CONVERSION OF ARC TO TIME

0°–59°				60°–119°				120°–179°				180°–239°				240°–299°				300°–359°					0'·00	0'·25	0'·50	0'·75
°	h	m		°	h	m		°	h	m		°	h	m		°	h	m		°	h	m		'	m	s	m	s	m	s
0	0	00		60	4	00		120	8	00		180	12	00		240	16	00		300	20	00		0	0	00	0	01	0	02	0	03
1	0	04		61	4	04		121	8	04		181	12	04		241	16	04		301	20	04		1	0	04	0	05	0	06	0	07
2	0	08		62	4	08		122	8	08		182	12	08		242	16	08		302	20	08		2	0	08	0	09	0	10	0	11
3	0	12		63	4	12		123	8	12		183	12	12		243	16	12		303	20	12		3	0	12	0	13	0	14	0	15
4	0	16		64	4	16		124	8	16		184	12	16		244	16	16		304	20	16		4	0	16	0	17	0	18	0	19
5	0	20		65	4	20		125	8	20		185	12	20		245	16	20		305	20	20		5	0	20	0	21	0	22	0	23
6	0	24		66	4	24		126	8	24		186	12	24		246	16	24		306	20	24		6	0	24	0	25	0	26	0	27
7	0	28		67	4	28		127	8	28		187	12	28		247	16	28		307	20	28		7	0	28	0	29	0	30	0	31
8	0	32		68	4	32		128	8	32		188	12	32		248	16	32		308	20	32		8	0	32	0	33	0	34	0	35
9	0	36		69	4	36		129	8	36		189	12	36		249	16	36		309	20	36		9	0	36	0	37	0	38	0	39
10	0	40		70	4	40		130	8	40		190	12	40		250	16	40		310	20	40		10	0	40	0	41	0	42	0	43
11	0	44		71	4	44		131	8	44		191	12	44		251	16	44		311	20	44		11	0	44	0	45	0	46	0	47
12	0	48		72	4	48		132	8	48		192	12	48		252	16	48		312	20	48		12	0	48	0	49	0	50	0	51
13	0	52		73	4	52		133	8	52		193	12	52		253	16	52		313	20	52		13	0	52	0	53	0	54	0	55
14	0	56		74	4	56		134	8	56		194	12	56		254	16	56		314	20	56		14	0	56	0	57	0	58	0	59
15	1	00		75	5	00		135	9	00		195	13	00		255	17	00		315	21	00		15	1	00	1	01	1	02	1	03
16	1	04		76	5	04		136	9	04		196	13	04		256	17	04		316	21	04		16	1	04	1	05	1	06	1	07
17	1	08		77	5	08		137	9	08		197	13	08		257	17	08		317	21	08		17	1	08	1	09	1	10	1	11
18	1	12		78	5	12		138	9	12		198	13	12		258	17	12		318	21	12		18	1	12	1	13	1	14	1	15
19	1	16		79	5	16		139	9	16		199	13	16		259	17	16		319	21	16		19	1	16	1	17	1	18	1	19
20	1	20		80	5	20		140	9	20		200	13	20		260	17	20		320	21	20		20	1	20	1	21	1	22	1	23
21	1	24		81	5	24		141	9	24		201	13	24		261	17	24		321	21	24		21	1	24	1	25	1	26	1	27
22	1	28		82	5	28		142	9	28		202	13	28		262	17	28		322	21	28		22	1	28	1	29	1	30	1	31
23	1	32		83	5	32		143	9	32		203	13	32		263	17	32		323	21	32		23	1	32	1	33	1	34	1	35
24	1	36		84	5	36		144	9	36		204	13	36		264	17	36		324	21	36		24	1	36	1	37	1	38	1	39
25	1	40		85	5	40		145	9	40		205	13	40		265	17	40		325	21	40		25	1	40	1	41	1	42	1	43
26	1	44		86	5	44		146	9	44		206	13	44		266	17	44		326	21	44		26	1	44	1	45	1	46	1	47
27	1	48		87	5	48		147	9	48		207	13	48		267	17	48		327	21	48		27	1	48	1	49	1	50	1	51
28	1	52		88	5	52		148	9	52		208	13	52		268	17	52		328	21	52		28	1	52	1	53	1	54	1	55
29	1	56		89	5	56		149	9	56		209	13	56		269	17	56		329	21	56		29	1	56	1	57	1	58	1	59
30	2	00		90	6	00		150	10	00		210	14	00		270	18	00		330	22	00		30	2	00	2	01	2	02	2	03
31	2	04		91	6	04		151	10	04		211	14	04		271	18	04		331	22	04		31	2	04	2	05	2	06	2	07
32	2	08		92	6	08		152	10	08		212	14	08		272	18	08		332	22	08		32	2	08	2	09	2	10	2	11
33	2	12		93	6	12		153	10	12		213	14	12		273	18	12		333	22	12		33	2	12	2	13	2	14	2	15
34	2	16		94	6	16		154	10	16		214	14	16		274	18	16		334	22	16		34	2	16	2	17	2	18	2	19
35	2	20		95	6	20		155	10	20		215	14	20		275	18	20		335	22	20		35	2	20	2	21	2	22	2	23
36	2	24		96	6	24		156	10	24		216	14	24		276	18	24		336	22	24		36	2	24	2	25	2	26	2	27
37	2	28		97	6	28		157	10	28		217	14	28		277	18	28		337	22	28		37	2	28	2	29	2	30	2	31
38	2	32		98	6	32		158	10	32		218	14	32		278	18	32		338	22	32		38	2	32	2	33	2	34	2	35
39	2	36		99	6	36		159	10	36		219	14	36		279	18	36		339	22	36		39	2	36	2	37	2	38	2	39
40	2	40		100	6	40		160	10	40		220	14	40		280	18	40		340	22	40		40	2	40	2	41	2	42	2	43
41	2	44		101	6	44		161	10	44		221	14	44		281	18	44		341	22	44		41	2	44	2	45	2	46	2	47
42	2	48		102	6	48		162	10	48		222	14	48		282	18	48		342	22	48		42	2	48	2	49	2	50	2	51
43	2	52		103	6	52		163	10	52		223	14	52		283	18	52		343	22	52		43	2	52	2	53	2	54	2	55
44	2	56		104	6	56		164	10	56		224	14	56		284	18	56		344	22	56		44	2	56	2	57	2	58	2	59
45	3	00		105	7	00		165	11	00		225	15	00		285	19	00		345	23	00		45	3	00	3	01	3	02	3	03
46	3	04		106	7	04		166	11	04		226	15	04		286	19	04		346	23	04		46	3	04	3	05	3	06	3	07
47	3	08		107	7	08		167	11	08		227	15	08		287	19	08		347	23	08		47	3	08	3	09	3	10	3	11
48	3	12		108	7	12		168	11	12		228	15	12		288	19	12		348	23	12		48	3	12	3	13	3	14	3	15
49	3	16		109	7	16		169	11	16		229	15	16		289	19	16		349	23	16		49	3	16	3	17	3	18	3	19
50	3	20		110	7	20		170	11	20		230	15	20		290	19	20		350	23	20		50	3	20	3	21	3	22	3	23
51	3	24		111	7	24		171	11	24		231	15	24		291	19	24		351	23	24		51	3	24	3	25	3	26	3	27
52	3	28		112	7	28		172	11	28		232	15	28		292	19	28		352	23	28		52	3	28	3	29	3	30	3	31
53	3	32		113	7	32		173	11	32		233	15	32		293	19	32		353	23	32		53	3	32	3	33	3	34	3	35
54	3	36		114	7	36		174	11	36		234	15	36		294	19	36		354	23	36		54	3	36	3	37	3	38	3	39
55	3	40		115	7	40		175	11	40		235	15	40		295	19	40		355	23	40		55	3	40	3	41	3	42	3	43
56	3	44		116	7	44		176	11	44		236	15	44		296	19	44		356	23	44		56	3	44	3	45	3	46	3	47
57	3	48		117	7	48		177	11	48		237	15	48		297	19	48		357	23	48		57	3	48	3	49	3	50	3	51
58	3	52		118	7	52		178	11	52		238	15	52		298	19	52		358	23	52		58	3	52	3	53	3	54	3	55
59	3	56		119	7	56		179	11	56		239	15	56		299	19	56		359	23	56		59	3	56	3	57	3	58	3	59

