off the Micrometer Drum opposite the Vernier Index Mark. Seconds, or decimal places of minutes of arc, are read where one vernier graduation lines up perfectly with (any) one of the minute graduations on the Micrometer Drum. In Figure 2, the sextant reads 22° 10′ 00″ exactly. Note that the 60″ graduation on the vernier lines up perfectly with the 15′ graduation on the micrometer.

11. **Electric Light**
The Light Bulb is contained in an open ended rectangular tube so arranged that the light

illuminates the Arc, Micrometer Drum and Micrometer Vernier. It is operated from the handle and is particularly useful when taking star sights at twilight.

12. **Index Mirror**
The Index Mirror reflects the observed object into the Horizon Mirror. It is rectangular in shape and set in a frame attached to the movable Index Arm. When properly adjusted, the Index Mirror should be perpendicular to the Plane of the Instrument.
13. **Index Mirror Clips**
These are spring clips which hold the Index Mirror in its frame.
14. **Index Mirror (First) Adjustment Screw**
An adjustment screw situated on the centre line of the Index Mirror. By turning the screw the Index Mirror is pushed against its spring clips and adjusted to the perpendicular position.
15. **Index Mirror Shades**
Made of high quality optical glass, Index Mirror Shades are neutral or coloured light filters used, as necessary, to reduce the intensity of the sun's reflected image and to protect the eyes. Four index shades are normally fitted.
16. **Horizon Mirror**
The Horizon Mirror receives the reflected image from the Index Mirror and reflects it back to the observer through the Telescope. It is a semi circular mirror held in a circular frame. As the Horizon Mirror occupies only half the space enclosed by its frame, the observer is able to see both the reflected image and the horizon at one and the same time. When properly adjusted, the Horizon Mirror should be perpendicular to the Plane of the Instrument and parallel to the Index Mirror when the Index Arm is set at zero.

    Designs vary and the Horizon Mirror may consist of either (a) a half silvered rectangular glass, (b) a half silvered circular glass, or (c) a semi circular mirror only.
17. **Horizon Mirror Clips**
Spring clips which hold the Horizon Mirror in its frame.
18. **Horizon Mirror (Second) Adjustment Screw**
This adjustment screw is located on the centre line of the Horizon Mirror. It may be at the top or bottom (depending on mirror design) and is used to adjust the Horizon Mirror to the perpendicular position.

    Figure 1 shows a half silvered Horizon Glass and the adjustment screw located at the top, furthest from the plane of the instrument.

    Figure 2 shows a semi circular Horizon Mirror with the adjustment screw at the bottom, nearest to the plane of the instrument.
19. **Horizon Mirror (Third) Adjustment Screw**
This adjustment screw is located on the edge of the mirror and is used to adjust the Horizon Mirror parallel to the Index Mirror when the Index Arm is set at zero.
20. **Horizon Mirror Shades**
These shades are used to reduce the intensity of a brightly lit horizon and are similar to the Index Mirror Shades. Two or three Horizon Mirror Shades are normally fitted.

Sextant Case and Accessories

Usually of polished hardwood, the sextant case is fitted with a carrying handle, patent fasteners, lock and key. Wooden chocks are built into the case to prevent the sextant being dislodged. A wooden toggle is sometimes fitted to lock the sextant handle in position.

Accessories normally included in the Sextant Case:

1. Sextant Spanner.
2. Sextant Screw Driver or Ball Headed Adjustment Pin.
3. Sextant Oil in small bottle.
4. Spare Telescopes (if carried).
5. Soft cloth or chamois leather.

Housing the Sextant

To house the sextant in its case it is generally necessary to set the Index Arm about the middle of the Arc and to turn all Shades towards the centre of the instrument. Transfer the sextant to the left hand, open the sextant handle toggle and gently place the instrument in the box. Lock the toggle over the handle and make a final check to ensure the sextant is correctly positioned in its case. Gently lower the lid and be prepared to repeat the operation if the Shades, or any other part of the sextant, are fouling the lid. Having carefully closed the lid, secure the patent fasteners and place the sextant case on a safe shelf fitted with heavy weather "fiddles".

Using the Sextant

Practical Sextant Procedure and Exercises are included on page 520.

READING THE MICROMETER SEXTANT

Reading the micrometer sextant is extremely easy and requires little explanation.

Degrees Read directly from the Arc of the Sextant.
(Opposite the Index Mark on the Index Arm.)

Minutes Read directly from the Micrometer Drum.
(Opposite the Vernier Index Mark.)

Seconds Read directly from the Vernier.
(Where one of the Vernier graduations lines up with one of the Micrometer graduations.)
N.B.—Some sextants are graduated to 10″ of arc, others to 0·2′ (12″) of arc.

Example 1

What angle is the sextant reading in Figure 2? (Refer to the Figure on page 524.)

Degrees The Index Mark on the Index Arm indicates slightly over 22° on the sextant's arc.

Minutes The Vernier Index Mark appears to lie directly opposite the 10′ graduation on the Micrometer Drum—but check the Vernier to see if the reading is exactly 10′, slightly more than 10′ or slightly less than 10′.

Seconds The Vernier is graduated from 0″ to 60″ and has 6 intervals—it is therefore graduated to 10″ of arc.

Study the exact position of each vernier graduation relative to each micrometer graduation and ask the question, "Which Vernier graduation lines up with a Micrometer graduation?"

The Vernier Index Mark (0″) appears to line up perfectly with the 10′ graduation on the Micrometer. The 10″, 20″, 30″, 40″ and 50″ Vernier graduations DO NOT line up with the Micrometer graduations. The 60″ Vernier graduation appears to line up perfectly with the 15′ graduation.

In summary, both the 0″ and 60″ Vernier graduations line up with Micrometer graduations—this indicates that the sextant is reading an exact number of minutes, i.e. 10′ 00″ or expressed another way, 9′ 60″ which is the same thing.

Answer: The Sextant is reading 22° 10′ 00″.

Sextant Readings "On" and "Off" the Arc

For reasons later described under Sextant Errors, it is essential to be able to read the sextant both on and off the arc. To read angles (particularly very small angles) on and off the arc it is helpful to understand the working of the Micrometer Drum.

Refer to Figure 2

When holding the sextant with the right hand and the Micrometer Drum with the left forefinger and thumb, the micrometer will be viewed from the rear.

By turning the micrometer drum CLOCKWISE (when viewed from the rear) it should be apparent that (in Figure 2) the Micrometer Reading will INCREASE from 22° 10′ to (say) 22° 20′.

By turning the micrometer drum ANTI-CLOCKWISE the Micrometer Reading will DECREASE from 22° 10′ to (say) 22° 00′.

Turning the Micrometer Drum CLOCKWISE—INCREASES the Reading.

Turning the Micrometer Drum ANTI-CLOCKWISE—DECREASES the Reading.

Now refer to Figure 3

The Index Mark indicates 0° on the sextant's arc.

On the Micrometer Drum the 0′ and 10′ graduations are visible and the actual reading is slightly more than 1′.

By turning the micrometer drum CLOCKWISE the Micrometer Reading will INCREASE to (say) 0° 05′ "On" the arc.

By slowly turning the micrometer drum ANTI-CLOCKWISE the Micrometer Reading will DECREASE, first to 0° 01′ exactly, then to 0° 00′. If it is turned 1′ further (anti-clockwise) the micrometer will read 59′, i.e. from 0′ (which is also the 60′ graduation) to 59′ is 1′. This sextant reading is referred to as 1′ "Off" the arc.

The Micrometer Drum is primarily designed for readings "On" the arc that is from 0° upwards. If the Index Arm is moved to a position on the Arc of Excess (that is BELOW) the zero degree position) readings on the micrometer drum must be subtracted from 60, e.g. $60 - 59 = 1'$.

Readings "On" and "Off" the arc are often necessary (particularly when checking the Sextant's Index Error) and it is essential to be able to accurately read the sextant in both positions.

Example 2

(Refer to Figure 3)

What angle is the sextant reading in Fig 3?

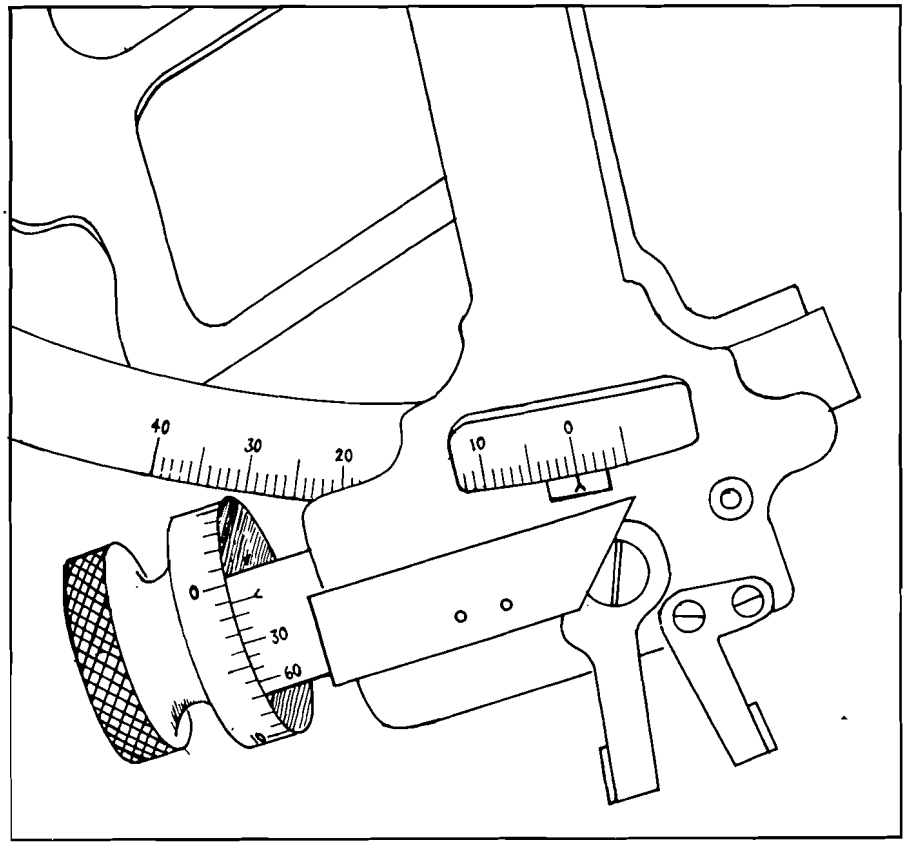


Figure 3. Micrometer Sextant reading 0° 01′ 10″ On the Arc.

Degrees The Index Mark on the Index Arm indicates almost exactly 0° on the sextant's arc.

Minutes First note that the 0′ and 10′ graduations are visible on the Micrometer Drum and that the Vernier Index Mark indicates slightly over 1′. This means that the reading is slightly over 1′ "On" the Arc.

Seconds Studying the relative positions of the 10″ graduations on the Vernier. Only one of the 10″ graduations lines up perfectly with one of the 1′ graduations on the Micrometer Drum, i.e. the 10″ Vernier graduation lines up with the 2′ graduation on the Micrometer, the 20″, 30″, 40″, 50″ and 60″ graduations do not line up.

In summary, the sextant reads 0° on the Arc, 1′ on the Micrometer Drum and 10″ on the Micrometer Vernier.

Answer The Sextant is reading 0° 01′ 10″.

(If this reading had been obtained when checking the sextant for Index Error, the error would be referred to as 1′ 10″ "On" the Arc.)

Example 3
(Refer to Figure 4)

What angle is the sextant reading in Figure 4?

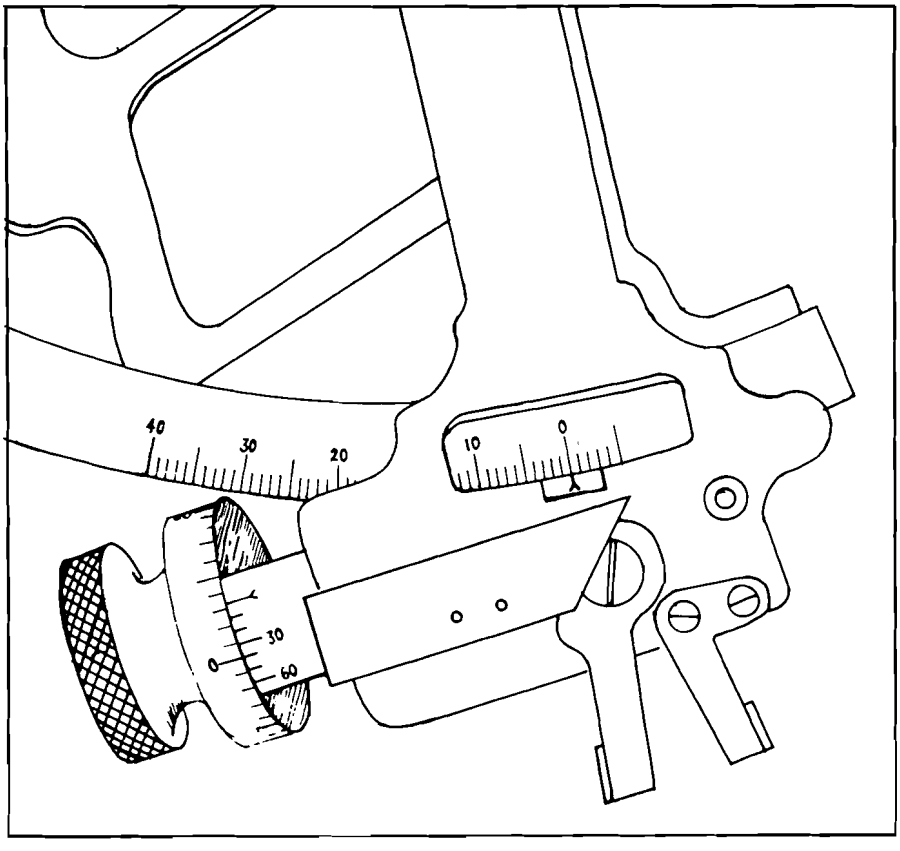


Figure 4. Micrometer Sextant reading 0° 03′ 20″ Off the Arc.

Degrees The Index Mark on the Index Arm indicates almost exactly 0° on the sextant's arc.

Minutes First note that the 0′ and 50′ graduations are visible on the Micrometer Drum and that the Vernier Index Mark lies between them. This means that the reading is "Off" the Arc. The Vernier Index Mark indicates slightly more than 56·5′ on the Micrometer.

Seconds Studying the relative positions of the 10″ graduations on the Vernier. Only one of the 10″ graduations lines up perfectly with one of the 1′ graduations on the Micrometer Drum, i.e. the 40″ Vernier graduation lines up with the 0′ graduation on the Micrometer.

The micrometer indicates precisely 56′ 40″.

Nevertheless, the Index Mark is indicating almost exactly 0° and it should be apparent that if the Micrometer Drum was turned 3′ 20″ CLOCKWISE (60′ 00″–56′ 40″) the reading would be exactly 0° 00′ 00″.

Answer The Sextant is reading 0° 03′ 20″ "Off" the Arc.

(If this reading had been obtained when checking the sextant for Index Error, the error would be referred to as 3′ 20″ "Off" the Arc.)

READING THE VERNIER SEXTANT

(Refer to Figures 5, 6 and 7)

The upper scale represents part of the fixed scale on the arc of a Vernier Sextant. Degrees are numbered at 10° intervals commencing at 0° and the observer counts the intermediate degrees which are indicated by graduation marks only. Each degree space is divided into six equal parts of 10′ each.

The lower scale represents the movable vernier, which enables more accurate readings to be made than is possible by simply dividing the 10′ space on the main scale by eye and estimating the minutes. The vernier is divided up into ten equal parts, every second one being numbered as in the illustration. The vernier is an enlargement of the 10′ spaces of the main scale which is subdivided into ten equal parts, each part being one minute of arc.

The length of the vernier is equal to 119 divisions of the main scale, but instead of being divided into 120 parts it has been divided off into 60 equal spaces. This practice is adopted as it gives a wider spacing of the vernier divisions and makes it easier to read without loss of accuracy.

Example 4

What angle is the Vernier Sextant reading in Figure 5?

1. Note the arrow which indicates zero on the vernier.
2. Count the number of degrees the arrow lies to the left of 0° on the main scale. It is to the left of 4° and falls short of 5°. The reading will be 4° and some odd minutes.
3. Count the number of tens of minutes the arrow lies to the left of 4°. It is a little to the left of 50′. The reading is now 4° 50′ and some odd minutes.
4. Run the eye along the vernier looking at each minute division in turn (for the moment, disregard the intermediate lines between the 1′ vernier divisions).
5. Select the 1′ vernier division which happens to be exactly in a line with a main scale division.

   Is it 1′? No, the 1′ division is just a little to the left of a main scale division.

   Is it 2′? Probably, it seems to be almost coincident with a main scale division.

   Is it 3′? No, the 3′ division is a little to the right of a main scale division.

   It is concluded that the vernier indicates that 2′ have to be added to the 50′ minutes already read from the main scale.

   Answer: Vernier Sextant reading 4° 52′.

Approximate Readings on the Vernier Sextant

An approximate reading can be made without consulting the vernier. By eye, divide the space on the main scale between 4° 50′ and 4° 60′ into ten parts and estimate the odd minutes, whether 51′, 52′, 53′, etc.

Example 5

What angle is the Vernier Sextant reading in Figure 6?

When the arrow of the vernier is to the right of 0° on the main scale the reading is said to be off the arc. The method of reading is the same as previously explained, except that the vernier scale is read from left to right and the numbers altered mentally so that 10 = 0′, 8 = 2′, 6 = 4′, 4 = 6′ and 2 = 8′.

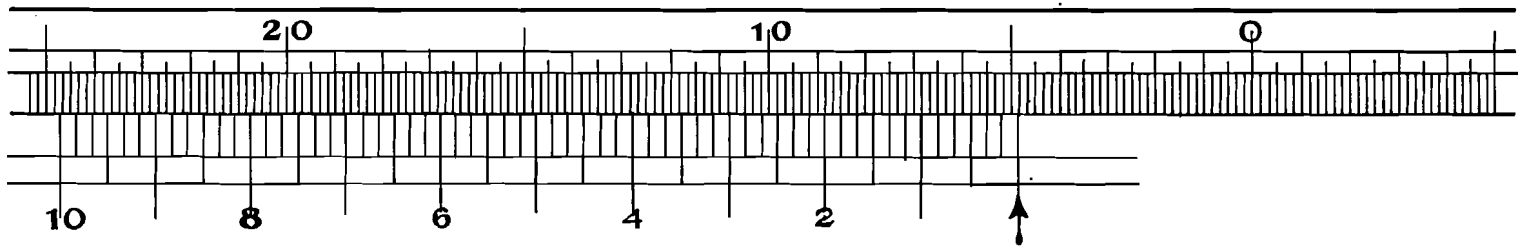


Figure 5. Vernier Sextant reading 4° 52′ On the Arc.

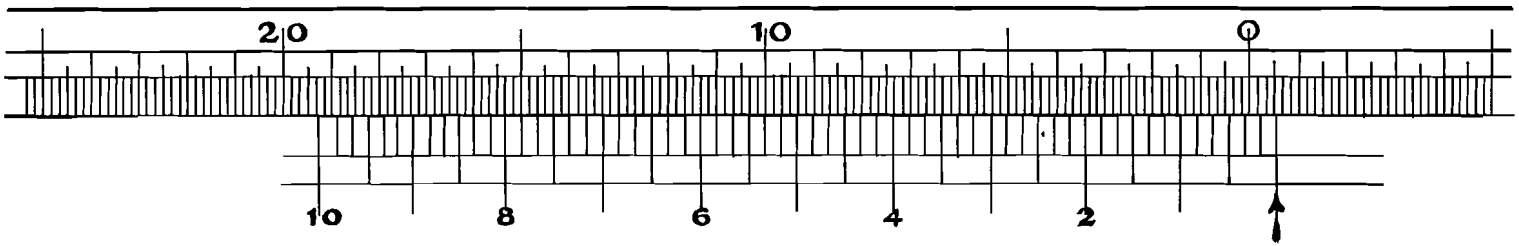


Figure 6. Vernier Sextant reading 0° 32′ 30″ Off the Arc.

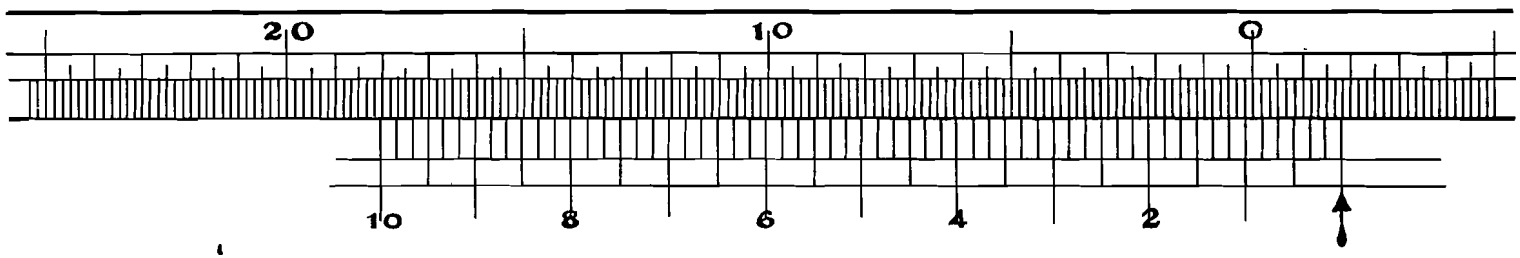


Figure 7. Vernier Sextant reading 1° 47′ 30″ Off the Arc.

1. Note that the arrow is just a little to the right of 30′, somewhere between 30′ and 40′.
2. Run the eye along the vernier beginning at the left hand end, remember 10 is 0.
3. Is 10 in line with a division on the fixed scale? No.
4. Is 9 in line? No.
5. Is the 8 in line? It is very nearly so, just a little to the right of a division on the top scale.
6. Is 7 in line? Not quite, it is a little to the left of a division on the top scale.
7. When "Off" the Arc, the vernier is read from left to right. The vernier indicates between 7 and 8 (read right to left) which gives us a reading between 2 and 3 when read left to right.
   The vernier, therefore indicates that 2′ or 3′ have to be added to the 30′ as read from the main scale.
8. A closer study of the intermediate vernier divisions and we might agree that the long line half way between 2′ and 3′, those divisions actually numbered 8 and 7 on the vernier, is the one where coincidence takes place.
   Answer: Vernier Sextant reading is 0° 32′ 30″ Off the Arc.

Example 6

What angle is the vernier sextant reading in Figure 7?

1. Note that the arrow is just to the left of 1° 50′ Off the Arc. The reading will be between 1° 40′ and 1° 50′ Off the Arc.
2. The vernier (reading from right to left) indicates 2′ 30″ but the angle is Off the Arc so the vernier reading (from left to right) is 7′ 30″.
   Answer: Vernier Sextant reading 1° 47′ 30″ Off the Arc.

SEXTANT ERRORS

A sextant may have the following Adjustable and Non-Adjustable Errors:

1. Perpendicularity Error	Adjustable
2. Side Error	,,
3. Index Error	,,
4. Collimation Error	Adjustable by Instrument Maker
5. Vernier Error	,, ,, ,, ,,
6. Centring Error	Non-Adjustable
7. Graduation Error	,,
8. Micrometer Error	,,
9. Shade Error	,,
10. Prismatic Error	,,

Order of Making Corrections

The first three errors MUST be corrected in the order stated. Correcting the sextant for Perpendicularity Error is referred to as making the 1st Adjustment, correcting for Side Error as making the 2nd Adjustment and correcting for Index Error as making the 3rd Adjustment.

Manufacturer's Sextant Certificate

Some non-adjustable (residual) errors are found in even the finest sextants. Such errors are

tabulated as corrections on the Manufacturer's Certificate which is attached to the inside lid of the sextant case.

Admiralty Test Certificate

For an additional fee, the Admiralty Compass Observatory will test a sextant and issue an Admiralty Test Certificate. Class A certificates indicate that residual errors do not exceed 0·8′ (48″) on any part of the arc.

Applying Residual Errors

On certificates, the signs of residual errors are reversed so that they can be applied as corrections.



Certificate of Examination

THE SEXTANT No. 5258..

NAMED ..... COOKE HULL.....

of ..... 6.5" ..... RADIUS and READING to ..... 10" .....

has been examined and found satisfactory. The following corrections should be applied: —

ANGLE	30°	60°	90°	120°
CORRECTION	0"	+10"	−30"	−30"

The SHADES and MIRRORS are satisfactory.

TELESCOPE DATA:

Magnification	Angle of Field of View	Effective Aperture
6x	8°	30mm.

The definition is satisfactory.

Date 2/11/83. B. COOKE & SON LTD. Signed H. Tudor

Figure 8. Manufacturer's Sextant Certificate.

Adjustment Screws

When correcting a sextant it is necessary to use the sextant adjustment screws. The design of these screws varies. Some are fitted with conventional screw driver slots and dust covers. Others, as illustrated, have round heads through which a small hole has been drilled. A thin stiff wire (the Adjustment Pin) is used to turn this type of adjustment screw.

To make an adjustment, the screw driver or adjustment pin is inserted in the adjustment screw and gently turned clockwise or anti-clockwise to achieve the required result. To prevent mirror breakage, a delicate movement is advised.

Perpendicularity Error

(Refer to Figure 9)

The Index Mirror must be Perpendicular to the Plane of the Instrument—if not, Perpendicularity Error is present.

To Check a sextant for Perpendicularity Error:

1. Remove the Telescope or Monocle.
2. Turn all Shades AWAY from the mirrors.
3. Unclamp and set the Index Arm about the MIDDLE of the Arc.
4. Clamp the Index Arm.
5. Look obliquely into the Index Mirror so that the True Arc is visible (to the left of the mirror) and the Reflected Image of the Arc is seen in the mirror.
6. If the True and Reflected Arcs appear in a Straight Line Perpendicularity Error is NOT present.
7. If the True and Reflected Arcs are NOT in a Straight Line (as shown in Figure 9) Perpendicularity Error is PRESENT and should be removed.
8. To remove Perpendicularity Error make the 1st Adjustment.

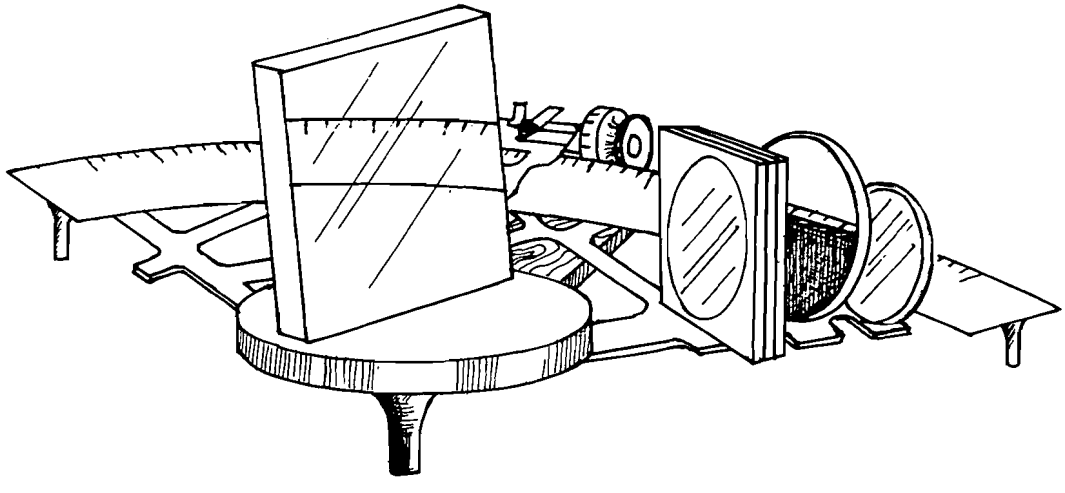


Figure 9. Perpendicularity Error—the Index Mirror is NOT Perpendicular to the Plane of the Instrument.

1st Adjustment (To remove Perpendicularity Error)

With the telescope or monocle removed, shades away from the mirrors and the Index Arm clamped about the middle of the arc:

1. Take the Adjustment Pin from its housing in the Sextant Case.
2. Insert the pin in the Index Mirror adjustment screw (note there is only ONE such screw on the Index Mirror).
3. Using only gentle pressure, turn the adjustment screw until the True and Reflected Arc appears in a Straight Line
4. Carefully remove the adjustment pin (so as not to alter the adjustment screw setting) and replace in the sextant case.
5. The sextant is now free of Perpendicularity Error.

Side Error

(Refer to Figures 10 a, 11 a)

The Horizon Mirror MUST be Perpendicular to the Plane of the Instrument—if not, Side Error is present.

There are two methods of checking the sextant for Side Error:

1. Horizon Observation.
2. Star Observation (2nd Magnitude Star).

The Horizon Method is probably the quickest but it does, of course, require a good clear horizon to work with.

The Star Method requires more practice but is probably more accurate when used by an experienced navigator. Both methods should be practised.

A 2nd Magnitude Star provides a sharp point of light whereas a 1st Magnitude Star provides too much light and cannot be so clearly seen. In consequence, a 2nd Magnitude Star of suitable altitude should be selected. By reason of its extreme distance, a star cannot be magnified but use of the telescope or monocle will improve image definition.

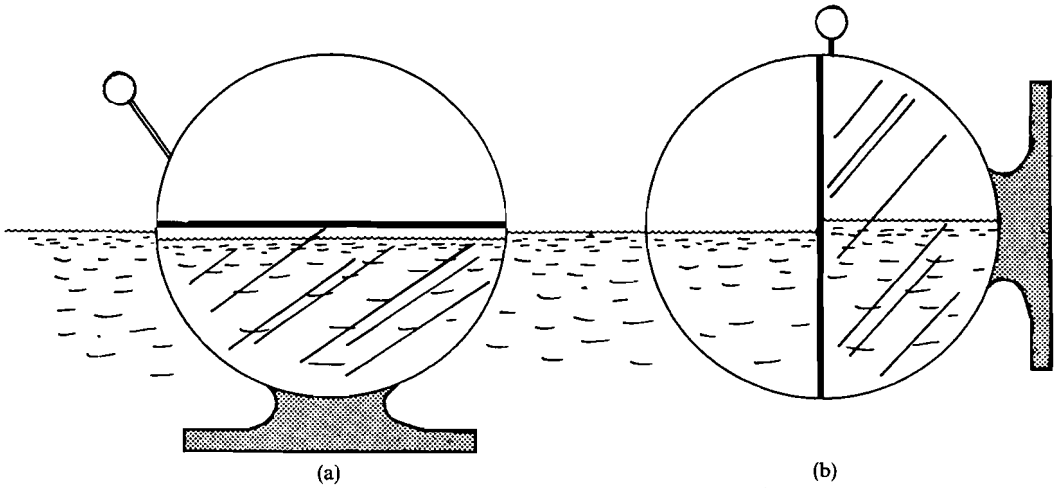


Figure 10. The Horizon Method for checking Side Error and Index Error. The Adjustment Pin is shown in position.

It is a good, seamanlike, practice to check the sextant before taking an angle or altitude—particularly more important ones such as when making a landfall or when in the vicinity of some special danger.

In summary, the navigator should always check the sextant whenever possible and particularly before taking important angles. The Horizon Method should be used in daylight hours and a 2nd Magnitude Star before a.m. star sights.

Checking a Sextant for Side Error (Horizon Method)

(Refer to Figure 10a)

1. Remove the telescope and swing all shades away from the mirrors. (With a brightly lit horizon a Horizon Shade may be necessary.)
2. Set the Index Arm and Micrometer exactly to zero.
3. Hold the sextant horizontally and look through the Horizon Mirror at the horizon.
4. If the True and Reflected Horizons appear IN a Straight Line—Side Error is NOT present.
5. If the True and Reflected Horizons are NOT in a Straight Line (as shown in Fig. 10(a)—Side Error IS present and should be removed.
6. To remove Side Error make the 2nd Adjustment.

2nd Adjustment (To remove Side Error) Horizon Method

With the telescope removed and shades away from the mirrors:

1. Identify the 2nd Adjustment Screw.
   N.B.—There are two adjustment screws on the Horizon Mirror.
2. Take the Adjustment Pin from the Sextant Case.
3. Insert the pin in the 2nd Adjustment Screw.
4. Hold the sextant in the horizontal position and look through the Horizon Mirror at the horizon.
5. Using only gentle pressure, turn the adjustment screw until the True and Reflected Horizons appear in a Straight Line
6. Carefully remove the adjustment pin (so as not to alter the adjustment screw setting) and replace in the sextant case.
7. The sextant is now free of Side Error

Checking a Sextant for Side Error (Star Method)

(Refer to Figure 11a)

1. Ship the Star Telescope or Monocle and swing all shades away from the mirrors.
2. Set the Index Arm and Micrometer to zero.
3. Select a suitable 2nd Magnitude Star.
4. Hold the sextant in the vertical position and look directly at the star through the telescope.
5. Adjust the Micrometer Drum so that the True and Reflected image of the star pass over one another.
6. If the True and Reflected images coincide exactly as they pass over one another Side Error is NOT present.
7. If the True and Reflected images pass to the side of one another Side Error IS present and should be removed.

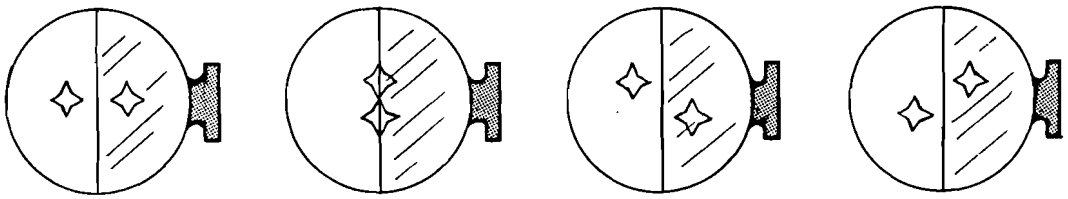


Figure 11. The Star Method for Checking Side Error and Index Error. (a) Side Error Only. (b) Index Error Only. (c) and (d) Side Error and Index Error Combined.

2nd Adjustment (To remove Side Error) Star Method

With the star telescope or monocle in position and the Index Arm at zero:

1. Identify the 2nd Adjustment Screw.
2. Insert the Adjustment Pin in the 2nd Adjustment Screw.
3. Look directly at the star (as before).
4. Adjust the Horizon Mirror (as before) such that the true and reflected image of the star exactly coincide as the micrometer drum is turned.
5. Carefully remove the adjustment pin (as before) and replace in the sextant case.

Index Error (I.E.)

The Index Mirror must be Parallel to the Horizon Mirror when the Index Arm is at Zero—if not, Index Error is present.

As with Side Error, there are two deletion methods of checking the sextant for Index Error:

1. Horizon Observation.
2. Star Observation (2nd Magnitude Star).

A third possibility would be to check the sextant using the Sun but this method has several disadvantages (particularly practical observation difficulties) and is less frequently used in practice. Nevertheless, the Sun is sometimes used to find the value of any Residual Index Error which may remain AFTER all the sextant adjustments have been made and this method is explained later.

Before studying the instructions for checking the sextant for Index Error, refer to the preceding pages for general instructions on the use of the Horizon and 2nd Magnitude Stars for checking Side Error.

Checking a Sextant for Index Error—Horizon and Star Methods

(Refer to Figures 10 b and 11 b)

The procedure is similar to those for checking Perpendicularity and Side Error and is summarised as follows:

1. Ship the Telescope or Monocle.
2. Set the Index Arm and Micrometer PRECISELY at zero.
3. Hold the sextant in the vertical position and look at the Horizon (or a 2nd Magnitude Star).

4. If the true and reflected images of the Horizon (or Star) appear in a straight line (side by side or coincident)—Index Error is NOT present.
5. If the True and Reflected images are NOT in a straight line (not side by side or coincident)—Index Error IS present and should be removed.
6. To remove Index Error make the 3rd Adjustment.

3rd Adjustment (To remove Index Error)

With the telescope or monocle in position and shades away from the mirrors:
1. Set the Index Arm and Micrometer PRECISELY at zero.
2. Identify the 3rd Adjustment Screw on the Horizon Glass.
3. Take the Adjustment Pin from the case and insert in the 3rd Adjustment Screw.
4. Hold the sextant in the vertical position.
5. Look directly at the Horizon (or Star).
6. Adjust the Horizon Mirror until the true and reflected images are in a straight line (side by side).
7. Carefully remove the adjustment pin and place in the sextant case.
8. The sextant is now free of Index Error.

Interaction (between the two adjustment screws on the Horizon Mirror)

There is interaction between the two screws on the Horizon Mirror. When adjusting for Side Error it is possible to introduce Index Error and vice versa. For this reason it is necessary to repeat the procedure for Side Error and Index Error, and repeat again as necessary, until no further errors can be detected.

Residual Index Error

Index Error is said to exist when the Index Mirror and Horizon Mirror are not parallel when the sextant is set exactly at zero. Index Error is also referred to in another sense, i.e. the residual error which remains AFTER making the 1st, 2nd and 3rd adjustments.

Until now it has been assumed that it is possible to completely remove any error in the sextant—in practice this is not always possible. Indeed, continual use of the adjustment screws will eventually loosen them to an extent where even the slightest jolt will alter their setting and introduce error. In practice the navigator will thoroughly check and adjust the sextant at periodic, fairly lengthy intervals of time. Thereafter, the sextant will be regularly checked AT SHORT INTERVALS OF TIME to determine any remaining error (Index Error) which is then applied as a small correction to observed altitudes and angles. It must be stressed that it is of vital importance to CHECK THE SEXTANT FOR INDEX ERROR *BEFORE* TAKING AN OBSERVATION (particularly an important one). The Index Error thus found MUST then be applied to all observed angles.

An Index Error of 1′ or 2′ is quite acceptable and easily applied. If this error increases, say to 3′ or 4′, it is probably necessary to completely adjust the sextant by carrying out the 1st, 2nd and 3rd Adjustments and then find the NEW Index Error (if any) to apply. The non-adjustable (residual) errors listed on the Manufacturer's or Admiralty Test Certificate should also be applied.

Finding the Value of Index Error

Having made the 1st, 2nd and 3rd adjustments, three methods are available for finding the value of any remaining Index Error:

1. Horizon Observation.
2. Star Observation.
3. Sun Observation.

The following summaries deal with the Horizon and Star Methods, the Sun Method will be dealt with in greater detail.

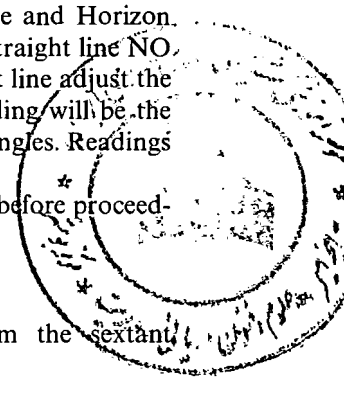
Finding Index Error (Horizon Method)

(Refer to Figure 10b)

Set the sextant exactly at zero. Swing the shades away from the mirrors.
N.B.—A Horizon Shade may be necessary but avoid the use of all shades if possible.

Hold the sextant in the vertical position and look through the telescope and Horizon Mirror at the horizon. If the true and reflected horizons are in a continuous straight line NO Index Error is present. If the true and reflected horizons are NOT in a straight line adjust the Micrometer Drum until they appear in a straight line. The Micrometer reading will be the value of Index Error. Readings On the Arc are SUBTRACTED from sextant angles. Readings Off the Arc are ADDED to sextant angles.

Note the following definitions of Sextant Altitude and Observed Altitude before proceeding with Examples 7 and 8.



Definitions

Sextant Altitude (or Angle)	The altitude (or angle) read directly from the sextant BEFORE applying Index Error (if present).
Observed Altitude (or Angle)	The altitude or angle read from the sextant AND corrected for Index Error (if present), i.e. Obs Angle = Sext Angle (+) or (−) I.E. as appropriate.

Example 7

A sextant's Index Error was found to be 1·5′ On the Arc, and the Sextant Altitude of the Sun was 23° 26·5′. Find the Sun's altitude corrected for Index Error.

Sext Alt Sun		23° 26·5′	(Read directly from the sextant)
I.E.	(−)	1·5′	On the Arc
Obs Alt		23° 25·0′	(Altitude corrected for Index Error)

Example 8

A sextant's Index Error was found to be 0·8′ Off the Arc, and the Vertical Sextant Angle of a distant object was 2° 46·7′. Find the Vertical Angle corrected for Index Error.

Vertical Sext Angle		2° 46·7′	
I.E.	(+)	0·8	Off the Arc
Obs Angle		2° 47·5′	

Finding Index Error (Star Method)

(Refer to Figure 11 b)

Set the sextant exactly at zero. Swing all shades away from the mirrors. Hold the sextant in the vertical position and look through the telescope and Horizon Mirror at a 2nd Magnitude Star. If the true and reflected images of the star are in exact coincidence (or exactly side by side) NO Index Error is present. If the true and reflected images are seen higher or lower than each other adjust the Micrometer Drum until they appear in exact coincidence (or exactly side by side). The Micrometer reading will be the value of Index Error. Readings On the arc are SUBTRACTED from sextant angles. Readings Off the arc are ADDED to sextant angles.

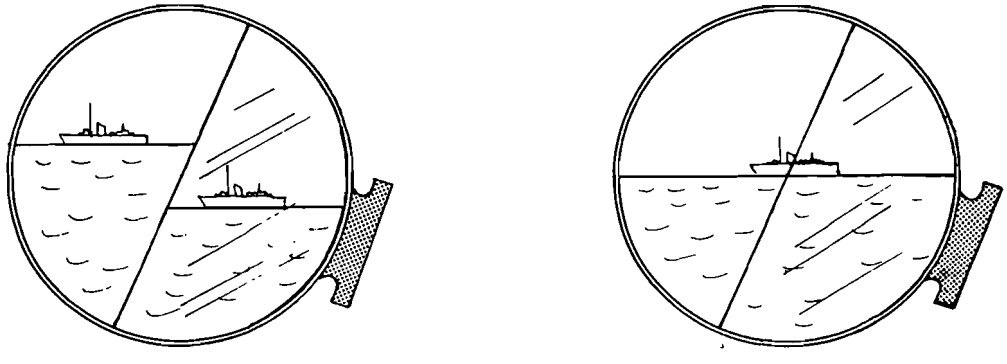
Combination of Errors

(Refer to Figures 11 and 12)

In Figure 11(a) the sextant has no Index Error but some Side Error and hence the true and reflected images of the star are seen "exactly side by side" as described previously.

Various combinations are possible, Side Error only, Index Error only, Side Error combined with Index Error On the arc, and Side Error combined with Index Error Off the arc.

Figure 12 shows a quick method of checking the sextant for Side Error and Index Error at the same time. The sextant is held at an angle to some distant ship or other object on the horizon. If both errors are present the horizon will be "split" and two images of the object will be seen.



(a)
Side Error and Index Error

(b)
No Side Error or Index Error

Figure 12. Combination of Errors. (a) Side Error and Index Error Present. (b) No Side Error or Index Error.

Semi-Diameter Sun—Tabulated Values

Before proceeding to an explanation of the Sun Method for finding Index Error it should be noted that the diameter of the Sun is approximately 32′ of arc and the semi-diameter approximately 16′ of arc. The true value of the Sun's diameter varies, of course, with the Sun's distance from the Earth and hence the seasons and month of the year. The precise value of the Sun's semi-diameter is tabulated in the Nautical Almanac for the middle day of the three days quoted on each page. As demonstrated later, this information provides a convenient method for checking the accuracy of an observation for finding a sextant's Index Error by the Sun.

Finding the Value of Index Error (Sun Method)

(Refer to Figure 13)

1. Ship the Telescope or Monocle.
2. Clamp the Index Arm at zero.
3. Adjust the Micrometer to read approximately 32′ Off the arc.
4. Select a suitable combination of Index Mirror Shades.
5. Hold the sextant in the vertical position.
6. Look through the telescope at the Sun and re-select more suitable Shades if necessary.
7. Look again at the Sun, the True and Reflected Image will be seen with the reflected image above the true image.
8. Adjust the Micrometer Drum until the Lower Limb of the Reflected Image *just* touches the Upper Limb of the True Image.
9. Note the Micrometer Reading and label it "Off" the arc.
10. Adjust the Micrometer to read approximately 32′ On the arc.
11. Look again at the Sun, the True and Reflected Image will be seen with the reflected image BELOW the true image.
12. Adjust the Micrometer Drum until the Upper Limb of the Reflected Image *just* touches the Lower Limb of the True Image.
13. Note the Micrometer Reading and label it "On" the arc.
14. Subtract the smaller reading from the greater reading and divide by 2 to obtain the Index Error.
15. Name the Index Error the SAME as the GREATER READING:

    i.e.—Greater Reading On the Arc Index Error is On the Arc (−)
    Greater Reading Off the Arc Index Error is Off the Arc (+)

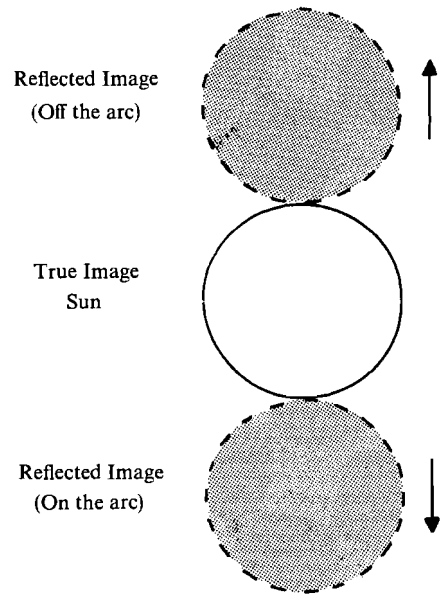


Figure 13. Index Error by the Sun.

Checking the Accuracy of an Observation for Index Error by the Sun

1. Add the two readings (On and Off the arc). The result is the Sun's Diameter × 2.
2. Divide the result by 4. The result is the Sun's Observed Semi-Diameter.
3. Open the Nautical Almanac for the day in question.
4. Note the tabulated value of the Sun's Semi-Diameter.
5. Compare the Observed and Tabulated values for Semi-Diameter.
6. If the Observed and Tabulated values AGREE the observation was ACCURATE and the previously obtained Index Error may be used.
7. If the Observed and Tabulated values DO NOT AGREE the observation was INACCURATE and the previously obtained Index Error may NOT be USED.
   A new pair of observations must be taken and Index Error recalculated.

Example 9
(Refer to Figure 13)

On 11th October two cadets are instructed to find the Index Error of the ship's sextant. Each cadet makes the necessary observations of the Sun and their results are as follows:

Cadet	A		B	
Sun's Diameter Off the arc	30′		30′	
Sun's Diameter On the arc	32′		34′	
Difference	2) 2′		2) 4′	Divide by 2
Index Error	1′	On the arc	2′	On the arc

From the information provided find the Index Error to apply to the ship's sextant.

The two cadets have obtained different results and it will be necessary to check the accuracy of their observations by reference to the Tabulated Value of the Sun's semi-diameter.

Cadet	A	B	
Sun's Obs Diameter Off the arc	30′	30′	
Sun's Obs Diameter On the arc	32′	34′	
2 Diameters	4)62′	4)64′	Divide by 4
Obs Semi-Diameter	15·5′	16·0′	
Tab Semi-Diameter for 11th Oct	16·0′	16·0′	From Nautical Almanac
Error	0·5′	Nil	

Answer: Index Error 2′ On the arc (Cadet A's observation was unreliable).

Collimation Error

The axis (or Line of Collimation) of the telescope or monocle must be parallel to the Plane of the Instrument—if not, Collimation Error is present.

In the past, making the correction for Collimation Error was referred to as making the 4th Adjustment. To make this adjustment a special Collimating Telescope, fitted with spider threads (cross wires) in the eye piece, is required. Vernier Sextants were supplied with this

special telescope but they are not supplied with Micrometer Sextants. In consequence, any correction of Collimation Error must now be carried out by the instrument maker.

Fortunately, collimation error is not common. In the case of a modern Micrometer Sextant of non flexible metal construction it is almost impossible for the telescope, or monocle, to get out of collimation unless, of course, it has sustained a severe knock and the Rising Piece has become bent. Some of the less expensive, alloy, sextants are more prone to collimation error than the more strongly built sextants such as the one used for illustration.

Quick Approximate Method for Checking the Presence of Collimation Error

Most people are capable of detecting (by eye) a mis-alignment of about 1°. A quick, visual, check may be carried out as follows:

1. Ship the Telescope or Monocle.
2. Place the sextant on a level table.
3. Position the eye level with a line mid-way between the telescope and the Plane of the Instrument.
4. Make a visual inspection of the Rising Piece to see if it is *vertical* to the Plane of the Instrument.
5. Make visual inspection to see if the Telescope or Monocle is *parallel* to the Plane of the Instrument.
6. If in doubt, return the sextant to the instrument maker.

Checking a Vernier Sextant for Collimation Error—Summary

To remove Collimation Error it is first necessary to remove Perpendicularity and Side Error. In the Vernier Sextant, the Collimating Telescope is shipped and two observations are made. The first observation is of a low altitude star and the cross wires are set parallel to the Plane of the Instrument.

The second observation involves two celestial bodies situated about 90°–120° apart. The true and reflected images are brought into coincidence on the left cross wire and the Index Arm is clamped. The sextant position is then slightly altered so as to bring the two bodies into coincidence on the right cross wire. If the images separate when transferred from left to right Collimation Error is present and should be removed.

Some older sextants are fitted with an adjustable Telescope Collar attached to the Rising Piece. This type of collar has two adjustment screws which can be slackened or tightened to bring the telescope parallel to the Plane of the Instrument. Before attempting this adjustment it is advisable to consult specialist sextant manuals.

Vernier Error

When the Vernier Index Mark (zero) is in coincidence with a division on the arc of a Vernier Sextant, the 10′ graduation on the vernier should also be in coincidence with a division on the arc—if not, Vernier Error is present and should be removed by the instrument maker.

Vernier Error results from the vernier being positioned too High, or too Low, on the arc. This error can only be removed by the instrument maker.

Non-Adjustable Errors

The following errors cannot be removed either by the navigator or the instrument maker and are referred to as Non-Adjustable Errors. Some non-adjustable errors can be eliminated by replacing the affected part.

Centring Error

The Index Arm's Centre of Rotation should be at the centre of the arc—if not, Centring Error is present.

Centring Error is a small error of manufacture. It cannot be removed but it can be allowed for. The error varies at different positions of the Index Arm but, in general, it increases with the angle measured. These errors are tabulated as corrections on the Manufacturer's or Admiralty Test Certificate and though frequently overlooked, they should always be applied to Sextant Altitudes and Angles.

At sea, Centring Error can only be detected with difficulty. Two simultaneous star observations are necessary. The stars should be of equal altitude North and South of the Observer's Zenith and the latitudes obtained from the two observations should be the same. If two different latitudes are obtained then *Half* the Difference of Latitude is the Centring Error FOR THAT ALTITUDE ONLY. A series of observations probably obtained at different times, will be required in order to find the errors for a range of different altitudes. Because of differences of temperature at different times, refraction may vary thus introducing a variable in addition to human error—for this reason it is extremely difficult to find Centring Error with any degree of accuracy at sea.

Graduation Error

On a Vernier Sextant the Arc Graduations should be accurate—if not, Graduation Error is present.

Graduation Error is another manufacturing error which cannot be remedied. It will not be present in a modern Micrometer Sextant having a Manufacturer's or Admiralty Test Certificate.

Micrometer Error

This is similar to Graduation Error and will not be present in a modern Micrometer Sextant having a Test Certificate.

Shade Error

The faces of *each* Shade should be ground *exactly* parallel—if not, Shade Error is present.

Shade Error can also occur if the shades become loose, damaged or twisted. Such error can be easily detected by visual examination and, if found, it is advisable to discontinue use of the affected shade which should be replaced as soon as possible.

In a modern Micrometer Sextant, the chance of Shade Error is reduced by fitting shades constructed of thin, high quality optical glass. In older Vernier Sextants Shade Error is more likely.

Shade Error cannot be adjusted but it can be eliminated by fitting new shades of suitable quality.

Detecting Shade Error

1. Make an observation of a distant fixed object without any shade in position.
2. Note the precise sextant reading.
3. Swing *one* shade into position and make a second observation of the same object.
4. Note the precise sextant reading.
5. Compare the readings WITH and WITHOUT SHADES.
6. Note the difference (if any) between the two readings—this is the Shade Error for *that* particular shade ONLY.
7. Repeat the procedure for ALL shades and ALL COMBINATIONS OF SHADES most frequently used.

Use of the Darkened Eyepiece (Vernier Sextants)

In the past many Vernier Sextants were provided with a darkened eyepiece which could be screwed onto the telescope.

The darkened eyepiece has two main advantages:

1. To largely remove the need for shades (so completely eliminating Shade Error).
2. To use for a Sun Observation (when testing shades for Shade Error).

The procedure for checking Shade Error by the Sun is as follows:

Ship the darkened eyepiece and bring the true and reflected images of the Sun into contact. Swing the shade into position and check if the true and reflected images are still exactly in contact. If not, the difference between the two readings with and without the shade is the Shade Error for that particular shade. If the Index Arm has to be moved higher on the arc to obtain contact (with the shade in position) the error must be subtracted from angles measured with that particular shade. (Added if the Index Arm has to be moved lower on the arc to obtain contact.)

Readings with and without each shade and with combinations of different shades are taken as before and a table of corrections drawn up.

Prismatic Error

The front and rear faces of each mirror must be ground exactly parallel—if not, Prismatic Error is present.

Prismatic Error is similar to Shade Error and though it cannot be adjusted it can be eliminated by replacing the mirrors. This error is unlikely in a modern sextant.

Artificial Horizon

An artificial horizon consists of a shallow dish containing pure mercury. When at rest the surface forms a perfectly horizontal plane which can be used as an Artificial Horizon. The angle obtained when using an artificial horizon is twice the angle obtained when using the sea horizon. Having applied Index Error in the usual way the resulting Observed Altitude should be divided by two and the Main Correction applied in the usual way. As the artificial horizon is perfectly horizontal, no correction for Dip of the Sea Horizon is required.

Unfortunately, the artificial horizon is of little use at sea as the ship (and mercury) are seldom steady. An alternative is the Bubble Horizon which can be of some use but which is not as accurate a method as using the visible sea horizon.

BACK ALTITUDES, SEXTANT ANGLES AND PRINCIPLES

Occasions will arise when the horizon beneath a body under observation is obscured by cloud, rain, fog or perhaps even land. By descending to a lower deck the navigator lowers height of eye and brings the horizon closer. If the horizon is still obscured it may be necessary to take a Back Altitude. Providing the body's altitude is not too low, the navigator can sometimes face the opposite horizon (which is unobscured) bend back the head and bring the body down to the opposite horizon—this technique being known as a Back Altitude, or Back Observation.

Clearly, the Observed Altitude will be in excess of 90° and will be limited to something less than the sextant's maximum value of about 120°. It follows that the minimum altitude above an obscured horizon will be something over 60°.

When correcting a Back Altitude of the Sun it is essential to make a sketch to decide which of the sun's limbs has been brought to the horizon, i.e. the Upper Limb or Lower Limb. Corrections for Index Error and Dip are applied in the normal way. The Apparent (Back) Altitude is then subtracted from 180° before applying the Main Almanac Correction.

Vertical Sextant Angles

Vertical sextant angles of shore objects such as a lighthouse are sometimes used to find distance off. Examples of this method are included in the chapter dealing with Chartwork. Such angles are normally quite small and, for this reason, the prudent navigator will observe the vertical sextant angle both "On" and "Off" the arc. The mean of the two angles should be used in calculation or to enter the Distance Off by Vertical Angle Table.

Horizontal Sextant Angles

Horizontal sextant angles can be used to fix the ship's position. This method is also explained in the chapter dealing with Chartwork. To observe a horizontal sextant angle it is necessary to hold the sextant in a horizontal position and to bring the right hand object to the left hand object—study Figure 2 and verify this statement by noting that the Index Arm must be rotated from the zero position on the right to some higher reading on the left.

If, for some reason, it is necessary to observe the horizontal sextant angle between two navigational lights the Fixed Light should be brought to the Flashing Light—to attempt the reverse would be to risk "losing" the reflected image mid-way. Should the Right Hand light be flashing and the Left Hand light fixed, it becomes necessary to hold the sextant face downwards in order to bring the Left Hand (fixed) light to the Right Hand (flashing) light. The technique for observing horizontal sextant angles requires some skill and considerable practice.

Sextant Parallax

The principle of the sextant assumes that light rays striking the mirrors are parallel. Rays of light from celestial bodies are parallel and may be assumed to be parallel from distant objects.

Light rays from closer objects are not parallel and the closer the object the more the light rays will diverge. Light rays which are not parallel produce an angle as they strike the mirrors and introduce Sextant Parallax.

Principle of the Vernier

The vernier was invented by Pierre Vernier in 1631. It is constructed on the principle that the length of the vernier is made equal to a certain number of divisions of a fixed scale and is then divided into one more, or one less, than that number of divisions.

For example, on the sextant used for illustration, 5 parts of the Micrometer Drum scale are divided into 6 parts on the Vernier scale—study Figure 2 and verify this statement. This type of vernier is known as a "Short Vernier" and is read in the same direction as the Micrometer, i.e. it reads from left to right. Another method would be to divide 5 parts of the Micrometer scale into 4 parts on the Vernier—a type which is known as a "Long Vernier". The Long Vernier is read from right to left which is the opposite direction to the way the Micrometer is read. For this reason, the Long Vernier is seldom used.

Principle of the Sextant

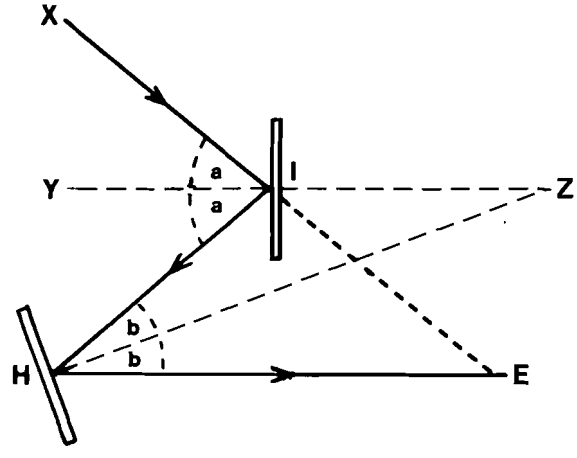


Figure 14. The angle between the first and last direction of the ray is twice the angle between the mirrors.

I	Index Mirror (perpendicular to the plane of the instrument).
H	Horizon Mirror (perpendicular to the plane of the instrument).
XI	Original ray from the body.
IH	1st Reflected Ray (passing from the Index Mirror to the Horizon Mirror).
HE	2nd Reflected Ray (passing through the telescope to the Observer's Eye).
IY	Normal to Index Mirror (perpendicular to the plane of the mirror).
HZ	Normal to Horizon Mirror (perpendicular to the plane of the mirror).
Z	Position at which the normals meet.
J	Position at which lines parallel to the two mirrors intersect, i.e. the angle of inclination of the two mirrors. (*J* is not shown in the figure.)
XIE	Original ray produced to meet 2nd Reflected Ray at *E*.
$\angle YZH$	The angle of inclination between the two mirrors.

Required to prove that: $\angle XEH = 2(\angle YZH)$, i.e. $E = 2Z$.

The proof depends upon two theorems:

1. If two straight lines intersect one another, then the vertically opposite angles are equal.
2. If a side of a triangle be produced then the exterior angle shall be equal to the sum of the two interior opposite angles.

$\angle XIY = \angle YIH$, because the angle of incidence is equal to the angle of reflection. $\angle IHZ = \angle EHZ$, for the same reason. For convenience, name these equal angles a and b respectively.

In $\triangle HZI$, the exterior angle

$$YIH = Z + IHZ$$

i.e. $$a = Z + b$$

and $$2a = 2Z + 2b$$

In $\triangle HIE$, the exterior angle

$$XIH = 2a = E + 2b$$

$\therefore$ $$2Z + 2b = E + 2b$$

i.e. $$2Z = E$$

Practical Sextant Procedure and Exercises

Handling the Sextant

1. Practice, unlocking and opening the sextant case, carefully.
2. Remove the sextant with the left hand holding the frame.
3. Transfer the sextant (handle) to the right hand.
4. Hand the sextant to another person with the left hand holding the frame.
5. Receive the sextant with the right hand.

Correcting the Sextant

(Items Nos. 6–10 may omitted if the sextant has been personally checked recently and has not sustained any recent knock.)

6. Remove telescope, check and adjust for perpendicular error.
7. Check and adjust for side error.
8. Check and adjust for index error.
9. Repeat side error adjustment.
10. Repeat index error adjustment.

Preparing for Sights

11. Unclamp the index bar.
12. Set the index bar to zero.
13. Check and adjust telescope.
14. Select correct combination of Index Glass Shades (Sun sights only).
15. Select correct combination of Horizon Glass Shades (only if essential).

Sighting the Body

16. Check index error (before taking sights).
17. With left hand lightly grasp micrometer drum (thumb and second finger) with index finger (to act as "brake") on bottom of Arc.

18. Assume a steady "open" stance and aim the telescope at sun or required body/object.
20. Release index arm clamp fully.

Taking the Altitude

The action of bringing the sun or star down to the horizon smoothly and without loss of the reflected image requires considerable practice. Jerky movements must be avoided.

21. Using left hand index finger as a brake (see 17) slowly rotate the right hand towards the horizon (this is a wrist action).
22. With the sun or star approximately on the horizon release the clamp and check it is fully engaged.
23. Adjust the micrometer drum until the sun or star just grazes the horizon.
24. "Swing" the sextant and adjust micrometer—sing out, "STAND BY" to your timekeeper at the chronometer position.
25. Make any final adjustment and when quite ready sing out, "TIME".

Recording the Chronometer Time

26. Time keeper records the Chronometer Time.
27. Navigator reads sextant angle in degrees minutes and tenths of minutes (or half minutes).
28. Navigator sings out sextant angle.
29. Time keeper records time of sextant angle.
30. Navigator prepares for next sight.

Cleaning and Stowing the Sextant

31. Wipe dry Index Mirror and Horizon Mirror.
32. Wipe dry telescope and remainder of sextant.
33. Place shades in housed position.
34. Place index bar in housed position.
35. Replace instrument in case, lock, and place on shelf with heavy weather "Fiddles".

Questions

1. Write a short description of the Micrometer Sextant.
2. List the parts of a modern Micrometer Sextant.
3. Explain the function of the clamp fitted to the Index Arm.
4. The sun was observed for Index Error, the readings being 35′ 10″ on the arc and 32′ 40″ off the arc. What is the index error?
5. A sextant reading is 8° 38′. Make a sketch of the scale and arc and Micrometer Drum to show where coincidence of the Vernier Index would take place.
6. A reading Off the Arc is 0° 33′. Make a sketch to show where coincidence would take place.
7. It is necessary to adjust a sextant on shore where no sea horizon is available. How may it be done by means of a single distant object?
8. What kind of angles can be measured with a sextant?
9. Gives examples of vertical and horizontal angles.
10. What is the largest angle that can be measured with a sextant?
11. Why is the arc of a sextant graduated to double the amount of its actual length?
12. On what principle is a sextant constructed?

13. What is the value of a division (a) On the arc on a Micrometer Sextant? (b) On the Micrometer Drum? (c) On the Micrometer Vernier?
14. What is the usual value of a division: (a) On the arc of a Vernier Sextant? (b) On the Vernier?
15. What is a vernier?
16. Describe the principle of the vernier?
17. What length of the arc is usually taken to form the vernier of a Vernier Sextant? To what degree of accuracy is it possible to read the Vernier Sextant?
18. How would you set the vernier to indicate a reading of 17′ 20″ off the arc?
19. What is **Perpendicular Error**?
20. How can Perpendicularity Error be corrected?
21. How do you make the **1st Adjustment**?
22. What is **Side Error**?
23. How can Side Error be corrected?
24. How do you make the **2nd Adjustment**?
25. How could you make the 2nd Adjustment at night when a distinct horizon is not visible?
26. What is the **3rd Adjustment**?
27. How would you make the 3rd Adjustment?
28. Is it possible to make the 3rd Adjustment at night?
29. Would the making of one adjustment upset the other?
30. What would you do if your sextant was found to have an Index Error less than 2′ or 3′?
31. What methods can be used to check **Index Error**?
32. Describe the Horizon Method of finding Index Error?
33. Described the Star Method of finding Index Error?
34. Describe the Sun Method of finding Index Error?
35. How is it possible to check the accuracy of an Index Error obtained by the Sun Method.
36. Why do you clamp the Index Arm about 32′ On or Off the Arc?
37. Which do your consider to be the best method of finding Index Error?
38. Using the Sun Method, readings of 34′ 30″ Off and 30′ 30″ On the Arc were obtained on October 11th. What is the Index Error and Semi-Diameter?
39. Do you expect the Index Error to vary in the course of time, or is it likely to remain constant?
40. Would it be possible to check Index Error by using any level line (close to the observer) to represent the horizon?
41. Explain Sextant Parallax?
42. What is the **Collimation Error**?
43. Can the navigator check and correct the sextant for Collimation Error?
44. What is **Graduation Error**?
45. What is **Vernier Error**?
46. What is **Shade Error**?
47. What is **Centring Error**?
48. Can the value of Centring Error be found?
49. If the sun was at the observer's Zenith, would the altitude measured with a sextant be exactly 90°?
50. By what method would you observe the altitude of the sun if it was over the land, or if for any other reason the horizon under it was not vislble?
51. How would you take a Back Angle?

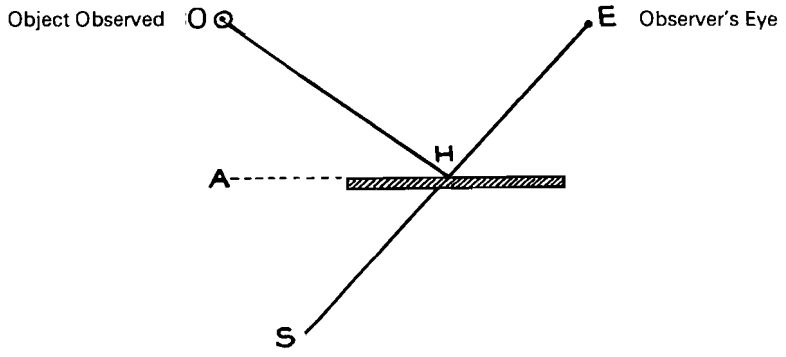


Figure 15. Principle of the Artificial (Mercury) Horizon. $\angle OHS = 2\angle OHA$.

52. How are angles corrected when obtained by Back Observation?
53. Find the Sun's True Altitude.
54. What is an **Artificial Horizon**?
55. Is the same angle obtained when taking altitudes using the artificial horizon instead of ordinary horizon? Explain with reference to a scale drawing of Figure 15.
56. Is there any limit to the altitude which may be observed in the artifical horizon?
57. How should corrections be applied to altitudes observed with an artificial horizon?
58. Is an artificial horizon of any use for observations at sea?
59. Will observations give reliable results using a Bubble Horizon?
60. Having adjusted a sextant, what should be done before observing an altitude?

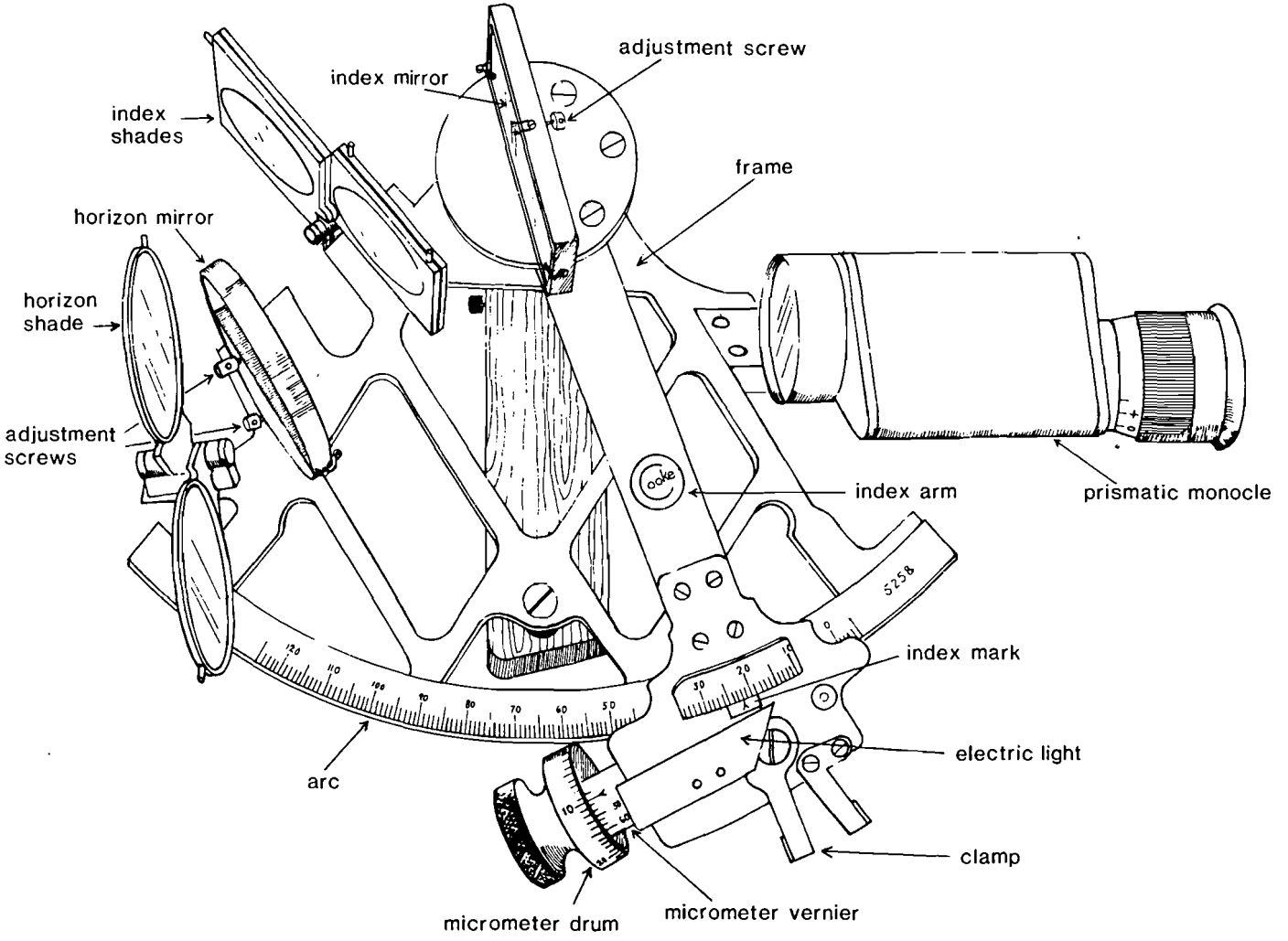


Figure 2. Parts of the Micrometer Sextant. Note that the sextant is reading 22° 10′ 00″ exactly. (A smaller reproduction of this figure also appears on page 494.)

Chapter 18

Principles of Astro-Navigation

Solar System

The term Solar System refers to the sun and its satellites. The centre of gravity of the system is situated near the centre of the sun around which the planets revolve in their appointed paths or Orbits.

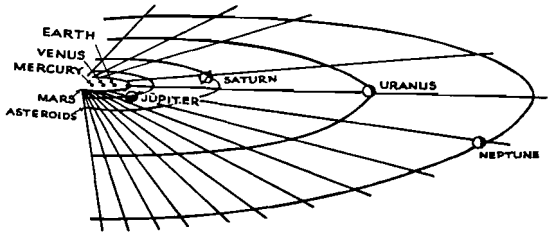


Figure 1.

Planets

The Planets named in the order of their distances from the sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, but four only are visible to the naked eye and bright enough for navigational purposes; they are *Venus, Jupiter, Mars* and *Saturn*, their brilliancy or stellar magnitude which, however, varies a little throughout the year, being in the order named.

Asteroids

The Asteroids or minor planets are a multitude of small planets circling around the sun in the space between Mars and Jupiter. The planets shine by light reflected from the sun and are distinguishable from stars by the steadiness of the light. Stars emanate their own light, just as the sun does, and appear to twinkle. Each star is probably the centre of another solar system similar to our sun with satellites revolving round it, but little is known of the stars owing to their vast distances from us.

Distances in Astronomy

The distances in astronomy are very great. The moon is about 240,000 miles from the earth. The mean distance of the earth from the sun is, in even figures, 93 million miles; Neptune, the furthest away planet, is 2792 million miles removed from the sun, and the distance of the nearest star, *a* Centauri, is reckoned to be twenty billion (20,000,000,000,000) miles away, a distance so

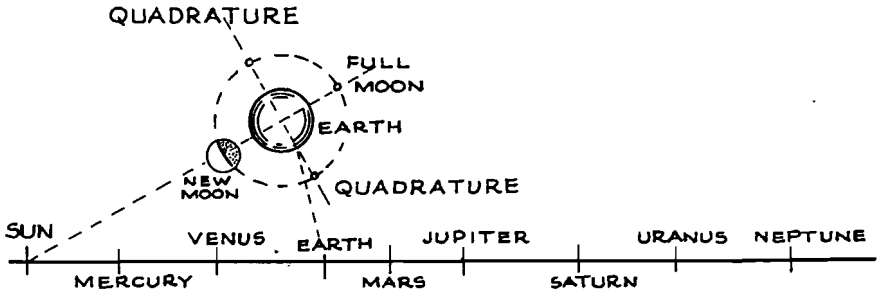


Figure 2.

great that, if the speed of light travelling at the rate of 186,000 miles per second be the unit of measure, it would take the light $3\frac{1}{2}$ years to traverse the intervening space. When one is told that it takes the light from the well-known star Capella 36 years to reach us, the mind fails to realise the tremendous distances which separate us from those stellar worlds. Another method of trying to conceive these distances is to assume the distance of the earth from the sun as unity, that is one mile instead of 93,000,000 miles, then Neptune, the furthest planet of the solar system, would be 30 miles away from the sun and the nearest star 275,000 miles away!

The **Year** of a planet is determined by the period of time it takes to make a complete circuit round the sun. The length of the year increases with the distance of the planet from the sun, thus the year of Venus is shorter than that of the earth, being nearer the sun; Mars, on the other hand, goes round at a distance about half as great again as ours and takes nearly two of our years to complete its circuit; whilst Jupiter, the giant planet of the solar system, being five times as far away from the sun as we are, takes nearly twelve of our years to make its revolution.

The planets also have satellites revolving round them. The earth has one Moon, Mars has two, and Saturn has seventeen. Each of these moons revolves round its parent body whilst the body itself is rotating on its axis, and at the same time each one of those secondary systems travels round the sun in the same manner as the earth-moon system illustrated in Figure 2, which shows the earth and the path of the moon round it, the two bodies together travelling round the sun.

THE SOLAR SYSTEM

Body	Mean Diameter in Miles	Mean Distance from Sun in Million Miles	Time of Revolution round Sun	Number of Moons
Sun	866,400	—	—	—
Mercury	3000	36	87·97 days	0
Venus	7000	67	224·70 days	0
Earth	7927	93	365·26 days	1
Mars	4200	142	687·00 days	2
Jupiter	88,250	483	11:86 years	16
Saturn	74,240	886	29·46 years	17
Uranus	32,000	1782	84·01 years	14
Neptune	32,900	2792	164·80 years	2
Pluto	—	3701	248·00 years	1

The number of moons listed in the table above has been updated for data received from *Pioneer 10* and *11* and *Voyager 1* and *2* and is correct at the date of publication for the present state of travel of *Voyager 2*. *Voyager 2* is due to reach Neptune in 1989.

Apogee and Perigee

The distance of the moon from the earth varies during her circuit from about 221 thousand miles to 252 thousand miles, the former position being called **Perigee** or nearest to the earth, and the latter **Apogee** or furthest from the earth.

The phases of the moon are given in the *Nautical Almanac* and the student should refer to the *Nautical Almanac* Extracts for January 4, June 15, September 19 and December 21 for examples.

Gravitation

Universal Gravitation is that force implanted in the celestial universe by which "every particle of matter attracts every other particle with a force that varies directly as the masses of the particles and inversely as the square of the distance between them." This is the only explanation that can be given as to why the moon does not leave the earth and fly off into space at a tangent to its orbit. It explains also why the planets and other bodies of the solar system keep to their appointed paths when travelling through space and maintain their positions relatively to each other and to the sun. The force of gravity acts throughout the whole celestial universe. Its interaction has been expressed in definite laws amenable to mathematical manipulation by which the motions, velocities and positions of the planets may be computed. Gravitation preserves the equipoise of the solar system, a sublime example of the equilibrium of forces.

ECLIPSE OF THE MOON

The earth casts a shadow behind which tapers off some 800,000 miles into space. The moon, being only some 240,000 miles from the earth passes, on occasions, through this shadow and the light she reflects from the sun is temporarily obscured by the earth.

Figure 4 illustrates the moon in successive positions 1, 2, 3, 4 and 5 during the period of

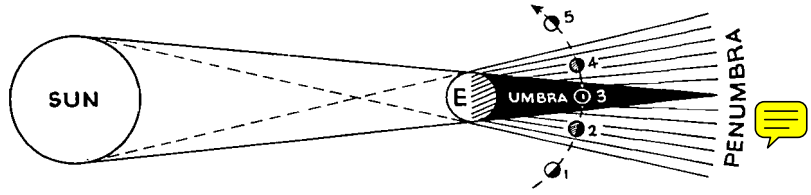


Figure 4.

eclipse. Position 2 shows the moon in the **Penumbra**, that is in the part shadow and is still faintly visible. Position 3 is in the **Umbra**, or perfectly dark space, and the moon is almost completely obscured.

Position 4 shows her again in the penumbra when she becomes faintly visible again; and, finally, position 5 shows the moon completely full and bright, the period of eclipse occupying up to an hour or more from start to finish depending upon the breadth of the shadow she passes through.

ECLIPSE OF THE SUN

An eclipse of the sun is caused by the moon being interposed between the earth and the sun. This can only happen at new moon—conjunction.

The phenomenon depends upon the relative positions of the sun, moon and earth and their distances from each other. When the shadow of the moon is long enough to reach the earth as in Fig. 5, then a **Total Eclipse** of the sun will be experienced at those places within the umbra (*b* to *c*), the perfectly dark portion of the shadow; and **Partial Eclipse** at places within the penumbra or "almost shadow," namely *a* to *b* and *c* to *d*.

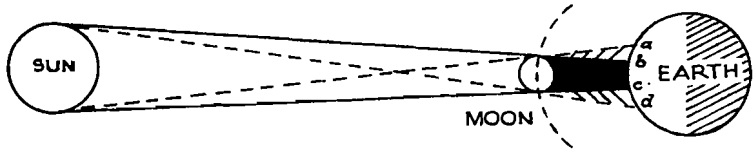


Figure 5.

The moon being so much smaller than the earth her shadow covers a comparatively small area of the earth's surface, hence the reason why eclipses of the sun are visible from certain parts only. An **Annular Eclipse** occurs when the point of the shadow cone cast by the moon does not reach the earth. The moon then passes across the face of the sun without obscuring the whole of it, thus leaving a ring of light round the central part darkened by the moon.

Position of Sun and Moon at Eclipse

There would be an eclipse of the sun at every new moon and an eclipse of the moon at every full moon were it not that the planes of the ecliptic and the moon's orbit are inclined to each other at an angle of 5°, so that it is only occasionally that the positions of sun, earth and moon are so related that a part of one can obscure the whole or part of another.

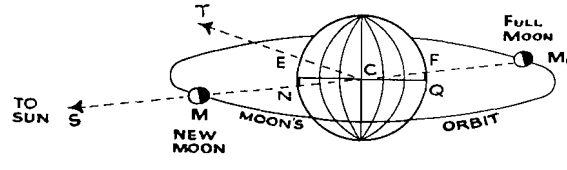


Figure 6.

In Figure 6, *C* is the centre of the earth, *M* the position of the new moon in its orbit when in conjunction with the sun *S*. If *EQ* be the plane of the equator, then *EN* will represent South declination of the moon and also of the sun at the time of an eclipse of the latter; and if *C*♈represents the direction of the First Point of Aries then arc ♈*FM* = arc ♈*FS* which measures the Sidereal Hour Angle of both moon and sun. It follows, therefore, that their S.H.A.'s and declinations must be the same, or nearly so, when the sun is being eclipsed by the moon. G.H.A. sun and moon are also equal at Solar Eclipse—see *Nautical Almanac* extract, Oct. 12, page 901.

Imagine the moon to be 14 days old and that she is now at M_1, the position of full moon,

and that the conditions are suitable for her eclipse, the sun being diametrically opposite at S. Then QF will represent North declination of the moon, and EN South declination of the sun, it follows, therefore, that the declinations of the sun and moon will be about *equal* but of *opposite name* at the period of an eclipse of the moon, but the S.H.A. of the moon will be 180° different from that of the sun. At Lunar Eclipse, G.H.A. sun and moon also differ by 180°.

If $360° - \angle \Upsilon CS$ represents the sun's S.H.A. then $360° - \angle \Upsilon CS + 180° = \angle \Upsilon CM$, which is the moon's S.H.A.

THE EARTH'S ORBIT

The earth travels round the sun in an orbit which is slightly elliptical in shape, its plane being called the **Ecliptic**, because eclipses happen only when the moon is crossing it. The earth turns on its axis daily and makes 365 complete rotations during the period of making its annual revolution round the sun.

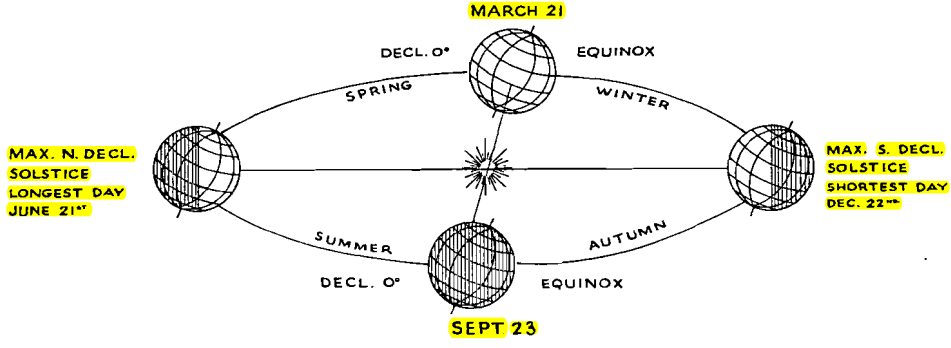


Figure 7.

Figure 7 shows the earth in its orbit viewed from an elevation above the plane of the ecliptic, with the sun almost at the centre of the ellipse and the earth at four successive positions. The reader must exercise the imagination freely in following out the earth's motions in space, as indeed he must always do when trying to visualise the real movements of the celestial bodies.

Ecliptic

The Ecliptic is an imaginary plane surface passing through the centres of the earth and sun so that half the spheres appear above, and half below, the level of this plane, just as if a ball were floating in water half submerged.

If the earth's axis were perpendicular to the plane of the ecliptic the sun would always be

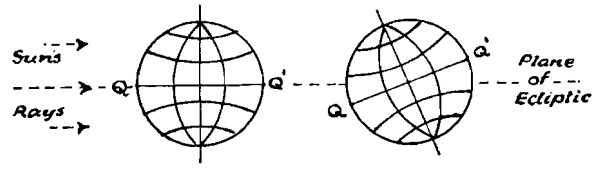


Figure 8.

vertically over the equator and we would not experience the phenomenon of the sun moving North and South annually, thus bringing about the seasons of the year and unequal day and night.

The axis of the earth, however, is tilted at an angle of $23\frac{1}{2}°$ to the plane of its orbit as in Fig. 8, and keeps pointing rigidly parallel to the same direction in space towards a spot in the heavens almost coincident with the Pole Star. We shall now trace the earth's movements in space with the help of the illustration, Fig. 7.

Note position of earth on June 21, and on looking outwards from the centre of the earth towards the sun it would appear to be North of the equator; indeed, on this date the sun reaches the furthest North point of its **apparent** annual journey as viewed from the earth. It is then over the Tropic of Cancer, when it attains its maximum declination of $23\frac{1}{2}°$ North; **declination** being defined as the angular distance of the sun North or South of the equator.

The North hemisphere, as indicated in the figure, is tilted towards the sun and receives more heat and light rays than the South hemisphere. Summer is then being experienced in the North hemisphere with more daylight and less darkness than in the South hemisphere which is experiencing winter conditions as shown by the shaded portion.

The earth, continuing on its journey, causes the sun to move South and to enter *Libra* on September 23. To an observer looking outwards from the centre of the earth, the sun would appear to be in line with the equator—its declination is then 0°–and all the world over the sun rises at 0600 and sets at 1800, the periods of daylight and darkness being equal, hence the name **Equinox**.

The sun is over the tropic of *Capricorn* on December 22, its maximum South declination. The North hemisphere is now tilted away from the sun and the South hemisphere towards him. It is now the Northern winter and the Southern summer, with short daylight North of the equator and long daylight down South.

Vernal and Autumnal Equinox

Three months later, on March 21st, the sun enters *Aries*, when the sun again appears over the equator—the declination is 0°—and equal day and night are experienced all over the world; this is called the **Vernal Equinox** to distinguish it from the **Autumnal Equinox** of September 23.

Finally, after twelve months, the earth has completed its journey, having during its circuit round the sun, traversed a distance through space of 578 million miles at a mean velocity of $18\frac{1}{3}$ miles per second, and turned upon its own axis 365 times, a supreme example of the divine conception of accurate and smooth running mechanism. The sun is not exactly at the centre of the earth's orbit so that our distance from the sun changes. The least distance is $90\frac{1}{2}$ million miles when the earth is said to be in **Perhelion**—its position when nearest to the sun—and this occurs on January 1st. The greatest distance, $93\frac{1}{2}$ million miles, is reached on July 4th, when the earth is said to be in **Aphelion**, its position when furthest from the sun.

The sun, therefore, appears larger when we are nearer to it than when further away, hence the reason why his diameter varies slightly from month to month. Refer to the *Nautical Almanac* and note that the sun's semi-diameter (16·3′) is greatest in December and least (15·8′) in July.

Summer and Winter Solstice

The Solstices are the two points in the ecliptic where the sun reaches its maximum North and

South declination ($23\frac{1}{2}°$), so named because the sun appears to "stand," that is, ceases to move N. or S. The **Summer Solstice** is on June 21, the **Winter Solstice** on December 22.

REAL AND APPARENT MOTION

The actual change of position of a body due to its own progression is called its **real** or **proper motion.**

The earth and planets travelling round the sun are examples, also the moon going round the earth.

Apparent Motion, on the other hand, is merely the **apparent** change of a body's position arising from a change in the position of the observer and not from the body itself.

The sun's motion in declination is apparent because it is due, not to the sun moving, but to the observer viewing the sun from successive positions on the earth's orbit. Nevertheless, it is very convenient to speak of the sun as travelling North and South, because, so far as the obvious appearance is concerned, it is a matter of indifference whether we suppose the earth to revolve round the sun and vice versa.

Again, the sun does not really rise out of the Eastern horizon but the earth rotating daily on its axis makes it appear to do so. The rising, culminating and setting of the sun is therefore called its **apparent** daily motion.

DAY AND NIGHT

The unequal duration of daylight and darkness is due to the change in the sun's declination.

The half of the earth turned towards the sun receives the rays of light, the other half is in darkness, as illustrated by the shaded portions in the three following figures. Four parallels of Latitude are shown in each figure; the Arctic Circle, Tropics of Cancer and Capricorn, and the Antarctic Circle. Every place on a parallel of Latitude, owing to the earth's daily rotation describes a complete circle round the pole in 24 hours, so that in 12 hours an observer at A is carried to A'; B to B'; C to C' and D to D'. The proportionate duration of day and night is represented by the illuminated and the shaded portions, the boundary line between being the position of an observer at the time he would see the sun rising.

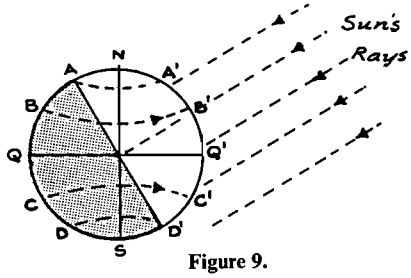


Figure 9.

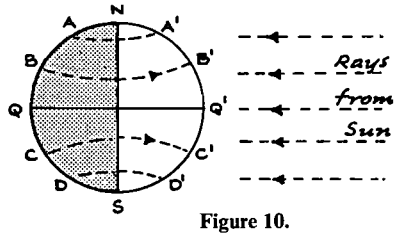


Figure 10.

Figure 9 represents the sun at the summer solstice (June 21), from which it will be seen that daylight is longer in the North hemisphere than in the South; that within the Arctic Circle (AA') the sun does not set; and within the Antarctic Circle (DD') it does not rise because the meridian distance from the sun ($B'D'$) is then 90°; it is equal day and night at the equator; at the Tropic of Cancer ($23\frac{1}{2}°$ N.) the sun is vertically overhead and passes the zenith of all observers on the parallel of latitude BB'.

Figure 10 represents the sun at the equinoxes (March 21 and September 23) when the declination is 0°. The

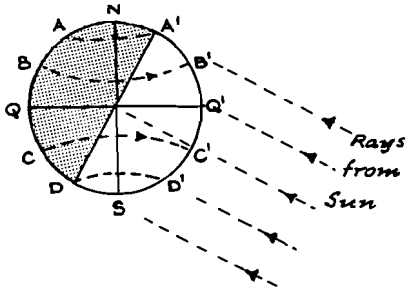


Figure 11.

duration of day and night is then equal, the sun rising at 0600 and setting at 1800 all the world over.

Figure 11 represents the sun at the winter solstice (December 22). The sun remains below the horizon to an observer within the Arctic Circle as the meridian distance from the sun, $A'C'$, is then 90°, and within the Antarctic Circle the sun remains above the horizon the whole day. On the equator it is, as always, equal day and night. The sun at this period of the year appears vertically over the Tropic of Capricorn, $23\frac{1}{2}$° S., and passes in succession over the zenith of every place in this Latitude.

APPARENT MOTION OF CELESTIAL BODIES

Apparent motion is due to a change in the observer's position relative to distant bodies, as distinct from proper motion which is due to the bodies themselves changing their positions with respect to a stationary observer.

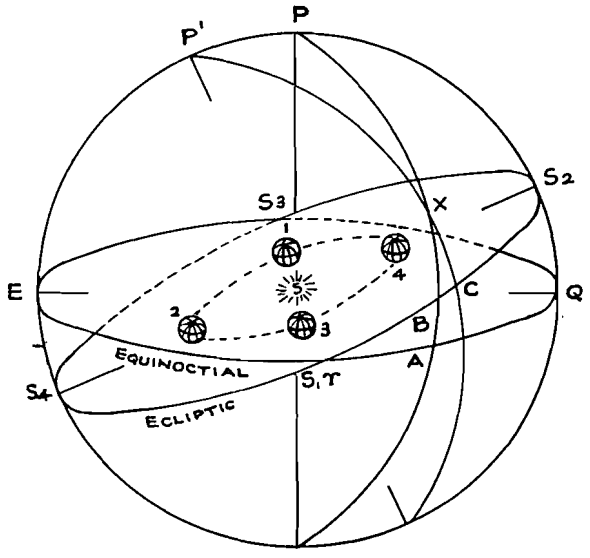


Figure 12.

Figure 12 is intended to represent the earth travelling round the sun, with the celestial sphere drawn outside of the earth's orbit, which is shown dotted with the earth at four successive positions, 1, 2, 3 and 4.

ES_1 QS_3 is the plane of the equator.

$S_1S_2S_3S_4$ is the plane of the ecliptic.

When the earth is at position 1, the sun appears on the celestial sphere in the direction of S_1, in a line with the First Point of Aries at the time of the vernal equinox on March 21, S.H.A. 0° Dec. 0° approximately.

When the earth is at position 2, the sun appears on the ecliptic in the direction of S_2, at the summer solstice on June 21, S.H.A. 270° Dec. 23½° N. approximately.

When the earth is at position 3, the sun appears to be at S_3, in the direction of Libra at the intersection of the ecliptic and the equator on September 22, the date of autumnal equinox, S.H.A. 180° Dec. 0° approximately.

When the earth is at position 4, the sun appears at S_4, the winter solstice, on December 22, S.H.A. 90° Dec. 23½° S. approximately.

Thus the sun's changes of Sidereal Hour Angle (S.H.A.) and declination are due to its "apparent" motion along the ecliptic, and this is brought about by the earth travelling round the sun and also to the plane of the ecliptic being inclined 23½° to the plane of the equator.

If X be a star on the celestial meridian PXA, then

ΥA Right Ascension and ΥES_3QA = S.H.A.
AX Declination
ΥC Celestial Longitude
CX Celestial Latitude.

These quantities change very little as the positions of the stars appear to be almost fixed in space.

Note: The relationship between S.H.A. and Right Ascension (R.A.) is dealt with later under the heading "Sidereal Hour Angle". In summary, S.H.A. is measured Westwards from Υ and R.A. is measured Eastwards from Υ. S.H.A. = 360° − R.A.

Precession of the Equinoxes

Precession of the Equinoxes is due to the pole of the equinoctial (P) describing a small circle round the pole of the ecliptic (P^1) which is fixed in space. This causes the Point of Aries to move slowly westward along the ecliptic at the rate of about 50″ in a year, this quantity being known as the precession. It takes about 26,000 years to perform a complete revolution. This can be readily figured out.

$$\frac{360° \times 60' \times 60''}{50''} = 25{,}920 \text{ years.}$$

The effect of precession is to produce a yearly increase in the celestial longitude of all stars, their latitudes being constant. It also partly accounts for the slight changes in the S.H.A.'s and declinations of the stars and the fact that some stars appear to be approaching the celestial pole and others receding from it. Polaris, for example, is about 1½° from the pole of the heavens at the present time and it will approach to within ½° and then begin to recede.

Leap Year

The reason for leap year is that the earth takes almost 365¼ days to make a complete circuit of the sun, not 365 days as in our civil year, with the result that the civil calendar differs by one-quarter of a day, or 6 hours, from the astronomical calendar in every succeeding year. In four years, therefore, it is one complete day behind the astronomical reckoning so that an extra day is added in February making a leap year of every fourth one.

But owing to the fact that the mean solar year is actually 365·24 days, that is ·01 of a day less than the 365¼ days allowed, an error creeps in which is rectified by not adding a day on every third successive century year but doing so on the fourth century year, thus the years 1700, 1800 and 1900 were not leap years but the century year 2000 will be.

RELATIVE MOTION OF PLANETS

The inferior planets complete their circuit of the sun in a shorter time than the earth; Venus, for example, occupies 224 of our days. The revolutions of the superior planets occupy longer periods, that of Mars being 1·88 of our year, Jupiter 11·86 years and Saturn 29·46 years.

The sun's S.H.A. decreases progressively from 360° at ♈ through 180° to 0°, due to the sun's apparent motion round the earth. But the relative positions of the earth and planets with respect to the sun, result in the S.H.A.'s of the planets sometimes increasing and sometimes decreasing.

INFERIOR PLANETS

In Figure 13, S represents the sun; V, V_1, V_2, V_3 and V_4, are successive orbital positions of Venus. E represents the earth in its orbit. The outer circle is intended for the equinoctial along which Sidereal Hour Angles are measured with Aries (♈) in the distance, a point so infinitely far away that no matter from whence it may be viewed on the orbit of Venus, or of the earth, the direction of the visual rays are parallel to each other.

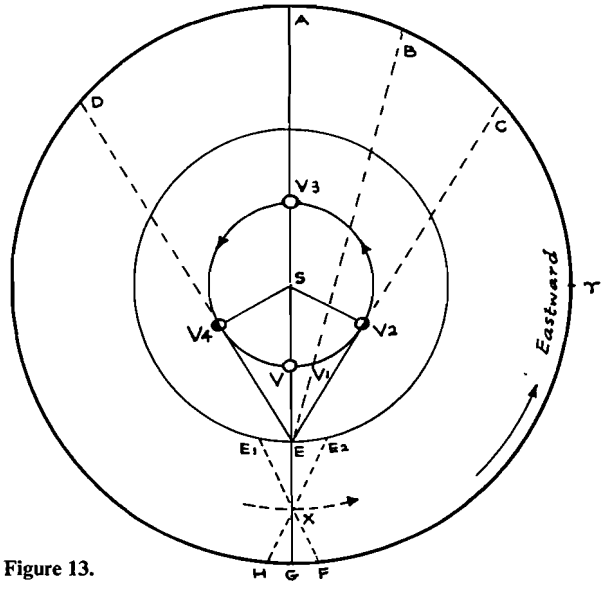


Figure 13.

The orbit of Venus is only inclined $3\frac{1}{2}°$ to that of the earth, and being small it is neglected in this illustration, and we are also ignoring the inclination of the equator to the ecliptic as we only wish to indicate roughly why the S.H.A. of planets sometimes increase instead of always decreasing as in the case of the sun.

It might be mentioned here that the points where the plane of a planet intersects the plane of the ecliptic are called nodal points, the ascending node being the point where the body crosses the ecliptic from south to north, and the descending node where it crosses going southward.

Imagine the earth at E and, to simplify matters, assume it to be stationary for the time being; assume also a position for Aries at ♈.

V Venus at Inferior Conjunction.
V_2 Greatest Westerly Elongation.
V_3 Superior Conjunction.
V_4 Greatest Easterly Elongation.

These positions are respectively projected at A, C, A, and D on the equinoctial.

When at V, Venus would be projected at A and the S.H.A. (ΥGA) approximately 270°.

When Venus reaches V_1 the position would be in the direction of B, the S.H.A. having

increased (ΥGB) and this retrograde motion would continue until the planet reached maximum elongation at V_2, when S.H.A. would be the measure of the arc ΥGC.

Thereafter, as the planet travelled from V_2 to V_3 the S.H.A. would decrease until eventually maximum East elongation was reached at V_4, then when travelling from V_4 to V and from V_1 to V_2, the S.H.A. would again increase as the projected points moved in succession through A, B and C. The regularity of this motion is interrupted by the earth travelling at the same time in her orbit.

The planets go through phases similar to the moon. When at V the dark half of Venus is next to the earth; when she is at V_2 we see a portion of the illuminated disc; when at V_3 the whole lighted half of the planet is directed towards us and she should appear very much brighter if brightness of the sun did not obscure that of the planet. These phases alone should account for the changes in the magnitudes of planets but, in the case of Venus, the increase of brightness due to phase is counteracted by her greater distance from us at superior conjunction, thus making her apparent diameter smaller.

SUPERIOR PLANETS

The same line of reasoning explains the occasional retrograde motion of superior planets which occurs when the earth comes between the planet and the sun.

Let X in Figure 13 be a superior planet and assume it to be temporarily stopped. Let E_1 be the earth, then planet X will be projected at F on the equinoctial. Later, when the earth has travelled to E, the planet will appear at G, and later still it will appear at H when the earth reaches E_2. The planet has apparently moved westward from F to H towards Aries, thus causing a temporary increase in S.H.A. Meantime, of course, the planet X will have travelled eastward in its orbit and the rate of change will not be so marked as indicated in the figure which, obviously, is very much out of proportion as indeed all astronomical illustrations are.

VENUS A MORNING OR AN EVENING STAR

Venus being an inferior planet is never visible from the earth at midnight, for then the observer is on that side of the earth which is turned away from the planet.

In Fig. 14, S is the sun; V_1 and V_2 are two positions of Venus in her orbit; P represents the pole of the earth and ZPZ_1 a meridian, Z being noon and Z_1 midnight.

At midnight the planet cannot be seen from Z_1 as the bulge of the earth is in the way, but when the earth has rotated the observer from Z_1 to Z_2 the planet will come into view a little before sunrise, which will not occur until the observer reaches position A. The line $Z_2\ V_1$ is the direction of the observer's horizon when Venus is rising and AS his horizon at sunrise. This represents Venus as a morning star.

The light of Venus is lost in the more brilliant light of the sun during the day. But if Venus were at position V_2 then she would be seen before sunset, that is before the observer reached position B, and she would remain visible until the observer was carried round from B to Z_3. She would, therefore, set after sunset and would be called an evening star.

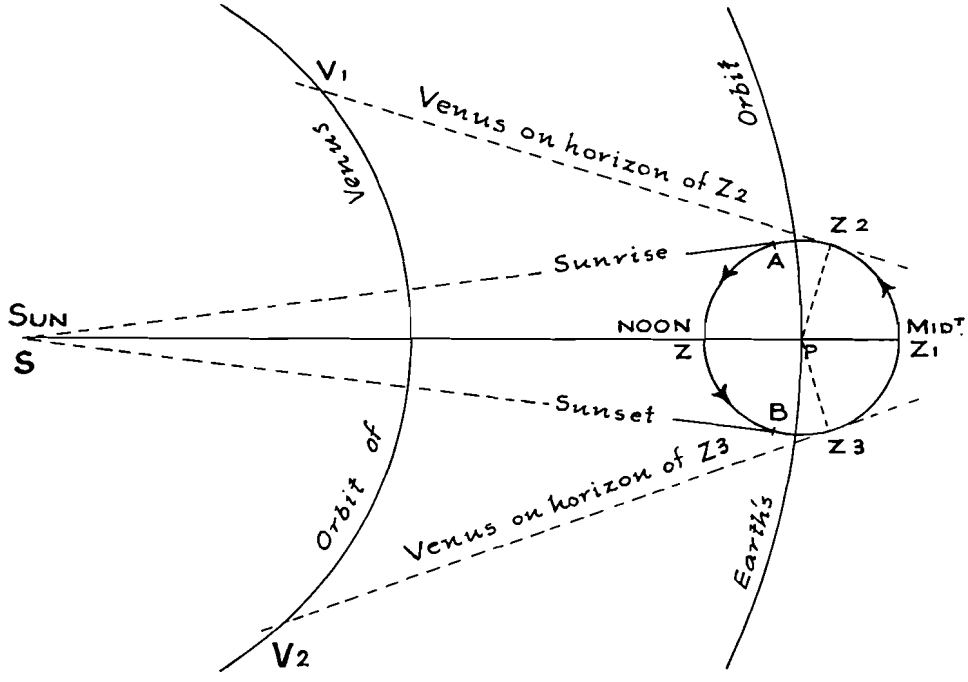


Figure 14.

REFRACTION

Atmospheric refraction is the most elusive of all the corrections in nautical astronomy as its value varies with the density of the atmosphere which, in turn, depends on the temperature and pressure of the air. Thus Tables of Mean Refraction are computed for a stated reading of barometer and thermometer, usually being for 1010 mb pressure and 10°C. When the temperature falls the air becomes denser, the pressure is greater and the barometer rises and with it an increase of refraction.

The quantity diminishes as the altitude increases, the refraction being 33′ 00″ when altitude is 0° decreasing to zero when the altitude is 90°. Its effect is to raise the visible height of bodies above the horizon so that celestial bodies appear to rise and set when they are really 33′ below the horizon, thus the time to observe an amplitude of the sun is when the true altitude of its centre is 0° and that is when the lower limb of the visible sun is about a semidiameter high.

Refraction changes rapidly for low altitudes owing to the rays of light passing obliquely through the layers of atmosphere, thus for altitude 0° the refraction is 33′ and for altitude 35′ the refraction is 27′ 41″. This causes the sun to appear oval in shape at rising and setting because the effect of refraction is to produce a difference of about 5′ between its lower and upper limbs, so that its vertical diameter is shortened by that amount and the disc appears to be flattened instead of truly circular.

Refraction accelerates the time of sunrise and retards the time of sunset so that the visible sun is longer above the horizon than the astronomical sun.

Dip and Refraction

The distance of the sea horizon is increased by refraction. In Fig. 15, if AB represents the height of eye and BV_1 a bent refracted ray, then AV_1 is the distance of the sea horizon. Draw BV a straight tangent to the earth's surface at V, then AV would be the distance of the horizon if there were no refraction. If BS represents the sensible horizon and BV_2 a tangent to the bent ray at B, then angle SBV_2 is the angle of dip which is diminished by refraction, angle SBV being the theoretical dip.

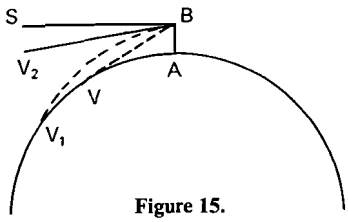


Figure 15.

The distance of the sea horizon in miles = $2{\cdot}095\sqrt{h}$ where h = Height of Eye in metres or $1{\cdot}15\sqrt{h}$ where h = Height of Eye in feet. Dip in minutes = $0{\cdot}98\sqrt{h}$ where h = Height of Eye in feet or $1{\cdot}76\sqrt{h}$ where h = Height of Eye in metres.

Refer to Chapter 19 for further remarks on dip and refraction.

TWILIGHT

Twilight is due jointly to the refraction and reflection of the scattered rays of sunlight. When the sun sinks below the horizon the rays illuminate the upper strata of the air, and, of the light thus received, a considerable portion is reflected in various directions, and illuminates the earth for a considerable time after sunset. Twilight lasts until the sun is 18° vertically below the horizon, and there will be continuous twilight at a place where its latitude plus the sun's declination exceeds 72°.

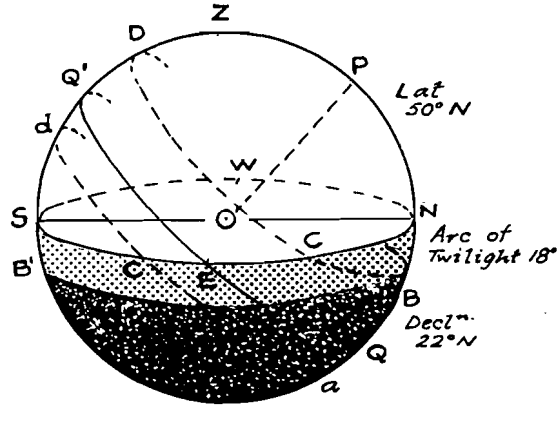


Figure 16.

Figure 16 represents the astronomical incidence of twilight, O being the centre of the earth, $NESW$ the horizon, Z the zenith, P the pole, $Q'Q$ the equator, NP the elevation of the pole above the horizon and equal to an assumed latitude of 50° in this illustration. NQ is the Co-Latitude, that is 90°—Lat., NB and SB' is the 18° arc of twilight below which the sun must go to produce complete darkness. Twilight continues while the sun is within the lightly shaded area.

For example, assuming the sun has South declination and travels along the diurnal arc *abcd*. When at position *a* the sun is on the observer's midnight meridian and complete darkness will prevail until the sun reaches *b*, then darkness merges into twilight during the period the sun takes to travel from *b* to *c*, and then half the period of daylight from the time it rises above the horizon at *c* until it crosses the mid-day meridian at *d*—a shorter period of daylight than of darkness.

Again, assuming the sun's declination to be 22° N., as represented by the arc *QB*, *B* being the position of the sun at midnight when at its maximum vertical distance below the horizon, that is arc *NB* is 18°, then there will not be complete darkness in Lat. 50° N. because Lat. 50° + Twilight arc 18° + Declination 22° N. = 90°. In this case twilight will continue until the sun rises at *C* and then the arc *CD* represents half the time the sun will be above the horizon—a longer period of daylight than of darkness.

Example

In what latitudes will there be continuous twilight when the Sun is at the Winter Solstice?

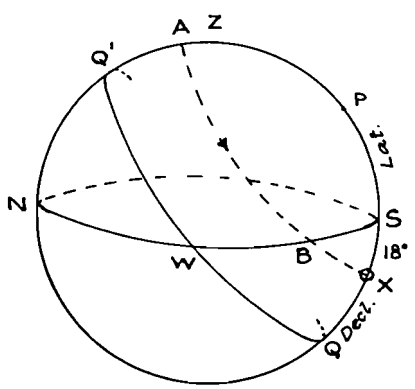


Figure 17.

SZN A meridian
SWN Plane of the Rational Horizon
Q'WQ Plane of the Equator
ABX Sun's Diurnal Path

The Sun was on the meridian at *A* at noon, set at *B* and is now at *X*. So *SX* is 18° vertically below the horizon when the sun is on the midnight meridian.

P South pole *Z* Zenith
PS South Latitude
SX = 18°
QX = South Declination = $23\frac{1}{2}$° S.
$PS + QX + 18° = 90° = PQ$
$\therefore$ Lat. + Dec. = 72°,
Lat. = 72° − Dec. = 72° − $23\frac{1}{2}$° = $48\frac{1}{2}$°

There will be continuous twilight from Latitude $48\frac{1}{2}$° S. to $66\frac{1}{2}$° S.; further South than this the sun will be continuously above the horizon at the winter solstice.

It will be obvious that when the sun ascends or descends perpendicularly to the horizon it will move through the 18° of altitude in a shorter time than when its daily path is oblique to the horizon. And so the reason why twilight is of shorter duration within the tropics than in the temperate zones is due to the sun rising and setting perpendicular, or nearly so, to the horizon.

SIGNS OF THE ZODIAC

The early astronomers were under the impression that the earth was stationary and that the sun travelled around it. They conceived a belt 16° wide (8° on each side of the ecliptic) and called it the **Zodiac**, then divided this imaginary circle of 360° by 12 and gave names and symbols to each of the twelve 30° arcs, not unlike our months of the year. These are still retained and named the "**Signs of the Zodiac**" although only four of them Cancer, Libra, Capricorn and Aries, are referred to in navigation.

SIGNS OF THE ZODIAC AND ASTRONOMICAL SEASONS

SPRING			
♈	*Aries* (The ram)	March 21*	Spring Equinox (Day and night equal)
♉	*Taurus* (The bull)	April 20	
♊	*Gemini* (The twins)	May 21	
SUMMER			
♋	*Cancer* (The crab)	June 21	Summer Solstice (Maximum North declination)
♌	*Leo* (The lion)	July 22	
♍	*Virgo* (The virgin)	August 22	
AUTUMN			
♎	*Libra* (The balance)	September 22	Autumnal Equinox (Day and night equal)
♏	*Scorpio* (The scorpion)	October 23	
♐	*Sagittarius* (The archer)	November 22	
WINTER			
♑	*Capricornus* (The goat)	December 22	Winter Solstice (Maximum South declination)
♒	*Aquarious* (Water bearer)	January 20	
♓	*Pisces* (The fishes)	February 19	

*The dates vary in different years.

SUN'S APPARENT MOTION

In some branches of astronomy, and particularly in nautical astronomy, it is convenient to imagine the earth as stationary and to trace out geometrically the paths the heavenly bodies would follow if such were actually the case; indeed, this **apparent** motion is the only one that appeals directly to our sense of vision.

The sun is impressed with two distinct apparent motions:—(1) That due to the earth travelling round the sun; this motion is traced by changes in the sun's Sidereal Hour Angle and declination, to be explained later. (2) That due to the earth turning daily on its axis; this

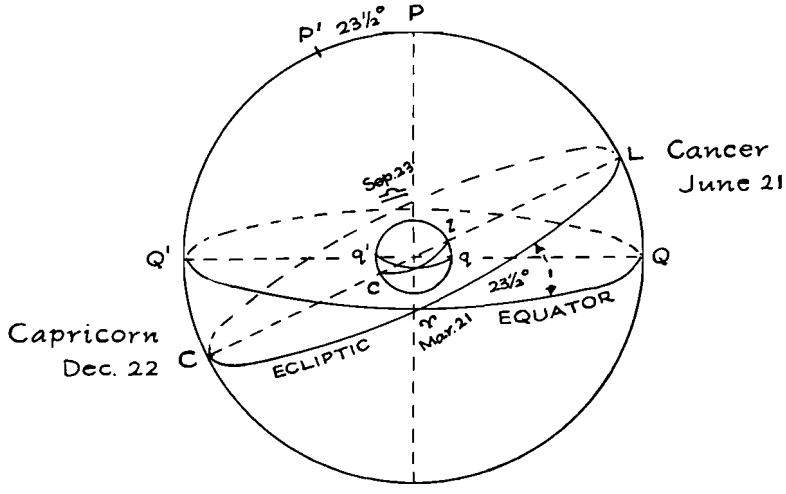


Figure 18.

motion is made apparent by the rising and setting of celestial bodies and their change of altitude and bearing.

Conceive then a transparent celestial sphere geocentric with and surrounding the earth sphere (geocentric means having the centre of the earth as its centre) and that an observer stationed at the centre of the earth looking outwards into space sees the heavenly bodies projected on its interior concave surface. It must, of course, be understood that this celestial sphere has no definite boundary, but that however far distant a body may be it would appear to lie in the direction of the observer's visual ray.

Equinoctial

The plane of the earth's equator ($q'q$) when extended to the celestial sphere marks out the celestial equator, or **Equinoctial** ($Q'Q$) as shown in Figure 18.

The sun's apparent path, named the **Ecliptic**, would be traced out on the great circle CL, having its counterpart projected on the earth as cl.

Obliquity of the Ecliptic

The Obliquity of the Ecliptic is the inclination of the plane of the ecliptic to the plane of the equinoctial. This angle is $23\frac{1}{2}°$ and it is measured by the angle $L\Upsilon Q$.

The earth's axis is at right angles to the plane of the equator, and when the axis is extended to the celestial sphere it marks the pole of the heavens (P). The pole of the ecliptic is at P', the arc PP' being $23\frac{1}{2}°$.

Imagine an observer at the centre of the earth watching the sun from day to day and month to month throughout the year and that the circles in the figure are seen as a skeleton or framework. The observer would see the sun in the direction of Aries (Υ) on March 21, just as it was crossing the equinoctial going Northward in spring. The ecliptic and the equinoctial intersect at this point so that the sun appears over the equator and the declination is 0°.

The observer would note, as day followed day, that the sun in travelling along the ecliptic gradually increased its distance North of the equator until it reached Cancer on June 21, this being the position of the sun's maximum North declination, the arc QL is $23\frac{1}{2}°$ N. It would then begin to move towards the equator, slowly at first but gradually gaining speed, and would reach Libra ($\simeq$) on September 23, the point diametrically opposite Aries where the planes of the ecliptic and equinoctial intersect, and the sun's declination would again be 0°. Continuing on its journey the sun would trace out that part of the ecliptic which is South of the equinoctial, and on December 22 it would reach Capricorn, when the maximum South declination is reached, the arc $Q'C$ being $23\frac{1}{2}°$ S.

The sun would then gradually come Northward to the equator again and return to Aries, true to time, on March 21. Thus the ecliptic is the sun's **apparent** path in the heavens during the year, and **Declination** is the measure of his distance North or South of the equinoctial, declination in this sense being similar to geographical Latitude.

Sidereal Hour Angle

In order to locate the exact position of a place on the earth's surface it is necessary to know its Longitude as well as its Latitude. In astronomy, a quantity called **Right Ascension** (R.A.) is used to define the angular distance of a body along the equinoctial Eastward from the **First Point of**

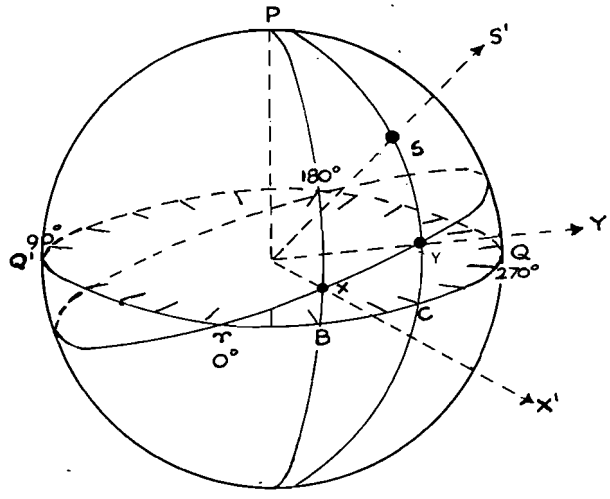


Figure 19.

Aries. Right Ascension is no longer included in the *Nautical Almanac*. Instead, **Sidereal Hour Angle** (S.H.A.), which is the angular distance along the Equinoctial Westwards from the First Point of Aries, is used in the *Nautical Almanac*.

S.H.A. = 24 hrs − R.A. (expressed in time)

S.H.A. = 360° − R.A. (expressed in degrees)

The equinoctial is assumed to be divided into 360° starting with 0° at the First Point of Aries (♈). The Sidereal Hour Angles and Declinations of the stars and planets tabulated in the *Nautical Almanac* define their positions relatively to the First Point of Aries, to the equinoctial and to each other.

Refer now to Fig. 19 and imagine the Sun to be at ♈ on March 21, when its S.H.A. is 0° and its declination 0°, setting out on its annual journey along the ecliptic.

The position X represents the sun a few weeks later and PXB the solar celestial meridian. The arc of the equinoctial ♈ B is its right ascension; and the arc of the meridian BX its declination. The position X is roughly that of the sun on April 22 when the S.H.A. is approximately 330° (arc ♈Q_1B) and Dec. 12° N. (arc BX).

The position of the sun a month later on May 22 is shown at Y, when its S.H.A. is approximately 300° (arc ♈Q_1C) and Dec. 20° N. (arc CY). If S were a star on the same meridian as Y it would have the same S.H.A. (arc ♈Q_1C) but a much higher declination (CS).

The stars are fixed and their Sidereal Hour Angles and declinations remain practically the same from year to year, the slight change recorded being due to the unequal motion of the earth.

It will be realised that points X, Y and S are merely in the direction of the ray projected outwards from the centre of the sphere towards the bodies X', Y' and S', and which are immeasurably distant from each other and from the earth. Two stars may be many millions of miles apart and yet appear to an observer to be close together because they happen to be nearly in his line of vision. Distances on the celestial sphere must therefore be angular distances, as the bodies, unlike places on the earth's surface, are not on the surface of the same sphere.

Again referring to Fig. 19, it might be pointed out that ♈BX is a right-angled spherical triangle in which $\angle B$ is 90°, $\angle X$♈B is 23½°, arc BX the declination of X and arc ♈B the right ascension of X i.e. (360° − S.H.A. X).

Similarly, in the right-angled spherical triangle ΥCY we have $\angle C 90°$, $\angle Y\Upsilon C\ 23\frac{1}{2}°$, the arc CY the declination of Y, and the arc ΥC the right ascension of Y (i.e. 360°—S.H.A. Y). The obliquity of the ecliptic $23\frac{1}{2}°$ is constant and common to both triangles, and the right angle is similarly placed in both, so that if we were given the sun's declination we could calculate its S.H.A. or if given the sun's S.H.A. we could calculate his declination by spherical trigonometry.

The spot on the earth's surface vertically below a celestial body is called the geographical position of the body. An observer, for example, stands on the geographical position of his zenith and his Latitude and Longitude define the position of his zenith relatively to the geographical positions of other points in the heavens. The sub-solar spot is the name given to the point on the earth's surface vertically below the sun; and sub-stellar spot to the point on the earth's surface vertically below a star.

CELESTIAL SPHERE

The conception of nautical astronomy we have to develop is that the observer stationed on the earth looks outward into space and imagines the celestial bodies to be projected on the interior concave surface of a celestial sphere which is geocentric with the terrestrial sphere. Further, at the time of observation the bodies are supposed to be momentarily stationary and are viewed outward from the centre of the earth so that they appear to be projected on the earth's surface as well as on the celestial sphere.

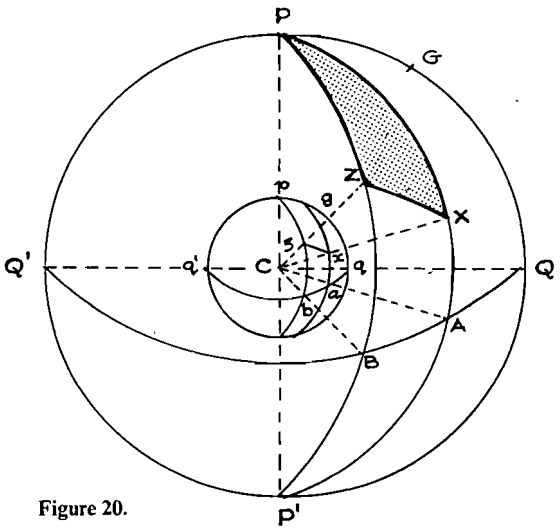


Figure 20.

Figure 20 represents this conception which is fundamental to astro-navigation, and the figure should be closely studied and thoroughly understood, together with the various terms, before proceeding further with the subject.

The celestial and terrestrial spheres are geocentric as shown, CP being the common axis, and C the common centre from which the visual rays are projected.

Meridians and parallels are conceived to be drawn on the celestial sphere just as they are on the earth. P represents the celestial pole; PGQ, PXA, and PZB are celestial meridians, and on the earth, pgq, pxa and pzb are the corresponding terrestrial meridians.

Celestial Equator (Equinoctial)

In Fig. 20 ($Q'Q$) is the plane of the earth's equator extended to the celestial sphere, so that CqQ, CaA, and CbB all lie on the same plane. This is referred to as the Celestial Equator or **Equinoctial.**

The arc QA corresponds to arc qa and both subtend $\angle QCA$
The arc QB corresponds to arc qb and both subtend $\angle QCB$
The arc AB corresponds to arc ab and both subtend $\angle ACB$

with this difference, however, that the celestial arcs can only be expressed in ° ′ ″, whereas the arcs on the earth's surface may also be measured in miles. Suppose, for example, the arc $QA = 30°$, then the arc qa in arcual or sexagesimal measure is 30°, but in lineal measure it is also $30° \times 60' = 1800$ miles.

Assume X to be the position of a celestial body, then x is its **Geographical Position**; that is to say, the body is vertically over position x on the earth's surface both being projected along the line CxX.

Please note in the description which follows that **block** letters represent the apparent positions of celestial bodies, circles and arcs, and that the corresponding *small* letters represent their respective geographical positions which, in the case of bodies, are definite positions on the earth's surface. We would again ask the student to study very closely this figure and the description, as we are trying to establish the basic principles of astro-navigation.

Declination

Declination (AX) of a body is the arc of the celestial meridian contained between the equinoctial and the body. The declination of X is the arc AX, and this corresponds to the arc ax on the earth as both arcs subtend the same angle ACX, so that declination of X = arc AX = arc ax.

Polar Distance

Polar Distance (PX) is the arc of a celestial meridian between the body and the elevated pole. PX represents the polar distance of X, and this arc corresponds to px on the earth as both arcs subtend the same angle PCX, so that the polar distance of X = arc PX = arc px.

The elevated pole is the one above the horizon. The North Pole is the elevated one for an observer in North Latitude; and the South Pole, being below the horizon, would be his depressed pole.

Zenith

The Zenith is the point vertically above the observer. Suppose z in the figure to be the position of an observer on the earth's surface, then cz produced would project the point Z on the celestial sphere. But bz represents the Latitude of z on the earth and this arc corresponds to the arc BZ on the celestial sphere as both subtend the same angle BCZ at the centre of the earth, so that Latitude z = arc bz = arc BZ.

Similarly, arc pz is equal to the celestial arc PZ as both subtend the same angle PCZ; this is the co-Latitude of z and is equal to 90° − Latitude = arc pz = arc PZ.

Again, if ZX be the arc of the celestial great circle joining points Z and X, then the arc zx is the terrestrial great circle joining the corresponding points on the earth's surface. The arcs ZX and zx are both equal to angle ZCX, the arc ZX measures the angular distance of the body X from the zenith, and the arc zx measures not only the angular distance between x and the observer, but also the great circle distance in miles between them.

We now begin to see that the three sides of the celestial spherical triangle PZX are projected downward on the earth's surface and form the three sides of the terrestrial spherical triangle pzx. It is known as the pole-zenith-star triangle, the three sides of which are found as follows:—

Side PZ = pz = co-Latitude = (90° − Lat.). Found from the ship's D.R. or E.P.

Side $PX = px$ = Polar Distance = (90° − Dec.). Found from the *Nautical Almanac.*
Side $ZX = zx$ = Zenith Distance = (90° − Alt.). Found by sextant observation.
Zenith Distance (ZX) is the angular distance of the body from the zenith.

True Altitude

True Altitude is the angular height of the centre of the body above the observer's rational horizon. This arc, in the first instance, is measured with a sextant and the altitude so obtained is reduced to what it would be if the body were observed from the centre of the earth instead of from the surface.

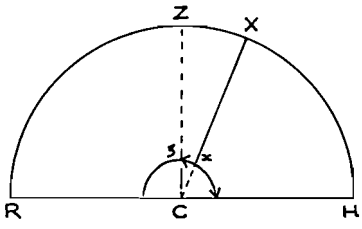


Figure 21.

In Fig. 21, RCH represents the plane of the rational horizon passing through the centre of the earth at C; z is the observer, Z his zenith and X is a celestial body.

The arc HX or angle HCX is the true altitude of X, ZX is the zenith distance, that is $(ZH - HX) = (90° - \text{alt.})$, and the arc ZX corresponds to the arc zx on the earth's surface or angle ZCX at the centre of the earth.

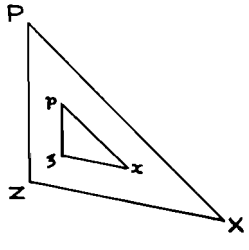


Figure 22.

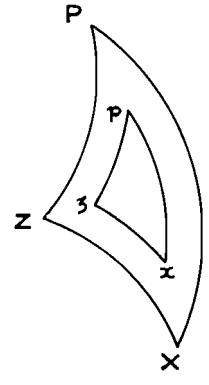


Figure 23.

In Figs. 22 and 23 we show two plane triangles and two spherical triangles similar to each other in which the angles P, Z and X of the outer triangle are respectively equal to p, z and x of the inner triangle, but in the plane triangles the corresponding sides are not equal to each other. In the spherical triangles, however, the arcual measures of the respective sides are equal and these values may be transferred from one triangle to the other, thus arc PZ = arc pz, arc ZX = arc zx, arc PX = arc px, not in length but they are equal to the same number of degrees, minutes, and seconds of arc.

Local Hour Angle (L.H.A.)

The angle P is perhaps the most important of the three angles in the PZX triangle on our general Fig. 20. It represents the Hour Angle of the body X.

Local Hour Angle of a body is the angle at the pole contained between the meridian of the

observer (PZ) and the meridian of the body (PX), that is the angle ZPX, which is the same angular measure as the arc AB.

$$\text{L.H.A. } X = \angle ZPX = \text{arc } AB.$$

Greenwich Hour Angle (G.H.A.)

Imagine pgq to be the meridian passing through Greenwich from which Longitude is measured, g being the observatory and G its counterpoint on the celestial meridian PGQ. Then the arc QA is the angular distance of the body X Westward from Greenwich, or, simply its G.H.A. If X were the **sun**, then QA would be the hour angle of the true sun West from Greenwich, written as G.H.A. Sun. But the arc of the equator qa is equal to the arc of the equinoctial QA, so that the G.H.A. Sun defines the Longitude of the sun's geographical meridian pxa.

Observer's Longitude

Similarly, the celestial arc QB is the angular distance of Z, the zenith, Westward from Greenwich, and QB is equal to the corresponding arc of the earth's equator qb, which, obviously, measures the Longitude of the observer, so that from Fig. 20 and in this particular case:

$$\text{Long. Observer} = \text{G.H.A. Zenith, i.e. arc } qb = \text{arc } QB.$$

On the earth's surface:	arc qb	$=$ arc $qa +$ arc ab.
On the celestial sphere:	arc QB	$=$ arc $QA +$ arc AB.
Expressed in navigational terms:	Obs. Long.	$=$ G.H.A. Sun $+$ L.H.A. Sun.
More generally:	Obs. Long.	$=$ G.H.A. body $\sim$ L.H.A. body.

The geographical position of the body X is x, and we have attempted to show that the geographical position of a body may be expressed in terms of its Declination (AX) and its Greenwich Hour Angle (QA), in much the same way as we would define the position of x in terms of its Latitude (ax) and its Longitude (qa). We have also attempted to show the relationship between the longitude of the observer and the G.H.A. and L.H.A. of the observed body.

Summary

We would again impress the student with the importance of mastering the names and the connection between the arcs and angles of the celestial sphere and their counter parts on the earth's surface, as their interchangeability forms the basis of astro-navigation. Draw Figure 20 several times and go through the description until fully understood.

When taking sights the observer measures the altitude of the body above the horizon with his sextant. Position is then found by correcting the sextant altitude and solving the Pole-Zenith-Star (PZX) Triangle.

Questions

1. Name the four planets used in navigation in the order of their brightness. What are the differences between a planet and a star?
2. What is an orbit? And what determines the length of the year of a planet?
3. How are the phases of the moon caused? And what is meant by a lunation?
4. Explain the terms "conjunction," "opposition," "quadrature." How often do they occur and what period of time separates them?
5. What is meant by "universal" gravitation?
6. What are the positions of the sun, earth and moon relatively to each other on the occasion of (*a*) an eclipse of the moon, (*b*) an eclipse of the sun?
7. Why is an eclipse of the sun visible only from some parts of the earth?
8. Explain the terms "Ecliptic," "Cancer," "Capricorn," "Libra," "Aries."
9. Explain why the sun appears to move North and South of the equator.
10. What is the cause of the astronomical seasons?
11. When is the earth said to be in aphelion and perihelion, and how is the sun's visible diameter affected at these epochs?
12. Name the dates of the summer and winter solstices and also of the equinoxes.
13. Distinguish between the real and the apparent motions of a body.
14. What is the cause of unequal day and night? Under what conditions will the sun not rise above the horizon?
15. Define the terms (*a*) Equinoctial, (*b*) Obliquity of the Ecliptic, (*c*) Sidereal Hour Angle, (*d*) Declination, (*e*) Hour angle, (*f*) Azimuth.
16. What is meant by the geographical position of a celestial body; and how is this position defined?
17. What do we conceive the celestial sphere to be? What imaginary circles are drawn upon it?
18. Is there any difference in our conceptions of measuring the length of an arc on the celestial sphere and its corresponding arc on the earth's surface?
19. What is (*a*) the sub-solar spot, (*b*) a sub-stellar spot?
20. Define (*a*) Zenith Distance, (*b*) Polar Distance.
21. Draw a figure to show that the hour angle of his zenith West of Greenwich is equal to the Longitude of the observer.
22. Draw a figure and show that the G.H.A. Sun is equal to the Longitude of the sub-solar spot.
23. Given Longitude of observer 75°W., G.H.A. Sun 30°. Draw a figure and show that the difference of Longitude between the zenith and the sun is 45°.
24. Name sides of the Pole-Zenith-Star triangle and state how the value of each may be derived.
25. Which are the more important of the three angles in the *PZX* triangle of nautical astronomy?

Chapter 19

Altitude Correction

Having taken an observation, the navigator must correct and modify the altitude, as read from the sextant, so as to put it into a form suitable for calculation.

In practical navigation the process is usually carried out with the aid of the *Nautical Almanac*, and falls into three stages:

1. **Instrumental Corrections** for Index Error and possibly Centring Error. Corrections for Centring Error (if present) are listed on the Sextant Certificate inside the Sextant Box.
2. **Dip** correction to allow for the observer's height of eye (H.E.) above sea level.
3. **Total Correction** which gives, in a compact form, the allowance for Refraction, Parallax and, where applicable, the Semi-Diameter of the body.

There may also be a small additional correction in respect of the nearer planets.

It will be noted that the Total Corrections are larger and more complicated for those bodies which are nearer to the earth. For DTp examination purposes a thorough knowledge of all individual altitude corrections is required and students attempting the Class 3 "Principles of Navigation" paper are required to demonstrate ability in their use. The use of total corrections is permitted in other DTp practical navigation examination papers. Both individual and total corrections are explained in this chapter.

More advanced students, or those requiring only a knowledge of *Nautical Almanac* total correction tables, may find it convenient to proceed directly to the summary (at the end of this chapter) before attempting the exercise papers.

Definitions

The effects of Dip and Parallax may be conveniently shown on an elevation of the celestial sphere. They are illustrated in Figure 1.

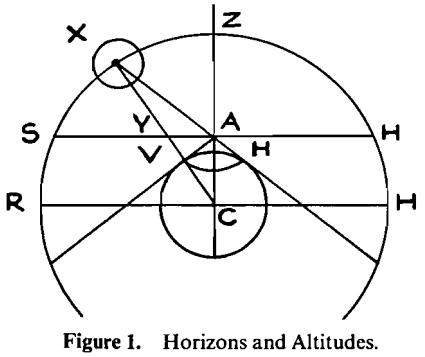


Figure 1. Horizons and Altitudes.

C	Centre of the earth.
A	Observer.
Z	Zenith.
X	Sun.
VH	Visible Horizon.
SAH	Sensible Horizon.
RCH	Rational Horizon.
SAV	Dip.
XAV	Observed altitude.
XAS	Apparent altitude.
XCR	True altitude.
AXC	Parallax.

In Figure 1, *C* represents the centre of the earth, *A* an observer, *Z* the zenith, *X* the body.

Visible Horizon (*VH* in Figure 1)

The circle bounding the observer's view at sea. *VH* is the boundary of the Sea Horizon as seen from *A*.

Sensible Horizon (*SAH*)

The circle whose plane passes through the observer at right angles to the vertical. *CAZ* is the vertical, *SAH* is the plane of the sensible horizon.

Rational Horizon (*RCH*)

The circle whose plane passes through the centre of the earth parallel to the sensible horizon. *RCH* is the plane of the rational horizon.

Dip ($\angle SAV$)

The angular depression of the visible horizon below the sensible horizon. *AV* is the direction of the sea horizon; *AS* the plane of the sensible horizon. $\angle SAV$ is the dip. The higher the observer's eye the bigger will be the angle of dip. Values of dip for heights of eye up to 48 metres are given in the *Nautical Almanac*.

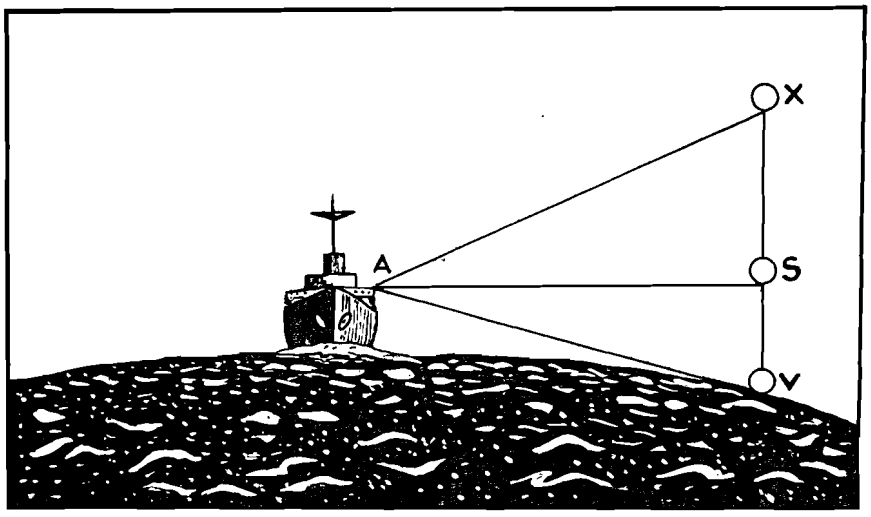


Figure 2.

Figure 2, gives a diagrammatic idea of dip. The navigator on the ship's bridge brings the body down to the line of the sea horizon at *V*, and obtains $\angle XAV$ with the sextant. The navigator should really measure angle *XAS*, its angular height above the Sensible Horizon *AS*; but angle *SAV* is the Dip and this is subtracted from angle *XAV* to obtain angle *XAS* indirectly. Now refer back to Figure 1.

It is obvious that if the horizons were viewed from an elevated position they would appear as circles. The sea horizon would be circular just as it is seen by an aviator high up; it is the only horizon which can be seen. The sensible and rational horizons are purely imaginary and are introduced to facilitate the steps in the correction of altitudes. The centre of the earth is selected

as the common point of reference to which observed altitudes must be reduced before the "sight" can be worked out.

Sextant Altitude

The angular height of an object above the Visible Horizon as read from the arc of a sextant.

Observed Altitude

The sextant altitude corrected for index error, if any.

Apparent Altitude

The apparent angular height of an object's centre above the sensible horizon. SAH is the sensible horizon. $\angle XAS$ is the apparent altitude of X.

True Altitude

The true angular height of an object's centre above the rational horizon. RCH is the rational horizon. $\angle XCR$ is the true altitude of X.

Zenith Distance

The angular distance of a body from the zenith of the observer. It is (90° − true altitude). $\angle ZCX$ is the true zenith distance of X.

Parallax in Altitude

Parallax in Altitude is caused by observing a body from the surface instead of from the centre of the earth. It is the angle at a body between a line drawn to observer and another to the centre of the earth. In Figure 1, A is the observer; C the centre of the earth; X the body. $\angle AXC$ is the parallax of X.

True Altitude $= \angle XCR = \angle XYS = \angle XAS + \angle AXC =$ **Apparent Altitude + Parallax**

Parallax increases with the nearness of the body to the earth.

Sun

The sun has a small parallax which never exceeds 0·2′ of arc.

Planets

The planets have each a very small parallax which varies slightly as their distances from the earth change during the year.

Stars

The stars have no parallax in altitude as they are so far away that the radius of the earth does not subtend an angle at such a great distance. If the earth were visible from any of the stars it could be nothing more than a tiny point.

Moon

The moon is the nearest celestial body and has the biggest parallax.

Horizontal Parallax—Moon

Horizontal Parallax of the moon is the parallax when the altitude is 0°. This quantity varies from 54′ to 61·5′ and is given in the *Nautical Almanac.*

Parallax in Altitude—Moon

Parallax in Altitude of the moon is the parallax corresponding to its altitude at the time of observation. It is equal to the horizontal parallax × cosine altitude.

In Figure 3, *E* represents the centre of the earth, *Z* an observer, *ZM* the sensible horizon, *M* the centre of the moon on the sensible horizon, *X* the centre of the moon with altitude *XZM*.

From the observer's position at *Z* the moon at *M* would appear to be at *D*, but from *E* it would appear to be at *C*, therefore angle *CMD* or *ZME* is the parallax when the moon is 90° from the observer's zenith. Angle *ZME*, therefore represents the horizontal parallax.

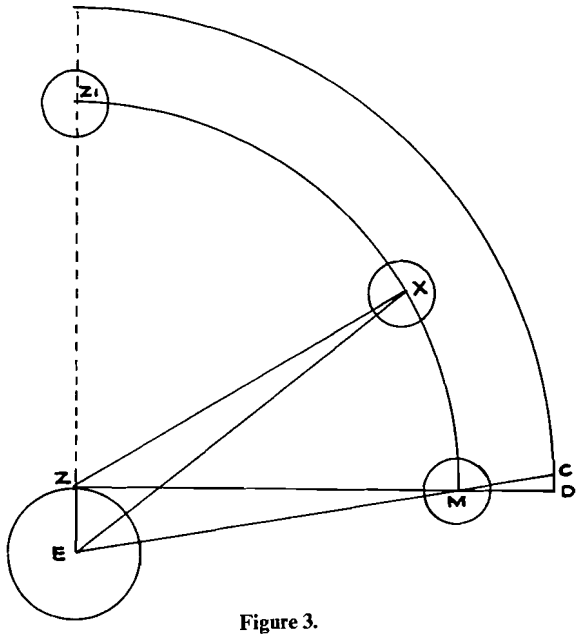


Figure 3.

Similarly, angle *ZXE* is the parallax for apparent altitude *XZM*; *i.e.*, parallax in altitude.

As the altitude increases so the parallax decreases until the moon reaches *Z'* with an altitude of 90°, when the parallax is zero.

Semi-Diameter

Semi-diameter is half the angular diameter of a body as viewed from the earth.

The altitude of a body's **centre** above the rational horizon is the quantity required in astro-navigation. We cannot locate the exact centre of the sun or moon, so the altitude of the edge nearest the horizon is measured and the semi-diameter as given in the *Nautical Almanac* is added to the altitude observed with the sextant.

In Figure 4, *C* is the centre of the earth; *X* the centre of the body; *B* its lower limb. $\angle XCB$ is the semi-diameter.

Augmentation of the Moon's Semi-Diameter

Augmentation of the moon's semi-diameter is a small correction given in Nautical Tables. It is due to the close proximity of the moon to the earth so that when it rises in altitude its distance from the observer is considerably less, and the diameter is visibly increased.

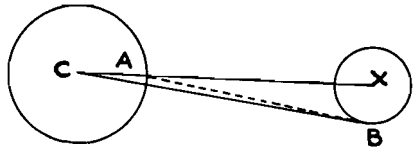


Figure 4.

In Figure 4, if A is an observer, and X the moon, then the moon would be in the observer's zenith, C is the centre of the earth and $\angle XCB$ is the semi-diameter given in the *Nautical Almanac*. But $\angle XAB$ is the semi-diameter measured from the position of the observer on the surface of the earth. The angle at A is bigger than the angle at C, so that $(\angle A - \angle C)$ is the augmentation to apply to the *Nautical Almanac* semi-diameter. It is a small correction and varies from zero when the altitude is 0° to 0·3′ when the altitude is 90° and the semi-diameter 17′.

Refraction

Refraction is the angle through which a ray of light is deflected in passing through the atmosphere to the eye of the observer.

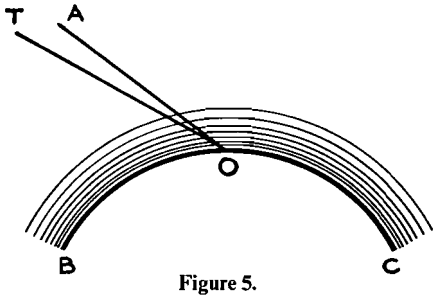


Figure 5.

The arc BC represents a portion of the earth's surface, the shading being the surrounding atmosphere.

O represents the observer's eye, T the true position of an object, A the apparent position, the angle AOT is the refraction.

Refraction makes an object appear higher than it really is, and the angle increases with a fall in the temperature of the air.

Correction Tables

In the *Nautical Almanac*, refraction is assumed to be for standard meteorological conditions of 10° C. and 1010 mb. When conditions vary greatly from these values reference should be made to the A4 Additional Correction Tables contained in the *Nautical Almanac*.

As the *Nautical Almanac* gives only Total Correction tables, it is necessary to refer to Nautical Tables when individual corrections are required. Amongst those given is one entitled "Reduction of the Moon's Horizontal Parallax". Referring to Figure 3 it will be seen that the HP is affected by the earth's radius, ZE. Due to the oblate shape of the earth, its radius decreases in higher latitudes, hence this small reduction.

THE SUN

Individual Corrections

The corrections to be applied to an observed altitude of the sun are:—Index Error, (if any); Dip for the Observer's Height at eye; refraction due to the atmosphere; parallax due to the altitude being observed from the surface instead of the centre of the earth; semi-diameter because the limb of the sun is observed instead of the centre, all as indicated in Example 1.

Example 1

On June 19 the Sextant Altitude of the Sun's lower limb was 41° 58·0′; Index Error 3′ on the arc. Height of Eye 12 m. Find the true altitude and zenith distance.

Sext. alt.		41° 58·0′	
I.E.	(−)	3·0	given, Negative **ON** the arc. Positive **OFF** the arc.
Obs. alt.		41 55·0	
Dip	(−)	6·1	Naut. Tables. Always **negative.**
App. alt.		41 48·9	
Ref.	(−)	1·1	Naut. Tables. Always **negative.**
		41 47·8	
Plx.	(+)	0·1	Naut. Tables. Always **positive**
		41 47·9	
Semi-diam.	(+)	15·8	Almanac **positive** L.L. **negative** U.L.
True alt.		42 03·7	
		90 00·0	
True Zen. Dist.		47 56·3	

Sun's Total Correction Tables (Norie's)

The sun's total correction is the algebraic sum of dip, refraction, parallax and semi-diameter. It is given in Nautical Tables. The Table is entered with the altitude and height of eye.

Note: Total Corrections used are taken from **Norie's Nautical Tables Revised Edition 1983** and **may differ** from corrections listed in earlier editions or corrections taken from other tables.

Example 2

Find the Sun's true altitude using data given in Example 1 and the Sun's Total Correction Tables contained in *Norie's Nautical Tables* (1983 Edition or later).

Sext. alt.		41° 58·0′	
I.E.	(−)	3·0	
Obs. alt.		41 55·0	
Total Corr. (H.E. 12 m)	(+)	9·0	From Norie's Nautical Tables (1983)
		42 04·0	
Add. Monthly Corr.	(−)	0·2	From Norie's Nautical Tables (1983)
True alt.		42 03·8	

Note: The additional monthly correction (given at the bottom of the tables) is required to allow for the slow change in the sun's semi-diameter during the year.

Nautical Almanac Corrections—Sun

The *Nautical Almanac* contains altitude correction tables which are shown at the beginning of this book. After the index error (if any) and dip have been applied, the appropriate Almanac tables are entered for Sun, Stars, Planets or Moon.

Example 3

Find the Sun's True Altitude using data given in Example 1 and the *Nautical Almanac* A2 Altitude Correction Tables contained at the front of this book.

Compare your answer with that obtained in Examples 1 and 2.

Sext. alt.		41° 58·0′	
I.E.	(−)	3·0	
Obs. alt.		41 55·0	
Dip	(−)	6·1	(Dip table).
App. alt.		41 48·9	
Main Corr.	(+)	14·9	(Lower Limb April-Sept. table).
True alt.		42 03·8	

Answer True Altitude 42° 03·8′ Almanac Corrections.
42 03·8 Norie's Total Corrections.
42 03·7 Individual Corrections.

Exercise 1 (Sun)

	Limb	Sext. alt.	I.E.	H.E.	Date
1.	L.L.	36° 23·5′	Nil	6 m	7 January
2.	L.L.	17° 44·2′	2·5′ Off the arc	8·7 m	21 June
3.	U.L.	56° 27·5′	4·0′ On the arc	18·5 m	12 October
4.	U.L.	17° 16·5′	2·0′ Off the arc	18 m	20 June

Answers: 1. 36° 34·1′ 2. 17° 54·5′ 3. 55° 59·2′ 4. 16° 52·1′

STARS AND PLANETS

The altitudes of stars and planets have to be corrected for Index Error, if any, dip and refraction. The additional corrections given in the *Nautical Almanac* altitude correction tables for Venus and Mars are due to the effects of parallax and phase. They should be ignored for daylight observations of Venus.

Example 4

The observed altitude of Arcturus was 25° 01′. Index Error, nil. H.E. 8 m. Find the true altitude and zenith distance.

Obs. alt.		25° 01·0′	
Dip	(−)	5·0	(Almanac)
App. alt.		24 56·0	
Corr.	(−)	2·1	(Almanac)
True alt.		24 53·9	
		90 00·0	
True zen. dist.		65 06·1	

Example 5

Find the True Altitude and Zenith Distance of Arcturus using data provided in Example 4 and individual corrections taken from *Norie's Nautical Tables.* Compare your results with Example 4.

Obs. alt.		25° 01·0′	
Dip	(−)	5·0	(Norie's Nautical Tables.)
App. alt.		24 56·0	
Ref.	(−)	2·0	(Norie's Nautical Tables.)
True alt.		24 54·0	
		90 00·0	
True Zen. Dist.		65 06·0	

Answer True Altitude 24° 54·0′ Individual Corrections.
24 53·9 Almanac Corrections.

Example 6

January 8, after sunset the sextant altitude of Venus was 28° 14·5′. Index Error 1·5′ off the arc; H.E. 6 m. Find the true altitude using *Nautical Almanac* Correction Tables.

Sext. alt.		28° 14·5′	
I.E.	(+)	1·5	
Obs. alt.		28 16·0	
Dip	(−)	4·3	(Almanac).
App. alt.		28 11·7	
Main Corr.	(−)	1·8	(Almanac).
		28 09·9	
Add. Corr.	(+)	0·7	(Almanac).
True alt.		28 10·6	

Note: The additional correction would be ignored if the observation had been taken during daylight hours.

Exercise 2 Stars and Planets

Find the True Altitudes from the following information:

			Sext. alt.	I.E.	H.E.	Date
1.	Star,	Castor	48° 40′	3·0′ On the arc	6·6 m	
2.	„	Polaris	28° 04′	Nil	8 m	
3.	„	Procyon	66° 07·2′	1·6′ Off the arc	11 m	
4.	„	Sirius	15° 24·6′	2·2′ On the arc	12 m	
5.	Planet,	Jupiter	82° 41′	1·0′ On the arc	13 m	
6.	„	Venus	46° 43·8′	3·0′ Off the arc	9·8 m	10 May
7.	„	Mars	26° 31·1′	2·5′ On the arc	14·2 m	12 Dec.
8.	„	Saturn	54° 37·8′	Nil	7 m	

Answers: 1. 48° 31·6′ 2. 27° 57·2′ 3. 66° 02·6′ 4. 15° 12·8′
5. 82° 33·6′ 6. 46° 40·6′ 7. 26° 20·3′ 8. 54° 32·4′

THE MOON

Individual Corrections

The observed altitude of the moon is subject to the same corrections as the sun, namely, dip, refraction, semi-diameter and parallax in altitude with this difference, however, that the GMT of the observation must be known if we wish to lift the semi-diameter and the horizontal parallax to the nearest decimal of a minute from the *Nautical Almanac*. The approximate latitude must also be known in order to enter Nautical Tables which give a small correction called "Reduction" to subtract from the moon's horizontal parallax and which is due to the earth's polar radius and the equatorial radius not being equal. The horizontal parallax is then converted into the parallax of the moon corresponding to its altitude at the time of observation.

Correcting for the Moon's Semi-Diameter

Copy down the semi-diameter for the day of GMT from the foot of the Moon column in the daily pages of the *Nautical Almanac*. (It is marked S.D. and given for each of the three days in order at 1200 hours GMT. The difference between semi-diameters for the day of GMT and the following day is the "variation in 1 day". It is always very small, not more than 0·2′ per day and the correction is obtained by inspection to be added if the semi-diameter is increasing or subtracted if decreasing. A correction called the "Augmentation of the Moon's Semi-Diameter", is given in the Nautical Tables and must always be added.

Correcting for the Moon's Horizontal Parallax

The Horizontal Parallax is given in the Moon column of the *Nautical Almanac* marked H.P. and is copied down for the time nearest the GMT of observation. A correction called the "Reduction of the Moon's Horizontal Parallax" which depends on the Latitude must then be subtracted. This correction is given in Nautical Tables.

The log cosine of the apparent altitude (after applying semi-diameter) added to the common log of the horizontal parallax (in minutes) gives the common log of the parallax in altitude, i.e.

Parallax in Altitude = Horizontal Parallax × cosine Apparent Altitude.

Individual Corrections—Moon (Lower Limb)

Example 7

On January 8, at 1430 GMT in Lat. 48° 30′ S the observed altitude of the moon's lower limb was 38° 50′. H.E. 12 m Find the true altitude using individual corrections.

Obs. alt.		38° 50·0′	Semi-diam.		16·3′
Dip	(−)	6·1	Augmentation	(+)	0·2
App. alt.		38 43·9	S.D.		16·5
Semi-diam	(+)	16·5			
		39 00·4	Hor. Plx.		59·8
Refraction	(−)	1·2	Reduction	(−)	0·1
		38 59·2	H.P.		59·7
Plx. in alt.	(+)	46·4			
True alt.		39 45·6			

Plx. in alt. = H.P. × cos. app. alt.

H.P.	59·7′	log	1·77597
App. alt.	39° 00′	log cos	9·89050
Plx. in alt.	46·4	log	1·66647

Nautical Almanac Corrections—Moon (Lower Limb)

The altitude correction tables for the moon given in the *Nautical Almanac* are used in practice at sea. The correction for dip of the sea horizon is found in the Dip Table using the Height of Eye (H.E.) which, when applied to the observed altitude, gives the Apparent Altitude. The main correction depends on the apparent altitude and is found in the column of degrees abreast of the minutes of apparent altitude. The second correction depends on the Horizontal Parallax and on whether the Upper or the Lower Limb of the moon is observed. The correction is found in the same column as the main correction under L for Lower or U for Upper limb and abreast H.P., the horizontal parallax. The main and second corrections are always added but 30′ must be subtracted from the altitude when the upper limb is observed.

Example 8

Find the Moon's True Altitude using data contained in Example 7 and the *Nautical Almanac* Altitude Correction Tables—Moon, contained in this book.

Obs. alt. moon's L.L.		38° 50·0′
Dip (12 m)	(−)	6·1
App. alt.		38 43·9
Main correction (app. alt.)	(+)	54·5
L.L. Corr. (H.P. 59·8′)	(+)	7·2
True altitude		39 45·6

Individual Corrections—Moon (Upper Limb)

Example 9

On June 15, at 1020 GMT in D.R. Lat. 48° N., the sextant altitude of the moon's Upper Limb was 59° 18′. I.E. 1·0′ off the arc. H.E. 13·5 m. Find the true altitude.

Sext. alt.		59° 18·0′	Semi-diam.		15·1
I.E.	(+)	1·0	Augmentation	(+)	0·2
Obs. alt.		59 19·0	S.D.		15·3
Dip	(−)	6·5			
App. alt.		59 12·5	Hor. Plx.		55·4
Semi-diam. (U.L.)	(−)	15·3	Reduction	(−)	0·1
		58 57·2	H.P.		55·3
Refraction	(−)	0·5			
		58 56·7	Plx. in alt. = H.P. × cos. app. alt.		
Plx. in alt.	(+)	28·5	H.P. 55·3 log		1·74273
True alt.		59 25·2	App. alt. 58° 57′ log cos		9·71247
			Plx. in alt. 28·5 log		1·45520

Nautical Almanac Corrections—Moon (Upper Limb)

Having applied the corrections for Index Error and Dip in the usual way, the main correction and Upper Limb correction are always added but 30′ are then subtracted because the Upper Limb has been used.

This method, which avoids the need for Negative Upper Limb corrections, is demonstrated in Example 10.

Example 10

Find the True Altitude of the Moon using data provided in Example 9 and the *Nautical Almanac* Altitude Correction Tables—Moon, contained in this book. Compare your results with Example 9.

Sext. alt.		59° 18·0′
I.E.	(+)	1·0
Obs. alt.		59 19·0
Dip	(−)	6·5
App. alt.		59 12·5
Main Corr.	(+)	39·6
U.L. Corr. (H.P. 55·3)	(+)	2·9
		59 55·0
Subtract 30′ for U.L.	(−)	30
True alt.		59 25·0

Answer True Alt. Moon 59° 25′ Almanac Corrections.
59° 25·2′ Individual Corrections.

Exercise 3 (Moon)

Find the Moon's true altitude from the following information.

	Limb	Sext. Alt.	Obs. alt.	I.E.	H.E.	Date	GMT	D.R. Lat.
1.	L.L.	—	34° 56′	—	10·5 m	Jan 12	0712	48° 20′ N.
2.	U.L.	27° 04′	—	1·5′ ON	11·0 m	June 21	1218	38 36 S.
3.	U.L.	33 06	—	2·0 OFF	8·0 m	Sept. 20	1802	38 30 N.
4.	L.L.	31 47	—	2·5 ON	11·5 m	Dec. 23	0815	41 20 S.

Answers: True altitudes 1. 35° 53·5′ 2. 27° 30·9′ 3. 33° 34·1′ 4. 32° 38·2′.

Examples

The student is advised to work the examples in this chapter by means of the *Nautical Almanac* and, where appropriate, also by individual corrections from *Norie's Nautical Tables.*

USE OF NAUTICAL ALMANAC CORRECTION TABLES—SUMMARY

The *Nautical Almanac* contains the following Altitude Correction Tables:

	Altitude Correction Tables			0°–35° & 35°–90° Moon.
A2	,,	,,	,,	10°–90° Sun, Stars & Planets.
A3	,,	,,	,,	0°–10° Sun, Stars & Planets.
A4	,,	,,	,,	Additional Refraction Corrections (for Non-Standard Conditions).

The use of these tables is summarised as follows:

1. Correction must first be made for sextant Index Error, if present.
   An Index Error On the Arc indicates that the true zero of the sextant lies to the left of the engraved zero and must be subtracted. Index Errors off the arc are added.

	I.E. 2′ On the arc		3′ Off the arc	
Sextant altitude ⊙		37° 32′		37° 32′
I.E.	(−)	2	(+)	3
Observed altitude ⊙		37 30		37 35

2. Correction for Dip using height of eye, is always negative.

Sext. alt. ⊙		37° 32′
I.E. 2′ on	(−)	2
Obs. alt.		37 30
H.E. 6·6 m	(−)	4·5
App. alt. ⊙		37 25·5

Use upper value for a critical entry. See *Nautical Almanac* page 259 para. 14.

3. The Main Correction is for Refraction, Semi-Diameter and Parallax (as appropriate) under standard conditions of 1010 mb at 10° C.

Arguments: Apparent altitude (found at side of Altitude Correction Tables)
Month (found at top of Altitude Correction Tables
Upper or Lower Limb)

Additional phase and parallax corrections are applied to twilight observations of Venus and to Mars.

Sun

		October Lower Limb		June Upper Limb
App. alt. $\underline{\odot}$		37° 25·5′	$\overline{\odot}$	37° 25·5′
Main Corr. L.L.	(+)	15·0	U.L. (−)	17·1
True alt.		37 40·5		37° 08·4

Star

App. alt.		37° 25·5′
Main Corr.	(−)	1·3
True alt.		37 24·2

No SD and Negative Parallax

Planet Venus

		May 10
App. alt.		37° 25·5′
Main Corr.	(−)	1·3
		37 24·2
Add. Corr.	(+)	0·2
True alt.		37 24·4

4. *Nautical Almanac* Altitude Corrections are quoted for standard conditions of 1010 mb at 10° C. Additional *Nautical Almanac* corrections should be made when taking observations under non-standard conditions of temperature and pressure.

The A4 Additional Correction Table extends from −30° C. to +45° C. and from 970 mb to 1050 mb for a range of altitudes 0–50°. In practice these tables are seldom used but the additional refraction corrections become increasingly more important as the altitude decreases. The table should always be consulted when altitudes fall below, say, 20°.

Example 11

Find the True Altitudes of the following bodies under the non-standard conditions stated on 12th January.

(a) Sun L.L. Sext. alt. 21° 19′
(b) Sun U.L. Sext alt. 3° 20′
(c) Venus Sext. alt. 4° 32′ (twilight)
(d) Polaris Sext. alt. 49° 36′

12th January — H.E. 16 m, I.E. 1′ on the arc — Temperature (−) 5° C., Pressure 980 mb

		Sun L.L.		Sun U.L.		Venus		Polaris
Sext. alt.		21° 19·0′		3° 20·0′		4° 32·0′		49° 36·0′
I.E.	(−)	1·0		1·0		1·0		1·0
Obs. alt.		21 18·0		3 19·0		4 31·0		49 35·0
Dip[1]	(−)	7·0		7·0		7·0		7·0
App. alt.		21 11·0		3 12·0		4 24·0		49 28·0
Main corr[2]	(+)	13·8	(−)	31·0	(−)	10·9	(−)	0·8
		21 24·8		2 41·0		4 13·1		49 27·2
Add. corr.[3] (Planets)		—		—	(+)	0·7		—
		21 24·8		2 41·0		4 13·8		49 27·2
Add. corr.[4] for Refraction	(−)	0·1	(−)	0·7	(−)	0·5		0·0
True alt.		21 24·7		2 40·3		4 13·3		49 27·2

Note:

1. Critical Entry. At critical entry 16 m take the upper of the two possible values i.e. select 7·0′ not 7·1′.
2. Altitude under 10°—use Altitude Correction Table A3.
3. Venus—additional correction applied for twilight observations only, i.e. do not apply for daylight observations.
4. Altitude Correction Table A4 is fully explained in the *Nautical Almanac*. When using this table use a parallel ruler to accurately plot the pressure and temperature co-ordinates—in this example they meet in Column E.

5. Main and Additional Corrections for the Moon.

The main correction is in two parts. The first correction is taken from the upper part of the Table with Argument Apparent Altitude. The second correction from the lower part of the Table using Argument Horizontal Parallax (H.P.) which must first be found from the Almanac's daily pages.

Additional corrections for non standard conditions are taken from the A4 Table.

Example 12

Find the True Altitude of the Moon for the non standard conditions stated on 12th January.

(a) Sext. alt. LL 33° 29′ (b) Sext. alt. UL 26° 08′

12th January 1000 GMT — H.E. 20 m, I.E. 2′ off the arc — Temperature 35° C., Pressure 1030 mb

From Daily Pages: 1000 GMT on 12 January gives Moons H.P. = 59·1′

		Moon L.L.		Moon U.L.
Sext. alt.		33° 29·0′		26° 08·0′
I.E.	(+)	2·0		2·0
Obs. alt.		33 31·0		26 10·0
Dip[1]	(−)	7·9		7·9
App. alt.		33 23·1		26 02·1
Main Corr.	(+)	57·4		60·5
		34 20·5		27 02·6
L.L. Corr. (H.P. 59·1′)	(+)	6·6	U.L.	4·5
		34 27·1		27 07·1
Subtract 30′ For U.L.	(−)	—		30·0
		34 27·1		26 37·1
Add. Corr.[2] for Refraction	(+)	0·1		0·2
True alt.		34 27·2		26 37·3

Note: 1. Non-Critical Entry. Only one value for H.E. 20 m.

2. The Additional Correction for Refraction changes from Negative to Positive at temperatures above 15° C.

In this case the correction is small but refer to the A4 Table and note how the correction steadily increases as the apparent altitude decreases.

Again note that when using the A4 Table it is advisable to use a parallel ruler to accurately plot the pressure and temperature co-ordinates—in this example they intersect in Column K.

Exercises

Exercises are included on preceding pages 555, 557 and 560.

Nautical Almanac Extracts, which are required for working examples and exercises, are included on Page 880.

Note carefully that, 1976 *Nautical Almanac* Extracts are included for use when working D.Tp. Specimen Examination Papers **only** and **must not** be used for the examples and exercises.

Chapter 20

The Measurement of Time and Hour Angle

THE DAY

The Day may be defined as the interval of time between successive passages of the Sun across the observer's Lower Meridian. The lower meridian is used because it is more convenient for the date to change at midnight, rather than at noon as would be the case if the upper meridian were used.

Due to the inclination of the earth's axis and its varying orbital speed, it is found that the length of the natural day varies by a few minutes during the course of the year. As in other branches of astro-navigation, it is convenient to consider the situation in terms of Relative Motion, with the Apparent Sun moving round a stationary earth.

Mean Time

The Apparent Sun moves at a speed, varying according to Kepler's Laws, along the Ecliptic which is inclined at an angle of $23\frac{1}{2}°$ to the Equinoctial. Two adjustments are therefore necessary to establish a regular timekeeper:

1. An imaginary body, the Dynamical Mean Sun, is assumed to move along the Ecliptic at the average angular speed of the Apparent Sun. The two coincide at Perigee, which occurs in early January.
2. The Astronomical Mean Sun, usually referred to as the Mean Sun, is assumed to move along the Equinoctial at the same speed as the Dynamical Mean Sun. The two coincide at the First Point of Aries.

The two corrections are combined algebraically, to give the Equation of Time, so that:

$$\begin{aligned} \text{GMT} &= \text{GAT} \pm \text{Equation of Time} \\ &= \text{GHA Sun} + 12 \text{ hours} \pm \text{Equation of Time.} \end{aligned}$$

GAT is Greenwich Apparent Time, i.e. time as measured by the Apparent Sun. GHA is the Greenwich Hour Angle.

Hour Angle

The Hour Angle of a body is the angle, measured Westwards, from the Observer's Meridian to the meridian through the body: it may be expressed in hours, minutes and seconds, or in degrees and minutes. GHA Sun is, therefore, measured Westwards from the Greenwich Meridian to the meridian through the Apparent Sun.

GMT and Universal Time (UT)

Since the introduction of time measurement on the atomic scale, irregularities have been found in the earth's rotational speed. When GMT is corrected for this factor it is known as Universal Time.

Although listed as "GMT", the basis of the entries in the *Nautical Almanac* is really UT. The difference is very small, and the error arising from the use of chronometer GMT will not exceed 0·7 sec corresponding to 0·2′ of longitude. In order to maintain this difference Radio Time Signals for GMT may be altered, on rare occasions, by one second either way. Any such change would be made at midnight on 30 June or 31 December. The navigator should accordingly consult the appropriate Notice to Mariners, so that the chronometer rate is correctly established.

The Sidereal Day

The Sidereal or Star Day commences when the First Point of Aries crosses the Observer's Upper Meridian and lasts until the next transit of that imaginary point of reference. It is shorter than the Mean Solar Day by about 4 minutes; more precisely its length is 23h 56m 3·45s of Mean Time.

During the course of a year the Apparent Sun completes one revolution of the Celestial Sphere, i.e. 360° in 365·25 days or about 1° per day. Being so remote, the stars may be regarded as fixed points in space; a Sidereal Day therefore, corresponds to exactly 360° of the earth's revolution and the Solar Day to about 361°, hence the latter is a little longer.

Sidereal Time

The apparent motion of the First Point of Aries measures Sidereal Time, so that, quite simply:

Local Sidereal Time = Local Hour Angle of First Point of Aries

Or, in abbreviation LST = LHA ♈

When planning stellar observations LST is needed to set up the Star Globe or Star Identifier. It is also useful in determining those stars which are on, or near the meridian at star time. As will be seen in certain of the examples in this chapter, Greenwich Sidereal Time or GHA ♈, is the first step in finding the LHA of a star.

Time By Chronometer

Since the chronometer is unlikely to show GMT exactly, it is necessary to apply a correction for its error. If, for some reason, there has been no recent check by time signal then the error must be calculated by means of the Daily Rate; as shown in the following example:

Example 1

Find the error of the chronometer at 1800Z (GMT) on 25th May, given the following extracts from the chronometer journal:

12th May, 1200Z	01m	03s	Fast
20th May, 1800Z	01	09	Fast
Accumulated Rate		06s	Gaining
Daily Rate = 6 ÷ 8·25		0·73s	Gaining

Accumulated Rate, 20th–25th May = 0·73 × 5 = 3·65 Gaining ≏ 4 seconds.

We write as:

Error 20th May, 1800Z	01m	09s	Fast
Accumulated Rate		04s	Gaining
Error 25th May, 1800Z	01m	13s	Fast

Exercise 1

Find the GMT in Questions 1–5:

1. September 3rd, at ship, the time by chronometer was 3d 0h 8m 44s, which on August 1st was 2m 11s fast of GMT, and was losing 3·3s daily.
2. July 19th, at ship, the time by chronometer was 20d 4h 21m 36s, which was 1m 35s slow of GMT on June 14th, and gaining 2·5s daily.
3. November 22nd, at ship, the time by chronometer was 22d 11h 45m 36s which on July 25th was 4m 36s slow of GMT, and on September 8th was 2m 3s slow.
4. October 30th, at ship when a chronometer showed 29d 22h 24m 36s which was 2m 18s slow of GMT on August 8th, and 1m 32s fast on September 27th.
5. March 8th, at ship, the time by a chronometer was 8d 17h 44m 36s, which was 3m 46s fast of GMT on December 22nd, and 2m 49s fast on January 29th.
6. On March 20th, Chron. *A* was 32m 19s fast of GMT and losing 2·5 secs daily. Chron. *B* was 1m 3s slow of *A* on above date. If *B* is 17 secs fast of *A* on April 30th, find *B*'s daily rate.
7. Chron. *A* was 32m 28s fast of GMT, Chron. *B* was 11m 35s slow of *A*, and Chron. *C* was 23m slow of *A*. Compare *B* and *C*.
8. Chron. *A* losing 2 secs daily, Chron. *B* gaining 3·2 secs daily. *A* is 10m 15s fast of *B*, what will be the difference after 20 days?

Answers in rear Answer Section.

Ship Time and Greenwich Time

The time used in everyday life, both at sea and ashore, is governed and fixed by the position of the sun, and depends on its distance East or West of the observer's meridian.

The earth turns on its axis once in 24 hours. The circumference of the earth is 360°, and if we divide 360° by 24 we get the number of degrees through which a place is turned in 1 hour, which is 15°. Fifteen degrees of Longitude, therefore, equal 1 hour of time, 30 degrees of Longitude equal 2 hours, and so on.

The apparent movement of the sun round the earth is from East to West, consequently if a ship is in East Longitude the sun will cross her meridian some time before it reaches the meridian of Greenwich. The time on board a ship in East Longitude is, therefore, always **ahead** of Greenwich time.

For example, we will take a definite date, say, May 8th. If a ship is in Longitude 45° E. the

sun will have crossed the meridian 3 hours before it reaches the meridian of Greenwich, but, later, when the time is 12 noon at Greenwich the sun will be 3 hours past the meridian of 45° E., and the time in that Longitude will be 3 p.m. This time would be written down as 8d 15h 00m.

The reverse is true for West Longitude. The sun will have crossed the meridian of Greenwich before it reaches the meridian of the ship. The time on board a ship in West Longitude is, therefore, always *behind* the time at Greenwich.

For example, when it is 12 noon at Greenwich on, say, June 6th, the time on board a ship in Longitude 45° W. would only be 9 a.m. on June 6th, because the sun will take another 3 hours before it reaches her meridian. This time at ship would be written down as 6d 09h 00m.

From the foregoing:

Greenwich time least, Longitude East.
Greenwich time best, Longitude West.

Longitude and time are therefore interrelated.

To Convert Time into Arc

There are several methods for converting Time into Arc or Arc into Time. The *Nautical Almanac* contains a "Conversion of Arc into Time" Table which is, perhaps the most convenient method. An alternative is as follows:

1 hour of time = 15° of arc
4 minutes „ = 1° „
4 seconds „ = 1′ „

Example 2

Convert 3h 30m 45s into Arc:

3h			4)30m			4)45s		
× 15			7·5°	or	7° 30′	11·25′	or	11′ 15″
45°								
+ 7°	30′							
+	11′	15″						
52°	41′	15″	or	52°	41·3′			

Example 3

Convert 9h 35m 27s into arc:

9h × 15° =	135°	00′
35m ÷ 4 =	8	45
27s ÷ 4 =		06·8
	143°	51·8′

Exercise 2

Express the following times in arc:

1.	3h	00m	19s	4.	2h	25m	00s
2.	10	00	12	5.	11	59	58
3.	1	12	30	6.	0	01	40

Answers:

1.	45°	04·8′		4.	36°	15′	
2.	150	03		5.	179	59·5	
3.	18	07·5		6.	0	25	

To Convert Arc into Time

To express Longitude in time multiply the Longitude in arc by 4 to change the degrees of arc into minutes of time, and the minutes of arc (′) into seconds of time (s). Should the minutes of time exceed 60, divide by 60 to bring them to hours.

Example 4

(a) Convert 143° of Longitude into its equivalent in time.

143° = the Long. in arc.
×4
60)572 = the Long. in minutes of time.
9h 32m = the Long. in time.

(b) Convert 136° 30′ of Longitude into time.

136° 30′ = the Long. in arc.
×4
544m + 120s = 546m
60)546m
9h 6m = Long. in time.

(c) Convert 81° 52·5′ of Longitude into time.

81° × 4 = 324
52·5′ × 4 = 60)210
5h 24m + 3m 30s = Long. in time.
= 5h 27m 30s

(d) 12° 17·5′ of Longitude into time.

×4
48m + 70s =
49m 10s = Long. in time.

Exercise 3

Express the following Longitudes in time:

1.	12°	30′	5.	136°	48′	9.	0°	36·5′
2.	36	45	6.	180	00	10.	100	30·75′
3.	124	00	7.	90	00·5	11.	111	11·25′
4.	82	17·5	8.	135	12	12.	16	0·5

Answers

1.	0h	50m	0s	5.	9h	7m	12s	9.	0h	2m	26s
2.	2	27	0	6.	12	0	0	10.	6	42	3
3.	8	16	0	7.	6	0	2	11.	7	24	45
4.	5	29	10	8.	9	0	48	12.	1	4	2

Exercise 4 (LMT, Ships Time and Zone Time)

Find the GMT in the following questions:

	LMT	*D.R.*	
1.	8d 0557	29° 42′ N.	59° 52′ W.
2.	15d 1750	35 53 S.	84 30 E.
3.	11d 0800	36 24 N.	144 10 E.

	Ships Time		*Time diff. from Greenwich*
4.	17d 0948	48° 20′ N. 43° 21′ W.	3 hrs
5.	18d 0030	48 29 S. 85 22 E.	$5\frac{1}{2}$ hrs
6.	22d 1811	28 00 N. 116 10 W.	$7\frac{1}{2}$ hrs

			Chronometer	*Error*
7.	A.M. twilight (29th)	58° 00′ N. 3° 30′ E.	02 30 00	NIL
8.	P.M. twilight (3rd)	19 16 N. 60 49 W.	10 26 02	5m 07 fast
9.	A.M. twilight (8th)	24 16 N. 130 00 E.	8 30 30	0m 05 fast

	Zone Time		*Zone*
10.	19d 17h 42m	10° 46′ N. 98° 02′ E.	−6
11.	24d 08 40	27 00 S. 146 17 W.	+10
12.	6d 07 59	37 25 N. 148 31 E.	−10

Answers (to nearest minute 1–6)

1.	8d	0956	5.	17d	1900	9.	7d	20	30	25
2.	15d	1212	6.	23d	0141	10.	19d	1142		
3.	10d	2223	7.	29d	02 30 00	11.	24d	1840		
4.	17d	1248	8.	3d	22 20 55	12.	5d	2159		

HOUR ANGLE EQUATIONS

In the past, a body's angular distance from the observer's meridian was measured in hours (minutes and seconds), each hour being equal to 15° of arc. Modern navigational practice is to measure all angles in degrees but the old term Hour Angle has been retained.

Local Hour Angle (LHA)

The Local Hour Angle of a body is its angular distance West of the observer's meridian, expressed in degrees, minutes and tenths from 0° to 360°, either as the arc of the celestial equator, or the angle at the pole contained between the observer's meridian and the meridian of the body. The hour angle of a body subtracted from 360° gives its Easterly Hour Angle as the two hour angles together make up 360°. It is understood that when Hour Angle Only is mentioned that the Westerly Hour Angle is referred to.

Sidereal Hour Angle (SHA)

The Sidereal Hour Angle of a body is its angular distance West of the First Point of Aries expressed in degrees, minutes and tenths of minutes from 0° to 360°. It is the arc of the celestial equator between Aries and the meridian passing through the body.

Greenwich Hour Angle (GHA)

The Greenwich Hour Angle of a body (or the First Point of Aries) is its angular distance West of the Greenwich meridian expressed in degrees, minutes and tenths of minutes 0° to 360°.

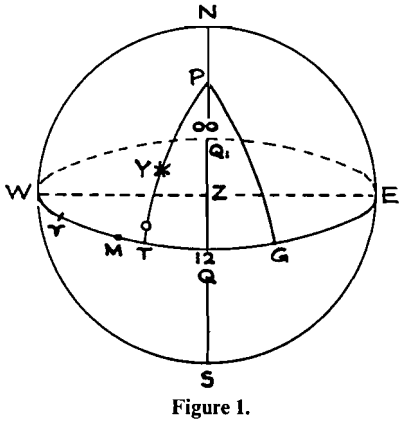


Figure 1.

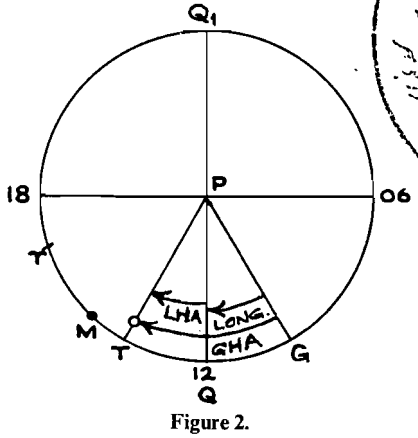


Figure 2.

Circle	$NESW$	Plane of the Rational (or Celestial) Horizon.
Circle	QQ_1	Celestial Equator (or Equinoctial).
Circle	PQ	Observer's Celestial Meridian.
	Z	Observer's Zenith.
	P	Pole.
Circle	PG	Celestial Meridian through Greenwich.
Circle	PT	Celestial Meridian of the True Sun and also of Star Y.
	M	Mean Sun.
	Υ	The First Point of Aries.
Arc	QT	Local Hour Angle of the body, i.e. LHA Sun or LHA Star Y.
Arc	$Q\Upsilon$	Local Hour Angle of Aries. (LHAΥ = Local Sidereal Time).
Arc	$\Upsilon Q_1 T$	Sidereal Hour Angle of Star Y, i.e. SHA Star Y.
Arc	$GQ\Upsilon$	Greenwich Hour Angle Aries. (GHAΥ = Greenwich Sidereal Time).
Arc	GQT	Greenwich Hour Angle of the body, i.e. GHA Sun or GHA Star Y.
Arc	GQ	Observer's Longitude, i.e. GHA Sun ~ LHA Sun or GHA* ~ LHA*.

The same information may be illustrated on the plane of the equinoctial as shown, the distinctive lettering being the same in both cases. Most problems in astro-navigation can be most conveniently illustrated on the plane of the horizon, because every body above the horizon must appear somewhere inside the circle and for this reason many students prefer Figure 1.

Local Mean Time (LMT)

Local Mean Time is the LHA Mean Sun (expressed in time) + 12 hours, and is represented by the arc Q_1QM in Figures 1 and 2, or simply, arc $MQ + 12$ hours.

Suppose PT were the meridian passing through the true sun, then the arc QT would be the LHA True Sun and this quantity which increases as the sun moves Westward, is found several times daily in clear weather by calculation from direct sextant and time observations on board ship. The true sun is the celestial body most frequently used for finding position at sea.

Local Apparent Time (LAT)

Local Apparent Time is the LHA True Sun + 12 hours (expressed in time) and is represented by the arc Q_1QT in Figures 1 and 2.

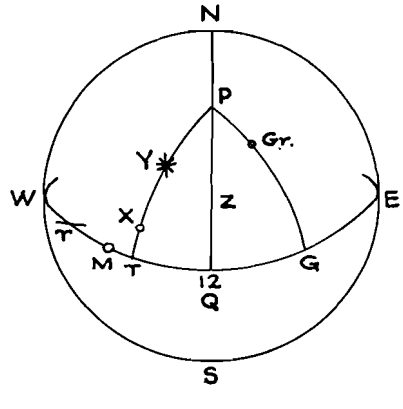


Figure 3(a) Arc MT = Equation of Time.

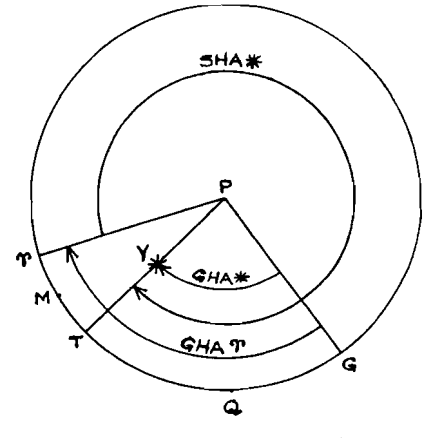


Figure 3(b) (GHA♈ + SHA*) − 360° = GHA*.

Equation of Time

The Equation of Time is the difference between Mean time and Apparent time. In the figures, arc ($QM + 12$ hours) − arc ($QT + 12$ hours) = arc MT the Eq. of Time.

It is subtracted from, or added to, the apparent time to get the corresponding mean time, as tabulated in the almanac. The equation of time would be plus to apparent time for the relative positions of M and T as shown in our figure, because the mean sun is ahead of the true sun.

In Figure 3:

PG	Meridian through Greenwich.
Υ	The First Point of Aries.
M	Mean Sun.
X	True Sun.
Y	A Star on the same meridian.
PZQ	Observer's Meridian.
GQ	Longitude of Observer West of Greenwich.
GT	Greenwich Hour Angle of the True Sun (GHA Sun). Geographical Longitude of the True Sun.
GM	Greenwich Hour Angle of the Mean Sun (GHA Mean Sun).
$G\Upsilon$	Greenwich Hour Angle of Aries (GHA Aries) Greenwich Sidereal Time.
TX	Declination = Geographical Latitude of True Sun.
$GM+12$ hours	Greenwich Mean Time (GMT)
$GT+12$ hours	Greenwich Apparent Time (GAT)
$GM-GT$	Equation of Time.

If Y is the position of a star, then:

$360°-\Upsilon T$	Sidereal Hour Angle (SHA) of the star which is the arc of the equinoctial Westwards from Aries to the meridian passing through the star.
ΥT	The Right Ascension of the Star.

The relationship between time, Longitude and hour angle may be deduced from a general figure and proved as follows:

1. LMT = GMT − West Longitude = GMT + East Longitude.
2. LMT = LAT ± Equation of Time.
3. LHA Sun = GHA Sun − West Long. = GHA Sun + East Long.
4. GHA Star = GHA Aries + SHA of Star (−360° if Necessary)

Proofs

1. LMT = GMT − West Long.
   arc $(QM+12\text{h})$ = $(GM+12\text{h})-GQ$.
   arc QM = $GM-GQ=QM$.

2. LMT = LAT ± Eq. of Time.
   arc $(QM+12\text{h})$ = arc $(QT+12\text{h})+MT$.
   arc QM = $QT+MT=QM$.
   (The Eq. of Time is shown in Figure 3 as plus to Apparent Time.)

3. LHA Sun = GHA Sun − West Long.
   arc QT = $GT-GQ=QT$.

4. GHA Star = GHA Aries + SHA Star (Refer to Fig. (3b)).
   arc GT = $G\Upsilon+\Upsilon T-360°$.

In Figure 3(b), note that SHA* (arc ΥT) is measured Westwards from Aries so that, in this case, after adding GHAΥ and SHA* the quantity exceeds 360°. In consequence, 360° must be subtracted. Compare this with Proof 5 and Figure 4(b).

The arc GX (GHA Body) is tabulated for every hour GMT where X is the True Sun, Moon, Venus, Mars, Jupiter or Saturn. Where X is a Star the arc GX (GHA Star) is found by adding arc $G\Upsilon$ (GHA Υ) to arc ΥX (SHA Star).

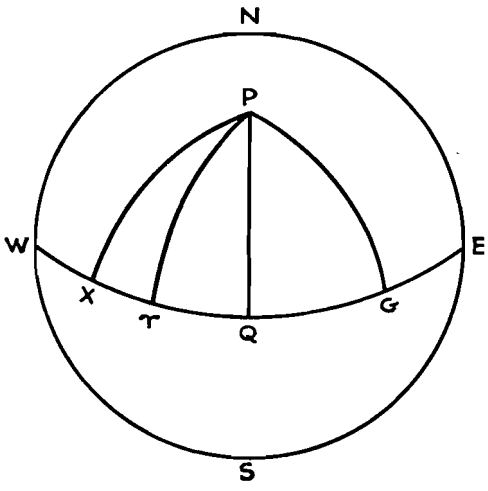


Figure 4(a)

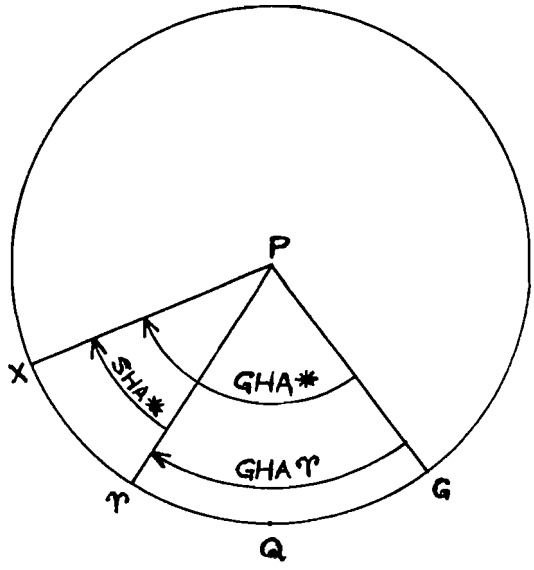


Figure 4(b) GHAΥ + SHA* = GHA*.

In Figure 4, if PG, PQ, $P\Upsilon$ and PX are meridians through Greenwich, the Observer, Aries and a Star then the arc ΥX is the Sidereal Hour Angle of the Star which is given in the *Nautical Almanac*.

5. GHA Star = GHA Aries + SHA Star (Refer to Fig. (4b)).
   arc GX = $G\Upsilon + \Upsilon X = GX$.
6. LHA Star = GHA Aries + SHA Star − West Long.
   arc QX = $G\Upsilon + \Upsilon X - GQ = QX$.

For all bodies:

$$\text{LHA body} = \text{GHA body} \begin{Bmatrix} +\text{East} \\ -\text{West} \end{Bmatrix} \text{Longitude.}$$

THE NAUTICAL ALMANAC

The Information given in the *Nautical Almanac* is calculated for several years in advance and produced jointly by the staff of H.M. Nautical Almanac Office, Royal Greenwich Observatory and the United States Naval Observatory. Without an *Almanac* astro-navigation would be impossible. The positions of the Sun, Moon, Planets and First Point of Aries are given in terms

of Declination and Hour Angle from Greenwich (GHA). These values are continually changing due to the rotation of the earth on its axis, its revolution round the sun, and the real motion of the bodies in space, so the information is tabulated at hourly intervals. Special interpolation tables are given in the *Almanac* so that the navigator can quickly find the exact position of a body corresponding to the GMT of his observation.

The stars are approximately fixed with reference to each other and for convenience their positions are given in terms of declination and hour angle West of the First Point of Aries, called the Sidereal Hour Angle (SHA). The GHA of a star is found by first looking up the GHA of Aries and then adding the SHA of the star.

The application of the elements to the various questions in astro-navigation is the same in principle throughout whether the body observed be the sun, moon, planet or star.

TO FIND GREENWICH HOUR ANGLE AND DECLINATION

Sun

Example 5 (Sun)

Find the correct values of GHA and Declination for the Sun at GMT, January 7d 02h 33m 15s.

Turn to the *Nautical Almanac* elements for January 7th, and note the GHA Sun at 02h, it is 208° 29·2′. Now turn to the Increments and Corrections Tables for 33 minutes and under the heading "Sun Planets" and abreast of 15 secs find the increment 8° 18·8′ to add to the GHA.

GHA Sun 7d 02h	208°	29·2′	Dec. at 02h		22° 27·1′S	(decreasing)
Increment for 33m 15s	8	18·8	Corr. for 33 m	(−)	0·2	(d = 0·3)
GHA Sun at 02h 33m 15s	216°	48·0′	Dec. at 02h 33m		22° 26·9′S	

The required declination of the sun lies between the values given for 02h and 03h and this can be allowed for mentally, or by proceeding as follows. Note the declination at 02h, it is 22° 27·1′ S., and it is decreasing as time goes on. The hourly difference in declination is given at the foot of the declination column, it is d = 0·3. Turn to the Increment and Correction Tables for 33 mins and abreast of 0·3′ in column "v or d correction" get the correction 0·2′ to be subtracted in this case because the declination is decreasing. The seconds of time are not required when finding this correction. The required declination is 22° 26·9′ S.

Increments for the Hour Angle

In the course of a day the apparent motions of the True Sun and the First Point of Aries may be regarded as being regular. The tabulated increments to their Hour Angles may therefore be used throughout the year.

Due to their comparative proximity the apparent motions of the Moon and Planets show appreciable variation. In consequence, the average increments for the Hour Angles of these bodies must be adjusted—an operation which is carried out by means of the "v" correction.

Example 6 (Sun)

Find the GHA and Declination of the Sun at GMT, June 15d 04h 52m 12s.

GHA Sun 15d 04h	239°	57·1′	Dec. at 04h	23°	17·1′ N.	
Incr. for 52m 12s	13	03·0	Corr. for 52m	(+)	0·1	($d = 0·1$)
GHA Sun	253°	00·1′	Declination	23°	17·2′ N.	

Aries

Example 7 (Aries)

Find the GHA of Aries at GMT, January 10d 21h 46m 12s.

GHA Aries 10d 21h	64°	52·4′
Incr. for 46m 12s	11	34·9
GHA Aries	76°	27·3′

The GHA Aries is taken from the daily pages of the *Almanac* for the hour of GMT, and the increment is found in the Increments and Corrections Tables for 46 mins and abreast of 12 secs in the column headed "Aries".

Star

Example 8 (Star)

Find the GHA of Altair at GMT, January 8d 06h 20m 42s.

GHA Star = GHA Aries + SHA Star

GHA Aries 8d 06h	197°	17·2′
Incr. for 20m 42s	5	11·4
GHA Aries	202	28·6
SHA Altair	62	49·2
GHA Altair	265°	17·8′

To the corrected GHA Aries add the SHA of the star which is found in the Star column on the daily pages.

Example 9 (Star)

Find the GHA of Regulus at GMT, January 8d 06h 22m 47s.

GHA Aries, Jan. 8d 06h	197°	17·2′
Incr. for 22m 47s	5	42·7
GHA Aries	202	59·9
SHA Regulus	208	27·5
	411	27·4
	(−)360	00·0
GHA Regulus	51°	27·4′

When the GHA of the star is found to exceed 360° as shown above, then 360° is subtracted.

Planets

Example 10 (Planet)

Find the correct values of GHA and Declination of Venus at GMT, January 10d 06h 18m 11s.

Turn to the *Almanac* to find the GHA Venus for the given day and hour and also note at the foot of the column a quantity called $v = 3{\cdot}0'$.

The increment to the GHA of all planets is found in the Sun and Planets column of the Increments and Corrections Tables, using the minutes and seconds of GMT given in the question. An adjustment called the v correction is necessary due to the method of making up the increments tables and it is found in the v or d correction column abreast of the given value of v in the table corresponding to the minutes of the GMT. This v correction is always added except in the case of the planet Venus when a minus sign can occur.

The declination is found in the same way as for the sun.

GHA Venus, Jan. 10d 06h	241°	29·6′	
Incr. for 18m 11s	4	32·8	
v correction ($v = 3{\cdot}0$)		0·9	
GHA at 10d 06h 18m 11s	246	03·3	
Dec. Venus at 10d 06h	13°	10·8′	S. (decreasing)
Correction for 18m ($d = 0{\cdot}5$)	(−)	0·2	
Declination	13°	10·6′	S.

The Moon

Example 11 (Moon)

Find the correct GHA and Declination of the Moon at GMT, January 8d 06h 28m 43s.

GHA Jan. 8d 06h	56°	44·0′	Declination	10°	13·4′ N.
Incr. for 28m 43s	6	51·1	d corr. (10·6) (−)		5·0
v corr. (8·3)		3·9			
GHA at 06h 28m 43s	63°	39·0′	Declination	10°	08·4′ N.

From the *Nautical Almanac* January 8th, abreast of 06 hours GMT note the GHA and Declination of the Moon. From the Increments Table for 28 minutes and abreast of 43 seconds find the increment to the GHA in the column headed Moon (6° 51·1′) and with $v = 8{\cdot}3$ in the "v or d" column find the correction (3·9′) to be added to the GHA. In the same table get the correction to the declination corresponding to $d = 10{\cdot}6$ for 28 minutes. It is 5·0′ to be subtracted because the declination is decreasing. It will be seen that the v and d corrections are given at hourly intervals in the case of the moon.

The Increments and Corrections Tables are made up using certain fixed values for the hourly change in GHA. For the Sun and Planets the value used is 15° 00′, for the Moon it is 14° 19′, and for the Stars 15° 02·46′. The quantity v is the difference between the fixed value used and the actual value as given in the *Nautical Almanac*. In Example 11, the actual change in GHA of the Moon can be seen in the almanac:

GHA Moon at 07h	71°	11·3′
GHA Moon at 06h	56	44·0
Actual hourly difference	14	27·3
Fixed value used in tables	14	19·0
Excess over fixed value		8·3′ = v correction

No v correction is required for GHA of the Sun or Stars.

Exercise 5 (GHA and Declination)

Required the correct values of the Sun's GHA and Declination for the:

1. Sun, January	10d 17h 12m 41s	GMT
2. Sun, January	11d 12h 51m 16s	GMT
3. Sun, June	21d 08h 22m 16s	GMT
4. Sun, September	20d 13h 17m 28s	GMT
5. Deneb, January	12d 18h 50m 10s	GMT
6. Capella, June	18d 21h 06m 32s	GMT
7. Spica, January	11d 07h 36m 52s	GMT
8. Moon, January	10d 21h 12m 16s	GMT
9. Moon, January	4d 15h 58m 40s	GMT
10. Mars, January	10d 17h 40m 28s	GMT
11. Mars, January	8d 06h 16m 03s	GMT
12. Jupiter, January	11d 17h 18m 39s	GMT
13. Saturn, January	11d 07h 36m 52s	GMT
14. Venus, January	12d 09h 34m 55s	GMT

Answers

1. Sun	76° 16·7′	21° 57·4′ S.	8. Moon	251° 13·7′	2° 05·9′ S.
2. Sun	10° 50·7′	21° 50·0′ S.	9. Moon	254° 51·8′	19° 32·8′ N.
3. Sun	305° 11·0′	23° 26·5′ N.	10. Mars	123° 17·8′	22° 23·3′ S.
4. Sun	20° 58·8′	1° 09·9′ N.	11. Mars	311° 36·4′	22° 08·0′ S.
5. Deneb	84° 18·2′	45° 08·0′ N.	12. Jupiter	162° 10·7′	10° 13·0′ S.
6. Capella	144° 49·7′	45° 57·3′ N.	13. Saturn	324° 40·3′	21° 46·6′ S.
7. Spica	23° 46·6′	10° 56·6′ S.	14. Venus	297° 46·9′	12° 45·1′ S.

TO FIND LOCAL HOUR ANGLE

Example 12 (Sun)

In Longitude 150° 36′ W. GMT, January 7d 19h 11m 56s. Find the LHA True Sun.

LHA Sun = GHA Sun − West Long.

January		
GHA, Sun 7d 19h	103°	24·7′
Increment 11m 56s	2	59·0
Corr. GHA	106	23·7
	(+)360	
	466	23·7
Longitude West	(−)150	36·0
LHA Sun	315°	47·7′

Example 13 (Star)

GMT, January 4d 18h 13m 24s, Longitude 82° 18′ E. Find the LHA of Regulus.

LHA* = GHA Aries + SHA* + East Long.

January		
GHA Aries 4d 18h	13°	50·2′
Incr. 13m 24s	3	21·6
GHA Aries	17	11·8
SHA Regulus	(+)208	27·6
GHA Regulus	225	39·4
Long. East	(+) 82	18·0
LHA Regulus	307°	57·4′

The SHA of the star is given in the Star column on the daily pages of the *Nautical Alamanac*.

Example 14 (Moon)

In Longitude 30° 47′ W. GMT, January 10d 08h 40m 26s. Find the LHA Moon.

LHA Moon = GHA Moon − West Long.

January			
GHA Moon 10d 08h	60°	03·6′	(v = 9·6)
Incr. for 40m 26s	9	38·9	
v corr. (9·6 for 40m)		6·5	
GHA Moon	69	49·0	
Long. West	(−) 30	47·0	
LHA Moon	39°	02·0′	

Example 15 (Planet)

GMT, June 18d 16h 35m 42s, Longitude 120° 11′ W. Find the LHA Venus.

LHA Venus = GHA Venus – West Long.

GHA Venus 18d 16h		97°	59·8′	($v = -0{\cdot}5$)
Incr. for 35m 42s		8	55·5	
v corr. (−0·5 for 35m)	(−)		0·3	
GHA Venus		106	55·0	
	(+)	360		
		466	55·0	
Long. West	(−)	120	11·0	
LHA Venus		346	44·0	

Note that the v correction is minus in this case. The correction is always added for the other planets and for the moon.

Exercise 6

Given the following information, find in each case the LHA of the body.

Name of body	GMT d	h	m	s	Long.
1. Sun, January	7	03	28	23	178° 18′ E.
2. Sun, January	11	12	44	09	40° 17′ W.
3. Vega, January	11	05	52	23	45° 22′ E.
4. Sirius, January	4	18	14	04	28° 42′ E.
5. Arcturus, January	8	20	29	56	177° 18′ W.
6. Capella, January	10	23	42	23	3° 28′ W.
7. Moon, January	8	22	15	33	31° 33′ E.
8. Moon, January	4	13	02	57	162° 05′ E.
9. Venus, January	7	06	28	48	93° 32′ E.
10. Mars, January	10	19	21	56	151° 14′ W.
11. Jupiter, January	11	07	08	06	15° 08′ E.
12. Saturn, January	11	20	36	29	156° 54′ W.

Answers

1.	48°	52·8′	7.	323°	22·0′
2.	328°	47·0′	8.	14°	40·2′
3.	324°	49·6′	9.	338°	59·6′
4.	305°	13·9′	10.	357°	26·7′
5.	24°	37·7′	11.	24°	17·8′
6.	23°	42·3′	12.	3°	08·9′

TO FIND THE LONGITUDE

To Find the Longitude

Example 16 (Sun)

January 8th, at ship, the LHA of True Sun calculated from sights was 64° 10′ when the GMT was 8d 16h 48m 20s. Find the Longitude.

Longitude = GHA Sun ~ LHA Sun

GHA Sun 8d 16h	58°	19·1′	
Incr. for 48m 20s	12	05·0	
GHA Sun	70	24·1	
LHA Sun	64	10·0	
Longitude	6°	14·1′	West

When the GHA of a body is greater than the LHA, the Longitude is West, as shown previously (GHA Best, Longitude West. GHA Least, Longitude East).

Example 17 (Sun)

The LHA of the Sun was calculated to be 344° 18′ at GMT, January 8d 09h 26m 23s. Find the Longitude.

Longitude = GHA Sun ~ LHA Sun

GHA Sun 8d 09h	313°	20·9′	
Incr. 26m 23s	6	35·8	
GHA Sun	319	56·7	
LHA Sun	344	18·0	
Longitude	24°	21·3′	East

Exercise 7

Given the following information, find the Longitude in each case:

	GMT	LHA Sun
1. January	10d 19h 17m 03s	60° 23′
2. „	10d 08h 14m 11s	327° 19′
3. „	11d 22h 09m 26s	327° 38′
4. „	12d 16h 08m 50s	331° 07′
5. „	12d 10h 57m 18s	27° 19′
6. „	7d 02h 05m 21s	46° 16′

Answers

	GHA Sun	Longitude
1.	107° 21·7′	46° 58·7′ W.
2.	301° 41·5′	25° 37·5′ E.
3.	150° 20·7′	177° 17·3′ E.
4.	60° 07·3′	89° 00·3′ W.
5.	342° 15·8′	45° 03·2′ E.
6.	209° 49·5′	163° 33·5′ W.

Questions

1. What is meant by the "daily" rate and the "accumulated" rate of a chronometer, and state how they are ascertained?
2. What time does a ship's clock register?
3. A ship sailing East changes her Longitude 10°. What alteration should be made on the hands of the clock?
4. A ship sails from 20° W. to 25° W. What alteration of time should be made on the clock?
5. Assuming the chronometer to be correct for GMT and the ship's clock set to mean time for the meridian of the ship, what is the ship's Longitude if the chronometer shows 10h 20m and the clock 13h 35m?
6. Ship *A* in Long. 135° E., and ship *B* in Long. 157° E., set their clocks correctly for their respective meridians. What is the difference between their times and which clock is the more advanced?
7. Explain what is meant by (a) Sidereal Day, (b) Solar Day.
8. Define the following terms: (a) Apparent Sun, (b) Mean Sun, (c) Apparent Time, (d) Mean Time, (e) Equation of Time.
9. What time is kept by clocks in Great Britain?
10. Which is the longer period, a Sidereal Day or a Solar Day?
11. Distinguish between the Civil Day and the Astronomical Day.
12. Define the terms: (a) First Point of Aries, (b) Sidereal Hour Angle. (c) Greenwich Hour Angle.
13. Draw a figure to illustrate: (a) GHA ♈ 45° and SHA* 55°, (b) GHA ♈ 300° and SHA* 30°, (c) GHA ♈ 200° and SHA* 190°. Show the GHA* in each case.
14. What is meant by the Meridian Passage of a body?
15. If the LHAMS is 45°, what is the LMT?
16. How is LMT obtained on board ship?
17. What is meant by LHA Sun.
18. Complete the following equations:
    (a) GMT + *E* Long =
    (b) GHA Sun − W. Long. =
    (c) LAT ± Eq. of Time =
    (d) GHA Aries − GHA Star =
19. What is Zone Time?
20. What is the Date Line and why it is necessary?
21. Draw a figure to illustrate the truth of the equation GHA* = GHA ♈ + SHA*.

Chapter 21

The Marine Chronometer

Since its invention by John Harrison in 1735 the chronometer has been the navigational time-keeper aboard ship. The chronometer always records Greenwich Mean Time (GMT). All other ship board clocks indicate some form of civil time to regulate the routine and internal organisation of the ship.

The chronometer may be fast or slow of GMT but this is of no concern providing the exact error is known and applied to all chronometer readings. The value and reliability of a chronometer depends on the steadiness of its daily rate which is the amount by which it gains or loses time during the course of the day. In consequence, a daily change of one or two seconds is acceptable providing the amount is known and the daily rate is reasonably constant. But any error which is present is regularly checked by use of radio time signals. The error, together with details of the date, time, temperature and daily rate, is then recorded in the Chronometer Log Book.

The time of a navigational observation ("sight"), is always taken from the chronometer. Reference is then made to the Chronometer Log in order to check the accumulated daily rate which is then applied to Chronometer Time to obtain Corrected Chronometer Time. As the chronometer reads 12 hours (as opposed to 24 hours) it is then necessary to make a simple calculation to convert Ship Date and Time into an approximate Greenwich Date and Time. This done, the navigator can then decide if it is necessary to add or subtract 12 hours to the corrected chronometer time in order to obtain the GMT.

Types of Chronometer

Two types of chronometer are in use:

1. Traditional Marine Chronometer
2. Electronic Quartz Crystal Chronometer.

Both types are extremely accurate. Their care and maintenance will be discussed in the following pages.

TRADITIONAL MARINE CHRONOMETER

From its conception in the mid 18th century to its present form, the basic movement and layout of the marine chronometer has remained virtually unchanged. The original escapement design was mechanically so sound that no major modification has been found necessary. Nevertheless, automatic machining processes have meant that parts previously made by hand can now be made to more precise limits. An unusual blend of traditional craftsmanship combined with modern quality control and production techniques has thus enabled greater accuracy and interchangeability.

Types of Marine Chronometer

Two types of chronometer are produced by the makers:

1. Two Day Chronometer
2. Eight Day Chronometer.

Maintenance and Regulation of Marine Chronometers

The following text relating to the use, maintenance and regulation of marine chronometers is based on instructions recommended by Thomas Mercer Chronometers Ltd.

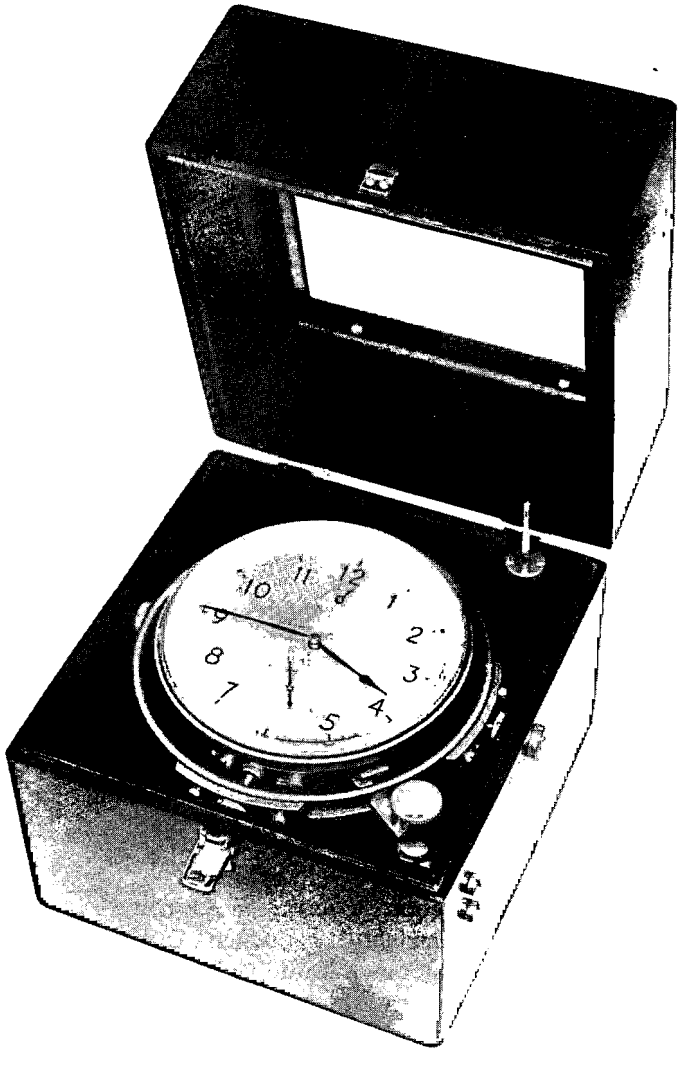


Figure 1. A Modern Marine Chronometer by Thomas Mercer Ltd of Cheltenham.

Parts of the Marine Chronometer and Accessories

The following chronometer parts and accessories are mentioned in the text:

1. Bowl
2. Bezel
3. Chronometer box
4. Compensating balance
5. Drum
6. Driving wheel and cone shaped spindle
7. Escapement
8. Fusee chain
9. Gimbals
10. Locking washer
11. Main spring
12. Winding key
13. Carrying case
14. Cork wedges
15. Tweezers
16. Rating Certificate.

Principle of the Marine Chronometer

The main spring is fitted inside a drum which is rotated as the spring uncoils. Several turns of the fusee chain encircle the drum. The chain then passes from the drum around the cone shaped spindle of the driving wheel.

Main spring tension is greatest when fully wound and gradually diminishes as it winds down. The first turns of the fusee chain are coiled around the smaller end of the cone shaped spindle attached to the driving wheel i.e. at the point which requires greatest tension to turn the driving wheel. Every succeeding turn of the chain passes around the cone at a greater distance from its axis so that gradually diminishing power is required to turn it. This increasing leverage on the driving wheel is designed to compensate for the decreasing tension of the uncoiling spring.

General Remarks

The chronometer is fitted in a special glass fronted box and slung on gimbals which allow it to maintain a horizontal position.

The steel spring must never become magnetised and, in consequence, the chronometer should be stowed well clear of spare magnets, electronic equipment and wiring. Where soft iron screening is not provided, chronometers should not be subjected to magnetic fields exceeding 1 gauss at the chronometer position.

Chronometers are fitted with a compensation balance which enables them to maintain a reasonably uniform rate at various temperatures. Nevertheless, change of temperature does cause an expansion and contraction of the chronometer's working parts. This disturbs the equilibrium of the mechanism and may affect the daily rate.

For these reasons the chronometer is usually housed in a special cabinet where it is unlikely to be subjected to sudden knocks or temperature changes and any magnetic influence. The cabinet is normally built into the chart table and has a perspex window.

Unpacking and Setting Up the Chronometer

(Refer to Figures 2–5)

1. A newly delivered chronometer will have a final wrapping of thin paper. Before unwrapping the chronometer, remove any packing or dust from inside its wooden box.
2. If the chronometer is in its gimbals, remove it from the gimbal ring by releasing the locking washer and removing the gimbal ring screw nearest to the front of the box. Take care to steady the chronometer and see that it does not fall. Place the chronometer on a clean stable base, if necessary.
3. The glass face (bezel) unscrews in an anti-clockwise direction. Hold the chronometer, face up, in the right hand and carefully unscrew the bezel with the left hand (as shown in Figure 2).
4. Transfer the chronometer to the left hand. Grasp the chronometer firmly with the right hand (fingers spaced evenly around the dial) and turn it upside down. The bowl can now be lifted off with the left hand (as shown in Figure 3). If resistance is felt, insert the the key in the winding hole and push gently.
5. Do no touch any part of the movement with the fingers.
6. Three cork wedges will have been inserted to protect the balance and escape wheel during transit – these must be removed. Two wedges are located under the balance (B in Figure 4). The third wedge is located under the escape wheel (C in Figure 5). Remove the cork wedges with a pair of tweezers.
7. Using a clean match stick (or pencil top) and a gentle brushing action, give the balance a slight swing.
8. If the chronometer starts well, stop it by placing the match stick on the balance wheel.
9. Replace the movement in the bowl taking care to locate the pin on the edge of the movement with the slot in the bowl.
10. Replace the bezel and fit the chronometer into the gimbal ring.

The chronometer is now ready to be started at any required time.

Starting the Chronometer

Hold the chronometer in the hands. At the required time, rotate the chronometer bodily with a gentle twist of the wrists – the chronometer should start.

Starting the Chronometer against a Time Signal

A chronometer which has been allowed to run down at sea should be started as follows:

Swing open the glass face. Fit the winding key on the "square" at the centre of the minute hand. Using the winding key, turn the minute hand, forward only, and set to the hour and minute of the next radio time signal. **Never touch the second hand.** Swing closed the glass face.

Wind the chronometer, gently return to the "rest" position to avoid accidental starting.

Await the time signal and, at the moment of transmission, start the chronometer by rotating it bodily with a gentle twist of the wrists (as previously described). Check the error as soon as possible after restarting.

Winding the Chronometer

To wind the chronometer, turn it over gently, face downwards, in the gimbal ring. Hold firmly



Figure 2. Unscrewing the Bezel.

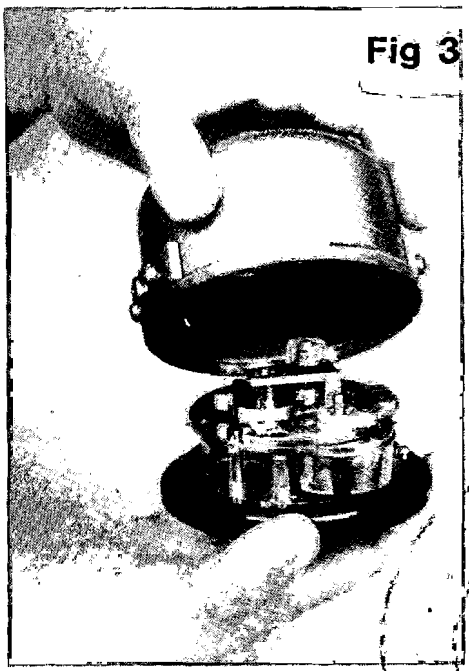


Figure 3. Removing the Bowl and exposing the Movement.

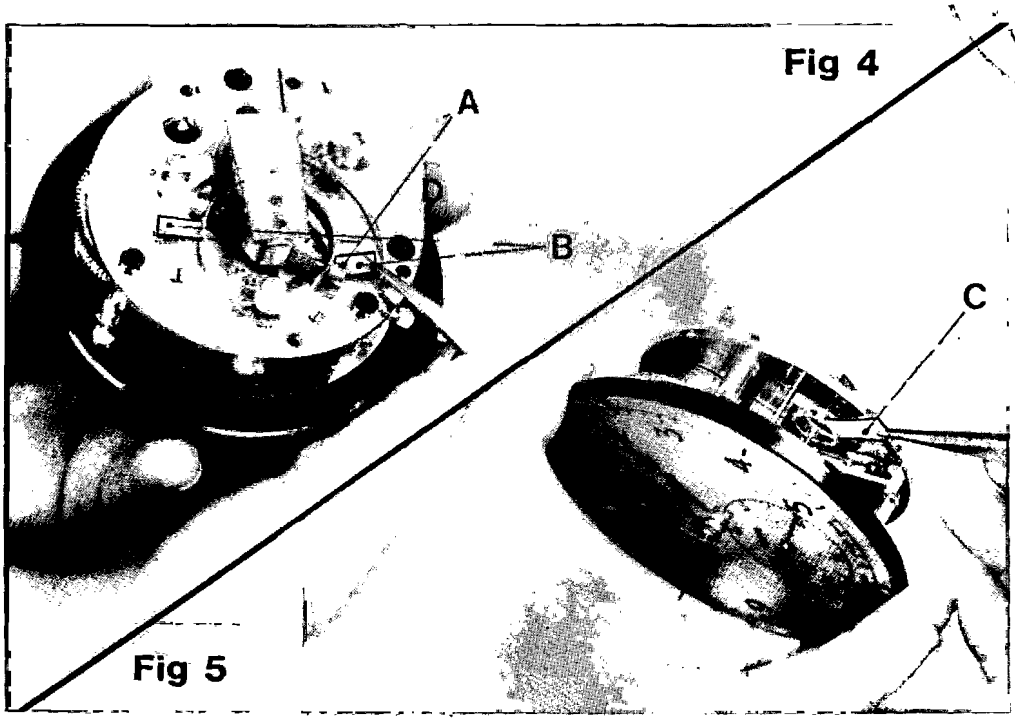


Figure 4. Balance Wheel Cross Bar with split brass nuts—shown at "A". Removing the cork wedges from beneath the Balance—shown at "B".

Figure 5. Removing the third cork wedge from beneath the Escape Wheel—shown at "C".

in position with the left hand. Take the winding key (tipsy key) in the right hand. Using one finger of the left hand, open the dust cover. Insert the winding key with the right hand. Wind gently and evenly in an anti-clockwise direction. Count the number of turns.

A two day chronometer should be wound daily, at about the same time each day, and requires about $7\frac{1}{2}$ turns of the key. It will run for a maximum period of about 54 hours without rewinding.

An eight day chronometer should be wound every seventh day.

Transporting and Handling the Chronometer

When transporting the chronometer by hand, even over short distances, lock the gimbal suspension to avoid any excess swinging movement to the instrument. Avoid any twisting motion, this could stop the balance wheel which will not restart of its own accord. Keep the instrument in the hand and place in the lap when sitting down – never on the floor or in the boot of a moving vehicle.

Jarring the chronometer can "mushroom" a pivot or crack a jewel and result in an irregular rate – never jar the instrument.

Packing for Transit

When packing for transit, the chronometer should be removed from its gimbal ring. The balance wheel must be wedged. Use the original cork wedges, if possible. Alternatively, wedge the balance wheel with stiff paper.

Having wedged and reassembled the chronometer, wrap it in thin paper to avoid contact with packing material. The gimbal ring is detached, well padded and placed at the bottom of the chronometer box. The chronometer is then softly but firmly padded so as to fit securely into the box and allow no movement. The chronometer box is then secured and placed inside the carrying (guard) case.

Whether in its inner case only, or in both inner and outer guard case, the chronometer should be placed in substantial wooden box or wicker basket and be well padded on all six sides with shock absorbing material. The box should then be labelled:

"DELICATE INSTRUMENT—HANDLE WITH CARE".

Regulation

Following transit, the chronometer may take on a new rate. Regulation then becomes necessary. Regulation is not difficult and requires only care and confidence to attempt it.

1. First remove the movement as previously described and shown in Figures 2 & 3.
2. Stop the balance wheel with the forefinger protected by tissue paper.
3. At opposite ends of the balance wheel cross-bar are two split brass nuts (shown at 'A' in Figure 4).

   Screw the two split brass nuts **clockwise** to make the chronometer **gain**. (This action will reduce the effective diameter of the balance wheel.)

   Screw the two split brass nuts **anti-clockwise** to make the chronometer **lose**. (This action will increase the effective diameter of the balance wheel.)
4. Reassemble and replace the chronometer.
5. Check the chronometer rate and error over the next few days.

As an approximate guide, movement of the split brass nuts by an amount equal to the width of the slots will alter the daily rate by one second. A special screwdriver (with a slot in the blade to clear the thread) should be used when regulating. If the special screwdriver is not available the operation can be carried out, with care, using a fine screwdriver in one slot only.

Cleaning the Marine Chronometer

The marine chronometer should be cleaned every two years by a competent technician from a reputable firm specialising in this work. Failing this, the chronometer may be returned to the makers.

CHRONOMETER TESTS

Marine chronometers of the type illustrated, are made from the finest quality materials available, each delivery of raw materials being tested to conform to high standards before machining. At each manufacturing and sub-assembly stage of the components a rigid inspection procedure is applied to maintain dimensional accuracy and to ensure a wide degree of interchangeability.

Both the manufacture and assembly of the instrument are carried out by highly skilled craftsmen whose care and attention to detail are reflected in the accuracy and finish of the final product.

When finally assembled each chronometer is subjected to a test procedure to produce an accuracy closer than **0·5 seconds** per day. During this test period, the rate is compared with time signals of international standards.

Details of the Test Procedure are given below.

Isochronism Test

The mainspring of the two-day chronometer is let down two turns. The test is then carried out for two days at a temperature of 95° F. (35° C.) and the difference between the mean rate during the short arc test and the mean rate of the day before and the day after the short arc test must not exceed **2 seconds.**

Two-day Test

When the isochronism test is satisfactory, the chronometer must run for 48 hours at one temperature without re-winding; during this time the daily rate must not exceed **2 seconds.**

Submission to Test

At this stage the chronometer is subjected to five periods of test, each period consisting of three days at varying but predetermined temperatures:

Period 1:	21 °C	(70° F)
Period 2:	4° C	(40° F)
Period 3:	21° C	(70° F)
Period 4:	35° C	(95° F)
Period 5:	21° C	(70° F)

If necessary, final adjustment for compensation is made to bring the rate within the following limits:

In each period the difference between any two daily rates must not exceed **1·5 seconds**. The difference between the mean of periods 1, 3 and 5 must not exceed **1·5 seconds**. The difference between the means of periods 2 and 4 must not exceed **1·5 seconds**. The difference between the combined average of periods 1, 3 and 5 when compared with the mean of period 2 or 4 must not exceed **2 seconds**.

Final Rate

The rate is now closed to within ± **0·5 seconds** per day and the chronometer must run for three days at that rate.

Having passed the above tests the chronometer is acceptable and is released for dispatch.

Rating Certificate

A detailed Rating Certificate is provided by the maker supplied with each instrument.

We Guarantee

This Chronometer, No .....
to be adjusted for isochronism and temperature to the standards stated in the test procedure.
We further guarantee this instrument for 2 years from ..... Any faulty performance due to bad material or bad workmanship, but not due to damage which occurs during this period will be corrected.

Signed for and on behalf of

THOMAS MERCER LTD.

Final Rating

Date	Temperature		Mean Daily Rate Sec.
	Fahr.	Celsius Cent.	

Daily Rate is .....

Figure 6.

THE QUARTZ CRYSTAL CHRONOMETER

Like the traditional chronometer, the electronic quartz crystal chronometer is extremely accurate and makers claim a daily rate stability of 0·1 seconds per day.

General Remarks

The quartz crystal chronometer is relatively light and easily carried. It is sealed to resist the entry of dust and spray and, in the case of the type illustrated, has undergone stringent tests for shock, vibration and extremes of temperature.

The type TC, shown in Figure 7, has luminous hands and dial and can be either console mounted or placed in the chronometer cabinet, described earlier. This type of chronometer is powered by a 1·5 volt, AA alkaline battery which should be replaced at least once per year. A spare battery is carried inside the chronometer case.

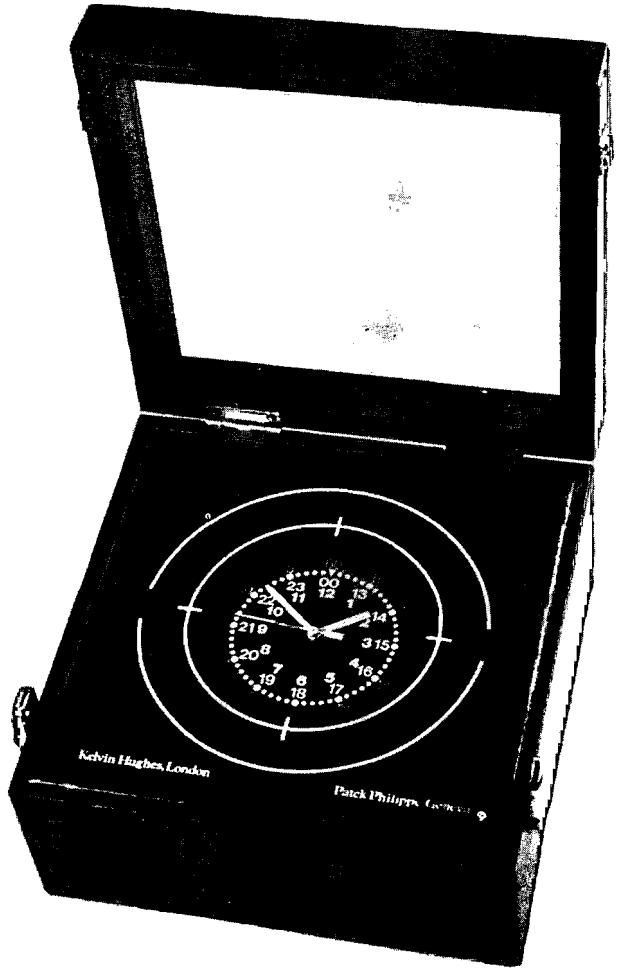


Figure 7. A Quartz Crystal Chronometer by Kevin Hughes of London.

Maintenance and Regulation of Quartz Crystal Chronometers

The following text relating to the use, maintenance and regulation of Type TC quartz crystal chronometers is based on tests carried out by the writer and instructions recommended by Kelvin Hughes, a division of Smiths Industries Ltd.

Disassembling the Quartz Crystal TC Chronometer

(Refer to Figures 8 and 9)

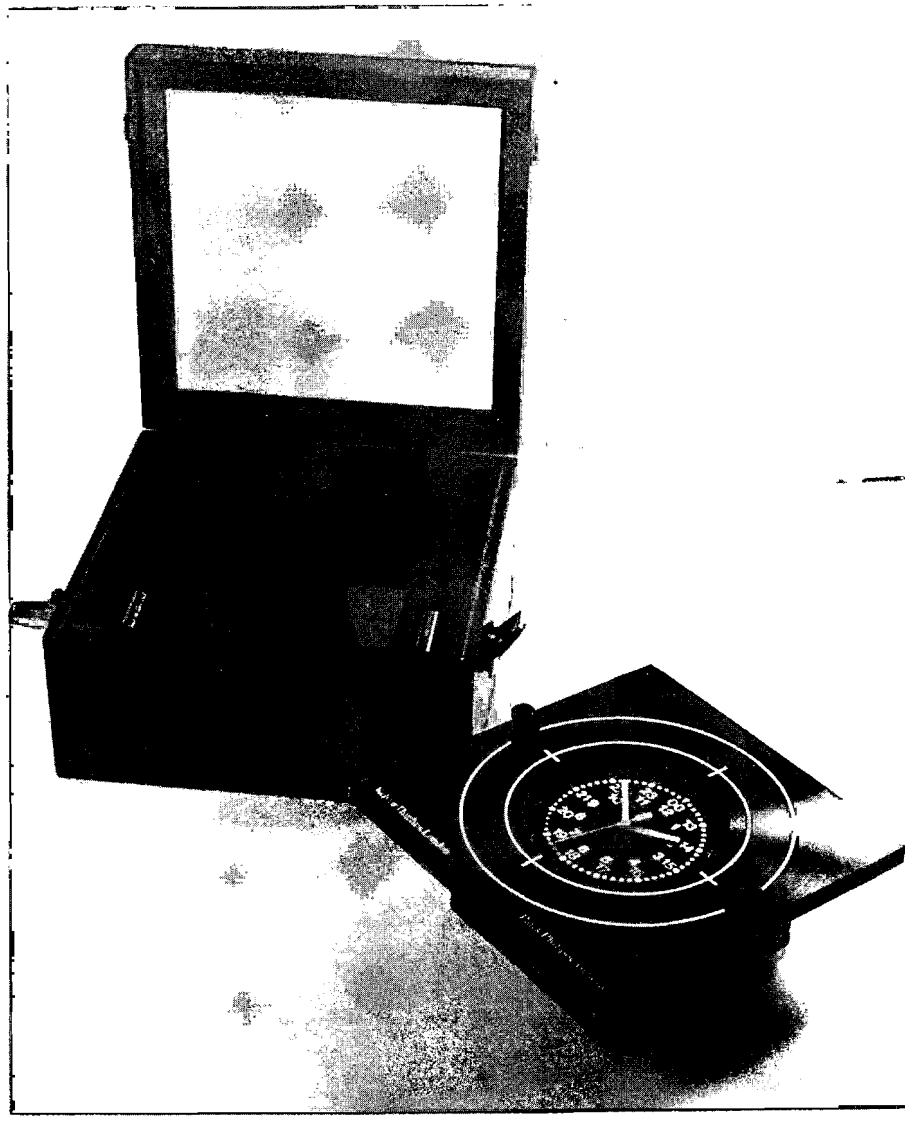


Figure 8. Chronometer case with spare batteries. Face plate and captive bolts.



Figure 9. Outer spacing case. Back plate with bolts and spacers. Quartz crystal movement.

1. Undo the quick release catches and open the hinged lid.
2. Unscrew the two captive bolts on the dial plate using a suitable coin.
3. Carefully lift the dial plate and movement from the chronometer case.
4. Holding the dial plate (face downwards) unscrew the four bolts on the rear of the movement case.
5. Remove backplate, outer spacing case and the four bolts – the makers recommend that this be carried out with the movement case upwards.

Starting the Quartz Crystal Chronometer against a Time Signal

(Refer to Figure 10.)

1. Disassemble the chronometer.
2. Press the "stop" button.
3. Pull the "hand set" knob outwards and turn gently in the direction shown and set to the time of the next radio time signal. Release the hand set knob.
4. Await the time signal and, at the moment of transmission, release the stop button.
5. Reassemble the chronometer and tighten the back plate screws firmly.
6. Check the error as soon as possible.

The above procedure requires some time and a little practice. Unless previously attempted, it is probably better carried out in port.

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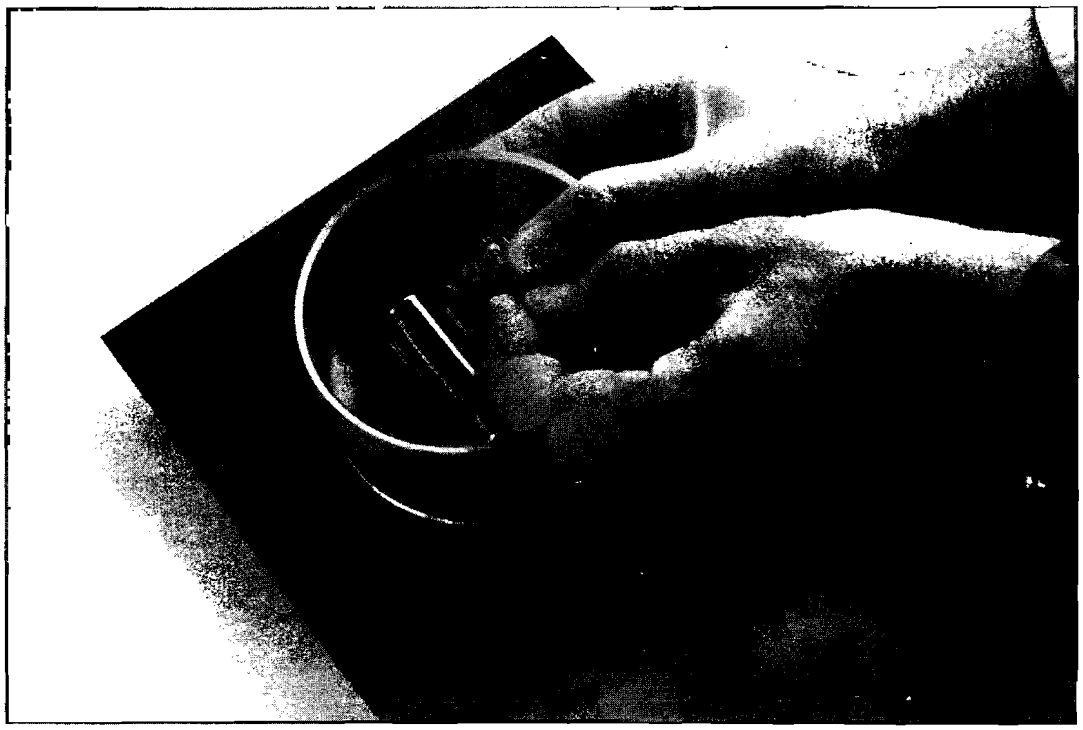


Figure 10. Depressing the "stop" button (right thumb) and operating the "hand set" knob (left thumb and forefinger).

Battery Replacement

1. Disassemble the chronometer.
2. Remove the spare battery found in the recess beneath the faceplate.
3. Using the tab provided, remove the battery cover.
4. Change the battery and immediately discard the old one.
5. Replace the battery cover firmly and write the new battery change date in the space provided.
6. Reassemble the chronometer making sure to tighten the backplate screws.
7. Check the error as soon as possible.

Whenever possible insert a new spare battery in the spare battery recess.

Specifications

The following specifications refer to the Type TC quartz crystal chronometer.

Dimensions	181 mm ($7\frac{1}{8}$ ins) square 99 mm ($3\frac{7}{8}$ ins) high
Weight	2240 gms (4 lbs 15 oz)
Daily rate stability (18° C to 28° C)	0·1 sec day

Stability at constant temperature	0·02 sec/day
Temperature range	−10° C to +60° C
Battery life	1 year (approx.)
Battery	One Mallory ZM9 or MN1500 1·5 volt Size AA

Questions

1. What is the purpose of a marine chronometer?
2. What time does a marine chronometer keep?
3. What is the importance of a chronometer's daily rate?
4. "It is unimportant if a chronometer is fast or slow". Comment on this statement.
5. What information is recorded in the Chronometer Log?
6. Explain chronometer time, corrected chronometer time and how to decide the correct GMT.
7. The chronometer shows 9 hrs 12 m 10 s at the time of taking a sight in longitude 150° W. Explain, in detail, if this time should be used for extracting data from the *Nautical Almanac*. Assume values.
8. Describe the traditional marine chronometer.
9. Describe the quartz crystal chronometer.
10. List the main parts of the traditional marine chronometer.
11. Explain the principle of the traditional marine chronometer.
12. Explain how you would unpack a traditional marine chronometer.
13. Explain how you would start a chronometer against a radio time signal.
14. List the steps in winding a chronometer.
15. Describe how you would pack a chronometer.
16. What is the purpose of the cork wedges supplied with a chronometer?
17. How would you regulate a chronometer?
18. How often should a chronometer be cleaned and by whom?
19. List any tests to which a marine chronometer is subjected.
20. What is the accuracy of the marine chronometer?
21. List some important parts of the quartz crystal chronometer.
22. How would you replace a battery in a quartz crystal chronometer?
23. What special note would you make when changing a battery?
24. What type of battery is used?
25. Compare the traditional and quartz crystal marine chronometers.

Nautical Almanac Extracts, which are required for working examples and exercises, are included on Page 880.

Chapter 22

Latitude and Time of Meridian Passage

During the course of the day a celestial body will describe a circle around the pole and cross, or transit, the observer's meridian.

Under certain conditions a body will cross the observer's meridian twice, once at its highest daily altitude and once at its lowest daily altitude. In such cases the body (which is said to be "circumpolar") reaches its highest daily altitude when on the observers "upper meridian" and its lowest daily altitude on the "lower meridian". But under most conditions we are concerned with bodies which cross the observer's meridian only once in their daily path.

As the body crosses the meridian it will always bear either due North or due South of the observer. This is important to the navigator because a position line obtained from an observation always lies at right angles to the bearing, or azimuth, of the observed body. In the case of a meridian altitude observation, the position line will always run East – West (at right angles to the N.–S. bearing) and so co-incide with a parallel of latitude. Such an observation has great value because it enables the navigator to determine the exact latitude of the ship.

Finding the Latitude

The sextant altitude of a body is observed as it crosses the observer's meridian and, at upper meridian passage, reaches its highest altitude. As explained in an earlier chapter, corrections are then applied to convert the sextant altitude to true altitude which is named N or S according to the bearing. True altitude is then subtracted from 90° to obtain the true zenith distance which is named opposite to the bearing. Zenith distance is then combined with the body's adjusted declination in order to find the observer's true latitude. Refer quickly to Figure 5 and note that:

Zenith Distance (ZX) + Declination (QX) = Observer's South Latitude (ZQ).

In the case of circumpolar bodies observed on the observer's lower meridian (i.e. "below the pole") the latitude is found by combining true altitude with body's polar distance (90° – Declination).

Time of Meridian Passage

Before taking the body's meridian altitude it is first necessary to calculate the GMT of meridian passage. This is necessary so as to make the observation at the correct time and in order to enter the *Nautical Almanac* to extract the declination of the sun, moon, planet or star being observed. Stars and planets can be difficult to "find" and for these bodies it is advisable to pre-calculate the approximate meridian altitude to set on the sextant.

Finding the Time of Meridian Passage

When a celestial body is on the observer's upper meridian its Local Hour Angle (LHA) is 000°. For an observer in West longitude the body's Greenwich Hour Angle (GHA) when on the meridian equals LHA + West longitude i.e.

When LHA = 000° the GHA = the Observer's West Longitude

East longitude can be expressed as West longitude by subtracting the East longitude from 360° and the above expression is still valid as shown in Figures 1 and 2.

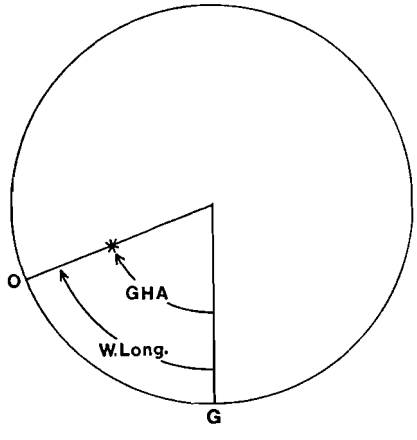


Figure 1.
West Longitude.

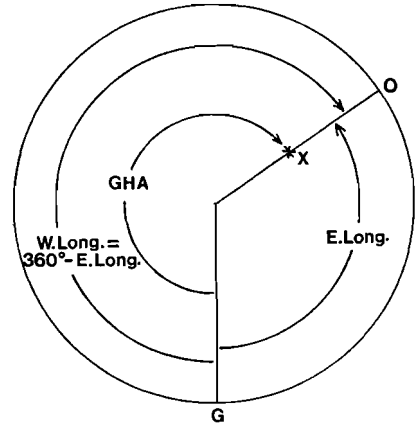


Figure 2.
East Longitude.

Knowing the GHA of the body when on the meridian, the GMT of meridian passage of the sun, moon and planets can be obtained by inspection from the *Nautical Almanac's* daily pages. This is achieved by inspecting their hourly tabulated values for GHA and the increment tables (for minutes and seconds) at the rear of the Almanac.

In the case of the moon and planets the "*v*" correction tables are also used.

In the case of a star

$$(360° - \text{SHA}^*) + \text{or} - \text{Longitude} = \text{GHA}\,\Upsilon$$

and time of meridian passage is found by inspection of GHA ♈ in the Almanac's daily pages.

LMT Meridian Passage Tabulated in the Nautical Almanac

The LMT of meridian passage across the Greenwich Meridian is tabulated in the *Nautical Almanac.*

Sun and Moon	values for each day
Planets	„ „ every 3rd day.

The time quoted is approximately the LMT of passage for any other meridian and can be used to check the Greenwich date of meridian passage – this is an important point to check. To check the Greenwich date proceed as follows:

$$\text{LMT Meridian Passage} \begin{matrix} + \text{ West Longitude} \\ - \text{ East Longitude} \end{matrix} = \text{GMT Meridian Passage.}$$

For planets, meridian passage information is given in the *Nautical Almanac* on each left hand page in the bottom right hand corner—as shown in Figure 3. For the sun and moon the information is given on each right hand page in the bottom right hand corner—as shown in Figure 4. Use of this information is demonstrated in Examples 5–8.

	S.H.A.	Mer. Pass.
	° ′	h M
Venus	304 08·0	9 33
Mars	347 37·3	6 39
Jupiter	159 20·8	19 09
Saturn	99 01·9	23 09

Figure 3.
(June 24–26).

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Upper.	MOON Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
24	02 06	02 13	12 02	18 15	05 49	07	
25	02 19	02 26	12 02	19 07	06 41	08	◐
26	02 32	02 38	12 03	20 01	07 34	09	

Figure 4.
(June 24–26).

The following examples will illustrate the method of working meridian altitude observations of the sun, planets and moon under various circumstances and circumpolar stars.

LATITUDE BY MERIDIAN ALTITUDE (SUN)

1. Find the GMT of meridian passage by writing down the Observer's West longitude equal to GHA Sun. (Convert East longitude to a West longitude by subtracting from 360°.) Take the nearest tabulated GHA less than the West longitude and note day and hours. Subtract tabulated GHA from West longitude to give increment, and note minutes and seconds. Add hours, minutes and seconds to give GMT.
2. Take Sun's declination for GMT from *Nautical Almanac*.
3. Correct observed altitude and subtract from 90° to give true meridional zenith distance.
4. Combine declination and zenith distance to find latitude.

Example 1 Lat. and Dec. Same Name. W. Long.
(Refer to Figure 5)

On January 10, in Longitude 32° 45′ W. the sextant meridian altitude of the Sun's L.L. was 63° 50·0′ North of observer. I.E. 3·3′ off the arc. H.E. 7·5 m.
Find the Observer's latitude.

At meridian passage: GHA = Observer's W. Long.

GHA Sun	32° 45·0′		
From Almanac	28 07·2	gives	10 d 14 h
Increment	4 37·8	gives	18 m 31 s
	GMT Meridian Passage		10 d 14 h 18 m 31 s

Dec. for 14h	S. 21° 58·6′	$d = -0{\cdot}4'$
d Corr. for 18m	(−) 0·1	
	S. 21° 58·5′	

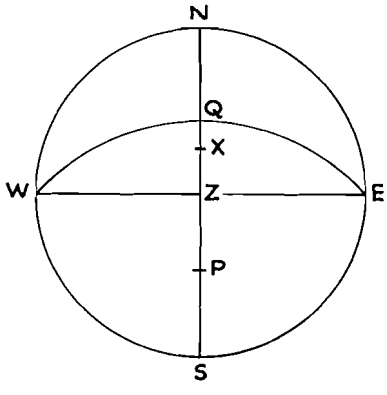


Figure 5.

Sext. alt. L.L.	63° 50·0′	N.	
I.E.	(+) 3·3		
Obs. alt. L.L.	63 53·3		
Dip	(−) 4·8		
App. alt. L.L.	63 48·5		
Main Corr.	(+) 15·7		
True alt.	64 04·2	N.	(*NX*)
	90		(*NZ*)
True Zen. Dist.	25 55·8	S.	(*ZX*)
Dec.	21 58·5	S.	(*QX*)
Latitude	47 54·3	S.	(*ZQ*)

In Figure 5:

NESW	The Rational Horizon.	*ZX*	Zenith Distance.
P	Pole	*PX*	Polar Distance.
Z	Zenith	*PZ*	co-Latitude.
X	Body.	*PS*	Observer's lower meridian.
WQE	Equinoctial.	*NX*	True altitude.
WZE	Prime Vertical.	*QX*	Declination.
NQZP	Observer's upper meridian.	*ZQ*	Latitude.

Example 2 Lat. and Dec. Same Name. E. Long.
(Refer to Figure 6)

On June 15 in Longitude 88° 42′ E. the sextant meridian altitude of the Sun's U.L. was 87° 32·0′ bearing South, I.E. 1·3′ on the arc. H.E. 7·5 m. Calculate the observer's latitude.

At meridian passage: GHA = Observer's W. Long = 360° − E. Long.

	360° 00′		
E. Long.	88° 42′	E.	
GHA Sun	271° 18·0′		
From Almanac	269° 56·9′	gives	15 d 06 h
Increment	1° 21·1′	gives	5 m 24 s
GMT Meridian Passage			15 d 06 h 5 m 24 s

Dec. for 06h	N. 23° 17·4′	$d = +0{\cdot}1'$
d Corr. for 5m (+)	0·0	
Dec.	N. 23° 17·4′	

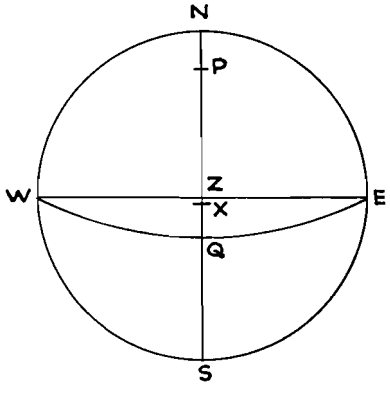


Figure 6.

Sext. alt. U.L.	87° 32·0′ S.	
I.E. (−)	1·3′	
Obs. alt. U.L.	87° 30·7′	
Dip. (−)	4·8′	
App. alt. U.L.	87° 25·9′	
Main Corr. (−)	15·9′	
True alt.	87° 10·0′ S.	(SX)
	90°	(SZ)
True Zen. Dist.	2° 50·0′ N.	(ZX)
Dec.	23° 17·4′ N.	(QX)
Latitude	26° 07·4′ N.	(ZQ)

SQZP Observer's upper meridian.
PN Observer's lower meridian.
SX True altitude.

Example 3 Lat. and Dec. Different Name. W. Long.
(Refer to Figure 7)

On September 23, in Longitude 29° 15′ W. the sextant meridian altitude of the Sun's L.L. was 48° 36·0′ bearing South, I.E. 1·7′ off the arc. H.E. 15·5 m. Calculate the observer's latitude and the Zone Time of meridian passage (Zone + 2).

GHA = Observer's W. Long.

GHA Sun	29° 15·0′		
From Almanac	16° 52·6′	gives	23 d 13 h
Increment	12° 22·4′	gives	49 m 29 s
GMT Meridian Passage			23 d 13 h 49 m 29 s
Zone (+2)			2 h
Zone Time Meridian Passage			23 d 11 h 49 m 29 s

Note: Zone Time + Zone = GMT

Dec. for 11h	N. 0° 00·2′	$d - 1{\cdot}0'$
d Corr. for 49m (−)	0·8′	
Dec.	S. 0° 00·6′	

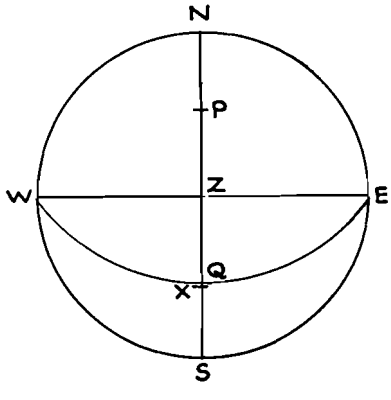


Figure 7.

Sext. alt. L.L.		48° 36·0′	S.
I.E.	(+)	1·7	
Obs. alt. L.L.		48 37·7	
Dip.	(−)	6·9	
App. alt. L.L.		48 30·8	
Main Corr.	(+)	15·1	
True alt.		48 45·9	S. (SX)
		90	
True Zen. Dist.		41 14·1	N. (ZX)
Dec.		0 00·6	S. (QX)
Latitude		41° 13·5′	N. (ZQ)

Note: In this example the d correction changes the name of the declination from N. to S.

Example 4 Lat. and Dec. Different Names. E. Long.

(Refer to Figure 8)

On June 21, in Longitude 98° E. the sextant meridian altitude of the Sun's U.L. was 55° 02′ the observer being South of the Sun, I.E. 1·5′ off the arc, H.E. 7·5 m. Calculate the observer's latitude.

GHA = Observer's W. Long. = 360° − E. Long.

		360° 00·0′		
E. Long.	(−)	98 00·0		
GHA Sun		262 00·0		
From Almanac		254 37·5	gives	21 d 05 h
Increment		7° 22·5′	gives	29 m 30 s
		GMT Meridian Passage		21 d 05 h 29 m 30 s
Dec. for 5h		N. 23° 26·4′	*d* − 0·0′	
d Corr. for 29m		0·0		
Dec.		N. 23° 26·4′		

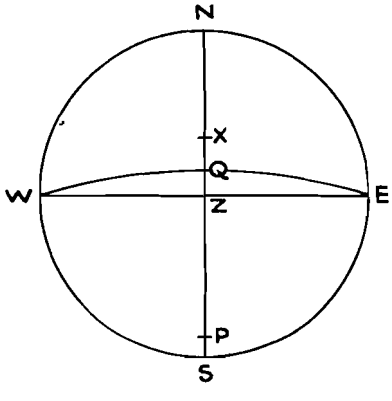


Figure 8.

Sext. alt. U.L.		55° 02·0′	N.
I.E.	(+)	1·5	
Obs. alt. U.L.		55 03·5′	
Dip.	(−)	4·8	
App. alt. U.L.		54 58·7	
Main Corr.	(−)	16·5	
True alt.		54 42·2	N. (*NX*)
		90	
True Zen. Dist.		35 17·8	S. (*ZX*)
Dec.		23 26·4	N. (*QX*)
Latitude		11° 51·4′	S. (*ZQ*)

Exercise 1(Sun)

An appropriate figure should be drawn for each example, lettered and marked so that the student can see what the arcs represent.

1. On January 7, in Longitude 37° 30′ W. the sextant meridian altitude of the Sun's L.L. was 41° 22·5′, bearing South, I.E. 2·5′ off the arc, H.E. 7·5 m. Find the observer's latitude.
2. On June 19, in Longitude 139° 30′ W. the sextant meridian altitude of the Sun's L.L. was 82° 34′, bearing South, I.E. 3·6′ on the arc, H.E. 10 m. Find the observer's latitude.
3. On June 15, in Longitude 84° W. the sextant meridian altitude of the Sun's U.L. was 74° 57·5′, bearing North, I.E. 2′ on the arc, H.E. 12 m. Find the observer's latitude.

4. On September 27, in Longitude 62° 38′ E. the observed meridian altitude of the Sun's L.L. was 68° 12·5′, the observer being North of the Sun, H.E. 7·5 m. Find the observer's latitude.
5. On December 25, in Longitude 10° 30′ E. the sextant meridian altitude of the Sun's U.L. was 56° 19′, bearing North, I.E. 3′ off the arc, H.E. 7·3 m. Find the observer's latitude.
6. On September 23, in Longitude 142° 30′ E. the sextant meridian altitude of the Sun's L.L. was 58° 42·5′, bearing South, I.E. 2·5′ on the arc, H.E. 10 m. Find the observer's latitude.
7. On September 24, in Longitude 125° E. the observed meridian altitude of the Sun's L.L. was 50° 12′, observer South of the Sun, H.E. 12 m. Find the observer's latitude.
8. On June 22, on the Greenwich Meridian, the sextant meridian altitude of the Sun's L.L. was 46° 18·5′, bearing North I.E. 2′ off the arc, H.E. 15·2 m. Find the observer's latitude.

Answers

	GMT	Dec.	True alt.	Lat.
1.	7 d 14 h 36 m 16 s	S. 22° 23·1′	41° 35·4′	26° 01·5′ N.
2.	19 d 21 h 19 m 13 s	N. 23° 25·7′	82° 40·6′	30° 45·1′ N.
3.	15 d 17 h 36 m 18 s	N. 23° 18·7′	74° 33·3′	7° 52·0′ N.
4.	27 d 07 h 40 m 39 s	S. 1° 28·2′	68° 23·3′	20° 08·5′ N.
5.	25 d 11 h 17 m 57 s	S. 23° 24·3′	56° 00·5′	57° 23·8′ S.
6.	23 d 02 h 22 m 39 s	N. 0° 10·5′	58° 49·8′	31° 20·7′ N.
7.	24 d 03 h 32 m 17 s	S. 0° 14·0′	50° 21·1′	39° 52·9′ S.
8.	22 d 12 h 01 m 47 s	N. 23° 26·5′	46° 28·7′	20° 04·8′ S.

LATITUDE BY MERIDIAN ALTITUDE (PLANET)

In order to obtain a successful and useful meridian altitude of one of the four planets tabulated in the *Nautical Almanac,* it is necessary to know the GMT of the planet's meridian passage, the approximate altitude to set on the Sextant, the planet's bearing (North or South), and whether, or not, there will be a suitably clear horizon at the time of meridian passage.

The planet Venus (and possibly Jupiter) can sometimes be observed in daylight for part of each year when it is not too close to the sun for observation. For the other planets the time of meridian passage must coincide with the time of morning or evening twilight to ensure a visible horizon.

The Planet Notes and Planet Diagram provided near the front of the *Nautical Almanac* enable the observer to see, at a glance, whether a planet is a morning or evening star, or too close to the sun for observation.

Since the local time of meridian passage of a planet can occur at any time, the GMT and LMT of passage may not be on the same day. In consequence, if the time of passage is to be obtained by inspection, as previously described, it may be necessary to check the Greenwich date of meridian passage using the LMT of passage tabulated at the bottom of the daily pages of the *Nautical Almanac.* Strictly speaking this is the LMT of passage across the Greenwich meridian, but it can be taken to be approximately the LMT for any other meridian without appreciable error. The following example should make this clear, but in practice, the check could easily be done mentally by applying longitude in time to the tabulated LMT.

Example 5 (To calculate GMT of passage and approximate altitude)
(Refer to Figure 9)

On December 26 a ship in D.R. 45° 00′ S. 170° 50′ W. Calculate the approximate sextant

meridian altitude of the planet Mars as a guide to setting the sextant for observation, I.E. 1·5′ on the arc, H.E. 12 m. Also estimate the GMT, and Zone Time of the planet's meridian passage for Zone (+11).

To Check Greenwich Date of Meridian Passage

		d	h	m
From Almanac:	LMT Mer. Pass.	25	20	40
	LMT Mer. Pass.	28	20	29
	Diff. for 3 days		(−)	11
	Diff. for 1 day		(−)	3·7

	d	h	m
LMT Mer. Pass.	25	20	40
Diff. for 1 day (+)	1	(−)	3·7
LMT Mer. Pass.	26	20	36·3
W. Long. (time)(+)		11	23·3
Approx. GMT Mer. Pass	27	07	59·6 ✓

Long. in time from tables 11 h 23 m 20 s

At meridian passage: GHA = Observer's West longitude

GHA Mars	170° 50·0′		
From Almanac	156 22·4	gives	27 d 07 h
Increment + v Corr.	14 27·6		
v = 2·2, Corr. (−)	2·1		
Increment	14° 25·5′	gives	57 m 42 s ✓

GMT Meridian Pass. 27 d 07 h 57 m 42 s
Zone (+11) 11 h
Zone Time Mer. Pass. 26 d 20 h 57 m 42 s

Note: Zone Time + Zone = GMT so GMT − Zone = Zone Time.

Dec. for 07 h	N. 18° 36·9′	d = +0·1′
d Corr. for 57 m (+)	0·1	
Dec.	N. 18° 37·0′	

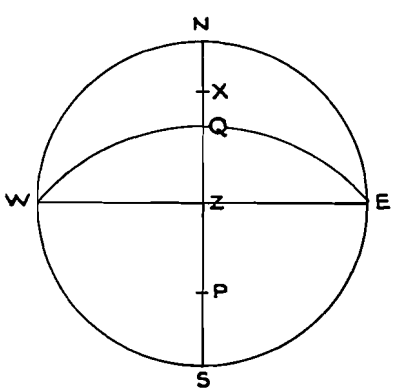


Figure 9.

D.R. Lat.		45° 00′	S. (ZQ)
Dec.		18 37	N. (QX)
Approx. Mer. Zen. Dist.		63 37	S. (ZX)
		90	
App. True alt.		26° 23·0′	N. (NX)
Add. Corr.	(−)	0·3	see note
Main Corr.	(+)	1·9	see note
Dip.	(+)	6·1	see note
I.E.	(+)	1·5	see note
Approx. Sext. Mer. alt.		26° 32·2′	N. ✓

Bearing North

Note: Signs are the reverse of those normally applied to the Sextant altitude.

Example 6

On June 25, in Longitude 166° 15′ E. the sextant meridian altitude of the planet Jupiter was 59° 49′, South of the observer, I.E. 1′ off the arc. H.E. 12 m. Find the observer's latitude.

		d	h	m
Check for Greenwich date from Almanac:	LMT Mer. Pass.	25	19	09
	E. Long. in time (−)		11	05
	Approx. GMT Mer. Pass.	25	08	04

GHA = Observer's W. Long. = 360° − Observer's E. Long.

	360° 00·0′		
E. Long.	(−) 166 15·0		
GHA Jupiter	193° 45·0′		
From Almanac	(−) 192 17·9	gives	25 d 08 h
Inc. + v Corr.	1° 27·1′		
(v = 2·4) v Corr.	(−) 0·2		
Inc.	1° 26·9′	gives	5 m 47 s
	GMT Meridian Passage		25 d 08 h 05 m 47 s

Dec. for 08 h	S. 7° 17·1′	d = 0·0′
d Corr. for 5 m	0·0	
Dec.	S. 7° 17·1′	

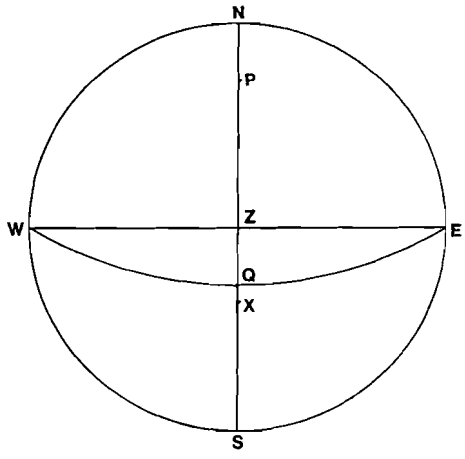


Figure 10.

Sext. alt.		59° 49·0′ S.
I.E.	(+)	1·0
Obs. alt.		59° 50·0′
Dip.	(−)	6·1
App. alt.		59° 43·9′
Main Corr.	(−)	0·6
True alt.		59° 43·3′ S. (SX)
		90
True Zen. Dist.		30° 16·7′ N. (ZX)
Dec.		7 17·1 S. (QX)
Latitude		22° 59·6′ N. (ZQ)

Exercise 2 (Planets)

1. On June 16, in D.R. 44° 22′ N., 163° 35′ W. Find the approximate sextant meridian altitude of the planet Venus to set on the Sextant. I.E. 1·5′ on the arc; H.E. 15·8 m.
2. On January 6, in D.R. 38° 17′ N., 151° 15′ E. Calculate the approximate sextant meridian altitude of the planet Venus to set on the Sextant. I.E. 2′ off the arc; H.E. 10 m.
3. On January 10, on the Greenwich Meridian the sextant meridian altitude of Jupiter was 42° 20′ bearing South. I.E. 1·5′ off the arc; H.E. 7·5 m. Find the observer's latitude.
4. On June 23, in Longitude 18° W., the sextant altitude of Jupiter when on the meridian was 41° 41′, South of the observer. I.E. 0·5′ on the arc; H.E. 12 m. Find the observer's latitude.

Answers

	GMT	Dec.	Sext. alt.	Bearing	Lat.
1.	16 d 20 h 21 m 03 s	N. 15° 16·3′	61° 03·3′	South	—
2.	6 d 04 h 06 m 22 s	S. 14° 06·5′	37° 41·4′	South	—
3.	10 d 06 h 35 m 04 s	S. 10° 10·2′	—	—	37° 34·2′ N.
4.	23 d 20 h 28 m 34 s	S. 7° 16·2′	—	—	41° 10·5′ N.

LATITUDE BY MERIDIAN ALTITUDE (MOON)

A latitude by Meridian Altitude of the moon can be found in the same way as for other bodies, i.e.

$$\text{Latitude} = \text{Zenith Distance} \pm \text{Declination}.$$

The procedure is as follows:

1. Estimate the GMT of meridian passage, checking the Greenwich date.
2. Observe the upper or lower limb of the moon when on the meridian.
3. Correct the Observed Altitude using the Altitude Correction Tables—Moon contained in the *Nautical Almanac* or Nautical Tables. To use these tables it is necessary to extract the moon's horizontal parallax (HP) from the Almanac.
4. Proceed as for other bodies.

Example 7
(Refer to Figure 11)

On September 20, in Longitude 150° 20′ E. the sextant meridian altitude of the moon's upper limb was 57° 51′, bearing North. I.E. 1′ on the arc; H.E. 12 m. Calculate the latitude.

		d	h	m	s
Check for Greenwich date: Approx. LMT Mer. Pass.		20	18	25	
	E. Long. (time)		10	01	20
Approx. GMT Mer. Pass.		20	08	23	40

GHA = Observer's W. Long = 360° − E. Long.

		360°		
E. Long	(−)	150 20·0		
GHA Moon		209° 40·0′		
From Almanac	(−)	209 25·3	gives	20 d 08 h
Increment + v Corr.		0° 14·7′		
(v = 8·0) v Corr.	(−)	0·2		
Increment		0° 14·5′	gives	01 m 01 s

GMT Meridian Passage 20 d 08 h 01 m 01 s

Dec. for 08 h	S. 18° 37·0′	d −1·1	HP 57·8′
d Corr. for 1 m	0·0		
Dec.	S. 18° 37·0′		

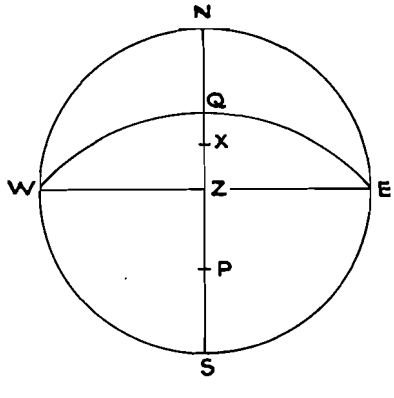


Figure 11.

Sext. alt. U.L.		57° 51·0′ N.
I.E.	(−)	1·0
Obs. alt. U.L.		57° 50·0′
Dip.	(−)	6·1
App. alt. U.L.		57° 43·9′
First Corr.	(+)	40·9
Second Corr.	(+)	3·7
		58° 28·5′
Subtract for U.L.	(−)	30·0
True alt.		57° 58·5′ N. (NX)
		90
True Zen. Dist.		32° 01·5′ S. (ZX)
Dec.		18 37·0 S. (QX)
Latitude		50° 38·5′ S. (ZQ)

Example 8

(Refer to Figure 12)

On June 25, in Longitude 135° 36′ W., the sextant meridian altitude of the moon's lower limb was 43° 02′, bearing South, I.E. 1·4′ on the arc; H.E. 10 m. Calculate the observer's latitude.

	d	h	m
Check for Greenwich date: Approx. LMT Mer. Pass.	25	19	07
W. Long. in time (+)		9	02·4
Approx. GMT Mer. Pass.	26	04	09·4

At meridian passage:

GHA = Observer's W. Long.

GHA Moon	135° 36·0′	
From Almanac	128 28·0	gives 26 d 04 h
Increment + v Corr.	7 08·0	
(v = 8·6) v Corr. (−)	4·2	
Increment	7° 03·8′	gives 29 m 36 s
GMT Meridian Passage		26 d 04 h 29 m 36 s

Dec. for 04 h	S. 10° 40·6′	d +9·8′	HP 59·4′
d Corr. for 29 m (+)	4·8		
Dec.	S. 10° 45·4′		

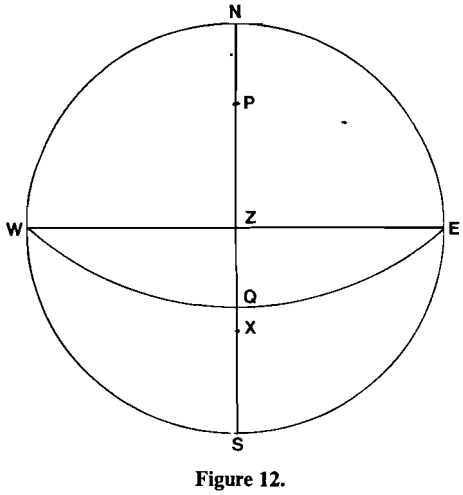


Figure 12.

Sext. alt. L.L.		43° 02·0′ S.
I.E.	(−)	1·4
Obs. alt. L.L.		43° 00·6′
Dip.	(−)	5·6
App. alt. L.L.		42° 55·0′
First Corr.	(+)	51·9
Second „	(+)	6·7
True alt.		43° 53·6′ S. (SX)
		90
True Zen. Dist.		46° 06·4′ N. (ZX)
Dec.		10 45·4 S. (QX)
Latitude		35° 21·0′ N. (ZQ)

Exercise 3 (Moon)

1. On September 19, in Longitude 60° W., the observed meridian altitude of the moon's L.L. was 53° 06′, bearing North. H.E. 12 m. Find the latitude.
2. On January 5, in Longitude 160° E., the sextant meridian altitude of the moon's U.L. was 42° 01′ North of the observer, I.E. 2·5′ on the arc; H.E. 18 m. Find the observer's latitude.
3. On January 9, in Longitude 150° 30′ W., the observed meridian altitude of the moon's L.L. was 44° 46′, bearing South. H.E. 15·5 m. Find the observer's latitude.
4. On December 25, in Longitude 140° 21′ E., the sextant meridian altitude of the moon's U.L. was 58° 40′ South of the observer, I.E. 2′ on the arc; H.E. 21 m. Find the observer's latitude.
5. On December 23, in Longitude 20° W., the sextant meridian altitude of the moon's U.L. was 71° 40′, bearing North, I.E. 1·5′ off the arc; H.E. 15·3 m. Find the observer's latitude.
6. On January 4, on the Greenwich Meridian, the sextant meridian altitude of the moon's L.L. was 53° 41′ South of the observer, I.E. 0·5′ on the arc; H.E. 12 m. Find the observer's latitude.

Answers

	GMT	Dec.	True alt.	Lat.
1.	19 d 21 h 39 m 23 s	S. 18° 41·9′	53° 49·9′	54° 52·0′ S.
2.	5 d 13 h 07 m 17 s	N. 18° 31·8′	42° 17·6′	29° 10·6′ S.
3.	9 d 13 h 22 m 31 s	N. 4° 17·7′	45° 36·9′	48° 40·8′ N.
4.	25 d 14 h 10 m 13 s	N. 18° 45·9′	58° 43·1′	50° 02·8′ N.
5.	23 d 23 h 34 m 24 s	N. 17° 48·0′	71° 36·7′	0° 35·3′ S.
6.	4 d 23 h 15 m 43 s	N. 19° 18·1′	54° 24·2′	54° 53·9 N.

LATITUDE BY MERIDIAN ALTITUDE (STAR)

An observer who wishes to obtain a latitude by taking a meridian altitude of a star first needs to know which (if any) stars are going to be crossing his meridian during the period of morning or evening twilight. For planning purposes, the LMT given in the *Nautical Almanac* for Civil Twilight on the Greenwich meridian can be taken, for practical purposes, as the LMT of the occurrence on any other meridian. At this time, the sun is 6° below the horizon and the brightest stars are visible with the horizon clearly defined. By applying the observer's D.R. Longitude in time to the LMT, the GMT of Civil Twilight is obtained, and this is used to take out the GHA Aries by inspection from the appropriate daily page. By applying the observer's D.R. Longitude to the GHA Aries, the LHA Aries at the time of twilight is obtained.

At the upper meridian passage of a Star:

$$\text{LHA}^* = 360°$$
$$\text{LHA}\Upsilon + \text{SHA}^* = \text{LHA}^*$$
$$\therefore \text{LHA}\Upsilon + \text{SHA}^* = 360°$$
$$\text{and} \quad \text{SHA}^* = 360° - \text{LHA}\Upsilon$$

In other words, any star having an SHA equal to $360° - \text{LHA}\Upsilon$ will be on the observer's upper meridian at the required twilight time.

To Calculate the Time of Meridian Passage of a Star

Hourly values of GHA of individual stars are not tabulated in the *Nautical Almanac,* but the GHA Aries (♈) is, and so is each star's Sidereal Hour Angle (SHA). However, as with the other bodies, the GHA of a star on the observer's upper meridian equals the observer's West longitude and therefore the following applies:

$$\text{GHA}^* = \text{Observer's West Longitude}$$
$$\text{and} \quad \text{GHA}^* = \text{GHA}\,\Upsilon + \text{SHA}^*$$
$$\therefore \text{GHA}\,\Upsilon + \text{SHA}^* = \text{Observer's West Longitude.}$$
$$\text{and} \quad \text{GHA}\,\Upsilon = \text{Observer's West Longitude} - \text{SHA}^*$$

By subtracting the chosen star's SHA from the observer's West longitude, the GHA Aries at the instant when the star is on the meridian is obtained and this by comparison with tabulated hourly values of GHA Aries and using the Increment Tables enables the GMT of the star's transit to be ascertained.

The following examples should illustrate the method of working.

Example 9

(Refer to Figure 13)

Name stars which might be suitable for observing a meridian altitude during morning twilight on January 5 in D.R. 30° 00′ N., 41° 30′ W. I.E. 1·5′ on the arc. H.E. 20 m. Calculate the approximate sextant altitude of one such star as a guide for setting the sextant and state its GMT of transit.

	d	h	m
From *Nautical Almanac*: LMT Civil Twilight (30° N.)	5	06	30
W. Longitude in time (+)		2	46
GMT Civil Twilight (30° N.)	5	09	16

For this GMT from *Nautical Almanac*:

GHA ♈ 5 d 09 h		239° 27·1′
Increment 16 m 00 s		4° 00·7
GHA ♈		243° 27·8′
W. Longitude	(−)	41° 30·0′
LHA ♈		201° 57·8′
		360°
SHA*		158° 02·2′

Possible stars with SHA's approximately 158°

	SHA	Dec.
Alkaid	153° 31·8′	N. 49° 31·1′
Spica	159° 15·2′	S. 10° 56·6′
Alioth	166° 57·2′	N. 56° 10·9′

To find GMT of transit of Star *Spica*:
At transit: GHA♈ = Observer's West Longitude − SHA*

Observer's West Long.		41° 30·0′		
	(+)	360		
		401° 30·0′		
SHA* Spica −	(−)	159 15·2		
GHA♈		242° 14·8′		
From Almanac	(−)	239 27·1	gives	5 d 09 h
Increment		2° 47·7′	gives	11 m 09 s
GMT Meridian Passage Spica				5 d 09 h 11 m 09 s

To estimate Star Spica's Altitude on Meridian for setting the Sextant

D.R. Lat.		30° 00·0′ N.	(*ZQ*)
Dec.		10 56·6 S.	(*QX*)
Approx. Zen. Dist.		40° 56·6′ N.	(*ZX*)
		90	
Approx. Mer. alt.		49° 03·4′ S.	(*SX*)
Main Corr.	(+)	0·8	Applied with usual sign (+) or (−) reversed.
Dip.	(+)	7·9	
I.E.	(+)	1·5	
Approx. Sext. Mer. alt.		49° 13·6′	Bearing South.

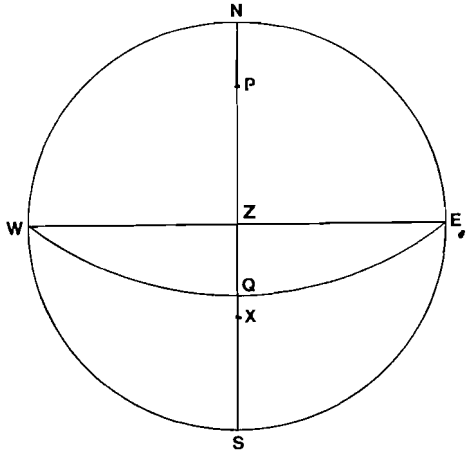


Figure 13.

Example 10
(Refer to Figure 13.)

At 0911 GMT January 5, D.R. 30° N., 41° 30′ W., the sextant meridian altitude of the star Spica, bearing South was 49° 24′. I.E. 1·5′ on the arc; H.E. 20 m. Find the observer's latitude.

Sext. Mer. alt.* Spica		49° 24·0′ S.	
I.E.	(−)	1·5	
Obs. Mer. alt.*		49° 22·5	
Dip.	(−)	7·9	
App. Mer. alt.*		49° 14·6′	
Main Corr.	(−)	0·8	
True Mer. alt*		49° 13·8′ S.	(*SX*)
		90	
True Mer. Zen. Dist.*		40° 46·2′ N.	(*ZX*)
Dec.*		10 56·6 S.	(*QX*)
Latitude		29° 49·6′ N.	(*ZQ*)

Exercise 4 (Stars)

1. Name five stars whose SHA's are within 5° either side of the meridian and which might be visible and suitable for meridian altitudes at about the time of AM Civil Twilight on September 22 in D.R. 20° S. 80° E.
2. Calculate the GMT of meridian passage of the star Capella in morning twilight on 22 September, and estimate the sextant meridian altitude as a guide for setting the Sextant, in D.R. 20° S. 80° E., I.E. 2·0′ on the arc; H.E. 14 m.
3. Name a North declination star that would be suitable for a meridian altitude at about the time of PM Civil Twilight on June 25 in D.R. 40° N. 20° W. Also calculate the GMT of the star's transit and estimate its approximate altitude on the meridian as a guide to setting the Sextant; H.E. 20 m., I.E. 1·5′ off the arc.
4. Name a South declination star that would be suitable for a meridian altitude at about the time of AM Civil Twilight on June 26 in D.R. 52° S. 120° W. Also calculate the GMT of the star's transit and estimate its approximate meridian altitude as a guide to setting the Sextant; H.E. 17 m., I.E. 2·0′ on the arc.
5. On January 11, the sextant meridian altitude of the star Elnath was 72° 11′, South of the observer, H.E. 7·4 m, I.E. of sextant 1·6′ on the arc. Find the latitude.
6. On December 25, the sextant altitude of the star Sirius on the meridian was 52° 05′, bearing North, H.E. 12 m., I.E. 1·4′ on the arc. Find the observer's latitude.
7. On January 12, the sextant meridian altitude of the star Pollux was 28° 40′, North of the observer, H.E. 7 m, I.E. 3′ on the arc. Find the latitude.
8. On June 15, the sextant altitude of the star Regulus on the meridian was 35° 15′, bearing North, H.E. 7·5 m, I.E. 3·5′ off the arc. Find the observer's latitude.

Answers

1. GMT Civil Twilight 22 d 00 h 08 m; SHA* 277° 38·7′ required.
   Stars: Alnilam, Bellatrix, Capella, Elnath, Rigel.
2. GMT Passage 21 d 23 h 52 m 17 s; Sext. alt. 24° 13·6′; Bearing North.
3. GMT Civil Twilight 25 d 21 h 26 m; SHA* required 144° 59·5′; Star Arcturus;
   GMT Passage 25 d 21 h 19 m 46 s; Sext. alt. 69° 30·8′; Bearing South.
4. GMT Civil Twilight 26 d 15 h 29 m; SHA* required 333° 30·0′; Star Achernar;
   GMT Passage 26 d 15 h 19 m 10 s; Sext. alt. 84° 42·8′; Bearing South.

	True Altitude	Latitude
5.	72° 04·3′	46° 30·0′ N.
6.	51° 56·7′	54° 43·0′ S.
7.	28° 30·5′	33° 22·0′ S.
8.	35° 12·3′	42° 37·5′ S.

MERIDIAN ALTITUDE STAR BELOW THE POLE

Circumpolar Stars

The apparent motion of a star describes a circle round the pole once in a sidereal day. If an observer's latitude is greater than a particular star's polar distance (i.e. 90° − declination), that star will be above the horizon continuously, and will cross the observer's meridian twice in a sidereal day, once "above the pole" from East to West, and once "below the pole" from West to East. If either transit coincides with morning or evening twilight, a latitude can be obtained by observing a meridian altitude. For "above the pole" or upper meridian passage, the method of working has already been described. When a star crosses the meridian "below the pole" at lower meridian passage its LHA is 180° and so:

$$\text{GHA}\Upsilon + \text{SHA*} = \text{GHA*}$$
$$= \text{LHA*} \begin{matrix} + \text{ West Long.} \\ - \text{ East Long.} \end{matrix}$$

But LHA* on the lower meridian = 180°

$$\therefore \quad \text{GHA}\Upsilon + \text{SHA*} = 180° \begin{matrix} + \text{ West Long.} \\ - \text{ East Long} \end{matrix}$$

and
$$\text{GHA}\Upsilon = (180° - \text{SHA*}) \begin{matrix} + \text{ West Long.} \\ - \text{ East Long.} \end{matrix}$$

That is, by applying the SHA* and longitude to 180°, as shown, the GHA ♈ when the star is on the lower meridian is obtained from which the corresponding GMT of lower meridian passage is available by inspection from the *Nautical Almanac*. The following examples show the working.

Example 11 (To calculate the GMT and altitude.)

(Refer to Figure 14.)

Estimate the GMT and LMT of lower meridian passage of the star Canopus on September 19 in D.R. 52° S. 100° W. Also calculate the approximate Sextant Meridian Altitude of the star as a guide to setting the Sextant. H.E. 19 m. I.E. 2·5′ on the arc.

To estimate GMT of Transit:

When on lower meridian: GHA ♈ = (180° − SHA*) $\begin{matrix}+\text{ W. Long.}\\-\text{ E. Long.}\end{matrix}$

	(+) 360° 00·0′			Note 1.
	(+) 180 00·0			
SHA*	(−) 264 14·5			
LHA ♈	275° 45·5′			
W. Long	(+) 100 00·0			
GHA ♈	015° 45·5′			
From Almanac	(−) 013 25·2	gives	20 d 01 h	Note 2.
Increment	2° 20·3′	gives	9 m 20 s	
GMT Meridian Passage			20 d 01 h 09 m 20 s	Note 2.
W. Long. in time			(−) 6 h 40 m	
LMT Meridian Passage			19 d 18 h 29 m 20 s	

Note 1: SHA > 180°, ADD 360°.

2: Greenwich date must be day later than local date because of large West Longitude. A check is required to ensure that the local date is correct in all circumstances.

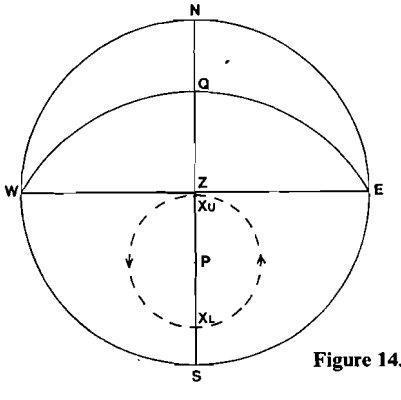


Figure 14.

In Figure 14:

True Altitude on Lower Meridian = $SX_L = PS - PX_L$ = D.R. Latitude − Polar Distance

Dec. = S. 52° 40·2′

D.R. Lat.	52° 00·0′ S.		
Polar dist.	37 19·8	∴ Polar dist.	= 90° − Dec.
			= 90° − 52° 40·2′
Approx. True Mer. alt.	14° 40·2′		= 37° 19·8′
Main Corr.	(+) 3·6	} opposite to usual signs	
Dip.	(+) 7·7		
I.E.	(+) 2·5		
Approx. Sext. Mer. alt.	14° 54·0′	Bearing South. (Same as declination.)	

Note: When a circumpolar body is on the meridian below the Pole its bearing is **always** named the same as the declination.

Explanation of Figure 14

NESW	Rational Horizon.	WQE	Equinoctial.
WZE	Prime Vertical.	NQZP	Observer's upper meridian.
X_U	Body on upper meridian.	PX_U	Polar Distance.
QX_U	Declination.	ZQ	Latitude.
PX_L	Polar Distance	SX_L	True altitude below pole.
PS	Observer's lower meridian = Latitude = Elevation of Pole.		

Example 12. (To calculate the Latitude)
(Refer to Figure 14.)

At 01 h 09 m 20 s GMT on September 20, the sextant meridian altitude of the Star Canopus below pole was 15° 04·5′ bearing South. Calculate the observer's latitude if H.E. 19 m, I.E. 2·5′ on the arc.

From Figure 14:

Latitude = ZQ = PS = Elevation of pole.
= $SX_L + PX_L$
= True Meridian Altitude + Polar distance.

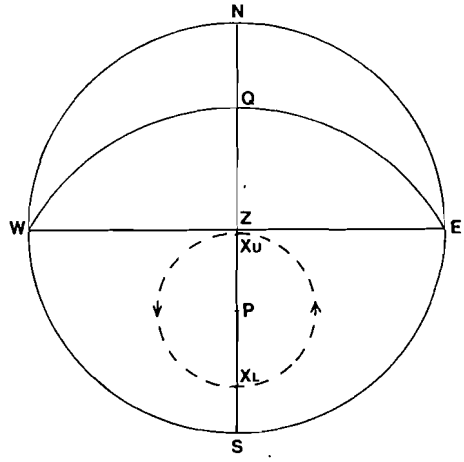


Figure 14.

Sext. Mer. alt.*		15° 04·5′ S.
I.E.	(−)	2·5
Obs. Mer. alt.		15° 02·0′
Dip.	(−)	7·7
App. Mer. alt.		14° 54·3′
Main Corr.	(−)	3·6
True Mer. alt.		14° 50·7′
Polar dist.		37 19·8
Latitude		52° 10·5′ S. (Named same as declination.)

		90° 00·0′
Dec.	(−)S.	52 40·2
Pol. dist.		37° 19·8′

Exercise 5 (Stars Below the Pole)

1. On September 22 in Longitude 99° 50′ W., the sextant meridian altitude of the star Canopus below the pole was 14° 12·5′ bearing South. I.E. 1·3′ off the arc; H.E. 12 m. Find the observer's latitude.
2. On September 20 in Longitude 159° 50′ W., the sextant meridian altitude of the star Atria below the pole was 30° 16′ bearing South. I.E. 2′ on the arc; H.E. 7·5 m. Find the observer's latitude.
3. On December 22 in D.R. 49° 52′ N. 170° E., estimate the approximate GMT of lower meridian passage of the star Dubhe and also the approximate sextant meridian altitude as a guide to setting the Sextant. I.E. 1·8′ on the arc; H.E. 10 m.
4. On September 19 in D.R. 51° 10′ S. 160° W., estimate the approximate GMT of lower meridian passage of the star Atria and also the approximate sextant meridian altitude as a guide to setting the Sextant. I.E. 1·5′ off the arc; H.E. 12 m.

Answers

1. Polar dist. 37° 19·8′; True alt. 14° 03·9′; Lat. 51° 23·7′ S.
2. Polar dist. 21° 02·6′; True alt. 30° 07·5′; Lat. 51° 10·1′ S.
3. GMT Passage 22 d 05 h 40 m 07 s; True alt. 21° 50·0′; Sext alt. 21° 59·8′.
4. GMT Passage 19 d 15 h 32 m 09 s; True alt. 30° 07·4′; Sext. alt. 30° 13·7′

LATITUDE BY ALTITUDE OF THE POLE STAR

The altitude of the celestial pole is equal to the Latitude of the observer, and if "Polaris" were exactly at the pole of the heavens its true altitude would be the Latitude. It is situated, however, about 57′ away from the pole and slowly approaching it, but the star describes such a small daily circle in the sky that Latitude can be computed from an altitude of the Pole star at any time. Polaris changes its azimuth from about 002° to 358°. during its daily circuit round the pole of the heavens, and bears due North only on two occasions each day when it crosses the meridian above and below the pole.

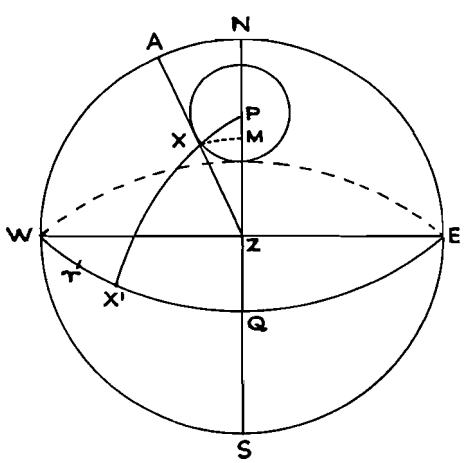


Figure 15.

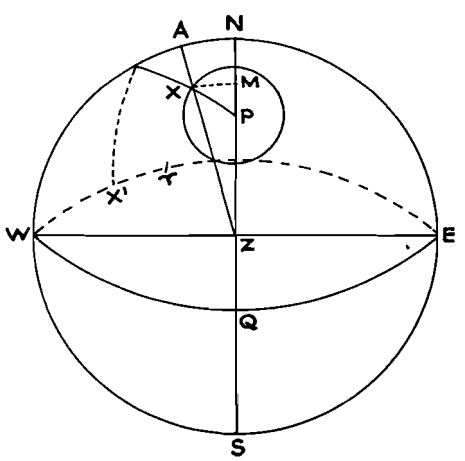


Figure 16.

The small circle represents (not to scale), the daily path of the Pole star (*X*), travelling clockwise round the Pole (*P*). When the star is on the meridian at upper transit its local hour angle is 0°; when at right angles to the meridian due West of the pole the L.H.A.* is 90°; then 180° when at its lower transit, and 270° when at right angles to the meridian East of the pole. The L.H.A.* $\angle ZPX$ shown in Figure 15 is about 50° and about 130° in Figure 16.

AX represents the true altitude of the star and *ZX* the zenith distance. With centre *Z* and radius *ZX* describe the arc *XM* cutting the meridian at *M*, thus making *NM* equal to the altitude of the star, then the arc *MP* would be the correction to apply to *NM* to get *NP* the Latitude required. The correction would be added to the true altitude if the star's L.H.A. was between 90° and 270° as shown in Figure 16 and subtracted when L.H.A. was 0° to 90° or 270° to 360° as indicated in Figure 15.

Pole Star Tables for determining the Latitude are given on three pages of the *Nautical Almanac* which are reproduced at the end of this book. The calculation is simple. The star's sextant altitude is corrected for index error (if any), dip and refraction, and to the true altitude thus obtained 1° is subtracted. The three corrections called a_0, a_1 and a_2 are then added. This converts the True altitude of the Pole star into the Latitude required.

The Tables are entered with the L.H.A. Aries which is found from the equation:

$$\text{L.H.A.}\Upsilon = \text{G.H.A.}\Upsilon \begin{cases} +\text{East} \\ -\text{West} \end{cases} \text{Long.}$$

Find the First Correction a_0. This is given for every degree of local hour angle Aries. Take out the correction by looking down the appropriate ten degree column until abreast of the degree line. If your L.H.A. Aries is not an exact degree it is necessary to interpolate mentally between the degrees.

Find the Second Correction a_1. This is given under the nearest ten degrees of L.H.A. Aries and abreast of the approximate Latitude. The altitude of the star gives the approximate Latitude, and no interpolation is necessary.

Find the Third Correction a_2. This is given under the nearest ten degrees of L.H.A. Aries and abreast of the Month. No interpolation is necessary.

The Pole Star Tables are based on the formula:

$$\text{Lat.—Corr. Sext. Alt.} = -p\cos h + \tfrac{1}{2}p^2 \sin p \sin^3 h \tan(\text{latitude}).$$

where p = the polar distance of Polaris

h = the L.H.A. Polaris = L.H.A. Aries + S.H.A.

a_0 is computed using mean values for Latitude and star's S.H.A. and Declination then 58·8′ is added.

a_1 is the adjustment for observer's Latitude then 0·6′ added.

a_2 is the adjustment for changes in Declination and S.H.A. then 0·6′ added.

The sum of the constants added is 1° so that in all cases:

$$\text{Latitude} = \text{True altitude} - 1° + a_0 + a_1 + a_2$$

The latitude obtained using the Pole Star Tables is strictly the latitude on the D.R. Longitude through which the position line should be drawn at right angles to the azimuth of Polaris. The azimuth of Polaris, which varies from about 002°T to 358°T can be obtained from the fourth part of the Pole Star Tables by entering with L.H.A. Aries and Latitude. In practice the position line is often drawn 090°T to 270°T as a parallel of latitude without appreciable error. Providing the altitude is not too high, the Pole Star can be used to obtain a compass error.

Example 13

June 21 in Longitude 17° 30′ W. GMT 04 h 46 m 30 s, Sextant altitude of Polaris 41° 26′. H.E. 10 m. I.E. 2′ on the arc. Find the latitude.

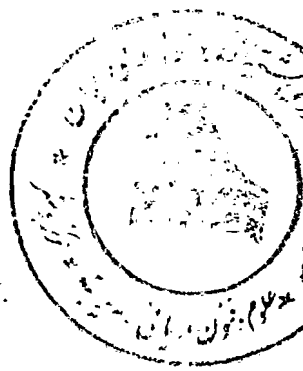
L.H.A. Aries = G.H.A. Aries − West Long.

GMT June 21 d 04 h 46 m 30 s.

GHA 21 d 04 h		328°	51·0′
Increment 46 m 30 s		11	39·4
GHA ♈		340	30·4
Long. W.	(−)	17	30
LHA ♈		323	00·4

Sext. alt.		41°	26′ N.
Index error	(−)		2
Obs. alt.		41	24
Dip.	(−)		5·6
App. alt.		41	18·4
Refraction	(−)		1·1
True alt.		41	17·3
Corr. a_0	(+)	0	36·4
Corr. a_1	(+)		0·5
Corr. a_2	(+)		0·3
Sum		41	54·5
	(−)	1	
Latitude		40°	54·5′ N.

True Azimuth 001·1°



Example 14

December 24 at 01 h 32 m LMT in Longitude 148° 54′ W. Observed altitude of Polaris 39° 14′. H.E. 7·4 m. Find the observer's latitude.

From conversion table: Longitude 148° 54′ = 9 h 55 m 36 s in time

	d	h	m	s
L.M.T.	24	01	32	00
W. Long (+)		9	55	36
G.M.T.	24	11	27	36

L.H.A. Aries = G.H.A. Aries − W. Long.

GHA ♈ 24 d 11 h	257° 28′	
Increment 27 m 36 s	6 55·1	
GHA ♈	264 23·1	
Long. W.	(−) 148 54·0	
LHA ♈	115° 29·1′	

Obs. alt.		39° 14·0′ N.
Dip.	(−)	4·8
		39 09·2
Refr.	(−)	1·2
True alt.		39 08·0
a_0	(+)	0 56·1
a_1	(+)	0·4
a_2	(+)	0·4
Sum		40 04·9
	(−)	1
Latitude		39° 04·9′ N.

True Azimuth 358·8°

Example 15

September 20, at 04 h 53 m LMT in Longitude 152° 30′ E. Sextant altitude of Polaris 36° 46′. I.E. 1·5 on the arc. H.E. 12 m. Find the observer's latitude and the compass error. Polaris bore 015° C. at the same time.

From conversion table: Longitude 152° 30′ = 10 h 10 m 00 s in time.

	d	h	m	s
LMT	20	04	53	00
E. Long.		10	10	00
GMT	19	18	43	00

GHA ♈ 19 d 18 h		268° 07·9′
Increment 43 m 00 s		10 46·8
GHA ♈		278 54·7
Long E.	(+)	152 30·0
		431 24·7
	(−)	360 00
LHA ♈		71° 24·7′

Sext. alt.		36° 46·0′ N.
I.E.	(−)	1·5
		36 44·5
Dip.	(−)	6·1
		36 38·4
Refr.	(−)	1·3
True alt.		36 37·1
a_0	(+)	0 18·0
a_1	(+)	0·5
a_2	(+)	0·3
		36 55·9
	(−)	1
Latitude		35° 55·9′ N

True Azimuth	359·1°
Compass Brg.	015·0° C.
Compass Error	15·9° W.

Exercise 6 (Polaris)

In each example find the latitude through which to draw the position line and the true azimuth of Polaris.

1. June 18 at 03 h 16 m LMT in Longitude 32° W. Sextant altitude of the Pole Star 45° 19′. H.E. 15·3 m. I.E. 1·5′ off the arc.
2. September 20 at 18 h 20 m LMT in Longitude 147° 20′ W. Sextant altitude of Polaris 34° 58′, I.E. 1′ on the arc. H.E. 10 m.
3. June 19 at GMT 18 d 16 h 07 m 28 s in Longitude 165° 18′ E. Observed altitude of Polaris 50° 59′. H.E. 18 m.
4. September 22 at GMT 23 d 00 h 36 m 31 s in Longitude 30° 40′ W. Observed altitude of Polaris 61° 09′, H.E. 12 m.
5. December 24 at GMT 15 h 17 m 40 s in Longitude 149° 30′ W. Sextant altitude of Polaris 42° 20′. I.E. 1·5′ off the arc. H.E. 10 m.
6. January 10 at GMT 9 d 22 h 53 m 40 s, in Longitude 20° 10′ E. Sextant altitude of Polaris 36° 02′. I.E. 1′ on the arc. H.E. 7·4 m.

Answers

	LHA Aries	True alt.	Corrections a_0	a_1	a_2	Lat.	Azimuth
1.	314° 57·0′	45° 12·6′	43·8′	0·5′	0·3′	44° 57·2′ N.	001·3°
2.	274° 32·1′	34° 50·0′	1° 22·1′	0·4′	0·9′	35° 13·4′ N.	001·1°
3.	313° 33·4′	50° 50·7′	45·1	0·6′	0·3′	50° 36·7′ N.	001·4°
4.	339° 49·3′	61° 02·4′	22·5′	0·8′	0·7′	60° 26·4′ N.	001·5°
5.	172° 33·5′	42° 14·8′	1° 43·9′	0·5′	0·2′	42° 59·4′ N.	359·3°
6.	112° 32·9′	35° 54·9′	53·2′	0·4′	0·7′	35° 49·2′ N.	358·8°

Questions

1. How can an observer tell when a body has crossed his meridian (*a*) above the pole, (*b*) below the pole?
2. How may the index error of a sextant be found before proceeding to observe an altitude?
3. Draw a figure to show that Latitude—Polar Distance is equal to the altitude of a body below the pole.
4. Why is the height of the observer's eye important as an altitude correction factor?
5. What is the time on a corrected ship's clock when the sun is on the meridian.
6. Write down the true azimuth of the sun when it is on the meridian in Latitude 55° N., and if it bore 190° C. by a compass, what is the Compass Error?
7. What is the local hour angle of the sun when it is on the observer's meridian?
8. Write down the equation which gives the GMT to observe the meridian altitude of the sun.
9. Where are the times of the meridian passages of planets, and also of the moon given? Why is the meridian passage necessary when working up their meridian altitudes to find the Latitude?
10. Why is there no correction for parallax in the case of stars and planets?
11. Why is the parallax in altitude of the moon usually considerably less than the horizontal parallax given in the *Nautical Almanac*?
12. Why is the Pole star a very convenient body for finding Latitude?
13. What are the limits of azimuth of Polaris?
14. The Pole star bore by a compass 012° C., what was the error of that compass?
15. How is a position line obtained from an observation of Polaris, and how would it be laid off on a chart?
16. Describe how the position line is drawn on the chart from the Latitude by meridian altitude of a body.
17. Describe the procedure of finding Latitude by an altitude of Polaris.
18. The horizontal parallax of the moon is 59·2′; what would the parallax in altitude be when (*a*) the moon is rising, (*b*) the moon is in the zenith?
19. Which method do you prefer in correcting an observed altitude of the moon, the detailed method or the total correction method?
20. When and how would you go about taking the observed meridian altitude of the sun?

Chapter 23

Amplitudes, Azimuths and Twilight

The Amplitude of a body is the arc of the horizon contained between the East point and the body when rising, or between the West point and the body when setting.

It may also be defined as the angle at the Zenith between the Prime Vertical and the Vertical Circle of the Body when on the horizon.

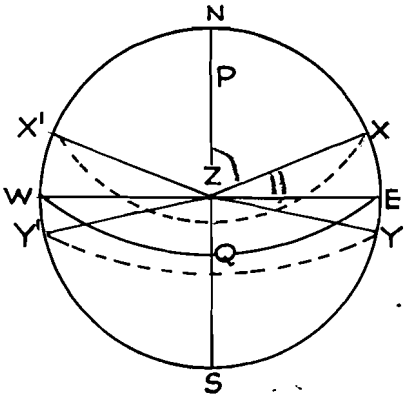


Figure 1.

Figure 1 illustrates a body X having 20° North declination, rising at X and setting at X' in Lat. 30° N.
Arc EX or $\angle EZX$ = Rising Amplitude E. 23·3° N.
Arc WX' or $\angle WZX'$ = Setting Amplitude W. 23·3° N.
Another body Y, having 10° South declination, is shown at Y when rising and at Y^1 when setting.
Arc EY or $\angle EZY$ = Rising Amplitude = E. 11·6° S.
Arc WY' or $\angle WZY'$ = Setting Amplitude = W. 11·6° S.

Rising and Setting Bearings

A body always rises and sets on a Northerly bearing when its declination is North and on a Southerly bearing when its declination is South, but when the declination is 0° the bearing is true East at rising and true West at setting. The amplitude therefore takes the *same name* as the declination. It is important to note that the amplitude is complementary to the azimuth so that

When rising, Azimuth = 090° T ± Amplitude.
When setting, Azimuth = 270° T ± Amplitude.

These azimuths are given in Azimuth Tables for bodies within the limits of the sun's declination. The angles of amplitude are also given in the True Amplitudes table in *Norie's Nautical Tables.*

Calculating Amplitude If the declination exceeds the limits of the tables, then the following formula, deduced by Napier's Rules, may be used:

$$\textbf{sin Amp.} = \textbf{sin Dec.} \times \textbf{sec Lat.}$$

The Moon Due to the proximity of the Moon it is actually below the horizon at the time of theoretical moonrise. Amplitudes cannot, therefore, be observed in the same manner as for the sun. Reference should be made to the instructions in the tables with regard to a special correction.

High Latitudes The use of amplitudes in high-latitudes is inadvisable because the rate of change of altitude is small making it difficult to accurately assess the correct time of the event.

AMPLITUDE

Refraction is greatest when the altitude is 0°, and its effect is to raise the **visible** position of the sun in the horizon 33′ above its **true** position, so that the sun is seen to rise some little time before it does so theoretically.

The theoretical time of sunrise occurs at the instant the centre of the true sun is on the observer's Rational Horizon. The bearing amplitude should therefore be taken when the centre of the sun is about 33′ above the Visible Horizon, which would be when the clearance between the lower limb and the horizon was equal to its semi-diameter.

Example 1

The sun set bearing 299½°C. From the following information find the True Amplitude, Compass Error and the Deviation for the ship's head.

LMT 2030 (approx) 17 June D.R. 47° 30′ N. 170° 20′ W.

GMT 07 h 51 m 20 s Variation 10° E.

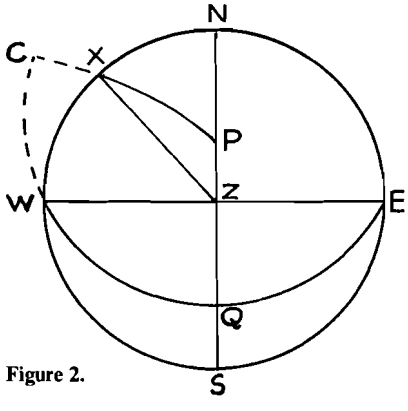


Figure 2.

In the figure:

NESW	Rational Horizon.		
WQE	Equinoctial.		
WZE	Prime Vertical.		
NZS	Observer's Meridian.		
P	Pole.	*PX*	Polar Dist.
Z	Zenith.	*CX*	Declination.
X	Sun.	*ZX*	Zenith Dist. (Alt. = 0°).
ZPX	H.A. (at Sunset)		
PZX	Azimuth (at Sunset)		
WZX	(or arc *WX*)	True Amplitude.	

N.B. The equator and hour circle have been produced to show Declination *CX*.

	d	h	m	s
LMT	17	20	30	
Long. W.		11	21	20
GMT	18	07	51	20

Dec.	18d 07h		N 23° 23·8′
d (0·1)	51m	(+)	0·1
Dec.	18d 07h 51m		N 23° 23·9′

sin Amp. = sin Dec. × sec Lat.

Lat.	47° 30′	log sec	10·17032
Dec.	23° 23·9′	log sin	9·59892
Amp.	36° 00·1′	log sin	9·76924

From tables: T. Amp. W. 36·0° N.[1]

True Amp.	W. 36·0° N.[1]
	270·0°
True Az.	306·0° T.
Bearing	299·5° C.
Compass Error	6·5° E.[2]
Variation	10·0° E.[3]
Deviation	3·5° W.

Alternatively

True Az.	306·0° T.
Variation	10·0° E.
Magnetic Brg.	296·0° M.
Compass Brg.	299·5° C.
Deviation	3·5° W.

Notes

1. The True Amplitude is named W. and N. because the body is setting and has N. declination.
2. The Compass Error is named E. from the rule "Compass least, error East".
3. When the error and the variation have the same name the deviation is given by the difference between them. By using the alternative method the names are given by the usual rule.

Example 2

From the following information find the Sun's True Amplitude, Compass Error and Deviation for the ship's head.

LMT 0549 September 23 D.R. 30° 20′ S. 110° 48′ W.
Variation 20° W. Sun rose bearing 090° C.

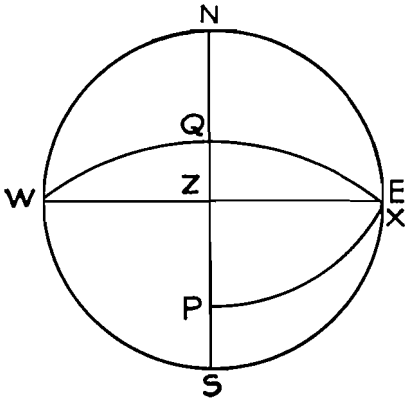


Figure 3.

Description of figure as in previous example.

N.B. $\angle ZPX$ E.H.A. (at sunrise) 90°.
$\angle PZX$ Azimuth (at sunrise) 90°.
Amp. = 0° Sun rising East.

	d	h	m	s
L.M.T.	23	05	49	00
Long. W.	+	7	23	12
G.M.T.	23	13	12	12

Dec. 23d 13h 0° 00·2′ N.
d. (1·0) 12m (−) 0·2
Dec. 23d 13h 12m 0° 00·0′ [1]

True Amp. E. 0° 0′ = 090° T.[2]
Compass Bearing 090° C.

Compass Error 0° [3]
Variation 20° W.

Deviation 20° E.

Notes

1. When the declination is decreasing, the correction to apply to the one copied down must be subtracted from it, in this case making the correct declination come to zero, because the sun is on the equator.
2. When the declination is 0° the sun rises bearing due East (090° T). The true amplitude is, therefore, E. 0° 0′ N. or S.

3. The true and observed amplitudes being both the same, there is no compass error. For the error to be nothing, the variation and deviation must exactly counteract each other; that is, they must be equal in amount but opposite in name. This makes the deviation East.

Exercise 1 (Amplitudes)

In the following questions find (a) True Amplitude
(b) Compass Error, and
(c) Deviation for the ship's head

	Date	Chronometer	D.R. Position		Brg.	Var.	Body
1.	January 9	10 h 45 m 03 s	44° 26′ N.	46° 29′ W.	134° C.	22½° W.	Sun
2.	June 15	01 h 13 m 00 s	17° 25′ N.	62° 42′ E.	072° C.	1½° E.	Sun
3.	December 29	16 h 05 m 00 s	38° 40′ S.	50° 45′ E.	272° C.	27° W.	Sun
4.	October 11	LMT 0448	23° 36′ S.	111° 40′ E.	100° C.	5° W.	Sun
5.	June 22	LAT 2045	55° 00′ N.	40° 00′ W.	001° C.	40° W.	Sun
6.	September 23	13 h 07 m 20 s Error 5 m 20 s Slow	10° 22′ N.	71° 15′ E.	264° C.	3° W.	Sun
7.	December 27	04 h 59 m 22 s Error 3 m 38 s Slow	48° 28′ N.	166° 30′ E.	240° C.	Nil	Sun
8.	January 11	02 h 40 m 00 s	31° 20′ N.	30° 00′ E.	257° C.	7° W.	Sirius
9.	January 10	LMT 0646	40° 30′ N.	25° 15′ W.	097° C.	15° E.	Venus
10.	June 15	LMT 0313	40° 30′ N.	64° 31′ W.	081° C.	12° W.	Moon
11.	September 26	—	15° 00′ S.	80° 00′ W.	220° C.	12° E.	Antares

Answers Answers in rear answer section.

AZIMUTHS

Azimuth is the term applied to the bearing of a heavenly body, and may be defined as the angle at the Zenith between the observer's meridian and the vertical circle passing through the body. It is the angle PZX, as shown in the figure.

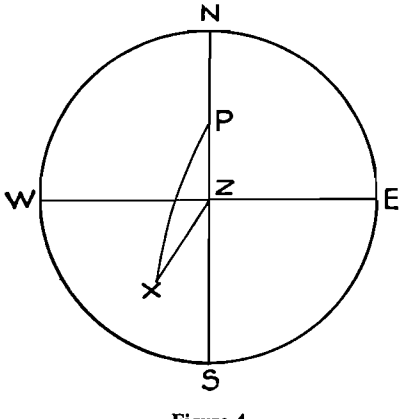


Figure 4.

Finding the True Azimuth is one of the most frequent operations in practical navigation, being required, not only for checking the compass error but also to establish the direction of the position line when plotting celestial observations.

Since calculation by spherical trigonometry is inconvenient, special tables have been devised for the purpose of finding the True Azimuth. Probably the most commonly used are the *ABC Tables* to be found in *Norie's* and *Burton's Nautical Tables.* There are also *Azimuth Tables*, published in separate volumes, which give the True Azimuth at a single entry.

Arguments used in ABC Tables

All tables are entered with three arguments:

1. Observer's Latitude.
2. Declination.
3. Local Hour Angle (LHA) of the body.

Declination is obtained directly from the *Nautical Almanac*, but LHA must be deduced from the GHA, or in the case of the stars, from GHA Aries.

For a Star $\quad GHA* = GHA\ Aries + SHA*,$

For all Bodies $\quad LHA = GHA \left.\begin{matrix} +E. \\ -W. \end{matrix}\right\}$ Longitude

Use of ABC Tables

When using these tables, first turn to the pages appropriate to the LHA. On the left hand page find quantity A corresponding to Latitude and LHA; and from the right hand page take out quantity B for the Declination and LHA. A and B are now combined algebraically, according to rules given in the tables, to form quantity C.

A separate table is entered with C and the Latitude to find the Azimuth, which is named according to the rules given in the tables. Although the overall method is the same in both cases, the rules for naming the Azimuth are different in *Norie's* and *Burton's Tables*. The drawing of a figure is strongly recommended as an aid in establishing the correct orientation of the Azimuth.

It will be appreciated that care is needed in interpolating values from the tables; a full explanation of this technique is given after the general working has been illustrated in Example 3.

Scope of ABC Tables

The main part of the tables is limited to 60° Latitude and Declination. Following this section will be found additional tables which extend both Latitude and Declination to much higher values.

Azimuth (Sun)

Example 3

On September 20 at 1119 GMT in D.R. 50° 10′ N., 15° 00′ W., the sun bore 170° C. Find the sun's true azimuth from ABC Tables, Compass Error and Deviation for the ship's head. Variation 24° W.

L.H.A. Sun = G.H.A. Sun − W. Long.

September			
G.H.A. Sun 20 d 11 h	346° 36·3′	Dec.	1° 12·1′ N.
Increment 19 m 00 s	4 45	*d* corr.	− 0·3′
G.H.A.	351 21·3	Dec.	1° 11·8′ N.
Long. W.	(−) 15 00		
L.H.A.	336° 21·3′	Lat.	50° 10′ N.

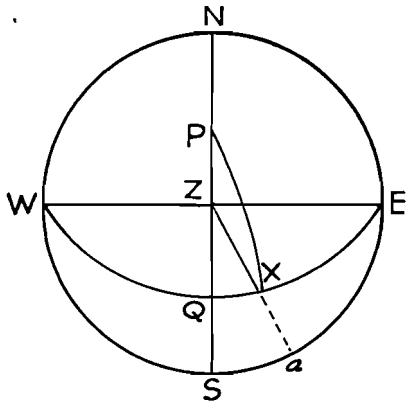


Figure 5.

In the Figure:

NESW	Rational Horizon	
WQE	Equinoctial	
WZE	Prime Vertical	
NZS	Observer's Meridian	
P	Pole	*PX* Polar Dist.
Z	Zenith	
X	Sun	*ZX* Zenith Dist.
aX	Altitude	

$\angle ZPX$ Hour Angle. $\angle PZX$ True Azimuth.
Declination is too small to be shown.

From the ABC Tables (Norie's)

Table	A	2·75 S.[1]	
Table	B	0·05 N.	
	C	2·70 S.[2]	
Table	C	S. 30·1° E.[3]	
		180°	
True Az.		149·9° [4]	

True Az.	149·9° T.
Compass Brg.	170·0 C.
Compass Error	20·1° W.[5]
Variation	24·0 W.[6]
Deviation	3·9° E.[7]

Notes

1. The rules for naming A and B are given in the Tables.
2. Being of opposite names, the smaller is subracted from the greater. C takes the name of the greater quantity.
3. The Azimuth is named S from the name of C; and E because the LHA indicates that the sun is rising and therefore, to the East of the Observer.
4. The Azimuth is converted from quadrantal notation into the standard 3 figure notation: S. 30·1° E = 149·9°.
5. The Error is named West since "Compass is Best".
6. Variation may be obtained from either the navigational chart, or from a special *Variation Chart.*
7. Check working by combining Variation and Deviation: 24° (W) − 3·9° (E) = 20·1° W.

Notes on Interpolation

Considering Example 3, where the arguments are:

Lat. 50° 10′ N. (50·2°) Dec. 1° 11·8′ N. (1·2°) LHA 336° 21·3′ (336·4°).

The exact values of A and B will be found somewhere between the four figures shown in each of these extracts from the two tables.

Table A		Hour Angle		
Lat		336° 30′	336° 00′	
50°		2·74	2·68	
51°		2·84	2·77	

Table 1

Table B		Hour Angle		
Dec		336° 30′	336° 00′	
1°		·04	·04	
2°		·09	·09	

Table 2

It is convenient to start with the top right hand figure, then both of the changes will be additive, i.e. start with the 'A' value of 2·68 for Lat. 50° and H.A. 336° 00′.

Interpolating A for LHA

(Refer to Table 1)

Moving left there is a difference of 2·68 ~ 2·74 = (+) 0·06 for a 30′ interval:

$$1' \qquad \text{Change} = 0{\cdot}06 \times \frac{1}{30}$$

$$21{\cdot}3' \qquad \text{Change} = 0{\cdot}06 \times \frac{21{\cdot}3}{30} \simeq 0{\cdot}043$$

The process of interpolation may be simplified by rounding off the arguments to the nearest $\frac{1}{10}$th of a degree. The accuracy of the result is very little affected. Accordingly this interpolation may be written as:

$$0{\cdot}06 \times \frac{0{\cdot}4}{0{\cdot}5} \simeq 0{\cdot}05$$

Interpolating A for Latitude

(Refer to Table 1)

Move down the table and note the difference is 2·68 ~ 2·77 = (+)0·09 for a 60′(1°) interval:

$$10' \text{ or } 0{\cdot}2^\circ \text{ Change} = 0{\cdot}09 \times 0{\cdot}2 \simeq 0{\cdot}02$$

Final Value of A

is thus:

$$2{\cdot}68 + 0{\cdot}05 + 0{\cdot}02 = 2{\cdot}75 \text{ S}$$

Tables B and C

The B and C values are interpolated by a similar process. Until experience has been gained it is advisable to write down the work of interpolation—a suitable layout is given below.

Table A′		2·68	A	2·75 S
LHA:	$0{\cdot}06 \times \frac{0{\cdot}4}{0{\cdot}5}$	(+) ·05	B	0·05 N
Lat:	0·09 × 0·2	(+) ·02	C	2·70 S
		A = 2·75		

Table B		0·04
LHA: No change in B		·00
Decl: 0·05 × 0·2	(+)	·01
	B =	0·05

Table C		30·0°
C: No change in C		0·0
Lat: 0·5 × 0·2	(+)	0·1
True Az	S	30·1° E.
or		149·9° T.

Azimuth (Sun)

Example 4

June 15, at ship in E.P. 49° 30′ S. 50° 45′ E., GMT 15d 12h 13m 30s. Sun bore 332° C, Variation 35° W. Find the true azimuth and deviation for the ship's head.

L.H.A. Sun = G.H.A. Sun + E. Long.

G.H.A. 15d 12h		359° 56·1′
Incre. 13m 30s		3 22·5
G.H.A. Sun		003 18·6
Long. E.	(+)	50 45
L.H.A. Sun		54° 03·6′
Dec.		23° 18′ N.
Lat.		49° 30′ S.

To Find the True Azimuth from ABC Tables.

L.H.A. Sun	54·1°	Lat. 49·5° S.	A ·86 N.
L.H.A. Sun	54·1	Dec. 23·3° N	B ·53 N.
			C 1·39 N.

True Azimuth N. 47·9° W.[1]

True Azimuth = N. 48° W.	312° T.[2]
Observed Azimuth	332° C.
Compass Error	20° W.[3]
Variation	35° W.
Deviation	15° E.[4]

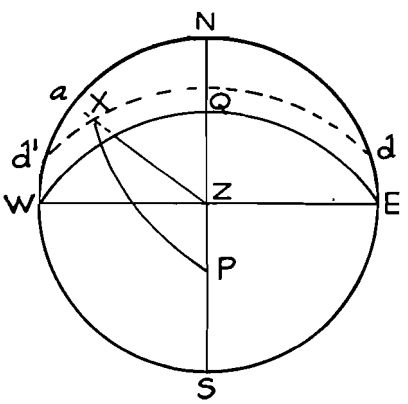


Figure 6.

Description of figure as for Example 1.
N.B. $\angle ZPX$ Hour Angle. $\angle PZX$ Azimuth.

Notes

1. Name azimuth N. or S. as directed on table C pages and E. or W. depending on the local hour angle.
2. Turn bearings into 360° notation.
3. The error is named West because compass bearing is "best".
4. Deviation is named East because combined with the variation must equal the error.

Azimuth (Star)

Example 5

June 22 in D.R. 49° 30′ S., 18° 45′ E., a chronometer which was 03 m 50 s slow on GMT indicated 16 h 35 m 04 s when the star *Sirius* bore 240° C. Find the star's true azimuth, Compass Error and deviation for the ship's head. Variation 31° E.

L.H.A.* = G.H.A.* + E. Long.
G.H.A.* = G.H.A.♈ + S.H.A.*

	d	h	m	s
June				
Chron.	22	16	35	04
Slow (+)			3	50
G.M.T.	22	16	38	54
Dec.	16° 39·6′ S.			
Lat.	49° 30·0′ S.			

G.H.A.♈	22 d	16 h	150° 19·7′
Incre.		38 m 54 s	9 45·1
G.H.A. Aries			160 04·8
S.H.A. Sirius			259 10·5
G.H.A. Sirius			419 15·3
		(−)	360
G.H.A. Sirius			59 15·3
Long. E.		(+)	18 45
L.H.A. Sirius			78° 00·3′

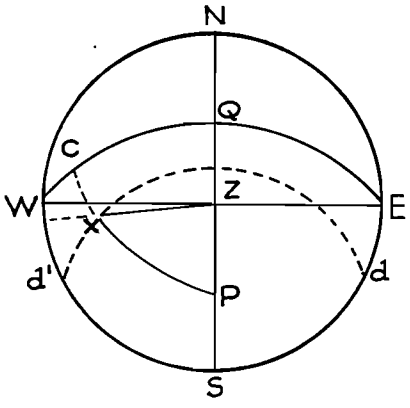


Figure 7.

The explanation of the figure is the same as in previous examples. It is desirable that a figure should be drawn at this stage of the work as it is helpful in approximating the true azimuth and for naming the error and deviation. Students preparing for examination should write out the description of the figure for every example as it is only by practice and repetition that a lesson is thoroughly mastered.

From ABC Tables

		Norie's		Burton's	
With L.H.A.*	78°	A	·25 N.	A	+·249
Lat.	49·5° S.	B	·30 S.	B	−·306
Dec.	16·6° S.	C	·05 S.	C	−·057
		From Table C - Az.	S. 88·1° W.	Az.	S. 87·9° W.

True Az.	268° T.
Obs. Az.	240° C.
Compass Error	28° E.
Variation	31° E.
Deviation	3° W.

Azimuth (Planet)

Example 6

January 5 at ship in D.R. 49° 12′ N., 21° 00′ W. GMT 5 d 19 h 07 m 15 s. Venus bore 260 C. Find the true azimuth and deviation for the ship's head. Variation 26° W.

L.H.A. Venus = G.H.A. Venus − W. Long.

G.H.A. 5 d 19 h	71° 47·4′	Dec.	14° 12·1′ S.	
Incre. 07 m 15 s	1 48·8	*d* 0·6	(−) 0·1	
v Corr. (2·4)	0·3			
G.H.A. Venus	73 36·5	Dec.	14° 12·0′ S.	
Long. W.	(−) 21 00			
L.H.A. Venus	52° 36·5′			

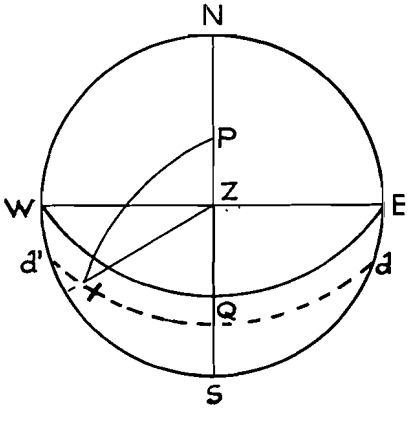


Figure 8.

Description of figure as in previous example.

From ABC Tables with:

			Norie's		Burton's
L.H.A.	52·6°	A	·89 S.	A	+·899
Lat.	49·2° N.	B	·32 S.	B	+·315
Dec.	14·2° S.	C	1·21 S.	C	+1·214

From Table C:

True Az. S. 51·6° W	231·6° T.
Obs. Az.	260·0° C.
Compass Error	28·4° W.
Variation	26·0° W.
Deviation	2·4° W.

Azimuth (Moon)

Example 7

September 19, at ship in E.P. 29° 00′ N., 61° 14′ W. GMT 19 d 18 h 26 m 08 s. Moon bore 159° C. Find the true azimuth and deviation for the ship's head. Variation 33° W.

L.H.A. Moon = G.H.A. Moon − W. Long.

September		
G.H.A. 19 d 18 h		7° 12·0′
Incre. 26 m 08 s		6 14·1
v Corr. (7·4)		3·3
G.H.A. Moon		13 29·4
	(+)	360
G.H.A. Moon		373 29·4
Long. W.	(−)	61 14·0
L.H.A. Moon		312° 15·4′

Dec.		18° 40·7′ S.
d (0·5)	(+)	0·2
Dec.		18° 40·9′ S.

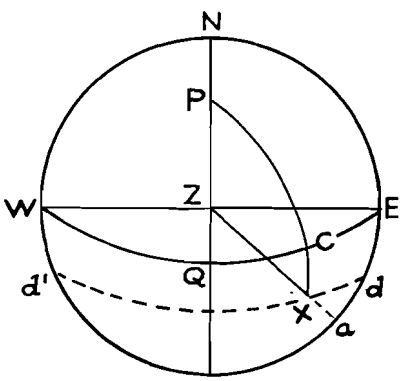


Figure 9.

Description of figure as in previous examples.

L.H.A.	312·3°	A	·50 S.
Lat.	29° N.	B	·46 S.
Dec.	18·7° S.	C	·96 S.

From Table C:

True Az S. 50° E.	130° T.
Obs. Az.	159° C.
Compass Error	29° W.
Variation	33° W.
Deviation	4° E.

TWILIGHT

Twilight is caused by the indirect rays of the sun reaching above the horizon owing to refraction and reflection of the rays of light in the atmosphere. Twilight begins when the sun is 18° below the horizon in the morning and continues until sunrise, and at night it continues during the period from sunset until the sun is 18° below the horizon.

Continuous Twilight

Continuous twilight is experienced throughout an 18° zone contained between a parallel of latitude where the Lat. + Dec. + 18° = 90° to a parallel of latitude 18° higher.

Example 8

Between what latitudes will there **not** be complete darkness when the declination of the sun is 22° N?

$$\text{Lat.} + \text{Dec.} + 18° = 90° \therefore \text{Lat.} = 90° - 22° - 18° = 50°$$

to which is added the 18° zone of twilight, so that the latitudes are from 50° to 68° N.

It may be noted that 90° − Dec. 22° = Polar Dist. 68° and that the sun would be circumpolar in latitudes higher than 68° N., it would not set and there would be continuous daylight.

Civil, Nautical and Astronomical Twilight

The time when the sun is depressed 18° below the true horizon marks the end, (or the beginning) of Astronomical Twilight when complete darkness may be said to commence (or terminate). The *Nautical Almanac*, however, lists the intermediate times of Civil and Nautical Twilight when the sun is depressed by 6° and 12° respectively. These times and those of sunset and sunrise are given in the daily pages in Local Mean Time so that the Longitude in Time must be applied to give GMT.

Exercise 2 (Azimuths)

In the following questions find (a) True Azimuth
(b) Compass Error, and
(c) Deviation for the ship's head

	Date		D.R.		Brg.	Var.	Body
1.	Sept. 26	LMT 1506	49° 30′ S.	115° 00′ E.	295° C.	10° W.	Sun
2.	June 19	GMT 04 h 28 m 00 s	49° 00′ S.	75° 15′ E.	052° C.	25° W.	Sun
3.	June 26	GMT 06 31 25	49° 30′ N.	155° 00′ E.	278° C.	Nil	Sun
4.	Dec. 24	Chron. 13 h 07 m 30 s Error Nil	49° 30′ N.	45° 00′ W.	182° C.	35° W.	Sun
5.	Jan. 7	GMT 14 h 52 m 20 s	41° 20′ N.	11° 00′ E.	246° C.	12° W.	Sun
6.	Sept. 18	GMT 01 05 30	38° 50′ S.	120° 00′ W.	260° C.	17° E.	Sun
7.	Sept. 26	LMT 2346	49° 50′ N.	22° 00′ W.	111° C.	20° W.	Bellatrix
8.	June 26	LMT 0504	49° 30′ N.	28° 30′ E.	095° C.	5° W.	Aldebaran
9.	June 20	00 h 16 m 42 s (21) Chron. 6 m 42 s Fast	41° 08′ N.	42° 30′ W.	090° C.	Nil	Altair

10. Dec. 22	Chron. 06 h 01 m 00 s Error 2 m 00 s Slow			52° 20′ N.	3° 00′ E.	272° C.	12° W. Procyon
11. Jan. 11	GMT 07 h 40 m 00 s			5° 00′ S.	5° 25′ W.	060° C.	19° W. Vega
12. Jan. 10	GMT 02	45	45	20° 00′ S.	40° 07′ E.	320° C.	13° W. Regulus
13. Sept. 20	GMT 02	57	00	35° 00′ S.	28° 45′ W.	055° C.	14° W. Mars
14. Sept. 23	GMT 06	11	12	47° 45′ N.	148° 18′ W.	208° C.	22° E. Saturn
15. Jan. 6	GMT 05	37	30	29° 00′ S.	40° 30′ W.	323° C.	10° W. Moon
16. Dec. 27	GMT 08	56	00	42° 00′ N.	158° 22′ E.	078° C.	2° W. Moon

Answers Answers in rear *Answer Section.*

Questions

1. Define the following terms:—(*a*) amplitude; (*b*) nautical twilight; (*c*) prime vertical.
2. How is an amplitude named? Repeat the rules for naming error of the compass and deviation.
3. Observer on the equator, declination of body 0°, what will be its bearing at rising and setting?
4. In Latitude 0°, declination of body *X* 12° N., and of body *Y* 15° S., what will be the true bearings of *X* and *Y* respectively on rising and setting?
5. In Latitude 35° N., declination of sun 0°, at what time will the sun set and what will be its true bearing?
6. What is the observed altitude of the sun at theoretical sunrise, and why is this so?
7. Under what conditions of Latitude and declination will the sun not set below the horizon?
8. Describe any Tables you know for finding the amplitude of a body.
9. What information is required to solve the *PZX* triangle in order to find the amplitude, and why are two parts only of the triangle required?
10. Define the terms, (*a*) Azimuth; (*b*) Hour Angle; (*c*) Compass Error; (*d*) Variation; (*e*) Deviation.
11. Name the arguments required for entering the ABC Tables.
12. Write down the equation to find (*a*) the local hour angle of the sun; (*b*) the local hour angle of a star.
13. Describe how the error of the compass is found at sea by means of the azimuth of a celestial body.
14. Azimuth 136° T., body bearing 145° C., variation 14° W. Required the deviation of the compass for the ship's head.
15. Azimuth 180° T., compass bearing of body 180° C., variation 10° E. Required the deviation.
16. True amplitude of sun 0°, compass bearing 270° C., variation 10° W. Required the deviation.
17. How will a body whose declination is 20° N. bear from an observer in Latitude 20° N. when it is on the observer's meridian?
18. What conditions are necessary to enable a body to reach the prime vertical?
19. Draw figures to illustrate whether or not the bodies will cross the prime vertical in (*a*) Lat. 45° S., Dec. 10° S.; (*b*) Lat. 30° N., Dec. 40° N.; (*c*) Lat. 40° N., Dec. 15° S.
20. What is the duration of daylight and darkness at the poles?
21. Between what dates did Venus rise before the Sun? Observer situated on the equator. Use the Almanac extracts provided.

22. On March 31st the sun sets 10° N. of the prime vertical. Is the observer in North or South Latitude? State reasons.
23. Why is the hour angle at sunset not always the same as the hour angle at sunrise?
24. When will the sun rise and set at 0600 and 1800 respectively?
25. What effect has declination on the length of the day in Lat. 50° N. ?
26. Between what dates will the sun be above the horizon all day in Latitude 69° N. ?
27. Why does the length of the day (sunrise and sunset) vary throughout the year?
28. Why is twilight of shorter duration in the torrid zones than in the temperate zones?
29. If twilight lasts until the sun is 18° below the horizon, in what latitudes will there not be complete darkness when the declination is 23° 20′ N.
    Answer. When Lat. = (72° − Decl.) = 48° 40′ N. to 66° 40′ N.

Chapter 24

Figure Drawing for Astro-Navigation

The instruments required for drawing figures are a good pair of compasses, a protractor and a scale of equal parts divided in tenths.

It has been said earlier that it is impossible to project the whole of a sphere on to a plane surface, that at most a half sphere only can be shown at one time and of that hemisphere only a small part can be drawn in its true proportion, the remainder being more or less distorted according to the principle of the projection adopted.

Natural Projection

A Natural Projection assumes the observer's eye to be situated at a fixed position, usually external to the sphere, and the points and circles projected on to a plane surface in the direction of the visual rays leading towards them.

Figure 1 is intended merely as a diagrammatic representation to illustrate the general idea of a natural projection, and, incidentally, to enable us to refer to some important fundamental notions relative to finding the Latitude from a body when it is crossing the observer's meridian.

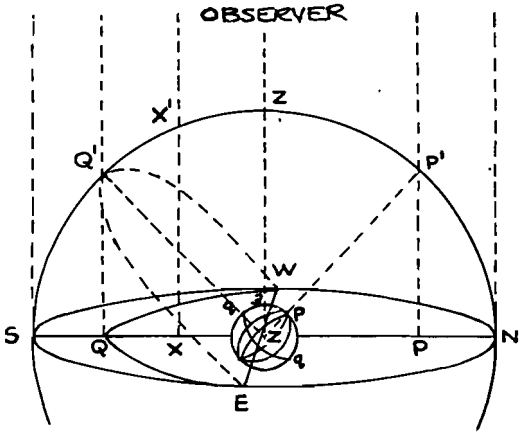


Figure 1.

The ellipse *NESW* represents the rational horizon tilted forward a little to suit our purpose, the points *N*, *E*, *S* and *W* being the four cardinal points of the horizon. The earth is shown in the centre of the imaginary celestial sphere; the plane of the earth's equator (*qq*) is extended to the celestial concave at Q^1; the polar axis (*Zp*) is extended to P^1, which is the celestial **elevated** pole, the South Pole, in this case, would be the **depressed** pole; the observer's position at *z* is projected upwards to the zenith at Z^1.

Orthographic Projection

The Orthographic Projection assumes the observer's eye to be situated infinitely far distant beyond the zenith, so that the visual rays are parallel to one another and everything, real or imaginary, is projected vertically downwards on to the plane of the rational horizon.

Thus the zenith (Z^1) and the observer (*z*) are both projected down to the centre of the earth

at Z, as they happen to be on the same visual ray $Z^1 z Z$. The celestial pole (P^1) would appear at P; the star (X^1) at X, and the celestial equator Q^1 at Q. The plane of the equator, shown as a dotted ellipse, would appear on the horizon as WQE. The observer's celestial meridian (NP^1Z^1S) geocentric with his terrestrial meridian (pzq) is projected as the straight line $NPZS$; indeed all great circles passing through Z, which is the centre of the primitive or bounding circle $NESW$, appear as straight lines.

If the reader will now turn the book a quarter turn to the left he will view the horizon looking North along the observer's meridian, and the various spots will be seen as they would appear under the orthographic projection. The relative positions are so grossly exaggerated by this system that it can only be used to depict a small portion of the globe in the region directly under the imaginary viewpoint of the observer, and the circles, being ellipses, are difficult to draw. This projection, therefore, is not adopted in nautical astronomy in which we require to show a hemisphere.

Before leaving the diagram, however, it might be pointed out that qzp is the observer's meridian on the earth's surface and that the circle $SQ^1X^1Z^1P^1N$ is his celestial meridian, that qz is the Latitude of the observer's position, and that Q^1Z^1 is the corresponding arc in the sky and that both of those arcs subtend the same angle Z^1ZQ^1 at the centre of the earth.

The question of finding the Latitude from the meridian altitude of a body resolves itself into finding the arc Q^1Z^1 as follows. The arc SX^1 is the true angular height or true altitude of the body X^1 above the South point of the horizon, and by subtracting this arc from 90° (SZ^1) we get the zenith distance (Z^1X^1).

The arc Q^1X^1 is the angular distance of the body X^1 North of the equator, that is its declination, obviously, therefore, the arc $Z^1X^1 + \text{arc}\, X^1Q^1 = \text{arc}\, Q^1Z^1 = \text{arc}\, qz$, which is the Latitude of the observer.

Looking down on the plane of the horizon we see those same arcs represented on the meridian NZS as $ZX + QX = ZQ$, that is, Zen. Dist. + Dec. = Lat.

This diagram is an attempt to illustrate the several planes.

SEN	Plane of the rational horizon.
Z	Zenith.
P	the pole.
X	a star.
C	the centre of the earth.
QEQ_1	the equator.

Referring to the body X we have:

AX	Altitude = $\angle ACX$.
ZX	Zenith Distance = $\angle ZCX$.
DX	Declination.
PX	Polar Distance = $\angle PCX$.
PZ	Observer's co-Latitude = $\angle ZCP$.
$\angle ZPX$	Hour Angle of X = arc of Equator QD.
$\angle PZX$	Azimuth of X = arc of horizon NA.

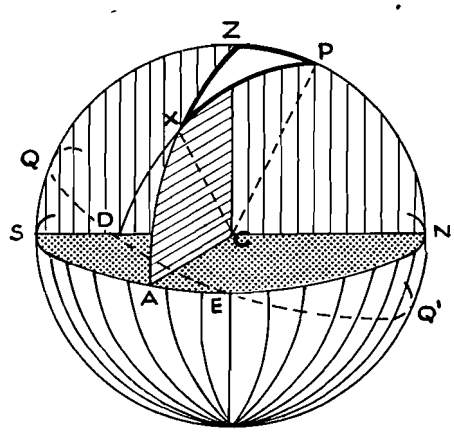


Figure 2(a).

Stereographic Projection

The Stereographic Projection is widely used in navigation text books, because all circles on the sphere appear either as straight lines or as arcs of circles when projected on the plane of the primitive. The eye is conceived to be placed on the surface of the sphere at the end of a diameter and the objects projected on to an imaginary transparent plane surface at right angles to that diameter.

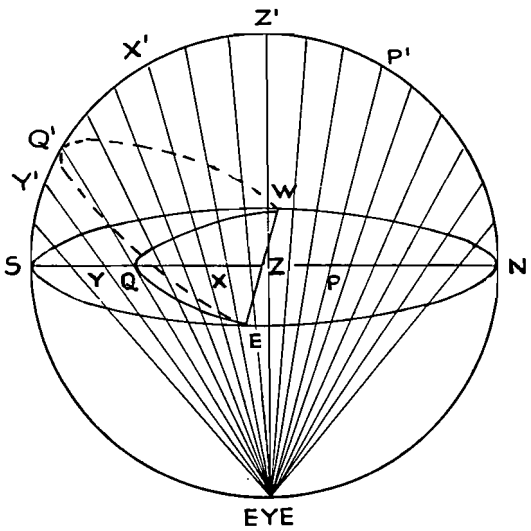


Figure 2(b).

The semi-circle NZ^1S, in Figure 2, represents the celestial sphere divided off into 10° arcs. Lines drawn from the eye to each point divide the meridian on the plane of the horizon (NZS) into a scale which is not quite equal throughout its length.

The plane of the horizon, $NESW$ is supposed to be transparent so that bodies such as P^1, Z^1, X^1, Q^1, Y^1 etc., are projected in the line of their respective visual rays as at P, Z, X, Q, Y, etc.

The distortion by this system is not violent, and a hemisphere may be shown with a fair measure of relative proportion. It will be observed that the scale on the meridian NZS is somewhat unduly enlarged as the visual rays recede from Z at the centre of the primitive.

The illustration depicts Lat. 60° N. on the stereographic projection. The elevation of the celestial pole (NP^1) is always equal to the Latitude and it is equal also to the arc Q^1Z^1. The spots P^1, Q^1 and Z^1 are projected on the plane of the horizon respectively, at P, Q and Z.

ZQ and NP represent Lat. 60° N.
QS and PZ represent co-Lat. 30°.

The celestial equator (dotted) is projected on the plane of the horizon as at WQE.

The spot X^1 in the sky is a body whose declination is 30° North, and Y^1 is another body in 10° South declination; X^1 is projected at X, and Y^1 at Y, so that

QX represents Dec. 30° N.
PX represents Polar Dist. 60°.
QY represents Dec. 10° S.
PY represents Polar Dist. 100°.

The plane of the horizon is at right angles to the observer's diametrical line of vision (ZZ^1) and would therefore actually appear as a circle $NESW$.

The simplest way to draw figures for practice on the stereographic projection is to draw on a card a circle of convenient radius and rule in the radial lines, then use it as the scale for all the figures, which must, however, be drawn with the same radius because the scale only applies to that particular circle. Nine-tenths of an inch is quite a suitable radius for the approximate figures required to illustrate problems in astro-navigation. This method saves the trouble of laying off the arcs on the circumference every time the circle is drawn and then having to draw in the particular radial lines required.

Example 1

Given Lat. 60° N., Dec. X 30° N., Dec. Y 10° S.

Construct a figure on the stereographic projection and measure the zenith distances of X and Y when on the meridian.

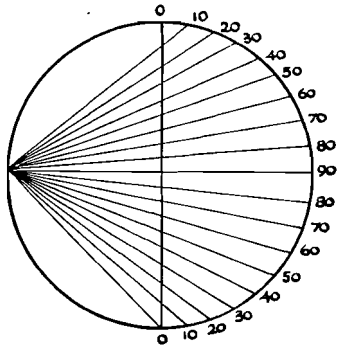


Figure 3. Scale for figures drawn on the stereographic projection.

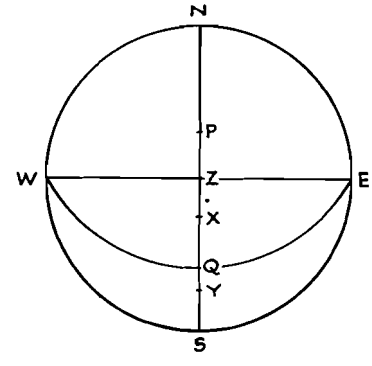


Figure 4.

1. Describe a circle $NESW$ having the same radius as the scale circle.
2. Draw in the meridian (NZS) and the prime vertical (WZE).
3. Measure off $NP = 60°$ from the central line of the scale and ZQ, also equal to 60°. Plot NP and ZQ on the meridian NZS.
4. Find by trial the centre of the circle WQE and draw in the equator which always passes through the East and West points of the horizon.
5. Measure off $QX = 30°$, the declination of X, and $QY = 10°$, the declination of Y, always keeping to their corresponding positions on the scale of the central line. The zenith distance of X (ZX) read from the scale is 30°, and of Y (ZY) 70°.

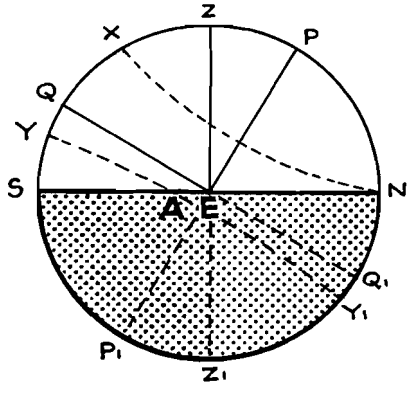


Figure 4(a).

Fig. 4a is drawn on the plane of the observer's meridian.

SEN Rational Horizon, P North Pole, QEQ_1 Equator, Z Zenith, Z_1 Nadir, E Centre of the earth, X and Y the two bodies on the observer's meridian PZS.

SX Upper Meridian Altitude Body X.
N Lower Meridian Altitude Body X (0°).
QX North Declination.
ZX Zenith Distance.
$ZX + QX = ZQ$ (Latitude).

SY Upper Meridian Altitude Body Y.
NY_1 Lower Meridian Altitude Body Y.
QY South Declination.
ZY Zenith Distance.
$ZY - QY = ZQ$ (Latitude).

Body Y rises at A. Culminates at Y.

Body X is Circumpolar and does not fall below the Horizon.

The Equidistant Projection

A more convenient and quicker system of figure drawing and one from which it is possible to obtain, by measurement, nearer approximations to the desired answers than is possible by the stereographic projection is the **Equidistant Projection.**

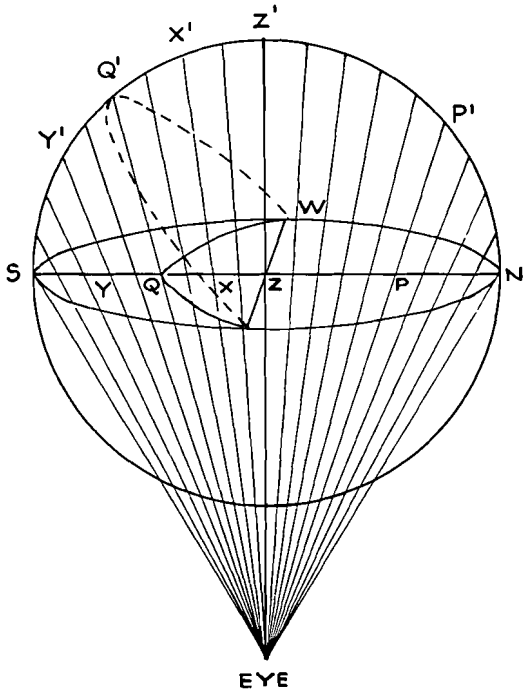


Figure 5.

The eye is assumed to be situated on a diameter produced beyond the sphere to a distance of $\frac{1}{\sqrt{2}}$ times the radius. The further semi-circle is then divided into arcs of 10°, and the visual rays to these points, when projected to the plane at right angles to the diametrical line of sight, divide its diameter into nine parts that are so nearly equal to each other that they may be considered so for the purpose of illustrating problems in astro-navigation. The scale of degrees on the meridian (*NZS*) is practically equal throughout, as indeed it is on all the great circles passing through *Z* which are vertical circles represented by straight lines on the projection, so that any convenient scale of equal parts may be used when measuring angular distances from the zenith.

Referring to the figure and measuring with a pair of compasses, it will be noticed that the elevation of the pole (*NP*) on the plane of the observer's horizon is equal to the Latitude (*ZQ*), and that the declination of *X'* which is 20° N. when measured by the arc of the meridian *QX* on the plane of the horizon is exactly the same measure of equal parts as *QY*, which represents the declination of the body *Y'* in 20° S. The scale on the meridian *NZS* is uniform throughout.

TO CONSTRUCT A FIGURE

Given Latitude, Declination and Azimuth

Example 2

Construct a figure on the equidistant projection for Lat. 40° N., Dec. of body 20° S. Find by measurement the zenith distances of the body when it crosses the meridian, and when it bore 130° T, 160° T and 220° T.

1. Describe a circle with nine equal parts as radius. Nine-tenths of an inch is a very convenient size for the purpose, each tenth representing 10°. Zenith to the horizon is 90°.

2. Draw in *NZS* and *WZE*.
3. Take 40°, that is four equal parts from the scale and lay off with the same opening of the compasses, *ZQ* the Lat., and *NP* also equal to the Lat.

   Draw in *WQE* the equator, the centre of which is somewhere on the meridian produced if need be.
4. Take 20°, that is two equal parts from the scale, and lay off *QX* the declination. Point *X* is the position of the body on crossing the meridian and its meridian zenith distance (*ZX*) measures 60°.

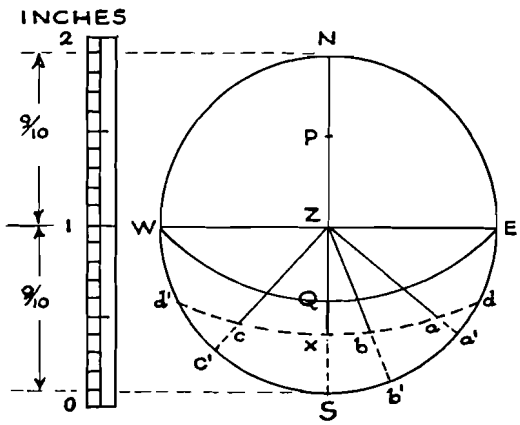


Figure 6.

To find its zenith distances at other times of the day we must first find the bearing of the body at rising and setting. These bearings are given in Nautical Tables under the heading of "True Amplitude and Amplitude Correction Tables".

Amplitude

The Amplitude of a body is the arc of the horizon between the East point and the body when it is rising, and between the West point and the body when it is setting. The Table is entered with 40° Lat. and 20° Dec. and the corresponding amplitude is found to be 26½°

5. Lay off on the figure with a protractor, $\angle EZd$ equal to 26½° and $\angle WZd^1$ 26½° to the South because the body has South declination. Then, by trial on the meridian, always moving the compasses out and in as required, find the centre of the circle *dxd'* and draw it in dotted. *dxd'* is a "small" circle and only applies to this particular body. This small circle, or parallel of declination, is the apparent daily path of the body over the plane of the horizon caused by the earth rotating on its axis. The body (if a star) really keeps stationary, the earth rotates under it, but in nautical astronomy we assume the earth to be fixed and the body to "travel" daily across the sky, rising at *d* and passing in succession through positions *a*, *b*, *x*, *c* and setting at *d'*, then completing its circuit round the back of the sphere and reappearing at *d* again the next day.
6. To find the zenith distances of the body when bearing 130° T, 160° T, and 220° T, lay off $\angle SZa = 50°$, $SZb = 20°$, $\angle SZC = 40°$ and *a*, *b* and *c* are its required positions. From the scale of equal parts measure the zenith distance,

   Zenith distance $Za = 78°$ when the body bears 130° T.
   $Zb = 63°$ when the body bears 160° T.
   $Zc = 71°$ when the body bears 220° T.

The altitude is the complement of the zenith distance so that the respective altitudes of *a*, *b* and *c* are represented on the figure by $a^1a = 12°$, $b^1b = 27°$ and $c^1c = 19°$, the maximum altitude *SX* being reached when the body is on the meridian.

Example 3

Construct a figure on the equidistant projection having given Lat. 43° S., Dec. of body 22° S., and Zenith Dist. 65°, and from it find the azimuth and true bearing of the body before and after it crossed the meridian.

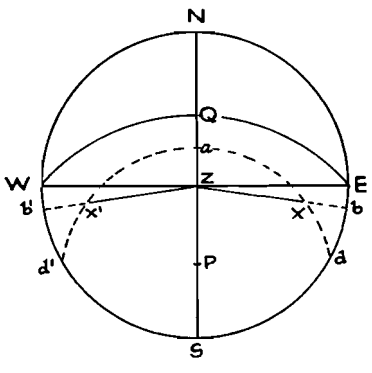


Figure 7.

1. Describe the horizon circle $NESW$ with a radius equal to nine-tenths from the scale.
2. Draw in NZS and WZE.
3. Take 43°, that is 4·3 equal parts from the scale, and lay off SP and ZQ the Lat. Draw in WQE the equator. The South Pole is the elevated one because the observer is in South Latitude.
4. From *Norie's Tables* find the amplitude corresponding to Lat. 43°, Dec. 22°. It is nearly 31°. With a protractor lay off $\angle EZd$ and $\angle WZd^1 = 31°$, then describe the dotted circle dad^1. This is the daily path of the body and it must be somewhere on this circle.
5. Open out the compasses to the zen. dist., that is 65° from the scale, and with centre Z describe an arc cutting the daily path at X and X^1. This gives the position of the body when East of the meridian and when West of the meridian.
6. Join ZX and ZX^1 and produce to the horizon if desired.
7. Lift off the angle SZX and SZX^1 with a protractor. These are found to be S. 82° E. and S. 82° W., and are called the **azimuth** of the body because they are named from the **elevated pole.**

   The true bearings are the angles NZX and NZX^1 and are obviously the supplements of the azimuth, i.e. 098° T and 262° T.

   The **Azimuth** of a body is the angle at the zenith between the observer's meridian and the vertical circle through the body. Thus, in Fig. 7, NZS is the observer's meridian, ZXb and $ZX'b'$ are the vertical circles passing through the body when a X and X^1 respectively and $\angle SZX$ and $\angle SZX^1$ are the corresponding azimuths.

To Construct Celestial Meridians and Hour Circles

Celestial Meridians are Semi-Great Circles joining the celestial poles. They correspond to celestial meridians. Hour Circles are the Great Circles which correspond to a celestial meridian and its anti-meridian. The term Hour Circle is generally used to mean celestial meridian. Hour Angle is so named because although it is normally expressed in degrees (0–360°) it can also be expressed in units of time (0–24 hrs) with each hour corresponding to 15° which is the hourly rate at which the mean sun increases its GHA. Time itself is measured from the observer's anti-meridian so that an Hour Angle of 180° corrosponds to 00 hrs and 360° or 0° corresponds with the 12 hour circle.

Example 4

Make a scale drawing showing the 24 celestial meridians (12 hour circles) which divide the horizon into 24 hours of Mean Solar Time.

Describe a circle to represent the horizon. Mark the position of the Pole and draw in the equator as shown in Figure 8. Find by trial point *O*, the centre of the circle passing through *W*, *P* and *E*. Through *O* draw a dotted line at right angles to the meridian. This line is called a **locus**, because the centres of all the great circles passing through *P* are situated on it.

Divide off the equator *WQE* into twelve equal parts, six on each side of the meridian to represent each hour circle as illustrated in the figure.

On the locus, opening and closing the compasses as required and moving them along the line, find by trial the centre of each hour circle in turn and draw it in. The centre of the 10 o'clock hour circle, for example, is at *C* and the others may be found and tested on the figure itself.

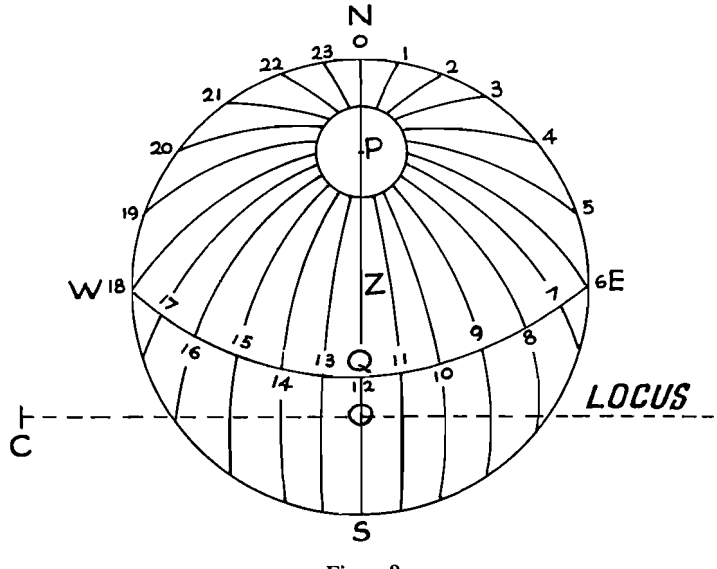


Figure 8.

Each hour circle passes through the pole and cuts the equator perpendicularly at its respective point. The figure shows the 12 hour circles and celestial meridians which divide the horizon into 24 hours.

Example 5

Construct a figure on the equidistant projection for Lat. 40° N., Dec. 12° S., Hour Angle 47°, body West of meridian, and from the figure find the approximate azimuth and zenith distance of the body.

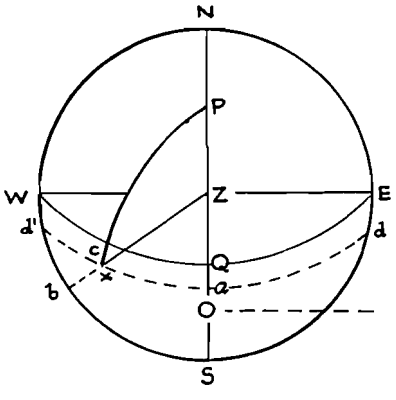


Figure 9.

1. Describe the circle *NESW* with a radius of nine equal parts to represent the rational horizon, and draw in *NZS* the observer's meridian, and *WZE* the prime vertical.
2. Elevate the pole *NP*, and depress the equator *ZQ*, equal to the Lat. 40° and draw in the equator *WQE*.
3. Make *Qa* equal to the Dec. 12° S., and $\angle EZd$ and $\angle WZd'$ equal to the amplitude 16° S. and describe the daily path *dad'*, finding the centre by trial. The body is somewhere on this dotted circle.
4. Again, by trial, on the meridian, find the centre *O* of a circle passing through *E*, *P* and *W*. We don't show the circle because we only want the location of its centre. Draw a line from *O* at right angles to the meridian. This line is called a "locus" and the centres of all the hour circles, or celestial meridians, are on this line.

The body in our question has an hour angle of 47°, so the hour circle *PX* must cut the equator at a point making the arc *Qc* equal to 47°. Divide the arc *QW* into six equal parts, each part representing an arc of 15°, and make a mark *c* at 47° approximately.

Now, with the point of the compasses on the locus, find by trial the centre of the circle passing through *P* and *c*, opening and closing the compasses as required, then draw in the hour circle *PX*.

5. Join *ZX* and produce to the horizon at *b*.

Lift off the angle *PZX*, with a protractor. It is 129°. The true azimuth is therefore N. 129° W. = 231° T.

Measure *ZX* from the scale of equal parts. It is 68°. The zenith distance is therefore 68°. the arc *Qc*, 47°, is equal to the $\angle ZPX$, so we have now got all the essential parts of the pole-zenith-star triangle, viz.

angle	*ZPX*	Hour angle	= 47°
angle	*PZX*	Azimuth	= N. 129° W = 231° T.
arc	*PZ*	Co-Lat.	= 50°
arc	*PX*	Polar dist.	= 102°
arc	*ZX*	Zen. dist.	= 68°

The angle *X* is seldom used in astro-navigation and is usually referred to as the Parallactic Angle.

The same information illustrated on the stereographic projection would be drawn as follows:

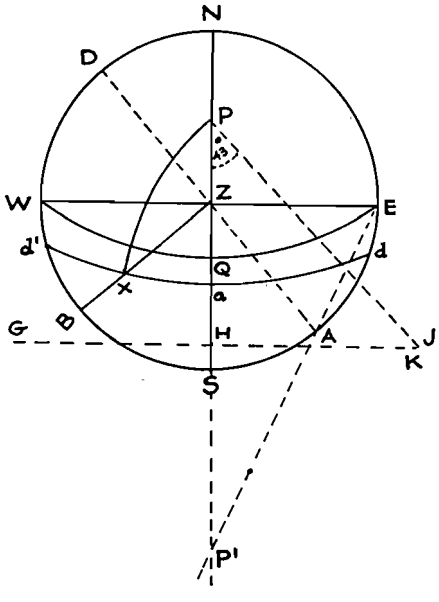


Figure 10.

1. Describe the primitive *NESW* with the same radius as the scale Figure 3.

   Draw in the meridian and the prime vertical.
2. Elevate the pole *NP*, and depress the equator *ZQ* according to scale and draw in the equator.
3. Spot *D* is the end of the visual ray *EPD*. Draw a line from *D* through *Z* to *A* on the circumference of the circle.
4. Draw the line *EA* meeting the meridian produced at *P'*. *P'* is the depressed pole.
5. Bisect *PP'* at *H* and draw in the line *GHJ* at right angles to the meridian. This is the locus of all the hour circles. To find the centre of the 47° Westerly hour circle, proceed as follows:
6. Find the complement of the hour angle $90° - 47° = 43°$.

   Put the centre of the protractor on *P* and lay off a line on the opposite side to the object making an angle of 43° with the meridian. This line will cut *GHJ* at *K*.

   K is the centre of the hour circle 47° West and *KP* is its radius.
7. With centre *K* and radius *KP* describe the hour circle *PX*, which meets the parallel of declination at *X* and indicates the position of the body at the time required.
8. Join *ZX* and produce to the horizon.
9. The parallel of declination *dad'* is drawn by laying off *Qa* = Dec., *Ed* and *Wd'* = amplitude from Nautical Tables, and then finding the centre of the circle passing through *d*, *a* and *d'* by trial.
10. Lift off angle *PZX*, the azimuth, with a protractor and measure arc *ZX*, the zenith distance, from the stereographic scale.

    This example has been given in order to compare the stereographic with the equidistance method of projection.

Example 6

Construct a figure on the Equidistant projection given Lat. 40° S., Dec. 15° S. Zen. Dist. 45°, body East of the meridian. Find the approximate Azimuth and Hour Angle of the body from the figure.

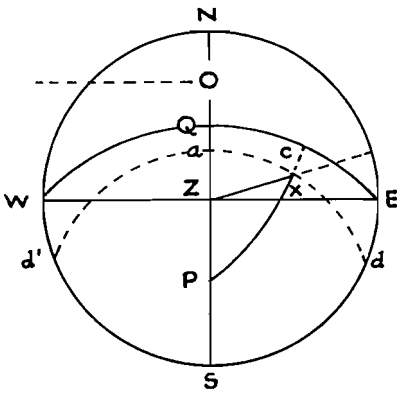


Figure 11.

1. Describe the circle *NESW*. Draw in *NZS* and *WZE*. Elevate the South Pole equal to the Lat. *SP* and depress the equator the same amount *ZQ*. Draw in *WQE*.
2. Make $Qa = 15°$ S. declination, and $\angle EZd$ and $\angle WZd' = 20°$ amplitude. Draw in the daily path *dad'*.
3. Centre *Z* and radius zen. dist. 45° from the scale, describe an arc cutting *dad'* at *X*. Join *ZX*. $\angle PZX$ is the azimuth required.

   It measures 110° by protractor.
4. Find *O*, the centre of the circle passing through *WPE*, and through *O* draw the locus at right angles to the meridian. Find by trial the centre of the hour circle *PX* and draw it in, continuing it to the equator at *c*.
5. Divide *QE* into six equal parts of 15° each. *c* appears to be at 45°, therefore the body is 45° East of the meridian. Its approximate E'ly hour angle is therefore 45° and its azimuth S. 110° E. (070° T) as measured with a protractor. If the body *X* were the sun, then the apparent time would be 0900 because it is 3 hours before it reaches the meridian at 1200 L.A.T.

LOWER MERIDIAN PASSAGE

When the Latitude is greater than the polar distance of a body then the body is continuously above the observer's horizon, it does not rise or set and has, therefore, no amplitude. The body has two meridian altitudes, one when it crosses the meridian "above" the pole, named its **Upper Meridian Passage**, and the other when it crosses the meridian "below" the pole, named its **Lower Meridian Passage**.

All celestial bodies are circumpolar, that is to say, they describe a circle round the pole, but the name "circumpolar" is generally used to designate those stars which are visible at their lower transit across the meridian.

Example 7

Lat. 50° N., Dec. of body 56° N. (Polar Dist. 34°). Draw a figure and from it measure approximately the altitudes of the body at its lower and upper meridian passages.

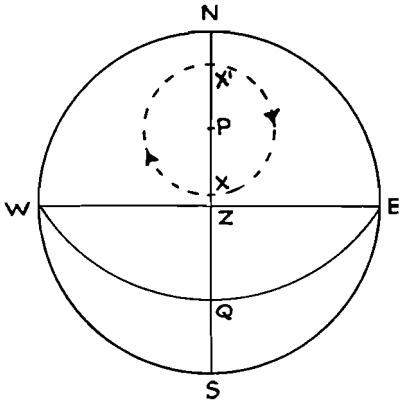


Figure 12.

1. Describe the circle *NESW* equal to nine equal parts from the scale, and draw in *NZS* and *WZE*.
2. Make $NP = ZQ$ = Lat. 50° N. and draw in *WQE* the equator.
3. With centre *P* and radius Polar Dist. 34°, describe the circular daily path of the body cutting the meridian at *X* and *X'*.

This is not strictly correct as the pole is not the centre of the diurnal arc unless the body is close to the pole, but the assumption is near enough for these approximate figures.

The upper meridian passage is at *X* when the body is between the pole and the zenith; the lower meridian passage is at *X'* when the body is between the pole and the horizon.

The altitudes are 16° when below the pole (*NX'*) and 84° when above the pole (*NX*). $PX = PX^1$ = polar distance.

The same example and figure will serve to show that the latitude may be found from an unknown circumpolar star by observing its upper and lower meridian altitudes as follows:

Lat. $= \frac{1}{2}$ (upper mer. alt. + lower mer. alt.) $= \frac{1}{2}(16° + 84°) = 50°$

From Fig. Lat. $= \frac{1}{2}(\ NX\ +\ NX'\ )$

Lat. $= \frac{1}{2}(NP + PX + NP - PX') = \frac{1}{2}(2NP) = NP$ = Lat.

LONGEST AND SHORTEST DAYS

Example 8

Find the latitude in which the LHA at sunset on the longest day is double the LHA at sunset on the shortest day.

The Dec. = $23\frac{1}{2}°$ N. and S. respectively. But $\frac{1}{2}$ longest day $+ \frac{1}{2}$ shortest day = 12 h always. The ratio here is 2 to 1 $\therefore \frac{12}{3}$h = 4 h = 60° for the smallest LHA and 120° for the largest LHA.

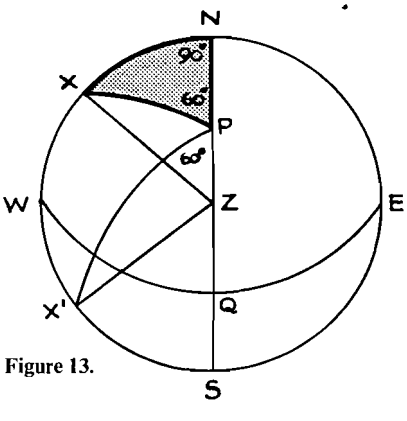


Figure 13.

In Figure 13, let *X* and *X'* be the sun at setting when Dec. = $23\frac{1}{2}°$ N. and $23\frac{1}{2}°$ S.

$\angle ZPX = 120°$; $\angle ZPX' = 60°$; $\angle NPX = 60°$

In $\triangle$ *NPX*, *PX* = P Dist., $\angle P = 60°$, $\angle N = 90°$

Find *PN* the latitude, by Napier's Rules.

sin co *P* = tan *PN* tan *co PX*	60°	cos	9·69897
cos *P* = tan *PN* cot *PX*	$23\frac{1}{2}°$	cot	0·36170
Cos *P* tan *PX* = tan *PN*		tan	10·06067
Cos 60° cot $23\frac{1}{2}°$ = tan lat.	48° 59′		

Lat. 48° 59′

The same method applies to other ratios of longest and shortest days; for example, if the ratio were 3 to 1, then $\frac{12}{4}$ h = 3 h = 45° = $\angle NPX = ZPX^1$, the LHA at sunset on the shortest day, and $\angle ZPX$ = 135° LHA on the longest day.

Exercise 1

Draw a figure on the plane of the rational horizon showing the position of the zenith, the body, the elevated pole, the equator and the daily path of the body, and from it find the approximate value of the parts asked for in the following questions.

Bodies on the Meridian

1. Lat. 20° S., Dec. 23° N. Find the zenith distance.
2. Lat. 48° N., Dec. 57° N. Find the zenith distance when the body is above and below the pole.

Given Latitude, Declination and Azimuth

3. Lat. 40° N. Dec. 20° N. Find from figure the approximate zenith distances of a body when its true azimuth is (*a*) 100° T (*b*) 280° T.
4. Lat. 50° S. Dec. 20° N. Find Zenith Distance when body bears (*a*) 040° T (*b*) 310° T.

Given Latitude, Declination and Zenith Distance

5. Lat. 35° N. Dec. 20° N. Zenith Distance 42°. Find from figure the approximate azimuth and hour angle of the body.
6. Lat. 50° N. Dec. 15° S. Zenith Dist. 70°. Find E.H.A. and Azimuth of the body.

Given Latitude, Declination and Hour Angle

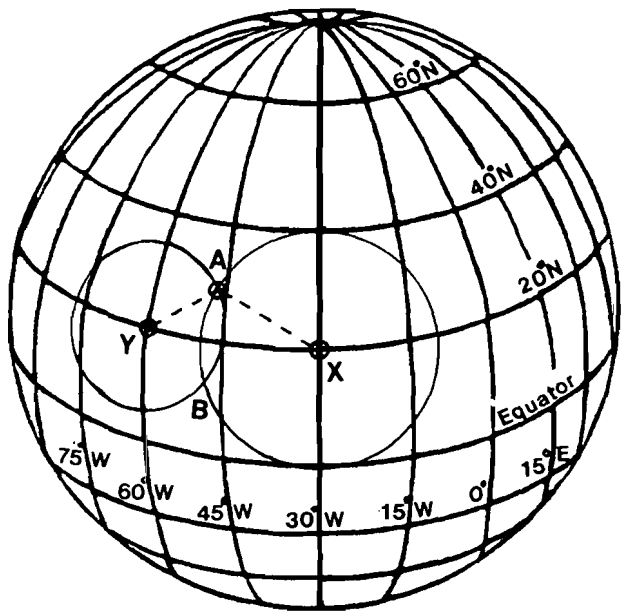
7. Lat. 38° N. Dec. 12° N., H.A. 60°. Find the Azimuth and Zenith Distance of the body.
8. Lat. 45° S. Dec. 5° S., E.H.A. 67½°. Find the Azimuth and Zenith Distance of body.

Answers

1.	Zen. Dist.	43°	5.	Az. 262° T	H.A. 45°
2.	„	75° below pole, 9° above pole	6.	„ 149° T	E.H.A. 30°
3.	„	(*a*) 47°, (*b*) 69°	7.	„ 260° T	Zen Dist. 60°
4.	„	(*a*) 75°, (*b*) 80°	8.	„ 078° T	„ „ 70°

Questions

1. What is meant by a natural projection? Name two such projections.
2. What are the advantages and disadvantages of the stereographic projection and why is it usually preferred to the orthographic projection?
3. Mention the advantages of the equidistant projection for figure drawing in navigational questions.
4. Explain the terms, Geocentric, Circumpolar, and Hour Circle.
5. What is meant by Upper Meridian Passage and Lower Meridian Passage? Under what circumstances will a body be visible at its lower transit?



The Principle of Position Lines.

Chapter 25

Principle of Position Lines

If at any given moment the altitude of a body be observed, corrected, and the true zenith distance deduced from it, this information alone merely defines a circle of position on the earth's surface, which may be drawn on a globe, with the geographical position of the body as its centre and the zenith distance as its radius.

Referring to the figure of the globe on the facing page, we have assumed a body X whose declination is 20° N. and G.H.A. 30°, its geographical position is therefore Lat. 20° N., Long. 30° W. Suppose, now, the corrected altitude (70°) gives a true zenith distance of 20°, then with centre X and radius 20° we have described a circle which is seen to touch the equator and to extend 20° all round X. Now, at every point on that circle the zenith distance of X would be 20° to all observers who observed the altitude of X simultaneously, but the positions of the observers on that circle would be indeterminate from this information alone. Let us imagine a number of ships to be on the circumference of this circle, then from each ship the zenith distance of X would be 20° from every one of them.

If, however, from a particular ship, the true bearing of X happened to be North, then that ship would be on the equator and on the same geographical meridian as X, i.e., 30° W. The observed position of this ship would be Lat. 0°, Long. 30° W., because the line of bearing, 000° T., cuts the circle at a definite position.

Suppose, from another ship, the body X bore 180° T then that ship would be on a parallel of latitude 20° due North of the geographical position of the body X, and the observation position of the ship would be Lat. 40° N., Long. 30° W., because the line of bearing, South, cuts the circle at a definite position.

Suppose from yet another ship the body X bore 125° T, as indicated by the dotted line on the illustration, then this line of bearing drawn on the globe would cut the circle at the ship's position.

Now consider another body, Y, which has the same declination as X (20° N) but a G.H.A. of 60°. Its geographical position (Y) will be Lat. 20° N Long. 60° W. Assume an observation is taken of body Y, simultaneously with the observation of body X. Zenith distance Y is found to be 15° and its bearing 240°T. With Y as centre, describe a circle of radius 15°. In the first instance this would only give us the ship's circle of position around Y, but the bearing, 240°T, could be used to fix position on that circle. The two circles intersect at A and B and indicate two possible positions. The two bearings of the body will indicate which of the two positions is the correct one, i.e. position A.

It would seem, therefore, that, given the geographical position of a body, zenith distance and azimuth at a particular moment of time the position of the observer on the earth's surface may be fixed relative to that body, and so it can be, in theory.

The method has to be modified in practice as the azimuth cannot be found with sufficient accuracy, nor is it possible to draw such large circles accurately. The underlying principle is,

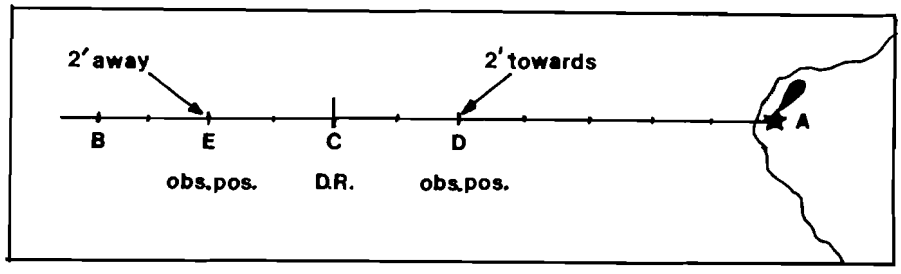


Figure 1. Principle of Intercepts.

however, similar to that involved in fixing the ship's position by a bearing and radar range of a lighthouse. The range gives a circle of position centred on the lighthouse while the bearing gives a radial line cutting the circumference at right angles.

Much the same practice is followed in position line methods by substituting a celestial body for the lighthouse, with this exception, however, that it is impossible to chart permanently the geographical position of a celestial body which is travelling daily across the sky and passing vertically in succession over points on the earth's surface.

Suppose we were to estimate the distance from a lighthouse to be 7 miles when bearing 090° T. We can lay off the bearing (*AB*) on the chart, and with the compasses opened out to 7 miles, plot the position *C* which would only be an approximate position, but we would know with certainty that the ship was somewhere on the line of position *AB*.

If now we were to obtain the distance from the lighthouse by a radar range, and we were to find the true distance to be only 5 miles not 7 miles, then we would know that *C* was not the position of the ship which was, in fact, 2 miles nearer the lighthouse along the line of direction *CA*.

The observed position of the ship would be at *D*, so we measure *CD*, 2 miles towards the lighthouse; *CD*, in position line navigation, would be called the intercept, 2′ towards. Had the distance by observation from the lighthouse been 9 miles, the observed position would have been at *E*, 2 miles further away from the lighthouse than the D.R. position *C*; and *CE*, the Intercept, would be 2′ away.

The method adopted in astro-navigation is much the same. An altitude of the body is observed which, when corrected in the usual way, gives the observed zenith distance, or, the great circle distance in nautical miles of the observer from the geographical position of the body; its azimuth at the time is also noted. We do not need to draw the complete circles but only those parts where they cut in the vicinity of the ship. The circles are so big that the curvature of the circumference may be neglected under normal conditions; and short lengths of the arcs are laid off on the chart as straight lines at right angles to a radius, the radius being the bearing of the body, are all that are necessary.

A D.R. position is assumed in the vicinity of the ship's likely position and the zenith distance of the body for this assumed D.R. is calculated for the instant that the altitude is observed. Although this calculated zenith distance may accidentally agree with the observed zenith distance, it does not follow that the ship is necessarily in the same Latitude and Longitude as the assumed D.R. position, but it is at a point somewhere on a line, called a position line, drawn through the D.R. position at right angles to the true bearing of the body observed.

If, however, the observed zenith distance were, say, 2′ less than the calculated zenith

distance, then the position line would be drawn through a point on the line of bearing 2 miles nearer to the body; this distance, called the intercept, is said to be 2 miles towards. We have to keep clearly in mind that the zenith distance as obtained by sextant observation is the actual or true distance of the ship from the geographical position of the body, and that the calculated zenith distance is the distance the ship would have been from the body had it been at the D.R. position.

Celestial Position Lines

A Celestial Position Line is a line drawn on a chart at right angles to the true bearing of the body under observation, the position of the ship being somewhere on the line. The position line is a tangent to the circle of position. The problem which presents itself in navigation is to find the position on the line of bearing through which to draw the position line. This position is known as the Intercept Terminal Position (I.T.P.).

PLOTTING POSITION LINES

The following information is required for plotting a celestial position line:

1. A suitable position, usually the D.R.
2. The true zenith distance, as obtained from a sextant observation.
3. The calculated zenith distance, using the position in (1) above.
4. The true azimuth of the body, as obtained from ABC or other tables.

Example 1

Given D.R. position of ship 43° 15′ N., 56° 15′ W., Observed Altitude when corrected gave a True Zenith Distance 34° 18′; the zenith distance as calculated for the D.R. position was 34° 12′; Azimuth of the Sun from Tables 152° T. Find the Latitude and Longitude of the position through which to draw the position line.

True Zen. Dist.	34° 18′
Calc. Zen. Dist.	34 12
Intercept	6′ Away
Azimuth	152° T (S. 28° E.)

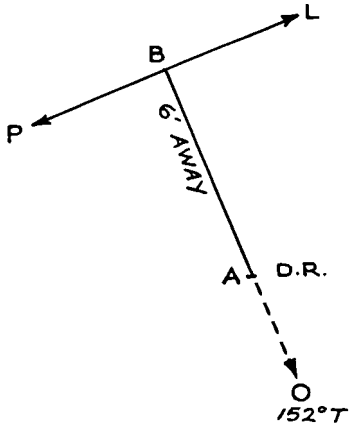


Figure 2. Navigator's Sketch.

1. Plot the D.R. position at *A* on the chart. This is only an assumed position.
2. Lay off from *A* the direction of the sun's true bearing 152° T and measure off the intercept *AB* 6 miles 332° T (N. 28° W.) from *A* because the true zenith of the observer is further away from the geographical position of the sun than the assumed zenith.
3. Through *B* draw the position line at right angles to the bearing of the sun. The ship is **somewhere** on *PL*, not necessarily at *B*, but *B* is the best position we can get. Lift off the Latitude and Longitude of *B* from the chart which now becomes the D.R. position nearest to the actual position of the ship, and we are no longer interested in position *A*.

   The Latitude and Longitude of *B* the I.T.P., may be found by means of the Traverse Table.

From Traverse Tables

(Intercept Away)		Lat.			Long.	
332° T, 6 miles	D.R. Pos. *A*	43° 15′	N.		56° 15′	W.
D. Lat. 5·3′ N.	D. Lat.	05·3	N.	D. Long.	03·8	W.
Dep. 2·8 W., D. Long. 3·8′ W.		43 20·3	N.		56 18·8	W.

Answer I.T.P. 43° 20·3′ N., 56° 18·8′ W.

Example 2

Given D.R. 38° 40′ S., 28° 12′ E., True Zenith Distance 45° 12′, Calculated Zenith Distance 45° 25′, Azimuth of body 060° T. Find the position through which to draw the position line.

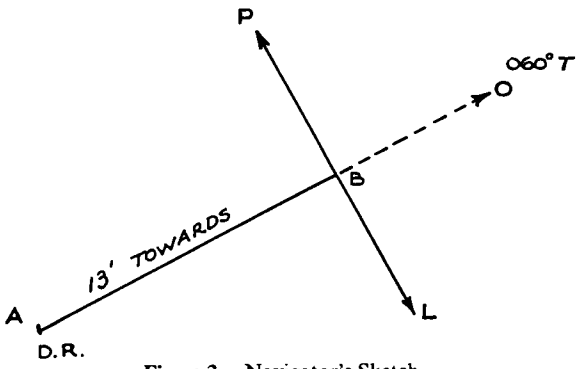


Figure 3. Navigator's Sketch.

True Zen. Dist.	45° 12′
Calc. „	45 25
Intercept	13′ Towards
Azimuth	060° T

Position line P/L 150° T – 330° T

From Traverse Tables

(Intercept Towards)		Lat.			Long.	
060° T, 13 miles	D.R. Pos. *A*	38° 40′	S.		28° 12′	E.
D. Lat. 6·5′ N.	D. Lat.	06·5	N.	D. Long.	14·6	E.
Dep. 11·3′ E., D. Long. 14·6′ E.	I.T.P.	38 33·5	S.		28 26·6	E.

Answer I.T.P. 38° 33·5′ S., 28° 26·6′ E.

TRANSFERRING POSITION LINES

A single observation only gives a line on which the observer is situated. To fix the position at least one further observation is needed, at the same time or at a later time. It may therefore be necessary to "run up" or "transfer" the Position Line to the time of the second observation. The basic principle is the same as for the Running Fix, described in the chapter on chartwork.

In order to obtain a satisfactory position two conditions should be satisfied:

1. There should be a "good cut" between the P/L's – not less than about 30°.
2. The first P/L should be run up as accurately as possible, so due allowance should be made for any current or leeway.

Although the run has been plotted, to illustrate Example 3, it is strongly recommended that the first P/L should be run up by Traverse Table so that the final plot may be done on a suitably large scale. Note also that many navigators find it convenient to transfer the D.R. position rather than the I.T.P., both intercepts being placed on the final plot; this method is also shown on the same figure.

It is customary to indicate a celestial P/L by means of a single arrow-head placed at each end, in the case of a transferred P/L a double arrow-head is used.

Example 3

Given D.R. 51° 30′ N., 178° 30′ W. True Zen. Dist. 39° 50′, Calc. Zen. Dist. 40° 05′, Azimuth of body 225° T. Find the position for drawing the position line. The ship then sailed 025° T 35 miles. Find the new position and show the transferred position line.

True Zen. Dist.	39° 50′
Calc. „	40 05
Intercept	15′ Towards
Azimuth	225° T

P/L 135° T – 315° T.

From Traverse Tables:

(Intercept Towards)					
225° T, 15 miles	D.R. *A*	51° 30·0′ N.		178° 30·0′ W.	
D. Lat. 10·6′ S.	D. Lat.	10·6 S.	D. Long.	16·9 W.	
Dep. 10·6′ W., D. Long. 16·9′ W.					
"Run *BC*"	Pos. *B*	51 19·4 N.		178 46·9 W.	
025° T, 35 miles	D. Lat.	31·7 N.	D. Long.	23·8 E.	
D. Lat. 31·7′ N.					
Dep. 14·8′ E., D. Long. 23·8′ E.	Pos. *C*	51 51·1 N.		178 23·1 W.	

In Figure 4

A The D.R. position.

B The position through which to draw the position line *PL*. *B* is the I.T.P.

C The position at the end of the run. Through *C* draw *P'L'* parallel to *PL*. The transferred position line is *P'L'* and the ship is presumed to be somewhere on this line but not necessarily at *C*. Alternatively the D.R. may be run up from *A* to *D* and then the intercept *DC* is drawn.

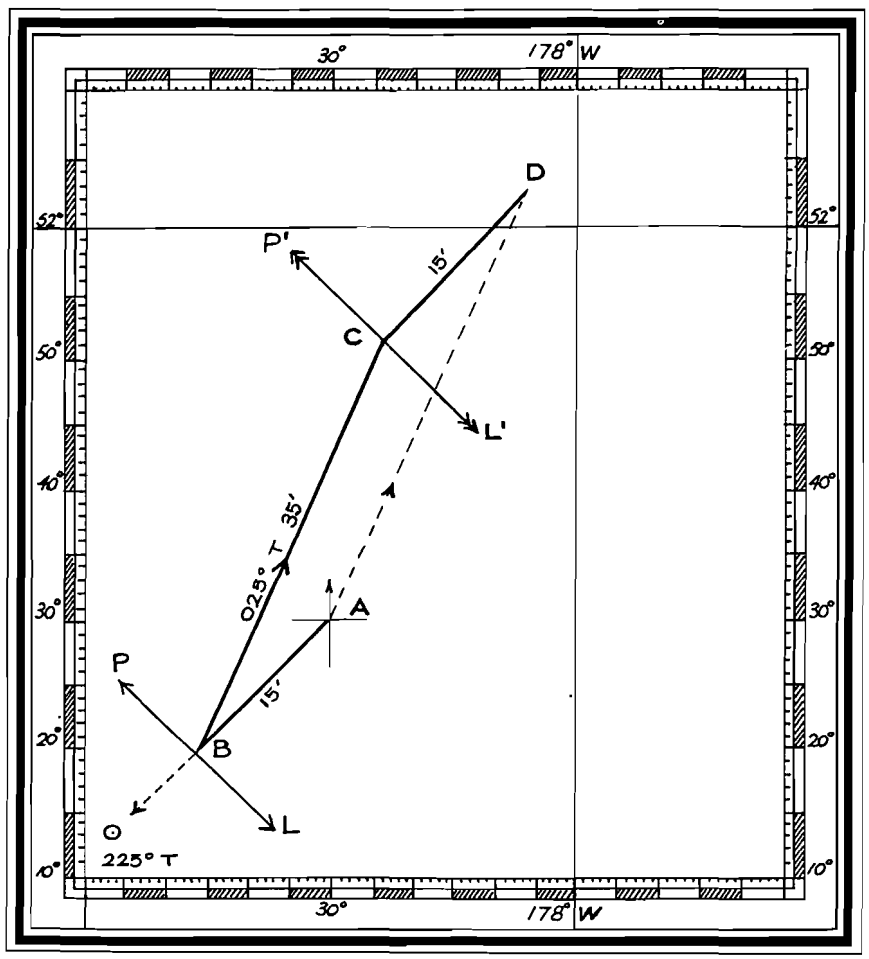


Figure 4. Navigator's Chart Plot.

Answer 51° 19·4′ N., 178° 46·9′ W. for the position line *PL*.
51 51·1 N., 178 23·1 W. for the transferred position line *P′ L′*.

Exercise 1

Draw a careful figure for the following examples and give the Latitude and Longitude of the position through which the position line should be drawn. In examples (3) and (4), find the Latitude and Longitude of the position through which to draw the transferred position line.

	D.R.	True Zen. Dist.	Calc. Zen. Dist.	Azimuth	Run
1.	29° 30′ N. 40 40 W.	35° 12′	35° 22′	200° T	
2.	38 12 S. 168 20 E.	40 53	40 36	050° T	
3.	51 12 N. 37 30 W.	53 18	53 05	145° T	067° T 25 miles.
4.	18 20 S. 30 30 W.	29 12	29 32	320° T	260° T 15 miles.

Answers

1. 29° 20·6′ N. 40° 43·9′ W.
2. 38 22·9 S. 168 03·4 E.
3. 51 22·6 N. 37 41·9 W.
   51 32·4 N. 37 05·1 W.
4. 18 04·7 S. 30 43·6 W.
   18 07·3 S. 30 59·2 W.

The Position Fixed by Two Position Lines with a Run Between Them

Example 4

(Refer to Figures 5 and 6)

At 0830 in position 48° 30′ N., 24° 20′ W. an observation of the sun gave an intercept of 4′ towards, azimuth 100° T. Ship's course and speed 250° T, 14 knots.

Later, at 1130, a second observation of the sun on a bearing of 175° T, gave an intercept of 3′ away; having run up the D.R. position for the calculation.

Required the ship's position at the time of the second observation and also at 1200.

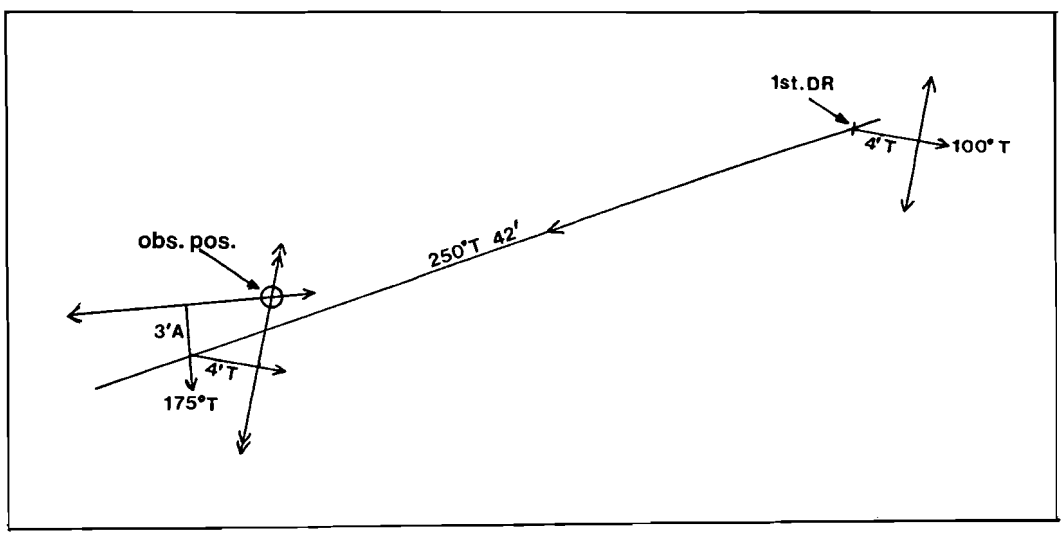


Figure 5. Overall Plot.

Notes:

When an intercept is given for the second observation it is necessary to consider what position was used in the calculation. This question states specifically that the D.R. was run up for this purpose.

In accordance with the advice previously given, the run up will be made by Traverse Table and the working plot will be used only for the final situation. A figure showing the overall plot is given for illustrative purposes.

Since there is but a short run from 1130 to 1200, this may conveniently be drawn on the working plot.

From Traverse Tables:

Co. 250° T, Run 42′	1st D.R.	48° 30·0′ N		24° 20·0′ W.
D. Lat. 14·4′ S.	D. Lat.	14·4 S.	D. Long.	59·4 W.
Dep. 39·5′, D. Long. 59·4′ W.	2nd D.R.	48 15·6 N.		25 19·4 W.

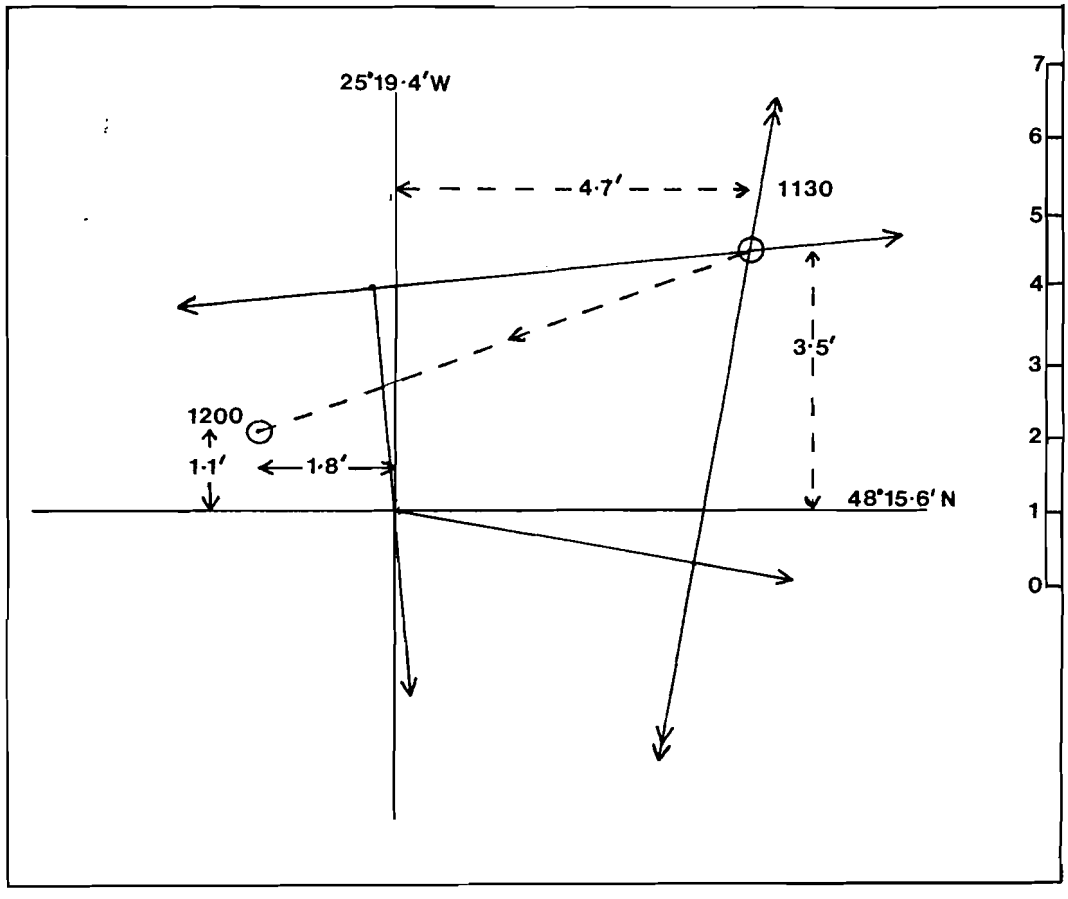


Figure. 6. Working Plot.

From the Plot:

D. Lat. 3·5′ N.	2nd D.R.	48° 15·6′N.	25° 19·4′ W.
Dep. 4·7′ E., D. Long. 7·1′ E.		3·5 N.	7·1 E.
	Position at 1130	48 19·1 N.	25 12·3 W.
D. Lat. 1·1′ N.	2nd D.R.	48° 15·6′ N.	25° 19·4′ W.
Dep. 1·8′ W., D. Long. 2·7′ W.		1·1 N.	2·7 W.
	Position at 1200	48 16·7 N.	25 22·1 W.

Other Methods of Plotting Position Lines

So far the Position Lines considered have been calculated by the Intercept Method. It should be appreciated that the result of any single celestial calculation will give a Position Line, but the manner of plotting varies with the method used. If the Longitude Method be used then the P/L is drawn through a position given by the D.R. latitude, and the longitude found by calculation.

In the Ex-Meridian Method, the latitude so found is combined with the D.R. longitude to give a position through which the P/L may be drawn. In the case of the Meridian Altitude the P/L coincides with a parallel of latitude.

Details of the various methods of calculation are given in the following chapters. In the present chapter we are concerned only with plotting the results of these calculations, as the next example will show.

Example 5

(Refer to Figure 7)

At 0900, in D.R. 12° 40′ S., 135° 18′ W., an observation of the sun bearing 080° T gave a longitude of 135° 24′ W. when worked by the Longitude Method. Ship steaming 280° T at 15 knots through a current setting 270° T, 3 knots throughout.

At 1100 an ex-meridian observation of the moon bearing 170° T gave a latitude of 12° 39·5′ S., using a longitude of 136° 05′ W. in the calculation. Required the position at the time of the second observation.

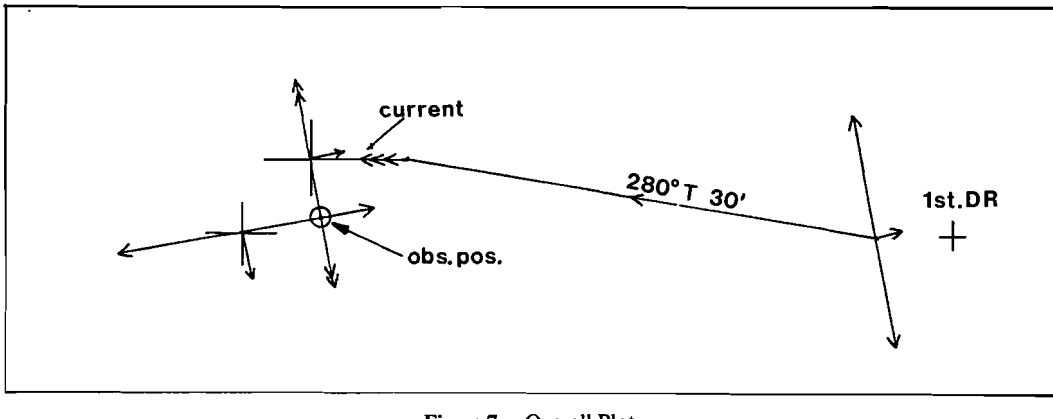


Figure 7. Overall Plot.

Notes:

The 1st P/L is transferred by running up the D.R. Latitude and the Observed Longitude; the effect of the current must also be taken into account. In order that there shall be no doubt, the question states the longitude used in calculating the latitude by the 2nd observation. The example shows how D. Lat. and Dep. are used to establish the relative locations of the final positions when the plotting sheet in use has no scales.

Position at 0900		12° 40·0′ S.		135° 24·0′ W.
Run 280° T 30′	D. Lat.	5·2 N.	D. Long.	30·3 W. (Dep. 29·5′)
Set 270° T 6′		0·0	,,	6·2 W. (,, 6·0′)
Transferred Position		12 34·8 S.		136 00·5 W.
2nd Obs.		12 39·5 S.		136 05·0 W.
For the Plot	D. Lat.	4·7′ S.	D. Long.	4·5′ W. Dep. 4·4′ W.

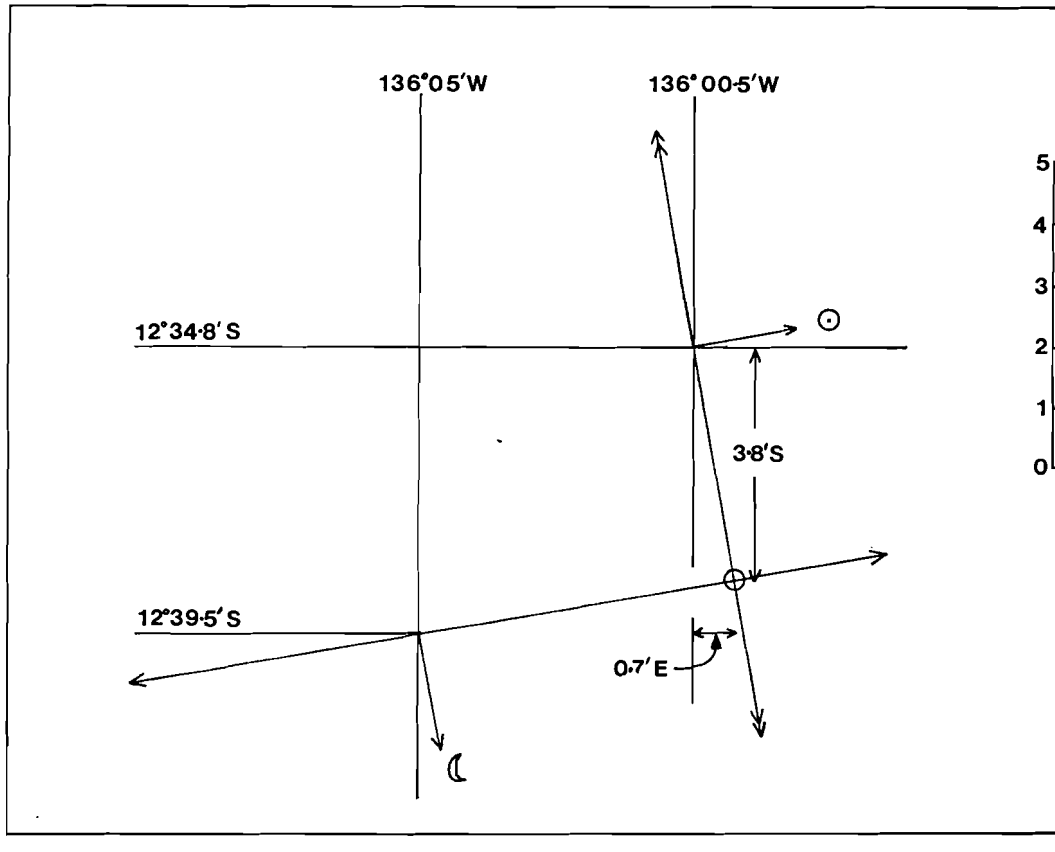


Figure 8. Working Plot.

Reference Position	12° 34·8′ S.	136° 00·5′ W.
From the Plot	3·8 S.	0·7 E. (Dep. 0·7′ E.)
Obs. Pos. at 1100	12 38·6 S.	135 59·8 W.

USE OF PLOTTING SHEETS

The following methods may be used for plotting Position Lines:

1. Navigational charts.
2. Blank plotting charts with scales for latitude and longitude.
3. Blank plotting charts having a compass rose but no scales.
4. Squared, or graph paper.
5. Blank paper.

In the case of methods 1 and 2, the plotting is effected in a manner similar to that used in chartwork. With the other methods it must be remembered that the East-West measurements are plotted by Departure, so it is convenient to have the Traverse Table open at the page corresponding to the Mean Latitude for converting D. Long. into Dep. and vice-versa. Alternatively the simple construction shown in Figure 9 may be used for this purpose.

When using blank paper it is necessary to draw a reference meridian of longitude and a parallel of latitude. Dep., D. Lat. and bearings may be measured from these.

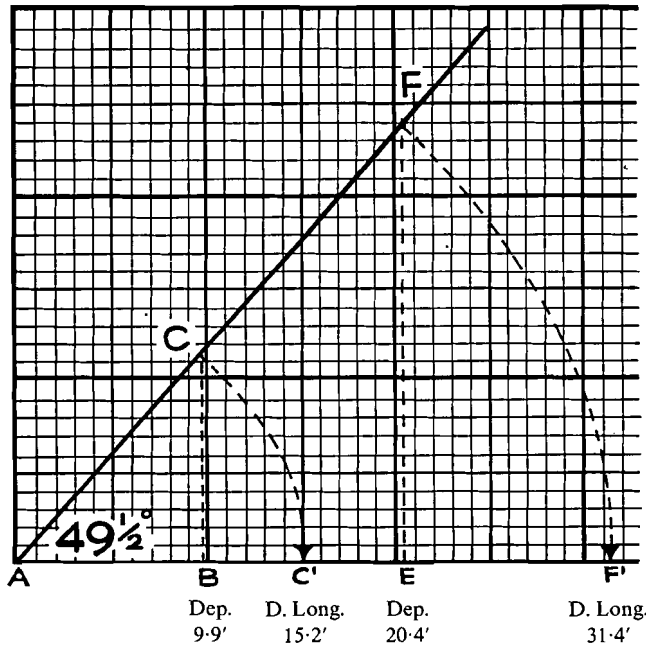


Figure 9. Converting Departure into D. Long by Construction.

THE VALUE OF A SINGLE POSITION LINE

In the preceding pages it has been assumed that the Position Line obtained from an observation is put aside and saved until a second observation is available, when the ship's position may be fixed as has been described. Incidentally, the second P/L, though usually obtained from a celestial observation, may theoretically be a Line of Position originating from a Terrestrial Bearing, a Radio Bearing, or, indeed from any other method of observation.

When approaching land a single P/L, provided the azimuth is suitable, may be of value to the navigator. By steering a course parallel to the P/L a vessel will then be proceeding along the safest track, the technique is illustrated in the following example.

Example 6
(Refer to Figure 10)

A vessel steering 320° T is approaching a passage through a group of islands. Position is uncertain and the land is obscured by rain. An observation of the sun gave an intercept of 8′ towards, azimuth 010° T. The situation is shown in Figure 10, where *A* is the D.R. and *B* the I.T.P. A safe track through the passage is laid off in a 280° T direction, parallel to the P/L, *DE* in the figure. The vessel will continue on her course, running the distance *BC*, when course will be altered to 280°T. Any current or leeway must, of course, be allowed for.

Although the vessel may be ahead, or astern of position *C* she will be on the safest track; a good look-out must be kept so as to confirm the position when land is sighted.

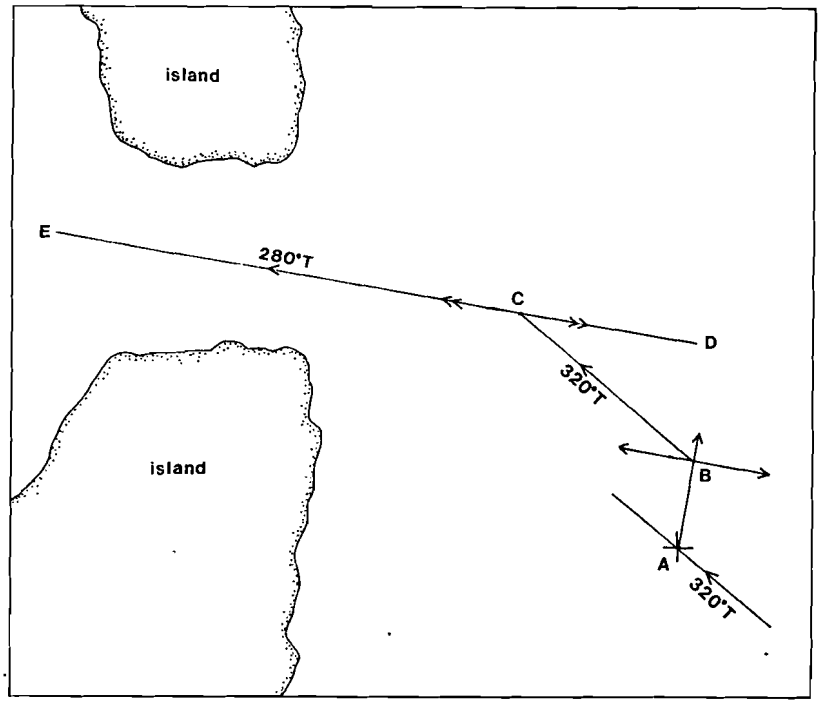


Figure 10. The Value of a Single Position Line.

HIGH ALTITUDE OBSERVATIONS

At the beginning of this chapter it was stated that the Position Circle normally has a very large radius and so the part of the circumference in the vicinity may be regarded as a straight line, at right angles to the azimuth. Occasionally, however, it may be necessary to observe a body near to the observer's zenith, when the assumption will no longer be valid.

In such cases the actual Position Circle should be plotted. Its radius is equal to the True Zenith Distance and its centre is located at the Geographical Position (G.P.) of the body:

Latitude of G.P. = Declination of the body observed
Longitude (West) of G.P. = GHA of the body observed
Longitude (East) of G.P. = 360°—GHA of the body observed

The approximate location of the observer, on the Position Circle, is indicated by the bearing at the time of observation; but it may not be transferred in the same way as a normal position line. Instead, the G.P. is run up to the time of the second observation and then the circle is redrawn. The procedure is explained in the following example:

Example 7
(Refer to Figure 11)

At 0803 an observer on a vessel steering 336° T at 14 knots found the true altitude of the sun to be 89° 29·2′, bearing S.E'ly. (Dec. Sun 13° 26′ S., GHA Sun 304° 51·2′).

Later, at 1012, a point of land in position 12° 18′ S., 54° 45′ E. was detected by radar at a range of 23 miles. Find the vessel's position at the time of the latter observation.

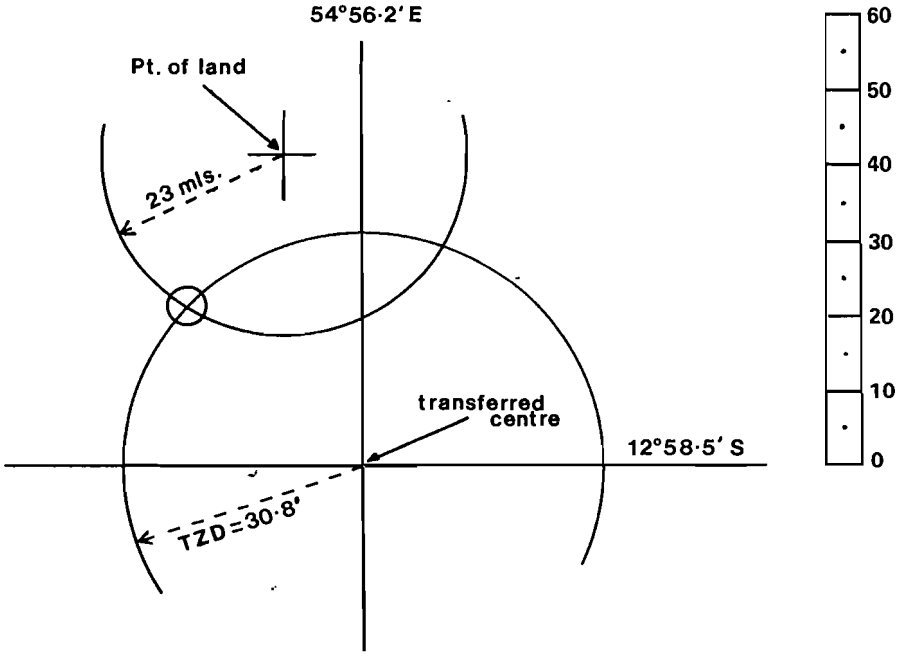


Figure 11. Plotting High Altitude Observations.

Procedure:

1. With the aid of the *Nautical Almanac* find the G.P. of the sun.
2. The G.P. is now transferred to the time of the latter observation, and a circle inscribed with radius = True Zenith Distance.
3. Using the Lat. and Long. of the transferred G.P. as references, the Point of Land is plotted and the range circle inscribed.
4. The circles intersect in two places. Since the original bearing of the sun was S.E'ly, the Westerly intersection indicates the vessel's position.

Lat. G.P. = Dec. Sun	13° 26′ S.	
Long. G.P. = GHA Sun	304 51·2 W.	
	360	
Long. G.P.	55° 08·8′ E.	

G.P. at 0803	13° 26·0′ S.	55° 08·8′ E.	
Run 336° T 30·1′	27·5 N.	12·6 W.	(Dep. 12·24)
Transferred G.P.	12 58·5 S.	54 56·2 E.	
Point of Land	12° 18·0′ S.	54° 45·0′ E.	
For plotting	40·5 N.	11·2 W.	Dep. 10·9′ W.
Reference position	12° 58·5′ S.	54° 56·2′ E.	
From the plot	21·0 N.	23·6 W.	(Dep. 23′)
Obs. Pos. at 1012	12 37·5 S.	54 32·6 W.	

Exercise 2

Given the ship's D.R., the azimuth of the body and the intercepts at the 1st and 2nd observations and the ship's run between the 1st observation and a 2nd observation taken later. Find the ship's observed position as determined by position lines.

In questions 1 to 4 alternative answers are given. Answers (A) assume that the second intercept has been calculated by using a position obtained by running up the I.T.P. of the first P/L; while in answers (B) the D.R. has been used for this purpose.

	Obs.	D.R. Positions Lat.	Long.	Azimuth	Intercept	Run between Observations Co.	Dist.
1.	1st	30° 20′ N.	42° 30′ W.	130° T	12′ Towards	240° T	40 miles
	2nd	—	—	250° T	6′ Away	—	—
2.	1st	50° 15′ N.	6° 45′ W.	103° T	39·9′ Away	315° T	25 miles
	2nd	—	—	149° T	17·2′ Away	—	—
3.	1st	46° 15′ N.	145° 12′ W.	145° T	15′ Away	205° T	42 miles
	2nd	—	—	225° T	20′ Towards	—	—
4.	1st	8° 12′ S.	116° 55′ W.	082° T	7′ Away	105° T	27 miles
	2nd	—	—	034° T	10′ Away	—	—
5.	1st	37° 30′ S.	70° 18′ E.	048° T	20′ Away	—	—
	2nd	—	—	330° T	10′ Towards	—	—
6.	1st	15° 40′ S.	175° 30′ E.	168° T	15′ Away	—	—
	2nd	—	—	220° T	12′ Away	—	—

Answers

(A) 1. 29° 57·5′ N., 42° 54·1′ W.
2. 51° 04·7′ N., 8° 05·1′ W.
3. 45° 37·7′ N., 146° 13·6′ W.
4. 8° 33·5′ S., 116° 33·6′ W.
5. 37° 32·5′ S., 69° 47·0′ E.
6. 15° 24·8′ S., 175° 30·3′ E.

(B) 1. 29° 52·1′ N., 42° 59·4′ W.
2. 50° 28·5′ N., 8° 17·6′ W.
3. 45° 36·1′ N., 146° 16·0′ W.
4. 8° 27·0′ S., 116° 34·7′ W.

Additional Plotting Exercises

Additional plotting exercises are included on:
Page 684 of Chapter 26 (Intercept Method) and
Page 702 of Chapter 27 (Longitude by Chronometer).

ERRORS IN POSITION LINES

Fixed and variable errors in position lines are dealt with on pages 679–683 of the next chapter.

Nautical Almanac Extracts, which are required for working all examples and exercises, are included on Page 880.

Chapter 26

Intercept Method of Determining Position Lines

The application of the Intercept Method (sometimes known by the name of its originator, Marcq. St. Hilaire) is as follows: The altitude of a body is observed and the exact time by chronometer at the instant of observation is noted from which the GMT is obtained. The observed altitude when corrected and subtracted from 90° gives the true zenith distance of the ship from the geographical position of the body.

A Latitude and Longitude is then decided upon as a position for use in the calculations. The zenith distance for this assumed position is calculated by solving the PZX triangle having given two sides, the co-Latitude (PZ) and Polar Distance (PX), also the Hour Angle (P). The azimuth is then found by ABC Tables.

The difference between the two zenith distances, the true and the calculated, gives the intercept. If the true zenith distance agrees exactly with the calculated zenith distance, then a position line is drawn on the plot through the assumed position.

If the true zenith distance was, say, 10′ less than the calculated zenith distance the position line would be drawn through a spot on the line of azimuth 10 miles nearer the body than the assumed position, or, conversely, if the true zenith distance were 10′ more than the calculated zenith distance it would be drawn through a spot on the line of azimuth 10 miles further away from the body than the assumed position.

Little more can be done meantime until a second observation is taken some time later, not necessarily of the same body, and the zenith distance, azimuth and another intercept worked up for the D.R. position at the second observation. This second position line is combined with the transferred position line of the 1st observation and the ship's position fixed at their crossing, as already described in plotting position lines.

When two bodies on a broadly different bearing are observed simultaneously by two observers by day, or during twilight, the ship's position can be fixed at once, but this is not always possible and so the single observer selects two suitably placed bodies, observes one and immediately afterwards observes the other, and works up the sights independently, using the same D.R. position for both.

The Intercept Method has the great advantage of being applicable to any observation, there being no restriction imposed by Hour Angle or bearing as in the cases of the Longitude and Ex-meridian methods, described in subsequent chapters.

Order of Work

1. Correct the chronometer time of observation for error, if any, and obtain the GMT. Check the Greenwich Date.
2. Find the GHA Aries and note the SHA and declination of the star.

3. Find the Local Hour Angle of the star by means of the equation.

$$\text{GHA}^* = \text{GHA}\,\Upsilon + \text{SHA}^*$$

$$\text{LHA}^* = \text{GHA}^* \begin{matrix} +\text{E} \\ -\text{W} \end{matrix} \Big\} \text{ Long.}$$

4. Correct the Sextant Altitude and find the True Zenith Distance.
5. Draw an appropriate figure, if required.
6. Solve the PZX triangle for ZX, the zenith distance for the assumed position, having given PZ, PX and $\angle P$, using the formula hav ZX = hav P sin PZ sin PX + hav $(PZ \sim PX)$ modified to

$$\text{hav}\, ZX = \text{hav}\, P \cos \text{Lat.} \cos \text{Dec.} + \text{hav}\,(\text{Lat.} \pm \text{Dec.})$$

(+ different names; ~ same names)

This modification saves at least two subtractions from 90° but it is a matter of choice which form is used.

7. The difference between the true zenith distance as found from the observed altitude, when corrected, and the calculated zenith distance is the intercept.
8. Find the Azimuth by ABC Tables.
9. Plotting will be done when a further P/L, or P/L's, are available; further notes on this aspect are given later in the chapter. Examination questions, however, often call for "a position through which the position line passes", in this case the Lat. and Long. of the ITP should be worked out.

Example 1 (Star)

From the following information find the direction of the position line and a position through which it passes. Sextant altitude Formalhaut 21° 44′. D.R. 12° 18′ S., 126° 00′ W., I.E. nil. H.E. 10·5 m, Chronometer 26 d 08 h 15 m 37 s error 0 m 43 s fast on GMT. Date at ship, June 25.

Chron.		26d	08h	15m	37s
Fast	(−)				43
GMT		26	08	14	54

GHA ♈	26d 08h	33°	56·5′
Increment	14m 54s	3	44·1
GHA ♈		37	40·6
SHA*		16	09·4
GHA*		53	50·0
	(+)	360	
GHA*		413	50
Long. W.	(−)	126	00
LHA*		287	50 (1)

SHA*		16°	09·4′
Dec.*		29°	50·3′ S.
Lat.		12	18·0 S.
(Lat. ~ Dec.)		17	32·3
Obs. alt.		21°	44·0′
Dip	(−)		5·7
App. alt.		21	38·3
Corr.	(−)		2·4
True alt.		21	35·9
		90	00
True zen. dist.		68	24·1

NESW	Rational Horizon,
WQE	Equinoctial,
P	Pole,
Z	Observer's Zenith,
X	Body,
PZ	co-Lat.,
PX	Polar Distance,
ZX	Zenith Distance
aX	Altitude,
$\angle NZX$	Azimuth.

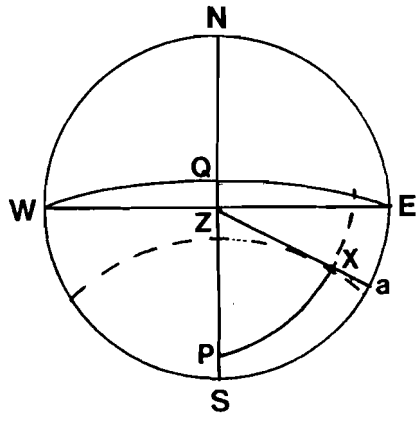


Figure 1.

hav ZX = hav P cos Lat. cos Dec. + hav (Dec. − Lat.)

LHA	287° 50′	log hav	9·54017
Lat.	12 18·0 S.	log cos	9·98992
Dec.	29 50·3 S.	log cos	9·93824
		log hav	9·46833
		nat hav	0·29401
(Dec. − Lat.)	17 32·3	nat hav	0·02324
Cal. zen. dist.	68° 33·8′	nat hav	0·31725
True zen. dist.	68 24·1		
Intercept	9·7′ Towards		

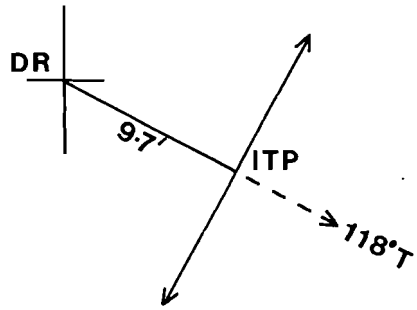


Figure 2.

	Azimuth
A	0·07 N.
B	0·61 S.
C	0·54 S.

Az. S. 62° E. = 118° T P/L 028°—208° T

Intercept.				
118° T, 9·7′	D.R.	12° 18·0′ S.		126° 00′ W.
D. Lat. 4·6′	D. Lat.	4·6 S.	D. Long.	8·8 E.
Dep. 8·6′				
D. Long. 8·8′ E.	I.T.P.	12 22·6 S.		125 51·2 W.

Note

1. An LHA of 287° 50′ indicates that the body is to the East of the observer.

LHA 0° to 180° – body to the West.
LHA 180° to 360° – body to the East.

Example 2 (Planet)

From the following information find the direction of the position line and a position through which it passes:

Time at ship 2206 on 20 September. D.R. 39° 38′ S 138° 35′ E. Sext alt. of Saturn 27° 45′. I.E. 0·3′ off the arc. H.E. 13·5 m. Chron. showed 00 h 52 m 16 s, correct on GMT.

Check the Greenwich Date:

approx. LMT		20d	22h	06m		
Long. E.			9	14		
approx. GMT		20d	12h	52m		

Chronometer	00h	52m	16s
Error	—	—	—
	+12		
GMT	12h	52m	16s

LHA = GHA + Long.

		d	h	m	s
GMT Sept.		20	12	52	16
GHA Saturn	20d 12h		279°	58·7′	
Increment	52m 16s		13	04·0	
v corr. (2·3)				2·0	
GHA Saturn			293	04·7	
Long. E.		(+)	138	35·0	
LHA Saturn			431	39·7	
			360	00	
LHA			71	39·7	(body to the West)

Dec.	21°	53·4′ S.
Lat.	39	38·0 S.
(Lat. – Dec.)	17	44·6

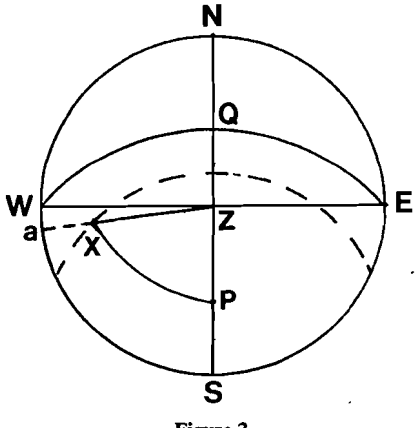


Figure 3.

NESW	Rational Horizon,
WQE	Equinoctial,
P	Pole,
Z	Observer's Zenith,
X	Body,·
PZ	co-Lat.,
PX	Polar Distance,
ZX	Zenith Distance,
aX	Altitude,
∠*NZX*	Azimuth.

hav ZX = hav P cos Lat. cos Lat. cos Dec. + hav (Lat. − Dec.)

P	71° 39·7′	log hav	9·53490	Sext. alt.		27° 45·0′
Lat.	39 38·0 S.	log cos	9·88657	Index error	(+)	0·3
Dec.	21 53·4 S.	log cos	9·96750			27 45·3
		log hav	9·38897	Dip	(−)	6·5
		nat hav	0·24488			27 38·8
(Lat. − Dec.)	17 44·6	nat hav	0·02379	Corr.	(−)	1·8
ZX	62 26·5	nat hav	0·26867	True alt.		27 37
						90 00
				True zen. dist.		62 23

		Azimuth	
Calc. zen. dist.	62° 26·5′	A	0·28 N.
True zen. dist.	62 23·0	B	0·42 S.
Intercept	3·5′ Towards	C	0·14 S.

Az. S. 84° W. = 264° T. P/L 174° − 354° T.

Intercept A B

264° T, 3·5 miles	D.R.	39° 38·0′ S.			138° 35·0′ E.
D. Lat. 0·3′ S.	D. Lat.	0·3 S.	D. Long		4·5 W.
Dep. 3·5′ W.					
D. Long. 4·5′ W.	I.T.P.	39 38·3 S.			138 30·5 E.

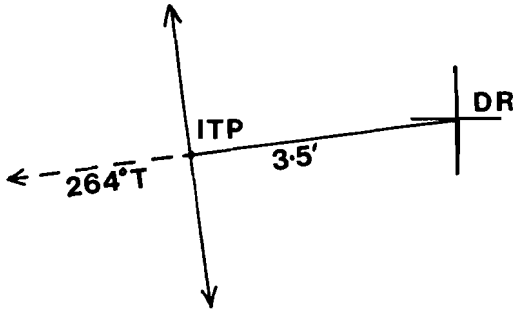


Figure 4.

Example 3 (Sun – Run – Sun)

(a) From the following information find the direction of the position line and the ITP: Time at ship 0840 on 19 September, D.R. 49° 30′ S., 69° 14′ E., Sext alt. of the sun's L.L. 23° 43′, I.E. 1′ on the arc; H.E. 12 m, GMT 19 d 04 h 00 m 15 s

(b) The weather being cloudy the sun was not again visible until about 1400. Find the position of the transferred ITP, the ship having steamed 35 miles on a course of 144° T.

(c) At about 1400, in D.R. 49° 53′ S., 69° 58′ E., the Sext alt. of the sun's L.L. was 32° 40′. GMT 19 d 09 h 11 m 41 s. Find the observed position.

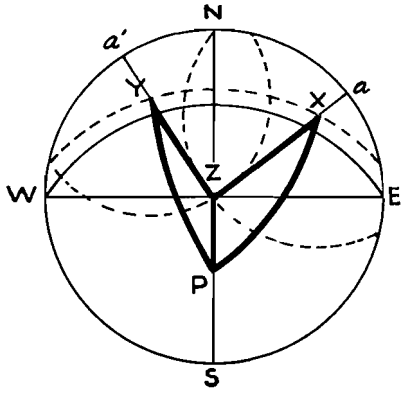


Figure 5.

In the Figure:

Description as in Figure 1. As a matter of convenience both observations have been shown on the same figure. *X* represents the first, and *Y* the second observation.

3. (a) GMT Sept. 19 d 04 h 00 m 15 s

LHA = GHA + E. Long.

GHA Sun	19d 04h	241° 29·5′	
Increment	00m 15s	0 03·8	
GHA		241 33·3	
Long. E.		(+) 69 14	
LHA		310 47·3	(East)
Declination		1° 42·2′	N.

Sext. alt.		23° 43·0′
I.E.	(−)	1·0
		23 42·0
Dip	(−)	6·1
		23 35·9
Corr.	(+)	13·8
True alt.		23 49·7
		90 00
True zen. dist.		66 10·3

hav *ZX* = hav *P* cos Lat. cos Dec. + hav (Lat. + Dec.)

P	310° 47·3′	log hav	9·23897
Lat.	49 30 S.	log cos	9·81254
Dec.	1 42·2 N.	log cos	9·99981
		log hav	9·05132
		nat hav	0·11255
(Lat. + Dec.)	51 12·2	nat hav	0·18672
ZX	66 19.8	nat hav	0·29927

Azimuth

A	1·00 N.
B	0·05 N.
C	1·05 N.

Calc. zen. dist.	66° 19·8′
True zen. dist.	66 10·3
Intercept	9·5′ Towards

Az. N 55·7° E = 056°T P/L 146° – 326° T

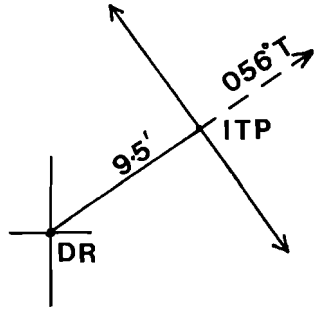


Figure 6.

3. (b) Intercept.

056° T, 9·5′	0840 D.R.	49° 30′ S.		69° 14′ E.
D. Lat. 5·3′ N., Dep. 7·9 E.	D. Lat.	5·3 N.	D. Long.	12·2 E.
D. Long. 12·2′ E.				
	I.T.P.	49 24·7 S.		69 26·2 E.
Run *BC*	D. Lat.	28·3 S.	D. Long.	31·8 E.
144° T, 35 miles				
D. Lat. 28·3′ S., Dep. 20·6′ E.	1400 D.R.	49 53·0 S.		69 58·0 E.
D. Long. 31·8′ E.				

Plotting need not be carried out until the results of the second observation are available. A small sketch of the P/L is used in order to check the direction of the intercept.

3. (c) GMT Sept. 19d 09h 11m 41s

LHA = GHA + E. Long.

GHA Sun	19d 09h	316° 30·6′	Sext. alt.		32° 40·0′
Increment	11h 41s	2 55·3	I.E.	(−)	1·0
GHA		319 25·9			32 39·0
Long. E.		(+) 69 58	Dip	(−)	6·1
LHA Sun		389 23·9			32 32·9
		360 00	Corr.	(+)	14·5
LHA Sun		29 23·9 (*P*)	True alt.		32 47·4
					90 00
Declination	1° 37·4′ N.		True zen. dist.		57 12·6
d (1·0)	(−) 0·2				
Corr. Dec.	1 37·2 N.				

Refer to Figure 5.

hav *ZY* = hav *P* cos Lat. cos Dec. + hav (Lat. + Dec.)

				Azimuth	
P	29° 23·9′	log hav	8·80879	A	2·06 N.
Lat.	49 53 S.	log cos	9·80912	B	0·05 N.
Dec.	1 37·2 N.	log cos	9·99983	C	2·11 N.
		log hav	8·61774		
		nat hav	0·04147	Calc. zen. dist.	57° 20·8′
(Lat. + Dec.)	51 30·2	nat hav	0·18876	True zen. dist.	57 12·6
ZY	57 20·8	nat hav	0·23023	Intercept	8·2′ Towards

Az. N. 36·3° W. = 324° T P/L 054° − 234° T

Plotting the Observations

The first P/L is laid off through its transfered ITP (the 1400 D.R.). As this position has been used in the second calculation, the intercept and P/L may be laid off from the same place. The P/L's intersect at a good angle of cut, nearly 90°. D. Lat. and Dep. are measured from the intersection with reference to the 1400 D.R., in order to obtain the latitude and longitude of the observed position.

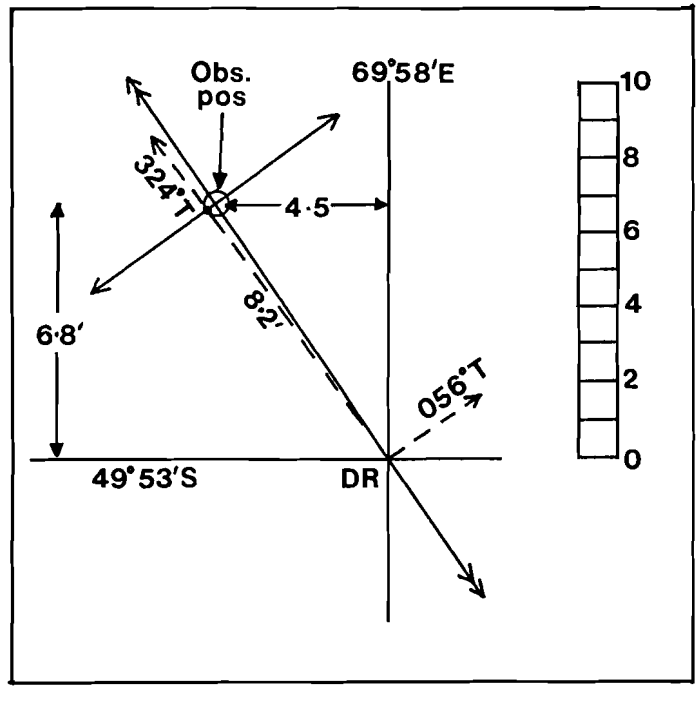


Figure 7.

1400 D.R.	Lat.	49° 53·0′ S.	Long.	69° 58·0′ E.
From the plot	D. Lat.	6·8 N.	D. Long.	7·0 W. (Dep 4·5′)
1400 Obs. pos.	Lat.	49° 46·2′ S.	Long.	69° 51·0′ E.

Example 4 (Moon and Sun)

(a) From the following information find the intercept and the direction of the position line: Time at ship 1410 on 20 September, D.R. 24° 30′ N., 33° 18′ W., Sext. alt. of the moon's L.L. 14° 38′, I.E. nil, H.E. 15·5 m, GMT 20 d 16 h 24 m 21 s.

(b) Immediately afterwards, at GMT 16 h 26 m 06 s, an observation of the sun bearing 238° T gave an intercept of 2·3′ Away, using the above D.R. position in the calculation. Required the observed position.

Note:

Since the time interval between the observations is so short, being less than 2 minutes, it is reasonable to regard the P/L's as simultaneous. Accordingly, it will neither be necessary to transfer the first P/L, nor to calculate the ITP's. Both intercepts may conveniently be laid off on the plot, as in Figure 9.

LHA = GHA − W. Long.

GHA Moon	20d 16h	325° 02·5′
Increment	24m 21s	5 48·6
v corr. (8·4)		3·4
GHA Moon		330 54·5
Long. W.	−	33 18
LHA moon		297 36·5 (East)

Dec.		18° 25·1′ S.
d (1·9)	(−)	0·8
Dec.		18 24·3 S.

H.P. 57·6′

Obs. alt.		14° 38·0′
Dip	(−)	6·9
		14 31·1
Corr.	(+)	1 02·8
		15 33·9
H.P. (*L*)	(+)	4·9
True alt.		15 38·8
		90 00
True zen. dist.		74 21·2

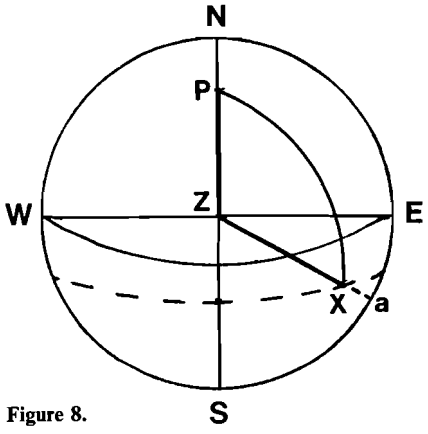


Figure 8. Description as in Figure 1.

hav *ZX* = hav *P* cos Lat. cos Dec. + hav (Lat. + Dec.)

P	297° 36·5′	log hav	9·42860
Lat.	24 30 N.	log cos	9·95902
Dec.	18 24·3 S.	log cos	9·97720
		log hav	9·36482
		nat hav	0·23165
(Lat. + Dec.)	42 54·3	nat hav	0·13376
ZX	74 23	nat hav	0·36541

Azimuth

A	0·24 S.
B	0·37 S.
C	0·61 S.

Calc. zen. dist.	74° 23·0′
True zen. dist.	74 21·2
Intercept	1·8′ Towards

Az. S. 61° E. — 119° T P/L 029° T. — 209° T

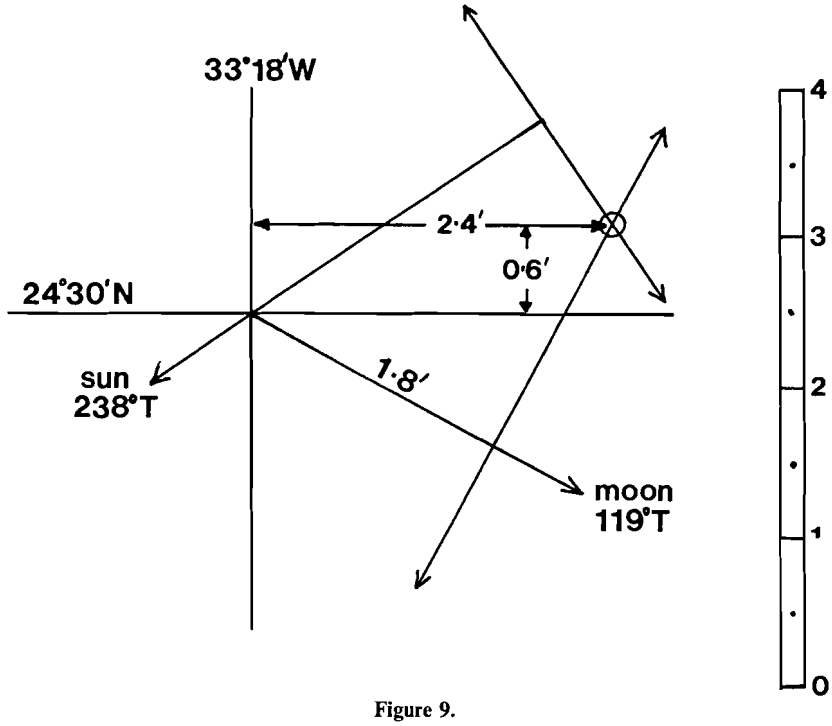


Figure 9.

1410 D.R.		24° 30·0′ N.			33° 18·0′ W.
From the plot	D. Lat.	0·6 N.	D. Long.		2·6 E. (Dep 2·4′)
Obs. Pos.		24° 30·6′ N.			33° 15·4′ W.

STELLAR OBSERVATIONS

The Intercept Method is especially convenient for the calculations associated with morning and evening stars, since there are no restrictions on its use and moreover, as will be explained below, there are a number of short cuts which reduce time and effort.

The position obtained by observation of several stars at twilight is potentially the most reliable of the celestial methods. Accuracy may be improved by the following routine:

1. From the *Nautical Almanac* find the times of Civil and Nautical Twilight. On average, star time will be about half-way between them.
2. Run up a position for the time so found.
3. With the aid of a Star Identifier, or a Star Globe, make a list of the approximate altitudes and bearings of the stars available.
4. Select 3 or 4 stars for observation. The azimuths should be well disposed all round the horizon and should give a good angle of cut. Altitudes to be not less than 15° and, if possible, not above 70°.
5. With the sextant set to the approximate altitude it will be possible to take observations before the stars are visible to the naked eye, and thus have the advantage of a good, clear horizon.

6. In addition to the selected stars, two or three extra stars should be observed; these need not be worked out, unless the original fix is unsatisfactory.

Examples given in the following pages give guidance on the selection of suitable stars and in the techniques of plotting multiple stellar observations.

The Chosen Position (CP)

In the preceding pages the D.R. position has generally been used in calculating the intercept. It is important, however, to appreciate that any position in the vicinity may be used for this purpose. There will be different intercepts for different positions, but the position line will always be situated in the same geographical location, as illustrated in Figure 10.

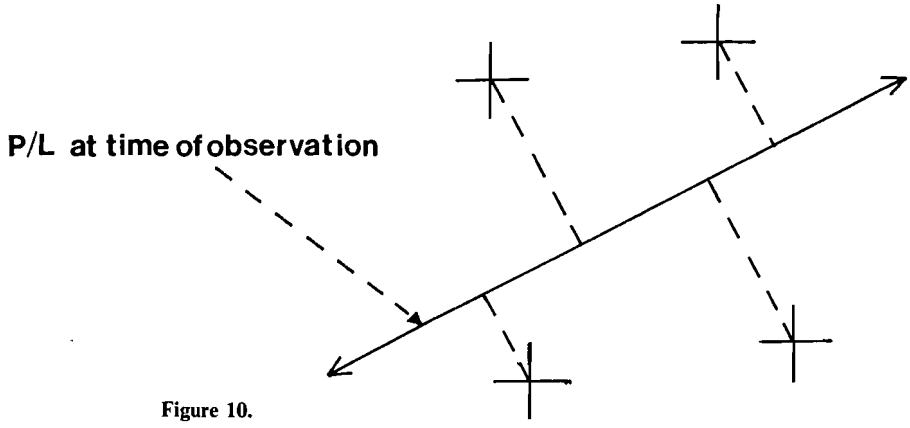


Figure 10.

Note that the location of the position line is valid only for its time of observation and so will have to be transferred, unless the other stars have been taken within a very short interval of time.

If several stars have been observed then the same position may be used in each of the calculations, even though the period may extend over 15 to 20 minutes. The time intervals between sights has no relevance to the present consideration; the question of time will be dealt with in the next section.

In many of the "Short Methods", latitude is rounded off to the nearest whole degree and a different longitude used for each star. This practice may produce very large intercepts, but there is little loss of accuracy.

The term "Chosen Position" is thus used when a position other than a D.R. or an E.P. is used in calculations for celestial observations.

Plotting Short Runs between Star Sights

If an interval of 3 minutes be neglected in a 14 knot ship, then a position line (P/L) could be in error by as much as 0·7′. In order to obtain an accurate position it is necessary, therefore, to allow for even short intervals of time when plotting P/L's. Having decided upon a suitable time for the fix, earlier P/L's must be run up in the direction of the ship's course, whilst later P/L's would have to be run backwards.

Example 5

Consider a ship steering 040° T at 18 knots. A sight at 1810 gave an Azimuth of 170° T, Intercept 2·5′ Towards. This P/L is to be transferred to conform with a second sight at 1820.

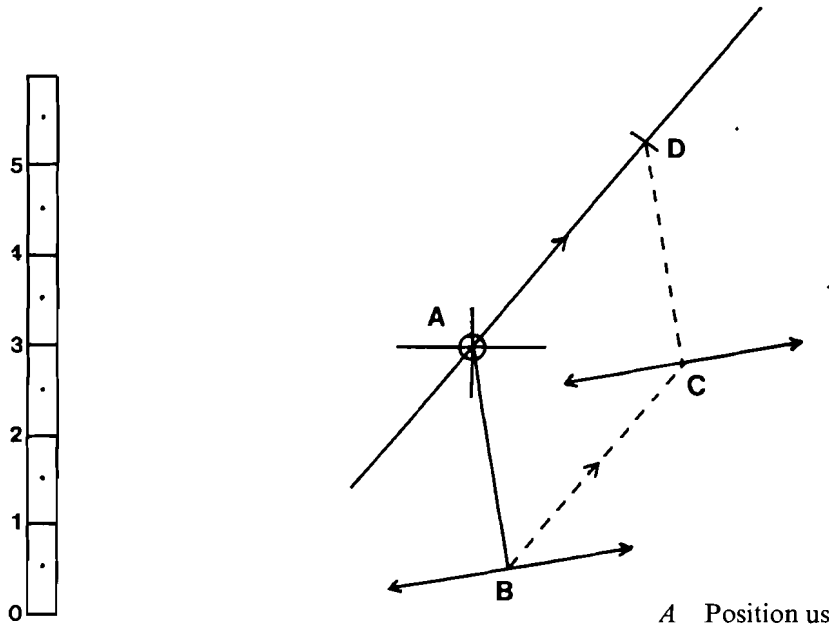


Figure 11.

A Position used in the calculation,
B ITP for 1810,
BC Run for 10 minutes (040° T, 3′),
C ITP for 1820.

Note that *C* may more conveniently be found by running up the plotting position from *A* to *D* (*AD* = *BC*). Not only does this method save time, but it also reduces the number of construction lines and thus leaves the plot clearer for interpretation, an important consideration if several stars have been observed. This method is illustrated in the following example.

Example 6

An observer on a ship steering 205° T at 16 knots obtained the following results from stellar observations. A C.P. of 34° 27′ N., 76° 42′ E. was used in all calculations. Find the observed position at 1830.

1.	Time 1820	Azimuth 167° T	Intercept 2·2′ Towards
2.	1824	081° T	4·5′ Towards
3.	1833	237° T	0·8′ Away

Procedure

1. Time intervals from 1830 and corresponding distances are calculated for each star.
2. On the plotting sheet the ship's track is laid off through the C.P. and the plotting positions measured off, early stars ahead and the late star backwards.
3. P/L's are plotted from their respective positions, and then the observed position is located.

4. D. Lat. and Dep. are measured from the position used in calculations (the C.P.), to give the latitude and longitude of the observed position.

1820	167° T	2·2′ T	Interval	10 minutes, Run	2·7′
1824	081° T	4·5′ T		6	1·6′
1833	237° T	0·8′ A		−3	−0·8′

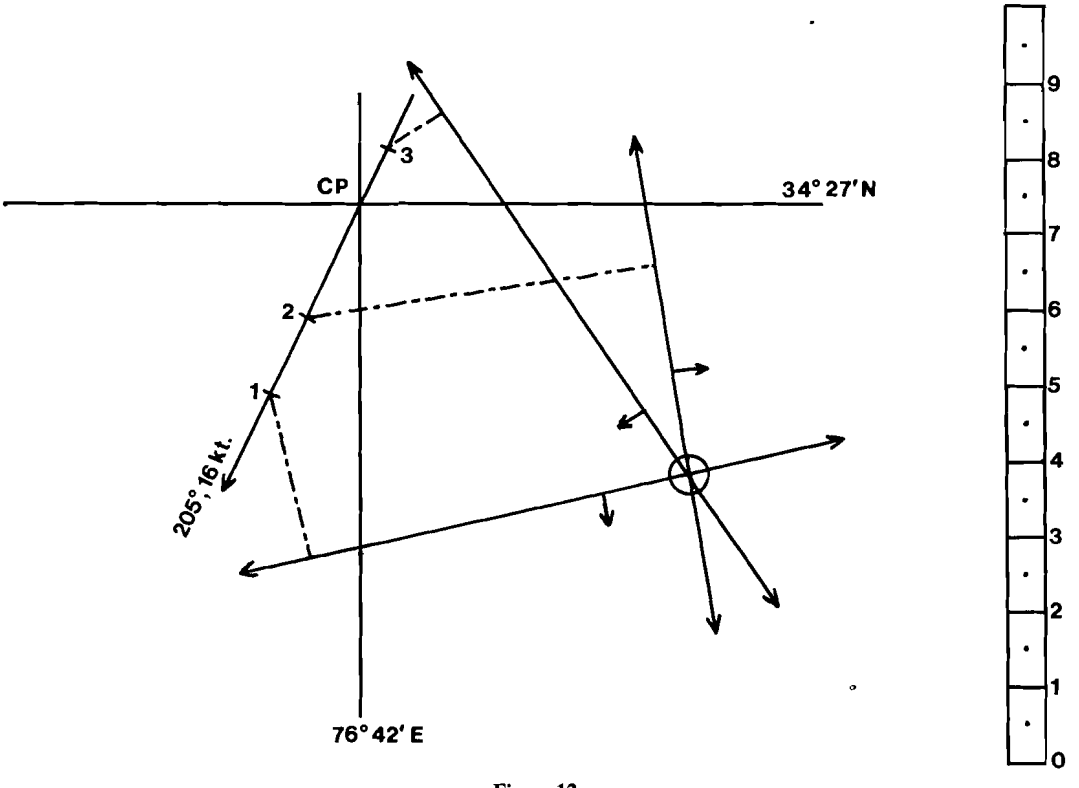


Figure 12.

C.P.		34° 27·0′ N.		76° 42·0′ E.	
From the plot	D. Lat.	3·5 S.	D. Long.	5·1′ E.	(Dep 4·2′)
1830 Obs. Pos.		34° 23·5′ N.		76° 47·1′ E.	

ERRORS IN POSITION LINES

It is comparatively unusual for three P/L's to pass through the same point. More often they form a triangle, commonly known as a "Cocked Hat". The latter situation can indicate the presence of errors.

Assuming that all calculations have been correctly made and the run for any time interval between sights correctly plotted there are two types of errors:

1. Variable Errors, which are generally small and may be disregarded in this context.

2. Fixed Errors, which apply equally to each P/L and so may be allowed for. Such errors are sometimes caused by the habit of an observer in "cutting too deep" with his sextant, or by conditions causing abnormal refraction.

Consider the plot shown in Figure 13, where the observer has "cut too deep" by 2′. If each P/L is moved "away" by this quantity then there will be a good cross and so a satisfactory position is obtained.

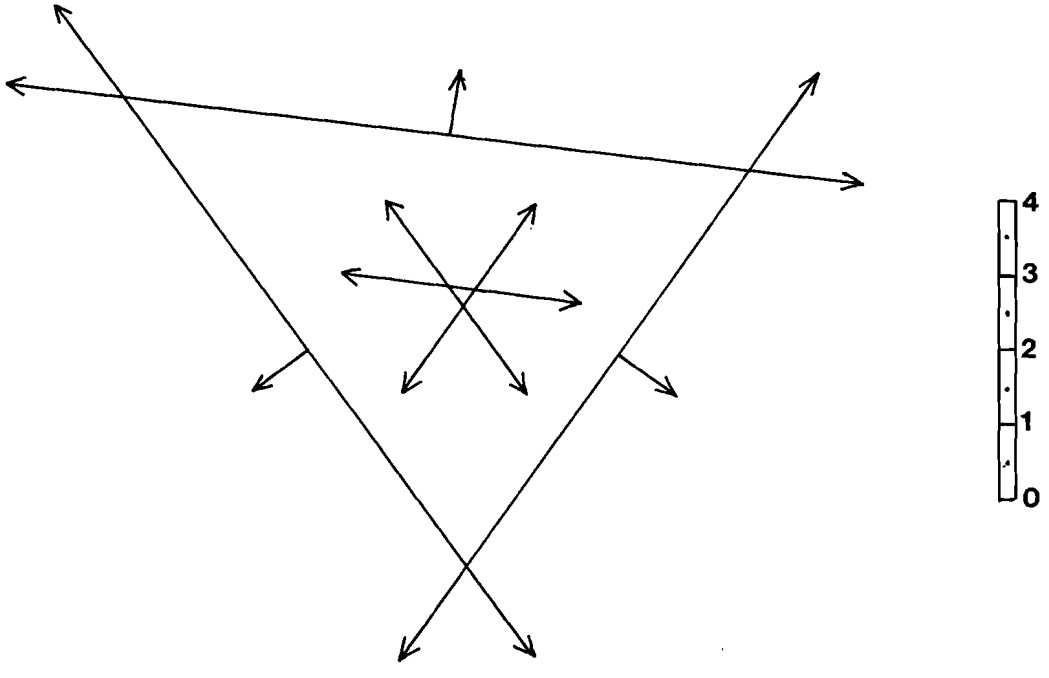


Figure 13.

A geometrical construction is available for this purpose. Draw the bisectors of each angle, their point of intersection gives the observed position, since it will be found to be equidistant from each P/L. See Figure 14.

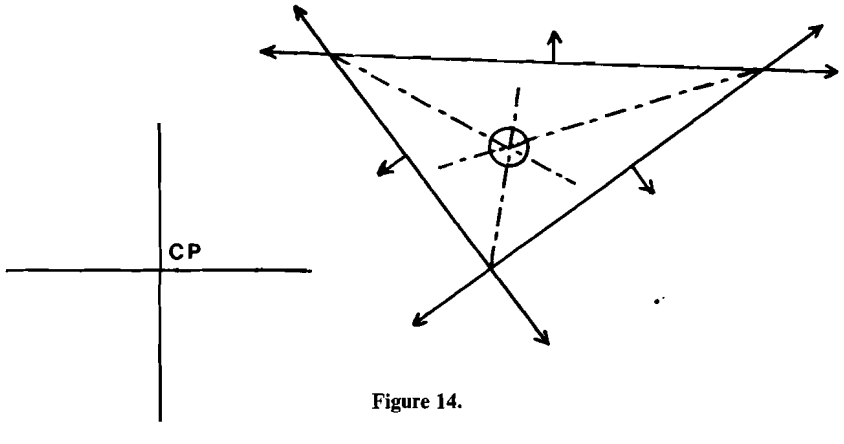


Figure 14.

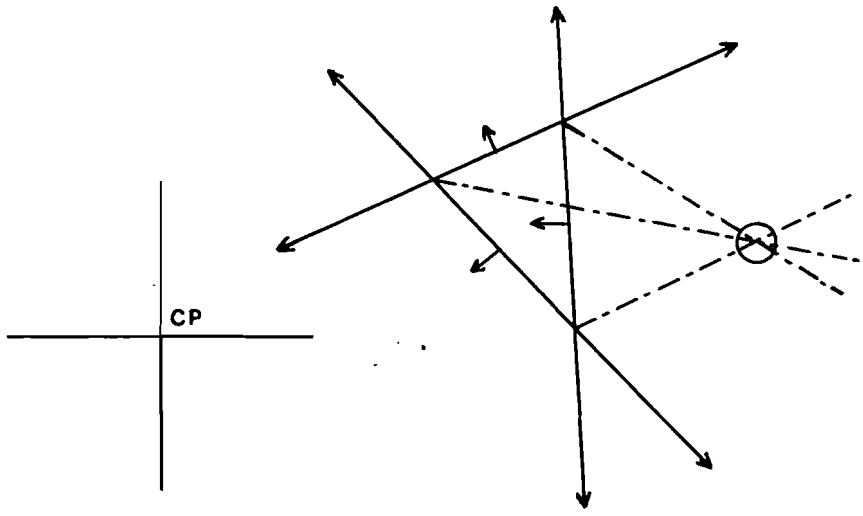


Figure 15.

The construction is slightly different when the stars observed have azimuths contained within 180°. Incidentally, this is not good practice as it tends to conceal any fixed errors. In Figure 15 note that the azimuths are all Westerly and that the exterior angles associated with the P/L of the middle azimuth have been bisected. Check the figure and confirm that each P/L has been shifted "away" by the same distance.

When plotting 3 stars it is assumed that the fixed error is the same for each P/L. A more accurate technique is to select 4 stars disposed in opposite pairs, as nearly as possible at right angles. Figure 16 shows the arrangement.

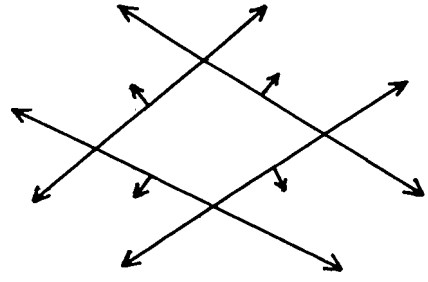


Figure 16.

The distance between a pair of opposite P/L's represents twice the fixed error. If both distances are about the same, then it is a reasonable assumption that all errors are consistent and the observed position may be placed, with confidence, at the centre of the "box". There is no geometrical construction, so the position is located by eye.

Example 7

An observer on a ship steering 158° T at 15 knots obtained the following results from stellar observations. The E.P. at 1745, 36° 23′ N., 38° 41′ W., was used in all calculations. Find the observed position at 1800.

1. Time	1750	Azimuth 139° T	Intercept 2·0′ Towards
2.	1753	308° T	1·8′ Away
3.	1757	228° T	0·6′ Away
4.	1804	035° T	1·2′ Towards

Note:

For convenience in plotting, time intervals and the corresponding runs are calculated for each star, as in example 6, above.

1. 1750	Interval	10 min	Run 2·5′	
2. 1753		7	1·75′	Civil Twilight 1736
3. 1757		3	0·75′	Nautical Twilight 1806
4. 1804		−4	−1·0′	

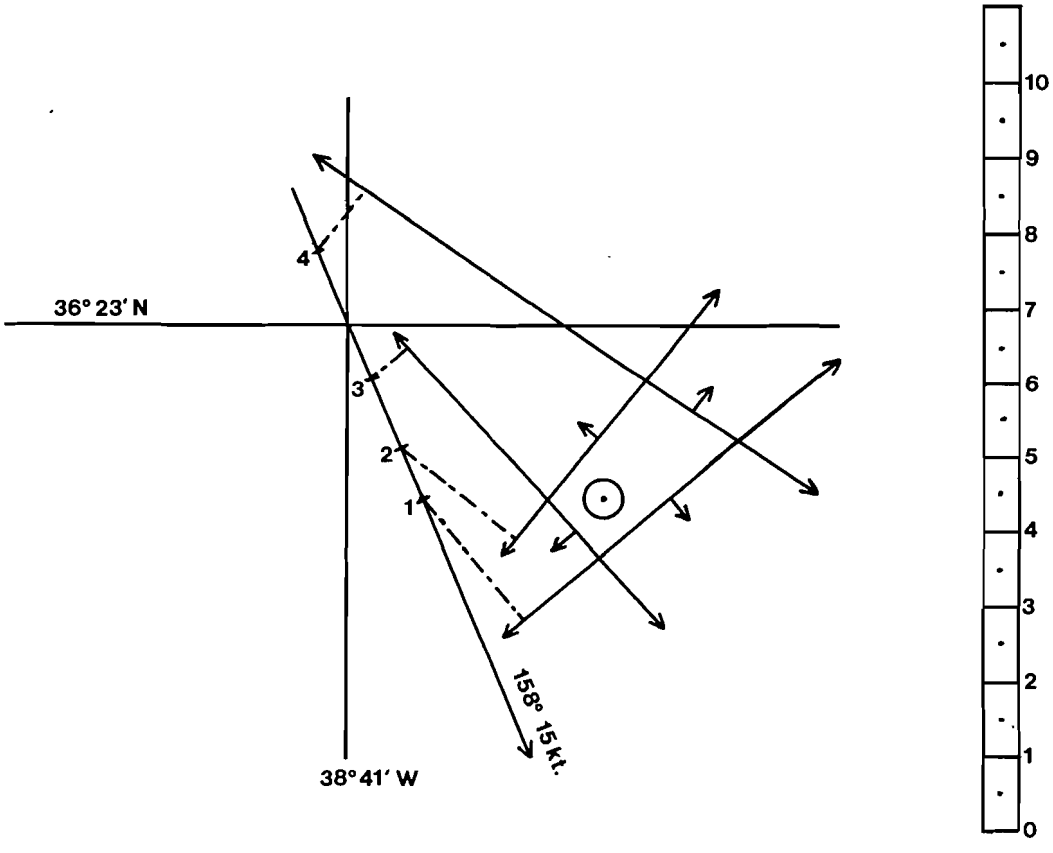


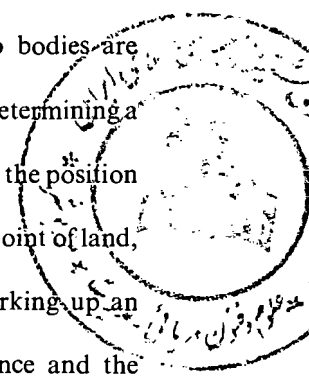
Figure 17.

Note:
When plotted, the shape of the "box" shows that the Fixed Errors are not all consistent. Consideration should be given to the possibility that one or more of the P/L's may be of doubtful accuracy. In this particular case it is possible that there was a poor horizon for the last observation (see times of twilight). In placing the position within the "box" more reliance was therefore given to the first three P/L's.

Ref. Pos.		36° 23·0′ N.		38° 41·0′ W.
From the plot	D. Lat.	2·3 S.	D. Long.	4·0′ E. (Dep 3·2′)
1830 Obs. Pos.		36° 20·7′ N.		38° 37·0′ W.

Questions

1. Give an explanation of the Intercept Method of determining a position line.
2. Describe the procedure of working up the sights.
3. How are the position lines combined to get the ship's position when two bodies are observed simultaneously?
4. What is the special advantage of the Intercept Method over other methods of determining a position line?
5. Will an error in estimating the run between the 1st and 2nd observations affect the position as determined by position lines?
6. Suppose you are given a P/L from the sun and at the same time a bearing of a point of land, discuss the value of the position so obtained.
7. State the effect of using another position, rather than the D.R., when working up an observation.
8. What information may be derived from a knowledge of the zenith distance and the geographical position of a heavenly body?
9. What is the difference between Greenwich Hour Angle and Longitude?
10. Give the SHA and LHA of a star, also the GHA Aries, explain how you would find longitude. Illustrate your answer by a suitable figure.



Exercise 1 (Intercept Method)

1. On January 11, in E.P. 36° 29′ N., 179° 45′ W., the sextant altitude of the star Aldebaran after crossing the meridian was 40° 32′, I.E. 1·2′ off the arc, H.E. 12 m, time by chronometer 11 d 12 h 40 m 55 s, error on GMT 4 m 42 s fast. Required the position line and the ITP.
2. On January 11, in D.R. 36° 29′ N., 179° 45′ W., the sextant altitude of the star Regulus was 53° 02′, I.E. 1·2′ off the arc, H.E. 12 m. Time by chronometer 11 d 12 h 42 m 52 s which was 4 m 42 s fast on GMT. Find the position line and the ITP.

   Given 36° 29′ N., 179° 45′ W., as an estimated position, plot the position lines obtained from Example (1) Aldebaran and Example (2) Regulus and determine the ship's position by observation.
3. On June 16, in D.R. 24° 00′ N., 29° 30′ W., the sextant altitude of the star Spica was 42° 27′ East of the meridian. I.E. 1·2′ off the arc. H.E. 11 m. Time by chronometer 19 h 28 m 30 s error on GMT 2 m 12 s, slow. Find the position line and the ITP.
4. On June 16, in 24° 00′ N., 29° 30′ W. by D.R., the sextant altitude of the star Procyon, West of the meridian was 35° 25′, I.E. 1·2′ off the arc, H.E. 11 m, time by chronometer 19 h 29 m 05 s which was slow on GMT 2 m 12 s. Required the position line and the ITP.

Given the D.R. position 24° 00′ N., 29° 30′ W., plot the position lines obtained from Spica (Example 3) and Procyon (Example 4) and find the ship's position by observation.

5. On June 16, in D.R. position 35° 02′ S., 46° 10′ W., the observed altitude of Jupiter, East of the meridian was 49° 35′. H.E. 12 m. Time by chronometer 20 h 41 m 33 s, which was fast of GMT 1 m 08 s. Find the ITP and the position line.

6. On June 16, in D.R. position 35° 02′ S., 46° 10′ W., the observed altitude of Procyon, West of the meridian, was 24° 56·5′. H.E. 12 m. Time by chronometer 16 d 20 h 42 m 46 s which was fast of GMT 1 m 08 s. Required the ITP and the position line.

Using the D.R. position 35° 02′ S., 46° 10′ W., draw the intercepts and position lines obtain from Jupiter (Example 5) and Procyon (Example 6) and find the ship's position by observation.

7. On January 7, in D.R. 45° 10′ N., 20° 40′ W., the sextant altitude of Betelgeuse was 37° 31′. I.E. 2·2′ off the arc. H.E. 12 m. GMT 7 d 21 h 17 m 49 s. Find the position line and the ITP.
8. On January 7, 45° 10′ N., 20° 40′ W., by D.R., the sextant altitude of Capella was 67° 22′. I.E. 2·2′ off the arc. H.E. 12 m. GMT 7 d 21 h 18 m 17 s. Find the position line and the ITP.

   Find also the ship's position by combining the position lines obtained from Betelgeuse (Example 7) and Capella (Example 8).
9. On June 15, about 0808 hours at ship, in D.R. 49° 10′ N., 8° 25′ W., the observed altitude of the sun's L.L. was 37° 47′. H.E. 11·5 m. GMT 15 d 08 h 41 m 23 s. Find the position line and the ITP.

   The ship then sailed 326° T., distance 29 miles. Find the position for the transferred position line.
10. On June 15, about 1010 hours at ship, in D.R. 49° 35′ N., 9° 01′ W., the observed altitude of the sun's L.L. was 55° 54′. H.E. 11·5 m. GMT 15 d 10 h 45 m 36 s. Find the ITP and the position line.

    Given Lat. 49° 35′ N., Long. 9° 01′ W., a position through which to draw the transferred position line from Example (9), plot the intercept and position line from Example (10) and find the ship's position by observation.
11. On December 24, about 2100 hours at ship, in E.P. 5° 25′ S., 4° 15′ W., the observed altitude of the moon's L.L. was 51° 17′, H.E. 9 m, GMT 24 d 21 h 14 m 22 s. Required the intercept, the ITP and the position line.

    The ship then sailed 247° T., distance 57 miles from Lat. 5° 20·7′ S., Long. 4° 09·8′ W. Required the position through which to draw the transferred position line as found in the previous Example 11.
12. On December 25, about 0100 hours at ship, in D.R. 5° 43′ S., 5° 02·5′ W., the observed altitude of the moon's L.L. was 50° 52′, H.E. 9 m, GMT 25 d 01 h 25 m 58 s. Required the intercept, the position line, and the ITP

    Find the ship's position as determined by the transferred position line from Example 11 and the position line from Example 12.

Answers in rear *Answer Section.*

Exercise 2 (Plotting Position Lines)

Whenever an example gives the ship's course and speed, then due allowance should be made for the run between observations when plotting P/L's, even though the time interval be short.

1. Simultaneous observations of Hamal bearing 077° T, and Formalhaut bearing 160° T, gave

intercepts of 5′ Away and 10′ Towards respectively; using a D.R. of 31° 47′ N., 49° 49′ W. in the calculations. Find the ship's position.

2. In D.R. 21° 02′ S., 179° 05′ W., an observation of the sun bearing 038° T gave an intercept of 7′ Towards. After making good a course of 252° T for 38 miles, the latitude by meridian altitude was found to be 21° 05′ S. Find the noon position.
3. From the following information regarding stellar observations, find the position at 1900.

   Ship's course and speed, 132° T, 25 knots

   D.R. 47° 38·7′ N., 30° 17·2′ W. (used in each calculation)

1. Time	1848	Venus	Az 258° T	Int 6·7′ T
2.	1853	Sirius	141° T	2·4′ A
3.	1905	Dubhe	027° T	4·9′ A

4. From the following information, find the vessel's position at the time of the second observation.

   Time at ship 0617 on 17 June. D.R. 36° 49′ S., 128° 23′ E.
   Sext. alt. of Rigel Kent 15° 02·2′. Chron 9 h 18 m 21 s
   Sext. alt. of Achernar 60° 43·8′. Chron 9 h 19 m 37 s
   I.E. 0·5′ off the arc. Chron error 2 m 15 s fast on GMT
   H.E. 14·5 m. Ship steering 100° T at 19 knots.

5. Find the ship's position at 1900, given the following information derived from stellar observations.

   Course and speed 208° T, 18 knots. C.P. 24° 17′ N., 19° 41′ W.

1. Time	1845	Az 168° T	Int 1·9′ T
2.	1848	062° T	5·0′ T
3.	1855	257° T	2·3′ A
4.	1903	001° T	3·3′ A

6. After calculating the following simultaneous observations, using D.R. 15° 46′ S., 64° 12′ E., it was found that the correction for Index Error had been omitted. Find the vessel's position and also the Index Error.

1. Capella	Az 023° T	Int 6·4′ T
2. Canopus	147° T	3·0′ A
3. Formalhaut	244° T	1·4′ T

7. An observer obtained the following results from stellar observations, using D.R. 53° 42′ N., 28° 07′ W. Find the position and comment on its accuracy. Deduce also, his Height of Eye; the correction for Dip having been omitted from the calculation.

1. Regulus	Az 120° T	Int 7·3′ T
2. Procyon	168° T	3·7′ T
3. Bellatrix	212° T	1·7′ T

8. The following information was derived from stellar observations, using a D.R. of 23° 46·2′ S., 176° 13·7′ W. Ship steering 257° T at 27 knots. Nautical twilight ended at 1855. Find the position at 1900 and comment on its accuracy.

1. Time	1843	Canopus	Az 222° T	Int 0·5′ A
2.	1848	Arcturus	051° T	1·8′ T
3.	1854	Rigel Kent	148° T	5·2′ T
4.	1907	Pollux	327° T	Nil

9. At about noon on 25 June a sight of the sun, to the South of the observer, gave a true altitude of 89° 48·8′, GMT 25 d 13 h 16 m 35 s. The vessel then steamed 342° T for 34 miles when a point of land in position 24° 23·5′ N., 18° 26′ W. was sighted bearing 034° T. Find the ship's position at the time of the second observation.

Answers to Exercise 2

1. 31° 35·5′ N., 49° 51·9′ W.
2. 21° 05·0′ N., 179° 43·5′ W.
3. 47° 35·5′ N., 30° 22·0′ W.
4. Rigel Kent LHA 132° 50·0′ Az 202° T, P/L 112–292° T Int 3·1′ T
   Achernar 328° 19·2′ 145° T, 055–235° T 2·3′ A
   Run for plot 100° 0·4′ Obs. Pos. 36° 50′ S., 128° 16′ E.
5. 24° 13·2′ N., 19° 37·4′ W.
6. The P/L's must be moved 2·2′ away, which is equivalent to reducing the altitude; correction to be subtracted.
   I.E. 2·2′ on the arc.
   Obs. Pos. 15° 40·8′ S., 64° 10·3′ E.
7. P/L's displaced 5·7′, due to omission of Dip. Corresponds to a H.E. 10·3–10·6 m.
   The position is valid since the construction allows for this fixed error, but it is not good practice to observe stars in the same sector.
   Obs. Pos. 53° 44·7′ N., 28° 01·5′ W.
8. Plot suggests some inconsistency in the fixed errors. Likely that there was a poor horizon for Pollux. The position is therefore located as equidistant from the first three P/L's.
   Obs. Pos. 23° 50·9′ S., 176° 15·3′ W.
9. G.P. Sun 23° 23·8′ N., 18° 32·2′ W. Radius of pos. circle 11·2′.
   Obs. Pos. 24° 06·3′ N., 18° 38·3′ W.

Chapter 27

Longitude by Chronometer

"Longitude by Chronometer", sometimes referred to as the Longitude Method is an alternative technique for finding a position through which to draw a Position Line (P/L). This position is given by the D.R. Latitude and the Calculated Longitude. When the body observed bears due East or West the P/L coincides with a meridian, and only in this case will the method give a true longitude.

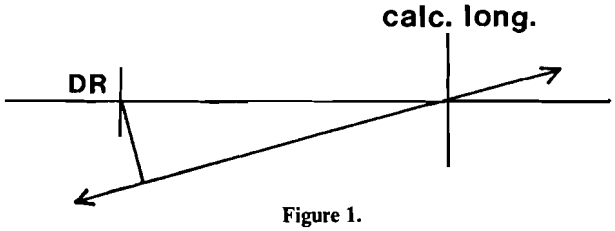


Figure 1.

The method is not suitable for a body approaching the meridian. Figure 1 shows that there is an inconveniently large displacement of longitude for quite a small intercept. In higher latitudes, especially in wintertime, the morning sight of the sun should be taken early, when it is bearing Easterly, so as to get a good angle of cut with the noon observation. In the tropics, when the sun is passing nearly overhead, the a.m. sight may be taken later in the forenoon.

When limited to one or two observations, the Longitude Method has an advantage in that plotting is somewhat simplified. Many navigators prefer the method for the a.m. sight of the sun for this reason; moreover, if it be crossed with a meridian altitude then plotting may be dispensed with entirely by use of the "C" correction.

Derivation of the Formula

In the PZX triangle the haversine formula is arranged so that the Hour Angle (P) is expressed in terms of Zenith Distance (ZX), co-Latitude (PZ) and Polar Distance (PX).

$$\text{hav}\, P = \frac{\text{hav}\, ZX - \text{hav}(PZ \sim PX)}{\sin PZ \times \sin PX}$$

$$= [\text{hav}\, ZX - \text{hav}(PZ \sim PX)] \operatorname{cosec} PZ \times \operatorname{cosec} PX$$

By taking complementary values, the working of the formula may be simplified:

$$= [\text{hav}\, ZX - \text{hav}\, (\text{Lat.} \pm \text{Dec.})] \sec \text{Lat.} \times \sec \text{Dec.}$$

(Lat. + Dec.) when the names are different
(Lat. ~ Dec.) when the names are the same.

Order of Work

1. Run up the ship's position.
2. From the *Nautical Almanac*, find the Declination and GHA.
3. Correct the altitude and obtain the Zenith Distance.
4. Draw a figure, if required.
5. Calculate the LHA by the formula.
6. Longitude is found by one of the following equations:
   East Long. = LHA – GHA
   West Long. = GHA – LHA
   In order to avoid complications in the manipulation of these equations, proceed as follows:
   (a) Body West of the Meridian – LHA lies between 0° and 180°.
   (b) Body East of the Meridian – LHA lies between 180° and 360°; this value is found at the bottom of the page in the haversine table.
   (c) If necessary, add 360° to the first term on the right hand side of the equation.
7. Find the Azimuth and P/L by ABC Tables, or other method.
8. Note the results, together with the time and log reading in readiness for the next observation.

Example 1(a) Sun (AM Sight)
(Refer to Figure 2)

June 26, about 0800 hours at ship, D.R. 32° 06′ N., 140° 54′ E., the Sextant altitude of the Sun's L.L. was 36° 01′, I.E. 3·6′ on the arc, H.E. 12 m, time by chronometer 25 d 22 h 32 m 07 s which was 2 m 40 s slow on GMT. Find the position line and the Longitude through which to draw it.

To Find the Longitude and Azimuth

Chron.		25d 22h 32m 07s	
Slow	(+)	2 40	
GMT		25 22 34 47	
GHA Sun	25d 22h	149° 22·2′	
Incre.	34m 47s	8 41·8	
GHA Sun		158 04·0	
Dec. Sun.		23° 23·2′ N.	*d* (0·0)
		90 00	
Polar Dist.		66° 36·8′	(*PX*)

Sext. alt. L.L.		36° 01·0′	
I.E.	(−)	3·6	
		35 57·4	
Dip	(−)	6·1	
		35 51·3	
Corr. (Almanac)	(+)	14·7	
True alt.		36 06·0	
		90 00	
Zen. Dist.		53 54	(*ZX*)
Lat.		32° 06′	N.
		90 00	
co-Lat.		57° 54′	(*PZ*)

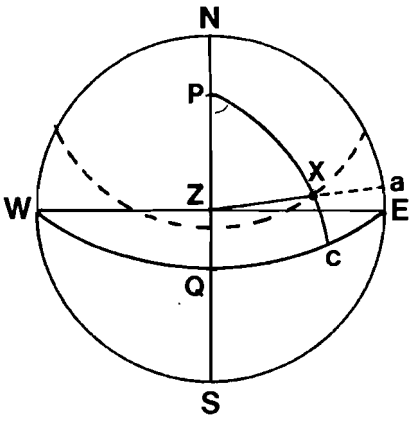


Figure 2.

NESW	Rational Horizon.
P	Pole.
Z	Zenith.
X	Sun.
WQE	Equinoctial.
NZS	Observer's Meridian.
WZE	Prime Vertical.
PZ	co-Lat.
ZQ	Lat.
PX	Polar Dist.
CX	Declination.
aX	Altitude.
ZX	Zen. Dist.
$\angle ZPX$	Hour Angle.
$\angle PZX$	Azimuth.

Given *PZ*, *PX* and *ZX*, find the LHA $\angle P$.

To find the LHA

$$\text{hav } P = \frac{\text{hav } ZX - \text{hav } (PZ \sim PX)}{\sin PZ \sin PX}$$

ZX	53°	54′	nat hav	0·20540
PZ~*PX*	8	42·8	nat hav	0·00577
			nat hav	0·19963
			log nat hav	9·30021
PZ	57	54	cosec	10·07205
PX	66	36·8	cosec	10·03723
P	60	53·3	log hav	9·40949
	360	00		
LHA	299°	06·7′	(1)	

To find the Azimuth

ABC Tables

A	0·35 S.
B	0·50 N.
C	0·15 N.
Az	N. 82·8° E = 083° T
P/L	173°—353° T

To find the Longitude

East Long = LHA − GHA

LHA Sun	299° 06·7′
GHA Sun	158 04·0
Long.	141° 02·7′ E.

Answer P/L runs 173°—353° T through 32° 06′ N, 141° 02·7′ E. (2)

Notes:

1. Since the time is a.m., the sun is East of the meridian and the LHA is therefore between 180° and 360°. If preferred, this LHA could have been lifted directly from the foot of the page in the haversine tables.
2. When using this method there is no intercept, so the P/L is drawn straight through the calculated position, (or the transferred position).

COMBINING A LONGITUDE P/L WITH A LATITUDE

Position lines obtained by the Longitude Method can be combined with a Latitude by Meridian Altitude of the Sun. In practice, the problem presents itself as follows:

1. Given a D.R. position, the GMT and observed altitude to calculate the Longitude and azimuth for a position line.
2. Given a course and distance sailed to transfer the position line.
3. Given a meridian altitude of the sun to find the Latitude, and thence a position line to get the ship's position by observation at noon.

In the case of PM sights the order is:

1. A position line from a meridian altitude of the sun.
2. The ship's run to transfer the position line to get a D.R. position with which to work up the sights.
3. Given the GMT and an observed altitude to work up the local hour angle and azimuth to get Longitude and a position line, thence the ship's position by observation.
   The Longitude and position line found in Example 1(a) is now used to determine the position at noon.

Example 1(b)

Between sights and noon the ship sailed 225° T, Log distance 33 miles. Transfer the position line. Use the 0800 position obtained at sights in Example 1(a).

To Transfer the Position Line

From Traverse Tables: 6·1 S.

225° T, 33 miles	Pos. at sights	32° 06·0′ N.	141° 02·7′ E.
D. Lat. 23·3′ S.	Run	23·3 S.	27·5 W.
Dep 23·3,			
D. Long 27·5′ W.	D.R. at 2nd obs.	31° 42·7′ N.	140° 35·2′ E.

The position line is now ready for the second observation.

Example 1(c)

(Refer to Figure 3)

At noon the Latitude was found to be 31° 36·6′ N. by observation of the sun's meridian altitude. Find the ship's position as determined by the position lines. Use the noon D.R. obtained in Example 1(b).

	Obs. Lat.	31° 36·6′ N.
	D.R. Lat.	31° 42·7′ N.
Difference =	Intercept	6·1′ S.
	Azimuth	180° T.

The two observations may now be plotted, (Figure 3). By measurement the observed position is to the East of the D.R. Long by a Dep of 0·8′, which converts to D. Long 0·9′ E.

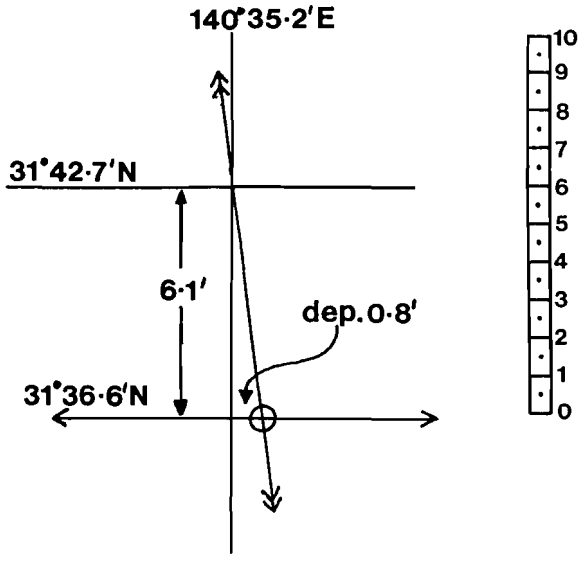


Figure 3.

Obs. Lat.	31° 36·6	D.R. Long.	140° 35·2′ E.
		From plot	0·9 E.
Obs. Pos.	31° 36·6′ N.		140° 36·1′ E.

Answer Ship's Noon Position 31° 36·6′ N., 140° 36·1′ E.

THE "C" CORRECTION

The ABC Tables are designed so that the quantity "C", in addition to finding the azimuth, may also be used as a factor to convert D. Lat into D. Long when combining an observation for Latitude with a P/L calculated by the Longitude Method. This technique is **not** applicable to an Ex-Meridian observation.

In Example 1(c), the Obs. Lat. is 6·1′ to the South of the D.R., and C = 0·15.

$$\text{D. Long} = \text{D. Lat} \times C = 6{\cdot}1 \times 0{\cdot}15 = 0{\cdot}9'$$

Since there is no plot to consult, it is advisable to sketch the P/L in order to find the direction in which the Longitude correction should be applied. Figure 4 shows that it lies to the East.

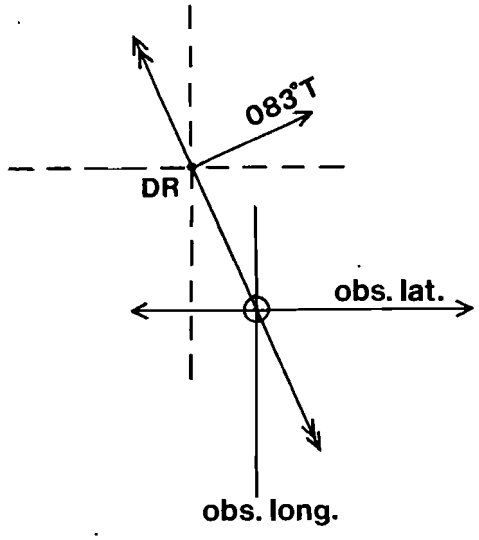


Figure 4.

D.R. Long	140° 35·2′ E.
Correction	0·9′ E.
Obs. Long	140° 36·1′ E.

Note that: P/L runs N. and W.
S. and E.
As the observer's latitude is South the correction for D. Long. is East.

TO FIND GMT OF APPARENT NOON

After taking a morning sun sight, the navigator should estimate the GMT and Ship's Time at which the sun will cross the Meridian, so that the mid-day routine may be organised.

The LMT of the Sun's Meridian Passage is given at the foot of the right hand daily page of the *Nautical Almanac* and

$$\text{GMT} = \text{LMT} \pm \text{Longitude in time}$$

Unfortunately, it is necessary to know the noon GMT in order to find the steaming time and hence the Longitude at noon. This difficulty may be resolved by making two successive estimates; the first using the Longitude at sights and the second using a recalculated Longitude. The method is illustrated in Example 2.

It should be noted that ship's clocks do not show LMT. It is customary to alter them by the hour, so that the ship's time is really Zone Time, i.e. GMT ± a certain number of hours. Zone +2, for example, means that GMT = Ship's Time + 2 hours.

Example 2

A morning sight of the sun, taken at 0832 (Zone −4) on 11 October gave a position, through which the P/L passed, of 39° 25′ S., 62° 17′ E.

Using an estimated speed of 19 knots on a course of 261° T., find the GMT and Zone Time of the sun's meridian passage and the D.R. at this time.

Ship's time		11d 08h 32m
Zone	(−)	4
GMT at sights		11d 04h 32m

1st Estimate

LMT noon	11h 47m
Long E. (62° 17′)	4 09
Approx. GMT	7 38
GMT at sights	4 32
Time Interval	3h 06m

3·1h at 19 knots = 58·9 miles

Long at sights	62° 17·0′ E.
261°T, 58·9′ (Dep 58·2)	1 15·4 W.
Approx. Long at noon	61° 01·6′ E.

2nd Estimate

LMT noon		11h 47m
Long E. (61° 01·6′)		4 04
GMT noon		11d 07h 43m
Zone	(−)	4
ZT of noon		11d 11h 43m

GMT at noon	07h 43m
GMT at sights	04 32
Time interval	3h 11m

3·18h at 19 knots = 60·4 miles

From Traverse Tables

Co 261° T, 60·4 miles
D. Lat. 9·4′ S.
Dep 59·7′
D. Long 77·4′ W.

Pos. at sights	39° 25·0′ S.	62° 17·0′ E.
Run	9·4 S.	1 17·4 W.
D.R. at noon	39° 34·4′ S.	60° 59·6′ E.

Answer GMT noon 11d 07h 43m, ZT 11d 11h 43m.
D.R. noon 39° 34·4′ S., 60° 59·6′ E.

Example 3(a) Planet – run – Moon
(Refer to Figure 5)

From the following information find the direction of the P/L and a position through which it passes:

Time at ship 1322 on 23 September, D.R. 25° 42′ S., 169° 12′W., Sext. alt. of Venus 47° 39′ West of the meridian, H.E. 15 m, GMT 00 h 21 m 43 s. I.E. 1·8′ off the arc.

GMT	24d 00h	192° 52·0′		Sext. alt.		47° 39·0′
Incre.	21m 43s	5 25·8		I.E.	(+)	1·8
		198 17·8		Obs. alt.		47 40·8
v. corr.	(−0·4)	0·1		Dip	(−)	6·8
GHA	Venus	198° 17·7′				47 34·0
				Corr.	(−)	0·9
Dec	24d 00h	6° 04·1′ N.				47 33·1
Incre.	21m 43s	(−) 0·4	*d*(1·2)	Venus corr		0
Dec	Venus	6 03·7 N.		True alt.		47 33·1
Lat.		25 42·0 S.				90
(L+D)		31° 45·7′		*ZX*		42° 26·9′

To Find the LHA

hav P = [hav ZX − hav (L+D)] sec Lat. × sec Dec.

ZX	42° 26·9′	nat hav	0·13106
(L+D)	31 45·7	nat hav	0·07488
		nat hav	0·05618
		log hav	8·74958
Lat.	25 42·0	log sec	10·04524
Dec.	6 03·7	log sec	10·00244
P	29 00·1	log hav	8·79726

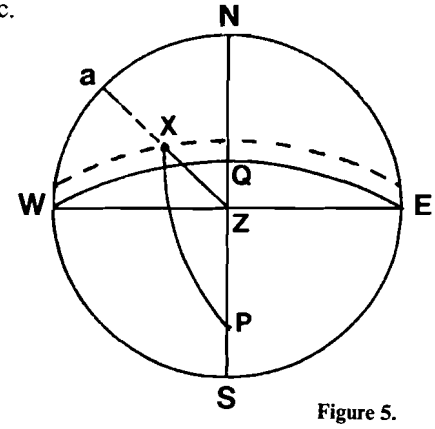


Figure 5.

To Find the Azimuth

A	0·85 N.
B	0·21 N.
C	1·06 N.

Az. N. 46·3° W ≃ 314° T.

To Find the Longitude

W. Long = GHA − LHA

GHA	198° 17·7′
LHA	29 00·1
Long	169° 17·6′ W.

Answer P/L runs 044 − 224° T through 25° 42·0′ S., 169° 17·6′ W.

Example 3(b)
(Refer to Figure 6)

Having made good a course of 253° T, 58 miles; find the vessel's position from the following information:

Time at ship 1731 on 23 September, C.P. 26° 00′ S., 170° 19′ W., Sext. alt. of the Moon's U.L. 31° 02′, East of the meridian, GMT 04 h 31 m 17 s

GMT 24d 04h 31m 17s		
GHA 24d 04h		102° 38·5′
Incre. 31m 17s		7 27·9
v corr. (13·0)		6·8
GHA Moon		110° 13·2′
Dec. 24d 04h		10° 41·1′ S.
Incre., d = 8·3 (−)		4·4
Dec. Moon		10 36·7 S.
Lat.		26 00·0 S.
(L ~ D)		15° 23·3′

Sext. alt.		31° 02·0′
I.E.	(+)	1·8
		31 03·8
Dip	(−)	6·8
		30 57·0
Corr	(+)	58·5
H.P. 55·4′	(+)	2·3
		31 57·8
U.L.	(−)	30
True alt.		31 27·8
		90
ZX		58° 32·2′

To Find the LHA

hav *P* = [hav *ZX* − hav (L ~ D)] sec Lat. × sec Dec.

ZX	58° 32·2′	nat hav	0·23902
(L ~ D)	15 23·3	nat hav	0·01793
		nat hav	0·22109
		log hav	9·34457
Lat.	26 00·0	log sec	10·04634
Dec.	10 36·7	log sec	10·00750
P	299° 57·8′	log hav	9·39841

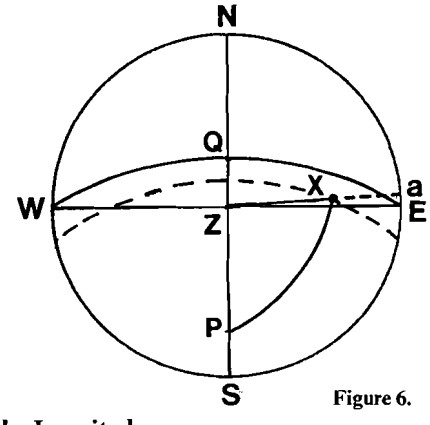


Figure 6.

To Find the Azimuth

A 0·28N.
B 0·21 S.
C 0·07 N.

Az N. 86·4° E. = 086½° T

P/L runs 176½ − 356½° T. through 26° 00·0′ S., 170° 15·4′ W.

To Find the Longitude

W. Long = GHA − LHA

GHA	470° 13·2′
LHA	299 57·8
Long	170° 15·4′ W.

PLOTTING THE OBSERVATIONS

Example 3(c)

Using data from the two sights taken at 1322, in Example 3(a), and 1731, in Example 3(b), find the vessel's position at 1731.

Using plain or squared paper, a parallel and a meridian are drawn to represent the position obtained by the second observation. The P/L is drawn through the intersection.

Since it may not be exactly the same as the C.P., the position by the first observation at 1322 must be transferred to 1731 and plotted by D. Lat. and Dep. with reference to the position by sights at 1731.

From Traverse Tables:

Run 253° T, 58 miles

D. Lat. 17·0′ S.
Dep. 55·5′
D. Long. 61·7′ W.

1322 By sights	25° 42·0′ S.	169° 17·6′ W.
Run	17·0 S.	1 01·7 W.
1731 D.R.	25 59·0 S.	170 19·3 W.
1731 By sights	26 00·0 S.	170 15·4 W
	1·0′ N	3·9′ W.
For plotting the 1731 D.R.	D. Lat. 1·0′ N.	Dep. 3·5′ W.

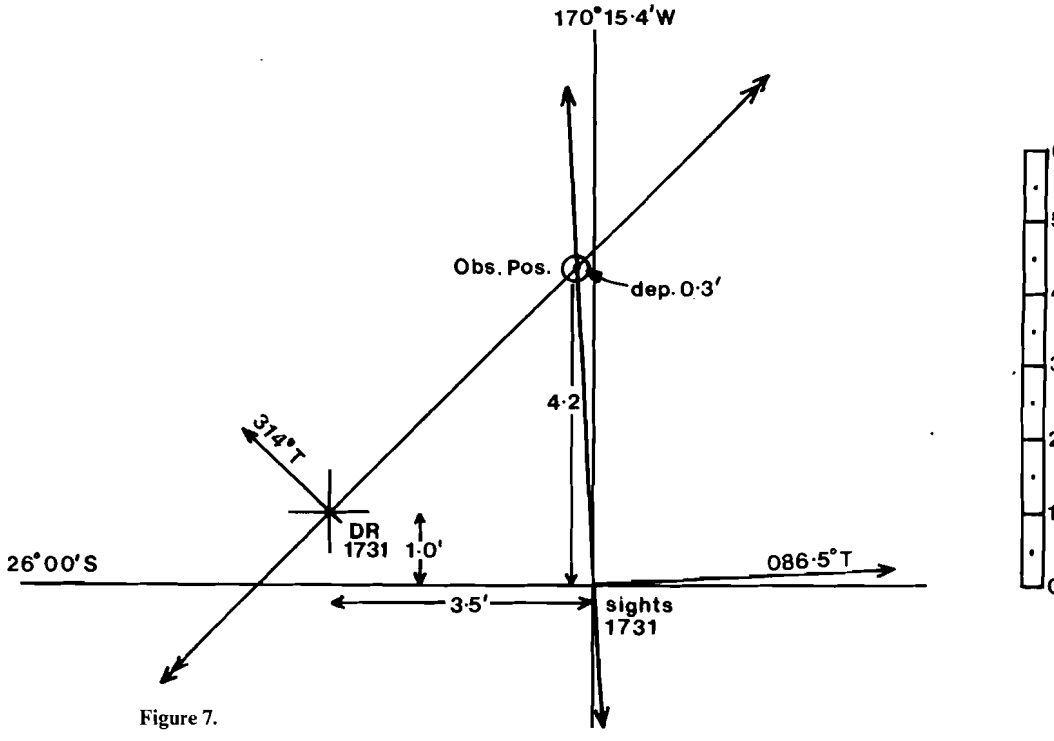


Figure 7.

Reference Pos.	26° 00·0′ S.	170° 15·4′ W.
From the plot	4·2 N.	0·3 W. (Dep. 0·3′)
Obs. Pos. 1731	25° 55·8′ S.	170° 15·7′ W.

Answer 1731 Obs. Pos. 25° 55·8′ S., 170° 15·7′ W.

SIMULTANEOUS OBSERVATIONS

In Examples 4(a) and 4(b) two stars are observed at about the same time, and the results used to find the vessel's position.

Example 4(a)
(Refer to Figure 8)

On January 12, in D.R. 19° 42′ S., 80° 05′ E., the observed altitude of the star Arcturus, West of the meridian was 24° 59′, H.E. 10·5 m. Time by a chronometer 12 d 05 h 06 m 18 s, which was fast of GMT 5 m 14 s. Find the direction of the position line and a position through which it passes.

Time by chron.	12d	05h	06m	18s
Error fast (−)	12		5	14
GMT	12	05	01	04

SHA Arcturus	146° 33·8′
Declination	19° 23·9′ N.
Latitude	19 42·0′ S.
(L + D)	39° 05·9′

Obs. alt.	24° 59·0′
Dip. (−)	5·7
App. alt.	24 53·3
Corr. (−)	2·1
True alt.	24 51·2
	90 00
Zen. dist.	65° 08·8′ = *ZX*

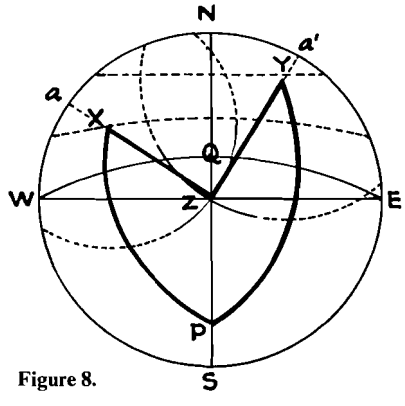


Figure 8.

X star *Arcturus*, *Y* star *Deneb*. The short arcs drawn through *Z* represent the circles of position round *Arcturus* and *Deneb*.

To Find LHA

hav P = [hav ZX − hav (L + D)] sec Lat. × sec Dec.

ZX	65° 08·8′ N.	nat hav	0·28986
(L + D)	39 05·9	nat hav	0·11197
		nat hav	0·17789
		log hav	9·25015
Lat.	19 42 S.	log sec	0·02619
Dec.	19 23·9 N.	log sec	0·02539
P = LHA	53 10·6	log hav	9·30173
	+ 360 00 0		
LHA	413° 10·6′		

To Find Longitude

GHA Aries + SHA Star = GHA Star

LHA − GHA = Longitude East

GHA	12d	05h	186° 11·2′
Incre.	01m	04s	0 16·0
GHA			186 27·2
SHA*			146 33·8
GHA*			333 01·0
LHA*			413 10·6
Longitude			80° 09·6′ E.

To Find the Azimuth

Sin Z = sin P × sin PX × cosec ZX or sin Az = sin LHA × cos Dec. × sec alt., as preferred.

P	53° 10·6′	sin	9·90336
Dec.	19 24	cos	9·97461
Alt.	24 51·2	sec	0·04220
Az	N. 56° 19′ W.	sin	9·92017

ABC Tables.

A	0·27 N.
B	0·44 N.
C	0·71 N.

Az. N. 56·2° W. = 303·8° T.

P/L 033·8° − 213·8° T.

With Lat. 19° 42′ S., Long. 80° 09·6′ E., P/L 034° − 214° T. Plot the position line as shown on squared paper after the next example.

Note: The use of the Sine Formula is unsatisfactory when the body is near the prime vertical. Due to the ambiguity of the sine it is not possible to distinguish between, for example, an azimuth of 088° and 092°.

Example 4(b)

January 12, about the same time as Arcturus was observed in Example 4(a), the sextant altitude of Deneb was 14° 04′ East of the meridian, I.E. 1·1 off the arc, H.E. 10·5 m. Time by chronometer 12 d 05 h 05 m 30 s, which was fast of GMT 5 m 14 s. Latitude 19° 42′ S. Find the Longitude through which to draw the position line. Find also the ship's position by combining the position lines from Arcturus and Deneb.

Chron.	12d	05h	05m	30s
Fast			5	14
GMT	12	05	00	16

SHA Deneb	50° 00·3′	
Dec.	45° 08′	N.
Lat.	19 42	S.
(L+D)	64° 50′	

Sext. alt.		14° 04·0′
I.E.	(+)	1·1′
		14 05·1
Dip	(−)	5·7
		13 59·4
Corr.	(−)	3·8
True alt.		13 55·6
		90 00
Zen. dist.		76° 04·4′ = ZY

hav P = [hav ZY − hav (L+D)] sec Lat. × sec Dec.

ZY	76° 04·4′		nat hav	0·37966
(L+D)	64 50		nat hav	0·28737
			nat hav	0·09229
			log hav	8·96515
Lat.	19 42	S.	log sec	0·02619
Dec.	45 08	N.	log sec	0·15153
P = LHA	316 13·7		log hav	9·14287

East Long. = LHA − GHA

GHA	12d	05h	186° 11·2′
Incre.	00m	16s	0 04·0
GHA Aries			186 15·2
SHA*			50 00·3
GHA*			236 15·5
LHA*			316 13·7
Longitude			79° 58·2′ E.

To Find the Azimuth

sin Az. = sin P × cos Dec. × sec. alt.

P	43° 46′	sin	9·83993
Dec.	45 08	cos	9·84847
Alt.	13 55	sec	0·01294
Az. N.	30° 11′ E.	sin	9·70134

ABC Tables

A	0·38 N.
B	1·45 N.
C	1·83 N.

Az. N. 30° E. = 030° T.
P/L 120°—300° T.

Note:

When drawing circles of declination the following hints will be found useful. Up to about Lat. 20° the amplitude of a body is approximately equal to its declination.

Between Lat. 20° and 30° the amplitude of a body averages about $\frac{1}{10}$ more than its declination.

Between Lat. 30° and 40° it is about $\frac{1}{4}$ more than the declination; between Lat. 40° and 50° about $\frac{1}{2}$ more; between Lat. 50° and 55° about $\frac{3}{4}$ more; and between Lat. 55° and 60° about double the declination, after which the amplitude increases over the declination at a rapidly increasing ratio. In this example the Lat. is about 20°, Dec. 45°, and the correct amplitude is $48\frac{1}{2}°$, just a little more than the declination.

Plotting the Observations

For the axes of reference it would be convenient to draw the meridian of 80° E; the parallel of 19° 42′ S. is, of course, common to both sights.

For each star the plotting position must be laid off by the relevant departure:

Arcturus, D. Long. 9·6′ E., Dep. 9·0′ E.
Deneb, D. Long. 1·8′ W., Dep. 1·7′ W.

Having drawn the P/L's through their respective positions, the D. Lat. and Dep. of their point of intersection are measured from the axes of reference, as shown.

Reference Pos.	19° 42·0′ S.	80° 00·0′ E.	
From the plot	4·5′ S.	6·3′ E.	(Dep. 5·9′)
Obs. Pos.	19° 46·5′ S.	80° 06·3′ E.	

Answer Obs. Pos. 19° 46·5′ S., 80° 06·3′ E.

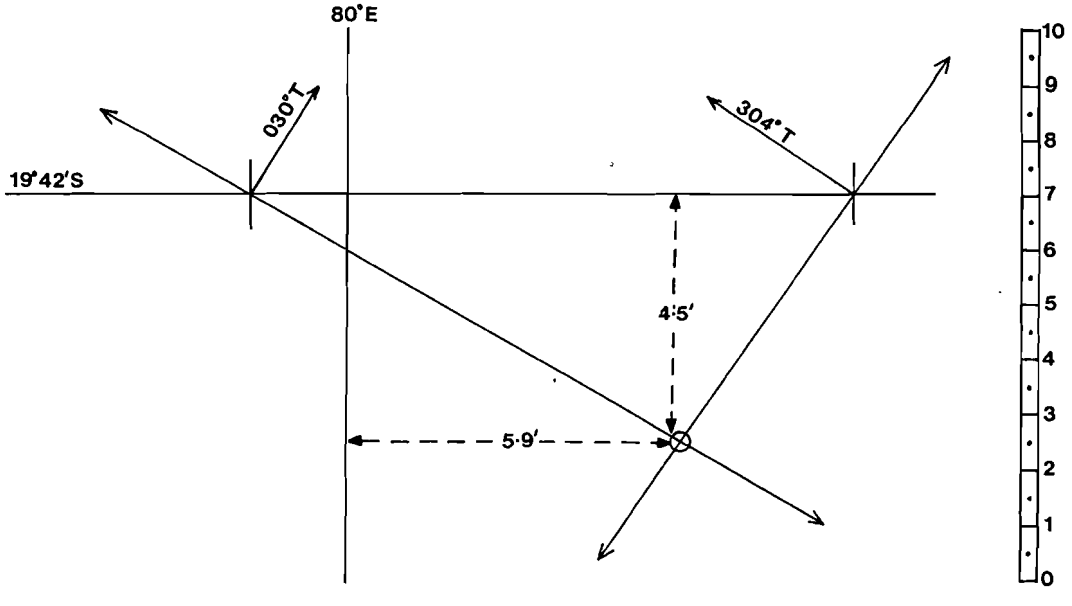


Figure 9.

Exercise 1 (Sun Sights by the Longitude Method)

1. January 12, about 0900 hours at ship, in D.R. 31° 46′ N., 151° 26′ W., the Observed Altitude of the Sun's L.L. was 19° 57′, H.E. 10 m. Time by chronometer 12 d 19 h 03 m 26 s which was 2 m 10 s slow on GMT Find the Longitude in which the P/L crosses the D.R. Latitude.
2. January 9, in D.R. 28° 10′ N., 60° 10′ W., the Observed Altitude of the Sun's L.L. was 25° 10′, H.E. 7·5 m. Time by chronometer 9 d 18 h 48 m 04 s which was 8 m 44 s slow on GMT Find the P/L and the Longitude through which it crosses the D.R. Latitude.
3. January 9, about 0915 hours at ship, in D.R. 45° 02′ S., 172° 08′ E., GMT 8 d 20 h 50 m 40 s, the Observed Altitude of the Sun's L.L. was 38° 32′, H.E. 12 m. Find the Longitude and P/L.
4. September 22, about 0740 hour at ship, in D.R. 31° 46′ N., 151° 36′ W., the Observed Altitude of the Sun's L.L. was 21° 36′, H.E. 15·3 m, GMT 22 d 17 h 41 m 05 s. Find the P/L and the Longitude in which it crosses the D.R. Latitude.
5. June 26, about 1700 hours at ship, in D.R. 46° 32′ N., 155° 10′ E., the Sextant Altitude of the Sun's L.L. was 27° 20′, I.E. 1′ off the arc, H.E. 7·3 m. Time by chronometer 26 d 06 h 33 m 33 s which was 4 m 36 s slow on GMT. Find the P/L and the Longitude in which it crosses the D.R. Latitude.
6. January 7, about 1600 hours at ship, in D.R. 42° 36′ S., 47° 28′ W., the Observed Altitude of the Sun's L.L. was 36° 17·5′, H.E. 15·5 m. Time by chronometer 7 d 19 h 20 m 20 s which was 3 m 03 s fast on GMT. Find the P/L and the Longitude through which it crosses the D.R. Latitude.
7. An a.m. sight for Longitude which may be combined with a Run and Latitude by Meridian Altitude at noon.
   (a) June 19, about 0930 hours at ship, D.R. 43° 18′ S., 70° 32′ E., the Sextant Altitude of the Sun's L.L. was 14° 29·5′, I.E. 2′ on the arc, H.E. 10·7 m. Chronometer 04 h 47 m 21 s which was 2 m 08 s fast on GMT. Find the P/L and the Longitude in which it crosses the D.R. Latitude.
   (b) Between sights and noon the ship sailed 098° T., 29 miles. Find the position for the transferred P/L.
   (c) At noon June 19, in D.R. 71° 18·5′ E., the Sextant Meridian Altitude of the Sun's L.L. was 22° 59′ bearing North, I.E. 2′ on the arc, H.E. 11 m. Find the Latitude and the ship's position as determined by the P/Ls.

Exercise 2 (Moon, Planet and Star Sights by the Longitude Method)

Questions 1 to 8, though expressed in different terms, are basically the same as those in the chapter on the Intercept Method. Students may find it interesting to compare the two techniques.

1. January 11, in D.R. 36° 29′ N., 179° 45′ W., the Sextant Altitude of the star Aldebaran, West of the meridian was 40° 32′, I.E. 1·2′ off the arc, H.E. 12 m. Chronometer 11 d 12 h 40 m 55 s which was 4 m 42 s fast of GMT. Find the Longitude and the star's true azimuth for a P/L.
2. On January 11, in D.R. 36° 29′ N., D.R. 179° 45′ W., the Sextant Altitude of the star Regulus, East of the meridian was 53° 02′, I.E. 1·2′ off the arc, H.E. 12 m, Chronometer 11 d 12 h 42 m 52 s which was fast of GMT 4 m 42 s. Find the Longitude in which the P/L crosses the D.R. Latitude, also the direction of the P/L.

   Combine the position lines from Aldebaran (Example 1) and Regulus (Example 2) and find the ship's position.

3. June 16, in D.R. 24° 00′ N., 29° 30′ W., the Sextant Altitude of the star Spica, East of the meridian was 42° 27′, I.E. 1·2′ off the arc, H.E. 10·8 m. Time by chronometer 19 h 28 m 30 s, which was 2 m 12 s slow of GMT Find the P/L and the Longitude in which it crosses the D.R. Latitude.
4. June 16, in D.R. 24° 00′ N., 29° 30′ W., the Sextant Altitude of the star Procyon, West of the meridian was 35° 25′, I.E. 1·2′ off the arc, H.E. 10·8 m. Time by chronometer 19 h 29 m 05 s which was 2 m 12 s slow of GMT. Find the Longitude in which the P/L crosses the D.R. Lat., also the P/L.

   Combine the P/L's from Spica (Example 3) and Procyon (Example 4) in order to fix the ship's position.
5. June 16, in D.R. 35° 02′ S., 46° 10′ W., the Observed Altitude of the planet Jupiter, East of the meridian was 49° 35′, H.E. 12 m, a chronometer which was 1 m 08 s fast of GMT indicated 20 h 41 m 33 s. Find the P/L and the Longitude through which it crosses the D.R. Latitude.
6. June 16, in D.R. 35° 02′ S., 46° 10′ W., the Observed Altitude of the star Procyon, West of the meridian was 24° 56·5, H.E. 12 m, GMT 16 d 20 h 41 m 38 s. Find the P/L and the Longitude in which it crosses the D.R. Latitude.

   Combine the P/L's from Jupiter (Example 5) and Procyon (Example 6) and find the ship's position.
7. January 7, in D.R. 45° 10′ N., 20° 40′ W., the Sextant Altitude of the star Betelgeuse, East of the meridian was 37° 31′, I.E. 2·2′ off the arc, H.E. 12 m, GMT 7 d 21 h 17 m 49 s. Find the P/L and the Longitude in which it crosses the D.R. Latitude.
8. January 7, in D.R. 45° 10′ N., 20° 40′ W., the Sextant Altitude of the star Capella, East of the meridian was 67° 22′, I.E. 2·2′ off the arc, H.E. 12 m, GMT 7 d 21 h 18 m 17 s. Find the P/L and the Longitude in which it crosses the D.R. Latitude.

   Combine the P/L's from Betelgeuse and Capella (Examples 7 and 8) and find the ship's position.
9. September 20, about 1410 hours at ship, in D.R. 24° 30′ N., 33° 18′ W., the Observed Altitude of the moon's lower limb was 14° 38′ East of the meridian, H.E. 15·3 m, GMT from chronometer 20 d 16 h 24 m 21 s. Find the Longitude in which the P/L crosses the D.R. Latitude.

   The course and distance made good from 24° 30′ N., 33° 15·7′ W., was 127° T., 64 miles, required the position through which to draw the transferred P/L, the azimuth being 119° T.
10. September 20, about 2008 hours at ship, in D.R. 23° 51·5′ N., 32° 19·7′ W., the Observed Altitude of the moon's L.L. was 41° 18·5′ West of the meridian, H.E. 15·3 m, GMT 20 d 22 h 16 m 48 s. Find the P/L and the Longitude in which it crosses the D.R. Latitude.

    Combine the P/L from the moon (Example 10) with the transferred P/L (Example 9) and find the ship's position.

Exercise 3 (Plotting Position Lines)

1. In D.R. Lat. 34° 11′ N., Obs. Long. 42° 25′ W., Sun bore 121° T. Log 40. Ship steered 022° C., Compass Error 20° E. until the log showed 72. The Latitude by a Meridian Altitude of the sun was then 34° 11′ N. Find noon position.

   Answer 34° 11′ N., 42° 16′ W.
2. Longitude from sights was 36° 58′ W., using D.R. Latitude 29° 32′ S., azimuth 130° T. Ship

then steamed 300° T., for 27 miles through a current setting 090° T., 5 miles. A star Meridian Altitude gave Lat. 29° 06′ S. Find the ship's position.

Answer 29° 06′ S., 37° 07·4′ W.

3. In D.R. Lat. 27° 43′ S., Obs. Long. 167° 29′ W., sun bore 171° T. Ship then steamed 217° T., for 49 miles. Sights were then taken and the D.R. Latitude gave Longitude 168° 03′ W., azimuth of the sun 247° T. Find the ship's position by P/L's.

Answer 28° 22′ S., 168° 03·0′ W.

4. Chosen position 20° 10′ S., 50° 37′ W., sun bore 050° T., intercept 5·7′ towards. Ship then steamed 310° T., distance by log 44 miles, when the Latitude by ex-meridian sights was found to be 19° 30′ S., sun bearing 007° T. After taking the ex-meridian sights the ship steamed 310° T., for 4 miles until noon. Find the position at noon after running up the I.T.P.

Answer 19° 26·5′ S., 51° 19·5′ W.

5. Chosen position 16° 41′ S., 163° 29′ E., sun bore 055° T., intercept 18′ away. Ship then steamed 208° T., for 33 miles, when sun bore 322° T., intercept 12′ towards. Find the ship's position at second observation.

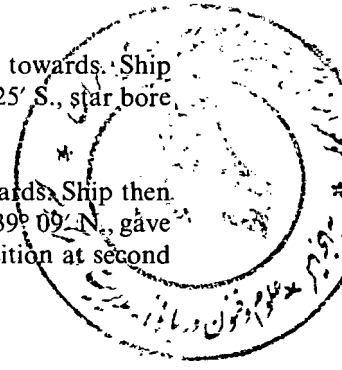
Answer 17° 10·6′ S., 162° 50·2′ E.

6. Chosen position 30° 19′ S., 24° 10′ W., star bore 060° T., intercept 11·5 towards. Ship steamed 090° T., distance 41 miles. Latitude by ex-meridian sights was 30° 25′ S., star bore 010° T. Find the position reached after running up the I.T.P.

Answer 30° 26·4′ S., 23° 02·4′ W.

7. Chosen position 39° 39′ N., 130° 47′ E., star bore 160° T., intercept 4′ towards. Ship then steered 196° T., for 20 miles and 186° T., for 18 miles, when a D.R. Latitude 39° 09′ N., gave Longitude 130° 47′ E., by observation, and star bore 200° T. Find the position at second observation.

Answer 39° 04·5′ N., 131° 02·2′ E.



Questions

1. Can the ship's position be determined in both Latitude and Longitude by a single observation when a body is on the meridian, close to the meridian and well away from the meridian? State what ordinate is in doubt in each case.
2. Explain how a Longitude position line is obtained.
3. Describe the procedure to be followed in computing a Longitude P/L by a star.
4. Distinguish between a circle of position and a line of position.
5. What determines the degree of dependence to be placed on the position by observation when a transferred P/L is involved?
6. What is meant by a "circle" of position? How is it obtained?
7. Two ships, *A* and *B*, on the same meridian observe the sun simultaneously at noon, and both get the same meridian zenith distance 40°, the declination of the sun being 10° N. The sun bears due North from *A* and due South from *B*. What Latitudes are the ships in?
8. Two ships, *C* and *D*, on the same parallel of Latitude observe Venus simultaneously and get the same Local Hour Angle 30°, one ship being to the westward of Venus, the other one to the eastward. GHA Venus 30°. What is the Longitude of each ship?
9. What is (a) a position line, (b) an intercept?
10. What information is required in order to plot a P/L?
11. What precautions must be taken when finding the Longitude from P/L's plotted on squared paper.

12. Describe the practical operation of taking a sight to find the hour angle of a body.
13. Write down the formula to solve the PZX triangle for $\angle P$.
14. The sun's true azimuth was 070°, the Latitude used to find the LHA, and thence the Longitude was 38° N., instead of 38° 20′ N. Draw a figure and show how the error of Longitude must be applied, whether to the East or to the West.
15. The sun's true azimuth was 160°, the Latitude used was 20° 30′ S., instead of 20° 40′ S. How must the error of Longitude be applied; to the East, or, to the West?
16. The azimuth of body was 210°, the Latitude used was 30° N., instead of 29° 40′ N., the resulting Longitude being 40° 20′ W. If the error in Longitude was 10′, required the correct Longitude. Illustrate by a sketch.
17. Describe in general terms the procedure in plotting the P/L for an a.m. sight of the sun combined with a run and a Latitude by meridian altitude of the sun.
18. Write down the equation to convert LHA Sun into East Longitude.
19. When is the best time to take an observation for Longitude, and why?
20. Find whether the Equation of Time is + or − to Apparent time on January 10. Draw a figure and show the relative positions of the Mean and True suns at 1620 LAT, ship in Long. 45° W.
21. By means of a figure show that the difference between LHA sun at ship, and GHA sun is the Longitude. How would you know whether the Long. was East or West?
22. Define Apparent Time, Mean Time and Sidereal Time. Give a figure, with explanation.
23. Explain Mean Solar Time.
24. A sundial in Lat. 52° N., Long. 4° W., shows a time of 9 h 30 m. It is not correct for GMT Explain the difference.
25. Explain the following rule:
    (a) Long. West, Greenwich time best.
    (b) Long. East, Greenwich time least.
26. What is meant by the magnitude of a star, and where do you find it?
27. Explain why the "v" correction for Venus is sometimes negative.
28. Sights were taken of a planet and a star at equal intervals on successive days and the planet's position was found to change with relation to the star's. Explain this.
29. Explain what is meant by "aphelion" and "perihelion".
30. Explain the conditions of GHA and Declination of Sun and Moon for an eclipse to occur. (See *Almanac* extracts for October 12.)
31. What is meant by the occultation of a star? Explain the circumstances leading up to it.

Chapter 28

Ex-Meridian Altitudes

Shortly before noon the prudent navigator will observe the sun at, say, 5 minute intervals; recording altitudes and chronometer times. Should the sun be obscured by cloud at noon, then the latest of his observations may be worked up by the Ex-Meridian method. This technique is also useful for sights of the moon and planets on the occasions when they may be crossed with a longitude sight of the sun. The Ex-Meridian method is also applicable to star sights but is now less used for this purpose since the Intercept method is generally more convenient.

When a body is observed "near the meridian", the calculation may be worked by one of the foliowing methods:

1. A formula derived from the PZX triangle.
2. Ex-Meridian Tables in *Norie's* or *Burton's Nautical Tables.*
3. The Intercept Method.

The first two methods should be used with some discretion since they are close approximations rather than rigorous calculations. The methods are unsatisfactory when the body will pass nearly overhead and the maximum meridian altitude should not exceed about 80°. There is also a limit, before and after the time of meridian passage. The D.R. latitude has to be used in both methods; if the result shows an appreciable difference then the calculation should be worked again with the latitude so found.

Despite these restrictions, there are many occasions when Ex-Meridian methods are of value. It must be emphasized that the latitudes obtained by these methods are not true latitudes; they must be associated with their respective D.R. longitudes to give positions through which to draw the P/L's.

If in doubt, there is always the Intercept Method, which may, of course, be used in all circumstances. Whichever method be used, there is likely to be some difficult interpolation associated with the use of the ABC Tables. An alternative is to find the Azimuth by means of the Sine Formula, derived from the PZX triangle:

$$\sin \angle PZX = \frac{\sin \angle ZPX \times \sin PX}{\sin ZX}$$

which may be expressed in the more convenient form:

$$\sin \text{Az} = \sin P \times \cos \text{Dec} \times \text{cosec } ZX$$

The general direction of the bearing is indicated by whether the body will pass N. or S. of the observer; and by the value of the LHA. It may also be found by inspection of the figure. (Note that the ambiguity of this formula makes its use unsatisfactory when the body bears nearly East or West.)

For the purpose of comparison, Example 1 will be worked by each of the three methods mentioned above.

Derivation of the Ex-Meridian Formula

The application of this method is limited to bodies close to the meridian, and the hour angle of the body under the most favourable conditions should seldom exceed one hour, an approximate rule being that the hour angle in minutes should not exceed the number of degrees in the meridian zenith distance, nor, as a rule, should the meridian zenith distance be less than 25°, except under most favourable conditions.

The observation consists of observing the altitude of the body and at the same time noting the GMT by chronometer, in order to obtain the LHA.

The figure represents on the equidistant projection Lat. 42° N, Dec. 22° S and the sun X approaching the meridian.

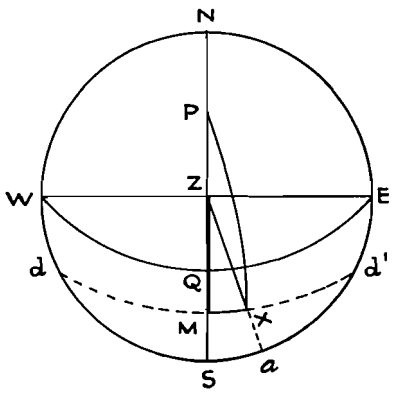


Figure 1.

$NESW$	Rational Horizon		
WQE	Equinoctial		
NZS	Observer's Meridian		
P	Pole	PZ	co-Lat.
Z	Zenith	ZQ	Lat.
X	Sun at time of observation		
M	Sun when on the Meridian		
$\angle ZPX$	Easterly hour angle of X.		
PX	Polar Distance, which in this illustration is $(90° + \text{Dec})$		
ZX	Zenith Distance of the body at the time of observation.		

ZM Zenith distance of the body when it is on the meridian, that is its M.Z.D.

ZQ Latitude is equal to $(ZM - QM)$, that is (M.Z.D. − Dec.) and the purpose of the calculation is to find ZM the meridian zenith distance.

Now, the least zenith distance of a body for the day occurs when it is on the observer's meridian, so that the zenith distance at any other time must be greater than its M.Z.D., and therefore ZX is slightly greater than ZM, and the operation of finding the smaller arc ZM is called "The Reduction to the Meridian."

The "Reduction" is a small quantity which is the difference between the M.Z.D. and the observed zenith distance, or, arc ZX − arc ZM.

The body is so close to the meridian that PX is practically equal to PM, and if $(PM - PZ)$ is equal to ZM then $(PX - PZ)$ is assumed to be also equal to ZM, the meridian zenith distance, which we are trying to find in triangle PZX.

The spherical formula is used:

$$\text{hav } P = \frac{\text{hav } ZX - \text{hav}(PZ \sim PX)}{\sin PZ \times \sin PX}$$

It is required to find $(PZ \sim PX)$. By cross multiplying and transposing the above we get $\text{hav } ZX - \text{hav } P \times \sin PZ \times \sin PX = \text{hav}(PZ \sim PX)$.

Example 1 (Sun)
(Refer to Figure 2)

From the following information find the direction of the P/L, and the latitude in which it crosses the D.R. longitude.

Date at ship 11 January, D.R. 42° 18′ N., 33° 26′ W., Sext. alt. of the sun's L.L. near the meridian 25° 21′, I.E. 1·6′ on the arc, H.E. 10 m, Chron. 14 h 04 m 07 s, error 11 m 32 s fast on GMT.

Order of Work (by Formula)

1. Convert GHA into LHA to obtain $\angle P$.
2. Correct Declination to obtain Polar Distance (PX).
3. Correct the Sextant Altitude and obtain the Observed Zenith Distance (ZX).
4. Apply the formula to find ($PZ \sim PX$), the meridian zenith distance, using PX, ZX, $\angle P$ and a D.R. co-Latitude PZ.
5. Apply Declination to the M.Z.D. to find the Latitude.

LHA Sun = GHA Sun − W. Long.

Chron.	11d	14h	04m	07s		
Fast	—		11	32		
GMT	11	13	52	35		
GHA Sun 11d 13h				13°	01·4′	
Incre. 52m 35s				13	08·8	
GHA Sun				26	10·2	
		(+)		360		
				386	10·2	
Long W.		(−)		33	26	
LHA Sun				352	44·2	
Easterly H.A. (P)				7°	15·8′	

Sext. alt.		25°	21′ S.
I.E.	(−)		1·6
Obs. alt.		25	19·4
Dip	(−)		5·6
App. alt.		25	13·8
Corr.	(+)		14·2
True alt.		25	28
		90	00
Obs. Zen. Dist.		64°	32′ = ZX

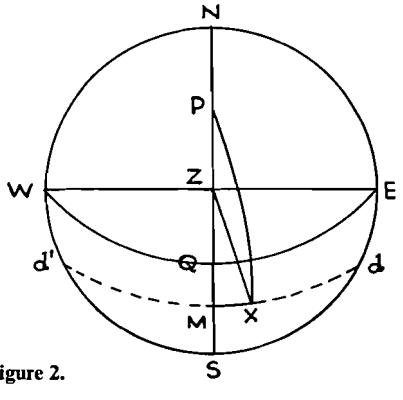


Figure 2.

Dec. 13 h		21°	49·9′ S.
Incre. 52 m	(−)		0·4
Dec.		21°	49·5′ S.
		90	00 N.
Polar Dist.		111°	49·5′ = PX
D.R. Lat.		42°	18′ N.
		90	00
Approx. co-Lat.		47°	42′ = PZ

$$\text{hav}\, ZX - (\text{hav}\, P \times \sin PZ \times \sin PX) = \text{hav}\,(PZ \sim PX).$$

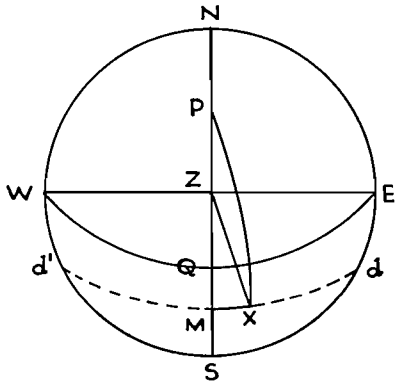
P (hour angle)	7° 15·8′	log hav	7·60339
PZ (approx. co-Lat.)	47 42	log sin	9·86902
PX (polar dist.)	111 49·5	log sin	9·96770
		log hav	7·44011
		nat hav	0·00275
ZX (obs. zen. dist.)	64 32	nat hav	0·28501
$PZ \sim PX$	64 11·1	nat hav	0·28226

ABC Tables

A	7·16 S.	Mer. Zen. Dist.	64° 11·1′ N. $= ZM$
B	3·16 S	Dec.	21 49·5 S. $= QM$
C	10·32 S.	Lat.	42° 21·6′N.

Az. S. 7·5° E. = 172·5° T

Answer (By Formula) P/L runs 082·5° – 262·5° T through 42° 21·6′ N., 33° 26′ W.



NESW	Rational Horizon		
WQE	Equinoctial		
NZS	Observer's Meridian		
P	Pole	*PZ*	co-Lat
Z	Zenith	*ZQ*	Lat.
X	Sun at time of observation		
M	Sun when on the Meridian		
$\angle ZPX$	Easterly hour angle of *X*.		
PX	Polar Distance, which in this illustration is (90° + Dec)		
ZX	Zenith Distance of the body at the time of observation.		

Ex-Meridian Tables

A number of these tables have been published, of which those given in *Norie's* or *Burton's Nautical Tables* are probably the most widely used. It is proposed to use Norie's to illustrate the example, but it will be found that the table in Burton's is similar. In either case the instructions for their use should be carefully studied beforehand.

The procedure is as follows (Norie's):

Table I enter with Lat. and Dec. to find quantity "A".

Table IV enter with "A" to check that the Hour Angle is within the limits of the Tables—if not, discontinue the calculation.

Table II enter with "A" and the LHA to find the "Reduction". Rules for applying the reduction are given on the pages of Table II, e.g. "Reduction Plus to True Altitude at Upper Transit". Alternatively, the reduction may be subtracted from the Zenith Distance.

Table III enter with Reduction and Altitude to find the Second Correction. This additional correction is required when the reduction is large. The Second Correction is **always subtracted from the First Correction.**

Ex-Meridian Tables (Norie's)

(Refer to Figure 2)

In Example 1 we used:

LHA 352° 44·2′. Dec. 21° 49·5′ S., Lat. 42° 18′ N.

Enter Table I. with:

Lat. 42° 18′ N., Dec. 21° 49·5′ S. (different names) and obtain 1·5″ (*A*).

Enter Table II. with:

LHA 352° 44·2′ and (*A*) 1″ and obtain		14·05′	Note 1
LHA 352° 44·2′ and (*A*) 5″ and obtain	(+)	7·03′	Note 2
the quantity corresponding to (*A*) 1·5″ is		21·08′ ≃ 21·1′	Note 3

21·1′ is the "Reduction" to be subtracted from the observed zenith distance or added to the true altitude at upper transit.

True alt.		25° 28·0′ S.	Obs. Zen. Dist.		64° 32·0′ N
Reduction	(+)	21·1	Reduction	(−)	21·1′
		25° 49·1	Mer. Zen. Dist.		64 10·9 N.
		90 00	Dec.		21 49·5 S.
Mer. Zen. Dist.		64 10·9 N.	Ex-Mer. Lat.		42° 21·4′ N. Note 4.
Dec.		21 49·5 S.			
Ex. Mer. Lat.		42° 21·4′ N.			

Notes:

1. The correction lies between that given for 352° 45′ and 352° 40′, that is between 14·0′ and 14·3′ namely 14·05′ after interpolation.
2. Take out the correction for 5″ instead of ·5″—it lies between 70·1′ and 71·7′ which, after interpolation, gives 70·3′. Shift the decimal one place to the left making it 7·03. This gives the correction for ·5″ to be added to the correction for 1″, thus finding the total quantity corresponding to 1·5″, i.e. 21·08′ or 21·1′.
3. Refer to Ex-Meridian Table III and note that for Altitude 30° and a First correction of 15′ (the nearest tabulated values) there is no Second Correction to apply to the First Correction.
4. Azimuth and P/L found previously—see Example 1 on the facing page.

Answer (By Ex-Meridian Tables) P/L runs 082·5°—262·5° T. through 42° 21·4′ N., 33° 26′ W.

The Intercept Method

(Refer to Figures 2 and 3)

The following calculation shows how the Intercept Method may be used for an Ex-Meridian observation, also shown is the use of the Sine Formula for finding the Azimuth. From Example 1 we have:

True Zen. Dist.	64° 32·0′	Lat.	42° 18·0′ N.
LHA	352 44·2	Dec.	21 49·5 S.
		(L+D)	64° 07·5′

$\text{hav } ZX = \text{hav } P \times \cos \text{Lat} \times \cos \text{Dec} + \text{hav (L+D)}$

$\sin \text{Az} = \sin P \,.\, \cos \text{Dec.} \operatorname{cosec} ZX$

P	352° 44·2′	log hav	7·60339	log sin	9·10185
Lat.	42 18·0	log cos	9·86902		
Dec.	21 49·5	log cos	9·96770	log cos	9·96770
		log hav	7·44011		
		nat hav	0·00275		
(L+D)	64 07·5	nat hav	0·28179		
Calc. Zen. Dist.	64 28·5	nat hav	0·28454	log cosec	10·04460.
				log sin	9·11415
Calc. Zen. Dist.	64° 28·5′				
True „ „	64 32·0			Az. = S. 7° 28·4′ E.	
				≃ 172·5° T.	
Intercept.	3·5′ Away			P/L 082·5° – 262·5° T.	

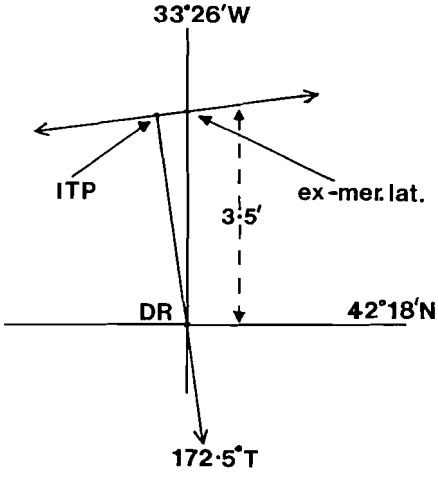


Figure 3.

D.R.	42° 18·0′ N.	33° 26·0′ W.
From the plot	3·5 N.	
Pos. for the P/L	42° 21·5′ N.	33° 26·0′ W.

Answer (By Intercept Method) P/L runs 082·5 – 262·5° T. through 42° 21·5′ N., 33° 26′ W.

Plotting the Ex-Meridian

Having completed the Ex-Meridian calculation, by whichever method was used, it is now necessary to plot it in conjunction with the forenoon sight of the sun (or any other P/L which may be available) in order to find the Observed Position (as shown in Figure 3), which may then be run up to 1200 ship's time, on the same plot.

Example 2 (Star)
(Refer to Figure 4)

From the following information find the direction of the P/L, and the latitude in which it crosses the D.R. longitude.

Date at ship 20 September, D.R. 28° 14′ S., 81° 15′ E., Sext. alt. of Aldebaran, near the meridian, 44° 56′, I.E. 1′ off the arc, H.E. 11·5 m, Chron. 23 h 41 m 45 s., error 1 m 12 s fast on GMT.

$$\text{LHA}^* = \text{GHA}\,\Upsilon + \text{SHA}^* + \text{E. Long.}$$

Chron.	19d	23h	41m	45s	GHA ♈	19d 23h	343° 20·2′
Fast (−)			1	12	Incre.	40m 33s	10 09·9
GMT	19	23	40	33	GHA ♈		353 30·1
					SHA Aldebaran		291 36·5
							645 06·6
							360
					GHA Aldebaran		285 06·6
					Long. E.	(+)	81 15
					LHA Aldebaran		366° 21·6′

SHA*	291° 36·5′	Sext. alt.		44° 56·0′ N.
Dec.	16 25·6 N.	I.E.	(+)	1·0
	90 00	Obs. alt.		44 57·0
Polar Dist.	106° 25·6′ (*PX*)	Dip	(−)	6·0
		App. alt.		44 51·0
		Corr.	(−)	1·0
D.R. Lat.	28° 14′ S.	True alt.		44 50
	90 00			90 00
Approx. co-Lat.	61° 46′ (*PZ*)	Obs. Zen. Dist.		45° 10′ S. (*ZX*)

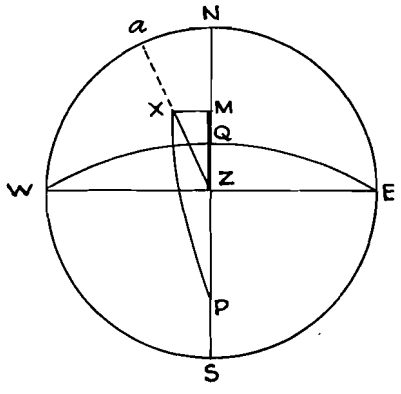


Figure 4.

NESW	Rational Horizon.		
WQE	Equinoctial.		
NZS	Observer's Meridian.		
P	Pole.	*PZ*	co-Lat.
Z	Zenith.	*ZQ*	Lat.
X	Star at time of observation.		
M	Star when on the Meridian.		
ZX	Zenith Distance at time of observation.		
ZM	Meridian Zenith Distance.		
ZM	$= (PX \sim PZ)$ approximately.		
ZQ	Latitude.		
QM	Declination.		
ZQ	$= ZM - QM$, or, Lat. = M.Z.D. − Dec.		

In triangle *PZX*, given *PZ* (the approx. co-Lat.), *PX* (the polar distance), *ZX* (the observed zenith distance) ∠ *P* (the hour angle). Required to find (*PZ* ~ *PX*) the meridian zenith distance.

The formula $\text{hav}\, ZX - \text{hav}\, P \times \sin PZ \times \sin PX = \text{hav}(PZ \sim PX)$

may be modified to $\text{hav}\, ZX - \text{hav}\, P \times \cos \text{Lat} \times \cos \text{Dec.} = \text{hav}(PZ \sim PX)$

because Lat. is the complement of co-Lat. and Dec. is the complement of Polar Distance. It follows that cos Lat. may be substituted for sin *PZ* and cos Dec. for sin *PX*, thus saving two manipulations of 90° and, perhaps, avoiding the common mistake of using the wrong Polar Distance.

P	6° 21·6′	log hav	7·48817
Lat.	28 14·0 S.	log cos	9·94499
Dec.	16 25·6	log cos	9·98191
		log hav	7·41507
		nat hav	0·00260
ZX	45 10	nat hav	0·14748
(*PZ* ~ *PX*)	44° 44·8′	nat hav	0·14488

Mer. Zen. Dist.	44° 44·8′ S. (*ZM*)	ABC Tables	
Dec.	16 25·6 N. (*QM*)	A	4·72 N.
		B	2·61 N.
Lat. at sights	28° 19·2′ S. (*ZQ*)	C	7·33 N.

Az. 351° T,
P/L 081° − 261° T.

Answer (By Formula) P/L runs 081° − 261° T. through 28° 19·2′ S., 81° 15′ E.

Ex-Meridian Table

Given LHA 6° 21·6′
Lat. 28° 14′ S. } contrary names
Dec. 16° 25·6′ N. }

Table I. Lat. 28° 14′, Dec. 16° 26′ gives A = 2·3″

Table II. LHA 6° 21·6′, A = 2·3″, 2″ gives 21·7′
0·3 „ 3·3

Reduction	(−)	25·0′
Obs. zen. dist.		45° 10·0′
M.Z.D.		44 45·0 S.
Dec.		16 25·6 N.
Lat.		28° 19·4′ S.

Answer (By Ex-Meridian Tables) P/L runs 081°–261° T. through 28° 19·4′ S., 81° 15′ E.

Ex-Meridian below the Pole

At Lower Transit the LHA of a body is 180°, so that the Hour Angle for entering the Tables is the difference between 180° and the LHA at the GMT of observation. Note also that there is a special section for bodies at Lower Meridian Transit, and that the Reduction is applied in the opposite way.

Example 3 (Star)
(Refer to Figure 5)

From the following information regarding a star near the meridian and below the pole, find the direction of the P/L and the latitude in which it crosses the D.R. longitude.

Date at ship 22 June, D.R. 44° 50′ S., 10° 47′ W., Sext. alt. of Acrux 17° 51′, I.E. 1·8′ off the arc, H.E. 10 m, Chron 07 h 29 m 24 s, correct on GMT.

GHA♈ 22d 07h		14° 57·5′
Incre. 29m 24s		7 22·2
GHA♈		22 19·7
SHA*		173 55·3
GHA*		196 15·0
Long. W.		10 47·0
LHA* (East)		185 28·0
Lower meridian		180 -
LHA (Table II)		5° 28·0′

Dec.	62° 52·5′
	90
Polar Dist.	27° 07·5′

Ex-Meridian Tables
Table I, Lat. 44° 50′ S., Dec. 62° 52·5′ S.
A = 0·7″

Table II, H.A. 5° 28′, A = 0·7

$$\text{Reduction} = \frac{55{\cdot}8}{10} = 5{\cdot}6'$$

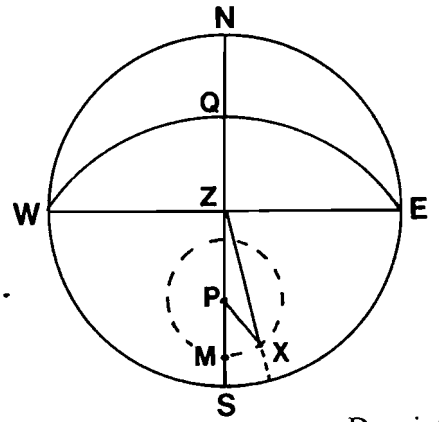


Figure 5.

Sext. alt.		17° 51·0′
I.E.	(+)	1·8
Obs. alt.		17 52·8
Dip	(−)	5·6
		17 47·2
Corr.	(−)	3·0
True alt.		17 44·2
Reduction	(−)	5·6
Mer. alt.		17° 38·6′

Description as for Figure 1.

NB. The azimuth has been enlarged for the sake of clarity.

ABC Tables		Lat. (SP) = True alt. (SM) + Polar Dist. (MP)	
A	10·4 S.	Mer. alt.	17° 38·6′
B	20·3 S.	Polar Dist.	27 07·5
C	30·7 S.	Lat.	44° 46·1′ S.

Az. S. 2·7° E. = 177° T.
P/L 087° − 267° T.

Answer P/L runs 087° − 267° T. through 44° 46·1′ S., 10° 47·0′ W.

Exercise 1 (Ex-Meridians)

In each of the following examples, find the direction of the P/L, and the latitude in which it crosses the D.R. longitude.

It is recommended that each example be worked by the Ex-Meridian Tables and then checked either by the Formula or by the Intercept Method.

1. On January 7, in D.R. 56° 18′ S., 67° 22′ W., the observed altitude of the sun's L.L. near the meridian was 55° 48′ North of the observer, H.E. 7·7 m. Time by a chronometer 16 h 16 m 35 s which was 9 m 14 s slow of GMT.
2. On June 16, in D.R. 48° 29′ N., 128° 31′ W., the sextant altitude of the sun's L.L. near the meridian was 64° 10′ South of the observer, I.E. 3′ on the arc, H.E. 7·3 m. Time by chronometer 21 h 06 m 43 s which was 5 m 16 s fast of GMT.
3. On June 16, in D.R. 28° 54′ S., 178° 56′ E. the observed altitude of the sun's L.L. near the meridian was 37° 32′, H.E. 7·5 m. Time by a chronometer 00 h 00 m 12 s which was 10 m 20 m fast of GMT.
4. On December 26, in D.R. 46° 37′ N., 179° 30′ E., the sextant altitude of the sun's U.L. near the meridian was 19° 56′ South of the observer, I.E. 2·5′ on the arc, H.E. 6 m. Time by chronometer (25 December) 23 h 43 m 10 s which was 16 m 40 s fast of GMT.
5. On December 24, in D.R. 25° 20′ N., 73° 26′ W., the sextant altitude of the sun's L.L. near the meridian as 40° 05′, I.E. 3·5′ off the arc, H.E. 11·5 m, GMT 24 d 16 h 15 m 22 s.

6. On June 17, in D.R. 34° 51′ S., 163° 27′ E., the sextant altitude of the sun's L.L. near the meridian was 31° 28′ North of observer, I.E. 3′ on the arc, H.E. 10·5 m, GMT 17 d 00 h 41 m 17 s.
7. On January 10, in D.R. 14° 20′ S., 32° 15′ W., GMT 10 d 07 h 28 m 16 s the observed ex-meridian altitude of the star *Acrux* was 41° 37′ South of the observer, H.E. 11·2 m.
8. On December 28, in D.R. 36° 43′ N., 124° 41′ W., at 08 h 21 m 30 s GMT, the sextant altitude of *Sirius* near the meridian was 36° 40′, H.E. 12 m.
9. On December 27, in D.R. 13° 50′ N., 86° 36′ E., at GMT 27 d 17 h 32 m 58 s, the sextant altitude of *Canopus* near the meridian was 22° 57′, I.E. 0·5′ on the arc, H.E. 13·5 m.
10. Explain the advantages and disadvantages of the various methods for obtaining an Ex-Meridian Latitude.

Answers in the rear *Answer Section.*

Chapter 29

Principles of the Gyro Compass

A gyro is a perfectly balanced mass that is arranged to spin at high speed symmetrically about an axis. As long as the mass is spinning at speed, it displays rigidity; this is the first property of the gyro and is called gyro inertia. By suspending the gyro (or spinner, as it is more often called) in a specially designed frame, it is possible to exploit this property of gyro inertia as a means of reference relative to a fixed datum.

There are three ways in which a gyro can be suspended in a frame, the method of suspension determining the type of gyroscope and its particular application. The three types of gyroscope are: the free gyroscope, the constrained gyroscope, and the spring restrained gyroscope. This description of gyroscope principles considers the free gyroscope only, since it is a version of this that is used in the S.G. Brown Gyro Compass System which is later described.

FREE GYROSCOPE

(Refer to Figure 1)

In this application, the spinner is suspended so as to be free to move about any of two axes in addition to the spin axis. This type of suspension, referred to as a balanced gimbal system, is shown in Figure 1, which also indicates the gyro's three main axes. Because the gyro spin axis is able to move about the vertical and horizontal axes, it is said to have two degrees of freedom.

Once a free gyroscope is spinning, it will maintain a fixed direction in space provided that no forces act upon it to alter the direction of the spin axis. Any restriction of movement of the gimbal system, or the transmission of any torque to the system, are examples of forces that can affect the rigidity of the spinner. Accurate balance of the gimbal system, and the efficiency of the bearings and pivots (which allow the outer gimbal to pivot about the vertical axis and the inner gimbal to pivot about the horizontal axis), prevent such forces from acting on the spin axis when the mounting platform is moved in any direction.

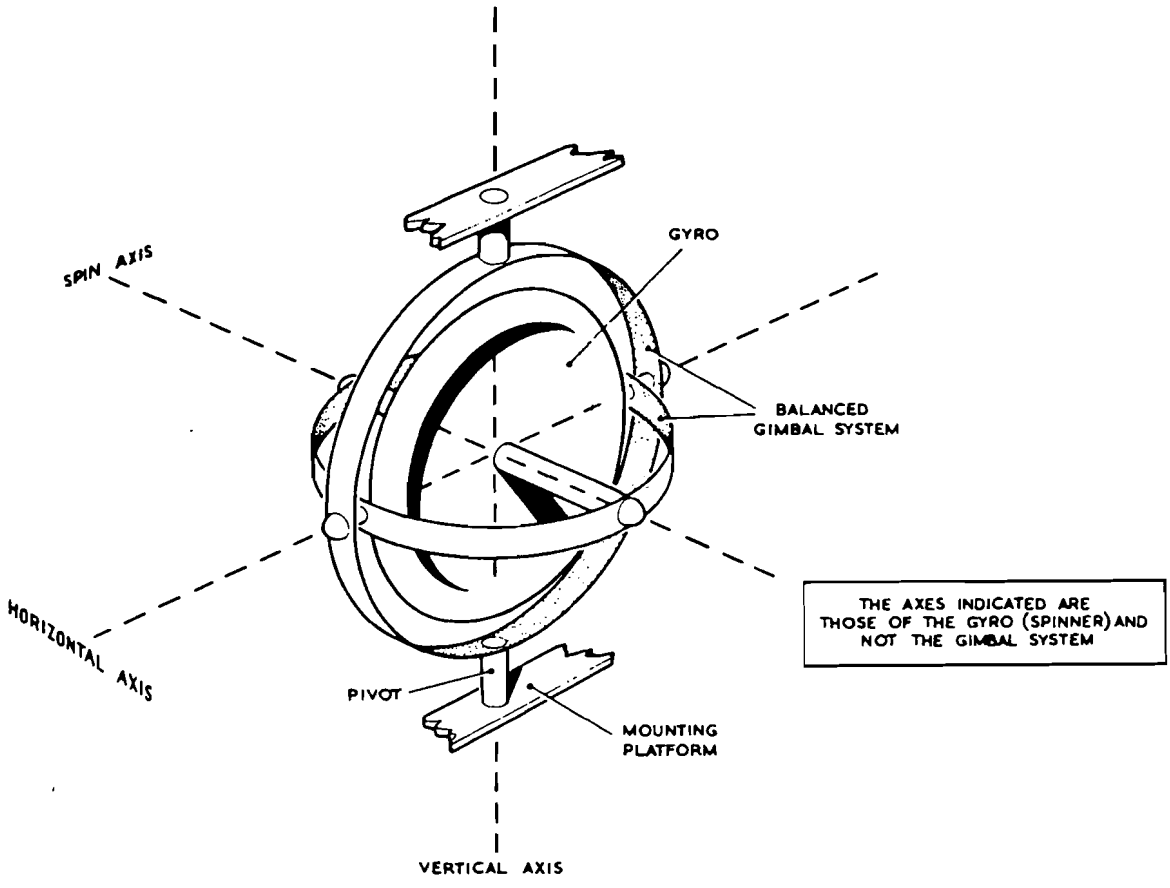


Figure 1. The Free Gyroscope.

Precession

(Refer to Figure 2)

If a force is applied to one end of the spin axis so as to produce a torque, the spin axis will not move in the direction of the applied force but at right angles to both applied force and spin axis, and in a direction determined by the direction of rotation of the spinner. This resultant motion is the second property of the gyro and is called precession.

Figure 2 demonstrates a simple rule by which the direction of precession can be determined. If it is imagined that the direction of the applied force is displaced 90° in the direction of rotation of the spinner, then a force applied from this imaginary point will indicate the direction of precession.

The angular rate of a resultant precession is proportional to the applied force and inversely proportional to the angular momentum of the spinner. The property of precession is used to control the movement of a gyroscope, and is induced by applied forces only; the speed of the spinner is maintained constant in practice. If forces are intentionally applied to control the movement of a gyroscope, it is obvious that unwanted forces must be completely eliminated so as not to induce unwanted precessions.

$$P = IS$$

Where P is Precession, I is the moment of Inertia and S is the angular velocity (speed of rotation).

In addition to the controlled movement of a gyroscope due to applied forces, there is also an apparent movement due to the earth's rotation. It is emphasized that this movement is apparent only; the gyro spinner is rigid relative to a celestial reference and not to a terrestrial reference.

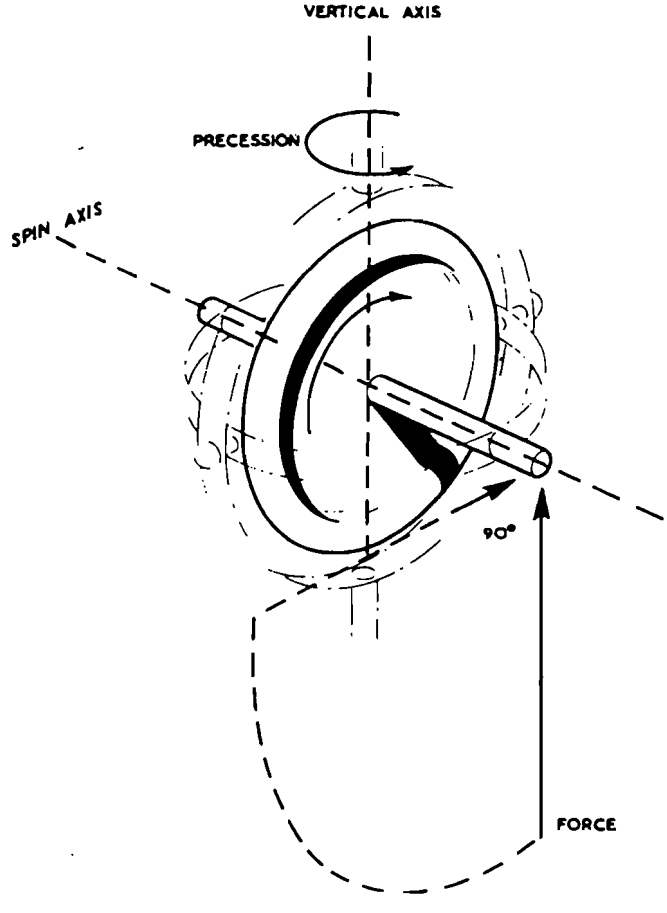


Figure 2. The Rule for Precession.

The Earth's Rotation

(Refer to Figure 3)

The earth rotates about its North-South axis once ever 24 hours (15° per hour). If a gyroscope is set spinning with its spin axis horizontal to the earth's surface, the following apparent movements will occur due to rotation of the earth:

(a) At the north pole (Figure 3a) the gyro spin axis will appear, when viewed from above, to drift clockwise in azimuth at a rate of 15° per hour. There will be no vertical movement (tilt) of the spin axis.

(b) At the equator (Figure 3b), with the gyro spin axis pointing East–West, the axis will appear to tilt east-end upwards when viewed from above. The tilt rate will be 15° per hour. There will be no azimuth drift of the gyro spin axis.

But if the gyroscope is set spinning at the equator with its spin axis horizontal and pointing North–South, there will be no movement in tilt or azimuth since the earth's spin axis is parallel to the gyro spin axis. From this it can be deduced that if the gyro spin axis is parallel to the earth's spin axis in any Latitude, the gyro will maintain its direction relative to the earth.

The effect of the earth's rotation on a gyro that is not located at the north pole or equator, and which does not have its spin axis parallel to the earth's spin axis, must now be considered. Since Figure 3(a) shows an azimuth drift of the gyro about the vertical axis when it is at the north pole, and Figure 3(b) shows a tilt of the gyro about the horizontal axis when it is at the equator, it follows that at any latitude between 0° and 90° North there must be a combined apparent tilt and azimuth movement.

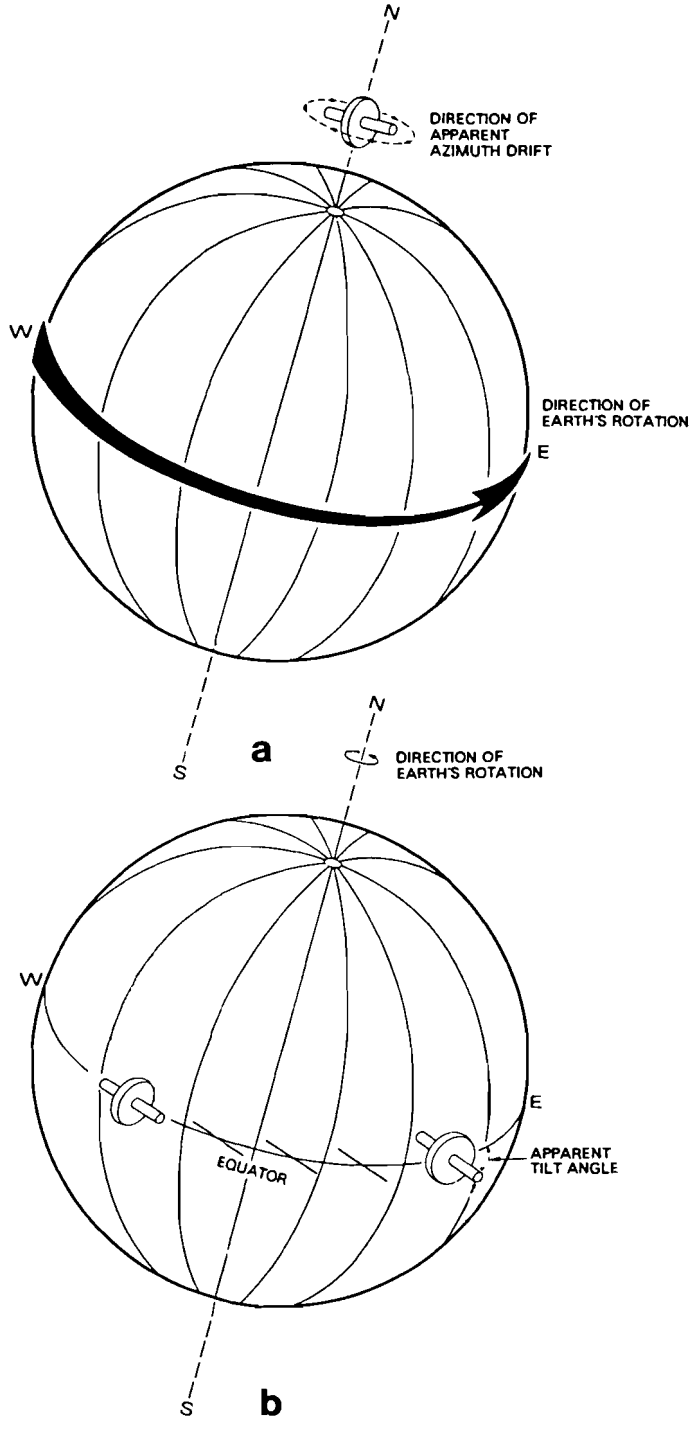


Figure 3. Effect of the Earth's Rotation on the Gyro.

Figure 4 shows an instance in which a gyroscope, mounted on a table, is set spinning with its axis horizontal to the earth and pointing North–South, i.e. along a meridian, at some latitude north of the equator (position time zero in Figure 4). Now assume that an observer is looking down on the gyro spin axis so that it appears as shown at 4(a). Six hours later (and without the observer moving from his viewing position by the table), the gyro spin axis will have appeared to move in azimuth and tilt to a position shown at 4(b). Twelve hours later, the observer sees the gyro spin axis as shown at 4(c). Eighteen hours later, it appears as at 4(d). At the end of 24 hours (one complete revolution of the earth), the observer sees the gyro spin axis as it was at time zero.

The rate at which the gyro spin axis will move in azimuth and tilt depends on the Latitude in which the gyroscope is functioning, the azimuth movement calculated from 15 sin Lat. degrees per hour and the tilt movement from 15 cos Lat. degrees per hour,

N.B. 15° per hour is the rotational speed (angular velocity) of the earth.

These combined azimuth and tilt movements are derived as the result of the earths rotation.

DIRECTIONAL GYROSCOPE

A gyroscope that is set spinning with its spin axis horizontal to the earth will display an apparent drift in azimuth of 15° sin λ degrees per hour due to the rotation of the earth. However, if a torque is applied to the gyro spin axis so that it can precess at a rate that is equal and opposite to the azimuth drift rate, then the spin axis will display no apparent drift and will thus maintain a fixed bearing relative to the meridian. At the same time, the apparent tilt movement due to earth rotation can be compensated by also applying to the gyro spin axis a torque that will cause it to precess at a rate equal and opposite to the tilt rate, thus maintaining the spin axis horizontal to the earth's surface. A gyroscope that is compensated in this manner is referred to as a Directional Gyroscope, and may be used to indicate a given reference with accuracy over a considerable period of time.

Since the recognized compass datum is North, the directional gyroscope is inadequate as a compass aid because:

1. It is unable to seek the meridian.
2. It must first be accurately aligned with the meridian, and then checked and adjusted from time to time.
3. Inherent frictional torque imposed by the gimbal assembly eventually causes the directional gyroscope to drift out of the meridian, and it has no means of regaining it.

For a free gyroscope to function as a gyroscopic compass, it must incorporate a means of seeking the north and subsequently be able to maintain this direction irrespective of any forces that would otherwise cause it to drift.

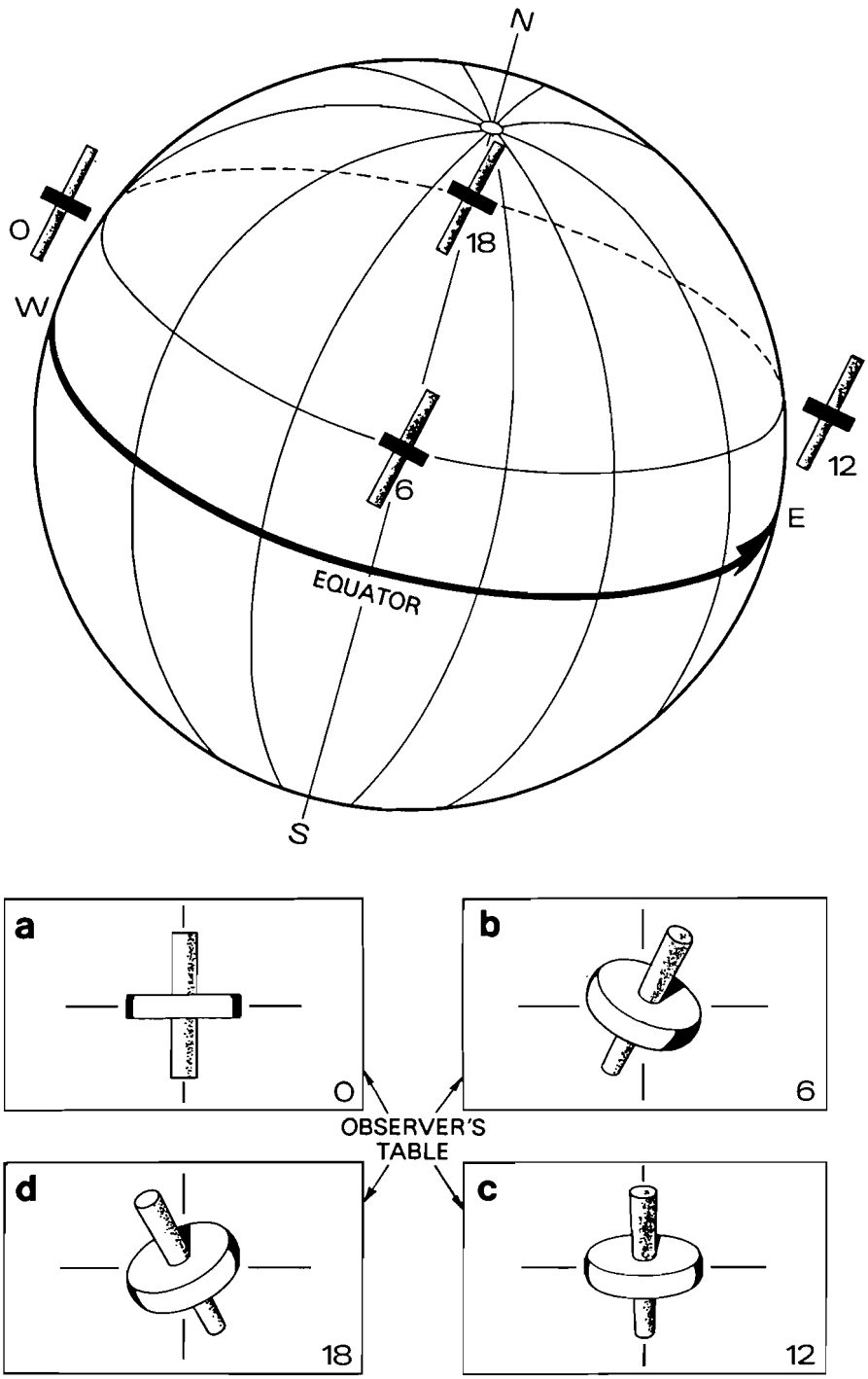


Figure 4. Apparent Movement of the Gyro.

NORTH-SEEKING (UNDAMPED) GYROSCOPE

(Refer to Figures 5 and 6)

A method of controlling the gyro spin axis so that it will "seek" the north is to incorporate a gravity control (a weight) on the spin axis (Figure 5a). Because the weight acts as a pendulum, it will always seek the centre of the earth's mass and, in so doing, will exert a torque about the gyro's horizontal axis and thus cause a precession about the vertical axis.

Before continuing with a description of the north-seeking gyro-compass, the reader should bear in mind the fundamental facts which have been described in the preceding paragraphs:

1. The gravity control will always point to the centre of the earth's mass (the centre of gravity).
2. The first property of the gyro (its rigidity in space) will tend to carry the gravity control away from the earth's centre of gravity as the earth rotates (earth movement).
3. In constantly maintaining the earth's centre of gravity, the gravity control exerts a force on the gyro spin axis and thus causes it to precess (the second property of the gyro). If the spinner is rotating clockwise as viewed from the south end (Figure 5), then the north end will precess to the east when it is below the horizontal, and to the west when it is above the horizontal. (Refer to the rule for direction of precession given in Figure 2.)
4. Because of the relative effects of gyro rigidity and earth rotation, the gyro axis always appears to tilt north end up when to the east of the meridian (in the Northern Hemisphere) as shown in Figure 4b.

Assume that the north end of the spinner of a free gyroscope, compensated for azimuth drift, is initially pointing towards point P and that the spinner is then set in motion in a clockwise direction when viewed from the south. Because of the gravity control, the resultant precessions, and the movement in tilt due to earth rotation, the north end of the spinner will describe an ellipse about the north. The ellipse results as a combination of the fundamental facts listed at (1), (2), (3) and (4) above and which is shown and described sequentially in Figure 6.

The rotation of the earth, the effect of gravity on the gravity control, and the subsequent precessional rate afforded by the gravity control are all constant and invariable factors, so that

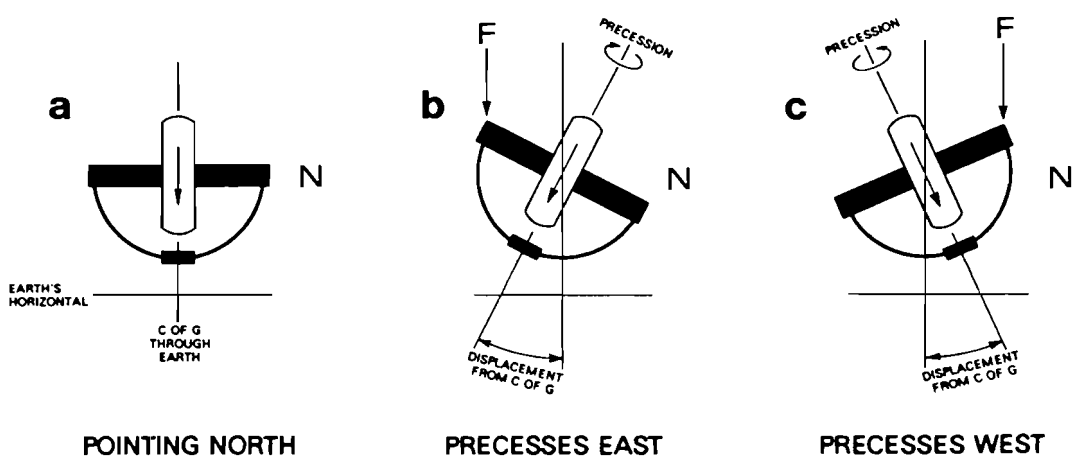


Figure 5.

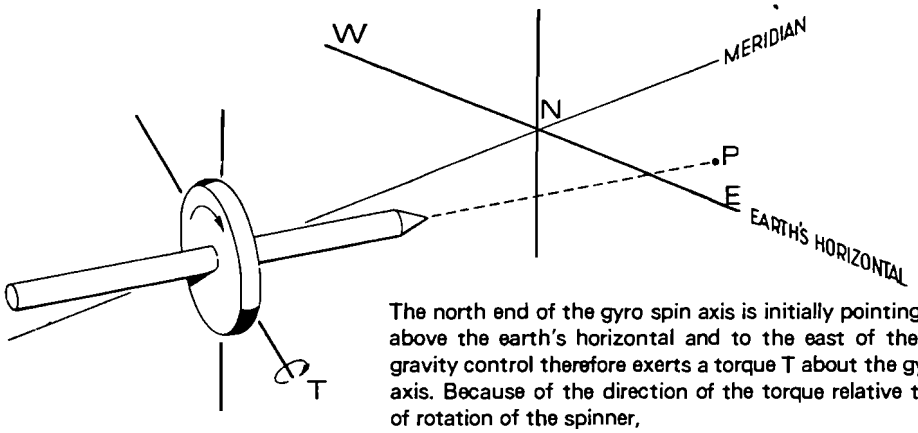
the ratio of the major and minor axes of the ellipse shown in Figure 6 is also constant. Only the size of the ellipse will vary, depending on the initial displacement of the gyro spin axis from the meridian and from the earth's horizontal.

The north-seeking gyroscope described in Figure 6 is still not suitable as a compass since it only wanders around the compass North (hence the term north-seeking), and therefore provides no tangible true bearing references. Because the ratio of the major and minor axes of the elliptical wander is always constant, it follows that if the length of one axis can be reduced then the length of the other axis will also be reduced proportionately; the gyro spin axis will eventually settle horizontally, and in the meridian, when the length of one axis has been reduced to zero.

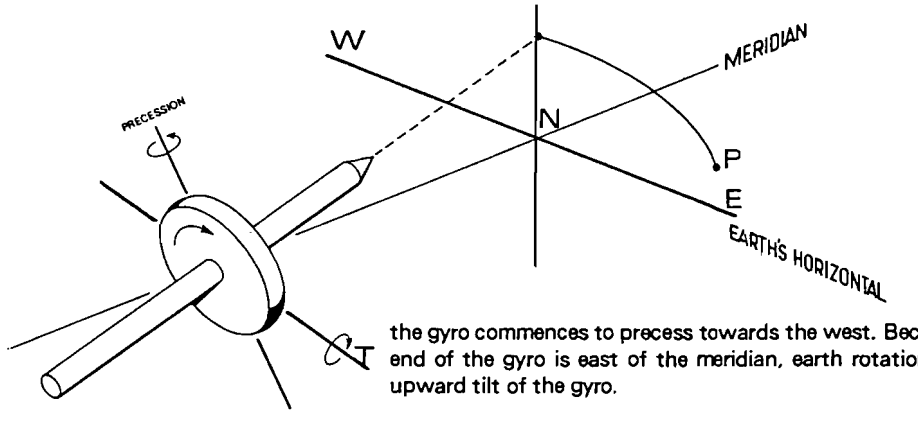
DAMPED GYROSCOPE

(Refer to Figures 6 and 7)

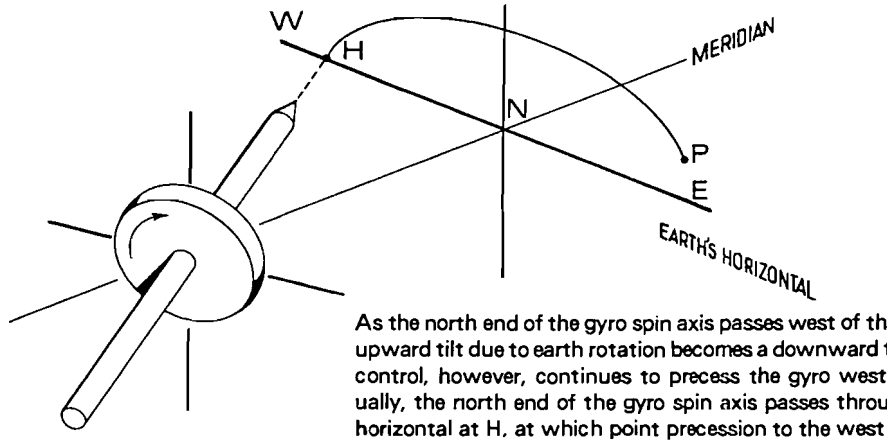
The gravity control described in the paragraph referring to Figure 5, produces a torque about the horizontal axis of the gyro whenever its spin axis is not horizontal to the earth's surface. If the gravity control can, at the same time, produce a damping torque about the vertical axis of the gyro so as to cause the spin axis to precess towards the horizontal, it is obvious that the minor axis of the ellipse shown in Figure 6 will be reduced. The combined precessions of the gyro will therefore be progressively nulled until, finally, the gyro spin axis is centred at the intersection of the earth's horizontal with the meridian. The overall effect is a progressive damping of the ellipse shown in Figure 6; this progressive damping is described sequentially in Figure 7.



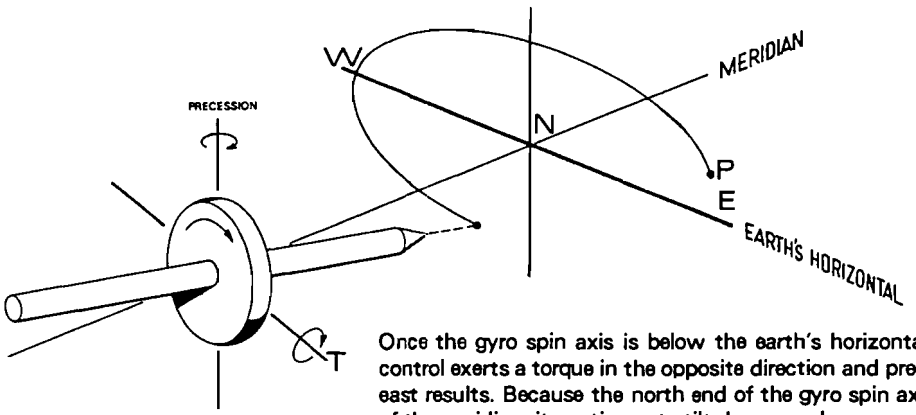
The north end of the gyro spin axis is initially pointing at P, which is above the earth's horizontal and to the east of the meridian. The gravity control therefore exerts a torque T about the gyro's horizontal axis. Because of the direction of the torque relative to the direction of rotation of the spinner,



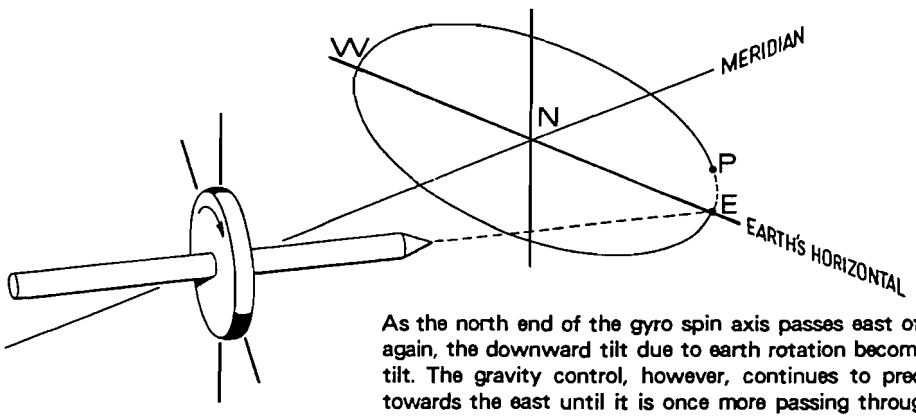
the gyro commences to precess towards the west. Because the north end of the gyro is east of the meridian, earth rotation results in an upward tilt of the gyro.