The above table is for converting expressions in arc to their equivalent in time; its main use in this Almanac is for the conversion of longitude for application to L.M.T. (*added* if *west*, *subtracted* if *east*) to give G.M.T. or vice versa, particularly in the case of sunrise, sunset, etc.

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

STARS AND PLANETS

App. Alt.	Corr^n
° ′	′
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	

VENUS

App. Alt.	Additional Corr^n
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

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

ALTITUDE CORRECTION TABLES 0°–35°—MOON

App. Alt.	0°–4°	5°–9°	10°–14°	15°–19°	20°–24°	25°–29°	30°–34°	App. Alt.
	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	Corrⁿ	
′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	′
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	Corrⁿ	Ht. of Eye	Corrⁿ
ft.	′	ft.	′	ft.	′
4·0	−2·0	24	−4·9	63	− 7·8
4·4	−2·1	26	−5·0	65	− 7·9
4·9	−2·2	27	−5·1	67	− 8·0
5·3	−2·3	28	−5·2	68	− 8·1
5·8	−2·4	29	−5·3	70	− 8·2
6·3	−2·5	30	−5·4	72	− 8·3
6·9	−2·6	31	−5·5	74	− 8·4
7·4	−2·7	32	−5·6	75	− 8·5
8·0	−2·8	33	−5·7	77	− 8·6
8·6	−2·9	35	−5·8	79	− 8·7
9·2	−3·0	36	−5·9	81	− 8·8
9·8	−3·1	37	−6·0	83	− 8·9
10·5	−3·2	38	−6·1	85	− 9·0
11·2	−3·3	40	−6·2	87	− 9·1
11·9	−3·4	41	−6·3	88	− 9·2
12·6	−3·5	42	−6·4	90	− 9·3
13·3	−3·6	44	−6·5	92	− 9·4
14·1	−3·7	45	−6·6	94	− 9·5
14·9	−3·8	47	−6·7	96	− 9·6
15·7	−3·9	48	−6·8	98	− 9·7
16·5	−4·0	49	−6·9	101	− 9·8
17·4	−4·1	51	−7·0	103	− 9·9
18·3	−4·2	52	−7·1	105	−10·0
19·1	−4·3	54	−7·2	107	−10·1
20·1	−4·4	55	−7·3	109	−10·2
21·0	−4·5	57	−7·4	111	−10·3
22·0	−4·6	58	−7·5	113	−10·4
22·9	−4·7	60	−7·6	116	−10·5
23·9	−4·8	62	−7·7	118	−10·6
24·9		63		120	