As the north end of the gyro spin axis passes west of the meridian, the upward tilt due to earth rotation becomes a downward tilt. The gravity control, however, continues to precess the gyro westwards. Eventually, the north end of the gyro spin axis passes through the earth's horizontal at H, at which point precession to the west ceases.

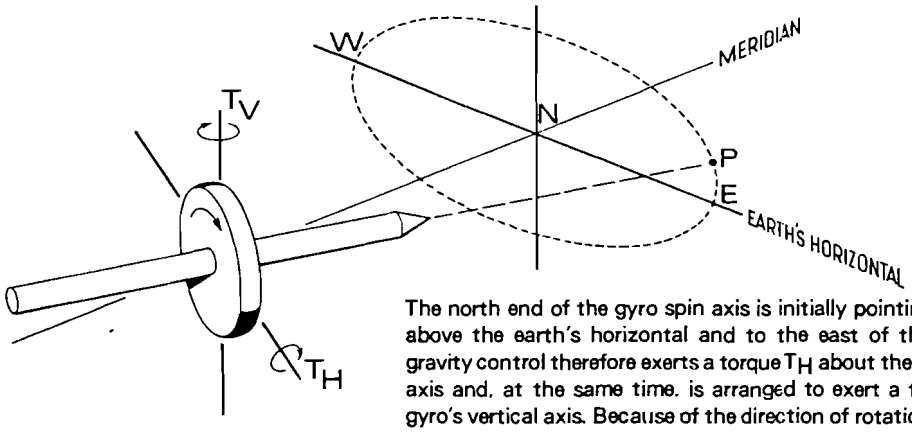


Once the gyro spin axis is below the earth's horizontal, the gravity control exerts a torque in the opposite direction and precession to the east results. Because the north end of the gyro spin axis is still west of the meridian, it continues to tilt downwards.

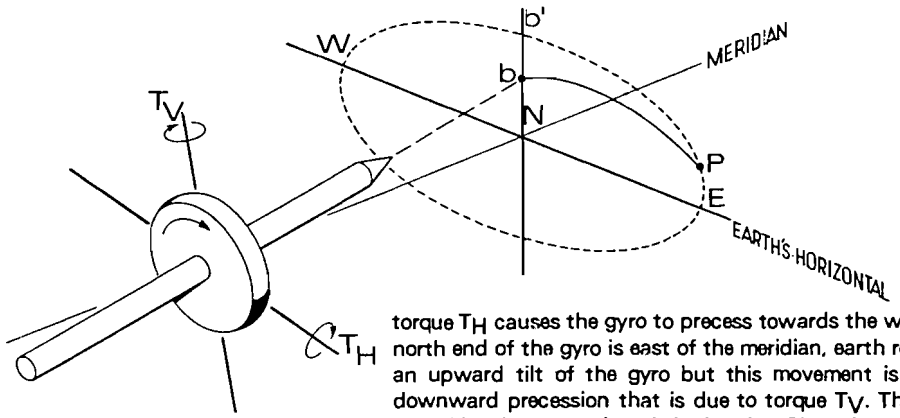


As the north end of the gyro spin axis passes east of the meridian again, the downward tilt due to earth rotation becomes an upward tilt. The gravity control, however, continues to precess the gyro towards the east until it is once more passing through the earth's horizontal. The gyro then commences to precess towards the west again (still tilting upwards) and will eventually pass through point P. The ellipse about North is thus completed and continues.

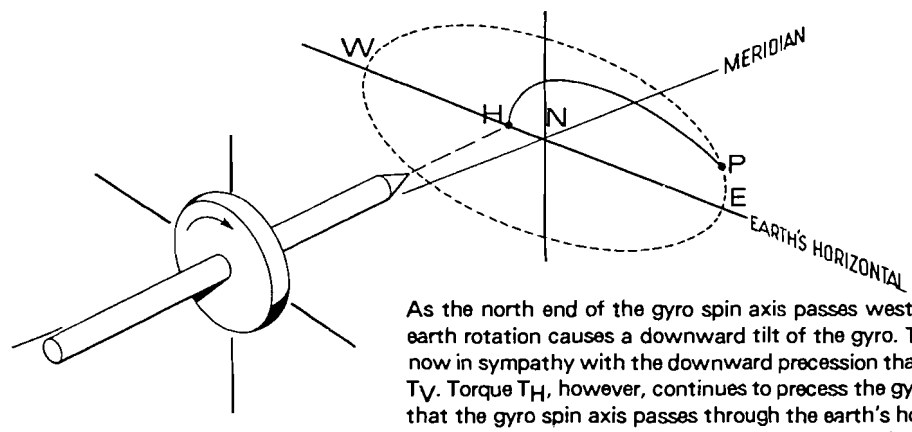
Figure 6. Behaviour of the Gravity-Controlled Gyro (Undamped).



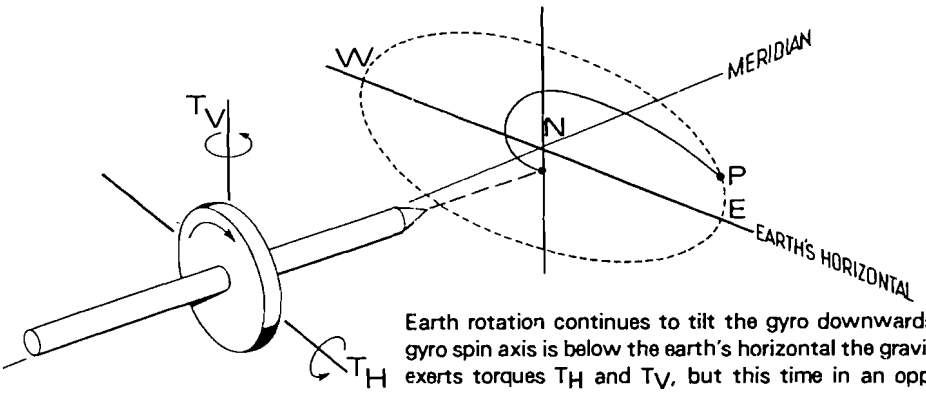
The north end of the gyro spin axis is initially pointing at P, which is above the earth's horizontal and to the east of the meridian. The gravity control therefore exerts a torque T_H about the gyro's horizontal axis and, at the same time, is arranged to exert a torque about the gyro's vertical axis. Because of the direction of rotation of the spinner,



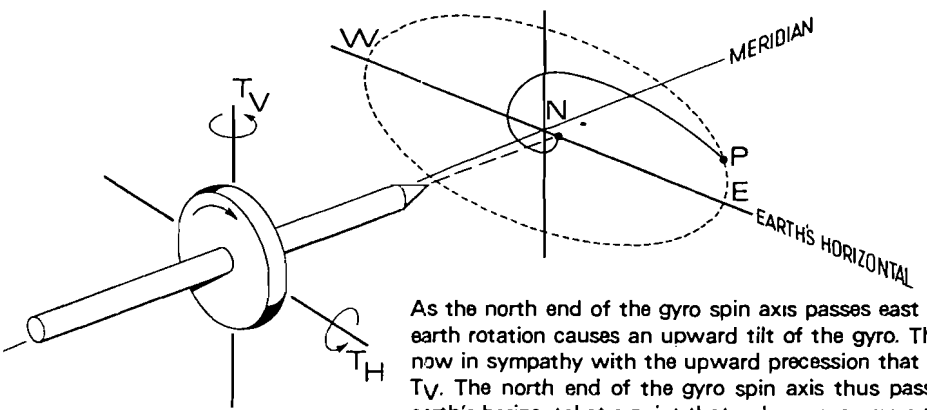
torque T_H causes the gyro to precess towards the west. Because the north end of the gyro is east of the meridian, earth rotation results in an upward tilt of the gyro but this movement is damped by the downward precession that is due to torque T_V. The resultant path traced by the gyro spin axis is therefore Pb and not Pb', as would be the case without the damping torque T_V. Note that the downward (damping) precession becomes more evident as the north end of the gyro spin axis approaches the meridian. Note also that the minor axis of the ellipse is decreased by the amount bb'



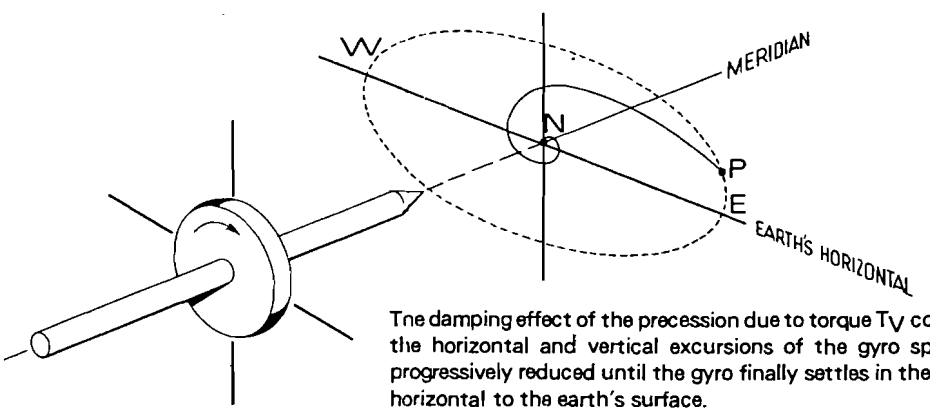
As the north end of the gyro spin axis passes west of the meridian, earth rotation causes a downward tilt of the gyro. This movement is now in sympathy with the downward precession that is due to torque T_V. Torque T_H, however, continues to precess the gyro westwards so that the gyro spin axis passes through the earth's horizontal at H, at which point torques T_H and T_V cease. Note that the major axis of the ellipse is considerably decreased.



Earth rotation continues to tilt the gyro downwards, and once the gyro spin axis is below the earth's horizontal the gravity control again exerts torques T_H and T_V, but this time in an opposite direction. Torque T_H now causes precession eastwards, whilst torque T_V causes precession upwards and thus damps the downward tilt that is due to earth rotation. The resultant movement of the gyro causes the north end of the gyro spin axis to pass through the meridian at a point that reduces even more the minor axis of the ellipse.



As the north end of the gyro spin axis passes east of the meridian, earth rotation causes an upward tilt of the gyro. This movement is now in sympathy with the upward precession that is due to torque T_V. The north end of the gyro spin axis thus passes through the earth's horizontal at a point that reduces even more the major axis of the ellipse.



The damping effect of the precession due to torque T_V continues, with the horizontal and vertical excursions of the gyro spin axis being progressively reduced until the gyro finally settles in the meridian and horizontal to the earth's surface.

Figure 7. Behaviour of the Gravity-Controlled Gyro (Damped).

Errors in the Settling Position

(Refer to Figure 8)

The ability of the damped gyroscope to settle with its spin axis horizontal and in the meridian is based on the assumption that there are no spurious torques acting about the gyro's horizontal or vertical axes which would result in unwanted precessions, and that the applied azimuth drift correction is precise. If spurious torques do exist, or imprecise azimuth drift correction is applied, then the gyro spin axis will settle at a point at which the precessional rates due to the spurious torques, or imprecise azimuth drift correction, are balanced by equal and opposite rates. This settling point will obviously not be in the meridian and thus presents an error in the settling position.

Since it must be assumed that the applied azimuth drift correction is always precise, then an error in the settling position can only be due to spurious torques. In the gyro-compass mounted in a ship, such torques are inevitably introduced to the gyro by the change in latitudes due to movement of the ship over the earth's surface, and by accelerations due to changes in the ship's speed and course. The resultant compass deflection error due to movement of the ship is referred to as **Speed Error**; that due to accelerations is referred to as **Ballistic Error**.

Speed Error

(Refer to Figure 8)

The gyro-compass installed in a ship senses an apparent motion that is compounded of the earth's movement and the speed of movement of the ship over the earth. If the ship's course has a northerly component, then the apparent motion of the gyro causes a westerly settling error; if the ship's course has a southerly component, the settling error is to the east.

Considering a ship's course that has a northerly component, the westerly settling error arises as explained in Figure 8. The value of the speed is approximated from the following formula:

$$\text{Speed Error in degrees} = \frac{\text{Ship's Speed in knots} \times \text{cosine Course}}{5\pi \times \text{cosine Latitude}}$$

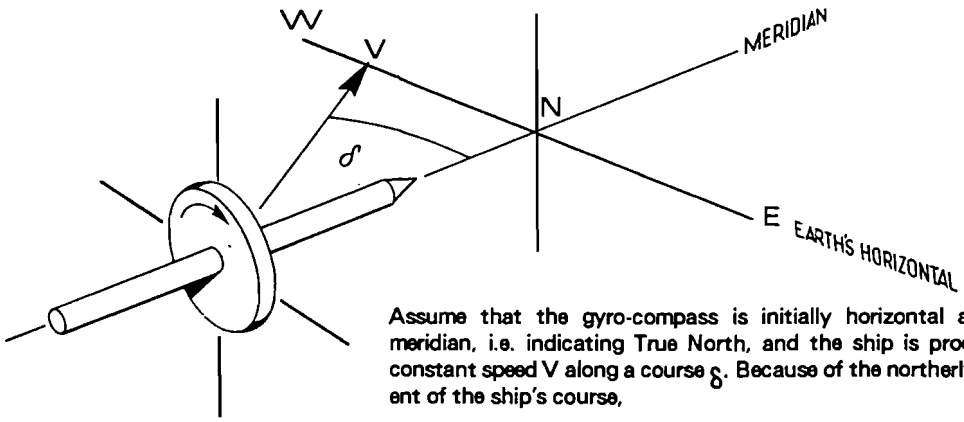
In latitude 50°, the error amounts to 1° for each 10 knots of northerly or southerly speed.

Since, from Figure 8, the speed error is due initially to a torque about the gyro's horizontal axis, and since the value of the torque depends on the ship's speed and course, it follows that the speed error can be compensated by applying about the vertical axis of the gyro a torque that is equal and opposite to the spurious torque. This applied torque, which is computed from ship's speed and course, gives a precessional rate in tilt which offsets the tilt rate that is due to the northerly component of the ship's speed. The gyro spin axis is therefore maintained in the meridian.

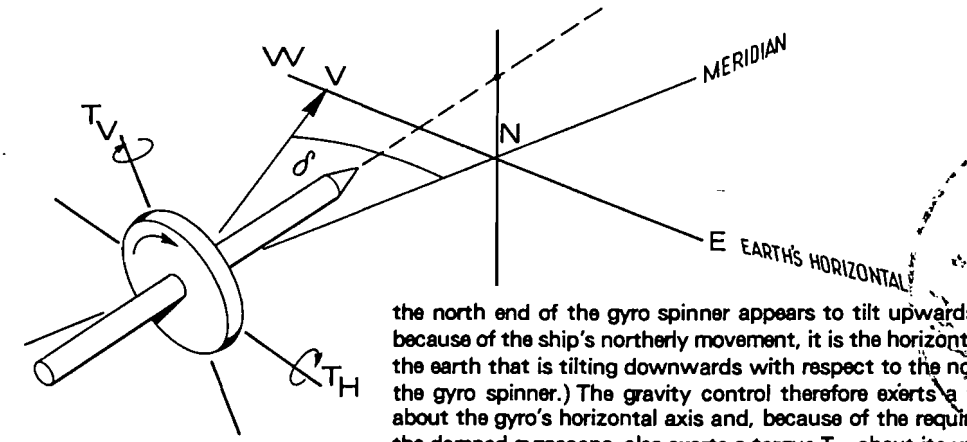
Ballistic Errors

(Refer to Figures 5 and 7)

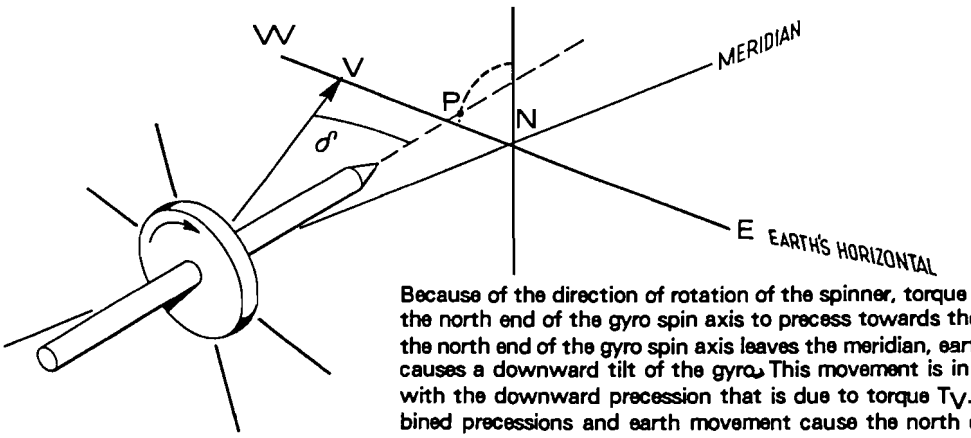
Because of its pendulous nature, the gravity control described in the paragraph which refers to Figure 5, moves away from the centre of gravity whenever the ship accelerates along a course that has a northerly or southerly component, or whenever the ship alters course. The movement



Assume that the gyro-compass is initially horizontal and in the meridian, i.e. indicating True North, and the ship is proceeding at constant speed V along a course δ. Because of the northerly component of the ship's course,



the north end of the gyro spinner appears to tilt upwards. (In fact, because of the ship's northerly movement, it is the horizontal plane of the earth that is tilting downwards with respect to the north end of the gyro spinner.) The gravity control therefore exerts a torque T_H about the gyro's horizontal axis and, because of the requirements of the damped gyroscope, also exerts a torque T_V about its vertical axis.



Because of the direction of rotation of the spinner, torque T_H causes the north end of the gyro spin axis to precess towards the west. As the north end of the gyro spin axis leaves the meridian, earth rotation causes a downward tilt of the gyro. This movement is in sympathy with the downward precession that is due to torque T_V. The combined precessions and earth movement cause the north end of the gyro spin axis to arrive at point P, at which the downward tilt is balanced by the upward tilt that is due to the northerly course of the ship. Because the upward and downward tilts are balanced, there is no torque T_H about the gyro's horizontal axis, so that the westerly precession also ceases. The azimuth displacement of the north end of the gyro spin axis from the meridian is the speed error.

Figure 8. Speed Error due to the Ship's Movement.

of the gravity control (its intertia) creates torques about the horizontal and vertical axes of the gyro, thus causing the gyro to precess in azimuth and tilt.

Note: Accelerations along a course that is due West or due East cause a torque about the gyro spin axis only. As has been previously described, such a torque does not induce precession.

The precession in azimuth is referred to as **Ballistic Deflection**, and the sense of the deflection depends on whether the ship is accelerating or decelerating. If the ship is **accelerating**, and the course has a **northerly** component, the inertia of the gravity control exerts a torque that tilts down the north end of the gyro spinner. Assuming that the gyro spinner is rotating in a clockwise direction as viewed from the south end, then the north end of the gyro spinner precesses westwards. When the ship's acceleration has a southerly component, the inertia of the gravity control exerts a torque that tilts up the north end of the gyro spinner and it precesses eastwards.

The precession in tilt is referred to as **Ballistic Tilt**, and in conjunction with ballistic deflection, causes the gyro spin axis to assume a false position. Because of the factors dictating the behaviour of the damped gyroscope (previously described and shown at Figure 7), the gyro spin axis will commence to return to the horizontal and meridian as soon as the acceleration is finished.

In practice, the design of the gyro-compass will produce varying results from ballistic deflection. In some compasses, the azimuth precession caused by ballistic deflection is used to precess the compass to its new settling position during a change in speed and course; in other words, a condition is introduced that makes the ballistic deflection equal to the change of speed error. Ballistic tilt is an undesirable factor resulting in a small temporary error that will attain a maximum after approximately 22 minutes but will damp out in the normal manner; the error is kept as small as possible. In other compasses, the movement of the gravity control is heavily damped and restricted to a small angle. Nevertheless, ballistic errors are evident and, where operating procedures include high-speed turns, a condition of "directional gyro mode" may be switched in during the turns, thus avoiding the errors.

SUMMARY OF GYROSCOPE PRINCIPLES

The preceding paragraphs, and the relevant illustrations, have explained the properties of the gyroscope and how, in the free gyroscope application, the phenomenon of the gyroscope can be modified to compensate for the rotation of the earth, its geological shape, and the movement of the ship, in order to give an accurate indication of True North.

In order to appreciate (without recourse to mathematics) the celestial reference of the gyroscope relative to a terrestrial observer, the reader must think in three dimensions. For this reason, the illustrations are, for the most part, given in perspective. When arguing about the attitude of a gyroscope for a given condition, e.g. the attitude of a gyroscope six hours after it was initially set up at latitude 35° North with its spin axis horizontal and in the meridian, one should mentally retain the pictorial aid given by the relevant illustration. In addition, the reader should bear in mind all the basic principles of the gyro-compass. For ready reference, a resume of these principles is given as follows:

1. The spin axis of the gyroscope becomes rigid when the rotor is spinning. This axis then points at a celestial reference.

2. The direction in which the spin axis points will be altered only if a torque is applied about the horizontal or vertical axes of the gyroscope (Figure 1) to cause a **precession**. The precessional movement is at right angles to the plane of the torque, and the direction of the precession depends on the direction of rotation of the spinner (Figure 2).
3. Because the spin axis of the gyroscope is fixed relative to a celestial reference point, the rotation of the earth causes the spin axis to move relative to an observer. This movement is **apparent** only, and shows itself to the observer as a drift in azimuth and/or a tilt (Figures 3(a), 3(b) and 4.
4. In order to maintain the gyroscope stationary in azimuth, thus compensating for earth rotation about the gyro's vertical axis, a torque is applied about the horizontal axis of the gyroscope in order to make it precess in azimuth at a rate that cancels the speed of rotation of the earth.
5. The movement in tilt due to earth rotation is employed, in conjunction with a **gravity control** (Figure 5), to enable the gyroscope to seek about the north (Figure 6). The torque applied by the gravity control whenever the gyro is not horizontal to the earth is also arranged to precess the gyroscope in tilt towards the horizontal, thus **damping** the gyroscope and enabling it to settle in the horizontal and in the meridian (Figure 7).
6. **Settling errors** displaced from True North will arise if spurious torques are not eliminated or compensated for. The movement of the ship through latitudes gives rise to a spurious torque that results in a **speed error** (Figure 8). **Ballistic errors** are due to accelerations of the ship along all courses that are not east or due west, and to changes in ship's course. Ballistic errors are not compensated for but are in practice minimised.

PRINCIPLES OF THE S.G. BROWN GYRO COMPASS

The principles of the S.G. Brown Gyro Compass are based on those described for the free gyroscope in the previous Section. In order to appreciate the technique by which these principles are applied, the components of the gyroscopic element in the S.G. Brown Compass must first be compared with equivalent components of the conventional free gyroscope. The equivalence of these components is shown in Figure 9 and is tabulated as follows:

The Free Gyroscope	**The Gyroscopic Element**
Gyro wheel (spinner)	The rotor of an electric motor with a spinner attached to each end of the rotor shaft.
Horizontal pivots	A pair of horizontal torsions wires.
Vertical pivots	A pair of vertical torsion wires.
Balanced gimbal system	The assembly comprising the vertical torsion wires, the alloy gimbal, the horizontal torsion wires and frame.
Mounting platform	The tank.

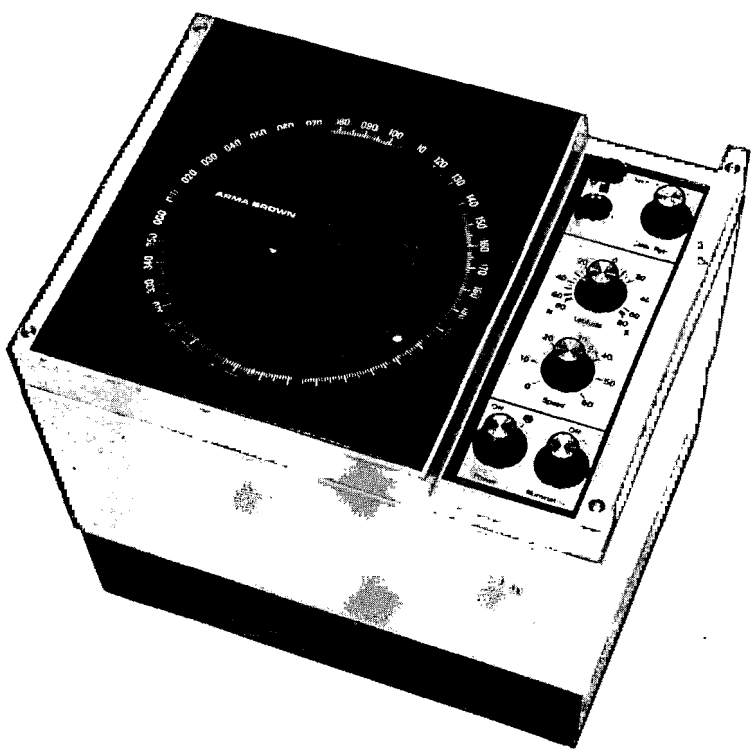


Figure 9. S.G. Brown Mk 10 Gyro Compass.

SENSITIVE ELEMENT

The gyroscopic element of the S.G. Brown Compass is referred to as the **sensitive element**, and includes the components shown schematically in Figure 10b.

Electric (Spin) Motor

The 3-phase electric motor is the heart of the sensitive element, and the angular momentum necessary for gyroscopic action is provided by a pair of heavy spinners carried on the rotor shaft. The stator windings of the motor are incorporated in the neck of the bobbin-shaped frame, at each end of which are housed the bearings carrying the rotor shaft. Each end of the frame is terminated by a thin-walled copper hemisphere that totally encloses the spinner. The frame thus resembles a sphere with an annulus around its middle, and the complete assembly is referred to as the **gyro ball**.

Horizontal and Vertical Torsion Wires

The gyro ball is centred within an alloy gimbal by means of a pair of horizontally aligned fine metal ligaments, or torsion wires, which are anchored to two spring plates bridging the annulus in the gyro ball. The alloy gimbal is, in turn, centred within the tank by a pair of vertically aligned torsion wires. The assembly is therefore similar in principle to that of the conventional free gyroscope, and the gyro spin axis has a potential freedom of movement about the horizontal and vetical axis.

Note: As explained later, movement of the gyro ball is finely controlled about the horizontal and vertical axes. This movement is, in fact, limited to only a few degrees in each direction.

Apart from forming what are virtually friction-free pivots, the torsion wires perform two other important functions:

1. They are the means by which controlling torques can be applied to the gyroscope vertical and horizontal axes, thus causing precessions of the gyro axis in azimuth and tilt.
2. They route electrical supplies to the gyro ball.

Tank

The tank is machined internally to accommodate the gyro ball and alloy gimbal. On assembly, the tank is filled with a viscous fluid (having the trade name of Fluorolube) such that all assemblies are completely immersed, and the tank sealed. At normal operating ambient temperatures ($-10°$ C to $50°$ C) the specific gravity of the fluid has a value that gives the gyro ball neutral buoyancy, so that no weight is taken by the torsion wires, nor is any linear acceleration force transmitted by them from the tank to the gyro ball.

SECONDARY GIMBAL SYSTEM

(Refer to Figure 11)

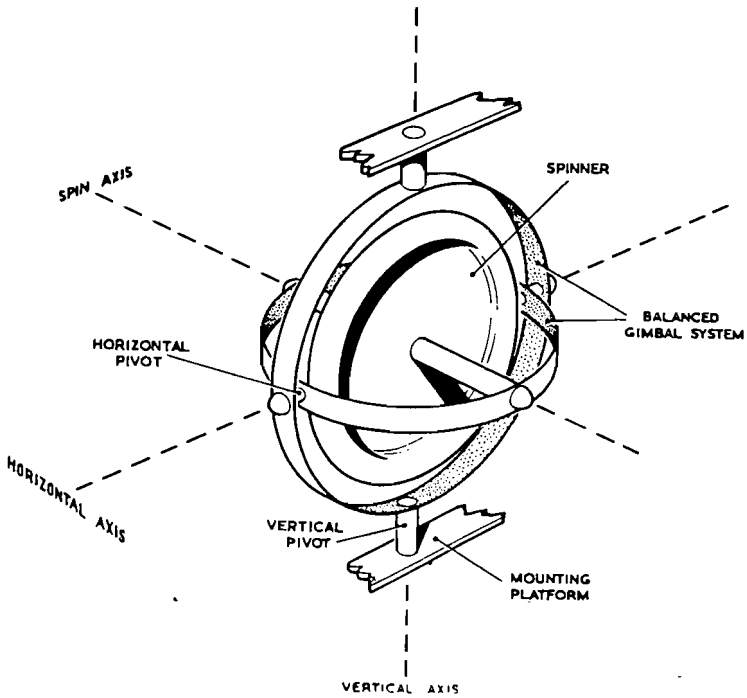
The tank is suspended within a gimbal so as to free-swing about an axis, and this axis is in line with the gyro spin axis. When the instrument is functioning normally as a gyro compass, the free-swinging axis is horizontal and in line with the local meridian. The ends of the tank that are normally to the North and South are marked accordingly.

The gimbal mounting the tank is suspended so as to rotate about its east/west axis within another gimbal. The overall arrangement of the gimbals is referred to as the **secondary gimbal system**; the primary gimbal system is that incorporated in the sensitive element.

Electro-Magnetic Pick-Up System

As long as there is no twist in the horizontal and verical torsion wires, and provided that no spurious torques are present about the gyro spin axis, no precession of the gyro ball will take place. The position of the gyro ball within the tank under zero twist conditions is such that the gyro spin axis is aligned with the north/south axis of the tank. This alignment is maintained by the secondary gimbals, which are servo-driven in response to signals from an electro-magnetic pick-up system.

The pick-up system consists of an electro-magnet, located on each hemisphere of the gyro ball so that the magnet is in line with the gyro spin axis, and pick-up coils mounted on the North and South ends of the tank. The pick-up coils are arranged and connected so that any angular misalignment of the tank with the gyro ball results in output voltages that are proportional to the azimuth and tilt displacement. These voltages are applied to a pair of amplifiers – one associated with tilt signal voltages and the other with azimuth signal voltages. The outputs from these amplifiers control the azimuth and tilt servo motors, which drive the secondary gimbals in such a direction as to cancel the pick-up voltages and so maintain correct alignment of the tank with the gyro ball.



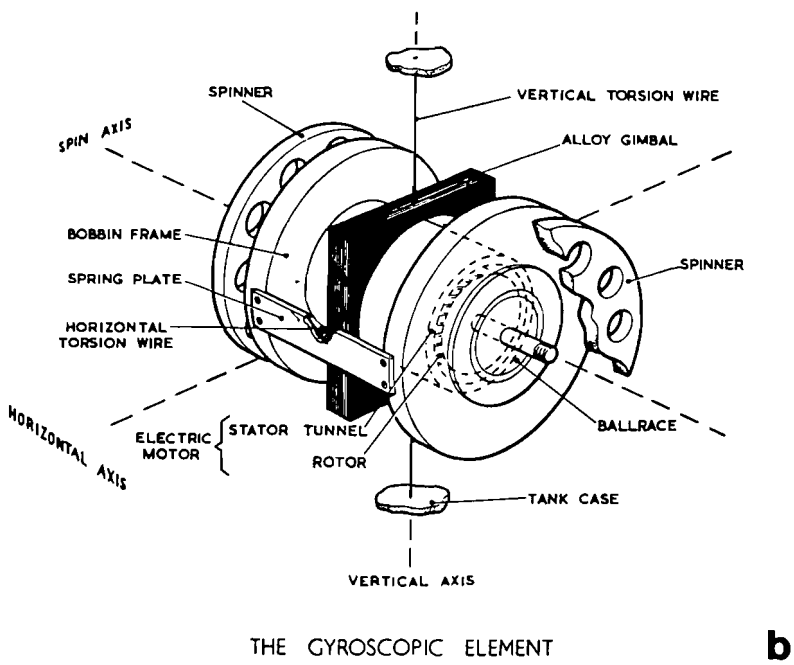


Figure 10. Equivalence of Gyroscope Components.

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CONTROL OF THE GYRO COMPASS

With a means of tank/gyro ball alignment established, controlled precessions are effected as follows. If the gyro ball is to be precessed in azimuth, an external signal is injected into the tilt amplifier. This signal unbalances the null signal condition achieved by the pick-up coil alignment so that there is now an output from the amplifier. This output causes the tilt servo motor to drive the tilt secondary gimbal to a position at which the tilt pick-up coil misalignment voltage is equal and opposite to the exernal signal applied to the amplifier. The tilt servo loop is therefore nulled, but the tank is out of alignment with the gyro ball in the tilt sense. A twist is thus imparted to the horizontal torsion wires, producing a torque about the horizontal axis of the gyro ball and causing it to precess in azimuth.

As the gyro ball precesses in azimuth, misalignment of the tank with the gyro ball in terms of azimuth also occurs but this is detected by the azimuth pick-up coils and the azimuth amplifier. The azimuth servo motor thus drives the azimuth secondary gimbal, rotating the tank in azimuth to seek cancellation of the misalignment signal. Since the azimuth secondary gimbal maintains a fixed position relative to the gyro spin axis in azimuth, a direct heading indication is obtained from a compass card that is carried by this gimbal. Remote indication is obtained from synchro transmitters driven from the azimuth gear train as shown in Figure 11.

Control of the sensitive element in tilt is effected in a similar manner. Thus, control of the gyro compass is achieved by injecting into the azimuth and tilt servo loops signals having a sign and amplitude that produce the required precessional directions and rates.

Gravity Control

Gravity control, an essential to make the gyro compass north seeking, is effected in the S.G. Brown gyro compass by means of a pendulum unit which is sensitive to movement of the tank about its east/west axis. The pendulum, which is heavily damped by a viscous fluid, controls an electro-magnetic pick-up so that a voltage appears across its output terminals whenever the tank is displaced about the east/west axis from the horizontal. This output is applied to the tilt amplifier, which causes a misalignment of the tank in the tilt sense and hence a twist of the horizontal torsion wires. The result is a precession of the sensitive element as previously described in the paragraphs relating to Control of the Gyro Compass.

Vertical Damping

The damping required to make the gyro settle in the meridian is obtained by applying a calibrated portion of the pendulum signal to the azimuth amplifier. This will cause a misalignment of the tank in the azimuth sense and hence a twist of the vertical torsion wires. The result is a precession of the sensitive element in tilt. The direction of the tilt precession will depend on whether the gyro spin axis inclined North end up or South end up with respect to the horizontal.

Latitude and Speed Correction

The necessary corrections for latitude and speed are applied by injecting electrical signals into the servo loops so that the tank is misaligned in tilt and azimuth. This results in the required precessional rates in azimuth (for latitude correction) and in tilt (for speed correction).

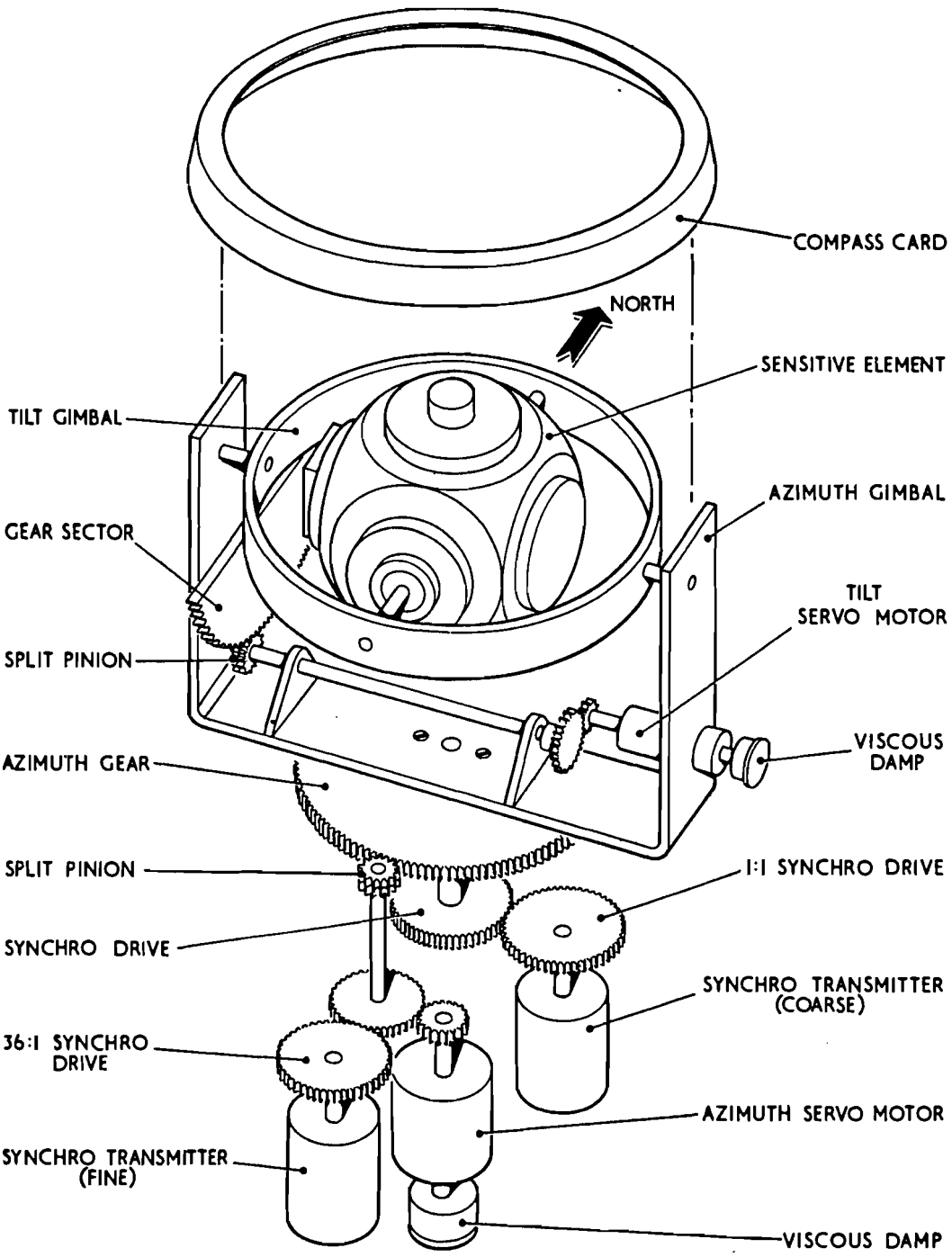


Figure 11. Schematic Arrangement of Compass.

OPERATION AS A DIRECTIONAL GYRO

To enable the compass to be used as a directional gyro, the pendulum signal is disconnected from the tilt amplifier, but applied, suitably scaled, to the azimuth amplifier.

The latitude correction signal provideds the necessary compensation for azimuth drift due to earth rotation, but the gyro ball will have a tendency to drift in tilt if the gyro spin axis is not in the meridian. The tank will follow the movement of the gyro spin axis in tilt, but any signal from the pendulum due to the tilt angle will cause the tank to be offset in azimuth and thus produce a torque about the vertical torsion wires. This will precess the gyro in tilt towards the horizontal position.

A position of equilibrium will finally be reached with the gyro spin axis displaced in tilt and the tank offset in azimuth through small angles sufficient to give a precessional rate equal and opposite to the drift rate in tilt due to earth rotation.

Whenever the gyro spin axis is horizontal and in the meridian, only the vertical component

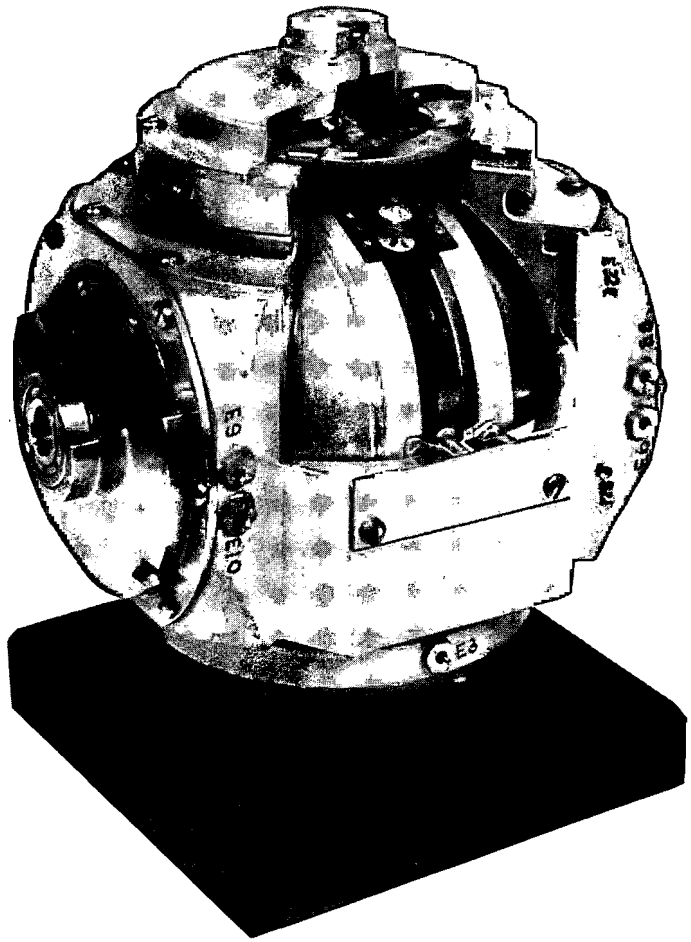


Figure 12. Sensitive Element.

of earth rotation is sensed by the gyro. Hence if accurate compensation for this component is made, the gyro spin axis will show no tendency to wander from the meridian, provided that no spurious torque is present to give unwanted precession.

The compass may, however, be set to any desired reference and used as a directional gyro, especially if heading checks can be made periodically, and the necessary correction made for gyro drift. In high latitudes, in which the performance of the gyro-compass as a North-seeking device deteriorates, the performance of the directional gyro improves, so that above 65° the gyro spin axis may be set to any heading without appreciable loss of accuracy.

Decoupling

In instances when violent movement of a vessel, especially under roll conditions, may affect the accuracy of the gyro compass, partial compensation is made by means of a decoupling circuit.

If the base of the compass is rotated about the north/south axis relative to the tank, an angular misalignment will exist between the servo-drive axes and the position sensing coil axes. Any error signal that may arise with the compass in this condition will produce gimbal movement about the appropriate axes in the direction to null the error, but since the gimbal axes will not be parallel to the axes of the position sensing coils generating the signal, the gimbal movement will have components about both tilt and azimuth position sensing coil axes, giving rise to tank displacement errors and consequent spurious gyro drift rates and, in extreme cases, instability.

Full compensation for this effect would involve computing error signal components about axes parallel to the servo-drive axes for all compass base displacements up to 60° in each direction, and applying the resultant signals to the tilt and azimuth amplifiers.

Partial but adequate compensation is made by applying, to the tilt amplifier only, the resultant signal for that axis computed for 60° displacement in each direction when the compass base displacement exceeds 25° in each direction.

Questions

1. What is meant by the term, "free gyroscope"?
2. Explain what is meant by the term, "precession". Make a simple sketch to illustrate your answer.
3. As a result of the earth's rotation, what apparent movements will occur to a gyroscope which is set spinning with its spin axis horizontal to the earth's surface?
4. Why is the directional gyroscope inadequate as a compass?
5. Discuss the main differences between the "damped" and "undamped" gyroscope.
6. Write notes on errors in the settling position of a gyro-compass.
7. Summarise, the principles of the gyroscope.
8. Compare the components of the sensitive element of a gyro-compass with the equivalent components of a conventional free gyroscope.
9. In connection with a modern gyro-compass, write notes on: (a) The sensitive element. (b) The secondary gimbal system.
10. Discuss gravity control, vertical damping and latitude and speed correction.
11. Discuss use of the compass as a directional gyro.
12. Explain how partial compensation is made for loss of accuracy resulting from violent movement such as heavy rolling.

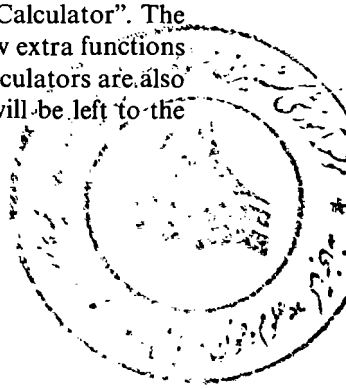
Chapter 30

Calculators and Computers in Navigation

The purpose of this chapter is to provide an introduction to the use of calculators and computers in practical navigation. At this stage no attempt will be made to consider sophisticated programs which include elements of the *Nautical Almanac*. Unless they are to be in continuous use, the step from simple formulae to such programs is out of proportion to the time and effort required to write them.

CALCULATORS

The type of calculator required for navigational problems is the "Scientific Calculator". The scientific calculator has the principal trigonometrical ratios and perhaps a few extra functions such as the facility for entering degrees and minutes of arc. Programmable calculators are also available but there is some variation in the methods of using these and it will be left to the student to study the relevant instructions.



General Notes

In the following formulae:

North and East are assigned Positive (+) Values
South and West „ „ Negative (−) „

and minutes of arc are first converted to decimal notation.

eg Latitude 20° 30′ S is entered as 20·5.

Next, the [+/−] (change sign) key is pressed.

The final display will be −20·5.

Longitude 40° 48′ E would be entered and displayed as 40·8.

Take careful note of the difference between

sin −30° and −sin 30°.

The expression sin Lat 30° S must be keyed as follows:

Key in	30	Display	30
„ „	[+/−]	„	−30
„ „	[sin]	„	−0·5

Like formulae, answers are arranged so that:

a positive (+) answer indicates N or E

a negative (−) „ „ S or W.

The following abbreviations have been used:

[ME] store in memory.

[MR] recall memory to display.

[MX] exchange display and memory. (NB. If this facility is not available, note the current display in your workbook and use [MR] to recall the stored memory.)

Worked Examples

In the following worked examples values which are "keyed in" on the numeral and decimal place keys are shown thus:

3·5

Functions keyed in are shown thus:

[tan]

The following symbols have been used to represent the keying operation required to display the angle corresponding to the currently displayed tangent value:

[Arc] [tan]

Unless stated otherwise, the listed keying operations should be keyed in continuously.

Intermediate calculator displays are not included.

Final displays are shown thus:

Display 23.12 (minutes).

Combined Use of Calculator and Work Book

In Example 1, we will use the calculator to find the values for D Lat, D Long etc and then enter these values in the workbook and find the final position in the usual way, ie we make use of both calculator and work book.

DR by Calculator

Example 1

A vessel steered 155° T at 12 knots from a 1200 Observed Position in 36° 45′ N 22° 12′ W. Find the DR at 1530.

Formulae used in the keying operations shown below:

1. Time (hrs) × Speed (knots) = Dist
2. Dist × cos Co = D Lat
3. D Lat ÷ 2 = ½ D Lat
4. Dist × sin Co = Dep
5. Mins. of Lat ÷ 60 + Deg. of Lat = Decimal Lat
6. Dep ÷ cos Mean Lat = D Long

Calculator Keying Operations

Note that the following calculator operations are arranged in their correct keying sequence—NOT in standard mathematical order. Only the first three decimal places have been shown.

1. 3·5 [×] 12 [=] 42

2. 42 [×] 155 [cos] [=] −38·064

Insert in workbook and find Final Latitude.

3. −38·064 [÷] 2 [=] −19·032

Insert in workbook and find Mean Lat.

4. 42 [×] 155 [sin] [=] 17·75 [ME]

5. 25·9 [÷] 60 [+] 36 [=] 36·432 [MX]

Use Mean Lat from workbook.

6. 17·75 [÷] [MR] [cos] [=] 22·062

Insert in workbook and find Final Longitude.

Workbook Entries:

1200 Obs Pos	36° 45·0′ N	22° 12·0′ W
155° T 42 miles	38·1′ S	22·1′ E
1530 DR	36° 06·9′ N	21° 49·9′ W
½ D Lat	19·0′	
Mean Lat	36° 25·9′	

Answer 1530 DR 36° 06·9′ N 21° 49·9′ W by calculator.

Using the Calculator for all Operations (Without Using the Workbook)

In Example 1 we made use of both the calculator and the workbook, ie D Lat and D Long were found by use of the calculator, entered in the workbook and applied to the initial position (Obs Pos) to find the final (DR) latitude and longitude. The workbook was also used to find the Mean Latitude.

In Example 2 we solve the same problem but this time use the calculator to carry out all the calculations, ie no use is made of the workbook.

Having worked the same problem by both methods it should be possible to make comparison between the amount of work involved in each method and the time required to carry out all operations on the calculator.

Example 2

A vessel steered 155° T at 12 knots from a 1200 Observed Position in 36° 45° N 22° 12'W.

Use the calculator to carry out all calculations necessary to find the DR at 1530.

1. Convert the initial latitude into a decimal latitude:

   45 [÷] 60 [+] 36 [=] 36·75 [ME]

2. Find the distance run.
   Convert distance in miles into angular measure (degrees).
   Find the final (DR) latitude:

   Speed × Time = Dist
   Dist × cos Co = D Lat
   D Lat + Initial Lat = Final Lat

   12 [×] 3·5 [=] 42 [÷] 60 [×] 155 [cos] [+] [MR] [=] 36·116 [MX]

3. Find the Mean Latitude:

   36·75 [+] [MR] [÷] 2 [=] 36·433 [MX]

4. Convert the final (decimal) latitude into degrees and minutes:

   36·116 [−] 36 [×] 60 [=]

   Display 6·96 (minutes) ie final DR Lat 36° 07'.

5. Convert distance into angular measure (degrees).
   Find the D Long:

   Dist × sin Co = Dep
   Dep ÷ cos Mn Lat = D Long

   42 [÷] 60 [×] 155 [sin] [÷] [MR] [cos] [=] 0·368 [ME]

6. Apply the D Long, convert degrees and decimals to degrees and minutes and find the final longitude.

-12 [÷] 60 [−] 22 [+] [MR] [=] $-21{\cdot}832$ [+] 21 [×] 60 [=]

Display 49·9 (minutes) ie Final DR Long 21° 49·9′ W.

Answer 1530 DR 36° 07′ N 21° 49·9′ W by calculator.

Comparison Between Methods Used in Examples 1 and 2

Compare the time taken to work the same example by the two methods:

Example 1. Using a combination of calculator and workbook calculations, and

Example 2. Using the calculator to carry out all calculations.

The first method is found to take about half the time of the second. It can also be recommended on the grounds of having less complicated keying, though this problem can be simplified if the calculator has multiple memories. With practice, the student may well find alternative methods more suited to the type of calculator used.

Set and Drift by Calculator

Example 3

A vessel in DR 32° 17′ S 37° 43′ E obtains an Observed Position of 32° 29′ S 37° 38′E. Find the set and drift.

DR	32° 17′ S		37° 43′ E
Obs Pos	32° 29′ S		37° 38′ E
D Lat	12′ S	D Long	5′ W
Mean Lat	32° 23′ S		

Formulae:

1. minutes of Lat ÷ 60 + degrees of Lat = Decimal Lat
2. Cos Mean Lat × D Long = Departure
3. Departure ÷ D Lat = tan Course
4. D Lat ÷ cos Course = Distance

OR

For convenience in keying, cos Course can be divided by D Lat and the result inverted.

Calculator Keying Operations

The respective values for formulae 1–4, above, are keyed in continuously:

23 [÷] 60 [+] 32 [=] cos [×] 5 [÷] 12 [=] [Arc] [tan] [ME] [cos] [÷]

12 [=] [1/x]

Display 12·72 (miles)

[MR] [−] 19 [×] 60 [=]

Display 23·12 (minutes) ie S 19° 23·1′ W.

Angle named South and West according to the D Lat and D Long previously found.

Notes

1. The angle of set was stored in memory so that it could be later separated into degrees and minutes of arc in the final keying sequence.
2. As the direction of set (South and West) was found from the D Lat and D Long it was unnecessary to assign a negative value to the South latitude.
3. Alternative Formula 4, Distance = cos Course ÷ D Lat inverted, has been used to enable continuous keying.

Answer Set 199° 23′ T Drift 12·7 miles by calculator.

Mercator Sailing by Calculator

Where the distance between two positions is considerable, the Mercator Sailing should be used to find the course and distance.

There is no simple formula which can be used on the calculator for obtaining Meridional Parts. In consequence, when working a Mercator Sailing the calculator is used, in conjunction with tables and workbook, as a substitute for logarithmic tables.

Example 4

On the 19th March the Observed Noon Position was 22° 55′ N 131° 52′ W, and on the previous it was 21° 14′ N 124° 33′ W. Find the distance and track made good, Noon to Noon.

Workbook Entries:

Obs Pos 19th	22° 55′ N	Mer Parts	1404·09		131° 52′ W
„ „ 18th	21° 14′ N	„ „	1295·73		124° 33′ W
D Lat	1° 41′ N	DMP	108·36	D Long	7° 19′ W
	101′				439′

Formulae:

1. D Long ÷ DMP = tan Course
2. D Lat ÷ cos Course = Distance

OR

cos Course ÷ D Lat (all inverted) = Distance

Calculator Keying Operations:

439 [÷] 108·36 [=] [Arc] [tan] [ME] [cos] [÷] 101 [=] [$1/x$]

Display 421·5 (miles)

[MR] [−] 76 [×] 60 [=]

Display 8·1 (minutes) ie Course angle N 76° 08·1′ W.

Notes

1. Once again, the alternative formula, Distance = cos Course ÷ D Lat and the invert key [$1/x$], have been used to enable continuous keying.
2. Course angle, 76·135°, may be written down at either the memory enter or memory recall stage.
3. The course has been named N and W according to the D Lat and D Long previously found.

Answer Course N 76° 08·1′ W or 283° 51·9′ T
Distance 421·5 miles by calculator.

Calculated Zenith Distance by Calculator

As the haversine formula is awkward to key into the calculator it is more convenient to use the spherical cosine formula for calculating zenith distance. The form in which it is used in the following example is designed to avoid use of calculator memory.

Once again, note that S'ly quantities must always be keyed in as negative (−).

For speed and convenience, it is recommended that values should be first converted into degrees and decimals and written down in the workbook before commencing the main calculation. Three places of decimals should be sufficient.

Example 5

Given, DR Latitude 24° 30′ N, Declination 18° 24·3′ S and LHA 297° 36·5′. Find the calculated zenith distance.

Workbook Summary Entries:

Lat 24·5° N Dec −18·405° S LHA 297·608°

Formula:

(tan Lat × tan Dec + cos LHA) × cos Lat × cos Dec = cos Zenith Distance

Calculator Keying Operations

24·5 [tan] [×] 18·405 [+/−] [tan] [+] 297·608 [cos] [×] 24·5 [cos]

[×] 18·405 [+/−] [cos] [=] [Arc] [cos]

Display 74·384 degrees

74·384 [−] 74 [×] 60 [=]

Display 23 (minutes) ie 74° 23′

Answer Calculated Zenith Distance 74° 23′ by calculator.

Great Circle Distance by Calculator

The formula used for calculating the distance along a Great Circle track is, in effect, the same as that used for calculating zenith distance. Declination becomes the latitude of the final position and LHA becomes the difference of longitude. This is demonstrated in the following example.

Example 6

Find the great circle distance from "A" 21° 18′ N 157° 52′ W to "B" 48° 34′ N 126° 04′ W.

Summary Workbook Entries

"A"	21·3° N	157° 52′ W
"B"	48·567° N	126° 04′ W
	D Long	31° 48′ E
		31·8°

Formula

(tan Lat A × tan Lat B + cos D Long) × cos Lat A × cos Lat B = cos GC Distance

Calculator Keying Operations

21·3 [tan] [×] 48·567 [tan] [+] 31·8 [cos] [×] 21·3 [cos] [×]

48·567 [cos] [=] [Arc] [cos]

Display 37·219 (degrees)

37·219 [×] 60 [=]

Display 2233·14 (miles)

Answer Great Circle Distance 2233·14 miles by calculator.

Azimuth by Calculator

In the following example note that:

1. | sin LHA | means that the function must always be positive (+).
2. If LHA exceeds 180° then its sine will have a negative value which must be changed by keying [+/−].
3. Having found the cotangent Azimuth, operate the [$^1/_x$] key to obtain the reciprocal which is then evaluated using the [Arc] [tan] key or keys.
4. A negative (−) Azimuth indicates that it is to be measured from the South Pole. The LHA shows if the azimuth is to the East or West.
5. It is sufficiently accurate to enter the quantities to one place of decimals—which can be evaluated mentally.

Example 7

Given, Latitude 29° 00′ N, Declination 18° 40·9′ S and LHA 312° 15·4′. Find the true azimuth.

Summary Workbook Entries

Lat 29·0° Dec −18·7° LHA 312·3°

Formula

$$\left(\frac{\tan \text{Dec}}{\tan \text{Lat}} - \cos \text{LHA}\right) \times \frac{\sin \text{Lat}}{|\sin \text{LHA}|} = \cot \text{Azimuth}$$

Calculator Keying Operations

18·7 [+/−] [tan] [÷] 29 [tan] [−] 312·3 [cos] [×] 29 [sin] [÷]

312·3 [+/−] [sin] [=] [$^1/_x$] [Arc] [tan]

Display −49·9 (degrees) ie Az S 49·9° E

Azimuth named South because the value was negative (−) and East because the LHA was Easterly.

Answer Azimuth S 49·9° E or 130·1° T by calculator.

Further Exercise

The foregoing examples should give a fairly clear idea of the most convenient methods for using the scientific calculator to solve navigational problems. Further exercise can be had by using the calculator to check answers to examples of navigational problems given in other chapters of this volume.

Use of Calculators in DTp Navigation Examinations

In compliance with The Merchant Shipping (Carriage of Nautical Publications) Rules, 1975 and the Fishing Vessel's (Safety Provisions) Rules 1975, navigation tables must be carried on UK ships and fishing vessels which are 12 metres or more in length and proceeding more than 5 miles from the coast—refer to the relevant rules or Annual Notice to Mariners No. 18 for further information.

A consequence of the above requirements is that candidates for all first certificates of competency must demonstrate their ability to use navigational tables which ships are required to carry under current legislation.

Use of Calculators in Class 5, Class 4 and Class 2 (Fishing) Examinations

Other than for checking the arithmetic of answers obtained by use of conventional tables, the use of non-programmable electronic calculators in DTp examinations for Class 5, Class 4 and Class 2 (Fishing) is not permitted. Use of conventional navigational tables is obligatory in these examinations.

Use of Calculators in the Extra Master, Class 1, Class 2, Command Endorsement and Class 1 (Fishing) Examinations

Providing that procedural steps are clearly indicated and that the formulae used confirm with good practice, the use of non-programmable electronic calculators is permitted throughout the DTp examinations for Extra Master, Class 1, Class 2, Command Endorsement and Class 1 (Fishing).

DTp Examination Rules Regarding the Use of Calculators

The following rules apply to the use of non-programmable electronic calculators in DTp examinations:

1. Permission to use a calculator must be obtained from the Examiner before the start of the examination.
2. A note must be made on each script where an electronic calculator is used.
3. All intermediate working and steps taken in arriving at an answer must be shown.
4. Failure to show all steps will result in a loss of marks.

Date of Effect

The Department of Transport's policy on the use of non-programmable electronic calculators has effect from 1 September 1986.

Programmable Calculators

Programs for solving navigational problems are available in some "dedicated" calculators. These programs are comparatively easy to use since the display indicates the "input" which is required for each step of the calculation. Calculator answers may differ from standard calculations and Great Circle distances, for example, may be adjusted to take into account the earth's oblate shape.

The use of programmable calculators and computers is not permitted in DTp examinations.

COMPUTERS

Any small computer will have sufficient storage (memory) for routine navigational calculations and programs. In practice, one kilobyte should be sufficient even for fairly advanced programs but would only permit very limited amounts of data storage.

Types of Computer

For navigational calculations and navigation related purposes, computers can be classified under four main headings:

1. On Board Computers, eg The Satellite Navigator Computer.
2. Compact (Pocket) Computers
   (*a*) Dedicated computers
   (*b*) Standard computers
   (*c*) Standard computers supplied with special navigational software.
3. Less expensive "Scientific" Microcomputers.
4. Business Computers including Second Processors and other "extensions" which convert personal computers into business computers (using CPM or MS DOS) capable of running a wide range of special application programs likely to be of assistance in handling many of the clerical aspects of navigation related duties.

On Board Computers

The most likely "on board computer" is that included in the satellite navigator. In addition to its normal position fixing function, it can be used for calculating course, distance and DR.

Compact (Pocket) Computers

Several manufacturers produce "dedicated" pocket computers which include elements from the *Nautical Almanac* and which are extremely useful for working out sights, azimuths, course and distance and running up positions. This type of computer (or in some cases computer/calculator) is much favoured by yachtsmen.

"Standard" pocket computers can also be used for solving a wide range of navigational problems but it is, of course, necessary either to write or purchase the necessary programs. Those produced by the Sharp Corporation have available RAM of 1–13 kilobytes and are well suited for navigational calculations. A feature of this type of computer is the small printer/cassette interface which can be used for loading existing programs and producing "hard copy" of new ones.

As part of a "package deal", pocket computers can also be supplied with specially written navigational software. Packages either for the Sharp PC 1251, 1350 or 1401 include voyage planning, GC and Mercator sailings, astro-navigation and tidal stream calculations. Elements from the *Nautical Almanac* and Tidal Diamond data are included in some of these packages.

Less Expensive "Scientific" Microcomputers

Some of the less expensive "scientific" microcomputers, such as the BBC Model B, are likely to be already available to many students and are ideally suited for carrying out navigational calculations. Having excellent graphics, the BBC can also be used to produce the type of plot normally required in coastal and ocean navigation and radar plotting.

For data storage, "desk top" computers, like the BBC Model B, have the advantage of either magnetic tape, soft and/or hard disc storage. This facility is particularly useful for storing and using navigational training programs.

Business Computers

By adding a second processor, a "scientific" microcomputer, like the BBC, can be converted into a business machine operating with CPM or MS DOS—this allows use of the widest possible range of business applications software which can be of assistance in handling many of the clerical aspects of navigation related duties.

Torch Computers Ltd produce a Z80 second processor which can be installed either inside the case of the BBC Model B or incorporated within a double sided, double density twin

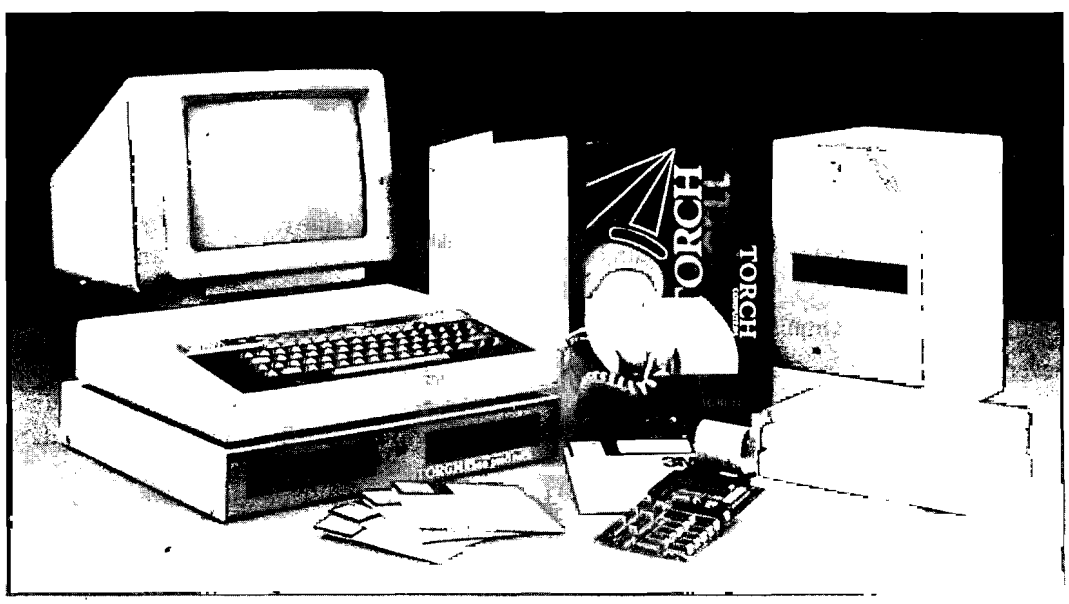


Figure 1. BBC Model B microcomputer mounted on the Torch Z80 Disc Pack. The second processor, modem, hard disc and business software are also shown. *By kind permission of Torch Computers Ltd, Cambridge.*

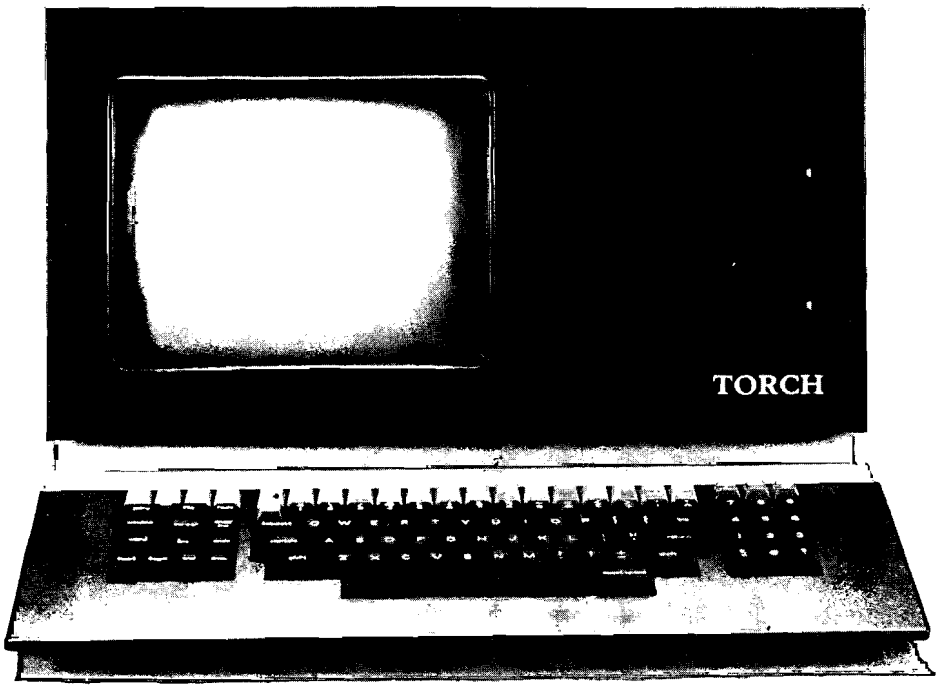


Figure 2. "C" Series Torch Business Computer fitted with the 6502 processor which enables the Torch to be run as a BBC Model B when required. This model is fitted with auto-answer, auto-dial communications facilities. *By kind permission of Torch Computers Ltd, Cambridge.*

disc drive unit, as shown in Figure 1. This extension processor converts the BBC into a full business machine. Further addition of a modem makes available a wide range of sophisticated communications packages.

Navigation Related Uses of Business Software

Certain items of business software can be of considerable assistance in handling many of the clerical aspects of navigation related duties, eg

1. Word-processing, eg Wordstar or Perfect Writer, for preparing and updating Passage Plans, Abstracts, Supplies Lists etc.
2. Spreadsheets, eg Lotus 1-2-3 or Perfect Calç, for Coastal Distance Tables, Stability and Cargo Calculations and Summaries.
3. Database Management, eg dBase II or III, for Charts and Chart Corrections, Nav-aid Spares and Stores.
4. Communications, eg Torch Mail, Computer to Computer, Electronic Mail, Telex etc.

Use of some of these special applications packages can greatly increase efficiency and save time and energy for other duties.

Computer Programs for Navigation

In order to write accurate and reliable computer programs it is essential to:

1. Fully understand the principles of navigation.
2. To have a sound knowledge of computer programming.
3. To have a suitable computer on which to test the reliability of new programs—against results obtained by conventional navigational methods and tables.

Various computer languages are in use. The computer language most commonly used and which is suitable for writing navigational programs is, "BASIC", the Beginner's All Purpose Symbolic Instruction Code.

It is not the purpose of this section to attempt to familiarise the student with programming but simply to give some hints and simple examples.

Stages in Developing a Program

There are four main stages in developing a computer program:

1. Designing the program.
2. Writing the program.
3. Running the program.
4. Debugging the program.

Though relatively straightforward, Example 8 should serve to illustrate the need for a thorough understanding of first principles at stages 1 and 2, and also for a comprehensive set of test examples, which include all possible sets of conditions, at stage 3.

Mercator Sailing by Computer

Calculator Examples 1–7 are all suitable subjects for computer programs. Example 8 illustrates a program for calculating Mercator course and distance and which is then run with data from Example 4.

As in the calculator examples, positive values represent North and East and negative values represent South and West. The program could, of course, be expanded to allow entry in degrees and minutes "North" or "South", and the relevant part of the program would then automatically convert minutes into decimals and assign a positive or negative value as appropriate.

Example 8

Design and write a simple program, in **BBC BASIC**, to find course and distance by Mercator Sailing. The required input should consist of the Latitudes of the initial and final positions and the D. Long. between them.

Run the program to find the course and distance:

From 21° 14′ N 124° 33′ W **To** 22° 55′ N 131° 52′ W (D. Long. 7° 19′ W)

The Program Print-Out

```
>LIST
  1Ø MODEØ
  2Ø PRINTTAB(17,2)"MERCATOR COURSE & DISTANCE PROGRAM"
  25 PRINTTAB(13,4)"Copyright E J Coolen & B R Sanderson 1986"
  3Ø PRINTTAB (2,7)"ENTER LAT. & D.LONG. in Degrees first, THEN Minutes."
```

```
 35 PRINTTAB(2,9)"** If SOUTH Latitude enter a Minus Sign (-) BEFORE both values **"
 37 PRINTTAB(2,11)"** If D.Long. is WEST enter a Minus Sign (-) BEFORE both values **"
 40 INPUT"LATITUDE A ",A,"MINUTES A ",A1
 50 IF A>89 OR A1>59 PRINTTAB(20,15)"MISTAKE":FOR D=1TO2500:NEXTD:GOTO10
 60 INPUT"LATITUDE B ",B,"MINUTES B ",B1
 65 IF B>89 OR B1>59 PRINTTAB(20,18)"MISTAKE":FOR D=1TO2500:NEXTD:GOTO10
 70 PRINTTAB(10,20)"ENTER D.LONG. in Degrees first, THEN Minutes."
 80 A1=A1/60:A=A+A1:B1=B1/60:B=B+B1
 90 INPUT ""D.LONG., DEGREES ",D,"MINUTES ",D1
 95 IF D<60 OR D1<60 GOTO 100 ELSE PRINTTAB(40,22)"MISTAKE":PRINTTAB(20,23)
          "(20,24)"                                  ":FORD=1TO2000:NEXTD
 97 PRINTTAB(40,22)"            ":GOTO90
100 D=D*60+D1
110 X=A:GOSUB 390
120 E=X2: REM/ MER.PARTS LAT.A
130 X=B:GOSUB 390
140 F=X2:REM/ MER.PARTS
150 K=F-E: IF K= 0 THEN K=1 : REM/ D.M.P.
160 C=D/K: C=ATN(C)*57.3 : H=C : REM/ COURSE CALC.
170 L=B-A: IF B=A THEN 180 ELSE 190
180 G=D*COS(A/57.3): GOTO 200 : REM/ ZERO D'LAT,PLANE SAILING CALC.
190 C=C/57.3: G=L*60/COS C : REM/ DIST. CALC.
200 IF G<0 THEN G=G*-1
210 @%=&20109: PRINTTAB(10,25)"DISTANCE =  ";G;" miles."
220 IF A=B THEN H=90
230 IF H<0 THEN H=H*-1
250 IF A>B AND D>0 THEN H=180-H
260 IF A<B AND D>0 THEN H=H
270 IF A>B AND D<0 THEN H=H+180
280 IF A<B AND D<0 THEN H=360-H
290 IF A>B AND D=0 THEN H=180
300 IF A<B AND D=0 THEN H=0
310 PRINTTAB(10,27)"COURSE =  ";H;" degrees TRUE"
370 @%=10
380 PRINTTAB(22,29)"To repeat, type RUN . To escape, press ESCAPE.":END
390 X1 = X/57.3
400 X2=LN TAN(X1/2+45/57.3)*3437.75-(SIN X1*23.43)
410 RETURN
```

Saving the Program

```
>SAVE "M.PROG"                    (Or other suitable file name.)
```

Running the Program

```
>LOAD "M.PROG"
>RUN
```

The program will run as follows:

```
                MERCATOR COURSE & DISTANCE PROGRAM

                Copyright E J Coolen & B R Sanderson 1986


        ENTER LAT. & D.LONG. in Degrees first, THEN Minutes.
        ** If SOUTH Latitude enter a Minus Sign (-) BEFORE both values **
        ** If D.Long. is WEST enter a Minus Sign (-) BEFORE both values **
```

```
LATITUDE A ?21
MINUTES A ?14

LATITUDE B ?22
MINUTES B ?55

          ENTER D.LONG. in Degrees first, THEN Minutes.

D.LONG., DEGREES ?-7
MINUTES ?-19


          DISTANCE = 421·5 miles.

          COURSE = 283.9 degrees TRUE

                         To repeat, type RUN.  To escape, press ESCAPE.
>
```

Note This program could be expanded to make provision for entering two longitudes rather than the D. Long. Entering two longitudes would introduce the possibility of crossing the 180th meridian and part of the expanded program would have to prevent the track from going the longer way around the earth's surface.

Questions

1. Discuss the advantages and disadvantages of using a calculator to carry out all operations required for the solution of a navigational problem.
2. How would you enter the following data on a calculator? 25° N Latitude, 56° S Declination, 31° 16′ South Latitude.
3. (*a*) An azimuth worked out by calculator produces a final display which does not directly indicate the quadrant. How would you name the azimuth? (*b*) Using LHA 160° an azimuth worked out by calculator gave a final display of 31·2°. What was the azimuth?
4. Compare the use of calculators and computers for solving navigational problems.
5. Explain why you consider it essential to fully understand the principles of navigation before using a computer to solve navigational problems.
6. Navigational calculations apart, for what other uses could a computer be of assistance to the navigating officers?
7. What particular points would you watch out for when writing a navigational program for a new computer?
8. Compare the advantages and disadvantages of "pocket" and "desk top" computers.
9. What do you consider to be the practical dangers of using a computer, exclusively, to solve navigational problems at sea?
10. "Computers save time". Discuss this statement and make specific mention of the time required to become fully conversant with a particular computer and software and also to write and test new programs.

DEPARTMENT OF TRANSPORT

Specimen Examination Papers

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Important Note: These papers *must* be worked using the 1976 *Nautical Almanac* Extracts. Tide problems to be worked with A.T.T. Extracts on page 815.

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SPECIMEN PAPERS

1. The symbols, abbreviations and conventions used in the examinations will follow the SI system and will generally be in accordance with the list prepared by the Council of Technical Examining Bodies.

2. The following abbreviations will also be used:

(a) Navigation and Chartwork

(i)

CP	The chosen position is that position nearest to the observer chosen so that the latitude is an integral degree and the longitude is such that the local hour angle of the body at the time of observation is also an integral degree.
DR	The dead reckoning position is that obtained by allowing for courses steered and distances run only.
EP	The estimated position is that obtained by allowing for courses and distances and for leeway and current if any.
Sext alt	The sextant altitude is that read off a sextant.

(ii)

az	azimuth
C	compass
Co	course
chron	chronometer
CPA	closest point of approach
HE	height of eye
IE	index error
LL	lower limb
M	magnetic
P/L	position line
T	true
UL	upper limb

(c) Magnetism and Compass

Hf	Horizontal component of Earth's magnetic field
Z	Vertical component of Earth's magnetic field.

CLASS 5 CERTIFICATE OF COMPETENCY

Chartwork and Practical Navigation

Paper 1 *3 hours (excluding Oral questions)*

Candidates should note that 130 marks *are allocated to the section on Chartwork and* 70 marks *are allocated to the section on Practical Navigation. In order to achieve a pass on this paper, candidates must obtain at least* 90 marks *in the Chartwork section and* 50 marks *in the Practical Navigation section.*

Chartwork

Use Deviation Card No. 7 where applicable and Variation 7½°W throughout. The positions given after the names of prominent points are approximate to 1′ and are to be used for identification purposes only.

1. At 1000 on 11 March a vessel was in position 50° 19′N, 2° 08′W. Find the compass course to steer to pass 2 miles off Anvil Pt. Lt. Ho. (55° 35′N, 1° 58′W). Make allowance for any tidal streams you may expect to experience and estimate the time of arrival off Anvil Pt. Vessel steaming at 9 knots.

(35 marks)

2. From a vessel steering 247° C at 10 knots Bill of Portland Lt. Ho. (50° 31′N, 2° 27′W) and the Hardy Monument (240) are seen in transit bearing 358°C. After maintaining this course for 1 hour Bill of Portland Lt. H. is observed bearing 047 °C. If a current set 246° T at 1 knot during the interval between the bearings find the latitude and longitude of the ship's position at time of taking the second bearing.

(25 marks)

3. At what distance would you expect to raise Start Pt. Gp. Fl. (3) light from a vessel with height of eye 5 m?

(20 marks)

4. A vessel steering 103° C and steaming at 12 knots observes the following corrected Decca readings *Red H3* and *Purple D74*. After 1 hour and 18 mins a second corrected Decca fix is obtained *Red I18* and *Purple E59*. Find the true course, distance and speed made good also the set and rate of the current experienced during this period.

(25 marks)

Oral questions. (25 marks)

[Continued]

Practical Navigation

1. Find by Mercator sailing the true course and distance from 43° 42′N, 9° 49′W to 47° 10′N, 2° 58′W.

(25 marks)

2. A vessel on passage from Bilbao to La Rochelle is in position 43° 51′N, 8° 09′W at 1650 and is proceeding on a course 065° T at 14 knots.

At 1820 due to a fire on board, course is altered to 355° T and the speed is reduced to eight knots. At 2120 course is again altered to 040° T and speed further reduced to 6 knots.

Assuming the last course and speed is maintained find by Traverse tables the vessel's position at 2400.

(20 marks)

3. From the following information find the compass error and the deviation for the direction of the ship's head:

Time at ship 1427 BST on 17 May 1976
D.R. position 58° 42′N, 8° 10′W
Compass bearing of the Sun 212°

Chronometer showed 1 h 28 m 47 s, error 1 m 37 s fast on GMT. Variation 13° W.

(25 marks)

CLASS 4 CERTIFICATE OF COMPETENCY

Chartwork

Paper 2 *2 hours (excluding Oral questions)*

Use Deviation Card No. 7 where applicable and Variation $7\frac{1}{2}°$ W throughout. Each question carries 25 marks.

The positions given after the names of prominent points are approximate to 1′ and are to be used for identification purposes only.

Luminous and geographical range diagrams for use in question 2 are attached.

1. At 1000 Bill of Portland Lt. Ho. (50° 31′N 2° 27′W) and the Hardy Monument (240) are seen in transit bearing 343° Gyro and at the same time the radar distance off Bill of Portland is 13·4 miles. Find the gyro course to steer and speed to steam so as to arrive at a position 1 mile South of the Needles Channel fairway buoy (50° 38′N 1° 39′W) at 1224. Make allowance for a tidal stream at Springs, four hours after H.W. Devonport.

2. A vessel steering 084° C allowing for a current setting 234° T at 2·4 knots observed Berry Head Lt. (50° 24′N 3° 29′W) bearing 348° C and Start Pt. Lt. (50° 13′N 3° 38′W) bearing 245° C. Find the vessel's position and estimate the relative bearing and distance off Bill of Portland Lt. on first sighting. Meteorological visibility is estimated to be 5 miles. Height of observer 10 m. Steaming speed 12 knots.

3. A vessel steering 109° G and steaming at 15 knots observes the following corrected Decca readings: *Red G09* and *Purple D68*. After 1 hour and 20 mins a second corrected Decca fix is obtained: *Red I21* and *Purple D77*. Find the true course, distance and speed made good, and also the set and rate of the current experienced during this period.
   Gyro error 1° low.

4. From the information shown on the chart, describe the appearance of the coast between Straight Point and St. Alban's Head both to the eye on a fine day and to a radar observer. Your ship is on passage from Teignmouth up Channel, passing 5 miles off Portland Bill. Describe also the bottom topography along your course.

5. Find the GMT during the rising tide on the morning of 13 May after which there is 10 metres of water at the entrance to Tilbury Dock (ATT Vol. 1, No. 111) at a place where the charted depth is 7·5 metres.

Oral questions. (25 marks)

[Continued]

Practical Navigation

Paper 3 *2 hours*

1. From the following observation find the direction of the P/L and a position through which it passes:

   Time at ship 0515 on 15 April 1976 DR position 17° 12′N, 124° 19′E.
   Sext alt of the star Markab 29° 03′.
   IE 2′·4 on the arc HE 14·2 m.
   Chron showed 9 h 01 m 17 s, error 2 m 32 s fast of GMT.

   (50 marks)

2. From the following observation find the direction of the P/L and the latitude in which it crosses the DR longitude:

   Time at ship 1810 on 1 January 1976 DR position 32° 15′N, 168° 14′E.
   Sext alt Jupiter near the meridian 62° 35′.
   IE 1′·5 on the arc HE 15·0 m.
   Chron showed 6 h 55 m 37 s, error 2 m 53 s fast of GMT.

   (40 marks)

3. From the following observations of Polaris during morning twilight find the latitude:

   Date at ship 7 July 1976 DR position 35° 53′N, 154° 27′E.
   Sext alt 36° 35′.
   IE 1′·5 off the arc HE 15·5 m.
   Chron showed 5 h 55 m 14 s, error 2 m 04 s slow of GMT.

   (25 marks)

4. From the following sights find the position of the ship at the time of the second observation:

   Time 1430: EP 43° 13′N, 150° 46′E, intercept 1′·6 towards, az 217° T.
   Run 60 miles. Co 290° T.
   Time 1800: Using EP run up, intercept 5′·0 away, az 100°T.

   (35 marks)

CLASS 3 CERTIFICATE OF COMPETENCY

Principles of Navigation

Paper 6 *2 hours*

Candidates are not to answer more than FIVE questions. All questions carry equal marks.

1. Calculate the initial course and distance on the great circle track from 35° 03'S, 56° 17'W to 34° 30'S, 17° 20'E.

2. Draw a figure of the celestial sphere on the plane of the observer's rational horizon for a latitude of 31° N. (Use a radius of 4·5 cm.) The LHA of Aries is 60°:
   (a) indicate the position of a body having SHA 230° 00′ and Declination 10° S;
   (b) complete the PZX triangle;
   (c) measure the approximate altitude and azimuth of the body.

3. (a) Explain the difference between Local Mean Time, Local Apparent Time and Standard Time.
   (b) At 0145 Standard Time on 27 August 1976 in Bombay (18° 55'N, 72° 50'E) what was the LMT, LAT and Standard Time in Georgetown, Guyana (6° 48'N, 58° 15'W)?

4. (a) A Mercator chart is constructed on a scale of 12·5 cm to 1° of longitude. What is the length on the latitude scale between 48° 13'N and 49° 07'N?
   (b) Describe how areas of the Earth's surface are distorted on a Mercator chart and explain why some areas are distorted more than others.

5. Describe the phenomena causing phases of the moon and state the approximate Local Apparent Time of upper meridian transit of the moon when it is:
   (a) new;
   (b) at first quarter;
   (c) full;
   (d) at last quarter.

6. Explain the meaning of the terms tilt and drift with respect to a free gyroscope. Illustrate your answer with suitable diagrams.

CLASS 3 CERTIFICATE OF COMPETENCY

Mathematics (Pure and Applied)

Paper 7 *2½ hours*

Candidates are not to answer more than SIX questions, of which at least 2 must be taken from Section B. All questions carry equal marks.

SECTION "A"

1. Simplify: (a) $\left(\frac{\sqrt[3]{128y^{3n}}}{4} \times 27^{\circ}\right)(2y^{n+3})^{-1}$ (b) $\frac{1}{(a^2-ab)(a-b)} - \frac{1}{(b^2-ab)(b-a)}$

2. (a) Solve the exponential equation:
$$3^{3x-1} = 7^{x+2}$$
(b) Convert to a common logarithm and find a decimal approximation for:
(i) $\text{Log}_2 17$
(ii) $\text{Log}_3 \pi$

3. A garden roller comes to rest against a rectangular concrete block, of height 12 cm, with its lowest point on a horizontal level surface, 24 cm from the block. By the chord and tangent properties of a circle find the radius of the roller. Verify the result by another method.

4. Solve the equation $\text{Tan}\,\chi - \text{Cot}\,\chi = 2$ for all values of χ between 0° and 360°.

5. (a) In the spherical triangle PZX: $X = 90°$, $p = 114° 20'$, $Z = 46° 15'$. Calculate side x.
(b) In the spherical triangle PZX: $Z = 86°$, $p = 108° 50'$, $x = 84° 20'$. Calculate side z.

SECTION "B"

6. A dictionary of mass 3 kg is pushed across a table with a constant horizontal force. ($\mu = 0{\cdot}4$.)
(a) If it is pushed 1 m from rest in 0·5 s, what force is applied?
(b) How much further will it travel before coming to rest, when the force is removed?

7. A force of 500 N accelerates a mass of 25 kg, from rest, for 0·5 s. Calculate the gain in momentum and kinetic energy. Also, calculate the distance required to stop the mass with a force of 500 N.

8. A manufactured unit, of uniform construction, having an overall length of 740 mm is made up with 3 sections joined together. The first section is 100 mm long with a diameter of 60 mm, the second 380 mm long with 120 mm diameter and the third 260 mm long by 80 mm diameter. Calculate the distance of the centre of gravity from one end.

CLASS 2 CERTIFICATE OF COMPETENCY

Coastal Navigation

Paper 1 *2½ hours*

In Chart questions use Deviation Card No. 6 and Variation 10° W.

The positions given after prominent points on the chart are approximate to 1′ and are to be used for identification purposes only.

1. The following echoes are observed on the radar, ship steering 261° T at 8 knots in reduced visibility:

	Target "A"		*Target "B"*	
Time	*True bearing*	*Range in miles*	*True bearing*	*Range in miles*
0240	236°	12·0	247½	12·0
0249	231°	10·2	251°	9·6
0258	225°	8·6	256°	7·3
0307	216°	7·1	265½°	5·1

Find: (a) the course and speed of each target;
(b) the true bearing and range of each target at CPA;
(c) the aspect of each target at CPA.

(45 marks)

2. From a ship in DR 51° 30′N, 10° 25′W, steering 146° gyro and steaming at 10 knots, Bull Lt. Ho. (51° 35′N, 10° 18′W) bore 033° gyro and at the same time the relative bearing of Mizen Head Ro. Bn (51° 27′N, 9° 49′W) was 306°.

Find the position of the ship at this time and the gyro course to steer to pass 7·5 miles off Fastnet Rock Lt. Ho. (51° 23′N, 9° 36′W) allowing for a tidal stream estimated to be setting 045° T at 1½ knots.

The gyro compass reads 1½° low of true throughout.

(45 marks)

3. From a ship steering 087° C at 12 knots Galley Head (51° 32′N, 8° 57′W) bore 037° C and 30 minutes later it bore 352° C. Find the position of the ship at the time of the second bearing if a current set 155° T at 1½ knots throughout.

(35 marks)

4. You are on a small vessel in DR position 51° 05′N, 9° 30′W in very restricted visibility, making for Cork from the southwest. Your vessel is equipped with gyro compass, radar, DF, and echo sounder.

Using the chart provided describe how you would approach the Irish coast and thence Cork Harbour safely and efficiently. Explain the use you would make of the various aids available, saying when you would use them and mentioning the degree of reliance you would place on them and any practical limitations on their usefulness.

(45 marks)

5. Between what times would there be at least 9·1 m of water over a 1·8 m shoal off St Malo (ATT 1614) on the morning of 13 August?

(30 marks)

CLASS 2 CERTIFICATE OF COMPETENCY

Ocean and Offshore Navigation

Paper 2 *2½ hours*

Candidates are to answer ALL questions. In order to pass, a minimum of 70 % must be obtained in Part A, 50 % in Part B and 60 % overall.

Part A

1. From the following observation find the direction of the **P/L** and a position through which it passes:

   Time at ship 1715 on 1 January 1976
   DR position 36° 10′N, 18° 47′E.
   Sext alt of Mars 24° 43′.
   IE 2′·0 on the arc. HE 14·5 m.
   Chron showed 3 h 55 m 13 s error 1 m 20 s slow of GMT.

   (30 marks)

2. From the following sights find the position of the ship at the time of the second observation:

   Time 1630: EP 16° 54′S, 160° 02′E, intercept 5′·4 away, az 351° T.
   Run 27 miles Co 307° T.
   Time 1815: Using EP run up, intercept 4′·4 towards, az 053° T.

   (25 marks)

3. From the following observation of Polaris during evening twilight find the latitude:

   Date at ship 10 September 1976 DR position 59° 54′N, 13° 12′W.
   Sext alt 59° 43′.
   IE 2′·0 off the arc. HE 8 m.
   Chron showed 7 h 58 m 56 s error 0 m 43 s fast of GMT.

   (20 marks)

Part B

4. Outline the causes of the fixed and variable errors to which the Decca navigation system is subject and explain, in detail, how these errors are allowed for and/or assessed in practice.

   (25 marks)

5. Describe how the following unwanted echoes may be produced in a marine radar:
   (a) second trace echoes;
   (b) side lobe echoes;
   (c) multiple echoes.

   (25 marks)

6. (a) Describe the receiving characteristics of a fixed loop aerial, illustrating your answer with a polar diagram.
   (b) Explain why the DF bearing is more easily determined by the 'nil aural' method than by seeking the maximum aural signal.

   (25 marks)

CLASS 1 CERTIFICATE OF COMPETENCY MASTER MARINER

Navigation

(Two examples of this paper are given)

First example

Paper 2 — *2½ hours*

1. A radar plotting sheet is to be used.

The following details were recorded in reduced visibility:

	Target A (lightvessel)		*Target B*		
Time	*True brg*	*Range in miles*	*True brg*	*Range in miles*	*Remarks*
2330	253½°	10·0	307½°	11·4	Own course 258° T at 9 knots.
2338	251½°	8·7	306½°	9·6	
2346	249°	7·4	305½°	7·7	Own engines stopped.
0010					Own vessel stopped in water heading 258° T after an advance of 1·5 miles.

(a) Find: (i) the set and rate of the current;
(ii) the course and speed of target B.
(b) Find the distance target B will pass ahead of own vessel when stopped in the water.
(c) Find the time and distance from the lightvessel when it is abeam if course and speed are resumed at 0018, assuming this to have immediate effect.

(50 marks)

2. Discuss the procedures for searching for survivors from an aircraft which has crashed into the sea about 40 miles away from your vessel in the open ocean.

What factors would have to be taken into consideration when deciding on the search pattern to be used?

(30 marks)

3. List, and discuss the philosophy behind, the Standing Orders you would draw up on joining a vessel as Master.

(30 marks)

4. Discuss how you would plan a voyage from Liverpool to New York.

List all the factors that must be taken into account and describe how you would use the Admiralty Charts and Publications appropriate for this voyage.

(40 marks)

5. You are on a voyage from Lisbon to Ceuta for bunkers in a loaded 14,000 ton, 14 knot vessel.

Using the chart and extracts from the sailing directions and Tide Tables provided, plan the passage from a position with Cape Trafalgar distant 4 miles bearing 040° T at 1800 hours GMT 7 February 1977 to a position off Ceuta suitable for picking up the pilot. Explain your plan and give the ETA of your vessel off Ceuta. What additional factors may affect the time of your vessel's arrival?

(50 marks)

CLASS 1 CERTIFICATE OF COMPETENCY MASTER MARINER

Navigation

Second example

Paper 2 *2½ hours*

Your vessel is to proceed from Milford Haven to Cork on completion of loading.

The vessel's draught will be 8·1 m for'd and 8·3 m aft. Her service speed is 14 kts. HE 12 m.

Her navigational aids are made up of a gyro compass with repeaters, magnetic compasses, two radars, Decca navigator, DF and echo-sounder.

Using the extracts from the publications and charts provided plan the passage from a position one mile due south of St. Anne's Head (51° 41′N, 5° 10°W) to a position off Whitegate Marine Terminal and, assuming that your vessel will be at the departure position at 0430 on 21 February, determine an ETA at the Pilot off Roche's Pt.

In giving your answer, prepare a bridge notebook listing the courses, the distance between alterations of course, the intended method of position fixing together with one or more additional methods to check the positions obtained and as an alternative in the event of reduced visibility, together with other information you consider necessary.

Mark on the chart the courses, distances between alterations of course and the acceptable margins of deviations from the courses layed, also mark off the rising and dipping ranges of lights etc.

In addition to preparing the bridge notebook and marking the courses etc. on the chart, you should give a detailed account of the reasons for making your choice of courses to be followed and explain how you determined your ETA at the Pilot.

Discuss the navigational aids you would use during the voyage; at what times you would use them and for what reasons.

A weather bulletin for 0030 hrs gave for Fastnet and Lundy areas a light to moderate SW'ly breeze with moderate visibility, the wind veering slightly during the day and continuing overcast with periods of continuous rain.

It can be assumed that the extracts provided are up to date for the passage.

CLASS 1 CERTIFICATE OF COMPETENCY MASTER MARINER

Navigational Aids and Instruments

Paper 5 *3 hours*

Candidates are to answer any SIX questions. All questions carry equal marks.

1. The following observations were made of the Sun when swinging ship slowly to adjust a well placed standard compass at a position where the variation was 20°W.

Compass Heading	000°	045°	090°	135°	180°	225°	270°	315°
Compass Bearing	140°	138½°	140½°	142°	143½°	145°	146°	147½°
True Bearing	124°	124½°	125½°	127°	127½°	128°	129°	129½°

(i) Obtain a list of deviations.
(ii) Analyse them into the various coefficients.
(iii) Explain how you would attempt to locate the cause and remove the effect of the largest coefficient observed.

2. A vessel had a list on completion of loading and during the river passage to sea the following deviations were noted:

Compass Heading	090°	135°	180°
Deviation	5° E	7° E	6° E

Coefficients A and E each equal 0°.
Variation = 8° E.

Find the true course steered when course was set 025° C from the fairway buoy, assuming the list remained constant throughout.

3. Describe how control and damping are achieved in any type of commercial gyro compass, stating the make and model to which your answer refers.

4. Describe the operation of an automatic steering device controlled by the magnetic compass.

5. (a) Explain how the following are achieved with respect to true motion marine radar:
   (i) a ground stabilized display;
   (ii) a sea stabilized display.
   (b) Discuss the tracking of fixed navigational targets with each type of presentation and state the circumstances under which one method of presentation would be preferable to the other and vice versa.

6. (a) Explain the properties of the hyperbola which enable it to be used as a line of position in a marine hyperbolic navigation system. Illustrate your answer with a suitable diagram.
   (b) Discuss how these properties are utilised in the Omega system.

7. (a) Describe the action of a typical echo sounding system of the recording type illustrating your answer with a block schematic diagram.
   (b) Enumerate the factors upon which the accuracy of such a system depends.

8. Describe the principle of operation and the essential components of an electromagnetic log, and discuss the merits of this instrument as compared with other types of log.

MASTER (MIDDLE TRADE) ENDORSEMENT

Magnetic and Gyro Compass and Navigational Aids

Paper 3 *2 hours*

1. (a) Discuss the circumstances which would make it necessary for a ship to be swung for compass adjustment.
   (b) From the following information calculate the magnetic bearing of the distant object and construct a table of deviations for the magnetic compass in question:

Ship's head by compass	*Compass bearing of distant object*
000°	184°
045°	176°
090°	177°
135°	180°
180°	176°
225°	174°
270°	183°
315°	190°

(40 marks)

2. (a) Describe how wind and rain can affect the display shown on the ppi of a marine radar set.
   (b) Discuss the influence of each of the above conditions on the detectable range of other targets and state the practical measures which can be taken to combat any undue adverse effects which may be present.

(30 marks)

3. Discuss the factors upon which the magnitude of the course and speed error to which a gyro compass is subject depends. Illustrate your answer with a suitable diagram.

(30 marks)

4. Explain, with the aid of a suitable diagram, the principle of the Decca marine hyperbolic navigation system.

(25 marks)

5. Explain how the direction-finding equipment on board ship can be used by a ship going to the aid of a vessel in distress.

(25 marks)

MASTER (NEAR CONTINENTAL) ENDORSEMENT

Magnetic Compass and Navigational Aids

Paper 2 *2 hours*

1. The following echoes are observed on the radar, ship steering 165° T at 9 knots:

Time	*True bearing*	*Range in miles*
1610	270°	12·0
1620	269°	9·9
1630	267½°	7·8

(a) Find the course and speed of the target vessel.
(b) Find the reduction in speed of the observer's ship at 1640, such that the target will pass ahead at a distance of 2·5 miles, assuming the reduction in speed to have immediate effect.
(c) Find the time and range at CPA subsequent to making this reduction.

(40 marks)

2. Describe the characteristics of a marine radar set which determine the range accuracy and state the provisions laid down regarding range accuracy in the Marine Radar Performance Specification.

(30 marks)

3. Discuss the correctors which would normally be necessary to correct the effects of the ship's magnetic field at the standard compass position on board a typical merchant ship designed for the near continental trade.

(30 marks)

4. Explain what is meant by the grouping of beacons and outline the method of operation of a typical group. State the advantages of the system to the navigator.

(25 marks)

5. Describe the routine care required to ensure the efficient operation of an echo sounding system of the recording type.

(25 marks)

DEVIATION CARD

No. 6

Ship s head by Compass	Deviation
000°	2·5° E
010°	
020°	1·5° E
030°	
040°	0·5° E
050°	
060°	0·5° W
070°	
080°	2·0° W
090°	
100°	3·0° W
110°	
120°	4·0° W
130°	
140°	4·5° W
150°	
160°	5·0° W
170°	
180°	5·0° W
190°	
200°	4·0° W
210°	
220°	3·0° W
230°	
240°	1·5° W
250°	
260°	0·0.
270°	
280°	2·0° E
290°	
300°	4·0° E
310°	
320°	5·0° E
330°	
340°	4·0° E
350°	

7634/1397L. D.894679 360 9/71 T.P. Gp.658

DEVIATION CARD

No. 7

Ship's Head by Compass	Deviation
000°	3°0 E
010°	
020°	1°.5 W
030°	
040°	4°.5 W
050°	
060°	3°.5 W
070°	
080°	0°.5 E
090°	
100°	5°.5 E
110°	
120°	9°.0 E
130°	
140°	8°.5 E
150°	
160°	4°.0 E
170°	
180°	1°.0 W
190°	
200°	7°.0 W
210°	
220°	9°.5 W
230°	
240°	9°.0 W
250°	
260°	4°.0 W
270°	
280°	2°.0 E
290°	
300°	7°.5 E
310°	
320°	9°.0 E
330°	
340°	7°.5 E
350°	

2292/1397L D527507 360 10/76 TP Gp 3628/2

Nautical Almanac
1976
Extracts

For use with D.Tp. Specimen Papers *ONLY*.
(Not to be used with other Exercises and Papers.)

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ALTITUDE CORRECTION TABLES 10°-90°—SUN, STARS, PLANETS

SUN

OCT.—MAR. App. Alt.	Lower Limb	Upper Limb	APR.—SEPT. App. Alt.	Lower Limb	Upper Limb
° ′	′	′	° ′	′	′
9 34	+10·8	−21·5	9 39	+10·6	−21·2
9 45	+10·9	−21·4	9 51	+10·7	−21·1
9 56	+11·0	−21·3	10 03	+10·8	−21·0
10 08	+11·1	−21·2	10 15	+10·9	−20·9
10 21	+11·2	−21·1	10 27	+11·0	−20·8
10 34	+11·3	−21·0	10 40	+11·1	−20·7
10 47	+11·4	−20·9	10 54	+11·2	−20·6
11 01	+11·5	−20·8	11 08	+11·3	−20·5
11 15	+11·6	−20·7	11 23	+11·4	−20·4
11 30	+11·7	−20·6	11 38	+11·5	−20·3
11 46	+11·8	−20·5	11 54	+11·6	−20·2
12 02	+11·9	−20·4	12 10	+11·7	−20·1
12 19	+12·0	−20·3	12 28	+11·8	−20·0
12 37	+12·1	−20·2	12 46	+11·9	−19·9
12 55	+12·2	−20·1	13 05	+12·0	−19·8
13 14	+12·3	−20·0	13 24	+12·1	−19·7
13 35	+12·4	−19·9	13 45	+12·2	−19·6
13 56	+12·5	−19·8	14 07	+12·3	−19·5
14 18	+12·6	−19·7	14 30	+12·4	−19·4
14 42	+12·7	−19·6	14 54	+12·5	−19·3
15 06	+12·8	−19·5	15 19	+12·6	−19·2
15 32	+12·9	−19·4	15 46	+12·7	−19·1
15 59	+13·0	−19·3	16 14	+12·8	−19·0
16 28	+13·1	−19·2	16 44	+12·9	−18·9
16 59	+13·2	−19·1	17 15	+13·0	−18·8
17 32	+13·3	−19·0	17 48	+13·1	−18·7
18 06	+13·4	−18·9	18 24	+13·2	−18·6
18 42	+13·5	−18·8	19 01	+13·3	−18·5
19 21	+13·6	−18·7	19 42	+13·4	−18·4
20 03	+13·7	−18·6	20 25	+13·5	−18·3
20 48	+13·8	−18·5	21 11	+13·6	−18·2
21 35	+13·9	−18·4	22 00	+13·7	−18·1
22 26	+14·0	−18·3	22 54	+13·8	−18·0
23 22	+14·1	−18·2	23 51	+13·9	−17·9
24 21	+14·2	−18·1	24 53	+14·0	−17·8
25 26	+14·3	−18·0	26 00	+14·1	−17·7
26 36	+14·4	−17·9	27 13	+14·2	−17·6
27 52	+14·5	−17·8	28 33	+14·3	−17·5
29 15	+14·6	−17·7	30 00	+14·4	−17·4
30 46	+14·7	−17·6	31 35	+14·5	−17·3
32 26	+14·8	−17·5	33 20	+14·6	−17·2
34 17	+14·9	−17·4	35 17	+14·7	−17·1
36 20	+15·0	−17·3	37 26	+14·8	−17·0
38 36	+15·1	−17·2	39 50	+14·9	−16·9
41 08	+15·2	−17·1	42 31	+15·0	−16·8
43 59	+15·3	−17·0	45 31	+15·1	−16·7
47 10	+15·4	−16·9	48 55	+15·2	−16·6
50 46	+15·5	−16·8	52 44	+15·3	−16·5
54 49	+15·6	−16·7	57 02	+15·4	−16·4
59 23	+15·7	−16·6	61 51	+15·5	−16·3
64 30	+15·8	−16·5	67 17	+15·6	−16·2
70 12	+15·9	−16·4	73 16	+15·7	−16·1
76 26	+16·0	−16·3	79 43	+15·8	−16·0
83 05	+16·1	−16·2	86 32	+15·9	−15·9
90 00			90 00		

STARS AND PLANETS

App. Alt.	Corrⁿ
° ′	′
9 56	−5·3
10 08	−5·2
10 20	−5·1
10 33	−5·0
10 46	−4·9
11 00	−4·8
11 14	−4·7
11 29	−4·6
11 45	−4·5
12 01	−4·4
12 18	−4·3
12 35	−4·2
12 54	−4·1
13 13	−4·0
13 33	−3·9
13 54	−3·8
14 16	−3·7
14 40	−3·6
15 04	−3·5
15 30	−3·4
15 57	−3·3
16 26	−3·2
16 56	−3·1
17 28	−3·0
18 02	−2·9
18 38	−2·8
19 17	−2·7
19 58	−2·6
20 42	−2·5
21 28	−2·4
22 19	−2·3
23 13	−2·2
24 11	−2·1
25 14	−2·0
26 22	−1·9
27 36	−1·8
28 56	−1·7
30 24	−1·6
32 00	−1·5
33 45	−1·4
35 40	−1·3
37 48	−1·2
40 08	−1·1
42 44	−1·0
45 36	−0·9
48 47	−0·8
52 18	−0·7
56 11	−0·6
60 28	−0·5
65 08	−0·4
70 11	−0·3
75 34	−0·2
81 13	−0·1
87 03	0·0
90 00	

Additional Corrⁿ
1976
VENUS
Jan. 1 —Dec. 12
° ′ 42 + 0·1
Dec. 13 —Dec. 31
° ′ 47 + 0·2
MARS
Jan. 1 —Feb. 19
° ′ 41 + 0·2 75 + 0·1
Feb. 20 —Dec. 31
° ′ 60 + 0·1

DIP

Ht. of Eye	Corrⁿ	Ht. of Eye	Ht. of Eye	Corrⁿ
m	′	ft.	m	′
2·4	2·8	8·0	1·0 —	1·8
2·6	2·9	8·6	1·5 —	2·2
2·8	3·0	9·2	2·0 —	2·5
3·0	3·1	9·8	2·5 —	2·8
3·2	3·2	10·5	3·0 —	3·0
3·4	3·3	11·2	See table	
3·6	3·4	11·9	←	
3·8	3·5	12·6	m	′
4·0	3·6	13·3	20 —	7·9
4·3	3·7	14·1	22 —	8·3
4·5	3·8	14·9	24 —	8·6
4·7	3·9	15·7	26 —	9·0
5·0	4·0	16·5	28 —	9·3
5·2	4·1	17·4		
5·5	4·2	18·3	30 —	9·6
5·8	4·3	19·1	32 —	10·0
6·1	4·4	20·1	34 —	10·3
6·3	4·5	21·0	36 —	10·6
6·6	4·6	22·0	38 —	10·8
6·9	4·7	22·9		
7·2	4·8	23·9	40 —	11·1
7·5	4·9	24·9	42 —	11·4
7·9	5·0	26·0	44 —	11·7
8·2	5·1	27·1	46 —	11·9
8·5	5·2	28·1	48 —	12·2
8·8	5·3	29·2	ft.	′
9·2	5·4	30·4	2 —	1·4
9·5	5·5	31·5	4 —	1·9
9·9	5·6	32·7	6 —	2·4
10·3	5·7	33·9	8 —	2·7
10·6	5·8	35·1	10 —	3·1
11·0	5·9	36·3	See table	
11·4	6·0	37·6	←	
11·8	6·1	38·9	ft.	
12·2	6·2	40·1	70 —	8·1
12·6	6·3	41·5	75 —	8·4
13·0	6·4	42·8	80 —	8·7
13·4	6·5	44·2	85 —	8·9
13·8	6·6	45·5	90 —	9·2
14·2	6·7	46·9	95 —	9·5
14·7	6·8	48·4		
15·1	6·9	49·8	100 —	9·7
15·5	7·0	51·3	105 —	9·9
16·0	7·1	52·8	110 —	10·2
16·5	7·2	54·3	115 —	10·4
16·9	7·3	55·8	120 —	10·6
17·4	7·4	57·4	125 —	10·8
17·9	7·5	58·9		
18·4	7·6	60·5	130 —	11·1
18·8	7·7	62·1	135 —	11·3
19·3	7·8	63·8	140 —	11·5
19·8	7·9	65·4	145 —	11·7
20·4	8·0	67·1	150 —	11·9
20·9	8·1	68·8	155 —	12·1
21·4		70·5		

App. Alt. = Apparent altitude = Sextant altitude corrected for index error and dip.

For daylight observations of Venus, see page 260.

INDEX TO SELECTED STARS, 1976

Name	No.	Mag.	S.H.A.	Dec.
			°	°
Acamar	7	3·1	316	S. 40
Achernar	5	0·6	336	S. 57
Acrux	30	1·1	174	S. 63
Adhara	19	1·6	256	S. 29
Aldebaran	10	1·1	291	N. 16
Alioth	32	1·7	167	N. 56
Alkaid	34	1·9	153	N. 49
Al Na'ir	55	2·2	28	S. 47
Alnilam	15	1·8	276	S. 1
Alphard	25	2·2	218	S. 9
Alphecca	41	2·3	127	N. 27
Alpheratz	1	2·2	358	N. 29
Altair	51	0·9	63	N. 9
Ankaa	2	2·4	354	S. 42
Antares	42	1·2	113	S. 26
Arcturus	37	0·2	146	N. 19
Atria	43	1·9	108	S. 69
Avior	22	1·7	234	S. 59
Bellatrix	13	1·7	279	N. 6
Betelgeuse	16	Var.*	272	N. 7
Canopus	17	−0·9	264	S. 53
Capella	12	0·2	281	N. 46
Deneb	53	1·3	50	N. 45
Denebola	28	2·2	183	N. 15
Diphda	4	2·2	349	S. 18
Dubhe	27	2·0	194	N. 62
Elnath	14	1·8	279	N. 29
Eltanin	47	2·4	91	N. 51
Enif	54	2·5	34	N. 10
Fomalhaut	56	1·3	16	S. 30
Gacrux	31	1·6	173	S. 57
Gienah	29	2·8	176	S. 17
Hadar	35	0·9	149	S. 60
Hamal	6	2·2	329	N. 23
Kaus Australis	48	2·0	84	S. 34
Kochab	40	2·2	137	N. 74
Markab	57	2·6	14	N. 15
Menkar	8	2·8	315	N. 4
Menkent	36	2·3	149	S. 36
Miaplacidus	24	1·8	222	S. 70
Mirfak	9	1·9	309	N. 50
Nunki	50	2·1	77	S. 26
Peacock	52	2·1	54	S. 57
Pollux	21	1·2	244	N. 28
Procyon	20	0·5	245	N. 5
Rasalhague	46	2·1	97	N. 13
Regulus	26	1·3	208	N. 12
Rigel	11	0·3	282	S. 8
Rigil Kentaurus	38	0·1	140	S. 61
Sabik	44	2·6	103	S. 16
Schedar	3	2·5	350	N. 56
Shaula	45	1·7	97	S. 37
Sirius	18	−1·6	259	S. 17
Spica	33	1·2	159	S. 11
Suhail	23	2·2	223	S. 43
Vega	49	0·1	81	N. 39
Zubenelgenubi	39	2·9	138	S. 16

No.	Name	Mag.	S.H.A.	Dec.
			°	°
1	*Alpheratz*	2·2	358	N. 29
2	*Ankaa*	2·4	354	S. 42
3	*Schedar*	2·5	350	N. 56
4	*Diphda*	2·2	349	S. 18
5	*Achernar*	0·6	336	S. 57
6	*Hamal*	2·2	329	N. 23
7	*Acamar*	3·1	316	S. 40
8	*Menkar*	2·8	315	N. 4
9	*Mirfak*	1·9	309	N. 50
10	*Aldebaran*	1·1	291	N. 16
11	*Rigel*	0·3	282	S. 8
12	*Capella*	0·2	281	N. 46
13	*Bellatrix*	1·7	279	N. 6
14	*Elnath*	1·8	279	N. 29
15	*Alnilam*	1·8	276	S. 1
16	*Betelgeuse*	Var.*	272	N. 7
17	*Canopus*	−0·9	264	S. 53
18	*Sirius*	−1·6	259	S. 17
19	*Adhara*	1·6	256	S. 29
20	*Procyon*	0·5	245	N. 5
21	*Pollux*	1·2	244	N. 28
22	*Avior*	1·7	234	S. 59
23	*Suhail*	2·2	223	S. 43
24	*Miaplacidus*	1·8	222	S. 70
25	*Alphard*	2·2	218	S. 9
26	*Regulus*	1·3	208	N. 12
27	*Dubhe*	2·0	194	N. 62
28	*Denebola*	2·2	183	N. 15
29	*Gienah*	2·8	176	S. 17
30	*Acrux*	1·1	174	S. 63
31	*Gacrux*	1·6	173	S. 57
32	*Alioth*	1·7	167	N. 56
33	*Spica*	1·2	159	S. 11
34	*Alkaid*	1·9	153	N. 49
35	*Hadar*	0·9	149	S. 60
36	*Menkent*	2·3	149	S. 36
37	*Arcturus*	0·2	146	N. 19
38	*Rigil Kentaurus*	0·1	140	S. 61
39	*Zubenelgenubi*	2·9	138	S. 16
40	*Kochab*	2·2	137	N. 74
41	*Alphecca*	2·3	127	N. 27
42	*Antares*	1·2	113	S. 26
43	*Atria*	1·9	108	S. 69
44	*Sabik*	2·6	103	S. 16
45	*Shaula*	1·7	97	S. 37
46	*Rasalhague*	2·1	97	N. 13
47	*Eltanin*	2·4	91	N. 51
48	*Kaus Australis*	2·0	84	S. 34
49	*Vega*	0·1	81	N. 39
50	*Nunki*	2·1	77	S. 26
51	*Altair*	0·9	63	N. 9
52	*Peacock*	2·1	54	S. 57
53	*Deneb*	1·3	50	N. 45
54	*Enif*	2·5	34	N. 10
55	*Al Na'ir*	2·2	28	S. 47
56	*Fomalhaut*	1·3	16	S. 30
57	*Markab*	2·6	14	N. 15

* 0·1—1·2

1976 JANUARY 1, 2, 3 (THURS., FRI., SAT.)

G.M.T.	ARIES	VENUS −3.6		MARS −1.1		JUPITER −2.1		SATURN 0.0	
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1 00	99 47.2	222 06.2	S17 51.6	23 50.3	N25 57.4	84 58.5	N 4 54.8	336 26.6	N20 10.4
01	114 49.6	237 05.6	52.3	38 53.4	57.3	100 00.8	54.9	351 29.3	10.5
02	129 52.1	252 05.0	53.0	53 56.6	57.3	115 03.1	55.0	6 31.9	10.5
03	144 54.6	267 04.4	·· 53.7	68 59.8	·· 57.2	130 05.4	·· 55.1	21 34.6	·· 10.6
04	159 57.0	282 03.8	54.4	84 03.0	57.2	145 07.7	55.1	36 37.2	10.6
05	174 59.5	297 03.2	55.1	99 06.2	57.2	160 10.0	55.2	51 39.9	10.7
06	190 02.0	312 02.6	S17 55.8	114 09.4	N25 57.1	175 12.3	N 4 55.3	66 42.5	N20 10.7
07	205 04.4	327 02.0	56.5	129 12.6	57.1	190 14.6	55.4	81 45.2	10.8
T 08	220 06.9	342 01.4	57.2	144 15.8	57.0	205 16.9	55.5	96 47.8	10.8
H 09	235 09.4	357 00.8	·· 57.9	159 19.0	·· 57.0	220 19.2	·· 55.6	111 50.5	·· 10.8
U 10	250 11.8	12 00.2	58.5	174 22.2	56.9	235 21.5	55.6	126 53.2	10.9
R 11	265 14.3	26 59.6	59.2	189 25.3	56.9	250 23.8	55.7	141 55.8	10.9
S 12	280 16.7	41 59.0	S17 59.9	204 28.5	N25 56.9	265 26.1	N 4 55.8	156 58.5	N20 11.0
D 13	295 19.2	56 58.4	18 00.6	219 31.7	56.8	280 28.4	55.9	172 01.1	11.0
A 14	310 21.7	71 57.8	01.3	234 34.9	56.8	295 30.7	56.0	187 03.8	11.1
Y 15	325 24.1	86 57.2	·· 02.0	249 38.1	·· 56.7	310 33.0	·· 56.0	202 06.4	·· 11.1
16	340 26.6	101 56.6	02.7	264 41.2	56.7	325 35.3	56.1	217 09.1	11.2
17	355 29.1	116 56.0	03.4	279 44.4	56.6	340 37.6	56.2	232 11.7	11.2
18	10 31.5	131 55.4	S18 04.1	294 47.6	N25 56.6	355 39.9	N 4 56.3	247 14.4	N20 11.2
19	25 34.0	146 54.8	04.7	309 50.8	56.6	10 42.2	56.4	262 17.1	11.3
20	40 36.5	161 54.2	05.4	324 53.9	56.5	25 44.5	56.5	277 19.7	11.3
21	55 38.9	176 53.5	·· 06.1	339 57.1	·· 56.5	40 46.8	·· 56.5	292 22.4	·· 11.4
22	70 41.4	191 52.9	06.8	355 00.3	56.4	55 49.1	56.6	307 25.0	11.4
23	85 43.9	206 52.3	07.5	10 03.4	56.4	70 51.4	56.7	322 27.7	11.5
2 00	100 46.3	221 51.7	S18 08.2	25 06.6	N25 56.3	85 53.7	N 4 56.8	337 30.3	N20 11.5
01	115 48.8	236 51.1	08.8	40 09.7	56.3	100 56.0	56.9	352 33.0	11.6
02	130 51.2	251 50.5	09.5	55 12.9	56.3	115 58.3	57.0	7 35.6	11.6
03	145 53.7	266 49.9	·· 10.2	70 16.1	·· 56.2	131 00.6	·· 57.1	22 38.3	·· 11.7
04	160 56.2	281 49.3	10.9	85 19.2	56.2	146 02.8	57.1	37 41.0	11.7
05	175 58.6	296 48.7	11.6	100 22.4	56.1	161 05.1	57.2	52 43.6	11.7
06	191 01.1	311 48.1	S18 12.2	115 25.5	N25 56.1	176 07.4	N 4 57.3	67 46.3	N20 11.8
07	206 03.6	326 47.4	12.9	130 28.7	56.0	191 09.7	57.4	82 48.9	11.8
08	221 06.0	341 46.8	13.6	145 31.8	56.0	206 12.0	57.5	97 51.6	11.9
F 09	236 08.5	356 46.2	·· 14.3	160 35.0	·· 56.0	221 14.3	·· 57.6	112 54.2	·· 11.9
R 10	251 11.0	11 45.6	14.9	175 38.1	55.9	236 16.6	57.6	127 56.9	12.0
I 11	266 13.4	26 45.0	15.6	190 41.3	55.9	251 18.9	57.7	142 59.6	12.0
D 12	281 15.9	41 44.4	S18 16.3	205 44.4	N25 55.8	266 21.2	N 4 57.8	158 02.2	N20 12.1
A 13	296 18.4	56 43.7	16.9	220 47.6	55.8	281 23.5	57.9	173 04.9	12.1
Y 14	311 20.8	71 43.1	17.6	235 50.7	55.7	296 25.8	58.0	188 07.5	12.2
15	326 23.3	86 42.5	·· 18.3	250 53.9	·· 55.7	311 28.0	·· 58.1	203 10.2	·· 12.2
16	341 25.7	101 41.9	19.0	265 57.0	55.7	326 30.3	58.2	218 12.8	12.2
17	356 28.2	116 41.3	19.6	281 00.1	55.6	341 32.6	58.2	233 15.5	12.3
18	11 30.7	131 40.7	S18 20.3	296 03.3	N25 55.6	356 34.9	N 4 58.3	248 18.2	N20 12.3
19	26 33.1	146 40.0	21.0	311 06.4	55.5	11 37.2	58.4	263 20.8	12.4
20	41 35.6	161 39.4	21.6	326 09.6	55.5	26 39.5	58.5	278 23.5	12.4
21	56 38.1	176 38.8	·· 22.3	341 12.7	·· 55.4	41 41.8	·· 58.6	293 26.1	·· 12.5
22	71 40.5	191 38.2	23.0	356 15.8	55.4	56 44.1	58.7	308 28.8	12.5
23	86 43.0	206 37.5	23.6	11 19.0	55.3	71 46.4	58.8	323 31.5	12.6
3 00	101 45.5	221 36.9	S18 24.3	26 22.1	N25 55.3	86 48.6	N 4 58.8	338 34.1	N20 12.6
01	116 47.9	236 36.3	24.9	41 25.2	55.3	101 50.9	58.9	353 36.8	12.7
02	131 50.4	251 35.7	25.6	56 28.3	55.2	116 53.2	59.0	8 39.4	12.7
03	146 52.8	266 35.1	·· 26.3	71 31.5	·· 55.2	131 55.5	·· 59.1	23 42.1	·· 12.8
04	161 55.3	281 34.4	26.9	86 34.6	55.1	146 57.8	59.2	38 44.8	12.8
05	176 57.8	296 33.8	27.6	101 37.7	55.1	162 00.1	59.3	53 47.4	12.8
06	192 00.2	311 33.2	S18 28.3	116 40.8	N25 55.0	177 02.4	N 4 59.4	68 50.1	N20 12.9
07	207 02.7	326 32.6	28.9	131 43.9	55.0	192 04.6	59.5	83 52.7	12.9
S 08	222 05.2	341 31.9	29.6	146 47.1	55.0	207 06.9	59.5	98 55.4	13.0
A 09	237 07.6	356 31.3	·· 30.2	161 50.2	·· 54.9	222 09.2	·· 59.6	113 58.0	·· 13.0
T 10	252 10.1	11 30.7	30.9	176 53.3	54.9	237 11.5	59.7	129 00.7	13.1
U 11	267 12.6	26 30.0	31.5	191 56.4	54.8	252 13.8	59.8	144 03.4	13.1
R 12	282 15.0	41 29.4	S18 32.2	206 59.5	N25 54.8	267 16.1	N 4 59.9	159 06.0	N20 13.2
D 13	297 17.5	56 28.8	32.8	222 02.6	54.7	282 18.4	5 00.0	174 08.7	13.2
A 14	312 20.0	71 28.2	33.5	237 05.7	54.7	297 20.6	00.1	189 11.3	13.3
Y 15	327 22.4	86 27.5	·· 34.1	252 08.8	·· 54.6	312 22.9	·· 00.2	204 14.0	·· 13.3
16	342 24.9	101 26.9	34.8	267 11.9	54.6	327 25.2	00.3	219 16.7	13.3
17	357 27.3	116 26.3	35.4	282 15.0	54.6	342 27.5	00.3	234 19.3	13.4
18	12 29.8	131 25.6	S18 36.1	297 18.1	N25 54.5	357 29.8	N 5 00.4	249 22.0	N20 13.4
19	27 32.3	146 25.0	36.7	312 21.2	54.5	12 32.0	00.5	264 24.6	13.5
20	42 34.7	161 24.4	37.4	327 24.3	54.4	27 34.3	00.6	279 27.3	13.5
21	57 37.2	176 23.7	·· 38.0	342 27.4	·· 54.4	42 36.6	·· 00.7	294 30.0	·· 13.6
22	72 39.7	191 23.1	38.7	357 30.5	54.3	57 38.9	00.8	309 32.6	13.6
23	87 42.1	206 22.5	39.3	12 33.6	54.3	72 41.2	00.9	324 35.3	13.7
Mer. Pass.	h m 17 14.1	v −0.6	d 0.7	v 3.1	d 0.0	v 2.3	d 0.1	v 2.7	d 0.0

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 39.4	S40 24.2
Achernar	335 47.5	S57 21.8
Acrux	173 40.7	S62 57.8
Adhara	255 34.2	S28 56.5
Aldebaran	291 21.3	N16 27.7
Alioth	166 45.4	N56 05.0
Alkaid	153 21.2	N49 25.7
Al Na'ir	28 19.3	S47 04.8
Alnilam	276 14.5	S 1 13.1
Alphard	218 23.4	S 8 33.4
Alphecca	126 35.1	N26 47.6
Alpheratz	358 12.6	N28 57.7
Altair	62 35.9	N 8 48.4
Ankaa	353 43.4	S42 26.3
Antares	113 01.1	S26 22.7
Arcturus	146 21.5	N19 18.3
Atria	108 28.6	S68 58.9
Avior	234 28.9	S59 25.9
Bellatrix	279 01.8	N 6 19.6
Betelgeuse	271 31.4	N 7 24.1
Canopus	264 08.0	S52 41.1
Capella	281 15.5	N45 58.5
Deneb	49 51.0	N45 11.9
Denebola	183 02.2	N14 42.2
Diphda	349 24.1	S18 07.1
Dubhe	194 25.8	N61 52.4
Elnath	278 47.8	N28 35.2
Eltanin	90 59.7	N51 29.5
Enif	34 14.9	N 9 46.0
Fomalhaut	15 55.1	S29 45.0
Gacrux	172 32.2	S56 58.5
Gienah	176 21.2	S17 24.5
Hadar	149 28.0	S60 15.2
Hamal	328 32.4	N23 21.1
Kaus Aust.	84 21.5	S34 23.7
Kochab	137 19.6	N74 14.9
Markab	14 06.5	N15 04.7
Menkar	314 44.2	N 3 59.8
Menkent	148 40.9	S36 15.0
Miaplacidus	221 44.8	S69 37.0
Mirfak	309 20.3	N49 46.8
Nunki	76 33.5	S26 19.6
Peacock	54 04.0	S56 48.8
Pollux	244 01.7	N28 04.9
Procyon	245 28.8	N 5 17.1
Rasalhague	96 32.9	N12 34.6
Regulus	208 13.2	N12 04.9
Rigel	281 38.7	S 8 13.8
Rigil Kent.	140 30.4	S60 43.9
Sabik	102 45.1	S15 41.7
Schedar	350 12.6	N56 24.7
Shaula	97 00.5	S37 05.1
Sirius	258 58.1	S16 41.1
Spica	159 00.9	S11 02.2
Suhail	223 12.7	S43 20.1
Vega	80 58.4	N38 45.7
Zuben'ubi	137 36.7	S15 56.5

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	121 05.4	9 13
Mars	284 20.3	22 15
Jupiter	345 07.4	18 14
Saturn	236 44.0	1 30

1976 JANUARY 1, 2, 3 (THURS., FRI., SAT.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
1 00	179 14.4	S23 05.2	187 33.2	7.6	S20 02.5	2.8	57.7
01	194 14.1	05.0	201 59.8	7.7	19 59.7	3.0	57.6
02	209 13.8	04.8	216 26.5	7.8	19 56.7	3.1	57.6
03	224 13.5	04.6	230 53.3	7.7	19 53.6	3.2	57.6
04	239 13.2	04.4	245 20.0	7.9	19 50.4	3.3	57.6
05	254 12.9	04.2	259 46.9	7.9	19 47.1	3.4	57.6
06	269 12.6	S23 04.1	274 13.8	7.9	S19 43.7	3.6	57.5
07	284 12.3	03.9	288 40.7	8.1	19 40.1	3.6	57.5
T 08	299 12.0	03.7	303 07.8	8.0	19 36.5	3.8	57.5
H 09	314 11.7	03.5	317 34.8	8.1	19 32.7	3.9	57.5
U 10	329 11.4	03.3	332 01.9	8.2	19 28.8	3.9	57.4
R 11	344 11.1	03.1	346 29.1	8.3	19 24.9	4.1	57.4
S 12	359 10.8	S23 02.9	0 56.4	8.3	S19 20.8	4.2	57.4
D 13	14 10.5	02.7	15 23.7	8.3	19 16.6	4.4	57.4
A 14	29 10.2	02.5	29 51.0	8.4	19 12.2	4.4	57.3
Y 15	44 09.9	02.3	44 18.4	8.5	19 07.8	4.5	57.3
16	59 09.6	02.1	58 45.9	8.6	19 03.3	4.6	57.3
17	74 09.3	01.9	73 13.5	8.6	18 58.7	4.8	57.3
18	89 09.0	S23 01.7	87 41.1	8.6	S18 53.9	4.8	57.2
19	104 08.7	01.5	102 08.7	8.8	18 49.1	5.0	57.2
20	119 08.4	01.3	116 36.5	8.8	18 44.1	5.0	57.2
21	134 08.1	01.1	131 04.3	8.8	18 39.1	5.2	57.2
22	149 07.8	00.9	145 32.1	9.0	18 33.9	5.2	57.1
23	164 07.5	00.7	160 00.1	8.9	18 28.7	5.4	57.1
2 00	179 07.2	S23 00.5	174 28.0	9.1	S18 23.3	5.4	57.1
01	194 06.9	00.3	188 56.1	9.1	18 17.9	5.5	57.1
02	209 06.6	23 00.1	203 24.2	9.2	18 12.4	5.7	57.0
03	224 06.3	22 59.9	217 52.4	9.3	18 06.7	5.7	57.0
04	239 06.0	59.7	232 20.7	9.3	18 01.0	5.8	57.0
05	254 05.8	59.5	246 49.0	9.4	17 55.2	6.0	57.0
06	269 05.5	S22 59.3	261 17.4	9.5	S17 49.2	6.0	56.9
07	284 05.2	59.0	275 45.9	9.5	17 43.2	6.1	56.9
08	299 04.9	58.8	290 14.4	9.6	17 37.1	6.2	56.9
F 09	314 04.6	58.6	304 43.0	9.7	17 30.9	6.3	56.9
R 10	329 04.3	58.4	319 11.7	9.8	17 24.6	6.3	56.8
I 11	344 04.0	58.2	333 40.5	9.8	17 18.3	6.5	56.8
D 12	359 03.7	S22 58.0	348 09.3	9.9	S17 11.8	6.5	56.8
A 13	14 03.4	57.8	2 38.2	9.9	17 05.3	6.7	56.8
Y 14	29 03.1	57.6	17 07.1	10.1	16 58.6	6.7	56.7
15	44 02.8	57.3	31 36.2	10.1	16 51.9	6.8	56.7
16	59 02.5	57.1	46 05.3	10.1	16 45.1	6.9	56.7
17	74 02.2	56.9	60 34.4	10.3	16 38.2	6.9	56.7
18	89 01.9	S22 56.7	75 03.7	10.3	S16 31.3	7.1	56.6
19	104 01.6	56.5	89 33.0	10.4	16 24.2	7.1	56.6
20	119 01.3	56.2	104 02.4	10.5	16 17.1	7.2	56.6
21	134 01.0	56.0	118 31.9	10.5	16 09.9	7.3	56.6
22	149 00.7	55.8	133 01.4	10.6	16 02.6	7.3	56.5
23	164 00.5	55.6	147 31.0	10.7	15 55.3	7.5	56.5
3 00	179 00.2	S22 55.4	162 00.7	10.7	S15 47.8	7.5	56.5
01	193 59.9	55.1	176 30.4	10.9	15 40.3	7.5	56.5
02	208 59.6	54.9	191 00.3	10.8	15 32.8	7.7	56.4
03	223 59.3	54.7	205 30.1	11.0	15 25.1	7.7	56.4
04	238 59.0	54.5	220 00.1	11.0	15 17.4	7.8	56.4
05	253 58.7	54.2	234 30.1	11.1	15 09.6	7.9	56.3
06	268 58.4	S22 54.0	249 00.2	11.2	S15 01.7	7.9	56.3
07	283 58.1	53.8	263 30.4	11.3	14 53.8	8.0	56.3
S 08	298 57.8	53.5	278 00.7	11.3	14 45.8	8.0	56.3
A 09	313 57.5	53.3	292 31.0	11.4	14 37.8	8.2	56.2
T 10	328 57.2	53.1	307 01.4	11.4	14 29.6	8.1	56.2
U 11	343 57.0	52.8	321 31.8	11.6	14 21.5	8.3	56.2
R 12	358 56.7	S22 52.6	336 02.4	11.6	S14 13.2	8.3	56.2
D 13	13 56.4	52.4	350 33.0	11.6	14 04.9	8.4	56.1
A 14	28 56.1	52.1	5 03.6	11.8	13 56.5	8.4	56.1
Y 15	43 55.8	51.9	19 34.4	11.8	13 48.1	8.5	56.1
16	58 55.5	51.7	34 05.2	11.9	13 39.6	8.6	56.1
17	73 55.2	51.4	48 36.1	11.9	13 31.0	8.6	56.0
18	88 54.9	S22 51.2	63 07.0	12.0	S13 22.4	8.6	56.0
19	103 54.6	51.0	77 38.0	12.1	13 13.8	8.8	56.0
20	118 54.3	50.7	92 09.1	12.2	13 05.0	8.7	56.0
21	133 54.0	50.5	106 40.3	12.2	12 56.3	8.9	55.9
22	148 53.8	50.2	121 11.5	12.3	12 47.4	8.8	55.9
23	163 53.5	50.0	135 42.8	12.3	12 38.6	9.0	55.9
	S.D. 16.3	d 0.2	S.D. 15.6		15.5		15.3

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 1	Moonrise 2	Moonrise 3	Moonrise 4
°	h m	h m	h m	h m	h m	h m	h m
N 72	08 24	10 42	▬	▬	11 43	11 04	10 46
N 70	08 05	09 49	▬	11 03	10 44	10 35	10 28
68	07 50	09 17	▬	09 59	10 09	10 13	10 14
66	07 37	08 53	10 27	09 24	09 44	09 55	10 02
64	07 27	08 34	09 49	08 58	09 24	09 41	09 53
62	07 17	08 19	09 23	08 38	09 08	09 29	09 44
60	07 09	08 05	09 02	08 22	08 55	09 19	09 37
N 58	07 02	07 54	08 45	08 08	08 43	09 10	09 31
56	06 56	07 44	08 31	07 56	08 33	09 02	09 25
54	06 50	07 36	08 19	07 46	08 24	08 55	09 20
52	06 44	07 28	08 08	07 36	08 16	08 49	09 15
50	06 39	07 20	07 58	07 28	08 09	08 43	09 11
45	06 28	07 05	07 38	07 10	07 54	08 30	09 02
N 40	06 18	06 52	07 22	06 56	07 41	08 20	08 54
35	06 09	06 40	07 08	06 43	07 30	08 11	08 48
30	06 00	06 30	06 56	06 33	07 21	08 04	08 42
20	05 44	06 11	06 35	06 14	07 04	07 50	08 32
N 10	05 28	05 54	06 17	05 58	06 50	07 38	08 23
0	05 11	05 38	06 00	05 43	06 37	07 27	08 15
S 10	04 53	05 20	05 43	05 28	06 23	07 16	08 07
20	04 31	05 00	05 24	05 12	06 09	07 04	07 58
30	04 02	04 35	05 02	04 53	05 52	06 51	07 48
35	03 44	04 20	04 50	04 43	05 43	06 43	07 42
40	03 21	04 02	04 35	04 30	05 32	06 34	07 35
45	02 51	03 40	04 17	04 16	05 19	06 23	07 27
S 50	02 08	03 11	03 55	03 58	05 03	06 11	07 18
52	01 41	02 57	03 45	03 49	04 56	06 05	07 14
54	01 01	02 39	03 33	03 40	04 47	05 58	07 09
56	////	02 18	03 19	03 29	04 38	05 51	07 04
58	////	01 50	03 03	03 17	04 28	05 42	06 58
S 60	////	01 06	02 43	03 03	04 16	05 33	06 51

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 1	Moonset 2	Moonset 3	Moonset 4
°	h m	h m	h m	h m	h m	h m	h m
N 72	▬	13 26	15 44	▬	14 07	16 30	18 26
N 70	▬	14 18	16 03	12 56	15 06	16 58	18 42
68	▬	14 51	16 18	13 59	15 40	17 19	18 55
66	13 40	15 15	16 30	14 34	16 04	17 36	19 05
64	14 18	15 33	16 41	15 00	16 23	17 49	19 14
62	14 45	15 49	16 50	15 19	16 38	18 00	19 21
60	15 05	16 02	16 58	15 35	16 51	18 10	19 27
N 58	15 22	16 13	17 05	15 49	17 02	18 18	19 33
56	15 36	16 23	17 12	16 01	17 12	18 25	19 38
54	15 49	16 32	17 18	16 11	17 21	18 32	19 42
52	15 59	16 40	17 23	16 20	17 28	18 38	19 46
50	16 09	16 47	17 28	16 28	17 35	18 43	19 50
45	16 29	17 03	17 40	16 45	17 50	18 54	19 58
N 40	16 46	17 16	17 50	16 59	18 01	19 03	20 04
35	16 59	17 27	17 59	17 11	18 12	19 11	20 10
30	17 12	17 38	18 08	17 21	18 21	19 18	20 15
20	17 32	17 56	18 24	17 39	18 36	19 30	20 23
N 10	17 50	18 13	18 39	17 55	18 49	19 41	20 30
0	18 07	18 30	18 56	18 09	19 01	19 51	20 37
S 10	18 25	18 48	19 15	18 23	19 14	20 00	20 44
20	18 43	19 08	19 37	18 39	19 27	20 11	20 51
30	19 05	19 32	20 05	18 56	19 42	20 22	20 59
35	19 17	19 47	20 23	19 06	19 50	20 29	21 04
40	19 32	20 05	20 46	19 18	20 00	20 37	21 09
45	19 50	20 27	21 16	19 31	20 11	20 45	21 15
S 50	20 12	20 56	21 59	19 48	20 25	20 56	21 22
52	20 22	21 10	22 25	19 55	20 31	21 01	21 26
54	20 34	21 27	23 04	20 04	20 39	21 06	21 29
56	20 48	21 48	////	20 14	20 46	21 12	21 33
58	21 04	22 16	////	20 24	20 55	21 19	21 38
S 60	21 23	22 59	////	20 37	21 05	21 26	21 43

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
1	03 02	03 16	12 03	11 56	24 23	29	
2	03 30	03 45	12 04	12 49	00 23	01	●
3	03 59	04 13	12 04	13 39	01 14	02	

1976 APRIL 12, 13, 14 (MON., TUES., WED.)

G.M.T.	ARIES	VENUS −3.3		MARS +1.2		JUPITER −1.6		SATURN +0.3		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
12 00	200 19.3	195 37.1	N 0 22.9	97 31.5	N24 56.8	168 21.0	N11 53.3	81 59.8	N21 17.7	Acamar	315 39.9	S40 24.1
01	215 21.8	210 36.7	24.2	112 32.6	56.7	183 22.9	53.5	97 02.1	17.7	Achernar	335 48.1	S57 21.4
02	230 24.2	225 36.4	25.4	127 33.6	56.5	198 24.8	53.7	112 04.5	17.7	Acrux	173 39.9	S62 58.3
03	245 26.7	240 36.0	·· 26.6	142 34.7	·· 56.4	213 26.7	·· 53.9	127 06.9	·· 17.7	Adhara	255 34.5	S28 56.7
04	260 29.2	255 35.6	27.8	157 35.8	56.3	228 28.6	54.1	142 09.3	17.7	Aldebaran	291 21.7	N16 27.6
05	275 31.6	270 35.3	29.0	172 36.9	56.1	243 30.5	54.3	157 11.7	17.7			
06	290 34.1	285 34.9	N 0 30.2	187 38.0	N24 56.0	258 32.4	N11 54.5	172 14.1	N21 17.7	Alioth	166 44.6	N56 05.2
07	305 36.6	300 34.5	31.5	202 39.0	55.8	273 34.2	54.7	187 16.5	17.7	Alkaid	153 20.4	N49 25.8
08	320 39.0	315 34.2	32.7	217 40.1	55.7	288 36.1	54.9	202 18.9	17.7	Al Na'ir	28 19.0	S47 04.4
M 09	335 41.5	330 33.8	·· 33.9	232 41.2	·· 55.5	303 38.0	·· 55.1	217 21.3	·· 17.6	Alnilam	276 14.9	S 1 13.2
O 10	350 43.9	345 33.5	35.1	247 42.3	55.4	318 39.9	55.3	232 23.7	17.6	Alphard	218 23.4	S 8 33.6
N 11	5 46.4	0 33.1	36.3	262 43.4	55.3	333 41.8	55.5	247 26.0	17.6			
D 12	20 48.9	15 32.7	N 0 37.5	277 44.4	N24 55.1	348 43.7	N11 55.7	262 28.4	N21 17.6	Alphecca	126 34.3	N26 47.5
A 13	35 51.3	30 32.4	38.8	292 45.5	55.0	3 45.6	55.9	277 30.8	17.6	Alpheratz	358 12.7	N28 57.5
Y 14	50 53.8	45 32.0	40.0	307 46.6	54.8	18 47.5	56.2	292 33.2	17.6	Altair	62 35.5	N 8 48.2
15	65 56.3	60 31.6	·· 41.2	322 47.7	·· 54.7	33 49.4	·· 56.4	307 35.6	·· 17.6	Ankaa	353 43.6	S42 26.0
16	80 58.7	75 31.3	42.4	337 48.7	54.5	48 51.3	56.6	322 38.0	17.6	Antares	113 00.3	S26 22.8
17	96 01.2	90 30.9	43.6	352 49.8	54.4	63 53.2	56.8	337 40.4	17.6			
18	111 03.7	105 30.5	N 0 44.8	7 50.9	N24 54.2	78 55.1	N11 57.0	352 42.8	N21 17.5	Arcturus	146 20.9	N19 18.2
19	126 06.1	120 30.2	46.1	22 52.0	54.1	93 57.0	57.2	7 45.1	17.5	Atria	108 26.8	S68 58.9
20	141 08.6	135 29.8	47.3	37 53.1	54.0	108 58.9	57.4	22 47.5	17.5	Avior	234 29.3	S59 26.4
21	156 11.0	150 29.5	·· 48.5	52 54.1	·· 53.8	124 00.8	·· 57.6	37 49.9	·· 17.5	Bellatrix	279 02.1	N 6 19.6
22	171 13.5	165 29.1	49.7	67 55.2	53.7	139 02.7	57.8	52 52.3	17.5	Betelgeuse	271 31.7	N 7 24.0
23	186 16.0	180 28.7	50.9	82 56.3	53.5	154 04.6	58.0	67 54.7	17.5			
13 00	201 18.4	195 28.4	N 0 52.2	97 57.4	N24 53.4	169 06.4	N11 58.2	82 57.1	N21 17.5	Canopus	264 08.7	S52 41.4
01	216 20.9	210 28.0	53.4	112 58.4	53.2	184 08.3	58.4	97 59.5	17.5	Capella	281 16.0	N45 58.5
02	231 23.4	225 27.6	54.6	127 59.5	53.1	199 10.2	58.6	113 01.8	17.4	Deneb	49 50.6	N45 11.5
03	246 25.8	240 27.3	·· 55.8	143 00.6	·· 52.9	214 12.1	·· 58.8	128 04.2	·· 17.4	Denebola	183 01.8	N14 42.1
04	261 28.3	255 26.9	57.0	158 01.7	52.8	229 14.0	59.0	143 06.6	17.4	Diphda	349 24.2	S18 07.0
05	276 30.8	270 26.6	58.2	173 02.7	52.6	244 15.9	59.2	158 09.0	17.4			
06	291 33.2	285 26.2	N 0 59.5	188 03.8	N24 52.5	259 17.8	N11 59.4	173 11.4	N21 17.4	Dubhe	194 25.3	N61 52.8
07	306 35.7	300 25.8	1 00.7	203 04.9	52.3	274 19.7	59.6	188 13.8	17.4	Elnath	278 48.1	N28 35.3
08	321 38.2	315 25.5	01.9	218 06.0	52.2	289 21.6	11 59.8	203 16.2	17.4	Eltanin	90 58.9	N51 29.3
T 09	336 40.6	330 25.1	·· 03.1	233 07.1	·· 52.0	304 23.5	12 00.0	218 18.5	·· 17.4	Enif	34 14.7	N 9 45.9
U 10	351 43.1	345 24.7	04.3	248 08.1	51.9	319 25.4	00.2	233 20.9	17.4	Fomalhaut	15 55.0	S29 44.8
E 11	6 45.5	0 24.4	05.5	263 09.2	51.8	334 27.3	00.4	248 23.3	17.3			
S 12	21 48.0	15 24.0	N 1 06.8	278 10.3	N24 51.6	349 29.2	N12 00.6	263 25.7	N21 17.3	Gacrux	172 31.5	S56 59.0
D 13	36 50.5	30 23.6	08.0	293 11.4	51.5	4 31.1	00.8	278 28.1	17.3	Gienah	176 20.7	S17 24.8
A 14	51 52.9	45 23.3	09.2	308 12.4	51.3	19 32.9	01.0	293 30.5	17.3	Hadar	149 26.9	S60 15.6
Y 15	66 55.4	60 22.9	·· 10.4	323 13.5	·· 51.2	34 34.8	·· 01.2	308 32.8	·· 17.3	Hamal	328 32.6	N23 21.0
16	81 57.9	75 22.6	11.6	338 14.6	51.0	49 36.7	01.4	323 35.2	17.3	Kaus Aust.	84 20.7	S34 23.7
17	97 00.3	90 22.2	12.8	353 15.6	50.9	64 38.6	01.6	338 37.6	17.3			
18	112 02.8	105 21.8	N 1 14.1	8 16.7	N24 50.7	79 40.5	N12 01.8	353 40.0	N21 17.3	Kochab	137 17.8	N74 15.0
19	127 05.3	120 21.5	15.3	23 17.8	50.6	94 42.4	02.0	8 42.4	17.2	Markab	14 06.4	N15 04.6
20	142 07.7	135 21.1	16.5	38 18.9	50.4	109 44.3	02.2	23 44.8	17.2	Menkar	314 44.6	N 3 59.7
21	157 10.2	150 20.7	·· 17.7	53 19.9	·· 50.3	124 46.2	·· 02.4	38 47.1	·· 17.2	Menkent	148 40.1	S36 15.3
22	172 12.6	165 20.4	18.9	68 21.0	50.1	139 48.1	02.6	53 49.5	17.2	Miaplacidus	221 45.2	S69 37.6
23	187 15.1	180 20.0	20.1	83 22.1	50.0	154 50.0	02.8	68 51.9	17.2			
14 00	202 17.6	195 19.7	N 1 21.4	98 23.2	N24 49.8	169 51.9	N12 03.0	83 54.3	N21 17.2	Mirfak	309 20.8	N49 46.7
01	217 20.0	210 19.3	22.6	113 24.2	49.7	184 53.8	03.3	98 56.7	17.2	Nunki	76 32.8	S26 19.5
02	232 22.5	225 18.9	23.8	128 25.3	49.5	199 55.7	03.5	113 59.0	17.2	Peacock	54 03.2	S56 48.4
03	247 25.0	240 18.6	·· 25.0	143 26.4	·· 49.3	214 57.6	·· 03.7	129 01.4	·· 17.1	Pollux	244 01.8	N28 05.0
04	262 27.4	255 18.2	26.2	158 27.4	49.2	229 59.4	03.9	144 03.8	17.1	Procyon	245 28.9	N 5 17.0
05	277 29.9	270 17.8	27.4	173 28.5	49.0	245 01.3	04.1	159 06.2	17.1			
06	292 32.4	285 17.5	N 1 28.7	188 29.6	N24 48.9	260 03.2	N12 04.3	174 08.6	N21 17.1	Rasalhague	96 32.2	N12 34.5
07	307 34.8	300 17.1	29.9	203 30.7	48.7	275 05.1	04.5	189 10.9	17.1	Regulus	208 13.0	N12 04.8
W 08	322 37.3	315 16.7	31.1	218 31.7	48.6	290 07.0	04.7	204 13.3	17.1	Rigel	281 39.1	S 8 13.9
E 09	337 39.8	330 16.4	·· 32.3	233 32.8	·· 48.4	305 08.9	·· 04.9	219 15.7	·· 17.1	Rigil Kent.	140 29.2	S60 44.2
D 10	352 42.2	345 16.0	33.5	248 33.9	48.3	320 10.8	05.1	234 18.1	17.1	Sabik	102 44.4	S15 41.8
N 11	7 44.7	0 15.7	34.7	263 34.9	48.1	335 12.7	05.3	249 20.5	17.0			
E 12	22 47.1	15 15.3	N 1 36.0	278 36.0	N24 48.0	350 14.6	N12 05.5	264 22.8	N21 17.0	Schedar	350 12.9	N56 24.4
S 13	37 49.6	30 14.9	37.2	293 37.1	47.8	5 16.5	05.7	279 25.2	17.0	Shaula	96 59.6	S37 05.1
D 14	52 52.1	45 14.6	38.4	308 38.2	47.7	20 18.4	05.9	294 27.6	17.0	Sirius	258 58.4	S16 41.3
A 15	67 54.5	60 14.2	·· 39.6	323 39.2	·· 47.5	35 20.3	·· 06.1	309 30.0	·· 17.0	Spica	159 00.4	S11 02.4
Y 16	82 57.0	75 13.8	40.8	338 40.3	47.4	50 22.2	06.3	324 32.4	17.0	Suhail	223 12.8	S43 20.6
17	97 59.5	90 13.5	42.0	353 41.4	47.2	65 24.0	06.5	339 34.7	17.0			
18	113 01.9	105 13.1	N 1 43.3	8 42.4	N24 47.0	80 25.9	N12 06.7	354 37.1	N21 16.9	Vega	80 57.7	N38 45.5
19	128 04.4	120 12.7	44.5	23 43.5	46.9	95 27.8	06.9	9 39.5	16.9	Zuben'ubi	137 36.0	S15 56.7
20	143 06.9	135 12.4	45.7	38 44.6	46.7	110 29.7	07.1	24 41.9	16.9			
21	158 09.3	150 12.0	·· 46.9	53 45.6	·· 46.6	125 31.6	·· 07.3	39 44.3	·· 16.9		S.H.A.	Mer. Pass.
22	173 11.8	165 11.7	48.1	68 46.7	46.4	140 33.5	07.5	54 46.6	16.9		° ′	h m
23	188 14.3	180 11.3	49.3	83 47.8	46.3	155 35.4	07.7	69 49.0	16.9	Venus	354 09.9	10 58
	h m									Mars	256 38.9	17 27
Mer. Pass.	10 33.0	v −0.4	d 1.2	v 1.1	d 0.1	v 1.9	d 0.2	v 2.4	d 0.0	Jupiter	327 48.0	12 42
										Saturn	241 38.6	18 25

1976 APRIL 12, 13, 14 (MON., TUES., WED.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
12 00	179 47.0	N 8 39.0	34 01.7	8.6	N 1 09.0	12.6	60.6
01	194 47.1	39.9	48 29.3	8.5	0 56.4	12.6	60.6
02	209 47.3	40.8	62 56.8	8.4	0 43.8	12.6	60.7
03	224 47.5	·· 41.7	77 24.2	8.5	0 31.2	12.7	60.7
04	239 47.6	42.6	91 51.7	8.4	0 18.5	12.7	60.7
05	254 47.8	43.5	106 19.1	8.3	N 0 05.8	12.6	60.7
06	269 48.0	N 8 44.5	120 46.4	8.4	S 0 06.8	12.7	60.8
07	284 48.1	45.4	135 13.8	8.3	0 19.5	12.7	60.8
08	299 48.3	46.3	149 41.1	8.3	0 32.2	12.8	60.8
M 09	314 48.4	·· 47.2	164 08.4	8.2	0 45.0	12.7	60.8
O 10	329 48.6	48.1	178 35.6	8.2	0 57.7	12.7	60.9
N 11	344 48.8	49.0	193 02.8	8.2	1 10.4	12.7	60.9
D 12	359 48.9	N 8 49.9	207 30.0	8.1	S 1 23.1	12.8	60.9
A 13	14 49.1	50.8	221 57.1	8.1	1 35.9	12.7	60.9
Y 14	29 49.3	51.7	236 24.2	8.1	1 48.6	12.7	61.0
15	44 49.4	·· 52.7	250 51.3	8.0	2 01.3	12.7	61.0
16	59 49.6	53.6	265 18.3	8.0	2 14.0	12.7	61.0
17	74 49.7	54.5	279 45.3	7.9	2 26.7	12.8	61.0
18	89 49.9	N 8 55.4	294 12.2	8.0	S 2 39.5	12.7	61.0
19	104 50.1	56.3	308 39.2	7.8	2 52.2	12.7	61.1
20	119 50.2	57.2	323 06.0	7.9	3 04.9	12.6	61.1
21	134 50.4	·· 58.1	337 32.9	7.8	3 17.5	12.7	61.1
22	149 50.5	59.0	351 59.7	7.7	3 30.2	12.7	61.1
23	164 50.7	8 59.9	6 26.4	7.7	3 42.9	12.6	61.1
13 00	179 50.9	N 9 00.8	20 53.1	7.7	S 3 55.5	12.6	61.2
01	194 51.0	01.7	35 19.8	7.6	4 08.1	12.6	61.2
02	209 51.2	02.6	49 46.4	7.6	4 20.7	12.6	61.2
03	224 51.3	·· 03.5	64 13.0	7.6	4 33.3	12.6	61.2
04	239 51.5	04.4	78 39.6	7.5	4 45.9	12.5	61.2
05	254 51.7	05.4	93 06.1	7.5	4 58.4	12.5	61.2
06	269 51.8	N 9 06.3	107 32.6	7.4	S 5 10.9	12.5	61.3
07	284 52.0	07.2	121 59.0	7.4	5 23.4	12.5	61.3
08	299 52.1	08.1	136 25.4	7.3	5 35.9	12.4	61.3
T 09	314 52.3	·· 09.0	150 51.7	7.3	5 48.3	12.4	61.3
U 10	329 52.5	09.9	165 18.0	7.3	6 00.7	12.3	61.3
E 11	344 52.6	10.8	179 44.3	7.2	6 13.0	12.3	61.3
S 12	359 52.8	N 9 11.7	194 10.5	7.1	S 6 25.3	12.3	61.3
D 13	14 52.9	12.6	208 36.6	7.2	6 37.6	12.3	61.3
A 14	29 53.1	13.5	223 02.8	7.0	6 49.9	12.2	61.3
Y 15	44 53.3	·· 14.4	237 28.8	7.1	7 02.1	12.1	61.4
16	59 53.4	15.3	251 54.9	7.0	7 14.2	12.1	61.4
17	74 53.6	16.2	266 20.9	6.9	7 26.3	12.1	61.4
18	89 53.7	N 9 17.1	280 46.8	6.9	S 7 38.4	12.0	61.4
19	104 53.9	18.0	295 12.7	6.9	7 50.4	12.0	61.4
20	119 54.1	18.9	309 38.6	6.8	8 02.4	11.9	61.4
21	134 54.2	·· 19.8	324 04.4	6.8	8 14.3	11.9	61.4
22	149 54.4	20.7	338 30.2	6.7	8 26.2	11.8	61.4
23	164 54.5	21.6	352 55.9	6.7	8 38.0	11.7	61.4
14 00	179 54.7	N 9 22.5	7 21.6	6.6	S 8 49.7	11.7	61.4
01	194 54.8	23.4	21 47.2	6.6	9 01.4	11.7	61.4
02	209 55.0	24.3	36 12.8	6.6	9 13.1	11.5	61.4
03	224 55.2	·· 25.2	50 38.4	6.5	9 24.6	11.5	61.4
04	239 55.3	26.1	65 03.9	6.4	9 36.1	11.5	61.4
05	254 55.5	27.0	79 29.3	6.4	9 47.6	11.4	61.4
06	269 55.6	N 9 27.9	93 54.7	6.4	S 9 59.0	11.3	61.4
W 07	284 55.8	28.8	108 20.1	6.3	10 10.3	11.2	61.4
E 08	299 55.9	29.7	122 45.4	6.3	10 21.5	11.2	61.4
D 09	314 56.1	·· 30.6	137 10.7	6.2	10 32.7	11.1	61.4
N 10	329 56.2	31.5	151 35.9	6.2	10 43.8	11.0	61.4
E 11	344 56.4	32.4	166 01.1	6.2	10 54.8	11.0	61.4
S 12	359 56.6	N 9 33.3	180 26.3	6.1	S11 05.8	10.8	61.4
D 13	14 56.7	34.2	194 51.4	6.1	11 16.6	10.8	61.4
A 14	29 56.9	35.1	209 16.5	6.0	11 27.4	10.7	61.4
Y 15	44 57.0	·· 36.0	223 41.5	6.0	11 38.1	10.6	61.4
16	59 57.2	36.9	238 06.5	5.9	11 48.7	10.6	61.4
17	74 57.3	37.8	252 31.4	5.9	11 59.3	10.4	61.4
18	89 57.5	N 9 38.7	266 56.3	5.9	S12 09.7	10.4	61.4
19	104 57.6	39.6	281 21.2	5.8	12 20.1	10.3	61.4
20	119 57.8	40.5	295 46.0	5.8	12 30.4	10.2	61.4
21	134 58.0	·· 41.4	310 10.8	5.7	12 40.6	10.1	61.4
22	149 58.1	42.2	324 35.5	5.7	12 50.7	10.0	61.4
23	164 58.3	43.1	339 00.2	5.7	13 00.7	9.9	61.4
	S.D. 16.0	d 0.9	S.D. 16.6		16.7		16.7

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 12	Moonrise 13	Moonrise 14	Moonrise 15
°	h m	h m	h m	h m	h m	h m	h m
N 72	////	02 16	03 51	16 53	19 02	21 20	23 56
N 70	////	02 48	04 06	16 49	18 49	20 54	23 03
68	01 11	03 11	04 18	16 46	18 39	20 35	22 30
66	01 57	03 28	04 28	16 44	18 31	20 20	22 07
64	02 26	03 42	04 36	16 41	18 24	20 07	21 48
62	02 47	03 54	04 43	16 40	18 18	19 57	21 33
60	03 04	04 04	04 49	16 38	18 13	19 48	21 20
N 58	03 18	04 12	04 55	16 37	18 08	19 40	21 10
56	03 30	04 20	05 00	16 35	18 04	19 34	21 00
54	03 40	04 26	05 04	16 34	18 01	19 27	20 52
52	03 48	04 32	05 08	16 33	17 57	19 22	20 44
50	03 56	04 38	05 11	16 32	17 54	19 17	20 38
45	04 12	04 49	05 19	16 30	17 48	19 06	20 23
N 40	04 24	04 57	05 25	16 29	17 43	18 58	20 12
35	04 34	05 05	05 31	16 27	17 38	18 50	20 02
30	04 42	05 11	05 35	16 26	17 34	18 44	19 53
20	04 55	05 21	05 44	16 24	17 27	18 32	19 38
N 10	05 05	05 29	05 51	16 22	17 21	18 23	19 25
0	05 12	05 36	05 57	16 20	17 16	18 13	19 13
S 10	05 18	05 42	06 04	16 19	17 10	18 04	19 01
20	05 22	05 48	06 10	16 17	17 05	17 55	18 48
30	05 26	05 54	06 18	16 15	16 58	17 44	18 33
35	05 27	05 57	06 22	16 14	16 54	17 38	18 25
40	05 28	06 00	06 27	16 12	16 50	17 31	18 15
45	05 29	06 03	06 33	16 11	16 45	17 23	18 04
S 50	05 29	06 06	06 39	16 09	16 39	17 13	17 51
52	05 29	06 08	06 42	16 09	16 37	17 08	17 45
54	05 29	06 10	06 46	16 08	16 34	17 03	17 38
56	05 28	06 12	06 49	16 07	16 31	16 58	17 30
58	05 28	06 13	06 53	16 06	16 27	16 52	17 22
S 60	05 27	06 15	06 58	16 05	16 23	16 45	17 12

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 12	Moonset 13	Moonset 14	Moonset 15
°	h m	h m	h m	h m	h m	h m	h m
N 72	20 14	21 52	////	03 54	03 44	03 32	03 16
N 70	19 58	21 18	////	03 54	03 50	03 47	03 43
68	19 46	20 54	23 03	03 54	03 56	03 59	04 03
66	19 36	20 36	22 10	03 54	04 00	04 09	04 20
64	19 27	20 21	21 40	03 54	04 04	04 17	04 33
62	19 20	20 09	21 17	03 53	04 08	04 24	04 44
60	19 13	19 59	21 00	03 53	04 11	04 31	04 54
N 58	19 08	19 50	20 46	03 53	04 14	04 36	05 03
56	19 03	19 43	20 34	03 53	04 16	04 41	05 10
54	18 58	19 36	20 23	03 53	04 18	04 46	05 17
52	18 54	19 30	20 14	03 53	04 20	04 50	05 23
50	18 51	19 25	20 06	03 53	04 22	04 53	05 29
45	18 43	19 13	19 50	03 53	04 26	05 01	05 41
N 40	18 36	19 05	19 38	03 53	04 29	05 08	05 50
35	18 31	18 57	19 28	03 52	04 32	05 14	05 59
30	18 26	18 50	19 19	03 52	04 35	05 19	06 06
20	18 18	18 40	19 06	03 52	04 39	05 28	06 19
N 10	18 10	18 32	18 57	03 52	04 43	05 36	06 31
0	18 04	18 25	18 49	03 52	04 46	05 43	06 41
S 10	17 57	18 19	18 43	03 51	04 50	05 50	06 52
20	17 51	18 13	18 38	03 51	04 54	05 58	07 04
30	17 43	18 07	18 35	03 51	04 58	06 07	07 17
35	17 38	18 04	18 33	03 50	05 01	06 12	07 24
40	17 33	18 01	18 32	03 50	05 04	06 18	07 33
45	17 28	17 57	18 31	03 50	05 07	06 25	07 43
S 50	17 21	17 54	18 31	03 49	05 11	06 33	07 55
52	17 18	17 52	18 31	03 49	05 13	06 37	08 01
54	17 14	17 50	18 31	03 49	05 15	06 41	08 07
56	17 11	17 48	18 32	03 49	05 17	06 46	08 14
58	17 07	17 47	18 32	03 49	05 19	06 51	08 22
S 60	17 02	17 44	18 32	03 48	05 22	06 57	08 31

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
12	00 52	00 45	12 01	22 33	10 06	13	
13	00 37	00 29	12 00	23 29	11 01	14	○
14	00 22	00 14	12 00	24 27	11 58	15	

1976 APRIL 15, 16, 17 (THURS., FRI., SAT.)

G.M.T.	ARIES	VENUS −3.3		MARS +1.3		JUPITER −1.6		SATURN +0.3	
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
15 00	203 16.7	195 10.9	N 1 50.6	98 48.9	N24 46.1	170 37.3	N12 07.9	84 51.4	N21 16.9
01	218 19.2	210 10.6	51.8	113 49.9	46.0	185 39.2	08.1	99 53.8	16.9
02	233 21.6	225 10.2	53.0	128 51.0	45.8	200 41.1	08.3	114 56.1	16.8
03	248 24.1	240 09.8	·· 54.2	143 52.1	·· 45.6	215 43.0	·· 08.5	129 58.5	·· 16.8
04	263 26.6	255 09.5	55.4	158 53.1	45.5	230 44.9	08.7	145 00.9	16.8
05	278 29.0	270 09.1	56.6	173 54.2	45.3	245 46.7	08.9	160 03.3	16.8
06	293 31.5	285 08.7	N 1 57.9	188 55.3	N24 45.2	260 48.6	N12 09.1	175 05.6	N21 16.8
07	308 34.0	300 08.4	1 59.1	203 56.3	45.0	275 50.5	09.3	190 08.0	16.8
T 08	323 36.4	315 08.0	2 00.3	218 57.4	44.9	290 52.4	09.5	205 10.4	16.8
H 09	338 38.9	330 07.6	·· 01.5	233 58.5	·· 44.7	305 54.3	·· 09.7	220 12.8	·· 16.7
U 10	353 41.4	345 07.3	02.7	248 59.5	44.5	320 56.2	09.9	235 15.1	16.7
R 11	8 43.8	0 06.9	03.9	264 00.6	44.4	335 58.1	10.1	250 17.5	16.7
S 12	23 46.3	15 06.5	N 2 05.2	279 01.7	N24 44.2	351 00.0	N12 10.3	265 19.9	N21 16.7
D 13	38 48.7	30 06.2	06.4	294 02.7	44.1	6 01.9	10.5	280 22.3	16.7
A 14	53 51.2	45 05.8	07.6	309 03.8	43.9	21 03.8	10.7	295 24.6	16.7
Y 15	68 53.7	60 05.5	·· 08.8	324 04.9	·· 43.7	36 05.7	·· 10.9	310 27.0	·· 16.7
16	83 56.1	75 05.1	10.0	339 05.9	43.6	51 07.5	11.1	325 29.4	16.6
17	98 58.6	90 04.7	11.2	354 07.0	43.4	66 09.4	11.3	340 31.8	16.6
18	114 01.1	105 04.4	N 2 12.4	9 08.1	N24 43.3	81 11.3	N12 11.5	355 34.1	N21 16.6
19	129 03.5	120 04.0	13.7	24 09.1	43.1	96 13.2	11.7	10 36.5	16.6
20	144 06.0	135 03.6	14.9	39 10.2	42.9	111 15.1	11.9	25 38.9	16.6
21	159 08.5	150 03.3	·· 16.1	54 11.3	·· 42.8	126 17.0	·· 12.1	40 41.3	·· 16.6
22	174 10.9	165 02.9	17.3	69 12.3	42.6	141 18.9	12.4	55 43.6	16.6
23	189 13.4	180 02.5	18.5	84 13.4	42.5	156 20.8	12.6	70 46.0	16.5
16 00	204 15.9	195 02.2	N 2 19.7	99 14.5	N24 42.3	171 22.7	N12 12.8	85 48.4	N21 16.5
01	219 18.3	210 01.8	21.0	114 15.5	42.1	186 24.6	13.0	100 50.7	16.5
02	234 20.8	225 01.4	22.2	129 16.6	42.0	201 26.5	13.2	115 53.1	16.5
03	249 23.2	240 01.1	·· 23.4	144 17.6	·· 41.8	216 28.3	·· 13.4	130 55.5	·· 16.5
04	264 25.7	255 00.7	24.6	159 18.7	41.7	231 30.2	13.6	145 57.9	16.5
05	279 28.2	270 00.3	25.8	174 19.8	41.5	246 32.1	13.8	161 00.2	16.5
06	294 30.6	285 00.0	N 2 27.0	189 20.8	N24 41.3	261 34.0	N12 14.0	176 02.6	N21 16.4
07	309 33.1	299 59.6	28.2	204 21.9	41.2	276 35.9	14.2	191 05.0	16.4
08	324 35.6	314 59.2	29.5	219 23.0	41.0	291 37.8	14.4	206 07.3	16.4
F 09	339 38.0	329 58.9	·· 30.7	234 24.0	·· 40.8	306 39.7	·· 14.6	221 09.7	·· 16.4
R 10	354 40.5	344 58.5	31.9	249 25.1	40.7	321 41.6	14.8	236 12.1	16.4
I 11	9 43.0	359 58.1	33.1	264 26.2	40.5	336 43.5	15.0	251 14.5	16.4
D 12	24 45.4	14 57.8	N 2 34.3	279 27.2	N24 40.3	351 45.4	N12 15.2	266 16.8	N21 16.4
A 13	39 47.9	29 57.4	35.5	294 28.3	40.2	6 47.3	15.4	281 19.2	16.3
Y 14	54 50.4	44 57.0	36.7	309 29.3	40.0	21 49.1	15.6	296 21.6	16.3
15	69 52.8	59 56.7	·· 38.0	324 30.4	·· 39.9	36 51.0	·· 15.8	311 23.9	·· 16.3
16	84 55.3	74 56.3	39.2	339 31.5	39.7	51 52.9	16.0	326 26.3	16.3
17	99 57.7	89 55.9	40.4	354 32.5	39.5	66 54.8	16.2	341 28.7	16.3
18	115 00.2	104 55.6	N 2 41.6	9 33.6	N24 39.4	81 56.7	N12 16.4	356 31.0	N21 16.3
19	130 02.7	119 55.2	42.8	24 34.7	39.2	96 58.6	16.6	11 33.4	16.3
20	145 05.1	134 54.8	44.0	39 35.7	39.0	112 00.5	16.8	26 35.8	16.2
21	160 07.6	149 54.5	·· 45.2	54 36.8	·· 38.9	127 02.4	·· 17.0	41 38.1	·· 16.2
22	175 10.1	164 54.1	46.5	69 37.8	38.7	142 04.3	17.2	56 40.5	16.2
23	190 12.5	179 53.7	47.7	84 38.9	38.5	157 06.2	17.4	71 42.9	16.2
17 00	205 15.0	194 53.4	N 2 48.9	99 40.0	N24 38.4	172 08.0	N12 17.6	86 45.3	N21 16.2
01	220 17.5	209 53.0	50.1	114 41.0	38.2	187 09.9	17.8	101 47.6	16.2
02	235 19.9	224 52.6	51.3	129 42.1	38.0	202 11.8	18.0	116 50.0	16.1
03	250 22.4	239 52.3	·· 52.5	144 43.1	·· 37.9	217 13.7	·· 18.2	131 52.4	·· 16.1
04	265 24.8	254 51.9	53.7	159 44.2	37.7	232 15.6	18.4	146 54.7	16.1
05	280 27.3	269 51.5	55.0	174 45.3	37.5	247 17.5	18.6	161 57.1	16.1
06	295 29.8	284 51.2	N 2 56.2	189 46.3	N24 37.4	262 19.4	N12 18.8	176 59.5	N21 16.1
07	310 32.2	299 50.8	57.4	204 47.4	37.2	277 21.3	19.0	192 01.8	16.1
S 08	325 34.7	314 50.4	58.6	219 48.4	37.0	292 23.2	19.2	207 04.2	16.1
A 09	340 37.2	329 50.1	2 59.8	234 49.5	·· 36.9	307 25.0	·· 19.4	222 06.6	·· 16.0
T 10	355 39.6	344 49.7	3 01.0	249 50.6	36.7	322 26.9	19.6	237 08.9	16.0
U 11	10 42.1	359 49.3	02.2	264 51.6	36.5	337 28.8	19.8	252 11.3	16.0
R 12	25 44.6	14 49.0	N 3 03.4	279 52.7	N24 36.3	352 30.7	N12 20.0	267 13.7	N21 16.0
D 13	40 47.0	29 48.6	04.7	294 53.7	36.2	7 32.6	20.2	282 16.0	16.0
A 14	55 49.5	44 48.2	05.9	309 54.8	36.0	22 34.5	20.4	297 18.4	16.0
Y 15	70 52.0	59 47.9	·· 07.1	324 55.9	·· 35.8	37 36.4	·· 20.6	312 20.7	·· 15.9
16	85 54.4	74 47.5	08.3	339 56.9	35.7	52 38.3	20.8	327 23.1	15.9
17	100 56.9	89 47.1	09.5	354 58.0	35.5	67 40.2	21.0	342 25.5	15.9
18	115 59.3	104 46.8	N 3 10.7	9 59.0	N24 35.3	82 42.1	N12 21.2	357 27.8	N21 15.9
19	131 01.8	119 46.4	11.9	25 00.1	35.2	97 43.9	21.4	12 30.2	15.9
20	146 04.3	134 46.0	13.1	40 01.2	35.0	112 45.8	21.6	27 32.6	15.9
21	161 06.7	149 45.7	·· 14.4	55 02.2	·· 34.8	127 47.7	·· 21.8	42 34.9	·· 15.8
22	176 09.2	164 45.3	15.6	70 03.3	34.6	142 49.6	22.0	57 37.3	15.8
23	191 11.7	179 44.9	16.8	85 04.3	34.5	157 51.5	22.2	72 39.7	15.8
	h m								
Mer. Pass.	10 21.2	*v* −0.4	*d* 1.2	*v* 1.1	*d* 0.2	*v* 1.9	*d* 0.2	*v* 2.4	*d* 0.0

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 39.9	S40 24.1
Achernar	335 48.1	S57 21.4
Acrux	173 39.9	S62 58.3
Adhara	255 34.5	S28 56.7
Aldebaran	291 21.7	N16 27.6
Alioth	166 44.6	N56 05.3
Alkaid	153 20.4	N49 25.8
Al Na'ir	28 19.0	S47 04.4
Alnilam	276 14.9	S 1 13.2
Alphard	218 23.4	S 8 33.6
Alphecca	126 34.3	N26 47.5
Alpheratz	358 12.7	N28 57.5
Altair	62 35.4	N 8 48.2
Ankaa	353 43.6	S42 26.0
Antares	113 00.2	S26 22.8
Arcturus	146 20.9	N19 18.2
Atria	108 26.8	S68 58.9
Avior	234 29.3	S59 26.4
Bellatrix	279 02.2	N 6 19.6
Betelgeuse	271 31.7	N 7 24.0
Canopus	264 08.7	S52 41.4
Capella	281 16.0	N45 58.5
Deneb	49 50.6	N45 11.5
Denebola	183 01.8	N14 42.1
Diphda	349 24.2	S18 07.0
Dubhe	194 25.3	N61 52.8
Elnath	278 48.1	N28 35.2
Eltanin	90 58.9	N51 29.3
Enif	34 14.7	N 9 45.9
Fomalhaut	15 55.0	S29 44.8
Gacrux	172 31.5	S56 59.1
Gienah	176 20.7	S17 24.8
Hadar	149 26.9	S60 15.6
Hamal	328 32.6	N23 21.0
Kaus Aust.	84 20.7	S34 23.7
Kochab	137 17.8	N74 15.1
Markab	14 06.4	N15 04.6
Menkar	314 44.6	N 3 59.7
Menkent	148 40.1	S36 15.3
Miaplacidus	221 45.2	S69 37.6
Mirfak	309 20.8	N49 46.7
Nunki	76 32.8	S26 19.5
Peacock	54 03.2	S56 48.4
Pollux	244 01.8	N28 05.0
Procyon	245 28.9	N 5 17.0
Rasalhague	96 32.2	N12 34.5
Regulus	208 13.0	N12 04.8
Rigel	281 39.1	S 8 13.9
Rigil Kent.	140 29.2	S60 44.2
Sabik	102 44.3	S15 41.8
Schedar	350 12.9	N56 24.4
Shaula	96 59.6	S37 05.1
Sirius	258 58.4	S16 41.3
Spica	159 00.4	S11 02.4
Suhail	223 12.8	S43 20.6
Vega	80 57.7	N38 45.5
Zuben'ubi	137 36.0	S15 56.7

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	350 46.3	11 00
Mars	254 58.6	17 22
Jupiter	327 06.8	12 33
Saturn	241 32.5	18 14

1976 APRIL 15, 16, 17 (THURS., FRI., SAT.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
15 00	179 58.4	N 9 44.0	353 24.9	5.6	S13 10.6	9.8	61.3
01	194 58.6	44.9	7 49.5	5.6	13 20.4	9.7	61.3
02	209 58.7	45.8	22 14.1	5.5	13 30.1	9.6	61.3
03	224 58.9	·· 46.7	36 38.6	5.5	13 39.7	9.6	61.3
04	239 59.0	47.6	51 03.1	5.5	13 49.3	9.4	61.3
05	254 59.2	48.5	65 27.6	5.5	13 58.7	9.3	61.3
06	269 59.3	N 9 49.4	79 52.1	5.4	S14 08.0	9.2	61.3
07	284 59.5	50.3	94 16.5	5.4	14 17.2	9.1	61.3
T 08	299 59.6	51.2	108 40.9	5.3	14 26.3	9.0	61.2
H 09	314 59.8	·· 52.1	123 05.2	5.3	14 35.3	8.9	61.2
U 10	329 59.9	53.0	137 29.5	5.3	14 44.2	8.8	61.2
R 11	345 00.1	53.9	151 53.8	5.2	14 53.0	8.7	61.2
S 12	0 00.2	N 9 54.7	166 18.0	5.3	S15 01.7	8.5	61.2
D 13	15 00.4	55.6	180 42.3	5.2	15 10.2	8.5	61.2
A 14	30 00.5	56.5	195 06.5	5.1	15 18.7	8.3	61.2
Y 15	45 00.7	·· 57.4	209 30.6	5.2	15 27.0	8.2	61.1
16	60 00.8	58.3	223 54.8	5.1	15 35.2	8.1	61.1
17	75 01.0	9 59.2	238 18.9	5.1	15 43.3	8.0	61.1
18	90 01.2	N10 00.1	252 43.0	5.0	S15 51.3	7.9	61.1
19	105 01.3	01.0	267 07.0	5.1	15 59.2	7.7	61.1
20	120 01.5	01.9	281 31.1	5.0	16 06.9	7.6	61.0
21	135 01.6	·· 02.7	295 55.1	5.0	16 14.5	7.5	61.0
22	150 01.8	03.6	310 19.1	5.0	16 22.0	7.4	61.0
23	165 01.9	04.5	324 43.1	5.0	16 29.4	7.3	61.0
16 00	180 02.1	N10 05.4	339 07.1	4.9	S16 36.7	7.1	60.9
01	195 02.2	06.3	353 31.0	4.9	16 43.8	7.0	60.9
02	210 02.4	07.2	7 54.9	4.9	16 50.8	6.9	60.9
03	225 02.5	·· 08.1	22 18.8	4.9	16 57.7	6.8	60.9
04	240 02.7	09.0	36 42.7	4.9	17 04.5	6.6	60.9
05	255 02.8	09.8	51 06.6	4.9	17 11.1	6.5	60.8
06	270 02.9	N10 10.7	65 30.5	4.9	S17 17.6	6.4	60.8
07	285 03.1	11.6	79 54.4	4.8	17 24.0	6.2	60.8
08	300 03.2	12.5	94 18.2	4.9	17 30.2	6.1	60.7
F 09	315 03.4	·· 13.4	108 42.1	4.8	17 36.3	6.0	60.7
R 10	330 03.5	14.3	123 05.9	4.9	17 42.3	5.9	60.7
I 11	345 03.7	15.1	137 29.8	4.8	17 48.2	5.7	60.7
D 12	0 03.8	N10 16.0	151 53.6	4.8	S17 53.9	5.6	60.6
A 13	15 04.0	16.9	166 17.4	4.8	17 59.5	5.4	60.6
Y 14	30 04.1	17.8	180 41.2	4.9	18 04.9	5.4	60.6
15	45 04.3	·· 18.7	195 05.1	4.8	18 10.3	5.1	60.6
16	60 04.4	19.6	209 28.9	4.8	18 15.4	5.1	60.5
17	75 04.6	20.4	223 52.7	4.9	18 20.5	4.9	60.5
18	90 04.7	N10 21.3	238 16.6	4.8	S18 25.4	4.8	60.5
19	105 04.9	22.2	252 40.4	4.8	18 30.2	4.6	60.4
20	120 05.0	23.1	267 04.2	4.9	18 34.8	4.5	60.4
21	135 05.2	·· 24.0	281 28.1	4.9	18 39.3	4.4	60.4
22	150 05.3	24.8	295 52.0	4.8	18 43.7	4.3	60.3
23	165 05.5	25.7	310 15.8	4.9	18 48.0	4.1	60.3
17 00	180 05.6	N10 26.6	324 39.7	4.9	S18 52.1	3.9	60.3
01	195 05.7	27.5	339 03.6	4.9	18 56.0	3.8	60.2
02	210 05.9	28.4	353 27.5	5.0	18 59.8	3.7	60.2
03	225 06.0	·· 29.2	7 51.5	4.9	19 03.5	3.6	60.2
04	240 06.2	30.1	22 15.4	5.0	19 07.1	3.4	60.1
05	255 06.3	31.0	36 39.4	5.0	19 10.5	3.3	60.1
06	270 06.5	N10 31.9	51 03.4	5.0	S19 13.8	3.1	60.1
07	285 06.6	32.8	65 27.4	5.0	19 16.9	3.0	60.0
S 08	300 06.8	33.6	79 51.4	5.1	19 19.9	2.9	60.0
A 09	315 06.9	·· 34.5	94 15.5	5.0	19 22.8	2.7	60.0
T 10	330 07.1	35.4	108 39.5	5.2	19 25.5	2.6	59.9
U 11	345 07.2	36.3	123 03.7	5.1	19 28.1	2.4	59.9
R 12	0 07.3	N10 37.1	137 27.8	5.2	S19 30.5	2.3	59.9
D 13	15 07.5	38.0	151 52.0	5.2	19 32.8	2.2	59.8
A 14	30 07.6	38.9	166 16.2	5.2	19 35.0	2.0	59.8
Y 15	45 07.8	·· 39.8	180 40.4	5.3	19 37.0	1.9	59.8
16	60 07.9	40.6	195 04.7	5.3	19 38.9	1.8	59.7
17	75 08.1	41.5	209 29.0	5.3	19 40.7	1.6	59.7
18	90 08.2	N10 42.4	223 53.3	5.4	S19 42.3	1.5	59.6
19	105 08.3	43.3	238 17.7	5.4	19 43.8	1.4	59.6
20	120 08.5	44.1	252 42.1	5.5	19 45.2	1.2	59.6
21	135 08.6	·· 45.0	267 06.6	5.5	19 46.4	1.0	59.5
22	150 08.8	45.9	281 31.1	5.5	19 47.4	1.0	59.5
23	165 08.9	46.8	295 55.6	5.6	19 48.4	0.8	59.5
	S.D. 16.0	d 0.9	S.D. 16.7		16.5		16.3

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 15	Moonrise 16	Moonrise 17	Moonrise 18
°	h m	h m	h m	h m	h m	h m	h m
N 72	////	01 48	03 33	23 56	▬	▬	▬
N 70	////	02 27	03 51	23 03	25 13	01 13	▬
68	////	02 54	04 05	22 30	24 17	00 17	01 39
66	01 33	03 14	04 16	22 07	23 44	25 00	01 00
64	02 08	03 30	04 26	21 48	23 19	24 33	00 33
62	02 33	03 43	04 34	21 33	23 00	24 12	00 12
60	02 52	03 54	04 40	21 20	22 44	23 55	24 49
N 58	03 07	04 04	04 47	21 10	22 31	23 40	24 35
56	03 20	04 12	04 52	21 00	22 20	23 28	24 23
54	03 31	04 19	04 57	20 52	22 10	23 17	24 12
52	03 41	04 25	05 01	20 44	22 01	23 08	24 03
50	03 49	04 31	05 05	20 38	21 53	22 59	23 55
45	04 06	04 43	05 14	20 23	21 36	22 41	23 37
N 40	04 19	04 53	05 21	20 12	21 22	22 26	23 23
35	04 30	05 01	05 27	20 02	21 10	22 14	23 11
30	04 39	05 08	05 32	19 53	21 00	22 03	23 00
20	04 53	05 19	05 41	19 38	20 42	21 44	22 42
N 10	05 03	05 28	05 49	19 25	20 27	21 28	22 26
0	05 11	05 35	05 56	19 13	20 13	21 13	22 11
S 10	05 18	05 42	06 04	19 01	19 59	20 58	21 56
20	05 23	05 49	06 11	18 48	19 44	20 41	21 40
30	05 27	05 55	06 20	18 33	19 27	20 23	21 21
35	05 29	05 59	06 24	18 25	19 17	20 12	21 11
40	05 31	06 03	06 30	18 15	19 05	20 00	20 59
45	05 32	06 06	06 36	18 04	18 52	19 45	20 44
S 50	05 33	06 11	06 44	17 51	18 36	19 28	20 27
52	05 34	06 13	06 47	17 45	18 28	19 19	20 18
54	05 34	06 15	06 51	17 38	18 20	19 10	20 09
56	05 34	06 17	06 55	17 30	18 10	19 00	19 59
58	05 34	06 20	07 00	17 22	18 00	18 48	19 47
S 60	05 34	06 22	07 05	17 12	17 47	18 34	19 33

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 15	Moonset 16	Moonset 17	Moonset 18
°	h m	h m	h m	h m	h m	h m	h m
N 72	20 30	22 21	////	03 16	02 45	▬	▬
N 70	20 12	21 38	////	03 43	03 39	03 35	▬
68	19 58	21 09	////	04 03	04 12	04 32	05 14
66	19 46	20 49	22 35	04 20	04 37	05 05	05 53
64	19 36	20 32	21 56	04 33	04 56	05 30	06 20
62	19 28	20 19	21 30	04 44	05 12	05 50	06 41
60	19 21	20 08	21 11	04 54	05 25	06 06	06 59
N 58	19 14	19 58	20 55	05 03	05 36	06 19	07 13
56	19 09	19 50	20 42	05 10	05 46	06 31	07 25
54	19 04	19 42	20 30	05 17	05 55	06 41	07 36
52	18 59	19 36	20 21	05 23	06 03	06 50	07 46
50	18 55	19 30	20 12	05 29	06 10	06 58	07 54
45	18 47	19 18	19 55	05 41	06 25	07 16	08 12
N 40	18 39	19 08	19 41	05 50	06 38	07 30	08 27
35	18 33	18 59	19 31	05 59	06 48	07 42	08 40
30	18 28	18 52	19 22	06 06	06 58	07 53	08 51
20	18 19	18 41	19 08	06 19	07 14	08 11	09 09
N 10	18 11	18 32	18 57	06 31	07 28	08 27	09 26
0	18 03	18 24	18 48	06 41	07 41	08 42	09 41
S 10	17 56	18 17	18 42	06 52	07 55	08 56	09 56
20	17 48	18 11	18 36	07 04	08 09	09 12	10 12
30	17 40	18 04	18 32	07 17	08 25	09 30	10 31
35	17 35	18 00	18 30	07 24	08 34	09 41	10 41
40	17 29	17 56	18 28	07 33	08 45	09 53	10 54
45	17 23	17 52	18 27	07 43	08 58	10 07	11 08
S 50	17 15	17 48	18 25	07 55	09 14	10 25	11 26
52	17 11	17 46	18 25	08 01	09 21	10 33	11 34
54	17 08	17 44	18 25	08 07	09 29	10 42	11 44
56	17 03	17 41	18 24	08 14	09 38	10 52	11 54
58	16 59	17 39	18 24	08 22	09 48	11 04	12 06
S 60	16 53	17 36	18 24	08 31	10 00	11 18	12 20

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
15	00 07	00 01	12 00	00 27	12 57	16	
16	00 08	00 15	12 00	01 27	13 57	17	○
17	00 22	00 29	12 00	02 27	14 57	18	

1976 MAY 15, 16, 17 (SAT., SUN., MON.)

G.M.T.	ARIES	VENUS −3.4		MARS +1.6		JUPITER −1.6		SATURN +0.4	
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
15 00	232 50.9	189 56.3	N15 23.5	111 09.0	N21 56.1	193 14.2	N14 27.1	112 36.9	N20 58.3
01	247 53.3	204 55.8	24.5	126 10.0	55.8	208 16.0	27.3	127 39.1	58.2
02	262 55.8	219 55.2	25.4	141 11.0	55.4	223 17.9	27.4	142 41.4	58.2
03	277 58.3	234 54.7	·· 26.4	156 12.0	·· 55.1	238 19.8	·· 27.6	157 43.6	·· 58.1
04	293 00.7	249 54.1	27.4	171 13.0	54.8	253 21.7	27.8	172 45.9	58.1
05	308 03.2	264 53.5	28.3	186 14.0	54.5	268 23.6	28.0	187 48.1	58.1
06	323 05.7	279 53.0	N15 29.3	201 15.0	N21 54.2	283 25.5	N14 28.2	202 50.4	N20 58.0
07	338 08.1	294 52.4	30.3	216 16.0	53.9	298 27.3	28.3	217 52.6	58.0
S 08	353 10.6	309 51.8	31.2	231 17.0	53.5	313 29.2	28.5	232 54.9	57.9
A 09	8 13.0	324 51.3	·· 32.2	246 18.0	·· 53.2	328 31.1	·· 28.7	247 57.1	·· 57.9
T 10	23 15.5	339 50.7	33.1	261 19.0	52.9	343 33.0	28.9	262 59.4	57.9
U 11	38 18.0	354 50.1	34.1	276 20.0	52.6	358 34.9	29.1	278 01.7	57.8
R 12	53 20.4	9 49.6	N15 35.1	291 21.0	N21 52.3	13 36.8	N14 29.3	293 03.9	N20 57.8
D 13	68 22.9	24 49.0	36.0	306 22.0	51.9	28 38.7	29.4	308 06.2	57.8
A 14	83 25.4	39 48.4	37.0	321 23.0	51.6	43 40.5	29.6	323 08.4	57.7
Y 15	98 27.8	54 47.9	·· 37.9	336 24.0	·· 51.3	58 42.4	·· 29.8	338 10.7	·· 57.7
16	113 30.3	69 47.3	38.9	351 25.0	51.0	73 44.3	30.0	353 12.9	57.6
17	128 32.8	84 46.7	39.8	6 26.1	50.7	88 46.2	30.2	8 15.2	57.6
18	143 35.2	99 46.2	N15 40.8	21 27.1	N21 50.3	103 48.1	N14 30.3	23 17.4	N20 57.6
19	158 37.7	114 45.6	41.8	36 28.1	50.0	118 50.0	30.5	38 19.7	57.5
20	173 40.2	129 45.0	42.7	51 29.1	49.7	133 51.8	30.7	53 21.9	57.5
21	188 42.6	144 44.5	·· 43.7	66 30.1	·· 49.4	148 53.7	·· 30.9	68 24.2	·· 57.5
22	203 45.1	159 43.9	44.6	81 31.1	49.1	163 55.6	31.1	83 26.4	57.4
23	218 47.5	174 43.3	45.6	96 32.1	48.7	178 57.5	31.2	98 28.7	57.4
16 00	233 50.0	189 42.8	N15 46.5	111 33.1	N21 48.4	193 59.4	N14 31.4	113 30.9	N20 57.3
01	248 52.5	204 42.2	47.5	126 34.1	48.1	209 01.3	31.6	128 33.2	57.3
02	263 54.9	219 41.6	48.4	141 35.1	47.8	224 03.2	31.8	143 35.4	57.3
03	278 57.4	234 41.0	·· 49.4	156 36.1	·· 47.4	239 05.0	·· 32.0	158 37.7	·· 57.2
04	293 59.9	249 40.5	50.3	171 37.1	47.1	254 06.9	32.1	173 40.0	57.2
05	309 02.3	264 39.9	51.3	186 38.1	46.8	269 08.8	32.3	188 42.2	57.1
06	324 04.8	279 39.3	N15 52.2	201 39.1	N21 46.5	284 10.7	N14 32.5	203 44.5	N20 57.1
07	339 07.3	294 38.7	53.2	216 40.1	46.2	299 12.6	32.7	218 46.7	57.1
08	354 09.7	309 38.2	54.1	231 41.1	45.8	314 14.5	32.9	233 49.0	57.0
S 09	9 12.2	324 37.6	·· 55.0	246 42.1	·· 45.5	329 16.4	·· 33.0	248 51.2	·· 57.0
U 10	24 14.7	339 37.0	56.0	261 43.1	45.2	344 18.2	33.2	263 53.5	57.0
N 11	39 17.1	354 36.4	56.9	276 44.1	44.9	359 20.1	33.4	278 55.7	56.9
D 12	54 19.6	9 35.9	N15 57.9	291 45.1	N21 44.5	14 22.0	N14 33.6	293 58.0	N20 56.9
A 13	69 22.0	24 35.3	58.8	306 46.1	44.2	29 23.9	33.8	309 00.2	56.8
Y 14	84 24.5	39 34.7	15 59.8	321 47.1	43.9	44 25.8	33.9	324 02.5	56.8
15	99 27.0	54 34.1	16 00.7	336 48.2	·· 43.6	59 27.7	·· 34.1	339 04.7	·· 56.8
16	114 29.4	69 33.6	01.6	351 49.2	43.2	74 29.6	34.3	354 07.0	56.7
17	129 31.9	84 33.0	02.6	6 50.2	42.9	89 31.4	34.5	9 09.2	56.7
18	144 34.4	99 32.4	N16 03.5	21 51.2	N21 42.6	104 33.3	N14 34.7	24 11.5	N20 56.6
19	159 36.8	114 31.8	04.5	36 52.2	42.3	119 35.2	34.8	39 13.7	56.6
20	174 39.3	129 31.2	05.4	51 53.2	41.9	134 37.1	35.0	54 16.0	56.6
21	189 41.8	144 30.7	·· 06.3	66 54.2	·· 41.6	149 39.0	·· 35.2	69 18.2	·· 56.5
22	204 44.2	159 30.1	07.3	81 55.2	41.3	164 40.9	35.4	84 20.5	56.5
23	219 46.7	174 29.5	08.2	96 56.2	41.0	179 42.8	35.6	99 22.7	56.4
17 00	234 49.2	189 28.9	N16 09.1	111 57.2	N21 40.6	194 44.6	N14 35.7	114 25.0	N20 56.4
01	249 51.6	204 28.3	10.1	126 58.2	40.3	209 46.5	35.9	129 27.2	56.4
02	264 54.1	219 27.7	11.0	141 59.2	40.0	224 48.4	36.1	144 29.5	56.3
03	279 56.5	234 27.2	·· 11.9	157 00.2	·· 39.6	239 50.3	·· 36.3	159 31.7	·· 56.3
04	294 59.0	249 26.6	12.9	172 01.2	39.3	254 52.2	36.5	174 33.9	56.2
05	310 01.5	264 26.0	13.8	187 02.2	39.0	269 54.1	36.6	189 36.2	56.2
06	325 03.9	279 25.4	N16 14.7	202 03.2	N21 38.7	284 56.0	N14 36.8	204 38.4	N20 56.2
07	340 06.4	294 24.8	15.7	217 04.2	38.3	299 57.8	37.0	219 40.7	56.1
08	355 08.9	309 24.2	16.6	232 05.2	38.0	314 59.7	37.2	234 42.9	56.1
M 09	10 11.3	324 23.6	·· 17.5	247 06.2	·· 37.7	330 01.6	·· 37.4	249 45.2	·· 56.1
O 10	25 13.8	339 23.1	18.4	262 07.2	37.3	345 03.5	37.5	264 47.4	56.0
N 11	40 16.3	354 22.5	19.4	277 08.2	37.0	0 05.4	37.7	279 49.7	56.0
D 12	55 18.7	9 21.9	N16 20.3	292 09.2	N21 36.7	15 07.3	N14 37.9	294 51.9	N20 55.9
A 13	70 21.2	24 21.3	21.2	307 10.2	36.4	30 09.2	38.1	309 54.2	55.9
Y 14	85 23.7	39 20.7	22.1	322 11.2	36.0	45 11.0	38.3	324 56.4	55.9
15	100 26.1	54 20.1	·· 23.1	337 12.3	·· 35.7	60 12.9	·· 38.4	339 58.7	·· 55.8
16	115 28.6	69 19.5	24.0	352 13.3	35.4	75 14.8	38.6	355 00.9	55.8
17	130 31.0	84 18.9	24.9	7 14.3	35.0	90 16.7	38.8	10 03.2	55.7
18	145 33.5	99 18.3	N16 25.8	22 15.3	N21 34.7	105 18.6	N14 39.0	25 05.4	N20 55.7
19	160 36.0	114 17.8	26.8	37 16.3	34.4	120 20.5	39.2	40 07.7	55.7
20	175 38.4	129 17.2	27.7	52 17.3	34.0	135 22.4	39.3	55 09.9	55.6
21	190 40.9	144 16.6	·· 28.6	67 18.3	·· 33.7	150 24.2	·· 39.5	70 12.1	·· 55.6
22	205 43.4	159 16.0	29.5	82 19.3	33.4	165 26.1	39.7	85 14.4	55.5
23	220 45.8	174 15.4	30.4	97 20.3	33.0	180 28.0	39.9	100 16.6	55.5
	h m								
Mer. Pass.	8 23.3	v −0.6	d 0.9	v 1.0	d 0.3	v 1.9	d 0.2	v 2.3	d 0.0

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 39.9	S40 24.0
Achernar	335 48.0	S57 21.3
Acrux	173 40.0	S62 58.4
Adhara	255 34.7	S28 56.7
Aldebaran	291 21.7	N16 27.6
Alioth	166 44.7	N56 05.4
Alkaid	153 20.4	N49 25.9
Al Na'ir	28 18.7	S47 04.3
Alnilam	276 14.9	S 1 13.1
Alphard	218 23.5	S 8 33.6
Alphecca	126 34.2	N26 47.6
Alpheratz	358 12.5	N28 57.5
Altair	62 35.2	N 8 48.3
Ankaa	353 43.4	S42 25.9
Antares	113 00.1	S26 22.8
Arcturus	146 20.8	N19 18.3
Atria	108 26.4	S68 59.1
Avior	234 29.6	S59 26.4
Bellatrix	279 02.2	N 6 19.6
Betelgeuse	271 31.7	N 7 24.1
Canopus	264 08.9	S52 41.3
Capella	281 16.1	N45 58.5
Deneb	49 50.3	N45 11.6
Denebola	183 01.9	N14 42.2
Diphda	349 24.1	S18 06.9
Dubhe	194 25.6	N61 52.9
Elnath	278 48.2	N28 35.2
Eltanin	90 58.6	N51 29.4
Enif	34 14.4	N 9 46.0
Fomalhaut	15 54.8	S29 44.7
Gacrux	172 31.6	S56 59.2
Gienah	176 20.8	S17 24.9
Hadar	149 26.9	S60 15.8
Hamal	328 32.5	N23 21.0
Kaus Aust.	84 20.4	S34 23.7
Kochab	137 17.8	N74 15.2
Markab	14 06.2	N15 04.6
Menkar	314 44.5	N 3 59.8
Menkent	148 40.1	S36 15.4
Miaplacidus	221 45.7	S69 37.6
Mirfak	309 20.8	N49 46.6
Nunki	76 32.6	S26 19.5
Peacock	54 02.8	S56 48.4
Pollux	244 02.0	N28 05.0
Procyon	245 29.0	N 5 17.0
Rasalhague	96 32.0	N12 34.6
Regulus	208 13.1	N12 04.9
Rigel	281 39.2	S 8 13.9
Rigil Kent.	140 29.1	S60 44.4
Sabik	102 44.2	S15 41.8
Schedar	350 12.7	N56 24.3
Shaula	96 59.4	S37 05.1
Sirius	258 58.5	S16 41.3
Spica	159 00.4	S11 02.4
Suhail	223 13.0	S43 20.6
Vega	80 57.5	N38 45.6
Zuben'ubi	137 36.0	S15 56.7

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	315 52.7	11 22
Mars	237 43.1	16 33
Jupiter	320 09.4	11 03
Saturn	239 40.9	16 23

1976 MAY 15, 16, 17 (SAT., SUN., MON.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
15 00	180 55.6	N18 50.7	343 39.2	4.5	S19 33.6	2.2	60.3
01	195 55.6	51.2	358 02.7	4.6	19 35.8	2.0	60.2
02	210 55.6	51.8	12 26.3	4.5	19 37.8	1.8	60.2
03	225 55.6	52.4	26 49.8	4.6	19 39.6	1.8	60.2
04	240 55.6	53.0	41 13.4	4.6	19 41.4	1.6	60.1
05	255 55.6	53.6	55 37.0	4.6	19 43.0	1.4	60.1
06	270 55.6	N18 54.2	70 00.6	4.7	S19 44.4	1.3	60.1
07	285 55.6	54.8	84 24.3	4.6	19 45.7	1.2	60.1
S 08	300 55.6	55.4	98 47.9	4.8	19 46.9	1.0	60.0
A 09	315 55.6	56.0	113 11.7	4.7	19 47.9	0.9	60.0
T 10	330 55.6	56.5	127 35.4	4.8	19 48.8	0.7	60.0
U 11	345 55.6	57.1	141 59.2	4.8	19 49.5	0.6	59.9
R 12	0 55.6	N18 57.7	156 23.0	4.9	S19 50.1	0.5	59.9
D 13	15 55.6	58.3	170 46.9	4.9	19 50.6	0.3	59.9
A 14	30 55.6	58.9	185 10.8	4.9	19 50.9	0.2	59.8
Y 15	45 55.6	18 59.5	199 34.7	5.0	19 51.1	0.1	59.8
16	60 55.5	19 00.0	213 58.7	5.0	19 51.2	0.1	59.8
17	75 55.5	00.6	228 22.7	5.1	19 51.1	0.3	59.7
18	90 55.5	N19 01.2	242 46.8	5.1	S19 50.8	0.3	59.7
19	105 55.5	01.8	257 10.9	5.2	19 50.5	0.5	59.7
20	120 55.5	02.4	271 35.1	5.2	19 50.0	0.6	59.6
21	135 55.5	03.0	285 59.3	5.2	19 49.4	0.8	59.6
22	150 55.5	03.5	300 23.5	5.4	19 48.6	0.9	59.6
23	165 55.5	04.1	314 47.9	5.3	19 47.7	1.0	59.5
16 00	180 55.5	N19 04.7	329 12.2	5.5	S19 46.7	1.2	59.5
01	195 55.5	05.3	343 36.7	5.5	19 45.5	1.3	59.5
02	210 55.5	05.8	358 01.2	5.5	19 44.2	1.4	59.4
03	225 55.4	06.4	12 25.7	5.6	19 42.8	1.6	59.4
04	240 55.4	07.0	26 50.3	5.7	19 41.2	1.7	59.4
05	255 55.4	07.6	41 15.0	5.7	19 39.5	1.8	59.3
06	270 55.4	N19 08.1	55 39.7	5.8	S19 37.7	1.9	59.3
07	285 55.4	08.7	70 04.5	5.8	19 35.8	2.1	59.3
08	300 55.4	09.3	84 29.3	6.0	19 33.7	2.2	59.2
S 09	315 55.4	09.9	98 54.3	5.9	19 31.5	2.4	59.2
U 10	330 55.4	10.4	113 19.2	6.1	19 29.1	2.4	59.2
N 11	345 55.3	11.0	127 44.3	6.1	19 26.7	2.6	59.1
D 12	0 55.3	N19 11.6	142 09.4	6.2	S19 24.1	2.7	59.1
A 13	15 55.3	12.2	156 34.6	6.3	19 21.4	2.8	59.0
Y 14	30 55.3	12.7	170 59.9	6.3	19 18.6	2.9	59.0
15	45 55.3	13.3	185 25.2	6.4	19 15.7	3.1	59.0
16	60 55.3	13.9	199 50.6	6.5	19 12.6	3.2	58.9
17	75 55.3	14.4	214 16.1	6.6	19 09.4	3.3	58.9
18	90 55.2	N19 15.0	228 41.7	6.6	S19 06.1	3.4	58.9
19	105 55.2	15.6	243 07.3	6.7	19 02.7	3.6	58.8
20	120 55.2	16.1	257 33.0	6.8	18 59.1	3.6	58.8
21	135 55.2	16.7	271 58.8	6.8	18 55.5	3.8	58.7
22	150 55.2	17.3	286 24.6	7.0	18 51.7	3.9	58.7
23	165 55.2	17.8	300 50.6	7.0	18 47.8	3.9	58.7
17 00	180 55.2	N19 18.4	315 16.6	7.1	S18 43.9	4.2	58.6
01	195 55.1	19.0	329 42.7	7.2	18 39.7	4.2	58.6
02	210 55.1	19.5	344 08.9	7.2	18 35.5	4.3	58.5
03	225 55.1	20.1	358 35.1	7.4	18 31.2	4.4	58.5
04	240 55.1	20.7	13 01.5	7.4	18 26.8	4.6	58.5
05	255 55.1	21.2	27 27.9	7.5	18 22.2	4.6	58.4
06	270 55.1	N19 21.8	41 54.4	7.6	S18 17.6	4.8	58.4
07	285 55.0	22.3	56 21.0	7.6	18 12.8	4.8	58.4
08	300 55.0	22.9	70 47.6	7.8	18 08.0	5.0	58.3
M 09	315 55.0	23.5	85 14.4	7.8	18 03.0	5.0	58.3
O 10	330 55.0	24.0	99 41.2	8.0	17 58.0	5.2	58.2
N 11	345 55.0	24.6	114 08.2	8.0	17 52.8	5.3	58.2
D 12	0 54.9	N19 25.1	128 35.2	8.1	S17 47.5	5.3	58.2
A 13	15 54.9	25.7	143 02.3	8.1	17 42.2	5.5	58.1
Y 14	30 54.9	26.2	157 29.4	8.3	17 36.7	5.5	58.1
15	45 54.9	26.8	171 56.7	8.4	17 31.2	5.7	58.0
16	60 54.9	27.4	186 24.1	8.4	17 25.5	5.7	58.0
17	75 54.8	27.9	200 51.5	8.5	17 19.8	5.9	58.0
18	90 54.8	N19 28.5	215 19.0	8.6	S17 13.9	5.9	57.9
19	105 54.8	29.0	229 46.6	8.7	17 08.0	6.0	57.9
20	120 54.8	29.6	244 14.3	8.8	17 02.0	6.1	57.8
21	135 54.8	30.1	258 42.1	8.9	16 55.9	6.2	57.8
22	150 54.7	30.7	273 10.0	9.0	16 49.7	6.3	57.8
23	165 54.7	31.2	287 38.0	9.0	16 43.4	6.4	57.7
	S.D. 15.8	d 0.6	S.D. 16.3		16.1		15.8

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 15	Moonrise 16	Moonrise 17	Moonrise 18
°	h m	h m	h m	h m	h m	h m	h m
N 72	▭	▭		▬	▬	▬	02 19
N 70	////	////	00 20	00 28	01 43	01 38	01 35
68	////	////	01 41	24 19	00 19	00 51	01 05
66	////	////	02 18	23 41	24 20	00 20	00 42
64	////	01 01	02 44	23 14	23 57	24 24	00 24
62	////	01 47	03 04	22 53	23 39	24 10	00 10
60	////	02 16	03 20	22 36	23 23	23 57	24 22
N 58	00 54	02 38	03 34	22 22	23 10	23 47	24 14
56	01 36	02 55	03 45	22 09	22 59	23 37	24 07
54	02 03	03 10	03 56	21 59	22 49	23 29	24 00
52	02 24	03 22	04 05	21 49	22 40	23 21	23 54
50	02 40	03 33	04 13	21 40	22 33	23 15	23 49
45	03 12	03 56	04 30	21 22	22 16	23 00	23 38
N 40	03 35	04 13	04 44	21 08	22 02	22 48	23 28
35	03 53	04 28	04 56	20 55	21 50	22 38	23 20
30	04 08	04 40	05 06	20 44	21 40	22 29	23 13
20	04 32	05 00	05 24	20 26	21 22	22 14	23 00
N 10	04 50	05 16	05 39	20 09	21 07	22 00	22 49
0	05 05	05 31	05 53	19 54	20 52	21 47	22 39
S 10	05 19	05 44	06 07	19 39	20 38	21 35	22 28
20	05 31	05 58	06 21	19 23	20 23	21 21	22 17
30	05 44	06 13	06 38	19 04	20 05	21 06	22 05
35	05 50	06 21	06 48	18 53	19 55	20 57	21 57
40	05 57	06 30	06 59	18 41	19 43	20 46	21 49
45	06 04	06 40	07 12	18 26	19 29	20 34	21 39
S 50	06 13	06 52	07 28	18 08	19 12	20 19	21 27
52	06 16	06 58	07 35	18 00	19 04	20 12	21 22
54	06 20	07 04	07 44	17 51	18 55	20 05	21 16
56	06 24	07 10	07 53	17 40	18 45	19 56	21 09
58	06 28	07 17	08 03	17 28	18 34	19 46	21 01
S 60	06 33	07 25	08 15	17 14	18 20	19 35	20 53

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 15	Moonset 16	Moonset 17	Moonset 18
°	h m	h m	h m	h m	h m	h m	h m
N 72	▭	▭	▭	▬	▬	▬	05 53
N 70	▭	▭	▭	01 45	02 36	04 41	06 37
68	22 17	////	////	03 00	04 00	05 28	07 06
66	21 38	////	////	03 38	04 38	05 58	07 28
64	21 11	23 00	////	04 04	05 05	06 21	07 45
62	20 51	22 10	////	04 25	05 25	06 39	07 59
60	20 34	21 39	////	04 42	05 42	06 54	08 11
N 58	20 20	21 17	23 05	04 56	05 56	07 06	08 21
56	20 09	20 59	22 20	05 08	06 09	07 17	08 30
54	19 58	20 44	21 52	05 19	06 19	07 27	08 38
52	19 49	20 32	21 31	05 28	06 29	07 35	08 45
50	19 41	20 20	21 14	05 37	06 37	07 43	08 51
45	19 23	19 58	20 42	05 55	06 55	07 59	09 05
N 40	19 09	19 40	20 18	06 09	07 10	08 13	09 16
35	18 57	19 26	20 00	06 22	07 22	08 24	09 26
30	18 47	19 13	19 45	06 33	07 33	08 34	09 34
20	18 29	18 53	19 21	06 51	07 51	08 51	09 48
N 10	18 14	18 36	19 03	07 07	08 07	09 05	10 01
0	18 00	18 22	18 47	07 23	08 22	09 19	10 12
S 10	17 46	18 08	18 34	07 38	08 37	09 33	10 24
20	17 31	17 54	18 21	07 54	08 53	09 47	10 36
30	17 14	17 39	18 08	08 12	09 11	10 04	10 50
35	17 04	17 31	18 02	08 23	09 22	10 13	10 58
40	16 53	17 22	17 55	08 36	09 34	10 24	11 07
45	16 40	17 12	17 48	08 50	09 48	10 37	11 18
S 50	16 24	17 00	17 40	09 08	10 06	10 53	11 31
52	16 17	16 55	17 36	09 16	10 14	11 00	11 37
54	16 08	16 49	17 32	09 26	10 23	11 08	11 43
56	15 59	16 42	17 28	09 36	10 33	11 17	11 51
58	15 49	16 35	17 24	09 48	10 45	11 27	11 59
S 60	15 37	16 26	17 19	10 02	10 58	11 39	12 08

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
15	03 43	03 42	11 56	01 08	13 38	16	
16	03 42	03 41	11 56	02 08	14 37	17	
17	03 41	03 40	11 56	03 06	15 33	18	◑

1976 JUNE 8, 9, 10 (TUES., WED., THURS.)

G.M.T.	ARIES	VENUS −3.5		MARS +1.8		JUPITER −1.6		SATURN +0.5	
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
8 00	256 30.2	183 15.1	N22 24.2	120 47.0	N18 18.2	211 25.7	N16 04.3	133 55.0	N20 31.6
01	271 32.7	198 14.3	24.6	135 48.1	17.7	226 27.6	04.5	148 57.2	31.5
02	286 35.1	213 13.5	25.1	150 49.1	17.3	241 29.5	04.6	163 59.4	31.5
03	301 37.6	228 12.6	·· 25.5	165 50.1	·· 16.9	256 31.4	·· 04.8	179 01.6	·· 31.4
04	316 40.1	243 11.8	25.9	180 51.1	16.4	271 33.4	04.9	194 03.7	31.4
05	331 42.5	258 11.0	26.4	195 52.1	16.0	286 35.3	05.1	209 05.9	31.3
06	346 45.0	273 10.2	N22 26.8	210 53.1	N18 15.5	301 37.2	N16 05.3	224 08.1	N20 31.2
07	1 47.5	288 09.3	27.3	225 54.1	15.1	316 39.1	05.4	239 10.3	31.2
08	16 49.9	303 08.5	27.7	240 55.1	14.7	331 41.0	05.6	254 12.5	31.1
T 09	31 52.4	318 07.7	·· 28.2	255 56.1	·· 14.2	346 42.9	·· 05.7	269 14.7	·· 31.1
U 10	46 54.8	333 06.9	28.6	270 57.1	13.8	1 44.8	05.9	284 16.9	31.0
E 11	61 57.3	348 06.0	29.0	285 58.1	13.4	16 46.7	06.0	299 19.1	31.0
S 12	76 59.8	3 05.2	N22 29.5	300 59.1	N18 12.9	31 48.6	N16 06.2	314 21.2	N20 30.9
D 13	92 02.2	18 04.4	29.9	316 00.1	12.5	46 50.6	06.3	329 23.4	30.9
A 14	107 04.7	33 03.6	30.4	331 01.1	12.0	61 52.5	06.5	344 25.6	30.8
Y 15	122 07.2	48 02.7	·· 30.8	346 02.2	·· 11.6	76 54.4	·· 06.6	359 27.8	·· 30.7
16	137 09.6	63 01.9	31.2	1 03.2	11.2	91 56.3	06.8	14 30.0	30.7
17	152 12.1	78 01.1	31.6	16 04.2	10.7	106 58.2	06.9	29 32.2	30.6
18	167 14.6	93 00.3	N22 32.1	31 05.2	N18 10.3	122 00.1	N16 07.1	44 34.4	N20 30.6
19	182 17.0	107 59.4	32.5	46 06.2	09.8	137 02.0	07.3	59 36.5	30.5
20	197 19.5	122 58.6	32.9	61 07.2	09.4	152 03.9	07.4	74 38.7	30.5
21	212 22.0	137 57.8	·· 33.4	76 08.2	·· 09.0	167 05.8	·· 07.6	89 40.9	·· 30.4
22	227 24.4	152 56.9	33.8	91 09.2	08.5	182 07.8	07.7	104 43.1	30.4
23	242 26.9	167 56.1	34.2	106 10.2	08.1	197 09.7	07.9	119 45.3	30.3
9 00	257 29.3	182 55.3	N22 34.6	121 11.2	N18 07.6	212 11.6	N16 08.0	134 47.5	N20 30.3
01	272 31.8	197 54.4	35.1	136 12.2	07.2	227 13.5	08.2	149 49.6	30.2
02	287 34.3	212 53.6	35.5	151 13.2	06.7	242 15.4	08.3	164 51.8	30.1
03	302 36.7	227 52.8	·· 35.9	166 14.2	·· 06.3	257 17.3	·· 08.5	179 54.0	·· 30.1
04	317 39.2	242 52.0	36.3	181 15.3	05.9	272 19.2	08.6	194 56.2	30.0
05	332 41.7	257 51.1	36.7	196 16.3	05.4	287 21.1	08.8	209 58.4	30.0
06	347 44.1	272 50.3	N22 37.2	211 17.3	N18 05.0	302 23.1	N16 08.9	225 00.6	N20 29.9
07	2 46.6	287 49.5	37.6	226 18.3	04.5	317 25.0	09.1	240 02.8	29.9
W 08	17 49.1	302 48.6	38.0	241 19.3	04.1	332 26.9	09.3	255 04.9	29.8
E 09	32 51.5	317 47.8	·· 38.4	256 20.3	·· 03.6	347 28.8	·· 09.4	270 07.1	·· 29.8
D 10	47 54.0	332 47.0	38.8	271 21.3	03.2	2 30.7	09.6	285 09.3	29.7
N 11	62 56.5	347 46.1	39.2	286 22.3	02.8	17 32.6	09.7	300 11.5	29.6
E 12	77 58.9	2 45.3	N22 39.6	301 23.3	N18 02.3	32 34.5	N16 09.9	315 13.7	N20 29.6
S 13	93 01.4	17 44.4	40.1	316 24.3	01.9	47 36.5	10.0	330 15.9	29.5
D 14	108 03.8	32 43.6	40.5	331 25.3	01.4	62 38.4	10.2	345 18.0	29.5
A 15	123 06.3	47 42.8	·· 40.9	346 26.3	·· 01.0	77 40.3	·· 10.3	0 20.2	·· 29.4
Y 16	138 08.8	62 41.9	41.3	1 27.3	00.5	92 42.2	10.5	15 22.4	29.4
17	153 11.2	77 41.1	41.7	16 28.4	18 00.1	107 44.1	10.6	30 24.6	29.3
18	168 13.7	92 40.3	N22 42.1	31 29.4	N17 59.6	122 46.0	N16 10.8	45 26.8	N20 29.3
19	183 16.2	107 39.4	42.5	46 30.4	59.2	137 47.9	10.9	60 29.0	29.2
20	198 18.6	122 38.6	42.9	61 31.4	58.7	152 49.8	11.1	75 31.1	29.1
21	213 21.1	137 37.8	·· 43.3	76 32.4	·· 58.3	167 51.8	·· 11.2	90 33.3	·· 29.1
22	228 23.6	152 36.9	43.7	91 33.4	57.9	182 53.7	11.4	105 35.5	29.0
23	243 26.0	167 36.1	44.1	106 34.4	57.4	197 55.6	11.5	120 37.7	29.0
10 00	258 28.5	182 35.2	N22 44.5	121 35.4	N17 57.0	212 57.5	N16 11.7	135 39.9	N20 28.9
01	273 30.9	197 34.4	44.9	136 36.4	56.5	227 59.4	11.8	150 42.1	28.9
02	288 33.4	212 33.6	45.3	151 37.4	56.1	243 01.3	12.0	165 44.2	28.8
03	303 35.9	227 32.7	·· 45.7	166 38.4	·· 55.6	258 03.3	·· 12.2	180 46.4	·· 28.8
04	318 38.3	242 31.9	46.1	181 39.4	55.2	273 05.2	12.3	195 48.6	28.7
05	333 40.8	257 31.0	46.5	196 40.5	54.7	288 07.1	12.5	210 50.8	28.6
06	348 43.3	272 30.2	N22 46.8	211 41.5	N17 54.3	303 09.0	N16 12.6	225 53.0	N20 28.6
07	3 45.7	287 29.4	47.2	226 42.5	53.8	318 10.9	12.8	240 55.2	28.5
T 08	18 48.2	302 28.5	47.6	241 43.5	53.4	333 12.8	12.9	255 57.3	28.5
H 09	33 50.7	317 27.7	·· 48.0	256 44.5	·· 52.9	348 14.7	·· 13.1	270 59.5	·· 28.4
U 10	48 53.1	332 26.8	48.4	271 45.5	52.5	3 16.7	13.2	286 01.7	28.4
R 11	63 55.6	347 26.0	48.8	286 46.5	52.0	18 18.6	13.4	301 03.9	28.3
S 12	78 58.1	2 25.2	N22 49.2	301 47.5	N17 51.6	33 20.5	N16 13.5	316 06.1	N20 28.3
D 13	94 00.5	17 24.3	49.5	316 48.5	51.1	48 22.4	13.7	331 08.2	28.2
A 14	109 03.0	32 23.5	49.9	331 49.5	50.7	63 24.3	13.8	346 10.4	28.1
Y 15	124 05.4	47 22.6	·· 50.3	346 50.5	·· 50.2	78 26.2	·· 14.0	1 12.6	·· 28.1
16	139 07.9	62 21.8	50.7	1 51.6	49.8	93 28.1	14.1	16 14.8	28.0
17	154 10.4	77 20.9	51.1	16 52.6	49.3	108 30.1	14.3	31 17.0	28.0
18	169 12.8	92 20.1	N22 51.4	31 53.6	N17 48.9	123 32.0	N16 14.4	46 19.2	N20 27.9
19	184 15.3	107 19.3	51.8	46 54.6	48.4	138 33.9	14.6	61 21.3	27.9
20	199 17.8	122 18.4	52.2	61 55.6	48.0	153 35.8	14.7	76 23.5	27.8
21	214 20.2	137 17.6	·· 52.6	76 56.6	·· 47.5	168 37.7	·· 14.9	91 25.7	·· 27.7
22	229 22.7	152 16.7	52.9	91 57.6	47.1	183 39.6	15.0	106 27.9	27.7
23	244 25.2	167 15.9	53.3	106 58.6	46.6	198 41.6	15.2	121 30.1	27.6
Mer. Pass.	h m 6 48.9	*v* −0.8	*d* 0.4	*v* 1.0	*d* 0.4	*v* 1.9	*d* 0.2	*v* 2.2	*d* 0.1

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 39.8	S40 23.8
Achernar	335 47.8	S57 21.1
Acrux	173 40.2	S62 58.5
Adhara	255 34.7	S28 56.6
Aldebaran	291 21.7	N16 27.7
Alioth	166 44.9	N56 05.4
Alkaid	153 20.5	N49 26.0
Al Na'ir	28 18.4	S47 04.2
Alnilam	276 14.9	S 1 13.1
Alphard	218 23.6	S 8 33.6
Alphecca	126 34.2	N26 47.7
Alpheratz	358 12.4	N28 57.5
Altair	62 35.1	N 8 48.4
Ankaa	353 43.3	S42 25.8
Antares	113 00.0	S26 22.8
Arcturus	146 20.9	N19 18.3
Atria	108 26.3	S68 59.2
Avior	234 29.8	S59 26.4
Bellatrix	279 02.2	N 6 19.6
Betelgeuse	271 31.7	N 7 24.1
Canopus	264 09.0	S52 41.2
Capella	281 16.0	N45 58.4
Deneb	49 50.1	N45 11.7
Denebola	183 02.0	N14 42.2
Diphda	349 23.9	S18 06.8
Dubhe	194 25.8	N61 52.9
Elnath	278 48.2	N28 35.2
Eltanin	90 58.5	N51 29.5
Enif	34 14.3	N 9 46.0
Fomalhaut	15 54.6	S29 44.6
Gacrux	172 31.7	S56 59.2
Gienah	176 20.8	S17 24.9
Hadar	149 26.9	S60 15.8
Hamal	328 32.4	N23 21.0
Kaus Aust.	84 20.3	S34 23.7
Kochab	137 18.0	N74 15.3
Markab	14 06.0	N15 04.7
Menkar	314 44.4	N 3 59.8
Menkent	148 40.1	S36 15.5
Miaplacidus	221 46.0	S69 37.6
Mirfak	309 20.7	N49 46.5
Nunki	76 32.4	S26 19.5
Peacock	54 02.5	S56 48.4
Pollux	244 02.0	N28 05.0
Procyon	245 29.1	N 5 17.0
Rasalhague	96 31.9	N12 34.7
Regulus	208 13.2	N12 04.9
Rigel	281 39.1	S 8 13.8
Rigil Kent.	140 29.1	S60 44.4
Sabik	102 44.1	S15 41.7
Schedar	350 12.4	N56 24.3
Shaula	96 59.3	S37 05.2
Sirius	258 58.6	S16 41.2
Spica	159 00.4	S11 02.4
Suhail	223 13.1	S43 20.6
Vega	80 57.4	N38 45.7
Zuben'ubi	137 35.9	S15 56.7

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	285 25.9	11 49
Mars	223 41.9	15 54
Jupiter	314 42.2	9 50
Saturn	237 18.1	14 59

1976 JUNE 8, 9, 10 (TUES., WED., THURS.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	v	MOON Dec.	d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
8 00	180 16.2	N22 50.2	58 28.3	8.2	S 9 44.4	10.8	60.0
01	195 16.0	50.4	72 55.5	8.3	9 55.2	10.8	60.0
02	210 15.9	50.7	87 22.8	8.1	10 06.0	10.7	60.0
03	225 15.8	·· 50.9	101 49.9	8.1	10 16.7	10.7	60.0
04	240 15.7	51.1	116 17.0	8.0	10 27.4	10.6	60.0
05	255 15.6	51.3	130 44.0	8.0	10 38.0	10.5	60.0
06	270 15.5	N22 51.5	145 11.0	8.0	S10 48.5	10.5	60.1
07	285 15.3	51.8	159 38.0	7.8	10 59.0	10.4	60.1
08	300 15.2	52.0	174 04.8	7.8	11 09.4	10.4	60.1
T 09	315 15.1	·· 52.2	188 31.6	7.8	11 19.8	10.2	60.1
U 10	330 15.0	52.4	202 58.4	7.6	11 30.0	10.3	60.1
E 11	345 14.9	52.7	217 25.0	7.7	11 40.3	10.1	60.1
S 12	0 14.7	N22 52.9	231 51.7	7.5	S11 50.4	10.1	60.1
D 13	15 14.6	53.1	246 18.2	7.5	12 00.5	10.0	60.1
A 14	30 14.5	53.3	260 44.7	7.5	12 10.5	9.9	60.2
Y 15	45 14.4	·· 53.5	275 11.2	7.4	12 20.4	9.9	60.2
16	60 14.3	53.7	289 37.6	7.3	12 30.3	9.8	60.2
17	75 14.1	54.0	304 03.9	7.3	12 40.1	9.7	60.2
18	90 14.0	N22 54.2	318 30.2	7.2	S12 49.8	9.6	60.2
19	105 13.9	54.4	332 56.4	7.1	12 59.4	9.6	60.2
20	120 13.8	54.6	347 22.5	7.1	13 09.0	9.4	60.2
21	135 13.7	·· 54.8	1 48.6	7.0	13 18.4	9.4	60.2
22	150 13.5	55.0	16 14.6	7.0	13 27.8	9.3	60.2
23	165 13.4	55.2	30 40.6	6.9	13 37.1	9.2	60.2
9 00	180 13.3	N22 55.4	45 06.5	6.8	S13 46.3	9.1	60.2
01	195 13.2	55.6	59 32.3	6.8	13 55.4	9.1	60.3
02	210 13.1	55.9	73 58.1	6.8	14 04.5	8.9	60.3
03	225 12.9	·· 56.1	88 23.9	6.6	14 13.4	8.9	60.3
04	240 12.8	56.3	102 49.5	6.6	14 22.3	8.7	60.3
05	255 12.7	56.5	117 15.1	6.6	14 31.0	8.7	60.3
06	270 12.6	N22 56.7	131 40.7	6.5	S14 39.7	8.6	60.3
W 07	285 12.5	56.9	146 06.2	6.4	14 48.3	8.5	60.3
E 08	300 12.3	57.1	160 31.6	6.4	14 56.8	8.3	60.3
D 09	315 12.2	·· 57.3	174 57.0	6.4	15 05.1	8.3	60.3
N 10	330 12.1	57.5	189 22.4	6.2	15 13.4	8.2	60.3
E 11	345 12.0	57.7	203 47.6	6.3	15 21.6	8.1	60.3
S 12	0 11.8	N22 57.9	218 12.9	6.1	S15 29.7	8.0	60.3
D 13	15 11.7	58.1	232 38.0	6.1	15 37.7	7.8	60.3
A 14	30 11.6	58.3	247 03.1	6.1	15 45.5	7.8	60.3
Y 15	45 11.5	·· 58.5	261 28.2	6.0	15 53.3	7.7	60.3
16	60 11.4	58.7	275 53.2	6.0	16 01.0	7.5	60.3
17	75 11.2	58.9	290 18.2	5.9	16 08.5	7.5	60.3
18	90 11.1	N22 59.1	304 43.1	5.8	S16 16.0	7.3	60.3
19	105 11.0	59.3	319 07.9	5.8	16 23.3	7.2	60.3
20	120 10.9	59.5	333 32.7	5.8	16 30.5	7.1	60.3
21	135 10.7	·· 59.7	347 57.5	5.7	16 37.6	7.0	60.3
22	150 10.6	22 59.9	2 22.2	5.7	16 44.6	6.9	60.3
23	165 10.5	23 00.1	16 46.9	5.6	16 51.5	6.8	60.3
10 00	180 10.4	N23 00.3	31 11.5	5.6	S16 58.3	6.7	60.3
01	195 10.3	00.5	45 36.1	5.5	17 05.0	6.5	60.3
02	210 10.1	00.6	60 00.6	5.5	17 11.5	6.4	60.3
03	225 10.0	·· 00.8	74 25.1	5.4	17 17.9	6.3	60.3
04	240 09.9	01.0	88 49.5	5.4	17 24.2	6.2	60.3
05	255 09.8	01.2	103 13.9	5.4	17 30.4	6.1	60.3
06	270 09.6	N23 01.4	117 38.3	5.3	S17 36.5	5.9	60.3
07	285 09.5	01.6	132 02.6	5.3	17 42.4	5.8	60.3
T 08	300 09.4	01.8	146 26.9	5.3	17 48.2	5.7	60.3
H 09	315 09.3	·· 02.0	160 51.2	5.2	17 53.9	5.6	60.3
U 10	330 09.1	02.2	175 15.4	5.2	17 59.5	5.4	60.3
R 11	345 09.0	02.3	189 39.6	5.1	18 04.9	5.3	60.3
S 12	0 08.9	N23 02.5	204 03.7	5.1	S18 10.2	5.2	60.3
D 13	15 08.8	02.7	218 27.8	5.1	18 15.4	5.1	60.3
A 14	30 08.6	02.9	232 51.9	5.1	18 20.5	4.9	60.2
Y 15	45 08.5	·· 03.1	247 16.0	5.0	18 25.4	4.8	60.2
16	60 08.4	03.3	261 40.0	5.0	18 30.2	4.7	60.2
17	75 08.3	03.4	276 04.0	5.0	18 34.9	4.5	60.2
18	90 08.1	N23 03.6	290 28.0	5.0	S18 39.4	4.4	60.2
19	105 08.0	03.8	304 52.0	4.9	18 43.8	4.3	60.2
20	120 07.9	04.0	319 15.9	4.9	18 48.1	4.1	60.2
21	135 07.8	·· 04.2	333 39.8	4.9	18 52.2	4.0	60.2
22	150 07.6	04.3	348 03.7	4.9	18 56.2	3.9	60.2
23	165 07.5	04.5	2 27.6	4.8	19 00.1	3.7	60.2
	S.D. 15.8	d 0.2	S.D. 16.4		16.4		16.4

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 8	Moonrise 9	Moonrise 10	Moonrise 11
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	17 46	20 16	▬	▬
N 70	□	□	□	17 20	19 24	21 34	▬
68	□	□	□	17 01	18 52	20 39	22 03
66	////	////	00 34	16 46	18 29	20 05	21 24
64	////	////	01 41	16 33	18 11	19 41	20 56
62	////	////	02 15	16 23	17 56	19 22	20 35
60	////	01 05	02 40	16 14	17 43	19 06	20 18
N 58	////	01 47	02 59	16 06	17 32	18 53	20 04
56	////	02 15	03 15	15 59	17 23	18 42	19 51
54	00 59	02 36	03 29	15 53	17 15	18 32	19 40
52	01 38	02 53	03 41	15 48	17 07	18 23	19 31
50	02 04	03 07	03 51	15 43	17 01	18 15	19 22
45	02 47	03 36	04 13	15 32	16 46	17 58	19 04
N 40	03 17	03 58	04 31	15 24	16 35	17 44	18 49
35	03 40	04 16	04 46	15 16	16 25	17 32	18 37
30	03 58	04 31	04 58	15 09	16 16	17 22	18 26
20	04 26	04 55	05 20	14 58	16 01	17 05	18 07
N 10	04 48	05 15	05 38	14 48	15 48	16 50	17 51
0	05 07	05 33	05 55	14 39	15 36	16 35	17 36
S 10	05 24	05 50	06 13	14 30	15 24	16 21	17 21
20	05 39	06 07	06 31	14 20	15 11	16 06	17 04
30	05 55	06 25	06 51	14 09	14 57	15 49	16 46
35	06 04	06 35	07 03	14 03	14 49	15 39	16 35
40	06 13	06 47	07 17	13 56	14 39	15 28	16 23
45	06 23	07 00	07 34	13 48	14 28	15 15	16 08
S 50	06 34	07 16	07 54	13 38	14 15	14 58	15 51
52	06 39	07 23	08 03	13 33	14 08	14 51	15 42
54	06 45	07 31	08 14	13 28	14 02	14 43	15 33
56	06 51	07 40	08 26	13 23	13 54	14 33	15 23
58	06 57	07 49	08 41	13 17	13 46	14 23	15 11
S 60	07 05	08 01	08 57	13 10	13 36	14 10	14 57

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 8	Moonset 9	Moonset 10	Moonset 11
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	23 41	23 11	▬	▬
N 70	□	□	□	00 11	00 08	{00 13 / 04 59}	▬
68	□	□	□	00 24	00 28	00 36	00 55
66	23 30	////	////	00 34	00 44	01 01	01 28
64	22 19	////	////	00 42	00 58	01 20	01 53
62	21 44	////	////	00 50	01 09	01 35	02 12
60	21 19	22 56	////	00 56	01 19	01 48	02 28
N 58	21 00	22 12	////	01 02	01 27	02 00	02 42
56	20 44	21 44	////	01 07	01 35	02 10	02 54
54	20 30	21 23	23 01	01 12	01 42	02 18	03 04
52	20 18	21 06	22 21	01 16	01 48	02 26	03 13
50	20 07	20 51	21 55	01 20	01 53	02 33	03 21
45	19 45	20 22	21 11	01 28	02 05	02 48	03 38
N 40	19 28	20 00	20 42	01 35	02 15	03 01	03 53
35	19 13	19 43	20 19	01 40	02 24	03 11	04 05
30	19 00	19 28	20 01	01 46	02 31	03 21	04 15
20	18 39	19 03	19 32	01 55	02 44	03 37	04 33
N 10	18 20	18 43	19 10	02 03	02 55	03 51	04 49
0	18 03	18 25	18 51	02 10	03 06	04 04	05 04
S 10	17 46	18 08	18 35	02 18	03 17	04 17	05 19
20	17 28	17 52	18 19	02 26	03 28	04 31	05 35
30	17 07	17 33	18 03	02 35	03 41	04 48	05 53
35	16 55	17 23	17 54	02 40	03 49	04 57	06 03
40	16 41	17 11	17 45	02 46	03 57	05 08	06 15
45	16 25	16 58	17 35	02 53	04 07	05 21	06 30
S 50	16 04	16 43	17 24	03 02	04 20	05 36	06 47
52	15 55	16 35	17 19	03 06	04 25	05 43	06 55
54	15 44	16 27	17 13	03 10	04 32	05 51	07 05
56	15 32	16 18	17 07	03 15	04 39	06 00	07 15
58	15 17	16 09	17 01	03 20	04 47	06 11	07 27
S 60	15 01	15 57	16 54	03 26	04 56	06 22	07 40

Day	SUN Eqn. of Time 00^h	SUN Eqn. of Time 12^h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
8	01 05	00 59	11 59	20 52	08 25	10	
9	00 53	00 48	11 59	21 50	09 21	11	◐
10	00 42	00 36	11 59	22 50	10 20	12	

1976 JULY 5, 6, 7 (MON., TUES., WED.)

G.M.T.	ARIES	VENUS −3.4		MARS +1.9		JUPITER −1.8		SATURN +0.5		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
5 00	283 07.0	173 47.2	N23 07.5	131 45.7	N12 57.2	232 23.4	N17 33.0	157 16.2	N19 51.2	Acamar	315 39.6	S40 23.7
01	298 09.4	188 46.4	07.2	146 46.7	56.6	247 25.4	33.1	172 18.4	51.1	Achernar	335 47.5	S57 21.0
02	313 11.9	203 45.5	06.9	161 47.8	56.1	262 27.4	33.2	187 20.5	51.0	Acrux	173 40.4	S62 58.5
03	328 14.4	218 44.7	·· 06.5	176 48.8	·· 55.5	277 29.3	·· 33.3	202 22.7	·· 51.0	Adhara	255 34.7	S28 56.5
04	343 16.8	233 43.8	06.2	191 49.8	55.0	292 31.3	33.4	217 24.8	50.9	Aldebaran	291 21.5	N16 27.7
05	358 19.3	248 43.0	05.9	206 50.8	54.4	307 33.3	33.6	232 27.0	50.8			
06	13 21.8	263 42.1	N23 05.5	221 51.9	N12 53.9	322 35.3	N17 33.7	247 29.1	N19 50.8	Alioth	166 45.0	N56 05.5
07	28 24.2	278 41.2	05.2	236 52.9	53.3	337 37.3	33.8	262 31.2	50.7	Alkaid	153 20.6	N49 26.1
08	43 26.7	293 40.4	04.9	251 53.9	52.8	352 39.2	33.9	277 33.4	50.6	Al Na'ir	28 18.2	S47 04.2
M 09	58 29.1	308 39.5	·· 04.5	266 54.9	·· 52.3	7 41.2	·· 34.0	292 35.5	·· 50.6	Alnilam	276 14.8	S 1 13.0
O 10	73 31.6	323 38.7	04.2	281 56.0	51.7	22 43.2	34.1	307 37.7	50.5	Alphard	218 23.6	S 8 33.5
N 11	88 34.1	338 37.8	03.9	296 57.0	51.2	37 45.2	34.3	322 39.8	50.4			
D 12	103 36.5	353 36.9	N23 03.5	311 58.0	N12 50.6	52 47.2	N17 34.4	337 42.0	N19 50.3	Alphecca	126 34.3	N26 47.8
A 13	118 39.0	8 36.1	03.2	326 59.0	50.1	67 49.1	34.5	352 44.1	50.3	Alpheratz	358 12.1	N28 57.6
Y 14	133 41.5	23 35.2	02.8	342 00.1	49.5	82 51.1	34.6	7 46.3	50.2	Altair	62 34.9	N 8 48.5
15	148 43.9	38 34.4	·· 02.5	357 01.1	·· 49.0	97 53.1	·· 34.7	22 48.4	·· 50.1	Ankaa	353 43.0	S42 25.7
16	163 46.4	53 33.5	02.2	12 02.1	48.4	112 55.1	34.8	37 50.5	50.1	Antares	113 00.0	S26 22.8
17	178 48.9	68 32.7	01.8	27 03.2	47.8	127 57.1	35.0	52 52.7	50.0			
18	193 51.3	83 31.8	N23 01.5	42 04.2	N12 47.3	142 59.1	N17 35.1	67 54.8	N19 49.9	Arcturus	146 20.9	N19 18.4
19	208 53.8	98 31.0	01.1	57 05.2	46.7	158 01.0	35.2	82 57.0	49.9	Atria	108 26.3	S68 59.3
20	223 56.2	113 30.1	00.8	72 06.2	46.2	173 03.0	35.3	97 59.1	49.8	Avior	234 29.9	S59 26.3
21	238 58.7	128 29.2	·· 00.4	87 07.3	·· 45.6	188 05.0	·· 35.4	113 01.2	·· 49.7	Bellatrix	279 02.1	N 6 19.7
22	254 01.2	143 28.4	23 00.1	102 08.3	45.1	203 07.0	35.5	128 03.4	49.7	Betelgeuse	271 31.7	N 7 24.1
23	269 03.6	158 27.5	22 59.7	117 09.3	44.5	218 09.0	35.7	143 05.5	49.6			
6 00	284 06.1	173 26.7	N22 59.4	132 10.3	N12 44.0	233 10.9	N17 35.8	158 07.7	N19 49.5	Canopus	264 09.0	S52 41.0
01	299 08.6	188 25.8	59.0	147 11.4	43.4	248 12.9	35.9	173 09.8	49.4	Capella	281 15.9	N45 58.4
02	314 11.0	203 25.0	58.7	162 12.4	42.9	263 14.9	36.0	188 12.0	49.4	Deneb	49 49.9	N45 11.8
03	329 13.5	218 24.1	·· 58.3	177 13.4	·· 42.3	278 16.9	·· 36.1	203 14.1	·· 49.3	Denebola	183 02.0	N14 42.2
04	344 16.0	233 23.3	57.9	192 14.4	41.8	293 18.9	36.2	218 16.2	49.2	Diphda	349 23.7	S18 06.7
05	359 18.4	248 22.4	57.6	207 15.5	41.2	308 20.9	36.3	233 18.4	49.2			
06	14 20.9	263 21.6	N22 57.2	222 16.5	N12 40.7	323 22.8	N17 36.5	248 20.5	N19 49.1	Dubhe	194 26.0	N61 52.9
07	29 23.4	278 20.7	56.9	237 17.5	40.1	338 24.8	36.6	263 22.7	49.0	Elnath	278 48.1	N28 35.2
08	44 25.8	293 19.9	56.5	252 18.5	39.6	353 26.8	36.7	278 24.8	49.0	Eltanin	90 58.5	N51 29.7
T 09	59 28.3	308 19.0	·· 56.1	267 19.6	·· 39.0	8 28.8	·· 36.8	293 27.0	·· 48.9	Enif	34 14.1	N 9 46.1
U 10	74 30.7	323 18.2	55.8	282 20.6	38.5	23 30.8	36.9	308 29.1	48.8	Fomalhaut	15 54.4	S29 44.5
E 11	89 33.2	338 17.3	55.4	297 21.6	37.9	38 32.8	37.0	323 31.2	48.7			
S 12	104 35.7	353 16.5	N22 55.0	312 22.6	N12 37.4	53 34.7	N17 37.2	338 33.4	N19 48.7	Gacrux	172 31.9	S56 59.2
D 13	119 38.1	8 15.6	54.7	327 23.7	36.8	68 36.7	37.3	353 35.5	48.6	Gienah	176 20.9	S17 24.8
A 14	134 40.6	23 14.8	54.3	342 24.7	36.3	83 38.7	37.4	8 37.7	48.5	Hadar	149 27.1	S60 15.9
Y 15	149 43.1	38 13.9	·· 53.9	357 25.7	·· 35.7	98 40.7	·· 37.5	23 39.8	·· 48.5	Hamal	328 32.2	N23 21.0
16	164 45.5	53 13.1	53.6	12 26.8	35.1	113 42.7	37.6	38 42.0	48.4	Kaus Aust.	84 20.2	S34 23.7
17	179 48.0	68 12.2	53.2	27 27.8	34.6	128 44.7	37.7	53 44.1	48.3			
18	194 50.5	83 11.4	N22 52.8	42 28.8	N12 34.0	143 46.7	N17 37.9	68 46.2	N19 48.3	Kochab	137 18.4	N74 15.4
19	209 52.9	98 10.5	52.4	57 29.8	33.5	158 48.6	38.0	83 48.4	48.2	Markab	14 05.8	N15 04.8
20	224 55.4	113 09.7	52.1	72 30.9	32.9	173 50.6	38.1	98 50.5	48.1	Menkar	314 44.3	N 3 59.9
21	239 57.9	128 08.8	·· 51.7	87 31.9	·· 32.4	188 52.6	·· 38.2	113 52.7	·· 48.0	Menkent	148 40.2	S36 15.5
22	255 00.3	143 08.0	51.3	102 32.9	31.8	203 54.6	38.3	128 54.8	48.0	Miaplacidus	221 46.3	S69 37.5
23	270 02.8	158 07.1	50.9	117 33.9	31.3	218 56.6	38.4	143 56.9	47.9			
7 00	285 05.2	173 06.3	N22 50.5	132 35.0	N12 30.7	233 58.6	N17 38.5	158 59.1	N19 47.8	Mirfak	309 20.4	N49 46.5
01	300 07.7	188 05.4	50.2	147 36.0	30.2	249 00.6	38.7	174 01.2	47.8	Nunki	76 32.3	S26 19.5
02	315 10.2	203 04.6	49.8	162 37.0	29.6	264 02.5	38.8	189 03.4	47.7	Peacock	54 02.3	S56 48.4
03	330 12.6	218 03.8	·· 49.4	177 38.0	·· 29.0	279 04.5	·· 38.9	204 05.5	·· 47.6	Pollux	244 02.0	N28 05.0
04	345 15.1	233 02.9	49.0	192 39.1	28.5	294 06.5	39.0	219 07.6	47.6	Procyon	245 29.1	N 5 17.1
05	0 17.6	248 02.1	48.6	207 40.1	27.9	309 08.5	39.1	234 09.8	47.5			
06	15 20.0	263 01.2	N22 48.2	222 41.1	N12 27.4	324 10.5	N17 39.2	249 11.9	N19 47.4	Rasalhague	96 31.9	N12 34.7
07	30 22.5	278 00.4	47.8	237 42.2	26.8	339 12.5	39.3	264 14.1	47.3	Regulus	208 13.2	N12 04.9
W 08	45 25.0	292 59.5	47.4	252 43.2	26.3	354 14.5	39.5	279 16.2	47.3	Rigel	281 39.0	S 8 13.7
E 09	60 27.4	307 58.7	·· 47.1	267 44.2	·· 25.7	9 16.4	·· 39.6	294 18.4	·· 47.2	Rigil Kent.	140 29.3	S60 44.5
D 10	75 29.9	322 57.8	46.7	282 45.2	25.2	24 18.4	39.7	309 20.5	47.1	Sabik	102 44.1	S15 41.7
N 11	90 32.4	337 57.0	46.3	297 46.3	24.6	39 20.4	39.8	324 22.6	47.1			
E 12	105 34.8	352 56.2	N22 45.9	312 47.3	N12 24.0	54 22.4	N17 39.9	339 24.8	N19 47.0	Schedar	350 12.1	N56 24.3
S 13	120 37.3	7 55.3	45.5	327 48.3	23.5	69 24.4	40.0	354 26.9	46.9	Shaula	96 59.2	S37 05.2
D 14	135 39.7	22 54.5	45.1	342 49.3	22.9	84 26.4	40.1	9 29.1	46.8	Sirius	258 58.5	S16 41.1
A 15	150 42.2	37 53.6	·· 44.7	357 50.4	·· 22.4	99 28.4	·· 40.3	24 31.2	·· 46.8	Spica	159 00.5	S11 02.4
Y 16	165 44.7	52 52.8	44.3	12 51.4	21.8	114 30.4	40.4	39 33.3	46.7	Suhail	223 13.2	S43 20.5
17	180 47.1	67 52.0	43.9	27 52.4	21.3	129 32.3	40.5	54 35.5	46.6			
18	195 49.6	82 51.1	N22 43.5	42 53.4	N12 20.7	144 34.3	N17 40.6	69 37.6	N19 46.6	Vega	80 57.3	N38 45.8
19	210 52.1	97 50.3	43.1	57 54.5	20.1	159 36.3	40.7	84 39.8	46.5	Zuben'ubi	137 36.0	S15 56.7
20	225 54.5	112 49.4	42.7	72 55.5	19.6	174 38.3	40.8	99 41.9	46.4		S.H.A.	Mer. Pass.
21	240 57.0	127 48.6	·· 42.3	87 56.5	·· 19.0	189 40.3	·· 40.9	114 44.0	·· 46.4		° ′	h m
22	255 59.5	142 47.8	41.9	102 57.6	18.5	204 42.3	41.1	129 46.2	46.3	Venus	249 20.6	12 27
23	271 01.9	157 46.9	41.5	117 58.6	17.9	219 44.3	41.2	144 48.3	46.2	Mars	208 04.2	15 10
	h m									Jupiter	309 04.8	8 26
Mer. Pass.	5 02.8	v −0.8	d 0.4	v 1.0	d 0.6	v 2.0	d 0.1	v 2.1	d 0.1	Saturn	234 01.6	13 26

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G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
5 00	178 53.0	N22 47.7	88 32.6	9.4	S 8 27.5	10.9	59.3
01	193 52.9	47.5	103 01.0	9.3	8 38.4	10.9	59.3
02	208 52.8	47.2	117 29.3	9.3	8 49.3	10.9	59.3
03	223 52.7	·· 47.0	131 57.6	9.2	9 00.2	10.7	59.3
04	238 52.6	46.8	146 25.8	9.2	9 10.9	10.8	59.3
05	253 52.5	46.5	160 54.0	9.2	9 21.7	10.6	59.3
06	268 52.4	N22 46.3	175 22.2	9.1	S 9 32.3	10.7	59.3
07	283 52.3	46.1	189 50.3	9.0	9 43.0	10.5	59.3
08	298 52.1	45.8	204 18.3	9.0	9 53.5	10.5	59.4
M 09	313 52.0	·· 45.6	218 46.3	9.0	10 04.0	10.5	59.4
O 10	328 51.9	45.4	233 14.3	8.9	10 14.5	10.4	59.4
N 11	343 51.8	45.1	247 42.2	8.9	10 24.9	10.4	59.4
D 12	358 51.7	N22 44.9	262 10.1	8.8	S10 35.3	10.2	59.4
A 13	13 51.6	44.6	276 37.9	8.8	10 45.5	10.3	59.4
Y 14	28 51.5	44.4	291 05.7	8.7	10 55.8	10.1	59.4
15	43 51.4	·· 44.1	305 33.4	8.7	11 05.9	10.1	59.4
16	58 51.3	43.9	320 01.1	8.6	11 16.0	10.0	59.4
17	73 51.2	43.7	334 28.7	8.6	11 26.0	10.0	59.4
18	88 51.1	N22 43.4	348 56.3	8.5	S11 36.0	9.9	59.4
19	103 51.0	43.2	3 23.8	8.5	11 45.9	9.8	59.4
20	118 50.9	42.9	17 51.3	8.5	11 55.7	9.8	59.4
21	133 50.8	·· 42.7	32 18.8	8.3	12 05.5	9.7	59.4
22	148 50.7	42.4	46 46.1	8.4	12 15.2	9.6	59.4
23	163 50.6	42.2	61 13.5	8.2	12 24.8	9.5	59.5
6 00	178 50.4	N22 41.9	75 40.7	8.3	S12 34.3	9.5	59.5
01	193 50.3	41.7	90 08.0	8.2	12 43.8	9.4	59.5
02	208 50.2	41.4	104 35.2	8.1	12 53.2	9.3	59.5
03	223 50.1	·· 41.2	119 02.3	8.1	13 02.5	9.2	59.5
04	238 50.0	40.9	133 29.4	8.0	13 11.7	9.2	59.5
05	253 49.9	40.7	147 56.4	8.0	13 20.9	9.1	59.5
06	268 49.8	N22 40.4	162 23.4	7.9	S13 30.0	9.0	59.5
07	283 49.7	40.2	176 50.3	7.9	13 39.0	8.9	59.5
08	298 49.6	39.9	191 17.2	7.8	13 47.9	8.8	59.5
T 09	313 49.5	·· 39.7	205 44.0	7.7	13 56.7	8.7	59.5
U 10	328 49.4	39.4	220 10.7	7.8	14 05.4	8.7	59.5
E 11	343 49.3	39.1	234 37.5	7.6	14 14.1	8.6	59.5
S 12	358 49.2	N22 38.9	249 04.1	7.7	S14 22.7	8.4	59.5
D 13	13 49.1	38.6	263 30.8	7.5	14 31.1	8.4	59.5
A 14	28 49.0	38.4	277 57.3	7.5	14 39.5	8.3	59.5
Y 15	43 48.9	·· 38.1	292 23.8	7.5	14 47.8	8.2	59.5
16	58 48.8	37.8	306 50.3	7.4	14 56.0	8.2	59.5
17	73 48.7	37.6	321 16.7	7.4	15 04.2	8.0	59.5
18	88 48.6	N22 37.3	335 43.1	7.3	S15 12.2	7.9	59.5
19	103 48.5	37.1	350 09.4	7.3	15 20.1	7.8	59.5
20	118 48.4	36.8	4 35.7	7.2	15 27.9	7.8	59.5
21	133 48.3	·· 36.5	19 01.9	7.2	15 35.7	7.6	59.5
22	148 48.2	36.3	33 28.1	7.1	15 43.3	7.5	59.5
23	163 48.1	36.0	47 54.2	7.1	15 50.8	7.5	59.5
7 00	178 48.0	N22 35.7	62 20.3	7.0	S15 58.3	7.3	59.5
01	193 47.9	35.5	76 46.3	7.0	16 05.6	7.3	59.5
02	208 47.8	35.2	91 12.3	6.9	16 12.9	7.1	59.5
03	223 47.7	·· 34.9	105 38.2	6.9	16 20.0	7.0	59.5
04	238 47.6	34.7	120 04.1	6.8	16 27.0	6.9	59.5
05	253 47.5	34.4	134 29.9	6.8	16 33.9	6.8	59.5
06	268 47.4	N22 34.1	148 55.7	6.8	S16 40.7	6.7	59.5
W 07	283 47.3	33.9	163 21.5	6.7	16 47.4	6.6	59.5
E 08	298 47.2	33.6	177 47.2	6.6	16 54.0	6.5	59.5
D 09	313 47.1	·· 33.3	192 12.8	6.7	17 00.5	6.4	59.5
N 10	328 47.0	33.1	206 38.5	6.5	17 06.9	6.3	59.5
E 11	343 46.9	32.8	221 04.0	6.6	17 13.2	6.1	59.5
S 12	358 46.8	N22 32.5	235 29.6	6.5	S17 19.3	6.1	59.5
D 13	13 46.7	32.2	249 55.1	6.4	17 25.4	5.9	59.5
A 14	28 46.6	32.0	264 20.5	6.5	17 31.3	5.8	59.5
Y 15	43 46.5	·· 31.7	278 46.0	6.4	17 37.1	5.7	59.5
16	58 46.4	31.4	293 11.4	6.3	17 42.8	5.6	59.5
17	73 46.3	31.1	307 36.7	6.3	17 48.4	5.5	59.5
18	88 46.2	N22 30.8	322 02.0	6.3	S17 53.9	5.3	59.5
19	103 46.1	30.6	336 27.3	6.2	17 59.2	5.3	59.5
20	118 46.0	30.3	350 52.5	6.2	18 04.5	5.1	59.5
21	133 45.9	·· 30.0	5 17.7	6.2	18 09.6	5.0	59.5
22	148 45.8	29.7	19 42.9	6.1	18 14.6	4.8	59.5
23	163 45.7	29.5	34 08.0	6.1	18 19.4	4.8	59.5
	S.D. 15.8	d 0.3	S.D. 16.2		16.2		16.2

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 5	Moonrise 6	Moonrise 7	Moonrise 8
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	15 10	17 25	▬	▬
N 70	□	□	□	14 50	16 48	18 50	20 56
68	□	□	□	14 34	16 22	18 08	19 41
66	////	////	00 52	14 22	16 02	17 39	19 04
64	////	////	01 51	14 11	15 46	17 17	18 38
62	////	////	02 24	14 02	15 33	17 00	18 17
60	////	01 16	02 48	13 55	15 22	16 46	18 01
N 58	////	01 56	03 07	13 48	15 12	16 33	17 47
56	////	02 23	03 23	13 42	15 04	16 23	17 35
54	01 10	02 44	03 36	13 37	14 57	16 13	17 24
52	01 47	03 01	03 48	13 32	14 50	16 05	17 15
50	02 12	03 15	03 58	13 28	14 44	15 58	17 06
45	02 55	03 43	04 20	13 19	14 31	15 42	16 49
N 40	03 24	04 05	04 37	13 12	14 21	15 29	16 34
35	03 46	04 22	04 52	13 05	14 12	15 18	16 22
30	04 04	04 37	05 04	12 59	14 04	15 08	16 11
20	04 32	05 01	05 26	12 50	13 50	14 52	15 53
N 10	04 54	05 21	05 44	12 41	13 39	14 38	15 37
0	05 13	05 39	06 01	12 33	13 28	14 24	15 22
S 10	05 29	05 55	06 18	12 25	13 17	14 11	15 08
20	05 44	06 12	06 36	12 17	13 05	13 57	14 52
30	06 00	06 30	06 56	12 07	12 52	13 41	14 34
35	06 09	06 40	07 08	12 02	12 44	13 31	14 23
40	06 18	06 51	07 22	11 56	12 36	13 21	14 11
45	06 27	07 04	07 38	11 49	12 26	13 08	13 57
S 50	06 39	07 20	07 58	11 40	12 14	12 53	13 40
52	06 43	07 27	08 07	11 37	12 08	12 46	13 32
54	06 49	07 35	08 18	11 32	12 02	12 39	13 23
56	06 55	07 43	08 30	11 28	11 56	12 30	13 13
58	07 01	07 53	08 44	11 22	11 48	12 20	13 02
S 60	07 08	08 04	09 00	11 16	11 39	12 09	12 49

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 5	Moonset 6	Moonset 7	Moonset 8
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	22 02	21 42	▬	▬
N 70	□	□	□	22 24	22 20	22 17	22 14
68	□	□	□	22 41	22 47	23 00	23 28
66	23 12	////	////	22 55	23 08	23 29	24 06
64	22 16	////	////	23 06	23 25	23 52	24 32
62	21 44	////	////	23 16	23 38	24 09	00 09
60	21 20	22 50	////	23 24	23 50	24 24	00 24
N 58	21 01	22 11	////	23 32	24 00	00 00	00 37
56	20 46	21 45	////	23 38	24 09	00 09	00 48
54	20 32	21 25	22 57	23 44	24 17	00 17	00 57
52	20 21	21 08	22 21	23 50	24 24	00 24	01 06
50	20 10	20 54	21 56	23 54	24 31	00 31	01 14
45	19 49	20 26	21 14	24 05	00 05	00 44	01 30
N 40	19 32	20 04	20 45	24 14	00 14	00 56	01 44
35	19 17	19 47	20 23	24 21	00 21	01 06	01 55
30	19 05	19 32	20 05	24 28	00 28	01 14	02 05
20	18 44	19 08	19 37	24 39	00 39	01 29	02 23
N 10	18 25	18 48	19 15	24 49	00 49	01 42	02 38
0	18 08	18 31	18 57	00 05	00 59	01 54	02 52
S 10	17 52	18 14	18 40	00 12	01 08	02 07	03 06
20	17 34	17 58	18 25	00 18	01 18	02 20	03 21
30	17 13	17 39	18 09	00 26	01 30	02 35	03 39
35	17 01	17 29	18 01	00 30	01 37	02 43	03 49
40	16 48	17 18	17 52	00 35	01 44	02 53	04 00
45	16 32	17 05	17 42	00 41	01 53	03 05	04 14
S 50	16 12	16 50	17 31	00 48	02 04	03 19	04 31
52	16 03	16 43	17 26	00 51	02 09	03 26	04 38
54	15 52	16 35	17 21	00 55	02 15	03 33	04 47
56	15 40	16 26	17 15	00 59	02 21	03 41	04 57
58	15 26	16 17	17 09	01 03	02 28	03 51	05 08
S 60	15 10	16 06	17 02	01 08	02 36	04 01	05 21

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
5	04 28	04 33	12 05	18 46	06 19	08	
6	04 38	04 43	12 05	19 41	07 13	09	
7	04 48	04 53	12 05	20 38	08 09	10	◐

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G.M.T.	ARIES	VENUS −3.3		MARS +1.9		JUPITER −2.1		SATURN +0.6	
d h	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
25 00	333 23.0	161 36.7	N 4 58.9	152 41.1	N 0 24.0	275 11.6	N19 08.9	200 52.7	N18 17.7
01	348 25.5	176 36.4	57.6	167 42.1	23.3	290 13.9	09.0	215 54.9	17.6
02	3 28.0	191 36.0	56.4	182 43.1	22.7	305 16.1	09.0	230 57.0	17.5
03	18 30.4	206 35.7	·· 55.1	197 44.1	·· 22.0	320 18.4	·· 09.0	245 59.2	·· 17.5
04	33 32.9	221 35.3	53.9	212 45.1	21.4	335 20.6	09.1	261 01.3	17.4
05	48 35.4	236 34.9	52.6	227 46.1	20.7	350 22.9	09.1	276 03.5	17.3
06	63 37.8	251 34.6	N 4 51.4	242 47.1	N 0 20.0	5 25.1	N19 09.2	291 05.6	N18 17.2
07	78 40.3	266 34.2	50.1	257 48.1	19.4	20 27.4	09.2	306 07.8	17.1
W 08	93 42.8	281 33.9	48.8	272 49.1	18.7	35 29.7	09.2	321 09.9	17.1
E 09	108 45.2	296 33.5	·· 47.6	287 50.1	·· 18.1	50 31.9	·· 09.3	336 12.1	·· 17.0
D 10	123 47.7	311 33.2	46.3	302 51.1	17.4	65 34.2	09.3	351 14.2	16.9
N 11	138 50.2	326 32.8	45.1	317 52.2	16.7	80 36.4	09.3	6 16.4	16.8
E 12	153 52.6	341 32.5	N 4 43.8	332 53.2	N 0 16.1	95 38.7	N19 09.4	21 18.5	N18 16.7
S 13	168 55.1	356 32.1	42.6	347 54.2	15.4	110 40.9	09.4	36 20.7	16.7
D 14	183 57.5	11 31.8	41.3	2 55.2	14.8	125 43.2	09.4	51 22.8	16.6
A 15	199 00.0	26 31.4	·· 40.1	17 56.2	·· 14.1	140 45.4	·· 09.5	66 25.0	·· 16.5
Y 16	214 02.5	41 31.1	38.8	32 57.2	13.4	155 47.7	09.5	81 27.1	16.4
17	229 04.9	56 30.7	37.5	47 58.2	12.8	170 50.0	09.6	96 29.3	16.4
18	244 07.4	71 30.4	N 4 36.3	62 59.2	N 0 12.1	185 52.2	N19 09.6	111 31.5	N18 16.3
19	259 09.9	86 30.0	35.0	78 00.2	11.5	200 54.5	09.6	126 33.6	16.2
20	274 12.3	101 29.7	33.8	93 01.2	10.8	215 56.7	09.7	141 35.8	16.1
21	289 14.8	116 29.3	·· 32.5	108 02.2	·· 10.1	230 59.0	·· 09.7	156 37.9	·· 16.0
22	304 17.3	131 29.0	31.2	123 03.2	09.5	246 01.2	09.7	171 40.1	16.0
23	319 19.7	146 28.6	30.0	138 04.2	08.8	261 03.5	09.8	186 42.2	15.9
26 00	334 22.2	161 28.3	N 4 28.7	153 05.2	N 0 08.2	276 05.8	N19 09.8	201 44.4	N18 15.8
01	349 24.6	176 27.9	27.5	168 06.2	07.5	291 08.0	09.9	216 46.5	15.7
02	4 27.1	191 27.6	26.2	183 07.2	06.9	306 10.3	09.9	231 48.7	15.7
03	19 29.6	206 27.2	·· 24.9	198 08.2	·· 06.2	321 12.5	·· 09.9	246 50.8	·· 15.6
04	34 32.0	221 26.9	23.7	213 09.2	05.5	336 14.8	10.0	261 53.0	15.5
05	49 34.5	236 26.5	22.4	228 10.2	04.9	351 17.1	10.0	276 55.1	15.4
06	64 37.0	251 26.2	N 4 21.2	243 11.2	N 0 04.2	6 19.3	N19 10.0	291 57.3	N18 15.3
07	79 39.4	266 25.8	19.9	258 12.2	03.6	21 21.6	10.1	306 59.4	15.3
T 08	94 41.9	281 25.5	18.6	273 13.2	02.9	36 23.9	10.1	322 01.6	15.2
H 09	109 44.4	296 25.1	·· 17.4	288 14.2	·· 02.2	51 26.1	·· 10.1	337 03.7	·· 15.1
U 10	124 46.8	311 24.8	16.1	303 15.2	01.6	66 28.4	10.2	352 05.9	15.0
R 11	139 49.3	326 24.4	14.9	318 16.2	00.9	81 30.6	10.2	7 08.0	14.9
S 12	154 51.8	341 24.1	N 4 13.6	333 17.2	N 0 00.3	96 32.9	N19 10.2	22 10.2	N18 14.9
D 13	169 54.2	356 23.7	12.3	348 18.2	S 0 00.4	111 35.2	10.3	37 12.4	14.8
A 14	184 56.7	11 23.4	11.1	3 19.2	01.1	126 37.4	10.3	52 14.5	14.7
Y 15	199 59.1	26 23.0	·· 09.8	18 20.2	·· 01.7	141 39.7	·· 10.3	67 16.7	·· 14.6
16	215 01.6	41 22.7	08.6	33 21.2	02.4	156 42.0	10.4	82 18.8	14.6
17	230 04.1	56 22.3	07.3	48 22.2	03.0	171 44.2	10.4	97 21.0	14.5
18	245 06.5	71 22.0	N 4 06.0	63 23.2	S 0 03.7	186 46.5	N19 10.5	112 23.1	N18 14.4
19	260 09.0	86 21.6	04.8	78 24.2	04.4	201 48.8	10.5	127 25.3	14.3
20	275 11.5	101 21.3	03.5	93 25.2	05.0	216 51.0	10.5	142 27.4	14.2
21	290 13.9	116 20.9	·· 02.2	108 26.2	·· 05.7	231 53.3	·· 10.6	157 29.6	·· 14.2
22	305 16.4	131 20.6	4 01.0	123 27.3	06.3	246 55.6	10.6	172 31.7	14.1
23	320 18.9	146 20.2	3 59.7	138 28.3	07.0	261 57.8	10.6	187 33.9	14.0
27 00	335 21.3	161 19.9	N 3 58.4	153 29.3	S 0 07.7	277 00.1	N19 10.7	202 36.0	N18 13.9
01	350 23.8	176 19.5	57.2	168 30.3	08.3	292 02.4	10.7	217 38.2	13.9
02	5 26.3	191 19.2	55.9	183 31.3	09.0	307 04.6	10.7	232 40.3	13.8
03	20 28.7	206 18.9	·· 54.7	198 32.3	·· 09.6	322 06.9	·· 10.8	247 42.5	·· 13.7
04	35 31.2	221 18.5	53.4	213 33.3	10.3	337 09.2	10.8	262 44.7	13.6
05	50 33.6	236 18.2	52.1	228 34.3	11.0	352 11.4	10.8	277 46.8	13.5
06	65 36.1	251 17.8	N 3 50.9	243 35.3	S 0 11.6	7 13.7	N19 10.9	292 49.0	N18 13.5
07	80 38.6	266 17.5	49.6	258 36.3	12.3	22 16.0	10.9	307 51.1	13.4
08	95 41.0	281 17.1	48.3	273 37.3	12.9	37 18.2	10.9	322 53.3	13.3
F 09	110 43.5	296 16.8	·· 47.1	288 38.3	·· 13.6	52 20.5	·· 11.0	337 55.4	·· 13.2
R 10	125 46.0	311 16.4	45.8	303 39.3	14.3	67 22.8	11.0	352 57.6	13.2
I 11	140 48.4	326 16.1	44.5	318 40.3	14.9	82 25.0	11.0	7 59.7	13.1
D 12	155 50.9	341 15.8	N 3 43.3	333 41.3	S 0 15.6	97 27.3	N19 11.1	23 01.9	N18 13.0
A 13	170 53.4	356 15.4	42.0	348 42.3	16.2	112 29.6	11.1	38 04.0	12.9
Y 14	185 55.8	11 15.1	40.7	3 43.3	16.9	127 31.9	11.1	53 06.2	12.8
15	200 58.3	26 14.7	·· 39.5	18 44.3	·· 17.6	142 34.1	·· 11.2	68 08.4	·· 12.8
16	216 00.7	41 14.4	38.2	33 45.3	18.2	157 36.4	11.2	83 10.5	12.7
17	231 03.2	56 14.0	36.9	48 46.3	18.9	172 38.7	11.2	98 12.7	12.6
18	246 05.7	71 13.7	N 3 35.7	63 47.3	S 0 19.5	187 40.9	N19 11.3	113 14.8	N18 12.5
19	261 08.1	86 13.3	34.4	78 48.3	20.2	202 43.2	11.3	128 17.0	12.5
20	276 10.6	101 13.0	33.1	93 49.3	20.9	217 45.5	11.3	143 19.1	12.4
21	291 13.1	116 12.7	·· 31.9	108 50.3	·· 21.5	232 47.8	·· 11.4	158 21.3	·· 12.3
22	306 15.5	131 12.3	30.6	123 51.3	22.2	247 50.0	11.4	173 23.4	12.2
23	321 18.0	146 12.0	29.3	138 52.3	22.9	262 52.3	11.4	188 25.6	12.1
Mer. Pass.	h m 1 42.2	v −0.3	d 1.3	v 1.0	d 0.7	v 2.3	d 0.0	v 2.2	d 0.1

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 39.2	S40 23.6
Achernar	335 47.0	S57 21.0
Acrux	173 40.8	S62 58.4
Adhara	255 34.5	S28 56.3
Aldebaran	291 21.2	N16 27.8
Alioth	166 45.4	N56 05.4
Alkaid	153 21.0	N49 26.0
Al Na'ir	28 17.9	S47 04.3
Alnilam	276 14.5	S 1 12.9
Alphard	218 23.5	S 8 33.4
Alphecca	126 34.5	N26 47.8
Alpheratz	358 11.8	N28 57.8
Altair	62 34.9	N 8 48.6
Ankaa	353 42.6	S42 25.7
Antares	113 00.2	S26 22.8
Arcturus	146 21.1	N19 18.4
Atria	108 26.7	S68 59.4
Avior	234 29.8	S59 26.0
Bellatrix	279 01.8	N 6 19.8
Betelgeuse	271 31.4	N 7 24.2
Canopus	264 08.7	S52 40.8
Capella	281 15.4	N45 58.3
Deneb	49 49.9	N45 12.1
Denebola	183 02.1	N14 42.2
Diphda	349 23.3	S18 06.6
Dubhe	194 26.2	N61 52.7
Elnath	278 47.7	N28 35.2
Eltanin	90 58.8	N51 29.9
Enif	34 13.9	N 9 46.3
Fomalhaut	15 54.1	S29 44.5
Gacrux	172 32.2	S56 59.1
Gienah	176 21.0	S17 24.7
Hadar	149 27.5	S60 15.8
Hamal	328 31.8	N23 21.2
Kaus Aust.	84 20.2	S34 23.8
Kochab	137 19.3	N74 15.4
Markab	14 05.5	N15 05.0
Menkar	314 43.9	N 4 00.0
Menkent	148 40.4	S36 15.4
Miaplacidus	221 46.3	S69 37.3
Mirfak	309 19.9	N49 46.6
Nunki	76 32.3	S26 19.5
Peacock	54 02.2	S56 48.6
Pollux	244 01.8	N28 04.9
Procyon	245 28.9	N 5 17.1
Rasalhague	96 32.0	N12 34.9
Regulus	208 13.2	N12 04.9
Rigel	281 38.7	S 8 13.6
Rigil Kent.	140 29.7	S60 44.5
Sabik	102 44.2	S15 41.7
Schedar	350 11.6	N56 24.5
Shaula	96 59.3	S37 05.3
Sirius	258 58.3	S16 41.0
Spica	159 00.6	S11 02.3
Suhail	223 13.2	S43 20.3
Vega	80 57.4	N38 46.0
Zuben'ubi	137 36.1	S15 56.7

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	187 06.1	13 14
Mars	178 43.0	13 47
Jupiter	301 43.6	5 35
Saturn	227 22.2	10 32

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G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
25 00	179 28.1	N10 47.6	186 56.9	9.3	N 8 26.3	10.8	59.1
01	194 28.3	46.7	201 25.2	9.2	8 15.5	10.8	59.2
02	209 28.5	45.9	215 53.4	9.3	8 04.7	11.0	59.2
03	224 28.7	·· 45.0	230 21.7	9.3	7 53.7	10.9	59.2
04	239 28.8	44.1	244 50.0	9.3	7 42.8	11.1	59.2
05	254 29.0	43.3	259 18.3	9.3	7 31.7	11.0	59.3
06	269 29.2	N10 42.4	273 46.6	9.3	N 7 20.7	11.2	59.3
07	284 29.3	41.5	288 14.9	9.3	7 09.5	11.2	59.3
08	299 29.5	40.7	302 43.2	9.3	6 58.3	11.2	59.3
09	314 29.7	·· 39.8	317 11.5	9.3	6 47.1	11.3	59.4
10	329 29.9	38.9	331 39.8	9.3	6 35.8	11.3	59.4
11	344 30.0	38.1	346 08.1	9.3	6 24.5	11.4	59.4
12	359 30.2	N10 37.2	0 36.4	9.3	N 6 13.1	11.4	59.4
13	14 30.4	36.3	15 04.7	9.3	6 01.7	11.5	59.4
14	29 30.5	35.5	29 33.0	9.3	5 50.2	11.5	59.5
15	44 30.7	·· 34.6	44 01.3	9.3	5 38.7	11.5	59.5
16	59 30.9	33.7	58 29.6	9.2	5 27.2	11.6	59.5
17	74 31.1	32.9	72 57.8	9.3	5 15.6	11.6	59.5
18	89 31.2	N10 32.0	87 26.1	9.3	N 5 04.0	11.7	59.6
19	104 31.4	31.1	101 54.4	9.3	4 52.3	11.7	59.6
20	119 31.6	30.3	116 22.7	9.2	4 40.6	11.7	59.6
21	134 31.8	·· 29.4	130 50.9	9.3	4 28.9	11.8	59.6
22	149 31.9	28.5	145 19.2	9.3	4 17.1	11.8	59.6
23	164 32.1	27.7	159 47.5	9.2	4 05.3	11.8	59.7
26 00	179 32.3	N10 26.8	174 15.7	9.3	N 3 53.5	11.9	59.7
01	194 32.5	25.9	188 44.0	9.2	3 41.6	11.9	59.7
02	209 32.6	25.1	203 12.2	9.2	3 29.7	11.9	59.7
03	224 32.8	·· 24.2	217 40.4	9.3	3 17.8	11.9	59.7
04	239 33.0	23.3	232 08.7	9.2	3 05.9	12.0	59.7
05	254 33.2	22.5	246 36.9	9.2	2 53.9	12.0	59.8
06	269 33.3	N10 21.6	261 05.1	9.2	N 2 41.9	12.0	59.8
07	284 33.5	20.7	275 33.3	9.2	2 29.9	12.0	59.8
08	299 33.7	19.8	290 01.5	9.2	2 17.9	12.1	59.8
09	314 33.9	·· 19.0	304 29.7	9.2	2 05.8	12.1	59.8
10	329 34.0	18.1	318 57.9	9.2	1 53.7	12.1	59.8
11	344 34.2	17.2	333 26.1	9.2	1 41.6	12.1	59.9
12	359 34.4	N10 16.4	347 54.3	9.1	N 1 29.5	12.1	59.9
13	14 34.6	15.5	2 22.4	9.2	1 17.4	12.1	59.9
14	29 34.7	14.6	16 50.6	9.1	1 05.3	12.2	59.9
15	44 34.9	·· 13.7	31 18.7	9.2	0 53.1	12.1	59.9
16	59 35.1	12.9	45 46.9	9.1	0 41.0	12.2	59.9
17	74 35.3	12.0	60 15.0	9.1	0 28.8	12.1	59.9
18	89 35.5	N10 11.1	74 43.1	9.1	N 0 16.7	12.2	60.0
19	104 35.6	10.2	89 11.2	9.1	N 0 04.5	12.2	60.0
20	119 35.8	09.4	103 39.3	9.1	S 0 07.7	12.2	60.0
21	134 36.0	·· 08.5	118 07.4	9.0	0 19.9	12.2	60.0
22	149 36.2	07.6	132 35.4	9.1	0 32.1	12.1	60.0
23	164 36.3	06.7	147 03.5	9.0	0 44.2	12.2	60.0
27 00	179 36.5	N10 05.9	161 31.5	9.0	S 0 56.4	12.2	60.0
01	194 36.7	05.0	175 59.5	9.1	1 08.6	12.2	60.0
02	209 36.9	04.1	190 27.6	8.9	1 20.8	12.1	60.0
03	224 37.1	·· 03.2	204 55.5	9.0	1 32.9	12.2	60.0
04	239 37.2	02.4	219 23.5	9.0	1 45.1	12.2	60.1
05	254 37.4	01.5	233 51.5	8.9	1 57.3	12.1	60.1
06	269 37.6	N10 00.6	248 19.4	9.0	S 2 09.4	12.1	60.1
07	284 37.8	9 59.7	262 47.4	8.9	2 21.5	12.2	60.1
08	299 38.0	58.9	277 15.3	8.9	2 33.7	12.1	60.1
09	314 38.1	·· 58.0	291 43.2	8.9	2 45.8	12.1	60.1
10	329 38.3	57.1	306 11.1	8.8	2 57.9	12.0	60.1
11	344 38.5	56.2	320 38.9	8.9	3 09.9	12.1	60.1
12	359 38.7	N 9 55.3	335 06.8	8.8	S 3 22.0	12.0	60.1
13	14 38.9	54.5	349 34.6	8.8	3 34.0	12.1	60.1
14	29 39.0	53.6	4 02.4	8.8	3 46.1	12.0	60.1
15	44 39.2	·· 52.7	18 30.2	8.7	3 58.1	11.9	60.1
16	59 39.4	51.8	32 57.9	8.8	4 10.0	12.0	60.1
17	74 39.6	50.9	47 25.7	8.7	4 22.0	11.9	60.1
18	89 39.8	N 9 50.1	61 53.4	8.7	S 4 33.9	11.9	60.1
19	104 39.9	49.2	76 21.1	8.7	4 45.8	11.9	60.1
20	119 40.1	48.3	90 48.8	8.7	4 57.7	11.8	60.1
21	134 40.3	·· 47.4	105 16.5	8.6	5 09.5	11.8	60.1
22	149 40.5	46.5	119 44.1	8.6	5 21.3	11.8	60.1
23	164 40.7	45.7	134 11.7	8.6	5 33.1	11.7	60.1
	S.D. 15.9	d 0.9	S.D. 16.2		16.3		16.4

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 25	Moonrise 26	Moonrise 27	Moonrise 28
°	h m	h m	h m	h m	h m	h m	h m
N 72	////	01 39	03 30	04 05	06 05	08 05	10 08
N 70	////	02 23	03 49	04 16	06 08	08 01	09 56
68	////	02 51	04 03	04 26	06 11	07 58	09 46
66	01 25	03 12	04 15	04 34	06 14	07 55	09 38
64	02 04	03 29	04 25	04 40	06 16	07 53	09 31
62	02 31	03 42	04 33	04 46	06 18	07 51	09 25
60	02 50	03 54	04 40	04 51	06 19	07 49	09 20
N 58	03 06	04 03	04 47	04 55	06 21	07 48	09 15
56	03 19	04 12	04 52	04 59	06 22	07 47	09 12
54	03 31	04 19	04 57	05 02	06 23	07 45	09 08
52	03 40	04 26	05 02	05 05	06 24	07 44	09 05
50	03 49	04 31	05 06	05 08	06 25	07 43	09 02
45	04 06	04 44	05 15	05 14	06 27	07 41	08 56
N 40	04 20	04 54	05 22	05 19	06 29	07 39	08 51
35	04 31	05 02	05 28	05 23	06 30	07 38	08 46
30	04 40	05 09	05 34	05 27	06 31	07 37	08 42
20	04 54	05 20	05 43	05 34	06 34	07 34	08 36
N 10	05 05	05 30	05 51	05 40	06 36	07 32	08 30
0	05 13	05 37	05 58	05 45	06 38	07 31	08 24
S 10	05 20	05 45	06 06	05 50	06 39	07 29	08 19
20	05 25	05 51	06 13	05 56	06 42	07 27	08 13
30	05 30	05 58	06 22	06 03	06 44	07 25	08 07
35	05 32	06 02	06 27	06 07	06 45	07 24	08 03
40	05 34	06 05	06 33	06 11	06 47	07 22	07 59
45	05 35	06 09	06 39	06 16	06 48	07 21	07 54
S 50	05 37	06 14	06 47	06 22	06 50	07 19	07 48
52	05 37	06 16	06 50	06 24	06 51	07 18	07 46
54	05 37	06 18	06 54	06 27	06 52	07 17	07 43
56	05 38	06 21	06 59	06 31	06 54	07 16	07 40
58	05 38	06 23	07 03	06 34	06 55	07 15	07 36
S 60	05 38	06 26	07 09	06 38	06 56	07 14	07 32

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 25	Moonset 26	Moonset 27	Moonset 28
°	h m	h m	h m	h m	h m	h m	h m
N 72	20 29	22 16	////	19 11	19 02	18 53	18 43
N 70	20 12	21 36	////	19 05	19 02	19 00	18 57
68	19 57	21 08	////	18 59	19 02	19 05	19 09
66	19 46	20 48	22 30	18 55	19 02	19 10	19 19
64	19 37	20 32	21 54	18 51	19 02	19 14	19 27
62	19 29	20 19	21 29	18 48	19 02	19 17	19 34
60	19 21	20 08	21 10	18 45	19 03	19 20	19 40
N 58	19 15	19 59	20 55	18 42	19 03	19 23	19 45
56	19 10	19 50	20 42	18 40	19 03	19 25	19 50
54	19 05	19 43	20 31	18 38	19 03	19 28	19 54
52	19 01	19 37	20 22	18 36	19 03	19 30	19 58
50	18 57	19 31	20 13	18 34	19 03	19 31	20 02
45	18 48	19 19	19 56	18 30	19 03	19 35	20 10
N 40	18 41	19 09	19 43	18 27	19 03	19 39	20 16
35	18 35	19 01	19 32	18 24	19 03	19 42	20 22
30	18 29	18 54	19 23	18 22	19 03	19 44	20 27
20	18 20	18 43	19 09	18 18	19 03	19 48	20 35
N 10	18 12	18 34	18 59	18 14	19 03	19 52	20 43
0	18 05	18 26	18 50	18 10	19 03	19 56	20 50
S 10	17 58	18 19	18 44	18 06	19 03	20 00	20 57
20	17 50	18 13	18 38	18 02	19 03	20 03	21 05
30	17 42	18 06	18 34	17 58	19 02	20 08	21 14
35	17 37	18 02	18 32	17 55	19 02	20 10	21 19
40	17 31	17 59	18 30	17 52	19 02	20 13	21 24
45	17 25	17 55	18 29	17 48	19 02	20 17	21 31
S 50	17 17	17 50	18 28	17 44	19 02	20 21	21 39
52	17 14	17 48	18 28	17 42	19 02	20 22	21 43
54	17 10	17 46	18 27	17 40	19 02	20 24	21 47
56	17 06	17 44	18 27	17 38	19 02	20 27	21 51
58	17 01	17 41	18 27	17 35	19 02	20 29	21 56
S 60	16 56	17 39	18 27	17 32	19 02	20 32	22 02

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
25	02 08	02 00	12 02	11 57	24 24	00	
26	01 51	01 43	12 02	12 50	00 24	01	●
27	01 34	01 26	12 01	13 43	01 17	02	

1976 SEPTEMBER 9, 10, 11 (THURS., FRI., SAT.)

G.M.T.	ARIES	VENUS −3.3		MARS +1.9		JUPITER −2.1		SATURN +0.6	
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
9 00	348 10.1	159 36.5	S 2 41.4	158 37.3	S 3 34.2	289 03.4	N19 18.1	213 51.2	N17 50.1
01	3 12.6	174 36.2	42.7	173 38.3	34.8	304 05.7	18.1	228 53.4	50.0
02	18 15.0	189 35.9	44.0	188 39.3	35.5	319 08.1	18.1	243 55.6	50.0
03	33 17.5	204 35.6	·· 45.3	203 40.2	·· 36.1	334 10.5	·· 18.1	258 57.8	·· 49.9
04	48 20.0	219 35.2	46.5	218 41.2	36.8	349 12.9	18.1	273 59.9	49.8
05	63 22.4	234 34.9	47.8	233 42.2	37.5	4 15.2	18.1	289 02.1	49.7
06	78 24.9	249 34.6	S 2 49.1	248 43.2	S 3 38.1	19 17.6	N19 18.2	304 04.3	N17 49.7
07	93 27.4	264 34.2	50.4	263 44.1	38.8	34 20.0	18.2	319 06.5	49.6
T 08	108 29.8	279 33.9	51.7	278 45.1	39.4	49 22.3	18.2	334 08.6	49.5
H 09	123 32.3	294 33.6	·· 53.0	293 46.1	·· 40.1	64 24.7	·· 18.2	349 10.8	·· 49.4
U 10	138 34.8	309 33.2	54.2	308 47.0	40.8	79 27.1	18.2	4 13.0	49.4
R 11	153 37.2	324 32.9	55.5	323 48.0	41.4	94 29.5	18.2	19 15.2	49.3
S 12	168 39.7	339 32.6	S 2 56.8	338 49.0	S 3 42.1	109 31.8	N19 18.2	34 17.4	N17 49.2
D 13	183 42.2	354 32.3	58.1	353 50.0	42.8	124 34.2	18.2	49 19.5	49.1
A 14	198 44.6	9 31.9	2 59.4	8 50.9	43.4	139 36.6	18.3	64 21.7	49.1
Y 15	213 47.1	24 31.6	3 00.7	23 51.9	·· 44.1	154 39.0	·· 18.3	79 23.9	·· 49.0
16	228 49.5	39 31.3	02.0	38 52.9	44.7	169 41.3	18.3	94 26.1	48.9
17	243 52.0	54 30.9	03.2	53 53.8	45.4	184 43.7	18.3	109 28.2	48.8
18	258 54.5	69 30.6	S 3 04.5	68 54.8	S 3 46.1	199 46.1	N19 18.3	124 30.4	N17 48.8
19	273 56.9	84 30.3	05.8	83 55.8	46.7	214 48.5	18.3	139 32.6	48.7
20	288 59.4	99 29.9	07.1	98 56.7	47.4	229 50.9	18.3	154 34.8	48.6
21	304 01.9	114 29.6	·· 08.4	113 57.7	·· 48.0	244 53.2	·· 18.3	169 36.9	·· 48.5
22	319 04.3	129 29.3	09.7	128 58.7	48.7	259 55.6	18.4	184 39.1	48.5
23	334 06.8	144 29.0	10.9	143 59.7	49.4	274 58.0	18.4	199 41.3	48.4
10 00	349 09.3	159 28.6	S 3 12.2	159 00.6	S 3 50.0	290 00.4	N19 18.4	214 43.5	N17 48.3
01	4 11.7	174 28.3	13.5	174 01.6	50.7	305 02.7	18.4	229 45.7	48.2
02	19 14.2	189 28.0	14.8	189 02.6	51.4	320 05.1	18.4	244 47.8	48.2
03	34 16.6	204 27.6	·· 16.1	204 03.5	·· 52.0	335 07.5	·· 18.4	259 50.0	·· 48.1
04	49 19.1	219 27.3	17.4	219 04.5	52.7	350 09.9	18.4	274 52.2	48.0
05	64 21.6	234 27.0	18.6	234 05.5	53.3	5 12.3	18.4	289 54.4	48.0
06	79 24.0	249 26.6	S 3 19.9	249 06.4	S 3 54.0	20 14.6	N19 18.4	304 56.5	N17 47.9
07	94 26.5	264 26.3	21.2	264 07.4	54.7	35 17.0	18.5	319 58.7	47.8
08	109 29.0	279 26.0	22.5	279 08.4	55.3	50 19.4	18.5	335 00.9	47.7
F 09	124 31.4	294 25.6	·· 23.8	294 09.3	·· 56.0	65 21.8	·· 18.5	350 03.1	·· 47.7
R 10	139 33.9	309 25.3	25.0	309 10.3	56.6	80 24.2	18.5	5 05.3	47.6
i 11	154 36.4	324 25.0	26.3	324 11.3	57.3	95 26.6	18.5	20 07.4	47.5
D 12	169 38.8	339 24.7	S 3 27.6	339 12.2	S 3 58.0	110 28.9	N19 18.5	35 09.6	N17 47.4
A 13	184 41.3	354 24.3	28.9	354 13.2	58.6	125 31.3	18.5	50 11.8	47.4
Y 14	199 43.8	9 24.0	30.2	9 14.2	59.3	140 33.7	18.5	65 14.0	47.3
15	214 46.2	24 23.7	·· 31.5	24 15.1	3 59.9	155 36.1	·· 18.5	80 16.2	·· 47.2
16	229 48.7	39 23.3	32.7	39 16.1	4 00.6	170 38.5	18.5	95 18.3	47.1
17	244 51.1	54 23.0	34.0	54 17.1	01.3	185 40.9	18.6	110 20.5	47.1
18	259 53.6	69 22.7	S 3 35.3	69 18.0	S 4 01.9	200 43.2	N19 18.6	125 22.7	N17 47.0
19	274 56.1	84 22.3	36.6	84 19.0	02.6	215 45.6	18.6	140 24.9	46.9
20	289 58.5	99 22.0	37.9	99 20.0	03.3	230 48.0	18.6	155 27.0	46.8
21	305 01.0	114 21.7	·· 39.1	114 20.9	·· 03.9	245 50.4	·· 18.6	170 29.2	·· 46.8
22	320 03.5	129 21.3	40.4	129 21.9	04.6	260 52.8	18.6	185 31.4	46.7
23	335 05.9	144 21.0	41.7	144 22.9	05.2	275 55.2	18.6	200 33.6	46.6
11 00	350 08.4	159 20.7	S 3 43.0	159 23.8	S 4 05.9	290 57.6	N19 18.6	215 35.8	N17 46.6
01	5 10.9	174 20.3	44.3	174 24.8	06.6	306 00.0	18.6	230 37.9	46.5
02	20 13.3	189 20.0	45.5	189 25.8	07.2	321 02.3	18.6	245 40.1	46.4
03	35 15.8	204 19.7	·· 46.8	204 26.7	·· 07.9	336 04.7	·· 18.7	260 42.3	·· 46.3
04	50 18.2	219 19.3	48.1	219 27.7	08.5	351 07.1	18.7	275 44.5	46.3
05	65 20.7	234 19.0	49.4	234 28.7	09.2	6 09.5	18.7	290 46.7	46.2
06	80 23.2	249 18.7	S 3 50.7	249 29.6	S 4 09.9	21 11.9	N19 18.7	305 48.8	N17 46.1
07	95 25.6	264 18.3	51.9	264 30.6	10.5	36 14.3	18.7	320 51.0	46.0
S 08	110 28.1	279 18.0	53.2	279 31.6	11.2	51 16.7	18.7	335 53.2	46.0
A 09	125 30.6	294 17.7	·· 54.5	294 32.5	·· 11.8	66 19.1	·· 18.7	350 55.4	·· 45.9
T 10	140 33.0	309 17.3	55.8	309 33.5	12.5	81 21.5	18.7	5 57.6	45.8
U 11	155 35.5	324 17.0	57.1	324 34.5	13.2	96 23.8	18.7	20 59.7	45.7
R 12	170 38.0	339 16.7	S 3 58.3	339 35.4	S 4 13.8	111 26.2	N19 18.7	36 01.9	N17 45.7
D 13	185 40.4	354 16.3	3 59.6	354 36.4	14.5	126 28.6	18.8	51 04.1	45.6
A 14	200 42.9	9 16.0	4 00.9	9 37.4	15.1	141 31.0	18.8	66 06.3	45.5
Y 15	215 45.4	24 15.7	·· 02.2	24 38.3	·· 15.8	156 33.4	·· 18.8	81 08.5	·· 45.5
16	230 47.8	39 15.3	03.5	39 39.3	16.5	171 35.8	18.8	96 10.7	45.4
17	245 50.3	54 15.0	04.7	54 40.2	17.1	186 38.2	18.8	111 12.8	45.3
18	260 52.7	69 14.7	S 4 06.0	69 41.2	S 4 17.8	201 40.6	N19 18.8	126 15.0	N17 45.2
19	275 55.2	84 14.3	07.3	84 42.2	18.4	216 43.0	18.8	141 17.2	45.2
20	290 57.7	99 14.0	08.6	99 43.1	19.1	231 45.4	18.8	156 19.4	45.1
21	306 00.1	114 13.7	·· 09.9	114 44.1	·· 19.8	246 47.8	·· 18.8	171 21.6	·· 45.0
22	321 02.6	129 13.3	11.1	129 45.1	20.4	261 50.2	18.8	186 23.7	44.9
23	336 05.1	144 13.0	12.4	144 46.0	21.1	276 52.6	18.8	201 25.9	44.9
	h m								
Mer. Pass.	0 43.3	v −0.3	d 1.3	v 1.0	d 0.7	v 2.4	d 0.0	v 2.2	d 0.1

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 39.1	S40 23.6
Achernar	335 46.9	S57 21.0
Acrux	173 40.8	S62 58.3
Adhara	255 34.4	S28 56.3
Aldebaran	291 21.0	N16 27.8
Alioth	166 45.4	N56 05.3
Alkaid	153 21.0	N49 26.0
Al Na'ir	28 17.9	S47 04.3
Alnilam	276 14.4	S 1 12.9
Alphard	218 23.5	S 8 33.4
Alphecca	126 34.5	N26 47.8
Alpheratz	358 11.7	N28 57.9
Altair	62 35.0	N 8 48.7
Ankaa	353 42.5	S42 25.7
Antares	113 00.2	S26 22.8
Arcturus	146 21.2	N19 18.4
Atria	108 26.9	S68 59.4
Avior	234 29.7	S59 25.9
Bellatrix	279 01.7	N 6 19.8
Betelgeuse	271 31.3	N 7 24.2
Canopus	264 08.6	S52 40.8
Capella	281 15.3	N45 58.3
Deneb	49 49.9	N45 12.2
Denebola	183 02.1	N14 42.2
Diphda	349 23.3	S18 06.6
Dubhe	194 26.2	N61 52.6
Elnath	278 47.6	N28 35.2
Eltanin	90 58.9	N51 29.9
Enif	34 13.9	N 9 46.3
Fomalhaut	15 54.0	S29 44.6
Gacrux	172 32.2	S56 59.0
Gienah	176 21.1	S17 24.7
Hadar	149 27.6	S60 15.8
Hamal	328 31.7	N23 21.2
Kaus Aust.	84 20.3	S34 23.8
Kochab	137 19.6	N74 15.4
Markab	14 05.5	N15 05.0
Menkar	314 43.8	N 4 00.0
Menkent	148 40.4	S36 15.4
Miaplacidus	221 46.2	S69 37.2
Mirfak	309 19.7	N49 46.6
Nunki	76 32.4	S26 19.5
Peacock	54 02.2	S56 48.6
Pollux	244 01.7	N28 04.9
Procyon	245 28.8	N 5 17.1
Rasalhague	96 32.1	N12 34.9
Regulus	208 13.2	N12 04.9
Rigel	281 38.6	S 8 13.6
Rigil Kent.	140 29.8	S60 44.5
Sabik	102 44.2	S15 41.7
Schedar	350 11.5	N56 24.6
Shaula	96 59.4	S37 05.3
Sirius	258 58.2	S16 40.9
Spica	159 00.6	S11 02.3
Suhail	223 13.1	S43 20.2
Vega	80 57.5	N38 46.1
Zuben'ubi	137 36.2	S15 56.7

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	170 19.4	13 22
Mars	169 51.4	13 23
Jupiter	300 51.1	4 39
Saturn	225 34.2	9 40

1976 SEPTEMBER 9, 10, 11 (THURS., FRI., SAT.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
9 00	180 39.0	N 5 21.2	357 09.7	14.5	S 0 05.1	10.2	55.0
01	195 39.3	20.2	11 43.2	14.6	N 0 05.1	10.2	55.0
02	210 39.5	19.3	26 16.8	14.5	0 15.3	10.2	54.9
03	225 39.7	·· 18.3	40 50.3	14.6	0 25.5	10.1	54.9
04	240 39.9	17.4	55 23.9	14.5	0 35.6	10.2	54.9
05	255 40.1	16.5	69 57.4	14.6	0 45.8	10.2	54.9
06	270 40.3	N 5 15.5	84 31.0	14.6	N 0 56.0	10.1	54.9
07	285 40.6	14.6	99 04.6	14.6	1 06.1	10.2	54.9
T 08	300 40.8	13.6	113 38.2	14.7	1 16.3	10.1	54.8
H 09	315 41.0	·· 12.7	128 11.9	14.6	1 26.4	10.1	54.8
U 10	330 41.2	11.7	142 45.5	14.6	1 36.5	10.1	54.8
R 11	345 41.4	10.8	157 19.1	14.7	1 46.6	10.1	54.8
S 12	0 41.6	N 5 09.8	171 52.8	14.7	N 1 56.7	10.1	54.8
D 13	15 41.9	08.9	186 26.5	14.7	2 06.8	10.1	54.8
A 14	30 42.1	08.0	201 00.2	14.6	2 16.9	10.0	54.8
Y 15	45 42.3	·· 07.0	215 33.8	14.7	2 26.9	10.0	54.7
16	60 42.5	06.1	230 07.5	14.8	2 36.9	10.0	54.7
17	75 42.7	05.1	244 41.3	14.7	2 46.9	10.0	54.7
18	90 43.0	N 5 04.2	259 15.0	14.7	N 2 56.9	10.0	54.7
19	105 43.2	03.2	273 48.7	14.7	3 06.9	10.0	54.7
20	120 43.4	02.3	288 22.4	14.8	3 16.9	9.9	54.7
21	135 43.6	·· 01.3	302 56.2	14.7	3 26.8	9.9	54.7
22	150 43.8	S 00.4	317 29.9	14.7	3 36.7	9.9	54.6
23	165 44.0	4 59.4	332 03.6	14.8	3 46.6	9.9	54.6
10 00	180 44.3	N 4 58.5	346 37.4	14.8	N 3 56.5	9.9	54.6
01	195 44.5	57.6	1 11.2	14.7	4 06.4	9.8	54.6
02	210 44.7	56.6	15 44.9	14.8	4 16.2	9.8	54.6
03	225 44.9	·· 55.7	30 18.7	14.7	4 26.0	9.8	54.6
04	240 45.1	54.7	44 52.4	14.8	4 35.8	9.8	54.6
05	255 45.4	53.8	59 26.2	14.8	4 45.6	9.7	54.6
06	270 45.6	N 4 52.8	74 00.0	14.7	N 4 55.3	9.7	54.5
07	285 45.8	51.9	88 33.7	14.8	5 05.0	9.7	54.5
08	300 46.0	50.9	103 07.5	14.8	5 14.7	9.7	54.5
F 09	315 46.2	·· 50.0	117 41.3	14.7	5 24.4	9.6	54.5
R 10	330 46.5	49.0	132 15.0	14.8	5 34.0	9.6	54.5
I 11	345 46.7	48.1	146 48.8	14.7	5 43.6	9.6	54.5
D 12	0 46.9	N 4 47.1	161 22.5	14.8	N 5 53.2	9.5	54.5
A 13	15 47.1	46.2	175 56.3	14.8	6 02.7	9.5	54.5
Y 14	30 47.3	45.2	190 30.1	14.7	6 12.2	9.5	54.4
15	45 47.5	·· 44.3	205 03.8	14.8	6 21.7	9.4	54.4
16	60 47.8	43.3	219 37.6	14.7	6 31.1	9.5	54.4
17	75 48.0	42.4	234 11.3	14.7	6 40.6	9.4	54.4
18	90 48.2	N 4 41.4	248 45.0	14.8	N 6 50.0	9.3	54.4
19	105 48.4	40.5	263 18.8	14.7	6 59.3	9.3	54.4
20	120 48.6	39.5	277 52.5	14.7	7 08.6	9.3	54.4
21	135 48.9	·· 38.6	292 26.2	14.7	7 17.9	9.3	54.4
22	150 49.1	37.6	306 59.9	14.7	7 27.2	9.2	54.4
23	165 49.3	36.7	321 33.6	14.7	7 36.4	9.2	54.4
11 00	180 49.5	N 4 35.7	336 07.3	14.7	N 7 45.6	9.1	54.3
01	195 49.7	34.8	350 41.0	14.7	7 54.7	9.1	54.3
02	210 50.0	33.8	5 14.7	14.6	8 03.8	9.1	54.3
03	225 50.2	·· 32.9	19 48.3	14.7	8 12.9	9.0	54.3
04	240 50.4	31.9	34 22.0	14.7	8 21.9	9.0	54.3
05	255 50.6	31.0	48 55.7	14.6	8 30.9	9.0	54.3
06	270 50.8	N 4 30.0	63 29.3	14.6	N 8 39.9	8.9	54.3
07	285 51.1	29.1	78 02.9	14.6	8 48.8	8.9	54.3
S 08	300 51.3	28.1	92 36.5	14.6	8 57.7	8.8	54.3
A 09	315 51.5	·· 27.2	107 10.1	14.6	9 06.5	8.8	54.3
T 10	330 51.7	26.2	121 43.7	14.6	9 15.3	8.7	54.3
U 11	345 51.9	25.3	136 17.3	14.5	9 24.0	8.7	54.2
R 12	0 52.2	N 4 24.3	150 50.8	14.6	N 9 32.7	8.7	54.2
D 13	15 52.4	23.4	165 24.4	14.5	9 41.4	8.6	54.2
A 14	30 52.6	22.4	179 57.9	14.5	9 50.0	8.6	54.2
Y 15	45 52.8	·· 21.5	194 31.4	14.5	9 58.6	8.5	54.2
16	60 53.0	20.5	209 04.9	14.5	10 07.1	8.5	54.2
17	75 53.3	19.6	223 38.4	14.5	10 15.6	8.5	54.2
18	90 53.5	N 4 18.6	238 11.9	14.4	N10 24.1	8.4	54.2
19	105 53.7	17.7	252 45.3	14.5	10 32.5	8.3	54.2
20	120 53.9	16.7	267 18.8	14.4	10 40.8	8.3	54.2
21	135 54.1	·· 15.8	281 52.2	14.4	10 49.1	8.3	54.2
22	150 54.4	14.8	296 25.6	14.3	10 57.4	8.2	54.2
23	165 54.6	13.8	310 58.9	14.4	11 05.6	8.1	54.2
	S.D. 15.9	d 0.9	S.D. 14.9		14.8		14.8

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 9	Moonrise 10	Moonrise 11	Moonrise 12
°	h m	h m	h m	h m	h m	h m	h m
N 72	01 14	03 28	04 44	18 08	18 00	17 51	17 41
N 70	02 04	03 45	04 52	18 12	18 09	18 07	18 06
68	02 35	03 59	04 59	18 15	18 17	18 20	18 25
66	02 57	04 10	05 04	18 17	18 24	18 31	18 41
64	03 14	04 19	05 09	18 20	18 29	18 40	18 53
62	03 27	04 26	05 13	18 22	18 34	18 48	19 04
60	03 39	04 33	05 16	18 24	18 38	18 54	19 13
N 58	03 48	04 39	05 19	18 25	18 42	19 00	19 22
56	03 57	04 43	05 22	18 27	18 45	19 06	19 29
54	04 04	04 48	05 24	18 28	18 48	19 10	19 35
52	04 10	04 52	05 26	18 29	18 51	19 15	19 41
50	04 16	04 55	05 28	18 30	18 54	19 19	19 46
45	04 27	05 03	05 32	18 32	18 59	19 27	19 57
N 40	04 36	05 09	05 36	18 34	19 04	19 34	20 07
35	04 44	05 14	05 39	18 36	19 08	19 40	20 15
30	04 49	05 18	05 42	18 37	19 11	19 46	20 22
20	04 58	05 24	05 46	18 40	19 17	19 55	20 35
N 10	05 05	05 29	05 50	18 42	19 23	20 04	20 45
0	05 09	05 33	05 54	18 45	19 28	20 11	20 56
S 10	05 12	05 36	05 57	18 47	19 33	20 19	21 06
20	05 13	05 39	06 01	18 49	19 39	20 28	21 17
30	05 13	05 41	06 05	18 52	19 45	20 37	21 30
35	05 12	05 41	06 07	18 54	19 49	20 43	21 37
40	05 11	05 42	06 09	18 56	19 53	20 50	21 45
45	05 09	05 43	06 12	18 58	19 58	20 57	21 55
S 50	05 06	05 43	06 15	19 00	20 04	21 06	22 07
52	05 04	05 43	06 17	19 01	20 06	21 10	22 13
54	05 02	05 43	06 18	19 03	20 09	21 15	22 19
56	05 00	05 43	06 20	19 04	20 13	21 20	22 26
58	04 58	05 43	06 22	19 06	20 16	21 26	22 34
S 60	04 55	05 43	06 24	19 08	20 20	21 32	22 42

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 9	Moonset 10	Moonset 11	Moonset 12
°	h m	h m	h m	h m	h m	h m	h m
N 72	19 07	20 22	22 28	06 34	08 13	09 52	11 33
N 70	18 59	20 06	21 43	06 33	08 05	09 37	11 09
68	18 53	19 52	21 15	06 32	07 59	09 25	10 51
66	18 48	19 42	20 54	06 31	07 54	09 16	10 36
64	18 44	19 33	20 37	06 30	07 49	09 08	10 24
62	18 40	19 26	20 24	06 30	07 46	09 01	10 14
60	18 36	19 19	20 13	06 29	07 42	08 55	10 06
N 58	18 34	19 14	20 04	06 28	07 40	08 50	09 58
56	18 31	19 09	19 56	06 28	07 37	08 45	09 52
54	18 29	19 05	19 49	06 28	07 35	08 41	09 46
52	18 27	19 01	19 42	06 27	07 33	08 37	09 40
50	18 25	18 57	19 37	06 27	07 31	08 34	09 36
45	18 20	18 50	19 25	06 26	07 27	08 26	09 25
N 40	18 17	18 44	19 17	06 26	07 23	08 20	09 17
35	18 14	18 40	19 10	06 25	07 20	08 15	09 09
30	18 12	18 36	19 04	06 24	07 18	08 10	09 03
20	18 07	18 29	18 55	06 24	07 13	08 02	08 52
N 10	18 04	18 25	18 49	06 23	07 09	07 55	08 42
0	18 00	18 21	18 45	06 22	07 06	07 49	08 33
S 10	17 57	18 18	18 42	06 21	07 02	07 42	08 24
20	17 54	18 16	18 41	06 21	06 58	07 35	08 14
30	17 50	18 14	18 41	06 20	06 53	07 27	08 03
35	17 48	18 13	18 42	06 19	06 51	07 23	07 56
40	17 45	18 12	18 44	06 19	06 48	07 18	07 49
45	17 43	18 12	18 46	06 18	06 45	07 12	07 41
S 50	17 39	18 12	18 49	06 17	06 41	07 05	07 31
52	17 38	18 12	18 51	06 17	06 39	07 01	07 26
54	17 36	18 12	18 53	06 16	06 37	06 58	07 21
56	17 35	18 12	18 55	06 16	06 34	06 54	07 15
58	17 33	18 12	18 58	06 15	06 32	06 49	07 09
S 60	17 31	18 12	19 01	06 15	06 29	06 45	07 02

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
9	02 36	02 46	11 57	00 12	12 33	15	
10	02 57	03 07	11 57	00 55	13 17	16	○
11	03 18	03 28	11 57	01 38	14 00	17	

1976 OCT. 30, 31, NOV. 1 (SAT., SUN., MON.)

G.M.T.	ARIES	VENUS −3.4		MARS +1.7		JUPITER −2.4		SATURN +0.6		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
30 00	38 26.2	148 54.2	S23 30.2	176 23.6	S16 11.6	341 45.7	N18 44.1	259 38.8	N16 40.3	Acamar	315 38.8	S40 23.8
01	53 28.6	163 53.4	30.8	191 24.4	12.1	356 48.4	44.0	274 41.2	40.3	Achernar	335 46.7	S57 21.3
02	68 31.1	178 52.6	31.3	206 25.1	12.7	11 51.2	43.9	289 43.5	40.3	Acrux	173 40.7	S62 58.1
03	83 33.6	193 51.8	·· 31.8	221 25.9	·· 13.2	26 54.0	·· 43.9	304 45.8	·· 40.2	Adhara	255 34.0	S28 56.3
04	98 36.0	208 51.0	32.3	236 26.6	13.7	41 56.7	43.8	319 48.2	40.2	Aldebaran	291 20.7	N16 27.8
05	113 38.5	223 50.2	32.9	251 27.4	14.3	56 59.5	43.8	334 50.5	40.2			
06	128 40.9	238 49.4	S23 33.4	266 28.1	S16 14.8	72 02.3	N18 43.7	349 52.8	N16 40.2	Aliath	166 45.4	N56 05.0
07	143 43.4	253 48.6	33.9	281 28.8	15.3	87 05.1	43.6	4 55.2	40.1	Alkaid	153 21.1	N49 25.7
S 08	158 45.9	268 47.8	34.4	296 29.6	15.9	102 07.8	43.6	19 57.5	40.1	Al Na'ir	28 18.1	S47 04.5
A 09	173 48.3	283 47.0	·· 35.0	311 30.3	·· 16.4	117 10.6	·· 43.5	34 59.8	·· 40.1	Alnilam	276 14.1	S 1 12.9
T 10	188 50.8	298 46.2	35.5	326 31.1	16.9	132 13.4	43.4	50 02.2	40.0	Alphard	218 23.2	S 8 33.4
U 11	203 53.3	313 45.4	36.0	341 31.8	17.5	147 16.1	43.4	65 04.5	40.0			
R 12	218 55.7	328 44.6	S23 36.5	356 32.5	S16 18.0	162 18.9	N18 43.3	80 06.8	N16 40.0	Alphecca	126 34.7	N26 47.7
D 13	233 58.2	343 43.8	37.0	11 33.3	18.6	177 21.7	43.2	95 09.2	39.9	Alpheratz	358 11.7	N28 58.0
A 14	249 00.7	358 43.0	37.5	26 34.0	19.1	192 24.4	43.2	110 11.5	39.9	Altair	62 35.2	N 8 48.7
Y 15	264 03.1	13 42.2	·· 38.1	41 34.8	·· 19.6	207 27.2	·· 43.1	125 13.8	·· 39.9	Ankaa	353 42.5	S42 25.9
16	279 05.6	28 41.4	38.6	56 35.5	20.2	222 30.0	43.0	140 16.2	39.8	Antares	113 00.4	S26 22.8
17	294 08.1	43 40.5	39.1	71 36.2	20.7	237 32.8	43.0	155 18.5	39.8			
18	309 10.5	58 39.7	S23 39.6	86 37.0	S16 21.2	252 35.5	N18 42.9	170 20.8	N16 39.8	Arcturus	146 21.2	N19 18.3
19	324 13.0	73 38.9	40.1	101 37.7	21.8	267 38.3	42.9	185 23.2	39.7	Atria	108 27.4	S68 59.3
20	339 15.4	88 38.1	40.6	116 38.5	22.3	282 41.1	42.8	200 25.5	39.7	Avior	234 29.2	S59 25.9
21	354 17.9	103 37.3	·· 41.1	131 39.2	·· 22.8	297 43.8	·· 42.7	215 27.8	·· 39.7	Bellatrix	279 01.3	N 6 19.8
22	9 20.4	118 36.5	41.6	146 39.9	23.4	312 46.6	42.7	230 30.2	39.6	Betelgeuse	271 30.9	N 7 24.2
23	24 22.8	133 35.7	42.1	161 40.7	23.9	327 49.4	42.6	245 32.5	39.6			
31 00	39 25.3	148 34.9	S23 42.6	176 41.4	S16 24.4	342 52.2	N18 42.5	260 34.9	N16 39.6	Canopus	264 08.1	S52 40.8
01	54 27.8	163 34.1	43.1	191 42.1	25.0	357 54.9	42.5	275 37.2	39.6	Capella	281 14.8	N45 58.4
02	69 30.2	178 33.3	43.6	206 42.9	25.5	12 57.7	42.4	290 39.5	39.5	Deneb	49 50.2	N45 12.3
03	84 32.7	193 32.5	·· 44.1	221 43.6	·· 26.0	28 00.5	·· 42.3	305 41.9	·· 39.5	Denebola	183 02.0	N14 42.1
04	99 35.2	208 31.7	44.6	236 44.4	26.5	43 03.2	42.3	320 44.2	39.5	Diphda	349 23.2	S18 06.7
05	114 37.6	223 30.9	45.1	251 45.1	27.1	58 06.0	42.2	335 46.5	39.4			
06	129 40.1	238 30.0	S23 45.6	266 45.8	S16 27.6	73 08.8	N18 42.1	350 48.9	N16 39.4	Dubhe	194 25.8	N61 52.3
07	144 42.6	253 29.2	46.1	281 46.6	28.1	88 11.6	42.1	5 51.2	39.4	Elnath	278 47.2	N28 35.2
08	159 45.0	268 28.4	46.6	296 47.3	28.7	103 14.3	42.0	20 53.6	39.3	Eltanin	90 59.3	N51 29.8
S 09	174 47.5	283 27.6	·· 47.1	311 48.0	·· 29.2	118 17.1	·· 41.9	35 55.9	·· 39.3	Enif	34 14.1	N 9 46.4
U 10	189 49.9	298 26.8	47.6	326 48.8	29.7	133 19.9	41.9	50 58.2	39.3	Fomalhaut	15 54.1	S29 44.7
N 11	204 52.4	313 26.0	48.1	341 49.5	30.3	148 22.7	41.8	66 00.6	39.2			
D 12	219 54.9	328 25.2	S23 48.6	356 50.2	S16 30.8	163 25.4	N18 41.7	81 02.9	N16 39.2	Gacrux	172 32.1	S56 58.8
A 13	234 57.3	343 24.4	49.1	11 51.0	31.3	178 28.2	41.7	96 05.3	39.2	Gienah	176 20.9	S17 24.7
Y 14	249 59.8	358 23.5	49.6	26 51.7	31.8	193 31.0	41.6	111 07.6	39.2	Hadar	149 27.6	S60 15.6
15	265 02.3	13 22.7	·· 50.1	41 52.4	·· 32.4	208 33.8	·· 41.6	126 09.9	·· 39.1	Hamal	328 31.5	N23 21.3
16	280 04.7	28 21.9	50.5	56 53.2	32.9	223 36.5	41.5	141 12.3	39.1	Kaus Aust.	84 20.6	S34 23.8
17	295 07.2	43 21.1	51.0	71 53.9	33.4	238 39.3	41.4	156 14.6	39.1			
18	310 09.7	58 20.3	S23 51.5	86 54.6	S16 34.0	253 42.1	N18 41.4	171 17.0	N16 39.0	Kochab	137 20.2	N74 15.1
19	325 12.1	73 19.5	52.0	101 55.4	34.5	268 44.9	41.3	186 19.3	39.0	Markab	14 05.6	N15 05.1
20	340 14.6	88 18.7	52.5	116 56.1	35.0	283 47.6	41.2	201 21.6	39.0	Menkar	314 43.6	N 4 00.0
21	355 17.1	103 17.8	·· 53.0	131 56.8	·· 35.5	298 50.4	·· 41.2	216 24.0	·· 38.9	Menkent	148 40.5	S36 15.3
22	10 19.5	118 17.0	53.4	146 57.6	36.1	313 53.2	41.1	231 26.3	38.9	Miaplacidus	221 45.5	S69 37.1
23	25 22.0	133 16.2	53.9	161 58.3	36.6	328 56.0	41.0	246 28.7	38.9			
1 00	40 24.4	148 15.4	S23 54.4	176 59.0	S16 37.1	343 58.7	N18 41.0	261 31.0	N16 38.9	Mirfak	309 19.3	N49 46.8
01	55 26.9	163 14.6	54.9	191 59.8	37.7	359 01.5	40.9	276 33.3	38.8	Nunki	76 32.6	S26 19.5
02	70 29.4	178 13.8	55.3	207 00.5	38.2	14 04.3	40.8	291 35.7	38.8	Peacock	54 02.6	S56 48.7
03	85 31.8	193 12.9	·· 55.8	222 01.2	·· 38.7	29 07.1	·· 40.8	306 38.0	·· 38.8	Pollux	244 01.3	N28 04.8
04	100 34.3	208 12.1	56.3	237 02.0	39.2	44 09.9	40.7	321 40.4	38.7	Procyon	245 28.4	N 5 17.1
05	115 36.8	223 11.3	56.7	252 02.7	39.8	59 12.6	40.6	336 42.7	38.7			
06	130 39.2	238 10.5	S23 57.2	267 03.4	S16 40.3	74 15.4	N18 40.6	351 45.0	N16 38.7	Rasalhague	96 32.3	N12 34.8
07	145 41.7	253 09.7	57.7	282 04.2	40.8	89 18.2	40.5	6 47.4	38.7	Regulus	208 12.9	N12 04.8
08	160 44.2	268 08.9	58.1	297 04.9	41.3	104 21.0	40.4	21 49.7	38.6	Rigel	281 38.3	S 8 13.6
M 09	175 46.6	283 08.0	·· 58.6	312 05.6	·· 41.9	119 23.7	·· 40.4	36 52.1	·· 38.6	Rigil Kent.	140 30.0	S60 44.3
O 10	190 49.1	298 07.2	59.1	327 06.3	42.4	134 26.5	40.3	51 54.4	38.6	Sabik	102 44.4	S15 41.7
N 11	205 51.5	313 06.4	23 59.5	342 07.1	42.9	149 29.3	40.2	66 56.8	38.5			
D 12	220 54.0	328 05.6	S24 00.0	357 07.8	S16 43.4	164 32.1	N18 40.2	81 59.1	N16 38.5	Schedar	350 11.4	N56 24.9
A 13	235 56.5	343 04.8	00.5	12 08.5	44.0	179 34.9	40.1	97 01.4	38.5	Shaula	96 59.6	S37 05.2
Y 14	250 58.9	358 03.9	00.9	27 09.3	44.5	194 37.6	40.0	112 03.8	38.4	Sirius	258 57.9	S16 41.0
15	266 01.4	13 03.1	·· 01.4	42 10.0	·· 45.0	209 40.4	·· 40.0	127 06.1	·· 38.4	Spica	159 00.6	S11 02.3
16	281 03.9	28 02.3	01.8	57 10.7	45.5	224 43.2	39.9	142 08.5	38.4	Suhail	223 12.7	S43 20.1
17	296 06.3	43 01.5	02.3	72 11.4	46.1	239 46.0	39.8	157 10.8	38.4			
18	311 08.8	58 00.6	S24 02.8	87 12.2	S16 46.6	254 48.8	N18 39.8	172 13.2	N16 38.3	Vega	80 57.8	N38 46.1
19	326 11.3	72 59.8	03.2	102 12.9	47.1	269 51.5	39.7	187 15.5	38.3	Zuben'ubi	137 36.3	S15 56.6
20	341 13.7	87 59.0	03.7	117 13.6	47.6	284 54.3	39.6	202 17.9	38.3		S.H.A.	Mer. Pass.
21	356 16.2	102 58.2	·· 04.1	132 14.3	·· 48.2	299 57.1	·· 39.6	217 20.2	·· 38.2		° ′	h m
22	11 18.7	117 57.3	04.6	147 15.1	48.7	314 59.9	39.5	232 22.5	38.2	Venus	109 09.6	14 06
23	26 21.1	132 56.5	05.0	162 15.8	49.2	330 02.7	39.4	247 24.9	38.2	Mars	137 16.1	12 13
	h m									Jupiter	303 26.9	1 08
Mer. Pass.	21 18.8	v −0.8	d 0.5	v 0.7	d 0.5	v 2.8	d 0.1	v 2.3	d 0.0	Saturn	221 09.6	6 37

1976 OCT. 30, 31, NOV. 1 (SAT., SUN., MON.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
30 00	184 04.4	S13 45.1	89 45.1	10.9	S13 14.2	8.0	57.0
01	199 04.4	45.9	104 15.0	11.1	13 06.2	8.0	56.9
02	214 04.4	46.7	118 45.1	11.1	12 58.2	8.1	56.9
03	229 04.5	·· 47.5	133 15.2	11.3	12 50.1	8.1	56.9
04	244 04.5	48.4	147 45.5	11.2	12 42.0	8.2	56.8
05	259 04.5	49.2	162 15.7	11.4	12 33.8	8.3	56.8
06	274 04.6	S13 50.0	176 46.1	11.4	S12 25.5	8.3	56.8
07	289 04.6	50.8	191 16.5	11.5	12 17.2	8.3	56.7
S 08	304 04.6	51.6	205 47.0	11.6	12 08.9	8.4	56.7
A 09	319 04.7	·· 52.4	220 17.6	11.6	12 00.5	8.5	56.7
T 10	334 04.7	53.3	234 48.2	11.7	11 52.0	8.5	56.6
U 11	349 04.7	54.1	249 18.9	11.8	11 43.5	8.5	56.6
R 12	4 04.7	S13 54.9	263 49.7	11.9	S11 35.0	8.6	56.6
D 13	19 04.8	55.7	278 20.6	11.9	11 26.4	8.7	56.5
A 14	34 04.8	56.5	292 51.5	12.0	11 17.7	8.7	56.5
Y 15	49 04.8	·· 57.3	307 22.5	12.0	11 09.0	8.7	56.5
16	64 04.9	58.2	321 53.5	12.1	11 00.3	8.8	56.4
17	79 04.9	59.0	336 24.6	12.2	10 51.5	8.8	56.4
18	94 04.9	S13 59.8	350 55.8	12.2	S10 42.7	8.9	56.4
19	109 04.9	14 00.6	5 27.0	12.3	10 33.8	8.9	56.3
20	124 05.0	01.4	19 58.3	12.4	10 24.9	8.9	56.3
21	139 05.0	·· 02.2	34 29.7	12.4	10 16.0	9.0	56.3
22	154 05.0	03.0	49 01.1	12.5	10 07.0	9.0	56.2
23	169 05.1	03.9	63 32.6	12.6	9 58.0	9.1	56.2
31 00	184 05.1	S14 04.7	78 04.2	12.6	S 9 48.9	9.1	56.2
01	199 05.1	05.5	92 35.8	12.7	9 39.8	9.2	56.2
02	214 05.1	06.3	107 07.5	12.7	9 30.6	9.1	56.1
03	229 05.2	·· 07.1	121 39.2	12.8	9 21.5	9.2	56.1
04	244 05.2	07.9	136 11.0	12.8	9 12.3	9.3	56.1
05	259 05.2	08.7	150 42.8	12.9	9 03.0	9.3	56.0
06	274 05.2	S14 09.5	165 14.7	13.0	S 8 53.7	9.3	56.0
07	289 05.3	10.3	179 46.7	13.0	8 44.4	9.3	56.0
08	304 05.3	11.1	194 18.7	13.1	8 35.1	9.4	55.9
S 09	319 05.3	·· 11.9	208 50.8	13.1	8 25.7	9.4	55.9
U 10	334 05.3	12.8	223 22.9	13.2	8 16.3	9.4	55.9
N 11	349 05.3	13.6	237 55.1	13.2	8 06.9	9.5	55.9
D 12	4 05.4	S14 14.4	252 27.3	13.3	S 7 57.4	9.4	55.8
A 13	19 05.4	15.2	266 59.6	13.3	7 48.0	9.6	55.8
Y 14	34 05.4	16.0	281 31.9	13.4	7 38.4	9.5	55.8
15	49 05.4	·· 16.8	296 04.3	13.4	7 28.9	9.6	55.8
16	64 05.4	17.6	310 36.7	13.5	7 19.3	9.5	55.7
17	79 05.5	18.4	325 09.2	13.5	7 09.8	9.7	55.7
18	94 05.5	S14 19.2	339 41.7	13.6	S 7 00.1	9.6	55.7
19	109 05.5	20.0	354 14.3	13.6	6 50.5	9.6	55.6
20	124 05.5	20.8	8 46.9	13.7	6 40.9	9.7	55.6
21	139 05.5	·· 21.6	23 19.6	13.7	6 31.2	9.7	55.6
22	154 05.6	22.4	37 52.3	13.7	6 21.5	9.7	55.6
23	169 05.6	23.2	52 25.0	13.8	6 11.8	9.8	55.5
1 00	184 05.6	S14 24.0	66 57.8	13.9	S 6 02.0	9.7	55.5
01	199 05.6	24.8	81 30.7	13.9	5 52.3	9.8	55.5
02	214 05.6	25.6	96 03.6	13.9	5 42.5	9.8	55.5
03	229 05.7	·· 26.4	110 36.5	14.0	5 32.7	9.8	55.4
04	244 05.7	27.2	125 09.5	14.0	5 22.9	9.8	55.4
05	259 05.7	28.0	139 42.5	14.0	5 13.1	9.9	55.4
06	274 05.7	S14 28.8	154 15.5	14.1	S 5 03.2	9.8	55.4
07	289 05.7	29.6	168 48.6	14.1	4 53.4	9.9	55.3
08	304 05.7	30.4	183 21.7	14.1	4 43.5	9.9	55.3
M 09	319 05.7	·· 31.2	197 54.8	14.2	4 33.6	9.9	55.3
O 10	334 05.8	32.0	212 28.0	14.3	4 23.7	9.9	55.3
N 11	349 05.8	32.8	227 01.3	14.2	4 13.8	9.9	55.3
D 12	4 05.8	S14 33.6	241 34.5	14.3	S 4 03.9	9.9	55.2
A 13	19 05.8	34.4	256 07.8	14.3	3 54.0	9.9	55.2
Y 14	34 05.8	35.2	270 41.1	14.4	3 44.1	10.0	55.2
15	49 05.8	·· 36.0	285 14.5	14.4	3 34.1	9.9	55.2
16	64 05.8	36.8	299 47.9	14.4	3 24.2	10.0	55.1
17	79 05.9	37.6	314 21.3	14.4	3 14.2	10.0	55.1
18	94 05.9	S14 38.4	328 54.7	14.5	S 3 04.2	9.9	55.1
19	109 05.9	39.2	343 28.2	14.5	2 54.3	10.0	55.1
20	124 05.9	40.0	358 01.7	14.6	2 44.3	10.0	55.1
21	139 05.9	·· 40.8	12 35.3	14.5	2 34.3	10.0	55.0
22	154 05.9	41.6	27 08.8	14.6	2 24.3	10.0	55.0
23	169 05.9	42.4	41 42.4	14.6	2 14.3	10.0	55.0
	S.D. 16.1	d 0.8	S.D. 15.4		15.2		15.1

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 30	Moonrise 31	Moonrise 1	Moonrise 2
°	h m	h m	h m	h m	h m	h m	h m
N 72	06 02	07 25	08 51	15 02	14 53	14 45	14 37
N 70	05 59	07 12	08 26	14 43	14 42	14 40	14 38
68	05 55	07 02	08 07	14 29	14 33	14 36	14 38
66	05 52	06 54	07 52	14 17	14 25	14 32	14 38
64	05 50	06 47	07 39	14 07	14 19	14 29	14 38
62	05 47	06 40	07 29	13 58	14 13	14 27	14 39
60	05 45	06 35	07 20	13 50	14 09	14 24	14 39
N 58	05 43	06 30	07 12	13 44	14 04	14 22	14 39
56	05 41	06 25	07 05	13 38	14 01	14 20	14 39
54	05 39	06 21	06 59	13 33	13 57	14 19	14 39
52	05 38	06 18	06 53	13 28	13 54	14 17	14 39
50	05 36	06 14	06 48	13 24	13 51	14 16	14 39
45	05 32	06 07	06 37	13 14	13 45	14 13	14 40
N 40	05 28	06 00	06 28	13 07	13 40	14 11	14 40
35	05 24	05 54	06 20	13 00	13 35	14 08	14 40
30	05 20	05 48	06 13	12 54	13 31	14 07	14 40
20	05 12	05 38	06 01	12 44	13 25	14 03	14 40
N 10	05 04	05 29	05 50	12 35	13 19	14 00	14 41
0	04 54	05 19	05 40	12 26	13 13	13 58	14 41
S 10	04 43	05 08	05 30	12 17	13 07	13 55	14 41
20	04 29	04 56	05 19	12 08	13 01	13 52	14 42
30	04 11	04 41	05 06	11 58	12 54	13 49	14 42
35	04 00	04 32	04 59	11 52	12 50	13 47	14 42
40	03 46	04 21	04 50	11 45	12 46	13 45	14 42
45	03 29	04 08	04 40	11 37	12 40	13 42	14 43
S 50	03 07	03 52	04 28	11 27	12 34	13 39	14 43
52	02 56	03 45	04 23	11 23	12 31	13 38	14 43
54	02 43	03 36	04 16	11 18	12 28	13 36	14 43
56	02 27	03 26	04 10	11 13	12 24	13 35	14 44
58	02 09	03 15	04 02	11 06	12 20	13 33	14 44
S 60	01 45	03 01	03 53	10 59	12 16	13 31	14 44

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 30	Moonset 31	Moonset 1	Moonset 2
°	h m	h m	h m	h m	h m	h m	h m
N 72	14 35	16 01	17 23	22 31	24 16	00 16	01 55
N 70	15 00	16 14	17 27	22 48	24 25	00 25	01 58
68	15 19	16 24	17 30	23 01	24 32	00 32	02 00
66	15 35	16 32	17 33	23 12	24 38	00 38	02 02
64	15 47	16 40	17 36	23 21	24 43	00 43	02 03
62	15 58	16 46	17 39	23 29	24 48	00 48	02 05
60	16 07	16 52	17 41	23 36	24 52	00 52	02 06
N 58	16 15	16 57	17 43	23 42	24 55	00 55	02 07
56	16 22	17 01	17 45	23 47	24 58	00 58	02 08
54	16 28	17 05	17 47	23 51	25 01	01 01	02 09
52	16 34	17 09	17 49	23 56	25 03	01 03	02 09
50	16 39	17 12	17 51	23 59	25 05	01 05	02 10
45	16 50	17 20	17 55	24 07	00 07	01 10	02 11
N 40	16 59	17 27	17 59	24 14	00 14	01 14	02 13
35	17 07	17 33	18 03	24 20	00 20	01 18	02 14
30	17 14	17 39	18 07	24 25	00 25	01 21	02 14
20	17 26	17 49	18 15	24 34	00 34	01 26	02 16
N 10	17 37	17 59	18 23	24 42	00 42	01 30	02 17
0	17 47	18 09	18 33	00 00	00 49	01 35	02 19
S 10	17 58	18 19	18 45	00 10	00 56	01 39	02 20
20	18 09	18 32	18 59	00 21	01 03	01 43	02 21
30	18 22	18 47	19 17	00 33	01 12	01 48	02 23
35	18 29	18 56	19 28	00 39	01 17	01 51	02 23
40	18 38	19 07	19 42	00 47	01 22	01 54	02 24
45	18 48	19 20	20 00	00 56	01 29	01 58	02 25
S 50	19 00	19 36	20 22	01 07	01 36	02 02	02 27
52	19 06	19 44	20 34	01 12	01 40	02 05	02 27
54	19 12	19 53	20 47	01 17	01 44	02 07	02 28
56	19 19	20 03	21 02	01 23	01 48	02 09	02 28
58	19 27	20 15	21 22	01 30	01 53	02 12	02 29
S 60	19 36	20 28	21 47	01 38	01 58	02 15	02 30

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
30	16 17	16 19	11 44	18 37	06 13	07	
31	16 20	16 21	11 44	19 24	07 01	08	
1	16 22	16 23	11 44	20 08	07 46	09	◐

1976 DECEMBER 23, 24, 25 (THURS., FRI., SAT.)

G.M.T.	ARIES	VENUS −3.8		MARS +1.6		JUPITER −2.3		SATURN +0.3	
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
23 00	91 39.7	132 50.8	S18 01.5	189 00.3	S23 48.3	41 41.6	N17 18.6	312 38.5	N16 46.1
01	106 42.1	147 50.4	18 00.6	204 00.8	48.4	56 44.3	18.6	327 41.0	46.1
02	121 44.6	162 50.0	17 59.6	219 01.2	48.5	71 46.9	18.6	342 43.6	46.2
03	136 47.1	177 49.6	·· 58.7	234 01.7	·· 48.6	86 49.6	·· 18.5	357 46.2	·· 46.2
04	151 49.5	192 49.2	57.7	249 02.1	48.7	101 52.3	18.5	12 48.7	46.2
05	166 52.0	207 48.8	56.8	264 02.5	48.8	116 54.9	18.4	27 51.3	46.3
06	181 54.5	222 48.4	S17 55.8	279 03.0	S23 49.0	131 57.6	N17 18.4	42 53.9	N16 46.3
07	196 56.9	237 48.0	54.9	294 03.4	49.1	147 00.3	18.4	57 56.5	46.4
T 08	211 59.4	252 47.6	53.9	309 03.9	49.2	162 02.9	18.3	72 59.1	46.4
H 09	227 01.8	267 47.2	·· 53.0	324 04.3	·· 49.3	177 05.6	·· 18.3	88 01.6	·· 46.4
U 10	242 04.3	282 46.8	52.0	339 04.8	49.4	192 08.2	18.2	103 04.2	46.5
R 11	257 06.8	297 46.4	51.1	354 05.2	49.5	207 10.9	18.2	118 06.8	46.5
S 12	272 09.2	312 46.0	S17 50.1	9 05.7	S23 49.6	222 13.6	N17 18.2	133 09.4	N16 46.6
D 13	287 11.7	327 45.6	49.2	24 06.1	49.8	237 16.2	18.1	148 11.9	46.6
A 14	302 14.2	342 45.2	48.2	39 06.5	49.9	252 18.9	18.1	163 14.5	46.7
Y 15	317 16.6	357 44.8	·· 47.3	54 07.0	·· 50.0	267 21.5	·· 18.1	178 17.1	·· 46.7
16	332 19.1	12 44.4	46.3	69 07.4	50.1	282 24.2	18.0	193 19.7	46.7
17	347 21.6	27 44.0	45.3	84 07.9	50.2	297 26.9	18.0	208 22.2	46.8
18	2 24.0	42 43.6	S17 44.4	99 08.3	S23 50.3	312 29.5	N17 17.9	223 24.8	N16 46.8
19	17 26.5	57 43.2	43.4	114 08.7	50.4	327 32.2	17.9	238 27.4	46.9
20	32 29.0	72 42.8	42.5	129 09.2	50.5	342 34.8	17.9	253 30.0	46.9
21	47 31.4	87 42.5	·· 41.5	144 09.6	·· 50.6	357 37.5	·· 17.8	268 32.5	·· 46.9
22	62 33.9	102 42.1	40.5	159 10.1	50.8	12 40.2	17.8	283 35.1	47.0
23	77 36.3	117 41.7	39.6	174 10.5	50.9	27 42.8	17.7	298 37.7	47.0
24 00	92 38.8	132 41.3	S17 38.6	189 11.0	S23 51.0	42 45.5	N17 17.7	313 40.3	N16 47.1
01	107 41.3	147 40.9	37.6	204 11.4	51.1	57 48.1	17.7	328 42.9	47.1
02	122 43.7	162 40.5	36.7	219 11.8	51.2	72 50.8	17.6	343 45.4	47.2
03	137 46.2	177 40.1	·· 35.7	234 12.3	·· 51.3	87 53.4	·· 17.6	358 48.0	·· 47.2
04	152 48.7	192 39.8	34.8	249 12.7	51.4	102 56.1	17.6	13 50.6	47.2
05	167 51.1	207 39.4	33.8	264 13.2	51.5	117 58.7	17.5	28 53.2	47.3
06	182 53.6	222 39.0	S17 32.8	279 13.6	S23 51.6	133 01.4	N17 17.5	43 55.8	N16 47.3
07	197 56.1	237 38.6	31.8	294 14.0	51.7	148 04.1	17.5	58 58.3	47.4
08	212 58.5	252 38.2	30.9	309 14.5	51.8	163 06.7	17.4	74 00.9	47.4
F 09	228 01.0	267 37.9	·· 29.9	324 14.9	·· 51.9	178 09.4	·· 17.4	89 03.5	·· 47.4
R 10	243 03.5	282 37.5	28.9	339 15.4	52.0	193 12.0	17.3	104 06.1	47.5
I 11	258 05.9	297 37.1	28.0	354 15.8	52.1	208 14.7	17.3	119 08.6	47.5
D 12	273 08.4	312 36.7	S17 27.0	9 16.2	S23 52.2	223 17.3	N17 17.3	134 11.2	N16 47.6
A 13	288 10.8	327 36.4	26.0	24 16.7	52.3	238 20.0	17.2	149 13.8	47.6
Y 14	303 13.3	342 36.0	25.1	39 17.1	52.4	253 22.6	17.2	164 16.4	47.7
15	318 15.8	357 35.6	·· 24.1	54 17.6	·· 52.5	268 25.3	·· 17.2	179 19.0	·· 47.7
16	333 18.2	12 35.2	23.1	69 18.0	52.6	283 27.9	17.1	194 21.5	47.7
17	348 20.7	27 34.9	22.1	84 18.4	52.7	298 30.6	17.1	209 24.1	47.8
18	3 23.2	42 34.5	S17 21.2	99 18.9	S23 52.8	313 33.2	N17 17.0	224 26.7	N16 47.8
19	18 25.6	57 34.1	20.2	114 19.3	52.9	328 35.9	17.0	239 29.3	47.9
20	33 28.1	72 33.8	19.2	129 19.7	53.0	343 38.5	17.0	254 31.9	47.9
21	48 30.6	87 33.4	·· 18.2	144 20.2	·· 53.1	358 41.2	·· 16.9	269 34.5	·· 48.0
22	63 33.0	102 33.0	17.2	159 20.6	53.2	13 43.8	16.9	284 37.0	48.0
23	78 35.5	117 32.6	16.3	174 21.1	53.3	28 46.5	16.9	299 39.6	48.0
25 00	93 38.0	132 32.3	S17 15.3	189 21.5	S23 53.4	43 49.1	N17 16.8	314 42.2	N16 48.1
01	108 40.4	147 31.9	14.3	204 21.9	53.5	58 51.8	16.8	329 44.8	48.1
02	123 42.9	162 31.6	13.3	219 22.4	53.6	73 54.4	16.8	344 47.4	48.2
03	138 45.3	177 31.2	·· 12.3	234 22.8	·· 53.7	88 57.1	·· 16.7	359 49.9	·· 48.2
04	153 47.8	192 30.8	11.4	249 23.3	53.8	103 59.7	16.7	14 52.5	48.3
05	168 50.3	207 30.5	10.4	264 23.7	53.9	119 02.4	16.7	29 55.1	48.3
06	183 52.7	222 30.1	S17 09.4	279 24.1	S23 54.0	134 05.0	N17 16.6	44 57.7	N16 48.3
07	198 55.2	237 29.7	08.4	294 24.6	54.1	149 07.7	16.6	60 00.3	48.4
S 08	213 57.7	252 29.4	07.4	309 25.0	54.2	164 10.3	16.6	75 02.9	48.4
A 09	229 00.1	267 29.0	·· 06.4	324 25.4	·· 54.3	179 13.0	·· 16.5	90 05.4	·· 48.5
T 10	244 02.6	282 28.7	05.4	339 25.9	54.4	194 15.6	16.5	105 08.0	48.5
U 11	259 05.1	297 28.3	04.4	354 26.3	54.5	209 18.3	16.4	120 10.6	48.6
R 12	274 07.5	312 27.9	S17 03.5	9 26.7	S23 54.6	224 20.9	N17 16.4	135 13.2	N16 48.6
D 13	289 10.0	327 27.6	02.5	24 27.2	54.7	239 23.5	16.4	150 15.8	48.6
A 14	304 12.4	342 27.2	01.5	39 27.6	54.7	254 26.2	16.3	165 18.4	48.7
Y 15	319 14.9	357 26.9	17 00.5	54 28.1	·· 54.8	269 28.8	·· 16.3	180 20.9	·· 48.7
16	334 17.4	12 26.5	16 59.5	69 28.5	54.9	284 31.5	16.3	195 23.5	48.8
17	349 19.8	27 26.2	58.5	84 28.9	55.0	299 34.1	16.2	210 26.1	48.8
18	4 22.3	42 25.8	S16 57.5	99 29.4	S23 55.1	314 36.8	N17 16.2	225 28.7	N16 48.9
19	19 24.8	57 25.5	56.5	114 29.8	55.2	329 39.4	16.2	240 31.3	48.9
20	34 27.2	72 25.1	55.5	129 30.2	55.3	344 42.0	16.1	255 33.9	48.9
21	49 29.7	87 24.8	·· 54.5	144 30.7	·· 55.4	359 44.7	·· 16.1	270 36.5	·· 49.0
22	64 32.2	102 24.4	53.5	159 31.1	55.5	14 47.3	16.1	285 39.0	49.0
23	79 34.6	117 24.1	52.5	174 31.5	55.6	29 50.0	16.0	300 41.6	49.1
	h m								
Mer. Pass.	17 46.5	*v* −0.4	*d* 1.0	*v* 0.4	*d* 0.1	*v* 2.7	*d* 0.0	*v* 2.6	*d* 0.0

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 38.9	S40 24.0
Achernar	335 47.0	S57 21.5
Acrux	173 40.0	S62 58.0
Adhara	255 33.7	S28 56.5
Aldebaran	291 20.5	N16 27.8
Alioth	166 44.9	N56 04.8
Alkaid	153 20.7	N49 25.4
Al Na'ir	28 18.4	S47 04.5
Alnilam	276 13.9	S 1 13.1
Alphard	218 22.8	S 8 33.6
Alphecca	126 34.5	N26 47.5
Alpheratz	358 11.9	N28 58.0
Altair	62 35.3	N 8 48.6
Ankaa	353 42.7	S42 26.0
Antares	113 00.3	S26 22.8
Arcturus	146 21.0	N19 18.0
Atria	108 27.3	S68 59.0
Avior	234 28.6	S59 26.1
Bellatrix	279 01.1	N 6 19.7
Betelgeuse	271 30.6	N 7 24.1
Canopus	264 07.7	S52 41.1
Capella	281 14.5	N45 58.5
Deneb	49 50.5	N45 12.1
Denebola	183 01.6	N14 41.9
Diphda	349 23.4	S18 06.8
Dubhe	194 25.1	N61 52.1
Elnath	278 46.9	N28 35.3
Eltanin	90 59.4	N51 29.6
Enif	34 14.2	N 9 46.3
Fomalhaut	15 54.3	S29 44.7
Gacrux	172 31.5	S56 58.8
Gienah	176 20.5	S17 24.8
Hadar	149 27.1	S60 15.5
Hamal	328 31.5	N23 21.3
Kaus Aust.	84 20.6	S34 23.7
Kochab	137 19.9	N74 14.8
Markab	14 05.7	N15 05.0
Menkar	314 43.5	N 4 00.0
Menkent	148 40.1	S36 15.3
Miaplacidus	221 44.7	S69 37.2
Mirfak	309 19.2	N49 46.9
Nunki	76 32.7	S26 19.5
Peacock	54 02.9	S56 48.6
Pollux	244 00.9	N28 04.8
Procyon	245 28.1	N 5 16.9
Rasalhague	96 32.3	N12 34.7
Regulus	208 12.5	N12 04.6
Rigel	281 38.1	S 8 13.8
Rigil Kent.	140 29.5	S60 44.1
Sabik	102 44.3	S15 41.7
Schedar	350 11.7	N56 25.0
Shaula	96 59.6	S37 05.1
Sirius	258 57.6	S16 41.2
Spica	159 00.3	S11 02.4
Suhail	223 12.2	S43 20.3
Vega	80 58.0	N38 45.9
Zuben'ubi	137 36.0	S15 56.7

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	40 02.5	15 10
Mars	96 32.1	11 23
Jupiter	310 06.7	21 05
Saturn	221 01.5	3 05

1976 DECEMBER 23, 24, 25 (THURS., FRI., SAT.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
23 00	180 15.1	S23 26.0	153 27.9	7.4	S15 45.4	7.0	59.1
01	195 14.8	26.0	167 54.3	7.5	15 38.4	7.0	59.1
02	210 14.5	26.0	182 20.8	7.6	15 31.4	7.2	59.1
03	225 14.1	·· 25.9	196 47.4	7.7	15 24.2	7.2	59.0
04	240 13.8	25.9	211 14.1	7.8	15 17.0	7.3	59.0
05	255 13.5	25.9	225 40.9	7.8	15 09.7	7.4	59.0
06	270 13.2	S23 25.8	240 07.7	8.0	S15 02.3	7.5	58.9
07	285 12.9	25.8	254 34.7	8.0	14 54.8	7.6	58.9
T 08	300 12.6	25.8	269 01.7	8.1	14 47.2	7.6	58.9
H 09	315 12.3	·· 25.7	283 28.8	8.2	14 39.6	7.7	58.8
U 10	330 12.0	25.7	297 56.0	8.3	14 31.9	7.8	58.8
R 11	345 11.6	25.7	312 23.3	8.3	14 24.1	7.9	58.7
S 12	0 11.3	S23 25.6	326 50.6	8.5	S14 16.2	8.0	58.7
D 13	15 11.0	25.6	341 18.1	8.5	14 08.2	8.0	58.7
A 14	30 10.7	25.6	355 45.6	8.7	14 00.2	8.1	58.6
Y 15	45 10.4	·· 25.5	10 13.3	8.7	13 52.1	8.1	58.6
16	60 10.1	25.5	24 41.0	8.8	13 44.0	8.3	58.6
17	75 09.8	25.5	39 08.8	8.9	13 35.7	8.3	58.5
18	90 09.5	S23 25.4	53 36.7	8.9	S13 27.4	8.4	58.5
19	105 09.2	25.4	68 04.6	9.1	13 19.0	8.4	58.5
20	120 08.8	25.3	82 32.7	9.2	13 10.6	8.5	58.4
21	135 08.5	·· 25.3	97 00.9	9.2	13 02.1	8.6	58.4
22	150 08.2	25.3	111 29.1	9.3	12 53.5	8.6	58.3
23	165 07.9	25.2	125 57.4	9.4	12 44.9	8.7	58.3
24 00	180 07.6	S23 25.2	140 25.8	9.5	S12 36.2	8.7	58.3
01	195 07.3	25.1	154 54.3	9.6	12 27.5	8.8	58.2
02	210 07.0	25.1	169 22.9	9.6	12 18.7	8.9	58.2
03	225 06.7	·· 25.0	183 51.5	9.8	12 09.8	8.9	58.2
04	240 06.3	25.0	198 20.3	9.8	12 00.9	9.0	58.1
05	255 06.0	24.9	212 49.1	9.9	11 51.9	9.0	58.1
06	270 05.7	S23 24.9	227 18.0	10.0	S11 42.9	9.1	58.0
07	285 05.4	24.8	241 47.0	10.1	11 33.8	9.1	58.0
08	300 05.1	24.8	256 16.1	10.2	11 24.7	9.2	58.0
F 09	315 04.8	·· 24.7	270 45.3	10.2	11 15.5	9.2	57.9
R 10	330 04.5	24.7	285 14.5	10.3	11 06.3	9.3	57.9
I 11	345 04.2	24.6	299 43.8	10.4	10 57.0	9.3	57.8
D 12	0 03.9	S23 24.6	314 13.2	10.5	S10 47.7	9.3	57.8
A 13	15 03.5	24.5	328 42.7	10.6	10 38.4	9.5	57.8
Y 14	30 03.2	24.5	343 12.3	10.6	10 28.9	9.4	57.7
15	45 02.9	·· 24.4	357 41.9	10.7	10 19.5	9.5	57.7
16	60 02.6	24.4	12 11.6	10.8	10 10.0	9.5	57.7
17	75 02.3	24.3	26 41.4	10.9	10 00.5	9.6	57.6
18	90 02.0	S23 24.2	41 11.3	11.0	S 9 50.9	9.6	57.6
19	105 01.7	24.2	55 41.3	11.0	9 41.3	9.7	57.5
20	120 01.4	24.1	70 11.3	11.1	9 31.6	9.6	57.5
21	135 01.0	·· 24.1	84 41.4	11.2	9 22.0	9.8	57.5
22	150 00.7	24.0	99 11.6	11.2	9 12.2	9.7	57.4
23	165 00.4	23.9	113 41.8	11.4	9 02.5	9.8	57.4
25 00	180 00.1	S23 23.9	128 12.2	11.4	S 8 52.7	9.8	57.4
01	194 59.8	23.8	142 42.6	11.5	8 42.9	9.9	57.3
02	209 59.5	23.7	157 13.1	11.5	8 33.0	9.8	57.3
03	224 59.2	·· 23.7	171 43.6	11.6	8 23.2	9.9	57.2
04	239 58.9	23.6	186 14.2	11.7	8 13.3	10.0	57.2
05	254 58.6	23.5	200 44.9	11.8	8 03.3	9.9	57.2
06	269 58 2	S23 23.5	215 15.7	11.8	S 7 53.4	10.0	57.1
07	284 57.9	23.4	229 46.5	11.9	7 43.4	10.0	57.1
S 08	299 57.6	23.3	244 17.4	12.0	7 33.4	10.1	57.1
A 09	314 57.3	·· 23.3	258 48.4	12.0	7 23.3	10.0	57.0
T 10	329 57.0	23.2	273 19.4	12.1	7 13.3	10.1	57.0
U 11	344 56.7	23.1	287 50.5	12.1	7 03.2	10.1	56.9
R 12	359 56.4	S23 23.0	302 21.6	12.3	S 6 53.1	10.1	56.9
D 13	14 56.1	23.0	316 52.9	12.3	6 43.0	10.2	56.9
A 14	29 55.8	22.9	331 24.2	12.3	6 32.8	10.1	56.8
Y 15	44 55.5	·· 22.8	345 55.5	12.4	6 22.7	10.2	56.8
16	59 55.1	22.7	0 26.9	12.5	6 12.5	10.2	56.8
17	74 54.8	22.7	14 58.4	12.5	6 02.3	10.2	56.7
18	89 54.5	S23 22.6	29 29.9	12.6	S 5 52.1	10.2	56.7
19	104 54.2	22.5	44 01.5	12.7	5 41.9	10.2	56.7
20	119 53.9	22.4	58 33.2	12.7	5 31.7	10.3	56.6
21	134 53.6	·· 22.3	73 04.9	12.8	5 21.4	10.2	56.6
22	149 53.3	22.3	87 36.7	12.8	5 11.2	10.3	56.6
23	164 53.0	22.2	102 08.5	12.9	5 00.9	10.3	56.5
	S.D. 16.3	d 0.1	S.D. 16.0		15.8		15.5

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 23	Moonrise 24	Moonrise 25	Moonrise 26
°	h m	h m	h m	h m	h m	h m	h m
N 72	08 27	10 58	▬	11 42	11 29	11 20	11 12
N 70	08 07	09 55	▬	11 12	11 11	11 10	11 08
68	07 51	09 20	▬	10 50	10 57	11 01	11 04
66	07 38	08 55	10 35	10 33	10 46	10 54	11 01
64	07 27	08 35	09 53	10 19	10 36	10 49	10 59
62	07 17	08 19	09 25	10 07	10 27	10 43	10 57
60	07 09	08 05	09 03	09 56	10 20	10 39	10 55
N 58	07 01	07 54	08 46	09 47	10 14	10 35	10 53
56	06 54	07 43	08 31	09 39	10 08	10 31	10 52
54	06 48	07 34	08 18	09 32	10 03	10 28	10 51
52	06 43	07 26	08 07	09 26	09 58	10 25	10 49
50	06 37	07 19	07 57	09 20	09 54	10 23	10 48
45	06 25	07 03	07 36	09 08	09 45	10 17	10 46
N 40	06 15	06 49	07 20	08 58	09 37	10 12	10 44
35	06 06	06 37	07 06	08 49	09 31	10 08	10 42
30	05 57	06 27	06 53	08 41	09 25	10 04	10 41
20	05 40	06 08	06 32	08 27	09 15	09 58	10 38
N 10	05 24	05 50	06 13	08 16	09 06	09 52	10 36
0	05 07	05 33	05 56	08 05	08 57	09 47	10 33
S 10	04 48	05 15	05 38	07 54	08 49	09 41	10 31
20	04 26	04 55	05 19	07 42	08 40	09 36	10 29
30	03 56	04 30	04 57	07 28	08 30	09 29	10 26
35	03 38	04 15	04 44	07 20	08 24	09 26	10 25
40	03 15	03 56	04 29	07 11	08 17	09 21	10 23
45	02 44	03 34	04 11	07 01	08 10	09 16	10 21
S 50	01 58	03 04	03 49	06 48	08 00	09 10	10 18
52	01 31	02 49	03 38	06 42	07 56	09 08	10 17
54	00 44	02 31	03 25	06 36	07 51	09 05	10 16
56	////	02 09	03 11	06 28	07 46	09 01	10 15
58	////	01 39	02 54	06 20	07 40	08 58	10 13
S 60	////	00 49	02 34	06 10	07 33	08 54	10 12

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 23	Moonset 24	Moonset 25	Moonset 26
°	h m	h m	h m	h m	h m	h m	h m
N 72	▬	13 02	15 33	17 09	19 09	20 59	22 42
N 70	▬	14 04	15 53	17 37	19 25	21 07	22 43
68	▬	14 39	16 08	17 58	19 38	21 13	22 45
66	13 24	15 05	16 22	18 15	19 49	21 19	22 46
64	14 06	15 24	16 33	18 28	19 57	21 24	22 46
62	14 35	15 40	16 42	18 39	20 05	21 27	22 47
60	14 56	15 54	16 51	18 49	20 11	21 31	22 48
N 58	15 14	16 06	16 58	18 57	20 17	21 34	22 48
56	15 29	16 16	17 05	19 05	20 22	21 37	22 49
54	15 41	16 25	17 11	19 11	20 26	21 39	22 49
52	15 52	16 33	17 17	19 17	20 30	21 41	22 50
50	16 02	16 41	17 22	19 22	20 34	21 43	22 50
45	16 23	16 57	17 34	19 34	20 42	21 47	22 51
N 40	16 40	17 10	17 44	19 43	20 48	21 51	22 52
35	16 54	17 22	17 54	19 51	20 54	21 54	22 52
30	17 06	17 33	18 03	19 58	20 59	21 57	22 53
20	17 27	17 52	18 19	20 10	21 07	22 02	22 54
N 10	17 46	18 09	18 35	20 21	21 15	22 06	22 54
0	18 03	18 26	18 52	20 30	21 21	22 09	22 55
S 10	18 21	18 44	19 11	20 40	21 28	22 13	22 56
20	18 40	19 05	19 34	20 50	21 35	22 17	22 56
30	19 02	19 30	20 03	21 02	21 44	22 22	22 57
35	19 15	19 45	20 22	21 09	21 48	22 24	22 57
40	19 30	20 03	20 45	21 16	21 54	22 27	22 58
45	19 48	20 26	21 15	21 25	22 00	22 30	22 58
S 50	20 11	20 55	22 01	21 36	22 07	22 34	22 59
52	20 22	21 10	22 28	21 41	22 10	22 36	22 59
54	20 34	21 28	23 15	21 46	22 14	22 38	23 00
56	20 48	21 50	////	21 52	22 18	22 40	23 00
58	21 05	22 20	////	21 59	22 23	22 43	23 00
S 60	21 25	23 10	////	22 06	22 28	22 45	23 01

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
23	01 01	00 46	11 59	14 18	01 50	02	
24	00 31	00 16	12 00	15 10	02 44	03	◑
25	00 01	00 14	12 00	15 58	03 34	04	

DEVIATION CARD No. 3			DEVIATION CARD No. 4		
Ship's Head by Compass	Deviation	Ship's Head Magnetic	Ship's Head Magnetic	Deviation	Ship's Head by Compass
000°C	2·0°W	358·0°M	000°M	2·4°W	002·4°C
010	3·5 W	006·5	010	4·4 W	014·4
020	5·5 W	014·5	020	6·4 W	026·4
030	7·0 W	023·0	030	8·8 W	038·8
040	9·0 W	031·0	040	10·3 W	050·3
050	10·3 W	039·7	050	11·4 W	061·4
060	11·5 W	048·5	060	12·3 W	072·3
070	12·2 W	057·8	070	12·6 W	082·6
080	12·6 W	067·4	080	12·3 W	092·3
090	12·5 W	077·5	090	11·4 W	101·4
100	11·6 W	088·4	100	10·5 W	110·5
110	10·5 W	099·5	110	9·0 W	119·0
120	9·0 W	111·0	120	7·5 W	127·5
130	7·0 W	123·0	130	6·0 W	136·0
140	5·0 W	135·0	140	4·2 W	144·2
150	3·0 W	147·0	150	2·5 W	152·5
160	1·0 W	159·0	160	0·9 W	160·9
170	0·5 E	170·5	170	0·5 E	169·5
180	2·0 E	182·0	180	1·7 E	178·3
190	3·5 E	193·5	190	3·1 E	186·9
200	5·1 E	205·1	200	4·5 E	195·5
210	6·8 E	216·8	210	5·8 E	204·2
220	8·5 E	228·5	220	7·2 E	212·8
230	10·0 E	240·0	230	8·7 E	221·3
240	11·0 E	251·0	240	10·0 E	230·0
250	12·0 E	262·0	250	10·9 E	239·1
260	12·8 E	272·8	260	11·8 E	248·2
270	12·5 E	282·5	270	12·6 E	257·4
280	11·5 E	291·5	280	12·4 E	267·6
290	10·0 E	300·0	290	11·7 E	278·3
300	8·2 E	308·2	300	10.0 E	290·0
310	6·5 E	316·5	310	7·9 E	302·1
320	4·5 E	324·5	320	5·7 E	314·3
330	2·5 E	332·5	330	3·3 E	326·7
340	1·0 E	341·0	340	1·2 E	338·8
350	0·5 W	349·5	350	0·5 W	350·5
360	2·0 W	358·0	360	2·4 W	002·4

Past Papers
Suitable for Class 4—Class 1
Examination Candidates

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Principles of Navigation 807

Chartwork 810

Compass Work 811

Mathematics 812

Use Nautical Almanac Extracts on page 880.

Practical Navigation

Paper 1

1. From the following data find the direction of the position line and a position through which it passes:

   Date 19 September, GMT 07 h 20 m 26 s. D.R. 33° 58′ S, 38° 03′ W. Star Canopus (17) Obs. Alt. 63° 54′. H.E. 10·5 m.

2. From the following particulars of an observation of the Sun's lower limb, near the meridian, required the direction of the position line and the Latitude in which it crosses the D.R. Longitude:

   Date at ship 12 January. D.R. position 47° 40′ N, 179° 45′ E. Sext. Alt. 20° 23′. I.E. Nil. H.E. 11 m. Chronometer time 23 h 43 m 26 s. Error 10 m 12 s slow on GMT.

3. January 7, in Longitude 17° 25′ W, the sextant altitude of the Pole star was 52° 10′, I.E. 2′ on the arc. Time by chronometer 17 h 42 m 00 s which was 5 m 13 s slow on GMT. H.E. 6·5 m. Find the Latitude.

4. Find by Mercator Sailing, the True Course and Distance from a position off Cape Leewin—34° 22′ S, 115° 08′ E, to Dondra Head (Sri Lanka) 5° 55½′ N, 80° 35½′ E.

5. At about 0930 in D.R. Latitude 48° 50′ N the Longitude calculated from an observation of the Sun bearing 148° C, was 17° 12′ W. Variation 10° W, Deviation 2° E.

   At noon the ship having made good 24 miles on course 210° T since 0930, the Latitude by meridian altitude was found to be 48° 27′ N. Find the ship's position at noon.

Paper 2

1. Calculate the True Course and Distance by Mercator Sailing from 15° 55′ S, 9° 20′ W, to 7° 17′ N, 32° 18′ W.

2. January 9, at ship in D.R. 41° 20′ N, 39° 50′ W, the Sun was observed to rise bearing 126° C. Chronometer 9 d 10 h 05 m 26 s. Chron. error 5 m 00 s slow on GMT. Find the true amplitude, and the deviation for the ship's head. Variation 26·3° W.

3. September 19, in D.R. 39° 04′ N, 133° 40′ W, the observed altitude of the Sun's L.L. near the meridian was 51° 55′. H.E. 8 m. Chronometer 20 h 29 m 47 s. Chron. error 1 m 20 s slow on GMT. Find the P/L and the Latitude in which it crosses the D.R. Longitude.

4. The sextant meridian altitude of the star Al Na'ir (55) on June 16 was 78° 17′ South of the observer. H.E. 6·5 m. I.E. 1·5′ on the arc. Find the Latitude.

5. June 15, in D.R. 36° 28′ S, 162° 53′ W, the sextant altitude of the star Antares West of the meridian was 41° 18′. I.E. 1′ off the arc. H.E. 8·8 m. Chronometer 13 h 27 m 40 s which was 4 m 20 s slow on GMT. Find the P/L and a position through which it passes.

6. Following the position line observation in question 5, the ship steamed 56 miles on a course 034° T, until the Latitude by meridian altitude of a star was found to be 35° 43·5′ S. Find the ship's position by combining the two position lines.

Paper 3

1. (a) At 1200, ship's position by observation 42° 12′ S, 178° 40′ W. Course 243° C. Deviation 5° W. Variation 17° E. Speed 12·5 knots.
   (b) 0400, altered course 245° C. Deviation 5° W. Variation 17° E. Speed 12·5 knots.
   (c) Current set 053° T, 1 knot throughout the day. Find the course and distance made good from 1200 to 1200, also the position reached.

2. January 7, in Longitude 46° 30′ W, the sextant meridian altitude of the Sun's L.L. was 23° 10·5′, the observer being to the Northward of the Sun, I.E. 3·5′ on the arc. H.E. 7·5 m. Find the Latitude.

3. June 20, in D.R. 41° 31′ S, 154° 16′ E. Sextant altitude of the Sun's L.L. near the meridian 24° 39′. I.E. 1·2′ on the arc. H.E. 8·7 m. Time by chronometer 02 h 09 m 22 s. Error 1 m 10 s fast on GMT. Find the Latitude in which the P/L crosses the D.R. Longitude.

4. January 11, in D.R. 36° 41′ N, 175° 00′ W. Sextant altitude of the Sun's L.L. was 20° 19′. I.E. 0·4′ off the arc. H.E. 6·8 m. GMT 11 d 21 h 07 m 51 s. Find the direction of the P/L and the position through which it passes.

5. Following the observation in question 4 the ship sailed 295° T, 30 miles until 1200 when the meridian altitude of the Sun gave Latitude 36° 59′ N. Find the ship's position.

Paper 4

1. Find the True Course and Distance from position 52° 10′ S, 68° 12′ W, to Montevideo, 34° 53′ S, 56° 15′ W by Mercator Sailing. Variation 25° E. Deviation 6° E. Find the initial course to steer by compass.

2. September 23, in D.R. 19° 42′ S, 110° 45′ W. Chronometer 13 h 08 m 00 s which was 2 m 50 s slow on GMT. The Sun rose bearing 073° C. Variation 12° E. Find the true amplitude and compass error.

3. June 26, about 1225 hours at ship in D.R. 39° 30′ S, 100° 13′ W. Observed altitude of the Sun's L.L. (near the meridian) was 26° 44′. Chronometer 19 h 19 m 00 s. Error 7 m 25 s fast on GMT. H.E. 13·5 m. Find the Latitude and the position line.

4. June 16, in D.R. 11° 38′ N, 154° 00′ W. Sextant altitude of the star Vega, West of the meridian, was 24° 20′, I.E. 1·2′ off the arc. H.E. 15·5 m. Chronometer 15 h 46 m 10 s. Error 0 m 18 s slow on GMT. Find the position line and a position through which it passes.

5. Position by D.R. 41° 05′ S, 27° 30′ W. An observation of the Sun gave bearing 040° T, intercept 4·7′ towards. Ship then steamed 080° T, 42 miles. Find the D.R. position for the transferred position line.

   A second observation of the Sun gave bearing 330° T, intercept 7·9′ away. Find the Observed Position by plotting or by Traverse Table Inspection.

Paper 5

1. A ship left position 49° 58′ N, 5° 12′ W, and reached position in Longitude 25° 08′ W, after making good a course of 229° 37½′ T. Find the Latitude reached by Mercator Sailing and the distance sailed.

2. June 15, in 41° 31′ S, 16° 32′ E, at 16 h 40 m 00 s GMT the star Sirius bore 293° C. Variation 31° W. Find the True Azimuth, Compass Error and Deviation.

3. January 7, in D.R. 36° 42′ N, 42° 45′ W, the observed altitude of the Sun's L.L. near the meridian was 30° 17′. H.E. 6·8 m. Time by chronometer 15 h 26 m 08 s which was 1 m 00 s slow on GMT. Find the Latitude for the P/L to be drawn through the D.R. Longitude.

4. June 21, in Longitude 171° 50′ E. Sextant meridian altitude of the Sun's L.L. 55° 04′, bearing North. I.E. 3′ off the arc. H.E. 11·2 m. Find the Latitude.

5. September 21, Latitude at noon by observation 45° 41′ S, ship then sailed 085° T, 46 miles by log, the sextant altitude of the Sun's L.L. was then 17° 28·5′. I.E. 2′ off the arc. H.E. 8 m. GMT 21 d 17 h 54 m 50 s. Find the Longitude and the P/L.

6. Following the observation in question 5 the ship sailed 180° T, 35 miles and the meridian altitude of a star gave Latitude 46° 04′ S. Find the ship's position.

Paper 6

1. Find the True Course and Distance from Malta 35° 53′ N, 14° 31′ E to Port Said, 31° 16′ N, 32° 19′ E.

2. At 1200 Lobos Island 35° 02′ S, 54° 53′ W bore 270° C distant 8 miles. Course 096° C. Deviation 2° E. Variation 5° E. Log set at 0.

   2400, course 096° C. Deviation 2° E. Variation 4° E Log 126.
   1200 Log 246. Current set 180° T 11 miles during the day.

   Find the course and distance made good from 1200 to 1200 and the position reached.

3. December 26, in D.R. 46° 37′ N, 179° 30′ E, the sextant altitude of the Sun's upper limb near the meridian was 19° 54′ South of the observer. I.E. 1·2′ on the arc. H.E. 7·8 m. Chronometer (December 25) 23 h 43 m 10 s was 16 m 40 s fast on GMT. Find the Latitude in which the position line crosses the D.R. Longitude.

4. September 20, at GMT 19 d 14 h 59 m 03 s in Longitude 152° 30′ E, the observed altitude of Polaris was 36° 44′. H.E. 11·5 m. Find the Latitude.

5. June 25, at GMT 26 d 08 h 17 m 42 s the D.R. position was 13° 28′ N, 127° 15′ W. Observed altitude Altair 64° 04′, East of the meridian. H.E. 15·5 m. Find the P/L and a position through which it passes.

6. June 20 in D.R. 62° 23′ N, 20° 00′ W. Find the sextant meridian altitude of the star Deneb below the pole. I.E. 2′ on the arc. H.E. 7·3 m.

Paper 7

1. January 4, in position 58° 25′ N, 2° 51′ E. GMT 14 h 57 m 35 s. Sun bearing 230° C. Find the Compass Error and Deviation. Variation 7·5° W.

2. January 12, in D.R. position 49° 04′ N, 7° 32′ W, the Sextant Altitude of the Sun's L.L. on the meridian was 19° 02·5′. H.E. 5·7 m. I.E. 0·5′ off the arc. Find the Latitude.

3. September 19, in E.P. 58° 30′ N, 2° 57′ W, when the correct GMT was 11 h 50 m 16 s, the Sextant Altitude of the Sun's L.L. near the meridian was 32° 49·6′. H.E. 6 m. I.E. 2·2′ off the arc. Find the direction of the P/L and the Latitude in which it crosses the estimated Longitude.

4. January 12, in D.R. 46° 15′ N, 9° 13′ W, when the correct GMT was 09 h 28 m 04 s, the Sextant Altitude of the Sun's lower limb, East of the meridian, was 8° 35′. H.E. 9·5 m. I.E. 2·2′ off the arc. Find the direction of the P/L and a position through which it passes.

Paper 8

1. September 20, in D.R. position 49° 10′ N, 42° 16′ W, time by a chronometer 19 h 04 m 02 s, which was correct GMT, the Sun bore 280° C. Find the true azimuth, and the deviation of the compass for the direction of the ship's head. Variation 32·5° W.

2. September 27, the Sextant meridian altitude of the Sun's U.L. was 37° 47′ bearing South of observer. I.E. 2′ on the arc. H.E. 8·7 m. D.R. 51° 03′ N, 2° 50′ E. Find the Latitude.

3. October 10, in D.R. 52° 50′ N, 10° 06′ W, at GMT 12 h 12 m 06 s, the Sextant Altitude of the Sun's L.L. near the meridian was 30° 24′. I.E. 1·3′ off the arc. H.E. 7·8 m. Find the P/L and the Latitude it crosses the D.R. Longitude.

4. September 21, in D.R. 50° 15′ N, 6° 38′ E, at GMT 08 h 36 m 12 s, the Sextant Altitude of the Sun's L.L. East of the meridian was 28° 47′. I.E. 1′ off the arc. H.E. 12 m. Find the P/L and a position through which it passes.

Paper 9

1. December 24, in D.R. 49° 30′ N, 45° 00′ W, when the correct GMT was 13 h 07 m 30 s, the Sun bore 182° C. Find the true bearing of the Sun, and thence the Compass Error and Deviation. Variation 35° W.

2. January 7, in D.R. 56° 22′ N, 10° 30′ E, the Sextant Altitude of the Sun's L.L. on the meridian was 11° 06′, I.E. 3′ off the arc. H.E. 6·3 m. Find the Latitude.

3. January 12, in D.R. 51° 30′ N, 7° 18′ W, at 12 h 10 m 18 s GMT the Observed Altitude of the Sun's L.L. near the meridian was 16° 21′. H.E. 6·2 m. Find the P/L and the Latitude in which it crosses the D.R. Longitude.

4. September 27, in D.R. 53° 20′ N, 8° 30′ E, when the correct GMT was 14 h 46 m 53 s, the Sextant Altitude of the Sun's L.L. West of the meridian was 19° 46′. I.E. 1·4′ off the arc. H.E. 10·5 m. Find the position line and a position through which to draw it.

Paper 10

1. January 7, in D.R. 56° 06′ N, 10° 15′ E, when the correct GMT was 13 h 35 m 00 s, the Sun bore 225° C. Find the true azimuth and thence the Compass Error and Deviation. Variation 12° W.

2. June 15, in Longitude 84° W, the Observed meridian altitude of the Sun's L.L. was 73° 30′, North of observer. H.E. 7 m. Find the Latitude.

3. September 23, in D.R. 55° 40′ N, 7° 32′ W, at GMT 12 h 45 m 02 s, the Sextant Altitude of the Sun's L.L. near the meridian was 33° 54′. I.E. 1·2′ on the arc. H.E. 6·2 m. Find the P/L and the Latitude it crosses the D.R. Longitude.

4. June 17, in D.R. position 56° 20′ N, 1° 48′ W, when correct GMT was 16 h 02 m 43 s, the Observed Altitude of the Sun's L.L. was 36° 21′. H.E. 6 m. Find the P/L and a position through which it passes.

Paper 11

1. June 16, in D.R. 30° 58′ N, 48° 15′ W, when the correct GMT was 11 h 08 m 40 s the Sun bore 102° C. Find the true azimuth and thence the Compass Error and Deviation. Variation 16° W.

2. December 21, in D.R. 53° 05′ N, 5° 18′ W, the Sextant meridian altitude of the Sun's L.L. was 13° 18′. I.E. 1′ off the arc. H.E. 10·5 m. Find the Latitude.

3. September 22, in E.P. 58° 22′ N, 5° 50′ W, when the correct GMT was 12 h 01 m 42 s, the Sextant Altitude of the Sun's U.L. near the meridian was 32° 21′. I.E. 1′ on the arc. H.E. 12 m. Find the direction of the P/L and the Latitude it crosses the estimated Longitude.

4. October 11, in D.R. 48° 12′ N, 18° 20′ W, when the GMT was 09 h 03 m 07 s, the Sextant Altitude of the Sun's L.L. was 14° 11′. I.E. 1·3′ off the arc. H.E. 7·5 m. Find the P/L and a position through which to draw it.

Paper 12

1. June 4, in position 57° 55′ N, 6° 20′ W, when the correct GMT was 17 h 32 m 00 s, the planet Venus bore 236° C. Find the Compass Error and Deviation. Variation 12° W.

2. Find the GMT (to the nearest minute) when the star Spica will be on the observer's meridian on June 15 in position 53° 16′ N, 4° 10′ E.

3. December 28, in D.R. 55° 40′ N, 7° 23′ W, when the correct GMT was 16 h 15 m 31 s, the Sextant Altitude of the Pole Star was 56° 15′. H.E. 9·5 m. I.E. 2·5′ off the arc. Find the Latitude.

4. January 6, in D.R. 50° 03′ N, 2° 30′ W, when the correct GMT was 21 h 53 m 10 s, the Sextant Altitude of the Moon's L.L. was 36° 07·8′, East of the meridian. H.E. 8 m. I.E. 2′ on the arc. Find the direction of the P/L and a position through which it passes.

5. How would you identify the star Regulus with reference to the constellations?

Paper 13

1. September 24, in D.R. 56° 06′ N, 6° 20′ E, when the correct GMT was 2 h 02 m 30 s, the star Aldebaran bore 145° C. Find the Compass Error and Deviation. Variation 9° W.

2. Find the GMT (to the nearest minute) that the star Regulus will be on the meridian of an observer in position 51° 40′ N, 9° 18′ E, on January 11.

3. December 24, in D.R. 39° 08′ N, 149° 30′ W, when the correct GMT was 15 h 17 m 40 s, the Sextant Altitude of the Pole Star was 38° 20′. H.E. 7·8 m. I.E. 1·5′ off the arc. Find the Latitude.

4. January 11, in D.R. 51° 40′ N, 9° 18′ W, when the correct GMT was 07 h 21 m 10 s, the Sextant Altitude of the star Regulus, West of the meridian was 28° 18′. H.E. 7·9 m. I.E. 1·6′ on the arc. Find the direction of the P/L and a position through which it passes.

5. How would you identify the star Spica with reference to the constellations?

Paper 14

1. January 9, in D.R. 50° 32′ N, 5° 36′ W, the star Denebola bore 129° C, GMT 01 h 34 m 30 s. Find the Compass Error and Deviation. Variation 14° W.

2. Find the GMT (to the nearest minute) that the star Capella will be on the observer's meridian in position 56° 12′ N, 10° 45′ E, on January 12.

3. January 10, in D.R. 36° 00′ N, 20° 40′ E. GMT 9 d 22 h 58 m 20 s. Observed Altitude Pole Star 36° 14′. H.E. 4·2 m. Find the Latitude.

4. June 15, GMT 02 h 07 m 40 s, in D.R. position 48° 12′ N, 18° 20′ W, the Observed Altitude of the star Arcturus, West of the meridian was 32° 23′. H.E. 5·5 m. Find the P/L and a position through which it passes.

5. How would you identify the star Capella with reference to the constellations?

Paper 15

1. January 12, in D.R. 46° 20′ N, 9° 13′ W, the correct GMT being 09 h 28 m 00 s, the observed azimuth of the Sun was 146° C. Find the Compass Error and Deviation. Variation 13° W.

2. Find the GMT (to the nearest minute) when the star Arcturus will be on the meridian of a position 48° 12′ N, 18° 20′ W on June 16.

3. January 4, in D.R. 57° 10′ N, 7° 16′ E, the correct GMT was 06 h 17 m 42 s. Sextant Altitude of the Pole Star was 49° 23′. H.E. 6·2 m. I.E. 2′ off the arc. Find the Latitude.

4. January 12, in D.R. 56° 12′ N, 10° 45′ E, when the correct GMT was 23 h 26 m 06 s, the Sextant Altitude of the star Capella was 65° 39·5′, West of the meridian. H.E. 9 m. I.E. 1·2′ off the arc. Find the direction of the P/L and a position through which it passes.

5. How would you identify the star Arcturus with reference to the constellations?

Paper 16

1. January 10, in D.R. 59° 30′ N, 4° 15′ W, when the correct GMT was 18 h 12 m 30 s, the planet Venus bore 249° C. Find the Compass Error and Deviation. Variation 14° W.

2. Find the GMT (to the nearest minute) when the star Rigel will be on the meridian of a position 53° 20′ N, 8° 30′ E on December 27.

3. June 18, in D.R. 51° 43′ N, 9° 18′ W. GMT 22 h 31 m 16 s. Sextant Altitude of the Pole Star 50° 59′. H.E. 6 m. I.E. 1·5′ off the arc. Find the Latitude.

4. December 27, in D.R. 53° 20′ N, 8° 30′ E, the correct GMT being 19 h 33 m 02 s, the Sextant Altitude of the star Rigel, East of the meridian, was 19° 41′. H.E. 6·5 m. I.E. 1·4′ on the arc. Find the direction of the P/L and a position through which it passes.

5. How would you identify the star Rigel with reference to the constellations?

Principles of Navigation

Paper 1 *Answer any 5 questions* *2 hours*

1. Two ships in Lat. 42° 00′ N are 480 miles apart and are steaming due South at the same speed. How many miles will they be apart in Lat. 32° 00′ N?

2. From 1200 a ship steers a Compass Course to make good 315 T at 15 knots. At 1600 it was discovered that the compass error of 9° W had been allowed the wrong. How far was the ship from the expected 1600 D.R. position? Use traverse tables.

3. Explain clearly why the most favourable time for determining the hour angle of a celestial body and thence the Longitude, is when the body is on the prime vertical.

4. What is a circumpolar star? What is the limiting declination for stars which are circumpolar in Lat. 60° 00′ N?

5. Define the following astronomical terms:
   apogee, perigee, conjunction, quadrature, opposition.

6. Why is it necessary to apply a correction for semi-diameter to an observed altitude of the Sun or the Moon? Explain clearly why the semi-diameter is augmented in the case of the Moon.

Paper 2

1. The chronometers are being rated by radio time signal. Chronometer A is 8 m 20 s slow of B, and B is 20 m 12 s fast of C. If C is 15 m 25 s slow of GMT find A's error on GMT.

2. A beacon, 45 feet high, subtends a vertical sextant angle of 1° 10′. After steering 3 cables it was observed to be abeam. What vertical angle would it subtend after steaming a further $2\frac{1}{2}$ cables on the same course?

3. Explain clearly what is meant by the obliquity of the Ecliptic. If the Right Ascension of the Apparent Sun was 09 h 53 m 26 s, what would be its Declination?

4. Define and illustrate, the terms Declination and Polar Distance. Give the dates when the Sun's declination is at maximum and zero values.

5. What is refraction? When is its effect greatest and when least?

6. What is meant by the geographical position of a celestial body? A ship is in position 40° 00′ N, 40° 00′ W, Declination Sun is 10° N, and L.H.A. Sun 30°. Give the Sun's geographical position, also that of a star whose declination is 20° S, and L.H.A. 337° 30′.

7. Describe the various methods of finding the deviation of the compass.

Paper 3

1. Two ships are 28 miles apart in Lat. 44° S, both steer 000° T keeping due East and West of each other until they are 37 miles apart. How far have they sailed?

2. Given L.H.A. Star 290° 07′, Declination 12° 18′ S, Latitude 28′ 21′ N. Find the true azimuth of the star.

3. By Mercator Sailing, the course from Cape of Good Hope to Cape Horn is 250° T. The variation at the Cape is 27° W. Deviation 12° E.
   Find the initial course to steer. If the ship were kept on the same Compass Course would she reach Cape Horn and if not, why not?

4. What is the Equation of Time and what is it used for?

5. Find by Traverse Tables, the course and distance from *A*, 34° 30′ N, 147° 18′ E, to *B*, 36° 56′ N, 145° 12′ E.

6. Explain and illustrate the terms:
   Spring Rise, Neap Rise, Spring Range, Neap Range.

7. List and explain the corrections to be applied to the Sextant Altitude of the Sun.

Paper 4

1. Given Latitude 46° 24′ N, Zenith Distance 75° 30·1′, Azimuth 209·8° T, calculate the Declination of the body.

2. The time by chronometer was July 1 d 18 h 02 m 30 s, which was 1 m 10 s fast for Mean noon at Greenwich on February 29, and 1 m 54 s fast on April 24. Find the GMT.
   For how long does a two day chronometer run? When should it be wound and what precautions should be taken when winding it?

3. A vessel sailed from 17° 11′ N to 16° 10′ N and changed her Longitude by 7° 13′ W. Find the distance sailed.

4. Distinguish clearly between a Sidereal Day, a Solar Day and a Lunar Day.

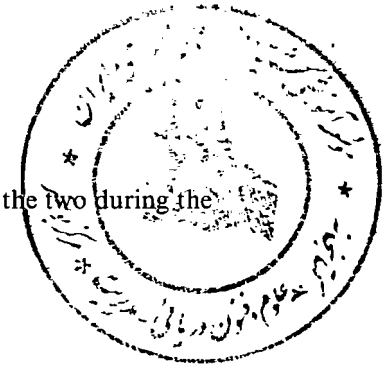
5. Name the Circles which separate the Frigid, Temperate and Torrid Zones and give their Latitudes.

6. Describe an Azimuth Mirror and a Pelorus. What are they used for?

7. What is a Position Line? Explain how a Celestial Position Line is obtained.

Paper 5

1. Explain why a D.F. bearing cannot be laid off directly on a Mercator chart? Ship in D.R. 40° 40′ S, 143° 40′ E; Radio station providing QTG service in position 40° 42′ S, 144° 43′ E, D.F. bearing of ship 310° T. What is the mercatorial bearing?
2. A place is rotated by the Earth at the rate of 530 miles per hour, in what Latitude is it situated?
3. Given L.H.A. 302° Latitude 49° 10′ N. Longitude 8° 25′ W, Declination 23° 12′ N, calculate the zenith distance of the body. Azimuth is 098° T. Intercept 7′ away. Find the D.R. position for drawing in the P/L.
4. What is the cause of unequal day and night? Under what conditions will the Sun not rise above an observer's horizon?
5. Prove that $\cos \text{Latitude} = \dfrac{\text{Dep.}}{\text{D. Long.}}$.
6. Draw a figure to illustrate your explanation of the terms:
   (a) Horizontal Parallax;
   (b) Parallax in Altitude.
7. Describe the Lunar and Solar Tides and the effects of a combination of the two during the period of a lunation.



Paper 6

1. Ship *A* steaming 020° T at 12 knots sights ship *B* 24° on her starboard bow steaming in the opposite direction. In 30 minutes *B* is 4 miles abeam of *A*. Find the speed of ship *B*.
2. What is the GMT of meridian passage of star Sirius (18) on January 10, Observer's Longitude 18° 15′ E.
3. Find the vertical angle to set on a sextant for a lighthouse 208 feet high to pass 5 cables clear of a submerged rock 6 cables from the base of the lighthouse.
4. Show clearly how the sum or difference of the Meridian Zenith Distance of a Heavenly Body and its Declination is equal to the Latitude of an observer.
5. Having been given a definite scale of Latitude for a Mercator Chart, explain how you draw up a scale of Longitude.
6. Draw a figure to illustrate and prove the equation:

   L.H.A. Star = G.H.A. Aries + S.H.A. Star + East Long.

7. What is meant by:
   (a) Age of Tide;
   (b) Priming;
   (c) Lagging?

Chartwork

Paper 1 *2 hours*

Use Deviation Card No. 3 (page 798) and Variation 14½° W.

1. Find the Compass Course to steer and the distance from a position with Ballycotton Island light bearing 000° T, distant 3 miles to a position in Longitude 7° 00′ W, at a distance of 4 miles to the Southward of Hook Point light.

2. From a position with Tuskar Rock bearing 000° T, distant 7 miles a vessel steers 260° C for a log distance of 32 miles through a current setting 083° T at 0·5 knots, time elapsed 4 hours. Required the E.P. of the vessel and the true course made good.

3. With the ship's head on 125 °C. Mine Head light bore 270° C and Helwick Head bore 343° C. Find the Compass Course to steer to reach a position in 51° 55′ N, 7° 17′ W, vessel steaming 8 knots and a current setting 225° T at 1 knot. Find also the time to reach the destination.

4. Find the Height of Tide off Greenock at 0700 GMT on 17 May.

Paper 2

Variation 12° W. Deviation Card No. 3 (page 798).

1. With the ship's head 150° C, the following Relative Bearings were obtained by D.F.: Mull of Kintyre Light House 338°; Tory Island 091°. Find the position of the ship and the Compass Course to steer to pass 2 miles off Altacarry Head Light. Find also the distance to bring that light abeam.

2. Find the Compass Course to steer from a position with Inistrahull Light House bearing 130° T, distant 3 miles to a position with Dubh Artach light bearing 275° T, distant 5 miles making allowance for a current setting 330° T, at 2 knots, vessel steaming 9 knots. Find also the speed that would be made good.

3. With the ship's head 062° C, Sanda light bore 027° C and 1 h 30 m later the same light bore 281° C. Find the position of the ship assuming a current setting 087° T at 1½ knots, ship steaming at 10 knots.

4. Find the Height of Tide off Greenock at 0505 GMT on June 16.

Compass Work

Paper 1 *1½ hours*

1. From the following bearings find the magnetic bearing of the object and construct a table of deviations:

Ship's Head by Compass	*Compass Bearing of distant Object*	*Ship's Head by Compass*	*Compass Bearing of distant Object*
000° C	007° C	180° C	343° C
045° C	350° C	225° C	354° C
090° C	339° C	270° C	011° C
135° C	338° C	315° C	018° C

2. For what part of the ship's magnetism is the Flinder's bar used to compensate? On what headings of the ship will it have greatest effect? Illustrate your answer with diagrams.

3. Why is it necessary to keep electrical appliances as far removed as possible from a magnetic compass?

4. Explain simply by what principles it is possible to correct the effects of the ship's permanent magnetic field, irrespective of its direction, by means of fore and aft and thwartship magnets.

Mathematics

Paper 1 — *2 hours*

Twenty-five marks are allotted to each question and SIX questions only are to be answered

1. Plot on squared paper the points whose co-ordinates are $(-1, 3)$, $(3, 5)$, $(2, -2)$. Find the area of the triangle formed by joining these points if each unit on your graph represents 30 feet.

2. If 130 men working 8 hours a day can complete a certain contract in 21 weeks, how many men working $7\frac{1}{2}$ hours a day at the same rate will be required to complete the work in 16 weeks?

3. Find the value of $\dfrac{\text{Cos } 145° \times 0{\cdot}006}{0{\cdot}036} + 0{\cdot}1365$.

4. Two places A and B are on the same meridian and on a certain day at noon the Sun was exactly overhead at A while its zenith distance at B was $7° 36'$. Considering the earth as a sphere of circumference 24,913 miles, what is the distance between A and B?

5. In the spherical triangle ABC, D is the mid-point of BC. If $BC = 67° 30'$, $AD = 57° 15'$, $ADC = 73° 10'$, find AB.

6. AOB is the diameter of a circle whose centre is O. OC is a radius and the chord AC is drawn. If $OC = R$ and $COB = \theta$ show that $AC^2 = 2R^2 (1 + \text{Cos } \theta)$.

7. Find the weight of a metal pipe 45 feet long of external diameter 5 inches, internal diameter $4\frac{3}{4}$ inches, if one cubic foot of the metal weighs 458 lbs. ($\pi = 3{\cdot}142$.)

Paper 2

1. Draw a graph of the equation $y = x^2$ between the values $x = 0$ and $x = 6$ and use it to find the square root of 14 and of $19\frac{1}{2}$.

2. A rectangle is 3 cm longer than it is wide. If the length and breadth were both increased by 2 cm, the area would be increased by 38 square cm. Find its length and breadth.

3. Find the value of $\sqrt[3]{\cdot 0088 \times \cdot 0099}$.

4. Find the number of bales measuring $4 \text{ ft} \times 3{\cdot}5 \text{ ft} \times 2 \text{ ft}$ that could be stowed in a hold 90 ft long, 40 ft broad and 9 ft high, assuming no broken stowage.

5. A vessel steaming 159° T at 10 knots observes a lighthouse bearing 123° T, and after steaming 45 minutes it was abeam. Find the distance off when abeam; and supposing it were 246 ft high, find the vertical angle subtended by the lighthouse.

6. The outer diameter of a hollow sphere is 12 cm, the inner diameter is 10 cm. Find the volume of the shell.

7. In spherical triangle MNO, $MN = 110° 10'$, $ON = 79° 11'$, angle $N = 33° 35' 15''$. Find side MO.

Paper 3

1. In the triangle ABC, if $a = 14$ m, $b = 15$ m, $c = 13$ m; find the length of the perpendicular from A to BC.

2. Solve the equations:

$$5x = 2y + 11$$
$$3x + 4y = 17.$$

3. A man heaving on a capstan bar walks round the capstan at a distance of 6 ft from the centre. If the diameter of the barrel of the capstan is 1 ft, how far will the man walk while hoisting a weight a distance of 15 ft with a gun-tackle, the fall of which is led to the capstan?

4. A celestial body on the horizon bears 070° T from an observer in Lat. 38° 36′ N. Find the declination of the body.

5. The external dimensions of a cylindrical sanitary tank are, length 6 ft 2 in and diameter 4 ft 3 in. It is constructed of $\frac{1}{2}$ in steel plates.

   How many tons of salt water can it carry and how many gallons of fresh water would be required to fill it?

6. In spherical triangle ABC, $AB = 50°$, $AC = 50°$, angle $A = 50°$. If the side BC is bisected at point D, find the length of AD.

Paper 4

Plot on squared paper the points whose co-ordinates are $(4, 2)$, $(-1, 1)$, $(-2, 3)$. Find the area of the triangle formed by joining these points if each unit on your graph represents 20 m.

2. After steaming 105 miles it is found that if the speed had been 2 knots less the ship would have been 6 hours longer in covering the distance. What was her speed?

3. Find the value of:

$$\sqrt[3]{\frac{19\frac{1}{4} \times 18\frac{6}{10}}{21\frac{4}{5}}}.$$

4. The length of a boiler is 30 ft and its inner diameter is 8 ft. What quantity of water will be in it when it is three-quarters full?

5. From a ship steaming North, two beacons of equal height were observed, one bearing North and the other East, their vertical angles being 1° 40′ and 1° 19′ respectively. Find the alteration of ship's course necessary to pass midway between them.

6. Find the shortest distance between position *A* in 43° 00′ N, 56° 00′ W, and *B* in 43° 00′ N, 10° 00′ W.

Paper 5

1. Find the volume of a sphere and the area of its surface if its radius is 2·5 ft.

2. Prove that natural haversine $60° = \frac{1}{4}$.

3. Find the natural value of $3\sec^2 60° + 4\cos^2 45° + \tan^2 60$.

4. Two ships approaching end on at 12 knots both alter course simultaneously 2 points to starboard; after 4 minutes each has the other 4 points on the port bow and each alters back to the original course. Find their distance apart when they come abeam of each other.

5. In a circle whose radius is 37 cm, a chord is drawn 70 cm in length. Find its distance from the centre.

6. A spherical triangle has two sides each 60° and the angle between them is 60°; find the third side.

Paper 6

1. Two places on the same meridian have a Difference of Latitude of 21° 12′. If they are 3·7 in apart on a globe, find its radius to the nearest tenth of an inch. Also find the number of miles between the two places assuming the earth's radius to be 4,000 miles.

2. Divide 85 into two parts such that one-fourth of one part may be equal to one-sixth of the other part.

3. Find the value of $\sqrt{\frac{0{\cdot}9 \times 0{\cdot}09 \times 0{\cdot}009}{33}}$.

4. Draw a figure and explain the geometry of fixing a ship's position by means of horizontal angles and the station pointer.

5. The internal volume of a gasometer is 150,000 cubic metres; if its radius is 30 metres what is its height?

6. A star on the prime vertical bearing West has an altitude of 23° and Declination 20°. Find the observer's Latitude.

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TABLE V

(ATT Vol. 1)

TIDAL LEVELS—DEFINITIONS AND NOTES

(*a*) The levels are referred to *CHART DATUM*, which is the same as the zero of the tidal predictions in all cases. By international agreement, Chart Datum is defined as a level so low that the tide will not frequently fall below it. In the United Kingdom, this level is normally approximately the level of Lowest Astronomical Tide.

(*b*) *H.A.T.* (*Highest Astronomical Tide*). *L.A.T.* (*Lowest Astronomical Tide*). The highest and lowest levels respectively which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; these levels will not be reached every year. H.A.T. and L.A.T. are not the extreme levels which can be reached, as storm surges (see page vii) may cause considerably higher and lower levels to occur.

(*c*) *M.H.W.S.* (*Mean High Water Springs*). *M.L.W.S.* (*Mean Low Water Springs*). The height of mean high water springs is the average, throughout a year when the average maximum declination of the moon is $23\frac{1}{2}°$, of the heights of *two* successive high waters during those periods of 24 hrs (approximately once a fortnight) when the range of the tide is greatest. The height of mean low water springs is the average height obtained by the two successive low waters during the same periods.

(*d*) *M.H.W.N.* (*Mean High Water Neaps*). *M.L.W.N.* (*Mean Low Water Neaps*). The height of mean high water neaps is the average, throughout a year as defined in (*b*) above, of the heights of two successive high waters during those periods (approximately once a fortnight) when the range of the tide is least. The height of mean low water neaps is the average height obtained from the two successive low waters during the same periods.

(*e*) The values of M.H.W.S., M.H.W.N., M.L.W.N. and M.L.W.S. vary from year to year in a cycle of approximately 18·6 years. In general the levels are computed from at least a year's predictions and are adjusted for the long period variations to give values which are the average over the whole cycle. The values of Lowest Astronomical Tide (L.A.T.) and Highest Astronomical Tide (H.A.T.) are determined by inspection over a span of years.

(*f*) *M.T.L.* (*Mean Tide Level*). Mean Tide Level, as given above, is the mean of the heights of M.H.W.S., M.H.W.N., M.L.W.S. and M.L.W.N.

(*g*) *Abbreviations for authorities:*

B.	L'Administration des Ponts et Chaussées, Belgium.
D.	Danish Meteorological Institute.
F.	Service Hydrographique et Océanographique de la Marine, France.
G.	German Hydrographic Institute.
H.A.	Local Harbour Authority.
Hyd.	Hydrographer of the Navy.
I.	Lighthouse and Harbour Administration, Iceland.
It.	Instituto Idografico, Genova, Italy.
N.	Department van Waterstaat, Netherlands.
Nor.	Norwegian Hydrographic Service.
P.	Ministerio de Marinha, Lisboa, Portugal.
R.	Russian sources.
I.O.S.	Institute of Oceangraphic Sciences.

(*h*) *Abbreviations for methods of predicting:*

H. By tide-predicting machine or electronic computer using harmonic constants.

H.C. As above but with additional shallow water corrections.

Diff. By variable differences on another port.

(*j*) *Years of observations.* Wherever possible tidal predictions for Standard Ports are based on the analysis of at least one complete year's observations. Where a period of less than one year has been used, the dates are given in italics.

TABLE V (*cont.*)

TIDAL LEVELS IN METRES AT STANDARD PORTS

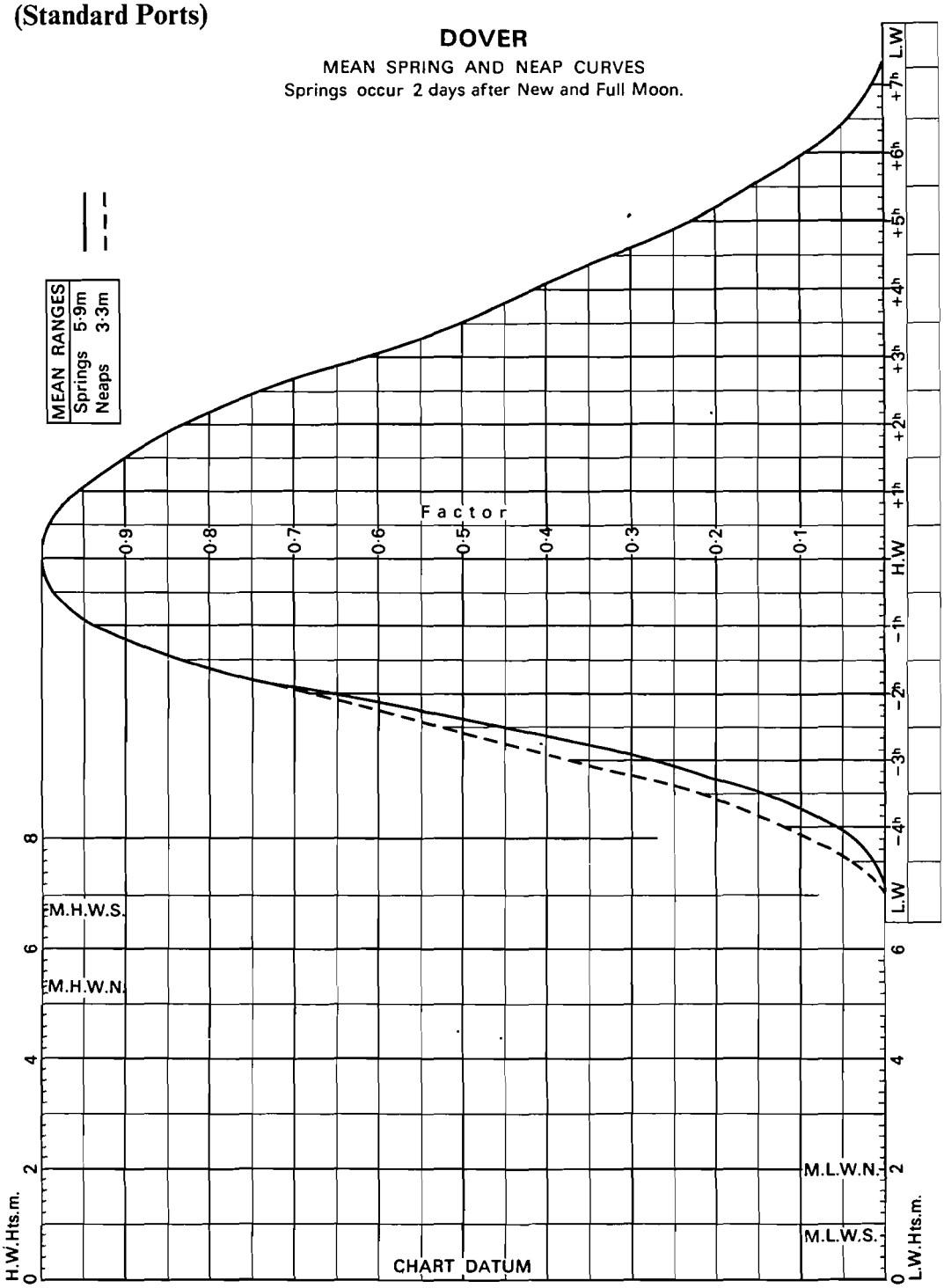
(with data concerning predictions, etc.)

Standard Port	L.A.T. (*b*)	M.L.W.S. (*c*)	M.L.W.N. (*d*)	M.T.L. (*f*)	M.H.W.N. (*d*)	M.H.W.S. (*c*)	H.A.T. (*b*)	Authority for (*g*) Observations	Constants	Predictions	Method of Predicting (*h*)	Years of Observations (*j*)
Plymouth (Devonport)	0·0	+0·8	+2·2	+3·2	+4·4	+5·5	+6·1	Hyd.	I.O.S.	Hyd.	H.	1961–62
Portland	−0·1	+0·2	+0·7	+1·1	+1·4	+2·1	+2·7	Hyd.	I.O.S.	Hyd.	H.C.	1961–62
Southampton	0·0	+0·5	+1·8	+2·6	+3·7	+4·5	+4·9	H.A.	I.O.S.	I.O.S.	H.C.	1957
Portsmouth	0·0	+0·6	+1·8	+2·7	+3·8	+4·7	+5·2	Hyd.	I.O.S.	Hyd.	H.C.	1961–62
Shoreham	0·0	+0·7	+1·9	+3·5	+5·0	+6·2	+6·7	H.A.	I.O.S.	I.O.S.	H.	1959
Dover	0·0	+0·8	+2·0	+3·7	+5·3	+6·7	+7·3	H.A	I.O.S.	I.O.S.	H.C.	1975
Margate	−0·1	+0·5	+1·4	+2·6	+3·9	+4·8	+5·2	H.A.	I.O.S.	I.O.S.	H.	1969–70
Sheerness	−0·1	+0·6	+1·5	+3·1	+4·8	+5·7	+6·4	H.A.	I.O.S.	I.O.S.	H.	1969–70
Chatham	−0·4	+0·4	+1·4	+3·2	+4·9	+6·0	+6·7	H.A.	I.O.S.	Hyd.	H.	1971
London Bridge	−0·2	+0·5	+1·6	+3·7	+5·8	+7·1	+7·9	H.A.	I.O.S.	I.O.S.	H.C.	1969–70
Walton-on-the-Naze	−0·1	+0·4	+1·1	+2·3	+3·4	+4·2	+4·7	H.A.	I.O.S.	I.O.S.	H.	1969–70
Harwich	−0·1	+0·4	+1·1	+2·2	+3·4	+4·0	+4·4	H.A.	I.O.S.	I.O.S.	H.C.	1961
Lowestoft	0·0	+0·5	+1·0	+1·5	+2·1	+2·4	+2·8	H.A.	I.O.S.	I.O.S.	H.	1959
Immingham	−0·1	+0·9	+2·6	+4·1	+5·8	+7·3	+8·0	H.A.	I.O.S.	I.O.S.	H.C.	1977
Hull	−0·1	+0·8	+2·4	+4·1	+5·8	+7·3	+8·3	H.A.	I.O.S.	I.O.S.	H.C.	1977
River Tees	0·0	+0·9	+2·0	+3·2	+4·3	+5·5	+6·1	H.A.	I.O.S.	I.O.S.	H.	1948
River Tyne	0·0	+0·7	+1·8	+2·9	+3·9	+5·0	+5·7	H.A.	I.O.S.	I.O.S.	H.	1962
Leith	0·0	+0·8	+2·1	+3·3	+4·5	+5·6	+6·1	H.A.	I.O.S.	I.O.S.	H.C.	1956
Rosyth	0·0	+0·8	+2·2	+3·4	+4·7	+5·8	+6·4	Hyd.	I.O.S.	Hyd.	H.C.	1966
Aberdeen	0·0	+0·6	+1·6	+2·5	+3·4	+4·3	+4·8	H.A.	I.O.S.	I.O.S.	H.	1964
Lerwick	0·0	+0·5	+0·9	+1·3	+1·6	+2·2	+2·5	H.A.	I.O.S.	Hyd.	H.	1967–71
Ullapool	0·0	+0·7	+2·1	+3·0	+3·9	+5·2	+5·8	H.A.	I.O.S.	Hyd.	H.	1966
Oban	0·0	+0·7	+1·8	+2·3	+2·9	+4·0	+4·5	Hyd.	I.O.S.	Hyd.	H.	1971–72
Greenock	−0·1	+0·4	+1·0	+1·9	+2·9	+3·4	+4·1	H.A.	I.O.S.	Hyd.	H.C.	1948
Glasgow	−0·1	+0·7	+1·6	+2·8	+4·0	+4·8	+5·4	H.A.	I.O.S.	I.O.S.	H.C.	1948
Liverpool	−0·2	+0·9	+2·9	+5·2	+7·4	+9·3	+10·3	H.A.	I.O.S.	I.O.S.	H.C.	1970
Holyhead	0·0	+0·7	+2·0	+3·2	+4·5	+5·7	+6·5	H.A.	I.O.S.	I.O.S.	H.	1959–60
Milford Haven	−0·1	+0·7	+2·5	+3·8	+5·2	+7·0	+8·0	Hyd.	I.O.S.	I.O.S.	H.	1961
Swansea	0·0	+1·0	+3·2	+5·3	+7·3	+9·6	+10·5	H.A.	I.O.S.	I.O.S.	H.C.	1961
Cardiff	0·0	+1·2	+3·8	+6·7	+9·4	+12·3	+13·4	H.A.	—	I.O.S.	Diff.	1956
Port of Bristol (Avonmouth)	0·0	+0·9	+3·5	+6·9	+10·0	+13·2	+14·6	H.A.	I.O.S.	I.O.S.	H.C.	1970

TABLE V (*cont.*)
TIDAL LEVELS IN METRES AT STANDARD PORTS
(with data concerning predictions, etc.)

Standard Port	L.A.T. (*b*)	M.L.W.S. (*c*)	M.L.W.N. (*d*)	M.T.L. (*f*)	M.H.W.N. (*d*)	M.H.W.S. (*c*)	H.A.T. (*b*)	Authority for (*g*) Observations	Constants	Predictions	Method of Predicting (*h*)	Years of Observations (*j*)
Dublin	0·0	+0·5	+1·5	+2·4	+3·4	+4·1	+4·7	H.A.	I.O.S.	I.O.S.	H.	1948–49
Belfast	0·0	+0·4	+1·1	+2·0	+3·0	+3·5	+3·9	H.A.	I.O.S.	I.O.S.	H.	1947–48
Londonderry	0·0	+0·4	+1·0	+1·5	+2·0	+2·7	+3·2	H.A.	I.O.S.	I.O.S.	H.	1935–36
Galway	−0·1	+0·6	+2·0	+2·9	+3·9	+5·1	+5·7	H.A.	I.O.S.	I.O.S.	H.	1965
Tarbert Island	0·0	+0·5	+1·7	+2·8	+3·8	+5·0	+5·5	H.A.	I.O.S.	I.O.S.	H.	1966
Cobh	−0·1	+0·5	+1·3	+2·3	+3·3	+4·1	+4·6	Hyd.	I.O.S.	I.O.S.	H.	1906
Reykjavik	−0·4	+0·2	+1·3	+2·1	+2·9	+4·0	+4·6	I.	I.	Hyd.	H.	1963
Port of Kem'	+0·1	+0·4	+0·6	+1·1	+1·6	+1·9	+2·0	R.	R.	Hyd.	H.	1910
Ostrov Yekaterininskaya	−0·1	+0·5	+1·3	+2·1	+3·0	+3·7	+4·2	R.	G.	G.	H.	1906–07
Narvik	+0·1	+0·5	+1·2	+1·8	+2·4	+3·2	+3·7	—	—	Nor.	—	—
Bergen	−0·1	+0·2	+0·5	+0·8	+1·1	+1·4	+1·6	—	—	Nor.	—	—
Esbjerg	−0·4	−0·1	+0·2	+0·8	+1·4	+1·6	+1·9	D.	D.	D.	H.	—
Helgoland	−0·3	0·0	+0·4	+1·3	+2·3	+2·6	+3·0	—	—	G.	—	—
Cuxhaven	−0·4	−0·1	+0·3	+1·5	+2·8	+3·2	+3·5	—	—	G.	—	—
Wilhelmshaven	−0·4	0·0	+0·6	+2·0	+3·7	+4·2	+4·5	—	—	G.	—	—
Hoek van Holland	−0·2	+0·4	+0·3	+1·2	+1·8	+2·3	+2·6	—	—	N.	—	—
Vlissingen (Flushing)	−0·4	+0·5	+1·0	+2·6	+4·0	+4·9	+5·3	—	—	N.	—	—
Antwerp (Prosperpolder)	−0·6	0·0	+0·9	+2·6	+4·3	+5·6	+5·9	B.	I.O.S.	I.O.S.	H.C.	1972
Dunkerque	+0·2	+0·6	+1·5	+3·1	+4·8	+5·8	+6·2	—	—	F.	—	—
Calais	+0·4	+1·0	+2·2	+4·1	+6·0	+7·2	+7·6	—	—	F.	—	—
Boulogne	+0·2	+1·1	+2·8	+5·0	+7·2	+8·9	+9·5	—	—	F.	—	—
Dieppe	+0·2	+0·7	+2·5	+4·9	+7·2	+9·3	+10·0	—	—	F.	—	—
Le Havre	+0·3	+1·1	+2·8	+4·5	+6·5	+7·8	+8·3	—	—	F.	—	—
Cherbourg	+0·5	+1·1	+2·5	+3·5	+5·0	+6·3	+7·0	—	—	F.	—	—
St. Helier	0·0	+1·3	+4·1	+6·2	+8·1	+11·1	+12·3	H.A.	I.O.S.	I.O.S.	H.	1952
Brest	+0·5	+1·4	+3·0	+4·4	+5·9	+7·5	+8·3	—	—	F.	—	—
Pointe de Grave	+0·5	+1·0	+2·1	+3·1	+4·3	+5·3	+6·0	—	—	F.	—	—
Lisbon	+0·0	+0·5	+1·4	+2·2	+3·0	+3·8	+4·2	—	—	P.	—	—
Gibraltar	−0·1	+0·1	+0·3	+0·5	+0·7	+1·0	+1·1	Hyd.	I.O.S.	Hyd.	H.	1961–62
Venezia (Venice)	−0·1	+0·1	+0·4	+0·5	+0·6	+0·8	+1·0	—	—	It.	—	—

Volume 1 EUROPEAN WATERS—Part I
(Standard Ports)



ENGLAND, SOUTH COAST - DOVER

LAT 51°07'N LONG 1°19'E

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

JANUARY

	TIME	M		TIME	M
1	0209	6.2	16	0312	6.3
F	0934	1.5	SA	1057	1.5
	1430	5.9		1543	5.7
	2146	1.6		2309	1.9
2	0256	6.1	17	0406	6.0
SA	1016	1.6	SU	1140	1.8
	1527	5.7		1642	5.5
	2231	1.8		2351	2.2
3	0352	6.0	18	0508	5.7
SU	1106	1.7	M	1232	2.0
	1633	5.6		1756	5.3
	2327	1.9			
4	0458	5.9	19	0046	2.4
M	1210	1.8	TU	0621	5.5
	1743	5.6		1335	2.2
				1914	5.3
5	0038	2.0	20	0201	2.4
TU	0607	5.9	W	0735	5.5
	1326	1.7		1451	2.1
	1850	5.7		2019	5.4
6	0157	1.9	21	0318	2.2
W	0713	6.0	TH	0836	5.6
	1439	1.5		1549	1.9
	1954	5.9		2111	5.7
7	0308	1.7	22	0412	1.9
TH	0815	6.2	F	0927	5.8
	1548	1.3		1634	1.6
	2056	6.2		2155	5.9
8	0414	1.4	23	0455	1.6
F	0914	6.4	SA	1007	6.0
	1651	1.1		1715	1.4
	2153	6.4		2231	6.2
9	0516	1.2	24	0539	1.4
SA	1010	6.6	SU	1041	6.1
	1751	0.9		1757	1.2
	2247	6.6		2304	6.3
10	0614	1.0	25	0619	1.2
SU	1102	6.7	M	1112	6.2
	1849	0.8		1838	1.1
	2336	6.8		2333	6.4
11	0709	0.8	26	0700	1.1
M	1153	6.7	TU	1142	6.3
	1942	0.8		1916	1.0
12	0021	6.8	27	0005	6.5
TU	0801	0.7	W	0737	1.0
	1239	6.7		1215	6.4
	2032	0.8		1948	1.0
13	0103	6.8	28	0039	6.6
W	0849	0.7	TH	0809	1.0
	1323	6.5		1252	6.4
	2115	1.0		2018	1.1
14	0144	6.7	29	0116	6.5
TH	0934	0.9	F	0840	1.0
	1406	6.3		1331	6.3
	2155	1.3		2049	1.1
15	0226	6.5	30	0152	6.4
F	1014	1.2	SA	0912	1.1
	1453	6.0		1412	6.2
	2231	1.6		2124	1.2
			31	0233	6.3
			SU	0950	1.2
				1500	6.0
				2204	1.4

FEBRUARY

	TIME	M		TIME	M
1	0322	6.1	16	0417	5.7
M	1557	5.8	TU	1654	5.2
	2254	1.7		2337	2.3
2	0421	5.9	17	0525	5.3
TU	1702	5.6	W	1819	5.0
	2357	1.9			
3	0529	5.8	18	0041	2.5
W	1815	5.5	TH	0653	5.1
				1333	2.4
				1942	5.1
4	0119	2.0	19	0211	2.4
TH	0643	5.7	F	0806	5.2
	1409	1.8		1500	2.2
	1933	5.6		2042	5.3
5	0244	1.8	20	0334	2.1
F	0759	5.8	SA	0901	5.4
	1532	1.5		1602	1.8
	2049	5.8		2127	5.7
6	0403	1.5	21	0428	1.7
SA	0910	6.0	SU	0943	5.7
	1645	1.2		1651	1.5
	2152	6.2		2203	5.9
7	0509	1.2	22	0516	1.3
SU	1009	6.3	M	1014	5.9
	1751	1.0		1737	1.2
	2241	6.4		2234	6.2
8	0611	0.9	23	0601	1.1
M	1058	6.5	TU	1044	6.2
	1850	0.8		1821	1.0
	2325	6.7		2305	6.4
9	0706	0.7	24	0643	0.9
TU	1143	6.6	W	1116	6.4
	1940	0.7		1900	0.9
				2340	6.6
10	0004	6.8	25	0721	0.8
W	0754	0.6	TH	1153	6.5
	1224	6.6		1933	0.8
	2020	0.7			
11	0043	6.8	26	0017	6.7
TH	0834	0.6	F	0752	0.8
	1302	6.5		1232	6.6
	2056	0.8		1958	0.8
12	0121	6.7	27	0055	6.7
F	0910	0.8	SA	0819	0.8
	1341	6.4		1312	6.5
	2124	1.1		2027	0.8
13	0201	6.6	28	0131	6.6
SA	0941	1.0	SU	0851	0.8
	1420	6.1		1352	6.4
	2146	1.4		2104	0.9
14	0242	6.4			
SU	1010	1.3			
	1504	5.9			
	2213	1.7			
15	0325	6.0			
M	1044	1.7			
	1553	5.5			
	2248	2.0			

MARCH

	TIME	M		TIME	M
1	0212	6.4	16	0243	6.0
M	1437	6.2	TU	1504	5.6
	2145	1.2		2210	1.8
2	0258	6.2	17	0325	5.6
TU	1531	5.9	W	1553	5.2
	2233	1.5		2255	2.1
3	0355	5.9	18	0420	5.1
W	1634	5.6	TH	1706	4.9
	2334	1.8		2354	2.4
4	0505	5.6	19	0556	4.8
TH	1751	5.3	F	1849	4.8
5	0100	1.9	20	0113	2.4
F	0628	5.4	SA	0727	4.9
	1357	1.9		1402	2.3
	1923	5.4		1958	5.1
6	0234	1.8	21	0250	2.2
SA	0801	5.5	SU	0825	5.2
	1528	1.6		1522	1.9
	2047	5.7		2047	5.5
7	0357	1.4	22	0356	1.7
SU	0918	5.9	M	0907	5.5
	1644	1.2		1620	1.5
	2145	6.0		2125	5.8
8	0506	1.0	23	0448	1.3
M	1009	6.2	TU	0939	5.9
	1747	0.9		1711	1.2
	2228	6.3		2159	6.2
9	0605	0.8	24	0536	1.0
TU	1051	6.4	W	1013	6.2
	1842	0.7		1757	0.9
	2306	6.6		2234	6.5
10	0656	0.6	25	0621	0.8
W	1127	6.5	TH	1049	6.5
	1924	0.6		1838	0.8
	2344	6.7		2312	6.7
11	0737	0.5	26	0659	0.6
TH	1203	6.5	F	1129	6.6
	1959	0.7		1909	0.7
				2350	6.8
12	0021	6.7	27	0728	0.6
F	0811	0.6	SA	1210	6.7
	1239	6.5		1937	0.6
	2025	0.8			
13	0057	6.7	28	0031	6.8
SA	0837	0.7	SU	0757	0.5
	1314	6.4		1252	6.6
	2044	1.0		2009	0.6
14	0133	6.5	29	0112	6.6
SU	0903	0.9	M	0832	0.6
	1349	6.2		1335	6.5
	2107	1.2		2049	0.7
15	0208	6.3	30	0154	6.4
M	0929	1.2	TU	0912	0.8
	1425	5.9		1422	6.2
	2135	1.4		2131	1.0
			31	0242	6.1
			W	0959	1.2
				1515	5.9
				2221	1.3

APRIL

	TIME	M		TIME	M
1	0342	5.8	16	0325	5.2
TH	1058	1.6	F	1054	2.0
	1619	5.6		1607	5.1
	2329	1.7		2319	2.2
2	0454	5.4	17	0449	4.8
F	1219	1.9	SA	1153	2.3
	1739	5.3		1740	4.9
3	0057	1.8	18	0028	2.3
SA	0628	5.3	SU	0631	4.8
	1354	1.8		1310	2.3
	1919	5.3		1902	5.1
4	0230	1.6	19	0159	2.1
SU	0809	5.5	M	0735	5.1
	1521	1.5		1433	2.0
	2036	5.7		1958	5.5
5	0349	1.2	20	0314	1.7
M	0912	5.9	TU	0823	5.5
	1630	1.1		1539	1.6
	2127	6.0		2043	5.9
6	0454	0.9	21	0412	1.2
TU	0957	6.1	W	0904	5.9
	1730	0.9		1633	1.2
	2207	6.3		2124	6.3
7	0549	0.7	22	0502	0.9
W	1033	6.3	TH	0942	6.3
	1818	0.7		1722	0.9
	2244	6.5		2203	6.5
8	0634	0.6	23	0549	0.7
TH	1105	6.4	F	1021	6.5
	1857	0.7		1805	0.8
	2319	6.6		2242	6.7
9	0710	0.6	24	0629	0.6
F	1140	6.5	SA	1104	6.7
	1926	0.8		1841	0.6
	2356	6.7		2325	6.8
10	0737	0.7	25	0703	0.5
SA	1215	6.4	SU	1149	6.8
	1947	0.9		1916	0.6
11	0032	6.6	26	0008	6.8
SU	0801	0.8	M	0738	0.5
	1249	6.3		1235	6.7
	2008	0.9		1955	0.6
12	0104	6.4	27	0053	6.6
M	0827	0.9	TU	0819	0.6
	1320	6.2		1324	6.5
	2036	1.1		2039	0.7
13	0134	6.2	28	0142	6.4
TU	0857	1.1	W	0904	0.8
	1351	6.0		1415	6.3
	2108	1.3		2127	0.9
14	0202	5.9	29	0236	6.1
W	0931	1.4	TH	0956	1.2
	1423	5.7		1609	6.0
	2143	1.6		2223	1.3
15	0236	5.6	30	0336	5.8
TH	1009	1.7	F	1101	1.5
	1505	5.4		1609	5.7
	2226	1.9		2333	1.5

HEIGHTS IN METRES

ENGLAND, SOUTH COAST - DOVER

LAT 51°07'N LONG 1°19'E

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

MAY

	TIME	M		TIME	M
1	0447	5.5	16	0407	5.1
SA	1219	1.7	SU	1118	2.0
	1723	5.4		1648	5.3
				2351	2.0
2	0055	1.6	17	0536	5.0
SU	0625	5.4	M	1224	2.1
	1342	1.7		1805	5.3
	1857	5.5			
3	0218	1.4	18	0109	1.9
M	0754	5.6	TU	0646	5.3
	1500	1.4		1341	1.9
	2009	5.7		1909	5.6
4	0329	1.1	19	0225	1.6
TU	0850	5.8	W	0740	5.6
	1604	1.2		1450	1.6
	2058	6.0		2001	6.0
5	0430	0.9	20	0328	1.3
W	0932	6.0	TH	0827	6.0
	1701	1.0		1549	1.3
	2141	6.2		2047	6.3
6	0522	0.8	21	0423	1.0
TH	1007	6.2	F	0912	6.3
	1746	1.0		1642	1.1
	2217	6.4		2132	6.6
7	0604	0.8	22	0513	0.8
F	1041	6.3	SA	0956	6.5
	1821	1.0		1730	0.9
	2255	6.5		2216	6.7
8	0635	0.9	23	0558	0.7
SA	1118	6.4	SU	1042	6.7
	1846	1.0		1815	0.7
	2332	6.5		2302	6.8
9	0700	0.9	24	0642	0.6
SU	1153	6.4	M	1132	6.7
	1910	1.0		1900	0.6
				2351	6.8
10	0008	6.5	25	0727	0.6
M	0727	0.9	TU	1224	6.7
	1228	6.3		1947	0.6
	1940	1.0			
11	0039	6.3	26	0043	6.6
TU	0758	0.9	W	0815	0.7
	1257	6.2		1316	6.6
	2012	1.1		2036	0.7
12	0106	6.1	27	0137	6.4
W	0832	1.1	TH	0905	0.9
	1326	6.0		1406	6.4
	2047	1.3		2129	0.9
13	0133	5.9	28	0230	6.2
TH	0905	1.3	F	1002	1.1
	1357	5.8		1457	6.1
	2124	1.5		2227	1.1
14	0206	5.7	29	0327	5.9
F	0943	1.6	SA	1102	1.4
	1437	5.6		1552	5.9
	2203	1.8		2330	1.3
15	0254	5.4	30	0431	5.6
SA	1024	1.8	SU	1207	1.6
	1534	5.4		1658	5.7
	2251	1.9			
			31	0038	1.4
			M	0553	5.5
				1317	1.6
				1817	5.6

JUNE

	TIME	M		TIME	M
1	0151	1.4	16	0021	1.8
TU	0714	5.6	W	0557	5.4
	1427	1.6		1248	1.9
	1928	5.8		1819	5.7
2	0300	1.3	17	0133	1.6
W	0812	5.7	TH	0657	5.6
	1531	1.4		1359	1.8
	2023	6.0		1919	6.0
3	0359	1.2	18	0240	1.4
TH	0858	5.9	F	0752	5.9
	1624	1.3		1505	1.5
	2110	6.1		2012	6.2
4	0448	1.1	19	0342	1.2
F	0939	6.0	SA	0844	6.2
	1708	1.3		1606	1.3
	2152	6.3		2104	6.4
5	0527	1.1	20	0440	1.0
SA	1019	6.2	SU	0936	6.4
	1742	1.3		1704	1.1
	2233	6.4		2155	6.6
6	0600	1.1	21	0536	0.8
SU	1057	6.3	M	1028	6.6
	1811	1.2		1758	0.9
	2311	6.4		2247	6.7
7	0628	1.1	22	0631	0.8
M	1134	6.3	TU	1122	6.7
	1842	1.1		1852	0.7
	2347	6.3		2340	6.7
8	0700	1.0	23	0724	0.7
TU	1208	6.3	W	1215	6.7
	1917	1.1		1945	0.6
9	0019	6.2	24	0035	6.6
W	0735	1.0	TH	0818	0.7
	1239	6.2		1304	6.7
	1954	1.1		2037	0.6
10	0046	6.1	25	0127	6.5
TH	0811	1.1	F	0910	0.8
	1309	6.2		1351	6.5
	2030	1.2		2129	0.7
11	0116	6.0	26	0216	6.3
F	0846	1.3	SA	0959	1.0
	1341	6.0		1437	6.4
	2105	1.4		2220	0.9
12	0152	5.8	27	0307	6.1
SA	0921	1.4	SU	1049	1.3
	1420	5.9		1527	6.1
	2143	1.5		2312	1.2
13	0237	5.6	28	0402	5.8
SU	0959	1.6	M	1142	1.5
	1507	5.8		1624	5.9
	2226	1.7			
14	0338	5.4	29	0008	1.4
M	1044	1.8	TU	0506	5.6
	1607	5.6		1236	1.7
	2316	1.8		1729	5.8
15	0449	5.4	30	0110	1.6
TU	1140	1.9	W	0621	5.5
	1715	5.6		1340	1.9
				1842	5.7

JULY

	TIME	M		TIME	M
1	0216	1.6	16	0042	1.7
TH	0728	5.6	F	0614	5.6
	1446	1.9		1312	1.9
	1947	5.8		1838	5.8
2	0319	1.6	17	0155	1.6
F	0825	5.7	SA	0719	5.7
	1543	1.8		1426	1.7
	2042	5.9		1942	6.0
3	0412	1.6	18	0308	1.5
SA	0914	5.9	SU	0823	6.0
	1630	1.6		1539	1.5
	2129	6.0		2044	6.2
4	0452	1.5	19	0417	1.2
SU	0957	6.0	M	0925	6.2
	1708	1.5		1647	1.2
	2213	6.1		2143	6.4
5	0527	1.4	20	0523	1.1
M	1038	6.2	TU	1021	6.5
	1744	1.3		1749	1.0
	2252	6.2		2240	6.5
6	0603	1.2	21	0627	0.9
TU	1115	6.3	W	1113	6.6
	1822	1.2		1848	0.8
	2327	6.2		2333	6.6
7	0641	1.1	22	0726	0.8
W	1149	6.3	TH	1201	6.8
	1900	1.1		1942	0.6
	2358	6.2			
8	0717	1.1	23	0024	6.7
TH	1219	6.3	F	0818	0.7
	1938	1.1		1246	6.8
				2033	0.5
9	0028	6.2	24	0110	6.6
F	0754	1.1	SA	0903	0.8
	1250	6.3		1330	6.7
	2015	1.2		2119	0.6
10	0100	6.1	25	0154	6.4
SA	0827	1.2	SU	0945	0.9
	1323	6.3		1412	6.6
	2049	1.2		2202	0.8
11	0137	6.0	26	0239	6.2
SU	0900	1.3	M	1023	1.2
	1359	6.2		1457	6.4
	2122	1.3		2242	1.1
12	0218	5.9	27	0327	6.0
M	1440	6.1	TU	1059	1.6
	2159	1.4		1546	6.1
				2325	1.5
13	0307	5.8	28	0421	5.7
TU	1529	5.9	W	1140	1.9
	2242	1.5		1644	5.8
14	0406	5.7	29	0012	1.8
W	1628	5.8	TH	0527	5.4
	2336	1.6		1229	2.1
				1754	5.6
15	0509	5.6	30	0112	2.0
TH	1732	5.8	F	0646	5.3
				1337	2.3
				1912	5.5
			31	0226	2.1
			SA	0755	5.4
				1457	2.2
				2018	5.6

AUGUST

	TIME	M		TIME	M
1	0331	2.0	16	0249	1.7
SU	0851	5.7	M	0816	5.7
	1555	2.0		1527	1.6
	2111	5.7		2040	5.9
2	0420	1.8	17	0410	1.4
M	0938	5.9	TU	0924	6.1
	1641	1.7		1640	1.3
	2156	5.9		2145	6.2
3	0502	1.5	18	0520	1.1
TU	1019	6.1	W	1017	6.4
	1723	1.4		1743	0.9
	2234	6.0		2237	6.5
4	0543	1.3	19	0624	0.9
W	1052	6.3	TH	1102	6.7
	1804	1.2		1843	0.7
	2305	6.1		2323	6.7
5	0622	1.2	20	0720	0.7
TH	1123	6.4	F	1144	6.8
	1845	1.1		1935	0.5
	2333	6.2			
6	0702	1.1	21	0005	6.7
F	1154	6.5	SA	0805	0.7
	1924	1.0		1225	6.9
				2019	0.5
7	0004	6.3	22	0046	6.7
SA	0737	1.1	SU	0843	0.7
	1227	6.5		1304	6.8
	1958	1.0		2057	0.6
8	0039	6.3	23	0126	6.5
SU	0808	1.1	M	0915	1.0
	1300	6.5		1344	6.7
	2029	1.0		2132	0.8
9	0116	6.3	24	0206	6.3
M	0837	1.2	TU	0942	1.3
	1334	6.4		1425	6.5
	2058	1.1		2202	1.2
10	0152	6.2	25	0249	6.0
TU	0908	1.3	W	1007	1.6
	1411	6.3		1508	6.2
	2132	1.2		2234	1.6
11	0234	6.0	26	0336	5.7
W	0946	1.4	TH	1040	1.9
	1453	6.1		1559	5.8
	2213	1.4		2313	1.9
12	0325	5.9	27	0435	5.4
TH	1030	1.6	F	1125	2.2
	1546	5.9		1705	5.4
	2301	1.6			
13	0427	5.7	28	0004	2.2
F	1125	1.9	SA	0558	5.1
	1651	5.8		1225	2.5
				1835	5.2
14	0005	1.8	29	0114	2.4
SA	0536	5.5	SU	0723	5.2
	1238	2.0		1357	2.5
	1804	5.6		1952	5.2
15	0124	1.8	30	0243	2.3
SU	0655	5.5	M	0826	5.4
	1402	1.9		1521	2.2
	1924	5.7		2051	5.5
			31	0346	2.0
			TU	0915	5.7
				1614	1.8
				2136	5.7

HEIGHTS IN METRES

ENGLAND, SOUTH COAST - DOVER

LAT 51°07'N LONG 1°19'E

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

SEPTEMBER

	TIME	M		TIME	M
1 W	0435	1.7	16 TH	0513	1.1
	0952	6.0		1006	6.5
	1701	1.4		1736	0.8
	2209	5.9		2228	6.5
2 TH	0519	1.4	17 F	0612	0.8
	1023	6.3		1045	6.7
	1744	1.2		1831	0.6
	2235	6.2		2306	6.7
3 F	0603	1.2	18 SA	0702	0.7
	1052	6.5		1122	6.9
	1827	1.0		1917	0.5
	2305	6.4		2343	6.7
4 SA	0643	1.1	19 SU	0741	0.7
	1125	6.6		1200	6.9
	1904	0.9		1954	0.6
	2337	6.5			
5 SU	0717	1.0	20 M	0019	6.7
	1158	6.7		0812	0.8
	1937	0.9		1238	6.9
				2026	0.7
6 M	0012	6.6	21 TU	0056	6.5
	0744	1.0		0834	1.0
	1234	6.7		1314	6.8
	2004	0.9		2051	0.9
7 TU	0049	6.5	22 W	0133	6.3
	0811	1.0		0857	1.3
	1307	6.6		1349	6.5
	2033	0.9		2119	1.2
8 W	0127	6.4	23 TH	0209	6.1
	0844	1.1		0924	1.6
	1342	6.5		1426	6.2
	2107	1.1		2149	1.6
9 TH	0206	6.2	24 F	0249	5.8
	0922	1.3		0957	1.9
	1423	6.2		1508	5.7
	2148	1.3		2227	2.0
10 F	0254	6.0	25 SA	0338	5.4
	1007	1.6		1041	2.2
	1515	6.0		1604	5.3
	2237	1.6		2315	2.3
11 SA	0356	5.7	26 SU	0452	5.0
	1104	1.9		1139	2.5
	1623	5.7		1743	4.9
	2344	1.9			
12 SU	0511	5.4	27 M	0019	2.5
	1221	2.1		0635	5.0
	1746	5.4		1259	2.6
				1919	5.0
13 M	0113	2.0	28 TU	0147	2.5
	0645	5.4		0748	5.2
	1354	2.0		1436	2.4
	1927	5.5		2020	5.2
14 TU	0247	1.8	29 W	0305	2.2
	0819	5.7		0839	5.6
	1522	1.6		1541	1.9
	2051	5.9		2103	5.6
15 W	0407	1.4	30 TH	0402	1.7
	0919	6.1		0917	6.0
	1634	1.2		1631	1.5
	2146	6.2		2134	5.9

OCTOBER

	TIME	M		TIME	M
1 F	0449	1.4	16 SA	0551	0.9
	0949	6.3		1023	6.7
	1716	1.1		1810	0.7
	2203	6.2		2245	6.6
2 SA	0534	1.1	17 SU	0634	0.8
	1020	6.6		1059	6.9
	1800	1.0		1849	0.7
	2234	6.5		2319	6.7
3 SU	0615	1.0	18 M	0707	0.9
	1054	6.8		1136	6.9
	1838	0.9		1920	0.8
	2309	6.7		2356	6.7
4 M	0649	0.9	19 TU	0730	1.0
	1129	6.9		1211	6.9
	1910	0.8		1945	0.9
	2347	6.8			
5 TU	0716	0.9	20 W	0031	6.6
	1205	6.9		0752	1.1
	1937	0.8		1246	6.7
				2012	1.0
6 W	0025	6.7	21 TH	0103	6.4
	0747	0.9		0820	1.3
	1242	6.8		1317	6.4
	2009	0.9		2042	1.3
7 TH	0104	6.6	22 F	0135	6.2
	0823	1.0		0853	1.5
	1320	6.6		1348	6.1
	2047	1.0		2115	1.6
8 F	0147	6.3	23 SA	0209	5.9
	0905	1.2		0928	1.8
	1404	6.3		1422	5.8
	2131	1.3		2152	1.9
9 SA	0237	6.0	24 SU	0250	5.6
	0953	1.5		1010	2.1
	1500	5.9		1510	5.3
	2226	1.7		2237	2.3
10 SU	0341	5.7	25 M	0350	5.2
	1055	1.9		1102	2.4
	1613	5.6		1633	4.9
	2340	2.0		2336	2.5
11 M	0458	5.4	26 TU	0522	5.0
	1218	2.0		1212	2.5
	1744	5.4		1819	4.9
12 TU	0113	2.1	27 W	0052	2.6
	0641	5.4		0648	5.2
	1354	1.9		1341	2.4
	1940	5.5		1928	5.1
13 W	0244	1.7	28 TH	0213	2.3
	0809	5.7		0747	5.5
	1517	1.4		1456	1.9
	2049	5.9		2016	5.5
14 TH	0357	1.3	29 F	0318	1.9
	0904	6.1		0832	5.9
	1623	1.0		1552	1.5
	2136	6.3		2053	5.9
15 F	0458	1.0	30 SA	0412	1.5
	0946	6.5		0910	6.3
	1719	0.8		1641	1.2
	2213	6.5		2129	6.3
31 SU	0458	1.2			
	0946	6.6			
	1726	0.9			
	2204	6.6			

NOVEMBER

	TIME	M		TIME	M
1 M	0542	1.0	16 TU	0628	1.2
	1023	6.8		1112	6.8
	1807	0.8		1843	1.0
	2244	6.8		2334	6.6
2 TU	0618	0.9	17 W	0652	1.2
	1102	6.9		1149	6.7
	1841	0.8		1910	1.0
	2323	6.9			
3 W	0652	0.9	18 TH	0010	6.6
	1142	6.9		0721	1.2
	1913	0.8		1222	6.6
				1940	1.1
4 TH	0005	6.8	19 F	0042	6.5
	0728	0.9		0755	1.3
	1222	6.8		1252	6.4
	1951	0.8		2013	1.3
5 F	0050	6.7	20 SA	0112	6.3
	0811	0.9		0830	1.5
	1307	6.6		1321	6.1
	2034	1.0		2047	1.5
6 SA	0140	6.5	21 SU	0144	6.1
	0857	1.2		0907	1.7
	1358	6.3		1354	5.8
	2124	1.4		2124	1.8
7 SU	0233	6.2	22 M	0222	5.9
	0952	1.4		0946	1.9
	1458	5.9		1439	5.5
	2224	1.7		2204	2.1
8 M	0334	5.8	23 TU	0312	5.6
	1058	1.7		1033	2.2
	1609	5.6		1543	5.2
	2342	2.0		2255	2.3
9 TU	0444	5.6	24 W	0421	5.4
	1218	1.8		1132	2.3
	1739	5.5		1712	5.1
10 W	0107	2.0	25 TH	0000	2.4
	0617	5.5		0540	5.4
	1342	1.7		1246	2.2
	1924	5.6		1827	5.2
11 TH	0227	1.7	26 F	0116	2.3
	0741	5.8		0648	5.6
	1458	1.3		1401	2.0
	2026	5.9		1924	5.5
12 F	0335	1.4	27 SA	0226	2.0
	0836	6.1		0741	5.9
	1600	1.1		1504	1.6
	2112	6.2		2012	5.9
13 SA	0431	1.2	28 SU	0327	1.7
	0919	6.4		0829	6.2
	1655	0.9		1600	1.3
	2149	6.4		2056	6.2
14 SU	0520	1.1	29 M	0420	1.4
	0957	6.6		0911	6.5
	1740	0.9		1649	1.1
	2223	6.5		2138	6.5
15 M	0600	1.1	30 TU	0509	1.2
	1035	6.7		0955	6.7
	1815	1.0		1736	0.9
	2258	6.6		2221	6.7

DECEMBER

	TIME	M		TIME	M
1 W	0554	1.0	16 TH	0627	1.3
	1038	6.8		1132	6.5
	1817	0.8		1843	1.2
	2306	6.8		2354	6.5
2 TH	0636	0.9	17 F	0700	1.2
	1123	6.9		1205	6.4
	1859	0.8		1917	1.2
	2356	6.8			
3 F	0720	0.9	18 SA	0027	6.5
	1211	6.8		0737	1.3
	1942	0.9		1235	6.3
				1952	1.2
4 SA	0045	6.8	19 SU	0056	6.4
	0808	0.9		0813	1.4
	1303	6.6		1304	6.1
	2033	1.0		2026	1.4
5 SU	0135	6.6	20 M	0127	6.3
	0858	1.0		0850	1.5
	1357	6.4		1337	6.0
	2127	1.3		2101	1.6
6 M	0225	6.4	21 TU	0202	6.1
	0955	1.2		0925	1.7
	1453	6.1		1418	5.6
	2227	1.6		2136	1.8
7 TU	0319	6.1	22 W	0244	6.0
	1058	1.4		1004	1.8
	1553	5.8		1508	5.5
	2334	1.8		2217	2.0
8 W	0420	5.9	23 TH	0336	5.8
	1205	1.6		1052	2.0
	1708	5.6		1616	5.3
				2309	2.2
9 TH	0045	1.9	24 F	0440	5.6
	0533	5.7		1151	2.0
	1317	1.6		1726	5.3
	1838	5.6			
10 F	0155	1.8	25 SA	0014	2.2
	0652	5.8		0546	5.6
	1429	1.5		1300	2.0
	1947	5.7		1829	5.4
11 SA	0301	1.7	26 SU	0126	2.2
	0757	6.0		0648	5.8
	1531	1.3		1409	1.8
	2039	5.9		1927	5.7
12 SU	0359	1.5	27 M	0236	2.0
	0847	6.2		0745	6.0
	1624	1.3		1515	1.5
	2122	6.1		2022	6.0
13 M	0447	1.5	28 TU	0341	1.7
	0932	6.3		0839	6.2
	1708	1.2		1616	1.3
	2202	6.3		2114	6.2
14 TU	0525	1.4	29 W	0441	1.4
	1014	6.4		0929	6.4
	1743	1.2		1711	1.1
	2241	6.4		2206	6.5
15 W	0556	1.4	30 TH	0536	1.1
	1054	6.5		1021	6.6
	1812	1.2		1804	0.9
	2319	6.5		2258	6.7
31 F	0628	1.0			
	1113	6.7			
	1855	0.9			
	2349	6.8			

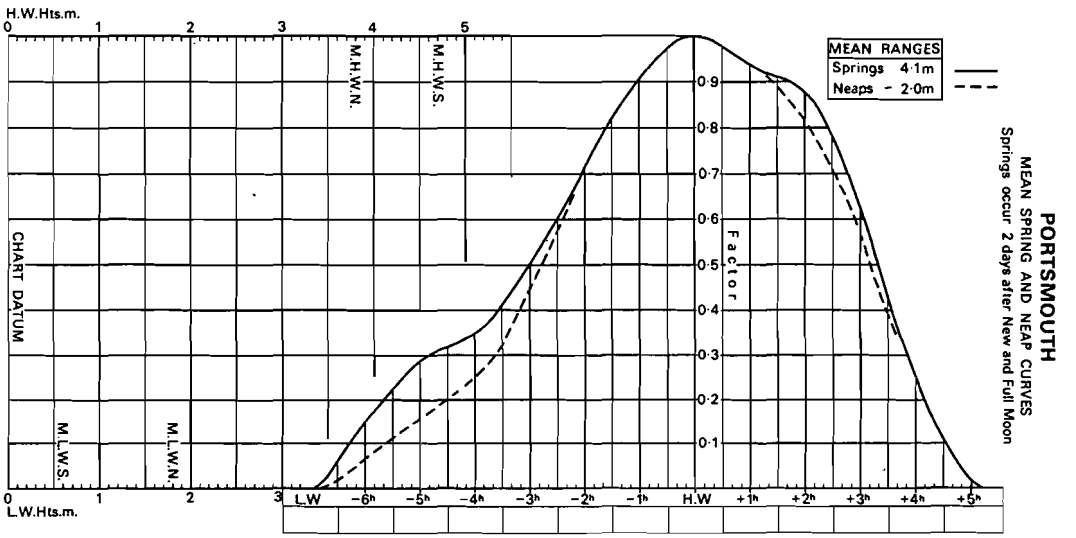
HEIGHTS IN METRES

ENGLAND, SOUTH COAST - PORTSMOUTH

LAT 50°48'N LONG 1°07'W

ME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

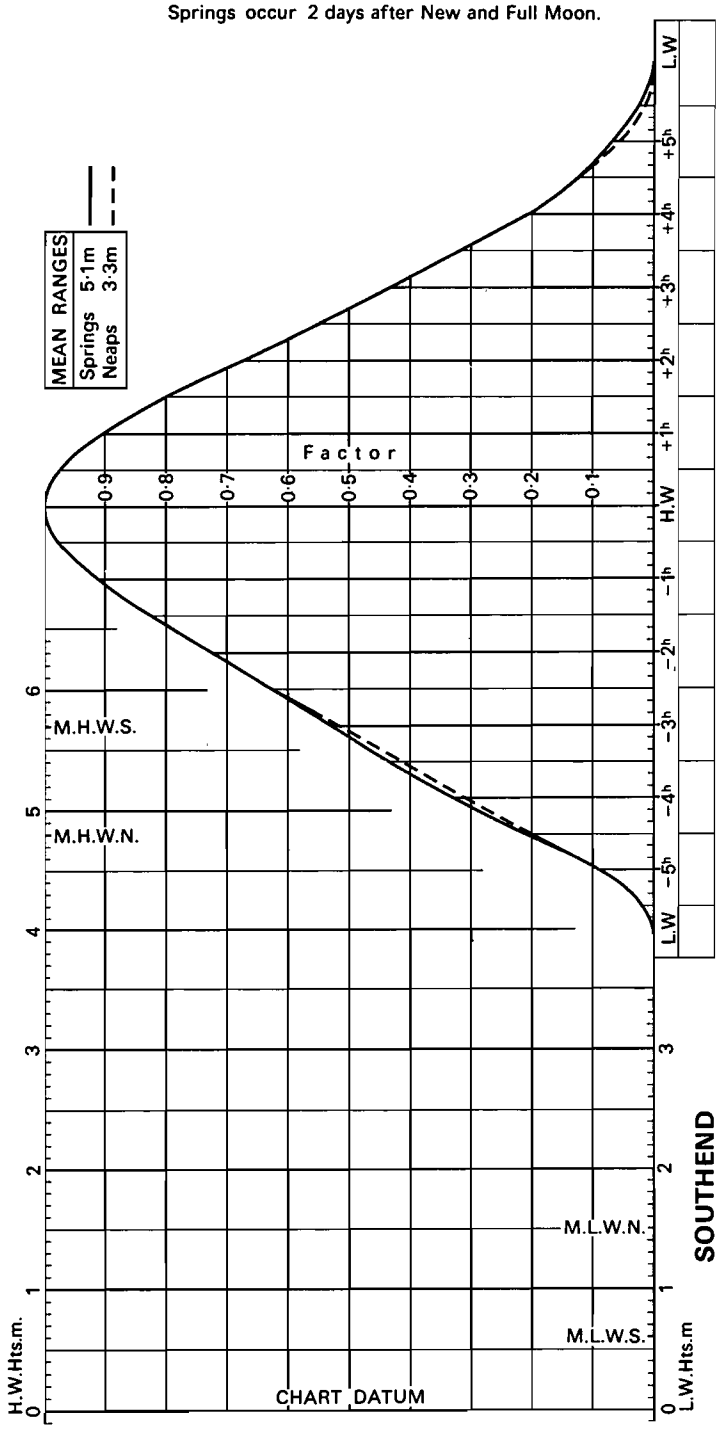
	MAY				JUNE				JULY				AUGUST			
	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M
13 TH	0205	4.2	0247	4.4	0303	3.9	0423	4.1	0326	4.1	0445	4.1	0447	4.0	0615	3.6
	0718	1.2	0810	1.0	0820	1.3	0951	1.3	0844	1.1	1011	1.5	1009	1.4	1143	2.1
	1440	4.1	1534	4.4	1546	4.0	1715	4.3	1608	4.2	1727	4.2	1727	4.1	1845	3.7
	1937	1.5	2038	1.4	2050	1.6	2228	1.6	2112	1.4	2246	1.7	2246	1.6		
14 F	0241	4.0	0345	4.2	0351	3.8	0530	4.0	0415	4.0	0551	3.8	0559	3.9	0026	2.0
	0757	1.4	0910	1.2	0912	1.4	1058	1.5	0937	1.2	1118	1.7	1127	1.6	0740	3.6
	1521	3.9	1640	4.3	1638	4.0	1820	4.2	1659	4.2	1829	4.0	1840	4.0	1305	2.1
	2023	1.7	2148	1.6	2149	1.7	2337	1.7	2210	1.5	2356	1.8			2001	3.8
15 SA	0325	3.8	0453	4.0	0449	3.8	0642	3.9	0515	3.9	0706	3.7	0008	1.6	0140	1.9
	0847	1.6	1021	1.4	1014	1.4	1207	1.5	1040	1.4	1230	1.8	0723	3.9	0852	3.7
	1612	3.8	1753	4.1	1739	4.0	1923	4.1	1800	4.1	1934	3.9	1249	1.6	1411	1.9
	2124	1.9	2305	1.7	2255	1.7			2318	1.5			1956	4.1	2105	3.9
28 F	0247	4.4	0810	1.0	1534	4.4										
29 SA	0345	4.2	0910	1.2	1640	4.3										
30 SU	0453	4.0	1021	1.4	1753	4.1										
31 M																



SHEERNESS

MEAN SPRING AND NEAP CURVES

Springs occur 2 days after New and Full Moon.



SOUTHEND

To obtain predictions for SOUTHEND the following corrections should be applied to the predictions for SHEERNESS:—

All Times	−5 mins.
H.W. Heights	Nil.
L.W. Heights	−0·1m

ENGLAND, EAST COAST - SHEERNESS

LAT 51°27'N LONG 0°46'E

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

JANUARY

	TIME	M		TIME	M
1	0349	5.4	16	0452	5.4
F	1002	1.0	SA	1111	1.0
	1623	5.3		1726	5.3
	2212	1.3		2304	1.5
2	0430	5.3	17	0539	5.2
SA	1042	1.0	SU	1151	1.1
	1709	5.1		1817	5.0
	2255	1.4		2351	1.6
3	0516	5.1	18	0632	5.0
SU	1130	1.1	M	1246	1.3
	1804	5.0		1916	4.8
	2350	1.5			
4	0614	5.0	19	0057	1.7
M	1232	1.1	TU	0738	4.7
	1913	4.9		1358	1.3
				2023	4.7
5	0059	1.5	20	0223	1.7
TU	0724	5.0	W	0853	4.7
	1342	1.1		1505	1.3
	2026	5.0		2132	4.8
6	0212	1.4	21	0336	1.6
W	0842	5.1	TH	1004	4.7
	1454	1.0		1602	1.2
	2135	5.2		2231	4.9
7	0325	1.2	22	0433	1.3
TH	0952	5.3	F	1059	4.9
	1609	0.9		1648	1.1
	2237	5.5		2316	5.1
8	0440	1.0	23	0518	1.1
F	1055	5.5	SA	1142	5.1
	1720	0.8		1729	1.0
	2333	5.7		2356	5.3
9	0550	0.8	24	0558	0.9
SA	1153	5.7	SU	1219	5.3
	1819	0.7		1808	0.9
10	0024	5.8	25	0031	5.5
SU	0649	0.6	M	0638	0.8
	1245	5.9		1255	5.5
	1912	0.7		1849	0.8
11	0112	5.9	26	0107	5.6
M	0741	0.4	TU	0719	0.7
	1335	6.0		1331	5.6
	1957	0.7		1928	0.7
12	0158	5.9	27	0145	5.7
TU	0829	0.3	W	0801	0.6
	1423	6.1		1409	5.7
	2039	0.8		2009	0.7
13	0243	5.9	28	0222	5.7
W	0914	0.4	TH	0842	0.6
	1510	8.0		1447	5.7
	2118	0.9		2047	0.8
14	0325	5.8	29	0258	5.7
TH	0956	0.5	F	0921	0.6
	1555	5.8		1525	5.7
	2153	1.1		2122	0.9
15	0409	5.6	30	0334	5.6
F	1034	0.7	SA	0955	0.7
	1640	5.5		1604	5.5
	2227	1.3		2155	1.1
			31	0412	5.5
			SU	1026	0.8
				1647	5.3
				2230	1.2

FEBRUARY

	TIME	M		TIME	M
1	0452	5.3	16	0542	5.0
M	1101	0.9	TU	1142	1.2
	1736	5.1		1814	4.8
	2315	1.3		2353	1.6
2	0543	5.2	17	0638	4.7
TU	1149	1.1	W	1243	1.5
	1836	4.9		1913	4.6
3	0014	1.4	18	0107	1.7
W	0648	5.0	TH	0751	4.4
	1256	1.2		1404	1.6
	1951	4.9		2027	4.5
4	0133	1.5	19	0244	1.7
TH	0811	4.9	F	0919	4.4
	1420	1.2		1518	1.5
	2107	5.0		2146	4.6
5	0301	1.3	20	0357	1.4
F	0932	5.0	SA	1031	4.7
	1549	1.2		1617	1.3
	2217	5.2		2247	4.9
6	0430	1.1	21	0452	1.2
SA	1045	5.3	SU	1119	5.0
	1709	1.0		1705	1.1
	2319	5.5		2332	5.2
7	0546	0.8	22	0539	0.9
SU	1146	5.6	M	1200	5.3
	1810	0.8		1750	0.9
8	0012	5.7	23	0012	5.4
M	0643	0.5	TU	0622	0.8
	1239	5.8		1236	5.5
	1900	0.7		1832	0.8
9	0100	5.8	24	0050	5.6
TU	0733	0.3	W	0706	0.6
	1326	6.0		1314	5.7
	1942	0.7		1914	0.7
10	0145	5.9	25	0127	5.8
W	0818	0.2	TH	0748	0.5
	1411	6.0		1351	5.8
	2023	0.7		1955	0.6
11	0226	5.9	26	0204	5.9
TH	0858	0.3	F	0829	0.4
	1451	6.0		1429	5.9
	2100	0.8		2034	0.7
12	0305	5.9	27	0239	5.9
F	0935	0.4	SA	0907	0.4
	1532	5.8		1507	5.8
	2132	0.9		2108	0.8
13	0343	5.7	28	0314	5.8
SA	1006	0.7	SU	0939	0.6
	1610	5.6		1545	5.7
	2159	1.1		2138	0.9
14	0420	5.5			
SU	1031	0.9			
	1647	5.3			
	2226	1.2			
15	0458	5.3			
M	1059	1.0			
	1726	5.1			
	2301	1.4			

MARCH

	TIME	M		TIME	M
1	0352	5.7	16	0421	5.3
M	1006	0.7	TU	1020	1.0
	1624	5.4		1641	5.2
	2209	1.0		2224	1.2
2	0433	5.5	17	0501	5.0
TU	1035	0.9	W	1057	1.2
	1711	5.2		1722	4.9
	2251	1.2		2308	1.4
3	0522	5.3	18	0550	4.7
W	1120	1.1	TH	1150	1.5
	1807	4.9		1812	4.6
	2349	1.3			
4	0628	5.0	19	0012	1.6
TH	1228	1.4	F	0656	4.4
	1921	4.8		1306	1.7
				1923	4.4
5	0112	1.4	20	0144	1.7
F	0755	4.8	SA	0827	4.3
	1404	1.5		1434	1.7
	2046	4.8		2054	4.4
6	0254	1.3	21	0314	1.5
SA	0924	5.0	SU	0953	4.6
	1542	1.4		1542	1.4
	2203	5.1		2210	4.7
7	0430	1.0	22	0417	1.2
SU	1040	5.3	M	1048	5.0
	1701	1.1		1637	1.2
	2308	5.4		2302	5.1
8	0540	0.6	23	0509	0.9
M	1139	5.6	TU	1132	5.3
	1758	0.9		1725	0.9
				2344	5.4
9	0000	5.6	24	0557	0.7
TU	0634	0.4	W	1211	5.6
	1228	5.9		1811	0.8
	1845	0.7			
10	0046	5.8	25	0024	5.6
W	0719	0.2	TH	0643	0.5
	1312	6.0		1250	5.8
	1926	0.6		1855	0.7
11	0127	5.9	26	0102	5.8
TH	0758	0.2	F	0727	0.4
	1352	6.0		1328	6.0
	2002	0.6		1937	0.6
12	0205	5.9	27	0140	6.0
F	0834	0.3	SA	0809	0.4
	1429	6.0		1406	6.0
	2036	0.6		2016	0.6
13	0242	5.9	28	0216	6.0
SA	0905	0.4	SU	0847	0.4
	1504	5.8		1444	6.0
	2105	0.8		2051	0.6
14	0315	5.7	29	0253	6.0
SU	0932	0.7	M	0919	0.5
	1536	5.6		1522	5.8
	2131	0.9		2124	0.7
15	0349	5.5	30	0334	5.9
M	0955	0.9	TU	0949	0.7
	1607	5.4		1603	5.5
	2153	1.1		2159	0.9
			31	0417	5.6
			W	1021	1.0
				1649	5.2
				2242	

APRIL

	TIME	M		TIME	M
1	0511	5.3	16	0513	4.8
TH	1109	1.3	F	1113	1.5
	1749	5.0		1727	4.7
	2343	1.2		2333	1.5
2	0621	5.0	17	0612	4.5
F	1219	1.5	SA	1219	1.7
	1903	4.8		1831	4.5
3	0112	1.3	18	0055	1.6
SA	0748	4.9	SU	0734	4.4
	1358	1.6		1345	1.7
	2027	4.8		1957	4.4
4	0257	1.1	19	0225	1.4
SU	0915	5.1	M	0904	4.6
	1534	1.4		1500	1.5
	2146	5.1		2122	4.7
5	0421	0.8	20	0332	1.1
M	1027	5.5	TU	1007	5.0
	1647	1.1		1559	1.2
	2251	5.4		2221	5.0
6	0525	0.5	21	0430	0.9
TU	1123	5.8	W	1057	5.4
	1740	0.9		1651	1.0
	2343	5.6		2309	5.4
7	0614	0.3	22	0523	0.6
W	1211	5.9	TH	1140	5.7
	1824	0.7		1740	0.8
				2353	5.6
8	0027	5.7	23	0614	0.5
TH	0655	0.3	F	1221	5.9
	1252	5.9		1828	0.7
	1902	0.6			
9	0106	5.8	24	0034	5.9
F	0731	0.3	SA	0700	0.4
	1328	5.9		1302	6.0
	1935	0.6		1913	0.6
10	0141	5.8	25	0113	6.0
SA	0802	0.4	SU	0744	0.4
	1402	5.9		1342	6.1
	2009	0.6		1957	0.5
11	0215	5.8	26	0154	6.1
SU	0832	0.5	M	0825	0.4
	1434	5.8		1422	6.0
	2039	0.7		2036	0.5
12	0247	5.7	27	0234	6.1
M	0858	0.7	TU	0903	0.6
	1503	5.6		1504	5.8
	2104	0.8		2115	0.6
13	0318	5.5	28	0319	6.0
TU	0922	0.9	W	0938	0.8
	1532	5.4		1548	5.6
	2128	1.0		2157	0.8
14	0352	5.3	29	0410	5.7
W	0949	1.1	TH	1017	1.1
	1603	5.2		1637	5.3
	2157	1.1		2245	0.9
15	0428	5.1	30	0508	5.4
TH	1026	1.3	F	1108	1.4
	1641	5.0		1736	5.1
	2237	1.3		2349	1.1

HEIGHTS IN METRES

ENGLAND, EAST COAST - SHEERNESS

LAT 51°27'N LONG 0°45'E

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

MAY

	TIME	M		TIME	M
1	0617	5.2	16	0540	4.7
SA	1217	1.6	SU	1143	1.6
	1846	4.9		1753	4.7
2	0116	1.1	17	0017	1.4
SU	0737	5.1	M	0648	4.8
	1347	1.6		1258	1.7
	2006	5.0		1904	4.6
3	0244	0.9	18	0135	1.3
M	0857	5.3	TU	0809	4.8
	1511	1.4		1411	1.5
	2122	5.2		2026	4.7
4	0400	0.6	19	0244	1.1
TU	1006	5.6	W	0919	5.1
	1621	1.1		1512	1.3
	2227	5.4		2135	5.0
5	0501	0.5	20	0343	0.8
W	1101	5.8	TH	1016	5.4
	1715	0.9		1610	1.0
	2319	5.6		2230	5.3
6	0547	0.4	21	0442	0.6
TH	1149	5.8	F	1106	5.7
	1757	0.8		1705	0.8
				2319	5.6
7	0003	5.6	22	0540	0.5
F	0625	0.5	SA	1153	5.9
	1228	5.8		1800	0.7
	1834	0.7			
8	0041	5.7	23	0005	5.9
SA	0657	0.5	SU	0634	0.5
	1303	5.8		1236	6.0
	1907	0.6		1852	0.6
9	0116	5.7	24	0050	6.0
SU	0728	0.6	M	0721	0.4
	1334	5.7		1321	6.0
	1941	0.6		1940	0.5
10	0148	5.7	25	0135	6.1
M	0758	0.6	TU	0806	0.5
	1404	5.7		1405	6.0
	2012	0.7		2026	0.5
11	0220	5.6	26	0222	6.1
TU	0827	0.8	W	0849	0.6
	1433	5.6		1450	5.8
	2042	0.8		2112	0.5
12	0254	5.5	27	0312	6.0
W	0856	0.9	TH	0931	0.8
	1503	5.5		1536	5.7
	2108	0.9		2200	0.6
13	0328	5.3	28	0404	5.9
TH	0927	1.1	F	1014	1.1
	1535	5.3		1628	5.5
	2139	1.0		2251	0.7
14	0406	5.1	29	0501	5.6
F	1002	1.3	SA	1104	1.3
	1613	5.1		1723	5.3
	2217	1.2		2351	0.8
15	0448	4.9	30	0604	5.4
SA	1045	1.5	SU	1204	1.5
	1657	4.9		1827	5.2
	2308	1.3			
			31	0103	0.9
			M	0714	5.3
				1319	1.5
				1937	5.2

JUNE

	TIME	M		TIME	M
1	0218	0.8	16	0050	1.1
TU	0826	5.4	W	0720	4.9
	1436	1.4		1319	1.5
	2050	5.2		1934	4.9
2	0327	0.7	17	0157	1.0
W	0935	5.5	TH	0832	5.1
	1545	1.2		1425	1.3
	2156	5.4		2047	5.0
3	0426	0.6	18	0301	0.9
TH	1033	5.6	F	0936	5.3
	1641	1.1		1528	1.1
	2251	5.4		2150	5.3
4	0512	0.6	19	0403	0.7
F	1120	5.8	SA	1034	5.6
	1726	1.0		1631	1.0
	2337	5.5		2248	5.5
5	0550	0.7	20	0509	0.6
SA	1201	5.6	SU	1126	5.8
	1805	0.9		1736	0.8
				2342	5.8
6	0017	5.5	21	0611	0.6
SU	0622	0.7	M	1217	5.9
	1236	5.6		1835	0.6
	1841	0.8			
7	0053	5.5	22	0034	6.0
M	0655	0.7	TU	0704	0.6
	1307	5.6		1304	5.9
	1914	0.7		1930	0.5
8	0126	5.5	23	0124	6.1
TU	0727	0.7	W	0754	0.6
	1338	5.6		1352	5.9
	1948	0.7		2020	0.4
9	0159	5.5	24	0215	6.1
W	0801	0.8	TH	0839	0.6
	1409	5.6		1439	5.9
	2022	0.8		2110	0.3
10	0234	5.5	25	0304	6.1
TH	0834	0.9	F	0924	0.8
	1443	5.5		1527	5.8
	2056	0.9		2157	0.4
11	0310	5.4	26	0356	6.0
F	0908	1.0	SA	1008	1.0
	1518	5.4		1614	5.7
	2129	1.0		2247	0.5
12	0348	5.3	27	0448	5.8
SA	0945	1.2	SU	1049	1.2
	1555	5.2		1705	5.5
	2207	1.0		2337	0.7
13	0430	5.1	28	0542	5.6
SU	1026	1.3	M	1137	1.4
	1637	5.1		1800	5.4
	2252	1.1			
14	0516	5.0	29	0032	0.8
M	1113	1.5	TU	0642	5.4
	1725	4.9		1236	1.5
	2347	1.2		1900	5.3
15	0611	4.9	30	0135	0.9
TU	1212	1.5	W	0747	5.3
	1822	4.8		1347	1.5
				2008	5.2

JULY

	TIME	M		TIME	M
1	0240	0.9	16	0109	1.1
TH	0854	5.2	F	0748	5.0
	1500	1.4		1338	1.4
	2118	5.1		2004	5.0
2	0341	0.9	17	0219	1.0
F	0956	5.3	SA	0900	5.1
	1603	1.3		1451	1.3
	2220	5.2		2118	5.2
3	0431	0.9	18	0334	1.0
SA	1051	5.3	SU	1006	5.3
	1654	1.1		1606	1.1
	2312	5.2		2226	5.4
4	0513	0.9	19	0448	0.9
SU	1134	5.3	M	1106	5.5
	1737	1.0		1719	0.9
	2356	5.3		2327	5.7
5	0550	0.9	20	0556	0.8
M	1212	5.4	TU	1201	5.7
	1817	0.9		1825	0.6
6	0034	5.3	21	0024	5.9
TU	0625	0.9	W	0652	0.7
	1245	5.4		1253	5.8
	1853	0.8		1923	0.4
7	0107	5.4	22	0116	6.1
W	0702	0.8	TH	0741	0.6
	1319	5.5		1341	5.9
	1930	0.8		2013	0.3
8	0142	5.5	23	0205	6.2
TH	0738	0.8	F	0827	0.6
	1352	5.6		1427	5.9
	2006	0.8		2101	0.2
9	0218	5.5	24	0253	6.2
F	0816	0.9	SA	0910	0.7
	1429	5.5		1512	5.9
	2044	0.8		2146	0.3
10	0254	5.5	25	0339	6.0
SA	0853	0.9	SU	0949	0.9
	1504	5.5		1556	5.8
	2122	0.8		2228	0.5
11	0332	5.5	26	0426	5.8
SU	0931	1.0	M	1027	1.1
	1541	5.4		1640	5.7
	2159	0.9		2309	0.7
12	0410	5.4	27	0512	5.6
M	1006	1.2	TU	1102	1.3
	1617	5.3		1726	5.5
	2237	1.0		2349	0.9
13	0452	5.2	28	0601	5.3
TU	1045	1.3	W	1144	1.5
	1659	5.2		1817	5.2
	2318	1.0			
14	0540	5.1	29	0036	1.1
W	1132	1.4	TH	0656	5.1
	1747	5.1		1242	1.6
				1919	5.0
15	0008	1.1	30	0140	1.3
TH	0638	5.0	F	0801	4.9
	1229	1.4		1402	1.6
	1849	5.0		2032	4.9
			31	0249	1.3
			SA	0911	4.9
				1519	1.5
				2148	4.9

AUGUST

	TIME	M		TIME	M
1	0348	1.3	16	0314	1.3
SU	1016	4.9	M	0943	5.1
	1623	1.3		1552	1.2
	2248	5.0		2214	5.3
2	0438	1.2	17	0435	1.1
M	1108	5.1	TU	1051	5.4
	1713	1.2		1713	0.9
	2336	5.1		2320	5.6
3	0522	1.1	18	0544	0.9
TU	1149	5.2	W	1150	5.6
	1756	1.0		1819	0.6
4	0014	5.3	19	0017	5.9
W	0603	1.0	TH	0639	0.8
	1225	5.3		1241	5.8
	1834	0.9		1913	0.3
5	0049	5.4	20	0106	6.1
TH	0641	0.9	F	0727	0.7
	1300	5.5		1326	5.9
	1912	0.8		2001	0.2
6	0124	5.5	21	0152	6.2
F	0719	0.8	SA	0811	0.6
	1335	5.6		1409	6.0
	1951	0.7		2044	0.2
7	0159	5.6	22	0236	6.1
SA	0758	0.8	SU	0850	0.7
	1411	5.7		1451	6.0
	2030	0.7		2125	0.3
8	0234	5.7	23	0317	6.0
SU	0836	0.8	M	0925	0.9
	1446	5.7		1531	5.9
	2108	0.7		2200	0.6
9	0311	5.7	24	0356	5.8
M	0912	0.9	TU	0956	1.1
	1521	5.6		1609	5.7
	2143	0.8		2230	0.9
10	0348	5.6	25	0435	5.5
TU	0945	1.0	W	1023	1.3
	1555	5.5		1648	5.4
	2216	0.9		2258	1.1
11	0427	5.4	26	0515	5.2
W	1017	1.2	TH	1055	1.4
	1633	5.4		1732	5.2
	2247	1.0		2333	1.3
12	0509	5.2	27	0600	4.9
TH	1057	1.3	F	1140	1.6
	1718	5.2		1825	4.8
	2327	1.1			
13	0603	5.0	28	0029	1.6
F	1147	1.4	SA	0658	4.7
	1815	5.1		1250	1.8
				1935	4.6
14	0025	1.2	29	0148	1.7
SA	0710	4.9	SU	0809	4.5
	1257	1.5		1430	1.7
	1933	4.9		2107	4.6
15	0145	1.3	30	0305	1.6
SU	0829	4.9	M	0934	4.6
	1425	1.4		1549	1.5
	2057	5.0		2221	4.8
			31	0406	1.4
			TU	1037	4.9
				1645	1.3
				2312	5.1

HEIGHTS IN METRES

ENGLAND, EAST COAST - SHEERNESS

LAT 51°27'N LONG 0°45'E

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

SEPTEMBER

	TIME	M		TIME	M
1	0455	1.2	16	0532	1.0
W	1123	5.1	TH	1136	5.6
	1732	1.1		1808	0.5
	2350	5.3			
2	0539	1.1	17	0004	5.9
TH	1201	5.3	F	0624	0.8
	1811	0.9		1224	5.8
				1657	0.3
3	0025	5.5	18	0050	6.1
F	0618	0.9	SA	0707	0.7
	1236	5.5		1305	5.9
	1850	0.8		1940	0.3
4	0100	5.6	19	0133	6.1
SA	0657	0.8	SU	0745	0.7
	1312	5.7		1347	6.0
	1930	0.7		2019	0.3
5	0135	5.8	20	0212	6.0
SU	0737	0.8	M	0822	0.7
	1347	5.8		1425	6.0
	2009	0.6		2053	0.5
6	0211	5.8	21	0249	5.9
M	0815	0.8	TU	0854	0.8
	1420	5.8		1501	5.9
	2047	0.6		2122	0.8
7	0246	5.8	22	0322	5.7
TU	0850	0.8	W	0922	1.0
	1456	5.8		1535	5.6
	2121	0.7		2146	1.0
8	0322	5.7	23	0355	5.4
W	0921	1.0	TH	0945	1.2
	1531	5.7		1610	5.4
	2149	0.9		2210	1.2
9	0400	5.5	24	0428	5.1
TH	0950	1.1	F	1010	1.4
	1609	5.6		1648	5.1
	2216	1.1		2242	1.5
10	0442	5.2	25	0506	4.9
F	1028	1.3	SA	1051	1.6
	1654	5.3		1736	4.8
	2255	1.3		2332	1.7
11	0533	5.0	26	0556	4.6
SA	1120	1.4	SU	1151	1.8
	1753	5.0		1841	4.5
	2354	1.5			
12	0642	4.8	27	0045	1.9
SU	1234	1.5	M	0704	4.4
	1914	4.9		1326	1.9
				2013	4.4
13	0124	1.6	28	0218	1.9
M	0806	4.8	TU	0837	4.4
	1416	1.5		1505	1.7
	2047	5.0		2143	4.6
14	0307	1.5	29	0329	1.6
TU	0929	5.0	W	0957	4.7
	1552	1.1		1609	1.3
	2207	5.3		2237	5.0
15	0428	1.2	30	0423	1.3
W	1038	5.3	TH	1048	5.1
	1709	0.8		1657	1.1
	2312	5.7		2319	5.3

OCTOBER

	TIME	M		TIME	M
1	0508	1.1	16	0601	0.9
F	1129	5.4	SA	1203	5.8
	1739	0.9		1835	0.4
	2356	5.6			
2	0549	0.9	17	0029	6.0
SA	1207	5.6	SU	0641	0.8
	1819	0.7		1243	5.9
				1912	0.5
3	0031	5.8	18	0109	6.0
SU	0629	0.6	M	0717	0.7
	1242	5.8		1320	5.9
	1900	0.6		1945	0.5
4	0107	5.9	19	0144	5.9
M	0710	0.7	TU	0751	0.7
	1317	5.9		1355	5.9
	1941	0.6		2015	0.7
5	0144	6.0	20	0216	5.8
TU	0748	0.7	W	0822	0.8
	1352	6.0		1430	5.8
	2019	0.6		2043	0.9
6	0220	5.9	21	0247	5.6
W	0825	0.8	TH	0849	1.0
	1429	6.0		1503	5.6
	2053	0.7		2107	1.1
7	0257	5.8	22	0317	5.4
TH	0858	0.9	F	0912	1.2
	1507	5.9		1536	5.4
	2122	0.9		2132	1.3
8	0336	5.5	23	0348	5.2
F	0932	1.1	SA	0938	1.3
	1550	5.7		1613	5.1
	2155	1.2		2203	1.5
9	0420	5.2	24	0421	5.0
SA	1013	1.2	SU	1013	1.5
	1640	5.4		1657	4.8
	2237	1.4		2248	1.7
10	0513	4.9	25	0506	4.7
SU	1109	1.4	M	1106	1.7
	1744	5.0		1754	4.5
	2342	1.7		2353	1.9
11	0624	4.7	26	0607	4.5
M	1232	1.5	TU	1227	1.8
	1909	4.9		1912	4.4
12	0117	1.8	27	0119	2.0
TU	0749	4.8	W	0731	4.4
	1420	1.4		1405	1.7
	2039	5.0		2044	4.5
13	0257	1.6	28	0239	1.7
W	0912	5.0	TH	0901	4.6
	1548	1.0		1517	1.4
	2156	5.4		2150	4.9
14	0414	1.3	29	0339	1.4
TH	1021	5.4	F	1003	5.0
	1657	0.6		1610	1.1
	2257	5.6		2238	5.3
15	0513	1.0	30	0428	1.2
F	1116	5.7	SA	1049	5.3
	1750	0.4		1658	0.8
	2347	5.9		2319	5.6
31	0513	0.9			
SU	1130	5.6			
	1744	0.7			
	2356	5.8			

NOVEMBER

	TIME	M		TIME	M
1	0558	0.8	16	0042	5.8
M	1210	5.8	TU	0646	0.8
	1829	0.6		1255	5.7
				1909	0.7
2	0038	6.0	17	0116	5.7
TU	0642	0.7	W	0720	0.8
	1248	6.0		1330	5.7
	1912	0.5		1937	0.8
3	0117	6.0	18	0147	5.7
W	0724	0.7	TH	0752	0.8
	1327	6.1		1402	5.7
	1952	0.6		2006	0.9
4	0155	5.9	19	0216	5.6
TH	0805	0.7	F	0822	0.9
	1408	6.1		1436	5.6
	2030	0.7		2034	1.0
5	0236	5.8	20	0246	5.5
F	0846	0.8	SA	0849	1.0
	1451	6.0		1511	5.4
	2105	0.9		2104	1.2
6	0318	5.6	21	0317	5.3
SA	0927	1.0	SU	0915	1.2
	1539	5.7		1548	5.2
	2145	1.2		2136	1.4
7	0406	5.3	22	0352	5.1
SU	1013	1.1	M	0950	1.3
	1634	5.4		1628	5.0
	2231	1.5		2217	1.6
8	0502	5.0	23	0434	4.9
M	1113	1.3	TU	1038	1.4
	1740	5.2		1718	4.7
	2336	1.8		2312	1.7
9	0610	4.9	24	0526	4.7
TU	1238	1.3	W	1143	1.5
	1859	5.0		1819	4.6
10	0103	1.8	25	0021	1.8
W	0728	4.9	TH	0632	4.6
	1411	1.2		1303	1.5
	2020	5.2		1938	4.6
11	0233	1.7	26	0138	1.8
TH	0847	5.1	F	0755	4.6
	1528	0.9		1418	1.3
	2134	5.4		2053	4.9
12	0348	1.4	27	0244	1.5
F	0955	5.4	SA	0907	4.9
	1633	0.6		1518	1.1
	2233	5.7		2152	5.2
13	0447	1.1	28	0342	1.3
SA	1051	5.6	SU	1003	5.2
	1725	0.6		1613	0.8
	2323	5.8		2241	5.5
14	0533	1.0	29	0435	1.0
SU	1137	5.7	M	1052	5.5
	1805	0.6		1706	0.7
				2327	5.8
15	0005	5.8	30	0527	0.9
M	0612	0.9	TU	1139	5.8
	1218	5.7		1758	0.6
	1838	0.7			

DECEMBER

	TIME	M		TIME	M
1	0011	5.9	16	0050	5.6
W	0618	0.8	TH	0656	0.8
	1224	5.9		1309	5.5
	1848	0.6		1906	0.8
2	0055	5.9	17	0121	5.6
TH	0707	0.7	F	0730	0.8
	1309	6.1		1344	5.5
	1933	0.6		1940	0.9
3	0138	5.9	18	0152	5.6
F	0755	0.7	SA	0802	0.8
	1355	6.1		1418	5.5
	2016	0.7		2012	0.9
4	0222	5.8	19	0225	5.5
SA	0842	0.7	SU	0834	0.9
	1443	6.0		1453	5.4
	2058	0.9		2044	1.1
5	0308	5.6	20	0258	5.4
SU	0931	0.8	M	0905	1.0
	1535	5.8		1529	5.3
	2142	1.2		2118	1.2
6	0357	5.5	21	0334	5.3
M	1021	0.9	TU	0939	1.1
	1630	5.6		1609	5.2
	2228	1.4		2156	1.3
7	0451	5.3	22	0412	5.1
TU	1118	1.0	W	1020	1.2
	1730	5.4		1651	5.0
	2323	1.6		2240	1.5
8	0551	5.1	23	0455	5.0
W	1227	1.1	TH	1111	1.2
	1838	5.2		1740	4.9
				2333	1.6
9	0032	1.7	24	0547	4.8
TH	0659	5.1	F	1211	1.3
	1341	1.0		1842	4.8
	1949	5.2			
10	0152	1.7	25	0038	1.6
F	0811	5.1	SA	0652	4.8
	1453	0.9		1319	1.2
	2100	5.3		1954	4.8
11	0307	1.5	26	0147	1.6
SA	0921	5.3	SU	0808	4.8
	1556	0.8		1426	1.1
	2203	5.4		2103	5.1
12	0412	1.3	27	0254	1.4
SU	1021	5.4	M	0918	5.0
	1648	0.8		1529	0.9
	2255	5.5		2204	5.3
13	0502	1.1	28	0359	1.2
M	1113	5.4	TU	1019	5.3
	1730	0.8		1633	0.8
	2340	5.5		2259	5.6
14	0544	1.0	29	0501	1.0
TU	1157	5.5	W	1115	5.6
	1803	0.8		1734	0.7
				2350	5.7
15	0018	5.5	30	0601	0.8
W	0621	0.9	TH	1207	5.8
	1234	5.5		1831	0.7
	1834	0.8			
31	0039	5.8			
F	0659	0.6			
	1257	6.0			
	1923	0.7			

HEIGHTS IN METRES

SCOTLAND, WEST COAST - GREENOCK

LAT 55°57'N LONG 4°46'W

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

MAY

	TIME	M		TIME	M
1	0525	3.2	16	0510	3.0
SA	1215	0.7	SU	1141	0.9
	1854	2.8		1754	2.8
2	0109	0.9	17	0001	1.2
SU	0634	3.0	M	0607	2.9
	1340	0.6		1252	0.9
	2058	2.7		1857	2.8
3	0222	0.8	18	0118	1.2
M	0824	2.9	TU	0726	2.9
	1446	0.5		1356	0.7
	2203	2.9		2021	2.8
4	0320	0.6	19	0225	1.1
TU	0940	3.0	W	0853	3.0
	1536	0.3		1449	0.6
	2246	3.0		2128	3.0
5	0405	0.5	20	0317	0.9
W	1030	3.1	TH	0952	3.1
	1618	0.3		1535	0.4
	2323	3.1		2217	3.1

JUNE

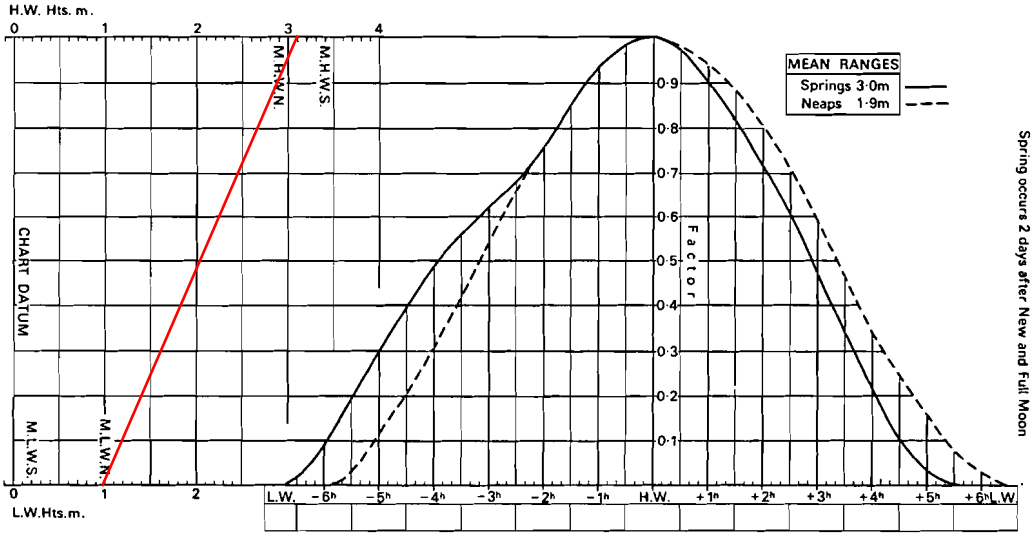
	TIME	M		TIME	M
1	0149	0.8	16	0020	1.1
TU	0738	2.9	W	0635	3.0
	1409	0.5		1300	0.7
	2124	2.8		1922	2.9
2	0247	0.7	17	0128	1.1
W	0858	2.9	TH	0756	3.0
	1503	0.5		1401	0.6
	2211	2.9		2036	3.0
3	0336	0.6	18	0233	0.9
TH	0954	3.0	F	0909	3.1
	1548	0.5		1457	0.5
	2251	3.0		2138	3.1
4	0418	0.6	19	0328	0.7
F	1041	3.1	SA	1008	3.3
	1629	0.5		1548	0.4
	2329	3.1		2229	3.3
5	0456	0.5	20	0416	0.5
SA	1125	3.2	SU	1103	3.3
	1708	0.5		1637	0.3
				2320	3.4

JULY

	TIME	M		TIME	M
1	0208	0.8	16	0039	1.0
TH	0807	2.9	F	0711	3.1
	1424	0.7		1320	0.7
	2130	2.8		1948	3.0
2	0304	0.8	17	0156	1.0
F	0914	2.9	SA	0833	3.1
	1518	0.7		1428	0.6
	2219	3.0		2102	3.1
3	0352	0.7	18	0304	0.8
SA	1009	3.0	SU	0945	3.1
	1605	0.7		1529	0.6
	2301	3.1		2205	3.2
4	0436	0.6	19	0401	0.6
SU	1057	3.0	M	1047	3.2
	1648	0.7		1623	0.5
	2340	3.2		2301	3.4
5	0516	0.5	20	0451	0.4
M	1142	3.0	TU	1147	3.2
	1728	0.6		1714	0.4
				2354	3.5

AUGUST

	TIME	M		TIME	M
1	0329	0.8	16	0253	0.8
SU	0939	2.8	M	0930	3.0
	1545	0.9		1521	0.7
	2236	3.0		2152	3.1
2	0417	0.7	17	0352	0.5
M	1035	2.9	TU	1046	3.0
	1631	0.8		1615	0.5
	2319	3.1		2252	3.3
3	0458	0.6	18	0442	0.3
TU	1123	2.9	W	1145	3.1
	1711	0.7		1704	0.4
	2357	3.2		2345	3.4
4	0535	0.4	19	0528	0.2
W	1207	2.9	TH	1239	3.1
	1745	0.6		1750	0.4
5	0031	3.2	20	0037	3.6
TH	0608	0.3	F	0612	0.1
	1247	2.9		1330	3.1
	1816	0.6		1835	0.4



GREENOCK
MEAN SPRING AND NEAP CURVES
Spring occurs 2 days after New and Full Moon

ENGLAND, WEST COAST - PORT OF BRISTOL (AVONMOUTH)

LAT 51°30'N LONG 2°43'W

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

SEPTEMBER

	TIME	M		TIME	M
11	0608	3.1	**26**	0003	9.5
	1210	10.4		0615	3.8
SA	1834	3.6	SU	1235	9.1
				1848	4.3
12	0100	10.1	**27**	0114	8.8
	0709	3.7		0716	4.6
SU	1340	10.0	M	1426	8.8
	2004	4.0		2040	4.7
13	0233	10.0	**28**	0310	9.0
	0905	3.8		0938	4.5
M	1511	10.3	TU	1600	9.6
	2200	3.4		2226	3.8
14	0400	10.7	**29**	0427	9.8
	1038	3.0		1051	3.5
TU	1634	11.2	W	1655	10.6
	2327	2.4		2323	2.8

OCTOBER

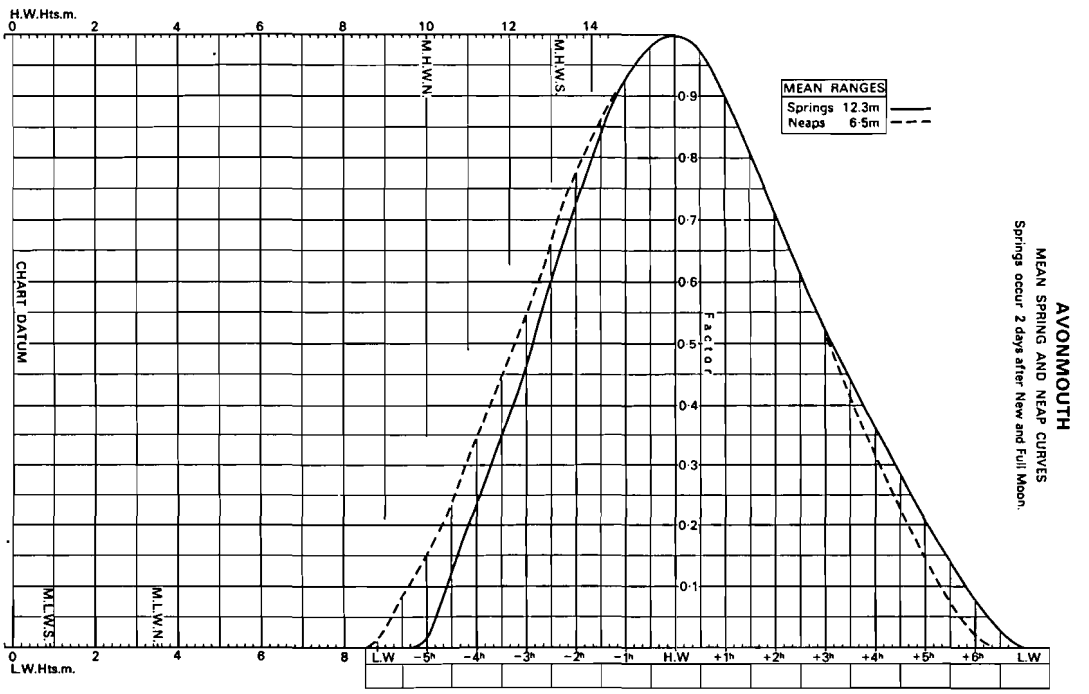
	TIME	M		TIME	M
11	0055	9.9	**26**	0015	8.8
	0700	3.9		0628	4.4
M	1328	9.9	TU	1300	8.7
	1959	3.9		1919	4.6
12	0220	9.9	**27**	0154	8.6
	0853	3.8		0751	4.7
TU	1457	10.3	W	1500	9.1
	2145	3.2		2122	4.3
13	0348	10.6	**28**	0331	9.4
	1021	2.9		0953	4.1
W	1620	11.3	TH	1603	10.2
	2306	2.2		2233	3.3
14	0459	11.7	**29**	0428	10.5
	1139	1.8		1058	3.1
TH	1723	12.3	F	1652	11.3
				2329	2.5

NOVEMBER

	TIME	M		TIME	M
11	0321	10.8	**26**	0218	9.6
	0952	2.8		0826	4.1
TH	1553	11.3	F	1503	10.2
	2230	2.2		2121	3.5
12	0433	11.7	**27**	0334	10.4
	1104	2.0		0953	3.4
F	1657	12.2	SA	1604	11.2
	2340	1.6		2231	2.7
13	0526	12.5	**28**	0431	11.5
	1207	1.4		1104	2.7
SA	1747	12.8	SU	1658	12.2
				2339	2.1
14	0035	1.2	**29**	0525	12.4
	0612	13.0		1212	2.0
SU	1257	1.2	M	1750	13.0
	1829	13.1			

DECEMBER

	TIME	M		TIME	M
11	0353	11.3	**26**	0237	10.5
	1016	2.5		0953	3.6
SA	1621	11.7	SU	1518	11.1
	2249	2.2		2142	3.0
12	0452	11.9	**27**	0349	11.3
	1120	2.1		1020	3.1
SU	1716	12.2	M	1623	11.9
	2351	2.0		2258	2.4
13	0543	12.4	**28**	0451	12.1
	1218	1.8		1136	2.4
M	1803	12.5	TU	1722	12.6
14	0042	1.7	**29**	0011	1.9
	0625	12.7		0550	12.8
TU	1304	1.6	W	1248	1.8
	1845	12.7		1819	13.1



IRELAND, NORTH COAST - LONDONDERRY

LAT 55°00'N LONG 7°19'W

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

MAY

	TIME	M		TIME	M
7 F	0131	0.4	22 SA	0113	0.4
	0748	2.5		0720	2.8
	1409	0.4		1335	0.3
	2001	2.5		1942	2.6
8 SA	0209	0.4	23 SU	0201	0.3
	0820	2.5		0805	2.8
	1443	0.4		1419	0.2
	2034	2.6		2023	2.7
9 SU	0246	0.4	24 M	0247	0.3
	0851	2.4		0850	2.8
	1515	0.4		1503	0.2
	2105	2.6		2105	2.7
10 M	0321	0.5	25 TU	0335	0.3
	0921	2.4		0935	2.7
	1546	0.5		1545	0.3
	2136	2.5		2148	2.7
11 TU	0353	0.6	26 W	0423	0.4
	0949	2.3		1021	2.5
	1617	0.5		1628	0.4
	2209	2.5		2233	2.6

JUNE

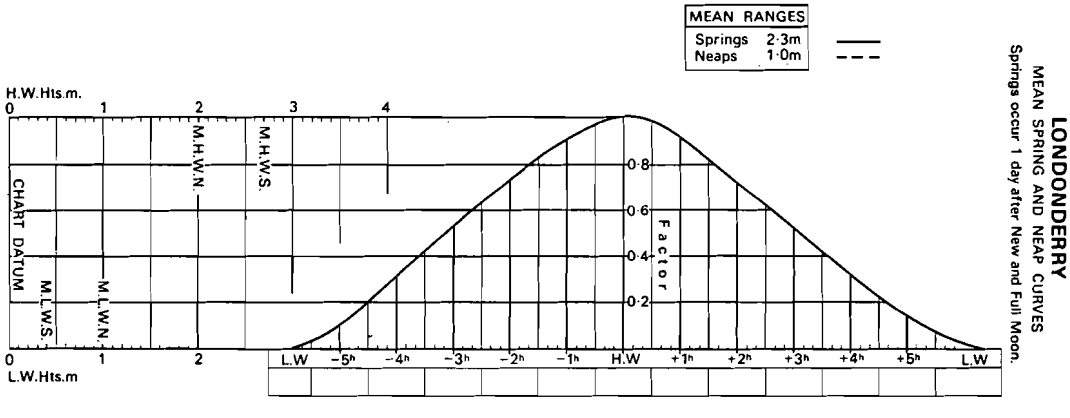
	TIME	M		TIME	M
7 M	0227	0.6	22 TU	0237	0.4
	0830	2.3		0837	2.7
	1450	0.5		1446	0.3
	2044	2.5		2054	2.8
8 TU	0304	0.6	23 W	0328	0.3
	0901	2.3		0924	2.7
	1524	0.5		1531	0.3
	2118	2.6		2139	2.8
9 W	0339	0.6	24 TH	0416	0.4
	0932	2.2		1012	2.5
	1556	0.5		1614	0.4
	2152	2.5		2224	2.7
10 TH	0414	0.7	25 F	0506	0.5
	1006	2.2		1059	2.4
	1631	0.6		1659	0.5
	2227	2.5		2313	2.6
11 F	0452	0.7	26 SA	0600	0.6
	1044	2.1		1153	2.2
	1709	0.7		1746	0.6
	2308	2.4			

JULY

	TIME	M		TIME	M
7 W	0250	0.7	22 TH	0318	0.3
	0844	2.3		0910	2.7
	1503	0.5		1515	0.3
	2100	2.6		2127	2.9
8 TH	0325	0.7	23 F	0404	0.4
	0918	2.3		0955	2.6
	1536	0.5		1557	0.3
	2134	2.6		2210	2.9
9 F	0400	0.7	24 SA	0449	0.4
	0950	2.3		1038	2.5
	1612	0.5		1640	0.4
	2209	2.6		2255	2.7
10 SA	0435	0.7	25 SU	0536	0.5
	1026	2.2		1125	2.3
	1647	0.6		1722	0.5
	2247	2.6		2342	2.5
11 SU	0513	0.7	26 M	0625	0.7
	1105	2.1		1214	2.1
	1725	0.7		1805	0.7
	2329	2.5			

AUGUST

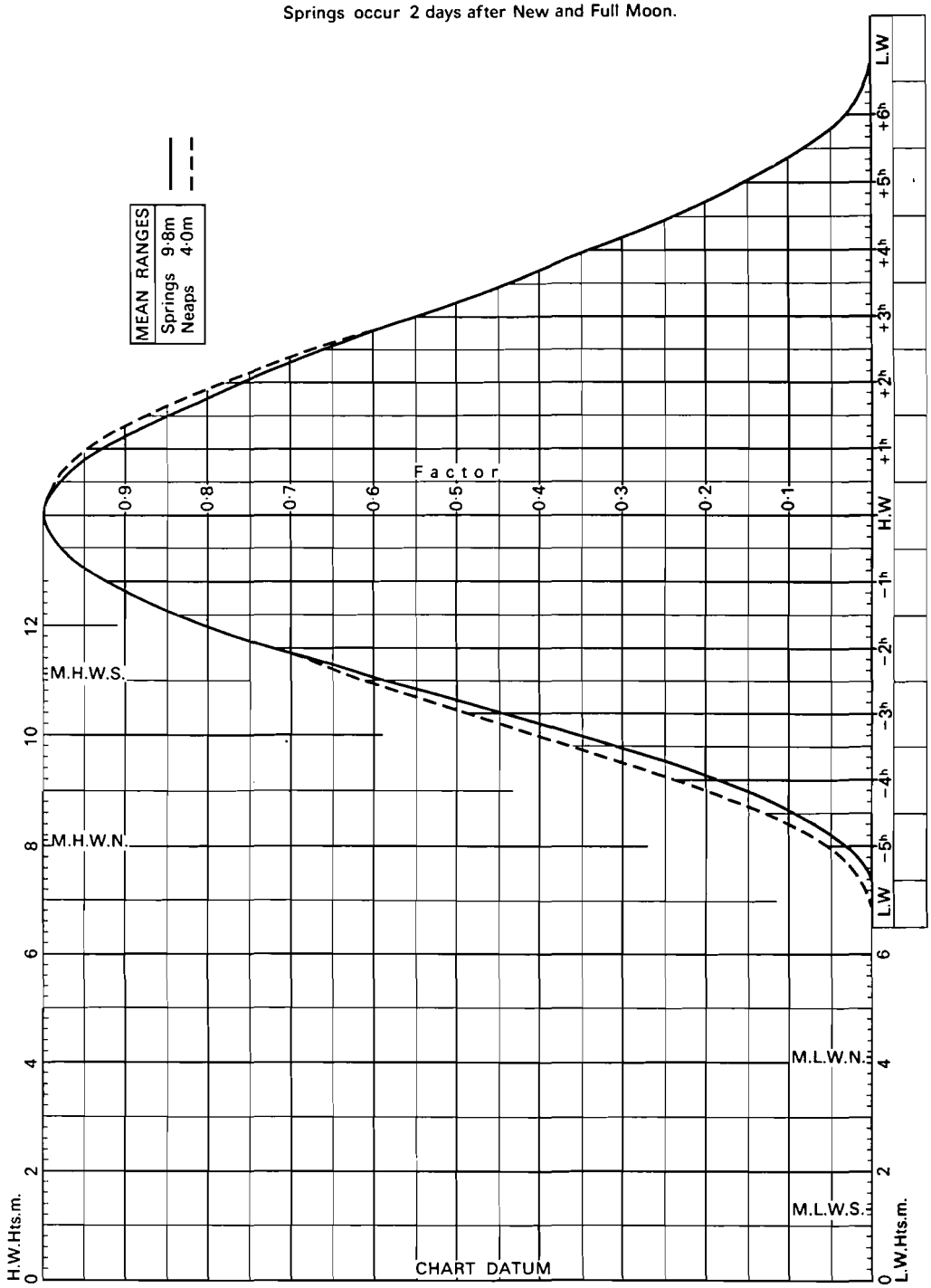
	TIME	M		TIME	M
7 SA	0338	0.6	22 SU	0424	0.4
	0931	2.4		1012	2.6
	1548	0.5		1614	0.3
	2148	2.8		2228	2.8
8 SU	0412	0.6	23 M	0504	0.5
	1003	2.4		1051	2.4
	1621	0.5		1654	0.5
	2223	2.8		2306	2.5
9 M	0448	0.6	24 TU	0544	0.7
	1040	2.3		1130	2.3
	1658	0.6		1732	0.6
	2304	2.7		2347	2.3
10 TU	0527	0.7	25 W	0628	0.9
	1118	2.2		1215	2.1
	1737	0.7		1815	0.8
	2349	2.5			
11 W	0612	0.7	26 TH	0035	2.1
	1204	2.1		0723	1.0
	1825	0.8		1313	2.0
				1909	1.0



ST HELIER

MEAN SPRING AND NEAP CURVES

Springs occur 2 days after New and Full Moon.



DDD

CHANNEL ISLANDS - ST. HELIER

LAT 49°11'N LONG 2°07'W

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

JANUARY

	TIME	M		TIME	M
1	0403	3.0	16	0502	3.2
F	0948	9.6	SA	1045	9.2
	1627	2.9		1727	3.3
	2210	9.3		2316	8.7
2	0440	3.4	17	0543	3.7
SA	1033	9.3	SU	1134	8.7
	1709	3.3		1812	3.8
	2301	9.0			
3	0530	3.7	18	0011	8.2
SU	1129	9.0	M	0638	4.1
	1807	3.5		1236	8.2
				1917	4.1
4	0005	8.8	19	0121	8.0
M	0639	3.8	TU	0749	4.1
	1242	8.8		1351	8.1
	1923	3.5		2030	4.1
5	0123	8.8	20	0236	8.2
TU	0804	3.6	W	0901	3.9
	1401	9.0		1504	8.2
	2042	3.2		2136	3.8
6	0240	9.2	21	0339	8.5
W	0919	3.1	TH	1004	3.5
	1514	9.5		1606	8.6
	2153	2.7		2234	3.4
7	0346	9.8	22	0434	9.0
TH	1027	2.5	F	1059	3.1
	1619	10.1		1658	9.0
	2257	2.1		2325	3.0
8	0447	10.5	23	0520	9.5
F	1129	1.8	SA	1150	2.6
	1718	10.6		1744	9.4
	2357	1.6			
9	0543	11.0	24	0011	2.6
SA	1228	1.3	SU	0603	9.9
	1812	11.0		1236	2.2
				1824	9.8
10	0053	1.2	25	0056	2.3
SU	0634	11.3	M	0641	10.2
	1324	0.9		1319	1.9
	1903	11.2		1900	10.1
11	0145	1.1	26	0135	2.0
M	0721	11.4	TU	0716	10.5
	1413	0.8		1358	1.7
	1951	11.2		1935	10.3
12	0233	1.1	27	0212	1.9
TU	0806	11.3	W	0749	10.7
	1458	1.0		1433	1.6
	2033	10.9		2008	10.4
13	0315	1.5	28	0247	1.9
W	0847	10.9	TH	0822	10.7
	1539	1.4		1507	1.7
	2114	10.4		2040	10.5
14	0353	2.0	29	0318	2.0
TH	0927	10.4	F	0854	10.6
	1616	2.0		1538	1.9
	2152	9.8		2112	10.3
15	0427	2.6	30	0349	2.3
F	1004	9.8	SA	0929	10.4
	1651	2.7		1610	2.2
	2231	9.2		2150	10.0
			31	0423	2.7
			SU	1009	10.0
				1647	2.6
				2233	9.6

FEBRUARY

	TIME	M		TIME	M
1	0504	3.1	16	0534	3.7
M	1058	9.5	TU	1130	8.4
	1734	3.1		1800	4.0
	2327	9.1			
2	0603	3.5	17	0005	8.0
TU	1200	9.0	W	0636	4.1
	1843	3.5		1239	7.8
				1913	4.4
3	0041	8.8	18	0133	7.8
W	0726	3.7	TH	0759	4.3
	1324	8.7		1415	7.7
	2011	3.5		2042	4.4
4	0209	8.8	19	0301	8.0
TH	0856	3.5	F	0924	4.1
	1454	8.9		1538	8.0
	2135	3.2		2159	4.0
5	0332	9.2	20	0407	8.5
F	1014	2.9	SA	1031	3.5
	1610	9.5		1637	8.6
	2247	2.6		2259	3.4
6	0438	9.9	21	0458	9.1
SA	1123	2.2	SU	1127	2.9
	1713	10.1		1723	9.2
	2351	2.0		2350	2.8
7	0536	10.6	22	0542	9.7
SU	1224	1.5	M	1215	2.3
	1807	10.7		1803	9.8
8	0046	1.4	23	0035	2.2
M	0627	11.1	TU	0619	10.3
	1316	1.0		1257	1.8
	1855	11.1		1839	10.3
9	0135	1.1	24	0114	1.8
TU	0712	11.3	W	0655	10.8
	1402	0.8		1337	1.4
	1937	11.2		1913	10.8
10	0219	1.0	25	0152	1.4
W	0752	11.3	TH	0728	11.1
	1443	0.8		1413	1.1
	2016	11.0		1945	11.0
11	0257	1.2	26	0227	1.3
TH	0829	11.1	F	0802	11.3
	1518	1.2		1447	1.1
	2050	10.7		2019	11.1
12	0328	1.6	27	0301	1.4
F	0901	10.7	SA	0834	11.2
	1549	1.7		1519	1.3
	2122	10.2		2053	11.0
13	0356	2.1	28	0334	1.7
SA	0934	10.2	SU	0910	10.9
	1614	2.3		1553	1.7
	2153	9.7		2128	10.6
14	0423	2.7			
SU	1006	9.6			
	1640	2.9			
	2227	9.1			
15	0452	3.2			
M	1042	9.0			
	1712	3.5			
	2308	8.6			

MARCH

	TIME	M		TIME	M
1	0407	2.1	16	0416	2.8
M	0948	10.4	TU	1003	9.3
	1628	2.3		1630	3.2
	2209	10.0		2221	8.9
2	0447	2.7	17	0452	3.4
TU	1033	9.7	W	1041	8.5
	1713	2.9		1709	3.9
	2259	9.3		2305	8.2
3	0540	3.4	18	0543	4.0
W	1132	8.9	TH	1136	7.8
	1818	3.6		1810	4.4
4	0008	8.6	19	0024	7.7
TH	0702	3.8	F	0702	4.5
	1300	8.3		1320	7.4
	1951	3.9		1945	4.7
5	0151	8.3	20	0220	7.7
F	0843	3.8	SA	0839	4.4
	1449	8.4		1504	7.7
	2127	3.6		2122	4.4
6	0325	8.8	21	0336	8.2
SA	1010	3.2	SU	1000	3.9
	1607	9.1		1607	8.3
	2242	2.9		2230	3.7
7	0433	9.6	22	0428	8.9
SU	1119	2.3	M	1058	3.1
	1708	9.9		1652	9.1
	2343	2.2		2322	2.9
8	0526	10.3	23	0511	9.7
M	1214	1.6	TU	1146	2.4
	1756	10.5		1732	9.9
9	0035	1.6	24	0005	2.2
TU	0612	10.9	W	0549	10.4
	1302	1.1		1228	1.7
	1839	11.0		1808	10.6
10	0119	1.2	25	0046	1.6
W	0653	11.2	TH	0625	11.0
	1344	0.8		1309	1.2
	1917	11.1		1845	11.2
11	0158	1.1	26	0127	1.2
TH	0730	11.3	F	0702	11.5
	1420	0.9		1347	0.8
	1951	11.1		1920	11.5
12	0232	1.2	27	0205	0.9
F	0804	11.1	SA	0738	11.7
	1451	1.1		1425	0.7
	2022	10.8		1957	11.6
13	0300	1.4	28	0242	1.0
SA	0833	10.8	SU	0815	11.6
	1517	1.6		1501	0.9
	2050	10.5		2032	11.4
14	0325	1.8	29	0318	1.3
SU	0903	10.4	M	0851	11.2
	1539	2.1		1538	1.4
	2118	10.1		2110	10.9
15	0349	2.3	30	0355	1.8
M	0931	9.9	TU	0931	10.6
	1603	2.6		1616	2.2
	2148	9.5		2150	10.2
			31	0437	2.6
			W	1017	9.7
				1702	3.0
				2241	9.3

APRIL

	TIME	M		TIME	M
1	0530	3.4	16	0511	3.9
TH	1116	8.8	F	1057	7.9
	1805	3.8		1730	4.4
	2353	8.4		2333	7.8
2	0652	3.9	17	0617	4.4
F	1255	8.1	SA	1225	7.4
	1942	4.2		1853	4.7
3	0144	8.2	18	0127	7.6
SA	0837	3.9	SU	0751	4.5
	1446	8.3		1418	7.6
	2121	3.8		2036	4.5
4	0315	8.7	19	0251	8.1
SU	1004	3.2	M	0917	4.0
	1559	9.0		1525	8.3
	2233	3.1		2150	3.9
5	0419	9.4	20	0346	8.8
M	1106	2.4	TU	1017	3.3
	1651	9.8		1613	9.1
	2327	2.4		2242	3.1
6	0508	10.1	21	0431	9.7
TU	1156	1.8	W	1106	2.5
	1736	10.4		1654	10.0
				2329	2.3
7	0012	1.8	22	0513	10.4
W	0550	10.7	TH	1151	1.7
	1238	1.3		1734	10.8
	1814	10.7			
8	0053	1.4	23	0014	1.6
TH	0628	11.0	F	0554	11.1
	1317	1.1		1236	1.1
	1850	10.9		1815	11.4
9	0130	1.3	24	0057	1.1
F	0703	11.0	SA	0635	11.6
	1351	1.2		1320	0.8
	1923	10.9		1855	11.7
10	0202	1.3	25	0141	0.8
SA	0735	10.9	SU	0716	11.8
	1420	1.4		1402	0.7
	1952	10.8		1934	11.8
11	0230	1.5	26	0223	0.8
SU	0805	10.7	M	0757	11.6
	1446	1.7		1444	0.9
	2020	10.5		2015	11.5
12	0256	1.8	27	0305	1.1
M	0834	10.4	TU	0837	11.2
	1510	2.1		1525	1.4
	2049	10.2		2056	11.0
13	0322	2.2	28	0348	1.7
TU	0903	9.9	W	0921	10.5
	1534	2.6		1609	2.2
	2117	9.7		2141	10.2
14	0350	2.7	29	0433	2.5
W	0932	9.3	TH	1010	9.6
	1602	3.2		1658	3.0
	2149	9.1		2234	9.3
15	0426	3.3	30	0529	3.2
TH	1007	8.6	F	1115	8.7
	1638	3.8		1801	3.8
	2228	8.5		2347	8.5

HEIGHTS IN METRES

CHANNEL ISLANDS - ST. HELIER

LAT 49°11'N LONG 2°07'W

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

MAY

	TIME	M		TIME	M
1	0646	3.8	16	0546	4.1
SA	1250	8.2	SU	1144	7.8
	1931	4.2		1812	4.5
2	0128	8.3	17	0029	7.9
SU	0823	3.8	M	0702	4.3
	1426	8.4		1317	7.8
	2101	3.9		1941	4.4
3	0251	8.6	18	0154	8.2
M	0942	3.3	TU	0823	3.9
	1534	8.9		1430	8.4
	2209	3.3		2058	3.9
4	0350	9.2	19	0257	8.8
TU	1040	2.7	W	0929	3.3
	1624	9.5		1527	9.1
	2259	2.6		2157	3.1
5	0438	9.8	20	0349	9.6
W	1126	2.1	TH	1023	2.6
	1706	10.0		1614	10.0
	2343	2.1		2249	2.4
6	0520	10.2	21	0437	10.3
TH	1207	1.8	F	1113	1.9
	1744	10.4		1701	10.7
				2339	1.7
7	0021	1.8	22	0525	11.0
F	0558	10.5	SA	1204	1.3
	1243	1.6		1747	11.3
	1819	10.6			
8	0057	1.6	23	0029	1.2
SA	0635	10.6	SU	0611	11.4
	1319	1.6		1255	0.9
	1853	10.6		1832	11.6
9	0131	1.6	24	0120	0.9
SU	0709	10.5	M	0657	11.6
	1349	1.8		1344	0.8
	1926	10.6		1919	11.7
10	0202	1.7	25	0209	0.8
M	0741	10.4	TU	0744	11.5
	1419	2.0		1430	1.0
	1955	10.4		2004	11.4
11	0233	1.9	26	0256	1.1
TU	0812	10.1	W	0830	11.1
	1447	2.3		1517	1.4
	2026	10.1		2049	10.9
12	0304	2.2	27	0343	1.6
W	0842	9.7	TH	0918	10.4
	1515	2.7		1603	2.1
	2056	9.7		2136	10.2
13	0335	2.7	28	0431	2.2
TH	0914	9.3	F	1009	9.6
	1545	3.1		1652	2.9
	2129	9.2		2230	9.5
14	0410	3.2	29	0525	2.9
F	0949	8.7	SA	1111	8.9
	1620	3.7		1751	3.6
	2209	8.7		2334	8.8
15	0451	3.7	30	0631	3.5
SA	1035	8.2	SU	1227	8.4
	1706	4.2		1904	3.9
	2305	8.2			
			31	0055	8.5
			M	0749	3.6
				1347	8.4
				2023	3.9

JUNE

	TIME	M		TIME	M
1	0211	8.6	16	0053	8.5
TU	0903	3.4	W	0727	3.7
	1453	8.7		1331	8.6
	2129	3.5		2004	3.8
2	0312	8.9	17	0204	8.8
W	1000	3.1	TH	0839	3.3
	1546	9.1		1439	9.1
	2220	3.1		2112	3.2
3	0403	9.3	18	0307	9.4
TH	1048	2.7	F	0942	2.7
	1631	9.5		1538	9.8
	2305	2.6		2212	2.6
4	0448	9.7	19	0404	10.0
F	1129	2.4	SA	1041	2.1
	1712	9.8		1633	10.4
	2346	2.3		2311	1.9
5	0529	9.9	20	0459	10.6
SA	1208	2.2	SU	1139	1.6
	1750	10.1		1725	11.0
6	0025	2.1	21	0008	1.4
SU	0608	10.0	M	0554	11.0
	1246	2.1		1235	1.2
	1827	10.2		1817	11.3
7	0103	2.0	22	0104	1.1
M	0646	10.0	TU	0646	11.3
	1321	2.1		1330	1.0
	1903	10.3		1907	11.5
8	0140	2.0	23	0159	0.9
TU	0721	10.0	W	0735	11.3
	1357	2.2		1422	1.1
	1937	10.2		1955	11.3
9	0216	2.0	24	0250	1.0
W	0755	9.9	TH	0825	11.0
	1430	2.4		1510	1.4
	2011	10.0		2043	11.0
10	0251	2.2	25	0336	1.3
TH	0829	9.6	F	0912	10.5
	1503	2.6		1556	1.9
	2043	9.8		2128	10.5
11	0325	2.5	26	0423	1.8
F	0901	9.3	SA	0959	9.9
	1535	3.0		1641	2.5
	2117	9.5		2216	9.8
12	0359	2.9	27	0509	2.5
SA	0936	9.0	SU	1049	9.3
	1609	3.4		1727	3.1
	2155	9.1		2308	9.2
13	0435	3.3	28	0600	3.1
SU	1019	8.7	M	1146	8.7
	1647	3.7		1822	3.7
	2241	8.7			
14	0519	3.6	29	0008	8.7
M	1111	8.4	TU	0700	3.5
	1737	4.0		1252	8.4
	2340	8.5		1927	3.9
15	0615	3.8	30	0114	8.5
TU	1218	8.3	W	0806	3.7
	1846	4.1		1359	8.4
				2033	3.8

JULY

	TIME	M		TIME	M
1	0222	8.5	16	0114	8.8
TH	0908	3.6	F	0754	3.4
	1500	8.6		1355	8.9
	2131	3.5		2032	3.4
2	0321	8.7	17	0230	9.1
F	1002	3.3	SA	0908	3.0
	1552	8.9		1507	9.4
	2223	3.2		2145	2.9
3	0414	9.0	18	0342	9.6
SA	1049	3.0	SU	1017	2.5
	1640	9.3		1613	10.0
	2309	2.8		2251	2.3
4	0502	9.3	19	0445	10.1
SU	1134	2.8	M	1122	2.0
	1725	9.6		1712	10.6
	2356	2.5		2356	1.7
5	0546	9.5	20	0544	10.7
M	1217	2.6	TU	1224	1.5
	1805	9.9		1807	11.1
6	0039	2.3	21	0056	1.2
TU	0628	9.7	W	0638	11.1
	1259	2.4		1320	1.2
	1845	10.1		1859	11.4
7	0123	2.1	22	0151	0.8
W	0706	9.8	TH	0728	11.2
	1340	2.3		1412	1.0
	1923	10.2		1947	11.4
8	0202	2.0	23	0240	0.8
TH	0742	9.9	F	0815	11.1
	1416	2.3		1458	1.2
	1957	10.2		2030	11.2
9	0239	2.1	24	0324	1.0
F	0816	9.8	SA	0857	10.8
	1451	2.4		1539	1.5
	2030	10.1		2111	10.8
10	0312	2.2	25	0404	1.5
SA	0847	9.7	SU	0938	10.3
	1524	2.6		1619	2.1
	2103	9.9		2152	10.2
11	0345	2.5	26	0442	2.1
SU	0919	9.6	M	1017	9.7
	1555	2.9		1655	2.7
	2136	9.7		2231	9.6
12	0416	2.8	27	0519	2.8
M	0956	9.3	TU	1059	9.0
	1627	3.2		1733	3.3
	2214	9.4		2316	9.0
13	0452	3.1	28	0600	3.5
TU	1038	9.1	W	1149	8.5
	1706	3.5		1821	3.8
	2301	9.1			
14	0537	3.3	29	0011	8.4
W	1132	8.9	TH	0655	3.9
	1801	3.7		1252	8.1
				1924	4.0
15	0001	8.8	30	0121	8.1
TH	0638	3.5	F	0802	4.1
	1239	8.8		1406	8.1
	1914	3.7		2034	4.0
			31	0237	8.1
			SA	0911	4.0
				1515	8.3
				2139	3.7

AUGUST

	TIME	M		TIME	M
1	0343	8.4	16	0332	9.1
SU	1012	3.7	M	1007	3.0
	1613	8.8		1603	9.6
	2238	3.3		2245	2.6
2	0441	8.8	17	0441	9.8
M	1105	3.3	TU	1115	2.3
	1704	9.2		1705	10.3
	2332	2.9		2350	1.8
3	0529	9.2	18	0539	10.5
TU	1154	2.9	W	1215	1.6
	1747	9.7		1758	11.0
4	0019	2.5	19	0048	1.2
W	0611	9.6	TH	0629	11.1
	1239	2.5		1310	1.2
	1828	10.0		1848	11.4
5	0104	2.1	20	0138	0.7
TH	0649	9.9	F	0714	11.3
	1321	2.2		1357	0.9
	1904	10.3		1931	11.5
6	0144	1.8	21	0223	0.6
F	0724	10.1	SA	0757	11.3
	1359	2.0		1439	1.0
	1938	10.5		2011	11.4
7	0220	1.7	22	0303	0.8
SA	0755	10.3	SU	0833	11.0
	1434	2.0		1515	1.3
	2011	10.5		2047	11.1
8	0254	1.7	23	0338	1.3
SU	0826	10.3	M	0908	10.6
	1505	2.1		1548	1.8
	2040	10.5		2121	10.5
9	0325	1.9	24	0407	2.0
M	0857	10.3	TU	0941	10.0
	1535	2.3		1616	2.4
	2112	10.3		2153	9.9
10	0355	2.2	25	0434	2.7
TU	0931	10.1	W	1013	9.4
	1604	2.6		1645	3.0
	2148	10.0		2230	9.2
11	0426	2.6	26	0504	3.4
W	1007	9.7	TH	1052	8.7
	1640	3.0		1722	3.6
	2228	9.6		2312	8.5
12	0505	3.0	27	0544	4.0
TH	1054	9.3	F	1143	8.2
	1726	3.4		1815	4.1
	2322	9.1			
13	0601	3.4	28	0015	7.9
F	1156	8.9	SA	0649	4.4
	1836	3.7		1304	7.8
				1934	4.3
14	0035	8.7	29	0151	7.6
SA	0720	3.7	SU	0816	4.5
	1319	8.6		1439	7.9
	2005	3.7		2100	4.2
15	0208	8.6	30	0319	7.9
SU	0849	3.5	M	0938	4.2
	1450	8.9		1550	8.4
	2131	3.3		2212	3.7
			31	0421	8.5
			TU	1041	3.6
				1642	9.0
				2309	3.1

HEIGHTS IN METRES

CHANNEL ISLANDS - ST. HELIER

LAT 49°11'N LONG 2°07'W

TIME ZONE GMT — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — YEAR 1982

SEPTEMBER

	TIME	M		TIME	M
1	0508	9.1	16	0527	10.6
W	1132	3.0	TH	1205	1.7
	1726	9.6		1746	11.0
	2357	2.5			
2	0549	9.7	17	0034	1.1
TH	1217	2.5	F	0614	11.1
	1804	10.2		1252	1.2
				1829	11.4
3	0041	2.0	18	0119	0.8
F	0624	10.2	SA	0655	11.4
	1257	2.0		1335	0.9
	1839	10.6		1909	11.5
4	0119	1.6	19	0159	0.7
SA	0657	10.6	SU	0731	11.4
	1335	1.7		1413	1.0
	1913	10.9		1945	11.4
5	0155	1.4	20	0234	1.0
SU	0728	10.9	M	0805	11.1
	1409	1.5		1446	1.3
	1944	11.1		2018	11.1
6	0229	1.3	21	0305	1.4
M	0801	11.0	TU	0836	10.7
	1443	1.6		1514	1.7
	2016	11.1		2049	10.6
7	0301	1.5	22	0331	2.0
TU	0832	10.9	W	0904	10.2
	1514	1.8		1539	2.3
	2049	10.9		2118	10.0
8	0332	1.8	23	0353	2.7
W	0905	10.7	TH	0934	9.6
	1545	2.2		1606	2.8
	2124	10.5		2149	9.3
9	0403	2.3	24	0419	3.3
TH	0942	10.2	F	1006	9.0
	1619	2.7		1638	3.4
	2203	9.9		2226	8.6
10	0442	2.9	25	0454	3.9
F	1026	9.5	SA	1048	8.3
	1705	3.3		1726	4.1
	2254	9.1		2318	7.9
11	0537	3.6	26	0550	4.5
SA	1126	8.8	SU	1201	7.7
	1814	3.8		1839	4.5
12	0010	8.4	27	0100	7.4
SU	0700	4.0	M	0723	4.8
	1259	8.3		1402	7.7
	1954	4.0		2019	4.5
13	0201	8.3	28	0250	7.7
M	0842	3.9	TU	0904	4.5
	1444	8.6		1521	8.2
	2129	3.5		2143	4.0
14	0332	8.9	29	0353	8.3
TU	1006	3.2	W	1014	3.9
	1559	9.4		1614	8.9
	2244	2.6		2241	3.3
15	0437	9.8	30	0438	9.1
W	1111	2.4	TH	1104	3.1
	1657	10.3		1655	9.6
	2343	1.8		2327	2.6

OCTOBER

	TIME	M		TIME	M
1	0516	9.8	16	0012	1.3
F	1147	2.5	SA	0551	11.0
	1733	10.3		1229	1.4
				1805	11.2
2	0008	2.0	17	0053	1.1
SA	0551	10.4	SU	0628	11.2
	1227	1.9		1309	1.2
	1808	10.8		1843	11.3
3	0048	1.5	18	0131	1.1
SU	0627	11.0	M	0703	11.2
	1304	1.5		1344	1.2
	1842	11.2		1919	11.2
4	0126	1.2	19	0204	1.3
M	0700	11.3	TU	0735	11.0
	1342	1.2		1415	1.5
	1917	11.5		1949	10.9
5	0202	1.1	20	0233	1.7
TU	0734	11.5	W	0805	10.7
	1418	1.2		1443	1.8
	1951	11.5		2020	10.5
6	0237	1.2	21	0257	2.2
W	0808	11.4	TH	0834	10.3
	1453	1.5		1510	2.2
	2027	11.2		2049	10.0
7	0312	1.6	22	0321	2.7
TH	0844	11.0	F	0903	9.8
	1529	1.9		1538	2.8
	2104	10.7		2119	9.4
8	0349	2.2	23	0348	3.2
F	0922	10.4	SA	0935	9.2
	1607	2.6		1610	3.3
	2146	9.9		2155	8.7
9	0431	3.0	24	0421	3.9
SA	1009	9.6	SU	1013	8.6
	1657	3.3		1654	3.9
	2240	9.0		2241	8.0
10	0527	3.7	25	0512	4.5
SU	1111	8.7	M	1115	7.9
	1810	3.9		1758	4.5
11	0004	8.3	26	0008	7.5
M	0655	4.2	TU	0632	4.9
	1253	8.2		1309	7.7
	1952	4.0		1931	4.6
12	0204	8.3	27	0204	7.6
TU	0840	4.1	W	0818	4.7
	1439	8.6		1437	8.1
	2127	3.5		2101	4.2
13	0327	8.9	28	0312	8.2
W	0959	3.3	TH	0935	4.1
	1548	9.4		1534	8.7
	2234	2.6		2202	3.5
14	0423	9.8	29	0359	9.0
TH	1058	2.5	F	1026	3.3
	1640	10.2		1617	9.5
	2326	1.9		2248	2.8
15	0509	10.5	30	0438	9.8
F	1146	1.8	SA	1109	2.6
	1725	10.8		1655	10.2
				2330	2.1
			31	0516	10.5
			SU	1151	1.9
				1734	10.8

NOVEMBER

	TIME	M		TIME	M
1	0012	1.5	16	0100	1.6
M	0554	11.1	TU	0636	10.8
	1232	1.4		1314	1.6
	1812	11.3		1853	10.7
2	0055	1.2	17	0134	1.8
TU	0632	11.5	W	0710	10.7
	1314	1.1		1348	1.7
	1852	11.6		1927	10.5
3	0135	1.0	18	0204	2.0
W	0710	11.7	TH	0741	10.5
	1357	1.1		1419	1.9
	1931	11.6		1958	10.2
4	0218	1.1	19	0233	2.3
TH	0749	11.6	F	0812	10.2
	1439	1.3		1449	2.3
	2012	11.3		2030	9.8
5	0258	1.5	20	0300	2.7
F	0830	11.1	SA	0843	9.9
	1521	1.7		1519	2.7
	2054	10.7		2101	9.4
6	0341	2.1	21	0331	3.2
SA	0912	10.5	SU	0917	9.4
	1604	2.4		1555	3.1
	2142	9.9		2136	8.9
7	0427	2.9	22	0404	3.6
SU	1002	9.6	M	0955	8.9
	1658	3.1		1634	3.7
	2240	9.0		2220	8.3
8	0526	3.7	23	0448	4.2
M	1108	8.8	TU	1047	8.3
	1808	3.7		1726	4.1
				2323	7.9
9	0004	8.4	24	0549	4.6
TU	0649	4.2	W	1204	8.0
	1242	8.4		1838	4.4
	1941	3.9			
10	0147	8.4	25	0053	7.8
W	0825	4.0	TH	0716	4.6
	1416	8.7		1331	8.1
	2108	3.4		2001	4.2
11	0304	8.9	26	0211	8.2
TH	0938	3.4	F	0839	4.2
	1524	9.3		1437	8.5
	2212	2.8		2110	3.7
12	0359	9.6	27	0308	8.8
F	1033	2.7	SA	0938	3.5
	1614	9.9		1529	9.2
	2301	2.2		2203	3.0
13	0444	10.1	28	0355	9.6
SA	1119	2.2	SU	1028	2.8
	1659	10.4		1617	9.9
	2344	1.8		2251	2.3
14	0525	10.5	29	0440	10.3
SU	1200	1.8	M	1115	2.1
	1740	10.7		1702	10.6
				2339	1.7
15	0024	1.6	30	0525	11.0
M	0601	10.7	TU	1204	1.6
	1239	1.6		1747	11.1
	1818	10.7			

DECEMBER

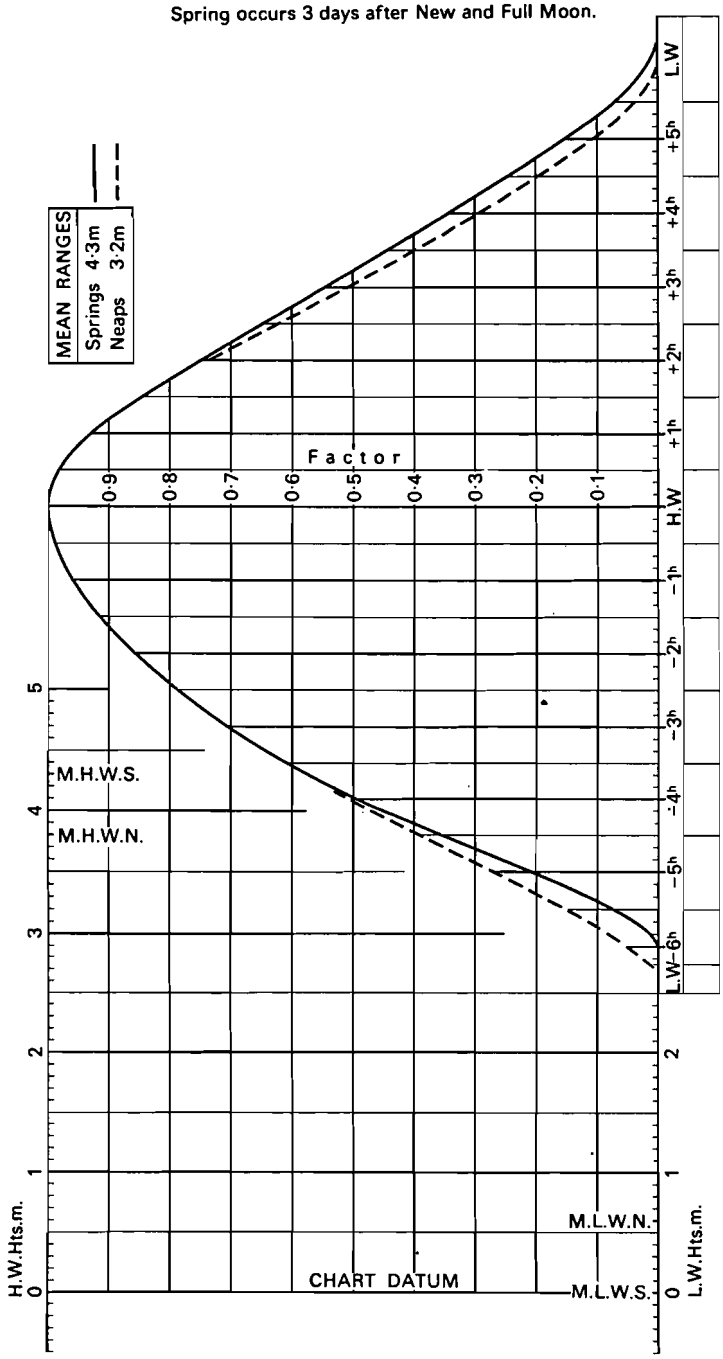
	TIME	M		TIME	M
1	0027	1.3	16	0109	2.2
W	0608	11.4	TH	0650	10.3
	1252	1.2		1327	2.0
	1834	11.4		1910	10.1
2	0116	1.1	17	0144	2.2
TH	0653	11.6	F	0726	10.3
	1341	1.0		1402	2.0
	1919	11.4		1945	10.0
3	0204	1.1	18	0216	2.4
F	0738	11.5	SA	0759	10.2
	1429	1.1		1437	2.2
	2005	11.2		2018	9.8
4	0250	1.4	19	0249	2.6
SA	0823	11.2	SU	0832	10.0
	1517	1.5		1510	2.4
	2051	10.7		2051	9.5
5	0338	1.9	20	0319	2.9
SU	0910	10.6	M	0905	9.7
	1604	2.0		1543	2.8
	2141	10.1		2124	9.2
6	0426	2.6	21	0352	3.2
M	1000	9.9	TU	0941	9.3
	1655	2.6		1617	3.2
	2237	9.3		2202	8.9
7	0520	3.3	22	0428	3.6
TU	1059	9.2	W	1021	8.9
	1757	3.2		1657	3.6
	2346	8.7		2247	8.5
8	0628	3.8	23	0512	4.0
W	1214	8.7	TH	1112	8.5
	1913	3.6		1746	3.9
				2344	8.3
9	0107	8.5	24	0611	4.2
TH	0748	3.9	F	1217	8.3
	1334	8.6		1852	4.0
	2030	3.5			
10	0223	8.7	25	0056	8.3
F	0900	3.6	SA	0728	4.1
	1444	8.9		1330	8.5
	2135	3.2		2006	3.8
11	0322	9.0	26	0208	8.6
SA	0957	3.2	SU	0843	3.7
	1542	9.3		1439	8.9
	2227	2.8		2114	3.3
12	0412	9.5	27	0311	9.2
SU	1047	2.7	M	0946	3.1
	1630	9.6		1539	9.5
	2312	2.5		2214	2.7
13	0455	9.8	28	0407	9.9
M	1129	2.4	TU	1044	2.5
	1713	9.9		1635	10.1
	2353	2.3		2312	2.1
14	0536	10.1	29	0501	10.6
TU	1210	2.1	W	1142	1.9
	1754	10.0		1730	10.7
15	0032	2.2	30	0008	1.6
W	0614	10.3	TH	0553	11.1
	1249	2.0		1238	1.3
	1834	10.1		1822	11.1
			31	0103	1.2
			F	0643	11.4
				1333	1.0
				1913	11.3

HEIGHTS IN METRES

WILHELMSHAVEN

MEAN SPRING AND NEAP CURVES

Spring occurs 3 days after New and Full Moon.



GERMANY - WILHELMSHAVEN

LAT 53°31'N LONG 8°09'E

TIME ZONE -0100 TIMES AND HEIGHTS OF HIGH AND LOW WATERS YEAR 1982

	JANUARY				FEBRUARY				MARCH				APRIL			
	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M
1 F	0408	4.1	16 0517	4.2	1 0523	4.1	16 0558	3.8	1 0428	4.2	16 0449	3.9	1 0541	3.9	16 0523	3.6
	1025	0.2	SA 1132	0.1	M 1136	0.1	TU 1156	0.2	M 1042	-0.1	TU 1049	0.1	TH 1137	0.2	F 1108	0.5
	1640	3.8	1749	3.7	1752	3.8	1818	3.5	1653	3.9	1701	3.7	1759	3.8	1739	3.7
	2234	0.3	2338	0.3	2347	0.3			2252	0.0	2257	0.1			2343	0.4
2 SA	0452	4.1	17 0559	4.0	2 0605	4.1	17 0009	0.3	2 0508	4.1	17 0518	3.8	2 0002	0.1	17 0615	3.5
	1108	0.2	SU 1209	0.2	TU 1215	0.3	W 0644	3.6	TU 1117	0.0	W 1111	0.3	F 0640	3.7	SA 1202	0.7
	1726	3.7	1830	3.6	1837	3.7	1240	0.5	1730	3.9	1730	3.7	1233	0.4	1844	3.6
	2319	0.4					1912	3.4	2326	0.1	2327	0.3	1907	3.8		
3 SU	0538	4.1	18 0017	0.3	3 0035	0.4	18 0110	0.5	3 0548	4.0	18 0556	3.6	3 0116	0.3	18 0052	0.5
	1154	0.3	M 0645	3.9	W 0700	4.0	TH 0751	3.5	W 1152	0.2	TH 1144	0.5	SA 0801	3.6	SU 0731	3.4
	1815	3.7	1252	0.3	1311	0.4	1348	0.6	1812	3.8	1817	3.5	1357	0.5	1323	0.7
			1917	3.5	1939	3.7	2029	3.5					2035	3.8	2008	3.7
11 M	0133	4.3	26 0138	4.1	11 0256	4.3	26 0233	4.1	11 0157	4.2	26 0134	4.1	11 0250	4.1	26 0230	4.3
	0753	0.0	TU 0751	0.0	TH 0915	-0.2	F 0848	-0.2	TH 0813	-0.3	F 0747	-0.3	SU 0855	-0.2	M 0842	-0.2
	1406	4.2	1403	3.9	1529	3.9	1501	3.9	1429	3.9	1404	4.0	1508	4.0	1455	4.1
	2015	0.1	2006	0.1	2127	-0.1	2101	-0.2	2027	-0.2	2006	-0.2	2108	-0.2	2101	-0.2

VOL. 1 EUROPEAN WATERS—PART II (Secondary Ports)

Seasonal Changes in Mean Level and Harmonic Constants (For worked examples and exercises.)

No.		Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Sep. 1	Oct. 1	Nov. 1	Dec. 1	Jan. 1
1–60								Negligible						
61–63a		+0·1	0·0	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	+0·1	+0·1	+0·1
64–130								Negligible						
308–390		+0·1	0·0	0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	+0·1	+0·1
391–398		+0·1	0·0	−0·1	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	+0·1	+0·1	+0·1
399–407		+0·2	+0·1	0·0	−0·1	−0·1	−0·1	−0·1	−0·1	0·0	0·0	+0·1	+0·2	+0·2
408–414		+0·1	0·0	−0·1	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	+0·1	+0·1	+0·1
415–444		0·0	0·0	0·0	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	+0·1	+0·1	0·0
445–464		0·0	0·0	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	0·0	+0·1	+0·1	0·0
466–478		+0·1	0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	+0·1	+0·1	+0·1
479–512		0·0	0·0	0·0	0·0	0·0	0·0	−0·1	0·0	0·0	0·0	+0·1	+0·1	0·0
513–534		0·0	0·0	0·0	0·0	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0
535–548		+0·1	0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	+0·1	+0·1	+0·1
601–644		0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	+0·1	+0·1	0·0
651–672		+0·1	0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	+0·1	+0·1
681–712		+0·1	0·0	−0·1	−0·1	0·0	0·0	0·0	−0·1	−0·1	0·0	+0·1	+0·1	+0·1
713–719								Negligible						
721–737		+0·1	0·0	0·0	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	0·0	+0·1	+0·1
741–766		0·0	0·0	0·0	−0·1	−0·1	−0·1	−0·1	0·0	0·0	+0·1	+0·1	+0·1	0·0
65	M_2	1·40	1·40	1·42	1·43	1·42	1·39	1·39	1·41	1·45	1·47	1·45	1·42	1·40
89	M_2	2·28	2·24	2·22	2·22	2·25	2·25	2·23	2·19	2·18	2·21	2·26	2·29	2·28
103	M_2	1·70	1·65	1·60	1·59	1·61	1·63	1·64	1·62	1·61	1·63	1·68	1·71	1·70
108	M_2	2·00	2·00	2·02	2·03	2·01	1·97	1·97	2·01	2·06	2·08	2·07	2·03	2·00
109	M_2	2·18	2·17	2·14	2·12	2·13	2·16	2·18	2·17	2·14	2·12	2·13	2·16	2·18
110	M_2	2·01	2·02	2·05	2·08	2·09	2·07	2·05	2·03	2·03	2·04	2·03	2·02	2·01
404	M_2	1·19	1·18	1·17	1·18	1·18	1·18	1·17	1·15	1·14	1·15	1·17	1·18	1·19
440	M_2	3·08	3·07	3·05	3·04	3·04	3·04	3·05	3·07	3·08	3·09	3·09	3·09	3·08
	S_2	0·99	1·09	1·13	1·08	0·98	0·92	0·94	0·98	0·98	0·93	0·87	0·89	0·99
441	M_2	3·19	3·17	3·17	3·16	3·15	3·14	3·15	3·18	3·22	3·25	3·24	3·22	3·19
	S_2	1·05	1·04	1·02	1·02	1·04	1·06	1·07	1·05	1·01	1·00	1·01	1·04	1·05
452	M_2	3·13	3·13	3·12	3·12	3·15	3·18	3·18	3·15	3·10	3·07	3·08	3·12	3·13
496	M_2	2·21	2·20	2·20	2·21	2·23	2·25	2·27	2·28	2·28	2·27	2·25	2·23	2·21
513a	M_2	3·77	3·82	3·89	3·94	3·97	4·00	3·97	3·91	3·84	3·78	3·75	3·75	3·77
523	M_2	4·30	4·26	4·23	4·25	4·31	4·35	4·31	4·21	4·13	4·13	4·21	4·28	4·30
751	M_2	1·42	1·42	1·43	1·43	1·41	1·39	1·39	1·42	1·45	1·47	1·46	1·43	1·42

Volume 1 EUROPEAN WATERS—Part II (Secondary Ports)

ENGLAND, SCOTLAND AND IRELAND

No.	PLACE	Lat. N.	Long. W.	TIME DIFFERENCES High Water (Zone G.M.T.)	TIME DIFFERENCES Low Water (Zone G.M.T.)	HEIGHT DIFFERENCES (IN METRES) MHWS	MHWN	MLWN	MLWS	M.L. Z_0 m.
65	**PORTSMOUTH** . (see page 14)			**0000 and 1200**	**0600 and 1800**	**0500 and 1700**	**1100 and 2300**	**4·7**	**3·8**	**1·8**	**0·6**	
51	Ventnor . .	50 36	1 12	−0025	−0030	−0025	−0030	−0·8	−0·6	−0·2	+0·2	2·33
53	Sandown . .	50 39	1 09	0000	+0005	+0010	+0025	−0·6	−0·5	−0·2	0·0	2·41
54	Brading . .	50 42	1 06	−0010	+0005	+0020	0000	−1·6	−1·5	−1·4	−0·6	⊙
58	Ryde . . .	50 44	1 07	−0010	+0010	−0005	−0010	−0·2	−0·1	0·0	+0·1	2·76
65	**PORTSMOUTH** . (see page 14)			**1000 and 2200**	**0500 and 1700**	**0000 and 1200**	**0600 and 1800**	**4·7**	**3·8**	**1·8**	**0·6**	**2·84**
	Chichester Harbour											
68	Entrance . .	50 47	0 56	+0005	−0010	+0015	+0020	+0·2	+0·2	0·0	+0·1	2·83
68a	Bosham . .	50 50	0 52	+0020	+0005	⊙	⊙	+0·4	+0·2	⊙	⊙	⊙
68b	Itchenor . .	50 48	0 52	+0015	0000	⊙	⊙	+0·4	+0·2	0·0	0·0	⊙
68c	Dell Quay . .	50 49	0 49	+0025	+0010	⊙	⊙	+0·4	+0·2	⊙	⊙	⊙
69	Selsey Bill . .	50 43	0 47	−0005	−0005	+0035	+0035	+0·6	+0·6	0·0	0·0	2·94
70	Nab Tower . .	50 40	0 57	0000	+0015	+0015	+0015	−0·2	0·0	+0·2	0·0	2·58
108	**SHEERNESS** . (see page 30)			**0600 and 1800**	**1100 and 2300**	**0100 and 1300**	**0800 and 2000**	**5·7**	**4·8**	**1·5**	**0·6**	
	River Thames											
110	Southend . .	51 31	0 43	−0005	−0005	−0005	−0005	0·0	0·0	−0·1	−0·1	3·02
110a	Thames Haven .	51 30	0 31	+0010	+0010	0000	+0010	+0·5	+0·4	−0·1	−0·1	3·15
111	Tilbury . .	51 28	0 22	+0010	+0030	+0005	+0035	+0·8	+0·6	0·0	−0·1	3·33
404	**GREENOCK** . (see page 94)			**0000 and 1200**	**0600 and 1800**	**0000 and 1200**	**0600 and 1800**	**3·4**	**2·9**	**1·0**	**0·4**	**2·00**
	River Clyde											
405	Port Glasgow .	55 56	4 41	+0011	+0005	+0010	+0018	+0·2	+0·1	0·0	0·0	⊙
406	Bowling . .	55 56	4 29	+0032	+0016	+0043	+0107	+0·6	+0·5	+0·3	+0·1	⊙
408	Brodick Bay .	55 35	5 08	0000	0000	+0005	+0005	−0·2	−0·2	0·0	0·0	1·86
409	Lamlash . .	55 32	5 07	−0016	−0036	−0024	−0004	−0·2	−0·2	⊙	⊙	⊙
410	Ardrossan . .	55 38	4 49	−0020	−0020	−0030	−0010	−0·2	−0·2	−0·1	−0·1	⊙
411	Irvine . .	55 36	4 41	−0020	−0020	−0030	−0010	−0·3	−0·3	−0·1	0·0	⊙
523	**PORT OF BRISTOL (AVONMOUTH)** (see page 122)			**0600 and 1800**	**1100 and 2300**	**0300 and 1500**	**0800 and 2000**	**13·2**	**10·0**	**3·5**	**0·9**	
513	Barry . . .	51 23	3 16	−0030	−0015	−0125	−0030	−1·8	−1·3	+0·2	0·0	6·11
514	**CARDIFF** . .	51 27	3 09	STANDARD PORT					See Table V			6·45
515	Newport . .	51 33	2 59	−0020	−0010	0000	−0020	−1·1	−1·0	−0·6	−0·7	*w*
	River Wye											
516	Chepstow . .	51 39	2 40	+0020	+0020	⊙	⊙	⊙	⊙	⊙	⊙	⊙
658	**LONDONDERRY** . (see page 134)			**0200 and 0400**	**0800 and 2000**	**1100 and 2300**	**0500 and 1700**	**2·7**	**2·0**	**1·0**	**0·4**	
652	Portrush . .	55 12	6 40	−0140	−0140	−0120	−0200	−0·6	−0·6	+0·1	0·0	1·37
653	Coleraine . .	55 08	6 40	−0108	−0126	−0037	−0101	−0·6	−0·4	−0·3	−0·1	⊙
	Lough Foyle											
654	Warren Point .	55 12	6 57	−0121	−0139	−0132	−0156	−0·4	−0·2	⊙	⊙	⊙
655	Moville . .	55 11	7 03	−0046	−0058	−0052	−0108	−0·4	−0·2	−0·2	−0·1	⊙
656	Quigley's Point .	55 07	7 11	−0025	−0040	−0040	−0025	−0·4	−0·3	−0·3	−0·2	⊙
657	Calmore Point .	55 03	7 15	−0010	−0030	−0040	−0020	−0·3	−0·3	−0·2	−0·1	⊙

No.	PLACE	Lat. N.	Long. E.	TIME DIFFERENCES (Zone G.M.T.) High Water	TIME DIFFERENCES (Zone G.M.T.) Low Water			HEIGHT DIFFERENCES (IN METRES) MHWS	MHWN	MLWN	MLWS	M.L. Z_0 m.	HARMONIC CONSTANTS (Zone G.M.T.) M_2 g°	M_2 H.m.	S_2 g°	S_2 H.m.	K_1 g°	K_1 H.m.	O_1 g°	O_1 H.m.	S.W. CORRECTIONS ‡ diurnal f_s	‡ diurnal F_s	‡ diurnal f_s	‡ diurnal F_s	
83	Newhaven	50 47	0 04	−0010	−0015	0000	0000	+0·4	+0·2	0·0	−0·2	3·61	323	2·26	010	0·73	107	0·07	331	0·01	322	0·020	⊛	⊛	
84	Eastbourne	50 46	0 17	−0005	−0010	+0015	+0020	+1·1	+0·6	+0·2	+0·1	3·77	325	2·48	006	0·80	091	0·04	345	0·03	307	0·022	⊛	⊛	
89	**DOVER**	(see page 22)		0000 and 1200	0600 and 1800	0100 and 1300	0700 and 1900	6·7	5·3	2·0	0·8														
85	Hastings	50 51	0 35	0000	−0010	−0030	−0030	+0·8	+0·5	+0·1	−0·1	3·85	323	2·47	017	0·89	095	0·08	223	0·01	302	0·035	272	0·001	
86	Rye (Approaches)	50 55	0 47	+0005	−0010	⊛	⊛	+1·0	+0·7	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	
86a	Rye (Harbour)	50 56	0 46	+0005	−0010	⊛	⊛	−1·4	−1·7	⊛	⊛	1·97	328	2·19	015	0·60	149	0·08	031	0·03	327	0·076	⊛	⊛	*l*
87	Dungeness	50 54	0 58	−0010	−0015	−0020	−0010	+1·0	+0·5	+0·2	−0·1	4·03	326	2·43	023	0·94	023	0·10	182	0·09	279	0·041	⊛	⊛	*l*
88	Folkestone	51 05	1 12	−0020	−0005	−0010	−0010	+0·4	+0·4	0·0	−0·1	3·74	332	2·45	032	0·79	055	0·05	241	0·02	282	0·057	⊛	⊛	
89	**DOVER**	51 07	1 19	STANDARD PORT				See Table V				3·70	332	*v*	023	0·71	046	0·06	172	0·06	278	0·054	188	0·006	*v*
98	Deal	51 13	1 25	+0010	+0020	+0010	+0005	−0·6	−0·3	0·0	0·0	3·13	336	2·07	027	0·63	020	0·06	175	0·07	274	0·044	187	0·009	*iv*
102	Ramsgate	51 20	1 25	+0020	+0020	−0007	−0007	−1·8	−1·5	−0·8	−0·4	2·56	339	1·86	030	0·56	012	0·08	182	0·09	281	0·038	191	0·007	
103	**MARGATE**	(see page 26)		0100 and 1300	0700 and 1900	0100 and 1300	0700 and 1900	4·8	3·9	1·4	0·5														
102a	Broadstairs	51 21	1 27	−0020	−0008	+0007	+0010	−0·2	−0·2	−0·1	−0·1	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	
103	**MARGATE**	51 24	1 23	STANDARD PORT				See Table V				2·67	342	*v*	034	0·47	008	0·10	184	0·12	339	0·017	⊛	⊛	*v*
104	Herne Bay	51 23	1 07	+0034	+0022	+0015	+0032	+0·4	+0·4	0·0	0·0	2·73	349	1·80	048	0·54	346	0·09	171	0·12	004	0·013	040	0·007	
105	Whitstable Approaches	51 22	1 02	+0042	+0029	+0025	+0050	+0·6	+0·6	+0·1	0·0	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	
108	**SHEERNESS**	(see page 30)		0200 and 1400	0800 and 2000	0200 and 1400	0700 and 1900	5·7	4·8	1·5	0·6														
	River Swale																								
106	Grovehurst Jetty	51 22	0 46	−0007	0000	0000	+0016	0·0	0·0	0·0	−0·1	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	
	River Medway																								
108	**SHEERNESS**	51 27	0 45	STANDARD PORT				See Table V				3·07	355	*v*	052	0·58	013	0·12	190	0·13	027	0·023	049	0·006	*v*
108a	Bee Ness	51 25	0 39	+0002	+0002	0000	+0005	+0·2	+0·1	0·0	0·0	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	●	
108b	Bartlett Creek	51 23	0 38	+0016	+0008	⊛	⊛	+0·1	0·0	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	
108c	Darnett Ness	51 24	0 36	+0004	+0004	0000	+0010	+0·2	+0·1	0·0	−0·1	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	

⊛ No data.
★ See notes on page 362.
c For intermediate heights, use harmonic constants and N.P.159.
i Constants inferred.
j For intermediate heights, see page xxiii.
k For intermediate heights, use Standard Curve for Shoreham on page 22.
l Constants from 15 days' observations.
v Owing to large seasonal variations, see Table VI.
x M.L. inferred.

No.	PLACE	Lat. N.	Long. E.	TIME DIFFERENCES High Water (Zone G.M.T.)	TIME DIFFERENCES Low Water (Zone G.M.T.)	HEIGHT DIFFERENCES (IN METRES) MHWS	MHWN	MLWN	MLWS	M.L. Z_0 m.	HARMONIC CONSTANTS (Zone G.M.T.) M_2 g°	M_2 H.m.	S_2 g°	S_2 H.m.	K_1 g°	K_1 H.m.	O_1 g°	O_1 H.m.	S.W. CORRECTIONS ½ diurnal f_4	½ diurnal F_4	½ diurnal f_6	½ diurnal F_6	
108	**SHEERNESS** . . .	(see page 30)		0200 and 1400	0800 and 2000	0200 and 1400	0700 and 1900	5·7	4·8	1·5	0·6														
109	**CHATHAM LOCK APPROACHES** . .			STANDARD PORT				See Table V				2·95	357	2·15	054	0·63	015	0·11	188	0·14	030	0·027	060	0·008	
109a	Upnor . .	51 25	0 32	+0015	+0015	+0015	+0025	+0·2	+0·2	−0·1	−0·1	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
109b	Rochester . . (Strood Pier) . .	51 24	0 30	+0018	+0018	+0018	+0028	+0·2	+0·2	−0·2	−0·3	2·91	000	2·19	056	0·59	011	0·10	200	0·16	030	0·033	⊙	⊙	
109c	Wouldham . .	51 22	0 27	+0030	+0025	+0035	+0120	−0·2	−0·3	−1·0	−0·3	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
109d	New Hythe . .	51 19	0 28	+0035	+0035	+0220	+0240	−1·6	−1·7	−1·2	−0·3	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
109e	Allington Lock . .	51 17	0 30	+0050	+0035	⊙	⊙	−2·1	−2·2	−1·3	−0·4	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
108	**SHEERNESS** . . .	(see page 30)		0600 and 1800	1100 and 2300	0100 and 1300	0800 and 2000	5·7	4·8	1·5	0·6														
	River Thames																								
110	Southend . .	51 31	0 43	−0005	−0005	−0005	−0005	0·0	0·0	−0·1	−0·1	3·02	354	*v*	049	0·59	011	0·11	188	0·13	021	0·022	050	0·006	* *v*
110a	Thames Haven .	51 30	0 31	+0010	+0010	0000	+0010	+0·5	+0·4	−0·1	−0·1	3·15	000	2·17	056	0·63	014	0·12	192	0·13	012	0·021	057	0·005	*
111	Tilbury . .	51 28	0 22	+0010	+0030	+0005	+0035	+0·8	+0·6	0·0	−0·1	3·33	009	2·32	069	0·66	021	0·13	197	0·14	007	0·016	053	0·005	*
113	**LONDON BRIDGE** .	(see page 38)		0300 and 1500	0900 and 2100	0400 and 1600	1100 and 2300	7·1	5·8	1·6	0·5														
112	Woolwich (Gallion's Point) . .	51 30	0 05	−0020	−0025	−0035	−0045	−0·1	+0·1	−0·1	0·0	*w*	021	2·53	084	0·74	027	0·13	202	0·14	358	0·010	053	0·007	**wx*
		N.	W.																						
113	**LONDON BRIDGE** .	51 30	0 05	STANDARD PORT				See Table V				*w*	034	2·50	100	0·71	035	0·13	208	0·14	311	0·016	048	0·008	**w*
114	Chelsea Bridge . .	51 29	0 09	+0020	+0015	+0055	+0100	−0·8	−0·7	−0·4	−0·1	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	*
115	Barnes Bridge .	51 28	0 15	+0045	+0040	+0220	+0210	−1·6	−1·7	−0·5	0·0	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	*
116	Richmond Lock . .	51 28	0 19	+0100	+0055	+0325	+0305	−2·1	−2·2	−0·3	+0·2	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	*
108	**SHEERNESS** . . .	(see page 30)		0200 and 1400	0700 and 1900	0100 and 1300	0700 and 1900	5·7	4·8	1·5	0·6														
		N.	E.																						
	Thames estuary																								
116a	Shivering Sand Tower .	51 30	1 05	−0025	−0019	−0008	−0026	−0·6	−0·6	−0·1	−0·1	2·75	347	1·80	040	0·52	010	0·10	185	0·13	010	0·024	032	0·007	*
103	**MARGATE** . . .	(see page 26)		0100 and 1300	0700 and 1900	0100 and 1300	0700 and 1900	4·8	3·9	1·4	0·5														
117	S.E. Longsand . .	51 32	1 21	−0006	−0003	−0004	−0004	0·0	+0·1	0·0	−0·1	2·5	338	1·69	032	0·49	351	0·08	167	0·12	000	0·032	043	0·004	* *

FRANCE, NORTH COAST

350

No.	PLACE		Lat. N.	Long. W.	TIME DIFFERENCES High Water (Zone −0100)	TIME DIFFERENCES Low Water (Zone −0100)	HEIGHT DIFFERENCES (IN METRES) MHWS	MHWN	MLWN	MLWS	M.L. Z_0 m.	HARMONIC CONSTANTS (Zone −0100) M_2 g°	M_2 H.m.	S_2 g°	S_2 H.m.	K_1 g°	K_1 H.m.	O_1 g°	O_1 H.m.	S.W. CORRECTIONS ¼ diurnal f_4	¼ diurnal F_4	½ diurnal f_8	½ diurnal F_8	
1605	**ST. HELIER** . . .	(see page 222)			0800 and 2000	0100 and 1300	0200 and 1400	0700 and 1900	11·1	8·1	4·1	1·3														
1609	Iles Chausey . . .		48 52	1 49	+0048	+0044	+0104	+0058	+1·8	+1·7	+0·8	+0·6	7·50	218	3·94	258	1·46	111	0·09	355	0·09	266	0·035	177	0·002	*i*
1610	Dielette . . .		49 33	1 52	+0119	+0116	+0115	+0120	−1·6	−0·9	−0·5	−0·1	5·51	223	3·07	263	1·13	111	0·09	355	0·09	300	0·026	034	0·002	*i*
1611	Carteret . . .		49 22	1 47	+0110	+0100	+0120	+0115	−0·1	−0·3	0·0	+0·1	6·30	223	3·50	263	1·30	111	0·09	355	0·09	293	0·020	073	0·001	*i*
1612	Granville . . .		48 50	1 36	+0049	+0040	+0115	+0053	+1·7	+1·5	+0·5	+0·1	7·21	218	4·16	258	1·54	111	0·09	355	0·09	323	0·025	347	0·003	*i*
1613	Cancale . . .		48 40	1 51	+0050	+0035	+0115	+0100	+2·2	+2·0	+1·0	+0·7	7·76	216	4·12	256	1·53	111	0·09	355	0·09	326	0·024	345	0·003	*i*
1614	St. Malo . .	F	48 38	2 02	+0044	+0034	+0105	+0050	+1·0	+1·0	+0·3	+0·1	6·85	207	3·69	257	1·44	111	0·09	355	0·09	286	0·020	⊙	⊙		
1615	Erquy . . .		48 38	2 28	+0040	+0030	+0035	+0032	+0·1	+0·4	0·0	0·0	6·40	204	3·58	244	1·32	111	0·09	355	0·09	302	0·016	041	0·001	*i*
1616	Dahouet . .		48 35	2 34	+0038	+0031	+0027	+0036	+0·1	+0·4	−0·2	−0·1	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
1617	Le Légué . .		48 32	2 44	+0045	+0030	+0035	+0031	+0·1	+0·4	0·0	0·0	5·6	205	3·61	245	1·34	111	0·09	355	0·09	345	0·027	004	0·004	*ix*
1618	Binic . . .		48 36	2 49	+0045	+0030	+0035	+0031	+0·1	+0·4	0·0	0·0	5·6	205	3·61	245	1·34	111	0·09	355	0·09	345	0·027	004	0·004	*ix*
1619	Portrieux . .		48 38	2 49	+0045	+0030	+0030	+0030	+0·1	+0·4	0·0	0·0	6·38	203	3·61	243	1·34	111	0·09	355	0·09	298	0·017	043	0·001	*i*
1620	Paimpol . . .		48 47	3 02	+0038	+0025	+0025	+0021	−0·8	−0·3	−0·9	−0·8	5·52	202	3·58	242	1·32	102	0·10	009	0·08	295	0·013	180	0·001	*i*
1621	Ile de Bréhat . .		48 51	3 00	+0040	+0020	+0010	+0015	−0·7	−0·1	−0·5	−0·2	5·85	198	3·36	238	1·24	102	0·10	009	0·08	321	0·008	072	0·001	*i*
1622	Les Heaux de Brehat	F	48 55	3 05	+0030	+0031	−0011	+0042	−1·3	−0·6	−0·7	−0·3	5·51	195	3·25	244	1·15	097	0·09	346	0·08	060	0·003	⊙	⊙		*i*
1623	Lezardrieux . .		48 47	3 06	+0038	+0026	+0015	+0020	−1·1	−0·6	−0·7	−0·4	5·57	193	3·15	241	1·22	102	0·10	009	0·08	290	0·006	⊙	⊙		
1624	Plougrescant . .		48 51	3 13	+0004	−0005	−0017	−0013	−1·5	−0·7	−0·6	0·0	5·55	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
1625	Tréguier . .		48 47	3 13	+0012	−0004	−0018	−0007	−1·4	−0·7	−0·8	−0·4	5·46	185	3·14	225	1·16	090	0·06	346	0·06	318	0·018	166	0·001	*i*
1626	Ploumanac'h . .		48 50	3 29	+0005	0000	−0025	−0015	−2·2	−1·1	−0·7	−0·4	5·15	181	2·85	221	1·05	090	0·06	346	0·06	194	0·017	140	0·003	*i*
1638	**BREST** . . .	(see page 226)			0500 and 1700	1000 and 2200	1100 and 2300	0400 and 1600	7·5	5·9	3·0	1·4														
1628	Trebeurden . .		48 46	3 35	+0111	+0107	+0120	+0100	+1·6	+1·3	+0·5	−0·1	5·28	175	2·81	215	1·04	090	0·06	346	0·06	259	0·025	158	0·005	*i*
	Rade de Morlaix																										
1629	Morlaix (Chateau du Taureau) . .	F	48 41	3 53	+0114	+0056	+0114	+0046	+1·5	+1·1	+0·5	−0·1	5·20	173	2·77	213	1·03	090	0·06	346	0·06	⊙	⊙	⊙	⊙		*i*
1630	Roscoff . . .		48 43	3 58	+0105	+0055	+0110	+0045	+1·4	+1·1	+0·5	−0·1	5·17	172	2·77	212	1·03	090	0·06	346	0·06	264	0·017	173	0·002	*i*
1631	Ile de Batz . .		48 44	4 00	+0105	+0045	+0105	+0045	+1·4	+1·1	+0·5	0·0	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙		
	L'Aberwrac'h																										
1632	Fort Cézon . .		48 37	4 36	+0035	+0020	+0035	+0015	+0·5	+0·2	−0·1	−0·3	4·52	154	2·45	194	0·90	090	0·06	346	0·06	254	0·016	199	0·003		*i*
1633	L'Aberbenoit . .		48 35	4 38	+0020	+0025	+0035	+0035	+0·6	+0·5	+0·1	−0·2	4·70	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙		
1638	**BREST** . . .	(see page 226)			0600 and 1800	0000 and 1200	0000 and 1200	0600 and 1800	7·5	5·9	3·0	1·4														
	Ushant (Ouessant)																										
1634	Baie de Lampaul . .		48 27	5 06	+0005	0000	−0005	−0005	0·0	−0·1	0·0	+0·1	4·45	139	2·06	180	0·83	093	0·07	338	0·06	⊙	⊙	⊙	⊙			

1635	Molene			48 24	4 58	+0·10	+0·10	+0·15	+0·15	−0·1	−0·1	−0·2	−0·2	4·30	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
1636	Le Conquet			48 22	4 47	0000	0000	+0·10	0000	−0·3	−0·3	−0·1	0·0	4·26	141	2·02	181	0·73	090	0·07	342	0·07	281	0·017	⊙	⊙	
1637	La Penfeld			48 23	4 30	−0·05	−0·05	0000	−0·05	+0·1	0·0	+0·2	+0·2	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
1638	**BREST**			48 23	4 29	STANDARD PORT					See Table V			*w*	138	2·02	178	0·74	090	0·06	346	0·06	258	0·011	⊙	⊙	*w*
1639	Camaret			48 16	4 36	−0·15	−0·15	−0·15	−0·20	−0·5	−0·5	−0·2	−0·1	4·14	132	1·96	170	0·72	089	0·07	335	0·06	270	0·007	⊙	⊙	
1640	Douarnenez			48 06	4 19	−0·10	−0·15	−0·15	−0·20	−0·5	−0·4	−0·2	0·0	4·17	133	1·91	170	0·64	085	0·07	339	0·07	266	0·012	⊙	⊙	
1641	Ile de Sein			48 02	4 51	−0·10	−0·10	−0·10	−0·15	−1·1	−0·9	−0·5	−0·3	3·78	133	1·90	173	0·70	090	0·06	346	0·06	341	0·020	351	0·006	*i*
1643	Audierne			48 01	4 33	−0·40	−0·20	−0·40	−0·20	−2·3	−1·8	−0·9	−0·5	3·08	122	1·57	162	0·58	090	0·06	346	0·06	330	0·013	135	0·007	*i*
1644	Guilvinec			47 48	4 17	−0·35	−0·10	−0·35	−0·20	−2·4	−1·9	−1·0	−0·5	3·03	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
	Pont l'Abbe River																										
1645	Loctudy			47 50	4 10	−0·30	−0·10	−0·30	−0·25	−2·6	−2·1	−1·2	−0·9	2·76	123	1·53	163	0·57	090	0·06	346	0·06	151	0·006	180	0·007	*i*
	Odet River																										
1646	Benodet			47 53	4 07	−0·25	−0·10	−0·40	−0·15	−2·6	−2·2	−1·2	−0·8	2·75	125	1·53	165	0·57	090	0·06	346	0·06	180	0·023	171	0·012	*i*
1647	Corniguel			47 58	4 06	+0·10	+0·15	−0·15	−0·10	−2·6	−2·1	−1·4	−1·1	2·66	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
1648	Concarneau			47 52	3 54	−0·35	−0·05	−0·30	−0·20	−2·5	−2·0	−1·0	−0·6	2·93	122	1·50	162	0·55	090	0·06	346	0·06	339	0·038	174	0·020	*i*
	Iles de Glenan																										
1649	Penfret			47 44	3 57	−0·25	−0·10	−0·30	−0·20	−2·6	−2·0	−1·2	−0·6	2·87	125	1·53	165	0·57	090	0·06	346	0·06	331	0·006	134	0·008	*i*
1650	Port Louis			47 42	3 21	−0·25	−0·10	−0·20	−0·20	−2·4	−1·9	−0·9	−0·5	3·04	127	1·62	167	0·57	090	0·06	346	0·06	191	0·032	192	0·008	*i*
1651	Lorient			47 45	3 21	−0·25	+0·05	−0·25	−0·15	−2·4	−1·9	−1·0	−0·5	3·04	130	1·50	163	0·55	092	0·06	345	0·06	189	0·026	⊙	⊙	
	Ile de Groix																										
1652	Port Tudy		F	47 39	3 27	−0·35	−0·05	−0·30	−0·25	−2·4	−1·9	−0·9	−0·5	3·06	129	1·49	163	0·55	093	0·06	346	0·06	196	0·028	⊙	⊙	
1653	Port-Haliguen			47 29	3 06	−0·20	0000	−0·25	−0·15	−2·3	−1·9	−1·0	−0·8	2·98	126	1·68	166	0·62	090	0·06	346	0·06	191	0·043	180	0·012	*i*
	Belle-Ile																										
1654	Le Palais			47 21	3 09	−0·30	−0·15	−0·30	−0·25	−2·3	−1·9	−1·0	−0·6	3·01	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
	Crac'h River																										
1655	La Trinite			47 35	3 01	−0·20	+0·10	−0·25	−0·15	−2·1	−1·7	−0·9	−0·7	3·09	127	1·68	167	0·62	090	0·06	346	0·06	219	0·030	135	0·008	*i*
	Morbihan																										
1656	Port-Navalo			47 33	2 55	−0·05	+0·25	−0·10	−0·05	−2·5	−2·0	−1·1	−0·7	2·90	135	1·53	175	0·57	090	0·06	346	0·06	202	0·043	⊙	⊙	*i*
1657	Auray			47 40	2 59	+0·05	+0·40	⊙	⊙	−2·2	−1·8	−1·1	−0·6	3·1	147	1·64	187	0·61	090	0·06	346	0·06	237	0·064	109	0·009	*ix*
1658	Vannes			47 40	2 46	+0·20	+0·20	⊙	⊙	−2·8	−1·9	−0·9	−0·1	2·7	207	1·39	247	0·51	090	0·06	346	0·06	307	0·070	000	0·003	*ix*
1659	Ile de Hoedic			47 20	2 52	−0·25	−0·05	−0·30	−0·20	−2·3	−1·9	−1·1	−0·8	2·95	125	1·64	165	0·61	093	0·06	347	0·07	166	0·036	169	0·008	*i*
1660	Pénerf			47 31	2 37	−0·20	−0·10	−0·25	−0·20	−2·0	−1·7	−1·0	−0·7	3·09	128	1·75	168	0·65	093	0·06	347	0·07	180	0·017	112	0·001	*i*
1661	Le Croisic			47 18	2 31	−0·30	+0·30	−0·15	−0·10	−2·3	−1·8	−1·1	−0·8	2·97	134	1·59	170	0·57	109	0·08	340	0·07	199	0·055	359	0·007	
	La Loire																										
1662	Le Pouliguen			47 17	2 25	−0·40	+0·15	0000	−0·20	−2·1	−1·8	−1·2	−0·8	2·95	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
1663	Le Grand-Charpentier			47 13	2 19	−0·30	+0·10	−0·20	−0·20	−2·2	−2·0	−1·3	−0·9	3·0	126	1·72	166	0·63	093	0·06	347	0·07	204	0·045	052	0·007	*ix*
1664	St. Nazaire		F	47 16	2 12	−0·25	+0·30	−0·05	−0·10	−2·0	−1·7	−1·1	−0·8	3·06	136	1·71	170	0·60	093	0·06	347	0·07	205	0·045	⊙	⊙	
1665	Paimboeuf			47 17	2 02	−0·05	+0·15	+0·20	+0·30	−1·9	−1·6	−1·3	−0·5	3·2	153	1·72	193	0·63	093	0·06	347	0·07	270	0·052	131	0·010	*ix*
1666	Le Pellerin			47 12	1 45	+0·00	+0·40	+0·30	+0·20	−1·7	−1·4	−1·2	+0·1	3·32	172	1·93	206	0·68	107	0·04	001	0·05	252	0·079	⊙	⊙	
1667	Nantes (Chantenay)			47 12	1 35	+0·40	+0·55	+0·30	+0·45	−1·7	−1·3	−1·1	+0·2	3·74	195	1·59	229	0·56	217	0·04	111	0·05	243	0·116	⊙	⊙	

⊙ No data.
F Tides predicted in French Tide Tables.
i Constants inferred.
w Owing to large fortnightly variations, see Table VIa.
x M.L. inferred.