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
57·9	5·2 3·7	5·2 3·7	5·2 3·7	5·2 3·7	5·2 3·7	5·1 3·6	5·1 3·6	5·1 3·6	5·1 3·6	5·1 3·6	5·1 3·6	57·9
58·2	5·5 3·9	5·5 3·8	5·5 3·8	5·4 3·8	5·4 3·7	5·4 3·7	5·3 3·7	5·3 3·6	5·2 3·6	5·2 3·5	5·2 3·5	58·2
58·5	5·9 4·0	5·8 4·0	5·8 3·9	5·7 3·9	5·6 3·8	5·6 3·8	5·5 3·7	5·5 3·6	5·4 3·6	5·3 3·5	5·3 3·4	58·5
58·8	6·2 4·2	6·1 4·1	6·0 4·1	6·0 4·0	5·9 3·9	5·8 3·8	5·7 3·7	5·6 3·6	5·5 3·5	5·4 3·5	5·3 3·4	58·8
59·1	6·5 4·3	6·4 4·3	6·3 4·2	6·2 4·1	6·1 4·0	6·0 3·9	5·9 3·8	5·8 3·6	5·7 3·5	5·6 3·4	5·4 3·3	59·1
59·4	6·8 4·5	6·7 4·4	6·6 4·3	6·5 4·2	6·4 4·1	6·2 3·9	6·1 3·8	6·0 3·7	5·8 3·5	5·7 3·4	5·5 3·2	59·4
59·7	7·1 4·6	7·0 4·5	6·9 4·4	6·8 4·3	6·6 4·1	6·5 4·0	6·3 3·8	6·2 3·7	6·0 3·5	5·8 3·3	5·6 3·2	59·7
60·0	7·5 4·8	7·3 4·7	7·2 4·5	7·0 4·4	6·9 4·2	6·7 4·0	6·5 3·9	6·3 3·7	6·1 3·5	5·9 3·3	5·7 3·1	60·0
60·3	7·8 5·0	7·6 4·8	7·5 4·7	7·3 4·5	7·1 4·3	6·9 4·1	6·7 3·9	6·5 3·7	6·3 3·5	6·0 3·2	5·8 3·0	60·3
60·6	8·1 5·1	7·9 5·0	7·7 4·8	7·6 4·6	7·3 4·4	7·1 4·2	6·9 3·9	6·7 3·7	6·4 3·4	6·2 3·2	5·9 2·9	60·6
60·9	8·4 5·3	8·2 5·1	8·0 4·9	7·8 4·7	7·6 4·5	7·3 4·2	7·1 4·0	6·8 3·7	6·6 3·4	6·3 3·2	6·0 2·9	60·9
61·2	8·7 5·4	8·5 5·2	8·3 5·0	8·1 4·8	7·8 4·5	7·6 4·3	7·3 4·0	7·0 3·7	6·7 3·4	6·4 3·1	6·1 2·8	61·2
61·5	9·1 5·6	8·8 5·4	8·6 5·1	8·3 4·9	8·1 4·6	7·8 4·3	7·5 4·0	7·2 3·7	6·9 3·4	6·5 3·1	6·2 2·7	61·5

NICHOLLS'S CONCISE GUIDE

VOLUME 2.

NICHOLLS'S CONCISE GUIDE

TO THE

NAVIGATION EXAMINATIONS

VOLUME 2.

FIRST REVISION BY

H. H. BROWN, D.S.C.*, R.D., F.R.A.S., EXTRA MASTER

REVISED BY

EDWARD J. COOLEN, M.N.I., M.R.I.N., D.M.S., A.I.P.M., F.B.I.M.

Liveryman of the Honourable Company of Master Mariners

Senior Lecturer, City of London Polytechnic, Sir John Cass Faculty of Transport

Director, Marine Services Division, Coolen Consultancy and Management Services, London W.2.

Past Commandant of the Bangladesh Mercantile Marine Academy, Chittagong

GLASGOW

BROWN, SON & FERGUSON, LTD., NAUTICAL PUBLISHERS

4–10 DARNLEY STREET, G41 2SD

Copyright in all Countries signatory to the Berne Convention
All rights reserved

9th Edition - - - *1953*
10th Edition - - - *1963*
Revised - - - - *1968*
Reprinted - - - - *1974*
Reprinted - - - - *1976*
Reprinted - - - - *1978*
11th Edition - - - *1984*

ISBN 0 85174 480 X

© 1984 Brown, Son & Ferguson, Ltd., Glasgow G41 2SD
Printed and Made in Great Britain

PREFACE

This is the eleventh edition of *Nicholls's Concise Guide, Volume 2.* It is complementary to and a continuation of the work contained in *Volume 1.* This new edition includes numerous changes, additions and new features.

Sections on the Sailings, Magnetic Compass, Ocean Passages and Tides have been revised and, to a large extent, re-written. Those relating to Radar Plotting, Tidal Calculations and Meridian Passage Star have been completely re-written. Information relating to charts and the section on Marine Surveying has been updated.

To take account of current practice, a list of symbols and abbreviations has been added, reference to quadrantal notation replaced by 360 degree notation, and terminology relating to celestial navigation updated.

Numerous figures have been re-drawn and new ones added.

New features include a check list system of instructions for Tidal Calculations, Radar Plotting, Passage Planning and for Finding Suitable Stars for Meridian Altitudes. Where appropriate, the various steps involved in calculations and procedure have been included in the worked examples and directly linked to the check lists and pro-formas provided. It is to be hoped that these inclusions will reduce learning times and be of assistance to the student working privately at sea and also, perhaps, to colleges in those parts of the developing world where there is a shortage of technical instructors.

Another new feature is the inclusion of a careful selection of extracts from official and other publications. The aim here has been to reduce the need for immediate reference to other publications and, so far as is possible, to make this volume self contained. For those with limited budgets, this feature could be important. Examples of these extracts include: relevant *Collision Avoidance Rules* in the passage planning and radar sections, the *Admiralty Method of Tidal Prediction* in the section on tidal calculations, paragraphs from *Ocean Passages for the World, Symbols and Abbreviations Chart 5011* and, finally, more comprehensive *Admiralty Tide Table* extracts.

Summary lists of the more advanced formulae used in navigation and astronomy have also been included.

As in previous editions, track and practice charts are included in the rear wallet. In this connection it should be noted that the new (Metric) practice chart BA 5053 can be used for the exercises on the English Channel. It should also be noted that the Department of Trade (D.o.T.) has now changed its name to the Department of Transport (D.Tp.) and text references should be read accordingly.