SEASONAL CHANGES IN MEAN LEVEL

No.	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Sep. 1	Oct. 1	Nov. 1	Dec. 1	Jan. 1
1605–1626	0·0	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	0·0	+0·1	+0·1	+0·1	0·0
1628–1643							Negligible						
1645–1667	0·0	0·0	0·0	0·0	0·0	0·0	−0·1	−0·1	0·0	0·0	0·0	+0·1	0·0

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TABLE V Tidal Levels at Standard Ports

(with data concerning predictions, etc.)

Standard Port	L.A.T.	M.L.W.S.	M.L.W.N.	M.S.L.	M.H.W.N.	M.H.W.S.	H.A.T.	Authority for (*b*) Observations	Constants	Predictions	Years of tidal observations (*c*)
	m.	m.	m.	m.	m.	m.	m.				
Puerto Gallegos	−0·4	+1·6	+3·8	+6·7	+9·5	+12·0	+13·2	Ar.	Ar.	Ar.	—
Puerto Madryn	−0·3	+0·3	+1·5	+3·0	+4·5	+5·3	+6·1	Ar.	Ar.	Ar.	1969 (1)
Puerto Belgrano (Bahia Blanca)	−0·1	+0·5	+1·0	+2·4	+3·7	+4·1	+4·3	Ar.	Ar.	Ar.	1905–37 (5)
Rio De Janeiro	−0·1	+0·1	+0·4	+0·7	+0·9	+1·2	+1·4	B.	B.	B.	1953 (1)
Georgetown (Guyana)	−0·1	+0·3	+1·0	+1·6	+2·2	+2·9	+3·4	H.A.	I.O.S.	I.O.S.	1974 (1)
Bermuda	−0·1	+0·2	+0·4	+0·7	+0·9	+1·2	+1·5	Hyd.	I.O.S.	I.O.S.	1853, 1920 (1)
Charleston	−0·5	−0·2	+0·1	+0·8	+1·4	+1·7	+2·1	U.S.	U.S.	U.S.	1948 (1)
Sandy Hook (New York Bay)	−0·4	−0·2	+0·2	+0·7	+1·2	+1·6	+2·0	U.S.	U.S.	U.S.	1940 (3)
Boston	−0·7	−0·2	+0·2	+1·5	+2·7	+3·2	+3·7	U.S.	U.S.	U.S.	1940 (5)
Saint John N.B.	−0·3	+0·6	+1·7	+4·3	+6·9	+8·0	+8·9	C.	C.	C.	(*d*)
Halifax	+0·1	+0·4	+0·7	+1·2	+1·7	+2·1	+2·4	C.	C.	C.	(*d*)
Pointe-au-Père	−0·1	+0·5	+1·4	+2·3	+3·1	+4·2	+4·9	C.	C.	C.	(*d*)
Quebec	−0·1	+0·3	+0·6	+2·6	+4·0	+5·2	+6·1	C.	C.	C.	(*d*)
Harrington	+0·1	+0·3	+0·7	+1·1	+1·4	+1·8	+2·3	C.	C.	C.	(*d*)
Argentia	0·0	+0·3	+0·7	+1·2	+1·7	+2·2	+2·7	C.	C.	C.	(*d*)
St. John's Harbour (Newfoundland)	0·0	+0·2	+0·5	+0·8	+0·9	+1·3	+1·6	C.	C.	C.	(*d*)
Ponta Delgada	0·0	+0·3	+0·7	+1·0	+1·3	+1·7	+2·0	P.	P.	P.	1939 (1)
Casablanca	+0·4	+0·7	+1·5	+2·1	+2·8	+3·6	+4·0	F.	F.	F.	1958 (1)
Dakar	0·0	+0·3	+0·7	+1·0	+1·3	+1·6	+1·9	F.	F.	F.	1965 (7)
Freetown (Sierra Leone)	0·0	+0·4	+1·0	+1·7	+2·3	+3·0	+3·4	H.A.	I.O.S.	I.O.S.	1926–27 (1)
Takoradi	−0·1	+0·2	+0·6	+1·0	+1·2	+1·5	+1·9	Gh.	I.O.S.	I.O.S.	1927–30 (2)
Bonny Town	0·0	+0·4	+0·9	+1·5	+1·9	+2·3	+2·7	H.A.	I.O.S.	I.O.S.	1958 (1)
Cape Town	+0·1	+0·3	+0·8	+1·0	+1·3	+1·8	+2·1	H.A.	S.A	S.A.	(*d*)
Durban	0·0	+0·2	+0·8	+1·1	+1·3	+2·0	+2·3	H.A.	S.A.	S.A.	(*d*)
Beira	+0·2	+0·9	+2·7	+3·5	+4·2	+6·5	+7·1	P.	P.	P.	1952, 3 (1)
Dar Es Salaam	−0·5	−0·1	+1·0	+1·5	+2·1	+3·2	+3·7	H.A.	I.O.S.	I.O.S.	1929–30 (1)
Zanzibar	−0·2	+0·2	+1·5	+2·1	+2·7	+3·9	+4·5	H.A.	I.O.S.	I.O.S.	1925–27 (1)
Kilindini	−0·1	+0·3	+1·3	+1·9	+2·4	+3·5	+4·0	H.A.	I.O.S.	I.O.S.	1975, 76 (1)
Suez	0·0	+0·4	+0·7	+1·1	+1·6	+1·9	+2·3	I.	I.	I.	1897–1904 (7)
Mina Salman	0·0	+0·6	+1·0	+1·5	+1·9	+2·4	+2·7	Hyd.	I.O.S.	Hyd.	1976 (1)
Bhavnagar	+0·3	+1·4	+3·5	+6·1	+8·3	+10·2	+12·2	I.	I.	I.	—
Bombay	−0·2	+0·8	+1·9	+2·5	+3·3	+4·4	+5·1	I.	I.	I.	1951–54 (4)
Colombo	−0·1	+0·1	+0·3	+0·4	+0·5	+0·7	+0·9	I.	I.	I.	1884–90 (6)
Trincomalee	0·0	+0·1	+0·3	+0·4	+0·5	+0·7	+0·9	I.	I.	I.	1890–95 (6)
Madras	−0·1	+0·1	+0·4	+0·6	+0·8	+1·1	+1·5	I.	I.	I.	1952–65 (6)
Sagar Roads (Hooghly river)	+0·2	+0·9	+2·2	+3·0	+3·8	+5·2	+5·9	H.A.	I.	I.	1948–64 (9)
Pussur River Ent.	−0·3	+0·6	+1·3	+1·8	+2·2	+3·0	+3·8	Pa.	I.O.S.	I.O.S.	1976 (1)
Chittagong	−0·1	+0·5	+1·0	+2·1	+3·0	+4·0	+5·0	Pa.	I.O.S.	I.O.S.	1978 (1)
Bassein River Ent. (Thamihla Kyun)	−0·2	+0·4	+1·1	+1·4	+1·8	+2·4	+2·8	I.	I.	I.	1895–99 (5)
Elephant Point (Rangoon river)	+0·1	+0·8	+2·5	+3·7	+4·9	+6·6	+7·3	I.	I.	I.	1884–88, 1930 (6)
Mergui	−0·8	+0·1	+2·0	+2·8	+3·6	+5·4	+6·2	I.	I.	I.	1889–94 (5)
Penang	+0·1	+0·6	+1·3	+1·6	+1·8	+2·5	+2·9	H.A.	I.O.S.	I.O.S.	1953 (1)
Pelabuhan Kelang	−0·1	+0·7	+2·3	+2·9	+3·6	+4·8	+5·4	H.A.	I.O.S.	I.O.S.	1911–12 (1)
Port Dickson	−0·1	+0·3	+1·1	+1·5	+1·9	+2·8	+3·4	I.T.S.	I.T.S.	I.O.S.	1979 (1)
Kuala Batu Pahat	−0·2	+0·3	+1·1	+1·5	+1·9	+2·7	+3·3	I.T.S.	I.T.S.	I.O.S.	1979 (1)
Singapore (Victoria Dock)	−0·3	+0·6	+1·1	+1·6	+2·1	+2·8	+3·3	H.A.	I.O.S.	H.A.	1954 (3)

The above levels, in metres, are referred to *CHART DATUM*, which is the same as the zero of the tidal predictions in all cases.

For Notes (*b*), (*c*) and (*d*) see ATT.

TABLE V—*continued*

Standard Port	L.A.T.	M.L.W.S.	M.L.W.N.	M.S.L.	M.H.W.N.	M.H.W.S.	H.A.T.	Authority for (*b*) Observations	Constants	Predictions	Years of tidal observations (*c*)
	m.	m.	m.	m.	m.	m.	m.				
Cape Horn (Orange Bay)	+0·1	+0·5	+0·9	+1·3	+1·7	+2·2	+2·7	U.S.	U.S.	U.S.	1882–83 (1)
Stanley	0·0	+0·4	+0·7	+1·0	+1·4	+1·6	+2·1	H.A.	Hyd.	Hyd.	1964 (3 mths.)
Buenos Aires (Rio de la Plata)	−0·1	+0·3	+0·5	+0·8	+1·0	+1·3	+1·7	Ar.	Ar.	Ar.	1970 (1)
Port of Spain	0·0	+0·4	+0·5	+0·7	+0·9	+1·1	+1·3	H.A.	I.O.S.	I.O.S.	1938 (1)
Maracaibo Appr. Malecon	0·0	+0·2	+0·5	+0·8	+1·2	+1·3	+1·7	H.A.	U.S.	U.S.	—
Colon	−0·2	0·0	0·0	+0·1	+0·1	+0·3	+0·5	U.S.	U.S.	U.S.	1950 (1)
Galveston	−0·4	0·0	+0·3	+0·2	+0·4	+0·4	+0·5	U.S.	U.S.	U.S.	1908, 23, 32 (3)
Pictou	−0·1	+0·5	+0·9	+1·1	+1·5	+1·7	+2·0	C.	C.	C.	(*d*)
Aden	−0·2	+0·5	+1·2	+1·3	+1·8	+2·0	+2·6	I.	I.	I.O.S.	1951–55 (4)
Muscat	−0·1	+0·8	+1·6	+1·9	+2·4	+2·7	+3·2	I.	I.	I.	—
Musay'id outer channel entr.	+0·3	+0·7	+1·0	+1·1	+1·2	+1·9	+2·5	Q.	I.O.S.	I.O.S.	1959 (1)
Mina Saud	−0·2	+0·4	+1·2	+1·2	+1·6	+2·0	+2·4	H.A.	I.O.S.	I.O.S.	1966–67 (1)
Mina Al Ahmadi	−0·2	+0·4	+1·2	+1·5	+2·0	+2·4	+2·9	A.I.	Hyd.	I.O.S.	1952 (2 mths.)
Shatt Al Arab Bar	−0·5	+0·4	+1·3	+1·7	+2·4	+3·0	+3·5	H.A.	Rob.	I.O.S.	1918–19 (1)
Khawr-e Musa Bar	0·0	+0·9	+1·9	+2·3	+2·9	+3·5	+4·3	Ir.	I.O.S.	I.O.S.	1960, 1963 (2)
Jazireh Ye Khark	+0·1	+0·5	+1·1	+1·2	+1·4	+2·0	+2·6	Ir.	I.O.S.	I.O.S.	1958, 1962 (2)
Karachi	−0·4	+0·4	+1·1	+1·6	+2·4	+2·7	+3·2	Pa.	I.O.S.	I.O.S.	1950, 1953 (2)
Cochin	0·0	+0·3	+0·6	+0·6	+0·8	+0·9	+1·2	I.	I.	I.	1886–92 (6)
Air Musi (Outer Bar)	−0·3	+0·9	△	+1·9	△	+3·1	+4·4	N.	N.	Hyd.	1954 (2)
Horsburgh Lt. Ho.	−0·3	+0·6	+1·3	+1·5	+2·1	+2·2	+2·8	I.T.S.	I.T.S.	I.O.S.	1979 (1)
Karang Djamuang	−0·2	+0·4	△	+1·1	△	+1·6	+2·2	N.	N.	Hyd.	—
Mui Vung Tau	−0·4	+0·9	+2·2	+2·4	+3·3	+3·5	+4·1	F.	F.	F.	—

Notes:

(*a*) The above levels, in metres, are referred to *CHART DATUM*, which is the same as the zero of the tidal predictions in all cases.

(*b*) *Abbreviations:*

- A.I. Anglo-Iranian Oil Company.
- Ar. Ministerio de Marina, Buenos Aires.
- B. Brazilian Government.
- C. Canadian Hydrographic Service, Ottawa.
- F. Service Hydrographique et Océanographique, Brest.
- Gh. Survey of Ghana.
- H.A. Local Harbour Authority.
- Hyd. Hydrographer of the Navy.
- I. Geodetic Branch, Survey of India.
- Ir. Iranian Oil Exploration and Producing Company.
- I.O.S. Institute of Oceanographic Sciences.
- I.T.S. International Tidal Survey.
- N. Netherlands Government.
- P. Ministerio de Marinha, Lisbon.
- Pa. Pakistan Navy.
- Q. Qatar Petroleum Company Limited.
- Rob. Messrs. Edward Roberts & Son.
- S.A. Hydrographer, South African Navy.
- U.S. United States National Ocean Survey.

(*c*) The years between which the observations were obtained are given, with the number of complete year's observations in brackets.

(*d*) Constants from the latest available year.

(*e*) All predictions in this volume are calculated by the harmonic method, except Sagar Roads, Elephant Point and Chittagong where the harmonic method with shallow water corrections is used. Predictions for Quebec have been prepared using constants obtained from the analysis of High and Low waters over a 19-year period.

(*f*) △ Tide is usually diurnal.

(*g*) For definitions of tidal levels see page 104.

Volume 2 ATLANTIC AND INDIAN OCEANS—Part I (Standard Ports)

CANADA, BAY OF FUNDY - SAINT JOHN, N.B.

LAT 45°16'N LONG 66°04'W

TIME ZONE +0400 TIMES AND HEIGHTS OF HIGH AND LOW WATERS YEAR 1982

JANUARY

	TIME	M		TIME	M		TIME	M		TIME	M
1	0320	7.3	16	0450	7.4	1	0435	7.4	16	0545	7.1
	0930	1.6		1100	1.5		1050	1.4		1205	1.7
F	1540	7.4	SA	1710	7.3	M	1655	7.1	TU	1815	6.8
	2155	1.2		2320	1.4		2320	1.8			
2	0410	7.3	17	0540	7.2	2	0530	7.3	17	0020	2.0
	1025	1.6		1155	1.6		1155	1.5		0635	7.0
SA	1620	7.3	SU	1605	7.0	TU	1805	7.0	W	1300	1.9
	2255	1.3								1910	6.7
3	0500	7.3	18	0025	1.6	3	0015	1.5	18	0115	2.0
	1115	1.6		0630	7.2		0640	7.4		0740	7.0
SU	1715	7.2	M	1250	1.6	W	1305	1.4	TH	1350	1.8
	2345	1.4		1915	6.9		1905	6.9		2000	6.7
4	0555	7.3	19	0115	1.7	4	0130	1.6	19	0215	2.0
	1220	1.6		0735	7.2		0745	7.4		0830	7.1
M	1820	7.1	TU	1355	1.6	TH	1405	1.3	F	1455	1.7
				2005	6.9		2025	7.1		2100	6.8
5	0050	1.4	20	0200	1.7	5	0230	1.4	20	0315	1.9
	0700	7.4		0815	7.3		0855	7.7		0920	7.3
TU	1315	1.4	W	1440	1.6	F	1515	1.0	SA	1530	1.5
	1930	7.1		2050	6.9		2120	7.3		2150	7.0
6	0155	1.3	21	0300	1.7	6	0335	1.1	21	0350	1.6
	0805	7.7		0905	7.3		0945	8.0		1010	7.5
W	1425	1.2	TH	1525	1.4	SA	1615	0.7	SU	1625	1.2
	2040	7.3		2140	7.0		2220	7.6		2230	7.2
7	0245	1.2	22	0345	1.7	7	0445	0.9	22	0445	1.4
	0905	7.9		0955	7.5		1050	8.2		1050	7.7
TH	1525	0.9	F	1610	1.3	SU	1700	0.4	M	1705	1.0
	2130	7.5		2220	7.1		2320	7.8		2305	7.4
8	0400	0.9	23	0420	1.6	8	0530	0.7	23	0515	1.2
	1005	8.1		1030	7.6		1135	8.3		1120	7.8
F	1620	0.5	SA	1645	1.1	M	1800	0.3	TU	1740	0.9
	2240	7.7		2305	7.3					2350	7.6

FEBRUARY

	TIME	M		TIME	M		TIME	M		TIME	M
1	0315	7.7	16	0410	7.3	1	0455	7.4	16	0500	7.0
	0940	1.0		1025	1.5		1120	1.4		1125	1.9
M	1540	7.4	TU	1635	6.9	TH	1735	6.9	F	1735	6.7
	2200	1.2		2240	1.9		2355	1.8		2345	2.3
2	0400	7.6	17	0450	7.0	2	0600	7.3	17	0550	6.9
	1035	1.2		1105	1.6		1230	1.5		1215	2.0
TU	1635	7.1	W	1720	6.7	F	1845	6.9	SA	1830	6.7
	2255	1.5		2335	2.1						
3	0500	7.4	18	0550	6.9	3	0100	1.8	18	0040	2.3
	1130	1.4		1210	2.0		0715	7.3		0650	6.9
W	1750	6.9	TH	1815	6.6	SA	1350	1.4	SU	1315	2.0
							2005	7.1		1925	6.8
4	0010	1.7	19	0030	2.3	4	0215	1.6	19	0140	2.1
	0620	7.3		0[illegible]	6.8		0630	7.5		0745	7.1
TH	1250	1.5	F	13[illegible]	2.0	SU	1445	1.2	M	1405	1.7
	1900	6.9		1925	6.6		2115	7.4		2015	7.1
5	0115	1.7	20	0130	2.2	5	0320	1.3	20	0240	1.8
	0735	7.3		0745	6.9		0935	7.7		0850	7.3
F	1355	1.4	SA	1405	1.9	M	1555	0.9	TU	1505	1.5
	2010	7.0		2020	6.7		2200	7.7		2110	7.4
6	0220	1.6	21	0220	2.0	6	0410	1.0	21	0320	1.5
	0840	7.5		0835	7.1		1020	8.0		0940	7.6
SA	1505	1.1	SU	1450	1.7	TU	1630	0.7	W	1555	1.2
	2120	7.3		2100	7.0		2255	7.9		2155	7.7
7	0330	1.2	22	0315	1.8	7	0500	0.7	22	0410	1.1
	0945	7.8		0925	7.3		1105	6.0		1025	7.8
SU	1605	0.8	M	1540	1.4	W	1715	0.6	TH	1640	0.9
	2215	7.6		2150	7.3		2335	8.0		2245	8.0
8	0420	0.9	23	0405	1.5	8	0545	0.6	23	0500	0.8
	1035	8.0		1010	7.6		1150	8.1		1115	7.9
M	1650	0.5	TU	1625	1.1	TH	1810	0.6	F	1725	0.8
	2300	7.8		2240	7.6					2325	8.2

MARCH

	TIME	M		TIME	M		TIME	M		TIME	M
1	0315	7.7	16	0410	7.3	1	0455	7.4	16	0500	7.0
	0940	1.0		1025	1.5		1120	1.4		1125	1.9
M	1540	7.4	TU	1635	6.9	TH	1735	6.9	F	1735	6.7
	2200	1.2		2240	1.9		2355	1.8		2345	2.3
2	0400	7.6	17	0450	7.0	2	0600	7.3	17	0550	6.9
	1035	1.2		1105	1.6		1230	1.5		1215	2.0
TU	1635	7.1	W	1720	6.7	F	1845	6.9	SA	1830	6.7
	2255	1.5		2335	2.1						
3	0500	7.4	18	0550	6.9	3	0100	1.8	18	0040	2.3
	1130	1.4		1210	2.0		0715	7.3		0650	6.9
W	1750	6.9	TH	1815	6.6	SA	1350	1.4	SU	1315	2.0
							2005	7.1		1925	6.8
4	0010	1.7	19	0030	2.3	4	0215	1.6	19	0140	2.1
	0620	7.3		0[illegible]	6.8		0630	7.5		0745	7.1
TH	1250	1.5	F	13[illegible]	2.0	SU	1445	1.2	M	1405	1.7
	1900	6.9		1925	6.6		2115	7.4		2015	7.1
5	0115	1.7	20	0130	2.2	5	0320	1.3	20	0240	1.8
	0735	7.3		0745	6.9		0935	7.7		0850	7.3
F	1355	1.4	SA	1405	1.9	M	1555	0.9	TU	1505	1.5
	2010	7.0		2020	6.7		2200	7.7		2110	7.4
6	0220	1.6	21	0220	2.0	6	0410	1.0	21	0320	1.5
	0840	7.5		0835	7.1		1020	8.0		0940	7.6
SA	1505	1.1	SU	1450	1.7	TU	1630	0.7	W	1555	1.2
	2120	7.3		2100	7.0		2255	7.9		2155	7.7
7	0330	1.2	22	0315	1.8	7	0500	0.7	22	0410	1.1
	0945	7.8		0925	7.3		1105	6.0		1025	7.8
SU	1605	0.8	M	1540	1.4	W	1715	0.6	TH	1640	0.9
	2215	7.6		2150	7.3		2335	8.0		2245	8.0
8	0420	0.9	23	0405	1.5	8	0545	0.6	23	0500	0.8
	1035	8.0		1010	7.6		1150	8.1		1115	7.9
M	1650	0.5	TU	1625	1.1	TH	1810	0.6	F	1725	0.8
	2300	7.8		2240	7.6					2325	8.2

APRIL

	TIME	M		TIME	M
1	0455	7.4	16	0500	7.0
	1120	1.4		1125	1.9
TH	1735	6.9	F	1735	6.7
	2355	1.8		2345	2.3
2	0600	7.3	17	0550	6.9
	1230	1.5		1215	2.0
F	1845	6.9	SA	1830	6.7
3	0100	1.8	18	0040	2.3
	0715	7.3		0650	6.9
SA	1350	1.4	SU	1315	2.0
	2005	7.1		1925	6.8
4	0215	1.6	19	0140	2.1
	0630	7.5		0745	7.1
SU	1445	1.2	M	1405	1.7
	2115	7.4		2015	7.1
5	0320	1.3	20	0240	1.8
	0935	7.7		0850	7.3
M	1555	0.9	TU	1505	1.5
	2200	7.7		2110	7.4
6	0410	1.0	21	0320	1.5
	1020	8.0		0940	7.6
TU	1630	0.7	W	1555	1.2
	2255	7.9		2155	7.7
7	0500	0.7	22	0410	1.1
	1105	6.0		1025	7.8
W	1715	0.6	TH	1640	0.9
	2335	8.0		2245	8.0
8	0545	0.6	23	0500	0.8
	1150	8.1		1115	7.9
TH	1810	0.6	F	1725	0.8
				2325	8.2

BURMA - BASSEIN RIVER ENTRANCE (THAMIHLA KYUN)

LAT 15°52'N LONG 94°16'E

TIME ZONE -0630 TIMES AND HEIGHTS OF HIGH AND LOW WATERS YEAR 1982

SEPTEMBER

	TIME	M		TIME	M		TIME	M		TIME	M
9	0053	2.5	24	0113	2.2	9	0120	2.4	24	0123	2.2
	0704	0.8		0726	1.1		0749	1.0		0749	1.2
TH	1300	2.3	F	1319	2.0	SA	1337	2.1	SU	1335	1.8
	1920	0.7		1933	1.0		1957	1.0		1947	1.2
10	0136	2.4	25	0158	2.1	10	0222	2.2	25	0220	2.0
	0757	1.0		0819	1.3		0910	1.1		0907	1.3
F	1348	2.2	SA	1405	1.8	SU	1457	1.9	M	1503	1.7
	2013	0.9		2030	1.2		2121	1 2		2111	1.3
11	0237	2.2	26	0308	1.9	11	0357	2.1	26	0400	1.9
	0912	1.1		0956	1.4		1054	1.2		1104	1.3
SA	1456	2.0	SU	1548	1.7	M	1704	1.9	TU	1732	1.7
	2129	1.0		2210	1.3		2311	1.2		2309	1.3
12	0406	2.1	27	0513	1.9	12	0556	2.1	27	0551	2.0
	1054	1.2		1222	1.3		1235	1.1		1238	1.2
SU	1644	1.8	M	1822	1.7	TU	1849	2.0	W	1852	1.9
	2311	1.1									
13	0603	2.1	28	0008	1.3	13	0049	1.1	28	0041	1.2
	1242	1.1		0655	2.0		0714	2.3		0655	2.1
M	1843	1.9	TU	1337	1.2	W	1340	0.9	TH	1326	1.0
				1928	1.8		1949	2.2		1934	2.1
14	0049	1.0	29	0121	1.1	14	0152	0.9	29	0134	1.0
	0727	2.3		0744	2.2		0805	2.4		0737	2.2
TU	1355	0.9	W	1413	1.0	TH	1426	0.7	F	1401	0.8
	1955	2.1		2006	2.0		2033	2.4		2009	2.3
15	0159	0.8	30	0206	1.0	15	0240	0.8	30	0216	0.9
	0822	2.5		0818	2.3		0846	2.5		0812	2.4
W	1447	0.7	TH	1443	0.8	F	1504	0.6	SA	1433	0.7
	2046	2.2		2039	2.2		2110	2.5		2042	2.4
									31	0253	0.7
									SU	0847	2.4
										1505	0.5
										2115	2.6

OCTOBER

	TIME	M		TIME	M		TIME	M		TIME	M
9	0348	2.1	24	0250	2.0	9	0438	2.0	24	0301	1.9
	1040	1.1		0945	1.2		1120	0.9		0949	0.9
TU	1702	1.9	W	1610	1.7	TH	1750	2.0	F	1621	1.8
	2301	1.2		2156	1.3					2226	1.1
10	0529	2.1	25	0420	1.9	10	0000	1.1	25	0421	1.8
	1207	1.0		1111	1.1		0558	2.0		1102	0.8
W	1832	2 0	TH	1746	1.8	F	1227	0.8	SA	1742	1.9
				2336	1.2		1855	2.1		2354	1.0
11	0034	1.1	26	0543	2.0	11	0110	1.0	26	0540	1.8
	0645	2.2		1218	1.0		0702	2.0		1210	0.7
TH	1310	0.9	F	1846	2.0	SA	1319	0.8	SU	1845	2.1
	1928	2.2					1941	2.2			
12	0135	1.0	27	0049	1.1	12	0202	0.8	27	0103	0.8
	0738	2.3		0643	2.1		0749	2.0		0648	1.9
F	1357	0.7	SA	1307	0.8	SU	1401	0.7	M	1309	0.5
	2011	2.4		1930	2.2		2019	2.3		1937	2.2
13	0223	0.8	28	0141	0.9	13	0243	0.7	28	0201	0.6
	0819	2.3		0731	2.2		0829	2.0		0744	2.0
SA	1434	0.6	SU	1351	0.6	M	1437	0.6	TU	1401	0.4
	2046	2.5		2009	2.4		2053	2.4		2025	2.4
14	0301	0.7	29	0226	0.7	14	0319	0.6	29	0251	0.5
	0854	2.3		0813	2.3		0903	2.0		0834	2.1
SU	1507	0.6	M	1430	0.5	TU	1511	0.5	W	1450	0.3
	2117	2.5		2049	2.6		2125	2.4		2111	2.5
15	0336	0.6	30	0310	0.6	15	0352	0.6	30	0339	0.4
	0927	2.3		0856	2.3		0935	2.0		0924	2.1
M	1538	0.6	TU	1511	0.4	W	1543	0.5	TH	1536	0.2
	2146	2.6		2128	2.7		2156	2.4		2157	2.6
									31	0426	0.3
									F	1013	2.1
										1623	0.2
										2242	2.6

NOVEMBER

	TIME	M		TIME	M		TIME	M		TIME	M
9	0348	2.1	24	0250	2.0	9	0438	2.0	24	0301	1.9
	1040	1.1		0945	1.2		1120	0.9		0949	0.9
TU	1702	1.9	W	1610	1.7	TH	1750	2.0	F	1621	1.8
	2301	1.2		2156	1.3					2226	1.1
10	0529	2.1	25	0420	1.9	10	0000	1.1	25	0421	1.8
	1207	1.0		1111	1.1		0558	2.0		1102	0.8
W	1832	2 0	TH	1746	1.8	F	1227	0.8	SA	1742	1.9
				2336	1.2		1855	2.1		2354	1.0
11	0034	1.1	26	0543	2.0	11	0110	1.0	26	0540	1.8
	0645	2.2		1218	1.0		0702	2.0		1210	0.7
TH	1310	0.9	F	1846	2.0	SA	1319	0.8	SU	1845	2.1
	1928	2.2					1941	2.2			
12	0135	1.0	27	0049	1.1	12	0202	0.8	27	0103	0.8
	0738	2.3		0643	2.1		0749	2.0		0648	1.9
F	1357	0.7	SA	1307	0.8	SU	1401	0.7	M	1309	0.5
	2011	2.4		1930	2.2		2019	2.3		1937	2.2
13	0223	0.8	28	0141	0.9	13	0243	0.7	28	0201	0.6
	0819	2.3		0731	2.2		0829	2.0		0744	2.0
SA	1434	0.6	SU	1351	0.6	M	1437	0.6	TU	1401	0.4
	2046	2.5		2009	2.4		2053	2.4		2025	2.4
14	0301	0.7	29	0226	0.7	14	0319	0.6	29	0251	0.5
	0854	2.3		0813	2.3		0903	2.0		0834	2.1
SU	1507	0.6	M	1430	0.5	TU	1511	0.5	W	1450	0.3
	2117	2.5		2049	2.6		2125	2.4		2111	2.5
15	0336	0.6	30	0310	0.6	15	0352	0.6	30	0339	0.4
	0927	2.3		0856	2.3		0935	2.0		0924	2.1
M	1538	0.6	TU	1511	0.4	W	1543	0.5	TH	1536	0.2
	2146	2.6		2128	2.7		2156	2.4		2157	2.6

DECEMBER

	TIME	M		TIME	M
9	0438	2.0	24	0301	1.9
	1120	0.9		0949	0.9
TH	1750	2.0	F	1621	1.8
				2226	1.1
10	0000	1.1	25	0421	1.8
	0558	2.0		1102	0.8
F	1227	0.8	SA	1742	1.9
	1855	2.1		2354	1.0
11	0110	1.0	26	0540	1.8
	0702	2.0		1210	0.7
SA	1319	0.8	SU	1845	2.1
	1941	2.2			
12	0202	0.8	27	0103	0.8
	0749	2.0		0648	1.9
SU	1401	0.7	M	1309	0.5
	2019	2.3		1937	2.2
13	0243	0.7	28	0201	0.6
	0829	2.0		0744	2.0
M	1437	0.6	TU	1401	0.4
	2053	2.4		2025	2.4
14	0319	0.6	29	0251	0.5
	0903	2.0		0834	2.1
TU	1511	0.5	W	1450	0.3
	2125	2.4		2111	2.5
15	0352	0.6	30	0339	0.4
	0935	2.0		0924	2.1
W	1543	0.5	TH	1536	0.2
	2156	2.4		2157	2.6
			31	0426	0.3
			F	1013	2.1
				1623	0.2
				2242	2.6

HEIGHTS IN METRES

Volume 2 ATLANTIC AND INDIAN OCEANS—Part II (Secondary Ports)

UNITED STATES: CANADA, BAY OF FUNDY

No.	Place		Lat. N.	Long. W.	Time Differences MHW (Zone+0500)	Time Differences MLW (Zone+0500)	Height Differences (in metres) MHWS	MHWN	MLWN	MLWS	M.L. Z_0 m.
2864	SAINT JOHN, N.B.		see page 51				**8·0**	**6·9**	**1·7**	**0·6**	
2837	Blue Hill Harbour		44 24	68 34	−0055	−0045	−4·6	−4·0	−1·5	−0·8	1·52
2838	Bar Harbour		44 23	68 12	−0111	−0111	−4·6	−4·0	−1·4	−0·8	1·58
2840	Prospect Harbour		44 24	68 01	−0105	−0055	−4·5	−3·9	−1·4	−0·8	1·58
2842	Jonesport		44 32	67 36	−0105	−0055	−4·3	−3·6	−1·4	−0·8	1·77
2843	Cutler, Little River		44 39	67 13	−0110	−0100	−3·5	−3·0	−1·4	−0·9	2·07
2845	West Quoddy Head		44 49	66 59	−0110	−0100	−2·0	−1·6	−0·4	0·0	3·29
	Canada				**(Zone+0400)**						
	BAY OF FUNDY										
	Grand Manan Island										
2847	Outer Wood Island		44 36	66 48	−0029	−0028	−2·5	−2·2	−0·2	+0·1	3·09
2849	North Head		44 46	66 45	−0006	−0004	−1·5	−1·2	−0·3	+0·1	3·56
2850	Lubec (U.S.)		44 52	66 59	+0005	+0015	−1·4	−1·1	−0·3	0·0	3·57
2853	Welshpool		44 53	66 57	+0005	+0010	−1·3	−1·0	−0·2	+0·1	3·72

Seasonal Changes in Mean Level

No.	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Sep. 1	Oct. 1	Nov. 1	Dec. 1	Jan. 1
2847–2902	0·0	−0·1	−0·1	0·0	0·0	+0·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0

INDIA, EAST COAST: BANGLADESH

No.	Place		Lat. N.	Long. E.	Time Differences MHW (Zone−0530)	Time Differences MLW (Zone−0530)	Height Differences (in metres) MHWS	MHWN	MLWN	MLWS	M.L. Z_0 m.
4512	**CHITTAGONG**		see page 168				**4·0**	**3·0**	**1·0**	**0·5**	
4507	Sandwip Island	B	22 30	91 25	+0320	+0320	+1·4	+1·1	+0·8	0·0	*w*
4507a	Ilsa Ghat	B	22 48	90 39	+0630	+0630	−1·2	−0·7	+0·4	+0·3	*w*
4508	Chandpur		23 15	90 35	+5000	⊙	−2·3	⊙	⊙	⊙	⊙
4509	Narayanganj		23 27	90 32	+0700	⊙	−3·1	⊙	⊙	⊙	⊙
	Kharnaphuli River										
4510	Norman Point		22 11	91 49	−0119	−0135	+0·6	+0·5	+0·9	+0·3	2·32
4512	CHITTAGONG		22 20	91 50	Standard Port			See Table V			*w*
4514	Kutubdia Island		21 52	91 50	−0152	−0222	−0·3	−0·3	+0·4	−0·1	2·04
4515	Cox's Bazaar		21 26	91 59	−0250	−0340	−0·6	−0·5	+0·3	−0·1	1·9
4539	**BASSEIN RIVER ENTRANCE**		see page 171				**2·4**	**1·8**	**1·1**	**0·4**	
4517	St. Martin's Island		20 37	92 19	−0056	−0101	+0·8	+0·5	+0·2	+0·1	1·83
	Burma				**(Zone−0630)**						
4520	Akyab	I	20 08	92 54	+0004	+0001	0·0	−0·1	−0·3	−0·3	1·27
4525	Kyauk Pyu		19 26	93 33	−0020	−0033	+0·6	+0·3	0·0	−0·2	1·62
4526	Searle Point		18 54	93 37	−0017	−0015	+0·4	+0·3	0·0	0·0	1·62
4529	Sagu Island		18 48	93 59	−0013	−0016	+0·4	+0·3	−0·3	−0·3	1·46

Seasonal Changes in Mean Level

No.	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Sep. 1	Oct. 1	Nov. 1	Dec. 1	Jan. 1
4510–4515	−0·3	−0·4	−0·4	−0·3	−0·1	+0·2	+0·4	+0·5	+0·4	+0·2	0·0	−0·2	−0·3
4517–4532	−0·2	−0·3	−0·3	−0·2	−0·1	+0·1	+0·2	+0·3	+0·2	+0·1	+0·1	0·0	−0·2
4534–4539	−0·1	−0·2	−0·3	−0·2	0·0	+0·1	+0·1	+0·1	+0·1	+0·1	+0·1	+0·1	−0·1
4541	−0·4	−0·5	−0·5	−0·5	−0·4	−0·1	+0·3	+0·7	+0·8	+0·6	+0·2	−0·2	−0·4

			Harmonic Constants								S.W. Corrections				
		M.L. Z_0	M_2		S_2		K_1		O_1		$\frac{1}{4}$-diurnal		$\frac{1}{6}$-diurnal		
No.	Place	m.	g°	H.m.	g°	H.m.	g°	H.m.	g°	H.m.	f_4	F_1	f_6	F_6	
2853	Welshpool	3·72	344	2·60	018	0·37	136	0·15	120	0·11	237	0·009	⊙	⊙	
3092*	QUEBEC	*w*	186	1·73	226	0·42	270	0·23	247	0·22	272	0·095	056	0·013	*w*
4574*	ELEPHANT POINT	*w*	099	1·80	142	0·73	020	0·23	000	0·10	247	0·032	129	0·012	*w*
6259	PORT HEDLAND	4·12	305	1·68	014	1·02	292	0·24	273	0·15	157	0·014	330	0·005	
6319	Daly River	3·7	139	1·9	194	0·9	336	0·6	310	0·3	⊙	⊙	⊙	⊙	

⊙ No data.
? Dries out except for river water.
n See notes on page 362.
c For intermediate heights, use harmonic constants and N.P. 159.
l Constants from 15 days' observations.
v Owing to large seasonal variations, see Table VI.
w Owing to large fortnightly variations, see Table VIa.
x M.L. inferred.

Table VIa FORTNIGHTLY SHALLOW WATER CORRECTIONS

Investigations have shown that at certain ports with large Shallow Water Effects the tidal constituent with a period of one cycle per fortnight (MSf) can be significant. The normal time and height difference allow for this effect but at certain ports predictions obtained by the use of the Admiralty Method of Tidal Prediction N.P. 159 can be improved by a simple additional adjustment. Corrected values of M.L. are given below for the ports concerned, for the day of Springs and for each day before or after springs. The day of springs should be found by inspection of the daily predictions for the Standard Port of the area concerned. The corrected value should be entered as M.L. on N.P. 159. The seasonal correction is then applied to this value as usual.

			Corrected M.L.						
			Days before or after springs						
Port No.	Average M.L.	At Springs	1	2	3	4	5	6	7
3092*	2·59	2·74	2·73	2·68	2·62	2·56	2·50	2·45	2·44
4547*	3·66	3·72	3·71	3·70	3·67	3·65	3·62	3·61	3·60

* *Important Note:* Port No. 3092 Assume time in question 7 days after Springs.
Port No. 4547 Assume time in question at Springs.

Table VII TIDAL ANGLES AND FACTORS YEAR 1982

JANUARY

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	128	0·99	001	0·80	001	1·33	126	0·92
2	152	1·03	001	0·81	001	1·35	150	0·96
3	176	1·07	002	0·81	001	1·37	176	1·00
4	202	1·11	003	0·81	001	1·39	202	1·04
5	228	1·15	003	0·81	001	1·41	229	1·08
6	255	1·19	004	0·81	000	1·42	257	1·11
7	282	1·22	005	0·81	000	1·42	285	1·13
8	310	1·23	005	0·82	000	1·42	314	1·15
9	338	1·23	006	0·82	359	1·41	343	1·15
10	005	1·22	007	0·82	358	1·40	012	1·14
11	033	1·20	007	0·83	358	1·38	040	1·12
12	060	1·16	008	0·83	357	1·35	069	1·09
13	087	1·12	008	0·84	356	1·31	096	1·05
14	113	1·07	009	0·84	356	1·28	123	1·00
15	138	1·02	009	0·85	355	1·24	149	0·96
16	162	0·97	010	0·85	354	1·20	174	0·91
17	185	0·93	010	0·86	354	1·17	198	0·87
18	207	0·90	011	0·87	353	1·14	221	0·84
19	229	0·88	011	0·87	353	1·12	244	0·83
20	250	0·87	012	0·88	352	1·11	266	0·82
21	272	0·87	012	0·88	352	1·10	289	0·82
22	293	0·88	012	0·89	351	1·10	312	0·83
23	315	0·89	013	0·90	350	1·10	335	0·84
24	338	0·91	013	0·91	350	1·11	358	0·85
25	000	0·92	014	0·91	349	1·12	021	0·87
26	023	0·94	014	0·92	348	1·14	045	0·88
27	046	0·96	014	0·93	347	1·15	069	0·90
28	069	0·98	014	0·94	347	1·16	094	0·92
29	093	1·01	015	0·94	346	1·18	118	0·95
30	117	1·04	015	0·95	346	1·19	143	0·97
31	142	1·07	015	0·96	345	1·20	169	1·00

FEBRUARY

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	167	1·10	015	0·97	345	1·21	195	1·03
2	193	1·13	015	0·98	344	1·22	222	1·06
3	220	1·15	015	0·99	344	1·22	250	1·08
4	246	1·17	016	0·99	344	1·21	277	1·10
5	273	1·18	016	1·00	343	1·20	305	1·11
6	301	1·18	016	1·01	342	1·19	334	1·11
7	328	1·17	016	1·02	342	1·16	002	1·10
8	355	1·16	016	1·03	341	1·13	030	1·09
9	022	1·13	016	1·04	340	1·10	057	1·06
10	048	1·09	016	1·04	339	1·06	085	1·03
11	073	1·05	016	1·05	339	1·02	111	0·99
12	098	1·01	016	1·06	338	0·98	137	0·95
13	122	0·97	016	1·07	337	0·94	162	0·92
14	145	0·94	016	1·08	336	0·91	186	0·88
15	168	0·91	016	1·08	336	0·87	210	0·85
16	190	0·89	016	1·09	335	0·85	233	0·83
17	211	0·88	015	1·10	334	0·83	255	0·83
18	233	0·88	015	1·11	333	0·82	278	0·83
19	254	0·89	015	1·11	332	0·82	300	0·83
20	276	0·90	015	1·12	330	0·82	323	0·85
21	299	0·92	015	1·13	329	0·82	346	0·87
22	322	0·95	015	1·14	327	0·83	010	0·89
23	345	0·97	015	1·14	325	0·85	035	0·92
24	009	1·00	014	1·15	324	0·86	059	0·94
25	033	1·02	014	1·16	322	0·87	084	0·97
26	057	1·05	014	1·16	321	0·88	110	0·99
27	082	1·07	014	1·17	320	0·89	136	1·01
28	108	1·10	014	1·18	319	0·89	162	1·03

MARCH

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	134	1·11	013	1·18	318	0·90	189	1·05
2	160	1·13	013	1·19	317	0·89	216	1·07
3	186	1·14	013	1·19	316	0·89	244	1·08
4	213	1·14	013	1·20	315	0·88	271	1·08
5	239	1·14	012	1·20	314	0·86	299	1·08
6	266	1·13	012	1·21	313	0·85	326	1·07
7	292	1·12	012	1·21	312	0·82	353	1·06
8	318	1·10	012	1·22	310	0·80	021	1·04
9	344	1·08	011	1·22	309	0·77	047	1·02
10	009	1·05	011	1·23	307	0·74	074	1·00
11	034	1·02	011	1·23	305	0·70	100	0·97
12	059	0·99	010	1·23	303	0·67	125	0·94
13	082	0·96	010	1·24	301	0·64	150	0·91
14	106	0·93	010	1·24	299	0·61	174	0·88
15	128	0·91	009	1·24	297	0·58	198	0·86
16	150	0·89	009	1·25	294	0·57	221	0·84
17	172	0·88	009	1·25	292	0·56	243	0·83
18	193	0·88	008	1·25	290	0·55	266	0·83
19	215	0·88	008	1·25	288	0·56	288	0·84
20	237	0·90	008	1·25	286	0·57	311	0·86
21	259	0·93	007	1·26	284	0·59	334	0·88
22	282	0·96	007	1·26	282	0·62	358	0·91
23	306	1·00	006	1·26	280	0·64	023	0·95
24	330	1·03	006	1·26	278	0·67	048	0·98
25	355	1·07	006	1·26	276	0·69	074	1·01
26	020	1·10	005	1·26	274	0·72	100	1·04
27	046	1·12	005	1·26	272	0·73	127	1·07
28	073	1·14	005	1·26	271	0·75	155	1·09
29	099	1·15	004	1·26	269	0·76	182	1·10
30	126	1·16	004	1·26	268	0·76	210	1·10
31	153	1·15	003	1·26	266	0·76	238	1·10

APRIL

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	179	1·14	003	1·26	265	0·76	265	1·09
2	206	1·12	003	1·26	263	0·75	293	1·07
3	232	1·10	002	1·25	262	0·74	320	1·05
4	258	1·08	002	1·25	260	0·72	347	1·03
5	283	1·05	001	1·25	258	0·71	013	1·00
6	308	1·03	001	1·25	256	0·70	039	0·98
7	332	1·00	001	1·25	253	0·68	064	0·96
8	356	0·98	000	1·24	250	0·67	089	0·93
9	020	0·96	000	1·24	248	0·66	114	0·91
10	043	0·94	000	1·24	245	0·65	138	0·89
11	066	0·92	359	1·23	242	0·64	162	0·87
12	089	0·90	359	1·23	240	0·64	186	0·86
13	111	0·89	358	1·23	237	0·64	209	0·84
14	133	0·88	358	1·22	236	0·65	232	0·84
15	154	0·87	358	1·22	234	0·66	254	0·83
16	176	0·88	357	1·21	234	0·68	277	0·84
17	197	0·90	357	1·21	233	0·71	299	0·86
18	219	0·93	356	1·20	233	0·74	322	0·89
19	242	0·97	356	1·20	232	0·77	346	0·92
20	266	1·01	356	1·19	232	0·81	011	0·96
21	290	1·05	355	1·19	231	0·84	036	1·01
22	316	1·10	355	1·18	231	0·88	062	1·05
23	342	1·14	355	1·17	230	0·91	090	1·09
24	009	1·17	354	1·17	229	0·94	117	1·12
25	036	1·19	354	1·16	228	0·97	145	1·14
26	063	1·20	354	1·16	227	0·98	174	1·15
27	091	1·20	353	1·15	226	1·00	202	1·15
28	118	1·19	353	1·14	225	1·00	231	1·14
29	145	1·17	353	1·13	224	1·00	259	1·12
30	172	1·14	352	1·13	223	0·99	287	1·09

Table VII—*continued*

MAY

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	198	1·10	352	1·12	222	0·98	314	1·06
2	224	1·07	352	1·11	220	0·97	340	1·02
3	249	1·03	351	1·11	219	0·96	006	0·99
4	273	0·99	351	1·10	218	0·95	032	0·95
5	297	0·97	351	1·09	216	0·94	056	0·93
6	320	0·94	350	1·08	215	0·93	080	0·90
7	343	0·92	350	1·07	213	0·92	104	0·89
8	005	0·91	350	1·07	212	0·92	128	0·87
9	028	0·90	350	1·06	210	0·92	151	0·86
10	050	0·89	349	1·05	209	0·92	175	0·85
11	072	0·88	349	1·04	208	0·93	198	0·85
12	094	0·88	349	1·03	207	0·94	221	0·84
13	116	0·87	349	1·02	207	0·95	243	0·84
14	137	0·88	349	1·01	206	0·97	266	0·84
15	159	0·89	348	1·00	206	1·00	288	0·86
16	181	0·92	348	1·00	206	1·02	311	0·89
17	203	0·96	348	0·99	206	1·06	334	0·92
18	227	1·01	348	0·98	207	1·09	359	0·97
19	251	1·06	348	0·97	207	1·13	024	1·02
20	276	1·11	348	0·96	206	1·16	051	1·07
21	303	1.16	348	0·95	206	1·20	078	1·11
22	330	1·20	347	0·94	206	1·23	106	1·15
23	357	1·22	347	0·93	205	1·25	135	1·18
24	025	1·24	347	0·92	204	1·27	164	1·19
25	053	1·24	347	0·91	203	1·27	193	1·19
26	081	1·23	347	0·90	203	1·28	222	1·18
27	109	1·20	347	0·90	202	1·27	250	1·16
28	136	1·17	347	0·89	201	1·26	279	1·12
29	163	1·12	347	0·88	200	1·24	306	1·08
30	189	1·08	347	0·87	199	1·22	333	1·04
31	214	1·03	347	0·86	198	1·20	359	0·99

JUNE

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	238	0·98	347	0·85	197	1·19	024	0·95
2	261	0·95	348	0·84	197	1·17	048	0·91
3	284	0·92	348	0·83	196	1·15	072	0·89
4	306	0·90	348	0·83	195	1·14	095	0·87
5	328	0·89	348	0·82	194	1·13	118	0·86
6	350	0·88	348	0·81	193	1·12	141	0·85
7	012	0·88	349	0·80	193	1·12	164	0·85
8	034	0·88	349	0·79	192	1·13	187	0·85
9	056	0·88	349	0·79	192	1·13	210	0·85
10	078	0·88	349	0·78	191	1·15	233	0·85
11	100	0·88	350	0·77	191	1·16	256	0·85
12	121	0·89	350	0·76	191	1·18	278	0·86
13	143	0·92	350	0·76	191	1·20	301	0·89
14	165	0·95	351	0·75	191	1·23	324	0·92
15	189	1·00	351	0·75	191	1·26	349	0·96
16	213	1·05	352	0·74	191	1·29	014	1·01
17	238	1·10	352	0·73	190	1·32	040	1·06
18	264	1·15	352	0·73	190	1·35	067	1·11
19	291	1·19	353	0·72	190	1·37	095	1·16
20	319	1·23	353	0·72	189	1·39	124	1·19
21	347	1·25	354	0·71	188	1·40	153	1·21
22	015	1·25	355	0·71	188	1·41	182	1·21
23	043	1·25	355	0·71	187	1·40	211	1·21
24	071	1·22	356	0·70	186	1·39	240	1·19
25	099	1·19	356	0·70	185	1·37	269	1·15
26	126	1·15	357	0·70	185	1·35	297	1·11
27	152	1·09	358	0·70	184	1·32	324	1·06
28	178	1·04	358	0·70	183	1·29	350	1·01
29	202	0·99	359	0·69	183	1·26	016	0·96
30	225	0·95	359	0·69	182	1·24	040	0·92

JULY

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	248	0·91	000	0·69	182	1·21	063	0·89
2	270	0·89	001	0·69	181	1·19	086	0·86
3	291	0·88	001	0·69	181	1·18	109	0·85
4	313	0·87	002	0·69	180	1·17	132	0·85
5	335	0·87	003	0·69	180	1·16	154	0·85
6	357	0·88	003	0·70	179	1·16	178	0·85
7	019	0·88	004	0·70	179	1·16	201	0·86
8	041	0·89	004	0·70	178	1·17	224	0·86
9	063	0·89	005	0·70	178	1·18	247	0·87
10	085	0·91	006	0·71	177	1·20	270	0·88
11	107	0·93	006	0·71	177	1·21	293	0·90
12	130	0·96	007	0·71	177	1·23	316	0·93
13	153	1·00	007	0·72	176	1·26	340	0·97
14	177	1·05	008	0·72	176	1·28	005	1·02
15	201	1·10	008	0.73	176	1·30	031	1·07
16	227	1·14	009	0·73	175	1·32	057	1·11
17	253	1·19	009	0·74	175	1·34	085	1·15
18	281	1·22	010	0·74	174	1·35	113	1·19
19	308	1·24	010	0·75	173	1·35	142	1·21
20	336	1·24	010	0·76	172	1·35	170	1·21
21	004	1·23	011	0·76	172	1·34	199	1·20
22	032	1·21	011	0·77	171	1·32	228	1·18
23	060	1·18	011	0·78	170	1·30	257	1·15
24	087	1·13	012	0·78	169	1·27	285	1·10
25	113	1·08	012	0·79	169	1·24	313	1·05
26	139	1·02	012	0·80	168	1·20	340	1·00
27	164	0·97	013	0·81	168	1·16	005	0·95
28	188	0·92	013	0·81	167	1·13	030	0·90
29	211	0·89	013	0·82	167	1·10	054	0·87
30	233	0·86	013	0·83	167	1·07	077	0·84
31	255	0·85	013	0·84	166	1·05	100	0·83

AUGUST

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	277	0·85	013	0·85	166	1·04	123	0·83
2	299	0·85	013	0·86	165	1·03	146	0·83
3	321	0·87	013	0·87	165	1·02	169	0·85
4	343	0·88	014	0·87	164	1·02	192	0·86
5	005	0·90	014	0·88	163	1·03	216	0·88
6	028	0·91	014	0·89	162	1·03	239	0·89
7	050	0·94	014	0·90	161	1·04	263	0·91
8	073	0·96	014	0·91	160	1·05	286	0·94
9	096	0·99	014	0·92	159	1·07	310	0·97
10	119	1·03	013	0·93	158	1·08	334	1·00
11	143	1·07	013	0·94	157	1·09	359	1·04
12	167	1·11	013	0·95	157	1·10	024	1·09
13	192	1·15	013	0·96	156	1·12	050	1·13
14	218	1·18	013	0·97	155	1·12	077	1·16
15	244	1·21	013	0·98	154	1·13	104	1·19
16	271	1·23	013	0·98	154	1·13	132	1·20
17	298	1·23	013	0·99	153	1·12	160	1·20
18	325	1·22	012	1·00	152	1·11	188	1·19
19	352	1·19	012	1·01	151	1·09	216	1·17
20	019	1·16	012	1·02	150	1·06	244	1·13
21	046	1·11	012	1·03	149	1·03	272	1·09
22	073	1·06	012	1·04	148	0·99	300	1·04
23	098	1·01	011	1·05	147	0·95	326	0·99
24	123	0·95	011	1·06	146	0·91	352	0·94
25	148	0·91	011	1·06	146	0·88	018	0·89
26	171	0·87	010	1·07	145	0·84	042	0·85
27	194	0·84	010	1·08	144	0·81	066	0·82
28	216	0·82	010	1·09	144	0·79	089	0·81
29	238	0·82	010	1·10	143	0·77	112	0·80
30	260	0·82	009	1·10	142	0·76	135	0·81
31	283	0·84	009	1·11	141	0·76	158	0·83

Table VII—*continued*

SEPTEMBER

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	305	0·86	009	1·12	139	0·76	182	0·85
2	328	0·89	008	1·13	137	0·76	206	0·87
3	351	0·92	008	1·14	135	0·77	230	0·90
4	014	0·95	008	1·14	133	0·78	254	0·93
5	038	0·98	007	1·15	132	0·79	279	0·97
6	061	1·02	007	1·16	130	0·80	303	1·00
7	085	1·06	007	1·16	128	0·81	328	1·04
8	110	1·09	006	1·17	127	0·82	354	1·08
9	134	1·13	006	1·18	125	0·83	019	1·11
10	159	1·16	005	1·18	124	0·84	045	1·14
11	185	1·18	005	1·19	123	0·84	072	1·17
12	210	1·20	005	1·19	122	0·84	098	1·18
13	236	1·21	004	1·20	120	0·84	125	1·19
14	262	1·20	004	1·20	119	0·83	152	1·19
15	289	1·19	003	1·21	118	0·82	179	1·17
16	315	1·17	003	1·22	116	0·81	206	1·15
17	341	1·13	003	1·22	114	0·79	233	1·12
18	007	1·09	002	1·22	113	0·76	260	1·08
19	032	1·04	002	1·23	111	0·73	287	1·03
20	057	0·99	001	1·23	109	0·70	313	0·98
21	082	0·95	001	1·24	107	0·67	339	0·93
22	106	0·90	001	1·24	105	0·64	004	0·89
23	130	0·86	000	1·24	103	0·61	028	0·85
24	153	0·83	000	1·25	101	0·59	052	0·82
25	175	0·81	359	1·25	099	0·58	076	0·80
26	197	0·80	359	1·25	097	0·57	099	0·79
27	220	0·81	359	1·26	095	0·57	122	0·80
28	242	0·82	358	1·26	093	0·57	146	0·81
29	265	0·84	358	1·26	090	0·59	169	0·83
30	288	0·88	357	1·26	088	0·61	193	0·87

OCTOBER

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	312	0·91	357	1·26	086	0·63	218	0·90
2	336	0·96	357	1·26	084	0·66	243	0·95
3	000	1·00	356	1·26	082	0·68	268	0·99
4	025	1·04	356	1·27	080	0·71	294	1·03
5	050	1·08	355	1·27	078	0·73	320	1·07
6	075	1·12	355	1·27	077	0·76	347	1·11
7	101	1·15	354	1·27	075	0·78	013	1·14
8	127	1·18	354	1·27	074	0·79	040	1·17
9	152	1·19	354	1·27	072	0·80	067	1·18
10	178	1·20	353	1·27	071	0·81	093	1·19
11	204	1·19	353	1·26	070	0·81	120	1·18
12	229	1·18	352	1·26	068	0·81	147	1·17
13	255	1·16	352	1·26	067	0·81	173	1·15
14	280	1·13	352	1·26	065	0·80	199	1·12
15	305	1·10	351	1·26	064	0·79	225	1·09
16	330	1·06	351	1·26	062	0·78	251	1·06
17	354	1·03	351	1·25	060	0·77	276	1·02
18	018	0·99	350	1·25	057	0·76	301	0·98
19	042	0·95	350	1·25	055	0·75	326	0·94
20	066	0·91	349	1·24	053	0·74	351	0·90
21	089	0·88	349	1·24	050	0·73	015	0·87
22	112	0·85	349	1·24	048	0·73	039	0·84
23	134	0·83	348	1·23	047	0·73	062	0·82
24	156	0·81	348	1·23	045	0·73	085	0·81
25	178	0·81	348	1·22	044	0·74	109	0·81
26	201	0·82	347	1·22	043	0·76	132	0·81
27	223	0·84	347	1·21	043	0·79	155	0·84
28	246	0·87	347	1·21	042	0·82	179	0·87
29	270	0·91	347	1·20	041	0·85	204	0·91
30	295	0·96	346	1·20	041	0·89	230	0·96
31	320	1·01	346	1·19	040	0·93	256	1·01

NOVEMBER

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	346	1·06	346	1·19	039	0·97	283	1·06
2	012	1·11	345	1·18	039	1·00	310	1·10
3	038	1·15	345	1·18	038	1·03	337	1·14
4	065	1·18	345	1·17	037	1·06	005	1·18
5	092	1·20	345	1·16	036	1·08	033	1·20
6	119	1·21	344	1·15	035	1·10	060	1·20
7	145	1·21	344	1·15	034	1·10	088	1·20
8	171	1·19	344	1·14	033	1·11	115	1·19
9	197	1·17	344	1·13	033	1·11	142	1·17
10	222	1·14	344	1·13	032	1·10	168	1·13
11	247	1·10	344	1·12	031	1·09	194	1·10
12	271	1·07	343	1·11	030	1·09	219	1·06
13	295	1·03	343	1·10	029	1·08	244	1·03
14	319	1·00	343	1·09	028	1·07	268	0·99
15	342	0·97	343	1·09	027	1·06	293	0·96
16	005	0·94	343	1·08	025	1·05	316	0·94
17	027	0·91	343	1·07	024	1·04	340	0·91
18	050	0·89	343	1·06	023	1·04	004	0·89
19	073	0·87	343	1·05	022	1·04	027	0·87
20	095	0·85	343	1·04	021	1·04	051	0·85
21	117	0·84	343	1·03	021	1·04	074	0·84
22	139	0·83	343	1·03	020	1·06	097	0·83
23	161	0·84	343	1·02	020	1·07	119	0·84
24	183	0·86	343	1·01	020	1·10	143	0·86
25	206	0·89	343	1·00	019	1·13	166	0·89
26	229	0·93	343	0·99	019	1·16	191	0·93
27	253	0·98	343	0·98	019	1·20	216	0·98
28	279	1·03	343	0·97	019	1·24	242	1·03
29	305	1·08	343	0·96	018	1·27	269	1·08
30	332	1·13	343	0·95	018	1·31	297	1·13

DECEMBER

	M2		S2		K1		O1	
DAY	A	F	A	F	A	F	A	F
1	359	1·17	343	0·95	017	1·34	325	1·17
2	026	1·20	344	0·94	016	1·36	354	1·21
3	054	1·22	344	0·93	016	1·38	023	1·22
4	082	1·23	344	0·92	015	1·39	051	1·23
5	109	1·22	344	0·91	014	1·39	080	1·22
6	136	1·19	345	0·90	014	1·39	108	1·20
7	163	1·16	345	0·89	013	1·38	135	1·17
8	189	1·12	345	0·89	013	1·37	162	1·13
9	214	1·08	346	0·88	012	1·35	188	1·08
10	238	1·03	346	0·87	012	1·33	214	1·04
11	262	0·99	347	0·86	011	1·31	238	1·00
12	285	0·96	347	0·86	011	1·29	262	0·96
13	307	0·93	348	0·85	010	1·27	286	0·94
14	329	0·91	348	0·84	010	1·26	309	0·92
15	352	0·90	349	0·84	009	1·25	332	0·90
16	014	0·89	349	0·83	009	1·23	355	0·89
17	036	0·88	350	0·82	008	1·23	018	0·88
18	058	0·87	350	0·82	008	1·22	041	0·87
19	080	0·86	351	0·81	007	1·23	064	0·87
20	102	0·86	352	0·81	007	1·23	087	0·87
21	123	0·87	352	0·80	006	1·24	110	0·87
22	145	0·88	353	0·80	006	1·26	133	0·89
23	167	0·91	354	0·79	006	1·28	156	0·92
24	190	0·95	354	0·79	006	1·31	180	0·96
25	214	1·00	355	0·79	005	1·34	204	1·01
26	239	1·05	356	0·79	005	1·37	230	1·06
27	265	1·11	356	0·78	004	1·40	257	1·11
28	291	1·16	357	0·78	004	1·43	285	1·16
29	319	1·20	358	0·78	003	1·46	313	1·20
30	347	1·22	359	0·78	002	1·47	342	1·23
31	015	1·24	359	0·78	002	1·48	011	1·25

Volume 3 PACIFIC OCEAN AND ADJACENT SEAS—Part I (Standard Ports)

Canada, British Columbia—Prince Rupert

LAT 54°19'N LONG 130°20'W

TIME ZONE +0800 TIMES AND HEIGHTS OF HIGH AND LOW WATERS YEAR 1982

MAY

	TIME	M		TIME	M
1	0150	2.8	16	0110	3.1
SA	0755	5.5	SU	0655	4.8
	1430	1.7		1335	2.0
	2110	5.4		2015	5.0
2	0310	2.6	17	0225	2.9
SU	0900	5.5	M	0820	4.9
	1535	1.7		1450	2.0
	2210	5.7		2115	5.3
3	0415	2.2	18	0335	2.5
M	1015	5.6	TU	0930	5.1
	1630	1.6		1550	1.9
	2300	6.0		2205	5.6

JUNE

	TIME	M		TIME	M
1	0355	2.0	16	0250	2.3
TU	0955	5.3	W	0850	4.9
	1555	2.0		1445	2.1
	2215	6.0		2125	5.8
2	0440	1.7	17	0355	1.8
W	1055	5.4	TH	0955	5.1
	1655	2.0		1545	2.1
	2310	6.1		2200	6.2
3	0530	1.4	18	0445	1.3
TH	1140	5.5	F	1100	5.4
	1740	2.0		1650	2.1
	2345	6.2		2255	6.6

JULY

	TIME	M		TIME	M
1	0405	1.8	16	0310	1.8
TH	1015	5.0	F	0930	4.9
	1605	2.5		1510	2.5
	2225	5.9		2135	6.1
2	0505	1.6	17	0420	1.3
F	1125	5.1	SA	1040	5.2
	1705	2.5		1625	2.4
	2305	6.0		2230	6.4
3	0550	1.3	18	0520	0.9
SA	1200	5.3	SU	1145	5.5
	1750	2.5		1725	2.3
	2345	6.1		2320	6.8

AUGUST

	TIME	M		TIME	M
1	0515	1.5	16	0510	1.0
SU	1155	5.1	M	1140	5.5
	1720	2.7		1705	2.3
	2325	5.9		2315	6.6
2	0615	1.3	17	0600	0.7
M	1230	5.3	TU	1220	5.9
	1810	2.5		1810	2.0
3	0015	6.0	18	0005	6.9
TU	0650	1.1	W	0655	0.3
	1310	5.5		1305	6.2
	1845	2.3		1850	1.6

Volume 3 PACIFIC OCEAN AND ADJACENT SEAS—Part II (Secondary Ports)

8850	PRINCE RUPERT		see page 207		MHW	MLW	MHWS 6·5	MHWN 5·2	MLWN 2·5	MLWS 1·1	M.L. Z_0 m.
9020	Port Hardy		50 43	127 29	−0025	−0030	−1·9	−1·4	−0·4	+0·1	2·94
9022	Bay		50 51	127 51	−0030	−0035	−2·1	−1·6	−0·6	−0·1	2·75
	QUEEN CHARLOTTE SOUND										
8936	Port Blackney		52 19	128 21	−0030	−0035	−2·0	−1·5	−0·6	−0·2	2·77
8937	Bellabella	C	52 10	128 08	−0030	−0030	−1·9	−1·4	−0·6	−0·1	2·85
	Cousins Inlet										
8939	Ocean Falls		52 21	127 41	−0041	−0035	−1·8	−1·3	−0·5	−0·1	2·93
8942	Bella Coola		52 23	126 48	−0025	−0030	−1·7	−1·3	−0·6	−0·2	2·90
8943	Namu Harbour		51 52	127 52	−0036	−0036	−2·2	−1·7	−0·8	−0·3	2·59
8944	Addenbroke Island		51 36	127 49	−0038	−0036	−2·2	−1·7	−0·6	−0·1	2·70
	Rivers Inlet										
8946	Wadhams		51 31	127 31	−0035	−0040	−2·2	−1·7	−0·7	−0·2	2·65
8947	Kildala		51 42	127 21	−0047	−0041	−2·2	−1·7	−0·7	−0·2	2·7

Seasonal Changes in Mean Level

No.	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Sep. 1	Oct. 1	Nov. 1	Dec. 1	Jan. 1
8850	+0·1	+0·1	0·0	0·0	0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0	+0·1	+0·1
8871–8881	+0·1	+0·1	+0·1	0·0	−0·1	−0·1	−0·1	−0·1	−0·1	0·0	0·0	+0·1	+0·1
8884–8927	+0·1	0·0	0·0	−0·1	−0·1	0·0	0·0	−0·1	0·0	0·0	+0·1	+0·1	+0·1
8928–8952	+0·1	+0·1	0·0	0·0	−0·1	−0·1	−0·1	−0·1	−0·1	0·0	0·0	+0·1	+0·1
9050	0·0	+0·1	+0·1	0·0	0·0	0·0	0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0
8850	+0·1	+0·1	0·0	0·0	0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0	+0·1	+0·1
8960–9022	+0·1	+0·1	0·0	0·0	−0·1	−0·1	−0·1	−0·1	−0·1	0·0	0·0	+0·1	+0·1
9023–9057	0·0	+0·1	+0·1	0·0	0·0	0·0	0·0	0·0	−0·1	−0·1	−0·1	0·0	0·0
9133	+0·1	+0·1	0·0	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	+0·1

ADMIRALTY TIDAL PREDICTION FORM—NP 204

INSTRUCTIONS FOR SECONDARY PORTS

Box No.

Complete heading (A.T.T. Part II).

1- 4. Enter HW/LW times and heights at Standard Port (A.T.T. Part I).

5. Calculate range at Standard Port (Difference between heights in boxes 3 and 4).

6. Enter Seasonal Change at Standard Port with sign changed (A.T.T. Part II).

7-10.* Calculate Differences (A.T.T. Part II). Interpolate/extrapolate.

11. Enter Seasonal Change at Secondary Port (A.T.T. Part II).

12-15.† Calculate Secondary HW/LW (i.e. box 1 adjusted by box 7; box 2 by box 8; box 3 by boxes 6, 9 and 11; box 4 by boxes 6, 10 and 11).

16.‡ Calculate Duration at Secondary Port (Difference between boxes 12 and 13) (Not required for A.T.T. Vol. 1).

TO FIND HEIGHT AT GIVEN TIME

First enter boxes 1 to 16.

‡ On appropriate Standard Port Curve diagram, plot heights of H.W. and L.W. occurring either side of required time and join by sloping line.
Enter H.W. time and sufficient others to embrace required time.
From required time proceed vertically to curves using Range at Standard Port (box 5) to interpolate between Springs and Neaps. Do NOT extrapolate.
Proceed horizontally to sloping line and thence vertically to Height scale.
Read off height above Chart Datum.

TO FIND TIME FOR A GIVEN HEIGHT ABOVE CHART DATUM

First enter boxes 1 to 16.

‡ On appropriate Standard Port Curve diagram, plot heights of H.W. and L.W. occuring either side of required event and join by sloping line.
Enter H.W. time and those for half-tidal cycle covering required event.
From required height, proceed vertically to sloping line, thence horizontally to curves, using Range at Standard Port (box 5) to interpolate between Springs and Neaps. Do NOT extrapolate.
Proceed vertically to Time scale.
Read off time.

INSTRUCTIONS FOR STANDARD PORTS

As above but boxes 6 to 15 are not required.

* A diagram to assist the interpolation of differences is on page 5.

† When calculating boxes 12 to 15 great care should be taken with the SIGNS of the contributions.

‡ In A.T.T. Vols. 2 and 3, use curves on pages 46 and 47. If the Duration is outside 5-7 hours, use Simplified Harmonic Method of Tidal Prediction (N.P. 159) or calculator equivalent).

NOTE For the area Swanage to Selsey see instructions in A.T.T. Vol. 1 and pages 8 to 11.

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* *Note:* Do not attempt to extrapolate additional curves. In ATT Vol. 1 use the Spring curve for Spring Ranges and greater, and the Neap curve for Neap Ranges and less. For intermediate ranges interpolate between curves using the Range at the Standard Port (Box 5) as argument. In ATT Vols. 2 and 3 if duration is outside those shown in Table II use NP 159.

ADMIRALTY TIDAL PREDICTION FORM—NP 204

STANDARD PORT.....TIME/HEIGHT REQUIRED.....

SECONDARY PORT.....DATE.....TIME ZONE.....

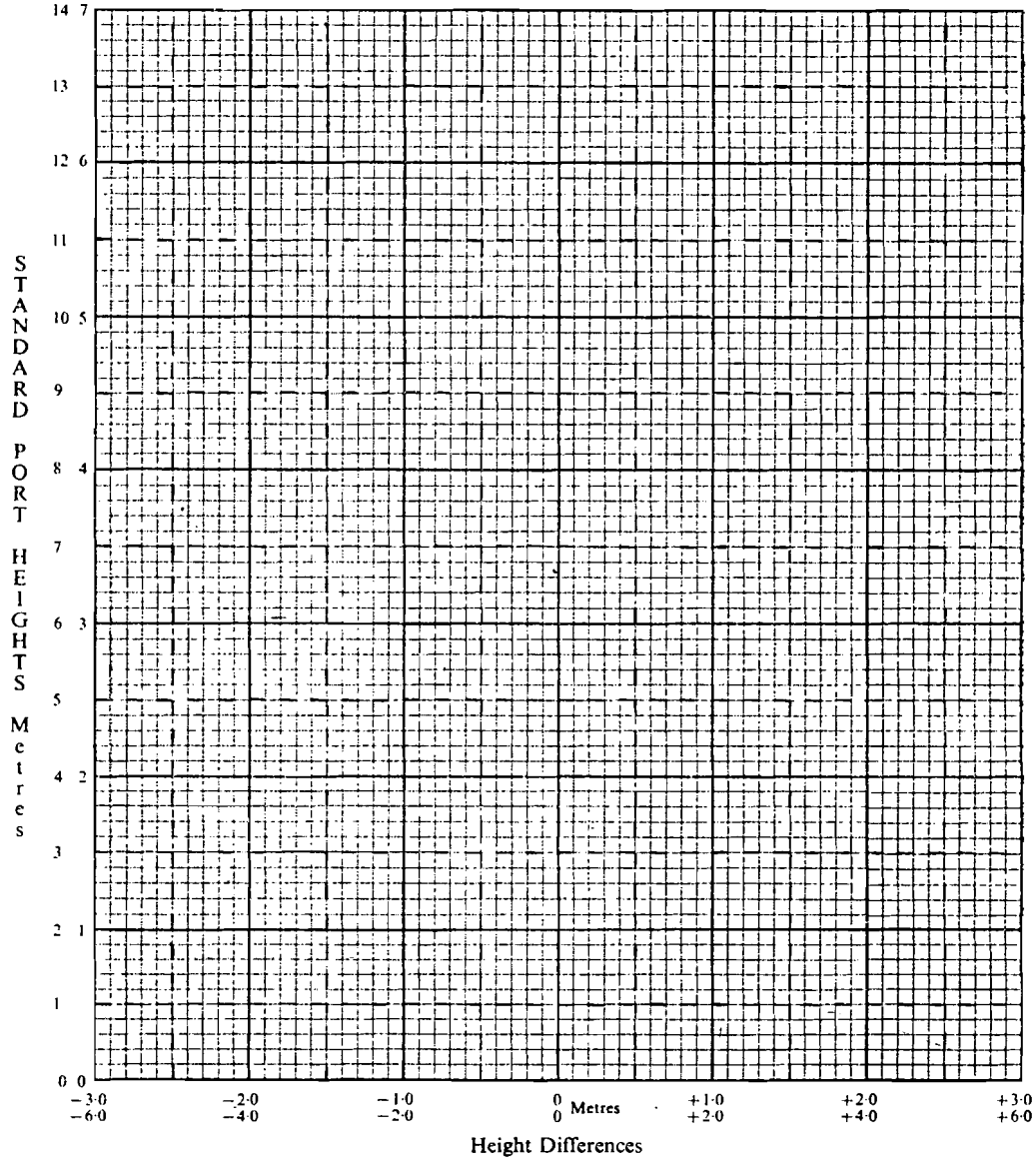
	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	1	2	3	4	5
Seasonal change	Standard Port		6	6	
DIFFERENCES	7*	8*	9*	10*	
Seasonal change	Secondary port		11	11	
SECONDARY PORT	12	13	14	15	
Duration	16				

STANDARD PORT.....TIME/HEIGHT REQUIRED.....

SECONDARY PORT.....DATE.....TIME ZONE.....

	TIME		HEIGHT		
STANDARD PORT	HW	LW	HW	LW	RANGE
	1	2	3	4	5
Seasonal change	Standard Port		6	6	
DIFFERENCES	7*	8*	9*	10*	
Seasonal change	Secondary port		11	11	
SECONDARY PORT	12	13	14	15	
Duration	16				

SECONDARY PORT HEIGHT DIFFERENCE INTERPOLATION



Height Difference Interpolation for High or Low Water

Plot two points using the left-hand and bottom scales for the two high or low water heights and their associated differences. Join these two points by a straight line and extend it to the edge of the diagram. From the intersection of this line with the horizontal line representing the predicted Standard Port height follow the vertical line to the bottom scale and read off the required height difference.

Notes: 1. Various scales are given to cover the ranges likely to be encountered. Further scales can be constructed if required. Care must be taken to ensure that the same scales are used for both plotting and reading off the results.

2. Where only one HW and one LW height value is tabulated in Part II, interpolation for both HW and LW must be made between these two values and extrapolating if necessary.

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CAPT. COOLEN'S TIDAL PREDICTION FORM—1

To Find the Height of Tide at an Intermediate Time Between HW and LW

(European Standard Port)

	Times		*Heights (m)*		*Step*
	HW	LW	HW	LW	1
Standard Port					
Index No.					

Time Interval

HW
Required Time _____
Interval from HW _____ 2

Ranges (m)

HW		Spring Range		
LW		Neap „		
	_____		_____	
Predicted Range		Spring ~ Neap		3 & 4

Predicted Range
Neap Range _____
Pred ~ Neap _____

Predicted Range lies _____ from Neaps towards Springs[1] use Spring/Neap/Both[2] Curves and Interpolate[3] 5

	Factor (s)	*Interpolation*	
Factor from Spring Curve			
„ „ Neap „	_____		
Spring ~ Neap Factor		Adjustment = ____ × ____	6 & 7
Neap Factor		≏	
Adjustment	_____		8

Rise of Tide (m)

Predicted Range
„ Factor (×) _____
Rise of Tide
LW (+) _____ 9
Height of Tide _____ 10

Notes:

[1] Can also be worked from Springs to Neaps.

[2] Delete as appropriate.

[3] Interpolation is carried out as follows:

$$\text{Adjustment (to Neap Factor)} = \frac{(\text{Spring Factor} \sim \text{Neap Factor}) \times (\text{Pred Range} \sim \text{Neap Range})}{\text{Spring Range} \sim \text{Neap Range}}$$

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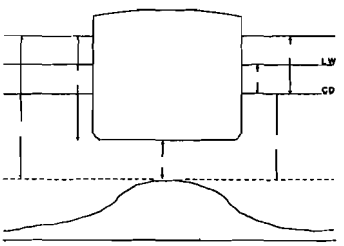
CAPT. COOLEN'S TIDAL PREDICTION FORM—2

To Find the Time at which the Required Depth is Reached

(European Standard Port)

	Times HW	LW	*Heights (m)* HW	LW	*Predicted Range*	*Step* 1 & 3
Standard Port						

Sketch and Preliminary Calculations



Draft		
Clearance	_____	
Required Depth		
Charted Depth	_____	
Height of Tide		
LW	_____	
Required Rise	═══	2

$$\frac{\textbf{Rise}}{\textbf{Range}} = \textbf{Factor} = \frac{\qquad}{\qquad} = \qquad 4$$

Ranges (m)

Spring Range		Predicted Range		
Neap „	_____	Neap „	_____	
Spring ~ Neap	═══	Pred ~ Neap	═══	5

(For Interpolation Only)

Predicted range lies _____ from Neaps towards Springs[1]—use Spring/Neap/Both[2] curves and interpolate.[3] 6

Time Intervals		*Interpolation*	
Interval from Spring Curve			
„ „ Neap „	_____	Adjustment = ____×____	7
Spring ~ Neap Interval	═══	≏	
Neap Interval			
Adjustment	_____		
Predicted Interval	═══		9

Time of Required Depth

HW		
Predicted Interval	_____	
Required Depth at	═══	10

Notes:

[1] Can also be worked from Springs to Neaps.

[2] Delete as appropriate.

[3] Interpolation is carried out as follows:

$$\text{Adjustment (to Neap Time Interval)} = \frac{(\text{Spring} \sim \text{Neap Time Intervals}) \times (\text{Pred} \sim \text{Neap Range})}{\text{Spring} \sim \text{Neap Range}}$$

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CAPT. COOLEN'S TIDAL PREDICTION FORM—3

To Find the Height of Tide at an Intermediate Time Between HW and LW

(European Secondary Port)

					Step
Secondary Port:	Index No.				1
Standard Port:					2
	Times		*Heights (m)*		
	HW	LW	HW	LW	
Standard Port					
Differences					3
Secondary Port					4

Time Interval

Secondary HW
Required Time _____

Interval from HW _____ 5

Ranges (m)

Secondary HW		Standard HW		Spring Range	
„ LW		„ LW		Neap „	
Secondary Range		Standard Range		Spring ~ Neap	6,7,8

Standard Range
Neap „ _____

Standard ~ Neap _____

Standard Port Range lies _____ from Neaps towards Springs—Interpolate. 9

Factors		*Interpolation*
Factor from Spring Curve		
„ „ Neap „		
Spring ~ Neap Factor		Adjustment = $\frac{\text{Secondary Range} \times \text{Spring} \sim \text{Neap Factor}}{\text{Standard Range}}$
Neap Factor Adjustment		
Predicted Factor		10

Rise of Tide (m)

Secondary Range			
Predicted Factor	(×)		11
Rise of Tide			
Secondary LW	(+)		12
Height of Tide		Metres	

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CAPT. COOLEN'S TIDAL PREDICTION FORM—4

To Find the Time at which the Required Depth is Reached

(European Secondary Port)

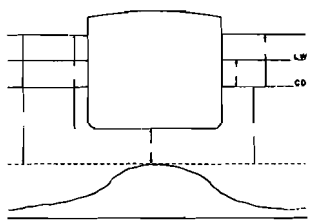
Steps

Secondary Port: Index No. 1

Standard Port: 2

	Times		*Heights (m)*	
	HW	LW	HW	LW
Standard Port				
Differences				3
Secondary Port				4

Sketch and Preliminary Calculations



Draft

Clearance

Drying Height

Height of Tide 5

Secondary LW

Required Rise

Ranges (m)

Secondary HW — Standard HW — Spring Range

„ LW — „ LW — Neap „

Secondary Range — Standard Range — Spring ~ Neap 6, 7, 8

Standard Range

Neap „

Standard ~ Neap

Standard Port Range lies ———— from Neaps Towards Springs[1]—Interpolate.[2] 9

Factor $= \frac{\text{Rise}}{\text{Range}} =$ ———— $=$ 10

Time Intervals — *Interpolation*

Interval from Spring Curve

„ „ Neap „

Adjustment $= \frac{\quad \times \quad}{\quad} \simeq$ 10

Spring ~ Neap Interval

Neap Interval Adjustment

Predicted Interval

Time of Required Depth

Secondary HW Predicted Interval 11

Required Depth at

Notes:

[1] Can also be worked from Springs to Neaps.

[2] Interpolation is carried out as follows:

$$\text{Adjustment (to Neap Time Interval)} = \frac{(\text{Spring} \sim \text{Neap Time Intervals}) \times (\text{Pred} \sim \text{Neap Range})}{\text{Spring} \sim \text{Neap Range}}$$

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Admiralty Method of Tidal Prediction — NP 159

Forms A, B & C for Predictions using Harmonic Constants and the Table of Tidal Angles and Factors in ATT.

FORM A

Place ..... Date .....

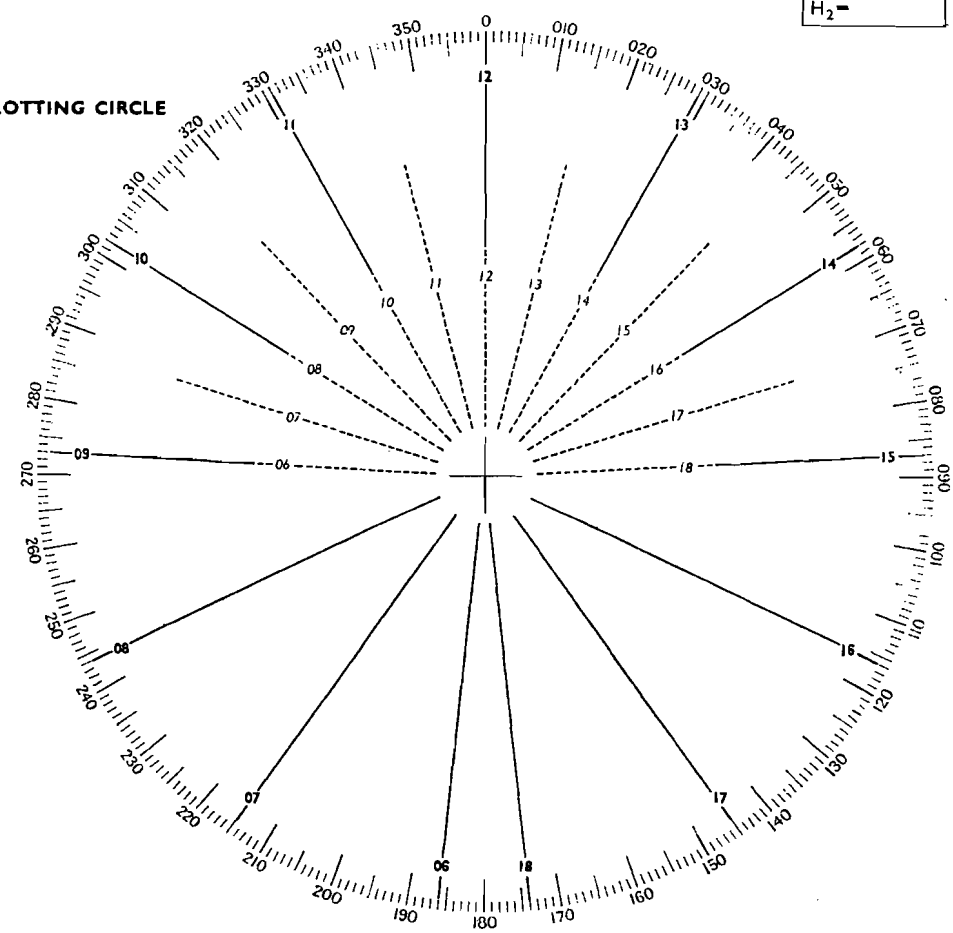
Lat ..... Long ..... Zone Time .....

TABLE

			M_2		S_2		K_1		O_1		M.L.	
	$\alpha°$		012		000		180		192			
from A.T.T., part II	$g°$	H										Mean level (Zo)
from A.T.T., table VII	$A°$	F										Seasonal correction
	$\alpha+g+A$	H×F	$=m°$	$=M$	$=s°$	$=S$	$=k°$	$=K$	$=o°$	$=O$	$=A_o$	ADD
logs:												

$h_2=$
$H_2=$

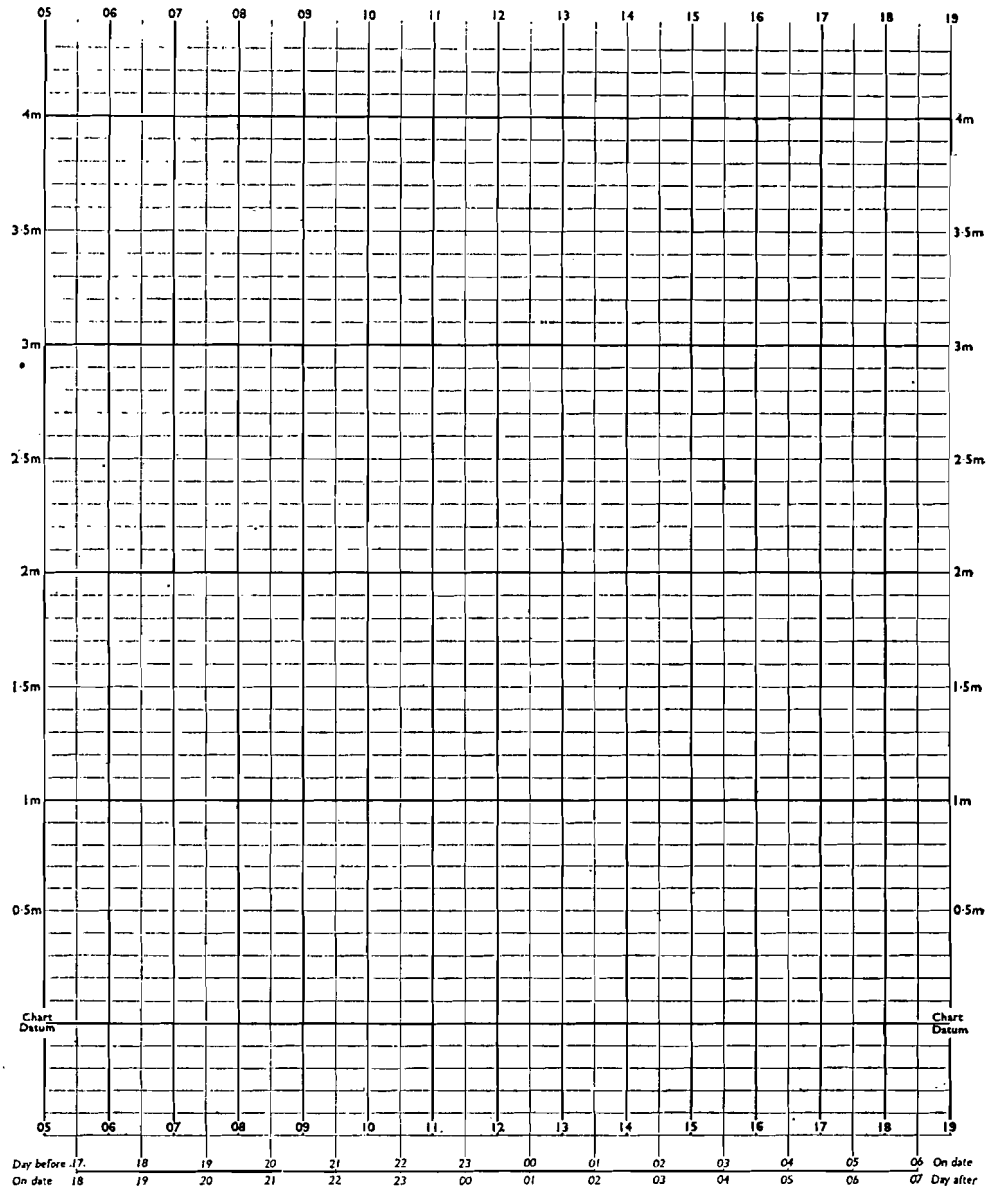
PLOTTING CIRCLE



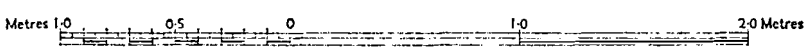
FORM B

Place ..... Date .....

Lat ..... Long ..... Zone Time .....



Times at top and bottom of main framework relate to continuous curve (drawn first)
Lower set of times (in italics) relate to pecked curve (drawn second).



FORM C

Place ..... Date .....

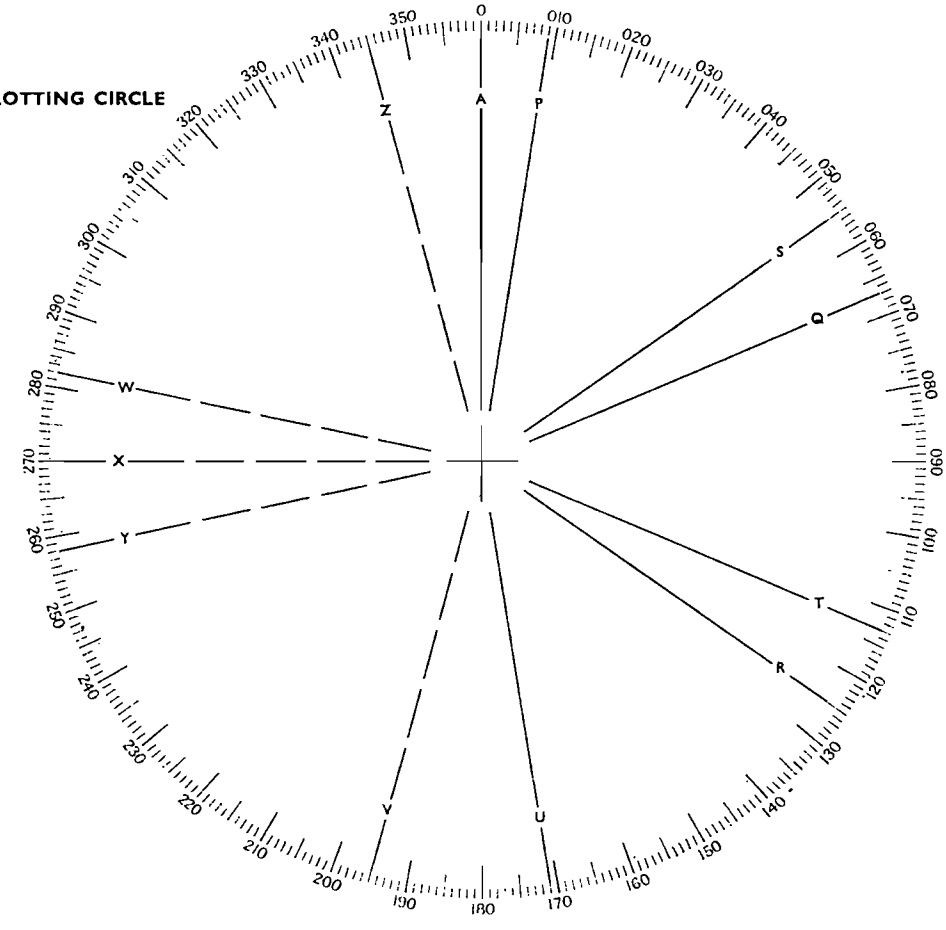
Lat ..... Long ..... Zone Time .....

TABLE

h_2 = .	$2h_2$ =	f_4 =	$h_4 = f_4 + 2h_2$ =	$3h_2$ =	f_6 =	$h_6 = f_6 + 3h_2$ =
H_2 =	H_2^2 =	F_4 =	$H_4 = F_4 \times H_2^2$ =	H_2^3 =	F_6 =	$H_6 = F_6 \times H_2^3$ =

logs: ....

PLOTTING CIRCLE



Metres 0·1 0·05 0 0·1 0·2 0·3 Metres

TABLE

Time	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800
QD	P	Q	R	–P	–Q	–R	A	S	T	U	–S	–T	–U
6-D	V	W	–V	–W	–A	X	A	–X	–A	Y	Z	–Y	–Z
Sum													

TABLE I

Conversion Table: Metres to Feet

Conversion Factor 1 Foot = 0·3048 m

Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet
0·05	0·2	4·05	13·3	8·05	26·4	12·05	39·5	16·05	52·7	20·05	65·8	24·05	78·9	28·05	92·0
0·10	0·3	4·10	13·5	8·10	26·6	12·10	39·7	16·10	52·8	20·10	65·9	24·10	79·1	28·10	92·2
0·15	0·5	4·15	13·6	8·15	26·7	12·15	39·9	16·15	53·0	20·15	66·1	24·15	79·2	28·15	92·4
0·20	0·7	4·20	13·8	8·20	26·9	12·20	40·0	16·20	53·1	20·20	66·3	24·20	79·4	28·20	92·5
0·25	0·8	4·25	13·9	8·25	27·1	12·25	40·2	16·25	53·3	20·25	66·4	24·25	79·6	28·25	92·7
0·30	1·0	4·30	14·1	8·30	27·2	12·30	40·4	16·30	53·5	20·30	66·6	24·30	79·7	28·30	92·8
0·35	1·1	4·35	14·3	8·35	27·4	12·35	40·5	16·35	53·6	20·35	66·8	24·35	79·9	28·35	93·0
0·40	1·3	4·40	14·4	8·40	27·6	12·40	40·7	16·40	53·8	20·40	66·9	24·40	80·1	28·40	93·2
0·45	1·5	4·45	14·6	8·45	27·7	12·45	40·8	16·45	54·0	20·45	67·1	24·45	80·2	28·45	93·3
0·50	1·6	4·50	14·8	8·50	27·9	12·50	41·0	16·50	54·1	20·50	67·3	24·50	80·4	28·50	93·5
0·55	1·8	4·55	14·9	8·55	28·1	12·55	41·2	16·55	54·3	20·55	67·4	24·55	80·5	28·55	93·7
0·60	2·0	4·60	15·1	8·60	28·2	12·60	41·3	16·60	54·5	20·60	67·6	24·60	80·7	28·60	93·8
0·65	2·1	4·65	15·3	8·65	28·4	12·65	41·5	16·65	54·6	20·65	67·7	24·65	80·9	28·65	94·0
0·70	2·3	4·70	15·4	8·70	28·5	12·70	41·7	16·70	54·8	20·70	67·9	24·70	81·0	28·70	94·2
0·75	2·5	4·75	15·6	8·75	28·7	12·75	41·8	16·75	55·0	20·75	68·1	24·75	81·2	28·75	94·3
0·80	2·6	4·80	15·7	8·80	28·9	12·80	42·0	16·80	55·1	20·80	68·2	24·80	81·4	28·80	94·5
0·85	2·8	4·85	15·9	8·85	29·0	12·85	42·2	16·85	55·3	20·85	68·4	24·85	81·5	28·85	94·7
0·90	3·0	4·90	16·1	8·90	29·2	12·90	42·3	16·90	55·4	20·90	68·6	24·90	81·7	28·90	94·8
0·95	3·1	4·95	16·2	8·95	29·4	12·95	42·5	16·95	55·6	20·95	68·7	24·95	81·9	28·95	95·0
1·00	3·3	5·00	16·4	9·00	29·5	13·00	42·7	17·00	55·8	21·00	68·9	25·00	82·0	29·00	95·1
1·05	3·4	5·05	16·6	9·05	29·7	13·05	42·8	17·05	55·9	21·05	69·1	25·05	82·2	29·05	95·3
1·10	3·6	5·10	16·7	9·10	29·9	13·10	43·0	17·10	56·1	21·10	69·2	25·10	82·3	29·10	95·5
1·15	3·8	5·15	16·9	9·15	30·0	13·15	43·1	17·15	56·3	21·15	69·4	25·15	82·5	29·15	95·6
1·20	3·9	5·20	17·1	9·20	30·2	13·20	43·3	17·20	56·4	21·20	69·6	25·20	82·7	29·20	95·8
1·25	4·1	5·25	17·2	9·25	30·3	13·25	43·5	17·25	56·6	21·25	69·7	25·25	82·8	29·25	96·0
1·30	4·3	5·30	17·4	9·30	30·5	13·30	43·6	17·30	56·8	21·30	69·9	25·30	83·0	29·30	96·1
1·35	4·4	5·35	17·6	9·35	30·7	13·35	43·8	17·35	56·9	21·35	70·0	25·35	83·2	29·35	96·3
1·40	4·6	5·40	17·7	9·40	30·8	13·40	44·0	17·40	57·1	21·40	70·2	25·40	83·3	29·40	96·5
1·45	4·8	5·45	17·9	9·45	31·0	13·45	44·1	17·45	57·3	21·45	70·4	25·45	83·5	29·45	96·6
1·50	4·9	5·50	18·0	9·50	31·2	13·50	44·3	17·50	57·4	21·50	70·5	25·50	83·7	29·50	96·8
1·55	5·1	5·55	18·2	9·55	31·3	13·55	44·5	17·55	57·6	21·55	70·7	25·55	83·8	29·55	96·9
1·60	5·2	5·60	18·4	9·60	31·5	13·60	44·6	17·60	57·7	21·60	70·9	25·60	84·0	29·60	97·1
1·65	5·4	5·65	18·5	9·65	31·7	13·65	44·8	17·65	57·9	21·65	71·0	25·65	84·2	29·65	97·3
1·70	5·6	5·70	18·7	9·70	31·8	13·70	44·9	17·70	58·1	21·70	71·2	25·70	84·3	29·70	97·4
1·75	5·7	5·75	18·9	9·75	32·0	13·75	45·1	17·75	58·2	21·75	71·4	25·75	84·5	29·75	97·6
1·80	5·9	5·80	19·0	9·80	32·2	13·80	45·3	17·80	58·4	21·80	71·5	25·80	84·6	29·80	97·8
1·85	6·1	5·85	19·2	9·85	32·3	13·85	45·4	17·85	58·6	21·85	71·7	25·85	84·8	29·85	97·9
1·90	6·2	5·90	19·4	9·90	32·5	13·90	45·6	17·90	58·7	21·90	71·9	25·90	85·0	29·90	98·1
1·95	6·4	5·95	19·5	9·95	32·6	13·95	45·8	17·95	58·9	21·95	72·0	25·95	85·1	29·95	98·3
2·00	6·6	6·00	19·7	10·00	32·8	14·00	45·9	18·00	59·1	22·00	72·2	26·00	85·3	30·00	98·4
2·05	6·7	6·05	19·8	10·05	33·0	14·05	46·1	18·05	59·2	22·05	72·3	26·05	85·5	30·05	98·6
2·10	6·9	6·10	20·0	10·10	33·1	14·10	46·3	18·10	59·4	22·10	72·5	26·10	85·6	30·10	98·8
2·15	7·1	6·15	20·2	10·15	33·3	14·15	46·4	18·15	59·5	22·15	72·7	26·15	85·8	30·15	98·9
2·20	7·2	6·20	20·3	10·20	33·5	14·20	46·6	18·20	59·7	22·20	72·8	26·20	86·0	30·20	99·1
2·25	7·4	6·25	20·5	10·25	33·6	14·25	46·8	18·25	59·9	22·25	73·0	26·25	86·1	30·25	99·2
2·30	7·5	6·30	20·7	10·30	33·8	14·30	46·9	18·30	60·0	22·30	73·2	26·30	86·3	30·30	99·4
2·35	7·7	6·35	20·8	10·35	34·0	14·35	47·1	18·35	60·2	22·35	73·3	26·35	86·5	30·35	99·6
2·40	7·9	6·40	21·0	10·40	34·1	14·40	47·2	18·40	60·4	22·40	73·5	26·40	86·6	30·40	99·7
2·45	8·0	6·45	21·2	10·45	34·3	14·45	47·4	18·45	60·5	22·45	73·7	26·45	86·8	30·45	99·9
2·50	8·2	6·50	21·3	10·50	34·4	14·50	47·6	18·50	60·7	22·50	73·8	26·50	86·9	30·50	100·1
2·55	8·4	6·55	21·5	10·55	34·6	14·55	47·7	18·55	60·9	22·55	74·0	26·55	87·1	30·55	100·2
2·60	8·5	6·60	21·7	10·60	34·8	14·60	47·9	18·60	61·0	22·60	74·1	26·60	87·3	30·60	100·4
2·65	8·7	6·65	21·8	10·65	34·9	14·65	48·1	18·65	61·2	22·65	74·3	26·65	87·4	30·65	100·6
2·70	8·9	6·70	22·0	10·70	35·1	14·70	48·2	18·70	61·4	22·70	74·5	26·70	87·6	30·70	100·7
2·75	9·0	6·75	22·1	10·75	35·3	14·75	48·4	18·75	61·5	22·75	74·6	26·75	87·8	30·75	100·9
2·80	9·2	6·80	22·3	10·80	35·4	14·80	48·6	18·80	61·7	22·80	74·8	26·80	87·9	30·80	101·0
2·85	9·4	6·85	22·5	10·85	35·6	14·85	48·7	18·85	61·8	22·85	75·0	26·85	88·1	30·85	101·2
2·90	9·5	6·90	22·6	10·90	35·8	14·90	48·9	18·90	62·0	22·90	75·1	26·90	88·3	30·90	101·4
2·95	9·7	6·95	22·8	10·95	35·9	14·95	49·0	18·95	62·2	22·95	75·3	26·95	88·4	30·95	101·5
3·00	9·8	7·00	23·0	11·00	36·1	15·00	49·2	19·00	62·3	23·00	75·5	27·00	88·6	31·00	101·7

Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet
3·05	10·0	7·05	23·1	11·05	36·3	15·05	49·4	19·05	62·5	23·05	75·6	27·05	88·7	31·05	101·9
3·10	10·2	7·10	23·3	11·10	36·4	15·10	49·5	19·10	62·7	23·10	75·8	27·10	88·9	31·10	102·0
3·15	10·3	7·15	23·5	11·15	36·6	15·15	49·7	19·15	62·8	23·15	76·0	27·15	89·1	31·15	102·2
3·20	10·5	7·20	23·6	11·20	36·7	15·20	49·9	19·20	63·0	23·20	76·1	27·20	89·2	31·20	102·4
3·25	10·7	7·25	23·8	11·25	36·9	15·25	50·0	19·25	63·2	23·25	76·3	27·25	89·4	31·25	102·5
3·30	10·8	7·30	24·0	11·30	37·1	15·30	50·2	19·30	63·3	23·30	76·4	27·30	89·6	31·30	102·7
3·35	11·0	7·35	24·1	11·35	37·2	15·35	50·4	19·35	63·5	23·35	76·6	27·35	89·7	31·35	102·9
3·40	11·2	7·40	24·3	11·40	37·4	15·40	50·5	19·40	63·6	23·40	76·8	27·40	89·9	31·40	103·0
3·45	11·3	7·45	24·4	11·45	37·6	15·45	50·7	19·45	63·8	23·45	76·9	27·45	90·1	31·45	103·2
3·50	11·5	7·50	24·6	11·50	37·7	15·50	50·9	19·50	64·0	23·50	77·1	27·50	90·2	31·50	103·3
3·55	11·6	7·55	24·8	11·55	37·9	13·55	51·0	19·55	64·1	23·55	77·3	27·55	90·4	31·55	103·5
3·60	11·8	7·60	24·9	11·60	38·1	15·60	51·2	19·60	64·3	23·60	77·4	27·60	90·6	31·60	103·7
3·65	12·0	7·65	25·1	11·65	38·2	15·65	51·3	19·65	64·5	23·65	77·6	27·65	90·7	31·65	103·8
3·70	12·1	7·70	25·3	11·70	38·4	15·70	51·5	19·70	64·6	23·70	77·8	27·70	90·9	31·70	104·0
3·75	12·3	7·75	25·4	11·75	38·5	15·75	51·7	19·75	64·8	23·75	77·9	27·75	91·0	31·75	104·2
3·80	12·5	7·80	25·6	11·80	38·7	15·80	51·8	19·80	65·0	23·80	78·1	27·80	91·2	31·80	104·3
3·85	12·6	7·85	25·8	11·85	38·9	15·85	52·0	19·85	65·1	23·85	78·2	27·85	91·4	31·85	104·5
3·90	12·8	7·90	25·9	11·90	39·0	15·90	52·2	19·90	65·3	23·90	78·4	27·90	91·5	31·90	104·7
3·95	13·0	7·95	26·1	11·95	39·2	15·95	52·3	19·95	65·5	23·95	78·6	27·95	91·7	31·95	104·8
4·00	13·1	8·00	26·2	12·00	39·4	16·00	52·5	20·00	65·6	24·00	78·7	28·00	91·9	32·00	105·0

ADMIRALTY METHOD OF TIDAL PREDICTION—NP 159
Calculator Box Diagram

A

Port	
A.T.T. No.	
Date	
Time Zone	

	Mean Level	
1.	Zo (Part II) or (Tab VIa)	
2.	Seasonal Corr. (Part II)	
3.	Sum = M.L.	

		M_2	S_2	K_1	O_1
4.	A1 (Tab VII)				
5.	A2 (Tab VII)				
6.	A1 − A2				
*7.	360. n				
8.	(A1 − A2) + 360.n = p				
9.	p/24				
10.	A1 (I.4.)				
11.	g. (Part II)				
12.	A1 + g.				
13.	F2 (Tab VII)				
14.	F1 (Tab VII)				
15.	F2 − F1 = P				
16.	P/24				

* n = 0 or smallest integer necessary to make 1.8 > 600° in M_2 and S_2 columns and > 300° in K_1 and O_1 columns.

† R sin r = sum of H.Ft sin Θ for M_2 and S_2
R cos r = sum of H.Ft cos Θ for M_2 and S_2

‡ H.Ft cos Θ (K_1)

§ H.Ft cos Θ (O_1)

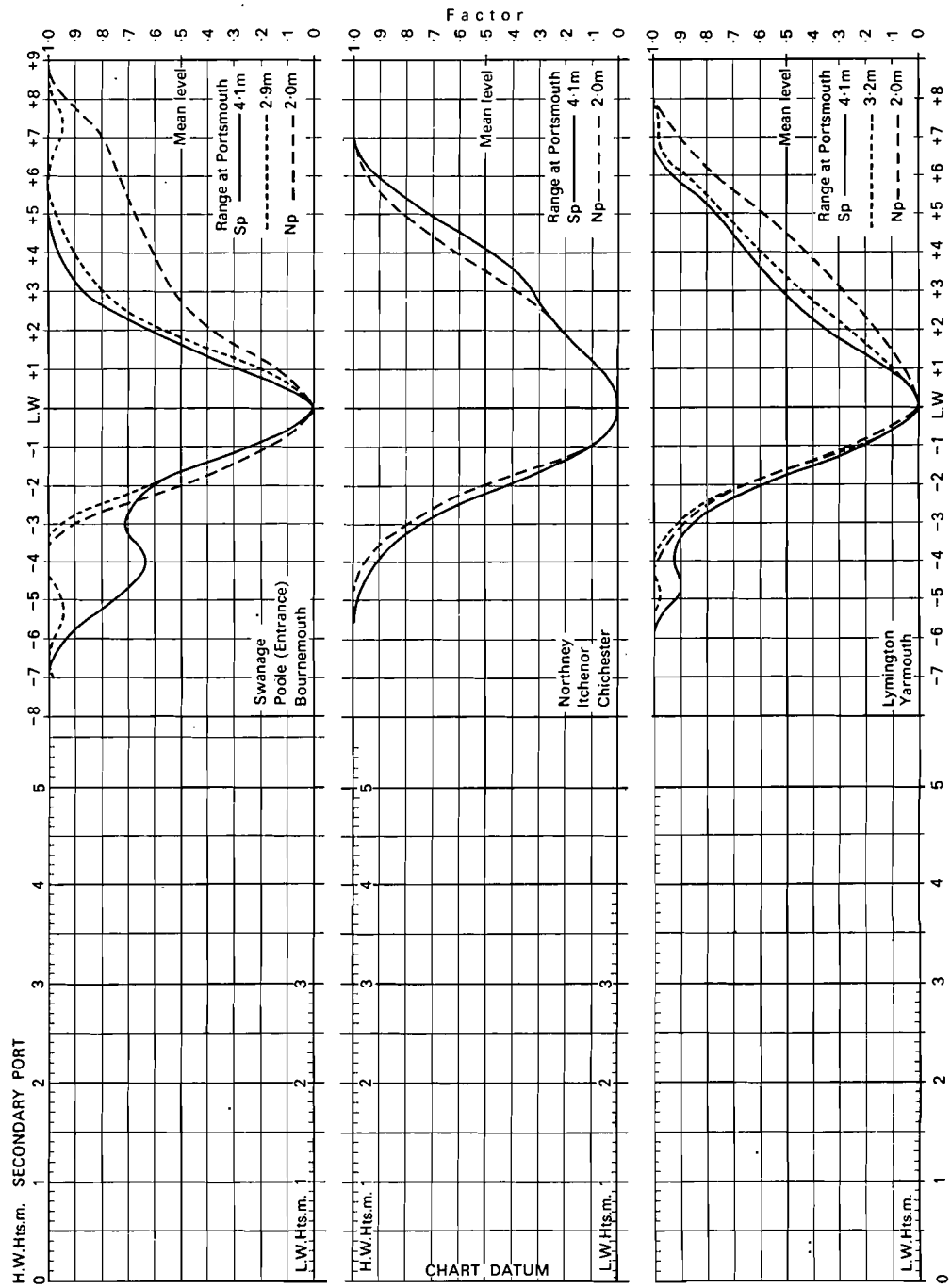
B

		M_2	S_2	K_1	O_1
17.	Time = T				
	H.C.				
18.	p/24 (I.9)				
19.	p/24 × T				
20.	(A1 + g) (I.12)				
21.	(A1 + g) − p.T/24 = Θ				
22.	Sin Θ				
23.	Cos Θ				
24.	P/24 (I.16)				
25.	P/24 × T				
26.	F1 (I.14)				
27.	F1 + P.T/24 = Ft				
28.	H. (Part II)				
29.	H × Ft.				
30.	(H × Ft) Sin Θ			‡	
31.	(H × Ft) Cos Θ			§	
132.	R sin r : R cos r			→	
33.	r : R			M.L. (I.3)	
34.	2r : R^2				
35.	f_4 : F_4 (Part II)				
36.	2r + f_4 = d_4 : $R^2.F_4 = D_4$			$D_4 \cos d_4$	
37.	3r : R^3				
38.	f_6 : F_6 (Part II)				
39.	3r + f_6 = d_6 : $R^3.F_6 = D_6$			$D_6 \cos d_6$	
40.		Sum lines 30-39 = Height			

FFF

VOL. 1 EUROPEAN WATERS

Tidal Curves—Swanage to Christchurch—Ryde to Selsey—Lymington to Cowes



VOLS. 2 AND 3 ATLANTIC, INDIAN AND PACIFIC OCEANS

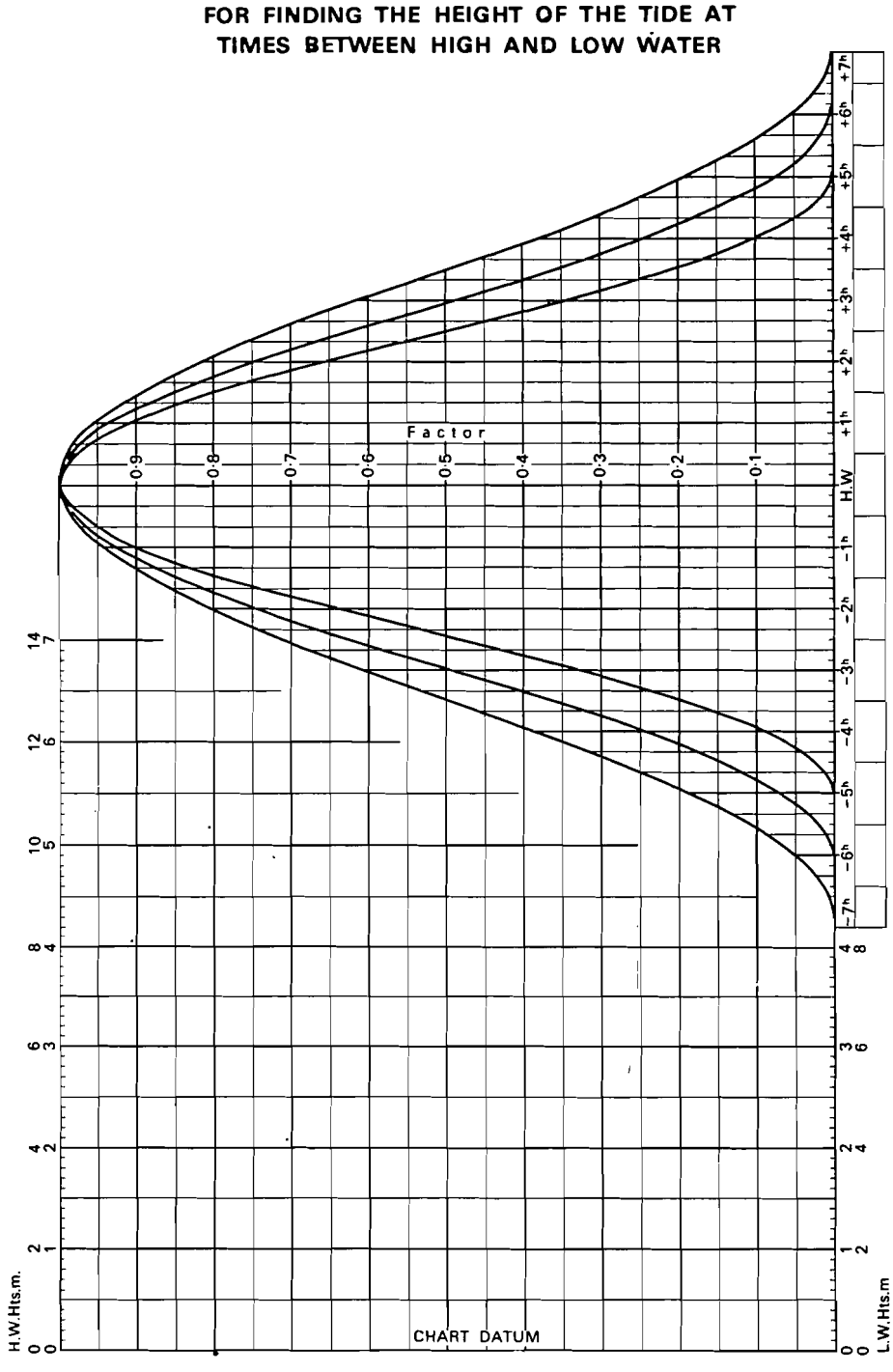


TABLE II

Multiplication Table

FACTOR	RANGE AT STANDARD PORT																													FACTOR
1·00	1·2	1·4	1·6	1·8	2·0	2·2	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·8	6·0	6·2	6·4	6·6	6·8	7·0	1·00	
0·98	1·2	1·4	1·6	1·8	2·0	2·2	2·4	2·5	2·7	2·9	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	4·9	5·1	5·3	5·5	5·7	5·9	6·1	6·3	6·5	6·7	6·9	0·98	
0·96	1·2	1·3	1·5	1·7	1·9	2·1	2·3	2·5	2·7	2·9	3·1	3·3	3·5	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·8	6·0	6·1	6·3	6·5	6·7	0·96	
0·94	1·1	1·3	1·5	1·7	1·9	2·1	2·3	2·4	2·6	2·8	3·0	3·2	3·4	3·6	3·8	3·9	4·1	4·3	4·5	4·7	4·9	5·1	5·3	5·5	5·6	5·8	6·0	6·2	6·4	6·6	0·94	
0·92	1·1	1·3	1·5	1·7	1·8	2·0	2·2	2·4	2·6	2·8	2·9	3·1	3·3	3·5	3·7	3·9	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·3	5·5	5·7	5·9	6·1	6·3	6·4	0·92	
0·90	1·1	1·3	1·4	1·6	1·8	2·0	2·2	2·3	2·5	2·7	2·9	3·1	3·2	3·4	3·6	3·8	4·0	4·1	4·3	4·5	4·7	4·9	5·0	5·2	5·4	5·6	5·8	5·9	6·1	6·3	0·90	
0·88	1·1	1·2	1·4	1·6	1·8	1·9	2·1	2·3	2·5	2·6	2·8	3·0	3·2	3·3	3·5	3·7	3·9	4·0	4·2	4·4	4·6	4·8	4·9	5·1	5·3	5·5	5·6	5·8	6·0	6·2	0·88	
0·86	1·0	1·2	1·4	1·5	1·7	1·9	2·1	2·2	2·4	2·6	2·8	2·9	3·1	3·3	3·4	3·6	3·8	4·0	4·1	4·3	4·5	4·6	4·8	5·0	5·2	5·3	5·5	5·7	5·8	6·0	0·86	
0·84	1·0	1·2	1·3	1·5	1·7	1·8	2·0	2·2	2·4	2·5	2·7	2·9	3·0	3·2	3·4	3·5	3·7	3·9	4·0	4·2	4·4	4·5	4·7	4·9	5·0	5·2	5·4	5·5	5·7	5·9	0·84	
0·82	1·0	1·1	1·3	1·5	1·6	1·8	2·0	2·1	2·3	2·5	2·6	2·8	3·0	3·1	3·3	3·4	3·6	3·8	3·9	4·1	4·3	4·4	4·6	4·8	4·9	5·1	5·2	5·4	5·6	5·7	0·82	
0·80	1·0	1·1	1·3	1·4	1·6	1·8	1·9	2·1	2·2	2·4	2·6	2·7	2·9	3·0	3·2	3·4	3·5	3·7	3·8	4·0	4·2	4·3	4·5	4·6	4·8	5·0	5·1	5·3	5·4	5·6	0·80	
0·78	0·9	1·1	1·2	1·4	1·6	1·7	1·9	2·0	2·2	2·3	2·5	2·7	2·8	3·0	3·1	3·3	3·4	3·6	3·7	3·9	4·1	4·2	4·4	4·5	4·7	4·8	5·0	5·1	5·3	5·5	0·78	
0·76	0·9	1·1	1·2	1·4	1·5	1·7	1·8	2·0	2·1	2·3	2·4	2·6	2·7	2·9	3·0	3·2	3·3	3·5	3·6	3·8	4·0	4·1	4·3	4·4	4·6	4·7	4·9	5·0	5·2	5·3	0·76	
0·74	0·9	1·0	1·2	1·3	1·5	1·6	1·8	1·9	2·1	2·2	2·4	2·5	2·7	2·8	3·0	3·1	3·3	3·4	3·6	3·7	3·8	4·0	4·1	4·3	4·4	4·6	4·7	4·9	5·0	5·2	0·74	
0·72	0·9	1·0	1·2	1·3	1·4	1·6	1·7	1·9	2·0	2·2	2·3	2·4	2·6	2·7	2·9	3·0	3·2	3·3	3·5	3·6	3·7	3·9	4·0	4·2	4·3	4·5	4·6	4·8	4·9	5·0	0·72	
0·70	0·8	1·0	1·1	1·3	1·4	1·5	1·7	1·8	2·0	2·1	2·2	2·4	2·5	2·7	2·8	2·9	3·1	3·2	3·4	3·5	3·6	3·8	3·9	4·1	4·2	4·3	4·5	4·6	4·8	4·9	0·70	
0·68	0·8	1·0	1·1	1·2	1·4	1·5	1·6	1·8	1·9	2·0	2·2	2·3	2·4	2·6	2·7	2·9	3·0	3·1	3·3	3·4	3·5	3·7	3·8	3·9	4·1	4·2	4·4	4·5	4·6	4·8	0·68	
0·66	0·8	0·9	1·1	1·2	1·3	1·5	1·6	1·7	1·8	2·0	2·1	2·2	2·4	2·5	2·6	2·8	2·9	3·0	3·2	3·3	3·4	3·6	3·7	3·8	4·0	4·1	4·2	4·4	4·5	4·6	0·66	
0·64	0·8	0·9	1·0	1·1	1·3	1·4	1·5	1·7	1·8	1·9	2·0	2·2	2·3	2·4	2·6	2·7	2·8	2·9	3·1	3·2	3·3	3·5	3·6	3·7	3·8	4·0	4·1	4·2	4·4	4·5	0·64	
0·62	0·7	0·9	1·0	1·1	1·2	1·4	1·5	1·6	1·7	1·9	2·0	2·1	2·2	2·4	2·5	2·6	2·7	2·9	3·0	3·1	3·2	3·3	3·5	3·6	3·7	3·8	4·0	4·1	4·2	4·3	0·62	
0·60	0·7	0·8	1·0	1·1	1·2	1·3	1·4	1·6	1·7	1·8	1·9	2·0	2·2	2·3	2·4	2·5	2·6	2·8	2·9	3·0	3·1	3·2	3·4	3·5	3·6	3·7	3·8	4·0	4·1	4·2	0·60	
0·58	0·7	0·8	0·9	1·0	1·2	1·3	1·4	1·5	1·6	1·7	1·9	2·0	2·1	2·2	2·3	2·4	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·4	3·5	3·6	3·7	3·8	3·9	4·1	0·58	
0·56	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·4	3·5	3·6	3·7	3·8	3·9	0·56	
0·54	0·6	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·5	3·6	3·7	3·8	0·54	
0·52	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·4	3·5	3·6	0·52	
0·50	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·4	3·5	0·50	
0·48	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·4	0·48	
0·46	0·6	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·7	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	2·9	3·0	3·1	3·2	0·46	
0·44	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·6	2·7	2·8	2·9	3·0	3·1	0·44	
0·42	0·5	0·6	0·7	0·8	0·8	0·9	1·0	1·1	1·2	1·3	1·3	1·4	1·5	1·6	1·7	1·8	1·8	1·9	2·0	2·1	2·2	2·3	2·4	2·4	2·5	2·6	2·7	2·8	2·9	2·9	0·42	
0·40	0·5	0·6	0·6	0·7	0·8	0·9	1·0	1·0	1·1	1·2	1·3	1·4	1·4	1·5	1·6	1·7	1·8	1·8	1·9	2·0	2·1	2·2	2·2	2·3	2·4	2·5	2·6	2·6	2·7	2·8	0·40	
0·38	0·5	0·5	0·6	0·7	0·8	0·8	0·9	1·0	1·1	1·1	1·2	1·3	1·4	1·4	1·5	1·6	1·7	1·7	1·8	1·9	2·0	2·1	2·1	2·2	2·3	2·4	2·4	2·5	2·6	2·7	0·38	
0·36	0·4	0·5	0·6	0·6	0·7	0·8	0·9	0·9	1·0	1·1	1·2	1·2	1·3	1·4	1·4	1·5	1·6	1·7	1·7	1·8	1·9	1·9	2·0	2·1	2·2	2·2	2·3	2·4	2·4	2·5	0·36	
0·34	0·4	0·5	0·5	0·6	0·7	0·7	0·8	0·9	1·0	1·0	1·1	1·2	1·2	1·3	1·4	1·4	1·5	1·6	1·6	1·7	1·8	1·8	1·9	2·0	2·0	2·1	2·2	2·2	2·3	2·4	0·34	
0·32	0·4	0·4	0·5	0·6	0·6	0·7	0·8	0·8	0·9	1·0	1·0	1·1	1·2	1·2	1·3	1·3	1·4	1·5	1·5	1·6	1·7	1·7	1·8	1·9	1·9	2·0	2·0	2·1	2·2	2·2	0·32	
0·30	0·4	0·4	0·5	0·5	0·6	0·7	0·7	0·8	0·8	0·9	1·0	1·0	1·1	1·1	1·2	1·3	1·3	1·4	1·4	1·5	1·6	1·6	1·7	1·7	1·8	1·9	1·9	2·0	2·0	2·1	0·30	
0·28	0·3	0·4	0·4	0·5	0·6	0·6	0·7	0·7	0·8	0·8	0·9	1·0	1·0	1·1	1·1	1·2	1·2	1·3	1·3	1·4	1·5	1·5	1·6	1·6	1·7	1·7	1·8	1·8	1·9	2·0	0·28	
0·26	0·3	0·4	0·4	0·5	0·5	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·1	1·1	1·2	1·2	1·3	1·4	1·4	1·5	1·5	1·6	1·6	1·7	1·7	1·8	1·8	0·26	
0·24	0·3	0·3	0·4	0·4	0·5	0·5	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·1	1·1	1·2	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·5	1·6	1·6	1·7	0·24	
0·22	0·3	0·3	0·4	0·4	0·4	0·5	0·5	0·6	0·6	0·7	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·1	1·1	1·1	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·5	1·5	0·22	
0·20	0·2	0·3	0·3	0·4	0·4	0·4	0·5	0·5	0·6	0·6	0·6	0·7	0·7	0·8	0·8	0·8	0·9	0·9	1·0	1·0	1·0	1·1	1·1	1·2	1·2	1·2	1·3	1·3	1·4	1·4	0·20	
0·18	0·2	0·3	0·3	0·3	0·4	0·4	0·4	0·5	0·5	0·5	0·6	0·6	0·6	0·7	0·7	0·8	0·8	0·8	0·9	0·9	0·9	1·0	1·0	1·0	1·1	1·1	1·2	1·2	1·2	1·3	0·18	
0·16	0·2	0·2	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·6	0·6	0·6	0·7	0·7	0·7	0·8	0·8	0·8	0·9	0·9	0·9	0·9	1·0	1·0	1·1	1·1	1·1	0·16	
0·14	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·7	0·7	0·7	0·8	0·8	0·8	0·9	0·9	0·9	1·0	1·0	1·0	0·14	
0·12	0·1	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·7	0·7	0·7	0·7	0·8	0·8	0·8	0·8	0·12	
0·10	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·7	0·7	0·7	0·10	
0·08	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·6	0·08	
0·06	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·06	
0·04	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·04	
0·02	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·02	

TABLE II—*continued*

RANGE AT STANDARD PORT																											
1·00	7·2	7·4	7·6	7·8	8·0	8·2	8·4	8·6	8·8	9·0	9·2	9·4	9·6	9·8	10·0	10·2	10·4	10·6	10·8	11·0	11·2	11·4	11·6	11·8	12·0	13·0	14·0	15·0	16·0	17·0	1·00
0·98	7·1	7·3	7·4	7·6	7·8	8·0	8·2	8·4	8·6	8·8	9·0	9·2	9·4	9·6	9·8	10·0	10·2	10·4	10·6	10·8	11·0	11·2	11·4	11·6	11·8	12·7	13·7	14·7	15·7	16·7	0·98
0·96	6·9	7·1	7·3	7·5	7·7	7·9	8·1	8·3	8·4	8·6	8·8	9·0	9·2	9·4	9·6	9·8	10·0	10·2	10·4	10·6	10·8	10·9	11·1	11·3	11·5	12·5	13·4	14·4	15·4	16·3	0·96
0·94	6·8	7·0	7·1	7·3	7·5	7·7	7·9	8·1	8·3	8·5	8·6	8·8	9·0	9·2	9·4	9·6	9·8	10·0	10·2	10·3	10·5	10·7	10·9	11·1	11·3	12·2	13·2	14·1	15·0	16·0	0·94
0·92	6·6	6·8	7·0	7·2	7·4	7·5	7·7	7·9	8·1	8·3	8·5	8·6	8·8	9·0	9·2	9·4	9·6	9·8	9·9	10·1	10·3	10·5	10·7	10·9	11·0	12·0	12·9	13·8	14·7	15·6	0·92
0·90	6·5	6·7	6·8	7·0	7·2	7·4	7·6	7·7	7·9	8·1	8·3	8·5	8·6	8·8	9·0	9·2	9·4	9·5	9·7	9·9	10·1	10·3	10·4	10·6	10·8	11·7	12·6	13·5	14·4	15·3	0·90
0·88	6·3	6·5	6·7	6·9	7·0	7·2	7·4	7·6	7·7	7·9	8·1	8·3	8·4	8·6	8·8	9·0	9·2	9·3	9·5	9·7	9·9	10·0	10·2	10·4	10·6	11·4	12·3	13·2	14·1	15·0	0·88
0·86	6·2	6·4	6·5	6·7	6·9	7·1	7·2	7·4	7·6	7·7	7·9	8·1	8·3	8·4	8·6	8·8	8·9	9·1	9·3	9·5	9·6	9·8	10·0	10·1	10·3	11·2	12·0	12·9	13·8	14·6	0·86
0·84	6·0	6·2	6·4	6·6	6·7	6·9	7·1	7·2	7·4	7·6	7·7	7·9	8·1	8·2	8·4	8·6	8·7	8·9	9·1	9·2	9·4	9·6	9·7	9·9	10·1	10·9	11·8	12·6	13·4	14·3	0·84
0·82	5·9	6·1	6·2	6·4	6·6	6·7	6·9	7·1	7·2	7·4	7·5	7·7	7·9	8·0	8·2	8·4	8·5	8·7	8·9	9·0	9·2	9·3	9·5	9·7	9·8	10·7	11·5	12·3	13·1	13·9	0·82
0·80	5·8	5·9	6·1	6·2	6·4	6·6	6·7	6·9	7·0	7·2	7·4	7·5	7·7	7·8	8·0	8·2	8·3	8·5	8·6	8·8	9·0	9·1	9·3	9·4	9·6	10·4	11·2	12·0	12·8	13·6	0·80
0·78	5·6	5·8	5·9	6·1	6·2	6·4	6·6	6·7	6·9	7·0	7·2	7·3	7·5	7·6	7·8	8·0	8·1	8·3	8·4	8·6	8·7	8·9	9·0	9·2	9·4	10·1	10·9	11·7	12·5	13·3	0·78
0·76	5·5	5·6	5·8	5·9	6·1	6·2	6·4	6·5	6·7	6·8	7·0	7·1	7·3	7·4	7·6	7·8	7·9	8·1	8·2	8·4	8·5	8·7	8·8	9·0	9·1	9·9	10·6	11·4	12·2	12·9	0·76
0·74	5·3	5·5	5·6	5·8	5·9	6·1	6·2	6·4	6·5	6·7	6·8	7·0	7·1	7·3	7·4	7·5	7·7	7·8	8·0	8·1	8·3	8·4	8·6	8·7	8·9	9·6	10·4	11·1	11·8	12·6	0·74
0·72	5·2	5·3	5·5	5·6	5·8	5·9	6·0	6·2	6·3	6·5	6·6	6·8	6·9	7·1	7·2	7·3	7·5	7·6	7·8	7·9	8·1	8·2	8·4	8·5	8·6	9·4	10·1	10·8	11·5	12·2	0·72
0·70	5·0	5·2	5·3	5·5	5·6	5·7	5·9	6·0	6·2	6·3	6·4	6·6	6·7	6·9	7·0	7·1	7·3	7·4	7·6	7·7	7·8	8·0	8·1	8·3	8·4	9·1	9·8	10·5	11·2	11·9	0·70
0·68	4·9	5·0	5·2	5·3	5·4	5·6	5·7	5·8	6·0	6·1	6·3	6·4	6·5	6·7	6·8	6·9	7·1	7·2	7·3	7·5	7·6	7·8	7·9	8·0	8·2	8·8	9·5	10·2	10·9	11·6	0·68
0·66	4·8	4·9	5·0	5·1	5·3	5·4	5·5	5·7	5·8	5·9	6·1	6·2	6·3	6·5	6·6	6·7	6·9	7·0	7·1	7·3	7·4	7·5	7·7	7·8	7·9	8·6	9·2	9·9	10·6	11·2	0·66
0·64	4·6	4·7	4·9	5·0	5·1	5·2	5·4	5·5	5·6	5·8	5·9	6·0	6·1	6·3	6·4	6·5	6·7	6·8	6·9	7·0	7·2	7·3	7·4	7·6	7·7	8·3	9·0	9·6	10·2	10·9	0·64
0·62	4·5	4·6	4·7	4·8	5·0	5·1	5·2	5·3	5·5	5·6	5·7	5·8	6·0	6·1	6·2	6·3	6·4	6·6	6·7	6·8	6·9	7·1	7·2	7·3	7·4	8·1	8·7	9·3	9·9	10·5	0·62
0·60	4·3	4·4	4·6	4·7	4·8	4·9	5·0	5·2	5·3	5·4	5·5	5·6	5·8	5·9	6·0	6·1	6·2	6·4	6·5	6·6	6·7	6·8	7·0	7·1	7·2	7·8	8·4	9·0	9·6	10·2	0·60
0·58	4·2	4·3	4·4	4·5	4·6	4·8	4·9	5·0	5·1	5·2	5·3	5·5	5·6	5·7	5·8	5·9	6·0	6·1	6·3	6·4	6·5	6·6	6·7	6·8	7·0	7·5	8·1	8·7	9·3	9·9	0·58
0·56	4·0	4·1	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·2	5·3	5·4	5·5	5·6	5·7	5·8	5·9	6·0	6·2	6·3	6·4	6·5	6·6	6·7	7·3	7·8	8·4	9·0	9·5	0·56
0·54	3·9	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·8	4·9	5·0	5·1	5·2	5·3	5·4	5·5	5·6	5·7	5·8	5·9	6·0	6·2	6·3	6·4	6·5	7·0	7·6	8·1	8·6	9·2	0·54
0·52	3·7	3·8	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	5·3	5·4	5·5	5·6	5·7	5·8	5·9	6·0	6·1	6·2	6·8	7·3	7·8	8·3	8·8	0·52
0·50	3·6	3·7	3·8	3·9	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	5·3	5·4	5·5	5·6	5·7	5·8	5·9	6·0	6·5	7·0	7·5	8·0	8·5	0·50
0·48	3·5	3·6	3·6	3·7	3·8	3·9	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	5·3	5·4	5·5	5·6	5·7	5·8	6·2	6·7	7·2	7·7	8·2	0·48
0·46	3·3	3·4	3·5	3·6	3·7	3·8	3·9	4·0	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	5·2	5·3	5·4	5·5	6·0	6·4	6·9	7·4	7·8	0·46
0·44	3·2	3·3	3·3	3·4	3·5	3·6	3·7	3·8	3·9	4·0	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·8	4·9	5·0	5·1	5·2	5·3	5·7	6·2	6·6	7·0	7·5	0·44
0·42	3·0	3·1	3·2	3·3	3·4	3·4	3·5	3·6	3·7	3·8	3·9	3·9	4·0	4·1	4·2	4·3	4·4	4·5	4·5	4·6	4·7	4·8	4·9	5·0	5·0	5·5	5·9	6·3	6·7	7·1	0·42
0·40	2·9	3·0	3·0	3·1	3·2	3·3	3·4	3·4	3·5	3·6	3·7	3·8	3·8	3·9	4·0	4·1	4·2	4·2	4·3	4·4	4·5	4·6	4·6	4·7	4·8	5·2	5·6	6·0	6·4	6·8	0·40
0·38	2·7	2·8	2·9	3·0	3·0	3·1	3·2	3·3	3·3	3·4	3·5	3·6	3·6	3·7	3·8	3·9	4·0	4·0	4·1	4·2	4·3	4·3	4·4	4·5	4·6	4·9	5·3	5·7	6·1	6·5	0·38
0·36	2·6	2·7	2·7	2·8	2·9	3·0	3·0	3·1	3·2	3·2	3·3	3·4	3·5	3·5	3·6	3·7	3·7	3·8	3·9	4·0	4·0	4·1	4·2	4·2	4·3	4·7	5·0	5·4	5·8	6·1	0·36
0·34	2·4	2·5	2·6	2·7	2·7	2·8	2·9	2·9	3·0	3·1	3·1	3·2	3·3	3·3	3·4	3·5	3·5	3·6	3·7	3·7	3·8	3·9	3·9	4·0	4·1	4·4	4·8	5·1	5·4	5·8	0·34
0·32	2·3	2·4	2·4	2·5	2·6	2·6	2·7	2·8	2·8	2·9	2·9	3·0	3·1	3·1	3·2	3·3	3·3	3·4	3·5	3·5	3·6	3·6	3·7	3·8	3·8	4·2	4·5	4·8	5·1	5·4	0·32
0·30	2·2	2·2	2·3	2·3	2·4	2·5	2·5	2·6	2·6	2·7	2·8	2·8	2·9	2·9	3·0	3·1	3·1	3·2	3·2	3·3	3·4	3·4	3·5	3·5	3·6	3·9	4·2	4·5	4·8	5·1	0·30
0·28	2·0	2·1	2·1	2·2	2·2	2·3	2·4	2·4	2·5	2·5	2·6	2·6	2·7	2·7	2·8	2·9	2·9	3·0	3·0	3·1	3·1	3·2	3·2	3·3	3·4	3·6	3·9	4·2	4·5	4·8	0·28
0·26	1·9	1·9	2·0	2·0	2·1	2·1	2·2	2·2	2·3	2·3	2·4	2·4	2·5	2·5	2·6	2·7	2·7	2·8	2·8	2·9	2·9	3·0	3·0	3·1	3·1	3·4	3·6	3·9	4·2	4·4	0·26
0·24	1·7	1·8	1·8	1·9	1·9	2·0	2·0	2·1	2·1	2·2	2·2	2·3	2·3	2·4	2·4	2·4	2·5	2·5	2·6	2·6	2·7	2·7	2·8	2·8	2·9	3·1	3·4	3·6	3·8	4·1	0·24
0·22	1·6	1·6	1·7	1·7	1·8	1·8	1·8	1·9	1·9	2·0	2·0	2·1	2·1	2·2	2·2	2·2	2·3	2·3	2·4	2·4	2·5	2·5	2·6	2·6	2·6	2·9	3·1	3·3	3·5	3·7	0·22
0·20	1·4	1·5	1·5	1·6	1·6	1·6	1·7	1·7	1·8	1·8	1·8	1·9	1·9	2·0	2·0	2·0	2·1	2·1	2·2	2·2	2·2	2·3	2·3	2·4	2·4	2·6	2·8	3·0	3·2	3·4	0·20
0·18	1·3	1·3	1·4	1·4	1·4	1·5	1·5	1·5	1·6	1·6	1·7	1·7	1·7	1·8	1·8	1·8	1·9	1·9	1·9	2·0	2·0	2·1	2·1	2·1	2·2	2·3	2·5	2·7	2·9	3·1	0·18
0·16	1·2	1·2	1·2	1·2	1·3	1·3	1·3	1·4	1·4	1·4	1·5	1·5	1·5	1·6	1·6	1·6	1·7	1·7	1·7	1·8	1·8	1·8	1·9	1·9	1·9	2·1	2·2	2·4	2·6	2·7	0·16
0·14	1·0	1·0	1·1	1·1	1·1	1·1	1·2	1·2	1·2	1·3	1·3	1·3	1·3	1·4	1·4	1·4	1·5	1·5	1·5	1·5	1·6	1·6	1·6	1·7	1·7	1·8	2·0	2·1	2·2	2·4	0·14
0·12	0·9	0·9	0·9	0·9	1·0	1·0	1·0	1·0	1·1	1·1	1·1	1·1	1·2	1·2	1·2	1·2	1·2	1·3	1·3	1·3	1·3	1·4	1·4	1·4	1·4	1·6	1·7	1·8	1·9	2·0	0·12
0·10	0·7	0·7	0·8	0·8	0·8	0·8	0·8	0·9	0·9	0·9	0·9	0·9	1·0	1·0	1·0	1·0	1·0	1·1	1·1	1·1	1·1	1·1	1·2	1·2	1·2	1·3	1·4	1·5	1·6	1·7	0·10
0·08	0·6	0·6	0·6	0·6	0·6	0·7	0·7	0·7	0·7	0·7	0·7	0·8	0·8	0·8	0·8	0·8	0·8	0·8	0·9	0·9	0·9	0·9	0·9	0·9	1·0	1·0	1·1	1·2	1·3	1·4	0·08
0·06	0·4	0·4	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·6	0·6	0·6	0·6	0·7	0·7	0·7	0·7	0·7	0·7	0·8	0·8	0·9	1·0	1·0	0·06
0·04	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·7	0·04	
0·02	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·02
FACTOR																											FACTOR

ADMIRALTY TIDAL STREAM ATLAS (EXTRACTS)

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3 Hours Before HW Sheerness 872

2 Hours Before HW Sheerness 873

HW Sheerness 874

2 Hours after HW Sheerness 875

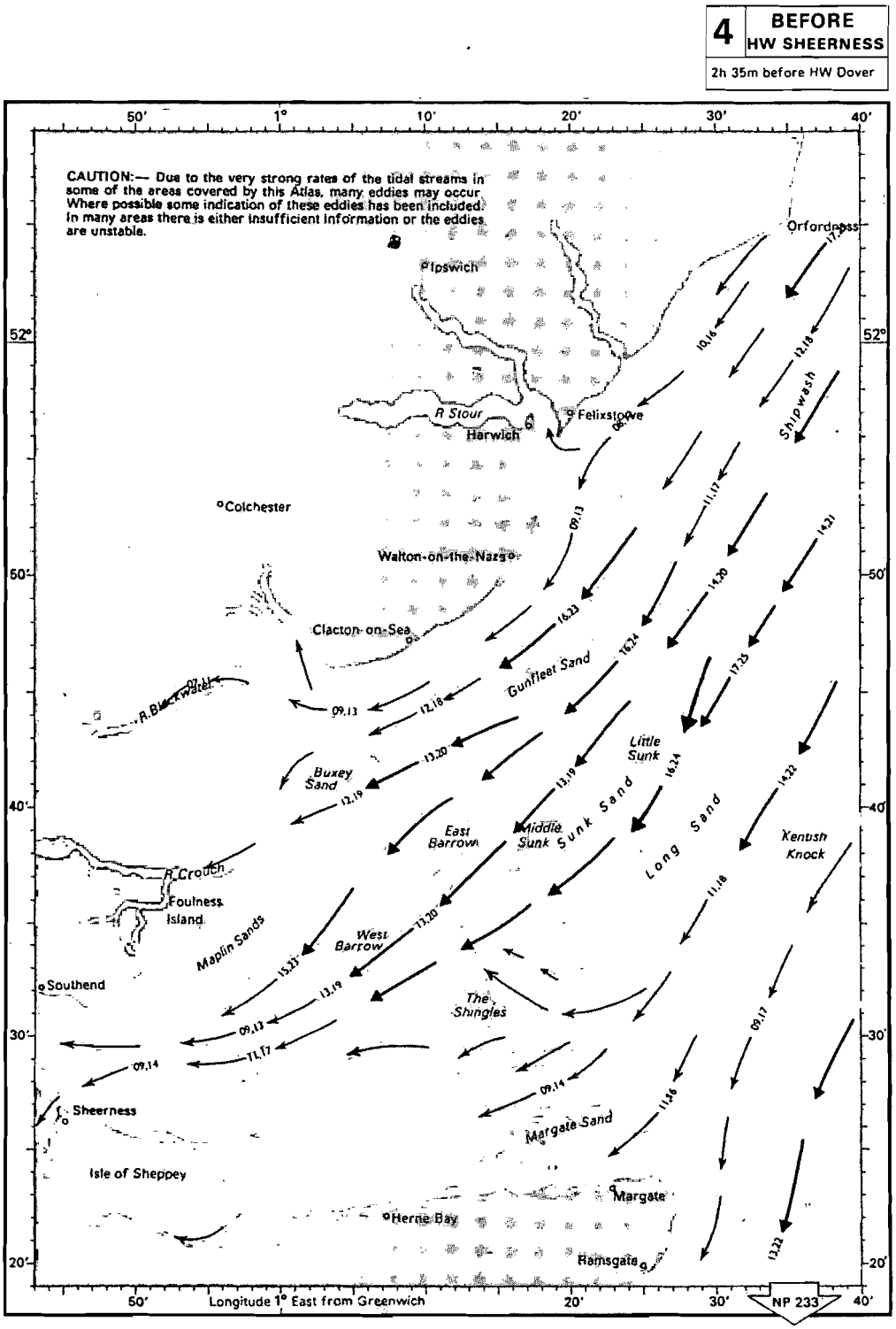
3 Hours after HW Sheerness 876

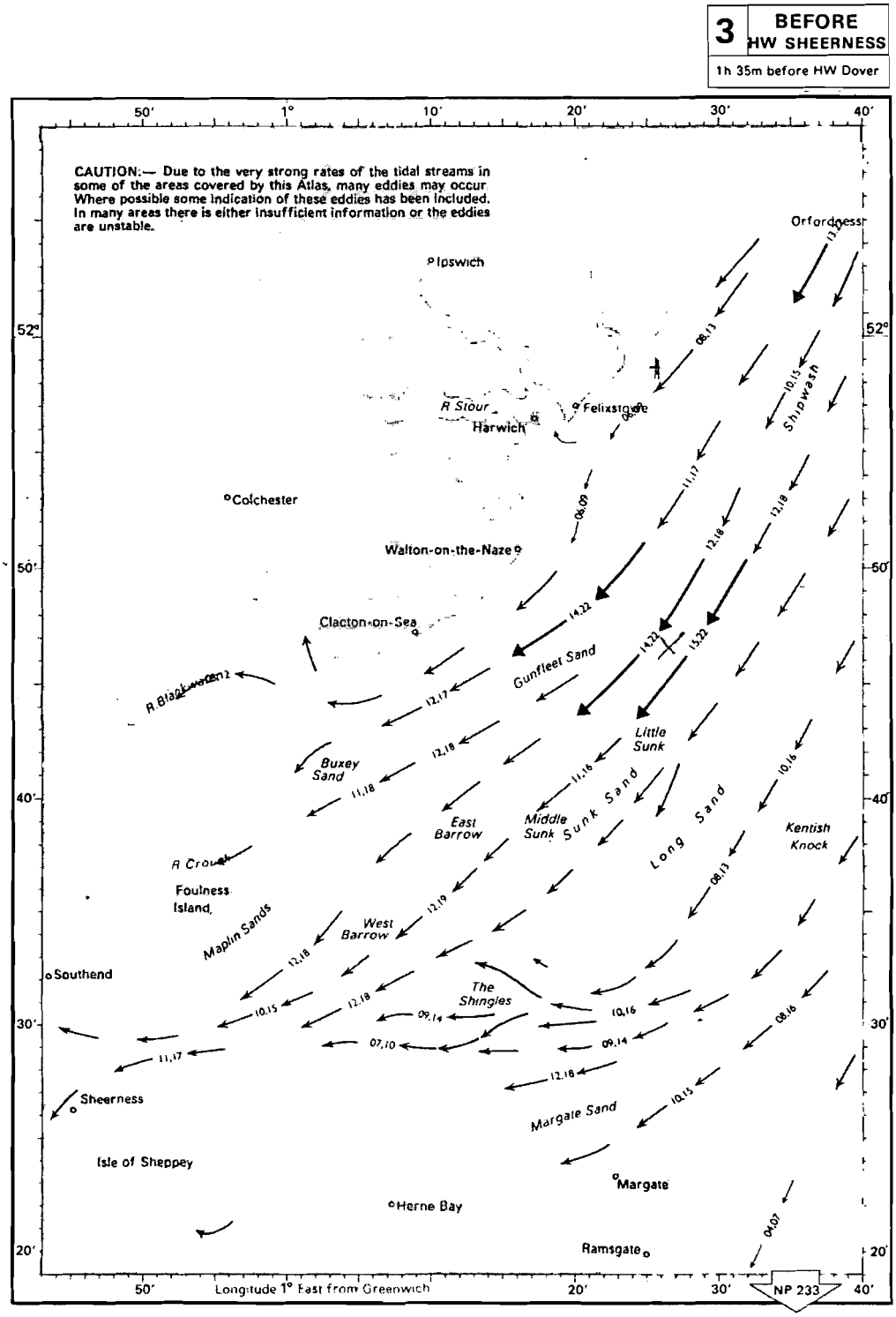
6 Hours after HW Sheerness 877

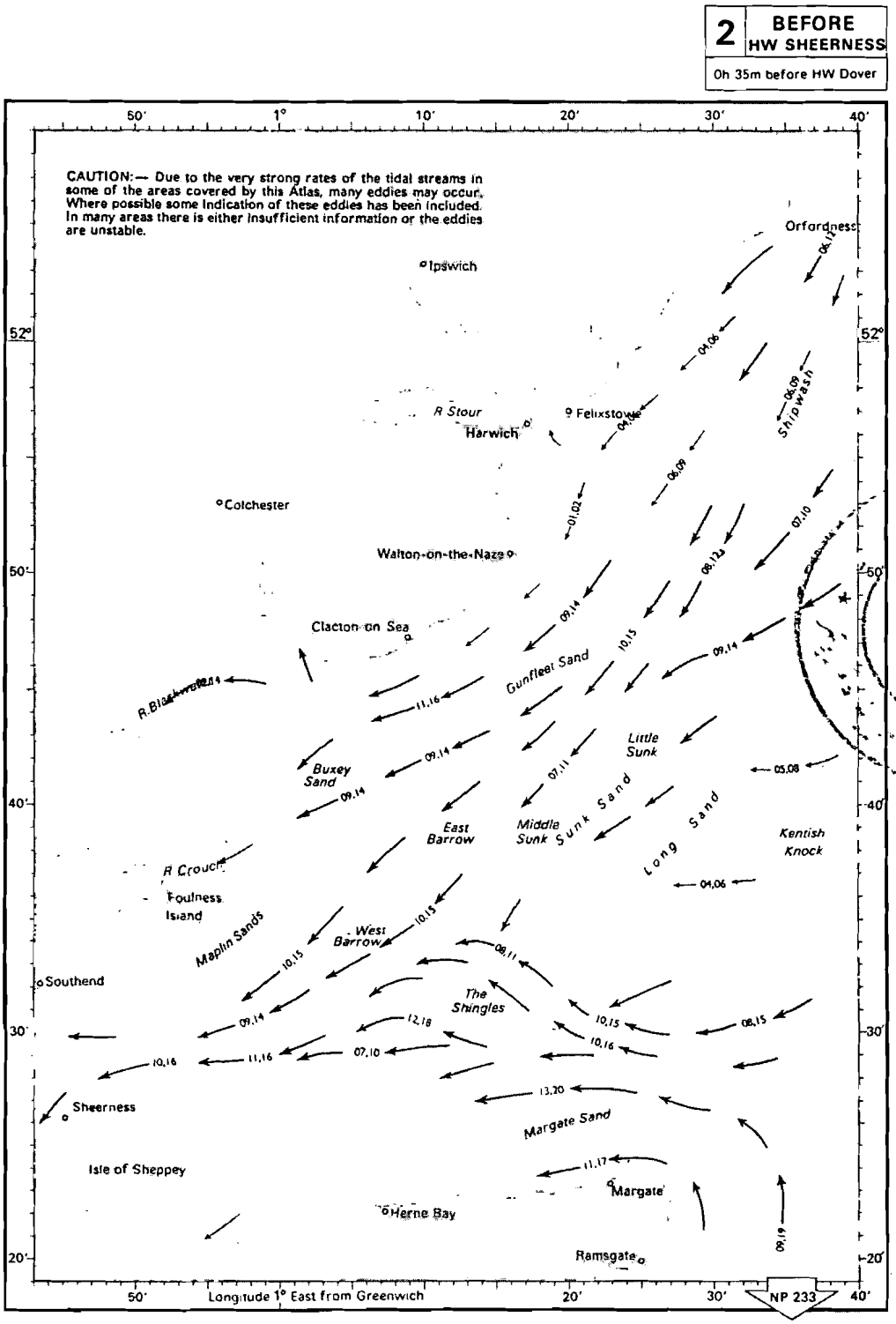
Computation of Rates Diagram 878

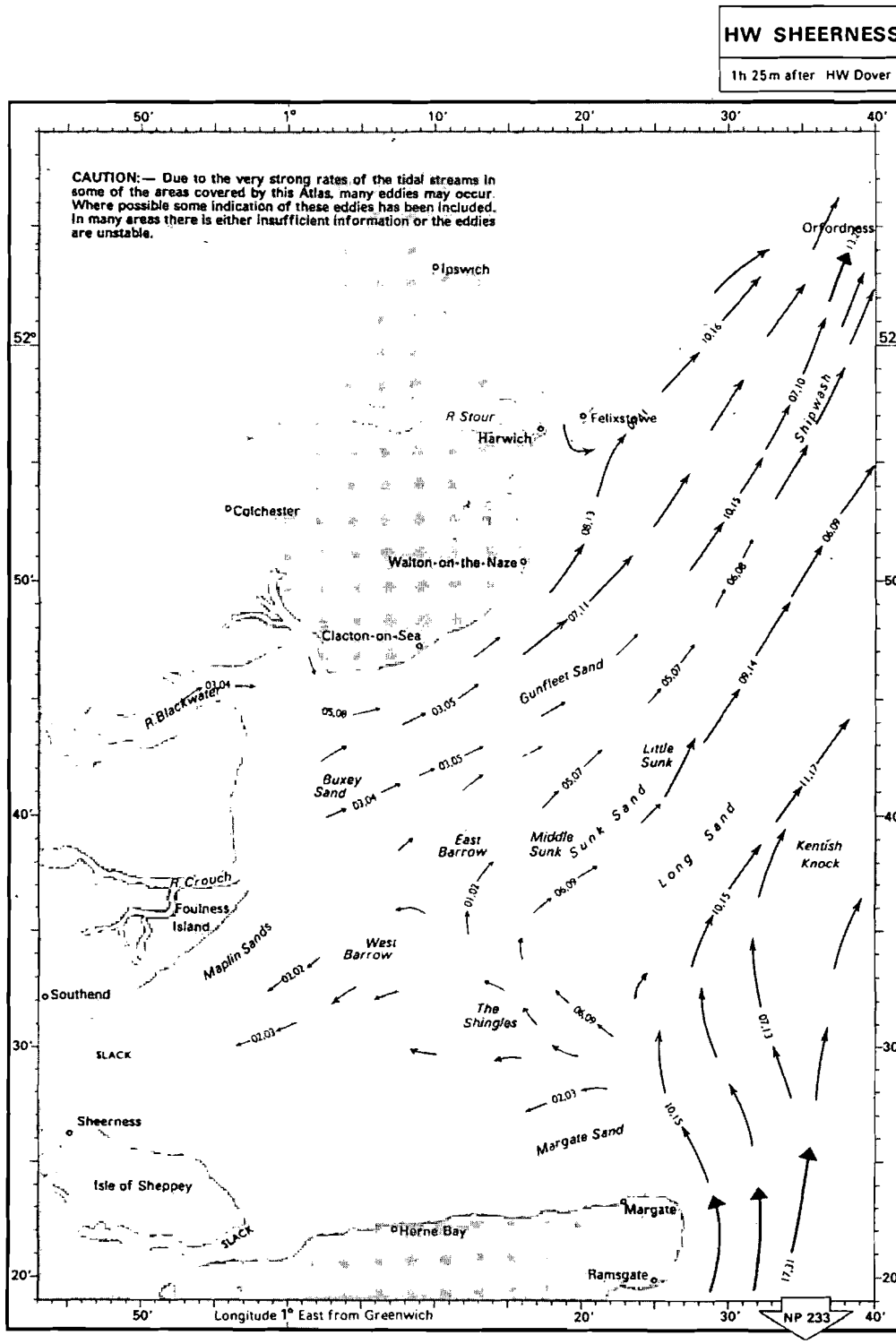
Sheerness Predictions 826

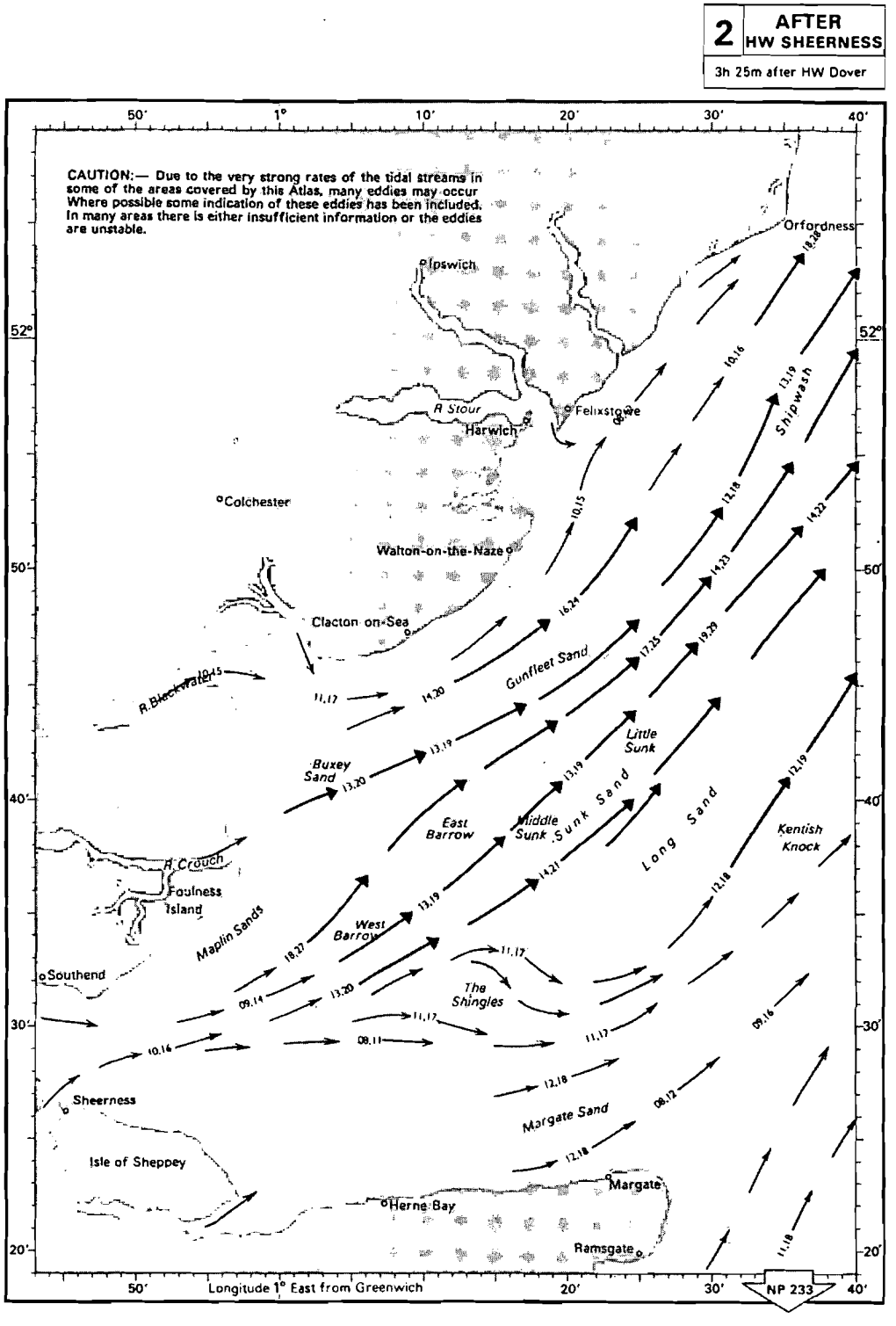
Reproduced by kind permission of the Hydrographic Dept, Taunton

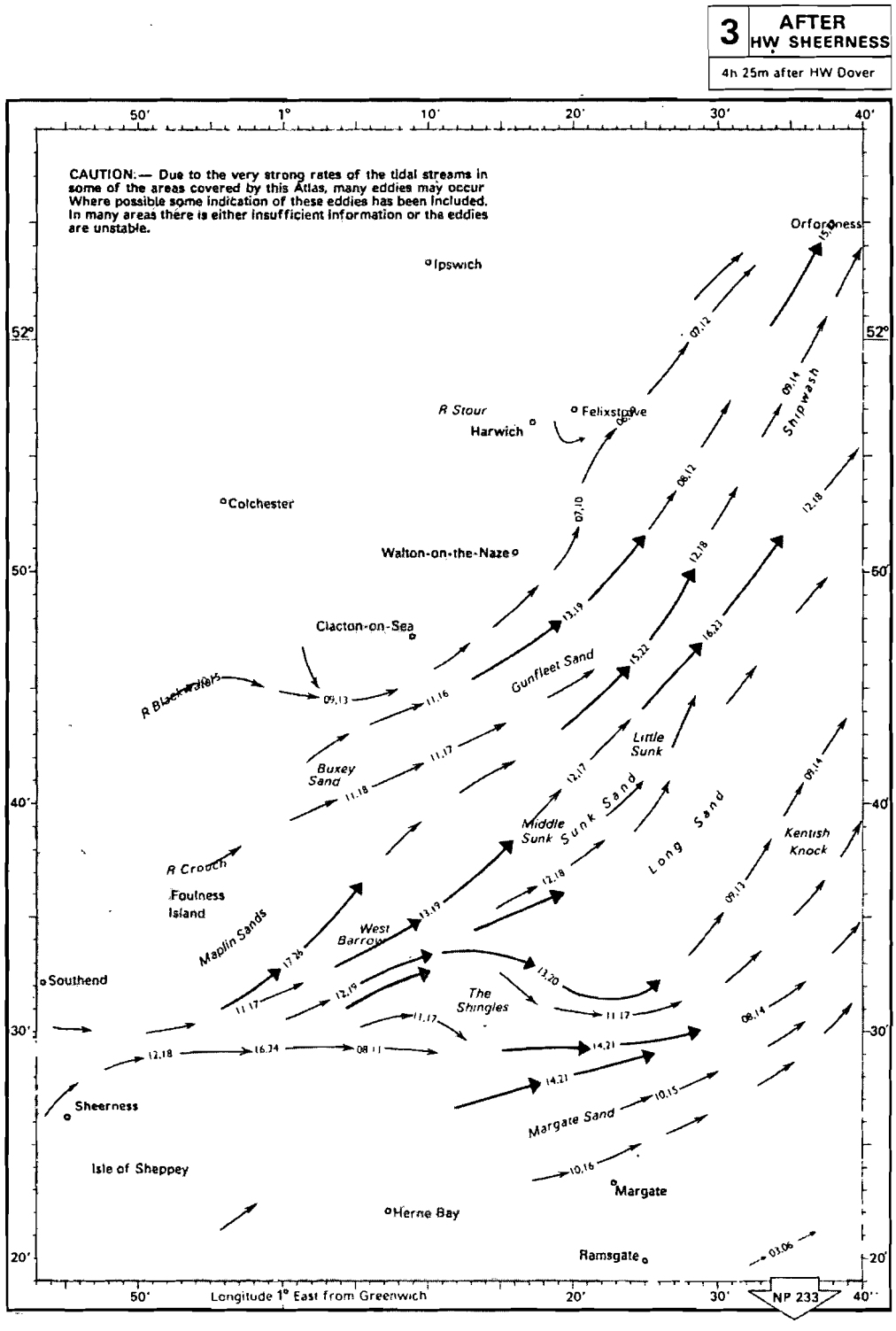

4 BEFORE HW SHEERNESS
2h 35m before HW Dover
CAUTION:— Due to the very strong rates of the tidal streams in some of the areas covered by this Atlas, many eddies may occur. Where possible some indication of these eddies has been included. In many areas there is either insufficient information or the eddies are unstable.
50'
1°
10'
20'
30'
40'
52°
50'
40'
30'
20'
Ipswich
Orfordness
17,23
R Stour
Harwich
Felixstowe
Shipwash
Colchester
Walton-on-the-Naze
Clacton-on-Sea
R Blackwater
Gunfleet Sand
Buxey Sand
Little Sunk
Middle Sunk
Sunk Sand
Long Sand
East Barrow
West Barrow
Maplin Sands
R Crouch
Foulness Island
Southend
Sheerness
Isle of Sheppey
The Shingles
Margate Sand
Margate
Herne Bay
Ramsgate
Kentish Knock
Longitude 1° East from Greenwich
NP 233

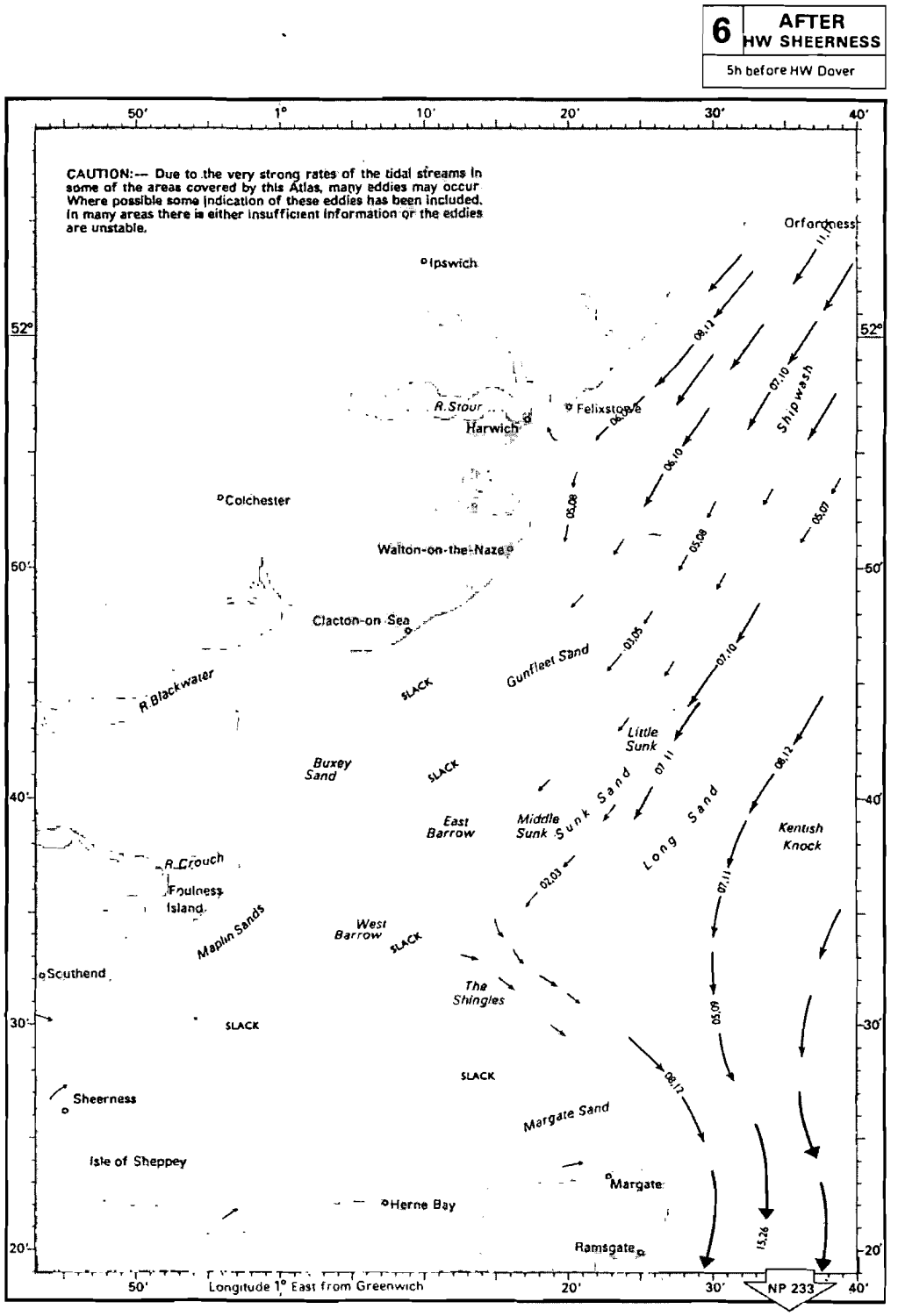

3 BEFORE HW SHEERNESS
1h 35m before HW Dover
CAUTION:— Due to the very strong rates of the tidal streams in some of the areas covered by this Atlas, many eddies may occur. Where possible some indication of these eddies has been included. In many areas there is either insufficient information or the eddies are unstable.
50'
1°
10'
20'
30'
40'
52°
50'
40'
30'
20'
Orfordness
Ipswich
R Stour
Harwich
Felixstowe
Shipwash
Colchester
Walton-on-the-Naze
Clacton-on-Sea
R Blackwater
Gunfleet Sand
Little Sunk
Buxey Sand
East Barrow
Middle Sunk
Sunk Sand
Long Sand
Kentish Knock
R Crouch
Foulness Island
Maplin Sands
West Barrow
Southend
The Shingles
Sheerness
Isle of Sheppey
Margate Sand
Margate
Herne Bay
Ramsgate
Longitude 1° East from Greenwich
NP 233

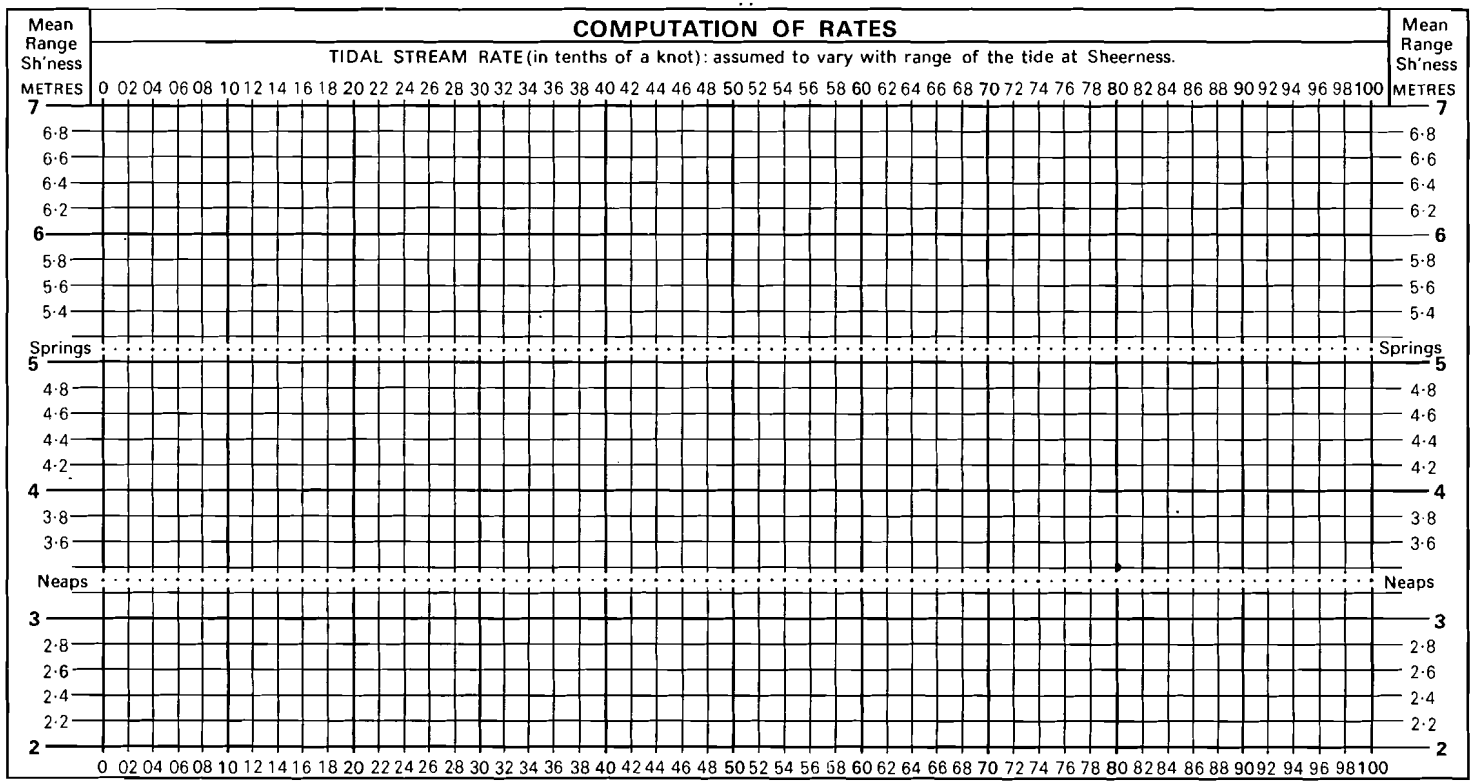

2 BEFORE HW SHEERNESS
0h 35m before HW Dover
CAUTION:— Due to the very strong rates of the tidal streams in some of the areas covered by this Atlas, many eddies may occur. Where possible some indication of these eddies has been included. In many areas there is either insufficient information or the eddies are unstable.
50'
1°
10'
20'
30'
40'
52°
50'
40'
30'
20'
Orfordness
Ipswich
R Stour
Harwich
Felixstowe
Shipwash
Colchester
Walton-on-the-Naze
Clacton-on Sea
R Blackwater
Gunfleet Sand
Little Sunk
Buxey Sand
East Barrow
Middle Sunk
Sunk Sand
Long Sand
Kentish Knock
R Crouch
Foulness Island
Maplin Sands
West Barrow
Southend
The Shingles
Sheerness
Isle of Sheppey
Margate Sand
Margate
Herne Bay
Ramsgate
04,06
06,09
01,02
07,10
08,12
09,14
10,15
11,16
07,11
05,08
12,18
13,20
08,15
10,16
11,17
09,19
Longitude 1° East from Greenwich
NP 233


HW SHEERNESS
1h 25m after HW Dover
CAUTION:— Due to the very strong rates of the tidal streams in some of the areas covered by this Atlas, many eddies may occur. Where possible some indication of these eddies has been included. In many areas there is either insufficient information or the eddies are unstable.
50'
1°
10'
20'
30'
40'
52°
50'
40'
30'
20'
Ipswich
Orfordness
R Stour
Harwich
Felixstowe
Shipwash
Colchester
Walton-on-the-Naze
Clacton-on-Sea
R Blackwater
Gunfleet Sand
Little Sunk
Buxey Sand
East Barrow
Middle Sunk
Sunk Sand
Long Sand
Kentish Knock
R Crouch
Foulness Island
Maplin Sands
West Barrow
Southend
The Shingles
SLACK
Sheerness
Margate Sand
Isle of Sheppey
Margate
Horne Bay
Ramsgate
Longitude 1° East from Greenwich
NP 233


2 AFTER HW SHEERNESS
3h 25m after HW Dover
CAUTION:— Due to the very strong rates of the tidal streams in some of the areas covered by this Atlas, many eddies may occur. Where possible some indication of these eddies has been included. In many areas there is either insufficient information or the eddies are unstable.
50'
1°
10'
20'
30'
40'
52°
50'
40'
30'
20'
Orfordness
Ipswich
R Stour
Harwich
Felixstowe
Shipwash
Colchester
Walton-on-the-Naze
Clacton-on-Sea
R Blackwater
Gunfleet Sand
Buxey Sand
East Barrow
Middle Sunk
Sunk Sand
Little Sunk
Long Sand
Kentish Knock
R Crouch
Foulness Island
Maplin Sands
West Barrow
The Shingles
Southend
Sheerness
Isle of Sheppey
Margate Sand
Herne Bay
Margate
Ramsgate
Longitude 1° East from Greenwich
NP 233


3 AFTER HW SHEERNESS
4h 25m after HW Dover
CAUTION:— Due to the very strong rates of the tidal streams in some of the areas covered by this Atlas, many eddies may occur. Where possible some indication of these eddies has been included. In many areas there is either insufficient information or the eddies are unstable.
Orfordness
Ipswich
R Stour
Harwich
Felixstowe
Shipwash
Colchester
Walton-on-the-Naze
Clacton-on-Sea
R Blackwater
Gunfleet Sand
Little Sunk
Buxey Sand
Middle Sunk
Sunk Sand
Long Sand
Kentish Knock
R Crouch
Foulness Island
Maplin Sands
West Barrow
The Shingles
Southend
Sheerness
Isle of Sheppey
Margate Sand
Margate
Herne Bay
Ramsgate
52°
50'
40'
30'
20'
50'
1°
10'
20'
30'
40'
Longitude 1° East from Greenwich
NP 233


6 AFTER HW SHEERNESS
5h before HW Dover
CAUTION:— Due to the very strong rates of the tidal streams in some of the areas covered by this Atlas, many eddies may occur. Where possible some indication of these eddies has been included. In many areas there is either insufficient information or the eddies are unstable.
50' 1° 10' 20' 30' 40'
52° 50' 40' 30' 20'
Orfordness
Ipswich
R.Stour
Harwich
Felixstowe
Shipwash
Colchester
Walton-on-the-Naze
Clacton-on Sea
R.Blackwater
Gunfleet Sand
SLACK
Little Sunk
Buxey Sand
East Barrow
Middle Sunk
Sunk Sand
Long Sand
Kentish Knock
R.Crouch
Foulness Island
Maplin Sands
West Barrow
Southend
The Shingles
Sheerness
Isle of Sheppey
Margate Sand
Margate
Herne Bay
Ramsgate
08.12
07.10
06.10
05.08
05.07
03.05
07.11
02.03
05.09
15.26
Longitude 1° East from Greenwich
NP 233


COMPUTATION OF RATES
TIDAL STREAM RATE (in tenths of a knot): assumed to vary with range of the tide at Sheerness.
Mean Range Sh'ness METRES
0 02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100
7
6·8
6·6
6·4
6·2
6
5·8
5·6
5·4
Springs
5
4·8
4·6
4·4
4·2
4
3·8
3·6
Neaps
3
2·8
2·6
2·4
2·2
2

Nautical Almanac
Extracts
To be Used for All Exercises and Examples

INDEX

January 880

June 886

September 894

October 900

December 902

Increments **908**

JANUARY 4, 5, 6 (SAT., SUN., MON.)

G.M.T.	ARIES	VENUS −4·3		MARS +1·7		JUPITER −1·5		SATURN +0·7	
d h	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
4 00	103 05·8	145 07·7	S 14 39·3	216 33·3	S 21 38·6	255 43·9	S 9 56·3	204 06·4	S 21 43·1
01	118 08·3	160 10·0	38·6	231 33·9	39·0	270 46·0	56·4	219 08·6	43·1
02	133 10·7	175 12·2	38·0	246 34·5	39·3	285 48·2	56·5	234 10·7	43·1
03	148 13·2	190 14·4	·· 37·3	261 35·2	·· 39·6	300 50·4	·· 56·6	249 12·9	·· 43·1
04	163 15·7	205 16·7	36·7	276 35·8	39·9	315 52·6	56·7	264 15·1	43·2
05	178 18·1	220 18·9	36·1	291 36·4	40·2	330 54·7	56·8	279 17·2	43·2
06	193 20·6	235 21·2	S 14 35·4	306 37·0	S 21 40·5	345 56·9	S 9 56·9	294 19·4	S 21 43·2
07	208 23·1	250 23·4	34·8	321 37·6	40·8	0 59·1	57·0	309 21·5	43·2
S 08	223 25·5	265 25·7	34·1	336 38·2	41·1	16 01·3	57·1	324 23·7	43·3
A 09	238 28·0	280 28·0	·· 33·5	351 38·9	·· 41·4	31 03·4	·· 57·2	339 25·9	·· 43·3
T 10	253 30·5	295 30·2	32·9	6 39·5	41·7	46 05·6	57·3	354 28·0	43·3
U 11	268 32·9	310 32·5	32·2	21 40·1	42·0	61 07·8	57·4	9 30·2	43·3
R 12	283 35·4	325 34·8	S 14 31·6	36 40·7	S 21 42·3	76 10·0	S 9 57·5	24 32·4	S 21 43·3
D 13	298 37·8	340 37·1	30·9	51 41·3	42·6	91 12·2	57·6	39 34·5	43·4
A 14	313 40·3	355 39·3	30·3	66 41·9	42·9	106 14·3	57·7	54 36·7	43·4
Y 15	328 42·8	10 41·6	·· 29·7	81 42·6	·· 43·2	121 16·5	·· 57·8	69 38·9	· 43·4
16	343 45·2	25 43·9	29·0	96 43·2	43·5	136 13·7	57·9	84 41·0	43·4
17	358 47·7	40 46·2	28·4	111 43·8	43·8	151 20·9	58·0	99 43·2	43·5
18	13 50·2	55 48·5	S 14 27·8	126 44·4	S 21 44·1	166 23·0	S 9 58·1	114 45·4	S 21 43·5
19	28 52·6	70 50·8	27·1	141 45·0	44·4	181 25·2	58·2	129 47·5	43·5
20	43 55·1	85 53·1	26·5	156 45·6	44·7	196 27·4	58·3	144 49·7	43·5
21	58 57·6	100 55·4	·· 25·9	171 46·2	· 44·9	211 29·6	· 58·4	159 51·9	·· 43·5
22	74 00·0	115 57·8	25·2	186 46·9	45·2	226 31·8	58·5	174 54·0	43·6
23	89 02·5	131 00·1	24·6	201 47·5	45·5	241 33·9	58·6	189 56·2	43·6
5 00	104 05·0	146 02·4	S 14 24·0	216 48·1	S 21 45·8	256 36·1	S 9 58·7	204 58·3	S 21 43·6
01	119 07·4	161 04·7	23·3	231 48·7	46·1	271 38·3	58·8	220 00·5	43·6
02	134 09·9	176 07·1	22·7	246 49·3	46·4	286 40·5	58·9	235 02·7	43·6
03	149 12·3	191 09·4	·· 22·1	261 49·9	· 46·7	301 42·7	·· 58·9	250 04·8	· 43·7
04	164 14·8	206 11·8	21·5	276 50·5	47·0	316 44·8	59·0	265 07·0	43·7
05	179 17·3	221 14·1	20·8	291 51·1	47·3	331 47·0	59·1	280 09·2	43·7
06	194 19·7	236 16·5	S 14 20·2	306 51·8	S 21 47·6	346 49·2	S 9 59·2	295 11·3	S 21 43·7
07	209 22·2	251 18·8	19·6	321 52·4	47·9	1 51·4	59·3	310 13·5	43·8
08	224 24·7	266 21·2	19·0	336 53·0	48·2	16 53·6	59·4	325 15·7	43·8
S 09	239 27·1	281 23·5	·· 18·3	351 53·6	· 48·5	31 55·8	·· 59·5	340 17·8	· 43·8
U 10	254 29·6	296 25·9	17·7	6 54·2	48·8	46 57·9	59·6	355 20·0	43·8
N 11	269 32·1	311 28·3	17·1	21 54·8	49·1	62 00·1	59·7	10 22·2	43·8
D 12	284 34·5	326 30·7	S 14 16·5	36 55·4	S 21 49·4	77 02·3	S 9 59·8	25 24·3	S 21 43·9
A 13	299 37·0	341 33·0	15·8	51 56·0	49·7	92 04·5	9 59·9	40 26·5	43·9
Y 14	314 39·4	356 35·4	15·2	66 56·7	49·9	107 06·7	10 00·0	55 28·7	43·9
15	329 41·9	11 37·0	·· 14·6	81 57·3	·· 50·2	122 08·9	·· 00·1	70 30·8	· 43·9
16	344 44·4	26 40·2	14·0	96 57·9	50·5	137 11·0	00·2	85 33·0	43·9
17	359 46·8	41 42·6	13·4	111 58·5	50·8	152 13·2	00·3	100 35·2	44·0
18	14 49·3	56 45·0	S 14 12·7	126 59·1	S 21 51·1	167 15·4	S 10 00·4	115 37·3	S 21 44·0
19	29 51·8	71 47·4	12·1	141 59·7	51·4	182 17·6	00·5	130 39·5	44·0
20	44 54·2	86 49·8	11·5	157 00·3	51·7	197 19·8	00·6	145 41·7	44·0
21	59 56·7	101 52·2	· 10·9	172 00·9	· 52·0	212 22·0	·· 00·7	160 43·8	· 44·0
22	74 59·2	116 54·6	10·3	187 01·5	52·3	227 24·2	00·8	175 46·0	44·1
23	90 01·6	131 57·1	09·7	202 02·1	52·5	242 26·3	00·9	190 48·2	44·1
6 00	105 04·1	146 59·5	S 14 09·1	217 02·7	S 21 52·8	257 28·5	S 10 01·0	205 50·3	S 21 44·1
01	120 06·6	162 01·9	08·4	232 03·4	53·1	272 30·7	01·0	220 52·5	44·1
02	135 09·0	177 04·4	07·8	247 04·0	53·4	287 32·9	01·1	235 54·7	44·2
03	150 11·5	192 06·8	·· 07·2	262 04·6	·· 53·7	302 35·1	· 01·2	250 56·8	·· 44·2
04	165 13·9	207 09·2	06·6	277 05·2	54·0	317 37·3	01·3	265 59·0	44·2
05	180 16·4	222 11·7	06·0	292 05·8	54·3	332 39·5	01·4	281 01·2	44·2
06	195 18·9	237 14·1	S 14 05·4	307 06·4	S 21 54·6	347 41·6	S 10 01·5	296 03·3	S 21 44·2
07	210 21·3	252 16·6	04·8	322 07·0	54·8	2 43·8	01·6	311 05·5	44·3
08	225 23·8	267 19·1	04·2	337 07·6	55·1	17 46·0	01·7	326 07·7	44·3
M 09	240 26·3	282 21·5	·· 03·6	352 08·2	·· 55·4	32 48·2	·· 01·8	341 09·8	·· 44·3
O 10	255 28·7	297 24·0	03·0	7 08·8	55·7	47 50·4	01·9	356 12·0	44·3
N 11	270 31·2	312 26·5	02·4	22 09·4	56·0	62 52·6	02·0	11 14·2	44·3
D 12	285 33·7	327 28·9	S 14 01·8	37 10·0	S 21 56·3	77 54·8	S 10 02·1	26 16·3	S 21 44·4
A 13	300 36·1	342 31·4	01·2	52 10·6	56·5	92 57·0	02·2	41 18·5	44·4
Y 14	315 38·6	357 33·9	00·6	67 11·3	56·8	107 59·1	02·3	56 20·7	44·4
15	330 41·1	12 36·4	14 00·0	82 11·9	·· 57·1	123 01·3	·· 02·4	71 22·8	·· 44·4
16	345 43·5	27 38·9	13 59·4	97 12·5	57·4	138 03·5	02·5	86 25·0	44·4
17	0 46·0	42 41·4	58·8	112 13·1	57·7	153 05·7	02·5	101 27·2	44·5
18	15 48·4	57 43·9	S 13 58·2	127 13·7	S 21 58·0	168 07·9	S 10 02·6	116 29·4	S 21 44·5
19	30 50·9	72 46·4	57·6	142 14·3	58·2	183 10·1	02·7	131 31·5	44·5
20	45 53·3	87 48·9	57·0	157 14·9	58·5	198 12·3	02·8	146 33·7	44·5
21	60 55·8	102 51·4	·· 56·4	172 15·5	·· 58·8	213 14·5	·· 02·9	161 35·9	·· 44·5
22	75 58·3	117 54·0	55·8	187 16·1	59·1	228 16·7	03·0	176 38·0	44·6
23	91 00·8	132 56·5	55·2	202 16·7	59·4	243 18·9	03·1	191 40·2	44·6
Mer. Pass.	h m 17 00·9	*v* 2·4	*d* 0·6	*v* 0·6	*d* 0·3	*v* 2·2	*d* 0·1	*v* 2·2	*d* 0·0

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 49·7	S 40 28·6
Achernar	335 57·7	S 57 27·3
Acrux	173 55·7	S 62 51·8
Adhara	255 44·8	S 28 55·0
Aldebaran	291 36·9	N 16 25·5
Alioth	166 57·2	N 56 10·9
Alkaid	153 31·8	N 49 31·1
Al Na'ir	28 36·3	S 47 10·0
Alnilam	276 28·3	S 1 13·8
Alphard	218 36·7	S 8 28·7
Alphecca	126 46·5	N 26 51·2
Alpheratz	358 26·7	N 28 51·7
Altair	62 49·2	N 8 45·5
Ankaa	353 56·8	S 42 32·2
Antares	113 17·6	S 26 20·3
Arcturus	146 33·8	N 19 23·9
Atria	108 57·3	S 68 56·9
Avior	234 34·4	S 59 22·5
Bellatrix	279 16·3	N 6 18·7
Betelgeuse	271 46·0	N 7 23·9
Canopus	264 14·1	S 52 40·5
Capella	281 35·5	N 45 57·4
Deneb	50 00·2	N 45 08·0
Denebola	183 16·0	N 14 48·2
Diphda	349 37·7	S 18 13·1
Dubhe	194 42·4	N 61 58·3
Elnath	279 04·9	N 28 34·3
Eltanin	91 06·0	N 51 29·6
Enif	34 28·2	N 9 41·0
Fomalhaut	16 10·1	S 29 50·3
Gacrux	172 47·2	S 56 52·5
Gienah	176 35·1	S 17 18·5
Hadar	149 47·1	S 60 10·0
Hamal	328 47·6	N 23 16·0
Kaus Aust.	84 39·4	S 34 24·2
Kochab	137 18·9	N 74 19·4
Markab	14 20·0	N 14 58·9
Menkar	314 58·4	N 3 55·5
Menkent	148 56·8	S 36 09·7
Miaplacidus	221 47·7	S 69 32·6
Mirfak	309 39·7	N 49 42·9
Nunki	76 50·3	S 26 20·9
Peacock	54 25·4	S 56 52·3
Pollux	244 18·2	N 28 07·5
Procyon	245 42·9	N 5 19·8
Rasalhague	96 45·4	N 12 35·4
Regulus	208 27·6	N 12 10·2
Rigel	281 51·8	S 8 15·1
Rigil Kent.	140 48·9	S 60 39·5
Sabik	103 00·6	S 15 40·4
Schedar	350 28·0	N 56 18·8
Shaula	97 18·8	S 37 04·3
Sirius	259 10·1	S 16 39·6
Spica	159 15·2	S 10 56·6
Suhail	223 22·7	S 43 15·8
Vega	81 07·6	N 38 44·7
Zuben'ubi	137 51·7	S 15 52·0

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	41 57·4	14 14
Mars	112 43·1	9 32
Jupiter	152 31·1	6 53
Saturn	100 53·3	10 19

JANUARY 4, 5, 6 (SAT., SUN., MON.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	v	MOON Dec.	d	H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
4 00	178 49·9	S 22 47·7	24 09·6	7·6	N 19 42·8	0·3	57·7
01	193 49·6	47·5	38 36·2	7·6	19 43·1	0·1	57·7
02	208 49·3	47·2	53 02·8	7·5	19 43·2	0·1	57·7
03	223 49·0	46·9	67 29·3	7·5	19 43·3	0·1	57·8
04	238 48·7	46·7	81 55·8	7·5	19 43·2	0·2	57·8
05	253 48·5	46·4	96 22·3	7·4	19 43·0	0·3	57·8
06	268 48·2	S 22 46·2	110 48·7	7·4	N 19 42·7	0·5	57·9
07	283 47·9	45·9	125 15·1	7·4	19 42·2	0·5	57·9
S 08	298 47·6	45·7	139 41·5	7·3	19 41·7	0·7	57·9
A 09	313 47·3	45·4	154 07·8	7·3	19 41·0	0·8	57·9
T 10	328 47·0	45·2	168 34·1	7·2	19 40·2	0·9	58·0
U 11	343 46·7	44·9	183 00·3	7·2	19 39·3	1·1	58·0
R 12	358 46·5	S 22 44·6	197 26·5	7·2	N 19 38·2	1·1	58·0
D 13	13 46·2	44·4	211 52·7	7·2	19 37·1	1·3	58·1
A 14	28 45·9	44·1	226 18·9	7·1	19 35·8	1·4	58·1
Y 15	43 45·6	43·9	240 45·0	7·1	19 34·4	1·6	58·1
16	58 45·3	43·6	255 11·1	7·1	19 32·8	1·6	58·2
17	73 45·0	43·3	269 37·2	7·0	19 31·2	1·8	58·2
18	88 44·8	S 22 43·1	284 03·2	7·0	N 19 29·4	1·9	58·2
19	103 44·5	42·8	298 29·2	7·0	19 27·5	2·0	58·2
20	118 44·2	42·5	312 55·2	7·0	19 25·5	2·1	58·3
21	133 43·9	42·3	327 21·2	7·0	19 23·4	2·3	58·3
22	148 43·6	42·0	341 47·2	6·9	19 21·1	2·4	58·3
23	163 43·4	41·7	356 13·1	6·9	19 18·7	2·5	58·4
5 00	178 43·1	S 22 41·5	10 39·0	6·9	N 19 16·2	2·7	58·4
01	193 42·8	41·2	25 04·9	6·9	19 13·5	2·7	58·4
02	208 42·5	40·9	39 30·8	6·9	19 10·8	2·9	58·4
03	223 42·2	40·7	53 56·7	6·8	19 07·9	3·0	58·5
04	238 41·9	40·4	68 22·5	6·8	19 04·9	3·1	58·5
05	253 41·7	40·1	82 48·3	6·9	19 01·8	3·3	58·5
06	268 41·4	S 22 39·9	97 14·2	6·8	N 18 58·5	3·4	58·6
07	283 41·1	39·6	111 40·0	6·8	18 55·1	3·5	58·6
08	298 40·8	39·3	126 05·8	6·8	18 51·6	3·6	58·6
S 09	313 40·5	39·0	140 31·6	6·8	18 48·0	3·7	58·6
U 10	328 40·3	38·8	154 57·4	6·8	18 44·3	3·9	58·7
N 11	343 40·0	38·5	169 23·2	6·7	18 40·4	4·0	58·7
D 12	358 39·7	S 22 38·2	183 48·9	6·8	N 18 36·4	4·1	58·7
A 13	13 39·4	37·9	198 14·7	6·8	18 32·3	4·2	58·7
Y 14	28 39·2	37·6	212 40·5	6·7	18 28·1	4·4	58·8
15	43 38·9	37·4	227 06·2	6·8	18 23·7	4·5	58·8
16	58 38·6	37·1	241 32·0	6·8	18 19·2	4·6	58·8
17	73 38·3	36·8	255 57·8	6·7	18 14·6	4·7	58·8
18	88 38·0	S 22 36·5	270 23·5	6·8	N 18 09·9	4·8	58·9
19	103 37·8	36·2	284 49·3	6·8	18 05·1	5·0	58·9
20	118 37·5	36·0	299 15·1	6·8	18 00·1	5·0	58·9
21	133 37·2	35·7	313 40·9	6·8	17 55·1	5·2	58·9
22	148 36·9	35·4	328 06·7	6·7	17 49·9	5·3	59·0
23	163 36·7	35·1	342 32·4	6·8	17 44·6	5·4	59·0
6 00	178 36·4	S 22 34·8	356 58·2	6·9	N 17 39·2	5·6	59·0
01	193 36·1	34·5	11 24·1	6·8	17 33·6	5·6	59·0
02	208 35·8	34·2	25 49·9	6·8	17 28·0	5·8	59·1
03	223 35·5	33·9	40 15·7	6·8	17 22·2	5·9	59·1
04	238 35·3	33·7	54 41·5	6·9	17 16·3	6·0	59·1
05	253 35·0	33·4	69 07·4	6·9	17 10·3	6·1	59·1
06	268 34·7	S 22 33·1	83 33·3	6·9	N 17 04·2	6·2	59·2
07	283 34·4	32·8	97 59·2	6·8	16 58·0	6·4	59·2
08	298 34·2	32·5	112 25·0	7·0	16 51·6	6·4	59·2
M 09	313 33·9	32·2	126 51·0	6·9	16 45·2	6·6	59·2
O 10	328 33·6	31·9	141 16·9	6·9	16 38·6	6·7	59·2
N 11	343 33·3	31·6	155 42·8	7·0	16 31·9	6·8	59·3
D 12	358 33·1	S 22 31·3	170 08·8	7·0	N 16 25·1	6·9	59·3
A 13	13 32·8	31·0	184 34·8	7·0	16 18·2	7·0	59·3
Y 14	28 32·5	30·7	199 00·8	7·0	16 11·2	7·1	59·3
15	43 32·2	30·4	213 26·8	7·1	16 04·1	7·2	59·3
16	58 32·0	30·1	227 52·9	7·0	15 56·9	7·3	59·4
17	73 31·7	29·8	242 18·9	7·1	15 49·6	7·4	59·4
18	88 31·4	S 22 29·5	256 45·0	7·1	N 15 42·2	7·6	59·4
19	103 31·2	29·2	271 11·1	7·2	15 34·6	7·6	59·4
20	118 30·9	28·9	285 37·3	7·2	15 27·0	7·7	59·4
21	133 30·6	28·6	300 03·5	7·2	15 19·3	7·9	59·4
22	148 30·3	28·3	314 29·7	7·2	15 11·4	7·9	59·5
23	163 30·1	28·0	328 55·9	7·2	15 03·5	8·0	59·5
	S.D. 16·3	d 0·3	S.D. 15·8		16·0		16·2

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 4	Moonrise 5	Moonrise 6	Moonrise 7
°	h m	h m	h m	h m	h m	h m	h m
N 72	08 20	10 31				14 39	16 57
N 70	08 02	09 43		11 43	13 25	15 22	17 19
68	07 47	09 12	11 32	12 48	14 10	15 50	17 37
66	07 35	08 50	10 20	13 23	14 39	16 12	17 51
64	07 25	08 31	09 45	13 49	15 02	16 29	18 03
62	07 16	08 16	09 19	14 09	15 19	16 43	18 13
60	07 08	08 04	09 00	14 25	15 34	16 54	18 21
N 58	07 01	07 53	08 44	14 39	15 47	17 05	18 28
56	06 55	07 43	08 30	14 51	15 57	17 13	18 35
54	06 49	07 35	08 18	15 01	16 07	17 21	18 40
52	06 44	07 27	08 07	15 10	16 15	17 28	18 46
50	06 39	07 20	07 58	15 18	16 23	17 35	18 50
45	06 28	07 05	07 38	15 36	16 39	17 48	19 00
N 40	06 18	06 52	07 22	15 50	16 52	17 59	19 09
35	06 09	06 41	07 08	16 03	17 04	18 09	19 16
30	06 01	06 30	06 57	16 13	17 14	18 17	19 22
20	05 45	06 12	06 36	16 31	17 31	18 32	19 33
N 10	05 29	05 55	06 18	16 47	17 45	18 44	19 43
0	05 13	05 39	06 02	17 02	17 59	18 56	19 51
S 10	04 55	05 22	05 45	17 17	18 13	19 07	20 00
20	04 33	05 02	05 26	17 33	18 28	19 20	20 10
30	04 05	04 38	05 05	17 51	18 44	19 34	20 21
35	03 47	04 23	04 52	18 02	18 54	19 42	20 27
40	03 25	04 06	04 38	18 14	19 05	19 52	20 34
45	02 56	03 44	04 21	18 29	19 19	20 03	20 42
S 50	02 13	03 16	03 59	18 46	19 34	20 16	20 52
52	01 48	03 01	03 49	18 55	19 42	20 22	20 56
54	01 11	02 45	03 37	19 04	19 50	20 29	21 01
56	////	02 24	03 24	19 14	19 59	20 36	21 07
58	////	01 57	03 08	19 26	20 10	20 45	21 13
S 60	////	01 17	02 49	19 40	20 22	20 55	21 20

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 4	Moonset 5	Moonset 6	Moonset 7
°	h m	h m	h m	h m	h m	h m	h m
N 72		13 40	15 51			10 56	10 36
N 70		14 27	16 09	09 54	10 11	10 12	10 11
68	12 38	14 58	16 23	08 49	09 25	09 43	09 53
66	13 50	15 21	16 35	08 13	08 55	09 21	09 37
64	14 25	15 39	16 46	07 48	08 33	09 03	09 25
62	14 51	15 54	16 54	07 28	08 14	08 49	09 14
60	15 11	16 06	17 02	07 11	07 59	08 36	09 05
N 58	15 27	16 17	17 09	06 58	07 46	08 26	08 57
56	15 41	16 27	17 15	06 46	07 35	08 16	08 50
54	15 53	16 36	17 21	06 35	07 26	08 08	08 43
52	16 03	16 44	17 27	06 26	07 17	08 00	08 37
50	16 13	16 51	17 32	06 18	07 09	07 54	08 32
45	16 33	17 06	17 43	06 00	06 52	07 39	08 21
N 40	16 49	17 19	17 53	05 46	06 39	07 27	08 11
35	17 02	17 30	18 02	05 33	06 27	07 17	08 03
30	17 14	17 40	18 10	05 22	06 17	07 08	07 56
20	17 34	17 58	18 26	05 04	05 59	06 53	07 44
N 10	17 52	18 15	18 41	04 48	05 44	06 39	07 33
0	18 09	18 32	18 57	04 33	05 29	06 26	07 22
S 10	18 26	18 49	19 16	04 18	05 15	06 13	07 12
20	18 44	19 09	19 38	04 02	04 59	05 59	07 01
30	19 05	19 33	20 05	03 43	04 41	05 43	06 48
35	19 18	19 47	20 23	03 32	04 31	05 34	06 41
40	19 32	20 05	20 46	03 20	04 19	05 24	06 32
45	19 49	20 26	21 14	03 05	04 05	05 11	06 22
S 50	20 11	20 54	21 56	02 47	03 48	04 56	06 10
52	20 21	21 08	22 21	02 39	03 39	04 49	06 04
54	20 33	21 25	22 56	02 30	03 30	04 41	05 58
56	20 46	21 45	////	02 19	03 20	04 32	05 51
58	21 02	22 12	////	02 07	03 09	04 21	05 43
S 60	21 20	22 51	////	01 53	02 55	04 10	05 34

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
4	04 40	04 54	12 05	23 16	10 47	14	
5	05 07	05 21	12 05	24 13	11 44	15	
6	05 34	05 47	12 06	00 13	12 41	16	

JANUARY 7, 8, 9 (TUES., WED., THURS.)

G.M.T.	ARIES	VENUS −4·2		MARS +1·7		JUPITER −1·5		SATURN +0·7	
d h	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
7 00	106 03·2	147 59·0	S13 54·6	217 17·3	S21 59·6	258 21·0	S10 03·2	206 42·4	S21 44·6
01	121 05·7	163 01·6	54·0	232 17·9	21 59·9	273 23·2	03·3	221 44·5	44·6
02	136 08·2	178 04·1	53·4	247 18·5	22 00·2	288 25·4	03·4	236 46·7	44·6
03	151 10·6	193 06·6	·· 52·8	262 19·1	·· 00·5	303 27·6	·· 03·5	251 48·9	·· 44·7
04	166 13·1	208 09·2	52·2	277 19·7	00·8	318 29·8	03·6	266 51·0	44·7
05	181 15·6	223 11·7	51·6	292 20·3	01·0	333 32·0	03·7	281 53·2	44·7
06	196 18·0	238 14·3	S13 51·0	307 20·9	S22 01·3	348 34·2	S10 03·8	296 55·4	S21 44·7
07	211 20·5	253 16·8	50·4	322 21·5	01·6	3 36·4	03·8	311 57·5	44·7
T 08	226 22·9	268 19·4	49·8	337 22·1	01·9	18 38·6	03·9	326 59·7	44·8
U 09	241 25·4	283 22·0	·· 49·3	352 22·7	·· 02·1	33 40·8	·· 04·0	342 01·9	·· 44·8
E 10	256 27·9	298 24·5	48·7	7 23·3	02·4	48 43·0	04·1	357 04·0	44·8
S 11	271 30·3	313 27·1	48·1	22 23·9	02·7	63 45·2	04·2	12 06·2	44·8
D 12	286 32·8	328 29·7	S13 47·5	37 24·5	S22 03·0	78 47·4	S10 04·3	27 08·4	S21 44·8
A 13	301 35·3	343 32·3	46·9	52 25·1	03·2	93 49·6	04·4	42 10·6	44·9
Y 14	316 37·7	358 34·9	46·3	67 25·7	03·5	108 51·7	04·5	57 12·7	44·9
15	331 40·2	13 37·5	·· 45·7	82 26·3	·· 03·8	123 53·9	·· 04·6	72 14·9	·· 44·9
16	346 42·7	28 40·1	45·2	97 26·9	04·1	138 56·1	04·7	87 17·1	44·9
17	1 45·1	43 42·7	44·6	112 27·5	04·3	153 58·3	04·8	102 19·2	44·9
18	16 47·6	58 45·3	S13 44·0	127 28·2	S22 04·6	169 00·5	S10 04·8	117 21·4	S21 45·0
19	31 50·1	73 47·9	43·4	142 28·8	04·9	184 02·7	04·9	132 23·6	45·0
20	46 52·5	88 50·5	42·9	157 29·4	05·2	199 04·9	05·0	147 25·7	45·0
21	61 55·0	103 53·1	·· 42·3	172 30·0	·· 05·4	214 07·1	·· 05·1	162 27·9	·· 45·0
22	76 57·4	118 55·7	41·7	187 30·6	05·7	229 09·3	05·2	177 30·1	45·0
23	91 59·9	133 58·4	41·1	202 31·2	06·0	244 11·5	05·3	192 32·3	45·1
8 00	107 02·4	149 01·0	S13 40·5	217 31·8	S22 06·2	259 13·7	S10 05·4	207 34·4	S21 45·1
01	122 04·8	164 03·6	40·0	232 32·4	06·5	274 15·9	05·5	222 36·6	45·1
02	137 07·3	179 06·3	39·4	247 33·0	06·8	289 18·1	05·6	237 38·8	45·1
03	152 09·8	194 08·9	·· 38·8	262 33·6	·· 07·1	304 20·3	·· 05·7	252 40·9	·· 45·1
04	167 12·2	209 11·6	38·3	277 34·2	07·3	319 22·5	05·7	267 43·1	45·2
05	182 14·7	224 14·2	37·7	292 34·8	07·6	334 24·7	05·8	282 45·3	45·2
06	197 17·2	239 16·9	S13 37·1	307 35·4	S22 07·9	349 26·9	S10 05·9	297 47·4	S21 45·2
W 07	212 19·6	254 19·6	36·5	322 36·0	08·1	4 29·1	06·0	312 49·6	45·2
E 08	227 22·1	269 22·2	36·0	337 36·6	08·4	19 31·3	06·1	327 51·8	45·2
D 09	242 24·5	284 24·9	·· 35·4	352 37·1	·· 08·7	34 33·5	·· 06·2	342 53·9	·· 45·3
N 10	257 27·0	299 27·6	34·8	7 37·7	08·9	49 35·7	06·3	357 56·1	45·3
E 11	272 29·5	314 30·2	34·3	22 38·3	09·2	64 37·9	06·4	12 58·3	45·3
S 12	287 31·9	329 32·9	S13 33·7	37 38·9	S22 09·5	79 40·1	S10 06·5	28 00·5	S21 45·3
D 13	302 34·4	344 35·6	33·2	52 39·5	09·7	94 42·3	06·5	43 02·6	45·3
A 14	317 36·9	359 38·3	32·6	67 40·1	10·0	109 44·5	06·6	58 04·8	45·4
Y 15	332 39·3	14 41·0	·· 32·0	82 40·7	· 10·3	124 46·7	· 06·7	73 07·0	· 45·4
16	347 41·8	29 43·7	31·5	97 41·3	10·5	139 48·9	06·8	88 09·1	45·4
17	2 44·3	44 46·4	30·9	112 41·9	10·8	154 51·1	06·9	103 11·3	45·4
18	17 46·7	59 49·1	S13 30·3	127 42·5	S22 11·1	169 53·3	S10 07·0	118 13·5	S21 45·4
19	32 49·2	74 51·8	29·8	142 43·1	11·3	184 55·5	07·1	133 15·7	45·5
20	47 51·7	89 54·6	29·2	157 43·7	11·6	199 57·7	07·2	148 17·8	45·5
21	62 54·1	104 57·3	·· 28·7	172 44·3	· 11·9	214 59·9	07·3	163 20·0	·· 45·5
22	77 56·6	120 00·0	28·1	187 44·9	12·1	230 02·1	07·3	178 22·2	45·5
23	92 59·0	135 02·7	27·6	202 45·5	12·4	245 04·3	07·4	193 24·3	45·5
9 00	108 01·5	150 05·5	S13 27·0	217 46·1	S22 12·7	260 06·5	S10 07·5	208 26·5	S21 45·6
01	123 04·0	165 08·2	26·5	232 46·7	12·9	275 08·7	07·6	223 28·7	45·6
02	138 06·4	180 11·0	25·9	247 47·3	13·2	290 10·9	07·7	238 30·8	45·6
03	153 08·9	195 13·7	·· 25·4	262 47·9	·· 13·4	305 13·1	· 07·8	253 33·0	·· 45·6
04	168 11·4	210 16·5	24·8	277 48·5	13·7	320 15·3	07·9	268 35·2	45·6
05	183 13·8	225 19·2	24·3	292 49·1	14·0	335 17·5	08·0	283 37·4	45·7
06	198 16·3	240 22·0	S13 23·7	307 49·7	S22 14·2	350 19·7	S10 08·0	298 39·5	S21 45·7
T 07	213 18·8	255 24·7	23·2	322 50·3	14·5	5 21·9	08·1	313 41·7	45·7
H 08	228 21·2	270 27·5	22·6	337 50·9	14·8	20 24·1	08·2	328 43·9	45·7
U 09	243 23·7	285 30·3	·· 22·1	352 51·5	·· 15·0	35 26·3	·· 08·3	343 46·0	·· 45·7
R 10	258 26·2	300 33·1	21·5	7 52·0	15·3	50 28·5	08·4	358 48·2	45·8
S 11	273 28·6	315 35·9	21·0	22 52·6	15·5	65 30·8	08·5	13 50·4	45·8
D 12	288 31·1	330 38·6	S13 20·4	37 53·2	S22 15·8	80 33·0	S10 08·6	28 52·6	S21 45·8
A 13	303 33·5	345 41·4	19·9	52 53·8	16·1	95 35·2	08·7	43 54·7	45·8
Y 14	318 36·0	0 44·2	19·4	67 54·4	16·3	110 37·4	08·7	58 56·9	45·8
15	333 38·5	15 47·0	·· 18·8	82 55·0	·· 16·6	125 39·6	·· 08·8	73 59·1	·· 45·9
16	348 40·9	30 49·8	18·3	97 55·6	16·8	140 41·8	08·9	89 01·3	45·9
17	3 43·4	45 52·6	17·7	112 56·2	17·1	155 44·0	09·0	104 03·4	45·9
18	18 45·9	60 55·5	S13 17·2	127 56·8	S22 17·3	170 46·2	S10 09·1	119 05·6	S21 45·9
19	33 48·3	75 58·3	16·7	142 57·4	17·6	185 48·4	09·2	134 07·8	45·9
20	48 50·8	91 01·1	16·1	157 58·0	17·9	200 50·6	09·3	149 09·9	46·0
21	63 53·3	106 03·9	·· 15·6	172 58·6	·· 18·1	215 52·8	·· 09·3	164 12·1	·· 46·0
22	78 55·7	121 06·8	15·1	187 59·2	18·4	230 55·0	09·4	179 14·3	46·0
23	93 58·2	136 09·6	14·5	202 59·7	18·6	245 57·2	09·5	194 16·5	46·0
Mer. Pass.	h m 16 49·1	v 2·7	d 0·6	v 0·6	d 0·3	v 2·2	d 0·1	v 2·2	d 0·0

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 49·7	S 40 28·6
Achernar	335 57·7	S 57 27·3
Acrux	173 55·6	S 62 51·8
Adhara	255 44·8	S 28 55·0
Aldebaran	291 36·9	N 16 25·5
Alioth	166 57·2	N 56 10·9
Alkaid	153 31·8	N 49 31·0
Al Na'ir	28 36·3	S 47 10·0
Alnilam	276 28·3	S 1 13·8
Alphard	218 36·7	S 8 28·7
Alphecca	126 46·5	N 26 51·2
Alpheratz	358 26·7	N 28 51·7
Altair	62 49·2	N 8 45·5
Ankaa	353 56·8	S 42 32·2
Antares	113 17·6	S 26 20·3
Arcturus	146 33·8	N 19 23·9
Atria	108 57·3	S 68 56·9
Avior	234 34·4	S 59 22·5
Bellatrix	279 16·3	N 6 18·7
Betelgeuse	271 46·0	N 7 23·9
Canopus	264 14·1	S 52 40·5
Capella	281 35·5	N 45 57·4
Deneb	49 50·3	N 45 08·0
Denebola	183 16·0	N 14 48·2
Diphda	349 37·7	S 18 13·1
Dubhe	194 42·4	N 61 58·3
Elnath	279 04·9	N 28 34·3
Eltanin	91 06·0	N 51 29·6
Enif	34 28·2	N 9 41·0
Fomalhaut	16 10·1	S 29 50·8
Gacrux	172 47·2	S 56 52·5
Glenah	176 35·1	S 17 18·5
Hadar	149 47·1	S 60 10·0
Hamal	328 47·7	N 23 16·0
Kaus Aust.	84 39·4	S 34 24·2
Kochab	137 18·8	N 74 19·4
Markab	14 20·0	N 14 58·9
Menkar	314 58·4	N 3 55·5
Menkent	148 56·8	S 36 09·7
Miaplacidus	221 47·6	S 69 32·6
Mirfak	309 39·7	N 49 42·9
Nunki	76 50·2	S 26 20·9
Peacock	54 25·4	S 56 52·2
Pollux	244 18·2	N 28 07·5
Procyon	245 42·9	N 5 19·8
Rasalhague	96 45·4	N 12 35·4
Regulus	208 27·5	N 12 10·2
Rigel	281 51·8	S 8 15·1
Rigil Kent.	140 48·8	S 60 39·5
Sabik	103 00·6	S 15 40·4
Schedar	350 28·0	N 56 18·8
Shaula	97 18·8	S 37 04·3
Sirius	259 10·1	S 16 39·6
Spica	159 15·2	S 10 56·6
Suhail	223 22·6	S 43 15·8
Vega	81 07·6	N 38 44·7
Zuben'ubi	137 51·7	S 15 52·0

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	41 58·6	14 01
Mars	110 23·4	9 29
Jupiter	152 11·3	6 42
Saturn	100 32·0	10 08

JANUARY 7, 8, 9 (TUES., WED., THURS.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
7 00	178 29·8	S 22 27·7	343 22·1	7·3	N 14 55·5	6·2	59·5
01	193 29·5	27·4	357 48·4	7·3	14 47·3	8·2	59·5
02	208 29·2	27·1	12 14·7	7·3	14 39·1	8·3	59·5
03	223 29·0	26·8	26 41·0	7·4	14 30·8	8·5	59·5
04	238 28·7	26·5	41 07·4	7·4	14 22·3	8·5	59·5
05	253 28·4	26·2	55 33·8	7·4	14 13·8	8·6	59·6
06	268 28·2	S 22 25·9	70 00·2	7·4	N 14 05·2	8·7	59·6
07	283 27·9	25·5	84 26·6	7·5	13 56·5	8·8	59·6
T 08	298 27·6	25·2	98 53·1	7·5	13 47·7	8·9	59·6
U 09	313 27·3	24·9	113 19·6	7·6	13 38·8	9·0	59·6
E 10	328 27·1	24·6	127 46·2	7·5	13 29·8	9·0	59·6
S 11	343 26·8	24·3	142 12·7	7·6	13 20·8	9·2	59·6
D 12	358 26·5	S 22 24·0	156 39·3	7·7	N 13 11·6	9·2	59·7
A 13	13 26·3	23·7	171 06·0	7·7	13 02·4	9·3	59·7
Y 14	28 26·0	23·3	185 32·7	7·7	12 53·1	9·4	59·7
15	43 25·7	23·0	199 59·4	7·7	12 43·7	9·5	59·7
16	58 25·5	22·7	214 26·1	7·8	12 34·2	9·6	59·7
17	73 25·2	22·4	228 52·9	7·8	12 24·6	9·6	59·7
18	88 24·9	S 22 22·1	243 19·7	7·8	N 12 15·0	9·6	59·7
19	103 24·7	21·8	257 46·5	7·9	12 05·2	9·8	59·7
20	118 24·4	21·4	272 13·4	7·9	11 55·4	9·8	59·7
21	133 24·1	21·1	286 40·3	7·9	11 45·6	10·0	59·7
22	148 23·9	20·8	301 07·2	8·0	11 35·6	10·0	59·8
23	163 23·6	20·5	315 34·2	8·0	11 25·6	10·1	59·8
8 00	178 23·3	S 22 20·1	330 01·2	8·1	N 11 15·5	10·2	59·8
01	193 23·1	19·8	344 28·3	8·1	11 05·3	10·3	59·8
02	208 22·8	19·5	358 55·4	8·1	10 55·0	10·3	59·8
03	223 22·5	19·2	13 22·5	8·1	10 44·7	10·4	59·8
04	238 22·3	18·8	27 49·6	8·2	10 34·3	10·4	59·8
05	253 22·0	18·5	42 16·8	8·2	10 23·9	10·5	59·8
06	268 21·7	S 22 18·2	56 44·0	8·3	N 10 13·4	10·6	59·8
W 07	283 21·5	17·9	71 11·3	8·3	10 02·8	10·6	59·8
E 08	298 21·2	17·5	85 38·6	8·3	9 52·2	10·7	59·8
D 09	313 20·9	17·2	100 05·9	8·4	9 41·5	10·8	59·8
N 10	328 20·7	16·9	114 33·3	8·3	9 30·7	10·8	59·8
E 11	343 20·4	16·5	129 00·6	8·5	9 19·9	10·9	59·8
S 12	358 20·1	S 22 16·2	143 28·1	8·4	N 9 09·0	10·9	59·8
D 13	13 19·9	15·9	157 55·5	8·5	8 58·1	11·0	59·8
A 14	28 19·6	15·5	172 23·0	8·5	8 47·1	11·1	59·8
Y 15	43 19·3	15·2	186 50·5	8·6	8 36·0	11·1	59·8
16	58 19·1	14·9	201 18·1	8·6	8 24·9	11·1	59·9
17	73 18·8	14·5	215 45·7	8·6	8 13·8	11·2	59·9
18	88 18·6	S 22 14·2	230 13·3	8·7	N 8 02·6	11·2	59·9
19	103 18·3	13·9	244 41·0	8·7	7 51·4	11·3	59·9
20	118 18·0	13·5	259 08·7	8·7	7 40·1	11·4	59·9
21	133 17·8	13·2	273 36·4	8·7	7 28·7	11·3	59·9
22	148 17·5	12·8	288 04·1	8·8	7 17·4	11·5	59·9
23	163 17·2	12·5	302 31·9	8·9	7 05·9	11·4	59·9
9 00	178 17·0	S 22 12·1	316 59·8	8·8	N 6 54·5	11·5	59·9
01	193 16·7	11·8	331 27·6	8·9	6 43·0	11·6	59·9
02	208 16·5	11·5	345 55·5	8·9	6 31·4	11·6	59·9
03	223 16·2	11·1	0 23·4	8·9	6 19·8	11·6	59·9
04	238 15·9	10·8	14 51·3	9·0	6 08·2	11·6	59·9
05	253 15·7	10·4	29 19·3	9·0	5 56·6	11·7	59·9
06	268 15·4	S 22 10·1	43 47·3	9·0	N 5 44·9	11·8	59·9
07	283 15·1	09·7	58 15·3	9·0	5 33·1	11·7	59·9
T 08	298 14·9	09·4	72 43·3	9·1	5 21·4	11·8	59·9
H 09	313 14·6	09·0	87 11·4	9·1	5 09·6	11·8	59·8
U 10	328 14·4	08·7	101 39·5	9·2	4 57·8	11·8	59·8
R 11	343 14·1	08·3	116 07·7	9·1	4 46·0	11·9	59·8
S 12	358 13·9	S 22 08·0	130 35·8	9·2	N 4 34·1	11·9	59·8
D 13	13 13·6	07·6	145 04·0	9·2	4 22·2	11·9	59·8
A 14	28 13·3	07·3	159 32·2	9·2	4 10·3	11·9	59·8
Y 15	43 13·1	06·9	174 00·4	9·3	3 58·4	12·0	59·8
16	58 12·8	06·6	188 28·7	9·3	3 46·4	12·0	59·8
17	73 12·6	06·2	202 57·0	9·3	3 34·4	12·0	59·8
18	88 12·3	S 22 05·9	217 25·3	9·3	N 3 22·4	12·0	59·8
19	103 12·0	05·5	231 53·6	9·3	3 10·4	12·0	59·8
20	118 11·8	05·2	246 21·9	9·4	2 58·4	12·0	59·8
21	133 11·5	04·8	260 50·3	9·4	2 46·4	12·1	59·8
22	148 11·3	04·4	275 18·7	9·4	2 34·3	12·0	59·8
23	163 11·0	04·1	289 47·1	9·5	2 22·3	12·1	59·8
	S.D. 16·3	d 0·3	S.D.	16·3		16·3	16·3

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 7	Moonrise 8	Moonrise 9	Moonrise 10
°	h m	h m	h m	h m	h m	h m	h m
N 72	08 15	10 20	▬	16 57	19 03	21 05	23 04
N 70	07 58	09 37	▬	17 19	19 15	21 09	23 00
68	07 44	09 08	11 11	17 37	19 25	21 12	22 57
66	07 33	08 46	10 13	17 51	19 33	21 14	22 54
64	07 23	08 29	09 40	18 03	19 39	21 16	22 52
62	07 14	08 14	09 16	18 13	19 45	21 18	22 50
60	07 07	08 02	08 57	18 21	19 50	21 20	22 49
N 58	07 00	07 51	08 42	18 28	19 55	21 21	22 47
56	06 54	07 42	08 28	18 35	19 58	21 23	22 46
54	06 48	07 34	08 16	18 40	20 02	21 24	22 45
52	06 43	07 26	08 06	18 46	20 05	21 25	22 44
50	06 38	07 19	07 57	18 50	20 08	21 26	22 43
45	06 28	07 04	07 38	19 00	20 14	21 28	22 41
N 40	06 18	06 52	07 22	19 09	20 19	21 30	22 39
35	06 09	06 41	07 08	19 16	20 24	21 31	22 38
30	06 01	06 31	06 57	19 22	20 28	21 32	22 37
20	05 46	06 13	06 37	19 33	20 34	21 35	22 34
N 10	05 31	05 57	06 19	19 43	20 40	21 37	22 33
0	05 15	05 40	06 03	19 51	20 46	21 39	22 31
S 10	04 56	05 23	05 46	20 00	20 51	21 41	22 29
20	04 35	05 04	05 28	20 10	20 57	21 43	22 27
30	04 07	04 40	05 07	20 21	21 04	21 45	22 25
35	03 50	04 26	04 55	20 27	21 08	21 46	22 24
40	03 28	04 09	04 41	20 34	21 12	21 48	22 23
45	03 00	03 47	04 24	20 42	21 17	21 50	22 21
S 50	02 18	03 20	04 03	20 52	21 23	21 52	22 20
52	01 55	03 06	03 53	20 56	21 26	21 53	22 19
54	01 21	02 50	03 41	21 01	21 29	21 54	22 18
56	////	02 30	03 28	21 07	21 32	21 55	22 17
58	////	02 04	03 13	21 13	21 36	21 57	22 16
S 60	////	01 27	02 55	21 20	21 40	21 58	22 15

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 7	Moonset 8	Moonset 9	Moonset 10
°	h m	h m	h m	h m	h m	h m	h m
N 72	▬	13 53	15 58	10 36	10 23	10 13	10 04
N 70	▬	14 36	16 15	10 11	10 09	10 07	10 04
68	13 02	15 05	16 29	09 53	09 58	10 01	10 04
66	14 00	15 27	16 41	09 37	09 49	09 57	10 04
64	14 33	15 44	16 50	09 25	09 41	09 53	10 04
62	14 57	15 59	16 59	09 14	09 34	09 49	10 04
60	15 16	16 11	17 06	09 05	09 28	09 47	10 04
N 58	15 32	16 22	17 13	08 57	09 22	09 44	10 04
56	15 45	16 31	17 19	08 50	09 17	09 41	10 04
54	15 57	16 40	17 25	08 43	09 13	09 39	10 04
52	16 07	16 47	17 30	08 37	09 09	09 37	10 04
50	16 16	16 54	17 35	08 32	09 06	09 36	10 04
45	16 36	17 09	17 46	08 21	08 58	09 32	10 04
N 40	16 51	17 22	17 55	08 11	08 52	09 29	10 04
35	17 05	17 32	18 04	08 03	08 46	09 26	10 04
30	17 16	17 42	18 12	07 56	08 41	09 23	10 04
20	17 36	18 00	18 27	07 44	08 32	09 19	10 04
N 10	17 54	18 16	18 43	07 33	08 25	09 15	10 04
0	18 10	18 33	18 59	07 22	08 17	09 11	10 03
S 10	18 27	18 50	19 17	07 12	08 10	09 07	10 03
20	18 45	19 09	19 38	07 01	08 02	09 03	10 03
30	19 06	19 33	20 05	06 48	07 53	08 59	10 03
35	19 18	19 47	20 23	06 41	07 48	08 56	10 03
40	19 32	20 04	20 45	06 32	07 42	08 53	10 03
45	19 49	20 25	21 13	06 22	07 35	08 49	10 03
S 50	20 10	20 53	21 54	06 10	07 27	08 45	10 02
52	20 20	21 06	22 17	06 04	07 23	08 43	10 02
54	20 31	21 22	22 49	05 58	07 19	08 41	10 02
56	20 44	21 42	////	05 51	07 14	08 38	10 02
58	20 59	22 07	////	05 43	07 09	08 35	10 02
S 60	21 17	22 43	////	05 34	07 03	08 32	10 02

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
7	06 00	06 13	12 06	01 09	13 37	17	
8	06 26	06 39	12 07	02 04	14 32	18	○
9	06 52	07 04	12 07	02 58	15 25	19	

JANUARY 10, 11, 12 (FRI., SAT., SUN.)

G.M.T.	ARIES	VENUS −4·1		MARS +1·7		JUPITER −1·5		SATURN +0·7		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
10 00	109 00·6	151 12·4	S13 14·0	218 00·3	S22 18·9	260 59·4	S10 09·6	209 18·6	S21 46·0	Acamar	315 49·7	S 40 28·6
01	124 03·1	166 15·3	13·5	233 00·9	19·1	276 01·6	09·7	224 20·8	46·1	Achernar	335 57·7	S 57 27·3
02	139 05·6	181 18·1	12·9	248 01·5	19·4	291 03·9	09·8	239 23·0	46·1	Acrux	173 55·6	S 62 51·8
03	154 08·0	196 21·0	·· 12·4	263 02·1	·· 19·6	306 06·1	· 09·9	254 25·2	·· 46·1	Adhara	255 44·8	S 28 55·0
04	169 10·5	211 23·8	11·9	278 02·7	19·9	321 08·3	09·9	269 27·3	46·1	Aldebaran	291 36·9	N 16 25·5
05	184 13·0	226 26·7	11·4	293 03·3	20·1	336 10·5	10·0	284 29·5	46·1			
06	199 15·4	241 29·6	S13 10·8	308 03·9	S22 20·4	351 12·7	S10 10·1	299 31·7	S21 46·2	Alioth	166 57·2	N 56 10·9
07	214 17·9	256 32·4	10·3	323 04·5	20·7	6 14·9	10·2	314 33·8	46·2	Alkaid	153 31·7	N 49 31·0
08	229 20·4	271 35·3	09·8	338 05·1	20·9	21 17·1	10·3	329 36·0	46·2	Al Na'ir	28 36·3	S 47 10·0
F 09	244 22·8	286 38·2	·· 09·3	353 05·7	· 21·2	36 19·3	·· 10·4	344 38·2	· 46·2	Alnilam	276 28·3	S 1 13·8
R 10	259 25·3	301 41·1	08·7	8 06·2	21·4	51 21·5	10·5	359 40·4	46·2	Alphard	218 36·7	S 8 28·7
I 11	274 27·8	316 44·0	08·2	23 06·8	21·7	66 23·7	10·5	14 42·5	46·2			
D 12	289 30·2	331 46·9	S13 07·7	38 07·4	S22 21·9	81 26·0	S10 10·6	29 44·7	S21 46·3	Alphecca	126 46·5	N 26 51·2
A 13	304 32·7	346 49·7	07·2	53 08·0	22·2	96 28·2	10·7	44 46·9	46·3	Alpheratz	358 26·7	N 28 51·7
Y 14	319 35·1	1 52·7	06·7	68 08·6	22·4	111 30·4	10·8	59 49·1	46·3	Altair	62 49·1	N 8 45·5
15	334 37·6	16 55·6	·· 06·2	83 09·2	·· 22·7	126 32·6	·· 10·9	74 51·2	· 46·3	Ankaa	353 56·9	S 42 32·2
16	349 40·1	31 58·5	05·6	98 09·8	22·9	141 34·8	11·0	89 53·4	46·3	Antares	113 17·6	S 26 20·3
17	4 42·5	47 01·4	05·1	113 10·4	23·2	156 37·0	11·0	104 55·6	46·4			
18	19 45·0	62 04·3	S13 04·6	128 11·0	S22 23·4	171 39·2	S10 11·1	119 57·8	S21 46·4	Arcturus	146 33·8	N 19 23·9
19	34 47·5	77 07·2	04·1	143 11·5	23·7	186 41·4	11·2	134 59·9	46·4	Atria	108 57·2	S 68 56·9
20	49 49·9	92 10·1	03·6	158 12·1	23·9	201 43·7	11·3	150 02·1	46·4	Avior	234 34·4	S 59 22·5
21	64 52·4	107 13·1	·· 03·1	173 12·7	· 24·2	216 45·9	·· 11·4	165 04·3	·· 46·4	Bellatrix	279 16·4	N 6 18·6
22	79 54·9	122 16·0	02·6	188 13·3	24·4	231 48·1	11·5	180 06·4	46·5	Betelgeuse	271 46·0	N 7 23·9
23	94 57·3	137 18·9	02·0	203 13·9	24·7	246 50·3	11·5	195 08·6	46·5			
11 00	109 59·8	152 21·9	S13 01·5	218 14·5	S22 24·9	261 52·5	S10 11·6	210 10·8	S21 46·5	Canopus	264 14·1	S 52 40·6
01	125 02·3	167 24·8	01·0	233 15·1	25·1	276 54·7	11·7	225 13·0	46·5	Capella	281 35·5	N 45 57·4
02	140 04·7	182 27·8	00·5	248 15·7	25·4	291 56·9	11·8	240 15·1	46·5	Deneb	50 00·3	N 45 08·0
03	155 07·2	197 30·7	13 00·0	263 16·2	·· 25·6	306 59·2	· 11·9	255 17·3	46·6	Denebola	183 15·9	N 14 48·2
04	170 09·6	212 33·7	12 59·5	278 16·8	25·9	322 01·4	12·0	270 19·5	46·6	Diphda	349 37·7	S 18 13·1
05	185 12·1	227 36·7	59·0	293 17·4	26·1	337 03·6	12·0	285 21·7	46·6			
06	200 14·6	242 39·6	S12 58·5	308 18·0	S22 26·4	352 05·8	S10 12·1	300 23·8	S21 46·6	Dubhe	194 42·3	N 61 58·3
07	215 17·0	257 42·6	58·0	323 18·6	·26·6	7 08·0	12·2	315 26·0	46·6	Elnath	279 04·9	N 28 34·3
S 08	230 19·5	272 45·6	· 57·5	338 19·2	26·9	22 10·2	12·3	330 28·2	46·6	Eltanin	91 06·0	N 51 29·6
A 09	245 22·0	287 48·6	· 57·0	353 19·8	·· 27·1	37 12·4	· 12·4	345 30·4	· 46·7	Enif	34 28·2	N 9 41·0
T 10	260 24·4	302 51·6	56·5	8 20·3	27·4	52 14·7	12·4	0 32·5	46·7	Fomalhaut	16 10·1	S 29 50·3
U 11	275 26·9	317 54·6	56·0	23 20·9	27·6	67 16·9	12·5	15 34·7	46·7			
R 12	290 29·4	332 57·6	S12 55·5	38 21·5	S22 27·8	82 19·1	S10 12·6	30 36·9	S21 46·7	Gacrux	172 47·1	S 56 52·5
D 13	305 31·8	348 00·6	55·0	53 22·1	28·1	97 21·3	12·7	45 39·1	46·7	Gienah	176 35·0	S 17 18·6
A 14	320 34·3	3 03·6	54·5	68 22·7	28·3	112 23·5	12·8	60 41·2	46·8	Hadar	149 47·0	S 60 10·0
Y 15	335 36·8	18 06·6	·· 54·0	83 23·3	· 28·6	127 25·7	· 12·9	75 43·4	· 46·8	Hamal	328 47·7	N 23 16·0
16	350 39·2	33 09·6	53·6	98 23·9	28·8	142 28·0	12·9	90 45·6	46·8	Kaus Aust.	84 39·4	S 34 24·2
17	5 41·7	48 12·6	53·1	113 24·4	29·0	157 30·2	13·0	105 47·8	46·8			
18	20 44·1	63 15·6	S12 52·6	128 25·0	S22 29·3	172 32·4	S10 13·1	120 49·9	S21 46·8	Kochab	137 18·8	N 74 19·3
19	35 46·6	78 18·6	52·1	143 25·6	29·5	187 34·6	13·2	135 52·1	46·9	Markab	14 20·0	N 14 58·9
20	50 49·1	93 21·7	51·6	158 26·2	29·8	202 36·8	13·3	150 54·3	46·9	Menkar	314 58·4	N 3 55·5
21	65 51·5	108 24·7	·· 51·1	173 26·8	· 30·0	217 39·1	·· 13·3	165 56·5	· 46·9	Menkent	148 56·7	S 36 09·7
22	80 54·0	123 27·7	50·6	188 27·4	30·2	232 41·3	13·4	180 58·7	46·9	Miaplacidus	221 47·6	S 69 32·7
23	95 56·5	138 30·8	50·1	203 27·9	30·5	247 43·5	13·5	196 00·8	46·9			
12 00	110 58·9	153 33·8	S12 49·7	218 28·5	S22 30·7	262 45·7	S10 13·6	211 03·0	S21 46·9	Mirfak	309 39·7	N 49 43·0
01	126 01·4	168 36·9	49·2	233 29·1	31·0	277 47·9	13·7	226 05·2	47·0	Nunki	76 50·2	S 26 20·9
02	141 03·9	183 39·9	48·7	248 29·7	31·2	292 50·2	13·8	241 07·4	47·0	Peacock	54 25·4	S 56 52·2
03	156 06·3	198 43·0	·· 48·2	263 30·3	·· 31·4	307 52·4	·· 13·8	256 09·5	·· 47·0	Pollux	244 18·2	N 28 07·5
04	171 08·8	213 46·1	47·7	278 30·8	31·7	322 54·6	13·9	271 11·7	47·0	Procyon	245 42·9	N 5 19·8
05	186 11·2	228 49·1	47·3	293 31·4	31·9	337 56·8	14·0	286 13·9	47·0			
06	201 13·7	243 52·2	S12 46·8	308 32·0	S22 32·1	352 59·0	S10 14·1	301 16·1	S21 47·1	Rasalhague	96 45·4	N 12 35·4
07	216 16·2	258 55·3	46·3	323 32·6	32·4	8 01·3	14·2	316 18·2	47·1	Regulus	208 27·5	N 12 10·2
08	231 18·6	273 58·4	45·8	338 33·2	32·6	23 03·5	14·2	331 20·4	47·1	Rigel	281 51·8	S 8 15·1
S 09	246 21·1	289 01·4	· 45·4	353 33·8	·· 32·9	38 05·7	·· 14·3	346 22·6	·· 47·1	Rigil Kent.	140 48·8	S 60 39·5
U 10	261 23·6	304 04·5	44·9	8 34·3	33·1	53 07·9	14·4	1 24·8	47·1	Sabik	103 00·6	S 15 40·4
N 11	276 26·0	319 07·6	44·4	23 34·9	33·3	68 10·2	14·5	16 26·9	47·1			
D 12	291 28·5	334 10·7	S12 43·9	38 35·5	S22 33·6	83 12·4	S10 14·6	31 29·1	S21 47·2	Schedar	350 28·1	N 56 18·8
A 13	306 31·0	349 13·8	43·5	53 36·1	33·8	98 14·6	14·6	46 31·3	47·2	Shaula	97 18·8	S 37 04·3
Y 14	321 33·4	4 16·9	43·0	68 36·7	34·0	113 16·8	14·7	61 33·5	47·2	Sirius	259 10·0	S 16 39·6
15	336 35·9	19 20·1	·· 42·5	83 37·2	·· 34·3	128 19·0	· 14·8	76 35·7	·· 47·2	Spica	159 15·1	S 10 56·6
16	351 38·4	34 23·2	42·1	98 37·8	34·5	143 21·3	14·9	91 37·8	47·2	Suhail	223 22·6	S 43 15·8
17	6 40·8	49 26·3	41·6	113 38·4	34·7	158 23·5	15·0	106 40·0	47·3			
18	21 43·3	64 29·4	S12 41·1	128 39·0	S22 35·0	173 25·7	S10 15·0	121 42·2	S21 47·3	Vega	81 07·6	N 38 44·7
19	36 45·7	79 32·5	40·7	143 39·6	35·2	188 27·9	15·1	136 44·4	47·3	Zuben'ubi	137 51·6	S 15 52·0
20	51 48·2	94 35·7	40·2	158 40·1	35·4	203 30·2	15·2	151 46·5	47·3			
21	66 50·7	109 38·8	·· 39·7	173 40·7	·· 35·6	218 32·4	·· 15·3	166 48·7	· 47·3		S.H.A.	Mer. Pass.
22	81 53·1	124 41·9	39·3	188 41·3	35·9	233 34·6	15·3	181 50·9	47·3		° ′	h m
23	96 55·6	139 45·1	38·8	203 41·9	36·1	248 36·8	15·4	196 53·1	47·4	Venus	42 22·1	13 48
										Mars	108 14·7	9 27
Mer. Pass.	16 37·3	v 3·0	d 0·5	v 0·6	d 0·2	v 2·2	d 0·1	v 2·2	d 0·0	Jupiter	151 52·7	6 31
										Saturn	100 11·0	9 58

JANUARY 10, 11, 12 (FRI., SAT., SUN.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	v	MOON Dec.	d	H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
10 00	178 10·8	S 22 03·7	304 15·6	9·4	N 2 10·2	12·1	59·8
01	193 10·5	03·4	318 44·0	9·5	1 58·1	12·1	59·8
02	208 10·2	03·0	333 12·5	9·5	1 46·0	12·1	59·8
03	223 10·0	02·6	347 41·0	9·5	1 33·9	12·1	59·8
04	238 09·7	02·3	2 09·5	9·5	1 21·8	12·1	59·7
05	253 09·5	01·9	16 38·0	9·5	1 09·7	12·1	59·7
06	268 09·2	S 22 01·5	31 06·5	9·6	N 0 57·6	12·1	59·7
07	283 09·0	01·2	45 35·1	9·5	0 45·5	12·1	59·7
08	298 08·7	00·8	60 03·6	9·6	0 33·4	12·1	59·7
F 09	313 08·5	00·4	74 32·2	9·6	0 21·3	12·1	59·7
R 10	328 08·2	22 00·1	89 00·8	9·6	N 0 09·2	12·1	59·7
I 11	343 08·0	21 59·7	103 29·4	9·6	S 0 02·9	12·1	59·7
D 12	358 07·7	S 21 59·3	117 58·0	9·7	S 0 15·0	12·1	59·7
A 13	13 07·4	59·0	132 26·7	9·6	0 27·1	12·1	59·7
Y 14	28 07·2	58·6	146 55·3	9·7	0 39·2	12·0	59·7
15	43 06·9	58·2	161 24·0	9·6	0 51·2	12·1	59·6
16	58 06·7	57·9	175 52·6	9·7	1 03·3	12·0	59·6
17	73 06·4	57·5	190 21·3	9·7	1 15·3	12·1	59·6
18	88 06·2	S 21 57·1	204 50·0	9·7	S 1 27·4	12·0	59·6
19	103 05·9	56·7	219 18·7	9·7	1 39·4	12·0	59·6
20	118 05·7	56·4	233 47·4	9·7	1 51·4	12·0	59·6
21	133 05·4	56·0	248 16·1	9·7	2 03·4	12·0	59·6
22	148 05·2	55·6	262 44·8	9·7	2 15·4	11·9	59·6
23	163 04·9	55·2	277 13·5	9·7	2 27·3	12·0	59·6
11 00	178 04·7	S 21 54·9	291 42·2	9·8	S 2 39·3	11·9	59·5
01	193 04·4	54·5	306 11·0	9·7	2 51·2	11·9	59·5
02	208 04·2	54·1	320 39·7	9·7	3 03·1	11·9	59·5
03	223 03·9	53·7	335 08·4	9·8	3 15·0	11·8	59·5
04	238 03·7	53·3	349 37·2	9·7	3 26·8	11·8	59·5
05	253 03·4	53·0	4 05·9	9·7	3 38·6	11·8	59·5
06	268 03·2	S 21 52·6	18 34·6	9·8	S 3 50·4	11·8	59·5
S 07	283 02·9	52·2	33 03·4	9·7	4 02·2	11·7	59·5
S 08	298 02·7	51·8	47 32·1	9·8	4 13·9	11·7	59·4
A 09	313 02·4	51·4	62 00·9	9·7	4 25·6	11·7	59·4
T 10	328 02·2	51·0	76 29·6	9·7	4 37·3	11·6	59·4
U 11	343 01·9	50·7	90 58·3	9·8	4 48·9	11·7	59·4
R 12	358 01·7	S 21 50·3	105 27·1	9·7	S 5 00·6	11·5	59·4
D 13	13 01·4	49·9	119 55·8	9·7	5 12·1	11·6	59·4
A 14	28 01·2	49·5	134 24·5	9·8	5 23·7	11·5	59·4
Y 15	43 00·9	49·1	148 53·3	9·7	5 35·2	11·4	59·3
16	58 00·7	48·7	163 22·0	9·7	5 46·6	11·5	59·3
17	73 00·4	48·3	177 50·7	9·7	5 58·1	11·4	59·3
18	88 00·2	S 21 47·9	192 19·4	9·7	S 6 09·5	11·3	59·3
19	103 00·0	47·5	206 48·1	9·7	6 20·8	11·3	59·3
20	117 59·7	47·1	221 16·8	9·7	6 32·1	11·2	59·3
21	132 59·5	46·7	235 45·5	9·7	6 43·3	11·3	59·3
22	147 59·2	46·4	250 14·2	9·6	6 54·6	11·1	59·2
23	162 59·0	46·0	264 42·8	9·7	7 05·7	11·1	59·2
12 00	177 58·7	S 21 45·6	279 11·5	9·6	S 7 16·8	11·1	59·2
01	192 58·5	45·2	293 40·1	9·7	7 27·9	11·0	59·2
02	207 58·2	44·8	308 08·8	9·6	7 38·9	11·0	59·2
03	222 58·0	44·4	322 37·4	9·6	7 49·9	10·9	59·2
04	237 57·8	44·0	337 06·0	9·7	8 00·8	10·9	59·1
05	252 57·5	43·6	351 34·7	9·5	8 11·7	10·8	59·1
06	267 57·3	S 21 43·2	6 03·2	9·6	S 8 22·5	10·8	59·1
07	282 57·0	42·8	20 31·8	9·6	8 33·3	10·7	59·1
08	297 56·8	42·4	35 00·4	9·6	8 44·0	10·6	59·1
S 09	312 56·5	42·0	49 29·0	9·5	8 54·6	10·6	59·1
U 10	327 56·3	41·6	63 57·5	9·5	9 05·2	10·6	59·1
N 11	342 56·1	41·2	78 26·0	9·6	9 15·8	10·4	59·0
D 12	357 55·8	S 21 40·8	92 54·6	9·5	S 9 26·2	10·5	59·0
A 13	12 55·6	40·4	107 23·1	9·5	9 36·7	10·3	59·0
Y 14	27 55·3	39·9	121 51·6	9·4	9 47·0	10·3	59·0
15	42 55·1	39·5	136 20·0	9·5	9 57·3	10·2	59·0
16	57 54·8	39·1	150 48·5	9·4	10 07·5	10·2	59·0
17	72 54·6	38·7	165 16·9	9·4	10 17·7	10·1	58·9
18	87 54·4	S 21 38·3	179 45·3	9·5	S 10 27·8	10·0	58·9
19	102 54·1	37·9	194 13·8	9·3	10 37·8	10·0	58·9
20	117 53·9	37·5	208 42·1	9·4	10 47·8	9·9	58·9
21	132 53·6	37·1	223 10·5	9·4	10 57·7	9·8	58·9
22	147 53·4	36·7	237 38·9	9·3	11 07·5	9·8	58·8
23	162 53·2	36·3	252 07·2	9·3	11 17·3	9·7	58·8
	S.D. 16·3	d 0·4	S.D.	16·3		16·2	16·1

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 10	Moonrise 11	Moonrise 12	Moonrise 13
°	h m	h m	h m	h m	h m	h m	h m
N 72	08 10	10 09	▬	23 04	25 03	01 03	03 05
N 70	07 54	09 30	▬	23 00	24 51	00 51	02 43
68	07 40	09 02	10 55	22 57	24 41	00 41	02 26
66	07 29	08 42	10 05	22 54	24 34	00 34	02 12
64	07 20	08 25	09 35	22 52	24 27	00 27	02 01
62	07 12	08 11	09 12	22 50	24 22	00 22	01 51
60	07 05	07 59	08 54	22 49	24 17	00 17	01 43
N 58	06 58	07 49	08 39	22 47	24 12	00 12	01 36
56	06 52	07 40	08 26	22 46	24 09	00 09	01 29
54	06 47	07 32	08 14	22 45	24 05	00 05	01 24
52	06 42	07 25	08 04	22 44	24 02	00 02	01 19
50	06 38	07 18	07 56	22 43	23 59	25 14	01 14
45	06 27	07 04	07 37	22 41	23 53	25 04	01 04
N 40	06 18	06 51	07 21	22 39	23 48	24 56	00 56
35	06 09	06 41	07 08	22 38	23 44	24 49	00 49
30	06 02	06 31	06 57	22 37	23 40	24 43	00 43
20	05 46	06 14	06 37	22 34	23 34	24 32	00 32
N 10	05 32	05 57	06 20	22 33	23 28	24 23	00 23
0	05 16	05 42	06 04	22 31	23 23	24 15	00 15
S 10	04 58	05 25	05 48	22 29	23 17	24 06	00 06
20	04 37	05 06	05 30	22 27	23 12	23 57	24 45
30	04 10	04 43	05 10	22 25	23 06	23 47	24 31
35	03 53	04 29	04 58	22 24	23 02	23 41	24 23
40	03 32	04 12	04 44	22 23	22 58	23 35	24 14
45	03 04	03 51	04 27	22 21	22 53	23 27	24 04
S 50	02 24	03 24	04 07	22 20	22 48	23 18	23 51
52	02 02	03 11	03 57	22 19	22 45	23 14	23 46
54	01 31	02 55	03 46	22 18	22 43	23 09	23 39
56	00 26	02 36	03 33	22 17	22 40	23 04	23 32
58	////	02 12	03 19	22 16	22 36	22 58	23 24
S 60	////	01 39	03 01	22 15	22 32	22 52	23 15

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 10	Moonset 11	Moonset 12	Moonset 13
°	h m	h m	h m	h m	h m	h m	h m
N 72	▬	14 07	16 06	10 04	09 54	09 44	09 32
N 70	▬	14 46	16 22	10 04	10 01	09 58	09 55
68	13 21	15 13	16 35	10 04	10 06	10 09	10 14
66	14 10	15 34	16 46	10 04	10 11	10 18	10 29
64	14 41	15 50	16 56	10 04	10 15	10 26	10 41
62	15 04	16 04	17 04	10 04	10 18	10 33	10 51
60	15 22	16 16	17 11	10 04	10 21	10 39	11 00
N 58	15 37	16 26	17 17	10 04	10 23	10 44	11 08
56	15 50	16 36	17 23	10 04	10 26	10 49	11 15
54	16 02	16 44	17 29	10 04	10 28	10 53	11 21
52	16 11	16 51	17 34	10 04	10 30	10 57	11 27
50	16 20	16 58	17 38	10 04	10 32	11 00	11 32
45	16 39	17 12	17 49	10 04	10 35	11 08	11 45
N 40	16 54	17 24	17 58	10 04	10 39	11 14	11 52
35	17 07	17 35	18 06	10 04	10 41	11 20	12 00
30	17 19	17 45	18 14	10 04	10 44	11 25	12 07
20	17 38	18 02	18 29	10 04	10 48	11 33	12 19
N 10	17 55	18 18	18 44	10 04	10 52	11 40	12 30
0	18 11	18 34	19 00	10 03	10 55	11 47	12 40
S 10	18 28	18 51	19 17	10 03	10 59	11 54	12 50
20	18 45	19 09	19 38	10 03	11 03	12 02	13 01
30	19 06	19 33	20 05	10 03	11 07	12 10	13 13
35	19 17	19 47	20 22	10 03	11 09	12 15	13 20
40	19 31	20 03	20 43	10 03	11 12	12 21	13 28
45	19 48	20 24	21 11	10 03	11 15	12 27	13 37
S 50	20 08	20 51	21 50	10 02	11 19	12 35	13 49
52	20 18	21 04	22 12	10 02	11 21	12 38	13 54
54	20 29	21 19	22 41	10 02	11 23	12 42	14 00
56	20 41	21 38	23 38	10 02	11 25	12 47	14 07
58	20 56	22 01	////	10 02	11 27	12 52	14 14
S 60	21 13	22 34	////	10 02	11 30	12 57	14 22

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
10	07 16	07 29	12 07	03 51	16 17	20	
11	07 41	07 53	12 08	04 43	17 09	21	
12	08 05	08 16	12 08	05 35	18 01	22	◑

JUNE 15, 16, 17 (SUN., MON., TUES.)

G.M.T.	ARIES	VENUS −3·5		MARS +0·4		JUPITER −1·8		SATURN +0·2	
d h	G.H.A. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′
15 00	262 46·3	218 37·6	N14 38·5	256 51·6	N 0 11·4	62 07·6	S 7 13·8	1 01·0	S21 48·2
01	277 48·7	233 37·2	39·4	271 52·4	12·0	77 10·1	13·8	16 03·7	48·2
02	292 51·2	248 36·8	40·2	286 53·2	12·7	92 12·6	13·8	31 06·4	48·2
03	307 53·7	263 36·4	·· 41·1	301 54·1	·· 13·4	107 15·1	·· 13·8	46 09·0	·· 48·2
04	322 56·1	278 36·0	42·0	316 54·9	14·1	122 17·6	13·8	61 11·7	48·2
05	337 58·6	293 35·6	42·8	331 55·8	14·7	137 20·1	13·8	76 14·3	48·2
06	353 01·0	308 35·1	N14 43·7	346 56·6	N 0 15·4	152 22·6	S 7 13·8	91 17·0	S21 48·2
07	8 03·5	323 34·7	44·5	1 57·4	16·1	167 25·1	13·8	106 19·7	48·2
08	23 06·0	338 34·3	45·4	16 58·3	16·8	182 27·6	13·8	121 22·3	48·2
S 09	38 08·4	353 33·9	·· 46·3	31 59·1	·· 17·4	197 30·1	·· 13·8	136 25·0	·· 48·2
U 10	53 10·9	8 33·5	47·1	46 59·9	18·1	212 32·6	13·8	151 27·7	48·1
N 11	68 13·4	23 33·1	48·0	62 00·8	18·8	227 35·1	13·8	166 30·3	48·1
D 12	83 15·8	38 32·7	N14 48·8	77 01·6	N 0 19·5	242 37·6	S 7 13·8	181 33·0	S21 48·1
A 13	98 18·3	53 32·3	49·7	92 02·4	20·1	257 40·1	13·8	196 35·6	48·1
Y 14	113 20·8	68 31·8	50·5	107 03·3	20·8	272 42·6	13·8	211 38·3	48·1
15	128 23·2	83 31·4	·· 51·4	122 04·1	·· 21·5	287 45·1	·· 13·8	226 41·0	·· 48·1
16	143 25·7	98 31·0	52·3	137 04·9	22·2	302 47·5	13·8	241 43·6	48·1
17	158 28·1	113 30·6	53·1	152 05·8	22·8	317 50·0	13·8	256 46·3	48·1
18	173 30·6	128 30·2	N14 54·0	167 06·6	N 0 23·5	332 52·5	S 7 13·8	271 49·0	S21 48·1
19	188 33·1	143 29·8	54·8	182 07·4	24·2	347 55·0	13·8	286 51·6	48·1
20	203 35·5	158 29·3	55·7	197 08·3	24·9	2 57·5	13·8	301 54·3	48·1
21	218 38·0	173 28·9	·· 56·5	212 09·1	·· 25·5	18 00·0	·· 13·8	316 56·9	·· 48·1
22	233 40·5	188 28·5	57·4	227 09·9	26·2	33 02·5	13·8	331 59·6	48·1
23	248 42·9	203 28·1	58·2	242 10·8	26·9	48 05·0	13·8	347 02·3	48·1
16 00	263 45·4	218 27·7	N14 59·1	257 11·6	N 0 27·6	63 07·5	S 7 13·8	2 04·9	S21 48·0
01	278 47·9	233 27·2	14 59·9	272 12·5	28·2	78 10·0	13·8	17 07·6	48·0
02	293 50·3	248 26·8	15 00·8	287 13·3	28·9	93 12·5	13·8	32 10·3	48·0
03	308 52·8	263 26·4	·· 01·6	302 14·1	·· 29·6	108 14·9	·· 13·8	47 12·9	·· 48·0
04	323 55·3	278 26·0	02·5	317 15·0	30·3	123 17·4	13·8	62 15·6	48·0
05	338 57·7	293 25·6	03·3	332 15·8	30·9	138 19·9	13·8	77 18·2	48·0
06	354 00·2	308 25·1	N15 04·2	347 16·6	N 0 31·6	153 22·4	S 7 13·8	92 20·9	S21 48·0
07	9 02·6	323 24·7	05·0	2 17·5	32·3	168 24·9	13·8	107 23·6	48·0
08	24 05·1	338 24·3	05·9	17 18·3	33·0	183 27·4	13·8	122 26·2	48·0
M 09	39 07·6	353 23·9	·· 06·7	32 19·1	·· 33·6	198 29·9	·· 13·8	137 28·9	·· 48·0
O 10	54 10·0	8 23·4	07·6	47 20·0	34·3	213 32·4	13·8	152 31·6	48·0
N 11	69 12·5	23 23·0	08·4	62 20·8	35·0	228 34·8	13·8	167 34·2	48·0
D 12	84 15·0	38 22·6	N15 09·3	77 21·7	N 0 35·7	243 37·3	S 7 13·8	182 36·9	S21 48·0
A 13	99 17·4	53 22·2	10·1	92 22·5	36·3	258 39·8	13·8	197 39·5	48·0
Y 14	114 19·9	68 21·7	11·0	107 23·3	37·0	273 42·3	13·8	212 42·2	47·9
15	129 22·4	83 21·3	·· 11·8	122 24·2	·· 37·7	288 44·8	·· 13·8	227 44·9	·· 47·9
16	144 24·8	98 20·9	12·6	137 25·0	38·3	303 47·3	13·8	242 47·5	47·9
17	159 27·3	113 20·5	13·5	152 25·8	39·0	318 49·8	13·8	257 50·2	47·9
18	174 29·8	128 20·0	N15 14·3	167 26·7	N 0 39·7	333 52·2	S 7 13·8	272 52·9	S21 47·9
19	189 32·2	143 19·6	15·2	182 27·5	40·4	348 54·7	13·8	287 55·5	47·9
20	204 34·7	158 19·2	16·0	197 28·4	41·0	3 57·2	13·8	302 58·2	47·9
21	219 37·1	173 18·7	·· 16·9	212 29·2	·· 41·7	18 59·7	·· 13·8	318 00·8	·· 47·9
22	234 39·6	188 18·3	17·7	227 30·0	42·4	34 02·2	13·8	333 03·5	47·9
23	249 42·1	203 17·9	18·5	242 30·9	43·1	49 04·7	13·9	348 06·2	47·9
17 00	264 44·5	218 17·5	N15 19·4	257 31·7	N 0 43·7	64 07·2	S 7 13·9	3 08·8	S21 47·9
01	279 47·0	233 17·0	20·2	272 32·6	44·4	79 09·6	13·9	18 11·5	47·9
02	294 49·5	248 16·6	21·1	287 33·4	45·1	94 12·1	13·9	33 14·2	47·9
03	309 51·9	263 16·2	·· 21·9	302 34·2	·· 45·7	109 14·6	·· 13·9	48 16·8	·· 47·9
04	324 54·4	278 15·7	22·7	317 35·1	46·4	124 17·1	13·9	63 19·5	47·8
05	339 56·9	293 15·3	23·6	332 35·9	47·1	139 19·6	13·9	78 22·1	47·8
06	354 59·3	308 14·9	N15 24·4	347 36·8	N 0 47·8	154 22·0	S 7 13·9	93 24·8	S21 47·8
07	10 01·8	323 14·4	25·2	2 37·6	48·4	169 24·5	13·9	108 27·5	47·8
T 08	25 04·3	338 14·0	26·1	17 38·4	49·1	184 27·0	13·9	123 30·1	47·8
U 09	40 06·7	353 13·6	·· 26·9	32 39·3	·· 49·8	199 29·5	·· 13·9	138 32·8	·· 47·8
E 10	55 09·2	8 13·1	27·7	47 40·1	50·4	214 32·0	13·9	153 35·5	47·8
S 11	70 11·6	23 12·7	28·6	62 41·0	51·1	229 34·4	13·9	168 38·1	47·8
D 12	85 14·1	38 12·2	N15 29·4	77 41·8	N 0 51·8	244 36·9	S 7 13·9	183 40·8	S21 47·8
A 13	100 16·6	53 11·8	30·2	92 42·6	52·5	259 39·4	13·9	198 43·4	47·8
Y 14	115 19·0	68 11·4	31·1	107 43·5	53·1	274 41·9	13·9	213 46·1	47·8
15	130 21·5	83 10·9	·· 31·9	122 44·3	·· 53·8	289 44·4	·· 13·9	228 48·8	·· 47·8
16	145 24·0	98 10·5	32·7	137 45·2	54·5	304 46·8	13·9	243 51·4	47·8
17	160 26·4	113 10·1	33·6	152 46·0	55·1	319 49·3	14·0	258 54·1	47·8
18	175 28·9	128 09·6	N15 34·4	167 46·8	N 0 55·8	334 51·8	S 7 14·0	273 56·8	S21 47·7
19	190 31·4	143 09·2	35·2	182 47·7	56·5	349 54·3	14·0	288 59·4	47·7
20	205 33·8	158 08·7	36·0	197 48·5	57·2	4 56·8	14·0	304 02·1	47·7
21	220 36·3	173 08·3	·· 36·9	212 49·4	·· 57·8	19 59·2	·· 14·0	319 04·7	·· 47·7
22	235 38·8	188 07·8	37·7	227 50·2	58·5	35 01·7	14·0	334 07·4	47·7
23	250 41·2	203 07·4	38·5	242 51·0	59·2	50 04·2	14·0	349 10·1	47·7
Mer. Pass.	h m 6 23·9	v −0·4	d 0·8	v 0·8	d 0·7	v 2·5	d 0·0	v 2·7	d 0·0

STARS		
Name	S.H.A. ° ′	Dec. ° ′
Acamar	315 50·1	S 40 28·1
Achernar	335 57·9	S 57 26·6
Acrux	173 55·3	S 62 52·5
Adhara	255 45·4	S 28 55·1
Aldebaran	291 37·2	N 16 25·5
Alioth	166 56·8	N 56 11·3
Alkaid	153 31·2	N 49 31·4
Al Na'ir	28 35·4	S 47 09·4
Alnilam	276 28·7	S 1 13·8
Alphard	218 36·9	S 8 28·8
Alphecca	126 45·7	N 26 51·4
Alpheratz	358 26·3	N 28 51·5
Altair	62 48·3	N 8 45·6
Ankaa	353 56·6	S 42 31·6
Antares	113 16·6	S 26 20·4
Arcturus	146 33·2	N 19 24·0
Atria	108 55·0	S 68 57·2
Avior	234 35·4	S 59 22·9
Bellatrix	279 16·7	N 6 18·7
Betelgeuse	271 46·4	N 7 23·9
Canopus	264 15·0	S 52 40·5
Capella	281 36·0	N 45 57·3
Deneb	49 59·3	N 45 07·8
Denebola	183 15·8	N 14 48·3
Diphda	349 37·5	S 18 12·7
Dubhe	194 42·5	N 61 58·7
Elnath	279 05·3	N 28 34·3
Eltanin	91 04·8	N 51 29·7
Enif	34 27·5	N 9 41·1
Fomalhaut	16 09·5	S 29 50·3
Gacrux	172 46·8	S 56 53·2
Glenah	176 34·8	S 17 18·8
Hadar	149 46·1	S 60 10·6
Hamal	328 47·7	N 23 15·9
Kaus Aust.	84 38·2	S 34 24·2
Kochab	137 17·4	N 74 19·8
Markab	14 19·5	N 14 58·9
Menkar	314 58·6	N 3 55·6
Menkent	148 56·1	S 36 10·1
Miaplacidus	221 49·0	S 69 33·1
Mirfak	309 40·0	N 49 42·7
Nunki	76 49·2	S 26 20·8
Peacock	54 23·9	S 56 51·9
Pollux	244 18·6	N 28 07·6
Procyon	245 43·3	N 5 19·8
Rasalhague	96 44·5	N 12 35·5
Regulus	208 27·6	N 12 19·2
Rigel	281 52·1	S 8 15·0
Rigil Kent.	140 47·7	S 60 40·1
Sabik	102 59·6	S 15 40·4
Schedar	350 27·8	N 56 18·3
Shaula	97 17·6	S 37 04·4
Sirius	259 10·5	S 16 39·7
Spica	159 14·7	S 10 56·8
Suhail	223 23·1	S 43 16·2
Vega	81 06·5	N 38 44·7
Zuben'ubi	137 50·9	S 15 52·2

	S.H.A. ° ′	Mer. Pass. h m
Venus	314 42·3	9 26
Mars	353 26·2	6 51
Jupiter	159 22·1	19 44
Saturn	98 19·5	23 47

JUNE 15, 16, 17 (SUN., MON., TUES.)

G.M.T.	SUN			MOON					Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 15	Moonrise 16	Moonrise 17	Moonrise 18
	G.H.A.	Dec.		G.H.A.	v	Dec.	d	H.P.								
d h	° ′	° ′		° ′	′	° ′	′	′	°	h m	h m	h m	h m	h m	h m	h m
15 00	179 57·7	N23 16·7		208 24·7	11·5	N17 06·1	4·7	55·2	N 72	□	□	□	00 18	00 28	00 59	02 11
01	194 57·5	16·8		222 55·2	11·4	17 10·8	4·6	55·2	N 70	□	□	□	00 50	01 13	01 53	02 57
02	209 57·4	16·9		237 25·6	11·4	17 15·4	4·5	55·3	68	□	□	□	01 14	01 42	02 26	03 28
03	224 57·3	17·0		251 56·0	11·3	17 19·9	4·5	55·3	66	□	□	□	01 33	02 05	02 50	03 50
04	239 57·1	17·1		266 26·3	11·2	17 24·4	4·4	55·3	64	////	////	01 33	01 48	02 23	03 09	04 09
05	254 57·0	17·2		280 56·5	11·3	17 28·8	4·3	55·3	62	////	////	02 10	02 01	02 37	03 25	04 23
06	269 56·9	N23 17·4		295 26·8	11·1	N17 33·1	4·2	55·3	60	////	00 52	02 36	02 01	02 37	03 25	04 23
07	284 56·7	17·5		309 56·9	11·1	17 37·3	4·1	55·4	N 58	////	01 41	02 56	02 12	02 50	03 38	04 36
08	299 56·6	17·6		324 27·0	11·1	17 41·4	4·0	55·4	56	////	02 11	03 13	02 22	03 01	03 49	04 47
S 09	314 56·5	17·7		338 57·1	11·0	17 45·4	4·0	55·4	54	00 48	02 33	03 27	02 31	03 11	03 59	04 57
U 10	329 56·3	17·8		353 27·1	11·0	17 49·4	3·8	55·4	52	01 33	02 51	03 39	02 38	03 19	04 08	05 05
N 11	344 56·2	17·9		7 57·1	10·9	17 53·2	3·8	55·4	50	02 00	03 06	03 50	02 45	03 27	04 16	05 13
D 12	359 56·1	N23 18·0		22 27·0	10·9	N17 57·0	3·7	55·5	45	02 46	03 35	04 13	03 00	03 43	04 33	05 29
A 13	14 55·9	18·1		36 56·9	10·8	18 00·7	3·6	55·5	N 40	03 16	03 58	04 30	03 13	03 57	04 47	05 43
Y 14	29 55·8	18·2		51 26·7	10·7	18 04·3	3·5	55·5	35	03 39	04 16	04 45	03 23	04 09	04 59	05 54
15	44 55·7	18·4		65 56·4	10·8	18 07·8	3·5	55·5	30	03 58	04 31	04 58	03 32	04 19	05 10	06 04
16	59 55·5	18·5		80 26·2	10·6	18 11·3	3·3	55·5	20	04 27	04 56	05 20	03 48	04 36	05 27	06 22
17	74 55·4	18·6		94 55·8	10·6	18 14·6	3·2	55·6	N 10	04 49	05 16	05 39	04 02	04 51	05 43	06 36
18	89 55·3	N23 18·7		109 25·4	10·6	N18 17·8	3·2	55·6	0	05 08	05 34	05 57	04 15	05 05	05 58	06 51
19	104 55·1	18·8		123 55·0	10·6	18 21·0	3·1	55·6	S 10	05 25	05 51	06 14	04 28	05 20	06 12	07 05
20	119 55·0	18·9		138 24·6	10·4	18 24·1	2·9	55·6	20	05 41	06 09	06 33	04 43	05 35	06 28	07 19
21	134 54·9	19·0		152 54·0	10·5	18 27·0	2·9	55·7	30	05 58	06 27	06 54	04 59	05 53	06 46	07 37
22	149 54·7	19·1		167 23·5	10·4	18 29·9	2·8	55·7	35	06 06	06 38	07 06	05 08	06 03	06 56	07 47
23	164 54·6	19·2		181 52·9	10·3	18 32·7	2·7	55·7	40	06 16	06 50	07 20	05 19	06 14	07 08	07 58
16 00	179 54·5	N23 19·3		196 22·2	10·3	N18 35·4	2·6	55·7	45	06 26	07 03	07 37	05 32	06 28	07 22	08 11
01	194 54·3	19·4		210 51·5	10·3	18 38·0	2·5	55·7	S 50	06 38	07 19	07 58	05 47	06 45	07 39	08 28
02	209 54·2	19·5		225 20·8	10·2	18 40·5	2·4	55·8	52	06 43	07 27	08 08	05 55	06 53	07 47	08 35
03	224 54·1	19·6		239 50·0	10·2	18 42·9	2·3	55·8	54	06 48	07 35	08 19	06 03	07 02	07 56	08 44
04	239 53·9	19·7		254 19·2	10·1	18 45·2	2·3	55·8	56	06 55	07 44	08 31	06 12	07 12	08 07	08 53
05	254 53·8	19·8		268 48·3	10·1	18 47·5	2·1	55·8	58	07 01	07 54	08 46	06 22	07 23	08 18	09 04
06	269 53·7	N23 19·9		283 17·4	10·0	N18 49·6	2·0	55·9	S 60	07 09	08 06	09 03	06 34	07 37	08 32	09 17
07	284 53·5	20·0		297 46·4	10·0	18 51·6	2·0	55·9								
08	299 53·4	20·1		312 15·4	10·0	18 53·6	1·8	55·9								
M 09	314 53·2	20·2		326 44·4	9·9	18 55·4	1·7	55·9								
O 10	329 53·1	20·3		341 13·3	9·9	18 57·1	1·7	55·9								
N 11	344 53·0	20·4		355 42·2	9·9	18 58·8	1·5	56·0								
D 12	359 52·8	N23 20·5		10 11·1	9·8	N19 00·3	1·4	56·0								
A 13	14 52·7	20·6		24 39·9	9·7	19 01·7	1·4	56·0								
Y 14	29 52·6	20·7		39 08·6	9·8	19 03·1	1·2	56·0								
15	44 52·4	20·7		53 37·4	9·7	19 04·3	1·1	56·1								
16	59 52·3	20·8		68 06·1	9·7	19 05·4	1·0	56·1								
17	74 52·2	20·9		82 34·8	9·6	19 06·4	1·0	56·1								
18	89 52·0	N23 21·0		97 03·4	9·6	N19 07·4	0·8	56·1								
19	104 51·9	21·1		111 32·0	9·5	19 08·2	0·7	56·1								
20	119 51·8	21·2		126 00·5	9·6	19 08·9	0·7	56·2								
21	134 51·6	21·3		140 29·1	9·5	19 09·6	0·5	56·2								
22	149 51·5	21·4		154 57·6	9·4	19 10·1	0·4	56·2								
23	164 51·4	21·4		169 26·0	9·5	19 10·5	0·3	56·2								
17 00	179 51·2	N23 21·5		183 54·5	9·4	N19 10·8	0·2	56·3								
01	194 51·1	21·6		198 22·9	9·4	19 11·0	0·1	56·3								
02	209 51·0	21·7		212 51·3	9·3	19 11·1	0·0	56·3								
03	224 50·8	21·8		227 19·6	9·3	19 11·1	0·1	56·3								
04	239 50·7	21·9		241 47·9	9·3	19 11·0	0·2	56·3								
05	254 50·5	21·9		256 16·2	9·3	19 10·8	0·3	56·4								
06	269 50·4	N23 22·0		270 44·5	9·3	N19 10·5	0·4	56·4								
07	284 50·3	22·1		285 12·8	9·2	19 10·1	0·6	56·4								
T 08	299 50·1	22·2		299 41·0	9·2	19 09·5	0·6	56·4								
U 09	314 50·0	22·3		314 09·2	9·2	19 08·9	0·7	56·5								
E 10	329 49·9	22·3		328 37·4	9·1	19 08·2	0·9	56·5								
S 11	344 49·7	22·4		343 05·5	9·2	19 07·3	0·9	56·5								
D 12	359 49·6	N23 22·5		357 33·7	9·1	N19 06·4	1·1	56·5								
A 13	14 49·5	22·6		12 01·8	9·1	19 05·3	1·1	56·6								
Y 14	29 49·3	22·6		26 29·9	9·0	19 04·2	1·3	56·6								
15	44 49·2	22·7		40 57·9	9·1	19 02·9	1·4	56·6								
16	59 49·1	22·8		55 26·0	9·0	19 01·5	1·5	56·6								
17	74 48·9	22·9		69 54·0	9·1	19 00·0	1·6	56·6								
18	89 48·8	N23 22·9		84 22·1	9·0	N18 58·4	1·7	56·7								
19	104 48·6	23·0		98 50·1	9·0	18 56·7	1·8	56·7								
20	119 48·5	23·1		113 18·1	8·9	18 54·9	1·9	56·7								
21	134 48·4	23·2		127 46·0	9·0	18 53·0	2·0	56·7								
22	149 48·2	23·2		142 14·0	9·0	18 51·0	2·1	56·8								
23	164 48·1	23·3		156 42·0	8·9	18 48·9	2·3	56·8								
	S.D. 15·8	d 0·1		S.D.	15·1		15·3									

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 15	Moonset 16	Moonset 17	Moonset 18
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	21 12	22 28	23 07	23·20
N 70	□	□	□	20 28	21 34	22 20	22 46
68	□	□	□	19 58	21 01	21 49	22 21
66	□	□	□	19 36	20 37	21 26	22 02
64	22 29	////	////	19 18	20 18	21 08	21 46
62	21 51	////	////	19 04	20 03	20 53	21 33
60	21 25	23 10	////	18 51	19 49	20 40	21 22
N 58	21 05	22 20	////	18 40	19 38	20 29	21 12
56	20 48	21 51	////	18 31	19 28	20 19	21 03
54	20 34	21 29	23 14	18 22	19 19	20 10	20 55
52	20 22	21 11	22·29	18 15	19 11	20 02	20 48
50	20 11	20 56	22 01	17 59	18 54	19 46	20 33
45	19 49	20 26	21 16	17 46	18 40	19 32	20 20
N 40	19 31	20 03	20 45	17 34	18 28	19 20	20 09
35	19 16	19 45	20 22	17 25	18 18	19 10	20 00
30	19 03	19 30	20 03	17 08	18 00	18 53	19 44
20	18 41	19 05	19 34	16 53	17 45	18 37	19 29
N 10	18 22	18 45	19 12	16 39	17 30	18 23	19 16
0	18 04	18 27	18 53	16 25	17 16	18 08	19 03
S 10	17 47	18 10	18 36	16 11	17 00	17 53	18 48
20	17 28	17 52	18 20	15 54	16 42	17 35	18 32
30	17 07	17 34	18 03	15 44	16 32	17 25	18 22
35	16 55	17 23	17 55	15 33	16 20	17 13	18 11
40	16 41	17 11	17 45	15 20	16 06	16 59	17 58
45	16 24	16 58	17 35	15 04	15 49	16 42	17 42
S 50	16 03	16 42	17 23	14 56	15 41	16 34	17 35
52	15 53	16 34	17 18	14 48	15 32	16 25	17 26
54	15 42	16 26	17·12	14 39	15 22	16 15	17 17
56	15 30	16 17	17 06	14 28	15 10	16 03	17 07
58	15 15	16 07	16 59	14 16	14 57	15 50	16 54
S 60	14 58	15 55	16 52				

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
15	00 09	00 15	12 00	10 27	22 52	28	
16	00 22	00 28	12 00	11 18	23 44	29	●
17	00 35	00 41	12 01	12 10	24 37	00	

JUNE 18, 19, 20 (WED., THURS., FRI.)