I am grateful to colleagues at the City of London Polytechnic, Sir John Cass Faculty of Transport, for their advice and assistance, particularly to Captain P. R. Jackson in connection with the sections on Magnetic Compass and Chartwork, Captain P. R. Lewis for contributing the new section on Passage Planning and for commenting

on other sections, Captain A. G. Blance for new figures and text on Radar Plotting, Captain D. B. Fantham for a substantial contribution to the section on Tides and Tidal Calculations, and finally to Captain T. C. Haile for commenting on Marine Surveying.

To Miss Margaret Mortimer, for her patient and invaluable assistance with proof reading and typing, I record my sincere appreciation.

Artwork for all new diagrams has been executed by Alison Murphy to whom I offer my sincere thanks for her work and careful attention to detail.

For kind permission to reprint from:
Admiralty Chart BA 5053, *Ocean Passages for the World* NP 136, *Admiralty Tide Tables*, Volumes 1-3, the *Admiralty Method of Tidal Prediction* NP 159, and the *International Collision Regulations*, 1972;

Grateful acknowledgement is made to:
The Hydrographic Dept. Ministry of Defence, Taunton,
The Controller of Her Majesty's Stationery Office, and the
International Maritime Organisation (IMO formerly IMCO).

It is hoped that this revision will be of some benefit to students and officers in the Merchant Navy wherever they may be, particularly those in the developing world, some of whom I have been privileged to serve, and in whom I have great faith and hope for the future.

Edward Coolen,
December 1983

CONTENTS

CHAPTER I

The Sailings .. 1
Modified Distance Formula .. 2
Long Distance Traverse .. 5

CHAPTER II

The Magnetic Compass .. 12
Variation and Deviation .. 12
Use of Deviation Cards and Curves .. 12
Constructing a Table of Deviations .. 15

Chartwork Examples .. 19

Ocean Passages .. 39
Trade Winds and Monsoons .. 39
Ocean Currents .. 42
Ocean Passages and Routeing .. 44

Passage Planning .. 50
Coastal Passage Planning .. 50
Coastal Passage Planning Example .. 52
Ocean Passage Planning .. 54

Radar Plotting .. 57
Radar as an Anti Collision Aid .. 60
Effect of Tide .. 70
Plotting Terms and Diagrams .. 73
Relevant Collision Avoidance Rules .. 75

CHAPTER III

Great Circle Sailing .. 81
Initial and Final Course .. 82
Vertex and Intermediate Positions .. 84
Gnomonic Charts .. 87
Composite Great Circle Sailing .. 88
Use of ABC Tables .. 93

CHAPTER IV

Tides and Tidal Levels .. 100

Secondary Port Tide Calculations .. 106
European .. 106
Atlantic and Indian Ocean .. 111
Pacific Ocean .. 113
Admiralty Method of Tidal Prediction (NP 159) .. 114
Admiralty Tidal Publications .. 123

CHAPTER V

Spherical Triangles 125

ABC and Ex-Meridian Tables 130

Hour Angle Equations 132

CHAPTER VI

Time of Meridian Passage Star 134
Circumpolar Stars 142

Finding Latitude by Meridian Altitude
Star 145
Stars Near the Meridian 148
Star Identification 153
Moon 160
Planet 162

CHAPTER VII

Latitude by Polaris 164

Ex-Meridian Star, Moon and Planets
Star 166
Planet 169
Moon 171

Ex-Meridian and Longitude Sights Combined 174
Star 174
Sun 176

CHAPTER VIII

Miscellaneous Problems on a Sea Passage 189

Past Examination Papers 201

CHAPTER IX

Marine Surveying 211
Constructing A Mercator Chart 215
Gnomonic Chart 219

CHAPTER X

Formulae Used in Navigation and Astronomy 225
Summary of Formulae 253

CHAPTER XI

Theoretical Problems 255
Algebraic Equations 255
Plane Triangles 267
Relative Velocities 277
Miscellaneous 283
Spherical Triangles 288

CHAPTER XII

Nautical and Spherical Astronomy 299
Summary of Formulae 330

CHAPTER XIII

Mensuration 333
Triangle and Quadrilateral 333
Circle 338
Relative Density 340
Polygons 342
Sphere 345
Cone, Prism and Frustums 350
Ellipse and Kepler's Laws 361

Examination Papers 371
Mathematics 371
Navigation 373

Answers 377

Admiralty Tide Table Extracts 391

Appendices 393

Nautical Almanac Extracts 421
Polaris (Pole Star) Tables 452
Increments and Corrections 455

Index 487

Track and Practice Charts in Pocket at Back

DEPARTMENT OF TRANSPORT

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

Reproduced by kind permission of the Department of Transport

Index

Class 5 xiii
Class 4 xiv
Class 3 xvi
Class 2 xvii
Class 1 Master Mariner xvii
Master (Middle Trade) Endorsement xix
Master (Near Continental) Endorsement xix
Oral Syllabus for Watchkeeping Licence xx
Prescribed Marking xxi
Symbols, Abbreviations and Definitions xxiv

Important Note.
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.

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 course 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 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†

(*a*) (*i*) To read and understand a barometer, thermometer, hydrometer and hygrometer. The intruments 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 of 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.

† 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 of 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*) Principles 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. (*2½ 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. Effects 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†

(*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.

† Navigational content *only*.

CLASS 1 CERTIFICATE OF COMPETENCY MASTER MARINER
Navigation

Paper 2. (*2½ 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 offshore 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 underlaying the choice of navigational systems for differing trades and geographical regions.

CLASS 1 CERTIFICATE OF COMPETENCY MASTER MARINER
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. Heeling Error. Gaussin 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 collison 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†

(*a*) (*iii*) Assisting a ship or aircraft in distress. The use of direction finding for homing on to a casualty.

(*vi*) Navigation in the vicinity of ice.

(*xi*) 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.*

† 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 equi-distant 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†

(*c*) (i) A thorough knowledge of search and rescue procedures. The use of direction finding for homing on to a casualty.

(*i*) Navigation in the vicinity of ice.

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†

(c) (i) A thorough knowledge of search and rescue procedures. The use of direction finding for homing on to a casualty.

† 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 with 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, Chart Work and Pilotage

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

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

Given variation and the deviation of the magnetic compass, to convert true course 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†

(*a*) Ability to take a compass bearing or bearings.
Ability to check compass bearings by transit.
The care and maintenance of liquid compasses. The avoidance of electrical and magnetic interference.

(*i*) Search and rescue.

† 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	2½ 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 70% ,, B 50% } 60%
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	2½ hrs	150	50%
		650 Aggregate	60%

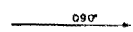
Orals: as arranged by Examiner.

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.

SYMBOLS and ABBREVIATIONS

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		
,, 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		
,, ,, port		
Observed position or fix	Obs Pos	
Dead reckoning position	DR	
Estimated position	EP	
Chosen position	CP	

DEFINITIONS

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.

NICHOLLS'S CONCISE GUIDE

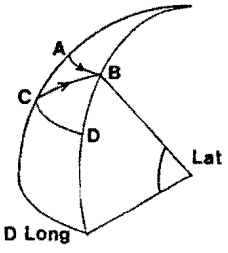
CHAPTER I.

PLANE, PARALLEL AND MERCATOR SAILINGS.

CHAPTER VII of Volume I dealt with Plane, Parallel and Mercator Sailings. In this chapter it is proposed to refer to some further applications of these sailings and to comment on their use.

Let us first consider the formulae used in problems which involve use of one or other of the three sailings:

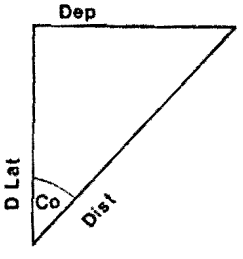
Parallel Sailing — Dep.=D. Long. × cos Lat.



Plane or Mean Latitude Sailing — Dep.=D. Long. × cos Mn. Lat.

$$\frac{\text{Dep.}}{\text{D. Lat.}} = \tan \text{Co}$$

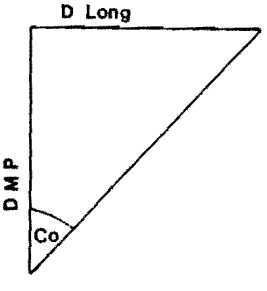
Dist.=D. Lat. × sec Co.



Mercator Sailing

$$\frac{\text{D. Long.}}{\text{D.M.P.}} = \tan \text{Co.}$$

Dist.=D. Lat. × sec Co.



When sailing along a parallel (*A* to *B*) the latitude does not change. When sailing obliquely (*C* to *B*) the latitude does change and to convert the D. Long. to Departure it becomes necessary to use the arithmetic mean of the latitudes of the

initial and final positions (*C* and *B*). Ideally, and for very accurate results, corrections should then 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.o.T. 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 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 $\frac{1}{2}\%$.

Use of the Modified Distance Formula.

At large course angles, say over 70°, there is a danger of inaccurate interpolation when lifting the secant course from the tables. In cases where the interpolation becomes critical it is advisable to modify the standard formula as follows:

	Dist. = D. Lat. × sec Co.	(Standard Formula)
but	sec Co. = tan Co. × cosec Co.	
so	Dist. = D. Lat. × tan Co. × cosec Co.	(Modified Formula)

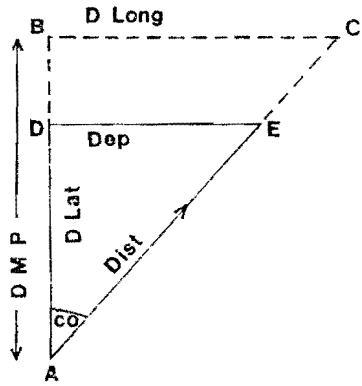
In the cases mentioned, the modified formula should be used for both Mean Latitude and Mercator Sailings. The student is advised to study the tables and verify that, at large angles, cosecant interpolation can be carried out quickly and with maximum accuracy. The modified formula can also be used to some advantage with course angles over 50°, at about which value the interval between successive cosecants becomes noticeably smaller than that between secants.

Another version of the modified formula can be used in conjunction with Mean Latitude Sailing. It will be recalled that:

$$\frac{\text{Dep.}}{\text{D. Lat.}} = \text{tan Co}$$

so	Dep. = D. Lat. × tan Co.	
but	Dist. = D. Lat. × tan Co. cosec Co.	(Modified Formula-1)
so	Dist. = Dep. × cosec Co.	(Modified Formula-2)

As the departure will have been already found in a Mean Latitude Sailing this modification can be used to further simplify the calculation of distance.



The adjoining figure is a general one for these types of problems, it shows the plane triangle *A D E* expanded into the mercatorial sailing triangle *A B C*. Angle *A*, the course, is common to both triangles, *A E* is the distance. The difference of latitude *A D* is expanded to *A B*, the difference of meridional parts on the Mercatorial projection, and departure *D E* is expanded into difference of longitude *B C*.

From fig:

Tan Co. $= \frac{\text{D. Long.}}{\text{D.M.P.}} = \frac{\text{Dep.}}{\text{D. Lat.}}$ which is a case of similar triangles as $\frac{BC}{AB} = \frac{DE}{AD}$ and this relationship may be used in finding the exact difference of longitude corresponding to a departure when sailing on an oblique course, viz. ·

$$\text{D. Long.} = \frac{\text{D.M.P.} \times \text{Dep.}}{\text{D. Lat.}}$$

Example.—From Lat. 45° N., Long. 40° W., a ship steered 030° T., for 800 miles. Required the latitude and longitude arrived at.