G.M.T.	ARIES	VENUS −3·4		MARS +0·4		JUPITER −1·8		SATURN +0·2		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
18 00	265 43·7	218 07·0	N15 39·4	257 51·9	N 0 59·8	65 06·7	S 7 14·0	4 12·7	S21 47·7	Acamar	315 50·0	S 40 28·1
01	280 46·1	233 06·5	40·2	272 52·7	1 00·5	80 09·1	14·0	19 15·4	47·7	Achernar	335 57·9	S 57 26·6
02	295 48·6	248 06·1	41·0	287 53·6	01·2	95 11·6	14·0	34 18·1	47·7	Acrux	173 55·3	S 62 52·5
03	310 51·1	263 05·6	·· 41·8	302 54·4	·· 01·8	110 14·1	·· 14·0	49 20·7	·· 47·7	Adhara	255 45·4	S 28 55·1
04	325 53·5	278 05·2	42·7	317 55·3	02·5	125 16·6	14·0	64 23·4	47·7	Aldebaran	291 37·2	N 16 26·5
05	340 56·0	293 04·7	43·5	332 56·1	03·2	140 19·0	14·0	79 26·0	47·7			
06	355 58·5	308 04·3	N15 44·3	347 56·9	N 1 03·9	155 21·5	S 7 14·1	94 28·7	S21 47·7	Alioth	166 56·8	N 56 11·3
W 07	11 00·9	323 03·9	45·1	2 57·8	04·5	170 24·0	14·1	109 31·4	47·7	Alkaid	153 31·2	N 49 31·4
E 08	26 03·4	338 03·4	45·9	17 58·6	05·2	185 26·5	14·1	124 34·0	47·6	Al Na'ir	28 35·4	S 47 09·4
D 09	41 05·9	353 03·0	·· 46·8	32 59·5	·· 05·9	200 28·9	·· 14·1	139 36·7	·· 47·6	Alnilam	276 28·7	S 1 13·6
N 10	56 08·3	8 02·5	47·6	48 00·3	06·5	215 31·4	14·1	154 39·4	47·6	Alphard	218 36·9	S 8 28·8
E 11	71 10·8	23 02·1	48·4	63 01·2	07·2	230 33·9	14·1	169 42·0	47·6			
S 12	86 13·2	38 01·6	N15 49·2	78 02·0	N 1 07·9	245 36·4	S 7 14·1	184 44·7	S21 47·6	Alphecca	126 45·7	N 26 51·4
D 13	101 15·7	53 01·2	50·0	93 02·8	08·5	260 38·8	14·1	199 47·3	47·6	Alpheratz	358 26·3	N 28 51·6
A 14	116 18·2	68 00·7	50·9	108 03·7	09·2	275 41·3	14·1	214 50·0	47·6	Altair	62 48·2	N 8 45·6
Y 15	131 20·6	83 00·3	·· 51·7	123 04·5	·· 09·9	290 43·8	·· 14·1	229 52·7	·· 47·6	Ankaa	353 56·6	S 42 31·6
16	146 23·1	97 59·8	52·5	138 05·4	10·5	305 46·2	14·1	244 55·3	47·6	Antares	113 16·6	S 26 20·4
17	161 25·6	112 59·4	53·3	153 06·2	11·2	320 48·7	14·1	259 58·0	47·6			
18	176 28·0	127 58·9	N15 54·1	168 07·1	N 1 11·9	335 51·2	S 7 14·2	275 00·6	S21 47·6	Arcturus	146 33·2	N 19 24·0
19	191 30·5	142 58·5	54·9	183 07·9	12·6	350 53·7	14·2	290 03·3	47·6	Atria	108 55·0	S 68 57·2
20	206 33·0	157 58·0	55·8	198 08·8	13·2	5 56·1	14·2	305 06·0	47·6	Avior	234 35·4	S 59 22·8
21	221 35·4	172 57·6	·· 56·6	213 09·6	·· 13·9	20 58·6	·· 14·2	320 08·6	·· 47·6	Bellatrix	279 16·7	N 6 18·7
22	236 37·9	187 57·1	57·4	228 10·4	14·6	36 01·1	14·2	335 11·3	47·5	Betelgeuse	271 46·4	N 7 23·9
23	251 40·4	202 56·7	58·2	243 11·3	15·2	51 03·5	14·2	350 14·0	47·5			
19 00	266 42·8	217 56·2	N15 59·0	258 12·1	N 1 15·9	66 06·0	S 7 14·2	5 16·6	S21 47·5	Canopus	264 15·0	S 52 40·5
01	281 45·3	232 55·7	15 59·8	273 13·0	16·6	81 08·5	14·2	20 19·3	47·5	Capella	281 36·0	N 45 57·3
02	296 47·7	247 55·3	16 00·6	288 13·8	17·2	96 10·9	14·2	35 21·9	47·5	Deneb	49 59·3	N 45 07·8
03	311 50·2	262 54·8	·· 01·4	303 14·7	·· 17·9	111 13·4	·· 14·2	50 24·6	·· 47·5	Denebola	183 15·8	N 14 48·3
04	326 52·7	277 54·4	02·2	318 15·5	18·6	126 15·9	14·3	65 27·3	47·5	Diphda	349 37·4	S 18 12·7
05	341 55·1	292 53·9	03·1	333 16·4	19·2	141 18·3	14·3	80 29·9	47·5			
06	356 57·6	307 53·5	N16 03·9	348 17·2	N 1 19·9	156 20·8	S 7 14·3	95 32·6	S21 47·5	Dubhe	194 42·6	N 61 58·7
07	12 00·1	322 53·0	04·7	3 18·0	20·6	171 23·3	14·3	110 35·2	47·5	Elnath	279 05·3	N 28 34·3
T 08	27 02·5	337 52·6	05·5	18 18·9	21·2	186 25·7	14·3	125 37·9	47·5	Eltanin	91 04·8	N 51 29·7
H 09	42 05·0	352 52·1	·· 06·3	33 19·7	·· 21·9	201 28·2	·· 14·3	140 40·6	·· 47·5	Enif	34 27·5	N 9 41·1
U 10	57 07·5	7 51·6	07·1	48 20·6	22·6	216 30·7	14·3	155 43·2	47·5	Fomalhaut	16 09·5	S 29 50·3
R 11	72 09·9	22 51·2	07·9	63 21·4	23·2	231 33·1	14·3	170 45·9	47·5			
S 12	87 12·4	37 50·7	N16 08·7	78 22·3	N 1 23·9	246 35·6	S 7 14·3	185 48·6	S21 47·4	Gacrux	172 46·8	S 56 53·2
D 13	102 14·9	52 50·3	09·5	93 23·1	24·6	261 38·1	14·4	200 51·2	47·4	Gienah	176 34·8	S 17 18·8
A 14	117 17·3	67 49·8	10·3	108 24·0	25·2	276 40·5	14·4	215 53·9	47·4	Hadar	149 46·1	S 60 10·6
Y 15	132 19·8	82 49·3	·· 11·1	123 24·8	·· 25·9	291 43·0	·· 14·4	230 56·5	·· 47·4	Hamal	328 47·6	N 23 15·9
16	147 22·2	97 48·9	11·9	138 25·7	26·6	306 45·5	14·4	245 59·2	47·4	Kaus Aust.	84 38·2	S 34 24·2
17	162 24·7	112 48·4	12·7	153 26·5	27·2	321 47·9	14·4	261 01·9	47·4			
18	177 27·2	127 47·9	N16 13·5	168 27·3	N 1 27·9	336 50·4	S 7 14·4	276 04·5	S21 47·4	Kochab	137 17·4	N 74 19·8
19	192 29·6	142 47·5	14·3	183 28·2	28·6	351 52·9	14·4	291 07·2	47·4	Markab	14 19·4	N 14 58·9
20	207 32·1	157 47·0	15·1	198 29·0	29·2	6 55·3	14·4	306 09·8	47·4	Menkar	314 58·5	N 3 55·6
21	222 34·6	172 46·6	·· 15·9	213 29·9	·· 29·9	21 57·8	·· 14·5	321 12·5	·· 47·4	Menkent	148 56·1	S 36 10·1
22	237 37·0	187 46·1	16·7	228 30·7	30·6	37 00·3	14·5	336 15·2	47·4	Miaplacidus	221 49·0	S 69 33·1
23	252 39·5	202 45·6	17·5	243 31·6	31·2	52 02·7	14·5	351 17·8	47·4			
20 00	267 42·0	217 45·2	N16 18·3	258 32·4	N 1 31·9	67 05·2	S 7 14·5	6 20·5	S21 47·4	Mirfak	309 40·0	N 49 42·7
01	282 44·4	232 44·7	19·1	273 33·3	32·6	82 07·6	14·5	21 23·1	47·4	Nunki	76 49·2	S 26 20·8
02	297 46·9	247 44·2	19·9	288 34·1	33·2	97 10·1	14·5	36 25·8	47·3	Peacock	54 23·9	S 56 51·9
03	312 49·4	262 43·8	·· 20·7	303 35·0	·· 33·9	112 12·6	·· 14·5	51 28·5	·· 47·3	Pollux	244 18·6	N 28 07·6
04	327 51·8	277 43·3	21·5	318 35·8	34·6	127 15·0	14·6	66 31·1	47·3	Procyon	245 43·3	N 5 19·8
05	342 54·3	292 42·8	22·3	333 36·7	35·2	142 17·5	14·6	81 33·8	47·3			
06	357 56·7	307 42·3	N16 23·1	348 37·5	N 1 35·9	157 19·9	S 7 14·6	96 36·4	S21 47·3	Rasalhague	96 44·5	N 12 35·5
07	12 59·2	322 41·9	23·9	3 38·4	36·6	172 22·4	14·6	111 39·1	47·3	Regulus	208 27·6	N 12 10·2
08	28 01·7	337 41·4	24·7	18 39·2	37·2	187 24·9	14·6	126 41·8	47·3	Rigel	281 52·1	S 8 15·0
F 09	43 04·1	352 40·9	·· 25·5	33 40·1	·· 37·9	202 27·3	·· 14·6	141 44·4	·· 47·3	Rigil Kent.	140 47·7	S 60 40·1
R 10	58 06·6	7 40·5	26·3	48 40·9	38·5	217 29·8	14·6	156 47·1	47·3	Sabik	102 59·6	S 15 40·4
I 11	73 09·1	22 40·0	27·0	63 41·8	39·2	232 32·2	14·7	171 49·8	47·3			
D 12	88 11·5	37 39·5	N16 27·8	78 42·6	N 1 39·9	247 34·7	S 7 14·7	186 52·4	S21 47·3	Schedar	350 27·7	N 56 18·3
A 13	103 14·0	52 39·1	28·6	93 43·5	40·5	262 37·2	14·7	201 55·1	47·3	Shaula	97 17·6	S 37 04·4
Y 14	118 16·5	67 38·6	29·4	108 44·3	41·2	277 39·6	14·7	216 57·7	47·3	Sirius	259 10·5	S 16 39·6
15	133 18·9	82 38·1	·· 30·2	123 45·2	·· 41·9	292 42·1	·· 14·7	232 00·4	·· 47·3	Spica	159 14·7	S 10 56·8
16	148 21·4	97 37·6	31·0	138 46·0	42·5	307 44·5	14·7	247 03·1	47·2	Suhail	223 23·1	S 43 16·2
17	163 23·8	112 37·2	31·8	153 46·9	43·2	322 47·0	14·7	262 05·7	47·2			
18	178 26·3	127 36·7	N16 32·6	168 47·7	N 1 43·9	337 49·4	S 7 14·8	277 08·4	S21 47·2	Vega	81 06·5	N 38 44·7
19	193 28·8	142 36·2	33·4	183 48·6	44·5	352 51·9	14·8	292 11·0	47·2	Zuben'ubi	137 50·9	S 15 52·2
20	208 31·2	157 35·7	34·1	198 49·4	45·2	7 54·4	14·8	307 13·7	47·2		S.H.A.	Mer. Pass.
21	223 33·7	172 35·3	·· 34·9	213 50·3	·· 45·9	22 56·8	·· 14·8	322 16·4	·· 47·2		° ′	h m
22	238 36·2	187 34·8	35·7	228 51·1	46·5	37 59·3	14·8	337 19·0	47·2	Venus	311 13·4	9 28
23	253 38·6	202 34·3	36·5	243 52·0	47·2	53 01·7	14·8	352 21·7	47·2	Mars	351 29·3	6 47
										Jupiter	159 23·2	19 32
Mer. Pass.	h m 6 12·1	v −0·5	d 0·8	v 0·8	d 0·7	v 2·5	d 0·0	v 2·7	d 0·0	Saturn	98 33·8	23 35

JUNE 18, 19, 20 (WED., THURS., FRI.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
18 00	179 48·0	N23 23·4	171 09·9	8·9	N18 46·6	2·3	56·8
01	194 47·8	23·4	185 37·8	8·9	18 44·3	2·5	56·8
02	209 47·7	23·5	200 05·7	9·0	18 41·8	2·5	56·8
03	224 47·6	23·6	214 33·7	8·9	18 39·3	2·7	56·9
04	239 47·4	23·6	229 01·6	8·8	18 36·6	2·7	56·9
05	254 47·3	23·7	243 29·4	8·9	18 33·9	2·9	56·9
06	269 47·1	N23 23·7	257 57·3	8·9	N18 31·0	3·0	56·9
W 07	284 47·0	23·8	272 25·2	8·9	18 28·0	3·1	57·0
E 08	299 46·9	23·9	286 53·1	8·9	18 24·9	3·2	57·0
D 09	314 46·7	23·9	301 21·0	8·8	18 21·7	3·3	57·0
N 10	329 46·6	24·0	315 48·8	8·9	18 18·4	3·4	57·0
E 11	344 46·5	24·1	330 16·7	8·9	18 15·0	3·5	57·0
S 12	359 46·3	N23 24·1	344 44·6	8·8	N18 11·5	3·6	57·1
D 13	14 46·2	24·2	359 12·4	8·9	18 07·9	3·8	57·1
A 14	29 46·1	24·2	13 40·3	8·8	18 04·1	3·8	57·1
Y 15	44 45·9	24·3	28 08·1	8·9	18 00·3	3·9	57·1
16	59 45·8	24·3	42 36·0	8·9	17 56·4	4·1	57·2
17	74 45·6	24·4	57 03·9	8·8	17 52·3	4·1	57·2
18	89 45·5	N23 24·5	71 31·7	8·9	N17 48·2	4·2	57·2
19	104 45·4	24·5	85 59·6	8·8	17 44·0	4·4	57·2
20	119 45·2	24·6	100 27·4	8·9	17 39·6	4·4	57·2
21	134 45·1	24·6	114 55·3	8·9	17 35·2	4·6	57·3
22	149 45·0	24·7	129 23·2	8·9	17 30·6	4·7	57·3
23	164 44·8	24·7	143 51·1	8·9	17 25·9	4·7	57·3
19 00	179 44·7	N23 24·8	158 19·0	8·9	N17 21·2	4·9	57·3
01	194 44·6	24·8	172 46·9	8·9	17 16·3	5·0	57·3
02	209 44·4	24·9	187 14·8	8·9	17 11·3	5·0	57·4
03	224 44·3	24·9	201 42·7	8·9	17 06·3	5·2	57·4
04	239 44·1	25·0	216 10·6	8·9	17 01·1	5·3	57·4
05	254 44·0	25·0	230 38·5	9·0	16 55·8	5·3	57·4
06	269 43·9	N23 25·1	245 06·5	8·9	N16 50·5	5·5	57·4
T 07	284 43·7	25·1	259 34·4	9·0	16 45·0	5·6	57·5
H 08	299 43·6	25·1	274 02·4	8·9	16 39·4	5·6	57·5
U 09	314 43·5	25·2	288 30·3	9·0	16 33·8	5·8	57·5
R 10	329 43·3	25·2	302 58·3	9·0	16 28·0	5·8	57·5
S 11	344 43·2	25·3	317 26·3	9·0	16 22·2	6·0	57·5
D 12	359 43·0	N23 25·3	331 54·3	9·0	N16 16·2	6·0	57·6
A 13	14 42·9	25·4	346 22·3	9·0	16 10·2	6·2	57·6
Y 14	29 42·8	25·4	0 50·3	9·1	16 04·0	6·2	57·6
15	44 42·6	25·4	15 18·4	9·0	15 57·8	6·4	57·6
16	59 42·5	25·5	29 46·4	9·1	15 51·4	6·4	57·7
17	74 42·4	25·5	44 14·5	9·1	15 45·0	6·5	57·7
18	89 42·2	N23 25·6	58 42·6	9·1	N15 38·5	6·6	57·7
19	104 42·1	25·6	73 10·7	9·1	15 31·9	6·8	57·7
20	119 42·0	25·6	87 38·8	9·2	15 25·1	6·8	57·7
21	134 41·8	25·7	102 07·0	9·1	15 18·3	6·9	57·7
22	149 41·7	25·7	116 35·1	9·2	15 11·4	6·9	57·8
23	164 41·5	25·7	131 03·3	9·2	15 04·5	7·1	57·8
20 00	179 41·4	N23 25·8	145 31·5	9·2	N14 57·4	7·2	57·8
01	194 41·3	25·8	159 59·7	9·2	14 50·2	7·2	57·8
02	209 41·1	25·8	174 27·9	9·2	14 43·0	7·4	57·8
03	224 41·0	25·9	188 56·1	9·3	14 35·6	7·4	57·9
04	239 40·9	25·9	203 24·4	9·3	14 28·2	7·5	57·9
05	254 40·7	25·9	217 52·7	9·3	14 20·7	7·6	57·9
06	269 40·6	N23 25·9	232 21·0	9·3	N14 13·1	7·7	57·9
F 07	284 40·5	26·0	246 49·3	9·3	14 05·4	7·8	57·9
R 08	299 40·3	26·0	261 17·6	9·4	13 57·6	7·8	58·0
I 09	314 40·2	26·0	275 46·0	9·3	13 49·8	7·9	58·0
D 10	329 40·0	26·1	290 14·3	9·4	13 41·9	8·1	58·0
A 11	344 39·9	26·1	304 42·7	9·4	13 33·8	8·1	58·0
Y 12	359 39·8	N23 26·1	319 11·1	9·5	N13 25·7	8·1	58·0
13	14 39·6	26·1	333 39·6	9·4	13 17·6	8·3	58·0
14	29 39·5	26·2	348 08·0	9·5	13 09·3	8·3	58·1
15	44 39·4	26·2	2 36·5	9·5	13 01·0	8·4	58·1
16	59 39·2	26·2	17 05·0	9·5	12 52·6	8·5	58·1
17	74 39·1	26·2	31 33·5	9·5	12 44·1	8·6	58·1
18	89 39·0	N23 26·2	46 02·0	9·6	N12 35·5	8·6	58·1
19	104 38·8	26·3	60 30·6	9·5	12 26·9	8·8	58·2
20	119 38·7	26·3	74 59·1	9·6	12 18·1	8·7	58·2
21	134 38·5	26·3	89 27·7	9·6	12 09·4	8·9	58·2
22	149 38·4	26·3	103 56·3	9·7	12 00·5	8·9	58·2
23	164 38·3	26·3	118 25·0	9·6	11 51·6	9·1	58·2
	S.D. 15·8	d 0·0	S.D.	15·5		15·7	15·8

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 18	Moonrise 19	Moonrise 20	Moonrise 21
°	h m	h m	h m	h m	h m	h m	h m
N 72					02 52	05 04	07 05
N 70				02 11	03 48	05 35	07 22
68				02 57	04 22	05 57	07 36
66				03 28	04 46	06 14	07 48
64	////	////	01 31	03 50	05 05	06 28	07 57
62	////	////	02 09	04 09	05 20	06 40	08 05
60	////	00 49	02 36	04 23	05 33	06 50	08 12
N 58	////	01 40	02 56	04 36	05 44	06 59	08 13
56	////	02 10	03 13	04 47	05 54	07 07	08 24
54	00 45	02 32	03 27	04 57	06 02	07 14	08 29
52	01 32	02 50	03 39	05 05	06 10	07 20	08 33
50	02 00	03 06	03 50	05 13	06 17	07 25	08 37
45	02 46	03 35	04 13	05 29	06 31	07 37	08 45
N 40	03 16	03 58	04 31	05 43	06 43	07 47	08 53
35	03 39	04 16	04 46	05 54	06 53	07 55	08 59
30	03 58	04 31	04 59	06 04	07 02	08 03	09 04
20	04 27	04 56	05 21	06 22	07 18	08 15	09 13
N 10	04 50	05 17	05 40	06 36	07 31	08 26	09 21
0	05 09	05 35	05 57	06 51	07 44	08 37	09 29
S 10	05 26	05 52	06 15	07 05	07 56	08 47	09 36
20	05 42	06 09	06 33	07 19	08 10	08 58	09 44
30	05 58	06 28	06 55	07 37	08 25	09 11	09 54
35	06 07	06 39	07 07	07 47	08 34	09 18	09 59
40	06 17	06 51	07 21	07 58	08 44	09 26	10 05
45	06 27	07 04	07 38	08 11	08 56	09 36	10 12
S 50	06 39	07 20	07 59	08 28	09 10	09 47	10 20
52	06 44	07 28	08 09	08 35	09 17	09 52	10 24
54	06 50	07 36	08 20	08 44	09 24	09 58	10 28
56	06 56	07 45	08 33	08 53	09 33	10 05	10 32
58	07 03	07 55	08 47	09 04	09 42	10 12	10 38
S 60	07 10	08 07	09 05	09 17	09 53	10 20	10 43

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 18	Moonset 19	Moonset 20	Moonset 21
°	h m	h m	h m	h m	h m	h m	h m
N 72					00 17 (23 56)	23 45	23 36
N 70				23 20	23 24	23 25	23 25
68				22 46	23 01	23 10	23 16
66				22 21	22 43	22 57	23 08
64	22 32	////	////	22 02	22 28	22 47	23 01
62	21 53	////	////	21 46	22 15	22 38	22 56
60	21 27	23 13	////	21 33	22 05	22 30	22 51
N 58	21 06	22 22	////	21 22	21 55	22 23	22 47
56	20 50	21 52	////	21 12	21 47	22 17	22 43
54	20 35	21 30	23 17	21 03	21 40	22 11	22 39
52	20 23	21 12	22 30	20 55	21 33	22 07	22 36
50	20 12	20 57	22 02	20 48	21 27	22 02	22 33
45	19 50	20 27	21 17	20 33	21 15	21 52	22 27
N 40	19 32	20 04	20 46	20 20	21 04	21 44	22 22
35	19 17	19 46	20 23	20 09	20 55	21 37	22 17
30	19 03	19 31	20 04	20 00	20 47	21 31	22 13
20	18 41	19 06	19 35	19 44	20 33	21 20	22 06
N 10	18 22	18 45	19 13	19 29	20 21	21 11	21 59
0	18 05	18 27	18 54	19 16	20 09	21 02	21 53
S 10	17 47	18 10	18 37	19 03	19 58	20 53	21 47
20	17 29	17 53	18 20	18 48	19 45	20 43	21 41
30	17 08	17 34	18 04	18 32	19 31	20 32	21 33
35	16 55	17 23	17 55	18 22	19 23	20 25	21 29
40	16 41	17 12	17 46	18 11	19 13	20 18	21 24
45	16 24	16 58	17 35	17 58	19 02	20 09	21 19
S 50	16 03	16 42	17 23	17 42	18 49	19 59	21 12
52	15 53	16 34	17 18	17 35	18 42	19 54	21 08
54	15 42	16 26	17 12	17 26	18 35	19 49	21 05
56	15 30	16 17	17 06	17 17	18 27	19 43	21 01
58	15 15	16 07	16 59	17 07	18 18	19 36	20 57
S 60	14 57	15 55	16 52	16 54	18 08	19 28	20 52

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
18	00 48	00 54	12 01	13 03	00 37	01	
19	01 01	01 08	12 01	13 56	01 30	02	
20	01 14	01 21	12 01	14 49	02 23	03	●

JUNE 21, 22, 23 (SAT., SUN., MON.)

G.M.T.	ARIES	VENUS −3·4		MARS +0·4		JUPITER −1·8		SATURN +0·2	
d h	G.H.A. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′
21 00	268 41·1	217 33·8	N16 37·3	258 52·8	N 1 47·9	68 04·2	S 7 14·8	7 24·3	S21 47·2
01	283 43·6	232 33·4	38·1	273 53·7	48·5	83 06·6	14·9	22 27·0	47·2
02	298 46·0	247 32·9	38·8	288 54·5	49·2	98 09·1	14·9	37 29·7	47·2
03	313 48·5	262 32·4	·· 39·6	303 55·4	·· 49·8	113 11·5	·· 14·9	52 32·3	·· 47·2
04	328 51·0	277 31·9	40·4	318 56·2	50·5	128 14·0	14·9	67 35·0	47·2
05	343 53·4	292 31·4	41·2	333 57·1	51·2	143 16·4	14·9	82 37·7	47·1
06	358 55·9	307 31·0	N16 42·0	348 57·9	N 1 51·8	158 18·9	S 7 14·9	97 40·3	S21 47·1
07	13 58·3	322 30·5	42·7	3 58·8	52·5	173 21·4	15·0	112 43·0	47·1
S 08	29 00·8	337 30·0	43·5	18 59·6	53·2	188 23·8	• 15·0	127 45·6	47·1
A 09	44 03·3	352 29·5	·· 44·3	34 00·5	·· 53·8	203 26·3	·· 15·0	142 48·3	·· 47·1
T 10	59 05·7	7 29·0	45·1	49 01·3	54·5	218 28·7	15·0	157 51·0	47·1
U 11	74 08·2	22 28·5	45·9	64 02·2	55·1	233 31·2	15·0	172 53·6	47·1
R 12	89 10·7	37 28·1	N16 46·6	79 03·0	N 1 55·8	248 33·6	S 7 15·0	187 56·3	S21 47·1
D 13	104 13·1	52 27·6	47·4	94 03·9	56·5	263 36·1	15·1	202 58·9	47·1
A 14	119 15·6	67 27·1	48·2	109 04·7	57·1	278 38·5	15·1	218 01·6	47·1
Y 15	134 18·1	82 26·6	·· 49·0	124 05·6	·· 57·8	293 41·0	·· 15·1	233 04·2	·· 47·1
16	149 20·5	97 26·1	49·7	139 06·4	58·4	308 43·4	15·1	248 06·9	47·1
17	164 23·0	112 25·6	50·5	154 07·3	59·1	323 45·9	15·1	263 09·6	47·1
18	179 25·5	127 25·1	N16 51·3	169 08·1	N 1 59·8	338 48·3	S 7 15·1	278 12·2	S21 47·1
19	194 27·9	142 24·7	52·0	184 09·0	2 00·4	353 50·8	15·2	293 14·9	47·0
20	209 30·4	157 24·2	52·8	199 09·8	01·1	8 53·2	15·2	308 17·5	47·0
21	224 32·8	172 23·7	·· 53·6	214 10·7	·· 01·8	23 55·7	·· 15·2	323 20·2	·· 47·0
22	239 35·3	187 23·2	54·4	229 11·5	02·4	38 58·1	15·2	338 22·9	47·0
23	254 37·8	202 22·7	55·1	244 12·4	03·1	54 00·6	15·2	353 25·5	47·0
22 00	269 40·2	217 22·2	N16 55·9	259 13·3	N 2 03·7	69 03·0	S 7 15·3	8 28·2	S21 47·0
01	284 42·7	232 21·7	56·7	274 14·1	04·4	84 05·5	15·3	23 30·8	47·0
02	299 45·2	247 21·2	57·4	289 15·0	05·1	99 07·9	15·3	38 33·5	47·0
03	314 47·6	262 20·7	·· 58·2	304 15·8	·· 05·7	114 10·3	·· 15·3	53 36·2	·· 47·0
04	329 50·1	277 20·3	59·0	319 16·7	06·4	129 12·8	15·3	68 38·8	47·0
05	344 52·6	292 19·8	16 59·7	334 17·5	07·0	144 15·2	15·4	83 41·5	47·0
06	359 55·0	307 19·3	N17 00·5	349 18·4	N 2 07·7	159 17·7	S 7 15·4	98 44·1	S21 47·0
07	14 57·5	322 18·8	01·2	4 19·2	08·4	174 20·1	15·4	113 46·8	47·0
08	29 59·9	337 18·3	02·0	19 20·1	09·0	189 22·6	15·4	128 49·5	47·0
S 09	45 02·4	352 17·8	·· 02·8	34 20·9	·· 09·7	204 25·0	·· 15·4	143 52·1	·· 47·0
U 10	60 04·9	7 17·3	03·5	49 21·8	10·3	219 27·5	15·5	158 54·8	46·9
N 11	75 07·3	22 16·8	04·3	64 22·7	11·0	234 29·9	15·5	173 57·4	46·9
D 12	90 09·8	37 16·3	N17 05·1	79 23·5	N 2 11·7	249 32·4	S 7 15·5	189 00·1	S21 46·9
A 13	105 12·3	52 15·8	05·8	94 24·4	12·3	264 34·8	15·5	204 02·8	46·9
Y 14	120 14·7	67 15·3	06·6	109 25·2	13·0	279 37·2	15·5	219 05·4	46·9
15	135 17·2	82 14·8	·· 07·3	124 26·1	·· 13·6	294 39·7	·· 15·6	234 08·1	·· 46·9
16	150 19·7	97 14·3	08·1	139 26·9	14·3	309 42·1	15·6	249 10·7	46·9
17	165 22·1	112 13·8	08·8	154 27·8	15·0	324 44·6	15·6	264 13·4	46·9
18	180 24·6	127 13·3	N17 09·6	169 28·6	N 2 15·6	339 47·0	S 7 15·6	279 16·0	S21 46·9
19	195 27·1	142 12·8	10·4	184 29·5	16·3	354 49·5	15·6	294 18·7	46·9
20	210 29·5	157 12·3	11·1	199 30·4	16·9	9 51·9	15·7	309 21·4	46·9
21	225 32·0	172 11·8	·· 11·9	214 31·2	·· 17·6	24 54·3	·· 15·7	324 24·0	·· 46·9
22	240 34·4	187 11·3	12·6	229 32·1	18·2	39 56·8	15·7	339 26·7	46·9
23	255 36·9	202 10·8	13·4	244 32·9	18·9	54 59·2	15·7	354 29·3	46·9
23 00	270 39·4	217 10·3	N17 14·1	259 33·8	N 2 19·6	70 01·7	S 7 15·7	9 32·0	S21 46·9
01	285 41·8	232 09·8	14·9	274 34·6	20·2	85 04·1	15·8	24 34·7	46·8
02	300 44·3	247 09·3	15·6	289 35·5	20·9	100 06·5	15·8	39 37·3	46·8
03	315 46·8	262 08·8	·· 16·4	304 36·4	·· 21·5	115 09·0	·· 15·8	54 40·0	·· 46·8
04	330 49·2	277 08·3	17·1	319 37·2	22·2	130 11·4	15·8	69 42·6	46·8
05	345 51·7	292 07·8	17·9	334 38·1	22·9	145 13·9	15·9	84 45·3	46·8
06	0 54·2	307 07·3	N17 18·6	349 38·9	N 2 23·5	160 16·3	S 7 15·9	99 48·0	S21 46·8
07	15 56·6	322 06·8	19·4	4 39·8	24·2	175 18·7	15·9	114 50·6	46·8
08	30 59·1	337 06·3	20·1	19 40·6	24·8	190 21·2	15·9	129 53·3	46·8
M 09	46 01·6	352 05·8	·· 20·9	34 41·5	·· 25·5	205 23·6	·· 15·9	144 55·9	·· 46·8
O 10	61 04·0	7 05·3	21·6	49 42·4	26·1	220 26·1	16·0	159 58·6	46·8
N 11	76 06·5	22 04·8	22·4	64 43·2	26·8	235 28·5	16·0	175 01·2	46·8
D 12	91 08·9	37 04·3	N17 23·1	79 44·1	N 2 27·5	250 30·9	S 7 16·0	190 03·9	S21 46·8
A 13	106 11·4	52 03·8	23·8	94 44·9	28·1	265 33·4	16·0	205 06·6	46·8
Y 14	121 13·9	67 03·3	24·6	109 45·8	28·8	280 35·8	16·1	220 09·2	46·8
15	136 16·3	82 02·8	·· 25·3	124 46·6	·· 29·4	295 38·2	·· 16·1	235 11·9	·· 46·7
16	151 18·8	97 02·2	26·1	139 47·5	30·1	310 40·7	16·1	250 14·5	46·7
17	166 21·3	112 01·7	26·8	154 48·4	30·7	325 43·1	16·1	265 17·2	46·7
18	181 23·7	127 01·2	N17 27·6	169 49·2	N 2 31·4	340 45·6	S 7 16·2	280 19·9	S21 46·7
19	196 26·2	142 00·7	28·3	184 50·1	32·1	355 48·0	16·2	295 22·5	46·7
20	211 28·7	157 00·2	29·0	199 50·9	32·7	10 50·4	16·2	310 25·2	46·7
21	226 31·1	171 59·7	·· 29·8	214 51·8	·· 33·4	25 52·9	·· 16·2	325 27·8	·· 46·7
22	241 33·6	186 59·2	30·5	229 52·7	34·0	40 55·3	16·2	340 30·5	46·7
23	256 36·0	201 58·7	31·2	244 53·5	34·7	55 57·7	16·3	355 33·1	46·7
Mer. Pass.	h m 6 00·3	♀ −0·5	♂ 0·9	♀ 0·9	♂ 0·7	♀ 2·4	♂ 0·0	♀ 2·7	♂ 0·0

STARS

Name	S.H.A. ° ′	Dec. ° ′
Acamar	315 50·0	S 40 28·1
Achernar	335 57·8	S 57 26·6
Acrux	173 55·3	S 62 52·5
Adhara	255 45·4	S 28 55·1
Aldebaran	291 37·1	N 16 25·5
Alioth	166 56·9	N 56 11·4
Alkaid	153 31·2	N 49 31·5
Al Na'ir	28 35·4	S 47 09·4
Alnilam	276 28·6	S 1 13·8
Alphard	218 36·9	S 8 28·8
Alphecca	126 45·7	N 26 51·4
Alpheratz	358 26·3	N 28 51·6
Altair	62 48·2	N 8 45·6
Ankaa	353 56·5	S 42 31·6
Antares	113 16·6	S 26 20·4
Arcturus	146 33·2	N 19 24·0
Atria	108 55·0	S 68 57·2
Avior	234 35·4	S 59 22·8
Bellatrix	279 16·7	N 6 18·7
Betelgeuse	271 46·4	N 7 23·9
Canopus	264 15·0	S 52 40·5
Capella	281 36·0	N 45 57·3
Deneb	49 59·2	N 45 07·9
Denebola	183 15·8	N 14 48·3
Diphda	349 37·4	S 18 12·7
Dubhe	194 42·6	N 61 58·7
Elnath	279 05·3	N 28 34·3
Eltanin	91 04·8	N 51 29·7
Enif	34 27·5	N 9 41·1
Fomalhaut	16 09·4	S 29 50·3
Gacrux	172 46·8	S 56 53·2
Gienah	176 34·8	S 17 18·8
Hadar	149 46·2	S 60 10·6
Hamal	328 47·6	N 23 15·9
Kaus Aust.	84 38·2	S 34 24·2
Kochab	137 17·5	N 74 19·8
Markab	14 19·4	N 14 58·9
Menkar	314 58·5	N 3 55·6
Menkent	148 56·1	S 36 10·1
Miaplacidus	221 49·0	S 69 33·1
Mirfak	309 39·9	N 49 42·7
Nunki	76 49·1	S 26 20·8
Peacock	54 23·8	S 56 51·9
Pollux	244 18·6	N 28 07·6
Procyon	245 43·3	N 5 19·8
Rasalhague	96 44·5	N 12 35·5
Regulus	208 27·6	N 12 10·2
Rigel	281 52·1	S 8 15·0
Rigil Kent.	140 47·7	S 60 40·1
Sabik	102 59·6	S 15 40·4
Schedar	350 27·7	N 56 18·3
Shaula	97 17·6	S 37 04·4
Sirius	259 10·5	S 16 39·6
Spica	159 14·7	S 10 56·8
Suhail	223 23·1	S 43 16·1
Vega	81 06·5	N 38 44·8
Zuben'ubi	137 51·0	S 15 52·2

	S.H.A. ° ′	Mer. Pass. h m
Venus	307 42·0	9 31
Mars	349 33·1	6 43
Jupiter	159 22·8	19 21
Saturn	98 48·0	23 22

JUNE 21, 22, 23 (SAT., SUN., MON.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	v	MOON Dec.	d	H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
21 00	179 38·1	N23 26·4	132 53·6	9·7	N11 42·5	9·0	58·2
01	194 38·0	26·4	147 22·3	9·7	11 33·5	9·2	58·3
02	209 37·9	26·4	161 51·0	9·7	11 24·3	9·2	58·3
03	224 37·7	26·4	176 19·7	9·7	11 15·1	9·3	58·3
04	239 37·6	26·4	190 48·4	9·7	11 05·8	9·3	58·3
05	254 37·5	26·4	205 17·1	9·8	10 56·5	9·4	58·3
06	269 37·3	N23 26·4	219 45·9	9·8	N10 47·1	9·5	58·3
07	284 37·2	26·4	234 14·7	9·8	10 37·6	9·6	58·4
S 08	299 37·0	26·5	248 43·5	9·8	10 28·0	9·6	58·4
A 09	314 36·9	26·5	263 12·3	9·9	10 18·4	9·6	58·4
T 10	329 36·8	26·5	277 41·2	9·8	10 08·8	9·8	58·4
U 11	344 36·6	26·5	292 10·0	9·9	9 59·0	9·8	58·4
R 12	359 36·5	N23 26·5	306 38·9	9·9	N 9 49·2	9·8	58·4
D 13	14 36·4	26·5	321 07·8	9·9	9 39·4	9·9	58·4
A 14	29 36·2	26·5	335 36·7	9·9	9 29·5	10·0	58·5
Y 15	44 36·1	26·5	350 05·6	10·0	9 19·5	10·0	58·5
16	59 35·9	26·5	4 34·6	9·9	9 09·5	10·1	58·5
17	74 35·8	26·5	19 03·5	10·0	8 59·4	10·1	58·5
18	89 35·7	N23 26·5	33 32·5	10·0	N 8 49·3	10·2	58·5
19	104 35·5	26·5	48 01·5	10·0	8 39·1	10·3	58·5
20	119 35·4	26·5	62 30·5	10·0	8 28·8	10·2	58·6
21	134 35·3	26·5	76 59·5	10·1	8 18·6	10·4	58·6
22	149 35·1	26·5	91 28·6	10·0	8 08·2	10·4	58·6
23	164 35·0	26·5	105 57·6	10·1	7 57·8	10·4	58·6
22 00	179 34·9	N23 26·5	120 26·7	10·1	N 7 47·4	10·5	58·6
01	194 34·7	26·5	134 55·8	10·1	7 36·9	10·6	58·6
02	209 34·6	26·5	149 24·9	10·1	7 26·3	10·5	58·6
03	224 34·4	26·5	163 54·0	10·1	7 15·8	10·7	58·7
04	239 34·3	26·5	178 23·1	10·1	7 05·1	10·6	58·7
05	254 34·2	26·5	192 52·2	10·1	6 54·5	10·8	58·7
06	269 34·0	N23 26·5	207 21·3	10·2	N 6 43·7	10·7	58·7
07	284 33·9	26·5	221 50·5	10·2	6 33·0	10·8	58·7
08	299 33·8	26·5	236 19·7	10·1	6 22·2	10·8	58·7
S 09	314 33·6	26·5	250 48·8	10·2	6 11·4	10·9	58·7
U 10	329 33·5	26·5	265 18·0	10·2	6 00·5	10·9	58·8
N 11	344 33·4	26·5	279 47·2	10·2	5 49·6	11·0	58·8
D 12	359 33·2	N23 26·5	294 16·4	10·2	N 5 38·6	11·0	58·8
A 13	14 33·1	26·4	308 45·6	10·2	5 27·6	11·0	58·8
Y 14	29 32·9	26·4	323 14·8	10·2	5 16·6	11·0	58·8
15	44 32·8	26·4	337 44·0	10·3	5 05·6	11·1	58·8
16	59 32·7	26·4	352 13·3	10·2	4 54·5	11·1	58·8
17	74 32·5	26·4	6 42·5	10·2	4 43·4	11·2	58·8
18	89 32·4	N23 26·4	21 11·7	10·3	N 4 32·2	11·2	58·9
19	104 32·3	26·4	35 41·0	10·2	4 21·0	11·2	58·9
20	119 32·1	26·4	50 10·2	10·3	4 09·8	11·2	58·9
21	134 32·0	26·3	64 39·5	10·2	3 58·6	11·3	58·9
22	149 31·9	26·3	79 08·7	10·3	3 47·3	11·2	58·9
23	164 31·7	26·3	93 38·0	10·2	3 36·1	11·4	58·9
23 00	179 31·6	N23 26·3	108 07·2	10·3	N 3 24·7	11·3	58·9
01	194 31·5	26·3	122 36·5	10·3	3 13·4	11·3	58·9
02	209 31·3	26·2	137 05·8	10·2	3 02·1	11·4	59·0
03	224 31·2	26·2	151 35·0	10·3	2 50·7	11·4	59·0
04	239 31·1	26·2	166 04·3	10·2	2 39·3	11·4	59·0
05	254 30·9	26·2	180 33·5	10·3	2 27·9	11·4	59·0
06	269 30·8	N23 26·2	195 02·8	10·2	N 2 16·5	11·5	59·0
07	284 30·6	26·1	209 32·0	10·3	2 05·0	11·5	59·0
08	299 30·5	26·1	224 01·3	10·2	1 53·5	11·4	59·0
M 09	314 30·4	26·1	238 30·5	10·3	1 42·1	11·5	59·0
O 10	329 30·2	26·1	252 59·8	10·2	1 30·6	11·5	59·0
N 11	344 30·1	26·0	267 29·0	10·2	1 19·1	11·5	59·1
D 12	359 30·0	N23 26·0	281 58·2	10·3	N 1 07·6	11·5	59·1
A 13	14 29·8	26·0	296 27·5	10·2	0 56·1	11·6	59·1
Y 14	29 29·7	26·0	310 56·7	10·2	0 44·5	11·5	59·1
15	44 29·6	25·9	325 25·9	10·2	0 33·0	11·6	59·1
16	59 29·4	25·9	339 55·1	10·2	0 21·4	11·5	59·1
17	74 29·3	25·9	354 24·3	10·1	N 0 09·9	11·6	59·1
18	89 29·2	N23 25·8	8 53·4	10·2	S 0 01·7	11·5	59·1
19	104 29·0	25·8	23 22·6	10·2	0 13·2	11·6	59·1
20	119 28·9	25·8	37 51·8	10·1	0 24·8	11·6	59·1
21	134 28·8	25·7	52 20·9	10·2	0 36·4	11·5	59·2
22	149 28·6	25·7	66 50·1	10·1	0 47·9	11·6	59·2
23	164 28·5	25·7	81 19·2	10·1	0 59·5	11·5	59·2
	S.D. 15·8	d 0·0	S.D. 15·9		16·0		16·1

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 21	Moonrise 22	Moonrise 23	Moonrise 24
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	07 05	09 01	10 55	12 51
N 70	□	□	□	07 22	09 10	10 57	12 45
68	□	□	□	07 36	09 17	10 59	12 41
66	□	□	□	07 48	09 23	11 00	12 37
64	////	////	01 31	07 57	09 28	11 01	12 34
62	////	////	02 09	08 05	09 33	11 01	12 31
60	////	00 49	02 36	08 12	09 37	11 02	12 29
N 58	////	01 40	02 56	08 18	09 40	11 03	12 27
56	////	02 10	03 13	08 24	09 43	11 04	12 25
54	00 45	02 33	03 27	08 29	09 46	11 04	12 23
52	01 32	02 51	03 40	08 33	09 48	11 05	12 22
50	02 00	03 06	03 51	08 37	09 50	11 05	12 20
45	02 46	03 36	04 13	08 45	09 55	11 06	12 17
N 40	03 17	03 58	04 31	08 53	09 59	11 07	12 15
35	03 40	04 17	04 46	08 59	10 03	11 07	12 13
30	03 59	04 32	04 59	09 04	10 06	11 08	12 11
20	04 28	04 57	05 22	09 13	10 11	11 09	12 08
N 10	04 50	05 17	05 40	09 21	10 16	11 10	12 05
0	05 09	05 36	05 58	09 29	10 20	11 11	12 02
S 10	05 26	05 53	06 16	09 36	10 24	11 12	12 00
20	05 43	06 10	06 34	09 44	10 29	11 13	11 57
30	05 59	06 29	06 55	09 54	10 34	11 14	11 54
35	06 08	06 40	07 08	09 59	10 37	11 15	11 52
40	06 17	06 51	07 22	10 05	10 41	11 16	11 50
45	06 28	07 05	07 39	10 12	10 45	11 17	11 48
S 50	06 40	07 21	08 00	10 20	10 50	11 18	11 46
52	06 45	07 29	08 10	10 24	10 52	11 18	11 44
54	06 50	07 37	08 21	10 28	10 54	11 19	11 43
56	06 57	07 46	08 33	10 32	10 57	11 19	11 42
58	07 03	07 56	08 48	10 38	11 00	11 20	11 40
S 60	07 11	08 08	09 06	10 43	11 03	11 21	11 38

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 21	Moonset 22	Moonset 23	Moonset 24
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	23 36	23 28	23 20	23 13
N 70	□	□	□	23 25	23 24	23 22	23 21
68	□	□	□	23 16	23 20	23 23	23 27
66	□	□	□	23 08	23 17	23 24	23 33
64	22 32	////	////	23 01	23 14	23 25	23 37
62	21 54	////	////	22 56	23 12	23 26	23 41
60	21 28	23 14	////	22 51	23 10	23 27	23 45
N 58	21 07	22 23	////	22 47	23 08	23 27	23 48
56	20 50	21 53	////	22 43	23 06	23 28	23 51
54	20 36	21 31	23 18	22 39	23 04	23 29	23 54
52	20 24	21 13	22 31	22 36	23 03	23 29	23 56
50	20 13	20 58	22 03	22 33	23 02	23 30	23 58
45	19 50	20 28	21 18	22 27	22 59	23 30	24 03
N 40	19 32	20 05	20 47	22 22	22 57	23 31	24 07
35	19 17	19 47	20 24	22 17	22 55	23 32	24 10
30	19 04	19 32	20 05	22 13	22 53	23 33	24 13
20	18 42	19 07	19 36	22 06	22 50	23 34	24 18
N 10	18 23	18 46	19 13	21 59	22 47	23 34	24 23
0	18 05	18 28	18 54	21 53	22 44	23 35	24 27
S 10	17 48	18 11	18 37	21 47	22 42	23 36	24 31
20	17 30	17 53	18 21	21 41	22 39	23 37	24 36
30	17 08	17 35	18 04	21 33	22 35	23 38	24 41
35	16 56	17 24	17 56	21 29	22 33	23 38	24 44
40	16 42	17 12	17 46	21 24	22 31	23 39	24 47
45	16 25	16 59	17 36	21 19	22 29	23 40	24 51
S 50	16 04	16 43	17 24	21 12	22 26	23 40	24 56
52	15 54	16 35	17 19	21 08	22 24	23 41	24 58
54	15 43	16 27	17 13	21 05	22 23	23 41	25 01
56	15 30	16 18	17 07	21 01	22 21	23 42	25 03
58	15 16	16 07	17 00	20 57	22 19	23 42	25 06
S 60	14 58	15 56	16 52	20 52	22 17	23 43	25 09

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
21	01 27	01 34	12 02	15 41	03 15	04	
22	01 40	01 47	12 02	16 32	04 07	05	
23	01 53	02 00	12 02	17 23	04 58	06	

JUNE 24, 25, 26 (TUES., WED., THURS.)

G.M.T.	ARIES	VENUS −3·4		MARS +0·3		JUPITER −1·7		SATURN +0·3		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
24 00	271 38·5	216 58·2	N17 32·0	259 54·4	N 2 35·3	71 00·2	S 7 16·3	10 35·0	S21 46·7	Acamar	315 50·0	S 40 28·1
01	286 41·0	231 57·6	32·7	274 55·2	36·0	86 02·6	16·3	25 38·5	46·7	Achernar	335 57·8	S 57 26·6
02	301 43·4	246 57·1	33·5	289 56·1	36·6	101 05·0	16·3	40 41·1	46·7	Acrux	173 55·4	S 62 52·5
03	316 45·9	261 56·6	·· 34·2	304 56·9	·· 37·3	116 07·5	·· 16·4	55 43·8	·· 46·7	Adhara	255 45·4	S 28 55·0
04	331 48·4	276 56·1	34·9	319 57·8	38·0	131 09·9	16·4	70 46·4	46·7	Aldebaran	291 37·1	N 16 25·5
05	346 50·8	291 55·6	35·7	334 58·7	38·6	146 12·3	16·4	85 49·1	46·6			
06	1 53·3	306 55·1	N17 36·4	349 59·5	N 2 39·3	161 14·8	S 7 16·4	100 51·7	S21 46·6	Alioth	166 56·9	N 56 11·4
07	16 55·8	321 54·5	37·1	5 00·4	39·9	176 17·2	16·5	115 54·4	46·6	Alkaid	153 31·3	N 49 31·5
T 08	31 58·2	336 54·0	37·8	20 01·2	40·6	191 19·6	16·5	130 57·1	46·6	Al Na'ir	28 35·4	S 47 09·4
U 09	47 00·7	351 53·5	·· 38·6	35 02·1	·· 41·2	206 22·1	·· 16·5	145 59·7	·· 46·6	Alnilam	276 28·6	S 1 13·7
E 10	62 03·2	6 53·0	39·3	50 03·0	41·9	221 24·5	16·5	161 02·4	46·6	Alphard	218 36·9	S 8 28·8
S 11	77 05·6	21 52·5	40·0	65 03·8	42·5	236 26·9	16·6	176 05·0	46·6			
D 12	92 08·1	36 52·0	N17 40·8	80 04·7	N 2 43·2	251 29·3	S 7 16·6	191 07·7	S21 46·6	Alphecca	126 45·7	N 26 51·4
A 13	107 10·5	51 51·4	41·5	95 05·6	43·8	266 31·8	16·6	206 10·3	46·6	Alpheratz	358 26·2	N 28 51·6
Y 14	122 13·0	66 50·9	42·2	110 06·4	44·5	281 34·2	16·6	221 13·0	46·6	Altair	62 48·2	N 8 45·6
15	137 15·5	81 50·4	·· 42·9	125 07·3	·· 45·2	296 36·6	·· 16·7	236 15·7	·· 46·6	Ankaa	353 56·5	S 42 31·6
16	152 17·9	96 49·9	43·7	140 08·1	45·8	311 39·1	16·7	251 18·3	46·6	Antares	113 16·6	S 26 20·4
17	167 20·4	111 49·4	44·4	155 09·0	46·5	326 41·5	16·7	266 21·0	46·6			
18	182 22·9	126 48·8	N17 45·1	170 09·9	N 2 47·1	341 43·9	S 7 16·7	281 23·6	S21 46·6	Arcturus	146 33·3	N 19 24·0
19	197 25·3	141 48·3	45·8	185 10·7	47·8	356 46·4	16·8	296 26·3	46·6	Atria	108 55·0	S 68 57·3
20	212 27·8	156 47·8	46·6	200 11·6	48·4	11 48·8	16·8	311 28·9	46·5	Avior	234 35·4	S 59 22·8
21	227 30·3	171 47·3	·· 47·3	215 12·4	·· 49·1	26 51·2	·· 16·8	326 31·6	·· 46·5	Bellatrix	279 16·7	N 6 18·7
22	242 32·7	186 46·7	48·0	230 13·3	49·7	41 53·6	16·9	341 34·3	46·5	Betelgeuse	271 46·4	N 7 23·9
23	257 35·2	201 46·2	48·7	245 14·2	50·4	56 56·1	16·9	356 36·9	46·5			
25 00	272 37·7	216 45·7	N17 49·4	260 15·0	N 2 51·0	71 58·5	S 7 16·9	11 39·6	S21 46·5	Canopus	264 15·0	S 52 40·5
01	287 40·1	231 45·2	50·2	275 15·9	51·7	87 00·9	16·9	26 42·2	46·5	Capella	281 36·0	N 45 57·3
02	302 42·6	246 44·6	50·9	290 16·8	52·3	102 03·3	17·0	41 44·9	46·5	Deneb	49 59·2	N 45 07·9
03	317 45·0	261 44·1	·· 51·6	305 17·6	·· 53·0	117 05·8	·· 17·0	56 47·5	·· 46·5	Denebola	183 15·8	N 14 48·3
04	332 47·5	276 43·6	52·3	320 18·5	53·6	132 08·2	17·0	71 50·2	46·5	Diphda	349 37·4	S 18 12·7
05	347 50·0	291 43·1	53·0	335 19·3	54·3	147 10·6	17·0	86 52·8	46·5			
06	2 52·4	306 42·5	N17 53·7	350 20·2	N 2 55·0	162 13·0	S 7 17·1	101 55·5	S21 46·5	Dubhe	194 42·6	N 61 58·7
W 07	17 54·9	321 42·0	54·5	5 21·1	55·6	177 15·5	17·1	116 58·2	46·5	Elnath	279 05·2	N 28 34·3
E 08	32 57·4	336 41·5	55·2	20 21·9	56·3	192 17·9	17·1	132 00·8	46·5	Eltanin	91 04·8	N 51 29·8
D 09	47 59·8	351 41·0	·· 55·9	35 22·8	·· 56·9	207 20·3	·· 17·2	147 03·5	·· 46·5	Enif	34 27·5	N 9 41·1
N 10	63 02·3	6 40·4	56·6	50 23·7	57·6	222 22·7	17·2	162 06·1	46·5	Fomalhaut	16 09·4	S 29 50·3
E 11	78 04·8	21 39·9	57·3	65 24·5	58·2	237 25·2	17·2	177 08·8	46·4			
S 12	93 07·2	36 39·4	N17 58·0	80 25·4	N 2 58·9	252 27·6	S 7 17·2	192 11·4	S21 46·4	Gacrux	172 46·8	S 56 53·2
D 13	108 09·7	51 38·8	58·7	95 26·2	2 59·5	267 30·0	17·3	207 14·1	46·4	Gienah	176 34·8	S 17 18·8
A 14	123 12·1	66 38·3	17 59·4	110 27·1	3 00·2	282 32·4	17·3	222 16·8	46·4	Hadar	149 46·2	S 60 10·7
Y 15	138 14·6	81 37·8	18 00·1	125 28·0	·· 00·8	297 34·9	·· 17·3	237 19·4	·· 46·4	Hamal	328 47·6	N 23 15·9
16	153 17·1	96 37·2	00·9	140 28·8	01·5	312 37·3	17·4	252 22·1	46·4	Kaus Aust.	84 38·2	S 34 24·2
17	168 19·5	111 36·7	01·6	155 29·7	02·1	327 39·7	17·4	267 24·7	46·4			
18	183 22·0	126 36·2	N18 02·3	170 30·6	N 3 02·8	342 42·1	S 7 17·4	282 27·4	S21 46·4	Kochab	137 17·5	N 74 19·8
19	198 24·5	141 35·6	03·0	185 31·4	03·4	357 44·5	17·4	297 30·0	46·4	Markab	14 19·4	N 14 58·9
20	213 26·9	156 35·1	03·7	200 32·3	04·1	12 47·0	17·5	312 32·7	46·4	Menkar	314 58·5	N 3 55·6
21	228 29·4	171 34·6	·· 04·4	215 33·2	·· 04·7	27 49·4	·· 17·5	327 35·3	·· 46·4	Menkent	148 56·1	S 36 10·1
22	243 31·9	186 34·0	05·1	230 34·0	05·4	42 51·8	17·5	342 38·0	46·4	Miaplacidus	221 49·0	S 69 33·1
23	258 34·3	201 33·5	05·8	245 34·9	06·0	57 54·2	17·6	357 40·7	46·4			
26 00	273 36·8	216 32·9	N18 06·5	260 35·8	N 3 06·7	72 56·6	S 7 17·6	12 43·3	S21 46·4	Mirfak	309 39·9	N 49 42·7
01	288 39·3	231 32·4	07·2	275 36·6	07·3	87 59·1	17·6	27 46·0	46·3	Nunki	76 49·1	S 26 20·8
02	303 41·7	246 31·9	07·9	290 37·5	08·0	103 01·5	17·6	42 48·6	46·3	Peacock	54 23·8	S 56 51·9
03	318 44·2	261 31·3	·· 08·6	305 38·4	·· 08·6	118 03·9	·· 17·7	57 51·3	·· 46·3	Pollux	244 18·6	N 28 07·6
04	333 46·6	276 30·8	09·3	320 39·2	09·3	133 06·3	17·7	72 53·9	46·3	Procyon	245 43·5	N 5 19·8
05	348 49·1	291 30·3	10·0	335 40·1	09·9	148 08·7	17·7	87 56·6	46·3			
06	3 51·6	306 29·7	N18 10·7	350 41·0	N 3 10·6	163 11·2	S 7 17·8	102 59·2	S21 46·3	Rasalhague	96 44·5	N 12 35·5
T 07	18 54·0	321 29·2	11·4	5 41·8	11·2	178 13·6	17·8	118 01·9	46·3	Regulus	208 27·6	N 12 10·2
H 08	33 56·5	336 28·6	12·1	20 42·7	11·9	193 16·0	17·8	133 04·6	46·3	Rigel	281 52·1	S 8 15·0
U 09	48 59·0	351 28·1	·· 12·8	35 43·6	·· 12·5	208 18·4	·· 17·9	148 07·2	·· 46·3	Rigil Kent.	140 47·8	S 60 40·1
R 10	64 01·4	6 27·6	13·5	50 44·4	13·2	223 20·8	17·9	163 09·9	46·3	Sabik	102 59·6	S 15 40·4
S 11	79 03·9	21 27·0	14·2	65 45·3	13·8	238 23·2	17·9	178 12·5	46·3			
D 12	94 06·4	36 26·5	N18 14·9	80 46·2	N 3 14·5	253 25·7	S 7 18·0	193 15·2	S21 46·3	Schedar	350 27·7	N 56 18·4
A 13	109 08·8	51 25·9	15·6	95 47·0	15·1	268 28·1	18·0	208 17·8	46·3	Shaula	97 17·6	S 37 04·4
Y 14	124 11·3	66 25·4	16·3	110 47·9	15·8	283 30·5	18·0	223 20·5	46·3	Sirius	259 10·5	S 16 39·6
15	139 13·8	81 24·8	·· 16·9	125 48·8	·· 16·4	298 32·9	·· 18·0	238 23·1	·· 46·3	Spica	159 14·7	S 10 56·8
16	154 16·2	96 24·3	17·6	140 49·6	17·1	313 35·3	18·1	253 25·8	46·2	Suhail	223 23·1	S 43 16·1
17	169 18·7	111 23·8	18·3	155 50·5	17·7	328 37·7	18·1	268 28·5	46·2			
18	184 21·1	126 23·2	N18 19·0	170 51·4	N 3 18·4	343 40·2	S 7 18·1	283 31·1	S21 46·2	Vega	81 06·5	N 38 44·8
19	199 23·6	141 22·7	19·7	185 52·2	19·0	358 42·6	18·2	298 33·8	46·2	Zuben'ubi	137 51·0	S 15 52·2
20	214 26·1	156 22·1	20·4	200 53·1	19·7	13 45·0	18·2	313 36·4	46·2		S.H.A.	Mer. Pass.
21	229 28·5	171 21·6	·· 21·1	215 54·0	·· 20·3	28 47·4	·· 18·2	328 39·1	·· 46·2		° ′	h m
22	244 31·0	186 21·0	21·8	230 54·8	21·0	43 49·8	18·3	343 41·7	46·2	Venus	304 08·0	9 33
23	259 33·5	201 20·5	22·5	245 55·7	21·6	58 52·2	18·3	358 44·4	46·2	Mars	347 37·3	6 39
										Jupiter	159 20·8	19 09
Mer. Pass.	h m 5 48·5	v −0·5	d 0·7	v 0·9	d 0·7	v 2·4	d 0·0	v 2·7	d 0·0	Saturn	99 01·9	23 09

JUNE 24, 25, 26 (TUES., WED., THURS.)

G.M.T.	SUN G.H.A.	Dec.	MOON G.H.A.	v	Dec.	d	H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
24 00	179 28·4	N23 25·6	95 48·3	10·1	S 1 11·0	11·6	59·2
01	194 28·2	25·6	110 17·4	10·1	1 22·6	11·5	59·2
02	209 28·1	25·6	124 46·5	10·0	1 34·1	11·6	59·2
03	224 28·0	25·5	139 15·5	10·1	1 45·7	11·5	59·2
04	239 27·8	25·5	153 44·6	10·0	1 57·2	11·6	59·2
05	254 27·7	25·4	168 13·6	10·0	2 08·8	11·5	59·2
06	269 27·5	N23 25·4	182 42·6	10·0	S 2 20·3	11·5	59·2
07	284 27·4	25·4	197 11·6	10·0	2 31·8	11·5	59·2
08	299 27·3	25·3	211 40·6	10·0	2 43·3	11·5	59·2
09	314 27·1	25·3	226 09·6	9·9	2 54·8	11·5	59·3
10	329 27·0	25·2	240 38·5	9·9	3 06·3	11·4	59·3
11	344 26·9	25·2	255 07·4	9·9	3 17·7	11·5	59·3
12	359 26·7	N23 25·2	269 36·3	9·9	S 3 29·2	11·4	59·3
13	14 26·6	25·1	284 05·2	9·8	3 40·6	11·4	59·3
14	29 26·5	25·1	298 34·0	9·8	3 52·0	11·4	59·3
15	44 26·3	25·0	313 02·8	9·8	4 03·4	11·4	59·3
16	59 26·2	25·0	327 31·6	9·8	4 14·8	11·3	59·3
17	74 26·1	24·9	342 00·4	9·8	4 26·1	11·3	59·3
18	89 25·9	N23 24·9	356 29·2	9·7	S 4 37·4	11·3	59·3
19	104 25·8	24·8	10 57·9	9·7	4 48·7	11·3	59·3
20	119 25·7	24·8	25 26·6	9·7	5 00·0	11·2	59·3
21	134 25·5	24·7	39 55·3	9·6	5 11·2	11·3	59·3
22	149 25·4	24·7	54 23·9	9·6	5 22·5	11·2	59·3
23	164 25·3	24·6	68 52·5	9·6	5 33·7	11·1	59·3
25 00	179 25·1	N23 24·6	83 21·1	9·6	S 5 44·8	11·2	59·4
01	194 25·0	24·5	97 49·7	9·5	5 56·0	11·1	59·4
02	209 24·9	24·5	112 18·2	9·5	6 07·1	11·0	59·4
03	224 24·7	24·4	126 46·7	9·5	6 18·1	11·1	59·4
04	239 24·6	24·3	141 15·2	9·4	6 29·2	11·0	59·4
05	254 24·5	24·3	155 43·6	9·4	6 40·2	10·9	59·4
06	269 24·3	N23 24·2	170 12·0	9·4	S 6 51·1	10·9	59·4
07	284 24·2	24·2	184 40·4	9·4	7 02·0	10·9	59·4
08	299 24·1	24·1	199 08·8	9·3	7 12·9	10·9	59·4
09	314 23·9	24·1	213 37·1	9·2	7 23·8	10·8	59·4
10	329 23·8	24·0	228 05·3	9·3	7 34·6	10·7	59·4
11	344 23·7	23·9	242 33·6	9·2	7 45·3	10·7	59·4
12	359 23·5	N23 23·9	257 01·8	9·2	S 7 56·0	10·7	59·4
13	14 23·4	23·8	271 30·0	9·1	8 06·7	10·6	59·4
14	29 23·3	23·8	285 58·1	9·1	8 17·3	10·6	59·4
15	44 23·1	23·7	300 26·2	9·0	8 27·9	10·5	59·4
16	59 23·0	23·6	314 54·2	9·1	8 38·4	10·5	59·4
17	74 22·9	23·6	329 22·3	9·0	8 48·9	10·5	59·4
18	89 22·7	N23 23·5	343 50·3	8·9	S 8 59·4	10·3	59·4
19	104 22·6	23·4	358 18·2	8·9	9 09·7	10·4	59·4
20	119 22·5	23·4	12 46·1	8·9	9 20·1	10·2	59·4
21	134 22·3	23·3	27 14·0	8·8	9 30·3	10·2	59·4
22	149 22·2	23·2	41 41·8	8·8	9 40·5	10·2	59·4
23	164 22·1	23·2	56 09·6	8·8	9 50·7	10·1	59·4
26 00	179 21·9	N23 23·1	70 37·4	8·7	S10 00·8	10·0	59·4
01	194 21·8	23·0	85 05·1	8·7	10 10·8	10·0	59·4
02	209 21·7	22·9	99 32·8	8·6	10 20·8	9·9	59·4
03	224 21·6	22·9	114 00·4	8·6	10 30·7	9·9	59·4
04	239 21·4	22·8	128 28·0	8·6	10 40·6	9·8	59·4
05	254 21·3	22·7	142 55·6	8·5	10 50·4	9·7	59·5
06	269 21·2	N23 22·7	157 23·1	8·5	S11 00·1	9·7	59·5
07	284 21·0	22·6	171 50·6	8·4	11 09·8	9·6	59·5
08	299 20·9	22·5	186 18·0	8·4	11 19·4	9·5	59·5
09	314 20·8	22·4	200 45·4	8·3	11 28·9	9·5	59·5
10	329 20·6	22·4	215 12·7	8·4	11 38·4	9·3	59·5
11	344 20·5	22·3	229 40·1	8·2	11 47·7	9·4	59·5
12	359 20·4	N23 22·2	244 07·3	8·2	S11 57·1	9·2	59·5
13	14 20·2	22·1	258 34·5	8·2	12 06·3	9·2	59·4
14	29 20·1	22·0	273 01·7	8·2	12 15·5	9·1	59·4
15	44 20·0	22·0	287 28·9	8·1	12 24·6	9·0	59·4
16	59 19·8	21·9	301 56·0	8·0	12 33·6	9·0	59·4
17	74 19·7	21·8	316 23·0	8·1	12 42·6	8·8	59·4
18	89 19·6	N23 21·7	330 50·1	7·9	S12 51·4	8·8	59·4
19	104 19·5	21·6	345 17·0	8·0	13 00·2	8·7	59·4
20	119 19·3	21·5	359 44·0	7·9	13 08·9	8·6	59·4
21	134 19·2	21·5	14 10·9	7·8	13 17·5	8·6	59·4
22	149 19·1	21·4	28 37·7	7·8	13 26·1	8·4	59·4
23	164 18·9	21·3	43 04·5	7·8	13 34·5	8·4	59·4
	S.D. 15·8	d 0·1	S.D.	16·2		16·2	16·2

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 24	25	26	27
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	12 51	14 49	16 52	19 08
N 70	□	□	□	12 45	14 35	16 28	18 22
68	□	□	□	12 41	14 24	16 09	17 53
66	□	□	□	12 37	14 15	15 54	17 30
64	////	////	01 32	12 34	14 08	15 42	17 13
62	////	////	02 10	12 31	14 01	15 31	16 59
60	////	00 51	02 37	12 29	13 56	15 22	16 47
N 58	////	01 42	02 57	12 27	13 51	15 15	16 36
56	////	02 12	03 14	12 25	13 47	15 08	16 27
54	00 47	02 34	03 28	12 23	13 43	15 02	16 19
52	01 34	02 52	03 41	12 22	13 39	14 56	16 12
50	02 01	03 07	03 51	12 20	13 36	14 52	16 06
45	02 47	03 37	04 14	12 17	13 29	14 41	15 52
N 40	03 18	03 59	04 32	12 15	13 23	14 32	15 41
35	03 41	04 17	04 47	12 13	13 19	14 25	15 31
30	03 59	04 33	05 00	12 11	13 14	14 18	15 22
20	04 28	04 58	05 22	12 08	13 07	14 07	15 08
N 10	04 51	05 18	05 41	12 05	13 00	13 57	14 55
0	05 10	05 36	05 59	12 02	12·54	13 48	14 44
S 10	05 27	05 53	06 16	12 00	12 49	13 39	14 32
20	05 43	06 11	06 35	11 57	12 42	13 29	14 19
30	06 00	06 30	06 56	11 54	12 35	13 19	14 05
35	06 08	06 40	07 08	11 52	12 31	13 12	13 57
40	06 18	06 52	07 22	11 50	12 27	13 05	13 48
45	06 28	07 05	07 39	11 48	12 21	12 57	13 37
S 50	06 40	07 21	08 00	11 46	12 15	12 47	13 24
52	06 45	07 29	08 10	11 44	12 12	12 43	13 18
54	06 51	07 37	08 21	11 43	12 09	12 38	13 11
56	06 57	07 46	08 34	11 42	12 05	12 32	13 04
58	07 04	07 57	08 48	11 40	12 02	12 26	12 56
S 60	07 11	08 08	09 06	11 38	11 57	12 19	12 46

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 24	25	26	27
°	h m	h m	h m	h m	h m	h m	h m
N 72	□	□	□	23 13	23 04	22 53	22 35
N 70	□	□	□	23 21	23 19	23 19	23 21
68	□	□	□	23 27	23 32	23 39	23 51
66	□	□	□	23 33	23 42	23 55	24 14
64	22 32	////	////	23 37	23 51	24 08	00 08
62	21 54	////	////	23 41	23 59	24 19	00 19
60	21 28	23 13	////	23 45	24 05	00 05	00 29
N 58	21 07	22 23	////	23 48	24 11	00 11	00 37
56	20 51	21 53	////	23 51	24 16	00 16	00 45
54	20 36	21 31	23 17	23 54	24 20	00 20	00 51
52	20 24	21 13	22 31	23 56	24 25	00 25	00 57
50	20 13	20 58	22 03	23 58	24 28	00 28	01 03
45	19 51	20 28	21 18	24 03	00 03	00 37	01 14
N 40	19 33	20 06	20 47	24 07	00 07	00 44	01 24
35	19 18	19 47	20 24	24 10	00 10	00 50	01 33
30	19 05	19 32	20 05	24 13	00 13	00 55	01 40
20	18 43	19 07	19 37	24 18	00 18	01 04	01 53
N 10	18 24	18 47	19 14	24 23	00 23	01 12	02 04
0	18 06	18 29	18 55	24 27	00 27	01 20	02 14
S 10	17 49	18 11	18 38	24 31	00 31	01 27	02 25
20	17 30	17 54	18 22	24 36	00 36	01 35	02 36
30	17 09	17 35	18 05	24 41	00 41	01 45	02 49
35	16 57	17 25	17 57	24 44	00 44	01 50	02 56
40	16 42	17 13	17 47	24 47	00 47	01 56	03 05
45	16 26	16 59	17 37	24 51	00 51	02 03	03 15
S 50	16 05	16 44	17 25	24 56	00 56	02 12	03 27
52	15 55	16 36	17 20	24 58	00 58	02 16	03 32
54	15 44	16 28	17 14	25 01	01 01	02 20	03 38
56	15 31	16 19	17 08	25 03	01 03	02 25	03 45
58	15 17	16 09	17 01	25 06	01 06	02 30	03 53
S 60	14 59	15 57	16 53	25 09	01 09	02 36	04 02

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
24	02 06	02 13	12 02	18 15	05 49	07	
25	02 19	02 26	12 02	19 07	06 41	08	◐
26	02 32	02 38	12 03	20 01	07 34	09	

SEPTEMBER 19, 20, 21 (FRI., SAT., SUN.)

G.M.T.	ARIES	VENUS −3·4		MARS −0·9		JUPITER −1·3		SATURN +0·7	
d h	G.H.A. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′
19 00	357 23·6	193 43·8	N 8 24·7	299 44·2	N18 05·6	147 02·1	S11 17·4	98 34·0	S21 52·8
01	12 26·0	208 43·3	23·5	314 45·9	05·8	162 04·1	17·6	113 36·4	52·8
02	27 28·5	223 42·9	22·4	329 47·7	06·0	177 06·1	17·8	128 38·8	52·9
03	42 31·0	238 42·5	.. 21·2	344 49·5	.. 06·2	192 08·1	.. 18·0	143 41·1	.. 52·9
04	57 33·4	253 42·0	20·1	359 51·2	06·4	207 10·1	18·1	158 43·5	52·9
05	72 35·9	268 41·6	18·9	14 53·0	06·6	222 12·1	18·3	173 45·8	52·9
06	87 38·4	283 41·1	N 8 17·8	29 54·8	N18 06·8	237 14·1	S11 18·5	188 48·2	S21 52·9
07	102 40·8	298 40·7	16·6	44 56·6	07·0	252 16·1	18·6	203 50·5	52·9
08	117 43·3	313 40·2	15·5	59 58·3	07·2	267 18·1	18·8	218 52·9	53·0
F 09	132 45·8	328 39·8	.. 14·3	75 00·1	.. 07·3	282 20·1	.. 19·0	233 55·2	.. 53·0
R 10	147 48·2	343 39·3	13·2	90 01·9	07·5	297 22·1	19·2	248 57·6	53·0
I 11	162 50·7	358 38·9	12·0	105 03·7	07·7	312 24·1	19·3	263 59·9	53·0
D 12	177 53·1	13 38·5	N 8 10·9	120 05·5	N18 07·9	327 26·1	S11 19·5	279 02·3	S21 53·0
A 13	192 55·6	28 38·0	09·7	135 07·2	08·1	342 28·1	19·7	294 04·6	53·0
Y 14	207 58·1	43 37·6	08·6	150 09·0	08·3	357 30·1	19·8	309 07·0	53·0
15	223 00·5	58 37·1	.. 07·4	165 10·8	.. 08·5	12 32·1	.. 20·0	324 09·3	.. 53·1
16	238 03·0	73 36·7	06·3	180 12·6	08·7	27 34·1	20·2	339 11·7	53·1
17	253 05·5	88 36·2	05·1	195 14·4	08·9	42 36·1	20·4	354 14·0	53·1
18	268 07·9	103 35·8	N 8 04·0	210 16·2	N18 09·1	57 38·1	S11 20·5	9 16·4	S21 53·1
19	283 10·4	118 35·4	02·8	225 18·0	09·3	72 40·1	20·7	24 18·7	53·1
20	298 12·9	133 34·9	01·6	240 19·7	09·5	87 42·1	20·9	39 21·1	53·1
21	313 15·3	148 34·5	8 00·5	255 21·5	.. 09·7	102 44·1	.. 21·1	54 23·4	.. 53·2
22	328 17·8	163 34·0	7 59·3	270 23·3	09·9	117 46·1	21·2	69 25·8	53·2
23	343 20·2	178 33·6	58·2	285 25·1	10·0	132 48·1	21·4	84 28·1	53·2
20 00	358 22·7	193 33·2	N 7 57·0	300 26·9	N18 10·2	147 50·1	S11 21·6	99 30·5	S21 53·2
01	13 25·2	208 32·7	55·9	315 28·7	10·4	162 52·1	21·8	114 32·8	53·2
02	28 27·6	223 32·3	54·7	330 30·5	10·6	177 54·0	21·9	129 35·2	53·2
03	43 30·1	238 31·8	.. 53·5	345 32·3	.. 10·8	192 56·0	22·1	144 37·5	.. 53·2
04	58 32·6	253 31·4	52·4	0 34·1	11·0	207 58·0	22·3	159 39·9	53·3
05	73 35·0	268 31·0	51·2	15 35·9	11·2	223 00·0	22·4	174 42·2	53·3
06	88 37·5	283 30·5	N 7 50·1	30 37·7	N18 11·4	238 02·0	S11 22·6	189 44·6	S21 53·3
S 07	103 40·0	298 30·1	48·9	45 39·5	11·6	253 04·0	22·8	204 46·9	53·3
A 08	118 42·4	313 29·7	47·7	60 41·3	11·8	268 06·0	23·0	219 49·3	53·3
T 09	133 44·9	328 29·2	.. 46·6	75 43·1	.. 12·0	283 08·0	.. 23·1	234 51·6	.. 53·3
U 10	148 47·4	343 28·8	45·4	90 44·9	12·1	298 10·0	23·3	249 54·0	53·4
R 11	163 49·8	358 28·3	44·2	105 46·7	12·3	313 12·0	23·5	264 56·3	53·4
D 12	178 52·3	13 27·9	N 7 43·1	120 48·5	N18 12·5	328 14·0	S11 23·7	279 58·7	S21 53·4
A 13	193 54·7	28 27·5	41·9	135 50·3	12·7	343 16·0	23·8	295 01·0	53·4
Y 14	208 57·2	43 27·0	40·8	150 52·2	12·9	358 18·0	24·0	310 03·4	53·4
15	223 59·7	58 26·6	.. 39·6	165 54·0	.. 13·1	13 20·0	.. 24·2	325 05·7	.. 53·4
16	239 02·1	73 26·2	38·4	180 55·8	13·3	28 22·0	24·3	340 08·1	53·5
17	254 04·6	88 25·7	37·3	195 57·6	13·5	43 24·0	24·5	355 10·4	53·5
18	269 07·1	103 25·3	N 7 36·1	210 59·4	N18 13·6	58 26·0	S11 24·7	10 12·8	S21 53·5
19	284 09·5	118 24·9	34·9	226 01·2	13·8	73 28·0	24·9	25 15·1	53·5
20	299 12·0	133 24·4	33·8	241 03·0	14·0	88 30·0	25·0	40 17·5	53·5
21	314 14·5	148 24·0	. 32·6	256 04·9	.. 14·2	103 32·0	.. 25·2	55 19·8	.. 53·5
22	329 16·9	163 23·5	31·4	271 06·7	14·4	118 34·0	25·4	70 22·1	53·5
23	344 19·4	178 23·1	30·3	286 08·5	14·6	133 36·0	25·6	85 24·5	53·6
21 00	359 21·8	193 22·7	N 7 29·1	301 10·3	N18 14·8	148 38·0	S11 25·7	100 26·8	S21 53·6
01	14 24·3	208 22·2	27·9	316 12·2	15·0	163 40·0	25·9	115 29·2	53·6
02	29 26·8	223 21·8	26·8	331 14·0	15·1	178 42·0	26·1	130 31·5	53·6
03	44 29·2	238 21·4	.. 25·6	346 15·8	.. 15·3	193 44·0	.. 26·2	145 33·9	.. 53·6
04	59 31·7	253 20·9	24·4	1 17·6	15·5	208 45·9	26·4	160 36·2	53·6
05	74 34·2	268 20·5	23·3	16 19·5	15·7	223 47·9	26·6	175 38·6	53·7
06	89 36·6	283 20·1	N 7 22·1	31 21·3	N18 15·9	238 49·9	S11 26·8	190 40·9	S21 53·7
07	104 39·1	298 19·6	20·9	46 23·1	16·1	253 51·9	26·9	205 43·3	53·7
08	119 41·6	313 19·2	19·7	61 25·0	16·3	268 53·9	27·1	220 45·6	53·7
S 09	134 44·0	328 18·8	. 18·6	76 26·8	.. 16·4	283 55·9	.. 27·3	235 47·9	.. 53·7
U 10	149 46·5	343 18·4	17·4	91 28·6	16·6	298 57·9	27·5	250 50·3	53·7
N 11	164 49·0	358 17·9	16·2	106 30·5	16·8	313 59·9	27·6	265 52·6	53·8
D 12	179 51·4	13 17·5	N 7 15·1	121 32·3	N18 17·0	329 01·9	S11 27·8	280 55·0	S21 53·8
A 13	194 53·9	28 17·1	13·9	136 34·1	17·2	344 03·9	28·0	295 57·3	53·8
Y 14	209 56·3	43 16·6	12·7	151 36·0	17·4	359 05·9	28·2	310 59·7	53·8
15	224 58·8	58 16·2	.. 11·5	166 37·8	.. 17·5	14 07·9	.. 28·3	326 02·0	.. 53·8
16	240 01·3	73 15·8	10·4	181 39·7	17·7	29 09·9	28·5	341 04·3	53·8
17	255 03·7	88 15·3	09·2	196 41·5	17·9	44 11·9	28·7	356 06·7	53·9
18	270 06·2	103 14·9	N 7 08·0	211 43·3	N18 18·1	59 13·9	S11 28·8	11 09·0	S21 53·9
19	285 08·7	118 14·5	06·9	226 45·2	18·3	74 15·8	29·0	26 11·4	53·9
20	300 11·1	133 14·0	05·7	241 47·0	18·5	89 17·8	29·2	41 13·7	53·9
21	315 13·6	148 13·6	.. 04·5	256 48·9	.. 18·6	104 19·8	29·4	56 16·1	53·9
22	330 16·1	163 13·2	03·3	271 50·7	18·8	119 21·8	29·5	71 18·4	53·9
23	345 18·5	178 12·8	02·2	286 52·6	19·0	134 23·8	29·7	86 20·7	54·0
Mer. Pass.	h m 0 06·5	v −0·4	d 1·2	v 1·8	d 0·2	v 2·0	d 0·2	v 2·3	d 0·0

STARS		
Name	S.H.A. ° ′	Dec. ° ′
Acamar	315 49·3	S 40 28·0
Achernar	335 56·9	S 57 26·6
Acrux	173 55·9	S 62 52·3
Adhara	255 45·0	S 28 54·8
Aldebaran	291 36·5	N 16 25·6
Alioth	166 57·4	N 56 11·1
Alkaid	153 31·7	N 49 31·3
Al Na'ir	28 35·0	S 47 09·6
Alnilam	276 28·1	S 1 13·6
Alphard	218 36·8	S 8 28·7
Alphecca	126 46·1	N 26 51·5
Alpheratz	358 25·7	N 28 51·9
Altair	62 48·2	N 8 45·8
Ankaa	353 55·9	S 42 31·6
Antares	113 16·9	S 26 20·4
Arcturus	146 33·6	N 19 24·0
Atria	108 55·8	S 68 57·4
Avior	234 35·2	S 59 22·4
Bellatrix	279 16·1	N 6 18·8
Betelgeuse	271 45·9	N 7 24·0
Canopus	264 14·5	S 52 40·2
Capella	281 35·2	N 45 57·2
Deneb	49 59·2	N 45 08·3
Denebola	183 15·9	N 14 48·2
Diphda	349 36·9	S 18 12·6
Dubhe	194 42·8	N 61 58·4
Elnath	279 04·6	N 28 34·3
Eltanin	91 05·3	N 51 30·0
Enif	34 27·2	N 9 41·4
Fomalhaut	16 09·0	S 29 50·3
Gacrux	172 47·3	S 56 52·9
Gienah	176 35·0	S 17 18·7
Hadar	149 46·6	S 60 10·5
Hamal	328 47·0	N 23 16·1
Kaus Aust.	84 38·3	S 34 24·3
Kochab	137 19·1	N 74 19·8
Markab	14 19·0	N 14 59·2
Menkar	314 57·9	N 3 55·8
Menkent	148 56·4	S 36 10·0
Miaplacidus	221 49·1	S 69 32·7
Mirfak	309 39·0	N 49 42·8
Nunki	76 49·2	S 26 20·9
Peacock	54 23·7	S 56 52·1
Pollux	244 18·2	N 28 07·5
Procyon	245 42·9	N 5 19·9
Rasalhague	96 44·7	N 12 35·6
Regulus	208 27·6	N 12 10·2
Rigel	281 51·6	S 8 14·8
Rigil Kent.	140 48·4	S 60 40·0
Sabik	102 59·8	S 15 40·4
Schedar	350 26·9	N 56 18·7
Shaula	97 17·8	S 37 04·5
Sirius	259 10·1	S 16 39·4
Spica	159 14·9	S 10 56·7
Suhail	223 23·0	S 43 15·8
Vega	81 06·7	N 38 45·1
Zuben'ubi	137 51·2	S 15 52·2

	S.H.A. °	Mer. Pass. h m
Venus	195 10·5	11 06
Mars	302 04·2	3 58
Jupiter	149 27·4	14 07
Saturn	101 07·8	17 19

SEPTEMBER 19, 20, 21 (FRI., SAT., SUN.)

G.M.T.	SUN			MOON					Lat.	Twilight		Sun-rise	Moonrise			
		G.H.A.	Dec.	G.H.A.	v	Dec.	d	H.P.		Naut.	Civil		19	20	21	22
d h		° ′	° ′	° ′	′	° ′	′	′	°	h m	h m	h m	h m	h m	h m	h m
19 00		181 28·6	N 1 46·1	107 22·5	6·9	S 18 12·2	2·5	58·9	N 72	02 42	04 18	05 27			18 02	17 46
01		196 28·8	45·1	121 48·4	6·8	18 14·7	2·5	58·8	N 70	03 05	04 28	05 30	16 04	16 50	17 07	17 13
02		211 29·0	44·1	136 14·2	6·9	18 17·2	2·4	58·8	68	03 23	04 36	05 32	15 14	16 05	16 33	16 49
03		226 29·2	43·2	150 40·1	6·9	18 19·6	2·2	58·8	66	03 37	04 42	05 34	14 43	15 35	16 09	16 31
04		241 29·5	42·2	165 06·0	7·0	18 21·8	2·1	58·7	64	03 48	04 48	05 36	14 20	15 13	15 50	16 16
05		256 29·7	41·2	179 32·0	7·0	18 23·9	2·0	58·7	62	03 58	04 52	05 37	14 01	14 55	15 34	16 03
									60	04 06	04 57	05 38	13 46	14 40	15 21	15 52
06		271 29·9	N 1 40·3	193 50·0	7·0	S 18 25·9	1·9	58·7	N 58	04 12	05 00	05 39	13 33	14 27	15 10	15 43
07		286 30·1	39·3	208 24·0	7·0	18 27·8	1·7	58·6	56	04 18	05 03	05 40	13 22	14 16	15 00	15 35
08		301 30·3	38·3	222 50·0	7·0	18 29·5	1·7	58·6	54	04 23	05 06	05 41	13 12	14 06	14 51	15 27
F 09		316 30·6	37·4	237 16·0	7·1	18 31·2	1·5	58·6	52	04 28	05 08	05 42	13 03	13 58	14 43	15 21
R 10		331 30·8	36·4	251 42·1	7·2	18 32·7	1·4	58·5	50	04 32	05 10	05 42	12 55	13 50	14 36	15 15
I 11		346 31·0	35·4	266 08·3	7·1	18 34·1	1·3	58·5	45	04 40	05 15	05 44	12 39	13 34	14 21	15 02
D 12		1 31·2	N 1 34·4	280 34·4	7·2	S 18 35·4	1·2	58·5	N 40	04 46	05 18	05 45	12 25	13 20	14 08	14 51
A 13		16 31·4	33·5	295 00·6	7·2	18 36·6	1·0	58·4	35	04 51	05 21	05 46	12 13	13 09	13 58	14 42
Y 14		31 31·7	32·5	309 26·8	7·3	18 37·6	1·0	58·4	30	04 55	05 23	05 47	12 03	12 59	13 49	14 34
15		46 31·9	31·5	323 53·1	7·2	18 38·6	0·8	58·4	20	05 01	05 26	05 48	11 46	12 41	13 33	14 20
16		61 32·1	30·6	338 19·3	7·4	18 39·4	0·7	58·4	N 10	05 04	05 28	05 49	11 31	12 26	13 19	14 08
17		76 32·3	29·6	352 45·7	7·3	18 40·1	0·6	58·3	0	05 06	05 30	05 50	11 17	12 12	13 06	13 56
18		91 32·6	N 1 28·6	7 12·0	7·4	S 18 40·7	0·5	58·3	S 10	05 06	05 30	05 51	11 03	11 58	12 52	13 45
19		106 32·8	27·7	21 38·4	7·5	18 41·2	0·3	58·3	20	05 04	05 30	05 52	10 48	11 43	12 38	13 33
20		121 33·0	26·7	36 04·9	7·4	18 41·5	0·3	58·2	30	05 01	05 29	05 53	10 30	11 26	12 22	13 19
21		136 33·2	25·7	50 31·3	7·5	18 41·8	0·1	58·2	35	04 59	05 28	05 53	10 20	11 16	12 13	13 11
22		151 33·4	24·7	64 57·8	7·6	18 41·9	0·0	58·2	40	04 55	05 27	05 54	10 09	11 04	12 02	13 01
23		166 33·7	23·8	79 24·4	7·6	18 41·9	0·1	58·1	45	04 51	05 25	05 54	09 56	10 51	11 50	12 51
20 00		181 33·9	N 1 22·8	93 51·0	7·6	S 18 41·8	0·2	58·1	S 50	04 45	05 22	05 54	09 39	10 35	11 35	12 37
01		196 34·1	21·8	108 17·6	7·7	18 41·6	0·3	58·1	52	04 42	05 21	05 55	09 32	10 27	11 27	12 31
02		211 34·3	20·9	122 44·3	7·7	18 41·3	0·5	58·0	54	04 39	05 20	05 55	09 23	10 18	11 20	12 25
03		226 34·6	19·9	137 11·0	7·8	18 40·8	0·5	58·0	56	04 35	05 18	05 55	09 13	10 09	11 11	12 17
04		241 34·8	18·9	151 37·8	7·8	18 40·3	0·7	58·0	58	04 30	05 16	05 55	09 03	09 58	11 01	12 08
05		256 35·0	18·0	166 04·6	7·8	18 39·6	0·8	57·9	S 60	04 25	05 14	05 56	08 50	09 45	10 49	11 59
06		271 35·2	N 1 17·0	180 31·4	7·9	S 18 38·8	0·8	57·9								
07		286 35·4	16·0	194 58·3	8·0	18 38·0	1·0	57·9								
S 08		301 35·7	15·0	209 25·3	8·0	18 37·0	1·1	57·8								
A 09		316 35·9	14·1	223 52·3	8·0	18 35·9	1·2	57·8								
T 10		331 36·1	13·1	238 19·3	8·1	18 34·7	1·4	57·8								
U 11		346 36·3	12·1	252 46·4	8·1	18 33·3	1·4	57·7								
R 12		1 36·5	N 1 11·2	267 13·5	8·2	S 18 31·9	1·5	57·7	N 70	18 15	19 17	20 38	18 55	20 04	21 37	23 15
D 13		16 36·8	10·2	281 40·7	8·2	18 30·4	1·7	57·7	68	18 13	19 09	20 21	19 45	20 49	22 10	23 38
A 14		31 37·0	09·2	296 07·9	8·3	18 28·7	1·7	57·6	66	18 11	19 03	20 08	20 16	21 19	22 34	23 55
Y 15		46 37·2	08·2	310 35·2	8·3	18 27·0	1·9	57·6	64	18 10	18 58	19 57	20 40	21 41	22 53	24 10
16		61 37·4	07·3	325 02·5	8·4	18 25·1	1·9	57·6	62	18 09	18 53	19 48	20 58	21 59	23 08	24 22
17		76 37·7	06·3	339 29·9	8·4	18 23·2	2·1	57·5	60	18 08	18 50	19 40	21 14	22 13	23 21	24 32
18		91 37·9	N 1 05·3	353 57·3	8·5	S 18 21·1	2·2	57·5	N 58	18 07	18 46	19 33	21 26	22 26	23 32	24 41
19		106 38·1	04·4	8 24·8	8·5	18 18·9	2·3	57·5	56	18 06	18 43	19 28	21 38	22 37	23 41	24 49
20		121 38·3	03·4	22 52·3	8·6	18 16·6	2·3	57·5	54	18 05	18 40	19 23	21 48	22 46	23 50	24 56
21		136 38·5	02·4	37 19·9	8·6	18 14·3	2·5	57·4	52	18 04	18 38	19 18	21 56	22 55	23 57	25 02
22		151 38·8	01·4	51 47·5	8·7	18 11·8	2·6	57·4	50	18 04	18 36	19 14	22 04	23 02	24 04	00 04
23		166 39·0	1 00·5	66 15·2	8·8	18 09·2	2·7	57·4	45	18 03	18 32	19 06	22 21	23 18	24 18	00 18
21 00		181 39·2	N 0 59·5	80 43·0	8·8	S 18 06·5	2·8	57·3	N 40	18 01	18 28	19 00	22 35	23 32	24 30	00 30
01		196 39·4	58·5	95 10·8	8·8	18 03·7	2·9	57·3	35	18 01	18 26	18 55	22 46	23 43	24 41	00 41
02		211 39·6	57·6	109 38·6	8·9	18 00·8	2·9	57·3	30	18 00	18 24	18 52	22 56	23 53	24 49	00 49
03		226 39·9	56·6	124 06·5	9·0	17 57·9	3·1	57·2	20	17 59	18 21	18 46	23 14	24 10	00 10	01 05
04		241 40·1	55·6	138 34·5	9·0	17 54·8	3·2	57·2	N 10	17 58	18 19	18 43	23 29	24 24	00 24	01 18
05		256 40·3	54·6	153 02·5	9·1	17 51·6	3·3	57·2	0	17 57	18 18	18 42	23 43	24 38	00 38	01 30
06		271 40·5	N 0 53·7	167 30·6	9·1	S 17 48·3	3·3	57·1	S 10	17 56	18 17	18 41	23 58	24 52	00 52	01 43
07		286 40·7	52·7	181 58·7	9·2	17 45·0	3·5	57·1	20	17 55	18 18	18 43	24 13	00 13	01 06	01 56
08		301 41·0	51·7	196 26·9	9·2	17 41·5	3·6	57·1	30	17 55	18 19	18 47	24 30	00 30	01 23	02 11
S 09		316 41·2	50·8	210 55·1	9·3	17 37·9	3·6	57·1	35	17 55	18 20	18 49	24 40	00 40	01 33	02 19
U 10		331 41·4	49·8	225 23·4	9·4	17 34·3	3·8	57·0	40	17 54	18 21	18 53	24 52	00 52	01 44	02 29
N 11		346 41·6	48·8	239 51·8	9·4	17 30·5	3·8	57·0	45	17 54	18 23	18 58	00 07	01 05	01 56	02 41
D 12		1 41·8	N 0 47·8	254 20·2	9·5	S 17 26·7	4·0	57·0	S 50	17 54	18 26	19 04	00 23	01 22	02 12	02 54
A 13		16 42·1	46·9	268 48·7	9·5	17 22·7	4·0	56·9	52	17 53	18 27	19 07	00 30	01 29	02 19	03 01
Y 14		31 42·3	45·9	283 17·2	9·6	17 18·7	4·1	56·9	54	17 53	18 29	19 11	00 39	01 38	02 28	03 08
15		46 42·5	44·9	297 45·8	9·6	17 14·6	4·2	56·9	56	17 53	18 30	19 14	00 48	01 48	02 37	03 16
16		61 42·7	44·0	312 14·4	9·7	17 10·4	4·3	56·9	58	17 53	18 32	19 19	00 59	01 59	02 47	03 25
17		76 43·0	43·0	326 43·1	9·8	17 06·1	4·4	56·8	S 60	17 53	18 34	19 24	01 11	02 11	02 59	03 35
18		91 43·2	N 0 42·0	341 11·9	9·8	S 17 01·7	4·5	56·8								
19		106 43·4	41·0	355 40·7	9·9	16 57·2	4·6	56·8								
20		121 43·6	40·1	10 09·6	9·9	16 52·6	4·6	56·7								
21		136 43·8	39·1	24 38·5	10·0	16 48·0	4·8	56·7								
22		151 44·1	38·1	39 07·5	10·1	16 43·2	4·8	56·7								
23		166 44·3	37·1	53 36·6	10·1	16 38·4	4·9	56·7								
		S.D. 16·0	d 1·0	S.D.	15·9		15·7		15·5							

Lat.	Sun-set	Twilight Civil	Twilight Naut.	Moonset 19	Moonset 20	Moonset 21	Moonset 22
°	h m	h m	h m	h m	h m	h m	h m
N 72	18 18	19 27	21 00			20 42	22 43
N 70	18 15	19 17	20 38	18 55	20 04	21 37	23 15
68	18 13	19 09	20 21	19 45	20 49	22 10	23 38
66	18 11	19 03	20 08	20 16	21 19	22 34	23 55
64	18 10	18 58	19 57	20 40	21 41	22 53	24 10
62	18 09	18 53	19 48	20 58	21 59	23 08	24 22
60	18 08	18 50	19 40	21 14	22 13	23 21	24 32
N 58	18 07	18 46	19 33	21 26	22 26	23 32	24 41
56	18 06	18 43	19 28	21 38	22 37	23 41	24 49
54	18 05	18 40	19 23	21 48	22 46	23 50	24 56
52	18 04	18 38	19 18	21 56	22 55	23 57	25 02
50	18 04	18 36	19 14	22 04	23 02	24 04	00 04
45	18 03	18 32	19 06	22 21	23 18	24 18	00 18
N 40	18 01	18 28	19 00	22 35	23 32	24 30	00 30
35	18 01	18 26	18 55	22 46	23 43	24 41	00 41
30	18 00	18 24	18 52	22 56	23 53	24 49	00 49
20	17 59	18 21	18 46	23 14	24 10	00 10	01 05
N 10	17 58	18 19	18 43	23 29	24 24	00 24	01 18
0	17 57	18 18	18 42	23 43	24 38	00 38	01 30
S 10	17 56	18 17	18 41	23 58	24 52	00 52	01 43
20	17 55	18 18	18 43	24 13	00 13	01 06	01 56
30	17 55	18 19	18 47	24 30	00 30	01 23	02 11
35	17 55	18 20	18 49	24 40	00 40	01 33	02 19
40	17 54	18 21	18 53	24 52	00 52	01 44	02 29
45	17 54	18 23	18 58	00 07	01 05	01 56	02 41
S 50	17 54	18 26	19 04	00 23	01 22	02 12	02 54
52	17 53	18 27	19 07	00 30	01 29	02 19	03 01
54	17 53	18 29	19 11	00 39	01 38	02 28	03 08
56	17 53	18 30	19 14	00 48	01 48	02 37	03 16
58	17 53	18 32	19 19	00 59	01 59	02 47	03 25
S 60	17 53	18 34	19 24	01 11	02 11	02 59	03 35

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
19	05 54	06 04	11 54	17 30	05 02	06	
20	06 15	06 26	11 54	18 25	05 58	07	
21	06 36	06 47	11 53	19 18	06 52	08	

SEPTEMBER 22, 23, 24 (MON., TUES., WED.)

G.M.T.	ARIES	VENUS −3·4		MARS −1·0		JUPITER −1·3		SATURN +0·7		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
22 00	0 21·0	193 12·3	N 7 01·0	301 54·4	N18 19·2	149 25·8	S11 29·9	101 23·1	S21 54·0	Acamar	315 49·3	S 40 28·0
01	15 23·5	208 11·9	6 59·8	316 56·3	19·4	164 27·8	30·1	116 25·4	54·0	Achernar	335 56·9	S 57 26·6
02	30 25·9	223 11·5	58·6	331 58·1	19·5	179 29·8	30·2	131 27·8	54·0	Acrux	173 55·9	S 62 52·2
03	45 28·4	238 11·0	·· 57·4	347 00·0	·· 19·7	194 31·8	·· 30·4	146 30·1	·· 54·0	Adhara	255 44·9	S 28 54·8
04	60 30·8	253 10·6	56·3	2 01·8	19·9	209 33·8	30·6	161 32·5	54·0	Aldebaran	291 36·5	N 16 25·6
05	75 33·3	268 10·2	55·1	17 03·7	20·1	224 35·8	30·8	176 34·8	54·1			
06	90 35·8	283 09·8	N 6 53·9	32 05·6	N18 20·3	239 37·8	S11 30·9	191 37·1	S21 54·1	Alioth	166 57·4	N 56 11·1
07	105 38·2	298 09·3	52·7	47 07·4	20·4	254 39·8	31·1	206 39·5	54·1	Alkaid	153 31·8	N 49 31·3
08	120 40·7	313 08·9	51·6	62 09·3	20·6	269 41·7	31·3	221 41·8	54·1	Al Na'ir	28 35·0	S 47 09·6
M 09	135 43·2	328 08·5	·· 50·4	77 11·1	·· 20·8	284 43·7	·· 31·4	236 44·2	·· 54·1	Alnilam	276 28·1	S 1 13·6
O 10	150 45·6	343 08·1	49·2	92 13·0	21·0	299 45·7	31·6	251 46·5	54·1	Alphard	218 36·7	S 8 28·7
N 11	165 48·1	358 07·6	48·0	107 14·9	21·2	314 47·7	31·8	266 48·8	54·2			
D 12	180 50·6	13 07·2	N 6 46·8	122 16·7	N18 21·3	329 49·7	S11 32·0	281 51·2	S21 54·2	Alphecca	126 46·1	N 26 51·5
A 13	195 53·0	28 06·8	45·7	137 18·6	21·5	344 51·7	32·1	296 53·5	54·2	Alpheratz	358 25·7	N 28 51·9
Y 14	210 55·5	43 06·4	44·5	152 20·5	21·7	359 53·7	32·3	311 55·9	54·2	Altair	62 48·2	N 8 45·8
15	225 57·9	58 05·9	·· 43·3	167 22·3	·· 21·9	14 55·7	·· 32·5	326 58·2	·· 54·2	Ankaa	353 55·9	S 42 31·6
16	241 00·4	73 05·5	42·1	182 24·2	22·0	29 57·7	32·7	342 00·5	54·2	Antares	113 16·9	S 26 20·4
17	256 02·9	88 05·1	40·9	197 26·1	22·2	44 59·7	32·8	357 02·9	54·2			
18	271 05·3	103 04·7	N 6 39·7	212 27·9	N18 22·4	60 01·7	S11 33·0	12 05·2	S21 54·3	Arcturus	146 33·6	N 19 24·0
19	286 07·8	118 04·2	38·6	227 29·8	22·6	75 03·6	33·2	27 07·5	54·3	Atria	108 55·8	S 68 57·4
20	301 10·3	133 03·8	37·4	242 31·7	22·8	90 05·6	33·4	42 09·9	54·3	Avior	234 35·2	S 59 22·4
21	316 12·7	148 03·4	·· 36·2	257 33·6	·· 22·9	105 07·6	·· 33·5	57 12·2	·· 54·3	Bellatrix	279 16·1	N 6 18·8
22	331 15·2	163 03·0	35·0	272 35·4	23·1	120 09·6	33·7	72 14·6	54·3	Betelgeuse	271 45·8	N 7 24·0
23	346 17·7	178 02·5	33·8	287 37·3	23·3	135 11·6	33·9	87 16·9	54·3			
23 00	1 20·1	193 02·1	N 6 32·6	302 39·2	N18 23·5	150 13·6	S11 34·1	102 19·2	S21 54·4	Canopus	264 14·5	S 52 40·2
01	16 22·6	208 01·7	31·5	317 41·1	23·6	165 15·6	34·2	117 21·6	54·4	Capella	281 35·2	N 45 57·2
02	31 25·1	223 01·3	30·3	332 43·0	23·8	180 17·6	34·4	132 23·9	54·4	Deneb	49 59·2	N 45 08·3
03	46 27·5	238 00·8	·· 29·1	347 44·9	·· 24·0	195 19·6	·· 34·6	147 26·3	·· 54·4	Denebola	183 15·9	N 14 48·2
04	61 30·0	253 00·4	27·9	2 46·7	24·2	210 21·6	34·8	162 28·6	54·4	Diphda	349 36·8	S 18 12·6
05	76 32·4	268 00·0	26·7	17 48·6	24·3	225 23·5	34·9	177 30·9	54·4			
06	91 34·9	282 59·6	N 6 25·5	32 50·5	N18 24·5	240 25·5	S11 35·1	192 33·3	S21 54·5	Dubhe	194 42·8	N 61 58·4
07	106 37·4	297 59·1	24·3	47 52·4	24·7	255 27·5	35·3	207 35·6	54·5	Elnath	279 04·6	N 28 34·3
T 08	121 39·8	312 58·7	23·1	62 54·3	24·9	270 29·5	35·4	222 37·9	54·5	Eltanin	91 05·3	N 51 30·0
U 09	136 42·3	327 58·3	·· 22·0	77 56·2	·· 25·0	285 31·5	·· 35·6	237 40·3	·· 54·5	Enif	34 27·3	N 9 41·4
E 10	151 44·8	342 57·9	20·8	92 58·1	25·2	300 33·5	35·8	252 42·6	54·5	Fomalhaut	16 09·0	S 29 50·3
S 11	166 47·2	357 57·5	19·6	108 00·0	25·4	315 35·5	36·0	267 44·9	54·5			
D 12	181 49·7	12 57·0	N 6 18·4	123 01·9	N18 25·5	330 37·5	S11 36·1	282 47·3	S21 54·6	Gacrux	172 47·3	S 56 52·9
A 13	196 52·2	27 56·6	17·2	138 03·8	25·7	345 39·4	36·3	297 49·6	54·6	Gienah	176 35·0	S 17 18·7
Y 14	211 54·6	42 56·2	16·0	153 05·7	25·9	0 41·4	36·5	312 51·9	54·6	Hadar	149 46·8	S 60 10·5
15	226 57·1	57 55·8	·· 14·8	168 07·5	·· 26·1	15 43·4	·· 36·7	327 54·3	·· 54·6	Hamal	328 46·9	N 23 16·1
16	241 59·5	72 55·4	13·6	183 09·4	26·2	30 45·4	36·8	342 56·6	54·6	Kaus Aust.	84 38·3	S 34 24·3
17	257 02·0	87 54·9	12·5	198 11·3	26·4	45 47·4	37·0	357 59·0	54·6			
18	272 04·5	102 54·5	N 6 11·3	213 13·3	N18 26·6	60 49·4	S11 37·2	13 01·3	S21 54·7	Kochab	137 19·2	N 74 19·7
19	287 06·9	117 54·1	10·1	228 15·2	26·8	75 51·4	37·4	28 03·6	54·7	Markab	14 19·0	N 14 59·2
20	302 09·4	132 53·7	08·9	243 17·1	26·9	90 53·4	37·5	43 06·0	54·7	Menkar	314 57·9	N 3 55·8
21	317 11·9	147 53·3	·· 07·7	258 19·0	·· 27·1	105 55·3	·· 37·7	58 08·3	·· 54·7	Menkent	148 56·4	S 36 10·0
22	332 14·3	162 52·8	06·5	273 20·9	27·3	120 57·3	37·9	73 10·6	54·7	Miaplacidus	221 49·0	S 69 32·7
23	347 16·8	177 52·4	05·3	288 22·8	27·4	135 59·3	38·1	88 13·0	54·7			
24 00	2 19·3	192 52·0	N 6 04·1	303 24·7	N18 27·6	151 01·3	S11 38·2	103 15·3	S21 54·8	Mirfak	309 39·0	N 49 42·8
01	17 21·7	207 51·6	02·9	318 26·6	27·8	166 03·3	38·4	118 17·6	54·8	Nunki	76 49·2	S 26 20·9
02	32 24·2	222 51·2	01·7	333 28·5	28·0	181 05·3	38·6	133 20·0	54·8	Peacock	54 23·7	S 56 52·2
03	47 26·7	237 50·7	6 00·5	348 30·4	·· 28·1	196 07·3	·· 38·8	148 22·3	·· 54·8	Pollux	244 18·2	N 28 07·5
04	62 29·1	252 50·3	5 59·3	3 32·3	28·3	211 09·3	38·9	163 24·6	54·8	Procyon	245 42·9	N 5 19·9
05	77 31·6	267 49·9	58·1	18 34·3	28·5	226 11·2	39·1	178 27·0	54·8			
06	92 34·0	282 49·5	N 5 57·0	33 36·2	N18 28·6	241 13·2	S11 39·3	193 29·3	S21 54·9	Rasalhague	96 44·7	N 12 35·6
W 07	107 36·5	297 49·1	55·8	48 38·1	28·8	256 15·2	39·5	208 31·6	54·9	Regulus	208 27·6	N 12 10·2
E 08	122 39·0	312 48·7	54·6	63 40·0	29·0	271 17·2	39·6	223 34·0	54·9	Rigel	281 51·6	S 8 14·8
D 09	137 41·4	327 48·2	·· 53·4	78 41·9	·· 29·1	286 19·2	·· 39·8	238 36·3	·· 54·9	Rigil Kent.	140 48·4	S 60 40·0
N 10	152 43·9	342 47·8	52·2	93 43·9	29·3	301 21·2	40·0	253 38·6	54·9	Sabik	102 59·8	S 15 40·4
E 11	167 46·4	357 47·4	51·0	108 45·8	29·5	316 23·2	40·2	268 41·0	54·9			
S 12	182 48·8	12 47·0	N 5 49·8	123 47·7	N18 29·6	331 25·1	S11 40·3	283 43·3	S21 55·0	Schedar	350 26·9	N 56 18·7
D 13	197 51·3	27 46·6	48·6	138 49·6	29·8	346 27·1	40·5	298 45·6	55·0	Shaula	97 17·9	S 37 04·5
A 14	212 53·8	42 46·2	47·4	153 51·6	30·0	1 29·1	40·7	313 48·0	55·0	Sirius	259 10·1	S 16 39·4
Y 15	227 56·2	57 45·7	·· 46·2	168 53·5	·· 30·2	16 31·1	·· 40·9	328 50·3	55·0	Spica	159 14·9	S 10 56·7
16	242 58·7	72 45·3	45·0	183 55·4	30·3	31 33·1	41·0	343 52·6	55·0	Suhail	223 23·0	S 43 15·8
17	258 01·2	87 44·9	43·8	198 57·3	30·5	46 35·1	41·2	358 54·9	55·0			
18	273 03·6	102 44·5	N 5 42·6	213 59·3	N18 30·7	61 37·1	S11 41·4	13 57·3	S21 55·1	Vega	81 06·8	N 38 45·1
19	288 06·1	117 44·1	41·4	229 01·2	30·8	76 39·0	41·6	28 59·6	55·1	Zuben'ubi	137 51·2	S 15 52·2
20	303 08·5	132 43·7	40·2	244 03·1	31·0	91 41·0	41·7	44 01·9	55·1		S.H.A.	Mer. Pass.
21	318 11·0	147 43·2	·· 39·0	259 05·1	·· 31·2	106 43·0	·· 41·9	59 04·3	·· 55·1		° ′	h m
22	333 13·5	162 42·8	37·8	274 07·0	31·3	121 45·0	42·1	74 06·6	55·1	Venus	191 42·0	11 08
23	348 15·9	177 42·4	36·6	289 09·0	31·5	136 47·0	42·3	89 08·9	55·1	Mars	301 19·1	3 49
										Jupiter	148 53·5	13 57
Mer. Pass.	h m 23 50·7	v −0·4	d 1·2	v 1·9	d 0·2	v 2·0	d 0·2	v 2·3	d 0·0	Saturn	100 59·1	17 08

SEPTEMBER 22, 23, 24 (MON., TUES., WED.)

G.M.T.	SUN			MOON					Lat.	Twilight		Sun-	Moonrise			
										Naut.	Civil	rise	22	23	24	25
	G.H.A.	Dec.		G.H.A.	v	Dec.	d	H.P.								
d h	° ′	° ′		° ′	′	° ′	′	′		h m	h m	h m	h m	h m	h m	h m
22 00	181 44·5	N 0 36·2		68 05·7	10·2	S 16 33·5	5·3	56·6	N 72	03 01	04 32	05 41	17 46	17 37	17 29	17 23
01	196 44·7	35·2		82 34·9	10·2	16 28·5	5·1	56·6	N 70	03 21	04 40	05 42	17 13	17 16	17 16	17 16
02	211 44·9	34·2		97 04·1	10·3	16 23·4	5·1	56·6	68	03 36	04 47	05 43	16 49	16 59	17 05	17 10
03	226 45·2	33·3		111 33·4	10·4	16 18·3	5·3	56·5	66	03 48	04 52	05 44	16 31	16 46	16 56	17 05
04	241 45·4	32·3		126 02·8	10·4	16 13·0	5·3	56·5	64	03 58	04 57	05 44	16 16	16 34	16 49	17 01
05	256 45·6	31·3		140 32·2	10·4	16 07·7	5·4	56·5	62	04 07	05 01	05 45	16 03	16 25	16 42	16 57
									60	04 14	05 04	05 45	15 52	16 17	16 37	16 54
06	271 45·8	N 0 30·3		155 01·6	10·6	S 16 02·3	5·4	56·5	N 58	04 20	05 07	05 46	15 43	16 09	16 32	16 51
07	286 46·0	29·4		169 31·2	10·5	15 56·9	5·6	56·4	56	04 25	05 09	05 46	15 35	16 03	16 27	16 48
08	301 46·3	28·4		184 00·7	10·7	15 51·3	5·6	56·4	54	04 29	05 11	05 46	15 27	15 57	16 23	16 46
M 09	316 46·5	27·4		198 30·4	10·7	15 45·7	5·7	56·4	52	04 33	05 13	05 47	15 21	15 52	16 19	16 44
O 10	331 46·7	26·4		213 00·1	10·8	15 40·0	5·8	56·4	50	04 37	05 15	05 47	15 15	15 47	16 16	16 42
N 11	346 46·9	25·5		227 29·9	10·8	15 34·2	5·9	56·3	45	04 44	05 18	05 48	15 02	15 37	16 09	16 38
D 12	1 47·1	N 0 24·5		241 59·7	10·9	S 15 28·3	5·9	56·3	N 40	04 49	05 21	05 48	14 51	15 29	16 03	16 34
A 13	16 47·4	23·5		256 29·6	10·9	15 22·4	6·0	56·3	35	04 53	05 23	05 48	14 42	15 21	15 58	16 31
Y 14	31 47·6	22·6		270 59·5	11·0	15 16·4	6·1	56·3	30	04 57	05 25	05 48	14 34	15 15	15 53	16 28
15	46 47·8	21·6		285 29·5	11·1	15 10·3	6·2	56·2	20	05 01	05 27	05 49	14 20	15 04	15 45	16 24
16	61 48·0	20·6		299 59·6	11·1	15 04·1	6·2	56·2	N 10	05 04	05 28	05 49	14 08	14 54	15 38	16 20
17	76 48·2	19·6		314 29·7	11·1	14 57·9	6·3	56·2	0	05 05	05 29	05 49	13 56	14 45	15 31	16 16
18	91 48·5	N 0 18·7		328 59·8	11·3	S 14 51·6	6·4	56·2	S 10	05 04	05 28	05 49	13 45	14 36	15 25	16 12
19	106 48·7	17·7		343 30·1	11·3	14 45·2	6·4	56·1	20	05 02	05 27	05 49	13 33	14 26	15 17	16 08
20	121 48·9	16·7		358 00·4	11·3	14 38·8	6·5	56·1	30	04 57	05 25	05 49	13 19	14 15	15 09	16 03
21	136 49·1	15·7		12 30·7	11·4	14 32·3	6·6	56·1	35	04 54	05 24	05 49	13 11	14 08	15 05	16 00
22	151 49·3	14·8		27 01·1	11·5	14 25·7	6·6	56·1	40	04 50	05 22	05 49	13 01	14 01	14 59	15 57
23	166 49·6	13·8		41 31·6	11·5	14 19·1	6·7	56·0	45	04 45	05 19	05 48	12 51	13 52	14 53	15 54
23 00	181 49·8	N 0 12·8		56 02·1	11·6	S 14 12·4	6·8	56·0	S 50	04 38	05 16	05 48	12 37	13 41	14 46	15 49
01	196 50·0	11·8		70 32·7	11·6	14 05·6	6·8	56·0	52	04 34	05 14	05 48	12 31	13 37	14 42	15 47
02	211 50·2	10·9		85 03·3	11·7	13 58·8	6·9	56·0	54	04 31	05 12	05 47	12 25	13 31	14 39	15 45
03	226 50·4	09·9		99 34·0	11·7	13 51·9	7·0	55·9	56	04 26	05 10	05 47	12 17	13 25	14 34	15 43
04	241 50·7	08·9		114 04·7	11·8	13 44·9	7·0	55·9	58	04 21	05 08	05 47	12 08	13 19	14 30	15 40
05	256 50·9	08·0		128 35·5	11·9	13 37·9	7·1	55·9	S 60	04 15	05 05	05 47	11 59	13 11	14 24	15 37
06	271 51·1	N 0 07·0		143 06·4	11·9	S 13 30·8	7·1	55·9								
07	286 51·3	06·0		157 37·3	11·9	13 23·7	7·2	55·8								
T 08	301 51·5	05·0		172 08·2	12·1	13 16·5	7·3	55·8								
U 09	316 51·7	04·1		186 39·3	12·0	13 09·2	7·3	55·8								
E 10	331 52·0	03·1		201 10·3	12·2	13 01·9	7·4	55·8								
S 11	346 52·2	02·1		215 41·5	12·1	12 54·5	7·4	55·8								
D 12	1 52·4	N 0 01·1		230 12·6	12·3	S 12 47·1	7·5	55·7								
A 13	16 52·6	N 0 00·2		244 43·9	12·3	12 39·6	7·5	55·7								
Y 14	31 52·8	S 0 00·8		259 15·2	12·3	12 32·1	7·6	55·7								
15	46 53·1	01·8		273 46·5	12·4	12 24·5	7·7	55·7								
16	61 53·3	02·8		288 17·9	12·4	12 16·8	7·7	55·6								
17	76 53·5	03·7		302 49·3	12·5	12 09·1	7·7	55·6								
18	91 53·7	S 0 04·7		317 20·8	12·6	S 12 01·4	7·8	55·6								
19	106 53·9	05·7		331 52·4	12·5	11 53·6	7·9	55·6								
20	121 54·2	06·6		346 23·9	12·7	11 45·7	7·9	55·6								
21	136 54·4	07·6		0 55·6	12·7	11 37·8	8·0	55·5								
22	151 54·6	08·6		15 27·3	12·7	11 29·8	8·0	55·5								
23	166 54·8	09·6		29 59·0	12·8	11 21·8	8·0	55·5								
24 00	181 55·0	S 0 10·5		44 30·8	12·9	S 11 13·8	8·1	55·5								
01	196 55·2	11·5		59 02·7	12·9	11 05·7	8·2	55·5								
02	211 55·5	12·5		73 34·6	12·9	10 57·5	8·2	55·4								
03	226 55·7	13·5		88 06·5	13·0	10 49·3	8·2	55·4								
04	241 55·9	14·4		102 38·5	13·0	10 41·1	8·3	55·4								
05	256 56·1	15·4		117 10·5	13·1	10 32·8	8·3	55·4								
06	271 56·3	S 0 16·4		131 42·6	13·1	S 10 24·5	8·4	55·4								
W 07	286 56·6	17·4		146 14·7	13·2	10 16·1	8·4	55·3								
E 08	301 56·8	18·3		160 46·9	13·2	10 07·7	8·4	55·3								
D 09	316 57·0	19·3		175 19·1	13·3	9 59·3	8·5	55·3								
N 10	331 57·2	20·3		189 51·4	13·3	9 50·8	8·5	55·3								
E 11	346 57·4	21·3		204 23·7	13·3	9 42·3	8·6	55·3								
S 12	1 57·6	S 0 22·2		218 56·0	13·4	S 9 33·7	8·6	55·2								
D 13	16 57·9	23·2		233 28·4	13·4	9 25·1	8·6	55·2								
A 14	31 58·1	24·2		248 00·8	13·5	9 16·5	8·7	55·2								
Y 15	46 58·3	25·1		262 33·3	13·5	9 07·8	8·7	55·2								
16	61 58·5	26·1		277 05·8	13·6	8 59·1	8·8	55·2								
17	76 58·7	27·1		291 38·4	13·6	8 50·3	8·8	55·1								
18	91 59·0	S 0 28·1		306 11·0	13·6	S 8 41·5	8·8	55·1								
19	106 59·2	29·0		320 43·6	13·7	8 32·7	8·8	55·1								
20	121 59·4	30·0		335 16·3	13·7	8 23·9	8·9	55·1								
21	136 59·6	31·0		349 49·0	13·8	8 15·0	8·9	55·1								
22	151 59·8	32·0		4 21·8	13·8	8 06·1	9·0	55·1								
23	167 00·0	32·9		18 54·6	13·8	7 57·1	8·9	55·0								
	S.D. 16·0	d 1·0		S.D.	15·3		15·2									

Lat.	Sun-	Twilight		Moonset			
	set	Civil	Naut.	22	23	24	25
°	h m	h m	h m	h m	h m	h m	h m
N 72	18 02	19 10	20 39	22 43	24 32	00 32	02 14
N 70	18 01	19 03	20 21	23 15	24 51	00 51	02 25
68	18 01	18 56	20 06	23 38	25 07	01 07	02 35
66	18 00	18 51	19 54	23 55	25 19	01 19	02 42
64	17 59	18 47	19 45	24 10	00 10	01 30	02 49
62	17 59	18 43	19 37	24 22	00 22	01 38	02 54
60	17 58	18 40	19 30	24 32	00 32	01 46	02 59
N 58	17 58	18 38	19 24	24 41	00 41	01 52	03 03
56	17 58	18 35	19 19	24 49	00 49	01 58	03 07
54	17 58	18 33	19 15	24 56	00 56	02 03	03 10
52	17 57	18 31	19 11	25 02	01 02	02 08	03 14
50	17 57	18 29	19 07	00 04	01 08	02 12	03 16
45	17 57	18 26	19 00	00 18	01 20	02 21	03 22
N 40	17 56	18 23	18 55	00 30	01 30	02 29	03 27
35	17 56	18 21	18 51	00 41	01 38	02 35	03 32
30	17 56	18 20	18 48	00 49	01 46	02 41	03 35
20	17 56	18 18	18 43	01 05	01 58	02 51	03 42
N 10	17 56	18 17	18 41	01 18	02 10	02 59	03 47
0	17 56	18 16	18 40	01 30	02 20	03 07	03 53
S 10	17 56	18 17	18 41	01 43	02 30	03 15	03 58
20	17 56	18 18	18 44	01 56	02 41	03 24	04 04
30	17 56	18 20	18 48	02 11	02 54	03 33	04 10
35	17 57	18 22	18 52	02 19	03 01	03 39	04 14
40	17 57	18 24	18 56	02 29	03 09	03 45	04 18
45	17 58	18 27	19 01	02 41	03 19	03 52	04 22
S 50	17 58	18 31	19 08	02 54	03 30	04 01	04 28
52	17 58	18 32	19 12	03 01	03 35	04 05	04 31
54	17 59	18 34	19 16	03 08	03 41	04 09	04 33
56	17 59	18 36	19 21	03 16	03 48	04 14	04 36
58	17 59	18 39	19 26	03 25	03 55	04 19	04 40
S 60	18 00	18 41	19 32	03 35	04 03	04 25	04 44

Day	SUN		Mer.	MOON			
	Eqn. of Time		Pass.	Mer. Pass.		Age	Phase
	00h	12h		Upper	Lower		
	m s	m s	h m	h m	h m	d	
22	06 58	07 08	11 53	20 08	07 43	09	
23	07 19	07 29	11 53	20 56	08 32	10	
24	07 40	07 50	11 52	21 42	09 19	11	○

SEPTEMBER 25, 26, 27 (THURS., FRI., SAT.)

G.M.T.	ARIES	VENUS −3·4		MARS −1·0		JUPITER −1·3		SATURN +0·7	
d h	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
25 00	3 18·4	192 42·0	N 5 35·4	304 10·9	N18 31·7	151 49·0	S11 42·4	104 11·3	S21 55·2
01	18 20·9	207 41·6	34·2	319 12·8	31·8	166 51·0	42·6	119 13·6	55·2
02	33 23·3	222 41·2	33·0	334 14·8	32·0	181 52·9	42·8	134 15·9	55·2
03	48 25·8	237 40·7	·· 31·8	349 16·7	·· 32·2	196 54·9	·· 43·0	149 18·2	·· 55·2
04	63 28·3	252 40·3	30·6	4 18·7	32·3	211 56·9	43·1	164 20·6	55·2
05	78 30·7	267 39·9	29·4	19 20·6	32·5	226 58·9	43·3	179 22·9	55·2
06	93 33·2	282 39·5	N 5 28·2	34 22·6	N18 32·6	242 00·9	S11 43·5	194 25·2	S21 55·3
07	108 35·7	297 39·1	27·0	49 24·5	32·8	257 02·9	43·7	209 27·6	55·3
T 08	123 38·1	312 38·7	25·8	64 26·5	33·0	272 04·8	43·8	224 29·9	55·3
H 09	138 40·6	327 38·3	·· 24·6	79 28·4	·· 33·1	287 06·8	·· 44·0	239 32·2	·· 55·3
U 10	153 43·0	342 37·9	23·4	94 30·4	33·3	302 08·8	44·2	254 34·5	55·3
R 11	168 45·5	357 37·4	22·2	109 32·3	33·5	317 10·8	44·4	269 36·9	55·3
S 12	183 48·0	12 37·0	N 5 21·0	124 34·3	N18 33·6	332 12·8	S11 44·5	284 39·2	S21 55·4
D 13	198 50·4	27 36·6	19·8	139 36·2	33·8	347 14·8	44·7	299 41·5	55·4
A 14	213 52·9	42 36·2	18·6	154 38·2	34·0	2 16·7	44·9	314 43·9	55·4
Y 15	228 55·4	57 35·8	·· 17·4	169 40·1	·· 34·1	17 18·7	·· 45·1	329 46·2	·· 55·4
16	243 57·8	72 35·4	16·2	184 42·1	34·3	32 20·7	45·2	344 48·5	55·4
17	259 00·3	87 35·0	15·0	199 44·1	34·4	47 22·7	45·4	359 50·8	55·4
18	274 02·8	102 34·6	N 5 13·8	214 46·0	N18 34·6	62 24·7	S11 45·6	14 53·2	S21 55·5
19	289 05·2	117 34·1	12·6	229 48·0	34·8	77 26·7	45·8	29 55·5	55·5
20	304 07·7	132 33·7	11·3	244 49·9	34·9	92 28·6	45·9	44 57·8	55·5
21	319 10·1	147 33·3	·· 10·1	259 51·9	·· 35·1	107 30·6	·· 46·1	60 00·1	·· 55·5
22	334 12·6	162 32·9	08·9	274 53·9	35·3	122 32·6	46·3	75 02·5	55·5
23	349 15·1	177 32·5	07·7	289 55·8	35·4	137 34·6	46·5	90 04·8	55·5
26 00	4 17·5	192 32·1	N 5 06·5	304 57·8	N18 35·6	152 36·6	S11 46·6	105 07·1	S21 55·6
01	19 20·0	207 31·7	05·3	319 59·8	35·7	167 38·6	46·8	120 09·4	55·6
02	34 22·5	222 31·3	04·1	335 01·8	35·9	182 40·5	47·0	135 11·8	55·6
03	49 24·9	237 30·9	·· 02·9	350 03·7	·· 36·1	197 42·5	·· 47·2	150 14·1	·· 55·6
04	64 27·4	252 30·5	01·7	5 05·7	36·2	212 44·5	47·3	165 16·4	55·6
05	79 29·9	267 30·0	5 00·5	20 07·7	36·4	227 46·5	47·5	180 18·7	55·6
06	94 32·3	282 29·6	N 4 59·3	35 09·7	N18 36·5	242 48·5	S11 47·7	195 21·1	S21 55·7
07	109 34·8	297 29·2	58·1	50 11·6	36·7	257 50·4	47·9	210 23·4	55·7
08	124 37·3	312 28·8	56·9	65 13·6	36·9	272 52·4	48·0	225 25·7	55·7
F 09	139 39·7	327 28·4	·· 55·7	80 15·6	·· 37·0	287 54·4	·· 48·2	240 28·0	·· 55·7
R 10	154 42·2	342 28·0	54·4	95 17·6	37·2	302 56·4	48·4	255 30·4	55·7
I 11	169 44·6	357 27·6	53·2	110 19·6	37·3	317 58·4	48·6	270 32·7	55·7
D 12	184 47·1	12 27·2	N 4 52·0	125 21·6	N18 37·5	333 00·4	S11 48·7	285 35·0	S21 55·8
A 13	199 49·6	27 26·8	50·8	140 23·5	37·6	348 02·3	48·9	300 37·3	55·8
Y 14	214 52·0	42 26·4	49·6	155 25·5	37·8	3 04·3	49·1	315 39·7	55·8
15	229 54·5	57 26·0	·· 48·4	170 27·5	·· 38·0	18 06·3	·· 49·3	330 42·0	·· 55·8
16	244 57·0	72 25·5	47·2	185 29·5	38·1	33 08·3	49·4	345 44·3	55·8
17	259 59·4	87 25·1	46·0	200 31·5	38·3	48 10·3	49·6	0 46·6	55·9
18	275 01·9	102 24·7	N 4 44·8	215 33·5	N18 38·4	63 12·2	S11 49·8	15 49·0	S21 55·9
19	290 04·4	117 24·3	43·5	230 35·5	38·6	78 14·2	50·0	30 51·3	55·9
20	305 06·8	132 23·9	42·3	245 37·5	38·7	93 16·2	50·1	45 53·6	55·9
21	320 09·3	147 23·5	·· 41·1	260 39·5	·· 38·9	108 18·2	·· 50·3	60 55·9	·· 55·9
22	335 11·7	162 23·1	39·9	275 41·5	39·1	123 20·2	50·5	75 58·2	55·9
23	350 14·2	177 22·7	38·7	290 43·5	39·2	138 22·1	50·7	91 00·6	56·0
27 00	5 16·7	192 22·3	N 4 37·5	305 45·5	N18 39·4	153 24·1	S11 50·8	106 02·9	S21 56·0
01	20 19·1	207 21·9	36·3	320 47·5	39·5	168 26·1	51·0	121 05·2	56·0
02	35 21·6	222 21·5	35·1	335 49·5	39·7	183 28·1	51·2	136 07·5	56·0
03	50 24·1	237 21·1	·· 33·8	350 51·5	·· 39·8	198 30·1	·· 51·4	151 09·9	·· 56·0
04	65 26·5	252 20·7	32·6	5 53·5	40·0	213 32·0	51·5	166 12·2	56·0
05	80 29·0	267 20·2	31·4	20 55·5	40·2	228 34·0	51·7	181 14·5	56·1
06	95 31·5	282 19·8	N 4 30·2	35 57·5	N18 40·3	243 36·0	S11 51·9	196 16·8	S21 56·1
07	110 33·9	297 19·4	29·0	50 59·5	40·5	258 38·0	52·1	211 19·1	56·1
S 08	125 36·4	312 19·0	27·8	66 01·6	40·6	273 40·0	52·2	226 21·5	56·1
A 09	140 38·9	327 18·6	·· 26·6	81 03·6	·· 40·8	288 41·9	·· 52·4	241 23·8	·· 56·1
T 10	155 41·3	342 18·2	25·3	96 05·6	40·9	303 43·9	52·6	256 26·1	56·1
U 11	170 43·8	357 17·8	24·1	111 07·6	41·1	318 45·9	52·8	271 28·4	56·2
R 12	185 46·2	12 17·4	N 4 22·9	126 09·6	N18 41·2	333 47·9	S11 52·9	286 30·7	S21 56·2
D 13	200 48·7	27 17·0	21·7	141 11·6	41·4	348 49·9	53·1	301 33·1	56·2
A 14	215 51·2	42 16·6	20·5	156 13·7	41·5	3 51·8	53·3	316 35·4	56·2
Y 15	230 53·6	57 16·2	·· 19·3	171 15·7	·· 41·7	18 53·8	·· 53·5	331 37·7	·· 56·2
16	245 56·1	72 15·8	18·0	186 17·7	41·8	33 55·8	53·6	346 40·0	56·3
17	260 58·6	87 15·4	16·8	201 19·7	42·0	48 57·8	53·8	1 42·3	56·3
18	276 01·0	102 15·0	N 4 15·6	216 21·8	N18 42·1	63 59·7	S11 54·0	16 44·7	S21 56·3
19	291 03·5	117 14·6	14·4	231 23·8	42·3	79 01·7	54·2	31 47·0	56·3
20	306 06·0	132 14·2	13·2	246 25·8	42·4	94 03·7	54·3	46 49·3	56·3
21	321 08·4	147 13·8	·· 12·0	261 27·8	·· 42·6	109 05·7	· 54·5	61 51·6	·· 56·3
22	336 10·9	162 13·4	10·7	276 29·9	42·7	124 07·7	54·7	76 53·9	56·4
23	351 13·4	177 12·9	09·5	291 31·9	42·9	139 09·6	54·9	91 56·3	56·4
Mer. Pass.	h m 23 38·9	v −0·4	d 1·2	v 2·0	d 0·2	v 2·0	d 0·2	v 2·3	d 0·0

STARS		
Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 49·3	S 40 28·0
Achernar	335 56·9	S 57 26·6
Acrux	173 55·9	S 62 52·2
Adhara	255 44·9	S 28 54·8
Aldebaran	291 36·5	N 16 25·6
Alioth	166 57·4	N 56 11·1
Alkaid	153 31·8	N 49 31·3
Al Na'ir	28 35·0	S 47 09·6
Alnilam	276 28·1	S 1 13·6
Alphard	218 36·7	S 8 28·7
Alphecca	126 46·1	N 26 51·5
Alpheratz	358 25·7	N 28 51·9
Altair	62 48·2	N 8 45·8
Ankaa	353 55·9	S 42 31·6
Antares	113 16·9	S 26 20·4
Arcturus	146 33·6	N 19 24·0
Atria	108 55·8	S 68 57·4
Avior	234 35·1	S 59 22·4
Bellatrix	279 16·1	N 6 18·8
Betelgeuse	271 45·8	N 7 24·0
Canopus	264 14·4	S 52 40·2
Capella	281 35·2	N 45 57·2
Deneb	49 59·2	N 45 08·3
Denebola	183 15·9	N 14 48·2
Diphda	349 36·8	S 18 12·6
Dubhe	194 42·8	N 61 58·3
Elnath	279 04·6	N 28 34·3
Eltanin	91 05·3	N 51 30·0
Enif	34 27·3	N 9 41·4
Fomalhaut	16 09·0	S 29 50·3
Gacrux	172 47·3	S 56 52·9
Gienah	176 35·0	S 17 18·7
Hadar	149 46·8	S 60 10·5
Hamal	328 46·9	N 23 16·1
Kaus Aust.	84 38·4	S 34 24·3
Kochab	137 19·2	N 74 19·7
Markab	14 19·0	N 14 59·2
Menkar	314 57·9	N 3 55·8
Menkent	148 56·5	S 36 10·0
Miaplacidus	221 49·0	S 69 32·7
Mirfak	309 39·0	N 49 42·8
Nunki	76 49·2	S 26 20·9
Peacock	54 23·7	S 56 52·2
Pollux	244 18·2	N 28 07·5
Procyon	245 42·9	N 5 19·9
Rasalhague	96 44·7	N 12 35·6
Regulus	208 27·6	N 12 10·2
Rigel	281 51·5	S 8 14·8
Rigil Kent.	140 48·5	S 60 40·0
Sabik	102 59·8	S 15 40·4
Schedar	350 26·9	N 56 18·7
Shaula	97 17·9	S 37 04·5
Sirius	259 10·0	S 16 39·4
Spica	159 14·9	S 10 56·7
Suhail	223 23·0	S 43 15·8
Vega	81 06·8	N 38 45·1
Zuben'ubi	137 51·3	S 15 52·2

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	188 14·6	11 10
Mars	300 40·3	3 40
Jupiter	148 19·1	13 48
Saturn	100 49·6	16 57

SEPTEMBER 25, 26, 27 (THURS., FRI., SAT.)

G.M.T.	SUN			MOON					Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 25	Moonrise 26	Moonrise 27	Moonrise 28
	G.H.A.	Dec.		G.H.A.	v	Dec.	d	H.P.								
d h	° ′	° ′		° ′	′	° ′	′	′	°	h m	h m	h m	h m	h m	h m	h m
									N 72	03 19	04 46	05 54	17 23	17 17	17 11	17 05
25 00	182 00·3	S 0 33·9		33 27·4	13·9	S 7 48·2	9·0	55·0	N 70	03 36	04 53	05 54	17 16	17 15	17 14	17 14
01	197 00·5	34·9		48 00·3	13·9	7 39·2	9·1	55·0	68	03 49	04 58	05 54	17 10	17 13	17 17	17 21
02	212 00·7	35·9		62 33·2	13·9	7 30·1	9·0	55·0	66	04 00	05 02	05 53	17 05	17 12	17 19	17 27
03	227 00·9	36·8		77 06·1	14·0	7 21·1	9·1	55·0	64	04 08	05 06	05 53	17 01	17 11	17 21	17 32
04	242 01·1	37·8		91 39·1	14·0	7 12·0	9·1	55·0	62	04 15	05 09	05 53	16 57	17 10	17 23	17 36
05	257 01·3	38·8		106 12·1	14·1	7 02·9	9·2	54·9	60	04 21	05 11	05 52	16 54	17 09	17 24	17 40
06	272 01·6	S 0 39·8		120 45·2	14·1	S 6 53·7	9·1	54·9	N 58	04 27	05 13	05 52	16 51	17 08	17 26	17 43
07	287 01·8	40·7		135 18·3	14·1	6 44·6	9·2	54·9	56	04 31	05 15	05 52	16 48	17 08	17 27	17 46
T 08	302 02·0	41·7		149 51·4	14·1	6 35·4	9·2	54·9	54	04 35	05 17	05 52	16 46	17 07	17 28	17 49
H 09	317 02·2	42·7		164 24·5	14·2	6 26·2	9·3	54·9	52	04 38	05 18	05 52	16 44	17 07	17 29	17 51
U 10	332 02·4	43·7		178 57·7	14·2	6 16·9	9·2	54·9	50	04 41	05 19	05 51	16 42	17 06	17 30	17 54
R 11	347 02·6	44·6		193 30·9	14·3	6 07·7	9·3	54·8	45	04 48	05 22	05 51	16 38	17 05	17 32	17 59
S 12	2 02·9	S 0 45·6		208 04·2	14·2	S 5 58·4	9·3	54·8	N 40	04 52	05 24	05 51	16 34	17 04	17 33	18 03
D 13	17 03·1	46·6		222 37·4	14·3	5 49·1	9·3	54·8	35	04 56	05 25	05 50	16 31	17 03	17 35	18 06
A 14	32 03·3	47·6		237 10·7	14·4	5 39·8	9·4	54·8	30	04 59	05 26	05 50	16 28	17 02	17 36	18 09
Y 15	47 03·5	48·5		251 44·1	14·3	5 30·4	9·3	54·8	20	05 02	05 28	05 50	16 24	17 01	17 38	18 15
16	62 03·7	49·5		266 17·4	14·4	5 21·1	9·4	54·8	N 10	05 04	05 28	05 49	16 20	17 00	17 40	18 20
17	77 03·9	50·5		280 50·8	14·4	5 11·7	9·4	54·8	0	05 04	05 28	05 48	16 16	16 59	17 42	18 25
18	92 04·2	S 0 51·5		295 24·2	14·5	S 5 02·3	9·4	54·7	S 10	05 02	05 26	05 47	16 12	16 58	17 44	18 29
19	107 04·4	52·4		309 57·7	14·5	4 52·9	9·4	54·7	20	04 59	05 24	05 47	16 08	16 57	17 46	18 34
20	122 04·6	53·4		324 31·2	14·5	4 43·5	9·5	54·7	30	04 53	05 21	05 45	16 03	16 56	17 48	18 40
21	137 04·8	54·4		339 04·7	14·5	4 34·0	9·4	54·7	35	04 50	05 19	05 44	16 00	16 55	17 49	18 43
22	152 05·0	55·4		353 38·2	14·6	4 24·6	9·5	54·7	40	04 45	05 17	05 44	15 57	16 54	17 51	18 47
23	167 05·2	56·3		8 11·8	14·5	4 15·1	9·5	54·7	45	04 39	05 13	05 43	15 54	16 53	17 53	18 53
26 00	182 05·5	S 0 57·3		22 45·3	14·6	S 4 05·6	9·5	54·7	S 50	04 31	05 09	05 41	15 49	16 52	17 55	18 57
01	197 05·7	58·3		37 18·9	14·7	3 56·1	9·5	54·6	52	04 27	05 07	05 41	15 47	16 52	17 56	18 59
02	212 05·9	0 59·2		51 52·6	14·6	3 46·6	9·5	54·6	54	04 23	05 05	05 40	15 45	16 51	17 57	19 02
03	227 06·1	1 00·2		66 26·2	14·7	3 37·1	9·6	54·6	56	04 18	05 02	05 39	15 43	16 51	17 58	19 05
04	242 06·3	01·2		80 59·9	14·7	3 27·5	9·5	54·6	58	04 12	04 59	05 38	15 40	16 50	17 59	19 08
05	257 06·5	02·2		95 33·6	14·7	3 18·0	9·5	54·6	S 60	04 06	04 56	05 37	15 37	16 49	18 01	19 12
06	272 06·7	S 1 03·1		110 07·3	14·7	S 3 08·5	9·6	54·6								
07	287 07·0	04·1		124 41·0	14·8	2 58·9	9·6	54·6								
08	302 07·2	05·1		139 14·8	14·7	2 49·3	9·6	54·6								
F 09	317 07·4	06·1		153 48·5	14·8	2 39·7	9·5	54·5								
R 10	332 07·6	07·0		168 22·3	14·8	2 30·2	9·6	54·5								
I 11	347 07·8	08·0		182 56·1	14·9	2 20·6	9·6	54·5								
D 12	2 08·0	S 1 09·0		197 30·0	14·8	S 2 11·0	9·6	54·5								
A 13	17 08·2	10·0		212 03·8	14·9	2 01·4	9·7	54·5								
Y 14	32 08·5	10·9		226 37·7	14·9	1 51·7	9·6	54·5								
15	47 08·7	11·9		241 11·6	14·9	1 42·1	9·6	54·5								
16	62 08·9	12·9		255 45·5	14·9	1 32·5	9·6	54·5								
17	77 09·1	13·9		270 19·4	14·9	1 22·9	9·6	54·4								
18	92 09·3	S 1 14·8		284 53·3	14·9	S 1 13·3	9·6	54·4								
19	107 09·5	15·8		299 27·2	15·0	1 03·7	9·6	54·4								
20	122 09·7	16·8		314 01·2	14·9	0 54·1	9·7	54·4								
21	137 10·0	17·8		328 35·1	15·0	0 44·4	9·6	54·4								
22	152 10·2	18·7		343 09·1	15·0	0 34·8	9·6	54·4								
23	167 10·4	19·7		357 43·1	15·0	0 25·2	9·6	54·4								
27 00	182 10·6	S 1 20·7		12 17·1	15·0	S 0 15·6	9·6	54·4								
01	197 10·8	21·6		26 51·1	15·1	S 0 06·0	9·6	54·4								
02	212 11·0	22·6		41 25·2	15·0	N 0 03·6	9·7	54·3								
03	227 11·2	23·6		55 59·2	15·0	0 13·3	9·6	54·3								
04	242 11·5	24·6		70 33·2	15·1	0 22·9	9·6	54·3								
05	257 11·7	25·5		85 07·3	15·0	0 32·5	9·6	54·3								
06	272 11·9	S 1 26·5		99 41·3	15·1	N 0 42·1	9·5	54·3								
07	287 12·1	27·5		114 15·4	15·1	0 51·6	9·6	54·3								
S 08	302 12·3	28·5		128 49·5	15·1	1 01·2	9·6	54·3								
A 09	317 12·5	29·4		143 23·6	15·0	1 10·8	9·6	54·3								
T 10	332 12·7	30·4		157 57·6	15·1	1 20·4	9·5	54·3								
U 11	347 12·9	31·4		172 31·7	15·1	1 29·9	9·6	54·3								
R 12	2 13·2	S 1 32·4		187 05·8	15·1	N 1 39·5	9·5	54·3								
D 13	17 13·4	33·3		201 39·9	15·1	1 49·0	9·5	54·2								
A 14	32 13·6	34·3		216 14·0	15·1	1 58·5	9·5	54·2								
Y 15	47 13·8	35·3		230 48·1	15·1	2 08·0	9·5	54·2								
16	62 14·0	36·3		245 22·2	15·2	2 17·5	9·5	54·2								
17	77 14·2	37·2		259 56·4	15·1	2 27·0	9·5	54·2								
18	92 14·4	S 1 38·2		274 30·5	15·1	N 2 36·5	9·5	54·2								
19	107 14·6	39·2		289 04·6	15·1	2 46·0	9·4	54·2								
20	122 14·8	40·1		303 38·7	15·1	2 55·4	9·5	54·2								
21	137 15·1	41·1		318 12·8	15·1	3 04·9	9·4	54·2								
22	152 15·3	42·1		332 46·9	15·1	3 14·3	9·4	54·2								
23	167 15·5	43·1		347 21·0	15·1	3 23·7	9·4	54·2								
	S.D. 16·0	d 1·0		S.D.	14·9	14·9		14·8								

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 25	Moonset 26	Moonset 27	Moonset 28
°	h m	h m	h m	h m	h m	h m	h m
N 72	17 47	18 54	20 20	02 14	03 51	05 27	07 01
N 70	17 47	18 48	20 04	02 25	03 57	05 26	06 55
68	17 48	18 43	19 51	02 35	04 01	05 25	06 49
66	17 48	18 39	19 41	02 42	04 04	05 25	06 45
64	17 49	18 36	19 33	02 49	04 07	05 24	06 41
62	17 49	18 33	19 26	02 54	04 10	05 24	06 38
60	17 49	18 31	19 20	02 59	04 12	05 24	06 35
N 58	17 50	18 29	19 15	03 03	04 14	05 23	06 32
56	17 50	18 27	19 11	03 07	04 15	05 23	06 30
54	17 50	18 25	19 07	03 10	04 17	05 23	06 28
52	17 50	18 24	19 03	03 14	04 18	05 23	06 26
50	17 51	18 23	19 00	03 16	04 20	05 22	06 25
45	17 51	18 20	18 54	03 22	04 23	05 22	06 21
N 40	17 51	18 18	18 50	03 27	04 25	05 22	06 18
35	17 52	18 17	18 47	03 32	04 27	05 21	06 15
30	17 52	18 16	18 44	03 35	04 29	05 21	06 13
20	17 53	18 15	18 41	03 42	04 32	05 21	06 09
N 10	17 54	18 15	18 39	03 47	04 34	05 20	06 06
0	17 55	18 15	18 39	03 53	04 37	05 20	06 02
S 10	17 56	18 17	18 41	03 58	04 39	05 19	05 59
20	17 57	18 19	18 44	04 04	04 42	05 19	05 56
30	17 58	18 22	18 50	04 10	04 45	05 18	05 52
35	17 59	18 24	18 54	04 14	04 46	05 18	05 49
40	18 00	18 27	18 59	04 18	04 48	05 18	05 47
45	18 01	18 31	19 05	04 22	04 50	05 17	05 44
S 50	18 03	18 35	19 13	04 28	04 53	05 17	05 40
52	18 03	18 37	19 17	04 31	04 54	05 16	05 39
54	18 04	18 40	19 22	04 33	04 55	05 16	05 37
56	18 05	18 42	19 27	04 36	04 57	05 16	05 35
58	18 06	18 45	19 33	04 40	04 58	05 16	05 33
S 60	18 07	18 49	19 40	04 44	05 00	05 15	05 30

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
25	08 01	08 11	11 52	22 26	10 04	12	
26	08 21	08 32	11 51	23 09	10 48	13	○
27	08 42	08 52	11 51	23 52	11 31	14	

OCTOBER 10, 11, 12 (FRI., SAT., SUN.)

G.M.T.	ARIES	VENUS −3·4		MARS −1·4		JUPITER −1·2		SATURN +0·8		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
10 00	18 05·5	190 18·4	S 1 48·9	317 20·1	N19 18·0	163 37·5	S12 45·9	117 59·8	S22 01·6	Acamar	315 49·2	S 40 28·0
01	33 07·9	205 18·0	50·1	332 22·6	18·1	178 39·4	46·1	133 02·1	01·6	Achernar	335 56·8	S 57 26·7
02	48 10·4	220 17·6	51·4	347 25·0	18·2	193 41·4	46·3	148 04·4	01·7	Acrux	173 55·9	S 62 52·2
03	63 12·9	235 17·2	•• 52·6	2 27·5	•• 18·3	208 43·3	•• 46·5	163 06·6	•• 01·7	Adhara	255 44·8	S 28 54·8
04	78 15·3	250 16·8	53·9	17 30·0	18·4	223 45·3	46·6	178 08·9	01·7	Aldebaran	291 36·4	N 16 25·6
05	93 17·8	265 16·4	55·1	32 32·5	18·5	238 47·2	46·8	193 11·2	01·7			
06	108 20·3	280 16·0	S 1 56·4	47 34·9	N19 18·5	253 49·2	S12 47·0	208 13·5	S22 01·7	Alioth	166 57·4	N 56 11·0
07	123 22·7	295 15·6	57·6	62 37·4	18·6	268 51·1	47·2	223 15·7	01·8	Alkaid	153 31·8	N 49 31·3
08	138 25·2	310 15·2	1 58·9	77 39·9	18·7	283 53·1	47·3	238 18·0	01·8	Al Na'ir	28 35·1	S 47 09·7
F 09	153 27·6	325 14·8	2 00·1	92 42·4	•• 18·8	298 55·0	•• 47·5	253 20·3	•• 01·8	Alnilam	276 28·0	S 1 13·6
R 10	168 30·1	340 14·4	01·4	107 44·9	18·9	313 57·0	47·7	268 22·5	01·8	Alphard	218 36·7	S 8 28·7
I 11	183 32·6	355 14·0	02·6	122 47·3	19·0	328 58·9	47·9	283 24·8	01·8			
D 12	198 35·0	10 13·6	S 2 03·9	137 49·8	N19 19·1	344 00·9	S12 48·0	298 27·1	S22 01·8	Alphecca	126 46·1	N 26 51·4
A 13	213 37·5	25 13·2	05·1	152 52·3	19·2	359 02·8	48·2	313 29·4	01·9	Alpheratz	358 25·7	N 28 52·0
Y 14	228 40·0	40 12·8	06·4	167 54·8	19·3	14 04·8	48·4	328 31·6	01·9	Altair	62 48·3	N 8 45·8
15	243 42·4	55 12·4	•• 07·6	182 57·3	•• 19·3	29 06·8	•• 48·6	343 33·9	•• 01·9	Ankaa	353 55·9	S 42 31·7
16	258 44·9	70 12·0	08·9	197 59·8	19·4	44 08·7	48·8	358 36·2	01·9	Antares	113 17·0	S 26 20·4
17	273 47·4	85 11·6	10·1	213 02·3	19·5	59 10·7	48·9	13 38·5	01·9			
18	288 49·8	100 11·2	S 2 11·4	228 04·8	N19 19·6	74 12·6	S12 49·1	28 40·7	S22 02·0	Arcturus	146 33·6	N 19 24·0
19	303 52·3	115 10·8	12·6	243 07·3	19·7	89 14·6	49·3	43 43·0	02·0	Atria	108 56·0	S 68 57·4
20	318 54·8	130 10·4	13·9	258 09·8	19·8	104 16·5	49·5	58 45·3	02·0	Avior	234 35·0	S 59 22·4
21	333 57·2	145 10·0	•• 15·1	273 12·3	•• 19·9	119 18·5	•• 49·6	73 47·5	•• 02·0	Bellatrix	279 16·0	N 6 18·8
22	348 59·7	160 09·6	16·4	288 14·8	20·0	134 20·4	49·8	88 49·8	02·0	Betelgeuse	271 45·7	N 7 24·0
23	4 02·1	175 09·2	17·6	303 17·3	20·0	149 22·4	50·0	103 52·1	02·1			
11 00	19 04·6	190 08·8	S 2 18·9	318 19·8	N19 20·1	164 24·3	S12 50·2	118 54·4	S22 02·1	Canopus	264 14·3	S 52 40·2
01	34 07·1	205 08·4	20·1	333 22·3	20·2	179 26·3	50·3	133 56·6	02·1	Capella	281 35·0	N 45 57·3
02	49 09·5	220 08·0	21·4	348 24·8	20·3	194 28·2	50·5	148 58·9	02·1	Deneb	49 59·3	N 45 08·4
03	64 12·0	235 07·6	•• 22·6	3 27·3	•• 20·4	209 30·2	•• 50·7	164 01·2	•• 02·1	Denebola	183 15·9	N 14 48·2
04	79 14·5	250 07·2	23·9	18 29·8	20·5	224 32·1	50·9	179 03·4	02·1	Diphda	349 36·8	S 18 12·6
05	94 16·9	265 06·8	25·1	33 32·3	20·6	239 34·1	51·1	194 05·7	02·2			
06	109 19·4	280 06·4	S 2 26·4	48 34·8	N19 20·5	254 36·0	S12 51·2	209 08·0	S22 02·2	Dubhe	194 42·7	N 61 58·3
07	124 21·9	295 06·0	27·6	63 37·4	20·7	269 38·0	51·4	224 10·3	02·2	Elnath	279 04·5	N 28 34·3
S 08	139 24·3	310 05·6	28·9	78 39·9	20·8	284 39·9	51·6	239 12·5	02·2	Eltanin	91 05·4	N 51 30·0
A 09	154 26·8	325 05·2	•• 30·1	93 42·4	•• 20·9	299 41·9	•• 51·8	254 14·8	•• 02·2	Enif	34 27·3	N 9 41·4
T 10	169 29·2	340 04·8	31·4	108 44·9	21·0	314 43·8	51·9	269 17·1	02·3	Fomalhaut	16 09·0	S 29 50·4
U 11	184 31·7	355 04·4	32·6	123 47·4	21·1	329 45·8	52·1	284 19·3	02·3			
R 12	199 34·2	10 04·0	S 2 33·9	138 50·0	N19 21·2	344 47·7	S12 52·3	299 21·6	S22 02·3	Gacrux	172 47·3	S 56 52·8
D 13	214 36·6	25 03·6	35·1	153 52·5	21·2	359 49·7	52·5	314 23·9	02·3	Gienah	176 35·0	S 17 18·7
A 14	229 39·1	40 03·2	36·3	168 55·0	21·3	14 51·6	52·6	329 26·1	02·3	Hadar	149 46·9	S 60 10·5
Y 15	244 41·6	55 02·8	•• 37·6	183 57·6	•• 21·4	29 53·6	•• 52·8	344 28·4	•• 02·4	Hamal	328 46·9	N 23 16·2
16	259 44·0	70 02·4	38·8	199 00·1	21·5	44 55·5	53·0	359 30·7	02·4	Kaus Aust.	84 38·4	S 34 24·3
17	274 46·5	85 02·0	40·1	214 02·6	21·6	59 57·5	53·2	14 32·9	02·4			
18	289 49·0	100 01·6	S 2 41·3	229 05·2	N19 21·7	74 59·4	S12 53·4	29 35·2	S22 02·4	Kochab	137 19·4	N 74 19·7
19	304 51·4	115 01·2	42·6	244 07·7	21·7	90 01·4	53·5	44 37·5	02·4	Markab	14 19·0	N 14 59·2
20	319 53·9	130 00·8	43·8	259 10·2	21·8	105 03·3	53·7	59 39·7	02·4	Menkar	314 57·8	N 3 55·8
21	334 56·4	145 00·4	•• 45·1	274 12·8	•• 21·9	120 05·3	•• 53·9	74 42·0	•• 02·5	Menkent	148 56·5	S 36 10·0
22	349 58·8	160 00·0	46·3	289 15·3	22·0	135 07·2	54·1	89 44·3	02·5	Miaplacidus	221 48·8	S 69 32·6
23	5 01·3	174 59·5	47·6	304 17·9	22·1	150 09·2	54·2	104 46·5	02·5			
12 00	20 03·7	189 59·1	S 2 48·8	319 20·4	N19 22·1	165 11·1	S12 54·4	119 48·8	S22 02·5	Mirfak	309 38·8	N 49 42·8
01	35 06·2	204 58·7	50·1	334 22·9	22·2	180 13·1	54·6	134 51·1	02·5	Nunki	76 49·3	S 26 20·9
02	50 08·7	219 58·3	51·3	349 25·5	22·3	195 15·0	54·8	149 53·3	02·6	Peacock	54 23·9	S 56 52·2
03	65 11·1	234 57·9	•• 52·6	4 28·0	•• 22·4	210 17·0	•• 55·0	164 55·6	•• 02·6	Pollux	244 18·0	N 28 07·5
04	80 13·6	249 57·5	53·8	19 30·6	22·5	225 18·9	55·1	179 57·9	02·6	Procyon	245 42·8	N 5 19·9
05	95 16·1	264 57·1	55·1	34 33·1	22·6	240 20·9	55·3	195 00·2	02·6			
06	110 18·5	279 56·7	S 2 56·3	49 35·7	N19 22·6	255 22·8	S12 55·5	210 02·4	S22 02·6	Rasalhague	96 44·8	N 12 35·6
07	125 21·0	294 56·3	57·6	64 38·3	22·7	270 24·8	55·7	225 04·7	02·7	Regulus	208 27·5	N 12 10·1
08	140 23·5	309 55·9	2 58·8	79 40·8	22·8	285 26·7	55·8	240 07·0	02·7	Rigel	281 51·4	S 8 14·8
09	155 25·9	324 55·5	3 00·0	94 43·4	•• 22·9	300 28·7	•• 56·0	255 09·2	•• 02·7	Rigil Kent.	140 48·5	S 60 39·9
10	170 28·4	339 55·1	01·3	109 45·9	23·0	315 30·6	56·2	270 11·5	02·7	Sabik	102 59·9	S 15 40·4
11	185 30·9	354 54·7	02·5	124 48·5	23·0	330 32·6	56·4	285 13·7	02·7			
12	200 33·3	9 54·3	S 3 03·8	139 51·1	N19 23·1	345 34·5	S12 56·5	300 16·0	S22 02·7	Schedar	350 26·8	N 56 18·8
13	215 35·8	24 53·9	05·0	154 53·6	23·2	0 36·5	56·7	315 18·3	02·8	Shaula	97 17·9	S 37 04·5
14	230 38·2	39 53·5	06·3	169 56·2	23·3	15 38·4	56·9	330 20·5	02·8	Sirius	259 09·9	S 16 39·4
15	245 40·7	54 53·1	•• 07·5	184 58·8	•• 23·3	30 40·4	•• 57·1	345 22·8	•• 02·8	Spica	159 14·9	S 10 56·7
16	260 43·2	69 52·7	08·8	200 01·3	23·4	45 42·3	57·3	0 25·1	02·8	Suhail	223 22·9	S 43 15·8
17	275 45·6	84 52·3	10·0	215 03·9	23·5	60 44·3	57·4	15 27·3	02·8			
18	290 48·1	99 51·9	S 3 11·3	230 06·5	N19 23·6	75 46·2	S12 57·6	30 29·6	S22 02·9	Vega	81 06·9	N 38 45·1
19	305 50·6	114 51·5	12·5	245 09·1	23·7	90 48·2	57·8	45 31·9	02·9	Zuben'ubi	137 51·3	S 15 52·1
20	320 53·0	129 51·0	13·8	260 11·6	23·7	105 50·1	58·0	60 34·1	02·9			
21	335 55·5	144 50·6	•• 15·0	275 14·2	•• 23·8	120 52·1	•• 58·1	75 36·4	•• 02·9		S.H.A.	Mer. Pass.
22	350 58·0	159 50·2	16·3	290 16·8	23·9	135 54·0	58·3	90 38·7	02·9	Venus	171 04·2	11 20
23	6 00·4	174 49·8	17·5	305 19·4	24·0	150 56·0	58·5	105 40·9	03·0	Mars	299 15·2	2 46
	h m									Jupiter	145 19·7	13 01
r. Pass.	22 40·0	v −0·4	d 1·2	v 2·5	d 0·1	v 2·0	d 0·2	v 2·3	d 0·0	Saturn	99 49·8	16 02

OCTOBER 10, 11, 12 (FRI., SAT., SUN.)

G.M.T.	SUN			MOON					Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 10	Moonrise 11	Moonrise 12	Moonrise 13
	G.H.A.	Dec.		G.H.A.	v	Dec.	d	H.P.								
d h	° ′	° ′		° ′	′	° ′	′	′	°	h m	h m	h m	h m	h m	h m	h m
									N 72	04 35	05 54	07 03	02 14	04 14	06 17	08 24
10 00	183 11·1	S 6 21·9		221 37·0	8·7	N 5 42·4	11·1	59·9	N 70	04 41	05 52	06 54	02 22	04 14	06 09	08 07
01	198 11·3	22·8		236 04·7	8·7	5 31·3	11·1	60·0	68	04 46	05 51	06 47	02 28	04 14	06 03	07 54
02	213 11·5	23·8		250 32·4	8·7	5 20·2	11·2	60·0	66	04 50	05 50	06 41	02 33	04 14	05 58	07 43
03	228 11·6	24·7		265 00·1	8·7	5 09·0	11·2	60·0	64	04 54	05 49	06 36	02 38	04 14	05 54	07 34
04	243 11·8	25·7		279 27·8	8·6	4 57·8	11·3	60·1	62	04 56	05 48	06 32	02 41	04 15	05 50	07 27
05	258 12·0	26·6		293 55·4	8·7	4 46·5	11·3	60·1	60	04 59	05 47	06 28	02 44	04 15	05 47	07 20
06	273 12·1	S 6 27·6		308 23·1	8·6	N 4 35·2	11·4	60·1	N 58	05 00	05 46	06 25	02 47	04 15	05 44	07 14
07	288 12·3	28·5		322 50·7	8·5	4 23·8	11·4	60·2	56	05 02	05 45	06 22	02 50	04 15	05 42	07 09
08	303 12·5	29·5		337 18·2	8·6	4 12·4	11·5	60·2	54	05 03	05 44	06 19	02 52	04 15	05 39	07 05
F 09	318 12·6	30·4		351 45·8	8·5	4 00·9	11·5	60·2	52	05 04	05 43	06 17	02 54	04 15	05 37	07 01
R 10	333 12·8	31·4		6 13·3	8·5	3 49·4	11·5	60·3	50	05 05	05 42	06 15	02 56	04 15	05 35	06 57
I 11	348 13·0	32·3		20 40·8	8·5	3 37·9	11·5	60·3	45	05 06	05 40	06 10	03 00	04 15	05 31	06 49
D 12	3 13·1	S 6 33·3		35 08·3	8·5	N 3 26·4	11·6	60·3	N 40	05 07	05 38	06 06	03 04	04 15	05 28	06 42
A 13	18 13·3	34·2		49 35·8	8·4	3 14·8	11·7	60·4	35	05 07	05 37	06 02	03 07	04 15	05 25	06 36
Y 14	33 13·5	35·2		64 03·2	8·4	3 03·1	11·6	60·4	30	05 07	05 35	05 59	03 09	04 15	05 23	06 31
15	48 13·6	36·1		78 30·6	8·4	2 51·5	11·7	60·4	20	05 06	05 31	05 53	03 13	04 15	05 18	06 23
16	63 13·8	37·1		92 58·0	8·3	2 39·8	11·7	60·5	N 10	05 03	05 27	05 48	03 18	04 15	05 15	06 15
17	78 14·0	38·0		107 25·3	8·4	2 28·1	11·8	60·5	0	04 59	05 23	05 44	03 21	04 16	05 11	06 08
18	93 14·1	S 6 39·0		121 52·7	8·3	N 2 16·3	11·7	60·5	S 10	04 53	05 18	05 39	03 25	04 16	05 08	06 01
19	108 14·3	39·9		136 20·0	8·2	2 04·6	11·8	60·5	20	04 45	05 11	05 33	03 29	04 16	05 04	05 54
20	123 14·5	40·9		150 47·2	8·3	1 52·8	11·8	60·6	30	04 35	05 03	05 27	03 34	04 16	05 00	05 46
21	138 14·6	41·8		165 14·5	8·2	1 41·0	11·9	60·6	35	04 28	04 58	05 24	03 36	04 16	04 58	05 41
22	153 14·8	42·8		179 41·7	8·2	1 29·1	11·8	60·6	40	04 19	04 52	05 19	03 39	04 17	04 55	05 35
23	168 15·0	43·7		194 08·9	8·2	1 17·3	11·9	60·7	45	04 09	04 44	05 15	03 43	04 17	04 52	05 29
11 00	183 15·1	S 6 44·7		208 36·1	8·1	N 1 05·4	11·9	60·7	S 50	03 55	04 36	05 09	03 47	04 17	04 48	05 22
01	198 15·3	45·6		223 03·2	8·1	0 53·5	11·9	60·7	52	03 49	04 31	05 06	03 49	04 17	04 47	05 18
02	213 15·4	46·5		237 30·3	8·1	0 41·6	12·0	60·7	54	03 42	04 26	05 03	03 51	04 18	04 45	05 15
03	228 15·6	47·5		251 57·4	8·0	0 29·6	11·9	60·8	56	03 33	04 21	05 00	03 53	04 18	04 43	05 11
04	243 15·8	48·4		266 24·4	8·0	0 17·7	12·0	60·8	58	03 24	04 15	04 56	03 55	04 18	04 41	05 06
05	258 15·9	49·4		280 51·4	8·0	N 0 05·7	11·9	60·8	S 60	03 12	04 08	04 52	03 58	04 18	04 39	05 01
06	273 16·1	S 6 50·3		295 18·4	8·0	S 0 06·2	12·0	60·8								
07	288 16·3	51·3		309 45·4	7·9	0 18·2	12·0	60·9								
S 08	303 16·4	52·2		324 12·3	7·9	0 30·2	12·0	60·9								
A 09	318 16·6	53·2		338 39·2	7·8	0 42·2	12·0	60·9								
T 10	333 16·7	54·1		353 06·0	7·9	0 54·2	12·0	60·9								
U 11	348 16·9	55·1		7 32·9	7·8	1 06·2	12·0	61·0								
R 12	3 17·1	S 6 56·0		21 59·7	7·7	S 1 18·2	12·0	61·0								
D 13	18 17·2	56·9		36 26·4	7·7	1 30·2	12·0	61·0								
A 14	33 17·4	57·9		50 53·1	7·7	1 42·2	12·0	61·0								
Y 15	48 17·5	58·8		65 19·8	7·7	1 54·2	12·0	61·0								
16	63 17·7	6 59·8		79 46·5	7·6	2 06·2	12·0	61·1								
17	78 17·9	7 00·7		94 13·1	7·6	2 18·2	12·0	61·1								
18	93 18·0	S 7 01·7		108 39·7	7·6	S 2 30·2	12·0	61·1								
19	108 18·2	02·6		123 06·3	7·5	2 42·2	11·9	61·1								
20	123 18·3	03·5		137 32·8	7·5	2 54·1	12·0	61·1								
21	138 18·5	04·5		151 59·3	7·5	3 06·1	11·9	61·2								
22	153 18·7	05·4		166 25·8	7·4	3 18·0	12·0	61·2								
23	168 18·8	06·4		180 52·2	7·4	3 30·0	11·9	61·2								
12 00	183 19·0	S 7 07·3		195 18·6	7·3	S 3 41·9	11·9	61·2								
01	198 19·1	08·3		209 44·9	7·3	3 53·8	11·8	61·2								
02	213 19·3	09·2		224 11·2	7·3	4 05·6	11·9	61·2								
03	228 19·4	10·2		238 37·5	7·3	4 17·5	11·8	61·2								
04	243 19·6	11·1		253 03·8	7·2	4 29·3	11·8	61·3								
05	258 19·8	12·0		267 30·0	7·1	4 41·1	11·8	61·3								
06	273 19·9	S 7 13·0		281 56·1	7·2	S 4 52·9	11·7	61·3								
07	288 20·1	13·9		296 22·3	7·1	5 04·6	11·7	61·3								
08	303 20·2	14·9		310 48·4	7·0	5 16·3	11·7	61·3								
S 09	318 20·4	15·8		325 14·4	7·1	5 28·0	11·7	61·3								
U 10	333 20·5	16·7		339 40·5	7·0	5 39·7	11·6	61·3								
N 11	348 20·7	17·7		354 06·5	6·9	5 51·3	11·6	61·3								
D 12	3 20·9	S 7 18·6		8 32·4	6·9	S 6 02·9	11·5	61·3								
A 13	18 21·0	19·6		22 58·3	6·9	6 14·4	11·6	61·4								
Y 14	33 21·2	20·5		37 24·2	6·9	6 26·0	11·4	61·4								
15	48 21·3	21·4		51 50·1	6·8	6 37·4	11·4	61·4								
16	63 21·5	22·4		66 15·9	6·7	6 48·8	11·4	61·4								
17	78 21·6	23·3		80 41·6	6·8	7 00·2	11·4	61·4								
18	93 21·8	S 7 24·3														
19	108 21·9	25·2														
20	123 22·1	26·1														
21	138 22·2	27·1														
22	153 22·4	28·0														
23	168 22·6	29·0														
	S.D. 16·0	d 0·9		S.D.	16·4		16·6	16·7								

A Total Eclipse of the Sun occurs to-day. See page 5.

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 10	Moonset 11	Moonset 12	Moonset 13
	h m	h m	h m	h m	h m	h m	h m
N 72	16 30	17 38	18 56	16 19	16 13	16 06	15 59
N 70	16 38	17 40	18 50	16 16	16 16	16 16	16 17
68	16 45	17 41	18 46	16 13	16 18	16 24	16 32
66	16 51	17 43	18 42	16 10	16 20	16 31	16 44
64	16 56	17 44	18 39	16 09	16 22	16 37	16 54
62	17 01	17 45	18 36	16 07	16 24	16 42	17 03
60	17 04	17 46	18 34	16 05	16 25	16 45	17 11
N 58	17 08	17 47	18 33	16 04	16 26	16 50	17 17
56	17 11	17 48	18 31	16 03	16 27	16 54	17 23
54	17 14	17 49	18 30	16 02	16 29	16 57	17 28
52	17 16	17 50	18 29	16 01	16 30	17 00	17 33
50	17 18	17 51	18 28	16 00	16 30	17 02	17 37
45	17 23	17 53	18 26	15 58	16 32	17 08	17 47
N 40	17 27	17 55	18 26	15 56	16 34	17 13	17 55
35	17 31	17 56	18 26	15 55	16 35	17 17	18 02
30	17 34	17 58	18 26	15 53	16 36	17 21	18 08
20	17 40	18 02	18 28	15 51	16 38	17 27	18 18
N 10	17 45	18 06	18 31	15 49	16 40	17 33	18 27
0	17 50	18 11	18 35	15 47	16 42	17 38	18 36
S 10	17 55	18 16	18 41	15 45	16 43	17 43	18 44
20	18 01	18 23	18 49	15 43	16 45	17 49	18 53
30	18 07	18 31	19 00	15 40	16 47	17 55	19 04
35	18 11	18 37	19 07	15 39	16 48	17 59	19 10
40	18 15	18 43	19 15	15 37	16 49	18 03	19 17
45	18 20	18 50	19 26	15 35	16 51	18 08	19 25
S 50	18 26	18 59	19 40	15 33	16 53	18 14	19 35
52	18 29	19 04	19 47	15 32	16 53	18 16	19 39
54	18 32	19 09	19 54	15 31	16 54	18 19	19 44
56	18 35	19 14	20 03	15 29	16 55	18 23	19 50
58	18 39	19 20	20 13	15 28	16 56	18 26	19 56
S 60	18 43	19 28	20 24	15 26	16 57	18 30	20 03

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
10	12 44	12 52	11 47	09 34	22 01	27	
11	13 00	13 08	11 47	10 29	22 56	28	●
12	13 16	13 23	11 47	11 24	23 53	29	

DECEMBER 21, 22, 23 (SUN., MON., TUES.)

G.M.T.	ARIES	VENUS −3·4		MARS −0·9		JUPITER −1·3		SATURN +0·6		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
21 00	89 03·5	170 02·9	S 24 01·8	45 27·3	N 16 25·3	219 20·9	S 17 20·2	181 01·9	S 22 27·9	Acamar	315 49·2	S 40 28·3
01	104 05·9	185 01·9	01·6	60 29·7	25·4	234 22·8	20·3	196 04·1	27·9	Achernar	335 57·1	S 57 27·0
02	119 08·4	200 00·9	01·5	75 32·2	25·5	249 24·8	20·5	211 06·2	27·9	Acrux	173 55·1	S 62 52·0
03	134 10·9	215 00·0	01·4	90 34·6	25·5	264 26·8	20·6	226 08·4	28·0	Adhara	255 44·3	S 28 55·0
04	149 13·3	229 59·0	01·3	105 37·1	25·6	279 28·7	20·7	241 10·5	28·0	Aldebaran	291 36·1	N 16 25·6
05	164 15·8	244 58·0	01·2	120 39·5	25·6	294 30·7	20·8	256 12·6	28·0			
06	179 18·2	259 57·1	S 24 01·1	135 42·0	N 18 25·7	309 32·7	S 17 21·0	271 14·8	S 22 28·0	Alioth	166 56·9	N 56 10·7
07	194 20·7	274 56·1	00·9	150 44·4	25·7	324 34·6	21·1	286 16·9	28·0	Alkaid	153 31·5	N 49 30·9
08	209 23·2	289 55·1	00·8	165 46·9	25·8	339 36·6	21·2	301 19·1	28·0	Al Na'ir	28 35·4	S 47 09·7
S 09	224 25·6	304 54·1	00·7	180 49·3	25·8	354 38·6	21·3	316 21·2	28·0	Alnilam	276 27·6	S 1 13·7
U 10	239 28·1	319 53·2	00·6	195 51·7	25·9	9 40·5	21·5	331 23·4	28·0	Alphard	218 36·1	S 8 28·9
N 11	254 30·6	334 52·2	00·5	210 54·2	26·0	24 42·5	21·6	346 25·5	28·0			
D 12	269 33·0	349 51·2	S 24 00·3	225 56·6	N 18 26·0	39 44·5	S 17 21·7	1 27·7	S 22 28·0	Alpheeca	126 46·0	N 26 51·1
A 13	284 35·5	4 50·3	00·2	240 59·1	26·1	54 46·4	21·8	16 29·8	28·0	Alpheratz	358 25·9	N 28 52·0
Y 14	299 38·0	19 49·3	24 00·1	256 01·5	26·1	69 48·4	22·0	31 32·0	28·0	Altair	62 48·5	N 8 45·7
15	314 40·4	34 48·3	23 59·9	271 03·9	26·2	84 50·4	22·1	46 34·1	28·0	Ankaa	353 56·1	S 42 31·9
16	329 42·9	49 47·3	59·8	286 06·4	26·2	99 52·3	22·2	61 36·2	28·0	Antares	113 16·9	S 26 20·4
17	344 45·4	64 46·4	59·7	301 08·8	26·3	114 54·3	22·3	76 38·4	28·0			
18	359 47·8	79 45·4	S 23 59·5	316 11·2	N 18 26·4	129 56·3	S 17 22·5	91 40·5	S 22 28·0	Arcturus	146 33·3	N 19 23·7
19	14 50·3	94 44·4	59·4	331 13·7	26·4	144 58·2	22·6	106 42·7	28·1	Atria	108 56·1	S 68 57·1
20	29 52·7	109 43·5	59·3	346 16·1	26·5	160 00·2	22·7	121 44·8	28·1	Avior	234 34·2	S 59 22·6
21	44 55·2	124 42·5	59·1	1 18·5	26·5	175 02·2	22·8	136 47·0	28·1	Bellatrix	279 15·6	N 6 18·7
22	59 57·7	139 41·5	59·0	16 20·9	26·6	190 04·1	23·0	151 49·1	28·1	Betelgeuse	271 45·3	N 7 23·9
23	75 00·1	154 40·5	58·9	31 23·4	26·7	205 06·1	23·1	166 51·3	28·1			
22 00	90 02·6	169 39·6	S 23 58·7	46 25·8	N 18 26·7	220 08·1	S 17 23·2	181 53·4	S 22 28·1	Canopus	264 13·8	S 52 40·5
01	105 05·1	184 38·6	58·6	61 28·2	26·8	235 10·0	23·3	196 55·5	28·1	Capella	281 34·6	N 45 57·4
02	120 07·5	199 37·6	58·4	76 30·6	26·8	250 12·0	23·5	211 57·7	28·1	Deneb	49 59·7	N 45 08·3
03	135 10·0	214 36·7	58·3	91 33·0	26·9	265 14·0	23·6	226 59·8	28·1	Denebola	183 15·4	N 14 48·0
04	150 12·5	229 35·7	58·1	106 35·5	27·0	280 15·9	23·7	242 02·0	28·1	Diphda	349 36·9	S 18 12·8
05	165 14·9	244 34·7	58·0	121 37·9	27·0	295 17·9	23·8	257 04·1	28·1			
06	180 17·4	259 33·7	S 23 57·8	136 40·3	N 18 27·1	310 19·9	S 17 23·9	272 06·3	S 22 28·1	Dubhe	194 41·8	N 61 58·0
07	195 19·8	274 32·8	57·7	151 42·7	27·2	325 21·8	24·1	287 08·4	28·1	Elnath	279 04·1	N 28 34·4
08	210 22·3	289 31·8	57·5	166 45·1	27·2	340 23·8	24·2	302 10·6	28·1	Eltanin	91 05·7	N 51 29·7
M 09	225 24·8	304 30·8	57·4	181 47·5	27·3	355 25·8	24·3	317 12·7	28·1	Enif	34 27·5	N 9 41·3
O 10	240 27·2	319 29·9	57·2	196 49·9	27·4	10 27·7	24·4	332 14·9	28·1	Fomalhaut	16 09·3	S 29 50·5
N 11	255 29·7	334 28·9	57·1	211 52·3	27·4	25 29·7	24·6	347 17·0	28·2			
D 12	270 32·2	349 27·9	S 23 56·9	226 54·7	N 18 27·5	40 31·7	S 17 24·7	2 19·1	S 22 28·2	Gacrux	172 46·6	S 56 52·7
A 13	285 34·6	4 27·0	56·8	241 57·1	27·5	55 33·7	24·8	17 21·3	28·2	Gienah	176 34·5	S 17 18·8
Y 14	300 37·1	19 26·0	56·6	256 59·5	27·6	70 35·6	24·9	32 23·4	28·2	Hadar	149 46·4	S 60 10·3
15	315 39·6	34 25·0	56·5	272 01·9	27·7	85 37·6	25·1	47 25·6	28·2	Hamal	328 46·8	N 23 16·2
16	330 42·0	49 24·1	56·3	287 04·3	27·7	100 39·6	25·2	62 27·7	28·2	Kaus Aust.	84 38·6	S 34 24·2
17	345 44·5	64 23·1	56·1	302 06·7	27·8	115 41·5	25·3	77 29·9	28·2			
18	0 47·0	79 22·1	S 23 56·0	317 09·1	N 18 27·9	130 43·5	S 17 25·4	92 32·0	S 22 28·2	Kochab	137 19·2	N 74 19·2
19	15 49·4	94 21·2	55·8	332 11·5	27·9	145 45·5	25·6	107 34·2	28·2	Markab	14 19·2	N 14 59·2
20	30 51·9	109 20·2	55·6	347 13·9	28·0	160 47·4	25·7	122 36·3	28·2	Menkar	314 57·7	N 3 55·7
21	45 54·3	124 19·2	55·5	2 16·3	28·1	175 49·4	25·8	137 38·4	28·2	Menkent	148 56·1	S 36 09·9
22	60 56·8	139 18·3	55·3	17 18·7	28·1	190 51·4	25·9	152 40·6	28·2	Miaplacidus	221 47·6	S 69 32·8
23	75 59·3	154 17·3	55·1	32 21·1	28·2	205 53·4	26·0	167 42·7	28·2			
23 00	91 01·7	169 16·3	S 23 55·0	47 23·5	N 18 28·3	220 55·3	S 17 26·2	182 44·9	S 22 28·2	Mirfak	309 38·6	N 49 43·1
01	106 04·2	184 15·4	54·8	62 25·9	28·3	235 57·3	26·3	197 47·0	28·2	Nunki	76 49·5	S 26 20·8
02	121 06·7	199 14·4	54·6	77 28·3	28·4	250 59·3	26·4	212 49·2	28·2	Peacock	54 24·3	S 56 52·1
03	136 09·1	214 13·4	54·4	92 30·7	28·5	266 01·2	26·5	227 51·3	28·2	Pollux	244 17·5	N 28 07·4
04	151 11·6	229 12·5	54·3	107 33·0	28·6	281 03·2	26·7	242 53·5	28·3	Procyon	245 42·3	N 5 19·7
05	166 14·1	244 11·5	54·1	122 35·4	28·6	296 05·2	26·8	257 55·6	28·3			
06	181 16·5	259 10·5	S 23 53·9	137 37·8	N 18 28·7	311 07·2	S 17 26·9	272 57·7	S 22 28·3	Rasalhague	96 44·9	N 12 35·5
07	196 19·0	274 09·6	53·7	152 40·2	28·8	326 09·1	27·0	287 59·9	28·3	Regulus	208 26·9	N 12 09·9
T 08	211 21·5	289 08·6	53·5	167 42·6	28·8	341 11·1	27·1	303 02·0	28·3	Rigel	281 51·1	S 8 15·0
U 09	226 23·9	304 07·6	53·4	182 44·9	28·9	356 13·1	27·3	318 04·2	28·3	Rigil Kent.	140 48·1	S 60 39·7
E 10	241 26·4	319 06·7	53·2	197 47·3	29·0	11 15·0	27·4	333 06·3	28·3	Sabik	102 59·9	S 15 40·4
S 11	256 28·8	334 05·7	53·0	212 49·7	29·0	26 17·0	27·5	348 08·5	28·3			
D 12	271 31·3	349 04·7	S 23 52·8	227 52·1	N 18 29·1	41 19·0	S 17 27·6	3 10·6	S 22 28·3	Schedar	350 27·1	N 56 19·1
A 13	286 33·8	4 03·8	52·6	242 54·4	29·2	56 21·0	27·8	18 12·8	28·3	Shaula	97 18·0	S 37 04·4
Y 14	301 36·2	19 02·8	52·4	257 56·8	29·3	71 22·9	27·9	33 14·9	28·3	Sirius	259 09·5	S 16 39·7
15	316 38·7	34 01·9	52·2	272 59·2	29·3	86 24·9	28·0	48 17·0	28·3	Spica	159 14·6	S 10 56·8
16	331 41·2	49 00·9	52·0	288 01·5	29·4	101 26·9	28·1	63 19·2	28·3	Suhail	223 22·2	S 43 15·9
17	346 43·6	63 59·9	51·8	303 03·9	29·5	116 28·8	28·2	78 21·3	28·3			
18	1 46·1	78 59·0	S 23 51·6	318 06·3	N 18 29·6	131 30·8	S 17 28·4	93 23·5	S 22 28·3	Vega	81 07·1	N 38 44·9
19	16 48·6	93 58·0	51·4	333 08·6	29·6	146 32·8	28·5	108 25·6	28·3	Zuben'ubi	137 51·1	S 15 52·2
20	31 51·0	108 57·0	51·3	348 11·0	29·7	161 34·8	28·6	123 27·8	28·3			
21	46 53·5	123 56·1	51·1	3 13·4	29·8	176 36·7	28·7	138 29·9	28·4		S.H.A.	Mer. Pass.
22	61 55·9	138 55·1	50·9	18 15·7	29·8	191 38·7	28·8	153 32·1	28·4		° ′	h m
23	76 58·4	153 54·1	50·7	33 18·1	29·9	206 40·7	29·0	168 34·2	28·4	Venus	79 37·0	12 42
	h m									Mars	316 23·2	20 51
Mer. Pass.	17 56·9	v −1·0	d 0·2	v 2·4	d 0·1	v 2·0	d 0·1	v 2·1	d 0·0	Jupiter	130 05·5	9 18
										Saturn	91 50·8	11 51

DECEMBER 21, 22, 23 (SUN., MON., TUES.)

G.M.T.	SUN			MOON					Lat.	Twilight		Sun-	Moonrise			
										Naut.	Civil	rise	21	22	23	24
	G.H.A.		Dec.	G.H.A.	v	Dec.	d	H.P.								
d h	° ′		° ′	° ′	′	° ′	′	′	°	h m	h m	h m	h m	h m	h m	h m
21 00	180 34·0	S	23 26·1	59 40·8	14·4	N 10 57·0	7·8	54·1	N 72	08 26	10 57		11 33	11 25	11 12	
01	195 33·7		26·1	74 14·2	14·4	11 04·8	7·8	54·1	N 70	08 06	09 54		11 55	11 57	12 04	12 19
02	210 33·3		26·1	88 47·6	14·3	11 12·6	7·6	54·1	68	07 50	09 19		12 11	12 21	12 36	13 02
03	225 33·0		26·2	103 20·9	14·3	11 20·2	7·7	54·2	66	07 36	08 54	10 35	12 25	12 39	13 00	13 30
04	240 32·7		26·2	117 54·2	14·3	11 27·9	7·6	54·2	64	07 25	08 34	09 52	12 36	12 54	13 18	13 52
05	255 32·4		26·2	132 27·5	14·2	11 35·5	7·5	54·2	62	07 16	08 18	09 24	12 46	13 07	13 34	14 09
									60	07 07	08 04	09 02	12 54	13 18	13 47	14 24
06	270 32·1	S	23 26·2	147 00·7	14·3	N 11 43·0	7·5	54·2	N 58	07 00	07 52	08 45	13 02	13 27	13 58	14 36
07	285 31·8		26·3	161 34·0	14·2	11 50·5	7·5	54·2	56	06 53	07 42	08 30	13 08	13 35	14 07	14 47
08	300 31·5		26·3	176 07·2	14·1	11 58·0	7·4	54·2	54	06 47	07 33	08 17	13 14	13 42	14 16	14 56
S 09	315 31·2		26·3	190 40·3	14·1	12 05·4	7·4	54·2	52	06 41	07 25	08 06	13 19	13 49	14 24	15 05
U 10	330 30·9		26·3	205 13·4	14·1	12 12·8	7·3	54·2	50	06 36	07 18	07 56	13 24	13 55	14 31	15 12
N 11	345 30·5		26·3	219 46·5	14·1	12 20·1	7·2	54·2	45	06 24	07 02	07 35	13 34	14 08	14 45	15 28
D 12	0 30·2	S	23 26·4	234 19·6	14·0	N 12 27·3	7·2	54·2	N 40	06 14	06 48	07 18	13 43	14 18	14 58	15 42
A 13	15 29·9		26·4	248 52·6	14·0	12 34·5	7·2	54·2	35	06 04	06 36	07 04	13 50	14 27	15 08	15 53
Y 14	30 29·6		26·4	263 25·6	13·9	12 41·7	7·1	54·2	30	05 56	06 26	06 52	13 57	14 35	15 17	16 03
15	45 29·3		26·4	277 58·5	13·9	12 48·8	7·0	54·2	20	05 39	06 07	06 31	14 08	14 49	15 33	16 20
16	60 29·0		26·4	292 31·4	13·9	12 55·8	7·0	54·2	N 10	05 23	05 49	06 12	14 18	15 01	15 47	16 35
17	75 28·7		26·4	307 04·3	13·9	13 02·8	7·0	54·2	0	05 06	05 32	05 55	14 28	15 13	16 00	16 49
18	90 28·4	S	23 26·4	321 37·2	13·8	N 13 09·8	6·9	54·2	S 10	04 47	05 14	05 37	14 37	15 24	16 13	17 03
19	105 28·1		26·5	336 10·0	13·7	13 16·7	6·8	54·2	20	04 24	04 53	05 18	14 47	15 37	16 27	17 18
20	120 27·8		26·5	350 42·7	13·8	13 23·5	6·8	54·2	30	03 55	04 28	04 56	14 59	15 51	16 43	17 35
21	135 27·4		26·5	5 15·5	13·7	13 30·3	6·7	54·2	35	03 37	04 13	04 43	15 05	15 59	16 53	17 45
22	150 27·1		26·5	19 48·2	13·6	13 37·0	6·7	54·2	40	03 13	03 55	04 28	15 13	16 09	17 03	17 57
23	165 26·8		26·5	34 20·8	13·6	13 43·7	6·6	54·2	45	02 43	03 32	04 10	15 22	16 20	17 16	18 10
22 00	180 26·5	S	23 26·5	48 53·4	13·6	N 13 50·3	6·5	54·2	S 50	01 57	03 03	03 47	15 33	16 33	17 31	18 27
01	195 26·2		26·5	63 26·0	13·6	13 56·8	6·5	54·2	52	01 29	02 47	03 36	15 38	16 39	17 39	18 35
02	210 25·9		26·5	77 58·6	13·5	14 03·3	6·4	54·3	54	00 41	02 29	03 24	15 44	16 46	17 47	18 43
03	225 25·6		26·5	92 31·1	13·4	14 09·7	6·4	54·3	56	////	02 07	03 10	15 50	16 54	17 55	18 53
04	240 25·3		26·5	107 03·5	13·5	14 16·1	6·3	54·3	58	////	01 37	02 53	15 57	17 03	18 06	19 04
05	255 25·0		26·5	121 36·0	13·3	14 22·4	6·3	54·3	S 60	////	00 47	02 32	16 05	17 13	18 18	19 17
06	270 24·6	S	23 26·5	136 08·3	13·4	N 14 28·7	6·2	54·3								
07	285 24·3		26·5	150 40·7	13·3	14 34·9	6·1	54·3								
08	300 24·0		26·5	165 13·0	13·3	14 41·0	6·1	54·3								
M 09	315 23·7		26·5	179 45·3	13·2	14 47·1	6·0	54·3								
O 10	330 23·4		26·5	194 17·5	13·2	14 53·1	5·9	54·3								
N 11	345 23·1		26·5	208 49·7	13·1	14 59·0	5·9	54·3								
D 12	0 22·8	S	23 26·5	223 21·8	13·1	N 15 04·9	5·8	54·3								
A 13	15 22·5		26·5	237 53·9	13·1	15 10·7	5·8	54·3								
Y 14	30 22·2		26·5	252 26·0	13·0	15 16·5	5·6	54·4								
15	45 21·8		26·5	266 58·0	13·0	15 22·1	5·7	54·4								
16	60 21·5		26·5	281 30·0	12·9	15 27·8	5·5	54·4								
17	75 21·2		26·5	296 01·9	12·9	15 33·3	5·5	54·4								
18	90 20·9	S	23 26·5	310 33·8	12·9	N 15 38·8	5·4	54·4								
19	105 20·6		26·5	325 05·7	12·8	15 44·2	5·4	54·4								
20	120 20·3		26·5	339 37·5	12·8	15 49·6	5·2	54·4								
21	135 20·0		26·5	354 09·3	12·7	15 54·8	5·2	54·4								
22	150 19·7		26·5	8 41·0	12·7	16 00·0	5·2	54·4								
23	165 19·4		26·4	23 12·7	12·6	16 05·2	5·1	54·5								
23 00	180 19·1	S	23 26·4	37 44·3	12·6	N 16 10·3	4·9	54·5								
01	195 18·7		26·4	52 15·9	12·6	16 15·2	5·0	54·5								
02	210 18·4		26·4	66 47·5	12·5	16 20·2	4·8	54·5								
03	225 18·1		26·4	81 19·0	12·5	16 25·0	4·8	54·5								
04	240 17·8		26·4	95 50·5	12·4	16 29·8	4·7	54·5								
05	255 17·5		26·4	110 21·9	12·4	16 34·5	4·7	54·5								
06	270 17·2	S	23 26·3	124 53·3	12·4	N 16 39·2	4·5	54·5								
07	285 16·9		26·3	139 24·7	12·3	16 43·7	4·5	54·5								
T 08	300 16·6		26·3	153 56·0	12·2	16 48·2	4·4	54·6								
U 09	315 16·3		26·3	168 27·2	12·3	16 52·6	4·3	54·6								
E 10	330 15·9		26·3	182 58·5	12·1	16 56·9	4·3	54·6								
S 11	345 15·6		26·2	197 29·6	12·2	17 01·2	4·2	54·6								
D 12	0 15·3	S	23 26·2	212 00·8	12·1	N 17 05·4	4·1	54·6								
A 13	15 15·0		26·2	226 31·9	12·1	17 09·5	4·0	54·6								
Y 14	30 14·7		26·2	241 03·0	12·0	17 13·5	4·0	54·6								
15	45 14·4		26·2	255 34·0	12·0	17 17·5	3·8	54·7								
16	60 14·1		26·1	270 05·0	11·9	17 21·3	3·8	54·7								
17	75 13·8		26·1	284 35·9	11·9	17 25·1	3·7	54·7								
18	90 13·5	S	23 26·1	299 06·8	11·9	N 17 28·8	3·6	54·7								
19	105 13·2		26·0	313 37·7	11·8	17 32·4	3·6	54·7								
20	120 12·8		26·0	328 08·5	11·7	17 36·0	3·5	54·7								
21	135 12·5		26·0	342 39·2	11·8	17 39·5	3·3	54·7								
22	150 12·2		26·0	357 10·0	11·7	17 42·8	3·3	54·8								
23	165 11·9		25·9	11 40·7	11·6	17 46·1	3·3	54·8								
	S.D. 16·3		d 0·0	S.D.	14·8	14·8		14·9								

Lat.	Sun-	Twilight		Moonset			
	set	Civil	Naut.	21	22	23	24
°	h m	h m	h m	h m	h m	h m	h m
N 72		12 59	15 30	04 44	06 26	08 16	
N 70		14 02	15 51	04 24	05 54	07 24	08 49
68		14 37	16 07	04 08	05 31	06 53	08 08
66	13 21	15 03	16 20	03 55	05 14	06 30	07 39
64	14 04	15 22	16 31	03 45	04 59	06 11	07 18
62	14 33	15 39	16 41	03 36	04 47	05 56	07 00
60	14 55	15 52	16 49	03 28	04 37	05 44	06 46
N 58	15 12	16 04	16 56	03 22	04 28	05 33	06 34
56	15 27	16 14	17 03	03 16	04 21	05 24	06 23
54	15 40	16 24	17 09	03 10	04 14	05 15	06 14
52	15 51	16 32	17 16	03 06	04 07	05 08	06 06
50	16 01	16 39	17 21	03 01	04 02	05 01	05 58
45	16 21	16 55	17 33	02 52	03 50	04 47	05 42
N 40	16 38	17 09	17 43	02 44	03 40	04 35	05 29
35	16 52	17 21	17 52	02 38	03 31	04 25	05 18
30	17 05	17 31	18 01	02 32	03 24	04 16	05 08
20	17 26	17 50	18 18	02 22	03 11	04 01	04 52
N 10	17 45	18 08	18 34	02 13	03 00	03 48	04 37
0	18 02	18 25	18 51	02 05	02 49	03 35	04 23
S 10	18 20	18 43	19 10	01 56	02 39	03 23	04 10
20	18 39	19 03	19 33	01 48	02 28	03 10	03 55
30	19 01	19 28	20 02	01 38	02 15	02 55	03 39
35	19 14	19 44	20 20	01 32	02 07	02 46	03 29
40	19 29	20 02	20 44	01 25	01 59	02 36	03 18
45	19 47	20 25	21 14	01 18	01 49	02 25	03 05
S 50	20 10	20 54	22 00	01 09	01 38	02 11	02 49
52	20 21	21 10	22 28	01 04	01 32	02 04	02 42
54	20 33	21 27	23 15	01 00	01 26	01 57	02 34
56	20 47	21 50	////	00 55	01 19	01 49	02 24
58	21 04	22 20	////	00 49	01 12	01 40	02 14
S 60	21 25	23 10	////	00 43	01 04	01 29	02 02

Day	SUN		Mer. Pass.	MOON			
	Eqn. of Time 00h	Eqn. of Time 12h		Mer. Pass. Upper	Mer. Pass. Lower	Age	Phase
	m s	m s	h m	h m	h m	d	
21	02 16	02 02	11 58	20 38	08 16	11	
22	01 47	01 32	11 58	21 24	09 01	12	
23	01 17	01 02	11 59	22 12	09 48	13	○

DECEMBER 24, 25, 26 (WED., THURS., FRI.)

G.M.T.	ARIES	VENUS −3·4		MARS −0·8		JUPITER −1·3		SATURN +0·6	
d h	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
24 00	92 00·9	160 53·2	S 23 50·4	48 20·4	N 18 30·0	221 42·7	S 17 29·1	183 36·4	S 22 28·4
01	107 03·3	183 52·2	50·2	63 22·8	30·1	236 44·6	29·2	198 38·5	28·4
02	122 05·8	198 51·3	50·0	78 25·1	30·1	251 46·6	29·3	213 40·6	28·4
03	137 08·3	213 50·3	·· 49·8	93 27·5	·· 30·2	266 48·6	·· 29·5	228 42·8	·· 28·4
04	152 10·7	228 49·3	49·6	108 29·9	30·3	281 50·5	29·6	243 44·9	28·4
05	167 13·2	243 48·4	49·4	123 32·2	30·4	296 52·5	29·7	258 47·1	28·4
06	182 15·7	258 47·4	S 23 49·2	138 34·5	N 18 30·5	311 54·5	S 17 29·8	273 49·2	S 22 28·4
W 07	197 18·1	273 46·4	49·0	153 36·9	30·5	326 56·5	29·9	288 51·4	28·4
E 08	212 20·6	288 45·5	48·8	168 39·2	30·6	341 58·4	30·1	303 53·5	28·4
D 09	227 23·1	303 44·5	·· 48·6	183 41·6	·· 30·7	357 00·4	·· 30·2	318 55·7	·· 28·4
N 10	242 25·5	318 43·6	48·4	198 43·9	30·8	12 02·4	30·3	333 57·8	28·4
E 11	257 28·0	333 42·6	48·1	213 46·3	30·8	27 04·4	30·4	349 00·0	28·4
S 12	272 30·4	348 41·6	S 23 47·9	228 48·6	N 18 30·9	42 06·3	S 17 30·5	4 02·1	S 22 28·4
D 13	287 32·9	3 40·7	47·7	243 51·0	31·0	57 08·3	30·7	19 04·2	28·4
A 14	302 35·4	18 39·7	47·5	258 53·3	31·1	72 10·3	30·8	34 06·4	28·5
Y 15	317 37·8	33 38·8	·· 47·3	273 55·6	·· 31·2	87 12·3	·· 30·9	49 08·5	·· 28·5
16	332 40·3	48 37·8	47·0	288 58·0	31·2	102 14·2	31·0	64 10·7	28·5
17	347 42·8	63 36·9	46·8	304 00·3	31·3	117 16·2	31·2	79 12·8	28·5
18	2 45·2	78 35·9	S 23 46·6	319 02·6	N 18 31·4	132 18·2	S 17 31·3	94 15·0	S 22 28·5
19	17 47·7	93 34·9	46·4	334 05·0	31·5	147 20·2	31·4	109 17·1	28·5
20	32 50·2	108 34·0	46·1	349 07·3	31·6	162 22·1	31·5	124 19·3	28·5
21	47 52·6	123 33·0	·· 45·9	4 09·6	·· 31·7	177 24·1	·· 31·6	139 21·4	·· 28·5
22	62 55·1	138 32·1	45·7	19 11·9	31·7	192 26·1	31·8	154 23·5	28·5
23	77 57·6	153 31·1	45·4	34 14·3	31·8	207 28·1	31·9	169 25·7	28·5
25 00	93 00·0	168 30·1	S 23 45·2	49 16·6	N 18 31·9	222 30·0	S 17 32·0	184 27·8	S 22 28·5
01	108 02·5	183 29·2	45·0	64 18·9	32·0	237 32·0	32·1	199 30·0	28·5
02	123 04·9	198 28·2	44·7	79 21·2	32·1	252 34·0	32·2	214 32·1	28·5
03	138 07·4	213 27·3	·· 44·5	94 23·6	·· 32·1	267 36·0	·· 32·4	229 34·3	·· 28·5
04	153 09·9	228 26·3	44·3	109 25·9	32·2	282 37·9	32·5	244 36·4	28·5
05	168 12·3	243 25·4	44·0	124 28·2	32·3	297 39·9	32·6	259 38·6	28·5
06	183 14·8	258 24·4	S 23 43·8	139 30·5	N 18 32·4	312 41·9	S 17 32·7	274 40·7	S 22 28·5
07	198 17·3	273 23·5	43·5	154 32·8	32·5	327 43·9	32·8	289 42·9	28·5
T 08	213 19·7	288 22·5	43·3	169 35·1	32·6	342 45·8	33·0	304 45·0	28·6
H 09	228 22·2	303 21·5	·· 43·1	184 37·5	·· 32·7	357 47·8	·· 33·1	319 47·1	·· 28·6
U 10	243 24·7	318 20·6	42·8	199 39·8	32·7	12 49·8	33·2	334 49·3	28·6
R 11	258 27·1	333 19·6	42·6	214 42·1	32·8	27 51·8	33·3	349 51·4	28·6
S 12	273 29·6	348 18·7	S 23 42·3	229 44·4	N 18 32·9	42 53·7	S 17 33·4	4 53·6	S 22 28·6
D 13	288 32·1	3 17·7	42·1	244 46·7	33·0	57 55·7	33·6	19 55·7	28·6
A 14	303 34·5	18 16·8	41·8	259 49·0	33·1	72 57·7	33·7	34 57·9	28·6
Y 15	318 37·0	33 15·8	·· 41·6	274 51·3	·· 33·2	87 59·7	·· 33·8	50 00·0	·· 28·6
16	333 39·4	48 14·9	41·3	289 53·6	33·3	103 01·7	33·9	65 02·2	28·6
17	348 41·9	63 13·9	41·0	304 55·9	33·3	118 03·6	34·0	80 04·3	28·6
18	3 44·4	78 13·0	S 23 40·8	319 58·2	N 18 33·4	133 05·6	S 17 34·1	95 06·5	S 22 28·6
19	18 46·8	93 12·0	40·5	335 00·5	33·5	148 07·6	34·3	110 08·6	28·6
20	33 49·3	108 11·1	40·3	350 02·8	33·6	163 09·6	34·4	125 10·8	28·6
21	48 51·8	123 10·1	·· 40·0	5 05·1	·· 33·7	178 11·5	·· 34·5	140 12·9	·· 28·6
22	63 54·2	138 09·1	39·8	20 07·4	33·8	193 13·5	34·6	155 15·0	28·6
23	78 56·7	153 08·2	39·5	35 09·7	33·9	208 15·5	34·7	170 17·2	28·6
26 00	93 59·2	168 07·2	S 23 39·2	50 12·0	N 18 34·0	223 17·5	S 17 34·9	185 19·3	S 22 28·6
01	109 01·6	183 06·3	39·0	65 14·3	34·1	238 19·5	35·0	200 21·5	28·6
02	124 04·1	198 05·3	38·7	80 16·6	34·1	253 21·4	35·1	215 23·6	28·6
03	139 06·5	213 04·4	·· 38·4	95 18·9	·· 34·2	268 23·4	·· 35·2	230 25·8	·· 28·6
04	154 09·0	228 03·4	38·2	110 21·2	34·3	283 25·4	35·3	245 27·9	28·7
05	169 11·5	243 02·5	37·9	125 23·4	34·4	298 27·4	35·5	260 30·1	28·7
06	184 13·9	258 01·5	S 23 37·6	140 25·7	N 18 34·5	313 29·4	S 17 35·6	275 32·2	S 22 28·7
07	199 16·4	273 00·6	37·3	155 28·0	34·6	328 31·3	35·7	290 34·4	28·7
08	214 18·9	287 59·6	37·1	170 30·3	34·7	343 33·3	35·8	305 36·5	28·7
F 09	229 21·3	302 58·7	·· 36·8	185 32·6	·· 34·8	358 35·3	·· 35·9	320 38·6	·· 28·7
R 10	244 23·8	317 57·7	36·5	200 34·9	34·9	13 37·3	36·0	335 40·8	28·7
I 11	259 26·3	332 56·8	36·2	215 37·1	35·0	28 39·3	36·2	350 42·9	28·7
D 12	274 28·7	347 55·8	S 23 36·0	230 39·4	N 18 35·1	43 41·2	S 17 36·3	5 45·1	S 22 28·7
A 13	289 31·2	2 54·9	35·7	245 41·7	35·2	58 43·2	36·4	20 47·2	28·7
Y 14	304 33·7	17 54·0	35·4	260 44·0	35·2	73 45·2	36·5	35 49·4	28·7
15	319 36·1	32 53·0	·· 35·1	275 46·2	·· 35·3	88 47·2	·· 36·6	50 51·5	·· 28·7
16	334 38·6	47 52·1	34·8	290 48·5	35·4	103 49·1	36·8	65 53·7	28·7
17	349 41·0	62 51·1	34·6	305 50·8	35·5	118 51·1	36·9	80 55·8	28·7
18	4 43·5	77 50·2	S 23 34·3	320 53·1	N 18 35·6	133 53·1	S 17 37·0	95 58·0	S 22 28·7
19	19 46·0	92 49·2	34·0	335 55·3	35·7	148 55·1	37·1	111 00·1	28·7
20	34 48·4	107 48·3	33·7	350 57·6	35·8	163 57·1	37·2	126 02·2	28·7
21	49 50·9	122 47·3	·· 33·4	5 59·9	·· 35·9	178 59·1	·· 37·3	141 04·4	·· 28·7
22	64 53·4	137 46·4	33·1	21 02·1	36·0	194 01·0	37·5	156 06·5	28·7
23	79 55·8	152 45·4	32·8	36 04·4	36·1	209 03·0	37·6	171 08·7	28·7
Mer. Pass.	h m 17 45·1	v −1·0	d 0·2	v 2·3	d 0·1	v 2·0	d 0·1	v 2·1	d 0·0

Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 49·2	S 40 28·3
Achernar	335 57·1	S 57 27·0
Acrux	173 55·1	S 62 52·0
Adhara	255 44·3	S 28 55·0
Aldebaran	291 36·1	N 16 25·6
Alioth	166 56·8	N 56 10·6
Alkaid	153 31·4	N 49 30·8
Al Na'ir	28 35·5	S 47 09·7
Alnilam	276 27·6	S 1 13·8
Alphard	218 36·1	S 8 28·9
Alphecca	126 46·0	N 26 51·1
Alpheratz	358 25·9	N 28 52·0
Altair	62 48·5	N 8 45·7
Ankaa	353 56·1	S 42 31·9
Antares	113 16·9	S 26 20·4
Arcturus	146 33·3	N 19 23·7
Atria	108 56·0	S 68 57·1
Avior	234 34·2	S 59 22·6
Bellatrix	279 15·6	N 6 18·7
Betelgeuse	271 45·3	N 7 23·9
Canopus	264 13·8	S 52 40·5
Capella	281 34·5	N 45 57·4
Deneb	49 59·7	N 45 08·3
Denebola	183 15·4	N 14 47·9
Diphda	349 37·0	S 18 12·8
Dubhe	194 41·8	N 61 58·9
Elnath	279 04·1	N 28 34·4
Eltanin	91 05·7	N 51 29·7
Enif	34 27·6	N 9 41·3
Fomalhaut	16 09·3	S 29 50·5
Gacrux	172 46·6	S 56 52·8
Gienah	176 34·5	S 17 18·8
Hadar	149 46·3	S 60 10·3
Hamal	328 46·8	N 23 16·2
Kaus Aust.	84 38·6	S 34 24·2
Kochab	137 19·2	N 74 19·2
Markab	14 19·3	N 14 59·2
Menkar	314 57·7	N 3 55·7
Menkent	148 56·1	S 36 09·9
Miaplacidus	221 47·6	S 69 32·8
Mirfak	309 38·6	N 49 43·1
Nunki	76 49·5	S 26 20·8
Peacock	54 24·3	S 56 52·1
Pollux	244 17·5	N 28 07·4
Procyon	245 42·3	N 5 19·7
Rasalhague	96 44·8	N 12 35·4
Regulus	208 26·9	N 12 09·9
Rigel	281 51·1	S 8 15·0
Rigil Kent.	140 48·1	S 60 39·7
Sabik	102 59·9	S 15 40·4
Schedar	350 27·1	N 56 19·1
Shaula	97 18·0	S 37 04·4
Sirius	259 09·5	S 16 39·7
Spica	159 14·6	S 10 56·8
Suhail	223 22·2	S 43 15·9
Vega	81 07·1	N 38 44·8
Zuben'ubi	137 51·0	S 15 52·2

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	75 30·1	12 47
Mars	316 16·6	20 40
Jupiter	129 30·0	9 09
Saturn	91 27·8	11 41

DECEMBER 24, 25, 26 (WED., THURS., FRI.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
24 00	180 11·6	S 23 25·9	26 11·3	11·7	N 17 49·4	3·1	54·8
01	195 11·3	25·9	40 42·0	11·5	17 52·5	3·0	54·8
02	210 11·0	25·8	55 12·5	11·6	17 55·5	3·0	54·8
03	225 10·7	25·8	69 43·1	11·5	17 58·5	2·9	54·8
04	240 10·4	25·8	84 13·6	11·5	18 01·4	2·8	54·9
05	255 10·0	25·7	98 44·1	11·4	18 04·2	2·7	54·9
06	270 09·7	S 23 25·7	113 14·5	11·4	N 18 06·9	2·6	54·9
W 07	285 09·4	25·7	127 44·9	11·3	18 09·5	2·4	54·9
E 08	300 09·1	25·6	142 15·2	11·4	18 12·1	2·4	54·9
D 09	315 08·8	25·6	156 45·6	11·2	18 14·5	2·4	54·9
N 10	330 08·5	25·5	171 15·8	11·3	18 16·9	2·2	55·0
E 11	345 08·2	25·5	185 46·1	11·2	18 19·1	2·2	55·0
S 12	0 07·9	S 23 25·5	200 16·3	11·2	N 18 21·3	2·1	55·0
D 13	15 07·6	25·4	214 46·5	11·1	18 23·4	2·0	55·0
A 14	30 07·3	25·4	229 16·6	11·1	18 25·4	2·0	55·0
Y 15	45 06·9	25·3	243 46·7	11·1	18 27·4	1·8	55·0
16	60 06·6	25·3	258 16·8	11·1	18 29·2	1·7	55·1
17	75 06·3	25·2	272 46·9	11·0	18 30·9	1·7	55·1
18	90 06·0	S 23 25·2	287 16·9	10·9	N 18 32·6	1·5	55·1
19	105 05·7	25·1	301 46·8	11·0	18 34·1	1·5	55·1
20	120 05·4	25·1	316 16·8	10·9	18 35·6	1·4	55·1
21	135 05·1	25·0	330 46·7	10·9	18 37·0	1·3	55·1
22	150 04·8	25·0	345 16·6	10·8	18 38·3	1·1	55·2
23	165 04·5	24·9	359 46·4	10·9	18 39·4	1·1	55·2
25 00	180 04·2	S 23 24·9	14 16·3	10·8	N 18 40·5	1·1	55·2
01	195 03·8	24·8	28 46·1	10·7	18 41·6	0·9	55·2
02	210 03·5	24·8	43 15·8	10·8	18 42·5	0·8	55·2
03	225 03·2	24·7	57 45·6	10·7	18 43·3	0·7	55·2
04	240 02·9	24·7	72 15·3	10·7	18 44·0	0·6	55·3
05	255 02·6	24·6	86 45·0	10·6	18 44·6	0·6	55·3
06	270 02·3	S 23 24·6	101 14·6	10·6	N 18 45·2	0·4	55·3
T 07	285 02·0	24·5	115 44·2	10·6	18 45·6	0·4	55·3
H 08	300 01·7	24·4	130 13·8	10·6	18 46·0	0·2	55·3
U 09	315 01·4	24·4	144 43·4	10·6	18 46·2	0·2	55·4
R 10	330 01·1	24·3	159 13·0	10·5	18 46·4	0·0	55·4
S 11	345 00·8	24·3	173 42·5	10·5	18 46·4	0·0	55·4
D 12	0 00·4	S 23 24·2	188 12·0	10·5	N 18 46·4	0·1	55·4
A 13	15 00·1	24·1	202 41·5	10·5	18 46·3	0·3	55·4
Y 14	29 59·8	24·1	217 11·0	10·4	18 46·0	0·3	55·5
15	44 59·5	24·0	231 40·4	10·4	18 45·7	0·4	55·5
16	59 59·2	24·0	246 09·8	10·4	18 45·3	0·5	55·5
17	74 58·9	23·9	260 39·2	10·4	18 44·8	0·6	55·5
18	89 58·6	S 23 23·8	275 08·6	10·4	N 18 44·2	0·7	55·5
19	104 58·3	23·8	289 38·0	10·3	18 43·5	0·8	55·5
20	119 58·0	23·7	304 07·3	10·3	18 42·7	0·9	55·6
21	134 57·7	23·6	318 36·6	10·3	18 41·8	1·0	55·6
22	149 57·3	23·6	333 05·9	10·3	18 40·8	1·1	55·6
23	164 57·0	23·5	347 35·2	10·3	18 39·7	1·2	55·6
26 00	179 56·7	S 23 23·4	2 04·5	10·3	N 18 38·5	1·3	55·6
01	194 56·4	23·3	16 33·8	10·2	18 37·2	1·4	55·7
02	209 56·1	23·3	31 03·0	10·2	18 35·8	1·5	55·7
03	224 55·8	23·2	45 32·2	10·3	18 34·3	1·6	55·7
04	239 55·5	23·1	60 01·5	10·2	18 32·7	1·7	55·7
05	254 55·2	23·0	74 30·7	10·2	18 31·0	1·8	55·7
06	269 54·9	S 23 23·0	88 59·9	10·1	N 18 29·2	1·8	55·8
07	284 54·6	22·9	103 29·0	10·2	18 27·4	2·0	55·8
08	299 54·3	22·8	117 58·2	10·2	18 25·4	2·1	55·8
F 09	314 53·9	22·7	132 27·4	10·1	18 23·3	2·2	55·8
R 10	329 53·6	22·7	146 56·5	10·2	18 21·1	2·2	55·8
I 11	344 53·3	22·6	161 25·7	10·1	18 18·9	2·4	55·9
D 12	359 53·0	S 23 22·5	175 54·8	10·1	N 18 16·5	2·5	55·9
A 13	14 52·7	22·4	190 23·9	10·1	18 14·0	2·5	55·9
Y 14	29 52·4	22·3	204 53·0	10·1	18 11·5	2·7	55·9
15	44 52·1	22·3	219 22·1	10·1	18 08·8	2·8	55·9
16	59 51·8	22·2	233 51·2	10·1	18 06·0	2·8	56·0
17	74 51·5	22·1	248 20·3	10·1	18 03·2	3·0	56·0
18	89 51·2	S 23 22·0	262 49·4	10·1	N 18 00·2	3·0	56·0
19	104 50·9	21·9	277 18·5	10·1	17 57·2	3·2	56·0
20	119 50·6	21·8	291 47·6	10·1	17 54·0	3·2	56·0
21	134 50·2	21·7	306 16·7	10·1	17 50·8	3·3	56·1
22	149 49·9	21·6	320 45·8	10·0	17 47·5	3·5	56·1
23	164 49·6	21·6	335 14·8	10·1	17 44·0	3·5	56·1
	S.D. 16·3	d 0·1	S.D. 15·0		15·1		15·2

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 24	Moonrise 25	Moonrise 26	Moonrise 27
°	h m	h m	h m	h m	h m	h m	h m
N 72	08 27	10 57	■	□	□	□	14 48
N 70	08 07	09 55	■	12 19	12 57	14 06	15 37
68	07 51	09 20	■	13 02	13 44	14 47	16 07
66	07 38	08 55	10 35	13 30	14 14	15 15	16 30
64	07 26	08 35	09 53	13 52	14 37	15 37	16 48
62	07 17	08 19	09 24	14 09	14 56	15 54	17 03
60	07 08	08 05	09 03	14 24	15 11	16 08	17 15
N 58	07 01	07 54	08 46	14 36	15 23	16 20	17 26
56	06 54	07 43	08 31	14 47	15 35	16 31	17 35
54	06 48	07 35	08 19	14 56	15 44	16 40	17 43
52	06 43	07 26	08 07	15 05	15 53	16 48	17 51
50	06 37	07 19	07 57	15 12	16 01	16 56	17 57
45	06 26	07 03	07 37	15 28	16 17	17 12	18 11
N 40	06 15	06 49	07 20	15 42	16 31	17 25	18 23
35	06 06	06 38	07 06	15 53	16 42	17 36	18 33
30	05 57	06 27	06 53	16 03	16 52	17 46	18 41
20	05 41	06 08	06 32	16 20	17 10	18 02	18 56
N 10	05 24	05 51	06 13	16 35	17 25	18 17	19 09
0	05 07	05 34	05 56	16 49	17 39	18 30	19 22
S 10	04 48	05 16	05 39	17 03	17 53	18 44	19 34
20	04 26	04 55	05 20	17 18	18 09	18 58	19 47
30	03 57	04 30	04 58	17 35	18 26	19 15	20 02
35	03 38	04 15	04 45	17 45	18 36	19 25	20 10
40	03 15	03 57	04 29	17 57	18 48	19 36	20 20
45	02 44	03 34	04 11	18 10	19 01	19 49	20 31
S 50	01 59	03 04	03 49	18 27	19 18	20 04	20 45
52	01 31	02 49	03 38	18 35	19 26	20 12	20 52
54	00 44	02 31	03 26	18 43	19 35	20 20	20 59
56	////	02 09	03 12	18 53	19 45	20 29	21 07
58	////	01 39	02 55	19 04	19 56	20 40	21 16
S 60	////	00 49	02 34	19 17	20 09	20 52	21 26

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 24	Moonset 25	Moonset 26	Moonset 27
°	h m	h m	h m	h m	h m	h m	h m
N 72	■	13 02	15 33	□	□	□	11 37
N 70	■	14 04	15 53	08 49	09 56	10 32	10 48
68	■	14 39	16 09	08 08	09 08	09 51	10 17
66	13 24	15 05	16 22	07 39	08 38	09 22	09 53
64	14 06	15 24	16 33	07 18	08 15	09 01	09 35
62	14 35	15 41	16 42	07 00	07 57	08 43	09 20
60	14 57	15 54	16 51	06 46	07 42	08 29	09 07
N 58	15 14	16 06	16 58	06 34	07 29	08 16	08 56
56	15 29	16 16	17 05	06 23	07 18	08 06	08 47
54	15 42	16 25	17 11	06 14	07 08	07 56	08 38
52	15 52	16 34	17 17	06 06	06 59	07 48	08 31
50	16 02	16 41	17 22	05 58	06 52	07 40	08 24
45	16 23	16 57	17 34	05 42	06 35	07 24	08 09
N 40	16 40	17 11	17 45	05 29	06 21	07 11	07 57
35	16 54	17 22	17 54	05 18	06 10	07 00	07 46
30	17 07	17 33	18 03	05 08	06 00	06 50	07 37
20	17 28	17 52	18 19	04 52	05 42	06 33	07 22
N 10	17 46	18 09	18 35	04 37	05 27	06 18	07 08
0	18 04	18 26	18 52	04 23	05 13	06 04	06 55
S 10	18 21	18 44	19 11	04 10	04 59	05 50	06 42
20	18 40	19 05	19 34	03 55	04 44	05 35	06 28
30	19 02	19 30	20 03	03 39	04 26	05 17	06 12
35	19 15	19 45	20 22	03 29	04 16	05 07	06 03
40	19 30	20 03	20 45	03 18	04 04	04 56	05 52
45	19 48	20 26	21 15	03 05	03 51	04 42	05 39
S 50	20 11	20 55	22 01	02 49	03 34	04 26	05 24
52	20 22	21 11	22 28	02 42	03 26	04 18	05 17
54	20 34	21 28	23 14	02 34	03 17	04 09	05 09
56	20 48	21 51	////	02 24	03 08	04 00	05 00
58	21 05	22 20	////	02 14	02 56	03 49	04 50
S 60	21 25	23 09	////	02 02	02 44	03 36	04 38

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
24	00 47	00 32	11 59	23 01	10 36	14	
25	00 17	00 02	12 00	23 51	11 26	15	○
26	00 12	00 27	12 00	24 42	12 17	16	

DECEMBER 27, 28, 29 (SAT., SUN., MON.)

G.M.T.	ARIES	VENUS −3·4		MARS −0·7		JUPITER −1·3		SATURN +0·7		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
27 00	94 58·3	167 44·5	S 23 32·5	51 06·6	N 18 36·2	224 05·0	S 17 37·7	186 10·8	S 22 28·8	Acamar	315 49·2	S 40 28·4
01	110 00·8	182 43·5	32·2	66 08·9	36·3	239 07·0	37·8	201 13·0	28·8	Achernar	335 57·1	S 57 27·0
02	125 03·2	197 42·6	31·9	81 11·2	36·4	254 09·0	37·9	216 15·1	28·8	Acrux	173 55·0	S 62 52·1
03	140 05·7	212 41·6	·· 31·6	96 13·4	·· 36·5	269 10·9	·· 38·0	231 17·3	·· 28·8	Adhara	255 44·3	S 28 55·1
04	155 08·2	227 40·7	31·3	111 15·7	36·6	284 12·9	38·2	246 19·4	28·8	Aldebaran	291 36·1	N 16 25·6
05	170 10·6	242 39·8	31·0	126 17·9	36·7	299 14·9	38·3	261 21·6	28·8			
06	185 13·1	257 38·8	S 23 30·7	141 20·2	N 18 36·8	314 16·9	S 17 38·4	276 23·7	S 22 28·8	Alioth	166 56·8	N 56 10·6
07	200 15·5	272 37·9	30·4	156 22·4	36·9	329 18·9	38·5	291 25·9	28·8	Alkaid	153 31·4	N 49 30·8
S 08	215 18·0	287 36·9	30·1	171 24·7	37·0	344 20·8	38·6	306 28·0	28·8	Al Na'ir	28 35·5	S 47 09·7
A 09	230 20·5	302 36·0	·· 29·8	186 27·0	·· 37·1	359 22·8	·· 38·8	321 30·1	·· 28·8	Alnilam	276 27·6	S 1 13·8
T 10	245 22·9	317 35·0	29·5	201 29·2	37·2	14 24·8	38·9	336 32·3	28·8	Alphard	218 36·1	S 8 28·9
U 11	260 25·4	332 34·1	29·2	216 31·4	37·3	29 26·8	39·0	351 34·4	28·8			
R 12	275 27·9	347 33·2	S 23 28·9	231 33·7	N 18 37·4	44 28·8	S 17 39·1	6 36·6	S 22 28·8	Alphecca	126 46·0	N 26 51·1
D 13	290 30·3	2 32·2	28·6	246 35·9	37·5	59 30·8	39·2	21 38·7	28·8	Alpheratz	358 25·9	N 28 52·0
A 14	305 32·8	17 31·3	28·3	261 38·2	37·6	74 32·7	39·3	36 40·9	28·8	Altair	62 48·5	N 8 45·7
Y 15	320 35·3	32 30·3	·· 28·0	276 40·4	·· 37·7	89 34·7	·· 39·5	51 43·0	·· 28·8	Ankaa	353 56·2	S 42 31·9
16	335 37·7	47 29·4	27·7	291 42·7	37·8	104 36·7	39·6	66 45·2	28·8	Antares	113 16·9	S 26 20·4
17	350 40·2	62 28·4	27·3	306 44·9	37·9	119 38·7	39·7	81 47·3	28·8			
18	5 42·7	77 27·5	S 23 27·0	321 47·2	N 18 38·0	134 40·7	S 17 39·8	96 49·5	S 22 28·8	Arcturus	146 33·3	N 19 23·7
19	20 45·1	92 26·6	26·7	336 49·4	38·1	149 42·7	39·9	111 51·6	28·8	Atria	108 56·0	S 68 57·1
20	35 47·6	107 25·6	26·4	351 51·6	38·2	164 44·6	40·0	126 53·7	28·8	Avior	234 34·1	S 59 22·6
21	50 50·0	122 24·7	·· 26·1	6 53·9	·· 38·3	179 46·6	·· 40·1	141 55·9	·· 28·9	Bellatrix	279 15·6	N 6 18·7
22	65 52·5	137 23·7	25·7	21 56·1	38·4	194 48·6	40·3	156 58·0	28·9	Betelgeuse	271 45·3	N 7 23·9
23	80 55·0	152 22·8	25·4	36 58·3	38·5	209 50·6	40·4	172 00·2	28·9			
28 00	95 57·4	167 21·9	S 23 25·1	52 00·6	N 18 38·6	224 52·6	S 17 40·5	187 02·3	S 22 28·9	Canopus	264 13·8	S 52 40·5
01	110 59·9	182 20·9	24·8	67 02·8	38·7	239 54·6	40·6	202 04·5	28·9	Capella	281 34·5	N 45 57·4
02	126 02·4	197 20·0	24·4	82 05·0	38·8	254 56·5	40·7	217 06·6	28·9	Deneb	49 59·8	N 45 08·3
03	141 04·8	212 19·1	·· 24·1	97 07·2	·· 38·9	269 58·5	·· 40·8	232 08·8	·· 28·9	Denebola	183 15·4	N 14 47·9
04	156 07·3	227 18·1	23·8	112 09·5	39·0	285 00·5	41·0	247 10·9	28·9	Diphda	349 37·0	S 18 12·8
05	171 09·8	242 17·2	23·5	127 11·7	39·1	300 02·5	41·1	262 13·1	28·9			
06	186 12·2	257 16·2	S 23 23·1	142 13·9	N 18 39·2	315 04·5	S 17 41·2	277 15·2	S 22 28·9	Dubhe	194 41·7	N 61 58·0
07	201 14·7	272 15·3	22·8	157 16·1	39·3	330 06·5	41·3	292 17·4	28·9	Elnath	279 04·1	N 28 34·4
08	216 17·2	287 14·4	22·5	172 18·4	39·4	345 08·5	41·4	307 19·5	28·9	Eltanin	91 05·7	N 51 29·7
S 09	231 19·6	302 13·4	·· 22·1	187 20·6	·· 39·5	0 10·4	·· 41·5	322 21·6	·· 28·9	Enif	34 27·6	N 9 41·3
U 10	246 22·1	317 12·5	21·8	202 22·8	39·6	15 12·4	41·7	337 23·8	28·9	Fomalhaut	16 09·3	S 29 50·5
N 11	261 24·5	332 11·6	21·5	217 25·0	39·7	30 14·4	41·8	352 25·9	28·9			
D 12	276 27·0	347 10·6	S 23 21·1	232 27·2	N 18 39·8	45 16·4	S 17 41·9	7 28·1	S 22 28·9	Gacrux	172 46·5	S 56 52·8
A 13	291 29·5	2 09·7	20·8	247 29·5	40·0	60 18·4	42·0	22 30·2	28·9	Gienah	176 34·5	S 17 18·8
Y 14	306 31·9	17 08·8	20·4	262 31·7	40·1	75 20·4	42·1	37 32·4	28·9	Hadar	149 46·3	S 60 10·3
15	321 34·4	32 07·8	·· 20·1	277 33·9	·· 40·2	90 22·4	·· 42·2	52 34·5	·· 28·9	Hamal	328 46·9	N 23 16·2
16	336 36·9	47 06·9	19·7	292 36·1	40·3	105 24·3	42·4	67 36·7	28·9	Kaus Aust.	84 38·6	S 34 24·2
17	351 39·3	62 06·0	19·4	307 38·3	40·4	120 26·3	42·5	82 38·8	28·9			
18	6 41·8	77 05·0	S 23 19·1	322 40·5	N 18 40·5	135 28·3	S 17 42·6	97 41·0	S 22 28·9	Kochab	137 19·1	N 74 19·2
19	21 44·3	92 04·1	18·7	337 42·7	40·6	150 30·3	42·7	112 43·1	28·9	Markab	14 19·3	N 14 59·2
20	36 46·7	107 03·2	18·4	352 44·9	40·7	165 32·3	42·8	127 45·3	29·0	Menkar	314 57·7	N 3 55·7
21	51 49·2	122 02·2	·· 18·0	7 47·1	·· 40·8	180 34·3	·· 42·9	142 47·4	·· 29·0	Menkent	148 56·1	S 36 09·9
22	66 51·6	137 01·3	17·7	22 49·3	40·9	195 36·3	43·0	157 49·5	29·0	Miaplacidus	221 47·6	S 69 32·8
23	81 54·1	152 00·4	17·3	37 51·5	41·0	210 38·2	43·2	172 51·7	29·0			
29 00	96 56·6	166 59·4	S 23 16·9	52 53·7	N 18 41·1	225 40·2	S 17 43·3	187 53·8	S 22 29·0	Mirfak	309 38·6	N 49 43·1
01	111 59·0	181 58·5	16·6	67 55·9	41·2	240 42·2	43·4	202 56·0	29·0	Nunki	76 49·5	S 26 20·8
02	127 01·5	196 57·6	16·2	82 58·1	41·4	255 44·2	43·5	217 58·1	29·0	Peacock	54 24·3	S 56 52·1
03	142 04·0	211 56·6	·· 15·9	98 00·3	·· 41·5	270 46·2	·· 43·6	233 00·3	·· 29·0	Pollux	244 17·4	N 28 07·4
04	157 06·4	226 55·7	15·5	113 02·5	41·6	285 48·2	43·7	248 02·4	29·0	Procyon	245 42·3	N 5 19·7
05	172 08·9	241 54·8	15·2	128 04·7	41·7	300 50·2	43·8	263 04·6	29·0			
06	187 11·4	256 53·9	S 23 14·8	143 06·9	N 18 41·8	315 52·2	S 17 44·0	278 06·7	S 22 29·0	Rasalhague	96 44·8	N 12 35·4
07	202 13·8	271 52·9	14·4	158 09·1	41·9	330 54·1	44·1	293 08·9	29·0	Regulus	208 26·9	N 12 09·9
08	217 16·3	286 52·0	14·1	173 11·3	42·0	345 56·1	44·2	308 11·0	29·0	Rigel	281 51·1	S 8 15·0
M 09	232 18·8	301 51·1	·· 13·7	188 13·5	·· 42·1	0 58·1	·· 44·3	323 13·2	·· 29·0	Rigil Kent.	140 48·0	S 60 39·7
O 10	247 21·2	316 50·1	13·3	203 15·7	42·2	16 00·1	44·4	338 15·3	29·0	Sabik	102 59·9	S 15 40·4
N 11	262 23·7	331 49·2	13·0	218 17·9	42·4	31 02·1	44·5	353 17·5	29·0			
D 12	277 26·1	346 48·3	S 23 12·6	233 20·1	N 18 42·5	46 04·1	S 17 44·6	8 19·6	S 22 29·0	Schedar	350 27·2	N 56 19·1
A 13	292 28·6	1 47·4	12·2	248 22·3	42·6	61 06·1	44·8	23 21·7	29·0	Shaula	97 18·0	S 37 04·4
Y 14	307 31·1	16 46·4	11·9	263 24·4	42·7	76 08·1	44·9	38 23·9	29·0	Sirius	259 09·5	S 16 39·7
15	322 33·5	31 45·5	·· 11·5	278 26·6	·· 42·8	91 10·0	·· 45·0	53 26·0	·· 29·0	Spica	159 14·5	S 10 56·8
16	337 36·0	46 44·6	11·1	293 28·8	42·9	106 12·0	45·1	68 28·2	29·0	Suhail	223 22·2	S 43 16·0
17	352 38·5	61 43·7	10·7	308 31·0	43·0	121 14·0	45·2	83 30·3	29·0			
18	7 40·9	76 42·7	S 23 10·4	323 33·2	N 18 43·2	136 16·0	S 17 45·3	98 32·5	S 22 29·0	Vega	81 07·1	N 38 44·8
19	22 43·4	91 41·8	10·0	338 35·3	43·3	151 18·0	45·4	113 34·6	29·0	Zuben'ubi	137 51·0	S 15 52·2
20	37 45·9	106 40·9	09·6	353 37·5	43·4	166 20·0	45·6	128 36·8	29·0			
21	52 48·3	121 40·0	·· 09·2	8 39·7	·· 43·5	181 22·0	·· 45·7	143 38·9	·· 29·1		S.H.A.	Mer. Pass.
22	67 50·8	136 39·0	08·8	23 41·9	43·6	196 24·0	45·8	158 41·1	29·1		° ′	h m
23	82 53·3	151 38·1	08·5	38 44·0	43·7	211 26·0	45·9	173 43·2	29·1	Venus	71 24·5	12 51
	h m									Mars	316 03·2	20 29
Mer. Pass.	17 33·3	v −0·9	d 0·3	v 2·2	d 0·1	v 2·0	d 0·1	v 2·1	d 0·0	Jupiter	128 55·2	8 59
										Saturn	91 04·9	11 30

DECEMBER 27, 28, 29 (SAT., SUN., MON.)

G.M.T.	SUN			MOON					Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 27	Moonrise 28	Moonrise 29	Moonrise 30
	G.H.A.	Dec.		G.H.A.	v	Dec.	d	H.P.								
d h	° ′	° ′		° ′	′	° ′	′	′	°	h m	h m	h m	h m	h m	h m	h m
27 00	179 49·3	S 23 21·5		349 43·9	10·1	N17 40·5	3·6	56·1	N 72	08 26	10 53		14 48	16 47	18 41	20 32
01	194 49·0	21·4		4 13·0	10·1	17 36·9	3·7	56·1	N 70	08 07	09 54		15 37	17 16	18 58	20 41
02	209 48·7	21·3		18 42·1	10·0	17 33·2	3·9	56·2	68	07 51	09 20		16 07	17 38	19 12	20 49
03	224 48·4	21·2		33 11·1	10·1	17 29·3	3·9	56·2	66	07 38	08 55	10 33	16 30	17 54	19 23	20 55
04	239 48·1	21·1		47 40·2	10·1	17 25·4	4·0	56·2	64	07 27	08 35	09 52	16 48	18 08	19 33	21 00
05	254 47·8	21·0		62 09·3	10·1	17 21·4	4·1	56·2	62	07 17	08 19	09 24	17 03	18 19	19 41	21 04
06	269 47·5	S 23 20·9		76 38·4	10·0	N17 17·3	4·2	56·2	60	07 09	08 06	09 03	17 15	18 29	19 47	21 08
07	284 47·2	20·8		91 07·4	10·1	17 13·1	4·3	56·3	N 58	07 02	07 54	08 46	17 26	18 37	19 54	21 12
S 08	299 46·9	20·7		105 36·5	10·1	17 08·8	4·3	56·3	56	06 55	07 44	08 32	17 35	18 45	19 59	21 15
A 09	314 46·6	20·6		120 05·6	10·1	17 04·5	4·5	56·3	54	06 49	07 35	08 19	17 43	18 51	20 04	21 18
T 10	329 46·2	20·5		134 34·7	10·1	17 00·0	4·6	56·3	52	06 44	07 27	08 08	17 51	18 57	20 08	21 20
U 11	344 45·9	20·4		149 03·8	10·1	16 55·4	4·6	56·3	50	06 38	07 20	07 58	17 57	19 03	20 12	21 22
R 12	359 45·6	S 23 20·3		163 32·9	10·1	N16 50·8	4·8	56·4	45	06 27	07 04	07 38	18 11	19 14	20 20	21 27
D 13	14 45·3	20·2		178 02·0	10·1	16 46·0	4·9	56·4	N 40	06 16	06 50	07 21	18 23	19 24	20 27	21 31
A 14	29 45·0	20·1		192 31·1	10·1	16 41·1	4·9	56·4	35	06 07	06 39	07 07	18 33	19 32	20 33	21 35
Y 15	44 44·7	20·0		207 00·2	10·1	16 36·2	5·0	56·4	30	05 58	06 28	06 54	18 41	19 39	20 38	21 38
16	59 44·4	19·9		221 29·3	10·2	16 31·2	5·1	56·4	20	05 42	06 09	06 33	18 56	19 52	20 47	21 43
17	74 44·1	19·8		235 58·5	10·1	16 26·1	5·3	56·5	N 10	05 26	05 52	06 15	19 09	20 02	20 55	21 48
18	89 43·8	S 23 19·7		250 27·6	10·1	N16 20·8	5·3	56·5	0	05 09	05 35	05 58	19 22	20 12	21 03	21 53
19	104 43·5	19·6		264 56·7	10·2	16 15·5	5·4	56·5	S 10	04 50	05 17	05 40	19 34	20 23	21 10	21 57
20	119 43·2	19·5		279 25·9	10·2	16 10·1	5·4	56·5	20	04 28	04 57	05 21	19 47	20 33	21 18	22 02
21	134 42·9	19·4		293 55·1	10·1	16 04·7	5·6	56·5	30	03 59	04 32	04 59	20 02	20 46	21 27	22 07
22	149 42·6	19·3		308 24·2	10·2	15 59·1	5·7	56·6	35	03 40	04 17	04 46	20 10	20 53	21 32	22 10
23	164 42·3	19·2		322 53·4	10·2	15 53·4	5·7	56·6	40	03 17	03 59	04 31	20 20	21 01	21 38	22 14
28 00	179 41·9	S 23 19·1		337 22·6	10·2	N15 47·7	5·9	56·6	45	02 47	03 36	04 13	20 31	21 10	21 45	22 18
01	194 41·6	18·9		351 51·8	10·2	15 41·8	5·9	56·6	S 50	02 01	03 07	03 51	20 45	21 21	21 53	22 22
02	209 41·3	18·8		6 21·0	10·2	15 35·9	6·0	56·6	52	01 34	02 52	03 40	20 52	21 26	21 57	22 25
03	224 41·0	18·7		20 50·2	10·2	15 29·9	6·1	56·7	54	00 49	02 34	03 28	20 59	21 32	22 01	22 27
04	239 40·7	18·6		35 19·4	10·3	15 23·8	6·2	56·7	56	///	02 12	03 14	21 07	21 38	22 06	22 30
05	254 40·4	18·5		49 48·7	10·2	15 17·6	6·2	56·7	58	///	01 42	02 57	21 16	21 46	22 11	22 33
06	269 40·1	S 23 18·4		64 17·9	10·3	N15 11·4	6·4	56·7	S 60	///	00 54	02 37	21 26	21 53	22 16	22 36
07	284 39·8	18·3		78 47·2	10·3	15 05·0	6·4	56·7								
08	299 39·5	18·1		93 16·5	10·3	14 58·6	6·6	56·8								
S 09	314 39·2	18·0		107 45·8	10·3	14 52·0	6·6	56·8								
U 10	329 38·9	17·9		122 15·1	10·3	14 45·4	6·6	56·8								
N 11	344 38·6	17·8		136 44·4	10·3	14 38·8	6·8	56·8								
D 12	359 38·3	S 23 17·7		151 13·7	10·3	N14 32·0	6·9	56·8								
A 13	14 38·0	17·6		165 43·0	10·4	14 25·1	6·9	56·9								
Y 14	29 37·7	17·4		180 12·4	10·3	14 18·2	7·0	56·9								
15	44 37·4	17·3		194 41·7	10·4	14 11·2	7·1	56·9								
16	59 37·1	17·2		209 11·1	10·4	14 04·1	7·2	56·9								
17	74 36·7	17·1		223 40·5	10·4	13 56·9	7·2	56·9								
18	89 36·4	S 23 16·9		238 09·9	10·4	N13 49·7	7·3	57·0								
19	104 36·1	16·8		252 39·3	10·5	13 42·4	7·4	57·0								
20	119 35·8	16·7		267 08·8	10·4	13 35·0	7·5	57·0								
21	134 35·5	16·6		281 38·2	10·5	13 27·5	7·6	57·0								
22	149 35·2	16·4		296 07·7	10·4	13 19·9	7·6	57·0								
23	164 34·9	16·3		310 37·1	10·5	13 12·3	7·7	57·1								
29 00	179 34·6	S 23 16·2		325 06·6	10·5	N13 04·6	7·8	57·1								
01	194 34·3	16·0		339 36·1	10·6	12 56·8	7·8	57·1								
02	209 34·0	15·9		354 05·7	10·5	12 49·0	8·0	57·1								
03	224 33·7	15·8		8 35·2	10·5	12 41·0	8·0	57·1								
04	239 33·4	15·6		23 04·7	10·6	12 33·0	8·0	57·2								
05	254 33·1	15·5		37 34·3	10·6	12 25·0	8·2	57·2								
06	269 32·8	S 23 15·4		52 03·9	10·6	N12 16·8	8·2	57·2								
07	284 32·5	15·2		66 33·5	10·6	12 08·6	8·3	57·2								
08	299 32·2	15·1		81 03·1	10·6	12 00·3	8·3	57·2								
M 09	314 31·9	15·0		95 32·7	10·6	11 52·0	8·4	57·3								
O 10	329 31·6	14·8		110 02·3	10·6	11 43·6	8·5	57·3								
N 11	344 31·3	14·7		124 31·9	10·7	11 35·1	8·6	57·3								
D 12	359 31·0	S 23 14·5		139 01·6	10·7	N11 26·5	8·6	57·3								
A 13	14 30·7	14·4		153 31·3	10·6	11 17·9	8·7	57·3								
Y 14	29 30·4	14·3		168 00·9	10·7	11 09·2	8·7	57·4								
15	44 30·0	14·1		182 30·6	10·8	11 00·5	8·8	57·4								
16	59 29·7	14·0		197 00·4	10·7	10 51·7	8·9	57·4								
17	74 29·4	13·8		211 30·1	10·7	10 42·8	8·9	57·4								
18	89 29·1	S 23 13·7		225 59·8	10·8	N10 33·9	9·0	57·4								
19	104 28·8	13·6		240 29·6	10·7	10 24·9	9·1	57·5								
20	119 28·5	13·4		254 59·3	10·8	10 15·8	9·1	57·5								
21	134 28·2	13·3		269 29·1	10·8	10 06·7	9·1	57·5								
22	149 27·9	13·1		283 58·9	10·8	9 57·6	9·3	57·5								
23	164 27·6	13·0		298 28·7	10·8	9 48·3	9·3	57·5								
	S.D. 16·3	d 0·1		S.D.	15·4		15·5		15·6							

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 27	Moonset 28	Moonset 29	Moonset 30
°	h m	h m	h m	h m	h m	h m	h m
N 72		13 09	15 36	11 37	11 24	11 16	11 09
N 70		14 09	15 56	10 48	10 54	10 57	10 58
68		14 43	16 11	10 17	10 32	10 42	10 49
66	13 29	15 08	16 24	09 53	10 15	10 30	10 41
64	14 10	15 27	16 35	09 35	10 00	10 20	10 35
62	14 38	15 43	16 45	09 20	09 48	10 11	10 29
60	14 59	15 57	16 53	09 07	09 38	10 03	10 24
N 58	15 17	16 08	17 01	08 56	09 29	09 56	10 20
56	15 31	16 19	17 07	08 47	09 21	09 50	10 16
54	15 44	16 28	17 13	08 38	09 14	09 45	10 12
52	15 55	16 36	17 19	08 31	09 08	09 40	10 09
50	16 05	16 43	17 25	08 24	09 02	09 36	10 06
45	16 25	16 59	17 36	08 09	08 50	09 26	10 00
N 40	16 42	17 12	17 46	07 57	08 39	09 18	09 55
35	16 56	17 24	17 56	07 46	08 30	09 11	09 50
30	17 09	17 35	18 05	07 37	08 23	09 05	09 46
20	17 29	17 53	18 21	07 22	08 09	08 55	09 39
N 10	17 48	18 11	18 37	07 08	07 57	08 45	09 33
0	18 05	18 28	18 54	06 55	07 46	08 37	09 27
S 10	18 23	18 46	19 13	06 42	07 35	08 28	09 21
20	18 41	19 06	19 35	06 28	07 23	08 18	09 14
30	19 03	19 31	20 04	06 12	07 09	08 07	09 07
35	19 16	19 46	20 23	06 03	07 01	08 01	09 02
40	19 31	20 04	20 46	05 52	06 52	07 54	08 58
45	19 49	20 26	21 16	05 39	06 41	07 45	08 52
S 50	20 12	20 56	22 01	05 24	06 28	07 35	08 45
52	20 22	21 11	22 28	05 17	06 22	07 30	08 42
54	20 34	21 29	23 12	05 09	06 15	07 25	08 38
56	20 49	21 50	///	05 00	06 07	07 19	08 34
58	21 05	22 20	///	04 50	05 59	07 13	08 30
S 60	21 25	23 07	///	04 38	05 49	07 05	08 25

Day	SUN Eqn. of Time 00h	SUN Eqn. of Time 12h	Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	Age	Phase
	m s	m s	h m	h m	h m	d	
27	00 42	00 57	12 01	00 42	13 08	17	
28	01 12	01 26	12 01	01 34	13 59	18	○
29	01 41	01 56	12 02	02 24	14 50	19	

INCREMENTS AND CORRECTIONS

0^m 1^m

0^m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	0 00·0	0 00·0	0 00·0	0·0	0·0	6·0	0·1	12·0	0·1
01	0 00·3	0 00·3	0 00·2	0·1	0·0	6·1	0·1	12·1	0·1
02	0 00·5	0 00·5	0 00·5	0·2	0·0	6·2	0·1	12·2	0·1
03	0 00·8	0 00·8	0 00·7	0·3	0·0	6·3	0·1	12·3	0·1
04	0 01·0	0 01·0	0 01·0	0·4	0·0	6·4	0·1	12·4	0·1
05	0 01·3	0 01·3	0 01·2	0·5	0·0	6·5	0·1	12·5	0·1
06	0 01·5	0 01·5	0 01·4	0·6	0·0	6·6	0·1	12·6	0·1
07	0 01·8	0 01·8	0 01·7	0·7	0·0	6·7	0·1	12·7	0·1
08	0 02·0	0 02·0	0 01·9	0·8	0·0	6·8	0·1	12·8	0·1
09	0 02·3	0 02·3	0 02·1	0·9	0·0	6·9	0·1	12·9	0·1
10	0 02·5	0 02·5	0 02·4	1·0	0·0	7·0	0·1	13·0	0·1
11	0 02·8	0 02·8	0 02·6	1·1	0·0	7·1	0·1	13·1	0·1
12	0 03·0	0 03·0	0 02·9	1·2	0·0	7·2	0·1	13·2	0·1
13	0 03·3	0 03·3	0 03·1	1·3	0·0	7·3	0·1	13·3	0·1
14	0 03·5	0 03·5	0 03·3	1·4	0·0	7·4	0·1	13·4	0·1
15	0 03·8	0 03·8	0 03·6	1·5	0·0	7·5	0·1	13·5	0·1
16	0 04·0	0 04·0	0 03·8	1·6	0·0	7·6	0·1	13·6	0·1
17	0 04·3	0 04·3	0 04·1	1·7	0·0	7·7	0·1	13·7	0·1
18	0 04·5	0 04·5	0 04·3	1·8	0·0	7·8	0·1	13·8	0·1
19	0 04·8	0 04·8	0 04·5	1·9	0·0	7·9	0·1	13·9	0·1
20	0 05·0	0 05·0	0 04·8	2·0	0·0	8·0	0·1	14·0	0·1
21	0 05·3	0 05·3	0 05·0	2·1	0·0	8·1	0·1	14·1	0·1
22	0 05·5	0 05·5	0 05·2	2·2	0·0	8·2	0·1	14·2	0·1
23	0 05·8	0 05·8	0 05·5	2·3	0·0	8·3	0·1	14·3	0·1
24	0 06·0	0 06·0	0 05·7	2·4	0·0	8·4	0·1	14·4	0·1
25	0 06·3	0 06·3	0 06·0	2·5	0·0	8·5	0·1	14·5	0·1
26	0 06·5	0 06·5	0 06·2	2·6	0·0	8·6	0·1	14·6	0·1
27	0 06·8	0 06·8	0 06·4	2·7	0·0	8·7	0·1	14·7	0·1
28	0 07·0	0 07·0	0 06·7	2·8	0·0	8·8	0·1	14·8	0·1
29	0 07·3	0 07·3	0 06·9	2·9	0·0	8·9	0·1	14·9	0·1
30	0 07·5	0 07·5	0 07·2	3·0	0·0	9·0	0·1	15·0	0·1
31	0 07·8	0 07·8	0 07·4	3·1	0·0	9·1	0·1	15·1	0·1
32	0 08·0	0 08·0	0 07·6	3·2	0·0	9·2	0·1	15·2	0·1
33	0 08·3	0 08·3	0 07·9	3·3	0·0	9·3	0·1	15·3	0·1
34	0 08·5	0 08·5	0 08·1	3·4	0·0	9·4	0·1	15·4	0·1
35	0 08·8	0 08·8	0 08·4	3·5	0·0	9·5	0·1	15·5	0·1
36	0 09·0	0 09·0	0 08·6	3·6	0·0	9·6	0·1	15·6	0·1
37	0 09·3	0 09·3	0 08·8	3·7	0·0	9·7	0·1	15·7	0·1
38	0 09·5	0 09·5	0 09·1	3·8	0·0	9·8	0·1	15·8	0·1
39	0 09·8	0 09·8	0 09·3	3·9	0·0	9·9	0·1	15·9	0·1
40	0 10·0	0 10·0	0 09·5	4·0	0·0	10·0	0·1	16·0	0·1
41	0 10·3	0 10·3	0 09·8	4·1	0·0	10·1	0·1	16·1	0·1
42	0 10·5	0 10·5	0 10·0	4·2	0·0	10·2	0·1	16·2	0·1
43	0 10·8	0 10·8	0 10·3	4·3	0·0	10·3	0·1	16·3	0·1
44	0 11·0	0 11·0	0 10·5	4·4	0·0	10·4	0·1	16·4	0·1
45	0 11·3	0 11·3	0 10·7	4·5	0·0	10·5	0·1	16·5	0·1
46	0 11·5	0 11·5	0 11·0	4·6	0·0	10·6	0·1	16·6	0·1
47	0 11·8	0 11·8	0 11·2	4·7	0·0	10·7	0·1	16·7	0·1
48	0 12·0	0 12·0	0 11·5	4·8	0·0	10·8	0·1	16·8	0·1
49	0 12·3	0 12·3	0 11·7	4·9	0·0	10·9	0·1	16·9	0·1
50	0 12·5	0 12·5	0 11·9	5·0	0·0	11·0	0·1	17·0	0·1
51	0 12·8	0 12·8	0 12·2	5·1	0·0	11·1	0·1	17·1	0·1
52	0 13·0	0 13·0	0 12·4	5·2	0·0	11·2	0·1	17·2	0·1
53	0 13·3	0 13·3	0 12·6	5·3	0·0	11·3	0·1	17·3	0·1
54	0 13·5	0 13·5	0 12·9	5·4	0·0	11·4	0·1	17·4	0·1
55	0 13·8	0 13·8	0 13·1	5·5	0·0	11·5	0·1	17·5	0·1
56	0 14·0	0 14·0	0 13·4	5·6	0·0	11·6	0·1	17·6	0·1
57	0 14·3	0 14·3	0 13·6	5·7	0·0	11·7	0·1	17·7	0·1
58	0 14·5	0 14·5	0 13·8	5·8	0·0	11·8	0·1	17·8	0·1
59	0 14·8	0 14·8	0 14·1	5·9	0·0	11·9	0·1	17·9	0·1
60	0 15·0	0 15·0	0 14·3	6·0	0·1	12·0	0·1	18·0	0·2

1^m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	0 15·0	0 15·0	0 14·3	0·0	0·0	6·0	0·2	12·0	0·3
01	0 15·3	0 15·3	0 14·6	0·1	0·0	6·1	0·2	12·1	0·3
02	0 15·5	0 15·5	0 14·8	0·2	0·0	6·2	0·2	12·2	0·3
03	0 15·8	0 15·8	0 15·0	0·3	0·0	6·3	0·2	12·3	0·3
04	0 16·0	0 16·0	0 15·3	0·4	0·0	6·4	0·2	12·4	0·3
05	0 16·3	0 16·3	0 15·5	0·5	0·0	6·5	0·2	12·5	0·3
06	0 16·5	0 16·5	0 15·7	0·6	0·0	6·6	0·2	12·6	0·3
07	0 16·8	0 16·8	0 16·0	0·7	0·0	6·7	0·2	12·7	0·3
08	0 17·0	0 17·0	0 16·2	0·8	0·0	6·8	0·2	12·8	0·3
09	0 17·3	0 17·3	0 16·5	0·9	0·0	6·9	0·2	12·9	0·3
10	0 17·5	0 17·5	0 16·7	1·0	0·0	7·0	0·2	13·0	0·3
11	0 17·8	0 17·8	0 16·9	1·1	0·0	7·1	0·2	13·1	0·3
12	0 18·0	0 18·0	0 17·2	1·2	0·0	7·2	0·2	13·2	0·3
13	0 18·3	0 18·3	0 17·4	1·3	0·0	7·3	0·2	13·3	0·3
14	0 18·5	0 18·6	0 17·7	1·4	0·0	7·4	0·2	13·4	0·3
15	0 18·8	0 18·8	0 17·9	1·5	0·0	7·5	0·2	13·5	0·3
16	0 19·0	0 19·1	0 18·1	1·6	0·0	7·6	0·2	13·6	0·3
17	0 19·3	0 19·3	0 18·4	1·7	0·0	7·7	0·2	13·7	0·3
18	0 19·5	0 19·6	0 18·6	1·8	0·0	7·8	0·2	13·8	0·3
19	0 19·8	0 19·8	0 18·9	1·9	0·0	7·9	0·2	13·9	0·3
20	0 20·0	0 20·1	0 19·1	2·0	0·1	8·0	0·2	14·0	0·4
21	0 20·3	0 20·3	0 19·3	2·1	0·1	8·1	0·2	14·1	0·4
22	0 20·5	0 20·6	0 19·6	2·2	0·1	8·2	0·2	14·2	0·4
23	0 20·8	0 20·8	0 19·8	2·3	0·1	8·3	0·2	14·3	0·4
24	0 21·0	0 21·1	0 20·0	2·4	0·1	8·4	0·2	14·4	0·4
25	0 21·3	0 21·3	0 20·3	2·5	0·1	8·5	0·2	14·5	0·4
26	0 21·5	0 21·6	0 20·5	2·6	0·1	8·6	0·2	14·6	0·4
27	0 21·8	0 21·8	0 20·8	2·7	0·1	8·7	0·2	14·7	0·4
28	0 22·0	0 22·1	0 21·0	2·8	0·1	8·8	0·2	14·8	0·4
29	0 22·3	0 22·3	0 21·2	2·9	0·1	8·9	0·2	14·9	0·4
30	0 22·5	0 22·6	0 21·5	3·0	0·1	9·0	0·2	15·0	0·4
31	0 22·8	0 22·8	0 21·7	3·1	0·1	9·1	0·2	15·1	0·4
32	0 23·0	0 23·1	0 22·0	3·2	0·1	9·2	0·2	15·2	0·4
33	0 23·3	0 23·3	0 22·2	3·3	0·1	9·3	0·2	15·3	0·4
34	0 23·5	0 23·6	0 22·4	3·4	0·1	9·4	0·2	15·4	0·4
35	0 23·8	0 23·8	0 22·7	3·5	0·1	9·5	0·2	15·5	0·4
36	0 24·0	0 24·1	0 22·9	3·6	0·1	9·6	0·2	15·6	0·4
37	0 24·3	0 24·3	0 23·1	3·7	0·1	9·7	0·2	15·7	0·4
38	0 24·5	0 24·6	0 23·4	3·8	0·1	9·8	0·2	15·8	0·4
39	0 24·8	0 24·8	0 23·6	3·9	0·1	9·9	0·2	15·9	0·4
40	0 25·0	0 25·1	0 23·9	4·0	0·1	10·0	0·3	16·0	0·4
41	0 25·3	0 25·3	0 24·1	4·1	0·1	10·1	0·3	16·1	0·4
42	0 25·5	0 25·6	0 24·3	4·2	0·1	10·2	0·3	16·2	0·4
43	0 25·8	0 25·8	0 24·6	4·3	0·1	10·3	0·3	16·3	0·4
44	0 26·0	0 26·1	0 24·8	4·4	0·1	10·4	0·3	16·4	0·4
45	0 26·3	0 26·3	0 25·1	4·5	0·1	10·5	0·3	16·5	0·4
46	0 26·5	0 26·6	0 25·3	4·6	0·1	10·6	0·3	16·6	0·4
47	0 26·8	0 26·8	0 25·5	4·7	0·1	10·7	0·3	16·7	0·4
48	0 27·0	0 27·1	0 25·8	4·8	0·1	10·8	0·3	16·8	0·4
49	0 27·3	0 27·3	0 26·0	4·9	0·1	10·9	0·3	16·9	0·4
50	0 27·5	0 27·6	0 26·2	5·0	0·1	11·0	0·3	17·0	0·4
51	0 27·8	0 27·8	0 26·5	5·1	0·1	11·1	0·3	17·1	0·4
52	0 28·0	0 28·1	0 26·7	5·2	0·1	11·2	0·3	17·2	0·4
53	0 28·3	0 28·3	0 27·0	5·3	0·1	11·3	0·3	17·3	0·4
54	0 28·5	0 28·6	0 27·2	5·4	0·1	11·4	0·3	17·4	0·4
55	0 28·8	0 28·8	0 27·4	5·5	0·1	11·5	0·3	17·5	0·4
56	0 29·0	0 29·1	0 27·7	5·6	0·1	11·6	0·3	17·6	0·4
57	0 29·3	0 29·3	0 27·9	5·7	0·1	11·7	0·3	17·7	0·4
58	0 29·5	0 29·6	0 28·2	5·8	0·1	11·8	0·3	17·8	0·4
59	0 29·8	0 29·8	0 28·4	5·9	0·1	11·9	0·3	17·9	0·4
60	0 30·0	0 30·1	0 28·6	6·0	0·2	12·0	0·3	18·0	0·5

2m INCREMENTS AND CORRECTIONS 3m

m 2	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	0 30·0	0 30·1	0 28·6	0·0	0·0	6·0	0·3	12·0	0·5
01	0 30·3	0 30·3	0 28·9	0·1	0·0	6·1	0·3	12·1	0·5
02	0 30·5	0 30·6	0 29·1	0·2	0·0	6·2	0·3	12·2	0·5
03	0 30·8	0 30·8	0 29·3	0·3	0·0	6·3	0·3	12·3	0·5
04	0 31·0	0 31·1	0 29·6	0·4	0·0	6·4	0·3	12·4	0·5
05	0 31·3	0 31·3	0 29·8	0·5	0·0	6·5	0·3	12·5	0·5
06	0 31·5	0 31·6	0 30·1	0·6	0·0	6·6	0·3	12·6	0·5
07	0 31·8	0 31·8	0 30·3	0·7	0·0	6·7	0·3	12·7	0·5
08	0 32·0	0 32·1	0 30·5	0·8	0·0	6·8	0·3	12·8	0·5
09	0 32·3	0 32·3	0 30·8	0·9	0·0	6·9	0·3	12·9	0·5
10	0 32·5	0 32·6	0 31·0	1·0	0·0	7·0	0·3	13·0	0·5
11	0 32·8	0 32·8	0 31·3	1·1	0·0	7·1	0·3	13·1	0·5
12	0 33·0	0 33·1	0 31·5	1·2	0·1	7·2	0·3	13·2	0·6
13	0 33·3	0 33·3	0 31·7	1·3	0·1	7·3	0·3	13·3	0·6
14	0 33·5	0 33·6	0 32·0	1·4	0·1	7·4	0·3	13·4	0·6
15	0 33·8	0 33·8	0 32·2	1·5	0·1	7·5	0·3	13·5	0·6
16	0 34·0	0 34·1	0 32·5	1·6	0·1	7·6	0·3	13·6	0·6
17	0 34·3	0 34·3	0 32·7	1·7	0·1	7·7	0·3	13·7	0·6
18	0 34·5	0 34·6	0 32·9	1·8	0·1	7·8	0·3	13·8	0·6
19	0 34·8	0 34·8	0 33·2	1·9	0·1	7·9	0·3	13·9	0·6
20	0 35·0	0 35·1	0 33·4	2·0	0·1	8·0	0·3	14·0	0·6
21	0 35·3	0 35·3	0 33·6	2·1	0·1	8·1	0·3	14·1	0·6
22	0 35·5	0 35·6	0 33·9	2·2	0·1	8·2	0·3	14·2	0·6
23	0 35·8	0 35·8	0 34·1	2·3	0·1	8·3	0·3	14·3	0·6
24	0 36·0	0 36·1	0 34·4	2·4	0·1	8·4	0·4	14·4	0·6
25	0 36·3	0 36·3	0 34·6	2·5	0·1	8·5	0·4	14·5	0·6
26	0 36·5	0 36·6	0 34·8	2·6	0·1	8·6	0·4	14·6	0·6
27	0 36·8	0 36·9	0 35·1	2·7	0·1	8·7	0·4	14·7	0·6
28	0 37·0	0 37·1	0 35·3	2·8	0·1	8·8	0·4	14·8	0·6
29	0 37·3	0 37·4	0 35·6	2·9	0·1	8·9	0·4	14·9	0·6
30	0 37·5	0 37·6	0 35·8	3·0	0·1	9·0	0·4	15·0	0·6
31	0 37·8	0 37·9	0 36·0	3·1	0·1	9·1	0·4	15·1	0·6
32	0 38·0	0 38·1	0 36·3	3·2	0·1	9·2	0·4	15·2	0·6
33	0 38·3	0 38·4	0 36·5	3·3	0·1	9·3	0·4	15·3	0·6
34	0 38·5	0 38·6	0 36·7	3·4	0·1	9·4	0·4	15·4	0·6
35	0 38·8	0 38·9	0 37·0	3·5	0·1	9·5	0·4	15·5	0·6
36	0 39·0	0 39·1	0 37·2	3·6	0·2	9·6	0·4	15·6	0·7
37	0 39·3	0 39·4	0 37·5	3·7	0·2	9·7	0·4	15·7	0·7
38	0 39·5	0 39·6	0 37·7	3·8	0·2	9·8	0·4	15·8	0·7
39	0 39·8	0 39·9	0 37·9	3·9	0·2	9·9	0·4	15·9	0·7
40	0 40·0	0 40·1	0 38·2	4·0	0·2	10·0	0·4	16·0	0·7
41	0 40·3	0 40·4	0 38·4	4·1	0·2	10·1	0·4	16·1	0·7
42	0 40·5	0 40·6	0 38·7	4·2	0·2	10·2	0·4	16·2	0·7
43	0 40·8	0 40·9	0 38·9	4·3	0·2	10·3	0·4	16·3	0·7
44	0 41·0	0 41·1	0 39·1	4·4	0·2	10·4	0·4	16·4	0·7
45	0 41·3	0 41·4	0 39·4	4·5	0·2	10·5	0·4	16·5	0·7
46	0 41·5	0 41·6	0 39·6	4·6	0·2	10·6	0·4	16·6	0·7
47	0 41·8	0 41·9	0 39·8	4·7	0·2	10·7	0·4	16·7	0·7
48	0 42·0	0 42·1	0 40·1	4·8	0·2	10·8	0·5	16·8	0·7
49	0 42·3	0 42·4	0 40·3	4·9	0·2	10·9	0·5	16·9	0·7
50	0 42·5	0 42·6	0 40·6	5·0	0·2	11·0	0·5	17·0	0·7
51	0 42·8	0 42·9	0 40·8	5·1	0·2	11·1	0·5	17·1	0·7
52	0 43·0	0 43·1	0 41·0	5·2	0·2	11·2	0·5	17·2	0·7
53	0 43·3	0 43·4	0 41·3	5·3	0·2	11·3	0·5	17·3	0·7
54	0 43·5	0 43·6	0 41·5	5·4	0·2	11·4	0·5	17·4	0·7
55	0 43·8	0 43·9	0 41·8	5·5	0·2	11·5	0·5	17·5	0·7
56	0 44·0	0 44·1	0 42·0	5·6	0·2	11·6	0·5	17·6	0·7
57	0 44·3	0 44·4	0 42·2	5·7	0·2	11·7	0·5	17·7	0·7
58	0 44·5	0 44·6	0 42·5	5·8	0·2	11·8	0·5	17·8	0·7
59	0 44·8	0 44·9	0 42·7	5·9	0·2	11·9	0·5	17·9	0·7
60	0 45·0	0 45·1	0 43·0	6·0	0·3	12·0	0·5	18·0	0·8

m 3	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	0 45·0	0 45·1	0 43·0	0·0	0·0	6·0	0·4	12·0	0·7
01	0 45·3	0 45·4	0 43·2	0·1	0·0	6·1	0·4	12·1	0·7
02	0 45·5	0 45·6	0 43·4	0·2	0·0	6·2	0·4	12·2	0·7
03	0 45·8	0 45·9	0 43·7	0·3	0·0	6·3	0·4	12·3	0·7
04	0 46·0	0 46·1	0 43·9	0·4	0·0	6·4	0·4	12·4	0·7
05	0 46·3	0 46·4	0 44·1	0·5	0·0	6·5	0·4	12·5	0·7
06	0 46·5	0 46·6	0 44·4	0·6	0·0	6·6	0·4	12·6	0·7
07	0 46·8	0 46·9	0 44·6	0·7	0·0	6·7	0·4	12·7	0·7
08	0 47·0	0 47·1	0 44·9	0·8	0·0	6·8	0·4	12·8	0·7
09	0 47·3	0 47·4	0 45·1	0·9	0·1	6·9	0·4	12·9	0·8
10	0 47·5	0 47·6	0 45·3	1·0	0·1	7·0	0·4	13·0	0·8
11	0 47·8	0 47·9	0 45·6	1·1	0·1	7·1	0·4	13·1	0·8
12	0 48·0	0 48·1	0 45·8	1·2	0·1	7·2	0·4	13·2	0·8
13	0 48·3	0 48·4	0 46·1	1·3	0·1	7·3	0·4	13·3	0·8
14	0 48·5	0 48·6	0 46·3	1·4	0·1	7·4	0·4	13·4	0·8
15	0 48·8	0 48·9	0 46·5	1·5	0·1	7·5	0·4	13·5	0·8
16	0 49·0	0 49·1	0 46·8	1·6	0·1	7·6	0·4	13·6	0·8
17	0 49·3	0 49·4	0 47·0	1·7	0·1	7·7	0·4	13·7	0·8
18	0 49·5	0 49·6	0 47·2	1·8	0·1	7·8	0·5	13·8	0·8
19	0 49·8	0 49·9	0 47·5	1·9	0·1	7·9	0·5	13·9	0·8
20	0 50·0	0 50·1	0 47·7	2·0	0·1	8·0	0·5	14·0	0·8
21	0 50·3	0 50·4	0 48·0	2·1	0·1	8·1	0·5	14·1	0·8
22	0 50·5	0 50·6	0 48·2	2·2	0·1	8·2	0·5	14·2	0·8
23	0 50·8	0 50·9	0 48·4	2·3	0·1	8·3	0·5	14·3	0·8
24	0 51·0	0 51·1	0 48·7	2·4	0·1	8·4	0·5	14·4	0·8
25	0 51·3	0 51·4	0 48·9	2·5	0·1	8·5	0·5	14·5	0·8
26	0 51·5	0 51·6	0 49·2	2·6	0·2	8·6	0·5	14·6	0·9
27	0 51·8	0 51·9	0 49·4	2·7	0·2	8·7	0·5	14·7	0·9
28	0 52·0	0 52·1	0 49·6	2·8	0·2	8·8	0·5	14·8	0·9
29	0 52·3	0 52·4	0 49·9	2·9	0·2	8·9	0·5	14·9	0·9
30	0 52·5	0 52·6	0 50·1	3·0	0·2	9·0	0·5	15·0	0·9
31	0 52·8	0 52·9	0 50·3	3·1	0·2	9·1	0·5	15·1	0·9
32	0 53·0	0 53·1	0 50·6	3·2	0·2	9·2	0·5	15·2	0·9
33	0 53·3	0 53·4	0 50·8	3·3	0·2	9·3	0·5	15·3	0·9
34	0 53·5	0 53·6	0 51·1	3·4	0·2	9·4	0·5	15·4	0·9
35	0 53·8	0 53·9	0 51·3	3·5	0·2	9·5	0·6	15·5	0·9
36	0 54·0	0 54·1	0 51·5	3·6	0·2	9·6	0·6	15·6	0·9
37	0 54·3	0 54·4	0 51·8	3·7	0·2	9·7	0·6	15·7	0·9
38	0 54·5	0 54·6	0 52·0	3·8	0·2	9·8	0·6	15·8	0·9
39	0 54·8	0 54·9	0 52·3	3·9	0·2	9·9	0·6	15·9	0·9
40	0 55·0	0 55·2	0 52·5	4·0	0·2	10·0	0·6	16·0	0·9
41	0 55·3	0 55·4	0 52·7	4·1	0·2	10·1	0·6	16·1	0·9
42	0 55·5	0 55·7	0 53·0	4·2	0·2	10·2	0·6	16·2	0·9
43	0 55·8	0 55·9	0 53·2	4·3	0·3	10·3	0·6	16·3	1·0
44	0 56·0	0 56·2	0 53·4	4·4	0·3	10·4	0·6	16·4	1·0
45	0 56·3	0 56·4	0 53·7	4·5	0·3	10·5	0·6	16·5	1·0
46	0 56·5	0 56·7	0 53·9	4·6	0·3	10·6	0·6	16·6	1·0
47	0 56·8	0 56·9	0 54·2	4·7	0·3	10·7	0·6	16·7	1·0
48	0 57·0	0 57·2	0 54·4	4·8	0·3	10·8	0·6	16·8	1·0
49	0 57·3	0 57·4	0 54·6	4·9	0·3	10·9	0·6	16·9	1·0
50	0 57·5	0 57·7	0 54·9	5·0	0·3	11·0	0·6	17·0	1·0
51	0 57·8	0 57·9	0 55·1	5·1	0·3	11·1	0·6	17·1	1·0
52	0 58·0	0 58·2	0 55·4	5·2	0·3	11·2	0·7	17·2	1·0
53	0 58·3	0 58·4	0 55·6	5·3	0·3	11·3	0·7	17·3	1·0
54	0 58·5	0 58·7	0 55·8	5·4	0·3	11·4	0·7	17·4	1·0
55	0 58·8	0 58·9	0 56·1	5·5	0·3	11·5	0·7	17·5	1·0
56	0 59·0	0 59·2	0 56·3	5·6	0·3	11·6	0·7	17·6	1·0
57	0 59·3	0 59·4	0 56·6	5·7	0·3	11·7	0·7	17·7	1·0
58	0 59·5	0 59·7	0 56·8	5·8	0·3	11·8	0·7	17·8	1·0
59	0 59·8	0 59·9	0 57·0	5·9	0·3	11·9	0·7	17·9	1·0
60	1 00·0	1 00·2	0 57·3	6·0	0·4	12·0	0·7	18·0	1·1

4^m INCREMENTS AND CORRECTIONS 5^m

$\bar{4}$	SUN PLANETS	ARIES	MOON	v or Corr^n d	v or Corr^n d	v or Corr^n d
s	° ′	° ′	° ′	′ ′	′ ′	′ ′
00	1 00·0	1 00·2	0 57·3	0·0 0·0	6·0 0·5	12·0 0·9
01	1 00·3	1 00·4	0 57·5	0·1 0·0	6·1 0·5	12·1 0·9
02	1 00·5	1 00·7	0 57·7	0·2 0·0	6·2 0·5	12·2 0·9
03	1 00·8	1 00·9	0 58·0	0·3 0·0	6·3 0·5	12·3 0·9
04	1 01·0	1 01·2	0 58·2	0·4 0·0	6·4 0·5	12·4 0·9
05	1 01·3	1 01·4	0 58·5	0·5 0·0	6·5 0·5	12·5 0·9
06	1 01·5	1 01·7	0 58·7	0·6 0·0	6·6 0·5	12·6 0·9
07	1 01·8	1 01·9	0 58·9	0·7 0·1	6·7 0·5	12·7 1·0
08	1 02·0	1 02·2	0 59·2	0·8 0·1	6·8 0·5	12·8 1·0
09	1 02·3	1 02·4	0 59·4	0·9 0·1	6·9 0·5	12·9 1·0
10	1 02·5	1 02·7	0 59·7	1·0 0·1	7·0 0·5	13·0 1·0
11	1 02·8	1 02·9	0 59·9	1·1 0·1	7·1 0·5	13·1 1·0
12	1 03·0	1 03·2	1 00·1	1·2 0·1	7·2 0·5	13·2 1·0
13	1 03·3	1 03·4	1 00·4	1·3 0·1	7·3 0·5	13·3 1·0
14	1 03·5	1 03·7	1 00·6	1·4 0·1	7·4 0·6	13·4 1·0
15	1 03·8	1 03·9	1 00·8	1·5 0·1	7·5 0·6	13·5 1·0
16	1 04·0	1 04·2	1 01·1	1·6 0·1	7·6 0·6	13·6 1·0
17	1 04·3	1 04·4	1 01·3	1·7 0·1	7·7 0·6	13·7 1·0
18	1 04·5	1 04·7	1 01·6	1·8 0·1	7·8 0·6	13·8 1·0
19	1 04·8	1 04·9	1 01·8	1·9 0·1	7·9 0·6	13·9 1·0
20	1 05·0	1 05·2	1 02·0	2·0 0·2	8·0 0·6	14·0 1·1
21	1 05·3	1 05·4	1 02·3	2·1 0·2	8·1 0·6	14·1 1·1
22	1 05·5	1 05·7	1 02·5	2·2 0·2	8·2 0·6	14·2 1·1
23	1 05·8	1 05·9	1 02·8	2·3 0·2	8·3 0·6	14·3 1·1
24	1 06·0	1 06·2	1 03·0	2·4 0·2	8·4 0·6	14·4 1·1
25	1 06·3	1 06·4	1 03·2	2·5 0·2	8·5 0·6	14·5 1·1
26	1 06·5	1 06·7	1 03·5	2·6 0·2	8·6 0·6	14·6 1·1
27	1 06·8	1 06·9	1 03·7	2·7 0·2	8·7 0·7	14·7 1·1
28	1 07·0	1 07·2	1 03·9	2·8 0·2	8·8 0·7	14·8 1·1
29	1 07·3	1 07·4	1 04·2	2·9 0·2	8·9 0·7	14·9 1·1
30	1 07·5	1 07·7	1 04·4	3·0 0·2	9·0 0·7	15·0 1·1
31	1 07·8	1 07·9	1 04·7	3·1 0·2	9·1 0·7	15·1 1·1
32	1 08·0	1 08·2	1 04·9	3·2 0·2	9·2 0·7	15·2 1·1
33	1 08·3	1 08·4	1 05·1	3·3 0·2	9·3 0·7	15·3 1·1
34	1 08·5	1 08·7	1 05·4	3·4 0·3	9·4 0·7	15·4 1·2
35	1 08·8	1 08·9	1 05·6	3·5 0·3	9·5 0·7	15·5 1·2
36	1 09·0	1 09·2	1 05·9	3·6 0·3	9·6 0·7	15·6 1·2
37	1 09·3	1 09·4	1 06·1	3·7 0·3	9·7 0·7	15·7 1·2
38	1 09·5	1 09·7	1 06·3	3·8 0·3	9·8 0·7	15·8 1·2
39	1 09·8	1 09·9	1 06·6	3·9 0·3	9·9 0·7	15·9 1·2
40	1 10·0	1 10·2	1 06·8	4·0 0·3	10·0 0·8	16·0 1·2
41	1 10·3	1 10·4	1 07·0	4·1 0·3	10·1 0·8	16·1 1·2
42	1 10·5	1 10·7	1 07·3	4·2 0·3	10·2 0·8	16·2 1·2
43	1 10·8	1 10·9	1 07·5	4·3 0·3	10·3 0·8	16·3 1·2
44	1 11·0	1 11·2	1 07·8	4·4 0·3	10·4 0·8	16·4 1·2
45	1 11·3	1 11·4	1 08·0	4·5 0·3	10·5 0·8	16·5 1·2
46	1 11·5	1 11·7	1 08·2	4·6 0·3	10·6 0·8	16·6 1·2
47	1 11·8	1 11·9	1 08·5	4·7 0·4	10·7 0·8	16·7 1·3
48	1 12·0	1 12·2	1 08·7	4·8 0·4	10·8 0·8	16·8 1·3
49	1 12·3	1 12·4	1 09·0	4·9 0·4	10·9 0·8	16·9 1·3
50	1 12·5	1 12·7	1 09·2	5·0 0·4	11·0 0·8	17·0 1·3
51	1 12·8	1 12·9	1 09·4	5·1 0·4	11·1 0·8	17·1 1·3
52	1 13·0	1 13·2	1 09·7	5·2 0·4	11·2 0·8	17·2 1·3
53	1 13·3	1 13·5	1 09·9	5·3 0·4	11·3 0·8	17·3 1·3
54	1 13·5	1 13·7	1 10·2	5·4 0·4	11·4 0·9	17·4 1·3
55	1 13·8	1 14·0	1 10·4	5·5 0·4	11·5 0·9	17·5 1·3
56	1 14·0	1 14·2	1 10·6	5·6 0·4	11·6 0·9	17·6 1·3
57	1 14·3	1 14·5	1 10·9	5·7 0·4	11·7 0·9	17·7 1·3
58	1 14·5	1 14·7	1 11·1	5·8 0·4	11·8 0·9	17·8 1·3
59	1 14·8	1 15·0	1 11·3	5·9 0·4	11·9 0·9	17·9 1·3
60	1 15·0	1 15·2	1 11·6	6·0 0·5	12·0 0·9	18·0 1·4

$\bar{5}$	SUN PLANETS	ARIES	MOON	v or Corr^n d	v or Corr^n d	v or Corr^n d
s	° ′	° ′	° ′	′ ′	′ ′	′ ′
00	1 15·0	1 15·2	1 11·6	0·0 0·0	6·0 0·6	12·0 1·1
01	1 15·3	1 15·5	1 11·8	0·1 0·0	6·1 0·6	12·1 1·1
02	1 15·5	1 15·7	1 12·1	0·2 0·0	6·2 0·6	12·2 1·1
03	1 15·8	1 16·0	1 12·3	0·3 0·0	6·3 0·6	12·3 1·1
04	1 16·0	1 16·2	1 12·5	0·4 0·0	6·4 0·6	12·4 1·1
05	1 16·3	1 16·5	1 12·8	0·5 0·0	6·5 0·6	12·5 1·1
06	1 16·5	1 16·7	1 13·0	0·6 0·1	6·6 0·6	12·6 1·2
07	1 16·8	1 17·0	1 13·3	0·7 0·1	6·7 0·6	12·7 1·2
08	1 17·0	1 17·2	1 13·5	0·8 0·1	6·8 0·6	12·8 1·2
09	1 17·3	1 17·5	1 13·7	0·9 0·1	6·9 0·6	12·9 1·2
10	1 17·5	1 17·7	1 14·0	1·0 0·1	7·0 0·6	13·0 1·2
11	1 17·8	1 18·0	1 14·2	1·1 0·1	7·1 0·7	13·1 1·2
12	1 18·0	1 18·2	1 14·4	1·2 0·1	7·2 0·7	13·2 1·2
13	1 18·3	1 18·5	1 14·7	1·3 0·1	7·3 0·7	13·3 1·2
14	1 18·5	1 18·7	1 14·9	1·4 0·1	7·4 0·7	13·4 1·2
15	1 18·8	1 19·0	1 15·2	1·5 0·1	7·5 0·7	13·5 1·2
16	1 19·0	1 19·2	1 15·4	1·6 0·1	7·6 0·7	13·6 1·2
17	1 19·3	1 19·5	1 15·6	1·7 0·2	7·7 0·7	13·7 1·3
18	1 19·5	1 19·7	1 15·9	1·8 0·2	7·8 0·7	13·8 1·3
19	1 19·8	1 20·0	1 16·1	1·9 0·2	7·9 0·7	13·9 1·3
20	1 20·0	1 20·2	1 16·4	2·0 0·2	8·0 0·7	14·0 1·3
21	1 20·3	1 20·5	1 16·6	2·1 0·2	8·1 0·7	14·1 1·3
22	1 20·5	1 20·7	1 16·8	2·2 0·2	8·2 0·8	14·2 1·3
23	1 20·8	1 21·0	1 17·1	2·3 0·2	8·3 0·8	14·3 1·3
24	1 21·0	1 21·2	1 17·3	2·4 0·2	8·4 0·8	14·4 1·3
25	1 21·3	1 21·5	1 17·5	2·5 0·2	8·5 0·8	14·5 1·3
26	1 21·5	1 21·7	1 17·8	2·6 0·2	8·6 0·8	14·6 1·3
27	1 21·8	1 22·0	1 18·0	2·7 0·2	8·7 0·8	14·7 1·3
28	1 22·0	1 22·2	1 18·3	2·8 0·3	8·8 0·8	14·8 1·4
29	1 22·3	1 22·5	1 18·5	2·9 0·3	8·9 0·8	14·9 1·4
30	1 22·5	1 22·7	1 18·7	3·0 0·3	9·0 0·8	15·0 1·4
31	1 22·8	1 23·0	1 19·0	3·1 0·3	9·1 0·8	15·1 1·4
32	1 23·0	1 23·2	1 19·2	3·2 0·3	9·2 0·8	15·2 1·4
33	1 23·3	1 23·5	1 19·5	3·3 0·3	9·3 0·9	15·3 1·4
34	1 23·5	1 23·7	1 19·7	3·4 0·3	9·4 0·9	15·4 1·4
35	1 23·8	1 24·0	1 19·9	3·5 0·3	9·5 0·9	15·5 1·4
36	1 24·0	1 24·2	1 20·2	3·6 0·3	9·6 0·9	15·6 1·4
37	1 24·3	1 24·5	1 20·4	3·7 0·3	9·7 0·9	15·7 1·4
38	1 24·5	1 24·7	1 20·7	3·8 0·3	9·8 0·9	15·8 1·4
39	1 24·8	1 25·0	1 20·9	3·9 0·4	9·9 0·9	15·9 1·5
40	1 25·0	1 25·2	1 21·1	4·0 0·4	10·0 0·9	16·0 1·5
41	1 25·3	1 25·5	1 21·4	4·1 0·4	10·1 0·9	16·1 1·5
42	1 25·5	1 25·7	1 21·6	4·2 0·4	10·2 0·9	16·2 1·5
43	1 25·8	1 26·0	1 21·8	4·3 0·4	10·3 0·9	16·3 1·5
44	1 26·0	1 26·2	1 22·1	4·4 0·4	10·4 1·0	16·4 1·5
45	1 26·3	1 26·5	1 22·3	4·5 0·4	10·5 1·0	16·5 1·5
46	1 26·5	1 26·7	1 22·6	4·6 0·4	10·6 1·0	16·6 1·5
47	1 26·8	1 27·0	1 22·8	4·7 0·4	10·7 1·0	16·7 1·5
48	1 27·0	1 27·2	1 23·0	4·8 0·4	10·8 1·0	16·8 1·5
49	1 27·3	1 27·5	1 23·3	4·9 0·4	10·9 1·0	16·9 1·5
50	1 27·5	1 27·7	1 23·5	5·0 0·5	11·0 1·0	17·0 1·6
51	1 27·8	1 28·0	1 23·8	5·1 0·5	11·1 1·0	17·1 1·6
52	1 28·0	1 28·2	1 24·0	5·2 0·5	11·2 1·0	17·2 1·6
53	1 28·3	1 28·5	1 24·2	5·3 0·5	11·3 1·0	17·3 1·6
54	1 28·5	1 28·7	1 24·5	5·4 0·5	11·4 1·0	17·4 1·6
55	1 28·8	1 29·0	1 24·7	5·5 0·5	11·5 1·1	17·5 1·6
56	1 29·0	1 29·2	1 24·9	5·6 0·5	11·6 1·1	17·6 1·6
57	1 29·3	1 29·5	1 25·2	5·7 0·5	11·7 1·1	17·7 1·6
58	1 29·5	1 29·7	1 25·4	5·8 0·5	11·8 1·1	17·8 1·6
59	1 29·8	1 30·0	1 25·7	5·9 0·5	11·9 1·1	17·9 1·6
60	1 30·0	1 30·2	1 25·9	6·0 0·6	12·0 1·1	18·0 1·7

INCREMENTS AND CORRECTIONS

6m

m 6	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	1 30·0	1 30·2	1 25·9	0·0	0·0	6·0	0·7	12·0	1·3
01	1 30·3	1 30·5	1 26·1	0·1	0·0	6·1	0·7	12·1	1·3
02	1 30·5	1 30·7	1 26·4	0·2	0·0	6·2	0·7	12·2	1·3
03	1 30·8	1 31·0	1 26·6	0·3	0·0	6·3	0·7	12·3	1·3
04	1 31·0	1 31·2	1 26·9	0·4	0·0	6·4	0·7	12·4	1·3
05	1 31·3	1 31·5	1 27·1	0·5	0·1	6·5	0·7	12·5	1·4
06	1 31·5	1 31·8	1 27·3	0·6	0·1	6·6	0·7	12·6	1·4
07	1 31·8	1 32·0	1 27·6	0·7	0·1	6·7	0·7	12·7	1·4
08	1 32·0	1 32·3	1 27·8	0·8	0·1	6·8	0·7	12·8	1·4
09	1 32·3	1 32·5	1 28·0	0·9	0·1	6·9	0·7	12·9	1·4
10	1 32·5	1 32·8	1 28·3	1·0	0·1	7·0	0·8	13·0	1·4
11	1 32·8	1 33·0	1 28·5	1·1	0·1	7·1	0·8	13·1	1·4
12	1 33·0	1 33·3	1 28·8	1·2	0·1	7·2	0·8	13·2	1·4
13	1 33·3	1 33·5	1 29·0	1·3	0·1	7·3	0·8	13·3	1·4
14	1 33·5	1 33·8	1 29·2	1·4	0·2	7·4	0·8	13·4	1·5
15	1 33·8	1 34·0	1 29·5	1·5	0·2	7·5	0·8	13·5	1·5
16	1 34·0	1 34·3	1 29·7	1·6	0·2	7·6	0·8	13·6	1·5
17	1 34·3	1 34·5	1 30·0	1·7	0·2	7·7	0·8	13·7	1·5
18	1 34·5	1 34·8	1 30·2	1·8	0·2	7·8	0·8	13·8	1·5
19	1 34·8	1 35·0	1 30·4	1·9	0·2	7·9	0·9	13·9	1·5
20	1 35·0	1 35·3	1 30·7	2·0	0·2	8·0	0·9	14·0	1·5
21	1 35·3	1 35·5	1 30·9	2·1	0·2	8·1	0·9	14·1	1·5
22	1 35·5	1 35·8	1 31·1	2·2	0·2	8·2	0·9	14·2	1·5
23	1 35·8	1 36·0	1 31·4	2·3	0·2	8·3	0·9	14·3	1·5
24	1 36·0	1 36·3	1 31·6	2·4	0·3	8·4	0·9	14·4	1·6
25	1 36·3	1 36·5	1 31·9	2·5	0·3	8·5	0·9	14·5	1·6
26	1 36·5	1 36·8	1 32·1	2·6	0·3	8·6	0·9	14·6	1·6
27	1 36·8	1 37·0	1 32·3	2·7	0·3	8·7	0·9	14·7	1·6
28	1 37·0	1 37·3	1 32·6	2·8	0·3	8·8	1·0	14·8	1·6
29	1 37·3	1 37·5	1 32·8	2·9	0·3	8·9	1·0	14·9	1·6
30	1 37·5	1 37·8	1 33·1	3·0	0·3	9·0	1·0	15·0	1·6
31	1 37·8	1 38·0	1 33·3	3·1	0·3	9·1	1·0	15·1	1·6
32	1 38·0	1 38·3	1 33·5	3·2	0·3	9·2	1·0	15·2	1·6
33	1 38·3	1 38·5	1 33·8	3·3	0·4	9·3	1·0	15·3	1·7
34	1 38·5	1 38·8	1 34·0	3·4	0·4	9·4	1·0	15·4	1·7
35	1 38·8	1 39·0	1 34·3	3·5	0·4	9·5	1·0	15·5	1·7
36	1 39·0	1 39·3	1 34·5	3·6	0·4	9·6	1·0	15·6	1·7
37	1 39·3	1 39·5	1 34·7	3·7	0·4	9·7	1·1	15·7	1·7
38	1 39·5	1 39·8	1 35·0	3·8	0·4	9·8	1·1	15·8	1·7
39	1 39·8	1 40·0	1 35·2	3·9	0·4	9·9	1·1	15·9	1·7
40	1 40·0	1 40·3	1 35·4	4·0	0·4	10·0	1·1	16·0	1·7
41	1 40·3	1 40·5	1 35·7	4·1	0·4	10·1	1·1	16·1	1·7
42	1 40·5	1 40·8	1 35·9	4·2	0·5	10·2	1·1	16·2	1·8
43	1 40·8	1 41·0	1 36·2	4·3	0·5	10·3	1·1	16·3	1·8
44	1 41·0	1 41·3	1 36·4	4·4	0·5	10·4	1·1	16·4	1·8
45	1 41·3	1 41·5	1 36·6	4·5	0·5	10·5	1·1	16·5	1·8
46	1 41·5	1 41·8	1 36·9	4·6	0·5	10·6	1·1	16·6	1·8
47	1 41·8	1 42·0	1 37·1	4·7	0·5	10·7	1·2	16·7	1·8
48	1 42·0	1 42·3	1 37·4	4·8	0·5	10·8	1·2	16·8	1·8
49	1 42·3	1 42·5	1 37·6	4·9	0·5	10·9	1·2	16·9	1·8
50	1 42·5	1 42·8	1 37·8	5·0	0·5	11·0	1·2	17·0	1·8
51	1 42·8	1 43·0	1 38·1	5·1	0·6	11·1	1·2	17·1	1·9
52	1 43·0	1 43·3	1 38·3	5·2	0·6	11·2	1·2	17·2	1·9
53	1 43·3	1 43·5	1 38·5	5·3	0·6	11·3	1·2	17·3	1·9
54	1 43·5	1 43·8	1 38·8	5·4	0·6	11·4	1·2	17·4	1·9
55	1 43·8	1 44·0	1 39·0	5·5	0·6	11·5	1·2	17·5	1·9
56	1 44·0	1 44·3	1 39·3	5·6	0·6	11·6	1·3	17·6	1·9
57	1 44·3	1 44·5	1 39·5	5·7	0·6	11·7	1·3	17·7	1·9
58	1 44·5	1 44·8	1 39·7	5·8	0·6	11·8	1·3	17·8	1·9
59	1 44·8	1 45·0	1 40·0	5·9	0·6	11·9	1·3	17·9	1·9
60	1 45·0	1 45·3	1 40·2	6·0	0·7	12·0	1·3	18·0	2·0

7m

m 7	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	1 45·0	1 45·3	1 40·2	0·0	0·0	6·0	0·8	12·0	1·5
01	1 45·3	1 45·5	1 40·5	0·1	0·0	6·1	0·8	12·1	1·5
02	1 45·5	1 45·8	1 40·7	0·2	0·0	6·2	0·8	12·2	1·5
03	1 45·8	1 46·0	1 40·9	0·3	0·0	6·3	0·8	12·3	1·5
04	1 46·0	1 46·3	1 41·2	0·4	0·1	6·4	0·8	12·4	1·6
05	1 46·3	1 46·5	1 41·4	0·5	0·1	6·5	0·8	12·5	1·6
06	1 46·5	1 46·8	1 41·6	0·6	0·1	6·6	0·8	12·6	1·6
07	1 46·8	1 47·0	1 41·9	0·7	0·1	6·7	0·8	12·7	1·6
08	1 47·0	1 47·3	1 42·1	0·8	0·1	6·8	0·9	12·8	1·6
09	1 47·3	1 47·5	1 42·4	0·9	0·1	6·9	0·9	12·9	1·6
10	1 47·5	1 47·8	1 42·6	1·0	0·1	7·0	0·9	13·0	1·6
11	1 47·8	1 48·0	1 42·8	1·1	0·1	7·1	0·9	13·1	1·6
12	1 48·0	1 48·3	1 43·1	1·2	0·2	7·2	0·9	13·2	1·7
13	1 48·3	1 48·5	1 43·3	1·3	0·2	7·3	0·9	13·3	1·7
14	1 48·5	1 48·8	1 43·6	1·4	0·2	7·4	0·9	13·4	1·7
15	1 48·8	1 49·0	1 43·8	1·5	0·2	7·5	0·9	13·5	1·7
16	1 49·0	1 49·3	1 44·0	1·6	0·2	7·6	1·0	13·6	1·7
17	1 49·3	1 49·5	1 44·3	1·7	0·2	7·7	1·0	13·7	1·7
18	1 49·5	1 49·8	1 44·5	1·8	0·2	7·8	1·0	13·8	1·7
19	1 49·8	1 50·1	1 44·8	1·9	0·2	7·9	1·0	13·9	1·7
20	1 50·0	1 50·3	1 45·0	2·0	0·3	8·0	1·0	14·0	1·8
21	1 50·3	1 50·6	1 45·2	2·1	0·3	8·1	1·0	14·1	1·8
22	1 50·5	1 50·8	1 45·5	2·2	0·3	8·2	1·0	14·2	1·8
23	1 50·8	1 51·1	1 45·7	2·3	0·3	8·3	1·0	14·3	1·8
24	1 51·0	1 51·3	1 45·9	2·4	0·3	8·4	1·1	14·4	1·8
25	1 51·3	1 51·6	1 46·2	2·5	0·3	8·5	1·1	14·5	1·8
26	1 51·5	1 51·8	1 46·4	2·6	0·3	8·6	1·1	14·6	1·8
27	1 51·8	1 52·1	1 46·7	2·7	0·3	8·7	1·1	14·7	1·8
28	1 52·0	1 52·3	1 46·9	2·8	0·4	8·8	1·1	14·8	1·9
29	1 52·3	1 52·6	1 47·1	2·9	0·4	8·9	1·1	14·9	1·9
30	1 52·5	1 52·8	1 47·4	3·0	0·4	9·0	1·1	15·0	1·9
31	1 52·8	1 53·1	1 47·6	3·1	0·4	9·1	1·1	15·1	1·9
32	1 53·0	1 53·3	1 47·9	3·2	0·4	9·2	1·2	15·2	1·9
33	1 53·3	1 53·6	1 48·1	3·3	0·4	9·3	1·2	15·3	1·9
34	1 53·5	1 53·8	1 48·3	3·4	0·4	9·4	1·2	15·4	1·9
35	1 53·8	1 54·1	1 48·6	3·5	0·4	9·5	1·2	15·5	1·9
36	1 54·0	1 54·3	1 48·8	3·6	0·5	9·6	1·2	15·6	2·0
37	1 54·3	1 54·6	1 49·0	3·7	0·5	9·7	1·2	15·7	2·0
38	1 54·5	1 54·8	1 49·3	3·8	0·5	9·8	1·2	15·8	2·0
39	1 54·8	1 55·1	1 49·5	3·9	0·5	9·9	1·2	15·9	2·0
40	1 55·0	1 55·3	1 49·8	4·0	0·5	10·0	1·3	16·0	2·0
41	1 55·3	1 55·6	1 50·0	4·1	0·5	10·1	1·3	16·1	2·0
42	1 55·5	1 55·8	1 50·2	4·2	0·5	10·2	1·3	16·2	2·0
43	1 55·8	1 56·1	1 50·5	4·3	0·5	10·3	1·3	16·3	2·0
44	1 56·0	1 56·3	1 50·7	4·4	0·6	10·4	1·3	16·4	2·1
45	1 56·3	1 56·6	1 51·0	4·5	0·6	10·5	1·3	16·5	2·1
46	1 56·5	1 56·8	1 51·2	4·6	0·6	10·6	1·3	16·6	2·1
47	1 56·8	1 57·1	1 51·4	4·7	0·6	10·7	1·3	16·7	2·1
48	1 57·0	1 57·3	1 51·7	4·8	0·6	10·8	1·4	16·8	2·1
49	1 57·3	1 57·6	1 51·9	4·9	0·6	10·9	1·4	16·9	2·1
50	1 57·5	1 57·8	1 52·1	5·0	0·6	11·0	1·4	17·0	2·1
51	1 57·8	1 58·1	1 52·4	5·1	0·6	11·1	1·4	17·1	2·1
52	1 58·0	1 58·3	1 52·6	5·2	0·7	11·2	1·4	17·2	2·2
53	1 58·3	1 58·6	1 52·9	5·3	0·7	11·3	1·4	17·3	2·2
54	1 58·5	1 58·8	1 53·1	5·4	0·7	11·4	1·4	17·4	2·2
55	1 58·8	1 59·1	1 53·3	5·5	0·7	11·5	1·4	17·5	2·2
56	1 59·0	1 59·3	1 53·6	5·6	0·7	11·6	1·5	17·6	2·2
57	1 59·3	1 59·6	1 53·8	5·7	0·7	11·7	1·5	17·7	2·2
58	1 59·5	1 59·8	1 54·1	5·8	0·7	11·8	1·5	17·8	2·2
59	1 59·8	2 00·1	1 54·3	5·9	0·7	11·9	1·5	17·9	2·2
60	2 00·0	2 00·3	1 54·5	6·0	0·8	12·0	1·5	18·0	2·3

8m INCREMENTS AND CORRECTIONS 9m

m 8	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	2 00·0	2 00·3	1 54·5	0·0	0·0	6·0	0·9	12·0	1·7
01	2 00·3	2 00·6	1 54·8	0·1	0·0	6·1	0·9	12·1	1·7
02	2 00·5	2 00·8	1 55·0	0·2	0·0	6·2	0·9	12·2	1·7
03	2 00·8	2 01·1	1 55·2	0·3	0·0	6·3	0·9	12·3	1·7
04	2 01·0	2 01·3	1 55·5	0·4	0·1	6·4	0·9	12·4	1·8
05	2 01·3	2 01·6	1 55·7	0·5	0·1	6·5	0·9	12·5	1·8
06	2 01·5	2 01·8	1 56·0	0·6	0·1	6·6	0·9	12·6	1·8
07	2 01·8	2 02·1	1 56·2	0·7	0·1	6·7	0·9	12·7	1·8
08	2 02·0	2 02·3	1 56·4	0·8	0·1	6·8	1·0	12·8	1·8
09	2 02·3	2 02·6	1 56·7	0·9	0·1	6·9	1·0	12·9	1·8
10	2 02·5	2 02·8	1 56·9	1·0	0·1	7·0	1·0	13·0	1·8
11	2 02·8	2 03·1	1 57·2	1·1	0·2	7·1	1·0	13·1	1·9
12	2 03·0	2 03·3	1 57·4	1·2	0·2	7·2	1·0	13·2	1·9
13	2 03·3	2 03·6	1 57·6	1·3	0·2	7·3	1·0	13·3	1·9
14	2 03·5	2 03·8	1 57·9	1·4	0·2	7·4	1·0	13·4	1·9
15	2 03·8	2 04·1	1 58·1	1·5	0·2	7·5	1·1	13·5	1·9
16	2 04·0	2 04·3	1 58·4	1·6	0·2	7·6	1·1	13·6	1·9
17	2 04·3	2 04·6	1 58·6	1·7	0·2	7·7	1·1	13·7	1·9
18	2 04·5	2 04·8	1 58·8	1·8	0·3	7·8	1·1	13·8	2·0
19	2 04·8	2 05·1	1 59·1	1·9	0·3	7·9	1·1	13·9	2·0
20	2 05·0	2 05·3	1 59·3	2·0	0·3	8·0	1·1	14·0	2·0
21	2 05·3	2 05·6	1 59·5	2·1	0·3	8·1	1·1	14·1	2·0
22	2 05·5	2 05·8	1 59·8	2·2	0·3	8·2	1·2	14·2	2·0
23	2 05·8	2 06·1	2 00·0	2·3	0·3	8·3	1·2	14·3	2·0
24	2 06·0	2 06·3	2 00·3	2·4	0·3	8·4	1·2	14·4	2·0
25	2 06·3	2 06·6	2 00·5	2·5	0·4	8·5	1·2	14·5	2·1
26	2 06·5	2 06·8	2 00·7	2·6	0·4	8·6	1·2	14·6	2·1
27	2 06·8	2 07·1	2 01·0	2·7	0·4	8·7	1·2	14·7	2·1
28	2 07·0	2 07·3	2 01·2	2·8	0·4	8·8	1·2	14·8	2·1
29	2 07·3	2 07·6	2 01·5	2·9	0·4	8·9	1·3	14·9	2·1
30	2 07·5	2 07·8	2 01·7	3·0	0·4	9·0	1·3	15·0	2·1
31	2 07·8	2 08·1	2 01·9	3·1	0·4	9·1	1·3	15·1	2·1
32	2 08·0	2 08·4	2 02·2	3·2	0·5	9·2	1·3	15·2	2·2
33	2 08·3	2 08·6	2 02·4	3·3	0·5	9·3	1·3	15·3	2·2
34	2 08·5	2 08·9	2 02·6	3·4	0·5	9·4	1·3	15·4	2·2
35	2 08·8	2 09·1	2 02·9	3·5	0·5	9·5	1·3	15·5	2·2
36	2 09·0	2 09·4	2 03·1	3·6	0·5	9·6	1·4	15·6	2·2
37	2 09·3	2 09·6	2 03·4	3·7	0·5	9·7	1·4	15·7	2·2
38	2 09·5	2 09·9	2 03·6	3·8	0·5	9·8	1·4	15·8	2·2
39	2 09·8	2 10·1	2 03·8	3·9	0·6	9·9	1·4	15·9	2·3
40	2 10·0	2 10·4	2 04 1	4·0	0·6	10·0	1·4	16·0	2·3
41	2 10·3	2 10·6	2 04·3	4·1	0·6	10·1	1·4	16·1	2·3
42	2 10·5	2 10·9	2 04·6	4·2	0·6	10·2	1·4	16·2	2·3
43	2 10·8	2 11·1	2 04·8	4·3	0·6	10·3	1·5	16·3	2·3
44	2 11·0	2 11·4	2 05·0	4·4	0·6	10·4	1·5	16·4	2·3
45	2 11·3	2 11·6	2 05·3	4·5	0·6	10·5	1·5	16·5	2·3
46	2 11·5	2 11·9	2 05·5	4·6	0·7	10·6	1·5	16·6	2·4
47	2 11·8	2 12·1	2 05·7	4·7	0·7	10·7	1·5	16·7	2·4
48	2 12·0	2 12·4	2 06·0	4·8	0·7	10·8	1·5	16·8	2·4
49	2 12·3	2 12·6	2 06·2	4·9	0·7	10·9	1·5	16·9	2·4
50	2 12·5	2 12·9	2 06·5	5·0	0·7	11·0	1·6	17·0	2·4
51	2 12·8	2 13·1	2 06·7	5·1	0·7	11·1	1·6	17·1	2·4
52	2 13·0	2 13·4	2 06·9	5·2	0·7	11·2	1·6	17·2	2·4
53	2 13·3	2 13·6	2 07·2	5·3	0·8	11·3	1·6	17·3	2·5
54	2 13·5	2 13·9	2 07·4	5·4	0·8	11·4	1·6	17·4	2·5
55	2 13·8	2 14·1	2 07·7	5·5	0·8	11·5	1·6	17·5	2·5
56	2 14·0	2 14·4	2 07·9	5·6	0·8	11·6	1·6	17·6	2·5
57	2 14·3	2 14·6	2 08·1	5·7	0·8	11·7	1·7	17·7	2·5
58	2 14·5	2 14·9	2 08·4	5·8	0·8	11·8	1·7	17·8	2·5
59	2 14·8	2 15·1	2 08·6	5·9	0·8	11·9	1·7	17·9	2·5
60	2 15·0	2 15·4	2 08·9	6·0	0·9	12·0	1·7	18·0	2·6

m 9	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	2 15·0	2 15·4	2 08·9	0·0	0·0	6·0	1·0	12·0	1·9
01	2 15·3	2 15·6	2 09·1	0·1	0·0	6·1	1·0	12·1	1·9
02	2 15·5	2 15·9	2 09·3	0·2	0·0	6·2	1·0	12·2	1·9
03	2 15·8	2 16·1	2 09·6	0·3	0·0	6·3	1·0	12·3	1·9
04	2 16·0	2 16·4	2 09·8	0·4	0·1	6·4	1·0	12·4	2·0
05	2 16·3	2 16·6	2 10·0	0·5	0·1	6·5	1·0	12·5	2·0
06	2 16·5	2 16·9	2 10·3	0·6	0·1	6·6	1·0	12·6	2·0
07	2 16·8	2 17·1	2 10·5	0·7	0·1	6·7	1·1	12·7	2·0
08	2 17·0	2 17·4	2 10·8	0·8	0·1	6·8	1·1	12·8	2·0
09	2 17·3	2 17·6	2 11·0	0·9	0·1	6·9	1·1	12·9	2·0
10	2 17·5	2 17·9	2 11·2	1·0	0·2	7·0	1·1	13·0	2·1
11	2 17·8	2 18·1	2 11·5	1·1	0·2	7·1	1·1	13·1	2·1
12	2 18·0	2 18·4	2 11·7	1·2	0·2	7·2	1·1	13·2	2·1
13	2 18·3	2 18·6	2 12·0	1·3	0·2	7·3	1·2	13·3	2·1
14	2 18·5	2 18·9	2 12·2	1·4	0·2	7·4	1·2	13·4	2·1
15	2 18·8	2 19·1	2 12·4	1·5	0·2	7·5	1·2	13·5	2·1
16	2 19·0	2 19·4	2 12·7	1·6	0·3	7·6	1·2	13·6	2·2
17	2 19·3	2 19·6	2 12·9	1·7	0·3	7·7	1·2	13·7	2·2
18	2 19·5	2 19·9	2 13·1	1·8	0·3	7·8	1·2	13·8	2·2
19	2 19·8	2 20·1	2 13·4	1·9	0·3	7·9	1·3	13·9	2·2
20	2 20·0	2 20·4	2 13·6	2·0	0·3	8·0	1·3	14·0	2·2
21	2 20·3	2 20·6	2 13·9	2·1	0·3	8·1	1·3	14·1	2·2
22	2 20·5	2 20·9	2 14·1	2·2	0·3	8·2	1·3	14·2	2·2
23	2 20·8	2 21·1	2 14·3	2·3	0·4	8·3	1·3	14·3	2·3
24	2 21·0	2 21·4	2 14·6	2·4	0·4	8·4	1·3	14·4	2·3
25	2 21·3	2 21·6	2 14·8	2·5	0·4	8·5	1·3	14·5	2·3
26	2 21·5	2 21·9	2 15·1	2·6	0·4	8·6	1·4	14·6	2·3
27	2 21·8	2 22·1	2 15·3	2·7	0·4	8·7	1·4	14·7	2·3
28	2 22·0	2 22·4	2 15·5	2·8	0·4	8·8	1·4	14·8	2·3
29	2 22·3	2 22·6	2 15·8	2·9	0·5	8·9	1·4	14·9	2·4
30	2 22·5	2 22·9	2 16·0	3·0	0·5	9·0	1·4	15·0	2·4
31	2 22·8	2 23·1	2 16·2	3·1	0·5	9·1	1·4	15·1	2·4
32	2 23·0	2 23·4	2 16·5	3·2	0·5	9·2	1·5	15·2	2·4
33	2 23·3	2 23·6	2 16·7	3·3	0·5	9·3	1·5	15·3	2·4
34	2 23·5	2 23·9	2 17·0	3·4	0·5	9·4	1·5	15·4	2·4
35	2 23·8	2 24·1	2 17·2	3·5	0·6	9·5	1·5	15·5	2·5
36	2 24·0	2 24·4	2 17·4	3·6	0·6	9·6	1·5	15·6	2·5
37	2 24·3	2 24·6	2 17·7	3·7	0·6	9·7	1·5	15·7	2·5
38	2 24·5	2 24·9	2 17·9	3·8	0·6	9·8	1·6	15·8	2·5
39	2 24·8	2 25·1	2 18·2	3·9	0·6	9·9	1·6	15·9	2·5
40	2 25·0	2 25·4	2 18·4	4·0	0·6	10·0	1·6	16·0	2·5
41	2 25·3	2 25·6	2 18·6	4·1	0·6	10·1	1·6	16·1	2·5
42	2 25·5	2 25·9	2 18·9	4·2	0·7	10·2	1·6	16·2	2·6
43	2 25·8	2 26·1	2 19·1	4·3	0·7	10·3	1·6	16·3	2·6
44	2 26·0	2 26·4	2 19·3	4·4	0·7	10·4	1·6	16·4	2·6
45	2 26·3	2 26·7	2 19·6	4·5	0·7	10·5	1·7	16·5	2·6
46	2 26·5	2 26·9	2 19·8	4·6	0·7	10·6	1·7	16·6	2·6
47	2 26·8	2 27·2	2 20·1	4·7	0·7	10·7	1·7	16·7	2·6
48	2 27·0	2 27·4	2 20·3	4·8	0·8	10·8	1·7	16·8	2·7
49	2 27·3	2 27·7	2 20·5	4·9	0·8	10·9	1·7	16·9	2·7
50	2 27·5	2 27·9	2 20·8	5·0	0·8	11·0	1·7	17·0	2·7
51	2 27·8	2 28·2	2 21·0	5·1	0·8	11·1	1·8	17·1	2·7
52	2 28·0	2 28·4	2 21·3	5·2	0·8	11·2	1·8	17·2	2·7
53	2 28·3	2 28·7	2 21·5	5·3	0·8	11·3	1·8	17·3	2·7
54	2 28·5	2 28·9	2 21·7	5·4	0·9	11·4	1·8	17·4	2·8
55	2 28·8	2 29·2	2 22·0	5·5	0·9	11·5	1·8	17·5	2·8
56	2 29·0	2 29·4	2 22·2	5·6	0·9	11·6	1·8	17·6	2·8
57	2 29·3	2 29·7	2 22·5	5·7	0·9	11·7	1·9	17·7	2·8
58	2 29·5	2 29·9	2 22·7	5·8	0·9	11·8	1·9	17·8	2·8
59	2 29·8	2 30·2	2 22·9	5·9	0·9	11·9	1·9	17·9	2·8
60	2 30·0	2 30·4	2 23·2	6·0	1·0	12·0	1·9	18·0	2·9

10m INCREMENTS AND CORRECTIONS 11m

10	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	2 30·0	2 30·4	2 23·2	0·0	0·0	6·0	1·1	12·0	2·1
01	2 30·3	2 30·7	2 23·4	0·1	0·0	6·1	1·1	12·1	2·1
02	2 30·5	2 30·9	2 23·6	0·2	0·0	6·2	1·1	12·2	2·1
03	2 30·8	2 31·2	2 23·9	0·3	0·1	6·3	1·1	12·3	2·2
04	2 31·0	2 31·4	2 24·1	0·4	0·1	6·4	1·1	12·4	2·2
05	2 31·3	2 31·7	2 24·4	0·5	0·1	6·5	1·1	12·5	2·2
06	2 31·5	2 31·9	2 24·6	0·6	0·1	6·6	1·2	12·6	2·2
07	2 31·8	2 32·2	2 24·8	0·7	0·1	6·7	1·2	12·7	2·2
08	2 32·0	2 32·4	2 25·1	0·8	0·1	6·8	1·2	12·8	2·2
09	2 32·3	2 32·7	2 25·3	0·9	0·2	6·9	1·2	12·9	2·3
10	2 32·5	2 32·9	2 25·6	1·0	0·2	7·0	1·2	13·0	2·3
11	2 32·8	2 33·2	2 25·8	1·1	0·2	7·1	1·2	13·1	2·3
12	2 33·0	2 33·4	2 26·0	1·2	0·2	7·2	1·3	13·2	2·3
13	2 33·3	2 33·7	2 26·3	1·3	0·2	7·3	1·3	13·3	2·3
14	2 33·5	2 33·9	2 26·5	1·4	0·2	7·4	1·3	13·4	2·3
15	2 33·8	2 34·2	2 26·7	1·5	0·3	7·5	1·3	13·5	2·4
16	2 34·0	2 34·4	2 27·0	1·6	0·3	7·6	1·3	13·6	2·4
17	2 34·3	2 34·7	2 27·2	1·7	0·3	7·7	1·3	13·7	2·4
18	2 34·5	2 34·9	2 27·5	1·8	0·3	7·8	1·4	13·8	2·4
19	2 34·8	2 35·2	2 27·7	1·9	0·3	7·9	1·4	13·9	2·4
20	2 35·0	2 35·4	2 27·9	2·0	0·4	8·0	1·4	14·0	2·5
21	2 35·3	2 35·7	2 28·2	2·1	0·4	8·1	1·4	14·1	2·5
22	2 35·5	2 35·9	2 28·4	2·2	0·4	8·2	1·4	14·2	2·5
23	2 35·8	2 36·2	2 28·7	2·3	0·4	8·3	1·5	14·3	2·5
24	2 36·0	2 36·4	2 28·9	2·4	0·4	8·4	1·5	14·4	2·5
25	2 36·3	2 36·7	2 29·1	2·5	0·4	8·5	1·5	14·5	2·5
26	2 36·5	2 36·9	2 29·4	2·6	0·5	8·6	1·5	14·6	2·6
27	2 36·8	2 37·2	2 29·6	2·7	0·5	8·7	1·5	14·7	2·6
28	2 37·0	2 37·4	2 29·8	2·8	0·5	8·8	1·5	14·8	2·6
29	2 37·3	2 37·7	2 30·1	2·9	0·5	8·9	1·6	14·7	2·6
30	2 37·5	2 37·9	2 30·3	3·0	0·5	9·0	1·6	15·0	2·6
31	2 37·8	2 38·2	2 30·6	3·1	0·5	9·1	1·6	15·1	2·6
32	2 38·0	2 38·4	2 30·8	3·2	0·6	9·2	1·6	15·2	2·7
33	2 38·3	2 38·7	2 31·0	3·3	0·6	9·3	1·6	15·3	2·7
34	2 38·5	2 38·9	2 31·3	3·4	0·6	9·4	1·6	15·4	2·7
35	2 38·8	2 39·2	2 31·5	3·5	0·6	9·5	1·7	15·5	2·7
36	2 39·0	2 39·4	2 31·8	3·6	0·6	9·6	1·7	15·6	2·7
37	2 39·3	2 39·7	2 32·0	3·7	0·6	9·7	1·7	15·7	2·7
38	2 39·5	2 39·9	2 32·2	3·8	0·7	9·8	1·7	15·8	2·8
39	2 39·8	2 40·2	2 32·5	3·9	0·7	9·9	1·7	15·9	2·8
40	2 40·0	2 40·4	2 32·7	4·0	0·7	10·0	1·8	16·0	2·8
41	2 40·3	2 40·7	2 32·9	4·1	0·7	10·1	1·8	16·1	2·8
42	2 40·5	2 40·9	2 33·2	4·2	0·7	10·2	1·8	16·2	2·8
43	2 40·8	2 41·2	2 33·4	4·3	0·8	10·3	1·8	16·3	2·9
44	2 41·0	2 41·4	2 33·7	4·4	0·8	10·4	1·8	16·4	2·9
45	2 41·3	2 41·7	2 33·9	4·5	0·8	10·5	1·8	16·5	2·9
46	2 41·5	2 41·9	2 34·1	4·6	0·8	10·6	1·9	16·6	2·9
47	2 41·8	2 42·2	2 34·4	4·7	0·8	10·7	1·9	16·7	2·9
48	2 42·0	2 42·4	2 34·6	4·8	0·8	10·8	1·9	16·8	2·9
49	2 42·3	2 42·7	2 34·9	4·9	0·9	10·9	1·9	16·9	3·0
50	2 42·5	2 42·9	2 35·1	5·0	0·9	11·0	1·9	17·0	3·0
51	2 42·8	2 43·2	2 35·3	5·1	0·9	11·1	1·9	17·1	3·0
52	2 43·0	2 43·4	2 35·6	5·2	0·9	11·2	2·0	17·2	3·0
53	2 43·3	2 43·7	2 35·8	5·3	0·9	11·3	2·0	17·3	3·0
54	2 43·5	2 43·9	2 36·1	5·4	0·9	11·4	2·0	17·4	3·0
55	2 43·8	2 44·2	2 36·3	5·5	1·0	11·5	2·0	17·5	3·1
56	2 44·0	2 44·4	2 36·5	5·6	1·0	11·6	2·0	17·6	3·1
57	2 44·3	2 44·7	2 36·8	5·7	1·0	11·7	2·0	17·7	3·1
58	2 44·5	2 45·0	2 37·0	5·8	1·0	11·8	2·1	17·8	3·1
59	2 44·8	2 45·2	2 37·2	5·9	1·0	11·9	2·1	17·9	3·1
60	2 45·0	2 45·5	2 37·5	6·0	1·1	12·0	2·1	18·0	3·2

11	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	2 45·0	2 45·5	2 37·5	0·0	0·0	6·0	1·2	12·0	2·3
01	2 45·3	2 45·7	2 37·7	0·1	0·0	6·1	1·2	12·1	2·3
02	2 45·5	2 46·0	2 38·0	0·2	0·0	6·2	1·2	12·2	2·3
03	2 45·8	2 46·2	2 38·2	0·3	0·1	6·3	1·2	12·3	2·4
04	2 46·0	2 46·5	2 38·4	0·4	0·1	6·4	1·2	12·4	2·4
05	2 46·3	2 46·7	2 38·7	0·5	0·1	6·5	1·2	12·5	2·4
06	2 46·5	2 47·0	2 38·9	0·6	0·1	6·6	1·3	12·6	2·4
07	2 46·8	2 47·2	2 39·2	0·7	0·1	6·7	1·3	12·7	2·4
08	2 47·0	2 47·5	2 39·4	0·8	0·2	6·8	1·3	12·8	2·5
09	2 47·3	2 47·7	2 39·6	0·9	0·2	6·9	1·3	12·9	2·5
10	2 47·5	2 48·0	2 39·9	1·0	0·2	7·0	1·3	13·0	2·5
11	2 47·8	2 48·2	2 40·1	1·1	0·2	7·1	1·4	13·1	2·5
12	2 48·0	2 48·5	2 40·3	1·2	0·2	7·2	1·4	13·2	2·5
13	2 48·3	2 48·7	2 40·6	1·3	0·2	7·3	1·4	13·3	2·5
14	2 48·5	2 49·0	2 40·8	1·4	0·3	7·4	1·4	13·4	2·6
15	2 48·8	2 49·2	2 41·1	1·5	0·3	7·5	1·4	13·5	2·6
16	2 49·0	2 49·5	2 41·3	1·6	0·3	7·6	1·5	13·6	2·6
17	2 49·3	2 49·7	2 41·5	1·7	0·3	7·7	1·5	13·7	2·6
18	2 49·5	2 50·0	2 41·8	1·8	0·3	7·8	1·5	13·8	2·6
19	2 49·8	2 50·2	2 42·0	1·9	0·4	7·9	1·5	13·9	2·7
20	2 50·0	2 50·5	2 42·3	2·0	0·4	8·0	1·5	14·0	2·7
21	2 50·3	2 50·7	2 42·5	2·1	0·4	8·1	1·6	14·1	2·7
22	2 50·5	2 51·0	2 42·7	2·2	0·4	8·2	1·6	14·2	2·7
23	2 50·8	2 51·2	2 43·0	2·3	0·4	8·3	1·6	14·3	2·7
24	2 51·0	2 51·5	2 43·2	2·4	0·5	8·4	1·6	14·4	2·8
25	2 51·3	2 51·7	2 43·4	2·5	0·5	8·5	1·6	14·5	2·8
26	2 51·5	2 52·0	2 43·7	2·6	0·5	8·6	1·6	14·6	2·8
27	2 51·8	2 52·2	2 43·9	2·7	0·5	8·7	1·7	14·7	2·8
28	2 52·0	2 52·5	2 44·2	2·8	0·5	8·8	1·7	14·8	2·8
29	2 52·3	2 52·7	2 44·4	2·9	0·6	8·9	1·7	14·9	2·9
30	2 52·5	2 53·0	2 44·6	3·0	0·6	9·0	1·7	15·0	2·9
31	2 52·8	2 53·2	2 44·9	3·1	0·6	9·1	1·7	15·1	2·9
32	2 53·0	2 53·5	2 45·1	3·2	0·6	9·2	1·8	15·2	2·9
33	2 53·3	2 53·7	2 45·4	3·3	0·6	9·3	1·8	15·3	2·9
34	2 53·5	2 54·0	2 45·6	3·4	0·7	9·4	1·8	15·4	3·0
35	2 53·8	2 54·2	2 45·8	3·5	0·7	9·5	1·8	15·5	3·0
36	2 54·0	2 54·5	2 46·1	3·6	0·7	9·6	1·8	15·6	3·0
37	2 54·3	2 54·7	2 46·3	3·7	0·7	9·7	1·9	15·7	3·0
38	2 54·5	2 55·0	2 46·6	3·8	0·7	9·8	1·9	15·8	3·0
39	2 54·8	2 55·2	2 46·8	3·9	0·7	9·9	1·9	15·9	3·0
40	2 55·0	2 55·5	2 47·0	4·0	0·8	10·0	1·9	16·0	3·1
41	2 55·3	2 55·7	2 47·3	4·1	0·8	10·1	1·9	16·1	3·1
42	2 55·5	2 56·0	2 47·5	4·2	0·8	10·2	2·0	16·2	3·1
43	2 55·8	2 56·2	2 47·7	4·3	0·8	10·3	2·0	16·3	3·1
44	2 56·0	2 56·5	2 48·0	4·4	0·8	10·4	2·0	16·4	3·1
45	2 56·3	2 56·7	2 48·2	4·5	0·9	10·5	2·0	16·5	3·2
46	2 56·5	2 57·0	2 48·5	4·6	0·9	10·6	2·0	16·6	3·2
47	2 56·8	2 57·2	2 48·7	4·7	0·9	10·7	2·1	16·7	3·2
48	2 57·0	2 57·5	2 48·9	4·8	0·9	10·8	2·1	16·8	3·2
49	2 57·3	2 57·7	2 49·2	4·9	0·9	10·9	2·1	16·9	3·2
50	2 57·5	2 58·0	2 49·4	5·0	1·0	11·0	2·1	17·0	3·3
51	2 57·8	2 58·2	2 49·7	5·1	1·0	11·1	2·1	17·1	3·3
52	2 58·0	2 58·5	2 49·9	5·2	1·0	11·2	2·1	17·2	3·3
53	2 58·3	2 58·7	2 50·1	5·3	1·0	11·3	2·2	17·3	3·3
54	2 58·5	2 59·0	2 50·4	5·4	1·0	11·4	2·2	17·4	3·3
55	2 58·8	2 59·2	2 50·6	5·5	1·1	11·5	2·2	17·5	3·4
56	2 59·0	2 59·5	2 50·8	5·6	1·1	11·6	2·2	17·6	3·4
57	2 59·3	2 59·7	2 51·1	5·7	1·1	11·7	2·2	17·7	3·4
58	2 59·5	3 00·0	2 51·3	5·8	1·1	11·8	2·3	17·8	3·4
59	2 59·8	3 00·2	2 51·6	5·9	1·1	11·9	2·3	17·9	3·4
60	3 00·0	3 00·5	2 51·8	6·0	1·2	12·0	2·3	18·0	3·5

12m INCREMENTS AND CORRECTIONS 13m

12	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	3 00·0	3 00·5	2 51·8	0·0	0·0	6·0	1·3	12·0	2·5
01	3 00·3	3 00·7	2 52·0	0·1	0·0	6·1	1·3	12·1	2·5
02	3 00·5	3 01·0	2 52·3	0·2	0·0	6·2	1·3	12·2	2·5
03	3 00·8	3 01·2	2 52·5	0·3	0·1	6·3	1·3	12·3	2·6
04	3 01·0	3 01·5	2 52·8	0·4	0·1	6·4	1·3	12·4	2·6
05	3 01·3	3 01·7	2 53·0	0·5	0·1	6·5	1·4	12·5	2·6
06	3 01·5	3 02·0	2 53·2	0·6	0·1	6·6	1·4	12·6	2·6
07	3 01·8	3 02·2	2 53·5	0·7	0·1	6·7	1·4	12·7	2·6
08	3 02·0	3 02·5	2 53·7	0·8	0·2	6·8	1·4	12·8	2·7
09	3 02·3	3 02·7	2 53·9	0·9	0·2	6·9	1·4	12·9	2·7
10	3 02·5	3 03·0	2 54·2	1·0	0·2	7·0	1·5	13·0	2·7
11	3 02·8	3 03·3	2 54·4	1·1	0·2	7·1	1·5	13·1	2·7
12	3 03·0	3 03·5	2 54·7	1·2	0·3	7·2	1·5	13·2	2·8
13	3 03·3	3 03·8	2 54·9	1·3	0·3	7·3	1·5	13·3	2·8
14	3 03·5	3 04·0	2 55·1	1·4	0·3	7·4	1·5	13·4	2·8
15	3 03·8	3 04·3	2 55·4	1·5	0·3	7·5	1·6	13·5	2·8
16	3 04·0	3 04·5	2 55·6	1·6	0·3	7·6	1·6	13·6	2·8
17	3 04·3	3 04·8	2 55·9	1·7	0·4	7·7	1·6	13·7	2·9
18	3 04·5	3 05·0	2 56·1	1·8	0·4	7·8	1·6	13·8	2·9
19	3 04·8	3 05·3	2 56·3	1·9	0·4	7·9	1·6	13·9	2·9
20	3 05·0	3 05·5	2 56·6	2·0	0·4	8·0	1·7	14·0	2·9
21	3 05·3	3 05·8	2 56·8	2·1	0·4	8·1	1·7	14·1	2·9
22	3 05·5	3 06·0	2 57·0	2·2	0·5	8·2	1·7	14·2	3·0
23	3 05·8	3 06·3	2 57·3	2·3	0·5	8·3	1·7	14·3	3·0
24	3 06·0	3 06·5	2 57·5	2·4	0·5	8·4	1·8	14·4	3·0
25	3 06·3	3 06·8	2 57·8	2·5	0·5	8·5	1·8	14·5	3·0
26	3 06·5	3 07·0	2 58·0	2·6	0·5	8·6	1·8	14·6	3·0
27	3 06·8	3 07·3	2 58·2	2·7	0·6	8·7	1·8	14·7	3·1
28	3 07·0	3 07·5	2 58·5	2·8	0·6	8·8	1·8	14·8	3·1
29	3 07·3	3 07·8	2 58·7	2·9	0·6	8·9	1·9	14·9	3·1
30	3 07·5	3 08·0	2 59·0	3·0	0·6	9·0	1·9	15·0	3·1
31	3 07·8	3 08·3	2 59·2	3·1	0·6	9·1	1·9	15·1	3·1
32	3 08·0	3 08·5	2 59·4	3·2	0·7	9·2	1·9	15·2	3·2
33	3 08·3	3 08·8	2 59·7	3·3	0·7	9·3	1·9	15·3	3·2
34	3 08·5	3 09·0	2 59·9	3·4	0·7	9·4	2·0	15·4	3·2
35	3 08·8	3 09·3	3 00·2	3·5	0·7	9·5	2·0	15·5	3·2
36	3 09·0	3 09·5	3 00·4	3·6	0·8	9·6	2·0	15·6	3·3
37	3 09·3	3 09·8	3 00·6	3·7	0·8	9·7	2·0	15·7	3·3
38	3 09·5	3 10·0	3 00·9	3·8	0·8	9·8	2·0	15·8	3·3
39	3 09·8	3 10·3	3 01·1	3·9	0·8	9·9	2·1	15·9	3·3
40	3 10·0	3 10·5	3 01·3	4·0	0·8	10·0	2·1	16·0	3·3
41	3 10·3	3 10·8	3 01·6	4·1	0·9	10·1	2·1	16·1	3·4
42	3 10·5	3 11·0	3 01·8	4·2	0·9	10·2	2·1	16·2	3·4
43	3 10·8	3 11·3	3 02·1	4·3	0·9	10·3	2·1	16·3	3·4
44	3 11·0	3 11·5	3 02·3	4·4	0·9	10·4	2·2	16·4	3·4
45	3 11·3	3 11·8	3 02·5	4·5	0·9	10·5	2·2	16·5	3·4
46	3 11·5	3 12·0	3 02·8	4·6	1·0	10·6	2·2	16·6	3·5
47	3 11·8	3 12·3	3 03·0	4·7	1·0	10·7	2·2	16·7	3·5
48	3 12·0	3 12·5	3 03·3	4·8	1·0	10·8	2·3	16·8	3·5
49	3 12·3	3 12·8	3 03·5	4·9	1·0	10·9	2·3	16·9	3·5
50	3 12·5	3 13·0	3 03·7	5·0	1·0	11·0	2·3	17·0	3·5
51	3 12·8	3 13·3	3 04·0	5·1	1·1	11·1	2·3	17·1	3·6
52	3 13·0	3 13·5	3 04·2	5·2	1·1	11·2	2·3	17·2	3·6
53	3 13·3	3 13·8	3 04·4	5·3	1·1	11·3	2·4	17·3	3·6
54	3 13·5	3 14·0	3 04·7	5·4	1·1	11·4	2·4	17·4	3·6
55	3 13·8	3 14·3	3 04·9	5·5	1·1	11·5	2·4	17·5	3·6
56	3 14·0	3 14·5	3 05·2	5·6	1·2	11·6	2·4	17·6	3·7
57	3 14·3	3 14·8	3 05·4	5·7	1·2	11·7	2·4	17·7	3·7
58	3 14·5	3 15·0	3 05·6	5·8	1·2	11·8	2·5	17·8	3·7
59	3 14·8	3 15·3	3 05·9	5·9	1·2	11·9	2·5	17·9	3·7
60	3 15·0	3 15·5	3 06·1	6·0	1·3	12·0	2·5	18·0	3·8

13	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	3 15·0	3 15·5	3 06·1	0·0	0·0	6·0	1·4	12·0	2·7
01	3 15·3	3 15·8	3 06·4	0·1	0·0	6·1	1·4	12·1	2·7
02	3 15·5	3 16·0	3 06·6	0·2	0·0	6·2	1·4	12·2	2·7
03	3 15·8	3 16·3	3 06·8	0·3	0·1	6·3	1·4	12·3	2·8
04	3 16·0	3 16·5	3 07·1	0·4	0·1	6·4	1·4	12·4	2·8
05	3 16·3	3 16·8	3 07·3	0·5	0·1	6·5	1·5	12·5	2·8
06	3 16·5	3 17·0	3 07·5	0·6	0·1	6·6	1·5	12·6	2·8
07	3 16·8	3 17·3	3 07·8	0·7	0·2	6·7	1·5	12·7	2·9
08	3 17·0	3 17·5	3 08·0	0·8	0·2	6·8	1·5	12·8	2·9
09	3 17·3	3 17·8	3 08·3	0·9	0·2	6·9	1·6	12·9	2·9
10	3 17·5	3 18·0	3 08·5	1·0	0·2	7·0	1·6	13·0	2·9
11	3 17·8	3 18·3	3 08·7	1·1	0·2	7·1	1·6	13·1	2·9
12	3 18·0	3 18·5	3 09·0	1·2	0·3	7·2	1·6	13·2	3·0
13	3 18·3	3 18·8	3 09·2	1·3	0·3	7·3	1·6	13·3	3·0
14	3 18·5	3 19·0	3 09·5	1·4	0·3	7·4	1·7	13·4	3·0
15	3 18·8	3 19·3	3 09·7	1·5	0·3	7·5	1·7	13·5	3·0
16	3 19·0	3 19·5	3 09·9	1·6	0·4	7·6	1·7	13·6	3·1
17	3 19·3	3 19·8	3 10·2	1·7	0·4	7·7	1·7	13·7	3·1
18	3 19·5	3 20·0	3 10·4	1·8	0·4	7·8	1·8	13·8	3·1
19	3 19·8	3 20·3	3 10·7	1·9	0·4	7·9	1·8	13·9	3·1
20	3 20·0	3 20·5	3 10·9	2·0	0·5	8·0	1·8	14·0	3·2
21	3 20·3	3 20·8	3 11·1	2·1	0·5	8·1	1·8	14·1	3·2
22	3 20·5	3 21·0	3 11·4	2·2	0·5	8·2	1·8	14·2	3·2
23	3 20·8	3 21·3	3 11·6	2·3	0·5	8·3	1·9	14·3	3·2
24	3 21·0	3 21·6	3 11·8	2·4	0·5	8·4	1·9	14·4	3·2
25	3 21·3	3 21·8	3 12·1	2·5	0·6	8·5	1·9	14·5	3·3
26	3 21·5	3 22·1	3 12·3	2·6	0·6	8·6	1·9	14·6	3·3
27	3 21·8	3 22·3	3 12·6	2·7	0·6	8·7	2·0	14·7	3·3
28	3 22·0	3 22·6	3 12·8	2·8	0·6	8·8	2·0	14·8	3·3
29	3 22·3	3 22·8	3 13·0	2·9	0·7	8·9	2·0	14·9	3·4
30	3 22·5	3 23·1	3 13·3	3·0	0·7	9·0	2·0	15·0	3·4
31	3 22·8	3 23·3	3 13·5	3·1	0·7	9·1	2·0	15·1	3·4
32	3 23·0	3 23·6	3 13·8	3·2	0·7	9·2	2·1	15·2	3·4
33	3 23·3	3 23·8	3 14·0	3·3	0·7	9·3	2·1	15·3	3·4
34	3 23·5	3 24·1	3 14·2	3·4	0·8	9·4	2·1	15·4	3·5
35	3 23·8	3 24·3	3 14·5	3·5	0·8	9·5	2·1	15·5	3·5
36	3 24·0	3 24·6	3 14·7	3·6	0·8	9·6	2·2	15·6	3·5
37	3 24·3	3 24·8	3 14·9	3·7	0·8	9·7	2·2	15·7	3·5
38	3 24·5	3 25·1	3 15·2	3·8	0·9	9·8	2·2	15·8	3·6
39	3 24·8	3 25·3	3 15·4	3·9	0·9	9·9	2·2	15·9	3·6
40	3 25·0	3 25·6	3 15·7	4·0	0·9	10·0	2·3	16·0	3·6
41	3 25·3	3 25·8	3 15·9	4·1	0·9	10·1	2·3	16·1	3·6
42	3 25·5	3 26·1	3 16·1	4·2	0·9	10·2	2·3	16·2	3·6
43	3 25·8	3 26·3	3 16·4	4·3	1·0	10·3	2·3	16·3	3·7
44	3 26·0	3 26·6	3 16·6	4·4	1·0	10·4	2·3	16·4	3·7
45	3 26·3	3 26·8	3 16·9	4·5	1·0	10·5	2·4	16·5	3·7
46	3 26·5	3 27·1	3 17·1	4·6	1·0	10·6	2·4	16·6	3·7
47	3 26·8	3 27·3	3 17·3	4·7	1·1	10·7	2·4	16·7	3·8
48	3 27·0	3 27·6	3 17·6	4·8	1·1	10·8	2·4	16·8	3·8
49	3 27·3	3 27·8	3 17·8	4·9	1·1	10·9	2·5	16·9	3·8
50	3 27·5	3 28·1	3 18·0	5·0	1·1	11·0	2·5	17·0	3·8
51	3 27·8	3 28·3	3 18·3	5·1	1·1	11·1	2·5	17·1	3·8
52	3 28·0	3 28·6	3 18·5	5·2	1·2	11·2	2·5	17·2	3·9
53	3 28·3	3 28·8	3 18·8	5·3	1·2	11·3	2·5	17·3	3·9
54	3 28·5	3 29·1	3 19·0	5·4	1·2	11·4	2·6	17·4	3·9
55	3 28·8	3 29·3	3 19·2	5·5	1·2	11·5	2·6	17·5	3·9
56	3 29·0	3 29·6	3 19·5	5·6	1·3	11·6	2·6	17·6	4·0
57	3 29·3	3 29·8	3 19·7	5·7	1·3	11·7	2·6	17·7	4·0
58	3 29·5	3 30·1	3 20·0	5·8	1·3	11·8	2·7	17·8	4·0
59	3 29·8	3 30·3	3 20·2	5·9	1·3	11·9	2·7	17·9	4·0
60	3 30·0	3 30·6	3 20·4	6·0	1·4	12·0	2·7	18·0	4·1

14m INCREMENTS AND CORRECTIONS 15m

14m s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corr″ ′	v or d ′	Corr″ ′	v or d ′	Corr″ ′
00	3 30·0	3 30·6	3 20·4	0·0	0·0	6·0	1·5	12·0	2·9
01	3 30·3	3 30·8	3 20·7	0·1	0·0	6·1	1·5	12·1	2·9
02	3 30·5	3 31·1	3 20·9	0·2	0·0	6·2	1·5	12·2	2·9
03	3 30·8	3 31·3	3 21·1	0·3	0·1	6·3	1·5	12·3	3·0
04	3 31·0	3 31·6	3 21·4	0·4	0·1	6·4	1·5	12·4	3·0
05	3 31·3	3 31·8	3 21·6	0·5	0·1	6·5	1·6	12·5	3·0
06	3 31·5	3 32·1	3 21·9	0·6	0·1	6·6	1·6	12·6	3·0
07	3 31·8	3 32·3	3 22·1	0·7	0·2	6·7	1·6	12·7	3·1
08	3 32·0	3 32·6	3 22·3	0·8	0·2	6·8	1·6	12·8	3·1
09	3 32·3	3 32·8	3 22·6	0·9	0·2	6·9	1·7	12·9	3·1
10	3 32·5	3 33·1	3 22·8	1·0	0·2	7·0	1·7	13·0	3·1
11	3 32·8	3 33·3	3 23·1	1·1	0·3	7·1	1·7	13·1	3·2
12	3 33·0	3 33·6	3 23·3	1·2	0·3	7·2	1·7	13·2	3·2
13	3 33·3	3 33·8	3 23·5	1·3	0·3	7·3	1·8	13·3	3·2
14	3 33·5	3 34·1	3 23·8	1·4	0·3	7·4	1·8	13·4	3·2
15	3 33·8	3 34·3	3 24·0	1·5	0·4	7·5	1·8	13·5	3·3
16	3 34·0	3 34·6	3 24·3	1·6	0·4	7·6	1·8	13·6	3·3
17	3 34·3	3 34·8	3 24·5	1·7	0·4	7·7	1·9	13·7	3·3
18	3 34·5	3 35·1	3 24·7	1·8	0·4	7·8	1·9	13·8	3·3
19	3 34·8	3 35·3	3 25·0	1·9	0·5	7·9	1·9	13·9	3·4
20	3 35·0	3 35·6	3 25·2	2·0	0·5	8·0	1·9	14·0	3·4
21	3 35·3	3 35·8	3 25·4	2·1	0·5	8·1	2·0	14·1	3·4
22	3 35·5	3 36·1	3 25·7	2·2	0·5	8·2	2·0	14·2	3·4
23	3 35·8	3 36·3	3 25·9	2·3	0·6	8·3	2·0	14·3	3·5
24	3 36·0	3 36·6	3 26·2	2·4	0·6	8·4	2·0	14·4	3·5
25	3 36·3	3 36·8	3 26·4	2·5	0·6	8·5	2·1	14·5	3·5
26	3 36·5	3 37·1	3 26·6	2·6	0·6	8·6	2·1	14·6	3·5
27	3 36·8	3 37·3	3 26·9	2·7	0·7	8·7	2·1	14·7	3·6
28	3 37·0	3 37·6	3 27·1	2·8	0·7	8·8	2·1	14·8	3·6
29	3 37·3	3 37·8	3 27·4	2·9	0·7	8·9	2·2	14·9	3·6
30	3 37·5	3 38·1	3 27·6	3·0	0·7	9·0	2·2	15·0	3·6
31	3 37·8	3 38·3	3 27·8	3·1	0·7	9·1	2·2	15·1	3·6
32	3 38·0	3 38·6	3 28·1	3·2	0·8	9·2	2·2	15·2	3·7
33	3 38·3	3 38·8	3 28·3	3·3	0·8	9·3	2·2	15·3	3·7
34	3 38·5	3 39·1	3 28·5	3·4	0·8	9·4	2·3	15·4	3·7
35	3 38·8	3 39·3	3 28·8	3·5	0·8	9·5	2·3	15·5	3·7
36	3 39·0	3 39·6	3 29·0	3·6	0·9	9·6	2·3	15·6	3·8
37	3 39·3	3 39·9	3 29·3	3·7	0·9	9·7	2·3	15·7	3·8
38	3 39·5	3 40·1	3 29·5	3·8	0·9	9·8	2·4	15·8	3·8
39	3 39·8	3 40·4	3 29·7	3·9	0·9	9·9	2·4	15·9	3·8
40	3 40·0	3 40·6	3 30·0	4·0	1·0	10·0	2·4	16·0	3·9
41	3 40·3	3 40·9	3 30·2	4·1	1·0	10·1	2·4	16·1	3·9
42	3 40·5	3 41·1	3 30·5	4·2	1·0	10·2	2·5	16·2	3·9
43	3 40·8	3 41·4	3 30·7	4·3	1·0	10·3	2·5	16·3	3·9
44	3 41·0	3 41·6	3 30·9	4·4	1·1	10·4	2·5	16·4	4·0
45	3 41·3	3 41·9	3 31·2	4·5	1·1	10·5	2·5	16·5	4·0
46	3 41·5	3 42·1	3 31·4	4·6	1·1	10·6	2·6	16·6	4·0
47	3 41·8	3 42·4	3 31·6	4·7	1·1	10·7	2·6	16·7	4·0
48	3 42·0	3 42·6	3 31·9	4·8	1·2	10·8	2·6	16·8	4·1
49	3 42·3	3 42·9	3 32·1	4·9	1·2	10·9	2·6	16·9	4·1
50	3 42·5	3 43·1	3 32·4	5·0	1·2	11·0	2·7	17·0	4·1
51	3 42·8	3 43·4	3 32·6	5·1	1·2	11·1	2·7	17·1	4·1
52	3 43·0	3 43·6	3 32·8	5·2	1·3	11·2	2·7	17·2	4·2
53	3 43·3	3 43·9	3 33·1	5·3	1·3	11·3	2·7	17·3	4·2
54	3 43·5	3 44·1	3 33·3	5·4	1·3	11·4	2·8	17·4	4·2
55	3 43·8	3 44·4	3 33·6	5·5	1·3	11·5	2·8	17·5	4·2
56	3 44·0	3 44·6	3 33·8	5·6	1·4	11·6	2·8	17·6	4·3
57	3 44·3	3 44·9	3 34·0	5·7	1·4	11·7	2·8	17·7	4·3
58	3 44·5	3 45·1	3 34·3	5·8	1·4	11·8	2·9	17·8	4·3
59	3 44·8	3 45·4	3 34·5	5·9	1·4	11·9	2·9	17·9	4·3
60	3 45·0	3 45·6	3 34·8	6·0	1·5	12·0	2·9	18·0	4·4

15m s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corr″ ′	v or d ′	Corr″ ′	v or d ′	Corr″ ′
00	3 45·0	3 45·6	3 34·8	0·0	0·0	6·0	1·6	12·0	3·1
01	3 45·3	3 45·9	3 35·0	0·1	0·0	6·1	1·6	12·1	3·1
02	3 45·5	3 46·1	3 35·2	0·2	0·1	6·2	1·6	12·2	3·2
03	3 45·8	3 46·4	3 35·5	0·3	0·1	6·3	1·6	12·3	3·2
04	3 46·0	3 46·6	3 35·7	0·4	0·1	6·4	1·7	12·4	3·2
05	3 46·3	3 46·9	3 35·9	0·5	0·1	6·5	1·7	12·5	3·2
06	3 46·5	3 47·1	3 36·2	0·6	0·2	6·6	1·7	12·6	3·3
07	3 46·8	3 47·4	3 36·4	0·7	0·2	6·7	1·7	12·7	3·3
08	3 47·0	3 47·6	3 36·7	0·8	0·2	6·8	1·8	12·8	3·3
09	3 47·3	3 47·9	3 36·9	0·9	0·2	6·9	1·8	12·9	3·3
10	3 47·5	3 48·1	3 37·1	1·0	0·3	7·0	1·8	13·0	3·4
11	3 47·8	3 48·4	3 37·4	1·1	0·3	7·1	1·8	13·1	3·4
12	3 48·0	3 48·6	3 37·6	1·2	0·3	7·2	1·9	13·2	3·4
13	3 48·3	3 48·9	3 37·9	1·3	0·3	7·3	1·9	13·3	3·4
14	3 48·5	3 49·1	3 38·1	1·4	0·4	7·4	1·9	13·4	3·5
15	3 48·8	3 49·4	3 38·3	1·5	0·4	7·5	1·9	13·5	3·5
16	3 49·0	3 49·6	3 38·6	1·6	0·4	7·6	2·0	13·6	3·5
17	3 49·3	3 49·9	3 38·8	1·7	0·4	7·7	2·0	13·7	3·5
18	3 49·5	3 50·1	3 39·0	1·8	0·5	7·8	2·0	13·8	3·6
19	3 49·8	3 50·4	3 39·3	1·9	0·5	7·9	2·0	13·9	3·6
20	3 50·0	3 50·6	3 39·5	2·0	0·5	8·0	2·1	14·0	3·6
21	3 50·3	3 50·9	3 39·8	2·1	0·5	8·1	2·1	14·1	3·6
22	3 50·5	3 51·1	3 40·0	2·2	0·6	8·2	2·1	14·2	3·7
23	3 50·8	3 51·4	3 40·2	2·3	0·6	8·3	2·1	14·3	3·7
24	3 51·0	3 51·6	3 40·5	2·4	0·6	8·4	2·2	14·4	3·7
25	3 51·3	3 51·9	3 40·7	2·5	0·6	8·5	2·2	14·5	3·7
26	3 51·5	3 52·1	3 41·0	2·6	0·7	8·6	2·2	14·6	3·8
27	3 51·8	3 52·4	3 41·2	2·7	0·7	8·7	2·2	14·7	3·8
28	3 52·0	3 52·6	3 41·4	2·8	0·7	8·8	2·3	14·8	3·8
29	3 52·3	3 52·9	3 41·7	2·9	0·7	8·9	2·3	14·9	3·8
30	3 52·5	3 53·1	3 41·9	3·0	0·8	9·0	2·3	15·0	3·9
31	3 52·8	3 53·4	3 42·1	3·1	0·8	9·1	2·4	15·1	3·9
32	3 53·0	3 53·6	3 42·4	3·2	0·8	9·2	2·4	15·2	3·9
33	3 53·3	3 53·9	3 42·6	3·3	0·9	9·3	2·4	15·3	4·0
34	3 53·5	3 54·1	3 42·9	3·4	0·9	9·4	2·4	15·4	4·0
35	3 53·8	3 54·4	3 43·1	3·5	0·9	9·5	2·5	15·5	4·0
36	3 54·0	3 54·6	3 43·3	3·6	0·9	9·6	2·5	15·6	4·0
37	3 54·3	3 54·9	3 43·6	3·7	1·0	9·7	2·5	15·7	4·1
38	3 54·5	3 55·1	3 43·8	3·8	1·0	9·8	2·5	15·8	4·1
39	3 54·8	3 55·4	3 44·1	3·9	1·0	9·9	2·6	15·9	4·1
40	3 55·0	3 55·6	3 44·3	4·0	1·0	10·0	2·6	16·0	4·1
41	3 55·3	3 55·9	3 44·5	4·1	1·1	10·1	2·6	16·1	4·2
42	3 55·5	3 56·1	3 44·8	4·2	1·1	10·2	2·6	16·2	4·2
43	3 55·8	3 56·4	3 45·0	4·3	1·1	10·3	2·7	16·3	4·2
44	3 56·0	3 56·6	3 45·2	4·4	1·1	10·4	2·7	16·4	4·2
45	3 56·3	3 56·9	3 45·5	4·5	1·2	10·5	2·7	16·5	4·3
46	3 56·5	3 57·1	3 45·7	4·6	1·2	10·6	2·7	16·6	4·3
47	3 56·8	3 57·4	3 46·0	4·7	1·2	10·7	2·8	16·7	4·3
48	3 57·0	3 57·6	3 46·2	4·8	1·2	10·8	2·8	16·8	4·3
49	3 57·3	3 57·9	3 46·4	4·9	1·3	10·9	2·8	16·9	4·4
50	3 57·5	3 58·2	3 46·7	5·0	1·3	11·0	2·8	17·0	4·4
51	3 57·8	3 58·4	3 46·9	5·1	1·3	11·1	2·9	17·1	4·4
52	3 58·0	3 58·7	3 47·2	5·2	1·3	11·2	2·9	17·2	4·4
53	3 58·3	3 58·9	3 47·4	5·3	1·4	11·3	2·9	17·3	4·5
54	3 58·5	3 59·2	3 47·6	5·4	1·4	11·4	2·9	17·4	4·5
55	3 58·8	3 59·4	3 47·9	5·5	1·4	11·5	3·0	17·5	4·5
56	3 59·0	3 59·7	3 48·1	5·6	1·4	11·6	3·0	17·6	4·5
57	3 59·3	3 59·9	3 48·4	5·7	1·5	11·7	3·0	17·7	4·6
58	3 59·5	4 00·2	3 48·6	5·8	1·5	11·8	3·0	17·8	4·6
59	3 59·8	4 00·4	3 48·8	5·9	1·5	11·9	3·1	17·9	4·6
60	4 00·0	4 00·7	3 49·1	6·0	1·6	12·0	3·1	18·0	4·7

16m INCREMENTS AND CORRECTIONS 17m

16m s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or Corr^n d ′	′	v or Corr^n d ′	′	v or Corr^n d ′	′
00	4 00·0	4 00·7	3 49·1	0·0	0·0	6·0	1·7	12·0	3·3
01	4 00·3	4 00·9	3 49·3	0·1	0·0	6·1	1·7	12·1	3·3
02	4 00·5	4 01·2	3 49·5	0·2	0·1	6·2	1·7	12·2	3·4
03	4 00·8	4 01·4	3 49·8	0·3	0·1	6·3	1·7	12·3	3·4
04	4 01·0	4 01·7	3 50·0	0·4	0·1	6·4	1·8	12·4	3·4
05	4 01·3	4 01·9	3 50·3	0·5	0·1	6·5	1·8	12·5	3·4
06	4 01·5	4 02·2	3 50·5	0·6	0·2	6·6	1·8	12·6	3·5
07	4 01·8	4 02·4	3 50·7	0·7	0·2	6·7	1·8	12·7	3·5
08	4 02·0	4 02·7	3 51·0	0·8	0·2	6·8	1·9	12·8	3·5
09	4 02·3	4 02·9	3 51·2	0·9	0·2	6·9	1·9	12·9	3·5
10	4 02·5	4 03·2	3 51·5	1·0	0·3	7·0	1·9	13·0	3·6
11	4 02·8	4 03·4	3 51·7	1·1	0·3	7·1	2·0	13·1	3·6
12	4 03·0	4 03·7	3 51·9	1·2	0·3	7·2	2·0	13·2	3·6
13	4 03·3	4 03·9	3 52·2	1·3	0·4	7·3	2·0	13·3	3·7
14	4 03·5	4 04·2	3 52·4	1·4	0·4	7·4	2·0	13·4	3·7
15	4 03·8	4 04·4	3 52·6	1·5	0·4	7·5	2·1	13·5	3·7
16	4 04·0	4 04·7	3 52·9	1·6	0·4	7·6	2·1	13·6	3·7
17	4 04·3	4 04·9	3 53·1	1·7	0·5	7·7	2·1	13·7	3·8
18	4 04·5	4 05·2	3 53·4	1·8	0·5	7·8	2·1	13·8	3·8
19	4 04·8	4 05·4	3 53·6	1·9	0·5	7·9	2·2	13·9	3·8
20	4 05·0	4 05·7	3 53·8	2·0	0·6	8·0	2·2	14·0	3·9
21	4 05·3	4 05·9	3 54·1	2·1	0·6	8·1	2·2	14·1	3·9
22	4 05·5	4 06·2	3 54·3	2·2	0·6	8·2	2·3	14·2	3·9
23	4 05·8	4 06·4	3 54·6	2·3	0·6	8·3	2·3	14·3	3·9
24	4 06·0	4 06·7	3 54·8	2·4	0·7	8·4	2·3	14·4	4·0
25	4 06·3	4 06·9	3 55·0	2·5	0·7	8·5	2·3	14·5	4·0
26	4 06·5	4 07·2	3 55·3	2·6	0·7	8·6	2·4	14·6	4·0
27	4 06·8	4 07·4	3 55·5	2·7	0·7	8·7	2·4	14·7	4·0
28	4 07·0	4 07·7	3 55·7	2·8	0·8	8·8	2·4	14·8	4·1
29	4 07·3	4 07·9	3 56·0	2·9	0·8	8·9	2·4	14·9	4·1
30	4 07·5	4 08·2	3 56·2	3·0	0·8	9·0	2·5	15·0	4·1
31	4 07·8	4 08·4	3 56·5	3·1	0·9	9·1	2·5	15·1	4·2
32	4 08·0	4 08·7	3 56·7	3·2	0·9	9·2	2·5	15·2	4·2
33	4 08·3	4 08·9	3 56·9	3·3	0·9	9·3	2·6	15·3	4·2
34	4 08·5	4 09·2	3 57·2	3·4	0·9	9·4	2·6	15·4	4·2
35	4 08·8	4 09·4	3 57·4	3·5	1·0	9·5	2·6	15·5	4·3
36	4 09·0	4 09·7	3 57·7	3·6	1·0	9·6	2·6	15·6	4·3
37	4 09·3	4 09·9	3 57·9	3·7	1·0	9·7	2·7	15·7	4·3
38	4 09·5	4 10·2	3 58·1	3·8	1·0	9·8	2·7	15·8	4·3
39	4 09·8	4 10·4	3 58·4	3·9	1·1	9·9	2·7	15·9	4·4
40	4 10·0	4 10·7	3 58·6	4·0	1·1	10·0	2·8	16·0	4·4
41	4 10·3	4 10·9	3 58·8	4·1	1·1	10·1	2·8	16·1	4·4
42	4 10·5	4 11·2	3 59·1	4·2	1·2	10·2	2·8	16·2	4·5
43	4 10·8	4 11·4	3 59·3	4·3	1·2	10·3	2·8	16·3	4·5
44	4 11·0	4 11·7	3 59·6	4·4	1·2	10·4	2·9	16·4	4·5
45	4 11·3	4 11·9	3 59·8	4·5	1·2	10·5	2·9	16·5	4·5
46	4 11·5	4 12·2	4 00·0	4·6	1·3	10·6	2·9	16·6	4·6
47	4 11·8	4 12·4	4 00·3	4·7	1·3	10·7	2·9	16·7	4·6
48	4 12·0	4 12·7	4 00·5	4·8	1·3	10·8	3·0	16·8	4·6
49	4 12·3	4 12·9	4 00·8	4·9	1·3	10·9	3·0	16·9	4·6
50	4 12·5	4 13·2	4 01·0	5·0	1·4	11·0	3·0	17·0	4·7
51	4 12·8	4 13·4	4 01·2	5·1	1·4	11·1	3·1	17·1	4·7
52	4 13·0	4 13·7	4 01·5	5·2	1·4	11·2	3·1	17·2	4·7
53	4 13·3	4 13·9	4 01·7	5·3	1·5	11·3	3·1	17·3	4·8
54	4 13·5	4 14·2	4 02·0	5·4	1·5	11·4	3·1	17·4	4·8
55	4 13·8	4 14·4	4 02·2	5·5	1·5	11·5	3·2	17·5	4·8
56	4 14·0	4 14·7	4 02·4	5·6	1·5	11·6	3·2	17·6	4·8
57	4 14·3	4 14·9	4 02·7	5·7	1·6	11·7	3·2	17·7	4·9
58	4 14·5	4 15·2	4 02·9	5·8	1·6	11·8	3·2	17·8	4·9
59	4 14·8	4 15·4	4 03·1	5·9	1·6	11·9	3·3	17·9	4·9
60	4 15·0	4 15·7	4 03·4	6·0	1·7	12·0	3·3	18·0	5·0

17m s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or Corr^n d ′	′	v or Corr^n d ′	′	v or Corr^n d ′	′
00	4 15·0	4 15·7	4 03·4	0·0	0·0	6·0	1·8	12·0	3·5
01	4 15·3	4 15·9	4 03·6	0·1	0·0	6·1	1·8	12·1	3·5
02	4 15·5	4 16·2	4 03·9	0·2	0·1	6·2	1·8	12·2	3·6
03	4 15·8	4 16·5	4 04·1	0·3	0·1	6·3	1·8	12·3	3·6
04	4 16·0	4 16·7	4 04·3	0·4	0·1	6·4	1·9	12·4	3·6
05	4 16·3	4 17·0	4 04·6	0·5	0·1	6·5	1·9	12·5	3·6
06	4 16·5	4 17·2	4 04·8	0·6	0·2	6·6	1·9	12·6	3·7
07	4 16·8	4 17·5	4 05·1	0·7	0·2	6·7	2·0	12·7	3·7
08	4 17·0	4 17·7	4 05·3	0·8	0·2	6·8	2·0	12·8	3·7
09	4 17·3	4 18·0	4 05·5	0·9	0·3	6·9	2·0	12·9	3·8
10	4 17·5	4 18·2	4 05·8	1·0	0·3	7·0	2·0	13·0	3·8
11	4 17·8	4 18·5	4 06·0	1·1	0·3	7·1	2·1	13·1	3·8
12	4 18·0	4 18·7	4 06·2	1·2	0·4	7·2	2·1	13·2	3·9
13	4 18·3	4 19·0	4 06·5	1·3	0·4	7·3	2·1	13·3	3·9
14	4 18·5	4 19·2	4 06·7	1·4	0·4	7·4	2·2	13·4	3·9
15	4 18·8	4 19·5	4 07·0	1·5	0·4	7·5	2·2	13·5	3·9
16	4 19·0	4 19·7	4 07·2	1·6	0·5	7·6	2·2	13·6	4·0
17	4 19·3	4 20·0	4 07·4	1·7	0·5	7·7	2·2	13·7	4·0
18	4 19·5	4 20·2	4 07·7	1·8	0·5	7·8	2·3	13·8	4·0
19	4 19·8	4 20·5	4 07·9	1·9	0·6	7·9	2·3	13·9	4·1
20	4 20·0	4 20·7	4 08·2	2·0	0·6	8·0	2·3	14·0	4·1
21	4 20·3	4 21·0	4 08·4	2·1	0·6	8·1	2·4	14·1	4·1
22	4 20·5	4 21·2	4 08·6	2·2	0·6	8·2	2·4	14·2	4·1
23	4 20·8	4 21·5	4 08·9	2·3	0·7	8·3	2·4	14·3	4·2
24	4 21·0	4 21·7	4 09·1	2·4	0·7	8·4	2·5	14·4	4·2
25	4 21·3	4 22·0	4 09·3	2·5	0·7	8·5	2·5	14·5	4·2
26	4 21·5	4 22·2	4 09·6	2·6	0·8	8·6	2·5	14·6	4·3
27	4 21·8	4 22·5	4 09·8	2·7	0·8	8·7	2·5	14·7	4·3
28	4 22·0	4 22·7	4 10·1	2·8	0·8	8·8	2·6	14·8	4·3
29	4 22·3	4 23·0	4 10·3	2·9	0·8	8·9	2·6	14·9	4·3
30	4 22·5	4 23·2	4 10·5	3·0	0·9	9·0	2·6	15·0	4·4
31	4 22·8	4 23·5	4 10·8	3·1	0·9	9·1	2·7	15·1	4·4
32	4 23·0	4 23·7	4 11·0	3·2	0·9	9·2	2·7	15·2	4·4
33	4 23·3	4 24·0	4 11·3	3·3	1·0	9·3	2·7	15·3	4·5
34	4 23·5	4 24·2	4 11·5	3·4	1·0	9·4	2·7	15·4	4·5
35	4 23·8	4 24·5	4 11·7	3·5	1·0	9·5	2·8	15·5	4·5
36	4 24·0	4 24·7	4 12·0	3·6	1·1	9·6	2·8	15·6	4·6
37	4 24·3	4 25·0	4 12·2	3·7	1·1	9·7	2·8	15·7	4·6
38	4 24·5	4 25·2	4 12·5	3·8	1·1	9·8	2·9	15·8	4·6
39	4 24·8	4 25·5	4 12·7	3·9	1·1	9·9	2·9	15·9	4·6
40	4 25·0	4 25·7	4 12·9	4·0	1·2	10·0	2·9	16·0	4·7
41	4 25·3	4 26·0	4 13·2	4·1	1·2	10·1	2·9	16·1	4·7
42	4 25·5	4 26·2	4 13·4	4·2	1·2	10·2	3·0	16·2	4·7
43	4 25·8	4 26·5	4 13·6	4·3	1·3	10·3	3·0	16·3	4·8
44	4 26·0	4 26·7	4 13·9	4·4	1·3	10·4	3·0	16·4	4·8
45	4 26·3	4 27·0	4 14·1	4·5	1·3	10·5	3·1	16·5	4·8
46	4 26·5	4 27·2	4 14·4	4·6	1·3	10·6	3·1	16·6	4·8
47	4 26·8	4 27·5	4 14·6	4·7	1·4	10·7	3·1	16·7	4·9
48	4 27·0	4 27·7	4 14·8	4·8	1·4	10·8	3·2	16·8	4·9
49	4 27·3	4 28·0	4 15·1	4·9	1·4	10·9	3·2	16·9	4·9
50	4 27·5	4 28·2	4 15·3	5·0	1·5	11·0	3·2	17·0	5·0
51	4 27·8	4 28·5	4 15·6	5·1	1·5	11·1	3·2	17·1	5·0
52	4 28·0	4 28·7	4 15·8	5·2	1·5	11·2	3·3	17·2	5·0
53	4 28·3	4 29·0	4 16·0	5·3	1·5	11·3	3·3	17·3	5·0
54	4 28·5	4 29·2	4 16·3	5·4	1·6	11·4	3·3	17·4	5·1
55	4 28·8	4 29·5	4 16·5	5·5	1·6	11·5	3·4	17·5	5·1
56	4 29·0	4 29·7	4 16·7	5·6	1·6	11·6	3·4	17·6	5·1
57	4 29·3	4 30·0	4 17·0	5·7	1·7	11·7	3·4	17·7	5·2
58	4 29·5	4 30·2	4 17·2	5·8	1·7	11·8	3·4	17·8	5·2
59	4 29·8	4 30·5	4 17·5	5·9	1·7	11·9	3·5	17·9	5·2
60	4 30·0	4 30·7	4 17·7	6·0	1·8	12·0	3·5	18·0	5·3

18m INCREMENTS AND CORRECTIONS 19m

m 18	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	4 30·0	4 30·7	4 17·7	0·0	0·0	6·0	1·9	12·0	3·7
01	4 30·3	4 31·0	4 17·9	0·1	0·0	6·1	1·9	12·1	3·7
02	4 30·5	4 31·2	4 18·2	0·2	0·1	6·2	1·9	12·2	3·8
03	4 30·8	4 31·5	4 18·4	0·3	0·1	6·3	1·9	12·3	3·8
04	4 31·0	4 31·7	4 18·7	0·4	0·1	6·4	2·0	12·4	3·8
05	4 31·3	4 32·0	4 18·9	0·5	0·2	6·5	2·0	12·5	3·9
06	4 31·5	4 32·2	4 19·1	0·6	0·2	6·6	2·0	12·6	3·9
07	4 31·8	4 32·5	4 19·4	0·7	0·2	6·7	2·1	12·7	3·9
08	4 32·0	4 32·7	4 19·6	0·8	0·2	6·8	2·1	12·8	3·9
09	4 32·3	4 33·0	4 19·8	0·9	0·3	6·9	2·1	12·9	4·0
10	4 32·5	4 33·2	4 20·1	1·0	0·3	7·0	2·2	13·0	4·0
11	4 32·8	4 33·5	4 20·3	1·1	0·3	7·1	2·2	13·1	4·0
12	4 33·0	4 33·7	4 20·6	1·2	0·4	7·2	2·2	13·2	4·1
13	4 33·3	4 34·0	4 20·8	1·3	0·4	7·3	2·3	13·3	4·1
14	4 33·5	4 34·2	4 21·0	1·4	0·4	7·4	2·3	13·4	4·1
15	4 33·8	4 34·5	4 21·3	1·5	0·5	7·5	2·3	13·5	4·2
16	4 34·0	4 34·8	4 21·5	1·6	0·5	7·6	2·3	13·6	4·2
17	4 34·3	4 35·0	4 21·8	1·7	0·5	7·7	2·4	13·7	4·2
18	4 34·5	4 35·3	4 22·0	1·8	0·6	7·8	2·4	13·8	4·3
19	4 34·8	4 35·5	4 22·2	1·9	0·6	7·9	2·4	13·9	4·3
20	4 35·0	4 35·8	4 22·5	2·0	0·6	8·0	2·5	14·0	4·3
21	4 35·3	4 36·0	4 22·7	2·1	0·6	8·1	2·5	14·1	4·3
22	4 35·5	4 36·3	4 22·9	2·2	0·7	8·2	2·5	14·2	4·4
23	4 35·8	4 36·5	4 23·2	2·3	0·7	8·3	2·6	14·3	4·4
24	4 36·0	4 36·8	4 23·4	2·4	0·7	8·4	2·6	14·4	4·4
25	4 36·3	4 37·0	4 23·7	2·5	0·8	8·5	2·6	14·5	4·5
26	4 36·5	4 37·3	4 23·9	2·6	0·8	8·6	2·7	14·6	4·5
27	4 36·8	4 37·5	4 24·1	2·7	0·8	8·7	2·7	14·7	4·5
28	4 37·0	4 37·8	4 24·4	2·8	0·9	8·8	2·7	14·8	4·6
29	4 37·3	4 38·0	4 24·6	2·9	0·9	8·9	2·7	14·9	4·6
30	4 37·5	4 38·3	4 24·9	3·0	0·9	9·0	2·8	15·0	4·6
31	4 37·8	4 38·5	4 25·1	3·1	1·0	9·1	2·8	15·1	4·7
32	4 38·0	4 38·8	4 25·3	3·2	1·0	9·2	2·8	15·2	4·7
33	4 38·3	4 39·0	4 25·6	3·3	1·0	9·3	2·9	15·3	4·7
34	4 38·5	4 39·3	4 25·8	3·4	1·0	9·4	2·9	15·4	4·7
35	4 38·8	4 39·5	4 26·1	3·5	1·1	9·5	2·9	15·5	4·8
36	4 39·0	4 39·8	4 26·3	3·6	1·1	9·6	3·0	15·6	4·8
37	4 39·3	4 40·0	4 26·5	3·7	1·1	9·7	3·0	15·7	4·8
38	4 39·5	4 40·3	4 26·8	3·8	1·2	9·8	3·0	15·8	4·9
39	4 39·8	4 40·5	4 27·0	3·9	1·2	9·9	3·1	15·9	4·9
40	4 40·0	4 40·8	4 27·2	4·0	1·2	10·0	3·1	16·0	4·9
41	4 40·3	4 41·0	4 27·5	4·1	1·3	10·1	3·1	16·1	5·0
42	4 40·5	4 41·3	4 27·7	4·2	1·3	10·2	3·1	16·2	5·0
43	4 40·8	4 41·5	4 28·0	4·3	1·3	10·3	3·2	16·3	5·0
44	4 41·0	4 41·8	4 28·2	4·4	1·4	10·4	3·2	16·4	5·1
45	4 41·3	4 42·0	4 28·4	4·5	1·4	10·5	3·2	16·5	5·1
46	4 41·5	4 42·3	4 28·7	4·6	1·4	10·6	3·3	16·6	5·1
47	4 41·8	4 42·5	4 28·9	4·7	1·4	10·7	3·3	16·7	5·1
48	4 42·0	4 42·8	4 29·2	4·8	1·5	10·8	3·3	16·8	5·2
49	4 42·3	4 43·0	4 29·4	4·9	1·5	10·9	3·4	16·9	5·2
50	4 42·5	4 43·3	4 29·6	5·0	1·5	11·0	3·4	17·0	5·2
51	4 42·8	4 43·5	4 29·9	5·1	1·6	11·1	3·4	17·1	5·3
52	4 43·0	4 43·8	4 30·1	5·2	1·6	11·2	3·5	17·2	5·3
53	4 43·3	4 44·0	4 30·3	5·3	1·6	11·3	3·5	17·3	5·3
54	4 43·5	4 44·3	4 30·6	5·4	1·7	11·4	3·5	17·4	5·4
55	4 43·8	4 44·5	4 30·8	5·5	1·7	11·5	3·5	17·5	5·4
56	4 44·0	4 44·8	4 31·1	5·6	1·7	11·6	3·6	17·6	5·4
57	4 44·3	4 45·0	4 31·3	5·7	1·8	11·7	3·6	17·7	5·5
58	4 44·5	4 45·3	4 31·5	5·8	1·8	11·8	3·6	17·8	5·5
59	4 44·8	4 45·5	4 31·8	5·9	1·8	11·9	3·7	17·9	5·5
60	4 45·0	4 45·8	4 32·0	6·0	1·9	12·0	3·7	18·0	5·6

m 19	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	4 45·0	4 45·8	4 32·0	0·0	0·0	6·0	2·0	12·0	3·9
01	4 45·3	4 46·0	4 32·3	0·1	0·0	6·1	2·0	12·1	3·9
02	4 45·5	4 46·3	4 32·5	0·2	0·1	6·2	2·0	12·2	4·0
03	4 45·8	4 46·5	4 32·7	0·3	0·1	6·3	2·0	12·3	4·0
04	4 46·0	4 46·8	4 33·0	0·4	0·1	6·4	2·1	12·4	4·0
05	4 46·3	4 47·0	4 33·2	0·5	0·2	6·5	2·1	12·5	4·1
06	4 46·5	4 47·3	4 33·4	0·6	0·2	6·6	2·1	12·6	4·1
07	4 46·8	4 47·5	4 33·7	0·7	0·2	6·7	2·2	12·7	4·1
08	4 47·0	4 47·8	4 33·9	0·8	0·3	6·8	2·2	12·8	4·2
09	4 47·3	4 48·0	4 34·2	0·9	0·3	6·9	2·2	12·9	4·2
10	4 47·5	4 48·3	4 34·4	1·0	0·3	7·0	2·3	13·0	4·2
11	4 47·8	4 48·5	4 34·6	1·1	0·4	7·1	2·3	13·1	4·3
12	4 48·0	4 48·8	4 34·9	1·2	0·4	7·2	2·3	13·2	4·3
13	4 48·3	4 49·0	4 35·1	1·3	0·4	7·3	2·4	13·3	4·3
14	4 48·5	4 49·3	4 35·4	1·4	0·5	7·4	2·4	13·4	4·4
15	4 48·8	4 49·5	4 35·6	1·5	0·5	7·5	2·4	13·5	4·4
16	4 49·0	4 49·8	4 35·8	1·6	0·5	7·6	2·5	13·6	4·4
17	4 49·3	4 50·0	4 36·1	1·7	0·6	7·7	2·5	13·7	4·5
18	4 49·5	4 50·3	4 36·3	1·8	0·6	7·8	2·5	13·8	4·5
19	4 49·8	4 50·5	4 36·6	1·9	0·6	7·9	2·6	13·9	4·5
20	4 50·0	4 50·8	4 36·8	2·0	0·7	8·0	2·6	14·0	4·6
21	4 50·3	4 51·0	4 37·0	2·1	0·7	8·1	2·6	14·1	4·6
22	4 50·5	4 51·3	4 37·3	2·2	0·7	8·2	2·7	14·2	4·6
23	4 50·8	4 51·5	4 37·5	2·3	0·7	8·3	2·7	14·3	4·6
24	4 51·0	4 51·8	4 37·7	2·4	0·8	8·4	2·7	14·4	4·7
25	4 51·3	4 52·0	4 38·0	2·5	0·8	8·5	2·8	14·5	4·7
26	4 51·5	4 52·3	4 38·2	2·6	0·8	8·6	2·8	14·6	4·7
27	4 51·8	4 52·5	4 38·5	2·7	0·9	8·7	2·8	14·7	4·8
28	4 52·0	4 52·8	4 38·7	2·8	0·9	8·8	2·9	14·8	4·8
29	4 52·3	4 53·1	4 38·9	2·9	0·9	8·9	2·9	14·9	4·8
30	4 52·5	4 53·3	4 39·2	3·0	1·0	9·0	2·9	15·0	4·9
31	4 52·8	4 53·6	4 39·4	3·1	1·0	9·1	3·0	15·1	4·9
32	4 53·0	4 53·8	4 39·7	3·2	1·0	9·2	3·0	15·2	4·9
33	4 53·3	4 54·1	4 39·9	3·3	1·1	9·3	3·0	15·3	5·0
34	4 53·5	4 54·3	4 40·1	3·4	1·1	9·4	3·1	15·4	5·0
35	4 53·8	4 54·6	4 40·4	3·5	1·1	9·5	3·1	15·5	5·0
36	4 54·0	4 54·8	4 40·6	3·6	1·2	9·6	3·1	15·6	5·1
37	4 54·3	4 55·1	4 40·8	3·7	1·2	9·7	3·2	15·7	5·1
38	4 54·5	4 55·3	4 41·1	3·8	1·2	9·8	3·2	15·8	5·1
39	4 54·8	4 55·6	4 41·3	3·9	1·3	9·9	3·2	15·9	5·2
40	4 55·0	4 55·8	4 41·6	4·0	1·3	10·0	3·3	16·0	5·2
41	4 55·3	4 56·1	4 41·8	4·1	1·3	10·1	3·3	16·1	5·2
42	4 55·5	4 56·3	4 42·0	4·2	1·4	10·2	3·3	16·2	5·3
43	4 55·8	4 56·6	4 42·3	4·3	1·4	10·3	3·3	16·3	5·3
44	4 56·0	4 56·8	4 42·5	4·4	1·4	10·4	3·4	16·4	5·3
45	4 56·3	4 57·1	4 42·8	4·5	1·5	10·5	3·4	16·5	5·4
46	4 56·5	4 57·3	4 43·0	4·6	1·5	10·6	3·4	16·6	5·4
47	4 56·8	4 57·6	4 43·2	4·7	1·5	10·7	3·5	16·7	5·4
48	4 57·0	4 57·8	4 43·5	4·8	1·6	10·8	3·5	16·8	5·5
49	4 57·3	4 58·1	4 43·7	4·9	1·6	10·9	3·5	16·9	5·5
50	4 57·5	4 58·3	4 43·9	5·0	1·6	11·0	3·6	17·0	5·5
51	4 57·8	4 58·6	4 44·2	5·1	1·7	11·1	3·6	17·1	5·6
52	4 58·0	4 58·8	4 44·4	5·2	1·7	11·2	3·6	17·2	5·6
53	4 58·3	4 59·1	4 44·7	5·3	1·7	11·3	3·7	17·3	5·6
54	4 58·5	4 59·3	4 44·9	5·4	1·8	11·4	3·7	17·4	5·7
55	4 58·8	4 59·6	4 45·1	5·5	1·8	11·5	3·7	17·5	5·7
56	4 59·0	4 59·8	4 45·4	5·6	1·8	11·6	3·8	17·6	5·7
57	4 59·3	5 00·1	4 45·6	5·7	1·9	11·7	3·8	17·7	5·8
58	4 59·5	5 00·3	4 45·9	5·8	1·9	11·8	3·8	17·8	5·8
59	4 59·8	5 00·6	4 46·1	5·9	1·9	11·9	3·9	17·9	5·8
60	5 00·0	5 00·8	4 46·3	6·0	2·0	12·0	3·9	18·0	5·9

20m INCREMENTS AND CORRECTIONS 21m

20m	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° ′	° ′	° ′	′	′	′	′	′	′
00	5 00·0	5 00·8	4 46·3	0·0	0·0	6·0	2·1	12·0	4·1
01	5 00·3	5 01·1	4 46·6	0·1	0·0	6·1	2·1	12·1	4·1
02	5 00·5	5 01·3	4 46·8	0·2	0·1	6·2	2·1	12·2	4·2
03	5 00·8	5 01·6	4 47·0	0·3	0·1	6·3	2·2	12·3	4·2
04	5 01·0	5 01·8	4 47·3	0·4	0·1	6·4	2·2	12·4	4·2
05	5 01·3	5 02·1	4 47·5	0·5	0·2	6·5	2·2	12·5	4·3
06	5 01·5	5 02·3	4 47·8	0·6	0·2	6·6	2·3	12·6	4·3
07	5 01·8	5 02·6	4 48·0	0·7	0·2	6·7	2·3	12·7	4·3
08	5 02·0	5 02·8	4 48·2	0·8	0·3	6·8	2·3	12·8	4·4
09	5 02·3	5 03·1	4 48·5	0·9	0·3	6·9	2·4	12·9	4·4
10	5 02·5	5 03·3	4 48·7	1·0	0·3	7·0	2·4	13·0	4·4
11	5 02·8	5 03·6	4 49·0	1·1	0·4	7·1	2·4	13·1	4·5
12	5 03·0	5 03·8	4 49·2	1·2	0·4	7·2	2·5	13·2	4·5
13	5 03·3	5 04·1	4 49·4	1·3	0·4	7·3	2·5	13·3	4·5
14	5 03·5	5 04·3	4 49·7	1·4	0·5	7·4	2·5	13·4	4·6
15	5 03·8	5 04·6	4 49·9	1·5	0·5	7·5	2·6	13·5	4·6
16	5 04·0	5 04·8	4 50·2	1·6	0·5	7·6	2·6	13·6	4·6
17	5 04·3	5 05·1	4 50·4	1·7	0·6	7·7	2·6	13·7	4·7
18	5 04·5	5 05·3	4 50·6	1·8	0·6	7·8	2·7	13·8	4·7
19	5 04·8	5 05·6	4 50·9	1·9	0·6	7·9	2·7	13·9	4·7
20	5 05·0	5 05·8	4 51·1	2·0	0·7	8·0	2·7	14·0	4·8
21	5 05·3	5 06·1	4 51·3	2·1	0·7	8·1	2·8	14·1	4·8
22	5 05·5	5 06·3	4 51·6	2·2	0·8	8·2	2·8	14·2	4·9
23	5 05·8	5 06·6	4 51·8	2·3	0·8	8·3	2·8	14·3	4·9
24	5 06·0	5 06·8	4 52·1	2·4	0·8	8·4	2·9	14·4	4·9
25	5 06·3	5 07·1	4 52·3	2·5	0·9	8·5	2·9	14·5	5·0
26	5 06·5	5 07·3	4 52·5	2·6	0·9	8·6	2·9	14·6	5·0
27	5 06·8	5 07·6	4 52·8	2·7	0·9	8·7	3·0	14·7	5·0
28	5 07·0	5 07·8	4 53·0	2·8	1·0	8·8	3·0	14·8	5·1
29	5 07·3	5 08·1	4 53·3	2·9	1·0	8·9	3·0	14·9	5·1
30	5 07·5	5 08·3	4 53·5	3·0	1·0	9·0	3·1	15·0	5·1
31	5 07·8	5 08·6	4 53·7	3·1	1·1	9·1	3·1	15·1	5·2
32	5 08·0	5 08·8	4 54·0	3·2	1·1	9·2	3·1	15·2	5·2
33	5 08·3	5 09·1	4 54·2	3·3	1·1	9·3	3·2	15·3	5·2
34	5 08·5	5 09·3	4 54·4	3·4	1·2	9·4	3·2	15·4	5·3
35	5 08·8	5 09·6	4 54·7	3·5	1·2	9·5	3·2	15·5	5·3
36	5 09·0	5 09·8	4 54·9	3·6	1·2	9·6	3·3	15·6	5·3
37	5 09·3	5 10·1	4 55·2	3·7	1·3	9·7	3·3	15·7	5·4
38	5 09·5	5 10·3	4 55·4	3·8	1·3	9·8	3·3	15·8	5·4
39	5 09·8	5 10·6	4 55·6	3·9	1·3	9·9	3·4	15·9	5·4
40	5 10·0	5 10·8	4 55·9	4·0	1·4	10·0	3·4	16·0	5·5
41	5 10·3	5 11·1	4 56·1	4·1	1·4	10·1	3·5	16·1	5·5
42	5 10·5	5 11·4	4 56·4	4·2	1·4	10·2	3·5	16·2	5·5
43	5 10·8	5 11·6	4 56·6	4·3	1·5	10·3	3·5	16·3	5·6
44	5 11·0	5 11·9	4 56·8	4·4	1·5	10·4	3·6	16·4	5·6
45	5 11·3	5 12·1	4 57·1	4·5	1·5	10·5	3·6	16·5	5·6
46	5 11·5	5 12·4	4 57·3	4·6	1·6	10·6	3·6	16·6	5·7
47	5 11·8	5 12·6	4 57·5	4·7	1·6	10·7	3·7	16·7	5·7
48	5 12·0	5 12·9	4 57·8	4·8	1·6	10·8	3·7	16·8	5·7
49	5 12·3	5 13·1	4 58·0	4·9	1·7	10·9	3·7	16·9	5·8
50	5 12·5	5 13·4	4 58·3	5·0	1·7	11·0	3·8	17·0	5·8
51	5 12·8	5 13·6	4 58·5	5·1	1·7	11·1	3·8	17·1	5·8
52	5 13·0	5 13·9	4 58·7	5·2	1·8	11·2	3·8	17·2	5·9
53	5 13·3	5 14·1	4 59·0	5·3	1·8	11·3	3·9	17·3	5·9
54	5 13·5	5 14·4	4 59·2	5·4	1·8	11·4	3·9	17·4	5·9
55	5 13·8	5 14·6	4 59·5	5·5	1·9	11·5	3·9	17·5	6·0
56	5 14·0	5 14·9	4 59·7	5·6	1·9	11·6	4·0	17·6	6·0
57	5 14·3	5 15·1	4 59·9	5·7	1·9	11·7	4·0	17·7	6·0
58	5 14·5	5 15·4	5 00·2	5·8	2·0	11·8	4·0	17·8	6·1
59	5 14·8	5 15·6	5 00·4	5·9	2·0	11·9	4·1	17·9	6·1
60	5 15·0	5 15·9	5 00·7	6·0	2·1	12·0	4·1	18·0	6·2

21m	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° ′	° ′	° ′	′	′	′	′	′	′
00	5 15·0	5 15·9	5 00·7	0·0	0·0	6·0	2·2	12·0	4·3
01	5 15·3	5 16·1	5 00·9	0·1	0·0	6·1	2·2	12·1	4·3
02	5 15·5	5 16·4	5 01·1	0·2	0·1	6·2	2·2	12·2	4·4
03	5 15·8	5 16·6	5 01·4	0·3	0·1	6·3	2·3	12·3	4·4
04	5 16·0	5 16·9	5 01·6	0·4	0·1	6·4	2·3	12·4	4·4
05	5 16·3	5 17·1	5 01·8	0·5	0·2	6·5	2·3	12·5	4·5
06	5 16·5	5 17·4	5 02·1	0·6	0·2	6·6	2·4	12·6	4·5
07	5 16·8	5 17·6	5 02·3	0·7	0·3	6·7	2·4	12·7	4·6
08	5 17·0	5 17·9	5 02·6	0·8	0·3	6·8	2·4	12·8	4·6
09	5 17·3	5 18·1	5 02·8	0·9	0·3	6·9	2·5	12·9	4·6
10	5 17·5	5 18·4	5 03·0	1·0	0·4	7·0	2·5	13·0	4·7
11	5 17·8	5 18·6	5 03·3	1·1	0·4	7·1	2·5	13·1	4·7
12	5 18·0	5 18·9	5 03·5	1·2	0·4	7·2	2·6	13·2	4·7
13	5 18·3	5 19·1	5 03·8	1·3	0·5	7·3	2·6	13·3	4·8
14	5 18·5	5 19·4	5 04·0	1·4	0·5	7·4	2·7	13·4	4·8
15	5 18·8	5 19·6	5 04·2	1·5	0·5	7·5	2·7	13·5	4·8
16	5 19·0	5 19·9	5 04·5	1·6	0·6	7·6	2·7	13·6	4·9
17	5 19·3	5 20·1	5 04·7	1·7	0·6	7·7	2·8	13·7	4·9
18	5 19·5	5 20·4	5 04·9	1·8	0·6	7·8	2·8	13·8	4·9
19	5 19·8	5 20·6	5 05·2	1·9	0·7	7·9	2·8	13·9	5·0
20	5 20·0	5 20·9	5 05·4	2·0	0·7	8·0	2·9	14·0	5·0
21	5 20·3	5 21·1	5 05·7	2·1	0·8	8·1	2·9	14·1	5·1
22	5 20·5	5 21·4	5 05·9	2·2	0·8	8·2	2·9	14·2	5·1
23	5 20·8	5 21·6	5 06·1	2·3	0·8	8·3	3·0	14·3	5·1
24	5 21·0	5 21·9	5 06·4	2·4	0·9	8·4	3·0	14·4	5·2
25	5 21·3	5 22·1	5 06·6	2·5	0·9	8·5	3·0	14·5	5·2
26	5 21·5	5 22·4	5 06·9	2·6	0·9	8·6	3·1	14·6	5·2
27	5 21·8	5 22·6	5 07·1	2·7	1·0	8·7	3·1	14·7	5·3
28	5 22·0	5 22·9	5 07·3	2·8	1·0	8·8	3·2	14·8	5·3
29	5 22·3	5 23·1	5 07·6	2·9	1·0	8·9	3·2	14·9	5·3
30	5 22·5	5 23·4	5 07·8	3·0	1·1	9·0	3·2	15·0	5·4
31	5 22·8	5 23·6	5 08·0	3·1	1·1	9·1	3·3	15·1	5·4
32	5 23·0	5 23·9	5 08·3	3·2	1·1	9·2	3·3	15·2	5·4
33	5 23·3	5 24·1	5 08·5	3·3	1·2	9·3	3·3	15·3	5·5
34	5 23·5	5 24·4	5 08·8	3·4	1·2	9·4	3·4	15·4	5·5
35	5 23·8	5 24·6	5 09·0	3·5	1·3	9·5	3·4	15·5	5·6
36	5 24·0	5 24·9	5 09·2	3·6	1·3	9·6	3·4	15·6	5·6
37	5 24·3	5 25·1	5 09·5	3·7	1·3	9·7	3·5	15·7	5·6
38	5 24·5	5 25·4	5 09·7	3·8	1·4	9·8	3·5	15·8	5·7
39	5 24·8	5 25·6	5 10·0	3·9	1·4	9·9	3·5	15·9	5·7
40	5 25·0	5 25·9	5 10·2	4·0	1·4	10·0	3·6	16·0	5·7
41	5 25·3	5 26·1	5 10·4	4·1	1·5	10·1	3·6	16·1	5·8
42	5 25·5	5 26·4	5 10·7	4·2	1·5	10·2	3·7	16·2	5·8
43	5 25·8	5 26·6	5 10·9	4·3	1·5	10·3	3·7	16·3	5·8
44	5 26·0	5 26·9	5 11·1	4·4	1·6	10·4	3·7	16·4	5·9
45	5 26·3	5 27·1	5 11·4	4·5	1·6	10·5	3·8	16·5	5·9
46	5 26·5	5 27·4	5 11·6	4·6	1·6	10·6	3·8	16·6	5·9
47	5 26·8	5 27·6	5 11·9	4·7	1·7	10·7	3·8	16·7	6·0
48	5 27·0	5 27·9	5 12·1	4·8	1·7	10·8	3·9	16·8	6·0
49	5 27·3	5 28·1	5 12·3	4·9	1·8	10·9	3·9	16·9	6·1
50	5 27·5	5 28·4	5 12·6	5·0	1·8	11·0	3·9	17·0	6·1
51	5 27·8	5 28·6	5 12·8	5·1	1·8	11·1	4·0	17·1	6·1
52	5 28·0	5 28·9	5 13·1	5·2	1·9	11·2	4·0	17·2	6·2
53	5 28·3	5 29·1	5 13·3	5·3	1·9	11·3	4·0	17·3	6·2
54	5 28·5	5 29·4	5 13·5	5·4	1·9	11·4	4·1	17·4	6·2
55	5 28·8	5 29·7	5 13·8	5·5	2·0	11·5	4·1	17·5	6·3
56	5 29·0	5 29·9	5 14·0	5·6	2·0	11·6	4·2	17·6	6·3
57	5 29·3	5 30·2	5 14·3	5·7	2·0	11·7	4·2	17·7	6·3
58	5 29·5	5 30·4	5 14·5	5·8	2·1	11·8	4·2	17·8	6·4
59	5 29·8	5 30·7	5 14·7	5·9	2·1	11·9	4·3	17·9	6·4
60	5 30·0	5 30·9	5 15·0	6·0	2·2	12·0	4·3	18·0	6·5

22m INCREMENTS AND CORRECTIONS 23m

22m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	5 30·0	5 30·9	5 15·0	0·0	0·0	6·0	2·3	12·0	4·5
01	5 30·3	5 31·2	5 15·2	0·1	0·0	6·1	2·3	12·1	4·5
02	5 30·5	5 31·4	5 15·4	0·2	0·1	6·2	2·3	12·2	4·6
03	5 30·8	5 31·7	5 15·7	0·3	0·1	6·3	2·4	12·3	4·6
04	5 31·0	5 31·9	5 15·9	0·4	0·2	6·4	2·4	12·4	4·7
05	5 31·3	5 32·2	5 16·2	0·5	0·2	6·5	2·4	12·5	4·7
06	5 31·5	5 32·4	5 16·4	0·6	0·2	6·6	2·5	12·6	4·7
07	5 31·8	5 32·7	5 16·6	0·7	0·3	6·7	2·5	12·7	4·8
08	5 32·0	5 32·9	5 16·9	0·8	0·3	6·8	2·6	12·8	4·8
09	5 32·3	5 33·2	5 17·1	0·9	0·3	6·9	2·6	12·9	4·8
10	5 32·5	5 33·4	5 17·4	1·0	0·4	7·0	2·6	13·0	4·9
11	5 32·8	5 33·7	5 17·6	1·1	0·4	7·1	2·7	13·1	4·9
12	5 33·0	5 33·9	5 17·8	1·2	0·5	7·2	2·7	13·2	5·0
13	5 33·3	5 34·2	5 18·1	1·3	0·5	7·3	2·7	13·3	5·0
14	5 33·5	5 34·4	5 18·3	1·4	0·5	7·4	2·8	13·4	5·0
15	5 33·8	5 34·7	5 18·5	1·5	0·6	7·5	2·8	13·5	5·1
16	5 34·0	5 34·9	5 18·8	1·6	0·6	7·6	2·9	13·6	5·1
17	5 34·3	5 35·2	5 19·0	1·7	0·6	7·7	2·9	13·7	5·1
18	5 34·5	5 35·4	5 19·3	1·8	0·7	7·8	2·9	13·8	5·2
19	5 34·8	5 35·7	5 19·5	1·9	0·7	7·9	3·0	13·9	5·2
20	5 35·0	5 35·9	5 19·7	2·0	0·8	8·0	3·0	14·0	5·3
21	5 35·3	5 36·2	5 20·0	2·1	0·8	8·1	3·0	14·1	5·3
22	5 35·5	5 36·4	5 20·2	2·2	0·8	8·2	3·1	14·2	5·3
23	5 35·8	5 36·7	5 20·5	2·3	0·9	8·3	3·1	14·3	5·4
24	5 36·0	5 36·9	5 20·7	2·4	0·9	8·4	3·2	14·4	5·4
25	5 36·3	5 37·2	5 20·9	2·5	0·9	8·5	3·2	14·5	5·4
26	5 36·5	5 37·4	5 21·2	2·6	1·0	8·6	3·2	14·6	5·5
27	5 36·8	5 37·7	5 21·4	2·7	1·0	8·7	3·3	14·7	5·5
28	5 37·0	5 37·9	5 21·6	2·8	1·1	8·8	3·3	14·8	5·6
29	5 37·3	5 38·2	5 21·9	2·9	1·1	8·9	3·3	14·9	5·6
30	5 37·5	5 38·4	5 22·1	3·0	1·1	9·0	3·4	15·0	5·6
31	5 37·8	5 38·7	5 22·4	3·1	1·2	9·1	3·4	15·1	5·7
32	5 38·0	5 38·9	5 22·6	3·2	1·2	9·2	3·5	15·2	5·7
33	5 38·3	5 39·2	5 22·8	3·3	1·2	9·3	3·5	15·3	5·7
34	5 38·5	5 39·4	5 23·1	3·4	1·3	9·4	3·5	15·4	5·8
35	5 38·8	5 39·7	5 23·3	3·5	1·3	9·5	3·6	15·5	5·8
36	5 39·0	5 39·9	5 23·6	3·6	1·4	9·6	3·6	15·6	5·9
37	5 39·3	5 40·2	5 23·8	3·7	1·4	9·7	3·6	15·7	5·9
38	5 39·5	5 40·4	5 24·0	3·8	1·4	9·8	3·7	15·8	5·9
39	5 39·8	5 40·7	5 24·3	3·9	1·5	9·9	3·7	15·9	6·0
40	5 40·0	5 40·9	5 24·5	4·0	1·5	10·0	3·8	16·0	6·0
41	5 40·3	5 41·2	5 24·7	4·1	1·5	10·1	3·8	16·1	6·0
42	5 40·5	5 41·4	5 25·0	4·2	1·6	10·2	3·8	16·2	6·1
43	5 40·8	5 41·7	5 25·2	4·3	1·6	10·3	3·9	16·3	6·1
44	5 41·0	5 41·9	5 25·5	4·4	1·7	10·4	3·9	16·4	6·2
45	5 41·3	5 42·2	5 25·7	4·5	1·7	10·5	3·9	16·5	6·2
46	5 41·5	5 42·4	5 25·9	4·6	1·7	10·6	4·0	16·6	6·2
47	5 41·8	5 42·7	5 26·2	4·7	1·8	10·7	4·0	16·7	6·3
48	5 42·0	5 42·9	5 26·4	4·8	1·8	10·8	4·1	16·8	6·3
49	5 42·3	5 43·2	5 26·7	4·9	1·8	10·9	4·1	16·9	6·3
50	5 42·5	5 43·4	5 26·9	5·0	1·9	11·0	4·1	17·0	6·4
51	5 42·8	5 43·7	5 27·1	5·1	1·9	11·1	4·2	17·1	6·4
52	5 43·0	5 43·9	5 27·4	5·2	2·0	11·2	4·2	17·2	6·5
53	5 43·3	5 44·2	5 27·6	5·3	2·0	11·3	4·2	17·3	6·5
54	5 43·5	5 44·4	5 27·9	5·4	2·0	11·4	4·3	17·4	6·5
55	5 43·8	5 44·7	5 28·1	5·5	2·1	11·5	4·3	17·5	6·6
56	5 44·0	5 44·9	5 28·3	5·6	2·1	11·6	4·4	17·6	6·6
57	5 44·3	5 45·2	5 28·6	5·7	2·1	11·7	4·4	17·7	6·6
58	5 44·5	5 45·4	5 28·8	5·8	2·2	11·8	4·4	17·8	6·7
59	5 44·8	5 45·7	5 29·0	5·9	2·2	11·9	4·5	17·9	6·7
60	5 45·0	5 45·9	5 29·3	6·0	2·3	12·0	4·5	18·0	6·8

23m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	5 45·0	5 45·9	5 29·3	0·0	0·0	6·0	2·4	12·0	4·7
01	5 45·3	5 46·2	5 29·5	0·1	0·0	6·1	2·4	12·1	4·7
02	5 45·5	5 46·4	5 29·8	0·2	0·1	6·2	2·4	12·2	4·8
03	5 45·8	5 46·7	5 30·0	0·3	0·1	6·3	2·5	12·3	4·8
04	5 46·0	5 46·9	5 30·2	0·4	0·2	6·4	2·5	12·4	4·9
05	5 46·3	5 47·2	5 30·5	0·5	0·2	6·5	2·5	12·5	4·9
06	5 46·5	5 47·4	5 30·7	0·6	0·2	6·6	2·6	12·6	4·9
07	5 46·8	5 47·7	5 31·0	0·7	0·3	6·7	2·6	12·7	5·0
08	5 47·0	5 48·0	5 31·2	0·8	0·3	6·8	2·7	12·8	5·0
09	5 47·3	5 48·2	5 31·4	0·9	0·4	6·9	2·7	12·9	5·1
10	5 47·5	5 48·5	5 31·7	1·0	0·4	7·0	2·7	13·0	5·1
11	5 47·8	5 48·7	5 31·9	1·1	0·4	7·1	2·8	13·1	5·1
12	5 48·0	5 49·0	5 32·1	1·2	0·5	7·2	2·8	13·2	5·2
13	5 48·3	5 49·2	5 32·4	1·3	0·5	7·3	2·9	13·3	5·2
14	5 48·5	5 49·5	5 32·6	1·4	0·5	7·4	2·9	13·4	5·2
15	5 48·8	5 49·7	5 32·9	1·5	0·6	7·5	2·9	13·5	5·3
16	5 49·0	5 50·0	5 33·1	1·6	0·6	7·6	3·0	13·6	5·3
17	5 49·3	5 50·2	5 33·3	1·7	0·7	7·7	3·0	13·7	5·4
18	5 49·5	5 50·5	5 33·6	1·8	0·7	7·8	3·1	13·8	5·4
19	5 49·8	5 50·7	5 33·8	1·9	0·7	7·9	3·1	13·9	5·4
20	5 50·0	5 51·0	5 34·1	2·0	0·8	8·0	3·1	14·0	5·5
21	5 50·3	5 51·2	5 34·3	2·1	0·8	8·1	3·2	14·1	5·5
22	5 50·5	5 51·5	5 34·5	2·2	0·9	8·2	3·2	14·2	5·6
23	5 50·8	5 51·7	5 34·8	2·3	0·9	8·3	3·3	14·3	5·6
24	5 51·0	5 52·0	5 35·0	2·4	0·9	8·4	3·3	14·4	5·6
25	5 51·3	5 52·2	5 35·2	2·5	1·0	8·5	3·3	14·5	5·7
26	5 51·5	5 52·5	5 35·5	2·6	1·0	8·6	3·4	14·6	5·7
27	5 51·8	5 52·7	5 35·7	2·7	1·1	8·7	3·4	14·7	5·8
28	5 52·0	5 53·0	5 36·0	2·8	1·1	8·8	3·4	14·8	5·8
29	5 52·3	5 53·2	5 36·2	2·9	1·1	8·9	3·5	14·9	5·8
30	5 52·5	5 53·5	5 36·4	3·0	1·2	9·0	3·5	15·0	5·9
31	5 52·8	5 53·7	5 36·7	3·1	1·2	9·1	3·6	15·1	5·9
32	5 53·0	5 54·0	5 36·9	3·2	1·3	9·2	3·6	15·2	6·0
33	5 53·3	5 54·2	5 37·2	3·3	1·3	9·3	3·6	15·3	6·0
34	5 53·5	5 54·5	5 37·4	3·4	1·3	9·4	3·7	15·4	6·0
35	5 53·8	5 54·7	5 37·6	3·5	1·4	9·5	3·7	15·5	6·1
36	5 54·0	5 55·0	5 37·9	3·6	1·4	9·6	3·8	15·6	6·1
37	5 54·3	5 55·2	5 38·1	3·7	1·4	9·7	3·8	15·7	6·1
38	5 54·5	5 55·5	5 38·4	3·8	1·5	9·8	3·8	15·8	6·2
39	5 54·8	5 55·7	5 38·6	3·9	1·5	9·9	3·9	15·9	6·2
40	5 55·0	5 56·0	5 38·8	4·0	1·6	10·0	3·9	16·0	6·3
41	5 55·3	5 56·2	5 39·1	4·1	1·6	10·1	4·0	16·1	6·3
42	5 55·5	5 56·5	5 39·3	4·2	1·6	10·2	4·0	16·2	6·3
43	5 55·8	5 56·7	5 39·5	4·3	1·7	10·3	4·0	16·3	6·4
44	5 56·0	5 57·0	5 39·8	4·4	1·7	10·4	4·1	16·4	6·4
45	5 56·3	5 57·2	5 40·0	4·5	1·8	10·5	4·1	16·5	6·5
46	5 56·5	5 57·5	5 40·3	4·6	1·8	10·6	4·2	16·6	6·5
47	5 56·8	5 57·7	5 40·5	4·7	1·8	10·7	4·2	16·7	6·5
48	5 57·0	5 58·0	5 40·7	4·8	1·9	10·8	4·2	16·8	6·6
49	5 57·3	5 58·2	5 41·0	4·9	1·9	10·9	4·3	16·9	6·6
50	5 57·5	5 58·5	5 41·2	5·0	2·0	11·0	4·3	17·0	6·7
51	5 57·8	5 58·7	5 41·5	5·1	2·0	11·1	4·3	17·1	6·7
52	5 58·0	5 59·0	5 41·7	5·2	2·0	11·2	4·4	17·2	6·7
53	5 58·3	5 59·2	5 41·9	5·3	2·1	11·3	4·4	17·3	6·8
54	5 58·5	5 59·5	5 42·2	5·4	2·1	11·4	4·5	17·4	6·8
55	5 58·8	5 59·7	5 42·4	5·5	2·2	11·5	4·5	17·5	6·9
56	5 59·0	6 00·0	5 42·6	5·6	2·2	11·6	4·5	17·6	6·9
57	5 59·3	6 00·2	5 42·9	5·7	2·2	11·7	4·6	17·7	6·9
58	5 59·5	6 00·5	5 43·1	5·8	2·3	11·8	4·6	17·8	7·0
59	5 59·8	6 00·7	5 43·4	5·9	2·3	11·9	4·7	17·9	7·0
60	6 00·0	6 01·0	5 43·6	6·0	2·4	12·0	4·7	18·0	7·1

24m INCREMENTS AND CORRECTIONS 25m

24m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	6 00·0	6 01·0	5 43·6	0·0	0·0	6·0	2·5	12·0	4·9
01	6 00·3	6 01·2	5 43·8	0·1	0·0	6·1	2·5	12·1	4·9
02	6 00·5	6 01·5	5 44·1	0·2	0·1	6·2	2·5	12·2	5·0
03	6 00·8	6 01·7	5 44·3	0·3	0·1	6·3	2·6	12·3	5·0
04	6 01·0	6 02·0	5 44·6	0·4	0·2	6·4	2·6	12·4	5·1
05	6 01·3	6 02·2	5 44·8	0·5	0·2	6·5	2·7	12·5	5·1
06	6 01·5	6 02·5	5 45·0	0·6	0·2	6·6	2·7	12·6	5·1
07	6 01·8	6 02·7	5 45·3	0·7	0·3	6·7	2·7	12·7	5·2
08	6 02·0	6 03·0	5 45·5	0·8	0·3	6·8	2·8	12·8	5·2
09	6 02·3	6 03·2	5 45·7	0·9	0·4	6·9	2·8	12·9	5·3
10	6 02·5	6 03·5	5 46·0	1·0	0·4	7·0	2·9	13·0	5·3
11	6 02·8	6 03·7	5 46·2	1·1	0·4	7·1	2·9	13·1	5·3
12	6 03·0	6 04·0	5 46·5	1·2	0·5	7·2	2·9	13·2	5·4
13	6 03·3	6 04·2	5 46·7	1·3	0·5	7·3	3·0	13·3	5·4
14	6 03·5	6 04·5	5 46·9	1·4	0·6	7·4	3·0	13·4	5·5
15	6 03·8	6 04·7	5 47·2	1·5	0·6	7·5	3·1	13·5	5·5
16	6 04·0	6 05·0	5 47·4	1·6	0·7	7·6	3·1	13·6	5·6
17	6 04·3	6 05·2	5 47·7	1·7	0·7	7·7	3·1	13·7	5·6
18	6 04·5	6 05·5	5 47·9	1·8	0·7	7·8	3·2	13·8	5·6
19	6 04·8	6 05·7	5 48·1	1·9	0·8	7·9	3·2	13·9	5·7
20	6 05·0	6 06·0	5 48·4	2·0	0·8	8·0	3·3	14·0	5·7
21	6 05·3	6 06·3	5 48·6	2·1	0·9	8·1	3·3	14·1	5·8
22	6 05·5	6 06·5	5 48·8	2·2	0·9	8·2	3·3	14·2	5·8
23	6 05·8	6 06·8	5 49·1	2·3	0·9	8·3	3·4	14·3	5·8
24	6 06·0	6 07·0	5 49·3	2·4	1·0	8·4	3·4	14·4	5·9
25	6 06·3	6 07·3	5 49·6	2·5	1·0	8·5	3·5	14·5	5·9
26	6 06·5	6 07·5	5 49·8	2·6	1·1	8·6	3·5	14·6	6·0
27	6 06·8	6 07·8	5 50·0	2·7	1·1	8·7	3·6	14·7	6·0
28	6 07·0	6 08·0	5 50·3	2·8	1·1	8·8	3·6	14·8	6·0
29	6 07·3	6 08·3	5 50·5	2·9	1·2	8·9	3·6	14·9	6·1
30	6 07·5	6 08·5	5 50·8	3·0	1·2	9·0	3·7	15·0	6·1
31	6 07·8	6 08·8	5 51·0	3·1	1·3	9·1	3·7	15·1	6·2
32	6 08·0	6 09·0	5 51·2	3·2	1·3	9·2	3·8	15·2	6·2
33	6 08·3	6 09·3	5 51·5	3·3	1·3	9·3	3·8	15·3	6·2
34	6 08·5	6 09·5	5 51·7	3·4	1·4	9·4	3·8	15·4	6·3
35	6 08·8	6 09·8	5 52·0	3·5	1·4	9·5	3·9	15·5	6·3
36	6 09·0	6 10·0	5 52·2	3·6	1·5	9·6	3·9	15·6	6·4
37	6 09·3	6 10·3	5 52·4	3·7	1·5	9·7	4·0	15·7	6·4
38	6 09·5	6 10·5	5 52·7	3·8	1·6	9·8	4·0	15·8	6·5
39	6 09·8	6 10·8	5 52·9	3·9	1·6	9·9	4·0	15·9	6·5
40	6 10·0	6 11·0	5 53·1	4·0	1·6	10·0	4·1	16·0	6·5
41	6 10·3	6 11·3	5 53·4	4·1	1·7	10·1	4·1	16·1	6·6
42	6 10·5	6 11·5	5 53·6	4·2	1·7	10·2	4·2	16·2	6·6
43	6 10·8	6 11·8	5 53·9	4·3	1·8	10·3	4·2	16·3	6·7
44	6 11·0	6 12·0	5 54·1	4·4	1·8	10·4	4·2	16·4	6·7
45	6 11·3	6 12·3	5 54·3	4·5	1·8	10·5	4·3	16·5	6·7
46	6 11·5	6 12·5	5 54·6	4·6	1·9	10·6	4·3	16·6	6·8
47	6 11·8	6 12·8	5 54·8	4·7	1·9	10·7	4·4	16·7	6·8
48	6 12·0	6 13·0	5 55·1	4·8	2·0	10·8	4·4	16·8	6·9
49	6 12·3	6 13·3	5 55·3	4·9	2·0	10·9	4·5	16·9	6·9
50	6 12·5	6 13·5	5 55·5	5·0	2·0	11·0	4·5	17·0	6·9
51	6 12·8	6 13·8	5 55·8	5·1	2·1	11·1	4·5	17·1	7·0
52	6 13·0	6 14·0	5 56·0	5·2	2·1	11·2	4·6	17·2	7·0
53	6 13·3	6 14·3	5 56·2	5·3	2·2	11·3	4·6	17·3	7·1
54	6 13·5	6 14·5	5 56·5	5·4	2·2	11·4	4·7	17·4	7·1
55	6 13·8	6 14·8	5 56·7	5·5	2·2	11·5	4·7	17·5	7·1
56	6 14·0	6 15·0	5 57·0	5·6	2·3	11·6	4·7	17·6	7·2
57	6 14·3	6 15·3	5 57·2	5·7	2·3	11·7	4·8	17·7	7·2
58	6 14·5	6 15·5	5 57·4	5·8	2·4	11·8	4·8	17·8	7·3
59	6 14·8	6 15·8	5 57·7	5·9	2·4	11·9	4·9	17·9	7·3
60	6 15·0	6 16·0	5 57·9	6·0	2·5	12·0	4·9	18·0	7·4

25m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	6 15·0	6 16·0	5 57·9	0·0	0·0	6·0	2·6	12·0	5·1
01	6 15·3	6 16·3	5 58·2	0·1	0·0	6·1	2·6	12·1	5·1
02	6 15·5	6 16·5	5 58·4	0·2	0·1	6·2	2·6	12·2	5·2
03	6 15·8	6 16·8	5 58·6	0·3	0·1	6·3	2·7	12·3	5·2
04	6 16·0	6 17·0	5 58·9	0·4	0·2	6·4	2·7	12·4	5·3
05	6 16·3	6 17·3	5 59·1	0·5	0·2	6·5	2·8	12·5	5·3
06	6 16·5	6 17·5	5 59·3	0·6	0·3	6·6	2·8	12·6	5·4
07	6 16·8	6 17·8	5 59·6	0·7	0·3	6·7	2·8	12·7	5·4
08	6 17·0	6 18·0	5 59·8	0·8	0·3	6·8	2·9	12·8	5·4
09	6 17·3	6 18·3	6 00·1	0·9	0·4	6·9	2·9	12·9	5·5
10	6 17·5	6 18·5	6 00·3	1·0	0·4	7·0	3·0	13·0	5·5
11	6 17·8	6 18·8	6 00·5	1·1	0·5	7·1	3·0	13·1	5·6
12	6 18·0	6 19·0	6 00·8	1·2	0·5	7·2	3·1	13·2	5·6
13	6 18·3	6 19·3	6 01·0	1·3	0·6	7·3	3·1	13·3	5·7
14	6 18·5	6 19·5	6 01·3	1·4	0·6	7·4	3·1	13·4	5·7
15	6 18·8	6 19·8	6 01·5	1·5	0·6	7·5	3·2	13·5	5·7
16	6 19·0	6 20·0	6 01·7	1·6	0·7	7·6	3·2	13·6	5·8
17	6 19·3	6 20·3	6 02·0	1·7	0·7	7·7	3·3	13·7	5·8
18	6 19·5	6 20·5	6 02·2	1·8	0·8	7·8	3·3	13·8	5·9
19	6 19·8	6 20·8	6 02·5	1·9	0·8	7·9	3·4	13·9	5·9
20	6 20·0	6 21·0	6 02·7	2·0	0·9	8·0	3·4	14·0	6·0
21	6 20·3	6 21·3	6 02·9	2·1	0·9	8·1	3·4	14·1	6·0
22	6 20·5	6 21·5	6 03·2	2·2	0·9	8·2	3·5	14·2	6·0
23	6 20·8	6 21·8	6 03·4	2·3	1·0	8·3	3·5	14·3	6·1
24	6 21·0	6 22·0	6 03·6	2·4	1·0	8·4	3·6	14·4	6·1
25	6 21·3	6 22·3	6 03·9	2·5	1·1	8·5	3·6	14·5	6·2
26	6 21·5	6 22·5	6 04·1	2·6	1·1	8·6	3·7	14·6	6·2
27	6 21·8	6 22·8	6 04·4	2·7	1·1	8·7	3·7	14·7	6·2
28	6 22·0	6 23·0	6 04·6	2·8	1·2	8·8	3·7	14·8	6·3
29	6 22·3	6 23·3	6 04·8	2·9	1·2	8·9	3·8	14·9	6·3
30	6 22·5	6 23·5	6 05·1	3·0	1·3	9·0	3·8	15·0	6·4
31	6 22·8	6 23·8	6 05·3	3·1	1·3	9·1	3·9	15·1	6·4
32	6 23·0	6 24·0	6 05·6	3·2	1·4	9·2	3·9	15·2	6·5
33	6 23·3	6 24·3	6 05·8	3·3	1·4	9·3	4·0	15·3	6·5
34	6 23·5	6 24·5	6 06·0	3·4	1·4	9·4	4·0	15·4	6·5
35	6 23·8	6 24·8	6 06·3	3·5	1·5	9·5	4·0	15·5	6·6
36	6 24·0	6 25·1	6 06·5	3·6	1·5	9·6	4·1	15·6	6·6
37	6 24·3	6 25·3	6 06·7	3·7	1·6	9·7	4·1	15·7	6·7
38	6 24·5	6 25·6	6 07·0	3·8	1·6	9·8	4·2	15·8	6·7
39	6 24·8	6 25·8	6 07·2	3·9	1·7	9·9	4·2	15·9	6·8
40	6 25·0	6 26·1	6 07·5	4·0	1·7	10·0	4·3	16·0	6·8
41	6 25·3	6 26·3	6 07·7	4·1	1·7	10·1	4·3	16·1	6·8
42	6 25·5	6 26·6	6 07·9	4·2	1·8	10·2	4·3	16·2	6·9
43	6 25·8	6 26·8	6 08·2	4·3	1·8	10·3	4·4	16·3	6·9
44	6 26·0	6 27·1	6 08·4	4·4	1·9	10·4	4·4	16·4	7·0
45	6 26·3	6 27·3	6 08·7	4·5	1·9	10·5	4·5	16·5	7·0
46	6 26·5	6 27·6	6 08·9	4·6	2·0	10·6	4·5	16·6	7·1
47	6 26·8	6 27·8	6 09·1	4·7	2·0	10·7	4·5	16·7	7·1
48	6 27·0	6 28·1	6 09·4	4·8	2·0	10·8	4·6	16·8	7·1
49	6 27·3	6 28·3	6 09·6	4·9	2·1	10·9	4·6	16·9	7·2
50	6 27·5	6 28·6	6 09·8	5·0	2·1	11·0	4·7	17·0	7·2
51	6 27·8	6 28·8	6 10·1	5·1	2·2	11·1	4·7	17·1	7·3
52	6 28·0	6 29·1	6 10·3	5·2	2·2	11·2	4·8	17·2	7·3
53	6 28·3	6 29·3	6 10·6	5·3	2·3	11·3	4·8	17·3	7·4
54	6 28·5	6 29·6	6 10·8	5·4	2·3	11·4	4·8	17·4	7·4
55	6 28·8	6 29·8	6 11·0	5·5	2·3	11·5	4·9	17·5	7·4
56	6 29·0	6 30·1	6 11·3	5·6	2·4	11·6	4·9	17·6	7·5
57	6 29·3	6 30·3	6 11·5	5·7	2·4	11·7	5·0	17·7	7·5
58	6 29·5	6 30·6	6 11·8	5·8	2·5	11·8	5·0	17·8	7·6
59	6 29·8	6 30·8	6 12·0	5·9	2·5	11·9	5·1	17·9	7·6
60	6 30·0	6 31·1	6 12·2	6·0	2·6	12·0	5·1	18·0	7·7

26m INCREMENTS AND CORRECTIONS 27m

26m	SUN PLANETS	ARIES	MOON	v or Corr^n d	v or Corr^n d	v or Corr^n d	v or Corr^n d
s	° ′	° ′	° ′	′	′	′	′
00	6 30·0	6 31·1	6 12·2	0·0	0·0	6·0	2·7	12·0	5·3
01	6 30·3	6 31·3	6 12·5	0·1	0·0	6·1	2·7	12·1	5·3
02	6 30·5	6 31·6	6 12·7	0·2	0·1	6·2	2·7	12·2	5·4
03	6 30·8	6 31·8	6 12·9	0·3	0·1	6·3	2·8	12·3	5·4
04	6 31·0	6 32·1	6 13·2	0·4	0·2	6·4	2·8	12·4	5·5
05	6 31·3	6 32·3	6 13·4	0·5	0·2	6·5	2·9	12·5	5·5
06	6 31·5	6 32·6	6 13·7	0·6	0·3	6·6	2·9	12·6	5·6
07	6 31·8	6 32·8	6 13·9	0·7	0·3	6·7	3·0	12·7	5·6
08	6 32·0	6 33·1	6 14·1	0·8	0·4	6·8	3·0	12·8	5·7
09	6 32·3	6 33·3	6 14·4	0·9	0·4	6·9	3·0	12·9	5·7
10	6 32·5	6 33·6	6 14·6	1·0	0·4	7·0	3·1	13·0	5·7
11	6 32·8	6 33·8	6 14·9	1·1	0·5	7·1	3·1	13·1	5·8
12	6 33·0	6 34·1	6 15·1	1·2	0·5	7·2	3·2	13·2	5·8
13	6 33·3	6 34·3	6 15·3	1·3	0·6	7·3	3·2	13·3	5·9
14	6 33·5	6 34·6	6 15·6	1·4	0·6	7·4	3·3	13·4	5·9
15	6 33·8	6 34·8	6 15·8	1·5	0·7	7·5	3·3	13·5	6·0
16	6 34·0	6 35·1	6 16·1	1·6	0·7	7·6	3·4	13·6	6·0
17	6 34·3	6 35·3	6 16·3	1·7	0·8	7·7	3·4	13·7	6·1
18	6 34·5	6 35·6	6 16·5	1·8	0·8	7·8	3·4	13·8	6·1
19	6 34·8	6 35·8	6 16·8	1·9	0·8	7·9	3·5	13·9	6·1
20	6 35·0	6 36·1	6 17·0	2·0	0·9	8·0	3·5	14·0	6·2
21	6 35·3	6 36·3	6 17·2	2·1	0·9	8·1	3·6	14·1	6·2
22	6 35·5	6 36·6	6 17·5	2·2	1·0	8·2	3·6	14·2	6·3
23	6 35·8	6 36·8	6 17·7	2·3	1·0	8·3	3·7	14·3	6·3
24	6 36·0	6 37·1	6 18·0	2·4	1·1	8·4	3·7	14·4	6·4
25	6 36·3	6 37·3	6 18·2	2·5	1·1	8·5	3·8	14·5	6·4
26	6 36·5	6 37·6	6 18·4	2·6	1·1	8·6	3·8	14·6	6·4
27	6 36·8	6 37·8	6 18·7	2·7	1·2	8·7	3·8	14·7	6·5
28	6 37·0	6 38·1	6 18·9	2·8	1·2	8·8	3·9	14·8	6·5
29	6 37·3	6 38·3	6 19·2	2·9	1·3	8·9	3·9	14·9	6·6
30	6 37·5	6 38·6	6 19·4	3·0	1·3	9·0	4·0	15·0	6·6
31	6 37·8	6 38·8	6 19·6	3·1	1·4	9·1	4·0	15·1	6·7
32	6 38·0	6 39·1	6 19·9	3·2	1·4	9·2	4·1	15·2	6·7
33	6 38·3	6 39·3	6 20·1	3·3	1·5	9·3	4·1	15·3	6·8
34	6 38·5	6 39·6	6 20·3	3·4	1·5	9·4	4·2	15·4	6·8
35	6 38·8	6 39·8	6 20·6	3·5	1·5	9·5	4·2	15·5	6·8
36	6 39·0	6 40·1	6 20·8	3·6	1·6	9·6	4·2	15·6	6·9
37	6 39·3	6 40·3	6 21·1	3·7	1·6	9·7	4·3	15·7	6·9
38	6 39·5	6 40·6	6 21·3	3·8	1·7	9·8	4·3	15·8	7·0
39	6 39·8	6 40·8	6 21·5	3·9	1·7	9·9	4·4	15·9	7·0
40	6 40·0	6 41·1	6 21·8	4·0	1·8	10·0	4·4	16·0	7·1
41	6 40·3	6 41·3	6 22·0	4·1	1·8	10·1	4·5	16·1	7·1
42	6 40·5	6 41·6	6 22·3	4·2	1·9	10·2	4·5	16·2	7·2
43	6 40·8	6 41·8	6 22·5	4·3	1·9	10·3	4·5	16·3	7·2
44	6 41·0	6 42·1	6 22·7	4·4	1·9	10·4	4·6	16·4	7·2
45	6 41·3	6 42·3	6 23·0	4·5	2·0	10·5	4·6	16·5	7·3
46	6 41·5	6 42·6	6 23·2	4·6	2·0	10·6	4·7	16·6	7·3
47	6 41·8	6 42·8	6 23·4	4·7	2·1	10·7	4·7	16·7	7·4
48	6 42·0	6 43·1	6 23·7	4·8	2·1	10·8	4·8	16·8	7·4
49	6 42·3	6 43·4	6 23·9	4·9	2·2	10·9	4·8	16·9	7·5
50	6 42·5	6 43·6	6 24·2	5·0	2·2	11·0	4·9	17·0	7·5
51	6 42·8	6 43·9	6 24·4	5·1	2·3	11·1	4·9	17·1	7·6
52	6 43·0	6 44·1	6 24·6	5·2	2·3	11·2	4·9	17·2	7·6
53	6 43·3	6 44·4	6 24·9	5·3	2·3	11·3	5·0	17·3	7·6
54	6 43·5	6 44·6	6 25·1	5·4	2·4	11·4	5·0	17·4	7·7
55	6 43·8	6 44·9	6 25·4	5·5	2·4	11·5	5·1	17·5	7·7
56	6 44·0	6 45·1	6 25·6	5·6	2·5	11·6	5·1	17·6	7·8
57	6 44·3	6 45·4	6 25·8	5·7	2·5	11·7	5·2	17·7	7·8
58	6 44·5	6 45·6	6 26·1	5·8	2·6	11·8	5·2	17·8	7·9
59	6 44·8	6 45·9	6 26·3	5·9	2·6	11·9	5·3	17·9	7·9
60	6 45·0	6 46·1	6 26·6	6·0	2·7	12·0	5·3	18·0	8·0

27m	SUN PLANETS	ARIES	MOON	v or Corr^n d	v or Corr^n d	v or Corr^n d	v or Corr^n d
s	° ′	° ′	° ′	′	′	′	′
00	6 45·0	6 46·1	6 26·6	0·0	0·0	6·0	2·8	12·0	5·5
01	6 45·3	6 46·4	6 26·8	0·1	0·0	6·1	2·8	12·1	5·5
02	6 45·5	6 46·6	6 27·0	0·2	0·1	6·2	2·8	12·2	5·6
03	6 45·8	6 46·9	6 27·3	0·3	0·1	6·3	2·9	12·3	5·6
04	6 46·0	6 47·1	6 27·5	0·4	0·2	6·4	2·9	12·4	5·7
05	6 46·3	6 47·4	6 27·7	0·5	0·2	6·5	3·0	12·5	5·7
06	6 46·5	6 47·6	6 28·0	0·6	0·3	6·6	3·0	12·6	5·8
07	6 46·8	6 47·9	6 28·2	0·7	0·3	6·7	3·1	12·7	5·8
08	6 47·0	6 48·1	6 28·5	0·8	0·4	6·8	3·1	12·8	5·9
09	6 47·3	6 48·4	6 28·7	0·9	0·4	6·9	3·2	12·9	5·9
10	6 47·5	6 48·6	6 28·9	1·0	0·5	7·0	3·2	13·0	6·0
11	6 47·8	6 48·9	6 29·2	1·1	0·5	7·1	3·3	13·1	6·0
12	6 48·0	6 49·1	6 29·4	1·2	0·6	7·2	3·3	13·2	6·1
13	6 48·3	6 49·4	6 29·7	1·3	0·6	7·3	3·3	13·3	6·1
14	6 48·5	6 49·6	6 29·9	1·4	0·6	7·4	3·4	13·4	6·1
15	6 48·8	6 49·9	6 30·1	1·5	0·7	7·5	3·4	13·5	6·2
16	6 49·0	6 50·1	6 30·4	1·6	0·7	7·6	3·5	13·6	6·2
17	6 49·3	6 50·4	6 30·6	1·7	0·8	7·7	3·5	13·7	6·3
18	6 49·5	6 50·6	6 30·8	1·8	0·8	7·8	3·6	13·8	6·3
19	6 49·8	6 50·9	6 31·1	1·9	0·9	7·9	3·6	13·9	6·4
20	6 50·0	6 51·1	6 31·3	2·0	0·9	8·0	3·7	14·0	6·4
21	6 50·3	6 51·4	6 31·6	2·1	1·0	8·1	3·7	14·1	6·5
22	6 50·5	6 51·6	6 31·8	2·2	1·0	8·2	3·8	14·2	6·5
23	6 50·8	6 51·9	6 32·0	2·3	1·1	8·3	3·8	14·3	6·6
24	6 51·0	6 52·1	6 32·3	2·4	1·1	8·4	3·9	14·4	6·6
25	6 51·3	6 52·4	6 32·5	2·5	1·1	8·5	3·9	14·5	6·6
26	6 51·5	6 52·6	6 32·8	2·6	1·2	8·6	3·9	14·6	6·7
27	6 51·8	6 52·9	6 33·0	2·7	1·2	8·7	4·0	14·7	6·7
28	6 52·0	6 53·1	6 33·2	2·8	1·3	8·8	4·0	14·8	6·8
29	6 52·3	6 53·4	6 33·5	2·9	1·3	8·9	4·1	14·9	6·8
30	6 52·5	6 53·6	6 33·7	3·0	1·4	9·0	4·1	15·0	6·9
31	6 52·8	6 53·9	6 33·9	3·1	1·4	9·1	4·2	15·1	6·9
32	6 53·0	6 54·1	6 34·2	3·2	1·5	9·2	4·2	15·2	7·0
33	6 53·3	6 54·4	6 34·4	3·3	1·5	9·3	4·3	15·3	7·0
34	6 53·5	6 54·6	6 34·7	3·4	1·6	9·4	4·3	15·4	7·1
35	6 53·8	6 54·9	6 34·9	3·5	1·6	9·5	4·4	15·5	7·1
36	6 54·0	6 55·1	6 35·1	3·6	1·7	9·6	4·4	15·6	7·2
37	6 54·3	6 55·4	6 35·4	3·7	1·7	9·7	4·4	15·7	7·2
38	6 54·5	6 55·6	6 35·6	3·8	1·7	9·8	4·5	15·8	7·2
39	6 54·8	6 55·9	6 35·9	3·9	1·8	9·9	4·5	15·9	7·3
40	6 55·0	6 56·1	6 36·1	4·0	1·8	10·0	4·6	16·0	7·3
41	6 55·3	6 56·4	6 36·3	4·1	1·9	10·1	4·6	16·1	7·4
42	6 55·5	6 56·6	6 36·6	4·2	1·9	10·2	4·7	16·2	7·4
43	6 55·8	6 56·9	6 36·8	4·3	2·0	10·3	4·7	16·3	7·5
44	6 56·0	6 57·1	6 37·0	4·4	2·0	10·4	4·8	16·4	7·5
45	6 56·3	6 57·4	6 37·3	4·5	2·1	10·5	4·8	16·5	7·6
46	6 56·5	6 57·6	6 37·5	4·6	2·1	10·6	4·9	16·6	7·6
47	6 56·8	6 57·9	6 37·8	4·7	2·2	10·7	4·9	16·7	7·7
48	6 57·0	6 58·1	6 38·0	4·8	2·2	10·8	5·0	16·8	7·7
49	6 57·3	6 58·4	6 38·2	4·9	2·2	10·9	5·0	16·9	7·7
50	6 57·5	6 58·6	6 38·5	5·0	2·3	11·0	5·0	17·0	7·8
51	6 57·8	6 58·9	6 38·7	5·1	2·3	11·1	5·1	17·1	7·8
52	6 58·0	6 59·1	6 39·0	5·2	2·4	11·2	5·1	17·2	7·9
53	6 58·3	6 59·4	6 39·2	5·3	2·4	11·3	5·2	17·3	7·9
54	6 58·5	6 59·6	6 39·4	5·4	2·5	11·4	5·2	17·4	8·0
55	6 58·8	6 59·9	6 39·7	5·5	2·5	11·5	5·3	17·5	8·0
56	6 59·0	7 00·1	6 39·9	5·6	2·6	11·6	5·3	17·6	8·1
57	6 59·3	7 00·4	6 40·2	5·7	2·6	11·7	5·4	17·7	8·1
58	6 59·5	7 00·6	6 40·4	5·8	2·7	11·8	5·4	17·8	8·2
59	6 59·8	7 00·9	6 40·6	5·9	2·7	11·9	5·5	17·9	8·2
60	7 00·0	7 01·1	6 40·9	6·0	2·8	12·0	5·5	18·0	8·3

28m INCREMENTS AND CORRECTIONS 29m

28m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	7 00·0	7 01·1	6 40·9	0·0	0·0	6·0	2·9	12·0	5·7
01	7 00·3	7 01·4	6 41·1	0·1	0·0	6·1	2·9	12·1	5·7
02	7 00·5	7 01·7	6 41·3	0·2	0·1	6·2	2·9	12·2	5·8
03	7 00·8	7 01·9	6 41·6	0·3	0·1	6·3	3·0	12·3	5·8
04	7 01·0	7 02·2	6 41·8	0·4	0·2	6·4	3·0	12·4	5·9
05	7 01·3	7 02·4	6 42·1	0·5	0·2	6·5	3·1	12·5	5·9
06	7 01·5	7 02·7	6 42·3	0·6	0·3	6·6	3·1	12·6	6·0
07	7 01·8	7 02·9	6 42·5	0·7	0·3	6·7	3·2	12·7	6·0
08	7 02·0	7 03·2	6 42·8	0·8	0·4	6·8	3·2	12·8	6·1
09	7 02·3	7 03·4	6 43·0	0·9	0·4	6·9	3·3	12·9	6·1
10	7 02·5	7 03·7	6 43·3	1·0	0·5	7·0	3·3	13·0	6·2
11	7 02·8	7 03·9	6 43·5	1·1	0·5	7·1	3·4	13·1	6·2
12	7 03·0	7 04·2	6 43·7	1·2	0·6	7·2	3·4	13·2	6·3
13	7 03·3	7 04·4	6 44·0	1·3	0·6	7·3	3·5	13·3	6·3
14	7 03·5	7 04·7	6 44·2	1·4	0·7	7·4	3·5	13·4	6·4
15	7 03·8	7 04·9	6 44·4	1·5	0·7	7·5	3·6	13·5	6·4
16	7 04·0	7 05·2	6 44·7	1·6	0·8	7·6	3·6	13·6	6·5
17	7 04·3	7 05·4	6 44·9	1·7	0·8	7·7	3·7	13·7	6·5
18	7 04·5	7 05·7	6 45·2	1·8	0·9	7·8	3·7	13·8	6·6
19	7 04·8	7 05·9	6 45·4	1·9	0·9	7·9	3·8	13·9	6·6
20	7 05·0	7 06·2	6 45·6	2·0	1·0	8·0	3·8	14·0	6·7
21	7 05·3	7 06·4	6 45·9	2·1	1·0	8·1	3·8	14·1	6·7
22	7 05·5	7 06·7	6 46·1	2·2	1·0	8·2	3·9	14·2	6·7
23	7 05·8	7 06·9	6 46·4	2·3	1·1	8·3	3·9	14·3	6·8
24	7 06·0	7 07·2	6 46·6	2·4	1·1	8·4	4·0	14·4	6·8
25	7 06·3	7 07·4	6 46·8	2·5	1·2	8·5	4·0	14·5	6·9
26	7 06·5	7 07·7	6 47·1	2·6	1·2	8·6	4·1	14·6	6·9
27	7 06·8	7 07·9	6 47·3	2·7	1·3	8·7	4·1	14·7	7·0
28	7 07·0	7 08·2	6 47·5	2·8	1·3	8·8	4·2	14·8	7·0
29	7 07·3	7 08·4	6 47·8	2·9	1·4	8·9	4·2	14·9	7·1
30	7 07·5	7 08·7	6 48·0	3·0	1·4	9·0	4·3	15·0	7·1
31	7 07·8	7 08·9	6 48·3	3·1	1·5	9·1	4·3	15·1	7·2
32	7 08·0	7 09·2	6 48·5	3·2	1·5	9·2	4·4	15·2	7·2
33	7 08·3	7 09·4	6 48·7	3·3	1·6	9·3	4·4	15·3	7·3
34	7 08·5	7 09·7	6 49·0	3·4	1·6	9·4	4·5	15·4	7·3
35	7 08·8	7 09·9	6 49·2	3·5	1·7	9·5	4·5	15·5	7·4
36	7 09·0	7 10·2	6 49·5	3·6	1·7	9·6	4·6	15·6	7·4
37	7 09·3	7 10·4	6 49·7	3·7	1·8	9·7	4·6	15·7	7·5
38	7 09·5	7 10·7	6 49·9	3·8	1·8	9·8	4·7	15·8	7·5
39	7 09·8	7 10·9	6 50·2	3·9	1·9	9·9	4·7	15·9	7·6
40	7 10·0	7 11·2	6 50·4	4·0	1·9	10·0	4·8	16·0	7·6
41	7 10·3	7 11·4	6 50·6	4·1	1·9	10·1	4·8	16·1	7·6
42	7 10·5	7 11·7	6 50·9	4·2	2·0	10·2	4·8	16·2	7·7
43	7 10·8	7 11·9	6 51·1	4·3	2·0	10·3	4·9	16·3	7·7
44	7 11·0	7 12·2	6 51·4	4·4	2·1	10·4	4·9	16·4	7·8
45	7 11·3	7 12·4	6 51·6	4·5	2·1	10·5	5·0	16·5	7·8
46	7 11·5	7 12·7	6 51·8	4·6	2·2	10·6	5·0	16·6	7·9
47	7 11·8	7 12·9	6 52·1	4·7	2·2	10·7	5·1	16·7	7·9
48	7 12·0	7 13·2	6 52·3	4·8	2·3	10·8	5·1	16·8	8·0
49	7 12·3	7 13·4	6 52·6	4·9	2·3	10·9	5·2	16·9	8·0
50	7 12·5	7 13·7	6 52·8	5·0	2·4	11·0	5·2	17·0	8·1
51	7 12·8	7 13·9	6 53·0	5·1	2·4	11·1	5·3	17·1	8·1
52	7 13·0	7 14·2	6 53·3	5·2	2·5	11·2	5·3	17·2	8·2
53	7 13·3	7 14·4	6 53·5	5·3	2·5	11·3	5·4	17·3	8·2
54	7 13·5	7 14·7	6 53·8	5·4	2·6	11·4	5·4	17·4	8·3
55	7 13·8	7 14·9	6 54·0	5·5	2·6	11·5	5·5	17·5	8·3
56	7 14·0	7 15·2	6 54·2	5·6	2·7	11·6	5·5	17·6	8·4
57	7 14·3	7 15·4	6 54·5	5·7	2·7	11·7	5·6	17·7	8·4
58	7 14·5	7 15·7	6 54·7	5·8	2·8	11·8	5·6	17·8	8·5
59	7 14·8	7 15·9	6 54·9	5·9	2·8	11·9	5·7	17·9	8·5
60	7 15·0	7 16·2	6 55·2	6·0	2·9	12·0	5·7	18·0	8·6

29m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	7 15·0	7 16·2	6 55·2	0·0	0·0	6·0	3·0	12·0	5·9
01	7 15·3	7 16·4	6 55·4	0·1	0·0	6·1	3·0	12·1	5·9
02	7 15·5	7 16·7	6 55·7	0·2	0·1	6·2	3·0	12·2	6·0
03	7 15·8	7 16·9	6 55·9	0·3	0·1	6·3	3·1	12·3	6·0
04	7 16·0	7 17·2	6 56·1	0·4	0·2	6·4	3·1	12·4	6·1
05	7 16·3	7 17·4	6 56·4	0·5	0·2	6·5	3·2	12·5	6·1
06	7 16·5	7 17·7	6 56·6	0·6	0·3	6·6	3·2	12·6	6·2
07	7 16·8	7 17·9	6 56·9	0·7	0·3	6·7	3·3	12·7	6·2
08	7 17·0	7 18·2	6 57·1	0·8	0·4	6·8	3·3	12·8	6·3
09	7 17·3	7 18·4	6 57·3	0·9	0·4	6·9	3·4	12·9	6·3
10	7 17·5	7 18·7	6 57·6	1·0	0·5	7·0	3·4	13·0	6·4
11	7 17·8	7 18·9	6 57·8	1·1	0·5	7·1	3·5	13·1	6·4
12	7 18·0	7 19·2	6 58·0	1·2	0·6	7·2	3·5	13·2	6·5
13	7 18·3	7 19·4	6 58·3	1·3	0·6	7·3	3·6	13·3	6·5
14	7 18·5	7 19·7	6 58·5	1·4	0·7	7·4	3·6	13·4	6·6
15	7 18·8	7 20·0	6 58·8	1·5	0·7	7·5	3·7	13·5	6·6
16	7 19·0	7 20·2	6 59·0	1·6	0·8	7·6	3·7	13·6	6·7
17	7 19·3	7 20·5	6 59·2	1·7	0·8	7·7	3·8	13·7	6·7
18	7 19·5	7 20·7	6 59·5	1·8	0·9	7·8	3·8	13·8	6·8
19	7 19·8	7 21·0	6 59·7	1·9	0·9	7·9	3·9	13·9	6·8
20	7 20·0	7 21·2	7 00·0	2·0	1·0	8·0	3·9	14·0	6·9
21	7 20·3	7 21·5	7 00·2	2·1	1·0	8·1	4·0	14·1	6·9
22	7 20·5	7 21·7	7 00·4	2·2	1·1	8·2	4·0	14·2	7·0
23	7 20·8	7 22·0	7 00·7	2·3	1·1	8·3	4·1	14·3	7·0
24	7 21·0	7 22·2	7 00·9	2·4	1·2	8·4	4·1	14·4	7·1
25	7 21·3	7 22·5	7 01·1	2·5	1·2	8·5	4·2	14·5	7·1
26	7 21·5	7 22·7	7 01·4	2·6	1·3	8·6	4·2	14·6	7·2
27	7 21·8	7 23·0	7 01·6	2·7	1·3	8·7	4·3	14·7	7·2
28	7 22·0	7 23·2	7 01·9	2·8	1·4	8·8	4·3	14·8	7·3
29	7 22·3	7 23·5	7 02·1	2·9	1·4	8·9	4·4	14·9	7·3
30	7 22·5	7 23·7	7 02·3	3·0	1·5	9·0	4·4	15·0	7·4
31	7 22·8	7 24·0	7 02·6	3·1	1·5	9·1	4·5	15·1	7·4
32	7 23·0	7 24·2	7 02·8	3·2	1·6	9·2	4·5	15·2	7·5
33	7 23·3	7 24·5	7 03·1	3·3	1·6	9·3	4·6	15·3	7·5
34	7 23·5	7 24·7	7 03·3	3·4	1·7	9·4	4·6	15·4	7·6
35	7 23·8	7 25·0	7 03·5	3·5	1·7	9·5	4·7	15·5	7·6
36	7 24·0	7 25·2	7 03·8	3·6	1·8	9·6	4·7	15·6	7·7
37	7 24·3	7 25·5	7 04·0	3·7	1·8	9·7	4·8	15·7	7·7
38	7 24·5	7 25·7	7 04·3	3·8	1·9	9·8	4·8	15·8	7·8
39	7 24·8	7 26·0	7 04·5	3·9	1·9	9·9	4·9	15·9	7·8
40	7 25·0	7 26·2	7 04·7	4·0	2·0	10·0	4·9	16·0	7·9
41	7 25·3	7 26·5	7 05·0	4·1	2·0	10·1	5·0	16·1	7·9
42	7 25·5	7 26·7	7 05·2	4·2	2·1	10·2	5·0	16·2	8·0
43	7 25·8	7 27·0	7 05·4	4·3	2·1	10·3	5·1	16·3	8·0
44	7 26·0	7 27·2	7 05·7	4·4	2·2	10·4	5·1	16·4	8·1
45	7 26·3	7 27·5	7 05·9	4·5	2·2	10·5	5·2	16·5	8·1
46	7 26·5	7 27·7	7 06·2	4·6	2·3	10·6	5·2	16·6	8·2
47	7 26·8	7 28·0	7 06·4	4·7	2·3	10·7	5·3	16·7	8·2
48	7 27·0	7 28·2	7 06·6	4·8	2·4	10·8	5·3	16·8	8·3
49	7 27·3	7 28·5	7 06·9	4·9	2·4	10·9	5·4	16·9	8·3
50	7 27·5	7 28·7	7 07·1	5·0	2·5	11·0	5·4	17·0	8·4
51	7 27·8	7 29·0	7 07·4	5·1	2·5	11·1	5·5	17·1	8·4
52	7 28·0	7 29·2	7 07·6	5·2	2·6	11·2	5·5	17·2	8·5
53	7 28·3	7 29·5	7 07·8	5·3	2·6	11·3	5·6	17·3	8·5
54	7 28·5	7 29·7	7 08·1	5·4	2·7	11·4	5·6	17·4	8·6
55	7 28·8	7 30·0	7 08·3	5·5	2·7	11·5	5·7	17·5	8·6
56	7 29·0	7 30·2	7 08·5	5·6	2·8	11·6	5·7	17·6	8·7
57	7 29·3	7 30·5	7 08·8	5·7	2·8	11·7	5·8	17·7	8·7
58	7 29·5	7 30·7	7 09·0	5·8	2·9	11·8	5·8	17·8	8·8
59	7 29·8	7 31·0	7 09·3	5·9	2·9	11·9	5·9	17·9	8·8
60	7 30·0	7 31·2	7 09·5	6·0	3·0	12·0	5·9	18·0	8·9

30	SUN PLANETS	ARIES	MOON	v or Corr n d		v or Corr n d		v or Corr n d	
s	° ′	° ′	° ′	′	′	′	′	′	′
00	7 30·0	7 31·2	7 09·5	0·0	0·0	6·0	3·1	12·0	6·1
01	7 30·3	7 31·5	7 09·7	0·1	0·1	6·1	3·1	12·1	6·2
02	7 30·5	7 31·7	7 10·0	0·2	0·1	6·2	3·2	12·2	6·2
03	7 30·8	7 32·0	7 10·2	0·3	0·2	6·3	3·2	12·3	6·3
04	7 31·0	7 32·2	7 10·5	0·4	0·2	6·4	3·3	12·4	6·3
05	7 31·3	7 32·5	7 10·7	0·5	0·3	6·5	3·3	12·5	6·4
06	7 31·5	7 32·7	7 10·9	0·6	0·3	6·6	3·4	12·6	6·4
07	7 31·8	7 33·0	7 11·2	0·7	0·4	6·7	3·4	12·7	6·5
08	7 32·0	7 33·2	7 11·4	0·8	0·4	6·8	3·5	12·8	6·5
09	7 32·3	7 33·5	7 11·6	0·9	0·5	6·9	3·5	12·9	6·6
10	7 32·5	7 33·7	7 11·9	1·0	0·5	7·0	3·6	13·0	6·6
11	7 32·8	7 34·0	7 12·1	1·1	0·6	7·1	3·6	13·1	6·7
12	7 33·0	7 34·2	7 12·4	1·2	0·6	7·2	3·7	13·2	6·7
13	7 33·3	7 34·5	7 12·6	1·3	0·7	7·3	3·7	13·3	6·8
14	7 33·5	7 34·7	7 12·8	1·4	0·7	7·4	3·8	13·4	6·8
15	7 33·8	7 35·0	7 13·1	1·5	0·8	7·5	3·8	13·5	6·9
16	7 34·0	7 35·2	7 13·3	1·6	0·8	7·6	3·9	13·6	6·9
17	7 34·3	7 35·5	7 13·6	1·7	0·9	7·7	3·9	13·7	7·0
18	7 34·5	7 35·7	7 13·8	1·8	0·9	7·8	4·0	13·8	7·0
19	7 34·8	7 36·0	7 14·0	1·9	1·0	7·9	4·0	13·9	7·1
20	7 35·0	7 36·2	7 14·3	2·0	1·0	8·0	4·1	14·0	7·1
21	7 35·3	7 36·5	7 14·5	2·1	1·1	8·1	4·1	14·1	7·2
22	7 35·5	7 36·7	7 14·7	2·2	1·1	8·2	4·2	14·2	7·2
23	7 35·8	7 37·0	7 15·0	2·3	1·2	8·3	4·2	14·3	7·3
24	7 36·0	7 37·2	7 15·2	2·4	1·2	8·4	4·3	14·4	7·3
25	7 36·3	7 37·5	7 15·5	2·5	1·3	8·5	4·3	14·5	7·4
26	7 36·5	7 37·7	7 15·7	2·6	1·3	8·6	4·4	14·6	7·4
27	7 36·8	7 38·0	7 15·9	2·7	1·4	8·7	4·4	14·7	7·5
28	7 37·0	7 38·3	7 16·2	2·8	1·4	8·8	4·5	14·8	7·5
29	7 37·3	7 38·5	7 16·4	2·9	1·5	8·9	4·5	14·9	7·6
30	7 37·5	7 38·8	7 16·7	3·0	1·5	9·0	4·6	15·0	7·6
31	7 37·8	7 39·0	7 16·9	3·1	1·6	9·1	4·6	15·1	7·7
32	7 38·0	7 39·3	7 17·1	3·2	1·6	9·2	4·7	15·2	7·7
33	7 38·3	7 39·5	7 17·4	3·3	1·7	9·3	4·7	15·3	7·8
34	7 38·5	7 39·8	7 17·6	3·4	1·7	9·4	4·8	15·4	7·8
35	7 38·8	7 40·0	7 17·9	3·5	1·8	9·5	4·8	15·5	7·9
36	7 39·0	7 40·3	7 18·1	3·6	1·8	9·6	4·9	15·6	7·9
37	7 39·3	7 40·5	7 18·3	3·7	1·9	9·7	4·9	15·7	8·0
38	7 39·5	7 40·8	7 18·6	3·8	1·9	9·8	5·0	15·8	8·0
39	7 39·8	7 41·0	7 18·8	3·9	2·0	9·9	5·0	15·9	8·1
40	7 40·0	7 41·3	7 19·0	4·0	2·0	10·0	5·1	16·0	8·1
41	7 40·3	7 41·5	7 19·3	4·1	2·1	10·1	5·1	16·1	8·2
42	7 40·5	7 41·8	7 19·5	4·2	2·1	10·2	5·2	16·2	8·2
43	7 40·8	7 42·0	7 19·8	4·3	2·2	10·3	5·2	16·3	8·3
44	7 41·0	7 42·3	7 20·0	4·4	2·2	10·4	5·3	16·4	8·3
45	7 41·3	7 42·5	7 20·2	4·5	2·3	10·5	5·3	16·5	8·4
46	7 41·5	7 42·8	7 20·5	4·6	2·3	10·6	5·4	16·6	8·4
47	7 41·8	7 43·0	7 20·7	4·7	2·4	10·7	5·4	16·7	8·5
48	7 42·0	7 43·3	7 21·0	4·8	2·4	10·8	5·5	16·8	8·5
49	7 42·3	7 43·5	7 21·2	4·9	2·5	10·9	5·5	16·9	8·6
50	7 42·5	7 43·8	7 21·4	5·0	2·5	11·0	5·6	17·0	8·6
51	7 42·8	7 44·0	7 21·7	5·1	2·6	11·1	5·6	17·1	8·7
52	7 43·0	7 44·3	7 21·9	5·2	2·6	11·2	5·7	17·2	8·7
53	7 43·3	7 44·5	7 22·1	5·3	2·7	11·3	5·7	17·3	8·8
54	7 43·5	7 44·8	7 22·4	5·4	2·7	11·4	5·8	17·4	8·8
55	7 43·8	7 45·0	7 22·6	5·5	2·8	11·5	5·8	17·5	8·9
56	7 44·0	7 45·3	7 22·9	5·6	2·8	11·6	5·9	17·6	8·9
57	7 44·3	7 45·5	7 23·1	5·7	2·9	11·7	5·9	17·7	9·0
58	7 44·5	7 45·8	7 23·3	5·8	2·9	11·8	6·0	17·8	9·0
59	7 44·8	7 46·0	7 23·6	5·9	3·0	11·9	6·0	17·9	9·1
60	7 45·0	7 46·3	7 23·8	6·0	3·1	12·0	6·1	18·0	9·2

31	SUN PLANETS	ARIES	MOON	v or Corr n d		v or Corr n d		v or Corr n d	
s	° ′	° ′	° ′	′	′	′	′	′	′
00	7 45·0	7 46·3	7 23·8	0·0	0·0	6·0	3·2	12·0	6·3
01	7 45·3	7 46·5	7 24·1	0·1	0·1	6·1	3·2	12·1	6·4
02	7 45·5	7 46·8	7 24·3	0·2	0·1	6·2	3·3	12·2	6·4
03	7 45·8	7 47·0	7 24·5	0·3	0·2	6·3	3·3	12·3	6·5
04	7 46·0	7 47·3	7 24·8	0·4	0·2	6·4	3·4	12·4	6·5
05	7 46·3	7 47·5	7 25·0	0·5	0·3	6·5	3·4	12·5	6·6
06	7 46·5	7 47·8	7 25·2	0·6	0·3	6·6	3·5	12·6	6·6
07	7 46·8	7 48·0	7 25·5	0·7	0·4	6·7	3·5	12·7	6·7
08	7 47·0	7 48·3	7 25·7	0·8	0·4	6·8	3·6	12·8	6·7
09	7 47·3	7 48·5	7 26·0	0·9	0·5	6·9	3·6	12·9	6·8
10	7 47·5	7 48·8	7 26·2	1·0	0·5	7·0	3·7	13·0	6·8
11	7 47·8	7 49·0	7 26·4	1·1	0·6	7·1	3·7	13·1	6·9
12	7 48·0	7 49·3	7 26·7	1·2	0·6	7·2	3·8	13·2	6·9
13	7 48·3	7 49·5	7 26·9	1·3	0·7	7·3	3·8	13·3	7·0
14	7 48·5	7 49·8	7 27·2	1·4	0·7	7·4	3·9	13·4	7·0
15	7 48·8	7 50·0	7 27·4	1·5	0·8	7·5	3·9	13·5	7·1
16	7 49·0	7 50·3	7 27·6	1·6	0·8	7·6	4·0	13·6	7·1
17	7 49·3	7 50·5	7 27·9	1·7	0·9	7·7	4·0	13·7	7·2
18	7 49·5	7 50·8	7 28·1	1·8	0·9	7·8	4·1	13·8	7·2
19	7 49·8	7 51·0	7 28·4	1·9	1·0	7·9	4·1	13·9	7·3
20	7 50·0	7 51·3	7 28·6	2·0	1·1	8·0	4·2	14·0	7·4
21	7 50·3	7 51·5	7 28·8	2·1	1·1	8·1	4·3	14·1	7·4
22	7 50·5	7 51·8	7 29·1	2·2	1·2	8·2	4·3	14·2	7·5
23	7 50·8	7 52·0	7 29·3	2·3	1·2	8·3	4·4	14·3	7·5
24	7 51·0	7 52·3	7 29·5	2·4	1·3	8·4	4·4	14·4	7·6
25	7 51·3	7 52·5	7 29·8	2·5	1·3	8·5	4·5	14·5	7·6
26	7 51·5	7 52·8	7 30·0	2·6	1·4	8·6	4·5	14·6	7·7
27	7 51·8	7 53·0	7 30·3	2·7	1·4	8·7	4·6	14·7	7·7
28	7 52·0	7 53·3	7 30·5	2·8	1·5	8·8	4·6	14·8	7·8
29	7 52·3	7 53·5	7 30·7	2·9	1·5	8·9	4·7	14·9	7·8
30	7 52·5	7 53·8	7 31·0	3·0	1·6	9·0	4·7	15·0	7·9
31	7 52·8	7 54·0	7 31·2	3·1	1·6	9·1	4·8	15·1	7·9
32	7 53·0	7 54·3	7 31·5	3·2	1·7	9·2	4·8	15·2	8·0
33	7 53·3	7 54·5	7 31·7	3·3	1·7	9·3	4·9	15·3	8·0
34	7 53·5	7 54·8	7 31·9	3·4	1·8	9·4	4·9	15·4	8·1
35	7 53·8	7 55·0	7 32·2	3·5	1·8	9·5	5·0	15·5	8·1
36	7 54·0	7 55·3	7 32·4	3·6	1·9	9·6	5·0	15·6	8·2
37	7 54·3	7 55·5	7 32·6	3·7	1·9	9·7	5·1	15·7	8·2
38	7 54·5	7 55·8	7 32·9	3·8	2·0	9·8	5·1	15·8	8·3
39	7 54·8	7 56·0	7 33·1	3·9	2·0	9·9	5·2	15·9	8·3
40	7 55·0	7 56·3	7 33·4	4·0	2·1	10·0	5·3	16·0	8·4
41	7 55·3	7 56·6	7 33·6	4·1	2·2	10·1	5·3	16·1	8·5
42	7 55·5	7 56·8	7 33·8	4·2	2·2	10·2	5·4	16·2	8·5
43	7 55·8	7 57·1	7 34·1	4·3	2·3	10·3	5·4	16·3	8·6
44	7 56·0	7 57·3	7 34·3	4·4	2·3	10·4	5·5	16·4	8·6
45	7 56·3	7 57·6	7 34·6	4·5	2·4	10·5	5·5	16·5	8·7
46	7 56·5	7 57·8	7 34·8	4·6	2·4	10·6	5·6	16·6	8·7
47	7 56·8	7 58·1	7 35·0	4·7	2·5	10·7	5·6	16·7	8·8
48	7 57·0	7 58·3	7 35·3	4·8	2·5	10·8	5·7	16·8	8·8
49	7 57·3	7 58·6	7 35·5	4·9	2·6	10·9	5·7	16·9	8·9
50	7 57·5	7 58·8	7 35·7	5·0	2·6	11·0	5·8	17·0	8·9
51	7 57·8	7 59·1	7 36·0	5·1	2·7	11·1	5·8	17·1	9·0
52	7 58·0	7 59·3	7 36·2	5·2	2·7	11·2	5·9	17·2	9·0
53	7 58·3	7 59·6	7 36·5	5·3	2·8	11·3	5·9	17·3	9·1
54	7 58·5	7 59·8	7 36·7	5·4	2·8	11·4	6·0	17·4	9·1
55	7 58·8	8 00·1	7 36·9	5·5	2·9	11·5	6·0	17·5	9·2
56	7 59·0	8 00·3	7 37·2	5·6	2·9	11·6	6·1	17·6	9·2
57	7 59·3	8 00·6	7 37·4	5·7	3·0	11·7	6·1	17·7	9·3
58	7 59·5	8 00·8	7 37·7	5·8	3·0	11·8	6·2	17·8	9·3
59	7 59·8	8 01·1	7 37·9	5·9	3·1	11·9	6·2	17·9	9·4
60	8 00·0	8 01·3	7 38·1	6·0	3·2	12·0	6·3	18·0	9·5

32m INCREMENTS AND CORRECTIONS 33m

32m	SUN PLANETS	ARIES	MOON	v or Corr^n d		v or Corr^n d		v or Corr^n d	
s	° ′	° ′	° ′	′	′	′	′	′	′
00	8 00·0	8 01·3	7 38·1	0·0	0·0	6·0	3·3	12·0	6·5
01	8 00·3	8 01·6	7 38·4	0·1	0·1	6·1	3·3	12·1	6·6
02	8 00·5	8 01·8	7 38·6	0·2	0·1	6·2	3·4	12·2	6·6
03	8 00·8	8 02·1	7 38·8	0·3	0·2	6·3	3·4	12·3	6·7
04	8 01·0	8 02·3	7 39·1	0·4	0·2	6·4	3·5	12·4	6·7
05	8 01·3	8 02·6	7 39·3	0·5	0·3	6·5	3·5	12·5	6·8
06	8 01·5	8 02·8	7 39·6	0·6	0·3	6·6	3·6	12·6	6·8
07	8 01·8	8 03·1	7 39·8	0·7	0·4	6·7	3·6	12·7	6·9
08	8 02·0	8 03·3	7 40·0	0·8	0·4	6·8	3·7	12·8	6·9
09	8 02·3	8 03·6	7 40·3	0·9	0·5	6·9	3·7	12·9	7·0
10	8 02·5	8 03·8	7 40·5	1·0	0·5	7·0	3·8	13·0	7·0
11	8 02·8	8 04·1	7 40·8	1·1	0·6	7·1	3·8	13·1	7·1
12	8 03·0	8 04·3	7 41·0	1·2	0·7	7·2	3·9	13·2	7·2
13	8 03·3	8 04·6	7 41·2	1·3	0·7	7·3	4·0	13·3	7·2
14	8 03·5	8 04·8	7 41·5	1·4	0·8	7·4	4·0	13·4	7·3
15	8 03·8	8 05·1	7 41·7	1·5	0·8	7·5	4·1	13·5	7·3
16	8 04·0	8 05·3	7 42·0	1·6	0·9	7·6	4·1	13·6	7·4
17	8 04·3	8 05·6	7 42·2	1·7	0·9	7·7	4·2	13·7	7·4
18	8 04·5	8 05·8	7 42·4	1·8	1·0	7·8	4·2	13·8	7·5
19	8 04·8	8 06·1	7 42·7	1·9	1·0	7·9	4·3	13·9	7·5
20	8 05·0	8 06·3	7 42·9	2·0	1·1	8·0	4·3	14·0	7·6
21	8 05·3	8 06·6	7 43·1	2·1	1·1	8·1	4·4	14·1	7·6
22	8 05·5	8 06·8	7 43·4	2·2	1·2	8·2	4·4	14·2	7·7
23	8 05·8	8 07·1	7 43·6	2·3	1·2	8·3	4·5	14·3	7·7
24	8 06·0	8 07·3	7 43·9	2·4	1·3	8·4	4·6	14·4	7·8
25	8 06·3	8 07·6	7 44·1	2·5	1·4	8·5	4·6	14·5	7·9
26	8 06·5	8 07·8	7 44·3	2·6	1·4	8·6	4·7	14·6	7·9
27	8 06·8	8 08·1	7 44·6	2·7	1·5	8·7	4·7	14·7	8·0
28	8 07·0	8 08·3	7 44·8	2·8	1·5	8·8	4·8	14·8	8·0
29	8 07·3	8 08·6	7 45·1	2·9	1·6	8·9	4·8	14·9	8·1
30	8 07·5	8 08·8	7 45·3	3·0	1·6	9·0	4·9	15·0	8·1
31	8 07·8	8 09·1	7 45·5	3·1	1·7	9·1	4·9	15·1	8·2
32	8 08·0	8 09·3	7 45·8	3·2	1·7	9·2	5·0	15·2	8·2
33	8 08·3	8 09·6	7 46·0	3·3	1·8	9·3	5·0	15·3	8·3
34	8 08·5	8 09·8	7 46·2	3·4	1·8	9·4	5·1	15·4	8·3
35	8 08·8	8 10·1	7 46·5	3·5	1·9	9·5	5·1	15·5	8·4
36	8 09·0	8 10·3	7 46·7	3·6	2·0	9·6	5·2	15·6	8·5
37	8 09·3	8 10·6	7 47·0	3·7	2·0	9·7	5·3	15·7	8·5
38	8 09·5	8 10·8	7 47·2	3·8	2·1	9·8	5·3	15·8	8·6
39	8 09·8	8 11·1	7 47·4	3·9	2·1	9·9	5·4	15·9	8·6
40	8 10·0	8 11·3	7 47·7	4·0	2·2	10·0	5·4	16·0	8·7
41	8 10·3	8 11·6	7 47·9	4·1	2·2	10·1	5·5	16·1	8·7
42	8 10·5	8 11·8	7 48·2	4·2	2·3	10·2	5·5	16·2	8·8
43	8 10·8	8 12·1	7 48·4	4·3	2·3	10·3	5·6	16·3	8·8
44	8 11·0	8 12·3	7 48·6	4·4	2·4	10·4	5·6	16·4	8·9
45	8 11·3	8 12·6	7 48·9	4·5	2·4	10·5	5·7	16·5	8·9
46	8 11·5	8 12·8	7 49·1	4·6	2·5	10·6	5·7	16·6	9·0
47	8 11·8	8 13·1	7 49·3	4·7	2·5	10·7	5·8	16·7	9·0
48	8 12·0	8 13·3	7 49·6	4·8	2·6	10·8	5·9	16·8	9·1
49	8 12·3	8 13·6	7 49·8	4·9	2·7	10·9	5·9	16·9	9·2
50	8 12·5	8 13·8	7 50·1	5·0	2·7	11·0	6·0	17·0	9·2
51	8 12·8	8 14·1	7 50·3	5·1	2·8	11·1	6·0	17·1	9·3
52	8 13·0	8 14·3	7 50·5	5·2	2·8	11·2	6·1	17·2	9·3
53	8 13·3	8 14·6	7 50·8	5·3	2·9	11·3	6·1	17·3	9·4
54	8 13·5	8 14·9	7 51·0	5·4	2·9	11·4	6·2	17·4	9·4
55	8 13·8	8 15·1	7 51·3	5·5	3·0	11·5	6·2	17·5	9·5
56	8 14·0	8 15·4	7 51·5	5·6	3·0	11·6	6·3	17·6	9·5
57	8 14·3	8 15·6	7 51·7	5·7	3·1	11·7	6·3	17·7	9·6
58	8 14·5	8 15·9	7 52·0	5·8	3·1	11·8	6·4	17·8	9·6
59	8 14·8	8 16·1	7 52·2	5·9	3·2	11·9	6·4	17·9	9·7
60	8 15·0	8 16·4	7 52·5	6·0	3·3	12·0	6·5	18·0	9·8

33m	SUN PLANETS	ARIES	MOON	v or Corr^n d		v or Corr^n d		v or Corr^n d	
s	° ′	° ′	° ′	′	′	′	′	′	′
00	8 15·0	8 16·4	7 52·5	0·0	0·0	6·0	3·4	12·0	6·7
01	8 15·3	8 16·6	7 52·7	0·1	0·1	6·1	3·4	12·1	6·8
02	8 15·5	8 16·9	7 52·9	0·2	0·1	6·2	3·5	12·2	6·8
03	8 15·8	8 17·1	7 53·2	0·3	0·2	6·3	3·5	12·3	6·9
04	8 16·0	8 17·4	7 53·4	0·4	0·2	6·4	3·6	12·4	6·9
05	8 16·3	8 17·6	7 53·6	0·5	0·3	6·5	3·6	12·5	7·0
06	8 16·5	8 17·9	7 53·9	0·6	0·3	6·6	3·7	12·6	7·0
07	8 16·8	8 18·1	7 54·1	0·7	0·4	6·7	3·7	12·7	7·1
08	8 17·0	8 18·4	7 54·4	0·8	0·4	6·8	3·8	12·8	7·1
09	8 17·3	8 18·6	7 54·6	0·9	0·5	6·9	3·9	12·9	7·2
10	8 17·5	8 18·9	7 54·8	1·0	0·6	7·0	3·9	13·0	7·3
11	8 17·8	8 19·1	7 55·1	1·1	0·6	7·1	4·0	13·1	7·3
12	8 18·0	8 19·4	7 55·3	1·2	0·7	7·2	4·0	13·2	7·4
13	8 18·3	8 19·6	7 55·6	1·3	0·7	7·3	4·1	13·3	7·4
14	8 18·5	8 19·9	7 55·8	1·4	0·8	7·4	4·1	13·4	7·5
15	8 18·8	8 20·1	7 56·0	1·5	0·8	7·5	4·2	13·5	7·5
16	8 19·0	8 20·4	7 56·3	1·6	0·9	7·6	4·2	13·6	7·6
17	8 19·3	8 20·6	7 56·5	1·7	0·9	7·7	4·3	13·7	7·6
18	8 19·5	8 20·9	7 56·7	1·8	1·0	7·8	4·4	13·8	7·7
19	8 19·8	8 21·1	7 57·0	1·9	1·1	7·9	4·4	13·9	7·8
20	8 20·0	8 21·4	7 57·2	2·0	1·1	8·0	4·5	14·0	7·8
21	8 20·3	8 21·6	7 57·5	2·1	1·2	8·1	4·5	14·1	7·9
22	8 20·5	8 21·9	7 57·7	2·2	1·2	8·2	4·6	14·2	7·9
23	8 20·8	8 22·1	7 57·9	2·3	1·3	8·3	4·6	14·3	8·0
24	8 21·0	8 22·4	7 58·2	2·4	1·3	8·4	4·7	14·4	8·0
25	8 21·3	8 22·6	7 58·4	2·5	1·4	8·5	4·7	14·5	8·1
26	8 21·5	8 22·9	7 58·7	2·6	1·5	8·6	4·8	14·6	8·2
27	8 21·8	8 23·1	7 58·9	2·7	1·5	8·7	4·9	14·7	8·2
28	8 22·0	8 23·4	7 59·1	2·8	1·6	8·8	4·9	14·8	8·3
29	8 22·3	8 23·6	7 59·4	2·9	1·6	8·9	5·0	14·9	8·3
30	8 22·5	8 23·9	7 59·6	3·0	1·7	9·0	5·0	15·0	8·4
31	8 22·8	8 24·1	7 59·8	3·1	1·7	9·1	5·1	15·1	8·4
32	8 23·0	8 24·4	8 00·1	3·2	1·8	9·2	5·1	15·2	8·5
33	8 23·3	8 24·6	8 00·3	3·3	1·8	9·3	5·2	15·3	8·5
34	8 23·5	8 24·9	8 00·6	3·4	1·9	9·4	5·2	15·4	8·6
35	8 23·8	8 25·1	8 00·8	3·5	2·0	9·5	5·3	15·5	8·7
36	8 24·0	8 25·4	8 01·0	3·6	2·0	9·6	5·4	15·6	8·7
37	8 24·3	8 25·6	8 01·3	3·7	2·1	9·7	5·4	15·7	8·8
38	8 24·5	8 25·9	8 01·5	3·8	2·1	9·8	5·5	15·8	8·8
39	8 24·8	8 26·1	8 01·8	3·9	2·2	9·9	5·5	15·9	8·9
40	8 25·0	8 26·4	8 02·0	4·0	2·2	10·0	5·6	16·0	8·9
41	8 25·3	8 26·6	8 02·2	4·1	2·3	10·1	5·6	16·1	9·0
42	8 25·5	8 26·9	8 02·5	4·2	2·3	10·2	5·7	16·2	9·0
43	8 25·8	8 27·1	8 02·7	4·3	2·4	10·3	5·8	16·3	9·1
44	8 26·0	8 27·4	8 02·9	4·4	2·5	10·4	5·8	16·4	9·2
45	8 26·3	8 27·6	8 03·2	4·5	2·5	10·5	5·9	16·5	9·2
46	8 26·5	8 27·9	8 03·4	4·6	2·6	10·6	5·9	16·6	9·3
47	8 26·8	8 28·1	8 03·7	4·7	2·6	10·7	6·0	16·7	9·3
48	8 27·0	8 28·4	8 03·9	4·8	2·7	10·8	6·0	16·8	9·4
49	8 27·3	8 28·6	8 04·1	4·9	2·7	10·9	6·1	16·9	9·4
50	8 27·5	8 28·9	8 04·4	5·0	2·8	11·0	6·1	17·0	9·5
51	8 27·8	8 29·1	8 04·6	5·1	2·8	11·1	6·2	17·1	9·5
52	8 28·0	8 29·4	8 04·9	5·2	2·9	11·2	6·3	17·2	9·6
53	8 28·3	8 29·6	8 05·1	5·3	3·0	11·3	6·3	17·3	9·7
54	8 28·5	8 29·9	8 05·3	5·4	3·0	11·4	6·4	17·4	9·7
55	8 28·8	8 30·1	8 05·6	5·5	3·1	11·5	6·4	17·5	9·8
56	8 29·0	8 30·4	8 05·8	5·6	3·1	11·6	6·5	17·6	9·8
57	8 29·3	8 30·6	8 06·1	5·7	3·2	11·7	6·5	17·7	9·9
58	8 29·5	8 30·9	8 06·3	5·8	3·2	11·8	6·6	17·8	9·9
59	8 29·8	8 31·1	8 06·5	5·9	3·3	11·9	6·6	17·9	10·0
60	8 30·0	8 31·4	8 06·8	6·0	3·4	12·0	6·7	18·0	10·1

34m INCREMENTS AND CORRECTIONS 35m

34	SUN PLANETS	ARIES	MOON	v or Corr^n d		v or Corr^n d		v or Corr^n d	
s	° ′	° ′	° ′	′	′	′	′	′	′
00	8 30·0	8 31·4	8 06·8	0·0	0·0	6·0	3·5	12·0	6·9
01	8 30·3	8 31·6	8 07·0	0·1	0·1	6·1	3·5	12·1	7·0
02	8 30·5	8 31·9	8 07·2	0·2	0·1	6·2	3·6	12·2	7·0
03	8 30·8	8 32·1	8 07·5	0·3	0·2	6·3	3·6	12·3	7·1
04	8 31·0	8 32·4	8 07·7	0·4	0·2	6·4	3·7	12·4	7·1
05	8 31·3	8 32·6	8 08·0	0·5	0·3	6·5	3·7	12·5	7·2
06	8 31·5	8 32·9	8 08·2	0·6	0·3	6·6	3·8	12·6	7·2
07	8 31·8	8 33·2	8 08·4	0·7	0·4	6·7	3·9	12·7	7·3
08	8 32·0	8 33·4	8 08·7	0·8	0·5	6·8	3·9	12·8	7·4
09	8 32·3	8 33·7	8 08·9	0·9	0·5	6·9	4·0	12·9	7·4
10	8 32·5	8 33·9	8 09·2	1·0	0·6	7·0	4·0	13·0	7·5
11	8 32·8	8 34·2	8 09·4	1·1	0·6	7·1	4·1	13·1	7·5
12	8 33·0	8 34·4	8 09·6	1·2	0·7	7·2	4·1	13·2	7·6
13	8 33·3	8 34·7	8 09·9	1·3	0·7	7·3	4·2	13·3	7·6
14	8 33·5	8 34·9	8 10·1	1·4	0·8	7·4	4·3	13·4	7·7
15	8 33·8	8 35·2	8 10·3	1·5	0·9	7·5	4·3	13·5	7·8
16	8 34·0	8 35·4	8 10·6	1·6	0·9	7·6	4·4	13·6	7·8
17	8 34·3	8 35·7	8 10·8	1·7	1·0	7·7	4·4	13·7	7·9
18	8 34·5	8 35·9	8 11·1	1·8	1·0	7·8	4·5	13·8	7·9
19	8 34·8	8 36·2	8 11·3	1·9	1·1	7·9	4·5	13·9	8·0
20	8 35·0	8 36·4	8 11·5	2·0	1·2	8·0	4·6	14·0	8·1
21	8 35·3	8 36·7	8 11·8	2·1	1·2	8·1	4·7	14·1	8·1
22	8 35·5	8 36·9	8 12·0	2·2	1·3	8·2	4·7	14·2	8·2
23	8 35·8	8 37·2	8 12·3	2·3	1·3	8·3	4·8	14·3	8·2
24	8 36·0	8 37·4	8 12·5	2·4	1·4	8·4	4·8	14·4	8·3
25	8 36·3	8 37·7	8 12·7	2·5	1·4	8·5	4·9	14·5	8·3
26	8 36·5	8 37·9	8 13·0	2·6	1·5	8·6	4·9	14·6	8·4
27	8 36·8	8 38·2	8 13·2	2·7	1·6	8·7	5·0	14·7	8·5
28	8 37·0	8 38·4	8 13·4	2·8	1·6	8·8	5·1	14·8	8·5
29	8 37·3	8 38·7	8 13·7	2·9	1·7	8·9	5·1	14·9	8·6
30	8 37·5	8 38·9	8 13·9	3·0	1·7	9·0	5·2	15·0	8·6
31	8 37·8	8 39·2	8 14·2	3·1	1·8	9·1	5·2	15·1	8·7
32	8 38·0	8 39·4	8 14·4	3·2	1·8	9·2	5·3	15·2	8·7
33	8 38·3	8 39·7	8 14·6	3·3	1·9	9·3	5·3	15·3	8·8
34	8 38·5	8 39·9	8 14·9	3·4	2·0	9·4	5·4	15·4	8·9
35	8 38·8	8 40·2	8 15·1	3·5	2·0	9·5	5·5	15·5	8·9
36	8 39·0	8 40·4	8 15·4	3·6	2·1	9·6	5·5	15·6	9·0
37	8 39·3	8 40·7	8 15·6	3·7	2·1	9·7	5·6	15·7	9·0
38	8 39·5	8 40·9	8 15·8	3·8	2·2	9·8	5·6	15·8	9·1
39	8 39·8	8 41·2	8 16·1	3·9	2·2	9·9	5·7	15·9	9·1
40	8 40·0	8 41·4	8 16·3	4·0	2·3	10·0	5·8	16·0	9·2
41	8 40·3	8 41·7	8 16·5	4·1	2·4	10·1	5·8	16·1	9·3
42	8 40·5	8 41·9	8 16·8	4·2	2·4	10·2	5·9	16·2	9·3
43	8 40·8	8 42·2	8 17·0	4·3	2·5	10·3	5·9	16·3	9·4
44	8 41·0	8 42·4	8 17·3	4·4	2·5	10·4	6·0	16·4	9·4
45	8 41·3	8 42·7	8 17·5	4·5	2·6	10·5	6·0	16·5	9·5
46	8 41·5	8 42·9	8 17·7	4·6	2·6	10·6	6·1	16·6	9·5
47	8 41·8	8 43·2	8 18·0	4·7	2·7	10·7	6·2	16·7	9·6
48	8 42·0	8 43·4	8 18·2	4·8	2·8	10·8	6·2	16·8	9·7
49	8 42·3	8 43·7	8 18·5	4·9	2·8	10·9	6·3	16·9	9·7
50	8 42·5	8 43·9	8 18·7	5·0	2·9	11·0	6·3	17·0	9·8
51	8 42·8	8 44·2	8 18·9	5·1	2·9	11·1	6·4	17·1	9·8
52	8 43·0	8 44·4	8 19·2	5·2	3·0	11·2	6·4	17·2	9·9
53	8 43·3	8 44·7	8 19·4	5·3	3·0	11·3	6·5	17·3	9·9
54	8 43·5	8 44·9	8 19·7	5·4	3·1	11·4	6·6	17·4	10·0
55	8 43·8	8 45·2	8 19·9	5·5	3·2	11·5	6·6	17·5	10·1
56	8 44·0	8 45·4	8 20·1	5·6	3·2	11·6	6·7	17·6	10·1
57	8 44·3	8 45·7	8 20·4	5·7	3·3	11·7	6·7	17·7	10·2
58	8 44·5	8 45·9	8 20·6	5·8	3·3	11·8	6·8	17·8	10·2
59	8 44·8	8 46·2	8 20·8	5·9	3·4	11·9	6·8	17·9	10·3
60	8 45·0	8 46·4	8 21·1	6·0	3·5	12·0	6·9	18·0	10·4

35	SUN PLANETS	ARIES	MOON	v or Corr^n d		v or Corr^n d		v or Corr^n d	
s	° ′	° ′	° ′	′	′	′	′	′	′
00	8 45·0	8 46·4	8 21·1	0·0	0·0	6·0	3·6	12·0	7·1
01	8 45·3	8 46·7	8 21·3	0·1	0·1	6·1	3·6	12·1	7·2
02	8 45·5	8 46·9	8 21·6	0·2	0·1	6·2	3·7	12·2	7·2
03	8 45·8	8 47·2	8 21·8	0·3	0·2	6·3	3·7	12·3	7·3
04	8 46·0	8 47·4	8 22·0	0·4	0·2	6·4	3·8	12·4	7·3
05	8 46·3	8 47·7	8 22·3	0·5	0·3	6·5	3·8	12·5	7·4
06	8 46·5	8 47·9	8 22·5	0·6	0·4	6·6	3·9	12·6	7·5
07	8 46·8	8 48·2	8 22·8	0·7	0·4	6·7	4·0	12·7	7·5
08	8 47·0	8 48·4	8 23·0	0·8	0·5	6·8	4·0	12·8	7·6
09	8 47·3	8 48·7	8 23·2	0·9	0·5	6·9	4·1	12·9	7·6
10	8 47·5	8 48·9	8 23·5	1·0	0·6	7·0	4·1	13·0	7·7
11	8 47·8	8 49·2	8 23·7	1·1	0·7	7·1	4·2	13·1	7·8
12	8 48·0	8 49·4	8 23·9	1·2	0·7	7·2	4·3	13·2	7·8
13	8 48·3	8 49·7	8 24·2	1·3	0·8	7·3	4·3	13·3	7·9
14	8 48·5	8 49·9	8 24·4	1·4	0·8	7·4	4·4	13·4	7·9
15	8 48·8	8 50·2	8 24·7	1·5	0·9	7·5	4·4	13·5	8·0
16	8 49·0	8 50·4	8 24·9	1·6	0·9	7·6	4·5	13·6	8·0
17	8 49·3	8 50·7	8 25·1	1·7	1·0	7·7	4·6	13·7	8·1
18	8 49·5	8 50·9	8 25·4	1·8	1·1	7·8	4·6	13·8	8·2
19	8 49·8	8 51·2	8 25·6	1·9	1·1	7·9	4·7	13·9	8·2
20	8 50·0	8 51·5	8 25·9	2·0	1·2	8·0	4·7	14·0	8·3
21	8 50·3	8 51·7	8 26·1	2·1	1·2	8·1	4·8	14·1	8·3
22	8 50·5	8 52·0	8 26·3	2·2	1·3	8·2	4·9	14·2	8·4
23	8 50·8	8 52·2	8 26·6	2·3	1·4	8·3	4·9	14·3	8·5
24	8 51·0	8 52·5	8 26·8	2·4	1·4	8·4	5·0	14·4	8·5
25	8 51·3	8 52·7	8 27·0	2·5	1·5	8·5	5·0	14·5	8·6
26	8 51·5	8 53·0	8 27·3	2·6	1·5	8·6	5·1	14·6	8·6
27	8 51·8	8 53·2	8 27·5	2·7	1·6	8·7	5·1	14·7	8·7
28	8 52·0	8 53·5	8 27·8	2·8	1·7	8·8	5·2	14·8	8·8
29	8 52·3	8 53·7	8 28·0	2·9	1·7	8·9	5·3	14·9	8·8
30	8 52·5	8 54·0	8 28·2	3·0	1·8	9·0	5·3	15·0	8·9
31	8 52·8	8 54·2	8 28·5	3·1	1·8	9·1	5·4	15·1	8·9
32	8 53·0	8 54·5	8 28·7	3·2	1·9	9·2	5·4	15·2	9·0
33	8 53·3	8 54·7	8 29·0	3·3	2·0	9·3	5·5	15·3	9·1
34	8 53·5	8 55·0	8 29·2	3·4	2·0	9·4	5·6	15·4	9·1
35	8 53·8	8 55·2	8 29·4	3·5	2·1	9·5	5·6	15·5	9·2
36	8 54·0	8 55·5	8 29·7	3·6	2·1	9·6	5·7	15·6	9·2
37	8 54·3	8 55·7	8 29·9	3·7	2·2	9·7	5·7	15·7	9·3
38	8 54·5	8 56·0	8 30·2	3·8	2·2	9·8	5·8	15·8	9·3
39	8 54·8	8 56·2	8 30·4	3·9	2·3	9·9	5·9	15·9	9·4
40	8 55·0	8 56·5	8 30·6	4·0	2·4	10·0	5·9	16·0	9·5
41	8 55·3	8 56·7	8 30·9	4·1	2·4	10·1	6·0	16·1	9·5
42	8 55·5	8 57·0	8 31·1	4·2	2·5	10·2	6·0	16·2	9·6
43	8 55·8	8 57·2	8 31·3	4·3	2·5	10·3	6·1	16·3	9·6
44	8 56·0	8 57·5	8 31·6	4·4	2·6	10·4	6·2	16·4	9·7
45	8 56·3	8 57·7	8 31·8	4·5	2·7	10·5	6·2	16·5	9·8
46	8 56·5	8 58·0	8 32·1	4·6	2·7	10·6	6·3	16·6	9·8
47	8 56·8	8 58·2	8 32·3	4·7	2·8	10·7	6·3	16·7	9·9
48	8 57·0	8 58·5	8 32·5	4·8	2·8	10·8	6·4	16·8	9·9
49	8 57·3	8 58·7	8 32·8	4·9	2·9	10·9	6·4	16·9	10·0
50	8 57·5	8 59·0	8 33·0	5·0	3·0	11·0	6·5	17·0	10·1
51	8 57·8	8 59·2	8 33·3	5·1	3·0	11·1	6·6	17·1	10·1
52	8 58·0	8 59·5	8 33·5	5·2	3·1	11·2	6·6	17·2	10·2
53	8 58·3	8 59·7	8 33·7	5·3	3·1	11·3	6·7	17·3	10·2
54	8 58·5	9 00·0	8 34·0	5·4	3·2	11·4	6·7	17·4	10·3
55	8 58·8	9 00·2	8 34·2	5·5	3·3	11·5	6·8	17·5	10·4
56	8 59·0	9 00·5	8 34·4	5·6	3·3	11·6	6·9	17·6	10·4
57	8 59·3	9 00·7	8 34·7	5·7	3·4	11·7	6·9	17·7	10·5
58	8 59·5	9 01·0	8 34·9	5·8	3·4	11·8	7·0	17·8	10·5
59	8 59·8	9 01·2	8 35·2	5·9	3·5	11·9	7·0	17·9	10·6
60	9 00·0	9 01·5	8 35·4	6·0	3·6	12·0	7·1	18·0	10·7

36m INCREMENTS AND CORRECTIONS 37m

36m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	9 00·0	9 01·5	8 35·4	0·0	0·0	6·0	3·7	12·0	7·3
01	9 00·3	9 01·7	8 35·6	0·1	0·1	6·1	3·7	12·1	7·4
02	9 00·5	9 02·0	8 35·9	0·2	0·1	6·2	3·8	12·2	7·4
03	9 00·8	9 02·2	8 36·1	0·3	0·2	6·3	3·8	12·3	7·5
04	9 01·0	9 02·5	8 36·4	0·4	0·2	6·4	3·9	12·4	7·5
05	9 01·3	9 02·7	8 36·6	0·5	0·3	6·5	4·0	12·5	7·6
06	9 01·5	9 03·0	8 36·8	0·6	0·4	6·6	4·0	12·6	7·7
07	9 01·8	9 03·2	8 37·1	0·7	0·4	6·7	4·1	12·7	7·7
08	9 02·0	9 03·5	8 37·3	0·8	0·5	6·8	4·1	12·8	7·8
09	9 02·3	9 03·7	8 37·5	0·9	0·5	6·9	4·2	12·9	7·8
10	9 02·5	9 04·0	8 37·8	1·0	0·6	7·0	4·3	13·0	7·9
11	9 02·8	9 04·2	8 38·0	1·1	0·7	7·1	4·3	13·1	8·0
12	9 03·0	9 04·5	8 38·3	1·2	0·7	7·2	4·4	13·2	8·0
13	9 03·3	9 04·7	8 38·5	1·3	0·8	7·3	4·4	13·3	8·1
14	9 03·5	9 05·0	8 38·7	1·4	0·9	7·4	4·5	13·4	8·2
15	9 03·8	9 05·2	8 39·0	1·5	0·9	7·5	4·6	13·5	8·2
16	9 04·0	9 05·5	8 39·2	1·6	1·0	7·6	4·6	13·6	8·3
17	9 04·3	9 05·7	8 39·5	1·7	1·0	7·7	4·7	13·7	8·3
18	9 04·5	9 06·0	8 39·7	1·8	1·1	7·8	4·7	13·8	8·4
19	9 04·8	9 06·2	8 39·9	1·9	1·2	7·9	4·8	13·9	8·5
20	9 05·0	9 06·5	8 40·2	2·0	1·2	8·0	4·9	14·0	8·5
21	9 05·3	9 06·7	8 40·4	2·1	1·3	8·1	4·9	14·1	8·6
22	9 05·5	9 07·0	8 40·6	2·2	1·3	8·2	5·0	14·2	8·6
23	9 05·8	9 07·2	8 40·9	2·3	1·4	8·3	5·0	14·3	8·7
24	9 06·0	9 07·5	8 41·1	2·4	1·5	8·4	5·1	14·4	8·8
25	9 06·3	9 07·7	8 41·4	2·5	1·5	8·5	5·2	14·5	8·8
26	9 06·5	9 08·0	8 41·6	2·6	1·6	8·6	5·2	14·6	8·9
27	9 06·8	9 08·2	8 41·8	2·7	1·6	8·7	5·3	14·7	8·9
28	9 07·0	9 08·5	8 42·1	2·8	1·7	8·8	5·4	14·8	9·0
29	9 07·3	9 08·7	8 42·3	2·9	1·8	8·9	5·4	14·9	9·1
30	9 07·5	9 09·0	8 42·6	3·0	1·8	9·0	5·5	15·0	9·1
31	9 07·8	9 09·2	8 42·8	3·1	1·9	9·1	5·5	15·1	9·2
32	9 08·0	9 09·5	8 43·0	3·2	1·9	9·2	5·6	15·2	9·2
33	9 08·3	9 09·8	8 43·3	3·3	2·0	9·3	5·7	15·3	9·3
34	9 08·5	9 10·0	8 43·5	3·4	2·1	9·4	5·7	15·4	9·4
35	9 08·8	9 10·3	8 43·8	3·5	2·1	9·5	5·8	15·5	9·4
36	9 09·0	9 10·5	8 44·0	3·6	2·2	9·6	5·8	15·6	9·5
37	9 09·3	9 10·8	8 44·2	3·7	2·3	9·7	5·9	15·7	9·6
38	9 09·5	9 11·0	8 44·5	3·8	2·3	9·8	6·0	15·8	9·6
39	9 09·8	9 11·3	8 44·7	3·9	2·4	9·9	6·0	15·9	9·7
40	9 10·0	9 11·5	8 44·9	4·0	2·4	10·0	6·1	16·0	9·7
41	9 10·3	9 11·8	8 45·2	4·1	2·5	10·1	6·1	16·1	9·8
42	9 10·5	9 12·0	8 45·4	4·2	2·6	10·2	6·2	16·2	9·9
43	9 10·8	9 12·3	8 45·7	4·3	2·6	10·3	6·3	16·3	9·9
44	9 11·0	9 12·5	8 45·9	4·4	2·7	10·4	6·3	16·4	10·0
45	9 11·3	9 12·8	8 46·1	4·5	2·7	10·5	6·4	16·5	10·0
46	9 11·5	9 13·0	8 46·4	4·6	2·8	10·6	6·4	16·6	10·1
47	9 11·8	9 13·3	8 46·6	4·7	2·9	10·7	6·5	16·7	10·2
48	9 12·0	9 13·5	8 46·9	4·8	2·9	10·8	6·6	16·8	10·2
49	9 12·3	9 13·8	8 47·1	4·9	3·0	10·9	6·6	16·9	10·3
50	9 12·5	9 14·0	8 47·3	5·0	3·0	11·0	6·7	17·0	10·3
51	9 12·8	9 14·3	8 47·6	5·1	3·1	11·1	6·8	17·1	10·4
52	9 13·0	9 14·5	8 47·8	5·2	3·2	11·2	6·8	17·2	10·5
53	9 13·3	9 14·8	8 48·0	5·3	3·2	11·3	6·9	17·3	10·5
54	9 13·5	9 15·0	8 48·3	5·4	3·3	11·4	6·9	17·4	10·6
55	9 13·8	9 15·3	8 48·5	5·5	3·3	11·5	7·0	17·5	10·6
56	9 14·0	9 15·5	8 48·8	5·6	3·4	11·6	7·1	17·6	10·7
57	9 14·3	9 15·8	8 49·0	5·7	3·5	11·7	7·1	17·7	10·8
58	9 14·5	9 16·0	8 49·2	5·8	3·5	11·8	7·2	17·8	10·8
59	9 14·8	9 16·3	8 49·5	5·9	3·6	11·9	7·2	17·9	10·9
60	9 15·0	9 16·5	8 49·7	6·0	3·7	12·0	7·3	18·0	11·0

37m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	9 15·0	9 16·5	8 49·7	0·0	0·0	6·0	3·8	12·0	7·5
01	9 15·3	9 16·8	8 50·0	0·1	0·1	6·1	3·8	12·1	7·6
02	9 15·5	9 17·0	8 50·2	0·2	0·1	6·2	3·9	12·2	7·6
03	9 15·8	9 17·3	8 50·4	0·3	0·2	6·3	3·9	12·3	7·7
04	9 16·0	9 17·5	8 50·7	0·4	0·3	6·4	4·0	12·4	7·8
05	9 16·3	9 17·8	8 50·9	0·5	0·3	6·5	4·1	12·5	7·8
06	9 16·5	9 18·0	8 51·1	0·6	0·4	6·6	4·1	12·6	7·9
07	9 16·8	9 18·3	8 51·4	0·7	0·4	6·7	4·2	12·7	7·9
08	9 17·0	9 18·5	8 51·6	0·8	0·5	6·8	4·3	12·8	8·0
09	9 17·3	9 18·8	8 51·9	0·9	0·6	6·9	4·3	12·9	8·1
10	9 17·5	9 19·0	8 52·1	1·0	0·6	7·0	4·4	13·0	8·1
11	9 17·8	9 19·3	8 52·3	1·1	0·7	7·1	4·4	13·1	8·2
12	9 18·0	9 19·5	8 52·6	1·2	0·8	7·2	4·5	13·2	8·3
13	9 18·3	9 19·8	8 52·8	1·3	0·8	7·3	4·6	13·3	8·3
14	9 18·5	9 20·0	8 53·1	1·4	0·9	7·4	4·6	13·4	8·4
15	9 18·8	9 20·3	8 53·3	1·5	0·9	7·5	4·7	13·5	8·4
16	9 19·0	9 20·5	8 53·5	1·6	1·0	7·6	4·8	13·6	8·5
17	9 19·3	9 20·8	8 53·8	1·7	1·1	7·7	4·8	13·7	8·6
18	9 19·5	9 21·0	8 54·0	1·8	1·1	7·8	4·9	13·8	8·6
19	9 19·8	9 21·3	8 54·3	1·9	1·2	7·9	4·9	13·9	8·7
20	9 20·0	9 21·5	8 54·5	2·0	1·3	8·0	5·0	14·0	8·8
21	9 20·3	9 21·8	8 54·7	2·1	1·3	8·1	5·1	14·1	8·8
22	9 20·5	9 22·0	8 55·0	2·2	1·4	8·2	5·1	14·2	8·9
23	9 20·8	9 22·3	8 55·2	2·3	1·4	8·3	5·2	14·3	8·9
24	9 21·0	9 22·5	8 55·4	2·4	1·5	8·4	5·3	14·4	9·0
25	9 21·3	9 22·8	8 55·7	2·5	1·6	8·5	5·3	14·5	9·1
26	9 21·5	9 23·0	8 55·9	2·6	1·6	8·6	5·4	14·6	9·1
27	9 21·8	9 23·3	8 56·2	2·7	1·7	8·7	5·4	14·7	9·2
28	9 22·0	9 23·5	8 56·4	2·8	1·8	8·8	5·5	14·8	9·3
29	9 22·3	9 23·8	8 56·6	2·9	1·8	8·9	5·6	14·9	9·3
30	9 22·5	9 24·0	8 56·9	3·0	1·9	9·0	5·6	15·0	9·4
31	9 22·8	9 24·3	8 57·1	3·1	1·9	9·1	5·7	15·1	9·4
32	9 23·0	9 24·5	8 57·4	3·2	2·0	9·2	5·8	15·2	9·5
33	9 23·3	9 24·8	8 57·6	3·3	2·1	9·3	5·8	15·3	9·6
34	9 23·5	9 25·0	8 57·8	3·4	2·1	9·4	5·9	15·4	9·6
35	9 23·8	9 25·3	8 58·1	3·5	2·2	9·5	5·9	15·5	9·7
36	9 24·0	9 25·5	8 58·3	3·6	2·3	9·6	6·0	15·6	9·8
37	9 24·3	9 25·8	8 58·5	3·7	2·3	9·7	6·1	15·7	9·8
38	9 24·5	9 26·0	8 58·8	3·8	2·4	9·8	6·1	15·8	9·9
39	9 24·8	9 26·3	8 59·0	3·9	2·4	9·9	6·2	15·9	9·9
40	9 25·0	9 26·5	8 59·3	4·0	2·5	10·0	6·3	16·0	10·0
41	9 25·3	9 26·8	8 59·5	4·1	2·6	10·1	6·3	16·1	10·1
42	9 25·5	9 27·0	8 59·7	4·2	2·6	10·2	6·4	16·2	10·1
43	9 25·8	9 27·3	9 00·0	4·3	2·7	10·3	6·4	16·3	10·2
44	9 26·0	9 27·5	9 00·2	4·4	2·8	10·4	6·5	16·4	10·3
45	9 26·3	9 27·8	9 00·5	4·5	2·8	10·5	6·6	16·5	10·3
46	9 26·5	9 28·1	9 00·7	4·6	2·9	10·6	6·6	16·6	10·4
47	9 26·8	9 28·3	9 00·9	4·7	2·9	10·7	6·7	16·7	10·4
48	9 27·0	9 28·6	9 01·2	4·8	3·0	10·8	6·8	16·8	10·5
49	9 27·3	9 28·8	9 01·4	4·9	3·1	10·9	6·8	16·9	10·6
50	9 27·5	9 29·1	9 01·6	5·0	3·1	11·0	6·9	17·0	10·6
51	9 27·8	9 29·3	9 01·9	5·1	3·2	11·1	6·9	17·1	10·7
52	9 28·0	9 29·6	9 02·1	5·2	3·3	11·2	7·0	17·2	10·8
53	9 28·3	9 29·8	9 02·4	5·3	3·3	11·3	7·1	17·3	10·8
54	9 28·5	9 30·1	9 02·6	5·4	3·4	11·4	7·1	17·4	10·9
55	9 28·8	9 30·3	9 02·8	5·5	3·4	11·5	7·2	17·5	10·9
56	9 29·0	9 30·6	9 03·1	5·6	3·5	11·6	7·3	17·6	11·0
57	9 29·3	9 30·8	9 03·3	5·7	3·6	11·7	7·3	17·7	11·1
58	9 29·5	9 31·1	9 03·6	5·8	3·6	11·8	7·4	17·8	11·1
59	9 29·8	9 31·3	9 03·8	5·9	3·7	11·9	7·4	17·9	11·2
60	9 30·0	9 31·6	9 04·0	6·0	3·8	12·0	7·5	18·0	11·3

38m INCREMENTS AND CORRECTIONS

38m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	9 30·0	9 31·6	9 04·0	0·0	0·0	6·0	3·9	12·0	7·7
01	9 30·3	9 31·8	9 04·3	0·1	0·1	6·1	3·9	12·1	7·8
02	9 30·5	9 32·1	9 04·5	0·2	0·1	6·2	4·0	12·2	7·8
03	9 30·8	9 32·3	9 04·7	0·3	0·2	6·3	4·0	12·3	7·9
04	9 31·0	9 32·6	9 05·0	0·4	0·3	6·4	4·1	12·4	8·0
05	9 31·3	9 32·8	9 05·2	0·5	0·3	6·5	4·2	12·5	8·0
06	9 31·5	9 33·1	9 05·5	0·6	0·4	6·6	4·2	12·6	8·1
07	9 31·8	9 33·3	9 05·7	0·7	0·4	6·7	4·3	12·7	8·1
08	9 32·0	9 33·6	9 05·9	0·8	0·5	6·8	4·4	12·8	8·2
09	9 32·3	9 33·8	9 06·2	0·9	0·6	6·9	4·4	12·9	8·3
10	9 32·5	9 34·1	9 06·4	1·0	0·6	7·0	4·5	13·0	8·3
11	9 32·8	9 34·3	9 06·7	1·1	0·7	7·1	4·6	13·1	8·4
12	9 33·0	9 34·6	9 06·9	1·2	0·8	7·2	4·6	13·2	8·5
13	9 33·3	9 34·8	9 07·1	1·3	0·8	7·3	4·7	13·3	8·5
14	9 33·5	9 35·1	9 07·4	1·4	0·9	7·4	4·7	13·4	8·6
15	9 33·8	9 35·3	9 07·6	1·5	1·0	7·5	4·8	13·5	8·7
16	9 34·0	9 35·6	9 07·9	1·6	1·0	7·6	4·9	13·6	8·7
17	9 34·3	9 35·8	9 08·1	1·7	1·1	7·7	4·9	13·7	8·8
18	9 34·5	9 36·1	9 08·3	1·8	1·2	7·8	5·0	13·8	8·9
19	9 34·8	9 36·3	9 08·6	1·9	1·2	7·9	5·1	13·9	8·9
20	9 35·0	9 36·6	9 08·8	2·0	1·3	8·0	5·1	14·0	9·0
21	9 35·3	9 36·8	9 09·0	2·1	1·3	8·1	5·2	14·1	9·0
22	9 35·5	9 37·1	9 09·3	2·2	1·4	8·2	5·3	14·2	9·1
23	9 35·8	9 37·3	9 09·5	2·3	1·5	8·3	5·3	14·3	9·2
24	9 36·0	9 37·6	9 09·8	2·4	1·5	8·4	5·4	14·4	9·2
25	9 36·3	9 37·8	9 10·0	2·5	1·6	8·5	5·5	14·5	9·3
26	9 36·5	9 38·1	9 10·2	2·6	1·7	8·6	5·5	14·6	9·4
27	9 36·8	9 38·3	9 10·5	2·7	1·7	8·7	5·6	14·7	9·4
28	9 37·0	9 38·6	9 10·7	2·8	1·8	8·8	5·6	14·8	9·5
29	9 37·3	9 38·8	9 11·0	2·9	1·9	8·9	5·7	14·9	9·6
30	9 37·5	9 39·1	9 11·2	3·0	1·9	9·0	5·8	15·0	9·6
31	9 37·8	9 39·3	9 11·4	3·1	2·0	9·1	5·8	15·1	9·7
32	9 38·0	9 39·6	9 11·7	3·2	2·1	9·2	5·9	15·2	9·8
33	9 38·3	9 39·8	9 11·9	3·3	2·1	9·3	6·0	15·3	9·8
34	9 38·5	9 40·1	9 12·1	3·4	2·2	9·4	6·0	15·4	9·9
35	9 38·8	9 40·3	9 12·4	3·5	2·2	9·5	6·1	15·5	9·9
36	9 39·0	9 40·6	9 12·6	3·6	2·3	9·6	6·2	15·6	10·0
37	9 39·3	9 40·8	9 12·9	3·7	2·4	9·7	6·2	15·7	10·1
38	9 39·5	9 41·1	9 13·1	3·8	2·4	9·8	6·3	15·8	10·1
39	9 39·8	9 41·3	9 13·3	3·9	2·5	9·9	6·4	15·9	10·2
40	9 40·0	9 41·6	9 13·6	4·0	2·6	10·0	6·4	16·0	10·3
41	9 40·3	9 41·8	9 13·8	4·1	2·6	10·1	6·5	16·1	10·3
42	9 40·5	9 42·1	9 14·1	4·2	2·7	10·2	6·5	16·2	10·4
43	9 40·8	9 42·3	9 14·3	4·3	2·8	10·3	6·6	16·3	10·5
44	9 41·0	9 42·6	9 14·5	4·4	2·8	10·4	6·7	16·4	10·5
45	9 41·3	9 42·8	9 14·8	4·5	2·9	10·5	6·7	16·5	10·6
46	9 41·5	9 43·1	9 15·0	4·6	3·0	10·6	6·8	16·6	10·7
47	9 41·8	9 43·3	9 15·2	4·7	3·0	10·7	6·9	16·7	10·7
48	9 42·0	9 43·6	9 15·5	4·8	3·1	10·8	6·9	16·8	10·8
49	9 42·3	9 43·8	9 15·7	4·9	3·1	10·9	7·0	16·9	10·8
50	9 42·5	9 44·1	9 16·0	5·0	3·2	11·0	7·1	17·0	10·9
51	9 42·8	9 44·3	9 16·2	5·1	3·3	11·1	7·1	17·1	11·0
52	9 43·0	9 44·6	9 16·4	5·2	3·3	11·2	7·2	17·2	11·0
53	9 43·3	9 44·8	9 16·7	5·3	3·4	11·3	7·3	17·3	11·1
54	9 43·5	9 45·1	9 16·9	5·4	3·5	11·4	7·3	17·4	11·2
55	9 43·8	9 45·3	9 17·2	5·5	3·5	11·5	7·4	17·5	11·2
56	9 44·0	9 45·6	9 17·4	5·6	3·6	11·6	7·4	17·6	11·3
57	9 44·3	9 45·8	9 17·6	5·7	3·7	11·7	7·5	17·7	11·4
58	9 44·5	9 46·1	9 17·9	5·8	3·7	11·8	7·6	17·8	11·4
59	9 44·8	9 46·4	9 18·1	5·9	3·8	11·9	7·6	17·9	11·5
60	9 45·0	9 46·6	9 18·4	6·0	3·9	12·0	7·7	18·0	11·6

39m INCREMENTS AND CORRECTIONS

39m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	9 45·0	9 46·6	9 18·4	0·0	0·0	6·0	4·0	12·0	7·9
01	9 45·3	9 46·9	9 18·6	0·1	0·1	6·1	4·0	12·1	8·0
02	9 45·5	9 47·1	9 18·8	0·2	0·1	6·2	4·1	12·2	8·0
03	9 45·8	9 47·4	9 19·1	0·3	0·2	6·3	4·1	12·3	8·1
04	9 46·0	9 47·6	9 19·3	0·4	0·3	6·4	4·2	12·4	8·2
05	9 46·3	9 47·9	9 19·5	0·5	0·3	6·5	4·3	12·5	8·2
06	9 46·5	9 48·1	9 19·8	0·6	0·4	6·6	4·3	12·6	8·3
07	9 46·8	9 48·4	9 20·0	0·7	0·5	6·7	4·4	12·7	8·4
08	9 47·0	9 48·6	9 20·3	0·8	0·5	6·8	4·5	12·8	8·4
09	9 47·3	9 48·9	9 20·5	0·9	0·6	6·9	4·5	12·9	8·5
10	9 47·5	9 49·1	9 20·7	1·0	0·7	7·0	4·6	13·0	8·6
11	9 47·8	9 49·4	9 21·0	1·1	0·7	7·1	4·7	13·1	8·6
12	9 48·0	9 49·6	9 21·2	1·2	0·8	7·2	4·7	13·2	8·7
13	9 48·3	9 49·9	9 21·5	1·3	0·9	7·3	4·8	13·3	8·8
14	9 48·5	9 50·1	9 21·7	1·4	0·9	7·4	4·9	13·4	8·8
15	9 48·8	9 50·4	9 21·9	1·5	1·0	7·5	4·9	13·5	8·9
16	9 49·0	9 50·6	9 22·2	1·6	1·1	7·6	5·0	13·6	9·0
17	9 49·3	9 50·9	9 22·4	1·7	1·1	7·7	5·1	13·7	9·0
18	9 49·5	9 51·1	9 22·6	1·8	1·2	7·8	5·1	13·8	9·1
19	9 49·8	9 51·4	9 22·9	1·9	1·3	7·9	5·2	13·9	9·2
20	9 50·0	9 51·6	9 23·1	2·0	1·3	8·0	5·3	14·0	9·2
21	9 50·3	9 51·9	9 23·4	2·1	1·4	8·1	5·3	14·1	9·3
22	9 50·5	9 52·1	9 23·6	2·2	1·4	8·2	5·4	14·2	9·3
23	9 50·8	9 52·4	9 23·8	2·3	1·5	8·3	5·5	14·3	9·4
24	9 51·0	9 52·6	9 24·1	2·4	1·6	8·4	5·5	14·4	9·5
25	9 51·3	9 52·9	9 24·3	2·5	1·6	8·5	5·6	14·5	9·5
26	9 51·5	9 53·1	9 24·6	2·6	1·7	8·6	5·7	14·6	9·6
27	9 51·8	9 53·4	9 24·8	2·7	1·8	8·7	5·7	14·7	9·7
28	9 52·0	9 53·6	9 25·0	2·8	1·8	8·8	5·8	14·8	9·7
29	9 52·3	9 53·9	9 25·3	2·9	1·9	8·9	5·9	14·9	9·8
30	9 52·5	9 54·1	9 25·5	3·0	2·0	9·0	5·9	15·0	9·9
31	9 52·8	9 54·4	9 25·7	3·1	2·0	9·1	6·0	15·1	9·9
32	9 53·0	9 54·6	9 26·0	3·2	2·1	9·2	6·1	15·2	10·0
33	9 53·3	9 54·9	9 26·2	3·3	2·2	9·3	6·1	15·3	10·1
34	9 53·5	9 55·1	9 26·5	3·4	2·2	9·4	6·2	15·4	10·1
35	9 53·8	9 55·4	9 26·7	3·5	2·3	9·5	6·3	15·5	10·2
36	9 54·0	9 55·6	9 26·9	3·6	2·4	9·6	6·3	15·6	10·3
37	9 54·3	9 55·9	9 27·2	3·7	2·4	9·7	6·4	15·7	10·3
38	9 54·5	9 56·1	9 27·4	3·8	2·5	9·8	6·5	15·8	10·4
39	9 54·8	9 56·4	9 27·7	3·9	2·6	9·9	6·5	15·9	10·5
40	9 55·0	9 56·6	9 27·9	4·0	2·6	10·0	6·6	16·0	10·5
41	9 55·3	9 56·9	9 28·1	4·1	2·7	10·1	6·6	16·1	10·6
42	9 55·5	9 57·1	9 28·4	4·2	2·8	10·2	6·7	16·2	10·7
43	9 55·8	9 57·4	9 28·6	4·3	2·8	10·3	6·8	16·3	10·7
44	9 56·0	9 57·6	9 28·8	4·4	2·9	10·4	6·8	16·4	10·8
45	9 56·3	9 57·9	9 29·1	4·5	3·0	10·5	6·9	16·5	10·9
46	9 56·5	9 58·1	9 29·3	4·6	3·0	10·6	7·0	16·6	10·9
47	9 56·8	9 58·4	9 29·6	4·7	3·1	10·7	7·0	16·7	11·0
48	9 57·0	9 58·6	9 29·8	4·8	3·2	10·8	7·1	16·8	11·1
49	9 57·3	9 58·9	9 30·0	4·9	3·2	10·9	7·2	16·9	11·1
50	9 57·5	9 59·1	9 30·3	5·0	3·3	11·0	7·2	17·0	11·2
51	9 57·8	9 59·4	9 30·5	5·1	3·4	11·1	7·3	17·1	11·3
52	9 58·0	9 59·6	9 30·8	5·2	3·4	11·2	7·4	17·2	11·3
53	9 58·3	9 59·9	9 31·0	5·3	3·5	11·3	7·4	17·3	11·4
54	9 58·5	10 00·1	9 31·2	5·4	3·6	11·4	7·5	17·4	11·5
55	9 58·8	10 00·4	9 31·5	5·5	3·6	11·5	7·6	17·5	11·5
56	9 59·0	10 00·6	9 31·7	5·6	3·7	11·6	7·6	17·6	11·6
57	9 59·3	10 00·9	9 32·0	5·7	3·8	11·7	7·7	17·7	11·7
58	9 59·5	10 01·1	9 32·2	5·8	3·8	11·8	7·8	17·8	11·7
59	9 59·8	10 01·4	9 32·4	5·9	3·9	11·9	7·8	17·9	11·8
60	10 00·0	10 01·6	9 32·7	6·0	4·0	12·0	7·9	18·0	11·9

40m INCREMENTS AND CORRECTIONS 41m

40m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	10 00·0	10 01·6	9 32·7	0·0	0·0	6·0	4·1	12·0	8·1
01	10 00·3	10 01·9	9 32·9	0·1	0·1	6·1	4·1	12·1	8·2
02	10 00·5	10 02·1	9 33·1	0·2	0·1	6·2	4·2	12·2	8·2
03	10 00·8	10 02·4	9 33·4	0·3	0·2	6·3	4·3	12·3	8·3
04	10 01·0	10 02·6	9 33·6	0·4	0·3	6·4	4·3	12·4	8·4
05	10 01·3	10 02·9	9 33·9	0·5	0·3	6·5	4·4	12·5	8·4
06	10 01·5	10 03·1	9 34·1	0·6	0·4	6·6	4·5	12·6	8·5
07	10 01·8	10 03·4	9 34·3	0·7	0·5	6·7	4·5	12·7	8·6
08	10 02·0	10 03·6	9 34·6	0·8	0·5	6·8	4·6	12·8	8·6
09	10 02·3	10 03·9	9 34·8	0·9	0·6	6·9	4·7	12·9	8·7
10	10 02·5	10 04·1	9 35·1	1·0	0·7	7·0	4·7	13·0	8·8
11	10 02·8	10 04·4	9 35·3	1·1	0·7	7·1	4·8	13·1	8·8
12	10 03·0	10 04·7	9 35·5	1·2	0·8	7·2	4·9	13·2	8·9
13	10 03·3	10 04·9	9 35·8	1·3	0·9	7·3	4·9	13·3	9·0
14	10 03·5	10 05·2	9 36·0	1·4	0·9	7·4	5·0	13·4	9·0
15	10 03·8	10 05·4	9 36·2	1·5	1·0	7·5	5·1	13·5	9·1
16	10 04·0	10 05·7	9 36·5	1·6	1·1	7·6	5·1	13·6	9·2
17	10 04·3	10 05·9	9 36·7	1·7	1·1	7·7	5·2	13·7	9·2
18	10 04·5	10 06·2	9 37·0	1·8	1·2	7·8	5·3	13·8	9·3
19	10 04·8	10 06·4	9 37·2	1·9	1·3	7·9	5·3	13·9	9·4
20	10 05·0	10 06·7	9 37·4	2·0	1·4	8·0	5·4	14·0	9·5
21	10 05·3	10 06·9	9 37·7	2·1	1·4	8·1	5·5	14·1	9·5
22	10 05·5	10 07·2	9 37·9	2·2	1·5	8·2	5·5	14·2	9·6
23	10 05·8	10 07·4	9 38·2	2·3	1·6	8·3	5·6	14·3	9·7
24	10 06·0	10 07·7	9 38·4	2·4	1·6	8·4	5·7	14·4	9·7
25	10 06·3	10 07·9	9 38·6	2·5	1·7	8·5	5·7	14·5	9·8
26	10 06·5	10 08·2	9 38·9	2·6	1·8	8·6	5·8	14·6	9·9
27	10 06·8	10 08·4	9 39·1	2·7	1·8	8·7	5·9	14·7	9·9
28	10 07·0	10 08·7	9 39·3	2·8	1·9	8·8	5·9	14·8	10·0
29	10 07·3	10 08·9	9 39·6	2·9	2·0	8·9	6·0	14·9	10·1
30	10 07·5	10 09·2	9 39·8	3·0	2·0	9·0	6·1	15·0	10·1
31	10 07·8	10 09·4	9 40·1	3·1	2·1	9·1	6·1	15·1	10·2
32	10 08·0	10 09·7	9 40·3	3·2	2·2	9·2	6·2	15·2	10·3
33	10 08·3	10 09·9	9 40·5	3·3	2·2	9·3	6·3	15·3	10·3
34	10 08·5	10 10·2	9 40·8	3·4	2·3	9·4	6·3	15·4	10·4
35	10 08·8	10 10·4	9 41·0	3·5	2·4	9·5	6·4	15·5	10·5
36	10 09·0	10 10·7	9 41·3	3·6	2·4	9·6	6·5	15·6	10·5
37	10 09·3	10 10·9	9 41·5	3·7	2·5	9·7	6·5	15·7	10·6
38	10 09·5	10 11·2	9 41·7	3·8	2·6	9·8	6·6	15·8	10·7
39	10 09·8	10 11·4	9 42·0	3·9	2·6	9·9	6·7	15·9	10·7
40	10 10·0	10 11·7	9 42·2	4·0	2·7	10·0	6·8	16·0	10·8
41	10 10·3	10 11·9	9 42·4	4·1	2·8	10·1	6·8	16·1	10·9
42	10 10·5	10 12·2	9 42·7	4·2	2·8	10·2	6·9	16·2	10·9
43	10 10·8	10 12·4	9 42·9	4·3	2·9	10·3	7·0	16·3	11·0
44	10 11·0	10 12·7	9 43·2	4·4	3·0	10·4	7·0	16·4	11·1
45	10 11·3	10 12·9	9 43·4	4·5	3·0	10·5	7·1	16·5	11·1
46	10 11·5	10 13·2	9 43·6	4·6	3·1	10·6	7·2	16·6	11·2
47	10 11·8	10 13·4	9 43·9	4·7	3·2	10·7	7·2	16·7	11·3
48	10 12·0	10 13·7	9 44·1	4·8	3·2	10·8	7·3	16·8	11·3
49	10 12·3	10 13·9	9 44·4	4·9	3·3	10·9	7·4	16·9	11·4
50	10 12·5	10 14·2	9 44·6	5·0	3·4	11·0	7·4	17·0	11·5
51	10 12·8	10 14·4	9 44·8	5·1	3·4	11·1	7·5	17·1	11·5
52	10 13·0	10 14·7	9 45·1	5·2	3·5	11·2	7·6	17·2	11·6
53	10 13·3	10 14·9	9 45·3	5·3	3·6	11·3	7·6	17·3	11·7
54	10 13·5	10 15·2	9 45·6	5·4	3·6	11·4	7·7	17·4	11·7
55	10 13·8	10 15·4	9 45·8	5·5	3·7	11·5	7·8	17·5	11·8
56	10 14·0	10 15·7	9 46·0	5·6	3·8	11·6	7·8	17·6	11·9
57	10 14·3	10 15·9	9 46·3	5·7	3·8	11·7	7·9	17·7	11·9
58	10 14·5	10 16·2	9 46·5	5·8	3·9	11·8	8·0	17·8	12·0
59	10 14·8	10 16·4	9 46·7	5·9	4·0	11·9	8·0	17·9	12·1
60	10 15·0	10 16·7	9 47·0	6·0	4·1	12·0	8·1	18·0	12·2

41m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	10 15·0	10 16·7	9 47·0	0·0	0·0	6·0	4·2	12·0	8·3
01	10 15·3	10 16·9	9 47·2	0·1	0·1	6·1	4·2	12·1	8·4
02	10 15·5	10 17·2	9 47·5	0·2	0·1	6·2	4·3	12·2	8·4
03	10 15·8	10 17·4	9 47·7	0·3	0·2	6·3	4·4	12·3	8·5
04	10 16·0	10 17·7	9 47·9	0·4	0·3	6·4	4·4	12·4	8·6
05	10 16·3	10 17·9	9 48·2	0·5	0·3	6·5	4·5	12·5	8·6
06	10 16·5	10 18·2	9 48·4	0·6	0·4	6·6	4·6	12·6	8·7
07	10 16·8	10 18·4	9 48·7	0·7	0·5	6·7	4·6	12·7	8·8
08	10 17·0	10 18·7	9 48·9	0·8	0·6	6·8	4·7	12·8	8·9
09	10 17·3	10 18·9	9 49·1	0·9	0·6	6·9	4·8	12·9	8·9
10	10 17·5	10 19·2	9 49·4	1·0	0·7	7·0	4·8	13·0	9·0
11	10 17·8	10 19·4	9 49·6	1·1	0·8	7·1	4·9	13·1	9·1
12	10 18·0	10 19·7	9 49·8	1·2	0·8	7·2	5·0	13·2	9·1
13	10 18·3	10 19·9	9 50·1	1·3	0·9	7·3	5·0	13·3	9·2
14	10 18·5	10 20·2	9 50·3	1·4	1·0	7·4	5·1	13·4	9·3
15	10 18·8	10 20·4	9 50·6	1·5	1·0	7·5	5·2	13·5	9·3
16	10 19·0	10 20·7	9 50·8	1·6	1·1	7·6	5·3	13·6	9·4
17	10 19·3	10 20·9	9 51·0	1·7	1·2	7·7	5·3	13·7	9·5
18	10 19·5	10 21·2	9 51·3	1·8	1·2	7·8	5·4	13·8	9·5
19	10 19·8	10 21·4	9 51·5	1·9	1·3	7·9	5·5	13·9	9·6
20	10 20·0	10 21·7	9 51·8	2·0	1·4	8·0	5·5	14·0	9·7
21	10 20·3	10 21·9	9 52·0	2·1	1·5	8·1	5·6	14·1	9·8
22	10 20·5	10 22·2	9 52·2	2·2	1·5	8·2	5·7	14·2	9·8
23	10 20·8	10 22·4	9 52·5	2·3	1·6	8·3	5·7	14·3	9·9
24	10 21·0	10 22·7	9 52·7	2·4	1·7	8·4	5·8	14·4	10·0
25	10 21·3	10 23·0	9 52·9	2·5	1·7	8·5	5·9	14·5	10·0
26	10 21·5	10 23·2	9 53·2	2·6	1·8	8·6	5·9	14·6	10·1
27	10 21·8	10 23·5	9 53·4	2·7	1·9	8·7	6·0	14·7	10·2
28	10 22·0	10 23·7	9 53·7	2·8	1·9	8·8	6·1	14·8	10·2
29	10 22·3	10 24·0	9 53·9	2·9	2·0	8·9	6·2	14·9	10·3
30	10 22·5	10 24·2	9 54·1	3·0	2·1	9·0	6·2	15·0	10·4
31	10 22·8	10 24·5	9 54·4	3·1	2·1	9·1	6·3	15·1	10·4
32	10 23·0	10 24·7	9 54·6	3·2	2·2	9·2	6·4	15·2	10·5
33	10 23·3	10 25·0	9 54·9	3·3	2·3	9·3	6·4	15·3	10·6
34	10 23·5	10 25·2	9 55·1	3·4	2·4	9·4	6·5	15·4	10·7
35	10 23·8	10 25·5	9 55·3	3·5	2·4	9·5	6·6	15·5	10·7
36	10 24·0	10 25·7	9 55·6	3·6	2·5	9·6	6·6	15·6	10·8
37	10 24·3	10 26·0	9 55·8	3·7	2·6	9·7	6·7	15·7	10·9
38	10 24·5	10 26·2	9 56·1	3·8	2·6	9·8	6·8	15·8	10·9
39	10 24·8	10 26·5	9 56·3	3·9	2·7	9·9	6·8	15·9	11·0
40	10 25·0	10 26·7	9 56·5	4·0	2·8	10·0	6·9	16·0	11·1
41	10 25·3	10 27·0	9 56·8	4·1	2·8	10·1	7·0	16·1	11·1
42	10 25·5	10 27·2	9 57·0	4·2	2·9	10·2	7·1	16·2	11·2
43	10 25·8	10 27·5	9 57·2	4·3	3·0	10·3	7·1	16·3	11·3
44	10 26·0	10 27·7	9 57·5	4·4	3·0	10·4	7·2	16·4	11·3
45	10 26·3	10 28·0	9 57·7	4·5	3·1	10·5	7·3	16·5	11·4
46	10 26·5	10 28·2	9 58·0	4·6	3·2	10·6	7·3	16·6	11·5
47	10 26·8	10 28·5	9 58·2	4·7	3·3	10·7	7·4	16·7	11·6
48	10 27·0	10 28·7	9 58·4	4·8	3·3	10·8	7·5	16·8	11·6
49	10 27·3	10 29·0	9 58·7	4·9	3·4	10·9	7·5	16·9	11·7
50	10 27·5	10 29·2	9 58·9	5·0	3·5	11·0	7·6	17·0	11·8
51	10 27·8	10 29·5	9 59·2	5·1	3·5	11·1	7·7	17·1	11·8
52	10 28·0	10 29·7	9 59·4	5·2	3·6	11·2	7·7	17·2	11·9
53	10 28·3	10 30·0	9 59·6	5·3	3·7	11·3	7·8	17·3	12·0
54	10 28·5	10 30·2	9 59·9	5·4	3·7	11·4	7·9	17·4	12·0
55	10 28·8	10 30·5	10 00·1	5·5	3·8	11·5	8·0	17·5	12·1
56	10 29·0	10 30·7	10 00·3	5·6	3·9	11·6	8·0	17·6	12·2
57	10 29·3	10 31·0	10 00·6	5·7	3·9	11·7	8·1	17·7	12·2
58	10 29·5	10 31·2	10 00·8	5·8	4·0	11·8	8·2	17·8	12·3
59	10 29·8	10 31·5	10 01·1	5·9	4·1	11·9	8·2	17·9	12·4
60	10 30·0	10 31·7	10 01·3	6·0	4·2	12·0	8·3	18·0	12·5

42m INCREMENTS AND CORRECTIONS 43m

42m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	10 30·0	10 31·7	10 01·3	0·0	0·0	6·0	4·3	12·0	8·5
01	10 30·3	10 32·0	10 01·5	0·1	0·1	6·1	4·3	12·1	8·6
02	10 30·5	10 32·2	10 01·8	0·2	0·1	6·2	4·4	12·2	8·6
03	10 30·8	10 32·5	10 02·0	0·3	0·2	6·3	4·5	12·3	8·7
04	10 31·0	10 32·7	10 02·3	0·4	0·3	6·4	4·5	12·4	8·8
05	10 31·3	10 33·0	10 02·5	0·5	0·4	6·5	4·6	12·5	8·9
06	10 31·5	10 33·2	10 02·7	0·6	0·4	6·6	4·7	12·6	8·9
07	10 31·8	10 33·5	10 03·0	0·7	0·5	6·7	4·7	12·7	9·0
08	10 32·0	10 33·7	10 03·2	0·8	0·6	6·8	4·8	12·8	9·1
09	10 32·3	10 34·0	10 03·4	0·9	0·6	6·9	4·9	12·9	9·1
10	10 32·5	10 34·2	10 03·7	1·0	0·7	7·0	5·0	13·0	9·2
11	10 32·8	10 34·5	10 03·9	1·1	0·8	7·1	5·0	13·1	9·3
12	10 33·0	10 34·7	10 04·2	1·2	0·9	7·2	5·1	13·2	9·4
13	10 33·3	10 35·0	10 04·4	1·3	0·9	7·3	5·2	13·3	9·4
14	10 33·5	10 35·2	10 04·6	1·4	1·0	7·4	5·2	13·4	9·5
15	10 33·8	10 35·5	10 04·9	1·5	1·1	7·5	5·3	13·5	9·6
16	10 34·0	10 35·7	10 05·1	1·6	1·1	7·6	5·4	13·6	9·6
17	10 34·3	10 36·0	10 05·4	1·7	1·2	7·7	5·5	13·7	9·7
18	10 34·5	10 36·2	10 05·6	1·8	1·3	7·8	5·5	13·8	9·8
19	10 34·8	10 36·5	10 05·8	1·9	1·3	7·9	5·6	13·9	9·8
20	10 35·0	10 36·7	10 06·1	2·0	1·4	8·0	5·7	14·0	9·9
21	10 35·3	10 37·0	10 06·3	2·1	1·5	8·1	5·7	14·1	10·0
22	10 35·5	10 37·2	10 06·5	2·2	1·6	8·2	5·8	14·2	10·1
23	10 35·8	10 37·5	10 06·8	2·3	1·6	8·3	5·9	14·3	10·1
24	10 36·0	10 37·7	10 07·0	2·4	1·7	8·4	6·0	14·4	10·2
25	10 36·3	10 38·0	10 07·3	2·5	1·8	8·5	6·0	14·5	10·3
26	10 36·5	10 38·2	10 07·5	2·6	1·8	8·6	6·1	14·6	10·3
27	10 36·8	10 38·5	10 07·7	2·7	1·9	8·7	6·2	14·7	10·4
28	10 37·0	10 38·7	10 08·0	2·8	2·0	8·8	6·2	14·8	10·5
29	10 37·3	10 39·0	10 08·2	2·9	2·1	8·9	6·3	14·9	10·6
30	10 37·5	10 39·2	10 08·5	3·0	2·1	9·0	6·4	15·0	10·6
31	10 37·8	10 39·5	10 08·7	3·1	2·2	9·1	6·4	15·1	10·7
32	10 38·0	10 39·7	10 08·9	3·2	2·3	9·2	6·5	15·2	10·8
33	10 38·3	10 40·0	10 09·2	3·3	2·3	9·3	6·6	15·3	10·8
34	10 38·5	10 40·2	10 09·4	3·4	2·4	9·4	6·7	15·4	10·9
35	10 38·8	10 40·5	10 09·7	3·5	2·5	9·5	6·7	15·5	11·0
36	10 39·0	10 40·7	10 09·9	3·6	2·6	9·6	6·8	15·6	11·1
37	10 39·3	10 41·0	10 10·1	3·7	2·6	9·7	6·9	15·7	11·1
38	10 39·5	10 41·3	10 10·4	3·8	2·7	9·8	6·9	15·8	11·2
39	10 39·8	10 41·5	10 10·6	3·9	2·8	9·9	7·0	15·9	11·3
40	10 40·0	10 41·8	10 10·8	4·0	2·8	10·0	7·1	16·0	11·3
41	10 40·3	10 42·0	10 11·1	4·1	2·9	10·1	7·2	16·1	11·4
42	10 40·5	10 42·3	10 11·3	4·2	3·0	10·2	7·2	16·2	11·5
43	10 40·8	10 42·5	10 11·6	4·3	3·0	10·3	7·3	16·3	11·5
44	10 41·0	10 42·8	10 11·8	4·4	3·1	10·4	7·4	16·4	11·6
45	10 41·3	10 43·0	10 12·0	4·5	3·2	10·5	7·4	16·5	11·7
46	10 41·5	10 43·3	10 12·3	4·6	3·3	10·6	7·5	16·6	11·8
47	10 41·8	10 43·5	10 12·5	4·7	3·3	10·7	7·6	16·7	11·8
48	10 42·0	10 43·8	10 12·8	4·8	3·4	10·8	7·7	16·8	11·9
49	10 42·3	10 44·0	10 13·0	4·9	3·5	10·9	7·7	16·9	12·0
50	10 42·5	10 44·3	10 13·2	5·0	3·5	11·0	7·8	17·0	12·0
51	10 42·8	10 44·5	10 13·5	5·1	3·6	11·1	7·9	17·1	12·1
52	10 43·0	10 44·8	10 13·7	5·2	3·7	11·2	7·9	17·2	12·2
53	10 43·3	10 45·0	10 13·9	5·3	3·8	11·3	8·0	17·3	12·3
54	10 43·5	10 45·3	10 14·2	5·4	3·8	11·4	8·1	17·4	12·3
55	10 43·8	10 45·5	10 14·4	5·5	3·9	11·5	8·1	17·5	12·4
56	10 44·0	10 45·8	10 14·7	5·6	4·0	11·6	8·2	17·6	12·5
57	10 44·3	10 46·0	10 14·9	5·7	4·0	11·7	8·3	17·7	12·5
58	10 44·5	10 46·3	10 15·1	5·8	4·1	11·8	8·4	17·8	12·6
59	10 44·8	10 46·5	10 15·4	5·9	4·2	11·9	8·4	17·9	12·7
60	10 45·0	10 46·8	10 15·6	6·0	4·3	12·0	8·5	18·0	12·8

43m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	10 45·0	10 46·8	10 15·6	0·0	0·0	6·0	4·4	12·0	8·7
01	10 45·3	10 47·0	10 15·9	0·1	0·1	6·1	4·4	12·1	8·8
02	10 45·5	10 47·3	10 16·1	0·2	0·1	6·2	4·5	12·2	8·8
03	10 45·8	10 47·5	10 16·3	0·3	0·2	6·3	4·6	12·3	8·9
04	10 46·0	10 47·8	10 16·6	0·4	0·3	6·4	4·6	12·4	9·0
05	10 46·3	10 48·0	10 16·8	0·5	0·4	6·5	4·7	12·5	9·1
06	10 46·5	10 48·3	10 17·0	0·6	0·4	6·6	4·8	12·6	9·1
07	10 46·8	10 48·5	10 17·3	0·7	0·5	6·7	4·9	12·7	9·2
08	10 47·0	10 48·8	10 17·5	0·8	0·6	6·8	4·9	12·8	9·3
09	10 47·3	10 49·0	10 17·8	0·9	0·7	6·9	5·0	12·9	9·4
10	10 47·5	10 49·3	10 18·0	1·0	0·7	7·0	5·1	13·0	9·4
11	10 47·8	10 49·5	10 18·2	1·1	0·8	7·1	5·1	13·1	9·5
12	10 48·0	10 49·8	10 18·5	1·2	0·9	7·2	5·2	13·2	9·6
13	10 48·3	10 50·0	10 18·7	1·3	0·9	7·3	5·3	13·3	9·6
14	10 48·5	10 50·3	10 19·0	1·4	1·0	7·4	5·4	13·4	9·7
15	10 48·8	10 50·5	10 19·2	1·5	1·1	7·5	5·4	13·5	9·8
16	10 49·0	10 50·8	10 19·4	1·6	1·2	7·6	5·5	13·6	9·9
17	10 49·3	10 51·0	10 19·7	1·7	1·2	7·7	5·6	13·7	9·9
18	10 49·5	10 51·3	10 19·9	1·8	1·3	7·8	5·7	13·8	10·0
19	10 49·8	10 51·5	10 20·2	1·9	1·4	7·9	5·7	13·9	10·1
20	10 50·0	10 51·8	10 20·4	2·0	1·5	8·0	5·8	14·0	10·2
21	10 50·3	10 52·0	10 20·6	2·1	1·5	8·1	5·9	14·1	10·2
22	10 50·5	10 52·3	10 20·9	2·2	1·6	8·2	5·9	14·2	10·3
23	10 50·8	10 52·5	10 21·1	2·3	1·7	8·3	6·0	14·3	10·4
24	10 51·0	10 52·8	10 21·3	2·4	1·7	8·4	6·1	14·4	10·4
25	10 51·3	10 53·0	10 21·6	2·5	1·8	8·5	6·2	14·5	10·5
26	10 51·5	10 53·3	10 21·8	2·6	1·9	8·6	6·2	14·6	10·6
27	10 51·8	10 53·5	10 22·1	2·7	2·0	8·7	6·3	14·7	10·7
28	10 52·0	10 53·8	10 22·3	2·8	2·0	8·8	6·4	14·8	10·7
29	10 52·3	10 54·0	10 22·5	2·9	2·1	8·9	6·5	14·9	10·8
30	10 52·5	10 54·3	10 22·8	3·0	2·2	9·0	6·5	15·0	10·9
31	10 52·8	10 54·5	10 23·0	3·1	2·2	9·1	6·6	15·1	10·9
32	10 53·0	10 54·8	10 23·3	3·2	2·3	9·2	6·7	15·2	11·0
33	10 53·3	10 55·0	10 23·5	3·3	2·4	9·3	6·7	15·3	11·1
34	10 53·5	10 55·3	10 23·7	3·4	2·5	9·4	6·8	15·4	11·2
35	10 53·8	10 55·5	10 24·0	3·5	2·5	9·5	6·9	15·5	11·2
36	10 54·0	10 55·8	10 24·2	3·6	2·6	9·6	7·0	15·6	11·3
37	10 54·3	10 56·0	10 24·4	3·7	2·7	9·7	7·0	15·7	11·4
38	10 54·5	10 56·3	10 24·7	3·8	2·8	9·8	7·1	15·8	11·5
39	10 54·8	10 56·5	10 24·9	3·9	2·8	9·9	7·2	15·9	11·5
40	10 55·0	10 56·8	10 25·2	4·0	2·9	10·0	7·3	16·0	11·6
41	10 55·3	10 57·0	10 25·4	4·1	3·0	10·1	7·3	16·1	11·7
42	10 55·5	10 57·3	10 25·6	4·2	3·0	10·2	7·4	16·2	11·7
43	10 55·8	10 57·5	10 25·9	4·3	3·1	10·3	7·5	16·3	11·8
44	10 56·0	10 57·8	10 26·1	4·4	3·2	10·4	7·5	16·4	11·9
45	10 56·3	10 58·0	10 26·4	4·5	3·3	10·5	7·6	16·5	12·0
46	10 56·5	10 58·3	10 26·6	4·6	3·3	10·6	7·7	16·6	12·0
47	10 56·8	10 58·5	10 26·8	4·7	3·4	10·7	7·8	16·7	12·1
48	10 57·0	10 58·8	10 27·1	4·8	3·5	10·8	7·8	16·8	12·2
49	10 57·3	10 59·0	10 27·3	4·9	3·6	10·9	7·9	16·9	12·3
50	10 57·5	10 59·3	10 27·5	5·0	3·6	11·0	8·0	17·0	12·3
51	10 57·8	10 59·6	10 27·8	5·1	3·7	11·1	8·0	17·1	12·4
52	10 58·0	10 59·8	10 28·0	5·2	3·8	11·2	8·1	17·2	12·5
53	10 58·3	11 00·1	10 28·3	5·3	3·8	11·3	8·2	17·3	12·5
54	10 58·5	11 00·3	10 28·5	5·4	3·9	11·4	8·3	17·4	12·6
55	10 58·8	11 00·6	10 28·7	5·5	4·0	11·5	8·3	17·5	12·7
56	10 59·0	11 00·8	10 29·0	5·6	4·1	11·6	8·4	17·6	12·8
57	10 59·3	11 01·1	10 29·2	5·7	4·1	11·7	8·5	17·7	12·8
58	10 59·5	11 01·3	10 29·5	5·8	4·2	11·8	8·6	17·8	12·9
59	10 59·8	11 01·6	10 29·7	5·9	4·3	11·9	8·6	17·9	13·0
60	11 00·0	11 01·8	10 29·9	6·0	4·4	12·0	8·7	18·0	13·1

44m INCREMENTS AND CORRECTIONS 45m

44m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	11 00·0	11 01·8	10 29·9	0·0	0·0	6·0	4·5	12·0	8·9
01	11 00·3	11 02·1	10 30·2	0·1	0·1	6·1	4·5	12·1	9·0
02	11 00·5	11 02·3	10 30·4	0·2	0·1	6·2	4·6	12·2	9·0
03	11 00·8	11 02·6	10 30·6	0·3	0·2	6·3	4·7	12·3	9·1
04	11 01·0	11 02·8	10 30·9	0·4	0·3	6·4	4·7	12·4	9·2
05	11 01·3	11 03·1	10 31·1	0·5	0·4	6·5	4·8	12·5	9·3
06	11 01·5	11 03·3	10 31·4	0·6	0·4	6·6	4·9	12·6	9·3
07	11 01·8	11 03·6	10 31·6	0·7	0·5	6·7	5·0	12·7	9·4
08	11 02·0	11 03·8	10 31·8	0·8	0·6	6·8	5·0	12·8	9·5
09	11 02·3	11 04·1	10 32·1	0·9	0·7	6·9	5·1	12·9	9·6
10	11 02·5	11 04·3	10 32·3	1·0	0·7	7·0	5·2	13·0	9·6
11	11 02·8	11 04·6	10 32·6	1·1	0·8	7·1	5·3	13·1	9·7
12	11 03·0	11 04·8	10 32·8	1·2	0·9	7·2	5·3	13·2	9·8
13	11 03·3	11 05·1	10 33·0	1·3	1·0	7·3	5·4	13·3	9·9
14	11 03·5	11 05·3	10 33·3	1·4	1·0	7·4	5·5	13·4	9·9
15	11 03·8	11 05·6	10 33·5	1·5	1·1	7·5	5·6	13·5	10·0
16	11 04·0	11 05·8	10 33·8	1·6	1·2	7·6	5·6	13·6	10·1
17	11 04·3	11 06·1	10 34·0	1·7	1·3	7·7	5·7	13·7	10·2
18	11 04·5	11 06·3	10 34·2	1·8	1·3	7·8	5·8	13·8	10·2
19	11 04·8	11 06·6	10 34·5	1·9	1·4	7·9	5·9	13·9	10·3
20	11 05·0	11 06·8	10 34·7	2·0	1·5	8·0	5·9	14·0	10·4
21	11 05·3	11 07·1	10 34·9	2·1	1·6	8·1	6·0	14·1	10·5
22	11 05·5	11 07·3	10 35·2	2·2	1·6	8·2	6·1	14·2	10·5
23	11 05·8	11 07·6	10 35·4	2·3	1·7	8·3	6·2	14·3	10·6
24	11 06·0	11 07·8	10 35·7	2·4	1·8	8·4	6·2	14·4	10·7
25	11 06·3	11 08·1	10 35·9	2·5	1·9	8·5	6·3	14·5	10·8
26	11 06·5	11 08·3	10 36·1	2·6	1·9	8·6	6·4	14·6	10·8
27	11 06·8	11 08·6	10 36·4	2·7	2·0	8·7	6·5	14·7	10·9
28	11 07·0	11 08·8	10 36·6	2·8	2·1	8·8	6·5	14·8	11·0
29	11 07·3	11 09·1	10 36·9	2·9	2·2	8·9	6·6	14·9	11·1
30	11 07·5	11 09·3	10 37·1	3·0	2·2	9·0	6·7	15·0	11·1
31	11 07·8	11 09·6	10 37·3	3·1	2·3	9·1	6·7	15·1	11·2
32	11 08·0	11 09·8	10 37·6	3·2	2·4	9·2	6·8	15·2	11·3
33	11 08·3	11 10·1	10 37·8	3·3	2·4	9·3	6·9	15·3	11·3
34	11 08·5	11 10·3	10 38·0	3·4	2·5	9·4	7·0	15·4	11·4
35	11 08·8	11 10·6	10 38·3	3·5	2·6	9·5	7·0	15·5	11·5
36	11 09·0	11 10·8	10 38·5	3·6	2·7	9·6	7·1	15·6	11·6
37	11 09·3	11 11·1	10 38·8	3·7	2·7	9·7	7·2	15·7	11·6
38	11 09·5	11 11·3	10 39·0	3·8	2·8	9·8	7·3	15·8	11·7
39	11 09·8	11 11·6	10 39·2	3·9	2·9	9·9	7·3	15·9	11·8
40	11 10·0	11 11·8	10 39·5	4·0	3·0	10·0	7·4	16·0	11·9
41	11 10·3	11 12·1	10 39·7	4·1	3·0	10·1	7·5	16·1	11·9
42	11 10·5	11 12·3	10 40·0	4·2	3·1	10·2	7·6	16·2	12·0
43	11 10·8	11 12·6	10 40·2	4·3	3·2	10·3	7·6	16·3	12·1
44	11 11·0	11 12·8	10 40·4	4·4	3·3	10·4	7·7	16·4	12·2
45	11 11·3	11 13·1	10 40·7	4·5	3·3	10·5	7·8	16·5	12·2
46	11 11·5	11 13·3	10 40·9	4·6	3·4	10·6	7·9	16·6	12·3
47	11 11·8	11 13·6	10 41·1	4·7	3·5	10·7	7·9	16·7	12·4
48	11 12·0	11 13·8	10 41·4	4·8	3·6	10·8	8·0	16·8	12·5
49	11 12·3	11 14·1	10 41·6	4·9	3·6	10·9	8·1	16·9	12·5
50	11 12·5	11 14·3	10 41·9	5·0	3·7	11·0	8·2	17·0	12·6
51	11 12·8	11 14·6	10 42·1	5·1	3·8	11·1	8·2	17·1	12·7
52	11 13·0	11 14·8	10 42·3	5·2	3·9	11·2	8·3	17·2	12·8
53	11 13·3	11 15·1	10 42·6	5·3	3·9	11·3	8·4	17·3	12·8
54	11 13·5	11 15·3	10 42·8	5·4	4·0	11·4	8·5	17·4	12·9
55	11 13·8	11 15·6	10 43·1	5·5	4·1	11·5	8·5	17·5	13·0
56	11 14·0	11 15·8	10 43·3	5·6	4·2	11·6	8·6	17·6	13·1
57	11 14·3	11 16·1	10 43·5	5·7	4·2	11·7	8·7	17·7	13·1
58	11 14·5	11 16·3	10 43·8	5·8	4·3	11·8	8·8	17·8	13·2
59	11 14·8	11 16·6	10 44·0	5·9	4·4	11·9	8·8	17·9	13·3
60	11 15·0	11 16·8	10 44·3	6·0	4·5	12·0	8·9	18·0	13·4

45m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	11 15·0	11 16·8	10 44·3	0·0	0·0	6·0	4·6	12·0	9·1
01	11 15·3	11 17·1	10 44·5	0·1	0·1	6·1	4·6	12·1	9·2
02	11 15·5	11 17·3	10 44·7	0·2	0·2	6·2	4·7	12·2	9·3
03	11 15·8	11 17·6	10 45·0	0·3	0·2	6·3	4·8	12·3	9·3
04	11 16·0	11 17·9	10 45·2	0·4	0·3	6·4	4·9	12·4	9·4
05	11 16·3	11 18·1	10 45·4	0·5	0·4	6·5	4·9	12·5	9·5
06	11 16·5	11 18·4	10 45·7	0·6	0·5	6·6	5·0	12·6	9·6
07	11 16·8	11 18·6	10 45·9	0·7	0·5	6·7	5·1	12·7	9·6
08	11 17·0	11 18·9	10 46·2	0·8	0·6	6·8	5·2	12·8	9·7
09	11 17·3	11 19·1	10 46·4	0·9	0·7	6·9	5·2	12·9	9·8
10	11 17·5	11 19·4	10 46·6	1·0	0·8	7·0	5·3	13·0	9·9
11	11 17·8	11 19·6	10 46·9	1·1	0·8	7·1	5·4	13·1	9·9
12	11 18·0	11 19·9	10 47·1	1·2	0·9	7·2	5·5	13·2	10·0
13	11 18·3	11 20·1	10 47·4	1·3	1·0	7·3	5·5	13·3	10·1
14	11 18·5	11 20·4	10 47·6	1·4	1·1	7·4	5·6	13·4	10·2
15	11 18·8	11 20·6	10 47·8	1·5	1·1	7·5	5·7	13·5	10·2
16	11 19·0	11 20·9	10 48·1	1·6	1·2	7·6	5·8	13·6	10·3
17	11 19·3	11 21·1	10 48·3	1·7	1·3	7·7	5·8	13·7	10·4
18	11 19·5	11 21·4	10 48·5	1·8	1·4	7·8	5·9	13·8	10·5
19	11 19·8	11 21·6	10 48·8	1·9	1·4	7·9	6·0	13·9	10·5
20	11 20·0	11 21·9	10 49·0	2·0	1·5	8·0	6·1	14·0	10·6
21	11 20·3	11 22·1	10 49·3	2·1	1·6	8·1	6·1	14·1	10·7
22	11 20·5	11 22·4	10 49·5	2·2	1·7	8·2	6·2	14·2	10·8
23	11 20·8	11 22·6	10 49·7	2·3	1·7	8·3	6·3	14·3	10·8
24	11 21·0	11 22·9	10 50·0	2·4	1·8	8·4	6·4	14·4	10·9
25	11 21·3	11 23·1	10 50·2	2·5	1·9	8·5	6·4	14·5	11·0
26	11 21·5	11 23·4	10 50·5	2·6	2·0	8·6	6·5	14·6	11·1
27	11 21·8	11 23·6	10 50·7	2·7	2·0	8·7	6·6	14·7	11·1
28	11 22·0	11 23·9	10 50·9	2·8	2·1	8·8	6·7	14·8	11·2
29	11 22·3	11 24·1	10 51·2	2·9	2·2	8·9	6·7	14·9	11·3
30	11 22·5	11 24·4	10 51·4	3·0	2·3	9·0	6·8	15·0	11·4
31	11 22·8	11 24·6	10 51·6	3·1	2·4	9·1	6·9	15·1	11·5
32	11 23·0	11 24·9	10 51·9	3·2	2·4	9·2	7·0	15·2	11·5
33	11 23·3	11 25·1	10 52·1	3·3	2·5	9·3	7·1	15·3	11·6
34	11 23·5	11 25·4	10 52·4	3·4	2·6	9·4	7·1	15·4	11·7
35	11 23·8	11 25·6	10 52·6	3·5	2·7	9·5	7·2	15·5	11·8
36	11 24·0	11 25·9	10 52·8	3·6	2·7	9·6	7·3	15·6	11·8
37	11 24·3	11 26·1	10 53·1	3·7	2·8	9·7	7·4	15·7	11·9
38	11 24·5	11 26·4	10 53·3	3·8	2·9	9·8	7·4	15·8	12·0
39	11 24·8	11 26·6	10 53·6	3·9	3·0	9·9	7·5	15·9	12·1
40	11 25·0	11 26·9	10 53·8	4·0	3·0	10·0	7·6	16·0	12·1
41	11 25·3	11 27·1	10 54·0	4·1	3·1	10·1	7·7	16·1	12·2
42	11 25·5	11 27·4	10 54·3	4·2	3·2	10·2	7·7	16·2	12·3
43	11 25·8	11 27·6	10 54·5	4·3	3·3	10·3	7·8	16·3	12·4
44	11 26·0	11 27·9	10 54·7	4·4	3·3	10·4	7·9	16·4	12·4
45	11 26·3	11 28·1	10 55·0	4·5	3·4	10·5	8·0	16·5	12·5
46	11 26·5	11 28·4	10 55·2	4·6	3·5	10·6	8·0	16·6	12·6
47	11 26·8	11 28·6	10 55·5	4·7	3·6	10·7	8·1	16·7	12·7
48	11 27·0	11 28·9	10 55·7	4·8	3·6	10·8	8·2	16·8	12·7
49	11 27·3	11 29·1	10 55·9	4·9	3·7	10·9	8·3	16·9	12·8
50	11 27·5	11 29·4	10 56·2	5·0	3·8	11·0	8·3	17·0	12·9
51	11 27·8	11 29·6	10 56·4	5·1	3·9	11·1	8·4	17·1	13·0
52	11 28·0	11 29·9	10 56·7	5·2	3·9	11·2	8·5	17·2	13·0
53	11 28·3	11 30·1	10 56·9	5·3	4·0	11·3	8·6	17·3	13·1
54	11 28·5	11 30·4	10 57·1	5·4	4·1	11·4	8·6	17·4	13·2
55	11 28·8	11 30·6	10 57·4	5·5	4·2	11·5	8·7	17·5	13·3
56	11 29·0	11 30·9	10 57·6	5·6	4·2	11·6	8·8	17·6	13·3
57	11 29·3	11 31·1	10 57·9	5·7	4·3	11·7	8·9	17·7	13·4
58	11 29·5	11 31·4	10 58·1	5·8	4·4	11·8	8·9	17·8	13·5
59	11 29·8	11 31·6	10 58·3	5·9	4·5	11·9	9·0	17·9	13·6
60	11 30·0	11 31·9	10 58·6	6·0	4·6	12·0	9·1	18·0	13·7

46m INCREMENTS AND CORRECTIONS 47m

46m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	11 30·0	11 31·9	10 58·6	0·0	0·0	6·0	4·7	12·0	9·3
01	11 30·3	11 32·1	10 58·8	0·1	0·1	6·1	4·7	12·1	9·4
02	11 30·5	11 32·4	10 59·0	0·2	0·2	6·2	4·8	12·2	9·5
03	11 30·8	11 32·6	10 59·3	0·3	0·2	6·3	4·9	12·3	9·5
04	11 31·0	11 32·9	10 59·5	0·4	0·3	6·4	5·0	12·4	9·6
05	11 31·3	11 33·1	10 59·8	0·5	0·4	6·5	5·0	12·5	9·7
06	11 31·5	11 33·4	11 00·0	0·6	0·5	6·6	5·1	12·6	9·8
07	11 31·8	11 33·6	11 00·2	0·7	0·5	6·7	5·2	12·7	9·8
08	11 32·0	11 33·9	11 00·5	0·8	0·6	6·8	5·3	12·8	9·9
09	11 32·3	11 34·1	11 00·7	0·9	0·7	6·9	5·3	12·9	10·0
10	11 32·5	11 34·4	11 01·0	1·0	0·8	7·0	5·4	13·0	10·1
11	11 32·8	11 34·6	11 01·2	1·1	0·9	7·1	5·5	13·1	10·2
12	11 33·0	11 34·9	11 01·4	1·2	0·9	7·2	5·6	13·2	10·2
13	11 33·3	11 35·1	11 01·7	1·3	1·0	7·3	5·7	13·3	10·3
14	11 33·5	11 35·4	11 01·9	1·4	1·1	7·4	5·7	13·4	10·4
15	11 33·8	11 35·6	11 02·1	1·5	1·2	7·5	5·8	13·5	10·5
16	11 34·0	11 35·9	11 02·4	1·6	1·2	7·6	5·9	13·6	10·5
17	11 34·3	11 36·2	11 02·6	1·7	1·3	7·7	6·0	13·7	10·6
18	11 34·5	11 36·4	11 02·9	1·8	1·4	7·8	6·0	13·8	10·7
19	11 34·8	11 36·7	11 03·1	1·9	1·5	7·9	6·1	13·9	10·8
20	11 35·0	11 36·9	11 03·3	2·0	1·6	8·0	6·2	14·0	10·9
21	11 35·3	11 37·2	11 03·6	2·1	1·6	8·1	6·3	14·1	10·9
22	11 35·5	11 37·4	11 03·8	2·2	1·7	8·2	6·4	14·2	11·0
23	11 35·8	11 37·7	11 04·1	2·3	1·8	8·3	6·4	14·3	11·1
24	11 36·0	11 37·9	11 04·3	2·4	1·9	8·4	6·5	14·4	11·2
25	11 36·3	11 38·2	11 04·5	2·5	1·9	8·5	6·6	14·5	11·2
26	11 36·5	11 38·4	11 04·8	2·6	2·0	8·6	6·7	14·6	11·3
27	11 36·8	11 38·7	11 05·0	2·7	2·1	8·7	6·7	14·7	11·4
28	11 37·0	11 38·9	11 05·2	2·8	2·2	8·8	6·8	14·8	11·5
29	11 37·3	11 39·2	11 05·5	2·9	2·2	8·9	6·9	14·9	11·5
30	11 37·5	11 39·4	11 05·7	3·0	2·3	9·0	7·0	15·0	11·6
31	11 37·8	11 39·7	11 06·0	3·1	2·4	9·1	7·1	15·1	11·7
32	11 38·0	11 39·9	11 06·2	3·2	2·5	9·2	7·1	15·2	11·8
33	11 38·3	11 40·2	11 06·4	3·3	2·6	9·3	7·2	15·3	11·9
34	11 38·5	11 40·4	11 06·7	3·4	2·6	9·4	7·3	15·4	11·9
35	11 38·8	11 40·7	11 06·9	3·5	2·7	9·5	7·4	15·5	12·0
36	11 39·0	11 40·9	11 07·2	3·6	2·8	9·6	7·4	15·6	12·1
37	11 39·3	11 41·2	11 07·4	3·7	2·9	9·7	7·5	15·7	12·2
38	11 39·5	11 41·4	11 07·6	3·8	2·9	9·8	7·6	15·8	12·2
39	11 39·8	11 41·7	11 07·9	3·9	3·0	9·9	7·7	15·9	12·3
40	11 40·0	11 41·9	11 08·1	4·0	3·1	10·0	7·8	16·0	12·4
41	11 40·3	11 42·2	11 08·3	4·1	3·2	10·1	7·8	16·1	12·5
42	11 40·5	11 42·4	11 08·6	4·2	3·3	10·2	7·9	16·2	12·6
43	11 40·8	11 42·7	11 08·8	4·3	3·3	10·3	8·0	16·3	12·6
44	11 41·0	11 42·9	11 09·1	4·4	3·4	10·4	8·1	16·4	12·7
45	11 41·3	11 43·2	11 09·3	4·5	3·5	10·5	8·1	16·5	12·8
46	11 41·5	11 43·4	11 09·5	4·6	3·6	10·6	8·2	16·6	12·9
47	11 41·8	11 43·7	11 09·8	4·7	3·6	10·7	8·3	16·7	12·9
48	11 42·0	11 43·9	11 10·0	4·8	3·7	10·8	8·4	16·8	13·0
49	11 42·3	11 44·2	11 10·3	4·9	3·8	10·9	8·4	16·9	13·1
50	11 42·5	11 44·4	11 10·5	5·0	3·9	11·0	8·5	17·0	13·2
51	11 42·8	11 44·7	11 10·7	5·1	4·0	11·1	8·6	17·1	13·3
52	11 43·0	11 44·9	11 11·0	5·2	4·0	11·2	8·7	17·2	13·3
53	11 43·3	11 45·2	11 11·2	5·3	4·1	11·3	8·8	17·3	13·4
54	11 43·5	11 45·4	11 11·5	5·4	4·2	11·4	8·8	17·4	13·5
55	11 43·8	11 45·7	11 11·7	5·5	4·3	11·5	8·9	17·5	13·6
56	11 44·0	11 45·9	11 11·9	5·6	4·3	11·6	9·0	17·6	13·6
57	11 44·3	11 46·2	11 12·2	5·7	4·4	11·7	9·1	17·7	13·7
58	11 44·5	11 46·4	11 12·4	5·8	4·5	11·8	9·1	17·8	13·8
59	11 44·8	11 46·7	11 12·6	5·9	4·6	11·9	9·2	17·9	13·9
60	11 45·0	11 46·9	11 12·9	6·0	4·7	12·0	9·3	18·0	14·0