Given N. 30° E., 800 miles → D. Lat. 692·8′ N., Dep. 400′ E.

Lat.	45° 00·0′ N.	M.P.	3013·4
D. Lat.	11 32·8 N.		
Lat.	56 32·8 N.	M.P.	4113·4
		D.M.P.	1100·0

As stated above:

D. Long. $= \frac{\text{D.M.P.} \times \text{Dep.}}{\text{D. Lat.}} = \frac{1100 \times 400}{692{\cdot}8} = 635{\cdot}3' = 10°\ 35{\cdot}3'$

Initial Long.	40° 00′ W.
D. Long.	10 35·3 E.
Final Long.	29 24·7 W.

Position reached Lat. 56° 32·8′ N., Long. 29° 24·7′ W.

The above Dep. could also be converted into the correct D. Long. as follows:—

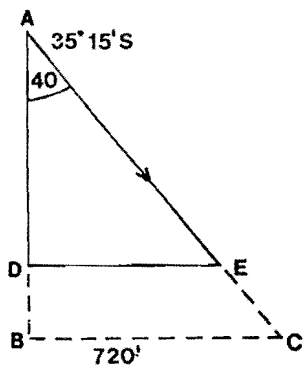
Dep. = D. Long. × cos Mn. Lat.
so D. Long. = Dep. × sec Mn. Lat.

Lat. - -	45° 00′ N.				
½ D. Lat. -	5 46·4 N.				
Mean Lat. -	50 46·4 N.	log sec	0·19901	Initial Long.	40° 00′ W.
Dep. - -	400′	log	2·60206	D. Long.	10 32·5 E.
D. Long. -	632·5′ ←	log	2·80107	Final Long.	29 27·5 W.

If the problem is worked by Mean Latitude Sailing the D. Long. so calculated will be 632·5′ instead of 635·3′ as obtained by Mercator Sailing—a difference of 2·8′.

Example.—Given Lat. 35° 15′ S., Course 140° T., D. Long. 12°. Find the latitude reached and the distance sailed.

The above information is indicated on the figure. It is required to find the difference of meridional parts *A B*, to apply to the meridional parts for latitude *A* to get the meridional parts for C, thence the latitude of *C* from the table of meridional parts; also *A E* the distance sailed.



$$\frac{\text{D. Long.}}{\text{D.M.P.}} = \text{tan Co.}$$

So D.M.P. = D. Long. cot Co. = 720 cot 40°

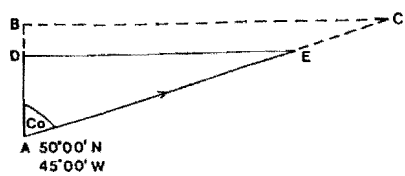
(*B C*)	D. Long.	720	log	2·85733
(∠*A*)	Course	40°	log cot	0·07619
(*A B*)	D.M.P.	858·1	log	2·93352
From Tables Lat. 35° 15′ →	M.P.	2249·1		
From Tables Lat. 46 06 ←	M.P.	3107·0		
D. Lat. 10 51	(*A D*)			

Dist. = D. Long. sec Co.

(*A*)	Course 40°		log sec	0·11575
(*A D*)	D. Lat.	651	log	2·85318
(*A E*)	Dist.	849·8	log	2·92933

Answer.—Lat. 46° 06′ S., Distance 849·5 miles.

Example.—Calculate the course and distance from Lat. 50° 00′ N., Long. 45° 00′ W. to Lat. 50° 31′ N., Long. 13° 49′ W., (i) Using the Mercator Sailing, (ii) using the Mean Latitude Sailing, and (iii) compare your results.



From	50° 00′ N.	M.P.	3456·53		45° 00′ W.	
To	50 31 N.	M.P.	3504·89		13 49 W.	
D. Lat.	31 N.	D.M.P.	48·36	D. Long.	31 11 E.	
				,,	1871′ E.	

$$\frac{\text{D. Long.}}{\text{D.M.P.}} = \text{tan Co.}$$

$$\text{Dist.} = \text{D. Lat.} \times \text{tan Co. cosec Co.}$$

D. Long.	1871′	log	3·27207
D.M.P.	48·36	log	1·68449
Co. N.	88° 31′ E. ←	log tan	1·58758
,,	,,	log cosec	0·00015
D. Lat.	31	log	1·49136
Dist.	1199·75 ←	log	3·07909

Answer (i) Course 088° 31′ T., Distance 1199·75 miles (by Mercator Sailing).

(ii) From 50° 00′ N. 45° 00′ W. Lat. 50° 00′ N.
To 50 31 N. 13 49 W. ½ D. Lat. 15·5 N.
D. Lat. 31 N. D. Long. 31 11 E. Mn. Lat. 50° 15·5′ N.
1871′ E.

Dep. = D. Long. × cos. Mn. Lat.	D. Long.	1871′	log	3·27207	
	Mn Lat.	50° 15·5′	log cos.	9·80572	
Dep. / D. Lat. = tan Co.	Dep.		log	3·07779	3·07779
	D. Lat.	31′ N.	log	1·49136	
Dist. = D. Lat. × tan Co. × cosec Co.	Co.	N. 88° 31′ E. ←	log tan	1·58643	
or			log cosec	0·00015	0·00015
Dist. = Dep. × cosec Co.	D. Lat.	31′ N.	log	1·49136	
	Dist.	1196·58′ ←	log	3·07794	3·07794

Answer (ii) Course 088° 31′ T., Distance 1196·58 miles (by Mean Latitude Sailing).