47m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	11 45·0	11 46·9	11 12·9	0·0	0·0	6·0	4·8	12·0	9·5
01	11 45·3	11 47·2	11 13·1	0·1	0·1	6·1	4·8	12·1	9·6
02	11 45·5	11 47·4	11 13·4	0·2	0·2	6·2	4·9	12·2	9·7
03	11 45·8	11 47·7	11 13·6	0·3	0·2	6·3	5·0	12·3	9·7
04	11 46·0	11 47·9	11 13·8	0·4	0·3	6·4	5·1	12·4	9·8
05	11 46·3	11 48·2	11 14·1	0·5	0·4	6·5	5·1	12·5	9·9
06	11 46·5	11 48·4	11 14·3	0·6	0·5	6·6	5·2	12·6	10·0
07	11 46·8	11 48·7	11 14·6	0·7	0·6	6·7	5·3	12·7	10·1
08	11 47·0	11 48·9	11 14·8	0·8	0·6	6·8	5·4	12·8	10·1
09	11 47·3	11 49·2	11 15·0	0·9	0·7	6·9	5·5	12·9	10·2
10	11 47·5	11 49·4	11 15·3	1·0	0·8	7·0	5·5	13·0	10·3
11	11 47·8	11 49·7	11 15·5	1·1	0·9	7·1	5·6	13·1	10·4
12	11 48·0	11 49·9	11 15·7	1·2	1·0	7·2	5·7	13·2	10·5
13	11 48·3	11 50·2	11 16·0	1·3	1·0	7·3	5·8	13·3	10·5
14	11 48·5	11 50·4	11 16·2	1·4	1·1	7·4	5·9	13·4	10·6
15	11 48·8	11 50·7	11 16·5	1·5	1·2	7·5	5·9	13·5	10·7
16	11 49·0	11 50·9	11 16·7	1·6	1·3	7·6	6·0	13·6	10·8
17	11 49·3	11 51·2	11 16·9	1·7	1·3	7·7	6·1	13·7	10·8
18	11 49·5	11 51·4	11 17·2	1·8	1·4	7·8	6·2	13·8	10·9
19	11 49·8	11 51·7	11 17·4	1·9	1·5	7·9	6·3	13·9	11·0
20	11 50·0	11 51·9	11 17·7	2·0	1·6	8·0	6·3	14·0	11·1
21	11 50·3	11 52·2	11 17·9	2·1	1·7	8·1	6·4	14·1	11·2
22	11 50·5	11 52·4	11 18·1	2·2	1·7	8·2	6·5	14·2	11·2
23	11 50·8	11 52·7	11 18·4	2·3	1·8	8·3	6·6	14·3	11·3
24	11 51·0	11 52·9	11 18·6	2·4	1·9	8·4	6·7	14·4	11·4
25	11 51·3	11 53·2	11 18·8	2·5	2·0	8·5	6·7	14·5	11·5
26	11 51·5	11 53·4	11 19·1	2·6	2·1	8·6	6·8	14·6	11·6
27	11 51·8	11 53·7	11 19·3	2·7	2·1	8·7	6·9	14·7	11·6
28	11 52·0	11 53·9	11 19·6	2·8	2·2	8·8	7·0	14·8	11·7
29	11 52·3	11 54·2	11 19·8	2·9	2·3	8·9	7·0	14·9	11·8
30	11 52·5	11 54·5	11 20·0	3·0	2·4	9·0	7·1	15·0	11·9
31	11 52·8	11 54·7	11 20·3	3·1	2·5	9·1	7·2	15·1	12·0
32	11 53·0	11 55·0	11 20·5	3·2	2·5	9·2	7·3	15·2	12·0
33	11 53·3	11 55·2	11 20·8	3·3	2·6	9·3	7·4	15·3	12·1
34	11 53·5	11 55·5	11 21·0	3·4	2·7	9·4	7·4	15·4	12·2
35	11 53·8	11 55·7	11 21·2	3·5	2·8	9·5	7·5	15·5	12·3
36	11 54·0	11 56·0	11 21·5	3·6	2·9	9·6	7·6	15·6	12·4
37	11 54·3	11 56·2	11 21·7	3·7	2·9	9·7	7·7	15·7	12·4
38	11 54·5	11 56·5	11 22·0	3·8	3·0	9·8	7·8	15·8	12·5
39	11 54·8	11 56·7	11 22·2	3·9	3·1	9·9	7·8	15·9	12·6
40	11 55·0	11 57·0	11 22·4	4·0	3·2	10·0	7·9	16·0	12·7
41	11 55·3	11 57·2	11 22·7	4·1	3·2	10·1	8·0	16·1	12·7
42	11 55·5	11 57·5	11 22·9	4·2	3·3	10·2	8·1	16·2	12·8
43	11 55·8	11 57·7	11 23·1	4·3	3·4	10·3	8·2	16·3	12·9
44	11 56·0	11 58·0	11 23·4	4·4	3·5	10·4	8·2	16·4	13·0
45	11 56·3	11 58·2	11 23·6	4·5	3·6	10·5	8·3	16·5	13·1
46	11 56·5	11 58·5	11 23·9	4·6	3·6	10·6	8·4	16·6	13·1
47	11 56·8	11 58·7	11 24·1	4·7	3·7	10·7	8·5	16·7	13·2
48	11 57·0	11 59·0	11 24·3	4·8	3·8	10·8	8·6	16·8	13·3
49	11 57·3	11 59·2	11 24·6	4·9	3·9	10·9	8·6	16·9	13·4
50	11 57·5	11 59·5	11 24·8	5·0	4·0	11·0	8·7	17·0	13·5
51	11 57·8	11 59·7	11 25·1	5·1	4·0	11·1	8·8	17·1	13·5
52	11 58·0	12 00·0	11 25·3	5·2	4·1	11·2	8·9	17·2	13·6
53	11 58·3	12 00·2	11 25·5	5·3	4·2	11·3	8·9	17·3	13·7
54	11 58·5	12 00·5	11 25·8	5·4	4·3	11·4	9·0	17·4	13·8
55	11 58·8	12 00·7	11 26·0	5·5	4·4	11·5	9·1	17·5	13·9
56	11 59·0	12 01·0	11 26·2	5·6	4·4	11·6	9·2	17·6	13·9
57	11 59·3	12 01·2	11 26·5	5·7	4·5	11·7	9·3	17·7	14·0
58	11 59·5	12 01·5	11 26·7	5·8	4·6	11·8	9·3	17·8	14·1
59	11 59·8	12 01·7	11 27·0	5·9	4·7	11·9	9·4	17·9	14·2
60	12 00·0	12 02·0	11 27·2	6·0	4·8	12·0	9·5	18·0	14·3

48m INCREMENTS AND CORRECTIONS 49m

48m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	12 00·0	12 02·0	11 27·2	0·0	0·0	6·0	4·9	12·0	9·7
01	12 00·3	12 02·2	11 27·4	0·1	0·1	6·1	4·9	12·1	9·8
02	12 00·5	12 02·5	11 27·7	0·2	0·2	6·2	5·0	12·2	9·9
03	12 00·8	12 02·7	11 27·9	0·3	0·2	6·3	5·1	12·3	9·9
04	12 01·0	12 03·0	11 28·2	0·4	0·3	6·4	5·2	12·4	10·0
05	12 01·3	12 03·2	11 28·4	0·5	0·4	6·5	5·3	12·5	10·1
06	12 01·5	12 03·5	11 28·6	0·6	0·5	6·6	5·3	12·6	10·2
07	12 01·8	12 03·7	11 28·9	0·7	0·6	6·7	5·4	12·7	10·3
08	12 02·0	12 04·0	11 29·1	0·8	0·6	6·8	5·5	12·8	10·3
09	12 02·3	12 04·2	11 29·3	0·9	0·7	6·9	5·6	12·9	10·4
10	12 02·5	12 04·5	11 29·6	1·0	0·8	7·0	5·7	13·0	10·5
11	12 02·8	12 04·7	11 29·8	1·1	0·9	7·1	5·7	13·1	10·6
12	12 03·0	12 05·0	11 30·1	1·2	1·0	7·2	5·8	13·2	10·7
13	12 03·3	12 05·2	11 30·3	1·3	1·1	7·3	5·9	13·3	10·8
14	12 03·5	12 05·5	11 30·5	1·4	1·1	7·4	6·0	13·4	10·8
15	12 03·8	12 05·7	11 30·8	1·5	1·2	7·5	6·1	13·5	10·9
16	12 04·0	12 06·0	11 31·0	1·6	1·3	7·6	6·1	13·6	11·0
17	12 04·3	12 06·2	11 31·3	1·7	1·4	7·7	6·2	13·7	11·1
18	12 04·5	12 06·5	11 31·5	1·8	1·5	7·8	6·3	13·8	11·2
19	12 04·8	12 06·7	11 31·7	1·9	1·5	7·9	6·4	13·9	11·2
20	12 05·0	12 07·0	11 32·0	2·0	1·6	8·0	6·5	14·0	11·3
21	12 05·3	12 07·2	11 32·2	2·1	1·7	8·1	6·5	14·1	11·4
22	12 05·5	12 07·5	11 32·4	2·2	1·8	8·2	6·6	14·2	11·5
23	12 05·8	12 07·7	11 32·7	2·3	1·9	8·3	6·7	14·3	11·6
24	12 06·0	12 08·0	11 32·9	2·4	1·9	8·4	6·8	14·4	11·6
25	12 06·3	12 08·2	11 33·2	2·5	2·0	8·5	6·9	14·5	11·7
26	12 06·5	12 08·5	11 33·4	2·6	2·1	8·6	7·0	14·6	11·8
27	12 06·8	12 08·7	11 33·6	2·7	2·2	8·7	7·0	14·7	11·9
28	12 07·0	12 09·0	11 33·9	2·8	2·3	8·8	7·1	14·8	12·0
29	12 07·3	12 09·2	11 34·1	2·9	2·3	8·9	7·2	14·9	12·0
30	12 07·5	12 09·5	11 34·4	3·0	2·4	9·0	7·3	15·0	12·1
31	12 07·8	12 09·7	11 34·6	3·1	2·5	9·1	7·4	15·1	12·2
32	12 08·0	12 10·0	11 34·8	3·2	2·6	9·2	7·4	15·2	12·3
33	12 08·3	12 10·2	11 35·1	3·3	2·7	9·3	7·5	15·3	12·4
34	12 08·5	12 10·5	11 35·3	3·4	2·7	9·4	7·6	15·4	12·4
35	12 08·8	12 10·7	11 35·6	3·5	2·8	9·5	7·7	15·5	12·5
36	12 09·0	12 11·0	11 35·8	3·6	2·9	9·6	7·8	15·6	12·6
37	12 09·3	12 11·2	11 36·0	3·7	3·0	9·7	7·8	15·7	12·7
38	12 09·5	12 11·5	11 36·3	3·8	3·1	9·8	7·9	15·8	12·8
39	12 09·8	12 11·7	11 36·5	3·9	3·2	9·9	8·0	15·9	12·9
40	12 10·0	12 12·0	11 36·7	4·0	3·2	10·0	8·1	16·0	12·9
41	12 10·3	12 12·2	11 37·0	4·1	3·3	10·1	8·2	16·1	13·0
42	12 10·5	12 12·5	11 37·2	4·2	3·4	10·2	8·2	16·2	13·1
43	12 10·8	12 12·8	11 37·5	4·3	3·5	10·3	8·3	16·3	13·2
44	12 11·0	12 13·0	11 37·7	4·4	3·6	10·4	8·4	16·4	13·3
45	12 11·3	12 13·3	11 37·9	4·5	3·6	10·5	8·5	16·5	13·3
46	12 11·5	12 13·5	11 38·2	4·6	3·7	10·6	8·6	16·6	13·4
47	12 11·8	12 13·8	11 38·4	4·7	3·8	10·7	8·6	16·7	13·5
48	12 12·0	12 14·0	11 38·7	4·8	3·9	10·8	8·7	16·8	13·6
49	12 12·3	12 14·3	11 38·9	4·9	4·0	10·9	8·8	16·9	13·7
50	12 12·5	12 14·5	11 39·1	5·0	4·0	11·0	8·9	17·0	13·7
51	12 12·8	12 14·8	11 39·4	5·1	4·1	11·1	9·0	17·1	13·8
52	12 13·0	12 15·0	11 39·6	5·2	4·2	11·2	9·1	17·2	13·9
53	12 13·3	12 15·3	11 39·8	5·3	4·3	11·3	9·1	17·3	14·0
54	12 13·5	12 15·5	11 40·1	5·4	4·4	11·4	9·2	17·4	14·1
55	12 13·8	12 15·8	11 40·3	5·5	4·4	11·5	9·3	17·5	14·1
56	12 14·0	12 16·0	11 40·6	5·6	4·5	11·6	9·4	17·6	14·2
57	12 14·3	12 16·3	11 40·8	5·7	4·6	11·7	9·5	17·7	14·3
58	12 14·5	12 16·5	11 41·0	5·8	4·7	11·8	9·5	17·8	14·4
59	12 14·8	12 16·8	11 41·3	5·9	4·8	11·9	9·6	17·9	14·5
60	12 15·0	12 17·0	11 41·5	6·0	4·9	12·0	9·7	18·0	14·6

49m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	12 15·0	12 17·0	11 41·5	0·0	0·0	6·0	5·0	12·0	9·9
01	12 15·3	12 17·3	11 41·8	0·1	0·1	6·1	5·0	12·1	10·0
02	12 15·5	12 17·5	11 42·0	0·2	0·2	6·2	5·1	12·2	10·1
03	12 15·8	12 17·8	11 42·2	0·3	0·2	6·3	5·2	12·3	10·1
04	12 16·0	12 18·0	11 42·5	0·4	0·3	6·4	5·3	12·4	10·2
05	12 16·3	12 18·3	11 42·7	0·5	0·4	6·5	5·4	12·5	10·3
06	12 16·5	12 18·5	11 42·9	0·6	0·5	6·6	5·4	12·6	10·4
07	12 16·8	12 18·8	11 43·2	0·7	0·6	6·7	5·5	12·7	10·5
08	12 17·0	12 19·0	11 43·4	0·8	0·7	6·8	5·6	12·8	10·6
09	12 17·3	12 19·3	11 43·7	0·9	0·7	6·9	5·7	12·9	10·6
10	12 17·5	12 19·5	11 43·9	1·0	0·8	7·0	5·8	13·0	10·7
11	12 17·8	12 19·8	11 44·1	1·1	0·9	7·1	5·9	13·1	10·8
12	12 18·0	12 20·0	11 44·4	1·2	1·0	7·2	5·9	13·2	10·9
13	12 18·3	12 20·3	11 44·6	1·3	1·1	7·3	6·0	13·3	11·0
14	12 18·5	12 20·5	11 44·9	1·4	1·2	7·4	6·1	13·4	11·1
15	12 18·8	12 20·8	11 45·1	1·5	1·2	7·5	6·2	13·5	11·1
16	12 19·0	12 21·0	11 45·3	1·6	1·3	7·6	6·3	13·6	11·2
17	12 19·3	12 21·3	11 45·6	1·7	1·4	7·7	6·4	13·7	11·3
18	12 19·5	12 21·5	11 45·8	1·8	1·5	7·8	6·4	13·8	11·4
19	12 19·8	12 21·8	11 46·1	1·9	1·6	7·9	6·5	13·9	11·5
20	12 20·0	12 22·0	11 46·3	2·0	1·7	8·0	6·6	14·0	11·6
21	12 20·3	12 22·3	11 46·5	2·1	1·7	8·1	6·7	14·1	11·6
22	12 20·5	12 22·5	11 46·8	2·2	1·8	8·2	6·8	14·2	11·7
23	12 20·8	12 22·8	11 47·0	2·3	1·9	8·3	6·8	14·3	11·8
24	12 21·0	12 23·0	11 47·2	2·4	2·0	8·4	6·9	14·4	11·9
25	12 21·3	12 23·3	11 47·5	2·5	2·1	8·5	7·0	14·5	12·0
26	12 21·5	12 23·5	11 47·7	2·6	2·1	8·6	7·1	14·6	12·0
27	12 21·8	12 23·8	11 48·0	2·7	2·2	8·7	7·2	14·7	12·1
28	12 22·0	12 24·0	11 48·2	2·8	2·3	8·8	7·3	14·8	12·2
29	12 22·3	12 24·3	11 48·4	2·9	2·4	8·9	7·3	14·9	12·3
30	12 22·5	12 24·5	11 48·7	3·0	2·5	9·0	7·4	15·0	12·4
31	12 22·8	12 24·8	11 48·9	3·1	2·6	9·1	7·5	15·1	12·5
32	12 23·0	12 25·0	11 49·2	3·2	2·6	9·2	7·6	15·2	12·5
33	12 23·3	12 25·3	11 49·4	3·3	2·7	9·3	7·7	15·3	12·6
34	12 23·5	12 25·5	11 49·6	3·4	2·8	9·4	7·8	15·4	12·7
35	12 23·8	12 25·8	11 49·9	3·5	2·9	9·5	7·8	15·5	12·8
36	12 24·0	12 26·0	11 50·1	3·6	3·0	9·6	7·9	15·6	12·9
37	12 24·3	12 26·3	11 50·3	3·7	3·1	9·7	8·0	15·7	13·0
38	12 24·5	12 26·5	11 50·6	3·8	3·1	9·8	8·1	15·8	13·0
39	12 24·8	12 26·8	11 50·8	3·9	3·2	9·9	8·2	15·9	13·1
40	12 25·0	12 27·0	11 51·1	4·0	3·3	10·0	8·3	16·0	13·2
41	12 25·3	12 27·3	11 51·3	4·1	3·4	10·1	8·3	16·1	13·3
42	12 25·5	12 27·5	11 51·5	4·2	3·5	10·2	8·4	16·2	13·4
43	12 25·8	12 27·8	11 51·8	4·3	3·5	10·3	8·5	16·3	13·4
44	12 26·0	12 28·0	11 52·0	4·4	3·6	10·4	8·6	16·4	13·5
45	12 26·3	12 28·3	11 52·3	4·5	3·7	10·5	8·7	16·5	13·6
46	12 26·5	12 28·5	11 52·5	4·6	3·8	10·6	8·7	16·6	13·7
47	12 26·8	12 28·8	11 52·7	4·7	3·9	10·7	8·8	16·7	13·8
48	12 27·0	12 29·0	11 53·0	4·8	4·0	10·8	8·9	16·8	13·9
49	12 27·3	12 29·3	11 53·2	4·9	4·0	10·9	9·0	16·9	13·9
50	12 27·5	12 29·5	11 53·4	5·0	4·1	11·0	9·1	17·0	14·0
51	12 27·8	12 29·8	11 53·7	5·1	4·2	11·1	9·2	17·1	14·1
52	12 28·0	12 30·0	11 53·9	5·2	4·3	11·2	9·2	17·2	14·2
53	12 28·3	12 30·3	11 54·2	5·3	4·4	11·3	9·3	17·3	14·3
54	12 28·5	12 30·5	11 54·4	5·4	4·5	11·4	9·4	17·4	14·4
55	12 28·8	12 30·8	11 54·6	5·5	4·5	11·5	9·5	17·5	14·4
56	12 29·0	12 31·1	11 54·9	5·6	4·6	11·6	9·6	17·6	14·5
57	12 29·3	12 31·3	11 55·1	5·7	4·7	11·7	9·7	17·7	14·6
58	12 29·5	12 31·6	11 55·4	5·8	4·8	11·8	9·7	17·8	14·7
59	12 29·8	12 31·8	11 55·6	5·9	4·9	11·9	9·8	17·9	14·8
60	12 30·0	12 32·1	11 55·8	6·0	5·0	12·0	9·9	18·0	14·9

50m INCREMENTS AND CORRECTIONS

50m	SUN PLANETS	ARIES	MOON	v or d	Corr	v or d	Corr	v or d	Corr
s	° ′	° ′	° ′	′	′	′	′	′	′
00	12 30·0	12 32·1	11 55·8	0·0	0·0	6·0	5·1	12·0	10·1
01	12 30·3	12 32·3	11 56·1	0·1	0·1	6·1	5·1	12·1	10·2
02	12 30·5	12 32·6	11 56·3	0·2	0·2	6·2	5·2	12·2	10·3
03	12 30·8	12 32·8	11 56·5	0·3	0·3	6·3	5·3	12·3	10·4
04	12 31·0	12 33·1	11 56·8	0·4	0·3	6·4	5·4	12·4	10·4
05	12 31·3	12 33·3	11 57·0	0·5	0·4	6·5	5·5	12·5	10·5
06	12 31·5	12 33·6	11 57·3	0·6	0·5	6·6	5·6	12·6	10·6
07	12 31·8	12 33·8	11 57·5	0·7	0·6	6·7	5·6	12·7	10·7
08	12 32·0	12 34·1	11 57·7	0·8	0·7	6·8	5·7	12·8	10·8
09	12 32·3	12 34·3	11 58·0	0·9	0·8	6·9	5·8	12·9	10·9
10	12 32·5	12 34·6	11 58·2	1·0	0·8	7·0	5·9	13·0	10·9
11	12 32·8	12 34·8	11 58·5	1·1	0·9	7·1	6·0	13·1	11·0
12	12 33·0	12 35·1	11 58·7	1·2	1·0	7·2	6·1	13·2	11·1
13	12 33·3	12 35·3	11 58·9	1·3	1·1	7·3	6·1	13·3	11·2
14	12 33·5	12 35·6	11 59·2	1·4	1·2	7·4	6·2	13·4	11·3
15	12 33·8	12 35·8	11 59·4	1·5	1·3	7·5	6·3	13·5	11·4
16	12 34·0	12 36·1	11 59·7	1·6	1·3	7·6	6·4	13·6	11·4
17	12 34·3	12 36·3	11 59·9	1·7	1·4	7·7	6·5	13·7	11·5
18	12 34·5	12 36·6	12 00·1	1·8	1·5	7·8	6·6	13·8	11·6
19	12 34·8	12 36·8	12 00·4	1·9	1·6	7·9	6·6	13·9	11·7
20	12 35·0	12 37·1	12 00·6	2·0	1·7	8·0	6·7	14·0	11·8
21	12 35·3	12 37·3	12 00·8	2·1	1·8	8·1	6·8	14·1	11·9
22	12 35·5	12 37·6	12 01·1	2·2	1·9	8·2	6·9	14·2	12·0
23	12 35·8	12 37·8	12 01·3	2·3	1·9	8·3	7·0	14·3	12·0
24	12 36·0	12 38·1	12 01·6	2·4	2·0	8·4	7·1	14·4	12·1
25	12 36·3	12 38·3	12 01·8	2·5	2·1	8·5	7·2	14·5	12·2
26	12 36·5	12 38·6	12 02·0	2·6	2·2	8·6	7·2	14·6	12·3
27	12 36·8	12 38·8	12 02·3	2·7	2·3	8·7	7·3	14·7	12·4
28	12 37·0	12 39·1	12 02·5	2·8	2·4	8·8	7·4	14·8	12·5
29	12 37·3	12 39·3	12 02·8	2·9	2·4	8·9	7·5	14·9	12·5
30	12 37·5	12 39·6	12 03·0	3·0	2·5	9·0	7·6	15·0	12·6
31	12 37·8	12 39·8	12 03·2	3·1	2·6	9·1	7·7	15·1	12·7
32	12 38·0	12 40·1	12 03·5	3·2	2·7	9·2	7·7	15·2	12·8
33	12 38·3	12 40·3	12 03·7	3·3	2·8	9·3	7·8	15·3	12·9
34	12 38·5	12 40·6	12 03·9	3·4	2·9	9·4	7·9	15·4	13·0
35	12 38·8	12 40·8	12 04·2	3·5	2·9	9·5	8·0	15·5	13·0
36	12 39·0	12 41·1	12 04·4	3·6	3·0	9·6	8·1	15·6	13·1
37	12 39·3	12 41·3	12 04·7	3·7	3·1	9·7	8·2	15·7	13·2
38	12 39·5	12 41·6	12 04·9	3·8	3·2	9·8	8·2	15·8	13·3
39	12 39·8	12 41·8	12 05·1	3·9	3·3	9·9	8·3	15·9	13·4
40	12 40·0	12 42·1	12 05·4	4·0	3·4	10·0	8·4	16·0	13·5
41	12 40·3	12 42·3	12 05·6	4·1	3·5	10·1	8·5	16·1	13·6
42	12 40·5	12 42·6	12 05·9	4·2	3·5	10·2	8·6	16·2	13·6
43	12 40·8	12 42·8	12 06·1	4·3	3·6	10·3	8·7	16·3	13·7
44	12 41·0	12 43·1	12 06·3	4·4	3·7	10·4	8·8	16·4	13·8
45	12 41·3	12 43·3	12 06·6	4·5	3·8	10·5	8·8	16·5	13·9
46	12 41·5	12 43·6	12 06·8	4·6	3·9	10·6	8·9	16·6	14·0
47	12 41·8	12 43·8	12 07·0	4·7	4·0	10·7	9·0	16·7	14·1
48	12 42·0	12 44·1	12 07·3	4·8	4·0	10·8	9·1	16·8	14·1
49	12 42·3	12 44·3	12 07·5	4·9	4·1	10·9	9·2	16·9	14·2
50	12 42·5	12 44·6	12 07·8	5·0	4·2	11·0	9·3	17·0	14·3
51	12 42·8	12 44·8	12 08·0	5·1	4·3	11·1	9·3	17·1	14·4
52	12 43·0	12 45·1	12 08·2	5·2	4·4	11·2	9·4	17·2	14·5
53	12 43·3	12 45·3	12 08·5	5·3	4·5	11·3	9·5	17·3	14·6
54	12 43·5	12 45·6	12 08·7	5·4	4·5	11·4	9·6	17·4	14·6
55	12 43·8	12 45·8	12 09·0	5·5	4·6	11·5	9·7	17·5	14·7
56	12 44·0	12 46·1	12 09·2	5·6	4·7	11·6	9·8	17·6	14·8
57	12 44·3	12 46·3	12 09·4	5·7	4·8	11·7	9·8	17·7	14·9
58	12 44·5	12 46·6	12 09·7	5·8	4·9	11·8	9·9	17·8	15·0
59	12 44·8	12 46·8	12 09·9	5·9	5·0	11·9	10·0	17·9	15·1
60	12 45·0	12 47·1	12 10·2	6·0	5·1	12·0	10·1	18·0	15·2

51m	SUN PLANETS	ARIES	MOON	v or d	Corr	v or d	Corr	v or d	Corr
s	° ′	° ′	° ′	′	′	′	′	′	′
00	12 45·0	12 47·1	12 10·2	0·0	0·0	6·0	5·2	12·0	10·3
01	12 45·3	12 47·3	12 10·4	0·1	0·1	6·1	5·2	12·1	10·4
02	12 45·5	12 47·6	12 10·6	0·2	0·2	6·2	5·3	12·2	10·5
03	12 45·8	12 47·8	12 10·9	0·3	0·3	6·3	5·4	12·3	10·6
04	12 46·0	12 48·1	12 11·1	0·4	0·3	6·4	5·5	12·4	10·6
05	12 46·3	12 48·3	12 11·3	0·5	0·4	6·5	5·6	12·5	10·7
06	12 46·5	12 48·6	12 11·6	0·6	0·5	6·6	5·7	12·6	10·8
07	12 46·8	12 48·8	12 11·8	0·7	0·6	6·7	5·8	12·7	10·9
08	12 47·0	12 49·1	12 12·1	0·8	0·7	6·8	5·8	12·8	11·0
09	12 47·3	12 49·4	12 12·3	0·9	0·8	6·9	5·9	12·9	11·1
10	12 47·5	12 49·6	12 12·5	1·0	0·9	7·0	6·0	13·0	11·2
11	12 47·8	12 49·9	12 12·8	1·1	0·9	7·1	6·1	13·1	11·2
12	12 48·0	12 50·1	12 13·0	1·2	1·0	7·2	6·2	13·2	11·3
13	12 48·3	12 50·4	12 13·3	1·3	1·1	7·3	6·3	13·3	11·4
14	12 48·5	12 50·6	12 13·5	1·4	1·2	7·4	6·4	13·4	11·5
15	12 48·8	12 50·9	12 13·7	1·5	1·3	7·5	6·4	13·5	11·6
16	12 49·0	12 51·1	12 14·0	1·6	1·4	7·6	6·5	13·6	11·7
17	12 49·3	12 51·4	12 14·2	1·7	1·5	7·7	6·6	13·7	11·8
18	12 49·5	12 51·6	12 14·4	1·8	1·5	7·8	6·7	13·8	11·8
19	12 49·8	12 51·9	12 14·7	1·9	1·6	7·9	6·8	13·9	11·9
20	12 50·0	12 52·1	12 14·9	2·0	1·7	8·0	6·9	14·0	12·0
21	12 50·3	12 52·4	12 15·2	2·1	1·8	8·1	7·0	14·1	12·1
22	12 50·5	12 52·6	12 15·4	2·2	1·9	8·2	7·0	14·2	12·2
23	12 50·8	12 52·9	12 15·6	2·3	2·0	8·3	7·1	14·3	12·3
24	12 51·0	12 53·1	12 15·9	2·4	2·1	8·4	7·2	14·4	12·4
25	12 51·3	12 53·4	12 16·1	2·5	2·1	8·5	7·3	14·5	12·4
26	12 51·5	12 53·6	12 16·4	2·6	2·2	8·6	7·4	14·6	12·5
27	12 51·8	12 53·9	12 16·6	2·7	2·3	8·7	7·5	14·7	12·6
28	12 52·0	12 54·1	12 16·8	2·8	2·4	8·8	7·6	14·8	12·7
29	12 52·3	12 54·4	12 17·1	2·9	2·5	8·9	7·6	14·9	12·8
30	12 52·5	12 54·6	12 17·3	3·0	2·6	9·0	7·7	15·0	12·9
31	12 52·8	12 54·9	12 17·5	3·1	2·7	9·1	7·8	15·1	13·0
32	12 53·0	12 55·1	12 17·8	3·2	2·7	9·2	7·9	15·2	13·0
33	12 53·3	12 55·4	12 18·0	3·3	2·8	9·3	8·0	15·3	13·1
34	12 53·5	12 55·6	12 18·3	3·4	2·9	9·4	8·1	15·4	13·2
35	12 53·8	12 55·9	12 18·5	3·5	3·0	9·5	8·2	15·5	13·3
36	12 54·0	12 56·1	12 18·7	3·6	3·1	9·6	8·2	15·6	13·4
37	12 54·3	12 56·4	12 19·0	3·7	3·2	9·7	8·3	15·7	13·5
38	12 54·5	12 56·6	12 19·2	3·8	3·3	9·8	8·4	15·8	13·6
39	12 54·8	12 56·9	12 19·5	3·9	3·3	9·9	8·5	15·9	13·6
40	12 55·0	12 57·1	12 19·7	4·0	3·4	10·0	8·6	16·0	13·7
41	12 55·3	12 57·4	12 19·9	4·1	3·5	10·1	8·7	16·1	13·8
42	12 55·5	12 57·6	12 20·2	4·2	3·6	10·2	8·8	16·2	13·9
43	12 55·8	12 57·9	12 20·4	4·3	3·7	10·3	8·8	16·3	14·0
44	12 56·0	12 58·1	12 20·6	4·4	3·8	10·4	8·9	16·4	14·1
45	12 56·3	12 58·4	12 20·9	4·5	3·9	10·5	9·0	16·5	14·2
46	12 56·5	12 58·6	12 21·1	4·6	3·9	10·6	9·1	16·6	14·2
47	12 56·8	12 58·9	12 21·4	4·7	4·0	10·7	9·2	16·7	14·3
48	12 57·0	12 59·1	12 21·6	4·8	4·1	10·8	9·3	16·8	14·4
49	12 57·3	12 59·4	12 21·8	4·9	4·2	10·9	9·4	16·9	14·5
50	12 57·5	12 59·6	12 22·1	5·0	4·3	11·0	9·4	17·0	14·6
51	12 57·8	12 59·9	12 22·3	5·1	4·4	11·1	9·5	17·1	14·7
52	12 58·0	13 00·1	12 22·6	5·2	4·5	11·2	9·6	17·2	14·8
53	12 58·3	13 00·4	12 22·8	5·3	4·5	11·3	9·7	17·3	14·8
54	12 58·5	13 00·6	12 23·0	5·4	4·6	11·4	9·8	17·4	14·9
55	12 58·8	13 00·9	12 23·3	5·5	4·7	11·5	9·9	17·5	15·0
56	12 59·0	13 01·1	12 23·5	5·6	4·8	11·6	10·0	17·6	15·1
57	12 59·3	13 01·4	12 23·8	5·7	4·9	11·7	10·0	17·7	15·2
58	12 59·5	13 01·6	12 24·0	5·8	5·0	11·8	10·1	17·8	15·3
59	12 59·8	13 01·9	12 24·2	5·9	5·1	11·9	10·2	17·9	15·4
60	13 00·0	13 02·1	12 24·5	6·0	5·2	12·0	10·3	18·0	15·5

52m INCREMENTS AND CORRECTIONS 53m

52m	SUN PLANETS	ARIES	MOON	v or Corrn d		v or Corrn d		v or Corrn d	
s	° ′	° ′	° ′	′	′	′	′	′	′
00	13 00·0	13 02·1	12 24·5	0·0	0·0	6·0	5·3	12·0	10·5
01	13 00·3	13 02·4	12 24·7	0·1	0·1	6·1	5·3	12·1	10·6
02	13 00·5	13 02·6	12 24·9	0·2	0·2	6·2	5·4	12·2	10·7
03	13 00·8	13 02·9	12 25·2	0·3	0·3	6·3	5·5	12·3	10·8
04	13 01·0	13 03·1	12 25·4	0·4	0·4	6·4	5·6	12·4	10·9
05	13 01·3	13 03·4	12 25·7	0·5	0·4	6·5	5·7	12·5	10·9
06	13 01·5	13 03·6	12 25·9	0·6	0·5	6·6	5·8	12·6	11·0
07	13 01·8	13 03·9	12 26·1	0·7	0·6	6·7	5·9	12·7	11·1
08	13 02·0	13 04·1	12 26·4	0·8	0·7	6·8	6·0	12·8	11·2
09	13 02·3	13 04·4	12 26·6	0·9	0·8	6·9	6·0	12·9	11·3
10	13 02·5	13 04·6	12 26·9	1·0	0·9	7·0	6·1	13·0	11·4
11	13 02·8	13 04·9	12 27·1	1·1	1·0	7·1	6·2	13·1	11·5
12	13 03·0	13 05·1	12 27·3	1·2	1·1	7·2	6·3	13·2	11·6
13	13 03·3	13 05·4	12 27·6	1·3	1·1	7·3	6·4	13·3	11·6
14	13 03·5	13 05·6	12 27·8	1·4	1·2	7·4	6·5	13·4	11·7
15	13 03·8	13 05·9	12 28·0	1·5	1·3	7·5	6·6	13·5	11·8
16	13 04·0	13 06·1	12 28·3	1·6	1·4	7·6	6·7	13·6	11·9
17	13 04·3	13 06·4	12 28·5	1·7	1·5	7·7	6·7	13·7	12·0
18	13 04·5	13 06·6	12 28·8	1·8	1·6	7·8	6·8	13·8	12·1
19	13 04·8	13 06·9	12 29·0	1·9	1·7	7·9	6·9	13·9	12·2
20	13 05·0	13 07·1	12 29·2	2·0	1·8	8·0	7·0	14·0	12·3
21	13 05·3	13 07·4	12 29·5	2·1	1·8	8·1	7·1	14·1	12·3
22	13 05·5	13 07·7	12 29·7	2·2	1·9	8·2	7·2	14·2	12·4
23	13 05·8	13 07·9	12 30·0	2·3	2·0	8·3	7·3	14·3	12·5
24	13 06·0	13 08·2	12 30·2	2·4	2·1	8·4	7·4	14·4	12·6
25	13 06·3	13 08·4	12 30·4	2·5	2·2	8·5	7·4	14·5	12·7
26	13 06·5	13 08·7	12 30·7	2·6	2·3	8·6	7·5	14·6	12·8
27	13 06·8	13 08·9	12 30·9	2·7	2·4	8·7	7·6	14·7	12·9
28	13 07·0	13 09·2	12 31·1	2·8	2·5	8·8	7·7	14·8	13·0
29	13 07·3	13 09·4	12 31·4	2·9	2·5	8·9	7·8	14·9	13·0
30	13 07·5	13 09·7	12 31·6	3·0	2·6	9·0	7·9	15·0	13·1
31	13 07·8	13 09·9	12 31·9	3·1	2·7	9·1	8·0	15·1	13·2
32	13 08·0	13 10·2	12 32·1	3·2	2·8	9·2	8·1	15·2	13·3
33	13 08·3	13 10·4	12 32·3	3·3	2·9	9·3	8·1	15·3	13·4
34	13 08·5	13 10·7	12 32·6	3·4	3·0	9·4	8·2	15·4	13·5
35	13 08·8	13 10·9	12 32·8	3·5	3·1	9·5	8·3	15·5	13·6
36	13 09·0	13 11·2	12 33·1	3·6	3·2	9·6	8·4	15·6	13·7
37	13 09·3	13 11·4	12 33·3	3·7	3·2	9·7	8·5	15·7	13·7
38	13 09·5	13 11·7	12 33·5	3·8	3·3	9·8	8·6	15·8	13·8
39	13 09·8	13 11·9	12 33·8	3·9	3·4	9·9	8·7	15·9	13·9
40	13 10·0	13 12·2	12 34·0	4·0	3·5	10·0	8·8	16·0	14·0
41	13 10·3	13 12·4	12 34·2	4·1	3·6	10·1	8·8	16·1	14·1
42	13 10·5	13 12·7	12 34·5	4·2	3·7	10·2	8·9	16·2	14·2
43	13 10·8	13 12·9	12 34·7	4·3	3·8	10·3	9·0	16·3	14·3
44	13 11·0	13 13·2	12 35·0	4·4	3·9	10·4	9·1	16·4	14·4
45	13 11·3	13 13·4	12 35·2	4·5	3·9	10·5	9·2	16·5	14·4
46	13 11·5	13 13·7	12 35·4	4·6	4·0	10·6	9·3	16·6	14·5
47	13 11·8	13 13·9	12 35·7	4·7	4·1	10·7	9·4	16·7	14·6
48	13 12·0	13 14·2	12 35·9	4·8	4·2	10·8	9·5	16·8	14·7
49	13 12·3	13 14·4	12 36·2	4·9	4·3	10·9	9·5	16·9	14·8
50	13 12·5	13 14·7	12 36·4	5·0	4·4	11·0	9·6	17·0	14·9
51	13 12·8	13 14·9	12 36·6	5·1	4·5	11·1	9·7	17·1	15·0
52	13 13·0	13 15·2	12 36·9	5·2	4·6	11·2	9·8	17·2	15·1
53	13 13·3	13 15·4	12 37·1	5·3	4·6	11·3	9·9	17·3	15·1
54	13 13·5	13 15·7	12 37·4	5·4	4·7	11·4	10·0	17·4	15·2
55	13 13·8	13 15·9	12 37·6	5·5	4·8	11·5	10·1	17·5	15·3
56	13 14·0	13 16·2	12 37·8	5·6	4·9	11·6	10·2	17·6	15·4
57	13 14·3	13 16·4	12 38·1	5·7	5·0	11·7	10·2	17·7	15·5
58	13 14·5	13 16·7	12 38·3	5·8	5·1	11·8	10·3	17·8	15·6
59	13 14·8	13 16·9	12 38·5	5·9	5·2	11·9	10·4	17·9	15·7
60	13 15·0	13 17·2	12 38·8	6·0	5·3	12·0	10·5	18·0	15·8

53m	SUN PLANETS	ARIES	MOON	v or Corrn d		v or Corrn d		v or Corrn d	
s	° ′	° ′	° ′	′	′	′	′	′	′
00	13 15·0	13 17·2	12 38·8	0·0	0·0	6·0	5·4	12·0	10·7
01	13 15·3	13 17·4	12 39·0	0·1	0·1	6·1	5·4	12·1	10·8
02	13 15·5	13 17·7	12 39·3	0·2	0·2	6·2	5·5	12·2	10·9
03	13 15·8	13 17·9	12 39·5	0·3	0·3	6·3	5·6	12·3	11·0
04	13 16·0	13 18·2	12 39·7	0·4	0·4	6·4	5·7	12·4	11·1
05	13 16·3	13 18·4	12 40·0	0·5	0·4	6·5	5·8	12·5	11·1
06	13 16·5	13 18·7	12 40·2	0·6	0·5	6·6	5·9	12·6	11·2
07	13 16·8	13 18·9	12 40·5	0·7	0·6	6·7	6·0	12·7	11·3
08	13 17·0	13 19·2	12 40·7	0·8	0·7	6·8	6·1	12·8	11·4
09	13 17·3	13 19·4	12 40·9	0·9	0·8	6·9	6·2	12·9	11·5
10	13 17·5	13 19·7	12 41·2	1·0	0·9	7·0	6·2	13·0	11·6
11	13 17·8	13 19·9	12 41·4	1·1	1·0	7·1	6·3	13·1	11·7
12	13 18·0	13 20·2	12 41·6	1·2	1·1	7·2	6·4	13·2	11·8
13	13 18·3	13 20·4	12 41·9	1·3	1·2	7·3	6·5	13·3	11·9
14	13 18·5	13 20·7	12 42·1	1·4	1·2	7·4	6·6	13·4	11·9
15	13 18·8	13 20·9	12 42·4	1·5	1·3	7·5	6·7	13·5	12·0
16	13 19·0	13 21·2	12 42·6	1·6	1·4	7·6	6·8	13·6	12·1
17	13 19·3	13 21·4	12 42·8	1·7	1·5	7·7	6·9	13·7	12·2
18	13 19·5	13 21·7	12 43·1	1·8	1·6	7·8	7·0	13·8	12·3
19	13 19·8	13 21·9	12 43·3	1·9	1·7	7·9	7·0	13·9	12·4
20	13 20·0	13 22·2	12 43·6	2·0	1·8	8·0	7·1	14·0	12·5
21	13 20·3	13 22·4	12 43·8	2·1	1·9	8·1	7·2	14·1	12·6
22	13 20·5	13 22·7	12 44·0	2·2	2·0	8·2	7·3	14·2	12·7
23	13 20·8	13 22·9	12 44·3	2·3	2·1	8·3	7·4	14·3	12·8
24	13 21·0	13 23·2	12 44·5	2·4	2·1	8·4	7·5	14·4	12·8
25	13 21·3	13 23·4	12 44·7	2·5	2·2	8·5	7·6	14·5	12·9
26	13 21·5	13 23·7	12 45·0	2·6	2·3	8·6	7·7	14·6	13·0
27	13 21·8	13 23·9	12 45·2	2·7	2·4	8·7	7·8	14·7	13·1
28	13 22·0	13 24·2	12 45·5	2·8	2·5	8·8	7·8	14·8	13·2
29	13 22·3	13 24·4	12 45·7	2·9	2·6	8·9	7·9	14·9	13·3
30	13 22·5	13 24·7	12 45·9	3·0	2·7	9·0	8·0	15·0	13·4
31	13 22·8	13 24·9	12 46·2	3·1	2·8	9·1	8·1	15·1	13·5
32	13 23·0	13 25·2	12 46·4	3·2	2·9	9·2	8·2	15·2	13·6
33	13 23·3	13 25·4	12 46·7	3·3	2·9	9·3	8·3	15·3	13·6
34	13 23·5	13 25·7	12 46·9	3·4	3·0	9·4	8·4	15·4	13·7
35	13 23·8	13 26·0	12 47·1	3·5	3·1	9·5	8·5	15·5	13·8
36	13 24·0	13 26·2	12 47·4	3·6	3·2	9·6	8·6	15·6	13·9
37	13 24·3	13 26·5	12 47·6	3·7	3·3	9·7	8·6	15·7	14·0
38	13 24·5	13 26·7	12 47·9	3·8	3·4	9·8	8·7	15·8	14·1
39	13 24·8	13 27·0	12 48·1	3·9	3·5	9·9	8·8	15·9	14·2
40	13 25·0	13 27·2	12 48·3	4·0	3·6	10·0	8·9	16·0	14·3
41	13 25·3	13 27·5	12 48·6	4·1	3·7	10·1	9·0	16·1	14·4
42	13 25·5	13 27·7	12 48·8	4·2	3·7	10·2	9·1	16·2	14·4
43	13 25·8	13 28·0	12 49·0	4·3	3·8	10·3	9·2	16·3	14·5
44	13 26·0	13 28·2	12 49·3	4·4	3·9	10·4	9·3	16·4	14·6
45	13 26·3	13 28·5	12 49·5	4·5	4·0	10·5	9·4	16·5	14·7
46	13 26·5	13 28·7	12 49·8	4·6	4·1	10·6	9·5	16·6	14·8
47	13 26·8	13 29·0	12 50·0	4·7	4·2	10·7	9·5	16·7	14·9
48	13 27·0	13 29·2	12 50·2	4·8	4·3	10·8	9·6	16·8	15·0
49	13 27·3	13 29·5	12 50·5	4·9	4·4	10·9	9·7	16·9	15·1
50	13 27·5	13 29·7	12 50·7	5·0	4·5	11·0	9·8	17·0	15·2
51	13 27·8	13 30·0	12 51·0	5·1	4·5	11·1	9·9	17·1	15·2
52	13 28·0	13 30·2	12 51·2	5·2	4·6	11·2	10·0	17·2	15·3
53	13 28·3	13 30·5	12 51·4	5·3	4·7	11·3	10·1	17·3	15·4
54	13 28·5	13 30·7	12 51·7	5·4	4·8	11·4	10·2	17·4	15·5
55	13 28·8	13 31·0	12 51·9	5·5	4·9	11·5	10·3	17·5	15·6
56	13 29·0	13 31·2	12 52·1	5·6	5·0	11·6	10·3	17·6	15·7
57	13 29·3	13 31·5	12 52·4	5·7	5·1	11·7	10·4	17·7	15·8
58	13 29·5	13 31·7	12 52·6	5·8	5·2	11·8	10·5	17·8	15·9
59	13 29·8	13 32·0	12 52·9	5·9	5·3	11·9	10·6	17·9	16·0
60	13 30·0	13 32·2	12 53·1	6·0	5·4	12·0	10·7	18·0	16·1

54m INCREMENTS AND CORRECTIONS 55m

54m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	13 30·0	13 32·2	12 53·1	0·0	0·0	6·0	5·5	12·0	10·9
01	13 30·3	13 32·5	12 53·3	0·1	0·1	6·1	5·5	12·1	11·0
02	13 30·5	13 32·7	12 53·6	0·2	0·2	6·2	5·6	12·2	11·1
03	13 30·8	13 33·0	12 53·8	0·3	0·3	6·3	5·7	12·3	11·2
04	13 31·0	13 33·2	12 54·1	0·4	0·4	6·4	5·8	12·4	11·3
05	13 31·3	13 33·5	12 54·3	0·5	0·5	6·5	5·9	12·5	11·4
06	13 31·5	13 33·7	12 54·5	0·6	0·5	6·6	6·0	12·6	11·4
07	13 31·8	13 34·0	12 54·8	0·7	0·6	6·7	6·1	12·7	11·5
08	13 32·0	13 34·2	12 55·0	0·8	0·7	6·8	6·2	12·8	11·6
09	13 32·3	13 34·5	12 55·2	0·9	0·8	6·9	6·3	12·9	11·7
10	13 32·5	13 34·7	12 55·5	1·0	0·9	7·0	6·4	13·0	11·8
11	13 32·8	13 35·0	12 55·7	1·1	1·0	7·1	6·4	13·1	11·9
12	13 33·0	13 35·2	12 56·0	1·2	1·1	7·2	6·5	13·2	12·0
13	13 33·3	13 35·5	12 56·2	1·3	1·2	7·3	6·6	13·3	12·1
14	13 33·5	13 35·7	12 56·4	1·4	1·3	7·4	6·7	13·4	12·2
15	13 33·8	13 36·0	12 56·7	1·5	1·4	7·5	6·8	13·5	12·3
16	13 34·0	13 36·2	12 56·9	1·6	1·5	7·6	6·9	13·6	12·4
17	13 34·3	13 36·5	12 57·2	1·7	1·5	7·7	7·0	13·7	12·4
18	13 34·5	13 36·7	12 57·4	1·8	1·6	7·8	7·1	13·8	12·5
19	13 34·8	13 37·0	12 57·6	1·9	1·7	7·9	7·2	13·9	12·6
20	13 35·0	13 37·2	12 57·9	2·0	1·8	8·0	7·3	14·0	12·7
21	13 35·3	13 37·5	12 58·1	2·1	1·9	8·1	7·4	14·1	12·8
22	13 35·5	13 37·7	12 58·3	2·2	2·0	8·2	7·4	14·2	12·9
23	13 35·8	13 38·0	12 58·6	2·3	2·1	8·3	7·5	14·3	13·0
24	13 36·0	13 38·2	12 58·8	2·4	2·2	8·4	7·6	14·4	13·1
25	13 36·3	13 38·5	12 59·1	2·5	2·3	8·5	7·7	14·5	13·2
26	13 36·5	13 38·7	12 59·3	2·6	2·4	8·6	7·8	14·6	13·3
27	13 36·8	13 39·0	12 59·5	2·7	2·5	8·7	7·9	14·7	13·4
28	13 37·0	13 39·2	12 59·8	2·8	2·5	8·8	8·0	14·8	13·4
29	13 37·3	13 39·5	13 00·0	2·9	2·6	8·9	8·1	14·9	13·5
30	13 37·5	13 39·7	13 00·3	3·0	2·7	9·0	8·2	15·0	13·6
31	13 37·8	13 40·0	13 00·5	3·1	2·8	9·1	8·3	15·1	13·7
32	13 38·0	13 40·2	13 00·7	3·2	2·9	9·2	8·4	15·2	13·8
33	13 38·3	13 40·5	13 01·0	3·3	3·0	9·3	8·4	15·3	13·9
34	13 38·5	13 40·7	13 01·2	3·4	3·1	9·4	8·5	15·4	14·0
35	13 38·8	13 41·0	13 01·5	3·5	3·2	9·5	8·6	15·5	14·1
36	13 39·0	13 41·2	13 01·7	3·6	3·3	9·6	8·7	15·6	14·2
37	13 39·3	13 41·5	13 01·9	3·7	3·4	9·7	8·8	15·7	14·3
38	13 39·5	13 41·7	13 02·2	3·8	3·5	9·8	8·9	15·8	14·4
39	13 39·8	13 42·0	13 02·4	3·9	3·5	9·9	9·0	15·9	14·4
40	13 40·0	13 42·2	13 02·6	4·0	3·6	10·0	9·1	16·0	14·5
41	13 40·3	13 42·5	13 02·9	4·1	3·7	10·1	9·2	16·1	14·6
42	13 40·5	13 42·7	13 03·1	4·2	3·8	10·2	9·3	16·2	14·7
43	13 40·8	13 43·0	13 03·4	4·3	3·9	10·3	9·4	16·3	14·8
44	13 41·0	13 43·2	13 03·6	4·4	4·0	10·4	9·4	16·4	14·9
45	13 41·3	13 43·5	13 03·8	4·5	4·1	10·5	9·5	16·5	15·0
46	13 41·5	13 43·7	13 04·1	4·6	4·2	10·6	9·6	16·6	15·1
47	13 41·8	13 44·0	13 04·3	4·7	4·3	10·7	9·7	16·7	15·2
48	13 42·0	13 44·3	13 04·6	4·8	4·4	10·8	9·8	16·8	15·3
49	13 42·3	13 44·5	13 04·8	4·9	4·5	10·9	9·9	16·9	15·4
50	13 42·5	13 44·8	13 05·0	5·0	4·5	11·0	10·0	17·0	15·4
51	13 42·8	13 45·0	13 05·3	5·1	4·6	11·1	10·1	17·1	15·5
52	13 43·0	13 45·3	13 05·5	5·2	4·7	11·2	10·2	17·2	15·6
53	13 43·3	13 45·5	13 05·7	5·3	4·8	11·3	10·3	17·3	15·7
54	13 43·5	13 45·8	13 06·0	5·4	4·9	11·4	10·4	17·4	15·8
55	13 43·8	13 46·0	13 06·2	5·5	5·0	11·5	10·4	17·5	15·9
56	13 44·0	13 46·3	13 06·5	5·6	5·1	11·6	10·5	17·6	16·0
57	13 44·3	13 46·5	13 06·7	5·7	5·2	11·7	10·6	17·7	16·1
58	13 44·5	13 46·8	13 06·9	5·8	5·3	11·8	10·7	17·8	16·2
59	13 44·8	13 47·0	13 07·2	5·9	5·4	11·9	10·8	17·9	16·3
60	13 45·0	13 47·3	13 07·4	6·0	5·5	12·0	10·9	18·0	16·4

55m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	13 45·0	13 47·3	13 07·4	0·0	0·0	6·0	5·6	12·0	11·1
01	13 45·3	13 47·5	13 07·7	0·1	0·1	6·1	5·6	12·1	11·2
02	13 45·5	13 47·8	13 07·9	0·2	0·2	6·2	5·7	12·2	11·3
03	13 45·8	13 48·0	13 08·1	0·3	0·3	6·3	5·8	12·3	11·4
04	13 46·0	13 48·3	13 08·4	0·4	0·4	6·4	5·9	12·4	11·5
05	13 46·3	13 48·5	13 08·6	0·5	0·5	6·5	6·0	12·5	11·6
06	13 46·5	13 48·8	13 08·8	0·6	0·6	6·6	6·1	12·6	11·7
07	13 46·8	13 49·0	13 09·1	0·7	0·6	6·7	6·2	12·7	11·7
08	13 47·0	13 49·3	13 09·3	0·8	0·7	6·8	6·3	12·8	11·8
09	13 47·3	13 49·5	13 09·6	0·9	0·8	6·9	6·4	12·9	11·9
10	13 47·5	13 49·8	13 09·8	1·0	0·9	7·0	6·5	13·0	12·0
11	13 47·8	13 50·0	13 10·0	1·1	1·0	7·1	6·6	13·1	12·1
12	13 48·0	13 50·3	13 10·3	1·2	1·1	7·2	6·7	13·2	12·2
13	13 48·3	13 50·5	13 10·5	1·3	1·2	7·3	6·8	13·3	12·3
14	13 48·5	13 50·8	13 10·8	1·4	1·3	7·4	6·8	13·4	12·4
15	13 48·8	13 51·0	13 11·0	1·5	1·4	7·5	6·9	13·5	12·5
16	13 49·0	13 51·3	13 11·2	1·6	1·5	7·6	7·0	13·6	12·6
17	13 49·3	13 51·5	13 11·5	1·7	1·6	7·7	7·1	13·7	12·7
18	13 49·5	13 51·8	13 11·7	1·8	1·7	7·8	7·2	13·8	12·8
19	13 49·8	13 52·0	13 12·0	1·9	1·8	7·9	7·3	13·9	12·9
20	13 50·0	13 52·3	13 12·2	2·0	1·9	8·0	7·4	14·0	13·0
21	13 50·3	13 52·5	13 12·4	2·1	1·9	8·1	7·5	14·1	13·0
22	13 50·5	13 52·8	13 12·7	2·2	2·0	8·2	7·6	14·2	13·1
23	13 50·8	13 53·0	13 12·9	2·3	2·1	8·3	7·7	14·3	13·2
24	13 51·0	13 53·3	13 13·1	2·4	2·2	8·4	7·8	14·4	13·3
25	13 51·3	13 53·5	13 13·4	2·5	2·3	8·5	7·9	14·5	13·4
26	13 51·5	13 53·8	13 13·6	2·6	2·4	8·6	8·0	14·6	13·5
27	13 51·8	13 54·0	13 13·9	2·7	2·5	8·7	8·0	14·7	13·6
28	13 52·0	13 54·3	13 14·1	2·8	2·6	8·8	8·1	14·8	13·7
29	13 52·3	13 54·5	13 14·3	2·9	2·7	8·9	8·2	14·9	13·8
30	13 52·5	13 54·8	13 14·6	3·0	2·8	9·0	8·3	15·0	13·9
31	13 52·8	13 55·0	13 14·8	3·1	2·9	9·1	8·4	15·1	14·0
32	13 53·0	13 55·3	13 15·1	3·2	3·0	9·2	8·5	15·2	14·1
33	13 53·3	13 55·5	13 15·3	3·3	3·1	9·3	8·6	15·3	14·2
34	13 53·5	13 55·8	13 15·5	3·4	3·1	9·4	8·7	15·4	14·2
35	13 53·8	13 56·0	13 15·8	3·5	3·2	9·5	8·8	15·5	14·3
36	13 54·0	13 56·3	13 16·0	3·6	3·3	9·6	8·9	15·6	14·4
37	13 54·3	13 56·5	13 16·2	3·7	3·4	9·7	9·0	15·7	14·5
38	13 54·5	13 56·8	13 16·5	3·8	3·5	9·8	9·1	15·8	14·6
39	13 54·8	13 57·0	13 16·7	3·9	3·6	9·9	9·2	15·9	14·7
40	13 55·0	13 57·3	13 17·0	4·0	3·7	10·0	9·3	16·0	14·8
41	13 55·3	13 57·5	13 17·2	4·1	3·8	10·1	9·3	16·1	14·9
42	13 55·5	13 57·8	13 17·4	4·2	3·9	10·2	9·4	16·2	15·0
43	13 55·8	13 58·0	13 17·7	4·3	4·0	10·3	9·5	16·3	15·1
44	13 56·0	13 58·3	13 17·9	4·4	4·1	10·4	9·6	16·4	15·2
45	13 56·3	13 58·5	13 18·2	4·5	4·2	10·5	9·7	16·5	15·3
46	13 56·5	13 58·8	13 18·4	4·6	4·3	10·6	9·8	16·6	15·4
47	13 56·8	13 59·0	13 18·6	4·7	4·3	10·7	9·9	16·7	15·4
48	13 57·0	13 59·3	13 18·9	4·8	4·4	10·8	10·0	16·8	15·5
49	13 57·3	13 59·5	13 19·1	4·9	4·5	10·9	10·1	16·9	15·6
50	13 57·5	13 59·8	13 19·3	5·0	4·6	11·0	10·2	17·0	15·7
51	13 57·8	14 00·0	13 19·6	5·1	4·7	11·1	10·3	17·1	15·8
52	13 58·0	14 00·3	13 19·8	5·2	4·8	11·2	10·4	17·2	15·9
53	13 58·3	14 00·5	13 20·1	5·3	4·9	11·3	10·5	17·3	16·0
54	13 58·5	14 00·8	13 20·3	5·4	5·0	11·4	10·5	17·4	16·1
55	13 58·8	14 01·0	13 20·5	5·5	5·1	11·5	10·6	17·5	16·2
56	13 59·0	14 01·3	13 20·8	5·6	5·2	11·6	10·7	17·6	16·3
57	13 59·3	14 01·5	13 21·0	5·7	5·3	11·7	10·8	17·7	16·4
58	13 59·5	14 01·8	13 21·3	5·8	5·4	11·8	10·9	17·8	16·5
59	13 59·8	14 02·0	13 21·5	5·9	5·5	11·9	11·0	17·9	16·6
60	14 00·0	14 02·3	13 21·7	6·0	5·6	12·0	11·1	18·0	16·7

56m INCREMENTS AND CORRECTIONS 57m

56	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 00·0	14 02·3	13 21·7	0·0	0·0	6·0	5·7	12·0	11·3
01	14 00·3	14 02·6	13 22·0	0·1	0·1	6·1	5·7	12·1	11·4
02	14 00·5	14 02·8	13 22·2	0·2	0·2	6·2	5·8	12·2	11·5
03	14 00·8	14 03·1	13 22·4	0·3	0·3	6·3	5·9	12·3	11·6
04	14 01·0	14 03·3	13 22·7	0·4	0·4	6·4	6·0	12·4	11·7
05	14 01·3	14 03·6	13 22·9	0·5	0·5	6·5	6·1	12·5	11·8
06	14 01·5	14 03·8	13 23·2	0·6	0·6	6·6	6·2	12·6	11·9
07	14 01·8	14 04·1	13 23·4	0·7	0·7	6·7	6·3	12·7	12·0
08	14 02·0	14 04·3	13 23·6	0·8	0·8	6·8	6·4	12·8	12·1
09	14 02·3	14 04·6	13 23·9	0·9	0·8	6·9	6·5	12·9	12·1
10	14 02·5	14 04·8	13 24·1	1·0	0·9	7·0	6·6	13·0	12·2
11	14 02·8	14 05·1	13 24·4	1·1	1·0	7·1	6·7	13·1	12·3
12	14 03·0	14 05·3	13 24·6	1·2	1·1	7·2	6·8	13·2	12·4
13	14 03·3	14 05·6	13 24·8	1·3	1·2	7·3	6·9	13·3	12·5
14	14 03·5	14 05·8	13 25·1	1·4	1·3	7·4	7·0	13·4	12·6
15	14 03·8	14 06·1	13 25·3	1·5	1·4	7·5	7·1	13·5	12·7
16	14 04·0	14 06·3	13 25·6	1·6	1·5	7·6	7·2	13·6	12·8
17	14 04·3	14 06·6	13 25·8	1·7	1·6	7·7	7·3	13·7	12·9
18	14 04·5	14 06·8	13 26·0	1·8	1·7	7·8	7·3	13·8	13·0
19	14 04·8	14 07·1	13 26·3	1·9	1·8	7·9	7·4	13·9	13·1
20	14 05·0	14 07·3	13 26·5	2·0	1·9	8·0	7·5	14·0	13·2
21	14 05·3	14 07·6	13 26·7	2·1	2·0	8·1	7·6	14·1	13·3
22	14 05·5	14 07·8	13 27·0	2·2	2·1	8·2	7·7	14·2	13·4
23	14 05·8	14 08·1	13 27·2	2·3	2·2	8·3	7·8	14·3	13·5
24	14 06·0	14 08·3	13 27·5	2·4	2·3	8·4	7·9	14·4	13·6
25	14 06·3	14 08·6	13 27·7	2·5	2·4	8·5	8·0	14·5	13·7
26	14 06·5	14 08·8	13 27·9	2·6	2·4	8·6	8·1	14·6	13·7
27	14 06·8	14 09·1	13 28·2	2·7	2·5	8·7	8·2	14·7	13·8
28	14 07·0	14 09·3	13 28·4	2·8	2·6	8·8	8·3	14·8	13·9
29	14 07·3	14 09·6	13 28·7	2·9	2·7	8·9	8·4	14·9	14·0
30	14 07·5	14 09·8	13 28·9	3·0	2·8	9·0	8·5	15·0	14·1
31	14 07·8	14 10·1	13 29·1	3·1	2·9	9·1	8·6	15·1	14·2
32	14 08·0	14 10·3	13 29·4	3·2	3·0	9·2	8·7	15·2	14·3
33	14 08·3	14 10·6	13 29·6	3·3	3·1	9·3	8·8	15·3	14·4
34	14 08·5	14 10·8	13 29·8	3·4	3·2	9·4	8·9	15·4	14·5
35	14 08·8	14 11·1	13 30·1	3·5	3·3	9·5	8·9	15·5	14·6
36	14 09·0	14 11·3	13 30·3	3·6	3·4	9·6	9·0	15·6	14·7
37	14 09·3	14 11·6	13 30·6	3·7	3·5	9·7	9·1	15·7	14·8
38	14 09·5	14 11·8	13 30·8	3·8	3·6	9·8	9·2	15·8	14·9
39	14 09·8	14 12·1	13 31·0	3·9	3·7	9·9	9·3	15·9	15·0
40	14 10·0	14 12·3	13 31·3	4·0	3·8	10·0	9·4	16·0	15·1
41	14 10·3	14 12·6	13 31·5	4·1	3·9	10·1	9·5	16·1	15·2
42	14 10·5	14 12·8	13 31·8	4·2	4·0	10·2	9·6	16·2	15·3
43	14 10·8	14 13·1	13 32·0	4·3	4·0	10·3	9·7	16·3	15·3
44	14 11·0	14 13·3	13 32·2	4·4	4·1	10·4	9·8	16·4	15·4
45	14 11·3	14 13·6	13 32·5	4·5	4·2	10·5	9·9	16·5	15·5
46	14 11·5	14 13·8	13 32·7	4·6	4·3	10·6	10·0	16·6	15·6
47	14 11·8	14 14·1	13 32·9	4·7	4·4	10·7	10·1	16·7	15·7
48	14 12·0	14 14·3	13 33·2	4·8	4·5	10·8	10·2	16·8	15·8
49	14 12·3	14 14·6	13 33·4	4·9	4·6	10·9	10·3	16·9	15·9
50	14 12·5	14 14·8	13 33·7	5·0	4·7	11·0	10·4	17·0	16·0
51	14 12·8	14 15·1	13 33·9	5·1	4·8	11·1	10·5	17·1	16·1
52	14 13·0	14 15·3	13 34·1	5·2	4·9	11·2	10·5	17·2	16·2
53	14 13·3	14 15·6	13 34·4	5·3	5·0	11·3	10·6	17·3	16·3
54	14 13·5	14 15·8	13 34·6	5·4	5·1	11·4	10·7	17·4	16·4
55	14 13·8	14 16·1	13 34·9	5·5	5·2	11·5	10·8	17·5	16·5
56	14 14·0	14 16·3	13 35·1	5·6	5·3	11·6	10·9	17·6	16·6
57	14 14·3	14 16·6	13 35·3	5·7	5·4	11·7	11·0	17·7	16·7
58	14 14·5	14 16·8	13 35·6	5·8	5·5	11·8	11·1	17·8	16·8
59	14 14·8	14 17·1	13 35·8	5·9	5·6	11·9	11·2	17·9	16·9
60	14 15·0	14 17·3	13 36·1	6·0	5·7	12·0	11·3	18·0	17·0

57	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 15·0	14 17·3	13 36·1	0·0	0·0	6·0	5·8	12·0	11·5
01	14 15·3	14 17·6	13 36·3	0·1	0·1	6·1	5·8	12·1	11·6
02	14 15·5	14 17·8	13 36·5	0·2	0·2	6·2	5·9	12·2	11·7
03	14 15·8	14 18·1	13 36·8	0·3	0·3	6·3	6·0	12·3	11·8
04	14 16·0	14 18·3	13 37·0	0·4	0·4	6·4	6·1	12·4	11·9
05	14 16·3	14 18·6	13 37·2	0·5	0·5	6·5	6·2	12·5	12·0
06	14 16·5	14 18·8	13 37·5	0·6	0·6	6·6	6·3	12·6	12·1
07	14 16·8	14 19·1	13 37·7	0·7	0·7	6·7	6·4	12·7	12·2
08	14 17·0	14 19·3	13 38·0	0·8	0·8	6·8	6·5	12·8	12·3
09	14 17·3	14 19·6	13 38·2	0·9	0·9	6·9	6·6	12·9	12·4
10	14 17·5	14 19·8	13 38·4	1·0	1·0	7·0	6·7	13·0	12·5
11	14 17·8	14 20·1	13 38·7	1·1	1·1	7·1	6·8	13·1	12·6
12	14 18·0	14 20·3	13 38·9	1·2	1·2	7·2	6·9	13·2	12·7
13	14 18·3	14 20·6	13 39·2	1·3	1·2	7·3	7·0	13·3	12·7
14	14 18·5	14 20·9	13 39·4	1·4	1·3	7·4	7·1	13·4	12·8
15	14 18·8	14 21·1	13 39·6	1·5	1·4	7·5	7·2	13·5	12·9
16	14 19·0	14 21·4	13 39·9	1·6	1·5	7·6	7·3	13·6	13·0
17	14 19·3	14 21·6	13 40·1	1·7	1·6	7·7	7·4	13·7	13·1
18	14 19·5	14 21·9	13 40·3	1·8	1·7	7·8	7·5	13·8	13·2
19	14 19·8	14 22·1	13 40·6	1·9	1·8	7·9	7·6	13·9	13·3
20	14 20·0	14 22·4	13 40·8	2·0	1·9	8·0	7·7	14·0	13·4
21	14 20·3	14 22·6	13 41·1	2·1	2·0	8·1	7·8	14·1	13·5
22	14 20·5	14 22·9	13 41·3	2·2	2·1	8·2	7·9	14·2	13·6
23	14 20·8	14 23·1	13 41·5	2·3	2·2	8·3	8·0	14·3	13·7
24	14 21·0	14 23·4	13 41·8	2·4	2·3	8·4	8·1	14·4	13·8
25	14 21·3	14 23·6	13 42·0	2·5	2·4	8·5	8·1	14·5	13·9
26	14 21·5	14 23·9	13 42·3	2·6	2·5	8·6	8·2	14·6	14·0
27	14 21·8	14 24·1	13 42·5	2·7	2·6	8·7	8·3	14·7	14·1
28	14 22·0	14 24·4	13 42·7	2·8	2·7	8·8	8·4	14·8	14·2
29	14 22·3	14 24·6	13 43·0	2·9	2·8	8·9	8·5	14·9	14·3
30	14 22·5	14 24·9	13 43·2	3·0	2·9	9·0	8·6	15·0	14·4
31	14 22·8	14 25·1	13 43·4	3·1	3·0	9·1	8·7	15·1	14·5
32	14 23·0	14 25·4	13 43·7	3·2	3·1	9·2	8·8	15·2	14·6
33	14 23·3	14 25·6	13 43·9	3·3	3·2	9·3	8·9	15·3	14·7
34	14 23·5	14 25·9	13 44·2	3·4	3·3	9·4	9·0	15·4	14·8
35	14 23·8	14 26·1	13 44·4	3·5	3·4	9·5	9·1	15·5	14·9
36	14 24·0	14 26·4	13 44·6	3·6	3·5	9·6	9·2	15·6	15·0
37	14 24·3	14 26·6	13 44·9	3·7	3·5	9·7	9·3	15·7	15·0
38	14 24·5	14 26·9	13 45·1	3·8	3·6	9·8	9·4	15·8	15·1
39	14 24·8	14 27·1	13 45·4	3·9	3·7	9·9	9·5	15·9	15·2
40	14 25·0	14 27·4	13 45·6	4·0	3·8	10·0	9·6	16·0	15·3
41	14 25·3	14 27·6	13 45·8	4·1	3·9	10·1	9·7	16·1	15·4
42	14 25·5	14 27·9	13 46·1	4·2	4·0	10·2	9·8	16·2	15·5
43	14 25·8	14 28·1	13 46·3	4·3	4·1	10·3	9·9	16·3	15·6
44	14 26·0	14 28·4	13 46·5	4·4	4·2	10·4	10·0	16·4	15·7
45	14 26·3	14 28·6	13 46·8	4·5	4·3	10·5	10·1	16·5	15·8
46	14 26·5	14 28·9	13 47·0	4·6	4·4	10·6	10·2	16·6	15·9
47	14 26·8	14 29·1	13 47·3	4·7	4·5	10·7	10·3	16·7	16·0
48	14 27·0	14 29·4	13 47·5	4·8	4·6	10·8	10·4	16·8	16·1
49	14 27·3	14 29·6	13 47·7	4·9	4·7	10·9	10·4	16·9	16·2
50	14 27·5	14 29·9	13 48·0	5·0	4·8	11·0	10·5	17·0	16·3
51	14 27·8	14 30·1	13 48·2	5·1	4·9	11·1	10·6	17·1	16·4
52	14 28·0	14 30·4	13 48·5	5·2	5·0	11·2	10·7	17·2	16·5
53	14 28·3	14 30·6	13 48·7	5·3	5·1	11·3	10·8	17·3	16·6
54	14 28·5	14 30·9	13 48·9	5·4	5·2	11·4	10·9	17·4	16·7
55	14 28·8	14 31·1	13 49·2	5·5	5·3	11·5	11·0	17·5	16·8
56	14 29·0	14 31·4	13 49·4	5·6	5·4	11·6	11·1	17·6	16·9
57	14 29·3	14 31·6	13 49·7	5·7	5·5	11·7	11·2	17·7	17·0
58	14 29·5	14 31·9	13 49·9	5·8	5·6	11·8	11·3	17·8	17·1
59	14 29·8	14 32·1	13 50·1	5·9	5·7	11·9	11·4	17·9	17·2
60	14 30·0	14 32·4	13 50·4	6·0	5·8	12·0	11·5	18·0	17·3

58m INCREMENTS AND CORRECTIONS

58m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 30·0	14 32·4	13 50·4	0·0	0·0	6·0	5·9	12·0	11·7
01	14 30·3	14 32·6	13 50·6	0·1	0·1	6·1	5·9	12·1	11·8
02	14 30·5	14 32·9	13 50·8	0·2	0·2	6·2	6·0	12·2	11·9
03	14 30·8	14 33·1	13 51·1	0·3	0·3	6·3	6·1	12·3	12·0
04	14 31·0	14 33·4	13 51·3	0·4	0·4	6·4	6·2	12·4	12·1
05	14 31·3	14 33·6	13 51·6	0·5	0·5	6·5	6·3	12·5	12·2
06	14 31·5	14 33·9	13 51·8	0·6	0·6	6·6	6·4	12·6	12·3
07	14 31·8	14 34·1	13 52·0	0·7	0·7	6·7	6·5	12·7	12·4
08	14 32·0	14 34·4	13 52·3	0·8	0·8	6·8	6·6	12·8	12·5
09	14 32·3	14 34·6	13 52·5	0·9	0·9	6·9	6·7	12·9	12·6
10	14 32·5	14 34·9	13 52·8	1·0	1·0	7·0	6·8	13·0	12·7
11	14 32·8	14 35·1	13 53·0	1·1	1·1	7·1	6·9	13·1	12·8
12	14 33·0	14 35·4	13 53·2	1·2	1·2	7·2	7·0	13·2	12·9
13	14 33·3	14 35·6	13 53·5	1·3	1·3	7·3	7·1	13·3	13·0
14	14 33·5	14 35·9	13 53·7	1·4	1·4	7·4	7·2	13·4	13·1
15	14 33·8	14 36·1	13 53·9	1·5	1·5	7·5	7·3	13·5	13·2
16	14 34·0	14 36·4	13 54·2	1·6	1·6	7·6	7·4	13·6	13·3
17	14 34·3	14 36·6	13 54·4	1·7	1·7	7·7	7·5	13·7	13·4
18	14 34·5	14 36·9	13 54·7	1·8	1·8	7·8	7·6	13·8	13·5
19	14 34·8	14 37·1	13 54·9	1·9	1·9	7·9	7·7	13·9	13·6
20	14 35·0	14 37·4	13 55·1	2·0	2·0	8·0	7·8	14·0	13·7
21	14 35·3	14 37·6	13 55·4	2·1	2·0	8·1	7·9	14·1	13·7
22	14 35·5	14 37·9	13 55·6	2·2	2·1	8·2	8·0	14·2	13·8
23	14 35·8	14 38·1	13 55·9	2·3	2·2	8·3	8·1	14·3	13·9
24	14 36·0	14 38·4	13 56·1	2·4	2·3	8·4	8·2	14·4	14·0
25	14 36·3	14 38·6	13 56·3	2·5	2·4	8·5	8·3	14·5	14·1
26	14 36·5	14 38·9	13 56·6	2·6	2·5	8·6	8·4	14·6	14·2
27	14 36·8	14 39·2	13 56·8	2·7	2·6	8·7	8·5	14·7	14·3
28	14 37·0	14 39·4	13 57·0	2·8	2·7	8·8	8·6	14·8	14·4
29	14 37·3	14 39·7	13 57·3	2·9	2·8	8·9	8·7	14·9	14·5
30	14 37·5	14 39·9	13 57·5	3·0	2·9	9·0	8·8	15·0	14·6
31	14 37·8	14 40·2	13 57·8	3·1	3·0	9·1	8·9	15·1	14·7
32	14 38·0	14 40·4	13 58·0	3·2	3·1	9·2	9·0	15·2	14·8
33	14 38·3	14 40·7	13 58·2	3·3	3·2	9·3	9·1	15·3	14·9
34	14 38·5	14 40·9	13 58·5	3·4	3·3	9·4	9·2	15·4	15·0
35	14 38·8	14 41·2	13 58·7	3·5	3·4	9·5	9·3	15·5	15·1
36	14 39·0	14 41·4	13 59·0	3·6	3·5	9·6	9·4	15·6	15·2
37	14 39·3	14 41·7	13 59·2	3·7	3·6	9·7	9·5	15·7	15·3
38	14 39·5	14 41·9	13 59·4	3·8	3·7	9·8	9·6	15·8	15·4
39	14 39·8	14 42·2	13 59·7	3·9	3·8	9·9	9·7	15·9	15·5
40	14 40·0	14 42·4	13 59·9	4·0	3·9	10·0	9·8	16·0	15·6
41	14 40·3	14 42·7	14 00·1	4·1	4·0	10·1	9·8	16·1	15·7
42	14 40·5	14 42·9	14 00·4	4·2	4·1	10·2	9·9	16·2	15·8
43	14 40·8	14 43·2	14 00·6	4·3	4·2	10·3	10·0	16·3	15·9
44	14 41·0	14 43·4	14 00·9	4·4	4·3	10·4	10·1	16·4	16·0
45	14 41·3	14 43·7	14 01·1	4·5	4·4	10·5	10·2	16·5	16·1
46	14 41·5	14 43·9	14 01·3	4·6	4·5	10·6	10·3	16·6	16·2
47	14 41·8	14 44·2	14 01·6	4·7	4·6	10·7	10·4	16·7	16·3
48	14 42·0	14 44·4	14 01·8	4·8	4·7	10·8	10·5	16·8	16·4
49	14 42·3	14 44·7	14 02·1	4·9	4·8	10·9	10·6	16·9	16·5
50	14 42·5	14 44·9	14 02·3	5·0	4·9	11·0	10·7	17·0	16·6
51	14 42·8	14 45·2	14 02·5	5·1	5·0	11·1	10·8	17·1	16·7
52	14 43·0	14 45·4	14 02·8	5·2	5·1	11·2	10·9	17·2	16·8
53	14 43·3	14 45·7	14 03·0	5·3	5·2	11·3	11·0	17·3	16·9
54	14 43·5	14 45·9	14 03·3	5·4	5·3	11·4	11·1	17·4	17·0
55	14 43·8	14 46·2	14 03·5	5·5	5·4	11·5	11·2	17·5	17·1
56	14 44·0	14 46·4	14 03·7	5·6	5·5	11·6	11·3	17·6	17·2
57	14 44·3	14 46·7	14 04·0	5·7	5·6	11·7	11·4	17·7	17·3
58	14 44·5	14 46·9	14 04·2	5·8	5·7	11·8	11·5	17·8	17·4
59	14 44·8	14 47·2	14 04·4	5·9	5·8	11·9	11·6	17·9	17·5
60	14 45·0	14 47·4	14 04·7	6·0	5·9	12·0	11·7	18·0	17·6

59m INCREMENTS AND CORRECTIONS

59m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 45·0	14 47·4	14 04·7	0·0	0·0	6·0	6·0	12·0	11·9
01	14 45·3	14 47·7	14 04·9	0·1	0·1	6·1	6·0	12·1	12·0
02	14 45·5	14 47·9	14 05·2	0·2	0·2	6·2	6·1	12·2	12·1
03	14 45·8	14 48·2	14 05·4	0·3	0·3	6·3	6·2	12·3	12·2
04	14 46·0	14 48·4	14 05·6	0·4	0·4	6·4	6·3	12·4	12·3
05	14 46·3	14 48·7	14 05·9	0·5	0·5	6·5	6·4	12·5	12·4
06	14 46·5	14 48·9	14 06·1	0·6	0·6	6·6	6·5	12·6	12·5
07	14 46·8	14 49·2	14 06·4	0·7	0·7	6·7	6·6	12·7	12·6
08	14 47·0	14 49·4	14 06·6	0·8	0·8	6·8	6·7	12·8	12·7
09	14 47·3	14 49·7	14 06·8	0·9	0·9	6·9	6·8	12·9	12·8
10	14 47·5	14 49·9	14 07·1	1·0	1·0	7·0	6·9	13·0	12·9
11	14 47·8	14 50·2	14 07·3	1·1	1·1	7·1	7·0	13·1	13·0
12	14 48·0	14 50·4	14 07·5	1·2	1·2	7·2	7·1	13·2	13·1
13	14 48·3	14 50·7	14 07·8	1·3	1·3	7·3	7·2	13·3	13·2
14	14 48·5	14 50·9	14 08·0	1·4	1·4	7·4	7·3	13·4	13·3
15	14 48·8	14 51·2	14 08·3	1·5	1·5	7·5	7·4	13·5	13·4
16	14 49·0	14 51·4	14 08·5	1·6	1·6	7·6	7·5	13·6	13·5
17	14 49·3	14 51·7	14 08·7	1·7	1·7	7·7	7·6	13·7	13·6
18	14 49·5	14 51·9	14 09·0	1·8	1·8	7·8	7·7	13·8	13·7
19	14 49·8	14 52·2	14 09·2	1·9	1·9	7·9	7·8	13·9	13·8
20	14 50·0	14 52·4	14 09·5	2·0	2·0	8·0	7·9	14·0	13·9
21	14 50·3	14 52·7	14 09·7	2·1	2·1	8·1	8·0	14·1	14·0
22	14 50·5	14 52·9	14 09·9	2·2	2·2	8·2	8·1	14·2	14·1
23	14 50·8	14 53·2	14 10·2	2·3	2·3	8·3	8·2	14·3	14·2
24	14 51·0	14 53·4	14 10·4	2·4	2·4	8·4	8·3	14·4	14·3
25	14 51·3	14 53·7	14 10·6	2·5	2·5	8·5	8·4	14·5	14·4
26	14 51·5	14 53·9	14 10·9	2·6	2·6	8·6	8·5	14·6	14·5
27	14 51·8	14 54·2	14 11·1	2·7	2·7	8·7	8·6	14·7	14·6
28	14 52·0	14 54·4	14 11·4	2·8	2·8	8·8	8·7	14·8	14·7
29	14 52·3	14 54·7	14 11·6	2·9	2·9	8·9	8·8	14·9	14·8
30	14 52·5	14 54·9	14 11·8	3·0	3·0	9·0	8·9	15·0	14·9
31	14 52·8	14 55·2	14 12·1	3·1	3·1	9·1	9·0	15·1	15·0
32	14 53·0	14 55·4	14 12·3	3·2	3·2	9·2	9·1	15·2	15·1
33	14 53·3	14 55·7	14 12·6	3·3	3·3	9·3	9·2	15·3	15·2
34	14 53·5	14 55·9	14 12·8	3·4	3·4	9·4	9·3	15·4	15·3
35	14 53·8	14 56·2	14 13·0	3·5	3·5	9·5	9·4	15·5	15·4
36	14 54·0	14 56·4	14 13·3	3·6	3·6	9·6	9·5	15·6	15·5
37	14 54·3	14 56·7	14 13·5	3·7	3·7	9·7	9·6	15·7	15·6
38	14 54·5	14 56·9	14 13·8	3·8	3·8	9·8	9·7	15·8	15·7
39	14 54·8	14 57·2	14 14·0	3·9	3·9	9·9	9·8	15·9	15·8
40	14 55·0	14 57·5	14 14·2	4·0	4·0	10·0	9·9	16·0	15·9
41	14 55·3	14 57·7	14 14·5	4·1	4·1	10·1	10·0	16·1	16·0
42	14 55·5	14 58·0	14 14·7	4·2	4·2	10·2	10·1	16·2	16·1
43	14 55·8	14 58·2	14 14·9	4·3	4·3	10·3	10·2	16·3	16·2
44	14 56·0	14 58·5	14 15·2	4·4	4·4	10·4	10·3	16·4	16·3
45	14 56·3	14 58·7	14 15·4	4·5	4·5	10·5	10·4	16·5	16·4
46	14 56·5	14 59·0	14 15·7	4·6	4·6	10·6	10·5	16·6	16·5
47	14 56·8	14 59·2	14 15·9	4·7	4·7	10·7	10·6	16·7	16·6
48	14 57·0	14 59·5	14 16·1	4·8	4·8	10·8	10·7	16·8	16·7
49	14 57·3	14 59·7	14 16·4	4·9	4·9	10·9	10·8	16·9	16·8
50	14 57·5	15 00·0	14 16·6	5·0	5·0	11·0	10·9	17·0	16·9
51	14 57·8	15 00·2	14 16·9	5·1	5·1	11·1	11·0	17·1	17·0
52	14 58·0	15 00·5	14 17·1	5·2	5·2	11·2	11·1	17·2	17·1
53	14 58·3	15 00·7	14 17·3	5·3	5·3	11·3	11·2	17·3	17·2
54	14 58·5	15 01·0	14 17·6	5·4	5·4	11·4	11·3	17·4	17·3
55	14 58·8	15 01·2	14 17·8	5·5	5·5	11·5	11·4	17·5	17·4
56	14 59·0	15 01·5	14 18·0	5·6	5·6	11·6	11·5	17·6	17·5
57	14 59·3	15 01·7	14 18·3	5·7	5·7	11·7	11·6	17·7	17·6
58	14 59·5	15 02·0	14 18·5	5·8	5·8	11·8	11·7	17·8	17·7
59	14 59·8	15 02·2	14 18·8	5·9	5·9	11·9	11·8	17·9	17·8
60	15 00·0	15 02·5	14 19·0	6·0	6·0	12·0	11·9	18·0	17·9

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CALENDAR, 1976

DAYS OF THE WEEK AND DAYS OF THE YEAR

Day of Month	JAN.		FEB.		MAR.		APR.		MAY		JUNE		JULY		AUG.		SEPT.		OCT.		NOV.		DEC.	
	Week	Year	Week	Year	Week	Year	Week	Year	Week	Year	Week	Year	Week	Year	Week	Year	Week	Year	Week	Year	Week	Year	Week	Year
1	Th.	1	☉	32	M.	61	Th.	92	S.	122	Tu.	153	Th.	183	☉	214	W.	245	F.	275	M.	306	W.	336
2	F.	2	M.	33	Tu.	62	F.	93	☉	123	W.	154	F.	184	M.	215	Th.	246	S.	276	Tu.	307	Th.	337
3	S.	3	Tu.	34	W.	63	S.	94	M.	124	Th.	155	S.	185	Tu.	216	F.	247	☉	277	W.	308	F.	338
4	☉	4	W.	35	Th.	64	☉	95	Tu.	125	F.	156	☉	186	W.	217	S.	248	M.	278	Th.	309	S.	339
5	M.	5	Th.	36	F.	65	M.	96	W.	126	S.	157	M.	187	Th.	218	☉	249	Tu.	279	F.	310	☉	340
6	Tu.	6	F.	37	S.	66	Tu.	97	Th.	127	☉	158	Tu.	188	F.	219	M.	250	W.	280	S.	311	M.	341
7	W.	7	S.	38	☉	67	W.	98	F.	128	M.	159	W.	189	S.	220	Tu.	251	Th.	281	☉	312	Tu.	342
8	Th.	8	☉	39	M.	68	Th.	99	S.	129	Tu.	160	Th.	190	☉	221	W.	252	F.	282	M.	313	W.	343
9	F.	9	M.	40	Tu.	69	F.	100	☉	130	W.	161	F.	191	M.	222	Th.	253	S.	283	Tu.	314	Th.	344
10	S.	10	Tu.	41	W.	70	S.	101	M.	131	Th.	162	S.	192	Tu.	223	F.	254	☉	284	W.	315	F.	345
11	☉	11	W.	42	Th.	71	☉	102	Tu.	132	F.	163	☉	193	W.	224	S.	255	M.	285	Th.	316	S.	346
12	M.	12	Th.	43	F.	72	M.	103	W.	133	S.	164	M.	194	Th.	225	☉	256	Tu.	286	F.	317	☉	347
13	Tu.	13	F.	44	S.	73	Tu.	104	Th.	134	☉	165	Tu.	195	F.	226	M.	257	W.	287	S.	318	M.	348
14	W.	14	S.	45	☉	74	W.	105	F.	135	M.	166	W.	196	S.	227	Tu.	258	Th.	288	☉	319	Tu.	349
15	Th.	15	☉	46	M.	75	Th.	106	S.	136	Tu.	167	Th.	197	☉	228	W.	259	F.	289	M.	320	W.	350
16	F.	16	M.	47	Tu.	76	F.	107	☉	137	W.	168	F.	198	M.	229	Th.	260	S.	290	Tu.	321	Th.	351
17	S.	17	Tu.	48	W.	77	S.	108	M.	138	Th.	169	S.	199	Tu.	230	F.	261	☉	291	W.	322	F.	352
18	☉	18	W.	49	Th.	78	☉	109	Tu.	139	F.	170	☉	200	W.	231	S.	262	M.	292	Th.	323	S.	353
19	M.	19	Th.	50	F.	79	M.	110	W.	140	S.	171	M.	201	Th.	232	☉	263	Tu.	293	F.	324	☉	354
20	Tu.	20	F.	51	S.	80	Tu.	111	Th.	141	☉	172	Tu.	202	F.	233	M.	264	W.	294	S.	325	M.	355
21	W.	21	S.	52	☉	81	W.	112	F.	142	M.	173	W.	203	S.	234	Tu.	265	Th.	295	☉	326	Tu.	356
22	Th.	22	☉	53	M.	82	Th.	113	S.	143	Tu.	174	Th.	204	☉	235	W.	266	F.	296	M.	327	W.	357
23	F.	23	M.	54	Tu.	83	F.	114	☉	144	W.	175	F.	205	M.	236	Th.	267	S.	297	Tu.	328	Th.	358
24	S.	24	Tu.	55	W.	84	S.	115	M.	145	Th.	176	S.	206	Tu.	237	F.	268	☉	298	W.	329	F.	359
25	☉	25	W.	56	Th.	85	☉	116	Tu.	146	F.	177	☉	207	W.	238	S.	269	M.	299	Th.	330	S.	360
26	M.	26	Th.	57	F.	86	M.	117	W.	147	S.	178	M.	208	Th.	239	☉	270	Tu.	300	F.	331	☉	361
27	Tu.	27	F.	58	S.	87	Tu.	118	Th.	148	☉	179	Tu.	209	F.	240	M.	271	W.	301	S.	332	M.	362
28	W.	28	S.	59	☉	88	W.	119	F.	149	M.	180	W.	210	S.	241	Tu.	272	Th.	302	☉	333	Tu.	363
29	Th.	29	☉	60	M.	89	Th.	120	S.	150	Tu.	181	Th.	211	☉	242	W.	273	F.	303	M.	334	W.	364
30	F.	30			Tu.	90	F.	121	☉	151	W.	182	F.	212	M.	243	Th.	274	S.	304	Tu.	335	Th.	365
31	S.	31			W.	91			M.	152			S.	213	Tu.	244			☉	305			F.	366

ECLIPSES

There are three eclipses, two of the Sun and one of the Moon.

1. *An Annular Eclipse of the Sun*, April 29. See map on page 6. The eclipse begins at $07^h\ 22^m$ and ends at $13^h\ 25^m$; the annular phase begins at $08^h\ 32^m$ and ends at $12^h\ 15^m$. The maximum duration of the annular phase is $6^m\ 36^s$.

2. *A Partial Eclipse of the Moon*, May 13. The eclipse begins at $19^h\ 16^m$ and ends at $20^h\ 33^m$. It is visible from Australasia, the Indian Ocean, Asia (except the north-eastern part), Europe (except the north-western part), Africa, Antarctica, the South Atlantic Ocean and the extreme north-eastern part of South America. At the time of maximum eclipse 0·13 of the Moon's diameter is obscured.

3. *A Total Eclipse of the Sun*, October 23. See map on page 7. The eclipse begins at $02^h\ 39^m$ and ends at $07^h\ 47^m$; the total phase begins at $03^h\ 36^m$ and ends at $06^h\ 50^m$. The maximum duration of the total phase is $4^m\ 47^s$.

PLANET NOTES, 1976

POSITIONS OF PLANETS

VENUS is easily identified by its superior brilliance. It is a morning star until the middle of May when it becomes too close to the Sun for observation. From the end of July onwards it is an evening star until the end of the year. Venus is in conjunction with Jupiter on May 11, with Mercury on July 24 and again on September 6 and with Mars on September 10.

MARS is an evening star until the beginning of October. For the remainder of the year it is too close to the Sun for observation. Mars is in Taurus at the beginning of the year and moves through Gemini (passing 5° S. of *Pollux* on May 5), Cancer, Leo, Virgo (passing 3° N. of *Spica* on September 27) and Libra before conjunction in Scorpius. Afterwards it moves through Ophiuchus and into Sagittarius by the end of the year. Mars is in conjunction with Saturn on May 12, *Regulus* on July 5 and Venus on September 10. The reddish tint of Mars should assist in its identification.

JUPITER is an evening star until early April when it becomes too close to the Sun for observation. From the middle of May until opposition on November 18 it is a morning star. It is an evening star for the rest of the year. Jupiter is in conjunction with Mercury on April 12 and with Venus on May 11.

SATURN is a morning star until January 20, when it is at opposition and becomes an evening star until the middle of July when it becomes too close to the Sun for observation. From the middle of August it is a morning star for the remainder of the year. Saturn is in Cancer at the beginning of the year, moving backwards into Gemini in February and forward into Cancer again early in May where it remains for the rest of the year. Saturn is in conjunction with Mars on May 12.

MERCURY can only be seen low in the east before sunrise, or low in the west after sunset (about the time of beginning or end of civil twilight). It is visible in the mornings during the following approximate dates: January 28 (+1·7) to March 23 (−0·9), May 29 (+2·3) to July 8 (−1·3), September 28 (+1·5) to October 25 (−1·0); the planet is brighter at the end of each period. It is visible in the evenings between the following approximate dates: January 1 (−0·6) to January 19 (+1·7), April 10 (−1·5) to May 14 (+2·5), July 25 (−1·1) to September 18 (+2·2), November 25 (−0·5) to December 31 (+1·0); the planet is brighter at the beginning of each period. The figures in parentheses are the magnitudes.

PLANET DIAGRAM

General Description. The diagram on the opposite page shows, in graphical form for any date during the year, the local mean time of meridian passage of the Sun, of the five planets Mercury, Venus, Mars, Jupiter, and Saturn, and of each 30° of S.H.A.; intermediate lines, corresponding to particular stars, may be drawn in by the user if he so desires. It is intended to provide a general picture of the availability of planets and stars for observation.

On each side of the line marking the time of meridian passage of the Sun a band, 45^m wide, is shaded to indicate that planets and most stars crossing the meridian within 45^m of the Sun are too close to the Sun for observation.

Method of use and interpretation. For any date the diagram provides immediately the local mean times of meridian passage of the Sun, planets and stars, and thus the following information:

(a) whether a planet or star is too close to the Sun for observation;
(b) whether a planet is a morning or evening star;
(c) some indication of its position during twilight;
(d) the proximity of other planets.

When the meridian passage occurs at midnight the body is in opposition to the Sun and is visible all night; planets may be observable in both morning and evening twilights. As the time of meridian passage decreases, the body ceases to be observable in the morning, but its altitude above the eastern horizon during evening twilight gradually increases; this continues until the body is on the meridian at twilight. From then onwards the body is observable above the western horizon and its altitude at evening twilight gradually decreases; eventually the body becomes too close to the Sun for observation. When the body again becomes visible it is seen as a morning star low in the east; its altitude at twilight increases until meridian passage occurs at the time of morning twilight. Then, as the time of meridian passage decreases to 0^h, the body is observable in the west in the morning twilight with a gradually decreasing altitude, until it once again reaches opposition.

DO NOT CONFUSE

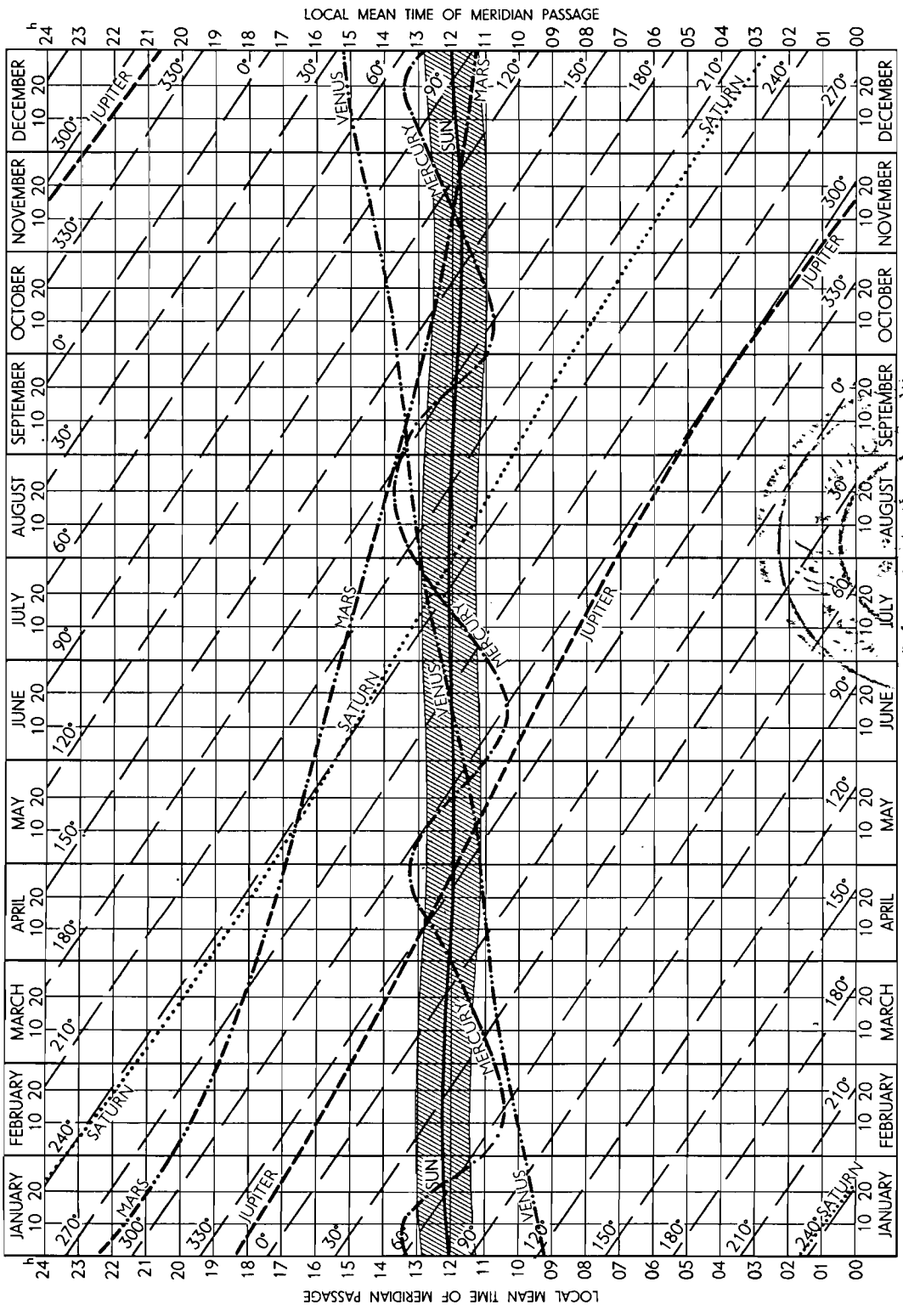
Mercury with Jupiter in April; Jupiter is slightly brighter than Mercury.

Venus with Jupiter in May; Venus is the brighter object.

Mars with Saturn in May; Saturn is the brighter object.

Mercury with Venus at the end of July; Venus is the brighter object.

Mercury with Mars in August, and with Mars and Venus in early September; Venus is the brightest object and Mars is the faintest.


LOCAL MEAN TIME OF MERIDIAN PASSAGE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
SUN
MERCURY
VENUS
MARS
JUPITER
SATURN
LOCAL MEAN TIME OF MERIDIAN PASSAGE

STANDARD TIMES (Corrected to September 1973)

LIST I—PLACES FAST ON G.M.T. (mainly those EAST OF GREENWICH)

The times given below should be *added* to G.M.T. to give Standard Time.
subtracted from Standard Time to give G.M.T.

	h	m
Aden (Southern Yemen)	03	
Admiralty Islands	10	
Afghanistan	04	30
Albania*	01	
Amirante Islands	04	
Andaman Islands	05	30
Angola (Portuguese West Africa)	01	
Annobon Island‡	01	
Arabian Emirates, Federation of	04	
Australia		
Australian Capital Territory*	10	
New South Wales[1]*	10	
Northern Territory	09	30
Queensland	10	
South Australia*	09	30
Tasmania*	10	
Victoria*	10	
Western Australia	08	
Austria	01	
Balearic Islands‡	01	
Bangladesh	06	
Belgium	01	
Botswana, Republic of	02	
British New Guinea	10	
Brunei	08	
Bulgaria	02	
Burma	06	30
Burundi	02	
Cambodia	07	
Cameroun Republic	01	
Caroline Islands, east of long. E. 160°	12	
west of long. E. 160°	10	
Truk, Ponape	11	
Central African Republic‡	01	
Ceylon (Sri Lanka)	05	30
Chad	01	
Chagos Archipelago	05	
Chatham Islands‡	12	45
China[2]	08	
Christmas Island, Indian Ocean	07	
Cocos Keeling Islands	06	30
Comoro Islands	03	
Congo Republic	01	
Corsica‡	01	
Crete	02	
Cyprus	02	
Cyrenaica‡	02	
Czechoslovakia	01	
Dahomey, Republic of	01	
Denmark	01	
Egypt* (United Arab Republic)	02	
Ellice Islands	12	
Equatorial Guinea, Republic of	01	
Estonia	03	
Ethiopia	03	
Fernando Póo‡	01	
Fiji	12	
Finland	02	
Formosa* (Taiwan)	08	
France‡	01	
French Territory of the Afars and Issas	03	
Friendly Islands	13	
Gabon	01	
Germany	01	
Gibraltar‡	01	
Gilbert and Ellice Islands	12	
Greece	02	
Guam	10	
Holland (The Netherlands)	01	
Hong Kong*	08	
Hungary	01	
India	05	30
Indonesia, Republic of		
Bali, Bangka, Billiton, Java, Lombok, Madura, Sumatra	07	
Borneo, Celebes, Flores, Sumba, Sumbawa, Timor	08	
Aru, Kei, Moluccas, Tanimbar, West Irian	09	
Iran	03	30
Iraq	03	
Irish Republic†	01	
Israel	02	
Italy*	01	
Japan	09	
Jordan	02	
Kamchatka Peninsula	12	
Kenya	03	
Korea	09	
Kuril Islands	11	
Kuwait	03	
Laccadive Islands	05	30
Ladrone Islands	10	
Laos	07	
Latvia	03	
Lebanon*	02	
Lesotho	02	

* Summer time may be kept in these countries.
† Winter time is kept in this country.
‡ This time is used throughout the year, but may differ from the legal time.
[1] Except Broken Hill Area which keeps $09^h\ 30^m$.
[2] All the coast, but some areas may keep summer time.

LIST I—(*continued*)

	h	m
Libya	02	
Liechtenstein	01	
Lithuania	03	
Lord Howe Island	10	30
Luxembourg‡	01	
Macao*	08	
Malagasy Republic	03	
Malawi	02	
Malaysia		
Malaya	07	30
Sabah, Sarawak	08	
Maldive Republic	05	
Malta*	01	
Manchuria	09	
Mariana Islands	10	
Marshall Islands[1]	12	
Mauritius	04	
Monaco‡	01	
Mozambique (Portuguese E. Africa)	02	
Muscat and Oman, Sultanate of	04	
Nauru	11	30
Netherlands, The	01	
New Caledonia	11	
New Guinea, British	10	
New Hebrides	11	
New Zealand	12	
Nicobar Islands	05	30
Niger	01	
Nigeria, Republic of	01	
Norfolk Island	11	30
North Vietnam	07	
Norway*	01	
Novaya Zemlya	05	
Ocean Island	11	30
Okinawa	09	
Pakistan	05	
Papua	10	
Persia (Iran)	03	30
Pescadores Islands*	08	
Philippine Republic	08	
Poland*	01	
Portugal	01	
Portuguese East Africa (Mozambique)	02	
Portuguese West Africa (Angola)	01	
Réunion	04	
Rhodesia, Republic of	02	
Romania	02	
Rwanda	02	
Ryukyu Islands	09	
Sakhalin	11	
Santa Cruz Islands	11	
Sardinia	01	
Saudi Arabia	03	
Schouten Islands	09	
Seychelles	04	
Siam (Thailand)	07	
Sicily	01	
Singapore	07	30
Socotra	03	
Solomon Islands	11	
Somali Republic	03	
South Africa, Republic of	02	
Southern Yemen	03	
South Vietnam	08	
South West Africa	02	
Spain‡	01	
Spitsbergen (Svalbard)	01	
Sri Lanka (Ceylon)	05	30
Sudan, Republic of*	02	
Swaziland	02	
Sweden	01	
Switzerland	01	
Syria* (Syrian Arab Republic)	02	
Taiwan* (Formosa)	08	
Tanzania	03	
Thailand	07	
Timor	08	
Tonga Islands	13	
Tripolitania	02	
Truk	11	
Tunisia*	01	
Turkey*	02	
Uganda	03	
Union of Soviet Socialist Republics[2]		
west of long. E. 40°	03	
long. E. 40° to E. 52° 30′	04	
long. E. 52° 30′ to E. 67° 30′	05	
long. E. 67° 30′ to E. 82° 30′	06	
long. E. 82° 30′ to E. 97° 30′	07	
long. E. 97° 30′ to E. 112° 30′	08	
long. E. 112° 30′ to E. 127° 30′	09	
long. E. 127° 30′ to E. 142° 30′	10	
long. E. 142° 30′ to E. 157° 30′	11	
long. E. 157° 30′ to E. 172° 30′	12	
east of long. E. 172° 30′	13	
Vietnam, North	07	
South	08	
Wrangell Island	13	
Yugoslavia	01	
Zaire		
Kinshasa, Mbandaka	01	
Orientale, Kivu, Katanga, Kasai	02	
Zambia, Republic of	02	

* Summer time may be kept in these countries.
‡ This time is used throughout the year, but may differ from the legal time.
[1] Except the islands of Kwajalein and Eniwetok which keep a time 24^h slow on that of the rest of the islands.
[2] The boundaries between the zones are irregular; the longitudes given are approximate only.

STANDARD TIMES (Corrected to September 1973)

LIST II—PLACES NORMALLY KEEPING G.M.T.

Algeria	Gambia	Ifni	Mali	St. Helena	Tangier
Ascension Island	Ghana	Ireland, Northern[1]	Mauritania	São Tomé	Togo Republic
Canary Islands‡	Great Britain[1]	Ivory Coast	Morocco*	Senegal	Tristan da Cunha
Channel Islands[1]	Guinea Republic	Liberia	Principe	Sierra Leone	Upper Volta
Faeroes, The	Iceland	Madeira	Rio de Oro‡	Spanish Sahara	

* Summer time may be kept in these countries.
‡ G.M.T. is in general use throughout the year, but the legal standard time differs from G.M.T.
[1] Summer time, one hour in advance of G.M.T., is kept from March 21d 02h to October 24d 02h G.M.T.

LIST III—PLACES SLOW ON G.M.T. (WEST OF GREENWICH)

The times given below should be *subtracted* from G.M.T. to give Standard Time. / *added* to Standard Time to give G.M.T.

	h	m
Argentina	03	
Austral Islands[1]	10	
Azores	01	
Bahamas*	05	
Barbados	04	
Belize	06	
Bermuda	04	
Bolivia	04	
Brazil*, eastern[2]	03	
Territory of Acre	05	
western	04	
British Antarctic Territory[3]	03	
Canada		
Alberta*	07	
British Columbia*	08	
Labrador*	04	
Manitoba*	06	
New Brunswick*	04	
Newfoundland*	03	30
Northwest Territories*		
east of long. W. 68°	04	
long. W. 68° to W. 85°	05	
long. W. 85° to W. 102°	06	
west of long. W. 102°	07	
Nova Scotia*	04	
Ontario*, east of long. W. 90°	05	
west of long. W. 90°	06	
Prince Edward Island*	04	
Quebec*, east of long. W. 63°	04	
west of long. W. 63°	05	
Saskatchewan*		
east of long. W. 106°	06	
west of long. W. 106°	07	
Yukon, east of long. W. 138°	08	
west of long. W. 138°	09	
Cape Verde Islands	02	
Cayman Islands	05	
Chile*	04	
Christmas Island, Pacific Ocean	10	
Colombia	05	
Cook Islands, except Niue	10	30
Costa Rica*	06	
Cuba*	05	
Curaçao Island	04	
Dominican Republic†	05	
Dutch Guiana (Surinam)	03	30
Easter Island (I. de Pascua)	07	
Ecuador	05	
Falkland Islands[4]	04	
Fanning Island	10	
Fernando de Noronha Island	02	
French Guiana	03	
Galápagos Islands	05	
Greenland, Scoresby Sound	02	
Angmagssalik and west coast	03	
Thule area	04	
Grenada*	04	
Guadeloupe	04	
Guatemala	06	
Guiana, Dutch	03	30
French	04	
Guyana, Republic of	03	45
Haiti	05	
Honduras	06	
Honduras, British (Belize)	06	
Jamaica	05	
Jan Mayen Island	01	

* Summer time may be kept in these countries.
† Winter time may be kept in these countries.
[1] This is the legal standard time, but local mean time is generally used.
[2] Including all the coast.
[3] Except South Georgia which keeps 02h.
[4] Port Stanley keeps summer time September to March.

STANDARD TIMES (Corrected to September 1973)

LIST III—(*continued*)

	h	m
Johnston Island	10	
Juan Fernandez Islands	04	
Leeward Islands	04	
Low Archipelago	10	
Marquesas Islands[1]	09	30
Martinique	04	
Mexico[2]	06	
Midway Islands	11	
Miquelon	03	
Nicaragua	06	
Niue Island	11	
Panama Canal Zone	05	
Panama, Republic of	05	
Paraguay	04	
Peru	05	
Portuguese Guinea	01	
Puerto Rico	04	
Rarotonga	10	30
St. Pierre and Miquelon	03	
Salvador, El	06	
Samoa	11	
Society Islands[1]	10	
South Georgia	02	
Surinam (Dutch Guiana)	03	30
Tobago	04	
Trinidade Island, South Atlantic	02	
Trinidad	04	
Tuamotu Archipelago[1]	10	
Tubuai Islands[1]	10	
Turks and Caicos Islands	05	
United States of America		
Alabama[3]	06	
Alaska[3], east of long. W. 137°	08	
long. W. 137° to W. 141°	09	
long. W. 141° to W. 161°	10	
long. W. 161° to W. 172° 30′	11	
Aleutian Islands	11	
Arizona	07	
Arkansas[3]	06	
California[3]	08	
Colorado[3]	07	
Connecticut[3]	05	
Delaware[3]	05	
District of Columbia[3]	05	
United States of America (continued)		
Florida[3, 4]	05	
Georgia[3]	05	
Hawaii	10	
Idaho[3, 4]	07	
Illinois[3]	06	
Indiana[4]	05	
Iowa[3]	06	
Kansas[3, 4]	06	
Kentucky[3, 4]	05	
Louisiana[3]	06	
Maine[3]	05	
Maryland[3]	05	
Massachusetts[3]	05	
Michigan[3, 4]	05	
Minnesota[3]	06	
Mississippi[3]	06	
Missouri[3]	06	
Montana[3]	07	
Nebraska[3, 4]	06	
Nevada[3]	08	
New Hampshire[3]	05	
New Jersey[3]	05	
New Mexico[3]	07	
New York[3]	05	
North Carolina[3]	05	
North Dakota[3, 4]	06	
Ohio[3]	05	
Oklahoma[3]	06	
Oregon[3, 4]	08	
Pennsylvania[3]	05	
Rhode Island[3]	05	
South Carolina[3]	05	
South Dakota[3], eastern part	06	
western part	07	
Tennessee[3, 4]	06	
Texas[3]	06	
Utah[3, 4]	07	
Vermont[3]	05	
Virginia[3]	05	
Washington, D.C.[3]	05	
Washington[3]	08	
West Virginia[3]	05	
Wisconsin[3]	06	
Wyoming[3]	07	
Uruguay	03	
Venezuela	04	
Virgin Islands	04	
Windward Islands	04	

* Summer time may be kept in these countries.

[1] This is the legal standard time, but local mean time is generally used.

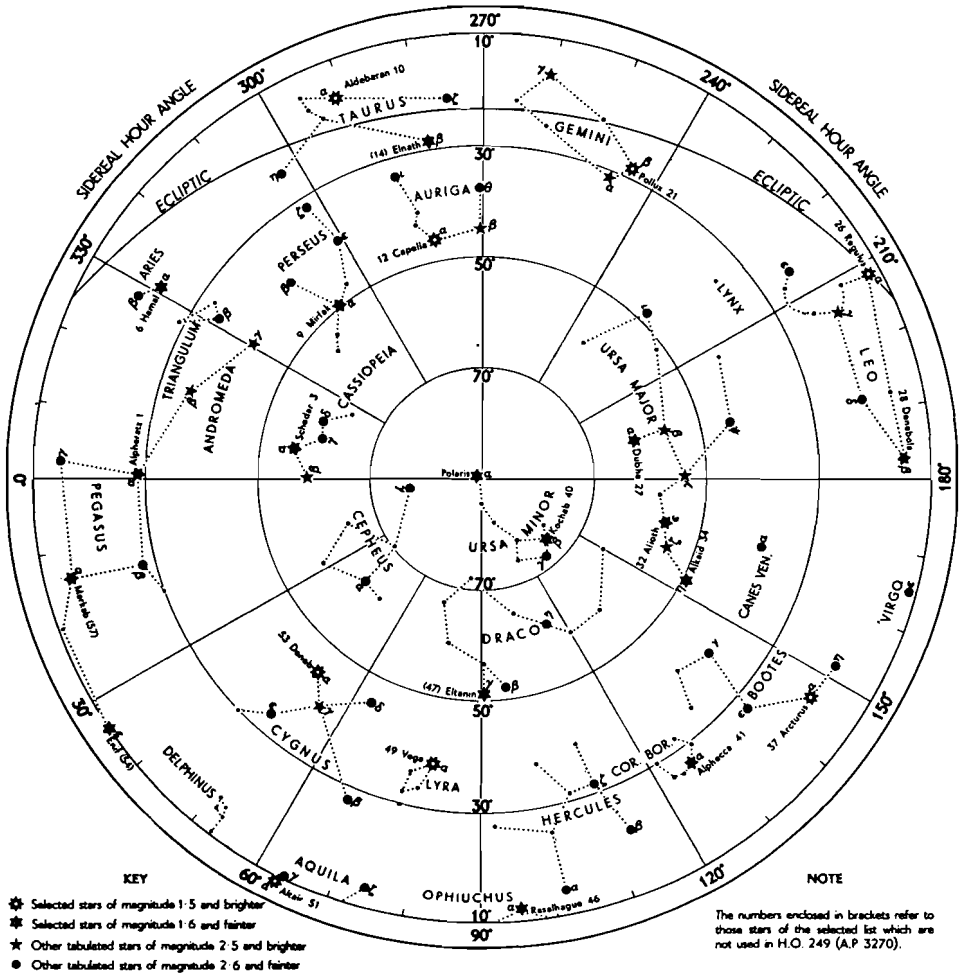
[2] Except the states of Sonora, Sinaloa, Nayarit, and the Southern District of Lower California which keep 07^h, and the Northern District of Lower California which keeps 08^h.

[3] Summer (daylight-saving) time, one hour fast on the time given, is kept in these states from the last Sunday in April to the last Sunday in October, changing at $02^h\ 00^m$ local clock time.

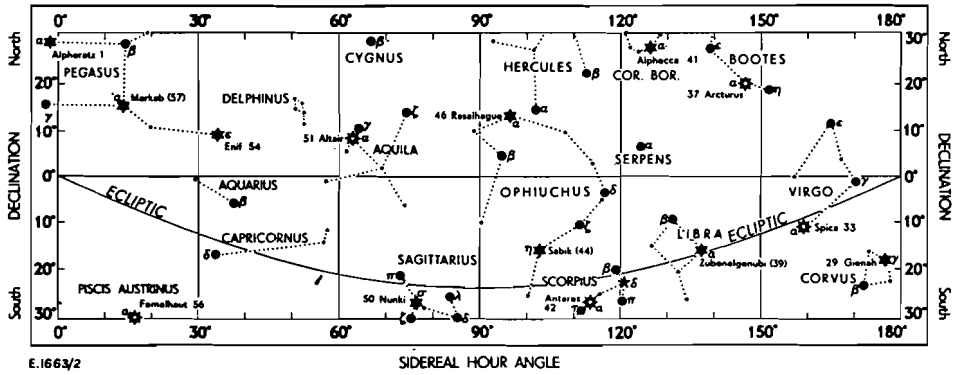
[4] This applies to the greater portion of the state.

STAR CHARTS

NORTHERN STARS



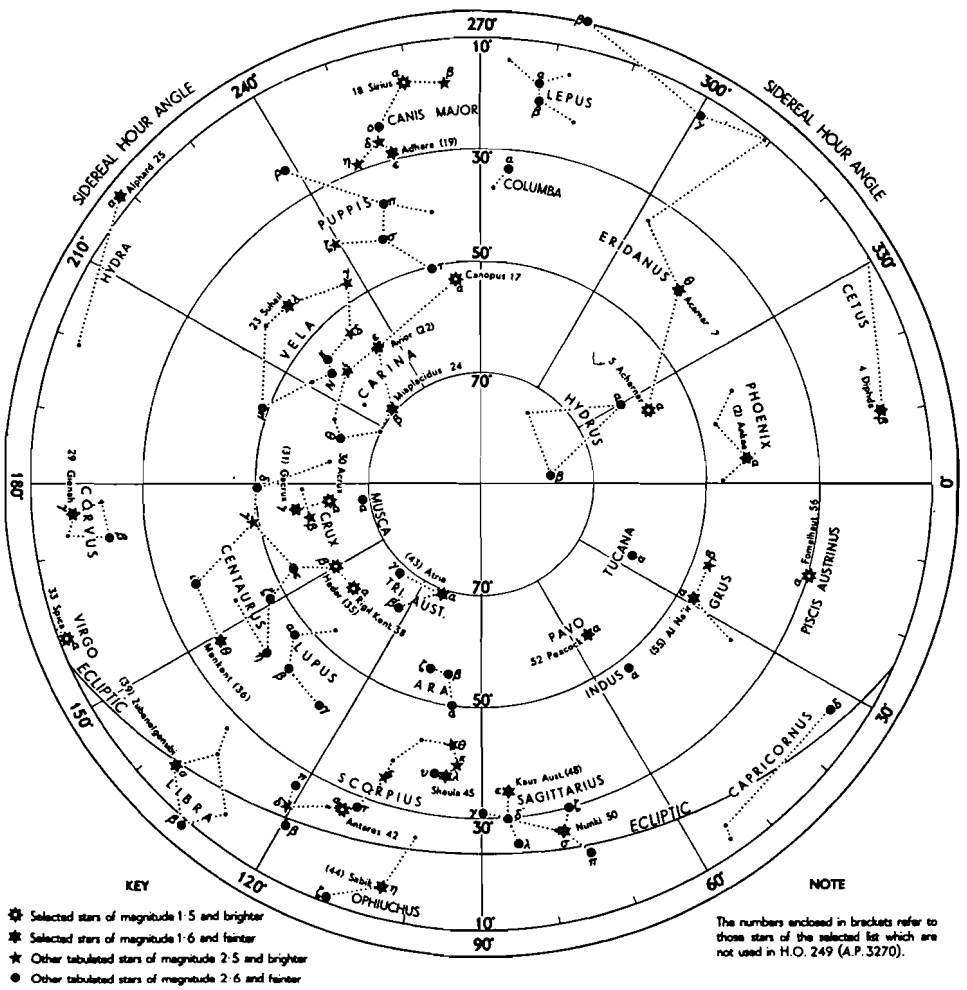
EQUATORIAL STARS (S.H.A. 0° to 180°)



E.1663/2

STAR CHARTS

SOUTHERN STARS



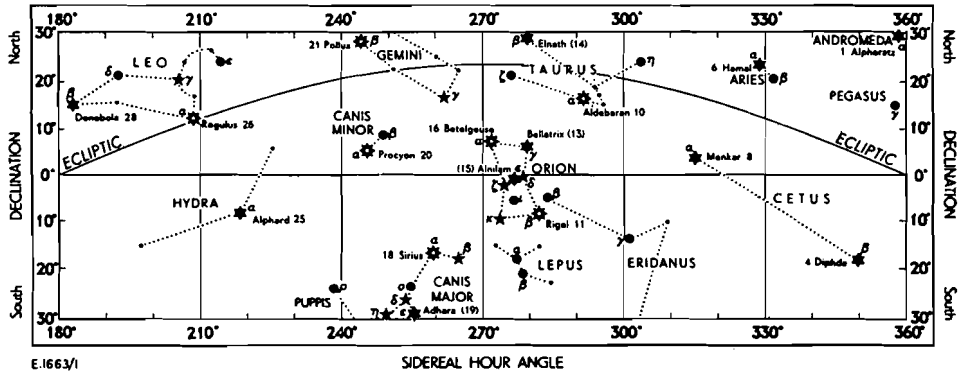
KEY

- Selected stars of magnitude 1·5 and brighter
- Selected stars of magnitude 1·6 and fainter
- Other tabulated stars of magnitude 2·5 and brighter
- Other tabulated stars of magnitude 2·6 and fainter
- Untabulated stars

NOTE

The numbers enclosed in brackets refer to those stars of the selected list which are not used in H.O. 249 (A.P.3270).

EQUATORIAL STARS (S.H.A. 180° to 360°)



E.1663/1

SIDEREAL HOUR ANGLE

Mag.	Name and Number	S.H.A.							Dec.						
			JAN.	FEB.	MAR.	APR.	MAY	JUNE		JAN.	FEB.	MAR.	APR.	MAY	JUNE
		°	′	′	′	′	′	′	°	′	′	′	′	′	′
3·4	γ Cephei †	5	24·8	25·3	25·5	25·2	24·6	23·8	N. 77	30·3	30·2	30·0	29·9	29·8	29·8
2·6	α Pegasi 57	14	06·5	06·5	06·5	06·4	06·2	06·0	N. 15	04·7	04·6	04·6	04·6	04·6	04·7
2·6	β Pegasi	14	20·8	20·9	20·9	20·7	20·5	20·3	N. 27	57·4	57·3	57·2	57·1	57·1	57·2
1·3	α Piscis Aust 56	15	55·1	55·2	55·1	55·0	54·8	54·5	S. 29	45·0	45·0	44·9	44·8	44·7	44·6
2·2	β Gruis	19	41·6	41·6	41·5	41·4	41·1	40·8	S. 47	00·7	00·6	00·5	00·4	00·2	00·2
2·9	α Tucanæ	25	47·3	47·3	47·2	47·0	46·6	46·2	S. 60	22·9	22·7	22·6	22·4	22·3	22·3
2·2	α Gruis 55	28	19·3	19·3	19·2	19·0	18·7	18·4	S. 47	04·7	04·6	04·5	04·4	04·3	04·2
3·0	δ Capricorni	33	34·3	34·3	34·2	34·0	33·8	33·5	S. 16	14·2	14·2	14·1	14·1	14·0	13·9
2·5	ε Pegasi 54	34	14·9	14·9	14·8	14·7	14·5	14·2	N. 9	46·0	45·9	45·9	45·9	46·0	46·1
3·1	β Aquarii	37	25·6	25·6	25·5	25·3	25·1	24·9	S. 5	40·6	40·6	40·6	40·5	40·5	40·4
2·6	α Cephei	40	30·3	30·3	30·2	29·8	29·4	29·1	N. 62	29·3	29·1	29·0	28·9	28·9	29·0
2·6	ε Cygni	48	41·6	41·5	41·4	41·2	40·9	40·7	N. 33	52·9	52·8	52·7	52·7	52·8	52·9
1·3	α Cygni 53	49	51·0	51·0	50·8	50·6	50·3	50·1	N. 45	11·8	11·7	11·6	11·5	11·6	11·7
3·2	α Indi	51	01·9	01·8	01·6	01·4	01·1	00·7	S. 47	22·5	22·4	22·3	22·2	22·2	22·2
2·1	α Pavonis 52	54	04·0	03·8	03·6	03·2	02·8	02·5	S. 56	48·8	48·6	48·5	48·4	48·4	48·4
2·3	γ Cygni	54	39·7	39·7	39·5	39·3	39·0	38·8	N. 40	10·9	10·8	10·7	10·6	10·7	10·8
0·9	α Aquilæ 51	62	35·9	35·8	35·7	35·5	35·2	35·0	N. 8	48·3	48·3	48·2	48·2	48·3	48·4
2·8	γ Aquilæ	63	43·3	43·2	43·1	42·9	42·6	42·4	N. 10	33·3	33·2	33·2	33·2	33·3	33·4
3·0	δ Cygni	63	56·9	56·8	56·6	56·4	56·1	55·9	N. 45	04·4	04·3	04·2	04·1	04·2	04·4
3·2	β Cygni	67	33·9	33·8	33·6	33·4	33·1	32·9	N. 27	54·6	54·5	54·4	54·4	54·5	54·6
3·0	π Sagittarii	72	55·0	54·9	54·7	54·5	54·2	54·0	S. 21	03·7	03·7	03·7	03·6	03·6	03·6
3·0	ζ Aquilæ	73	55·5	55·4	55·2	55·0	54·8	54·6	N. 13	49·7	49·6	49·5	49·6	49·6	49·7
2·7	ζ Sagittarii	74	43·8	43·7	43·4	43·2	42·9	42·7	S. 29	54·9	54·8	54·8	54·8	54·7	54·7
2·1	σ Sagittarii 50	76	33·4	33·3	33·0	32·8	32·6	32·4	S. 26	19·6	19·6	19·5	19·5	19·5	19·5
0·1	α Lyræ 49	80	58·4	58·2	58·0	57·7	57·5	57·3	N. 38	45·7	45·5	45·5	45·5	45·6	45·7
2·9	λ Sagittarii	83	22·7	22·6	22·3	22·1	21·9	21·7	S. 25	26·1	26·1	26·1	26·0	26·0	26·0
2·0	ε Sagittarii 48	84	21·4	21·2	20·9	20·7	20·4	20·2	S. 34	23·7	23·7	23·7	23·7	23·7	23·7
2·8	δ Sagittarii	85	08·2	08·0	07·8	07·5	07·3	07·1	S. 29	50·3	50·3	50·2	50·2	50·2	50·2
3·1	γ Sagittarii	88	56·1	55·9	55·6	55·4	55·2	55·0	S. 30	25·4	25·4	25·4	25·4	25·4	25·4
2·4	γ Draconis 47	90	59·7	59·5	59·2	58·9	58·7	58·5	N. 51	29·4	29·3	29·2	29·3	29·4	29·6
2·9	β Ophiuchi	94	25·8	25·6	25·4	25·2	25·0	24·9	N. 4	34·6	34·5	34·5	34·5	34·6	34·7
2·5	κ Scorpii	94	47·7	47·4	47·2	46·9	46·6	46·5	S. 39	01·0	01·0	01·0	01·0	01·0	01·1
2·0	θ Scorpii	96	06·2	05·9	05·6	05·3	05·1	04·9	S. 42	58·9	58·9	58·8	58·9	58·9	59·0
2·1	α Ophiuchi 46	96	32·8	32·6	32·4	32·2	32·0	31·9	N. 12	34·6	34·5	34·5	34·5	34·6	34·7
1·7	λ Scorpii 45	96	60·4	60·1	59·9	59·6	59·4	59·2	S. 37	05·1	05·1	05·1	05·1	05·1	05·2
3·0	α Aræ	97	30·3	30·0	29·7	29·4	29·1	28·9	S. 49	51·3	51·3	51·3	51·3	51·4	51·5
3·0	β Draconis	97	32·1	31·8	31·5	31·2	31·0	30·9	N. 52	19·0	18·9	18·9	18·9	19·0	19·2
2·8	υ Scorpii	97	43·1	42·8	42·6	42·3	42·1	41·9	S. 37	16·5	16·5	16·5	16·5	16·6	16·6
2·8	β Aræ	99	10·6	10·2	09·9	09·5	09·2	09·0	S. 55	30·3	30·3	30·3	30·3	30·4	30·5
Var.‡	α Herculis	101	36·8	36·6	36·4	36·2	36·0	35·9	N. 14	25·0	24·9	24·9	24·9	25·0	25·1
2·6	η Ophiuchi 44	102	45·0	44·8	44·6	44·4	44·2	44·1	S. 15	41·7	41·7	41·8	41·8	41·8	41·7
3·1	ζ Aræ	105	50·6	50·3	49·9	49·5	49·3	49·1	S. 55	57·0	57·0	57·0	57·1	57·1	57·2
2·4	ε Scorpii	107	50·9	50·6	50·4	50·1	49·9	49·8	S. 34	14·9	14·9	15·0	15·0	15·0	15·1
1·9	α Triang. Aust. 43	108	28·5	27·9	27·3	26·8	26·4	26·2	S. 68	58·9	58·8	58·9	58·9	59·0	59·2
3·0	ζ Herculis	109	54·4	54·2	54·0	53·8	53·6	53·5	N. 31	38·6	38·5	38·5	38·6	38·7	38·8
2·7	ζ Ophiuchi	111	02·5	02·2	02·0	01·8	01·7	01·6	S. 10	31·1	31·2	31·2	31·2	31·2	31·2
2·9	τ Scorpii	111	24·2	23·9	23·7	23·5	23·3	23·2	S. 28	09·9	10·0	10·0	10·0	10·0	10·1
2·8	β Herculis	112	42·3	42·1	41·8	41·6	41·5	41·4	N. 21	32·4	32·3	32·3	32·3	32·4	32·5
1·2	α Scorpii 42	113	01·0	00·7	00·5	00·3	00·1	00·0	S. 26	22·7	22·7	22·8	22·8	22·8	22·8
2·9	η Draconis	114	05·6	05·2	04·9	04·5	04·4	04·4	N. 61	33·9	33·8	33·8	33·9	34·0	34·2
3·0	δ Ophiuchi	116	43·7	43·5	43·2	43·1	42·9	42·9	S. 3	38·0	38·1	38·1	38·1	38·1	38·0
2·8	β Scorpii	118	59·4	59·1	58·9	58·7	58·6	58·5	S. 19	44·4	44·4	44·5	44·5	44·5	44·5
2·5	δ Scorpii	120	16·3	16·0	15·8	15·6	15·4	15·4	S. 22	33·2	33·2	33·3	33·3	33·3	33·3
3·0	π Scorpii	120	39·0	38·7	38·5	38·3	38·1	38·1	S. 26	02·7	02·7	02·8	02·8	02·8	02·9
3·0	β Trianguli Aust.	121	44·7	44·2	43·8	43·4	43·2	43·1	S. 63	21·2	21·2	21·3	21·4	21·5	21·6
2·8	α Serpentis	124	13·7	13·5	13·3	13·1	13·0	13·0	N. 6	30·0	29·9	29·8	29·9	29·9	30·0
2·3	α Coronæ Bor. 41	126	35·0	34·7	34·5	34·3	34·2	34·2	N. 26	47·5	47·4	47·4	47·5	47·6	47·7
3·0	γ Lupi †	126	36·8	36·5	36·3	36·0	35·9	35·8	S. 41	05·1	05·1	05·2	05·3	05·3	05·4

‡ 3·0—3·7 † Not suitable for use with H.O. 214 (H.D. 486)

Mag.	Name and Number		S.H.A. JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	Dec. JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
			° ′	′	′	′	′	′	° ′	′	′	′	′	′
3·4	γ Cephei †		5 23·0	22·5	22·2	22·4	22·8	23·4	N. 77 29·9	30·0	30·2	30·4	30·6	30·6
2·6	*Markab*	57	14 05·7	05·6	05·5	05·5	05·6	05·7	N. 15 04·8	04·9	05·0	05·1	05·1	05·1
2·6	*Scheat*		14 20·0	19·9	19·8	19·8	19·9	20·1	N. 27 57·3	57·5	57·6	57·7	57·7	57·7
1·3	*Fomalhaut*	56	15 54·3	54·1	54·0	54·1	54·2	54·3	S. 29 44·5	44·5	44·6	44·6	44·7	44·7
2·2	β Gruis		19 40·5	40·3	40·3	40·3	40·5	40·7	S. 47 00·1	00·2	00·3	00·4	00·4	00·5
2·9	α Tucanæ		25 45·8	45·6	45·6	45·7	46·0	46·2	S. 60 22·3	22·4	22·5	22·6	22·7	22·7
2·2	*Al Na'ir*	55	28 18·1	17·9	17·9	18·0	18·2	18·4	S. 47 04·2	04·2	04·3	04·4	04·5	04·5
3·0	δ Capricorni		33 33·3	33·2	33·2	33·3	33·4	33·5	S. 16 13·8	13·8	13·8	13·8	13·9	13·9
2·5	*Enif*	54	34 14·0	13·9	13·9	14·0	14·1	14·2	N. 9 46·2	46·3	46·3	46·4	46·4	46·3
3·1	β Aquarii		37 24·7	24·6	24·6	24·7	24·8	24·9	S. 5 40·3	40·2	40·2	40·2	40·2	40·3
2·6	*Alderamin*		40 28·8	28·7	28·8	29·1	29·4	29·7	N. 62 29·2	29·4	29·5	29·7	29·7	29·6
2·6	ε Cygni		48 40·5	40·5	40·5	40·7	40·8	41·0	N. 33 53·0	53·2	53·3	53·4	53·4	53·3
1·3	*Deneb*	53	49 49·9	49·9	49·9	50·1	50·3	50·5	N. 45 11·9	12·0	12·2	12·2	12·3	12·2
3·2	α Indi		51 00·5	00·4	00·5	00·7	00·9	01·0	S. 47 22·2	22·3	22·4	22·4	22·4	22·4
2·1	*Peacock*	52	54 02·2	02·2	02·3	02·5	02·7	02·9	S. 56 48·5	48·5	48·6	48·7	48·7	48·7
2·3	γ Cygni		54 38·6	38·6	38·7	38·9	39·0	39·2	N. 40 11·0	11·1	11·3	11·3	11·3	11·2
0·9	*Altair*	51	62 34·9	34·9	35·0	35·1	35·2	35·3	N. 8 48·5	48·6	48·7	48·7	48·6	48·6
2·8	γ Aquilæ		63 42·3	42·3	42·4	42·5	42·6	42·7	N. 10 33·5	33·6	33·7	33·7	33·6	33·6
3·0	δ Cygni		63 55·7	55·8	55·9	56·1	56·3	56·5	N. 45 04·5	04·7	04·8	04·9	04·8	04·7
3·2	*Albireo*		67 32·8	32·9	33·0	33·1	33·3	33·3	N. 27 54·8	54·9	55·0	55·0	55·0	54·9
3·0	π Sagittarii		72 53·9	53·9	54·0	54·1	54·3	54·3	S. 21 03·5	03·5	03·6	03·6	03·6	03·6
3·0	ζ Aquilæ		73 54·5	54·5	54·6	54·8	54·9	55·0	N. 13 49·9	49·9	50·0	50·0	50·0	49·9
2·7	ζ Sagittarii		74 42·6	42·6	42·7	42·9	43·0	43·0	S. 29 54·7	54·8	54·8	54·8	54·8	54·8
2·1	*Nunki*	50	76 32·3	32·3	32·4	32·5	32·6	32·7	S. 26 19·5	19·5	19·5	19·5	19·5	19·5
0·1	*Vega*	49	80 57·3	57·4	57·5	57·7	57·9	58·0	N. 38 45·9	46·0	46·1	46·1	46·0	45·9
2·9	λ Sagittarii		83 21·6	21·6	21·7	21·9	22·0	22·0	S. 25 26·0	26·0	26·0	26·0	26·0	26·0
2·0	*Kaus Australis*	48	84 20·2	20·2	20·3	20·5	20·6	20·6	S. 34 23·7	23·7	23·8	23·8	23·7	23·7
2·8	δ Sagittarii		85 07·0	07·1	07·2	07·3	07·5	07·5	S. 29 50·2	50·3	50·3	50·3	50·3	50·2
3·1	γ Sagittarii		88 54·9	55·0	55·1	55·2	55·3	55·3	S. 30 25·4	25·5	25·5	25·5	25·4	25·4
2·4	*Eltanin*	47	90 58·5	58·7	58·9	59·2	59·4	59·5	N. 51 29·7	29·9	29·9	29·9	29·8	29·6
2·9	β Ophiuchi		94 24·8	24·9	25·0	25·2	25·2	25·2	N. 4 34·7	34·8	34·8	34·8	34·8	34·7
2·5	κ Scorpii		94 46·4	46·5	46·7	46·8	46·9	46·9	S. 39 01·1	01·1	01·2	01·1	01·1	01·0
2·0	θ Scorpii		96 04·9	04·9	05·1	05·3	05·4	05·4	S. 42 59·0	59·1	59·1	59·1	59·0	58·9
2·1	*Rasalhague*	46	96 31·9	31·9	32·1	32·2	32·3	32·3	N. 12 34·8	34·8	34·9	34·9	34·8	34·7
1·7	*Shaula*	45	96 59·2	59·3	59·4	59·6	59·7	59·6	S. 37 05·2	05·3	05·3	05·2	05·2	05·2
3·0	α Aræ		97 28·9	29·0	29·2	29·4	29·5	29·5	S. 49 51·5	51·6	51·6	51·6	51·5	51·4
3·0	β Draconis		97 31·0	31·1	31·4	31·6	31·8	31·9	N. 52 19·4	19·5	19·5	19·5	19·4	19·2
2·8	υ Scorpii		97 41·9	42·0	42·1	42·3	42·4	42·3	S. 37 16·7	16·7	16·7	16·7	16·6	16·6
2·8	β Aræ		99 09·0	09·1	09·3	09·6	09·7	09·7	S. 55 30·6	30·6	30·7	30·6	30·5	30·4
Var.‡	α Herculis		101 35·9	36·0	36·1	36·3	36·3	36·3	N. 14 25·2	25·2	25·3	25·2	25·2	25·1
2·6	*Sabik*	44	102 44·0	44·1	44·2	44·4	44·4	44·4	S. 15 41·7	41·7	41·7	41·7	41·7	41·7
3·1	ζ Aræ		105 49·1	49·2	49·5	49·7	49·8	49·7	S. 55 57·3	57·4	57·4	57·3	57·2	57·1
2·4	ε Scorpii		107 49·8	49·9	50·1	50·2	50·3	50·2	S. 34 15·1	15·1	15·1	15·1	15·0	15·0
1·9	*Atria*	43	108 26·3	26·6	27·0	27·3	27·5	27·4	S. 68 59·3	59·4	59·4	59·3	59·2	59·1
3·0	ζ Herculis		109 53·6	53·7	53·9	54·0	54·1	54·1	N. 31 38·9	39·0	39·0	39·0	38·9	38·7
2·7	ζ Ophiuchi		111 01·6	01·7	01·8	01·9	01·9	01·9	S. 10 31·1	31·1	31·1	31·1	31·1	31·2
2·9	τ Scorpii		111 23·2	23·3	23·4	23·6	23·6	23·5	S. 28 10·1	10·1	10·1	10·1	10·0	10·0
2·8	β Herculis		112 41·5	41·6	41·7	41·8	41·9	41·9	N. 21 32·6	32·7	32·7	32·6	32·5	32·4
1·2	*Antares*	42	113 00·0	00·1	00·2	00·4	00·4	00·3	S. 26 22·8	22·8	22·8	22·8	22·8	22·8
2·9	η Draconis		114 04·5	04·8	05·2	05·5	05·7	05·6	N. 61 34·3	34·4	34·4	34·3	34·2	34·0
3·0	δ Ophiuchi		116 42·9	43·0	43·1	43·2	43·2	43·2	S. 3 38·0	38·0	37·9	37·9	38·0	38·0
2·8	β Scorpii		118 58·5	58·6	58·7	58·8	58·9	58·8	S. 19 44·5	44·5	44·5	44·4	44·4	44·5
2·5	*Dschubba*		120 15·4	15·5	15·6	15·7	15·8	15·7	S. 22 33·3	33·3	33·3	33·3	33·3	33·3
3·0	π Scorpii		120 38·1	38·2	38·3	38·4	38·5	38·4	S. 26 02·9	02·9	02·8	02·8	02·8	02·8
3·0	β Trianguli Aust.		121 43·2	43·4	43·8	44·0	44·0	43·8	S. 63 21·7	21·8	21·7	21·7	21·5	21·4
2·8	α Serpentis		124 13·0	13·1	13·2	13·3	13·3	13·2	N. 6 30·1	30·1	30·1	30·1	30·0	29·9
2·3	*Alphecca*	41	126 34·3	34·4	34·6	34·7	34·7	34·6	N. 26 47·8	47·8	47·8	47·8	47·6	47·5
3·0	γ Lupi †		126 35·9	36·0	36·2	36·3	36·3	36·2	S. 41 05·4	05·4	05·4	05·3	05·3	05·2

‡ 3·0—3·7 †Not suitable for use with H.O. 214 (H.D. 486)

Mag.	Name and Number	S.H.A.							Dec.						
			JAN.	FEB.	MAR.	APR.	MAY	JUNE		JAN.	FEB.	MAR.	APR.	MAY	JUNE
		°	′	′	′	′	′	′	°	′	′	′	′	′	′
3·1	γ Ursæ Minoris †	129	49·4	48·9	48·3	48·0	47·9	48·1	N. 71	54·9	54·8	54·9	55·0	55·1	55·3
3·1	γ Trianguli Aust.	130	50·1	49·5	49·0	48·6	48·4	48·4	S. 68	35·3	35·3	35·4	35·5	35·6	35·8
2·7	β Libræ	131	04·2	04·0	03·8	03·6	03·5	03·5	S. 9	17·7	17·8	17·8	17·9	17·8	17·8
2·8	β Lupi	135	45·5	45·2	44·9	44·7	44·6	44·6	S. 43	02·1	02·2	02·3	02·4	02·5	02·5
2·2	β Ursæ Minoris 40	137	19·4	18·7	18·1	17·8	17·8	18·0	N. 74	14·9	14·8	14·9	15·0	15·2	15·3
2·9	α Libræ 39	137	36·6	36·4	36·2	36·0	36·0	35·9	S. 15	56·5	56·6	56·7	56·7	56·7	56·7
2·6	ε Bootis	139	00·9	00·6	00·4	00·3	00·2	00·3	N. 27	10·3	10·2	10·2	10·3	10·4	10·5
2·9	α Lupi	139	54·9	54·5	54·3	54·1	54·0	54·0	S. 47	17·0	17·0	17·1	17·3	17·4	17·4
0·1	α Centauri 38	140	30·2	29·8	29·4	29·2	29·1	29·2	S. 60	43·9	44·0	44·1	44·2	44·4	44·5
2·6	η Centauri	141	30·1	29·8	29·6	29·4	29·3	29·3	S. 42	03·0	03·1	03·2	03·3	03·4	03·5
3·0	γ Bootis	142	13·3	13·1	12·8	12·7	12·7	12·7	N. 38	24·5	24·4	24·5	24·6	24·7	24·8
0·2	α Bootis 37	146	21·4	21·2	21·0	20·9	20·8	20·9	N. 19	18·2	18·1	18·1	18·2	18·3	18·3
2·3	θ Centauri 36	148	40·8	40·5	40·3	40·1	40·1	40·1	S. 36	15·0	15·1	15·2	15·3	15·4	15·5
0·9	β Centauri 35	149	27·9	27·4	27·1	26·9	26·9	26·9	S. 60	15·3	15·3	15·5	15·6	15·7	15·9
3·1	ζ Centauri	151	29·2	28·8	28·6	28·5	28·4	28·5	S. 47	10·1	10·2	10·3	10·4	10·5	10·6
2·8	η Bootis	151	36·7	36·5	36·3	36·2	36·2	36·2	N. 18	30·8	30·8	30·8	30·8	30·9	31·0
1·9	η Ursæ Majoris 34	153	21·0	20·7	20·5	20·4	20·4	20·5	N. 49	25·6	25·6	25·6	25·8	25·9	26·0
2·6	ε Centauri † 33	155	24·2	23·9	23·6	23·5	23·5	23·6	S. 53	20·5	20·6	20·7	20·9	21·0	21·1
1·2	α Virginis 33	159	00·8	00·6	00·5	00·4	00·4	00·4	S. 11	02·2	02·3	02·4	02·4	02·4	02·4
2·2	ζ Ursæ Majoris	159	15·5	15·2	15·0	14·9	14·9	15·1	N. 55	02·7	02·6	02·7	02·9	03·0	03·1
2·9	ι Centauri	160	11·0	10·7	10·6	10·5	10·5	10·5	S. 36	35·1	35·2	35·3	35·4	35·5	35·5
3·0	ε Virginis	164	45·0	44·8	44·7	44·6	44·6	44·7	N. 11	05·1	05·0	05·0	05·0	05·1	05·1
2·9	α Canum Venat.	166	16·2	15·9	15·8	15·7	15·8	15·9	N. 38	26·5	26·5	26·6	26·7	26·8	26·9
1·7	ε Ursæ Majoris 32	166	45·2	44·9	44·7	44·6	44·7	44·9	N. 56	05·0	05·0	05·1	05·2	05·4	05·5
1·5	β Crucis	168	24·8	24·4	24·2	24·2	24·2	24·4	S. 59	33·3	33·4	33·6	33·7	33·9	33·9
2·9	γ Virginis	169	53·1	52·8	52·7	52·7	52·7	52·8	S. 1	19·2	19·3	19·3	19·4	19·3	19·3
2·4	γ Centauri	169	56·7	56·4	56·3	56·2	56·3	56·4	S. 48	49·6	49·7	49·8	50·0	50·1	50·1
2·9	α Muscæ	171	03·2	02·7	02·5	02·4	02·5	02·8	S. 69	00·0	00·1	00·3	00·5	00·6	00·7
2·8	β Corvi	171	42·8	42·6	42·4	42·4	42·4	42·5	S. 23	15·9	16·0	16·1	16·2	16·2	16·2
1·6	γ Crucis 31	172	32·0	31·7	31·5	31·5	31·6	31·7	S. 56	58·6	58·7	58·9	59·0	59·2	59·2
1·1	α Crucis 30	173	40·5	40·1	39·9	39·9	40·0	40·2	S. 62	57·8	57·9	58·1	58·3	58·4	58·5
2·8	γ Corvi 29	176	21·1	20·9	20·8	20·7	20·8	20·8	S. 17	24·6	24·7	24·8	24·8	24·9	24·9
2·9	δ Centauri	178	12·8	12·6	12·4	12·4	12·5	12·6	S. 50	35·2	35·4	35·5	35·7	35·8	35·8
2·5	γ Ursæ Majoris	181	51·1	50·8	50·6	50·7	50·8	51·0	N. 53	49·3	49·3	49·4	49·6	49·7	49·7
2·2	β Leonis 28	183	02·1	01·9	01·8	01·8	01·9	02·0	N. 14	42·1	42·1	42·1	42·1	42·2	42·2
2·6	δ Leonis	191	47·1	46·9	46·8	46·9	47·0	47·0	N. 20	39·9	39·0	39·0	39·1	39·1	39·2
3·2	ψ Ursæ Majoris	192	54·8	54·6	54·5	54·6	54·7	54·8	N. 44	37·4	37·4	37·5	37·6	37·7	37·7
2·0	α Ursæ Majoris 27	194	25·6	25·3	25·2	25·3	25·6	25·8	N. 61	52·5	52·5	52·7	52·8	52·9	52·9
2·4	β Ursæ Majoris	194	53·5	53·2	53·1	53·2	53·4	53·6	N. 56	30·3	30·4	30·5	30·6	30·7	30·7
2·8	μ Velorum	198	33·3	33·2	33·1	33·2	33·4	33·5	S. 49	17·6	17·7	17·9	18·0	18·1	18·1
3·0	θ Carinæ †	199	27·7	27·4	27·4	27·6	27·8	28·1	S. 64	16·0	16·2	16·4	16·6	16·6	16·7
2·3	γ Leonis	205	19·7	19·6	19·6	19·6	19·7	19·8	N. 19	57·5	57·5	57·5	57·6	57·6	57·6
1·3	α Leonis 26	208	13·1	13·0	12·9	13·0	13·1	13·2	N. 12	04·9	04·8	04·8	04·8	04·9	04·9
3·1	ε Leonis	213	52·1	52·0	52·0	52·1	52·2	52·3	N. 23	52·9	52·8	52·9	52·9	53·0	53·0
3·0	*N* Velorum	217	21·8	21·7	21·8	22·0	22·3	22·5	S. 56	55·7	55·9	56·1	56·2	56·2	56·2
2·2	α Hydræ 25	218	23·3	23·3	23·3	23·4	23·5	23·6	S. 8	33·4	33·5	33·6	33·6	33·6	33·5
2·6	κ Velorum	219	38·7	38·6	38·7	38·9	39·1	39·3	S. 54	54·5	54·7	54·9	55·0	55·0	55·0
2·2	ι Carinæ	220	52·4	52·4	52·5	52·7	53·0	53·2	S. 59	10·5	10·7	10·9	11·0	11·0	11·0
1·8	β Carinæ 24	221	44·7	44·6	44·8	45·2	45·6	46·0	S. 69	37·1	37·3	37·5	37·6	37·6	37·6
2·2	λ Velorum 23	223	12·6	12·6	12·7	12·8	13·0	13·1	S. 43	20·2	20·4	20·5	20·6	20·6	20·6
3·1	ι Ursæ Majoris	225	35·7	35·6	35·7	35·9	36·0	36·2	N. 48	07·9	08·0	08·1	08·2	08·2	08·1
2·0	δ Velorum	228	58·6	58·6	58·7	58·9	59·2	59·4	S. 54	37·3	37·5	37·6	37·7	37·7	37·6
1·7	ε Carinæ 22	234	28·8	28·8	29·0	29·3	29·6	29·8	S. 59	26·0	26·2	26·4	26·4	26·4	26·3
1·9	γ Velorum	237	47·4	47·4	47·6	47·8	48·0	48·1	S. 47	16·1	16·2	16·4	16·4	16·4	16·3
2·9	ρ Puppis	238	21·6	21·6	21·7	21·8	21·9	22·0	S. 24	14·2	14·4	14·4	14·5	14·5	14·4
2·3	ζ Puppis	239	18·3	18·3	18·4	18·6	18·7	18·8	S. 39	56·3	56·4	56·5	56·6	56·5	56·5
1·2	β Geminorum 21	244	01·6	01·6	01·7	01·8	02·0	02·0	N. 28	04·9	04·9	05·0	05·0	05·0	05·0
0·5	α Canis Minoris 20	245	28·7	28·7	28·8	28·9	29·0	29·1	N. 5	17·1	17·0	17·0	17·0	17·0	17·0

† Not suitable for use with H.O. 214 (H.D. 486)

Mag.	Name and Number		S.H.A.							Dec.						
				JULY	AUG.	SEPT.	OCT.	NOV.	DEC.		JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
			°	′	′	′	′	′	′	°	′	′	′	′	′	′
3·1	γ Ursæ Minoris †		129	48·4	49·0	49·5	49·9	50·1	49·9	N. 71	55·4	55·4	55·4	55·2	55·0	54·9
3·1	γ Trianguli Aust.		130	48·6	48·9	49·3	49·5	49·5	49·3	S. 68	35·9	35·9	35·8	35·7	35·6	35·5
2·7	β Libræ		131	03·5	03·6	03·7	03·8	03·8	03·7	S. 9	17·8	17·8	17·7	17·7	17·8	17·8
2·8	β Lupi		135	44·7	44·8	45·0	45·1	45·1	44·9	S. 43	02·6	02·6	02·5	02·4	02·4	02·3
2·2	*Kochab*	40	137	18·5	19·1	19·7	20·1	20·2	20·0	N. 74	15·4	15·4	15·3	15·2	15·0	14·8
2·9	*Zubenelgenubi*	39	137	36·0	36·1	36·2	36·3	36·2	36·1	S. 15	56·7	56·7	56·7	56·6	56·6	56·7
2·6	ε Bootis		139	00·3	00·5	00·6	00·7	00·7	00·5	N. 27	10·6	10·6	10·6	10·5	10·3	10·2
2·9	α Lupi		139	54·1	54·3	54·4	54·5	54·5	54·3	S. 47	17·5	17·5	17·4	17·3	17·2	17·2
0·1	*RigilKent.*	38	140	29·3	29·6	29·9	30·0	29·9	29·7	S. 60	44·5	44·5	44·4	44·3	44·2	44·1
2·6	η Centauri		141	29·4	29·6	29·7	29·8	29·7	29·5	S. 42	03·5	03·5	03·4	03·3	03·3	03·2
3·0	γ Bootis		142	12·8	13·0	13·1	13·2	13·2	13·1	N. 38	24·9	24·9	24·8	24·7	24·6	24·4
0·2	*Arcturus*	37	146	20·9	21·1	21·2	21·2	21·2	21·0	N. 19	18·4	18·4	18·4	18·3	18·2	18·1
2·3	*Menkent*	36	148	40·2	40·3	40·5	40·5	40·4	40·2	S. 36	15·5	15·4	15·4	15·3	15·2	15·2
0·9	*Hadar*	35	149	27·1	27·4	27·6	27·7	27·6	27·3	S. 60	15·9	15·9	15·8	15·7	15·5	15·5
3·1	ζ Centauri		151	28·6	28·8	28·9	28·9	28·8	28·6	S. 47	10·6	10·6	10·5	10·4	10·3	10·3
2·8	η Bootis		151	36·3	36·4	36·5	36·6	36·5	36·3	N. 18	31·0	31·0	31·0	30·9	30·8	30·7
1·9	*Alkaid*	34	153	20·7	20·9	21·1	21·1	21·0	20·8	N. 49	26·1	26·1	26·0	25·8	25·6	25·5
2·6	ε Centauri †		155	23·7	23·9	24·1	24·1	24·0	23·7	S. 53	21·1	21·1	21·0	20·9	20·8	20·7
1·2	*Spica*	33	159	00·5	00·6	00·7	00·7	00·6	00·4	S. 11	02·4	02·4	02·3	02·3	02·3	02·4
2·2	*Mizar*		159	15·3	15·5	15·7	15·7	15·6	15·4	N. 55	03·1	03·1	03·0	02·8	02·6	02·5
2·9	ι Centauri		160	10·6	10·8	10·9	10·9	10·7	10·5	S. 36	35·5	35·5	35·4	35·3	35·3	35·3
3·0	ε Virginis		164	44·8	44·9	44·9	44·9	44·8	44·6	N. 11	05·2	05·2	05·2	05·1	05·0	04·9
2·9	*Cor Caroli*		166	16·0	16·1	16·2	16·2	16·1	15·9	N. 38	26·9	26·9	26·8	26·6	26·5	26·3
1·7	*Alioth*	32	166	45·1	45·3	45·4	45·5	45·3	45·0	N. 56	05·5	05·4	05·3	05·1	04·9	04·8
1·5	*Mimosa*		168	24·6	24·8	25·0	24·9	24·7	24·4	S. 59	34·0	33·9	33·8	33·6	33·5	33·5
2·9	γ Virginis		169	52·8	52·9	53·0	52·9	52·8	52·6	S. 1	19·3	19·2	19·2	19·2	19·3	19·4
2·4	*Muhlifain*		169	56·5	56·7	56·8	56·8	56·6	56·3	S. 48	50·1	50·1	49·9	49·8	49·8	49·8
2·9	α Muscæ		171	03·1	03·5	03·7	03·6	03·3	02·8	S. 69	00·7	00·7	00·5	00·4	00·3	00·2
2·8	β Corvi		171	42·6	42·7	42·7	42·7	42·5	42·3	S. 23	16·2	16·1	16·0	16·0	16·0	16·1
1·6	*Gacrux*	31	172	31·9	32·1	32·2	32·2	32·0	31·6	S. 56	59·2	59·1	59·0	58·9	58·8	58·8
1·1	*Acrux*	30	173	40·5	40·7	40·8	40·8	40·5	40·1	S. 62	58·5	58·4	58·3	58·1	58·0	58·0
2·8	*Gienah*	29	176	20·9	21·0	21·1	21·0	20·8	20·6	S. 17	24·8	24·8	24·7	24·7	24·7	24·8
2·9	δ Centauri		178	12·8	13·0	13·0	13·0	12·7	12·4	S. 50	35·8	35·7	35·6	35·5	35·4	35·4
2·5	*Phecda*		181	51·2	51·3	51·4	51·3	51·1	50·7	N. 53	49·7	49·6	49·5	49·3	49·2	49·0
2·2	*Denebola*	28	183	02·0	02·1	02·1	02·1	01·9	01·7	N. 14	42·2	42·2	42·2	42·1	42·0	41·9
2·6	δ Leonis		191	47·1	47·2	47·2	47·1	46·9	46·6	N. 20	39·2	39·2	39·1	39·0	38·9	38·8
3·2	ψ Ursæ Majoris		192	55·0	55·0	55·0	54·9	54·7	54·4	N. 44	37·7	37·6	37·5	37·4	37·2	37·1
2·0	*Dubhe*	27	194	26·0	26·2	26·2	26·0	25·7	25·2	N. 61	52·8	52·7	52·6	52·4	52·2	52·2
2·4	*Merak*		194	53·8	53·9	53·9	53·7	53·4	53·1	N. 56	30·7	30·5	30·4	30·2	30·1	30·0
2·8	μ Velorum		198	33·7	33·8	33·8	33·6	33·3	33·0	S. 49	18·0	17·9	17·8	17·7	17·7	17·7
3·0	θ Carinæ †		199	28·4	28·6	28·5	28·3	27·9	27·5	S. 64	16·6	16·5	16·3	16·2	16·1	16·2
2·3	*Algeiba*		205	19·9	19·9	19·8	19·7	19·5	19·2	N. 19	57·7	57·6	57·6	57·5	57·4	57·3
1·3	*Regulus*	26	208	13·2	13·2	13·2	13·0	12·8	12·6	N. 12	04·9	04·9	04·9	04·8	04·7	04·7
3·1	ε Leonis		213	52·3	52·3	52·2	52·0	51·8	51·6	N. 23	53·0	52·9	52·9	52·8	52·7	52·6
3·0	*N* Velorum		217	22·6	22·7	22·6	22·3	22·0	21·6	S. 56	56·1	55·9	55·8	55·7	55·7	55·8
2·2	*Alphard*	25	218	23·6	23·6	23·5	23·3	23·1	22·9	S. 8	33·5	33·4	33·4	33·4	33·5	33·6
2·6	κ Velorum		219	39·5	39·5	39·4	39·1	38·8	38·5	S. 54	54·8	54·7	54·6	54·5	54·5	54·6
2·2	ι Carinæ		220	53·4	53·4	53·3	53·0	52·6	52·3	S. 59	10·8	10·7	10·5	10·5	10·5	10·6
1·8	*Miaplacidus*	24	221	46·3	46·4	46·2	45·8	45·3	44·8	S. 69	37·5	37·3	37·2	37·1	37·1	37·2
2·2	*Suhail*	23	223	13·2	13·2	13·1	12·9	12·6	12·3	S. 43	20·4	20·3	20·2	20·1	20·2	20·3
3·1	ι Ursæ Majoris		225	36·2	36·1	36·0	35·7	35·4	35·1	N. 48	08·1	08·0	07·9	07·8	07·7	07·7
2·0	δ Velorum		228	59·5	59·5	59·3	59·0	58·7	58·4	S. 54	37·5	37·4	37·2	37·2	37·2	37·3
1·7	*Avior*	22	234	29·9	29·9	29·7	29·4	29·0	28·7	S. 59	26·2	26·1	25·9	25·9	25·9	26·0
1·9	γ Velorum		237	48·2	48·1	47·9	47·7	47·4	47·1	S. 47	16·2	16·0	15·9	15·9	15·9	16·1
2·9	ρ Puppis		238	22·0	21·9	21·8	21·6	21·3	21·1	S. 24	14·3	14·2	14·1	14·1	14·1	14·3
2·3	ζ Puppis		239	18·9	18·8	18·6	18·4	18·1	17·9	S. 39	56·3	56·2	56·1	56·1	56·1	56·3
1·2	*Pollux*	21	244	02·0	01·8	01·7	01·4	01·2	00·9	N. 28	05·0	04·9	04·9	04·8	04·8	04·8
0·5	*Procyon*	20	245	29·0	28·9	28·8	28·6	28·3	28·1	N. 5	17·1	17·1	17·1	17·1	17·0	17·0

† Not suitable for use with H.O. 214 (H.D. 486)

Mag.	Name and Number	S.H.A.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	Dec.	JAN.	FEB.	MAR.	APR.	MAY	JUNE
		°	′	′	′	′	′	′	°	′	′	′	′	′	′
1·6	α Geminorum	246	43·3	43·3	43·4	43·5	43·6	43·7	N. 31	56·3	56·4	56·4	56·4	56·4	56·4
3·3	σ Puppis	247	52·3	52·4	52·5	52·7	52·9	53·0	S. 43	15·3	15·5	15·6	15·6	15·6	15·5
3·1	β Canis Minoris	248	31·7	31·7	31·8	31·9	32·0	32·0	N. 8	20·1	20·1	20·1	20·1	20·1	20·1
2·4	η Canis Majoris	249	12·2	12·3	12·4	12·5	12·7	12·8	S. 29	15·5	15·7	15·7	15·7	15·7	15·6
2·7	π Puppis	250	55·0	55·0	55·2	55·3	55·5	55·6	S. 37	03·4	03·6	03·6	03·7	03·6	03·5
2·0	δ Canis Majoris	253	08·2	08·2	08·4	08·5	08·6	08·7	S. 26	21·5	21·6	21·6	21·7	21·6	21·5
3·1	ο Canis Majoris	254	29·1	29·1	29·3	29·4	29·5	29·6	S. 23	48·0	48·2	48·2	48·2	48·2	48·1
1·6	ε Canis Majoris 19	255	34·2	34·2	34·4	34·5	34·7	34·7	S. 28	56·5	56·6	56·7	56·7	56·7	56·6
2·8	τ Puppis	257	39·2	39·3	39·5	39·8	40·0	40·1	S. 50	35·3	35·5	35·6	35·6	35·5	35·4
−1·6	α Canis Majoris 18	258	58·1	58·2	58·3	58·4	58·5	58·6	S. 16	41·2	41·3	41·3	41·3	41·3	41·2
1·9	γ Geminorum	260	54·5	54·5	54·6	54·8	54·9	54·9	N. 16	25·1	25·1	25·1	25·1	25·1	25·1
−0·9	α Carinæ 17	264	08·1	08·2	08·4	08·7	08·9	09·0	S. 52	41·2	41·3	41·4	41·4	41·3	41·1
2·0	β Canis Majoris	264	34·8	34·9	35·0	35·2	35·3	35·3	S. 17	56·8	56·9	56·9	56·9	56·9	56·8
2·7	θ Aurigæ	270	28·0	28·1	28·2	28·4	28·5	28·5	N. 37	12·7	12·7	12·7	12·7	12·7	12·6
2·1	β Aurigæ	270	32·7	32·8	32·9	33·1	33·2	33·2	N. 44	56·7	56·8	56·8	56·8	56·8	56·7
Var.‡	α Orionis 16	271	31·4	31·4	31·5	31·7	31·7	31·7	N. 7	24·1	24·1	24·0	24·0	24·1	24·1
2·2	κ Orionis	273	20·2	20·3	20·4	20·6	20·6	20·6	S. 9	40·8	40·9	40·9	40·9	40·8	40·8
1·9	ζ Orionis	275	06·3	06·3	06·5	06·6	06·7	06·6	S. 1	57·4	57·5	57·5	57·5	57·4	57·4
2·8	α Columbæ	275	17·8	17·9	18·1	18·3	18·4	18·4	S. 34	05·4	05·5	05·5	05·5	05·4	05·3
3·0	ζ Tauri	275	56·3	56·3	56·5	56·6	56·7	56·6	N. 21	07·7	07·7	07·7	07·5	07·6	07·6
1·8	ε Orionis 15	276	14·6	14·6	14·7	14·9	14·9	14·9	S. 1	13·1	13·2	13·2	13·2	13·1	13·1
2·9	ι Orionis	276	25·6	25·7	25·8	25·9	26·0	26·0	S. 5	55·6	55·7	55·7	55·7	55·7	55·6
2·7	α Leporis	277	04·4	04·5	04·7	04·8	04·9	04·9	S. 17	50·5	50·6	50·6	50·6	50·5	50·4
2·5	δ Orionis	277	17·8	17·8	18·0	18·1	18·2	18·1	S. 0	19·1	19·1	19·2	19·2	19·1	19·1
3·0	β Leporis	278	11·3	11·3	11·5	11·6	11·7	11·7	S. 20	46·9	46·9	47·0	46·9	46·9	46·8
1·8	β Tauri 14	278	47·8	47·8	48·0	48·1	48·2	48·1	N. 28	35·3	35·3	35·3	35·3	35·2	35·2
1·7	γ Orionis 13	279	01·8	01·9	02·0	02·1	02·2	02·2	N. 6	19·6	19·6	19·6	19·6	19·6	19·6
0·2	α Aurigæ 12	281	15·5	15·6	15·8	16·0	16·1	16·0	N. 45	58·5	58·6	58·6	58·5	58·5	58·4
0·3	β Orionis 11	281	38·7	38·8	39·0	39·1	39·2	39·1	S. 8	13·9	13·9	13·9	13·9	13·9	13·8
2·9	β Eridani	283	19·5	19·6	19·7	19·8	19·9	19·8	S. 5	07·1	07·2	07·2	07·2	07·1	07·1
2·9	ι Arigæ †	286	07·9	08·0	08·2	08·3	08·4	08·3	N. 33	07·8	07·8	07·8	07·7	07·7	07·7
1·1	α Tauri 10	291	21·3	21·4	21·6	21·7	21·7	21·6	N. 16	27·7	27·7	27·7	27·6	27·6	27·7
3·2	γ Eridani	300	46·0	46·1	46·2	46·3	46·3	46·2	S. 13	34·7	34·8	34·8	34·7	34·6	34·5
3·0	ε Persei	300	55·8	55·9	56·1	56·2	56·2	56·1	N. 39	56·6	56·6	56·6	56·5	56·5	56·4
2·9	ζ Persei	301	50·2	50·3	50·4	50·5	50·5	50·4	N. 31	48·9	48·9	48·8	48·8	48·8	48·7
3·0	η Tauri	303	28·7	28·8	28·9	29·0	29·0	28·9	N. 24	02·0	01·9	01·9	01·9	01·9	01·9
1·9	α Persei 9	309	20·3	20·5	20·7	20·8	20·8	20·6	N. 49	46·8	46·8	46·8	46·7	46·6	46·5
Var.§	β Persei †	313	20·4	20·6	20·7	20·8	20·8	20·6	N. 40	52·0	52·0	52·0	51·9	51·8	51·8
2·8	α Ceti 8	314	44·3	44·4	44·5	44·6	44·5	44·4	N. 3	59·7	59·7	59·7	59·7	59·8	59·8
3·1	θ Eridani 7	315	39·5	39·6	39·8	39·9	39·9	39·8	S. 40	24·3	24·3	24·2	24·1	24·0	23·8
2·1	α Ursæ Minoris †	327	42·0	52·3	60·5	64·2	60·9	53·1	N. 89	09·6	09·6	09·5	09·4	09·2	09·1
3·1	β Trianguli	327	57·9	58·1	58·2	58·2	58·1	57·9	N. 34	52·6	52·6	52·5	52·5	52·4	52·4
2·2	α Arietis 6	328	32·4	32·5	32·6	32·6	32·6	32·4	N. 23	21·1	21·1	21·0	21·0	21·0	21·0
2·2	γ Andromedæ	329	23·3	23·4	23·6	23·6	23·5	23·3	N. 42	13·1	13·1	13·0	12·9	12·9	12·9
3·0	α Hydri	330	29·7	30·0	30·3	30·4	30·3	30·1	S. 61	41·5	41·4	41·3	41·2	41·0	40·8
2·7	β Arietis	331	40·0	40·1	40·2	40·2	40·1	39·9	N. 20	41·6	41·5	41·5	41·5	41·5	41·5
0·6	α Eridani 5	335	47·6	47·9	48·0	48·1	48·0	47·8	S. 57	21·8	21·7	21·6	21·4	21·3	21·1
2·8	δ Cassiopeiæ	338	56·1	56·3	56·5	56·5	56·3	56·0	N. 60	07·0	06·9	06·8	06·7	06·6	06·6
2·4	β Andromedæ	342	54·0	54·1	54·2	54·2	54·0	53·8	N. 35	29·8	29·8	29·7	29·6	29·6	29·6
Var.‖	γ Cassiopeiæ	346	10·9	11·2	11·3	11·3	11·1	10·7	N. 60	35·6	35·5	35·4	35·2	35·2	35·1
2·2	β Ceti 4	349	24·1	24·2	24·2	24·2	24·1	23·9	S. 18	07·2	07·2	07·1	07·0	06·9	06·8
2·5	α Cassiopeiæ 3	350	12·7	12·9	13·0	12·9	12·7	12·4	N. 56	24·7	24·6	24·5	24·4	24·3	24·3
2·4	α Phœnicis 2	353	43·5	43·6	43·7	43·6	43·5	43·2	S. 42	26·3	26·3	26·2	26·0	25·9	25·8
2·9	β Hydri †	353	53·0	53·5	53·8	53·7	53·4	52·7	S. 77	23·6	23·5	23·3	23·1	22·9	22·8
2·9	γ Pegasi	356	59·9	60·0	60·0	59·9	59·8	59·5	N. 15	03·1	03·1	03·0	03·0	03·1	03·1
2·4	β Cassiopeiæ	358	01·5	01·7	01·8	01·7	01·4	01·0	N. 59	01·4	01·3	01·2	01·0	01·0	01·0
2·2	α Andromedæ 1	358	12·7	12·8	12·8	12·7	12·6	12·3	N. 28	57·7	57·6	57·5	57·5	57·5	57·5

‡ 0·1—1·2 §2·3—3·5 ‖ Irregular variable; 1973 mag. 2·5 † Not suitable for use with H.O. 214 (H.D. 486)

Mag.	Name and Number		S.H.A. JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	Dec. JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
			° ′	′	′	′	′	′	° ′	′	′	′	′	′
1·6	*Castor*		246 43·6	43·5	43·3	43·1	42·8	42·6	N. 31 56·4	56·3	56·3	56·2	56·2	56·2
3·3	σ Puppis		247 53·0	52·9	52·7	52·5	52·2	52·0	S. 43 15·3	15·2	15·1	15·1	15·1	15·3
3·1	β Canis Minoris		248 32·0	31·9	31·7	31·5	31·2	31·1	N. 8 20·2	20·2	20·2	20·2	20·1	20·1
2·4	η Canis Majoris		249 12·7	12·6	12·4	12·2	12·0	11·8	S. 29 15·5	15·4	15·3	15·3	15·4	15·5
2·7	π Puppis		250 55·6	55·5	55·3	55·0	54·8	54·6	S. 37 03·4	03·2	03·2	03·1	03·2	03·4
2·0	*Wezen*		253 08·7	08·5	08·4	08·1	07·9	07·7	S. 26 21·4	21·3	21·2	21·2	21·3	21·4
3·1	ο Canis Majoris		254 29·5	29·4	29·2	29·0	28·8	28·6	S. 23 48·0	47·9	47·8	47·8	47·9	48·0
1·6	*Adhara*	19	255 34·7	34·6	34·4	34·1	33·9	33·7	S. 28 56·4	56·3	56·2	56·3	56·3	56·5
2·8	τ Puppis		257 40·1	40·0	39·7	39·4	39·1	38·9	S. 50 35·2	35·1	35·0	35·0	35·1	35·3
−1·6	*Sirius*	18	258 58·5	58·4	58·2	58·0	57·8	57·6	S. 16 41·1	41·0	40·9	41·0	41·0	41·2
1·9	*Alhena*		260 54·8	54·6	54·4	54·2	54·0	53·8	N. 16 25·1	25·1	25·1	25·1	25·1	25·1
−0·9	*Canopus*	17	264 09·0	08·8	08·5	08·2	07·9	07·8	S. 52 41·0	40·8	40·7	40·8	40·9	41·0
2·0	*Mirzam*		264 35·2	35·1	34·9	34·6	34·4	34·3	S. 17 56·7	56·6	56·5	56·5	56·6	56·7
2·7	θ Aurigæ		270 28·3	28·1	27·9	27·6	27·3	27·2	N. 37 12·6	12·6	12·5	12·5	12·6	12·6
2·1	*Menkalinan*		270 33·1	32·8	32·6	32·2	32·0	31·8	N. 44 56·6	56·6	56·6	56·6	56·6	56·6
Var.‡	*Betelgeuse*	16	271 31·6	31·4	31·2	31·0	30·8	30·7	N. 7 24·1	24·2	24·2	24·2	24·2	24·1
2·2	κ Orionis		273 20·5	20·3	20·1	19·9	19·7	19·6	S. 9 40·7	40·6	40·5	40·6	40·6	40·7
1·9	*Alnitak*		275 06·5	06·3	06·1	05·9	05·7	05·6	S. 1 57·3	57·2	57·2	57·2	57·3	57·3
2·8	*Phact*		275 18·3	18·1	17·9	17·6	17·4	17·3	S. 34 05·1	05·0	05·0	05·0	05·1	05·3
3·0	ζ Tauri		275 56·5	56·3	56·1	55·8	55·6	55·5	N. 21 07·6	07·7	07·7	07·7	07·7	07·7
1·8	*Alnilam*	15	276 14·8	14·6	14·4	14·2	14·0	13·9	S. 1 13·0	12·9	12·9	12·9	13·0	13·1
2·9	ι Orionis		276 25·9	25·7	25·5	25·3	25·1	25·0	S. 5 55·5	55·4	55·4	55·4	55·5	55·6
2·7	α Leporis		277 04·8	04·6	04·4	04·1	04·0	03·9	S. 17 50·3	50·2	50·2	50·2	50·3	50·4
2·5	δ Orionis		277 18·0	17·8	17·6	17·4	17·2	17·1	S. 0 19·0	18·9	18·9	18·9	18·9	19·0
3·0	β Leporis		278 11·6	11·4	11·2	11·0	10·8	10·7	S. 20 46·6	46·5	46·5	46·5	46·6	46·7
1·8	*Elnath*	14	278 48·0	47·8	47·5	47·3	47·1	46·9	N. 28 35·2	35·2	35·2	35·2	35·2	35·3
1·7	*Bellatrix*	13	279 02·0	01·9	01·6	01·4	01·2	01·1	N. 6 19·7	19·7	19·8	19·8	19·7	19·7
0·2	*Capella*	12	281 15·8	15·6	15·2	15·0	14·7	14·5	N. 45 58·3	58·3	58·3	58·4	58·4	58·5
0·3	*Rigel*	11	281 39·0	38·8	38·6	38·4	38·2	38·1	S. 8 13·7	13·6	13·6	13·6	13·7	13·8
2·9	β Eridani		283 19·7	19·5	19·3	19·1	18·9	18·8	S. 5 07·0	06·9	06·9	06·9	06·9	07·0
2·9	ι Aurigæ †		286 08·1	07·9	07·6	07·4	07·2	07·1	N. 33 07·7	07·7	07·7	07·7	07·7	07·8
1·1	*Aldebaran*	10	291 21·5	21·2	21·0	20·8	20·6	20·6	N. 16 27·7	27·7	27·8	27·8	27·8	27·8
3·2	γ Eridani		300 46·1	45·9	45·6	45·5	45·3	45·3	S. 13 34·4	34·3	34·3	34·3	34·4	34·5
3·0	ε Persei		300 55·9	55·6	55·3	55·1	54·9	54·8	N. 39 56·4	56·4	56·5	56·6	56·6	56·7
2·9	ζ Persei		301 50·2	49·9	49·7	49·5	49·3	49·2	N. 31 48·7	48·8	48·8	48·9	48·9	49·0
3·0	*Alcyone*		303 28·7	28·4	28·2	28·0	27·9	27·8	N. 24 01·9	01·9	02·0	02·0	02·1	02·1
1·9	*Mirfak*	9	309 20·3	20·0	19·7	19·4	19·3	19·2	N. 49 46·5	46·5	46·6	46·7	46·8	46·9
Var.§	*Algol* †		313 20·4	20·1	19·8	19·6	19·5	19·5	N. 40 51·8	51·8	51·9	52·0	52·1	52·2
2·8	*Menkar*	8	314 44·2	44·0	43·8	43·6	43·5	43·5	N. 3 59·9	60·0	60·0	60·0	60·0	60·0
3·1	*Acamar*	7	315 39·6	39·3	39·0	38·9	38·8	38·8	S. 40 23·7	23·6	23·6	23·7	23·8	24·0
2·1	*Polaris* †		327 42·3	30·8	21·2	15·3	14·6	19·3	N. 89 09·1	09·2	09·3	09·5	09·6	09·8
3·1	β Trianguli		327 57·7	57·4	57·2	57·0	57·0	57·0	N. 34 52·5	52·6	52·7	52·8	52·8	52·9
2·2	*Hamal*	6	328 32·1	31·9	31·7	31·6	31·5	31·5	N. 23 21·0	21·1	21·2	21·3	21·3	21·3
2·2	*Almak*		329 23·0	22·7	22·5	22·3	22·3	22·3	N. 42 12·9	13·0	13·1	13·2	13·3	13·4
3·0	α Hydri		330 29·7	29·3	29·0	28·9	28·9	29·1	S. 61 40·7	40·7	40·7	40·9	41·0	41·2
2·7	*Sheratan*		331 39·7	39·5	39·3	39·2	39·1	39·2	N. 20 41·6	41·7	41·7	41·8	41·8	41·9
0·6	*Achernar*	5	335 47·4	47·1	46·8	46·7	46·7	46·9	S. 57 21·0	21·0	21·1	21·2	21·3	21·5
2·8	*Ruchbah*		338 55·6	55·2	54·9	54·7	54·7	54·9	N. 60 06·6	06·7	06·8	07·0	07·1	07·2
2·4	*Mirach*		342 53·5	53·3	53·1	53·0	53·0	53·1	N. 35 29·7	29·8	29·9	30·0	30·1	30·1
Var.‖	γ Cassiopeiæ		346 10·3	09·9	09·7	09·6	09·6	09·8	N. 60 35·2	35·3	35·5	35·6	35·8	35·8
2·2	*Diphda*	4	349 23·6	23·4	23·3	23·2	23·2	23·3	S. 18 06·7	06·7	06·7	06·7	06·8	06·8
2·5	*Schedar*	3	350 12·0	11·7	11·5	11·4	11·5	11·6	N. 56 24·3	24·5	24·6	24·8	24·9	25·0
2·4	*Ankaa*	2	353 42·9	42·7	42·5	42·5	42·6	42·7	S. 42 25·7	25·7	25·7	25·8	26·0	26·0
2·9	β Hydri †		353 51·9	51·2	50·7	50·7	51·1	51·7	S. 77 22·8	22·8	23·0	23·1	23·3	23·3
2·9	*Algenib*		356 59·3	59·1	59·0	59·0	59·0	59·1	N. 15 03·2	03·3	03·4	03·5	03·5	03·5
2·4	*Caph*		358 00·7	00·3	00·2	00·1	00·3	00·5	N. 59 01·1	01·2	01·4	01·5	01·7	01·7
2·2	*Alpheratz*	1	358 12·1	11·9	11·7	11·7	11·8	11·9	N. 28 57·6	57·7	57·9	58·0	58·0	58·0

‡ 0·1—1·2 § 2·3—3·5 ‖ Irregular variable; 1973 mag. 2·5 † Not suitable for use with H.O. 214 (H.D. 486)

POLARIS (POLE STAR) TABLES, 1976

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	0°– 9°	10°– 19°	20°– 29°	30°– 39°	40°– 49°	50°– 59°	60°– 69°	70°– 79°	80°– 89°	90°– 99°	100°– 109°	110°– 119°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 16·3	0 12·2	0 09·5	0 08·3	0 08·8	0 10·7	0 14·2	0 19·0	0 25·0	0 32·1	0 40·0	0 48·4
1	15·8	11·8	09·3	08·3	08·9	11·0	14·6	19·5	25·7	32·8	40·8	49·3
2	15·3	11·5	09·1	08·3	09·0	11·3	15·0	20·1	26·4	33·6	41·6	50·2
3	14·9	11·2	09·0	08·3	09·2	11·6	15·5	20·7	27·0	34·4	42·5	51·0
4	14·5	10·9	08·8	08·3	09·4	11·9	15·9	21·3	27·7	35·2	43·3	51·9
5	0 14·0	0 10·6	0 08·7	0 08·4	0 09·5	0 12·3	0 16·4	0 21·9	0 28·4	0 35·9	0 44·1	0 52·8
6	13·6	10·4	08·6	08·4	09·8	12·6	16·9	22·5	29·2	36·7	45·0	53·7
7	13·2	10·1	08·5	08·5	10·0	13·0	17·4	23·1	29·9	37·5	45·8	54·5
8	12·9	09·9	08·4	08·5	10·2	13·4	17·9	23·7	30·6	38·3	46·7	55·4
9	12·5	09·7	08·4	08·6	10·5	13·8	18·4	24·4	31·3	39·2	47·6	56·3
10	0 12·2	0 09·5	0 08·3	0 08·8	0 10·7	0 14·2	0 19·0	0 25·0	0 32·1	0 40·0	0 48·4	0 57·2
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·5	0·6	0·6	0·6	0·6	0·5	0·5	0·4	0·3	0·3	0·2	0·2
10	·5	·6	·6	·6	·6	·5	·5	·4	·4	·3	·3	·2
20	·5	·6	·6	·6	·6	·6	·5	·5	·4	·4	·3	·3
30	·6	·6	·6	·6	·6	·6	·5	·5	·5	·4	·4	·4
40	0·6	0·6	0·6	0·6	·06	0·6	0·6	0·5	0·5	0·5	0·5	0·5
45	·6	·6	·6	·6	·6	·6	·6	·6	·6	·5	·5	·5
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·6	·6	·6	·6	·6	·6	·6	·6	·7	·7	·7	·7
60	·6	·6	·6	·6	·6	·6	·7	·7	·7	·8	·8	·8
62	0·7	0·6	0·6	0·6	0·6	0·6	0·7	0·7	0·8	0·8	0·8	0·9
64	·7	·6	·6	·6	·6	·6	·7	·7	·8	·9	0·9	0·9
66	·7	·6	·6	·6	·6	·7	·7	·8	·8	0·9	1·0	1·0
68	0·7	0·6	0·6	0·6	0·6	0·7	0·7	0·8	0·9	1·0	1·0	1·1
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7
Feb.	·6	·7	·7	·7	·8	·8	·8	·8	·8	·8	·8	·8
Mar.	·5	·5	·6	·6	·7	·8	·8	·8	·9	·9	·9	·9
Apr.	0·3	0·4	0·4	0·5	0·6	0·6	0·7	0·8	0·8	0·9	0·9	0·9
May	·2	·3	·3	·4	·4	·5	·6	·6	·7	·8	·8	·9
June	·2	·2	·2	·3	·3	·4	·4	·5	·5	·6	·7	·8
July	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·4	0·5	0·5	0·6
Aug.	·4	·3	·3	·3	·2	·2	·3	·3	·3	·3	·4	·4
Sept.	·5	·5	·4	·4	·3	·3	·3	·3	·3	·3	·3	·3
Oct.	0·7	0·7	0·6	0·5	0·5	0·4	0·4	0·3	0·3	0·3	0·3	0·2
Nov.	0·9	0·8	·8	·7	·7	·6	·5	·5	·4	·3	·3	·3
Dec.	1·0	1·0	0·9	0·9	0·8	0·8	0·7	0·6	0·5	0·5	0·4	0·3
Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	0·4	0·3	0·1	0·0	359·8	359·7	359·5	359·4	359·3	359·3	359·2	359·2
20	0·4	0·3	0·1	0·0	359·8	359·7	359·5	359·4	359·3	359·2	359·1	359·1
40	0·5	0·3	0·1	359·9	359·8	359·6	359·4	359·2	359·1	359·0	358·9	358·9
50	0·6	0·4	0·2	359·9	359·7	359·5	359·3	359·1	358·9	358·8	358·7	358·7
55	0·7	0·4	0·2	359·9	359·7	359·4	359·2	359·0	358·8	358·7	358·6	358·5
60	0·8	0·5	0·2	359·9	359·6	359·3	359·1	358·8	358·6	358·5	358·4	358·3
65	0·9	0·6	0·3	359·9	359·6	359·2	358·9	358·6	358·4	358·2	358·1	358·0

Latitude = Apparent altitude (corrected for refraction) − 1° + a_0 + a_1 + a_2

The table is entered with L.H.A. Aries to determine the column to be used; each column refers to a range of 10°. a_0 is taken, with mental interpolation, from the upper table with the units of L.H.A. Aries in degrees as argument; a_1, a_2 are taken, without interpolation, from the second and third tables with arguments latitude and month respectively. a_0, a_1, a_2 are always positive. The final table gives the azimuth of *Polaris*.

POLARIS (POLE STAR) TABLES, 1976

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	120°–129°	130°–139°	140°–149°	150°–159°	160°–169°	170°–179°	180°–189°	190°–199°	200°–209°	210°–219°	220°–229°	230°–239°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 57·2	1 06·0	1 14·5	1 22·6	1 29·9	1 36·3	1 41·6	1 45·6	1 48·2	1 49·3	1 48·9	1 47·0
1	58·1	06·8	15·3	23·4	30·6	36·9	42·0	45·9	48·3	49·3	48·7	46·7
2	58·9	07·7	16·2	24·1	31·3	37·5	42·5	46·2	48·5	49·3	48·6	46·4
3	0 59·8	08·6	17·0	24·9	32·0	38·0	42·9	46·5	48·6	49·3	48·4	46·1
4	1 00·7	09·4	17·8	25·6	32·6	38·6	43·3	46·8	48·8	49·3	48·3	45·8
5	1 01·6	1 10·3	1 18·6	1 26·4	1 33·3	1 39·1	1 43·7	1 47·0	1 48·9	1 49·2	1 48·1	1 45·5
6	02·5	11·1	19·4	27·1	33·9	39·6	44·1	47·3	49·0	49·2	47·9	45·1
7	03·3	12·0	20·2	27·8	34·5	40·1	44·5	47·5	49·1	49·1	47·7	44·8
8	04·2	12·8	21·0	28·5	35·1	40·6	44·9	47·8	49·2	49·1	47·5	44·4
9	05·1	13·7	21·8	29·2	35·7	41·1	45·2	48·0	49·2	49·0	47·2	44·0
10	1 06·0	1 14·5	1 22·6	1 29·9	1 36·3	1 41·6	1 45·6	1 48·2	1 49·3	1 48·9	1 47·0	1 43·6
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·2	0·2	0·2	0·3	0·4	0·4	0·5	0·6	0·6	0·6	0·6	0·5
10	·2	·2	·3	·3	·4	·5	·5	·6	·6	·6	·6	·5
20	·3	·3	·3	·4	·4	·5	·5	·6	·6	·6	·6	·6
30	·4	·4	·4	·4	·5	·5	·6	·6	·6	·6	·6	·6
40	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·6	0·6
45	·5	·5	·5	·5	·6	·6	·6	·6	·6	·6	·6	·6
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·7	·7	·7	·7	·6	·6	·6	·6	·6	·6	·6	·6
60	·8	·8	·8	·7	·7	·7	·6	·6	·6	·6	·6	·6
62	0·9	0·8	0·8	0·8	0·7	0·7	0·7	0·6	0·6	0·6	0·6	0·6
64	0·9	0·9	·9	·8	·8	·7	·7	·6	·6	·6	·6	·6
66	1·0	1·0	0·9	·9	·8	·7	·7	·6	·6	·6	·6	·7
68	1·1	1·1	1·0	0·9	0·9	0·8	0·7	0·6	0·6	0·6	0·6	0·7
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·6	0·6	0·6	0·6	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5
Feb.	·8	·8	·7	·7	·7	·6	·6	·5	·5	·5	·4	·4
Mar.	0·9	0·9	0·9	0·8	·8	·8	·7	·7	·6	·6	·5	·4
Apr.	1·0	1·0	1·0	1·0	0·9	0·9	0·9	0·8	0·8	0·7	0·6	0·6
May	0·9	1·0	1·0	1·0	1·0	1·0	1·0	0·9	0·9	·8	·8	·7
June	·8	0·9	0·9	1·0	1·0	1·0	1·0	1·0	1·0	0·9	0·9	·8
July	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·0	1·0	1·0	0·9
Aug.	·5	·6	·6	·7	·7	·8	0·8	0·9	0·9	0·9	1·0	1·0
Sept.	·3	·4	·4	·5	·6	·6	·7	·7	·8	·8	0·9	0·9
Oct.	0·3	0·3	0·3	0·3	0·4	0·4	0·5	0·5	0·6	0·7	0·7	0·8
Nov.	·2	·2	·2	·2	·2	·3	·3	·4	·4	·5	·5	·6
Dec.	0·3	0·3	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·4	0·4
Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	359·2	359·2	359·2	359·3	359·4	359·5	359·6	359·7	359·9	0·0	0·2	0·3
20	359·1	359·1	359·2	359·2	359·3	359·5	359·6	359·7	359·9	0·0	0·2	0·3
40	358·9	358·9	359·0	359·1	359·2	359·3	359·5	359·7	359·9	0·1	0·2	0·4
50	358·7	358·7	358·8	358·9	359·0	359·2	359·4	359·6	359·8	0·1	0·3	0·5
55	358·5	358·6	358·7	358·8	358·9	359·1	359·3	359·6	359·8	0·1	0·3	0·6
60	358·3	358·4	358·5	358·6	358·8	359·0	359·2	359·5	359·8	0·1	0·4	0·6
65	358·0	358·1	358·2	358·4	358·6	358·8	359·1	359·4	359·8	0·1	0·4	0·7

ILLUSTRATION

On 1976 May 22 at G.M.T. $23^h\ 18^m\ 56^s$ in longitude W. 37° 14′ the corrected sextant altitude of *Polaris* was 49° 31′·6.

From the daily pages:	° ′
G.H.A. Aries (23^h)	225 41·5
Increment ($18^m\ 56^s$)	4 44·8
Longitude (west)	−37 14
L.H.A. Aries	193 12

	° ′
Corr. Sext. Alt.	49 31·6
a_0 (argument 193° 12′)	1 46·6
a_1 (lat. 50° approx.)	0·6
a_2 (May)	0·9
Sum −1° = Lat. =	50 19·7

POLARIS (POLE STAR) TABLES, 1976

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	240°–249°	250°–259°	260°–269°	270°–279°	280°–289°	290°–299°	300°–309°	310°–319°	320°–329°	330°–339°	340°–349°	350°–359°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	1 43·6	1 38·9	1 33·1	1 26·1	1 18·4	1 10·0	1 01·3	0 52·5	0 43·9	0 35·7	0 28·2	0 21·7
1	43·2	38·4	32·4	25·4	17·6	09·2	1 00·4	51·6	43·0	34·9	27·5	21·1
2	42·8	37·9	31·8	24·6	16·8	08·3	0 59·6	50·8	42·2	34·2	26·8	20·5
3	42·4	37·3	31·1	23·9	15·9	07·4	58·7	49·9	41·4	33·4	26·2	19·9
4	41·9	36·7	30·4	23·1	15·1	06·6	57·8	49·0	40·6	32·6	25·5	19·4
5	1 41·4	1 36·1	1 29·7	1 22·3	1 14·3	1 05·7	0 56·9	0 48·2	0 39·7	0 31·9	0 24·8	0 18·8
6	41·0	35·6	29·0	21·6	13·4	04·8	56·0	47·3	38·9	31·1	24·2	18·3
7	40·5	34·9	28·3	20·8	12·6	03·9	55·1	46·4	38·1	30·4	23·5	17·8
8	40·0	34·3	27·6	20·0	11·7	03·1	54·3	45·6	37·3	29·7	22·9	17·2
9	39·5	33·7	26·9	19·2	10·9	02·2	53·4	44·7	36·5	28·9	22·3	16·7
10	1 38·9	1 33·1	1 26·1	1 18·4	1 10·0	1 01·3	0 52·5	0 43·9	0 35·7	0 28·2	0 21·7	0 16·3
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·5	0·4	0·3	0·3	0·2	0·2	0·2	0·2	0·2	0·3	0·4	0·4
10	·5	·4	·4	·3	·3	·2	·2	·2	·3	·3	·4	·5
20	·5	·5	·4	·4	·3	·3	·3	·3	·3	·4	·4	·5
30	·5	·5	·5	·4	·4	·4	·4	·4	·4	·4	·5	·5
40	0·6	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·6
45	·6	·6	·6	·5	·5	·5	·5	·5	·5	·5	·6	·6
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·6	·6	·7	·7	·7	·7	·7	·7	·7	·7	·6	·6
60	·7	·7	·7	·8	·8	·8	·8	·8	·8	·7	·7	·7
62	0·7	0·7	0·8	0·8	0·8	0·9	0·9	0·8	0·8	0·8	0·7	0·7
64	·7	·7	·8	·9	0·9	0·9	0·9	0·9	·9	·8	·8	·7
66	·7	·8	·8	0·9	1·0	1·0	1·0	1·0	0·9	·9	·8	·7
68	0·7	0·8	0·9	1·0	1·0	1·1	1·1	1·1	1·0	0·9	0·9	0·8
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·5	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·7	0·7
Feb.	·4	·4	·4	·4	·4	·4	·4	·4	·5	·5	·5	·6
Mar.	·4	·4	·3	·3	·3	·3	·3	·3	·3	·4	·4	·4
Apr.	0·5	0·4	0·4	0·3	0·3	0·3	0·2	0·2	0·2	0·2	0·3	0·3
May	·6	·6	·5	·4	·4	·3	·3	·2	·2	·2	·2	·2
June	·8	·7	·7	·6	·5	·4	·4	·3	·3	·2	·2	·2
July	0·9	0·9	0·8	0·7	0·7	0·6	0·5	0·5	0·4	0·4	0·3	0·3
Aug.	·9	·9	·9	·9	·8	·8	·7	·6	·6	·5	·5	·4
Sept.	·9	·9	·9	·9	·9	0·9	·9	·8	·8	·7	·6	·6
Oct.	0·8	0·9	0·9	0·9	0·9	1·0	0·9	0·9	0·9	0·9	0·8	0·8
Nov.	·7	·7	·8	·9	·9	0·9	1·0	1·0	1·0	1·0	1·0	0·9
Dec.	0·5	0·6	0·7	0·7	0·8	0·9	0·9	0·9	1·0	1·0	1·0	1·0

Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	0·5	0·6	0·7	0·7	0·8	0·8	0·8	0·8	0·8	0·7	0·6	0·5
20	0·5	0·6	0·7	0·8	0·9	0·9	0·9	0·9	0·8	0·8	0·7	0·5
40	0·6	0·7	0·9	1·0	1·0	1·1	1·1	1·1	1·0	0·9	0·8	0·7
50	0·7	0·9	1·0	1·2	1·2	1·3	1·3	1·3	1·2	1·1	1·0	0·8
55	0·8	1·0	1·2	1·3	1·4	1·5	1·5	1·4	1·4	1·2	1·1	0·9
60	0·9	1·1	1·3	1·5	1·6	1·7	1·7	1·7	1·6	1·4	1·3	1·0
65	1·0	1·3	1·6	1·7	1·9	2·0	2·0	2·0	1·9	1·7	1·5	1·2

Latitude = Apparent altitude (corrected for refraction) $-1° + a_0 + a_1 + a_2$

The table is entered with L.H.A. Aries to determine the column to be used; each column refers to a range of 10°. a_0 is taken, with mental interpolation, from the upper table with the units of L.H.A. Aries in degrees as argument; a_1, a_2 are taken, without interpolation, from the second and third tables with arguments latitude and month respectively. a_0, a_1, a_2 are always positive. The final table gives the azimuth of *Polaris*.

Answers

Please note that answers to some exercises are included on the page, or pages, immediately following the exercise whilst other answers are included in this section. The following pages list either answers, or location of answers, to all exercises.

Please also note that descriptive answers to Questions are not included—such answers may be found from a study of the relevant, preceding, text pages.

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CHAPTER 1 Algebra

Exercise 1 page 3 Addition

1. $4x+9y-8z$
2. $9a-7b+c+d$
3. $4s-10u$
4. $10p-5q-7r+9s$
5. $3x^2+2y^2+11z^2$
6. $-1\frac{1}{8}x+\frac{3}{8}y-14z$

Exercise 2 page 4 Subtraction

1. $2x^2-2x$
2. $2x^2-\frac{4}{3}xy-\frac{1}{2}y^2$
3. $-a^3+22a^2b-16ab^2+2b^3$
4. $4x^4-5x^3-2x^2-x+2$
5. $-\frac{1}{6}x^2-\frac{5}{6}x+\frac{7}{6}$
6. $7x^3-10x^2+2$
7. $8a^3-2a$
8. $2a^3+8a^2-4a-5$

Exercise 3 page 4 Brackets

1. $-3a+12b-2c$
2. $2a-4b+2c$
3. $11a-15b-3c$

Exercise 4 page 5 Brackets

1. $45b-50c$
2. $-21a+24b-18c$
3. $14a+2b-6c$
4. $56a+8b+4c+172$

Exercise 5 page 7 Substitution

1. $y=\frac{14}{3}$
2. $y=88$
3. $y=108$
4. $y=432$
5. $y=4$
6. $y=1\frac{9}{10}$

Exercise 6 page 10 Multiplication

2. $\begin{matrix} & y^2 \\ c & 2cd+d^2 \end{matrix}$
3. $6x^3-19x^2+25$
4. $a^2+ab+3ac-2b^2+6bc$
5. $a^2+2ab+b^2-c^2$
6. x^3-y^3
7. $a^4+4a^2x^2+16x^4$
8. $4x^4+12x^3-11x^2-30x+25$

Exercise 7 page 13 Division

1. $2x^2y^2$
2. $9ab-6b^4-5a^2b$
3. $x+2$
4. $a-6$
5. $2a^2-3a$
6. x^2+5x+6

Exercise 8 page 14 Square Roots

1. $2a$
2. $\dfrac{2xy}{a}$
3. $\dfrac{a^8b^4}{4}$
4. $\sqrt{3abx}$

Exercise 9 page 17 Simple Equations

1. $x = 1$
2. $x = 7$
3. $x = \frac{9}{11}$
4. $x = 11$
5. $x = -\frac{16}{29}$
6. $x = -\frac{1}{5}$
7. $x = 11$
8. $x = \frac{79}{9}$

Exercise 10 page 19 Simultaneous Equations

1. $x = 8, y = 5$
2. $x = 21, y = 5$
3. $x = -17\frac{17}{21}, y = -7\frac{3}{7}$
4. $x = 5, y = -3$
5. $x = \frac{185}{303}, y = \frac{220}{303}$
6. $x = \frac{321}{16}, y = \frac{197}{26}$
7. $x = 4, y = -2$
8. $x = \frac{14}{3}, y = 4$

Exercise 11 page 21 Quadratic Equations

1. $x = 1$ or -2
2. $x = 2$ or -16
3. $x = 9$ or -8
4. $x = 13$ or -12
5. $x = 10$ or -14
6. $x = \frac{11}{5}$ or -5
7. $x = \frac{4}{5}$ or -3
8. $x = 11$ or -17

Exercise 12 page 21 Problems

1. 10 hrs
2. 20 mins
3. £125
4. 24 ft
5. $x = 66{\cdot}66r$
   Books £66·67;
   Sextant £133·33;
   Kit £400
6. £300
7. £166·32
8. £200, £600, £1,200
9. 11 men
10. 7 kn
11. 360 miles
12. 3 hrs 20 mins
13. 4 kn and 2 kn
14. 2 mph
15. 10 kn
16. 100 benches
17. 3 kn
18. 7, 8, 9, 10 and 11
19. 51 and 34
20. £3,000 and £1,000
21. 2 hrs 21 mins
22. 7·5 hrs
23. 5 mph
24. 4 days

CHAPTER 2 Geometry

Exercise 1 page 39 . . . . . answers page 40

CHAPTER 3 Graphs

No exercises for this chapter.

CHAPTER 4 Measurement, Area and Volume

Exercise 1 page 59 . . . . . answers page 60

Exercise 2 page 71 Mensuration

1. 800 tiles
2. 13·7 lbs
3. 144 lbs
4. 154·3 tons
5. Area 48·9 × 2 = 97·8 sq ft
6. 66·66 sq yds £800 100 lineal yds
7. 100 tons 44·8 mins
8. 140 sq yds £32
9. 39·66 yds
10. 36,000 cu ft 1286 bales
11. 411·428 tons
12. 20·67 miles
13. 1309·5 tons
14. 3·49 miles
15. 16·33 lbs
16. 42 sq yds or 34·22 sq yds (open)
17. 1800 tiles
18. 10 m
19. 21,600 sq m
20. £4·1
21. 19·8 sq miles 3·96 miles
22. 609·375 lbs
23. 2·07 gallons 17·6 lbs
24. 17 ins
25. 413·6 sq ft
26. 65·5 cu m 78·5 sq m
27. About 29 lbs
28. 381 cu ins
29. 13·3 tons 3000 gallons
30. 22·4 say 22 casks
31. 7·64 cu ft 3·36 cu ft 1646·9 lbs

CHAPTER 5 Logarithms

Exercise 1 page 76

1. Log 3·53970
2. Log 2·53970
3. Log 1·79824
4. Log 2·57287
5. Log 2·99123
6. Log 1·99123
7. Log 0·99123
8. Log 4·54518
9. Log 3·78533
10. Log 4·99996
11. Log 2·00043
12. Log 0·00000

Exercise 2 page 76

1. Log 2·69669
2. Log 2·57575
3. Log 3·95019
4. Log 4·91634
5. Log 1·61095
6. Log 2·85312
7. Log 3·99167
8. Log 4·93450
9. Log 4·78803
10. Log 2·12189
11. Log 4·00004
12. Log 5·00000

Exercise 3 page 77

1. 196·9
2. 25970
3. 3·709
4. 729·0
5. 83·00
6. 8001
7. 666600
8. 72000
9. 8·6
10. 1002000
11. 100
12. 1

Exercise 4 page 79

1. 48354·4
2. 374566·6
3. 3887455
4. 498422·2
5. 6000·71
6. 750000·0
7. 91490·0
8. 9999·5
9. 3·702
10. 100800·0
11. 1100025·6
12. 100000

Exercise 5 page 80 Multiplication

1. 165300·0
2. 14495·7
3. 20520·0
4. 1827000·0
5. 120305·55
6. 47091·1
7. 3825090·9
8. 501122·2
9. 9742000·0
10. 851340·0
11. 9009800·0
12. 102978571·4
13. 711105·0
14. 21179047·6
15. 1008·05
16. 435236·0

Exercise 6 page 80 Division

1. 375·0
2. 193·4
3. 139·1
4. 3230·0
5. 5760·0
6. 66·43
7. 675·6
8. 14·73
9. 86·30
10. 361·5
11. 409·8
12. 7·108
13. 1·494
14. 22·18
15. 233·3
16. 4·204

Exercise 7 page 82 Multiplication

1. 0·00084
2. 25·52
3. 0·005036
4. 0·01844
5. 423·1
6. 0·000003930

Exercise 8 page 83 Division

1. 0·05773
2. 258·0
3. 0·258
4. 0·6227
5. 17·35
6. 0·07133
7. 0·00275
8. 0·00297

Exercise 9 page 85 Involution

1. 25
2. 9
3. $\frac{1}{219}$
4. $\frac{1}{32}$
5. $\frac{1}{4}$
6. $\frac{27}{8}$
7. $\frac{2187}{128}$
8. 1
9. $a^{\frac{1}{2}} = 3$
10. $x^{5/6}$
11. a^6b^9
12. $\frac{32}{3}$

Exercise 10 page 86 Evolution

1. 82·55 log 1·91670
2. 13·00 log 1·11394
3. 89·40 log 1·95135
4. 4·053 log 0·60774
5. 34786·2 log 4·54141
6. 1·597 log 0·20341
7. 1·01093 log 0·00473

Exercise 11 page 86 Involution

1. 0·4393 log 9·64276
2. 0·4407 log 9·64417
3. 0·0005392 log 6·73176
4. 0·000004528 log 4·65594
5. 0·6895 log 9·83853
6. 0·3108 log 9·49252

Exercise 12 page 87 Evolution

1. 0·7543 log 9·87756
2. 0·2 log 9·30103
3. 0·1457 log 9·16359
4. 0·1257 log 9·09949
5. 0·04433 log 8·64671
6. 0·9176 log 9·96268

Exercise 13 page 89 Various Examples

1. 7·844
2. 0·2021
3. 17·94
4. 0·000405
5. 2·162
6. 2·851
7. 2.3085
8. 6·288
9. 0·0047
10. 1·296
11. 2·6153
12. 2·1545
13. 139·47
14. 2·542
15. 0·02924
16. 0·001964
17. 11·61

Exercise 14 page 91

Answers to questions 1–3 can be found by looking up the relevant log tables.

Exercise 15 page 92

1. 2·698
2. 2·733
3. 3·006
4. 1·333
5. 2·446

CHAPTER 6 Trigonometry

Exercise 1 page 101 . . . . . answers page 101

Exercise 2 page 104 . . . . . proofs required

Exercise 3 page 112 . . . . . answers page 112

Exercise 4 page 115 . . . . . proofs required

Exercise 5 page 121 . . . . . answers page 121

Exercise 6 page 126 . . . . . answers page 126

Exercise 7 page 143 . . . . . answers page 143

Exercise 8 page 147 . . . . . answers page 148

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Exercise 10 page 161 . . . . . answers page 161

Exercise 11 page 168 . . . . . answers page 169

Miscellaneous Examples page 136 . . . . . answers page 137

Miscellaneous Examples page 152 . . . . . answers page 154

CHAPTER 7 The Sphere and Sailings

Exercise 1 page 180 . . . . . answers page 180

Exercise 2 page 182 Parallel Sailing

1.	D. Long. 351·4′ or 5° 51·4′		log	2·545740
2.	Dep.	234·1 miles	log	2·369362
3.	Lat.	43° 6·5′	log cos	9·863359
4.	Long.	71° 07′ E, D. Long. 6° 31′	log	2·592111
5.	Dep.	336·5 miles	log	2·526986
6.	Lat.	46° 56·5′	log sec	10·165775
7.	560·6 mph	log	2·748631	
8.	Lat. 60°	log cos	9·698970	
9.	Lat. 70° 31·5′	log cos	9·522878	
10.	38·57 miles	log	1·586218	
11.	Lat. 48° 11·5′	log cos	9·823909	
12.	472·8 miles	log	2·674683	

Exercise 3 page 188 Traverse Tables

	Course	Distance	D. Lat.	D. Long.	Dep.
1.	N 39·5° E 039·5° T	85·5 miles	66′ N	90′ E	54·5′ E
2.	N 41·5° W 318·5° T	146·5 miles	110′ N	126′ W	97·3′ W
3.	S 61·5° E 118·5° T	127·5 miles	61′ S	148′ E	112·2′ E
4.	S 63·5° E 116·5° T	221·0 miles	98′ S	198′ E	198·0′ E
5.	S 55° W 255° T	160·0 miles			
6.	S 74·5° E 105·5° T	224·5 miles			
7.	S 30·0° W 210° T	306·0 miles			

Exercise 4 page 197 Mercator Sailing

	D. Lat.	DMP	D. Long.	True Course	Distance
1.	2548	2664·41	1898	N 35° 28′ W 324° 32′ T	3128·4 miles
2.	669	935·15	1660	N 60° 36′ E 060° 36′ T	1363·0 miles
3.	812	809·00	1530	S 62° 00′ E 117° 52′ T	1738·0 miles
4.	134	182·00	471	S 68° 54′ N 111° 06′ T	372·3 miles
5.				N 39° 28′ W 320° 32′ T	3609·0 miles

6. Lat. 62° 44·0′ N Dist 1292·0 miles
7. Lat. 5° 20·0′ N Dist 1709·0 miles
8. Long. 37° 30·0′ W

Test Paper 1 page 201

1. 05°31·1′ E
2. 233·3 miles E
3. 55° 13·5′ N or S
4. 27° 32′ W
5. 40·56 miles
6. 44° 00′ N or S
7. 560·5 kn
8. 153·2 miles
9. 5174
10. 55° 00′ N 43° 01·8′ W

Test Paper 2 page 201

1. Co 060° 11′ T 466·6 miles
2. Co 247° 09·5′ T 507·6 miles
3. 40° 28·7′ N 9° 42·5′ W
4. 21° 42·5′ S 54° 42·9′ E

Test Paper 3 page 202

1. 216·5′ N 125·0 miles W
2. 24·6′ S 58·0 miles W
3. 97·1′ N 362·2 miles E
4. 13·9′ S 5·6 miles E
5. 326° T 310·0 miles
6. 097° T 111·0 miles
7. 015·5° T 197·5 miles
8. 258·5° T 269·5 miles
9. 143·5 miles W
10. 259·5′ E
11. 324·1′ W
12. 54·6 miles W

Test Paper 4 page 202

1. Set 081° T Drift 12·7 miles
2. Set 297·5° T Drift 13·0 miles
3. Set 265° T Drift 59·2 miles
4. Set 011·5° T Drift 31·0 miles

Test Paper 5 page 202

1. 149° 37·5′ T 181° 37·5′ C 98·52 miles
2. 035° 47′ T 039° 47′ C 4223·40 miles
3. 310° 07·5′ T 322° 07·5′ C 1717·8 miles
4. 60° 11′ S 797·6 miles
5. 49° 32′ S 14° 28·2′ E
6. 226° 35′ T 163° 36·4′ E
7. DR 35° 56·9′ N 144° 27·7′ W Set 124° T Drift 14·0 miles
8. 10° 15·1′ S 20° 00·4′ W
9. 088° 31·0′ T 1199·75 miles
10. 070° 25·4′ T 1128·1 miles
11. 301° 38·6′ T 432·7 miles
12. 267° 38·9′ T 5606·6 miles

CHAPTER 8 The Compass

Exercise 1 page 219 . . . . . Figures required

Exercise 2 page 225 Course Correction

True Course	True Course
1. 058° T	6. 266° T
2. 106° T	7. 337° T
3. 158° T	8. 015° T
4. 174° T	9. 083° T
5. 238° T	

Questions 1–22 page 225

CHAPTER 9 Dead Reckoning and Traverse Tables

Exercise 1 page 232

Track	Distance	Latitude	Longitude
1. 226° T S 46° W	126·5 miles	41° 44·1′ N	169° 22·0′ W
2. 236° T S 56° W	74·2 miles	38° 01·9′ S	95° 54·5′ E
3. 280° T N 80° W	19·1 miles	49° 13·3′ N	8° 53·7′ W
4. 263° T S 83° E	26·7 miles	49° 33·4′ S	69° 40·8′ E
5. 092° T S 88° E	34·0 miles	51° 08·9′ N	6° 36·0′ W
6. 122° T S 58° E	18·0 miles	12° 09·0′ S	134° 42·2′ W

Exercise 2 page 245

1. DR Track & Dist. DR Noon D. Lat. 100·4′ N
   302° T N 58° W 48° 40·4′ N D. Long. 241·0′ W
   190·0 miles 177° 07·0′ E Dep. 161·7′ W

Exercise 3 page 245

1. DR Track & Dist.	DR Noon	Track made good	Set & Drift	D. Lat. 43·6′S
106° T S 74° E	46° 16·4′ N	098° T S 82° E	067° T N 67° E	D. Long. 222·6′ E
159·0 miles	00° 17·4′ W	193 miles	42·4 miles	Dep. 152·8′ E

Exercise 4 page 246 Day's Work

1.
Initial Position:
Not required

True Course	Distance
276° T N 84° W	7 miles
215° T S 35° W	54 miles
225° T S 45° W	48 miles
236° T S 56° W	56 miles
038° T N 38° E	23 miles

D. Lat. 90·6′ S
Dep. 104·1′ W
D. Long. 2°44′ W
Co. S 49° W → 229° T
Dist. 138 miles
EP 49° 52′ N 12° 20′ W

2.
Initial Position:
42° 12·6′ S 144° 57′ E

True Course	Distance
306° T N 54° W	32 miles
303° T N 57° W	30 miles
299° T N 61° W	28 miles
292° T N 68° W	26 miles
290° T N 70° W	22 miles
287° T N 73° W	20 miles
178° T S 2° E	10 miles

D. Lat. 61·7′ N
Dep. 139·2′ W
D. Long. 3° 06′ W
Co. N 66° W → 294° T
Dist. 152 miles
EP 41° 11′ S 141° 51′ E

3.
Initial Position:
49° 46′ N 5° 11′ W

True Course	Distance
245° T S 65° W	25 miles
219° T S 39° W	22 miles
269° T S 89° W	19 miles
185° T S 5° W	16 miles
184° T S 4° W	14 miles
135° T S 45° E	13 miles
298° T N 62° W	6 miles

D. Lat. 64·3′ S
Dep. 54·0′ W
D. Long. 1° 23′ W
Co. S 40° W → 220° T
Dist. 84 miles
EP 48° 42′ N 6° 34′ W

4.
Initial Position:
Not required

True Course	Distance
084° T N 84° E	138 miles
086° T N 86° E	278 miles

D. Lat. 33·8′ N
Dep. 414·5′ E
D. Long. 9°28′ E
DR 42° 52′ S 9° 28′ E
D. Lat for current 13·0′ N
D. Long. for current 3·0′ W
Dep. for current 2·2′ W
Set N 10° W → 350° T
Drift 45 miles

5.

True Course	Distance
237° T S 57° W	218 miles
233° T S 53° W	210 miles

D. Lat. 245·1′ S
Dep. 350·5′ W
D. Long.
DR 28° 30′ N 23° 25′ W
D. Lat. for current
D. Long. for current
Dep. for current
Set N 46° E → 046° T
Drift 12 miles

6.
DR 34° 44·7′ S 23° 11·7′ E
Set S 71° W → 251° T
Drift 45 miles

7.
Initial Position
5° 46′ N 80° 37′ E
DR 3° 24′ N 83° 53′ E
Co. S 54° E → 126° T
Dist. 241 miles

8.
Position at 2400
50° 09·8′ N 2° 46·1′ W

9.
Set N 50° W → 310° T
Drift 16·5 miles in 10 hrs
Co. S 9° W → 189° T
Dist. 157 miles

10.
DR 39° 43·7′ S 18° 02·5′ W
Set S 30° W → 210° T
Drift 24·6 miles

11.
DR 42° 25·3′ S 140° 00·5′ E
EP 42° 15·3′ S 140° 23·8′ E
Set N 50° E 050° T
Drift 38·2 miles
Co. N 87°W 273° T
Dist. 236 miles

12.
DR 37° 22·7′ S 175° 47·6′ W
Co. 094·5° T
Dist. 363 miles

13.
DR 43° 10·4′ S 179° 36·8′ E
Set 104° T
Drift 20 miles
Co. 086·5° T
Dist. 284 miles

14.
EP 43° 36·3′ S 177° 00·3′ E
Co. 152° T
Dist. 138 miles

CHAPTER 10 Radar Plotting

Exercise page 269 . . . . . answers page 271

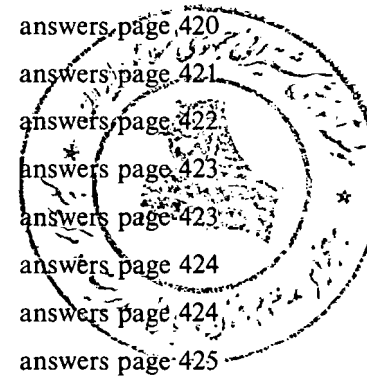
CHAPTER 11 Admiralty Publications

No exercises in this chapter.

CHAPTER 12 Chartwork

Questions 1–80 page 415

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Exercise 9 page 423 . . . . . answers page 423
Exercise 10 page 424 . . . . . answers page 424
Exercise 11 page 424 . . . . . answers page 424
Exercise 12 page 425 . . . . . answers page 425
Exercise 13 page 425 . . . . . answers page 425
Exercise 14 page 426 . . . . . answers page 426
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CHAPTER 13 Passage Planning

Questions 1–10 page 434

CHAPTER 14 Tides

Exercise 1 page 472 . . . . . answers page 475
Exercise 2 page 473 . . . . . answers page 475
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Tidal Stream Rates

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CHAPTER 15 Navigation in Ice

Questions 1–5 page 487

CHAPTER 16 Search and Rescue

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CHAPTER 17 Marine Sextant

Questions 1–60 page 520

CHAPTER 18 Principles of Astro-Navigation

Past Papers 1–5 page 807 . . . . . answers page 980

Questions 1–25 page 547

CHAPTER 19 Altitude Correction

Exercise 1 page 555 . . . . . answers page 555

Exercise 2 page 557 . . . . . answers page 557

Exercise 3 page 560 . . . . . answers page 560

CHAPTER 20 Time

Exercise 1 page 567 Finding the GMT by Chronometer

	Number of days for daily rate	Daily rate	Number of days for accumulated rate	Accumulated rate	GMT
1.	Daily rate given	3·3 seconds	32·5 days	(+) 1 m 47 s	3 d 00 h 08 m 20 s
2.	Daily rate given	2·5 seconds	35·7 days	1 m 29 s	20 d 04 h 21 m 42 s
3.	45 days	3·4 seconds	75·0 days	4 m 15 s	22 d 11 h 43 m 24 s
4.	50 days	4·6 seconds	32·4 days	(−) 2 m 29 s	29 d 22 h 20 m 35 s
5.	—	—	—	—	8 d 17 h 42 m 44 s

6. 0·55 sec losing
7. *C* is 11 m 25 s slow of *B*
8. 8 m 31 s

Exercise 2 page 569 . . . . . answers page 569

Exercise 3 page 570 . . . . . answers page 570

Exercise 4 page 570 . . . . . answers page 570

Hour Angle

Exercise 5 page 578 . . . . . answers page 578

Exercise 6 page 580 . . . . . answers page 580

Exercise 7 page 581 . . . . . answers page 581

Questions 1–21 page 582

CHAPTER 21 Marine Chronometer

Questions 1–25 page 595

CHAPTER 22 Latitude and Time of Meridian Passage

Exercise 1 page 603 . . . . . answers page 604

Exercise 2 page 607 . . . . . answers page 607

Exercise 3 page 610 . . . . . answers page 610

Exercise 4 page 613 . . . . . answers page 614

Exercise 5 page 617 . . . . . answers page 617

Exercise 6 page 621 . . . . . answers page 621

Questions 1—20 page 622

CHAPTER 23 Amplitudes, Azimuths and Twilight

Exercise 1 page 626

	GMT	Dec.	True Amplitude	Compass Error	Deviation
1.	09d 10h 45m 03s	22° 08·5′ S	121° 51·5′ T E 31° 51·5′ S	12° 08·5′ W	10° 21·5′ E
2.	15d 01h 13m 00s	23° 17·5′ N	065° 32·0′ T E 24° 28·0′ N	6° 28·0′ W	7° 58·0′ W
3.	29d 16h 05m 00s	23° 14·0′ S	239° 39·5′ T W 30° 20·5′ S	32° 20·5′ W	5° 20·5′ W
4.	10d 21h 21m 20s	6° 42·0′ S	097° 19·0′ T E 7° 19·0′ S	2° 41·0′ W	2° 19·0′ E
5.	—	—	313° 54·5′ T W 43° 54·5′ N	—	7° 05·5′ W
6.	—	—	270° T West	—	9° 00·0′ E
7.	—	—	233° 17·5′ T W 36° 42·5′ S	—	6° 42·5′ W
8.	—	—	250° 23·5′ T W 19° 36·5′ S	—	0° 23·5′ E
9.	—	—	107° 25·0′ T E 17° 25·0′ S	—	4° 35·0′ W
10.	—	—	066° 29·5′ T E 23° 30·5′ N	—	2° 30·5′ W
11.	—	—	242° 39·0′ T W 27° 21·0′ S	—	10° 39·0′ E

Exercise 2 page 634

	LHA	GHA	Dec.	Azimuth	Error	Dev.
1. Sun	48° 37·0′	—	1° 04·5′ S	303·0° T	8·0° E	18·0° E
2. Sun	321° 59·1′	—	23° 25·0′ N	035·0° T	17·0° W	8·0° E
3. Sun	72° 12·5′	—	23° 22·7′ N	273·0° T	5·0° W	5·0 W
4. Sun	332° 00·1′	—	23° 25·4′ N	153·8° T	28·2° W	6·8° E
5. Sun	52° 31·0′	—	22° 23·0′ S	228·0° T	18·0° W	6·0° W
6. Sun	77° 51·3′	—	1° 45·0′ N	279·3° T	19·3° E	2·3° E
7. Star	281° 05·8′	303° 05·8′	6° 18·8′ N	094·0° T	17·0° W	3·0° E
8. Star	281° 21·7′	252° 51·7′	16° 25·5′ N	087·4° T	7·4° W	2·4° W
9. Star	291° 29·7′	—	8° 45·6′ N	068·8° T	21·2° W	21·2° W
10. Star	69° 44·8′	—	5° 19·7′ N	257·0° T	15·0° W	3·0° W
11. Star	301° 01·2′	—	38° 44·7′ N	045·4° T	14·6° W	4·4° E
12. Star	39° 08·2′	—	12° 10·2′ N	307·0° T	13·0° W	nil
13. Planet	316° 02·2′	—	18° 10·8′ N	045·4° T	9·5°W	4·5° E
14. Planet	47° 59·7′	—	21° 54·9′ S	224·3° T	16·3° E	5·7° W
15. Moon	37° 38·6′	—	17° 06·5′ N	317·0° T	6·0° W	4·0° E
16. Moon	277° 29·7′	—	17° 04·8′ N	082·0° T	4·0° W	6·0° E

Questions 1–29 page 635

CHAPTER 24 Figure Drawing

Exercise 1 page 649 . . . . . answers page 649

Questions 1–5 page 649

CHAPTER 25 Position Lines

Exercise 1 page 656 . . . . . answers page 657

Exercise 2 page 665 . . . . . answers page 665

CHAPTER 26 Intercept Method

Exercise 1 page 683

	1. **Aldebaran**	2. **Regulus**
GMT	11d 12h 36m 13s	11d 12h 38m 10s
LHA	51° 26·0′	328° 46·0′
GHA ♈	299° 34·1′	300° 03·5′
Calc. Zen. Dist.	49° 32·3′	37° 07·1′
True Zen. Dist.	49° 34·0′	37° 03·6′
Intercept	1·7′ Away	3·5′ Towards
Azimuth	260·4° T	122·5° T
P/L plotted	170·5°—350·5° T	032·5°—212·5° T
Lat. for P/L	36° 29·3′ N	36° 26·9′ N
Long. for P/L	179° 42·9′ W	179° 41·3′ W
Position (1 & 2)	36° 26·0′ N 179° 37·5′ W	

	3. **Spica**	4. **Procyon**
GMT	16d 19h 30m 42s	16d 19h 31m 17s
LHA	326° 58·7′	53° 36·0′
GHA ♈	197° 14·0′	197° 22·7′
Calc. Zen. Dist.	47° 33·4′	54° 43·3′
True Zen. Dist.	47° 38·4′	54° 41·0′
Intercept	5·0′ away	2·3′ towards
Azimuth	133·8° T	259·0° T
P/L plotted	044·0°—224·0° T	169·0°—349·0° T
Lat. for P/L	24° 03·7′ N	23° 59·6′ N
Long. for P/L	29° 34·2′ W	29° 32·5′ W
Position (3 & 4)	24° 04·0′ N 29° 33·5′ W	

	5. **Jupiter**	6. **Procyon**
GMT	16d 20h 40m 25s	16d 20h 41m 38s
LHA	327° 55·2′	54° 34·2′
GHA ♈	—	215° 00·9′
Calc. Zen. Dist.	40° 29·4′	65° 12·6′
True Zen. Dist.	40° 31·9′	65° 11·7′
Intercept	2·5′ Away	0·9′ Towards
Azimuth	054·2° T	297·1° T
P/L	144·0°—324·0° T	027·0°—207·0° T
Lat. for P/L	35° 03·5′ S	35° 01·6′ S
Long. for P/L	46° 12·5′ W	46° 11·0′ W
Position (5 & 6)	35° 03·5′ S 46° 12·5′ W	

	7. **Betelgeuse**	8. **Capella**
GMT	7d 21h 17m 49s	7d 21h 18m 17s
LHA	317° 29·0′	327° 25·5′
GHA ♈	66° 23·0′	66° 30·0′
Cal. Zen. Dist.	52° 39·0′	22° 39·6′
True Zen. Dist.	52° 34·7′	22° 42·3′
Intercept	4·8′ Towards	2·7′ Away
Azimuth	122·7° T	076·1° T
P/L	032·5°—212·5 °T	166·0°—346·0 °T
Lat. for P/L	45° 07·5′ N	45° 09·4′ N
Long. for P/L	20° 34·3′ W	20° 43·5′ W
Position (7 & 8)	45° 01·5′ N 20° 40·5′ W	

	9. **Sun**	10. **Sun**
GMT	15d 08h 41m 23s·	15d 10h 45m 36s
LHA	301° 52·4′	332° 19·3′
GHA ♈	310° 17·4′	341° 20·3′
Cal. Zen. Dist.	51° 57·1′	34° 03·6′
True Zen. Dist.	52° 04·2′	33° 56·7′
Intercept	7·1′ Away	6·9′ Towards
Azimuth	097·8° T	130·3° T
P/L plotted	008·0°—188·0° T	040·0°—220·0° T
Lat. for P/L	49° 11·0′ N	49° 30·6′ N
Long. for P/L	8° 35·8′ W	8° 52·8′ W
Position (9 & 10)	49° 22·0′ S 9° 04·0′ W	

	11. **Moon**	12. **Moon**
GMT	24d 21h 14m 22s	25d 01h 25m 58s
LHA	330° 00·0′	29° 59·9′
GHA ♈	334° 15·0′	35° 02·4′
Cal. Zen. Dist.	38° 06·4′	38° 20·6′
True Zen. Dist.	37° 59·6′	38° 24·2′
Intercept	6·8′ Towards	3·6′ Away
Azimuth	050·4° T	310·2° T
P/L plotted	140·5°—320·5° T	040·0°—220·0° T
Lat. for P/L	5° 20·7′ S	5° 45·3′ S
Long. for P/L	4° 09·5′ W	4° 59·7′ W
Position (11 & 12)	5° 46·0′ S 5° 00·0′ W	

Exercise 2 page 684 . . . . . answers page 686

Questions 1–10 page 683

CHAPTER 27 Longitude by Chronometer

Exercise 1 page 701

	1. **Sun LL**	2. **Sun LL**
GMT	12d 19h 05m 36s	09d 18h 56m 48s
GHA	104° 18·1′	102° 24·3′
LHA	312° 50·8′	42° 11·1′
DR Lat.	31° 46·0′ N	28° 10·0′ N
Dec.	21° 37·9′ S	22° 05·6′ S
L ± D	53° 23·9′	50° 15·6′
True Zen. Dist.	69° 55·0′	64° 40·6′
Azimuth	133·3° T	223·5° T
P/L	043·5°—223·5° T	133·5°—313·5° T
Long. by Chron.	151° 27·4′ W	60° 13·2′ W

	3. **Sun LL**	4. **Sun LL**
GMT	08d 20h 50m 40s	22d 17h 41m 05s
GHA	130° 58·0′	87° 04·5′
LHA	303° 07·1′	295° 34·5′
DR Lat.	45° 02·0′ S	31° 46·0′ N
Dec.	22° 13·2′ S	0° 18·9′ N
L ± D	22° 48·8′	31° 27·1′
True Zen. Dist.	51° 19·1′	68° 17·3′
Azimuth	083·5° T	104·0° T
P/L	173·5°—353·5° T	014·0°—194·0° T
Long. by Chron.	172° 09·1′ E	151° 30·0′ W

	5. **Sun LL**	6. **Sun LL**
GMT	26d 06h 38m 09s	07d 19h 17m 17s
GHA	278° 53·5′	107° 44·0′
LHA	74° 00·9′	60° 24·0′
DR Lat.	46° 32·0′ N	42° 36·0′ S
Dec.	23° 22·6′ N	22° 21·7′ S
L ± D	23° 09·4′	20° 14·3′
True Zen. Dist.	62° 29·6′	53° 34·5′
Azimuth	275·5° T	272·0° T
P/L	005·5° — 185·5° T	002·0° — 182·0° T
Long. by Chron.	155° 07·4′ E	47° 20·0′ W

	7. (a) **Sun LL**	(b)
GMT	19d 04h 45m 13s	Run 098° T × 29 miles
GHA	251° 02·4′	D. Lat. 4·0′ S Dep. 29·0′ E
LHA	321° 41·6′	D. Long. 39·5′ E
DR Lat.	43° 18·0′ S	DR 43° 22·0′ S
Dec.	23° 25·0′ N	71° 18·7′ E
L ± D	66° 43·0′	
True Zen. Dist.	75° 26·0′	(c)
Azimuth	036° T	GMT Mer. Pass 19d 07h 16m
P/L	126·0° — 306·0° T	Obs. Pos. 43° 30·0′ S
Long. by Chron.	70° 39·2′ E	71° 33·9′ E

Exercise 2 page 701

	GMT	True Zen. Dist.	GHA Body	LHA	Longitude	Azimuth	Position
1. Aldebaran	11d 12h 36m 13s	49° 34·0′	231° 11·0′	51° 28·0′	179° 43·0′ W	260·4° T	36° 26·0′ N
2. Regulus	11d 12h 38m 10s	37° 03·6′	508° 31·0′	328° 46·0′	179° 39·8′ W	122·8° T	179° 42·3′ W
3. Spica	16d 19h 30m 42s	47° 38·7′	356° 28·7′	326° 51·1′	29° 37·6′ W	133·8° T	24° 04·0′ N
4. Procyon	16d 19h 31m 17s	54° 31·0′	83° 06·0′	53° 33·4′	29° 32·6′ W	259·1° T	29° 33·5′ W
5. Jupiter	16d 20h 40m 25s	40° 31·9′	14° 05·2′	327° 51·3′	46° 13·9′ W	054·2° T	35° 04·0′ N
6. Procyon	16d 20h 41m 38s	65° 11·7′	100° 44·2′	54° 33·1′	46° 11·1′ W	296·9° T	46° 12·3′ W
7. Betelgeuse	7d 21h 17m 49s	52° 34·2′	338° 09·0′	317° 37·2′	20° 31·8′ W	122·7° T	45° 00·7′ N
8. Capella	7d 21h 18m 17s	22° 42·3′	348° 05·5′	327° 21·8′	20° 43·7′ W	076·0° T	20° 40·3′ W
9. Moon	20d 16h 24m 21s	74° 21·2′	330° 54·5′	297° 38·7′	33° 15·8′ W	119·4° T	23° 51·5′ N 32° 19·7′ W
10. Moon	20d 22h 16m 48s	47° 50·7′	55° 50·4′	23° 24·3′	32° 26·1′ W	210·8° T	23° 48·8′ N 32° 21·3′ W

Exercise 3 page 702 . . . . . answers page 702

Questions 1–31 page 703

CHAPTER 28 Ex-Meridians

Exercise 1 page 715

	GMT	LHA	True Alt.	Reduction	Mer. Zen. Dist.	Lat.	P/L
1. Sun LL	7d 16h 25m 49s	357°30·8′	55°58·7′	3·0′	33°58·3′	56°20·9′S	094·1°—274·1°T
2. Sun LL	16d 21h 01m 27s	6°42·4′	64°17·7′	33·6′	25°08·7′	48°30·0′N	104·5°—284·5°T
3. Sun LL	15d 23h 49m 52s	356°18·6′	37°42·0′	7·2′	52°10·8′	28°51·5′S	094·3°—274·3°T
4. Sun UL	25d 23h 26m 30s	351°04·5′	19°30·5′	27·5′	70°02·0′	46°38·5′N	081·3°—261·3°T
5. Sun LL	24d 16h 15m 22s	350°31·1′	40°17·6′	51·7′	48°50·7′	25°25·4′N	078·5°—258·5°T
6. Sun LL	17d 00h 41m 17s	353°37·5′	31°33·7′	18·7′	58°07·6′	34°46·0′S	097·0°—277·0°T
7. Acrux	10d 07h 28m 16s	3°03·7′	41°30·0′	3·0′	48°27·0′	14°24·8′S	092·0°—272·0°T
8. Sirius	28d 08h 21m 30s	356°09·1′	36°32·6′	7·6′	53°19·8′	36°40·1′N	085·5°—265·5°T
9. Canopus	27d 17h 32m 58s	349°45·9′	22°47·7′	36·2′	66°36·1′	13°55·6′N	083·3°—263·3°T

CHAPTER 29 Gyro Compass

Questions 1–12 page 741

CHAPTER 30 Calculators and Computers

Questions 1–10 page 758

PAST PAPERS

PRACTICAL NAVIGATION

Paper 1 page 800

1. P/L 053°—233° T through 33° 58·0′ S 37° 47·5′ W, or 34° 04·2′ S 37° 54·7′ W
2. P/L 087·5°—267·5 T through 47° 38·3′ N 179° 45′ E
3. Lat. 51° 16·0′ N. Az. 000·8° T
4. Co. 320·8° T. Dist. 3121 miles
5. Noon position 48° 27′ N 17° 33·8′ W

Paper 2 page 800

1. Co. 315° 23′ T. Dist. 1955·5 miles
2. True Amplitude E 30° 08′ S 120° 08′ T. Dev. 20·5° E
3. LHA 355° 39·8′. MZD 37° 42·3′. Lat. 39° 08·5′ N. Az. 173° T. P/L 083°—263° T
4. Lat. 35° 20·6′ S
5. P/L 175·4°—355·4° T through 36° 28·0′ S 162° 51·1′ W. LHA 56° 45·1′
6. 35° 43·5′ S 162° 12·2′ W

Paper 3 page 801

1. Co. 258° T. Dist. 272 miles. 1200 position 43° 09′ S 175° 18′ E
2. Lat.44° 21·0′ N
3. P/L 084°—264° T through 41° 33·4′ S. MZD 64° 59·2′
4. Az. 140·6° T. P/L 050·6°—230·6° T through 36° 41′ N 174° 50·5′ W or Intercept 5·0′ towards ITP 36° 37·2′ N 174° 56·0′ W. LHA 320° 06·8′
5. DR 36° 53·7′ N 175° 24·5′ W
   Obs. Pos. 36° 59·0′ N 175° 16·5′ W

Paper 4 page 801

1. Co. 026° 27·5′ T. Dist. 1158 miles. Initial course 355° 27·5′ C
2. True Amplitude 0° 090° T. Error 17° E. Dev. 5° E
3. P/L 083°—263° T through 39° 26·9′ S 100° 13′ W
4. P/L 037·5°—217·5° T through 11° 38′ N 153° 56·2′ W or Intercept 3′ away. ITP 11° 36·2′ N 153° 57·5′ W. LHA 68° 11·6′
5. Transferred P/L through 40° 54′ S 26° 31′ W. Obs. Pos. 40° 59·4′ S 26° 22·5′ W

Paper 5 page 802

1. Lat. 37° 46·0′ N. Dist. 1130 miles
2. Az. 265° T. Error 28° W. Dev. 3° W
3. Az. 188° T P/L 098°—278° T through Lat. 36° 44·9′ N. MZD 59° 07·8′
4. Lat. 11° 17·2′ S
5. Az. 290° T. P/L 020°—200° T through 45° 37′ S 26° 54·0′ W. LHA 63° 31·5′
6. DR 46° 12′ S 26° 54′ W. Obs. Pos. 46° 04′ S 26° 49·7′ W

Paper 6 page 802

1. Co. 107° 13′ T. Dist. 935·9 miles
2. Co. 105° T. Dist. 249 miles. EP 36° 07′ S 49° 48′ W
3. Az. 171·3° T. P/L 081°—261° T through Lat. 46° 40·6′ N. MZD 70° 04·1′
4. Lat. 35° 42·5′ N
5. Az. 097·7° T. P/L 008°—188° T through 13° 28′ N 127° 18·9′ W or Intercept 3·6′ away. ITP 13° 28·5′ N 127° 18·6′ W
6. Approx. Sext. alt. 17° 40·6′ N of observer

Paper 7 page 803

1. Az. 221·5° T. Error 8·5° W. Dev. 1° W
2. Lat. 49° 07·0′ N
3. P/L 085·5°—265·5° T through 58° 27·6′ N 2° 57·0′ W
4. P/L 045·0°—225·0° T through 46° 15·0′ N 9° 19·8′ W or Intercept 3·6′ away. ITP 46° 17·6 N 9° 16·7′ W

Paper 8 page 803

1. Az. 251·2° T. Error 28·8° W. Dev. 3·7° E
2. Lat. 51° 06·3′ N
3. P/L 086°—266° T through 52° 46′ N. MZD 59° 19·5′
4. P/L 039·5°—219·5° T through 50° 15′ N 6° 54·3′ E or Intercept 8′ towards. ITP 50° 09·9′ N 6° 47·5′ E

Paper 9 page 803

1. Az. 153·7° T. Error 28·3° W. Dev. 6·7° E
2. Lat. 56° 19·7′ N
3. P/L 083·5°—263·5° T through 51° 35·2′ N. MZD 73° 15·9′
4. P/L 148°—328° T through 53° 20·0′ N 8° 37·0′ E or Intercept 3·5′ away. ITP 53° 21·8′ N 8° 35·0′ E

Paper 10 page 804

1. Az. 210° T. Error 15° W. Dev. 3° W
2. Lat. 6° 59·7′ N
3. P/L 097°—277° T through 55° 46·0′ N. MZD 55° 45·7′
4. P/L 167·5°—347·5° T through 56° 20·0′ N 1° 51·4′ W or Intercept 2·3′ towards. ITP 56° 19·5′ N 1° 52′ W

Paper 11 page 804

1. Az. 082° T. Error 20° W. Dev. 4° W
2. Lat. 53° 08′ N
3. P/L 085·7°—265·7° T through 58° 25·0′ N. MZD 58° 00·5′
4. P/L 028°—208° T through 48° 12′ N 18° 26·7′ W or Intercept 4′ away. ITP 48° 13·9′ N 18° 25·3′ W

Paper 12 page 805

1. Error 15·4° W. Dev. 3·4° W
2. GMT meridian passage 19h 23m 03s
3. Lat. 55° 41·8′ N
4. P/L 023°—203° T through 50° 03·0′ N 2° 26·9′ W or ITP 50° 02·0′ N 2° 26·8′ W.

Paper 13 page 805

1. Error 6° W. Dev. 3° E
2. GMT 02h 08m 37s
3. Lat. 39° 00·0′ N
4. P/L 163·5°—343·5° T through 51° 40·0′ N 9° 25·4′ W
   or Intercept 4·5′ towards. ITP 51° 38·7′ N 9° 25·0′ W

Paper 14 page 805

1. Error 16° W. Dev. 2° W
2. GMT 21h 03m 23s
3. Lat. 36° 03·8′ N
4. P/L 173·5°—353·5° T through 48° 12·0′ N 18° 27·0′ W
   or Intercept 4·6′ towards. ITP 48° 11·5′ N 18° 26·8′ W

Paper 15 page 806

1. Error 11° W. Dev. 2° E
2. GMT 21h 48m 31s
3. Lat. 50° 15·3′ N
4. P/L 171°—351° T through 56° 12·0′ N 10° 49·3′ E
   or Intercept 3·4′ away. ITP 56° 12·5′ N 10° 50·9′ E

Paper 16 page 806

1. Error 10·5° W. Dev. 3·5 E
2. GMT 22h 15m 03s
3. Lat. 51° 45·6′ N
4. P/L 047°—227° T through 53° 20·0′ N 8° 38·7′ E
   or Intercept 3·4′ towards ITP 53° 17·5′ N 8° 34·0′ E

PRINCIPLES OF NAVIGATION

Paper 1 page 807

1. 547·7 miles
2. 18·7 miles from DR

Paper 2 page 807

1. Chron. A, 3m 33s slow of GMT
2. Vertical angle 1° 18′ 24″ (1 cable = 600 ft)
3. Dec. 12° 50·0′ N by calculation
6. Geo. posn's: Sun 10° N 70° W, Star 20° S 17·5° W

Paper 3 page 808

1. 3725 miles to Lat. 18° 05·0′ N or 1554 miles to Lat. 18° 05·0′ S
2. Az. 110° 44·0′ T
3. Init. Co. 265° C
5. Co. 325° T. Dist. 178·5 miles

Paper 4 page 808

1. Dec. 23° 23·7′ S
2. GMT 1 d 17 h 59 m 41 s
3. Dist. 421·8 miles

Paper 5 page 809

1. Brg. 310·3° T
2. Lat. 53° 55·0′ N or S
3. Zen. Dist. 51° 56·5′. ITP 49° 11·0′ N 8° 35·5′ W

Paper 6 page 809

1. Spd. 5·97 kn
2. GMT 10d 22h 10m 39s
3. Vertical angle 1° 46·9′

CHARTWORK

Paper 1 page 810

1. Co. 091° C. Dev. 12·5° W. Dist. 40·5 miles
2. EP 51° 58·5′ N 6° 59·7′ W. Co. 258° T
3. Co. 140° C. Dev. 5° W. Steaming Time 1 h 06 m
4. Ht of tide

Paper 2 page 810

1. DF Pos. 55° 42·5′ N 7° 27·0′ W. Co. 135° C. Dist. to beam pos'n. 49·3 miles
2. Co. 069° C. Dev. 12° W. Spd. 9·75 kn
3. Pos. by running fix 55° 19·0′ N 5° 15′ W
4. Ht. of tide

COMPASS WORK

Paper 1 page 811

1. Mag. Brg. 355° M. Deviations: 12° W, 5° E, 16° E, 17° E, 12° E, 1° E, 16° W, 23° W

MATHEMATICS

Paper 1 page 812

1. 11,737 sq ft
2. 182 men
3. Zero
4. 525·94 miles
5. AB 71° 40·0′
7. 274·4 lbs

Paper 2 page 812

1. Sq roots 3·75 and 4·4
2. 10 ins and 7 ins
3. 0·04433
4. 1157 bales
5. Dist. 5·45 miles. Vert. angle 0° 25·5′
6. 381 cu ins
7. MO 45° 18·0′

Paper 3 page 813

1. 12 m
2. $x = 3, y = 2$
3. 360 ft
4. Dec. 15° 30·0′ N
5. 2·37 tons, 518·2 gallons
6. BC 47° 12·3′

Paper 4 page 813

1. 4611 sq m
2. Spd. 7 kn
3. 2·542
4. 1130·9 cu ft
5. 51° 41·0′ to starboard
6. 1992·5 miles

Paper 5 page 814

1. 65·5 cu ft, 78·5 sq ft
2. Proof
3. Value 17·0
4. 0·612 miles apart
5. 12 cm
6. 51° 19·0′

Paper 6 page 814

1. 10 ins. 1480 miles
2. 51 and 34
3. 0·0047
4. Figure required
5. 53 m
6. 61° 05·0′

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The "**Main Index**" covers all topics included in this volume. Reference can also be made to a number of other indexes which are listed in the "**Master Index**".

Please note that the "**Yachtmaster's and Diver's Index**" is divided into five sections:

1. Index to Chartwork Figures 1000
2. Chartwork Index 1001
3. Sextant Index 1003
4. Tidal Streams Index 1005
5. Tides Index 1005

The five indexes (above) provide fast, individual reference facilities to the named topics and, in the case of the "**Tides Index**", more detailed information. The preceding "**Quick Index**" provides fast reference facilities to broad topic areas, only.

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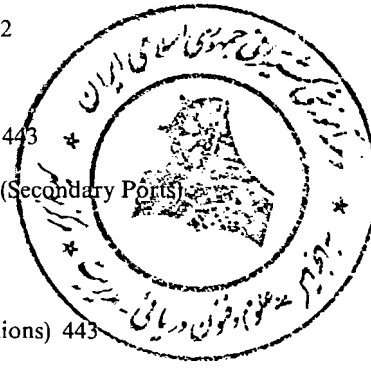
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FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	0°–9°	10°–19°	20°–29°	30°–39°	40°–49°	50°–59°	60°–69°	70°–79°	80°–89°	90°–99°	100°–109°	110°–119°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 10·1	0 06·1	0 03·8	0 03·1	0 04·2	0 06·9	0 11·3	0 17·1	0 24·2	0 32·4	0 41·3	0 50·8
1	09·7	05·8	03·6	03·1	04·4	07·3	11·8	17·8	25·0	33·2	42·2	51·7
2	09·2	05·5	03·5	03·2	04·6	07·7	12·3	18·4	25·8	34·1	43·2	52·7
3	08·8	05·3	03·4	03·2	04·8	08·1	12·9	19·1	26·6	35·0	44·1	53·7
4	08·3	05·0	03·3	03·3	05·1	08·5	13·4	19·8	27·4	35·9	45·0	54·6
5	0 07·9	0 04·7	0 03·2	0 03·4	0 05·3	0 08·9	0 14·0	0 20·5	0 28·2	0 36·7	0 46·0	0 55·6
6	07·5	04·5	03·2	03·5	05·6	09·4	14·6	21·2	29·0	37·6	46·9	56·6
7	07·2	04·3	03·1	03·7	05·9	09·8	15·2	22·0	29·8	38·5	47·9	57·6
8	06·8	04·1	03·1	03·8	06·2	10·3	15·8	22·7	30·7	39·5	48·9	58·5
9	06·5	03·9	03·1	04·0	06·6	10·8	16·5	23·5	31·5	40·4	49·8	0 59·5
10	0 06·1	0 03·8	0 03·1	0 04·2	0 06·9	0 11·3	0 17·1	0 24·2	0 32·4	0 41·3	0 50·8	1 00·5
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·5	0·6	0·6	0·6	0·6	0·5	0·4	0·3	0·2	0·2	0·1	0·1
10	·5	·6	·6	·6	·6	·5	·4	·4	·3	·2	·2	·1
20	·5	·6	·6	·6	·6	·5	·5	·4	·3	·3	·3	·2
30	·6	·6	·6	·6	·6	·5	·5	·5	·4	·4	·3	·3
40	0·6	0·6	0·6	0·6	0·6	0·6	0·5	0·5	0·5	0·5	0·5	0·4
45	·6	·6	·6	·6	·6	·6	·6	·6	·5	·5	·5	·5
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·6	·6	·6	·6	·6	·6	·6	·7	·7	·7	·7	·7
60	·6	·6	·6	·6	·6	·6	·7	·7	·8	·8	·8	·8
62	0·7	0·6	0·6	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	0·9
64	·7	·6	·6	·6	·6	·7	·7	·8	·9	0·9	1·0	1·0
66	·7	·6	·6	·6	·6	·7	·8	·9	0·9	1·0	1·0	1·1
68	0·7	0·6	0·6	0·6	0·7	0·7	0·8	0·9	1·0	1·1	1·1	1·2
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7
Feb.	·6	·7	·7	·7	·8	·8	·8	·8	·8	·8	·8	·8
Mar.	·5	·5	·6	·6	·7	·8	·8	·8	·9	·9	·9	0·9
Apr.	0·3	0·4	0·4	0·5	0·6	0·6	0·7	0·8	0·8	0·9	0·9	1·0
May	·2	·3	·3	·4	·4	·5	·6	·6	·7	·8	·8	0·9
June	·2	·2	·2	·3	·3	·4	·4	·5	·5	·6	·7	·8
July	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·5	0·6
Aug.	·4	·3	·3	·3	·2	·2	·3	·3	·3	·4	·4	·4
Sept.	·5	·5	·4	·4	·3	·3	·3	·3	·3	·3	·3	·3
Oct.	0·7	0·6	0·6	0·5	0·5	0·4	0·4	0·3	0·3	0·3	0·3	0·3
Nov.	0·9	·8	·8	·7	·7	·6	·5	·5	·4	·4	·3	·3
Dec.	1·0	0·9	0·9	0·9	0·8	0·8	0·7	0·6	0·6	0·5	0·4	0·4
Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	0·4	0·2	0·1	359·9	359·7	359·6	359·5	359·3	359·2	359·2	359·1	359·1
20	0·4	0·2	0·1	359·9	359·7	359·6	359·4	359·3	359·2	359·1	359·1	359·0
40	0·5	0·3	0·1	359·9	359·7	359·5	359·3	359·1	359·0	358·9	358·8	358·8
50	0·6	0·4	0·1	359·8	359·6	359·4	359·1	359·0	358·8	358·7	358·6	358·6
55	0·7	0·4	0·1	359·8	359·6	359·3	359·0	358·8	358·6	358·5	358·4	358·4
60	0·8	0·5	0·1	359·8	359·5	359·2	358·9	358·6	358·4	358·3	358·2	358·1
65	0·9	0·6	0·2	359·8	359·4	359·1	358·7	358·4	358·1	358·0	357·9	357·8

Latitude = Apparent altitude (corrected for refraction) $-1° + a_0 + a_1 + a_2$

The table is entered with L.H.A. Aries to determine the column to be used; each column refers to a range of 10°. a_0 is taken, with mental interpolation, from the upper table with the units of L.H.A. Aries in degrees as argument; a_1, a_2 are taken, without interpolation, from the second and third tables with arguments latitude and month respectively. a_0, a_1, a_2 are always positive. The final table gives the azimuth of *Polaris*.

POLARIS (POLE STAR) TABLES—Use Almanac Extracts on page 880

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	120°–129°	130°–139°	140°–149°	150°–159°	160°–169°	170°–179°	180°–189°	190°–199°	200°–209°	210°–219°	220°–229°	230°–239°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	1 00·5	1 10·1	1 19·4	1 28·0	1 35·8	1 42·4	1 47·7	1 51·6	1 53·9	1 54·5	1 53·5	1 50·8
1	01·5	11·1	20·3	28·9	36·5	43·0	48·2	51·9	54·0	54·5	53·3	50·5
2	02·4	12·0	21·2	29·7	37·2	43·6	48·6	52·2	54·1	54·4	53·1	50·1
3	03·4	13·0	22·1	30·5	37·9	44·1	49·0	52·4	54·2	54·4	52·9	49·7
4	04·4	13·9	22·9	31·3	38·6	44·7	49·4	52·7	54·3	54·3	52·6	49·3
5	1 05·3	1 14·8	1 23·8	1 32·0	1 39·2	1 45·2	1 49·8	1 52·9	1 54·4	1 54·2	1 52·4	1 48·6
6	06·3	15·7	24·7	32·8	39·9	45·8	50·2	53·1	54·4	54·1	52·1	48·5
7	07·3	16·7	25·5	33·6	40·5	46·3	50·6	53·3	54·5	54·0	51·8	48·0
8	08·2	17·6	26·4	34·3	41·2	46·8	50·9	53·5	54·5	53·8	51·5	47·6
9	09·2	18·5	27·2	35·1	41·8	47·3	51·3	53·7	54·5	53·7	51·2	47·1
10	1 10·1	1 19·4	1 28·0	1 35·8	1 42·4	1 47·7	1 51·6	1 53·9	1 54·5	1 53·5	1 50·8	1 46·6
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·1	0·1	0·2	0·3	0·3	0·4	0·5	0·6	0·6	0·6	0·6	0·5
10	·1	·2	·2	·3	·4	·5	·5	·6	·6	·6	·6	·5
20	·2	·3	·3	·4	·4	·5	·5	·6	·6	·6	·6	·5
30	·3	·3	·4	·4	·5	·5	·6	·6	·6	·6	·6	·5
40	0·4	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·6
45	·5	·5	·5	·5	·6	·6	·6	·6	·6	·6	·6	·6
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·7	·7	·7	·7	·7	·6	·6	·6	·6	·6	·6	·6
60	·8	·8	·8	·8	·7	·7	·6	·6	·6	·6	·6	·6
62	0·9	0·9	0·8	0·8	0·8	0·7	0·7	0·6	0·6	0·6	0·6	0·7
64	1·0	1·0	0·9	·9	·8	·7	·7	·6	·6	·6	·6	·7
66	1·1	1·0	1·0	0·9	·8	·8	·7	·6	·6	·6	·6	·7
68	1·2	1·1	1·1	1·0	0·9	0·8	0·7	0·6	0·6	0·6	0·7	0·7
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·6	0·6	0·6	0·6	0·6	0·5	0·5	0·5	0·5	0·5	0·5	0·5
Feb.	·8	·8	·7	·7	·7	·6	·6	·5	·5	·5	·4	·4
Mar.	0·9	0·9	0·9	0·8	0·8	·8	·7	·7	·6	·6	·5	·4
Apr.	1·0	1·0	1·0	1·0	1·0	0·9	0·9	0·8	0·8	0·7	0·6	0·6
May	0·9	1·0	1·0	1·0	1·0	1·0	1·0	0·9	0·9	·8	·8	·7
June	·8	0·9	0·9	1·0	1·0	1·0	1·0	1·0	1·0	0·9	0·9	·8
July	0·7	0·7	0·8	0·9	0·9	0·9	1·0	1·0	1·0	1·0	1·0	0·9
Aug.	·5	·6	·6	·7	·7	·8	0·8	0·9	0·9	0·9	1·0	1·0
Sept.	·4	·4	·5	·5	·6	·6	·7	·7	·8	·8	0·9	0·9
Oct.	0·3	0·3	0·3	0·4	0·4	0·4	0·5	0·6	0·6	0·7	0·7	0·8
Nov.	·2	·2	·2	·2	·3	·3	·3	·4	·4	·5	·5	·6
Dec.	0·3	0·3	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·4	0·4
Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	359·1	359·1	359·2	359·3	359·4	359·5	359·6	359·8	359·9	0·1	0·3	0·4
20	359·0	359·1	359·1	359·2	359·3	359·5	359·6	359·8	359·9	0·1	0·3	0·4
40	358·8	358·8	358·9	359·0	359·2	359·3	359·5	359·7	359·9	0·1	0·3	0·5
50	358·6	358·6	358·7	358·8	359·0	359·2	359·4	359·7	359·9	0·2	0·4	0·6
55	358·4	358·5	358·6	358·7	358·9	359·1	359·4	359·6	359·9	0·2	0·4	0·7
60	358·2	358·2	358·3	358·5	358·7	359·0	359·3	359·6	359·9	0·2	0·5	0·8
65	357·8	357·9	358·1	358·3	358·5	358·8	359·1	359·5	359·9	0·2	0·6	0·9

ILLUSTRATION

On 1958 January 10 at G.M.T. $22^h\ 17^m\ 50^s$ in longitude W. 27° 34′ the corrected sextant altitude of *Polaris* was 49° 31′·6.

From the daily pages	° ′
G.H.A. Aries (22^h)	79 54·9
Increment ($17^m\ 50^s$)	4 28·2
Longitude (west)	−27 34
L.H.A. Aries	56 49

Corr. Sext. Alt.	49°31′6
a_0 (argument 56°49′)	0 09·7
a_1 (lat. 50° approx.)	0·6
a_2 (January)	0·7
Sum −1° = Lat. =	48°42·6

POLARIS (POLE STAR) TABLES—Use Almanac Extracts on page 880

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	240°–249°	250°–259°	260°–269°	270°–279°	280°–289°	290°–299°	300°–309°	310°–319°	320°–329°	330°–339°	340°–349°	350°–359°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	1 46·6	1 41·0	1 34·0	1 26·1	1 17·3	1 07·9	0 58·2	0 48·5	0 39·1	0 30·4	0 22·4	0 15·6
1	46·1	40·3	33·3	25·2	16·3	06·9	57·2	47·6	38·2	29·5	21·7	15·0
2	45·6	39·7	32·5	24·4	15·4	06·0	56·3	46·6	37·3	28·7	21·0	14·4
3	45·1	39·0	31·7	23·5	14·5	05·0	55·3	45·7	36·4	27·9	20·2	13·8
4	44·5	38·3	31·0	22·6	13·6	04·0	54·3	44·7	35·5	27·1	19·5	13·2
5	1 43·9	1 37·6	1 30·2	1 21·7	1 12·6	1 03·1	0 53·3	0 43·8	0 34·7	0 26·3	0 18·9	0 12·7
6	43·4	36·9	29·4	20·9	11·7	02·1	52·4	42·8	33·8	25·5	18·2	12·1
7	42·8	36·2	28·6	20·0	10·7	01·1	51·4	41·9	32·9	24·7	17·5	11·6
8	42·2	35·5	27·7	19·1	09·8	1 00·1	50·4	41·0	32·1	23·9	16·9	11·1
9	41·6	34·8	26·9	18·2	08·8	0 59·2	49·5	40·1	31·2	23·2	16·2	10·6
10	1 41·0	1 34·0	1 26·1	1 17·3	1 07·9	0 58·2	0 48·5	0 39·1	0 30·4	0 22·4	0 15·6	0 10·1
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·4	0·3	0·2	0·2	0·1	0·1	0·1	0·1	0·2	0·3	0·3	0·4
10	·4	·4	·3	·2	·2	·1	·1	·2	·2	·3	·4	·5
20	·5	·4	·3	·3	·3	·2	·2	·3	·3	·4	·4	·5
30	·5	·5	·4	·4	·3	·3	·3	·3	·4	·4	·5	·5
40	0·5	0·5	0·5	0·5	0·5	0·4	0·4	0·5	0·5	0·5	0·5	0·5
45	·6	·6	·5	·5	·5	·5	·5	·5	·5	·5	·6	·6
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·6	·7	·7	·7	·7	·7	·7	·7	·7	·7	·7	·6
60	·7	·7	·8	·8	·8	·8	·8	·8	·8	·8	·7	·7
62	0·7	0·8	0·8	0·9	0·9	0·9	0·9	0·9	0·8	0·8	0·8	0·7
64	·7	·8	·9	0·9	1·0	1·0	1·0	1·0	0·9	·9	·8	·7
66	·8	·9	0·9	1·0	1·0	1·1	1·1	1·0	1·0	0·9	·8	·8
68	0·8	0·9	1·0	1·1	1·1	1·2	1·2	1·1	1·1	1·0	0·9	0·8
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·5	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·7
Feb.	·4	·4	·4	·4	·4	·4	·4	·4	·5	·5	·5	·6
Mar.	·4	·4	·3	·3	·3	·3	·3	·3	·3	·4	·4	·4
Apr.	0·5	0·4	0·4	0·3	0·3	0·2	0·2	0·2	0·2	0·2	0·2	0·3
May	·6	·6	·5	·4	·4	·3	·3	·2	·2	·2	·2	·2
June	·8	·7	·7	·6	·5	·4	·4	·3	·3	·2	·2	·2
July	0·9	0·8	0·8	0·7	0·7	0·6	0·5	0·5	0·4	0·3	0·3	0·3
Aug.	·9	·9	·9	·8	·8	·8	·7	·6	·6	·5	·5	·4
Sept.	·9	·9	·9	·9	·9	·9	·8	·8	·7	·7	·6	·6
Oct.	0·8	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·8	0·8	0·8
Nov.	·7	·7	·8	·8	·9	·9	1·0	1·0	1·0	1·0	0·9	0·9
Dec.	0·5	0·6	0·6	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·0	1·0
Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	0·5	0·7	0·8	0·8	0·9	0·9	0·9	0·9	0·8	0·7	0·6	0·5
20	0·6	0·7	0·8	0·9	0·9	1·0	1·0	0·9	0·9	0·8	0·7	0·5
40	0·7	0·9	1·0	1·1	1·2	1·2	1·2	1·2	1·1	1·0	0·8	0·7
50	0·8	1·0	1·2	1·3	1·4	1·4	1·4	1·4	1·3	1·2	1·0	0·8
55	0·9	1·1	1·3	1·5	1·6	1·6	1·6	1·6	1·5	1·3	1·1	0·9
60	1·1	1·3	1·5	1·7	1·8	1·8	1·8	1·8	1·7	1·5	1·3	1·0
65	1·3	1·5	1·8	1·9	2·1	2·2	2·2	2·1	2·0	1·8	1·6	1·3

Latitude = Apparent altitude (corrected for refraction) $-1° + a_0 + a_1 + a_2$

The table is entered with L.H.A. Aries to determine the column to be used; each column refers to a range of 10°. a^0 is taken, with mental interpolation, from the upper table with the units of L.H.A. Aries in degrees as argument; a_1, a_2 are taken, without interpolation, from the second and third tables with arguments latitude and month respectively. a_0, a_1, a_2 are always positive. The final table gives the azimuth of *Polaris*.

ALTITUDE CORRECTION TABLES 0°–35°—MOON

App. Alt.	0°–4° Corrⁿ	5°–9° Corrⁿ	10°–14° Corrⁿ	15°–19° Corrⁿ	20°–24° Corrⁿ	25°–29° Corrⁿ	30°–34° Corrⁿ	App. Alt.
′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	′
00	0 33·8	5 58·2	10 62·1	15 62·8	20 62·2	25 60·8	30 58·9	00
10	35·9	58·5	62·2	62·8	62·1	60·8	58·8	10
20	37·8	58·7	62·2	62·8	62·1	60·7	58·8	20
30	39·6	58·9	62·3	62·8	62·1	60·7	58·7	30
40	41·2	59·1	62·3	62·8	62·0	60·6	58·6	40
50	42·6	59·3	62·4	62·7	62·0	60·6	58·5	50
00	1 44·0	6 59·5	11 62·4	16 62·7	21 62·0	26 60·5	31 58·5	00
10	45·2	59·7	62·4	62·7	61·9	60·4	58·4	10
20	46·3	59·9	62·5	62·7	61·9	60·4	58·3	20
30	47·3	60·0	62·5	62·7	61·9	60·3	58·2	30
40	48·3	60·2	62·5	62·7	61·8	60·3	58·2	40
50	49·2	60·3	62·6	62·7	61·8	60·2	58·1	50
00	2 50·0	7 60·5	12 62·6	17 62·7	22 61·7	27 60·1	32 58·0	00
10	50·8	60·6	62·6	62·6	61·7	60·1	57·9	10
20	51·4	60·7	62·6	62·6	61·6	60·0	57·8	20
30	52·1	60·9	62·7	62·6	61·6	59·9	57·8	30
40	52·7	61·0	62·7	62·6	61·5	59·9	57·7	40
50	53·3	61·1	62·7	62·6	61·5	59·8	57·6	50
00	3 53·8	8 61·2	13 62·7	18 62·5	23 61·5	28 59·7	33 57·5	00
10	54·3	61·3	62·7	62·5	61·4	59·7	57·4	10
20	54·8	61·4	62·7	62·5	61·4	59·6	57·4	20
30	55·2	61·5	62·8	62·5	61·3	59·6	57·3	30
40	55·6	61·6	62·8	62·4	61·3	59·5	57·2	40
50	56·0	61·6	62·8	62·4	61·2	59·4	57·1	50
00	4 56·4	9 61·7	14 62·8	19 62·4	24 61·2	29 59·3	34 57·0	00
10	56·7	61·8	62·8	62·3	61·1	59·3	56·9	10
20	57·1	61·9	62·8	62·3	61·1	59·2	56·9	20
30	57·4	61·9	62·8	62·3	61·0	59·1	56·8	30
40	57·7	62·0	62·8	62·2	60·9	59·1	56·7	40
50	57·9	62·1	62·8	62·2	60·9	59·0	56·6	50

H.P.	L	U	L	U	L	U	L	U	L	U	L	U	L	U	H.P.
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
54·0	0·3	0·9	0·3	0·9	0·4	1·0	0·5	1·1	0·6	1·2	0·7	1·3	0·9	1·5	54·0
54·3	0·7	1·1	0·7	1·2	0·7	1·2	0·8	1·3	0·9	1·4	1·1	1·5	1·2	1·7	54·3
54·6	1·1	1·4	1·1	1·4	1·1	1·4	1·2	1·5	1·3	1·6	1·4	1·7	1·5	1·8	54·6
54·9	1·4	1·6	1·5	1·6	1·5	1·6	1·6	1·7	1·6	1·8	1·8	1·9	1·9	2·0	54·9
55·2	1·8	1·8	1·8	1·8	1·9	1·9	1·9	1·9	2·0	2·0	2·1	2·1	2·2	2·2	55·2
55·5	2·2	2·0	2·2	2·0	2·3	2·1	2·3	2·1	2·4	2·2	2·4	2·3	2·5	2·4	55·5
55·8	2·6	2·2	2·6	2·2	2·6	2·3	2·7	2·3	2·7	2·4	2·8	2·4	2·9	2·5	55·8
56·1	3·0	2·4	3·0	2·5	3·0	2·5	3·0	2·5	3·1	2·6	3·1	2·6	3·2	2·7	56·1
56·4	3·4	2·7	3·4	2·7	3·4	2·7	3·4	2·7	3·4	2·8	3·5	2·8	3·5	2·9	56·4
56·7	3·7	2·9	3·7	2·9	3·8	2·9	3·8	2·9	3·8	3·0	3·8	3·0	3·9	3·0	56·7
57·0	4·1	3·1	4·1	3·1	4·1	3·1	4·1	3·1	4·2	3·1	4·2	3·2	4·2	3·2	57·0
57·3	4·5	3·3	4·5	3·3	4·5	3·3	4·5	3·3	4·5	3·3	4·5	3·4	4·6	3·4	57·3
57·6	4·9	3·5	4·9	3·5	4·9	3·5	4·9	3·5	4·9	3·5	4·9	3·5	4·9	3·6	57·6
57·9	5·3	3·8	5·3	3·8	5·2	3·8	5·2	3·7	5·2	3·7	5·2	3·7	5·2	3·7	57·9
58·2	5·6	4·0	5·6	4·0	5·6	4·0	5·6	4·0	5·6	3·9	5·6	3·9	5·6	3·9	58·2
58·5	6·0	4·2	6·0	4·2	6·0	4·2	6·0	4·2	6·0	4·1	5·9	4·1	5·9	4·1	58·5
58·8	6·4	4·4	6·4	4·4	6·4	4·4	6·3	4·4	6·3	4·3	6·3	4·3	6·2	4·2	58·8
59·1	6·8	4·6	6·8	4·6	6·7	4·6	6·7	4·6	6·7	4·5	6·6	4·5	6·6	4·4	59·1
59·4	7·2	4·8	7·1	4·8	7·1	4·8	7·1	4·8	7·0	4·7	7·0	4·7	6·9	4·6	59·4
59·7	7·5	5·1	7·5	5·0	7·5	5·0	7·5	5·0	7·4	4·9	7·3	4·8	7·2	4·7	59·7
60·0	7·9	5·3	7·9	5·3	7·9	5·2	7·8	5·2	7·8	5·1	7·7	5·0	7·6	4·9	60·0
60·3	8·3	5·5	8·3	5·5	8·2	5·4	8·2	5·4	8·1	5·3	8·0	5·2	7·9	5·1	60·3
60·6	8·7	5·7	8·7	5·7	8·6	5·7	8·6	5·6	8·5	5·5	8·4	5·4	8·2	5·3	60·6
60·9	9·1	5·9	9·0	5·9	9·0	5·9	8·9	5·8	8·8	5·7	8·7	5·6	8·6	5·4	60·9
61·2	9·5	6·2	9·4	6·1	9·4	6·1	9·3	6·0	9·2	5·9	9·1	5·8	8·9	5·6	61·2
61·5	9·8	6·4	9·8	6·3	9·7	6·3	9·7	6·2	9·5	6·1	9·4	5·9	9·2	5·8	61·5

DIP

Ht. of Eye	Corrⁿ	Ht. of Eye	Ht. of Eye	Corrⁿ	Ht. of Eye
m	′	ft.	m	′	ft.
2·4	−2·8	8·0	9·5	−5·5	31·5
2·6	−2·9	8·6	9·9	−5·6	32·7
2·8	−3·0	9·2	10·3	−5·7	33·9
3·0	−3·1	9·8	10·6	−5·8	35·1
3·2	−3·2	10·5	11·0	−5·9	36·3
3·4	−3·3	11·2	11·4	−6·0	37·6
3·6	−3·4	11·9	11·8	−6·1	38·9
3·8	−3·5	12·6	12·2	−6·2	40·1
4·0	−3·6	13·3	12·6	−6·3	41·5
4·3	−3·7	14·1	13·0	−6·4	42·8
4·5	−3·8	14·9	13·4	−6·5	44·2
4·7	−3·9	15·7	13·8	−6·6	45·5
5·0	−4·0	16·5	14·2	−6·7	46·9
5·2	−4·1	17·4	14·7	−6·8	48·4
5·5	−4·2	18·3	15·1	−6·9	49·8
5·8	−4·3	19·1	15·5	−7·0	51·3
6·1	−4·4	20·1	16·0	−7·1	52·8
6·3	−4·5	21·0	16·5	−7·2	54·3
6·6	−4·6	22·0	16·9	−7·3	55·8
6·9	−4·7	22·9	17·4	−7·4	57·4
7·2	−4·8	23·9	17·9	−7·5	58·9
7·5	−4·9	24·9	18·4	−7·6	60·5
7·9	−5·0	26·0	18·8	−7·7	62·1
8·2	−5·1	27·1	19·3	−7·8	63·8
8·5	−5·2	28·1	19·8	−7·9	65·4
8·8	−5·3	29·2	20·4	−8·0	67·1
9·2	−5·4	30·4	20·9	−8·1	68·8
9·5		31·5	21·4		70·5

MOON CORRECTION TABLE

The correction is in two parts; the first correction is taken from the upper part of the table with argument apparent altitude, and the second from the lower part, with argument H.P., in the same column as that from which the first correction was taken. Separate corrections are given in the lower part for lower (L) and upper (U) limbs. All corrections are to be **added** to apparent altitude, *but 30′ is to be subtracted from the altitude of the upper limb.*

For corrections for pressure and temperature see page A4.

For bubble sextant observations ignore dip, take the mean of upper and lower limb corrections and subtract 15′ from the altitude.

App. Alt. = Apparent altitude = Sextant altitude corrected for index error and dip.

ALTITUDE CORRECTION TABLES 35°–90°—MOON

App. Alt.	35°–39°	40°–44°	45°–49°	50°–54°	55°–59°	60°–64°	65°–69°	70°–74°	75°–79°	80°–84°	85°–89°	App. Alt.
	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	
′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	′
00	35 56·5	40 53·7	45 50·5	50 46·9	55 43·1	60 38·9	65 34·6	70 30·1	75 25·3	80 20·5	85 15·6	00
10	56·4	53·6	50·4	46·8	42·9	38·8	34·4	29·9	25·2	20·4	15·5	10
20	56·3	53·5	50·2	46·7	42·8	38·7	34·3	29·7	25·0	20·2	15·3	20
30	56·2	53·4	50·1	46·5	42·7	38·5	34·1	29·6	24·9	20·0	15·1	30
40	56·2	53·3	50·0	46·4	42·5	38·4	34·0	29·4	24·7	19·9	15·0	40
50	56·1	53·2	49·9	46·3	42·4	38·2	33·8	29·3	24·5	19·7	14·8	50
00	36 56·0	41 53·1	46 49·8	51 46·2	56 42·3	61 38·1	66 33·7	71 29·1	76 24·4	81 19·6	86 14·6	00
10	55·9	53·0	49·7	46·0	42·1	37·9	33·5	29·0	24·2	19·4	14·5	10
20	55·8	52·8	49·5	45·9	42·0	37·8	33·4	28·8	24·1	19·2	14·3	20
30	55·7	52·7	49·4	45·8	41·8	37·7	33·2	28·7	23·9	19·1	14·1	30
40	55·6	52·6	49·3	45·7	41·7	37·5	33·1	28·5	23·8	18·9	14·0	40
50	55·5	52·5	49·2	45·5	41·6	37·4	32·9	28·3	23·6	18·7	13·8	50
00	37 55·4	42 52·4	47 49·1	52 45·4	57 41·4	62 37·2	67 32·8	72 28·2	77 23·4	82 18·6	87 13·7	00
10	55·3	52·3	49·0	45·3	41·3	37·1	32·6	28·0	23·3	18·4	13·5	10
20	55·2	52·2	48·8	45·2	41·2	36·9	32·5	27·9	23·1	18·2	13·3	20
30	55·1	52·1	48·7	45·0	41·0	36·8	32·3	27·7	22·9	18·1	13·2	30
40	55·0	52·0	48·6	44·9	40·9	36·6	32·2	27·6	22·8	17·9	13·0	40
50	55·0	51·9	48·5	44·8	40·8	36·5	32·0	27·4	22·6	17·8	12·8	50
00	38 54·9	43 51·8	48 48·4	53 44·6	58 40·6	63 36·4	68 31·9	73 27·2	78 22·5	83 17·6	88 12·7	00
10	54·8	51·7	48·2	44·5	40·5	36·2	31·7	27·1	22·3	17·4	12·5	10
20	54·7	51·6	48·1	44·4	40·3	36·1	31·6	26·9	22·1	17·3	12·3	20
30	54·6	51·5	48·0	44·2	40·2	35·9	31·4	26·8	22·0	17·1	12·2	30
40	54·5	51·4	47·9	44·1	40·1	35·8	31·3	26·6	21·8	16·9	12·0	40
50	54·4	51·2	47·8	44·0	39·9	35·6	31·1	26·5	21·7	16·8	11·8	50
00	39 54·3	44 51·1	49 47·6	54 43·9	59 39·8	64 35·5	69 31·0	74 26·3	79 21·5	84 16·6	89 11·7	00
10	54·2	51·0	47·5	43·7	39·6	35·3	30·8	26·1	21·3	16·5	11·5	10
20	54·1	50·9	47·4	43·6	39·5	35·2	30·7	26·0	21·2	16·3	11·4	20
30	54·0	50·8	47·3	43·5	39·4	35·0	30·5	25·8	21·0	16·1	11·2	30
40	53·9	50·7	47·2	43·3	39·2	34·9	30·4	25·7	20·9	16·0	11·0	40
50	53·8	50·6	47·0	43·2	39·1	34·7	30·2	25·5	20·7	15·8	10·9	50

H.P.	L U	L U	L U	L U	L U	L U	L U	L U	L U	L U	L U	H.P.
′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′
54·0	1·1 1·7	1·3 1·9	1·5 2·1	1·7 2·4	2·0 2·6	2·3 2·9	2·6 3·2	2·9 3·5	3·2 3·8	3·5 4·1	3·8 4·5	54·0
54·3	1·4 1·8	1·6 2·0	1·8 2·2	2·0 2·5	2·3 2·7	2·5 3·0	2·8 3·2	3·0 3·5	3·3 3·8	3·6 4·1	3·9 4·4	54·3
54·6	1·7 2·0	1·9 2·2	2·1 2·4	2·3 2·6	2·5 2·8	2·7 3·0	3·0 3·3	3·2 3·5	3·5 3·8	3·7 4·1	4·0 4·3	54·6
54·9	2·0 2·2	2·2 2·3	2·3 2·5	2·5 2·7	2·7 2·9	2·9 3·1	3·2 3·3	3·4 3·5	3·6 3·8	3·9 4·0	4·1 4·3	54·9
55·2	2·3 2·3	2·5 2·4	2·6 2·6	2·8 2·8	3·0 2·9	3·2 3·1	3·4 3·3	3·6 3·5	3·8 3·7	4·0 4·0	4·2 4·2	55·2
55·5	2·7 2·5	2·8 2·6	2·9 2·7	3·1 2·9	3·2 3·0	3·4 3·2	3·6 3·4	3·7 3·5	3·9 3·7	4·1 3·9	4·3 4·1	55·5
55·8	3·0 2·6	3·1 2·7	3·2 2·8	3·3 3·0	3·5 3·1	3·6 3·3	3·8 3·4	3·9 3·6	4·1 3·7	4·2 3·9	4·4 4·0	55·8
56·1	3·3 2·8	3·4 2·9	3·5 3·0	3·6 3·1	3·7 3·2	3·8 3·3	4·0 3·4	4·1 3·6	4·2 3·7	4·4 3·8	4·5 4·0	56·1
56·4	3·6 2·9	3·7 3·0	3·8 3·1	3·9 3·2	3·9 3·3	4·0 3·4	4·1 3·5	4·3 3·6	4·4 3·7	4·5 3·8	4·6 3·9	56·4
56·7	3·9 3·1	4·0 3·1	4·1 3·2	4·1 3·3	4·2 3·3	4·3 3·4	4·3 3·5	4·4 3·6	4·5 3·7	4·6 3·8	4·7 3·8	56·7
57·0	4·3 3·2	4·3 3·3	4·3 3·3	4·4 3·4	4·4 3·4	4·5 3·5	4·5 3·5	4·6 3·6	4·7 3·6	4·7 3·7	4·8 3·8	57·0
57·3	4·6 3·4	4·6 3·4	4·6 3·4	4·6 3·5	4·7 3·5	4·7 3·5	4·7 3·6	4·8 3·6	4·8 3·6	4·8 3·7	4·9 3·7	57·3
57·6	4·9 3·6	4·9 3·6	4·9 3·6	4·9 3·6	4·9 3·6	4·9 3·6	4·9 3·6	4·9 3·6	5·0 3·6	5·0 3·6	5·0 3·6	57·6
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VOL 1

SUPPLEMENT No. 1—1987

TO

NICHOLLS'S CONCISE GUIDE TO NAVIGATION

VOLUME 1
(Tenth Edition 1987)

CORRECTED TO 8th DECEMBER, 1987

Whenever reference is made to Nicholls's Concise Guide—Volume 1 this supplement must be consulted

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Information relating to British Admiralty charts and publications is promulgated in the weekly editions of *Admiralty Notices to Mariners*, the *Annual Summary of Admiralty Notices to Mariners* and *Supplements* to Admiralty publications. (NB Updates and corrections to other publications used by navigators, may be issued by other authorities, and publishers.).

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Whilst the publishers have endeavoured to ensure the accuracy of information contained in *Nicholls's Concise Guide to Navigation—10th Edition* liability for any errors or omissions which have escaped their attention cannot be accepted—THIS VOLUME IS FOR INSTRUCTIONAL PURPOSES ONLY.

The publishers will be pleased to receive suggestions for improving this volume and any information relating to the accuracy of either the text or calculations—a *Nicholls's Note* is included for this purpose.

Nigel Brown
Leslie Ingram-Brown
Joint Managing Directors
Brown Son & Ferguson Ltd
Glasgow G41 2SD

Additions, Corrections and Insert Block

222
Figure 18. *Insert a single arrow thus* ⟶ *on the Water Track.*

235–244
Figures 2–7. *Insert Obs. Pos'n's "⊙", DR Pos'n's "X" and E.P's "△", where appropriate.*

275
Under Meterology add "NB. HMSO publishes several other titles."

276
L 3–5. *Delete* "Vol I" *insert* "Volume 1"
Delete "Vol II" *insert* "Volume 2"
Delete "Vol III" *insert* "Volume 3"
Bottom, centre. *Paste in accompanying block.*

> More detailed information relating to Admiralty tidal publications (including Tidal Stream Atlases) is included on pages 471–472.

283
L 15–17. Instruction 5. *Delete last two sentences. Insert* "A full size Admiralty practice chart is included in the Pocket."

289
Instruction 10. *Add*
"NB Reading off or laying off reciprocal bearings is another common mistake."

310
Figure 10 on water track AC. *Between* 100 *and* T *insert degree sign* "°".

348
Below text. *Add*
" A *Days of the Week and Days of the Year* calendar is shown on page 939."

392
DF Bearing column C. *Insert* "49.6°" *below* "49°36.5'N".

455
Above "Swanage to Selsey...." *Delete* "NP 259" *insert* "NP 159".

489
L 6. *Delete* "3" *insert* "3."

531
L 22. *Delete* "tropic of *Capricorn*" *insert* "Tropic of Capricorn".
L 35. *Delete* "**Perhelion**" *insert* "**Perihelion**".

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N1 (December 1987)

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