By Mercator Sailing	Co.	088° 31′ T.	Dist.	1199·75 miles
,, Mean Latitude Sailing	,,	088° 31′ T.	,,	1196·58 ,,
Answer (iii) Difference.		Nil		3·17 miles

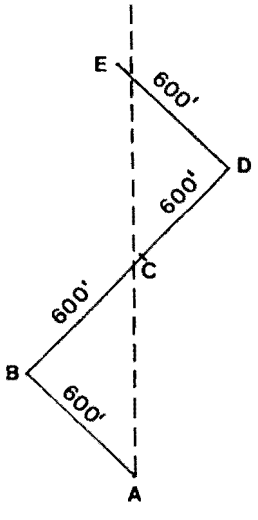
N.B.—Using advanced techniques the actual distance between the two positions has been calculated as being 1200·2 International Nautical Miles (6076·12 feet). In this case the Mercator Sailing gives very satisfactory results.

A LONG DISTANCE TRAVERSE.

Example.—A vessel set out from Lat. 20° N., Long. 30° W., and steered 315° for 600 miles, then 045° for 1200 miles, and again 315° for 600 miles. Required the position arrived at.

This type of question is intended to draw attention to the limitations of plane sailing for long stretches of distance in computing the longitude of the position arrived at.

If this example were worked out as a traverse we would get the latitude of arrival quite correctly but not the longitude, because the several East and West departures would cancel each other and indicate that the vessel had made no easting or westing which is not the case. For example—



Courses	Dist.	D. Lat.	Dep.
315° T.	600	424·3 N.	424·3 W.
045° T.	1200	848·6 N.	848·6 E.
315° T.	600	424·3 N.	424·3 W.
	D. Lat.	1697·2 N.	Dep 0·0

Lat. left	20° 00′ N.	Long. left	30° 00′ W.
D. Lat.	28 17·2 N.	Dep. 0, D. Long.	00 W.
Lat. arrd.	48 17·2 N.	Long. arrd.	30 00 W. which is wrong.

The departure in this case being zero we might assume the D. Long. to be zero which would be wrong.

We shall now work the question by inspection using the mean latitudes to convert the several departures into their corresponding differences of longitude.

		Co.	Dist.	D. Lat.	Dep.
Refer to figure,	1st Course *A* to *B*	315° T.	600	424·3 N.	424·3 W.
	2nd ,, *B* to *C*	045° T.	600	424·3 N.	424·3 E.
	3rd ,, *C* to *D*	045° T.	600	424·3 N.	424·3 E.
	4th ,, *D* to *E*	315° T.	600	424·3 N.	424·3 W.

	Lat.	Mean Lat.	Dep.	D. Long. by Inspection	Long.
A	20° 00·0′ N.				30° 00·0′ W.
D. Lat.	7 04·3 N.	23° 32·2′	424·3	462·8	= 7 42·8 W.
B	27 04·3 N.				37 42·8 W.
D. Lat.	7 04·3 N.	30 36·6	424·3	492·5	= 8 12·5 E.
C	34 8·6 N.				29 30·3 W.
D. Lat.	7 04·3 N.	37 40·8	424·3	536·1	= 8 56·1 E.
D	41 12·9 N.				20 34·2 W.
D. Lat.	7 04·3 N.	44 45·1	424·3	597·4	= 9 57·4 W.
E	48 17·2 N.				30 31·6 W.

Position reached, E. Lat. 48° 17·2′ N., Long. 30° 31·6′ W., not 30° 00′ W., as above.

Note.—The departures are the same but the corresponding differences of longitude increase as the latitude increases.

Example.—At 1200 L.M.T., Lat. 35° 10′ S., Long. 164° 30′ E., ship steaming 268° C. (deviation 8° E., variation 14° E.) at 10 knots until 2000 hrs. when a distress call signal was received from a ship in Lat. 37° 15′ S., Long. 159° 30′ E., urgently asking for assistance. Find the true course to steer and the G.M.T. on arrival at the ship if speed is increased to 12 knots.

	Lat.		Long.
1200 position	35° 10′ S.		164° 30′ E.
(290° T. 80 miles) D. Lat.	27·4 N.	D. Long.	1 32 W.
My position at 2000	34 42·6 S.		162 58 E.
Her position	37 15·0 S.		159 30 E.

Course by Mercator 228° T., dist. to go 227·7 miles at 12 knots = steaming time 18h 54m.

L.M.T.	0d 12h 00m
Long. 164° 30′ E.	— 10 58
G.M.T.	0 01 02
Steaming time (8h + 18h 54m)	1 2 54
G.M.T. on arrival at vessel	1 03 56

TERRESTRIAL AND CELESTIAL POSITION LINES COMBINED.

Ushant 33 M light (Lat. 48° 27·7′ N., Long. 5° 07·7′ W.) bearing 184° T., approx. distance 20 miles. Ship then steered 052° C. (deviation 5° E., variation 17° W.) for 30 miles by log; estimated set and drift of current 210° T., 4 miles. Sights of a star were then worked with this E.P. and gave azimuth 330° T., intercept 6′ away. Required the ship's Observed Position at sights.

(1) Work a three course traverse from Ushant and find the E.P. for working the star sights.

The Traverse. See Figure.		Distance	D. Lat.	Dep.
Reversed Bearing	004° T.	20 miles	20·0′ N.	1·4′ E.
Course	040° T.	30 ,,	23·0 N.	19·3 E.
Current	210° T.	4 ,,	3·5 S.	2·0 W.
A to *C*, Co. and Dist.	025° T.	43·6 ,,	39·5 N.	18·7 E.

	Lat.		Long.
Ushant Position *A*	48° 27·7′ N.		5° 07·7′ W.
025° T., 43·6 miles D. Lat.	39·5 N.	Dep. 18·7 = D. Long.	28·5 E.
Estimated Position *C*	49 07·2 N.		4 39·2 W.
C to F			
184° T., 7·2 miles D. Lat.	7·2 S.	D. Long.	0·8 W.
Ship's Observed Position *F*	49 00·0 N.		4 40·0 W.

In Figure—

A B is the reversed bearing and approx. distance of ship from Ushant.

B C is the course and distance made good.

C is the E.P.

P′ L′ the transferred position line of Ushant 004°—184°.

C D the intercept 6′ away.

D the Intercept Terminal Position.

P L the star position line.

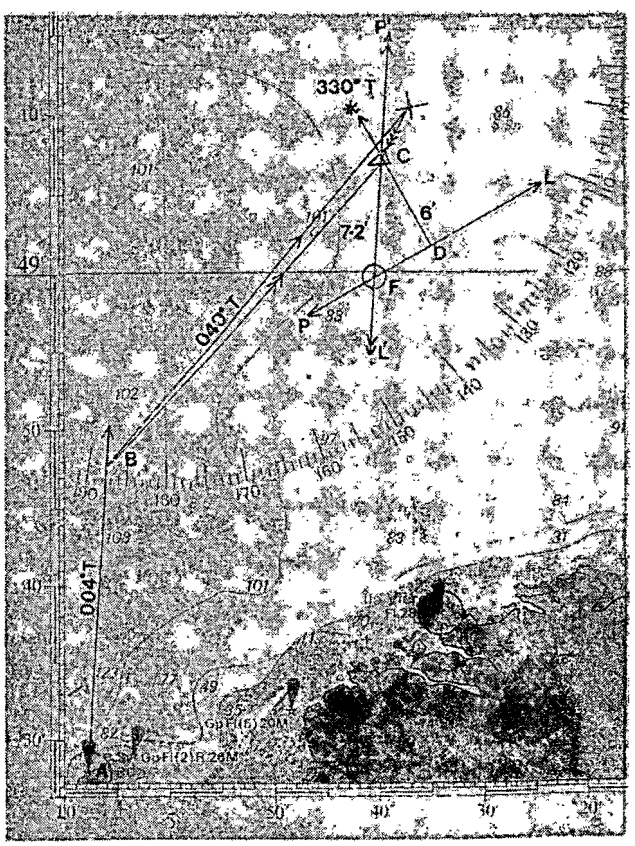
F the ship's position.

(2) Now obtain the ship's position by solving triangle *CDF* and finding distance *CF* by inspection of the Traverse Tables. The intercept is Away so reverse the azimuth (330° T.) to 150° T.
In triangle *CDF*, *C*=34° (184°—150°), use as Co; *CD*=6′ use as D. Lat.; *CF*=7·2′ found under Dist.

(3) Now *C* to *F* is 184° T. distance 7·2′ giving D. Lat. 7·2′ S. and Dep. 0·5′ W.

(4) Using Mean Lat. 49° and Dep. 0·5′ gives D. Long. 0·76′ W. (0·8′ W.).

(5) Apply D. Lat. 7·2′ S. and D. Long. 0·8′ W. (found at (3) and (4) above) to the E.P. found from the three course traverse. This is the ship's Observed Position (*F*) at the star sight.



Reproduced by kind permission of the Hydrographer of the Navy.

Though, in this case, all plotting could have been carried out on the chart, most navigators use a combination of plotting and Traverse Table inspection to work out star sights.

On small scale charts it is seldom possible to plot sights accurately.

Examples for Exercises.

SAILINGS—PLANE, PARALLEL AND MERCATOR.

1. Two ships are 28 miles apart in Lat. 44° S., both steam due North keeping due East and West of each other until they are 37 miles apart. How far have they sailed?
2. Given course 280° T., dep. 198 miles, D. Long. 240′. Required the latitudes and the distance sailed.
3. Given course 310° T., D. Long. 10°, left Lat. 57° 05′ N. Find the latitude reached.
4. Given course 210° T., D. Long. 11° 30′, left Lat. 37° 10′ S. Find the latitude reached and distance sailed.
5. From the equator sailed a 210° T. course and altered Longitude 12° 10′. Find the latitude reached and distance sailed.
6. A vessel sailed from Lat. 17° 11′ N. to Lat. 16° 10′ N., and changed her Longitude 7° 13′ W. Find the distance sailed.
7. A vessel left Lat. 40° 30′ N., Long. 48° 30′ W. and arrived in Lat. 48° 30′ N. after making 600 miles of westing. Find the longitude reached.
8. Find the true course and distance from Lat. 37° 14′ N., Long. 30° 00′ W., to Lat. 31° 26′ N., Long. 34° 00′ W.
9. Given Lat. 42° 20′ N., course 270° T. for 3 days 2 hours, D. Long. 17° 10′. Find the vessel's speed.
10. Ship *A* in Lat. 17° S., Long. 20° W., steers due West at 17 knots. A ship *B* in Lat. 18° S., Long. 21° W., wishes to intercept *A* in 4 hours. Find her course and speed to be able to do so.
11. From Lat. 52° 30′ N., Long. 168° 20′ W., a ship steered 215° T., 500 miles, then 135° T., 500 miles. Find the position arrived at.
12. From Lat. 50° S., Long. 70° E., a ship steered 050° T., 1000 miles, required the position reached.
13. On 8th May, at noon, apparent time at ship, in Lat. 39° 16′ N., Long. 72° 51½′ W., find the mercatorial course and distance to a position 10 miles, 180° T. from Fastnet (Lat. 51° 23½′ N., Long. 9° 36½′ W.), also the apparent time at ship on arrival allowing a speed of 10 knots.
14. On 11th January, at noon, apparent time at ship, in Lat. 49° 17′ N., Long. 45° 50′ W., steaming 260° at 15½ knots. At 7h 30m P.M., apparent time at ship, an S.O.S. was received from a disabled ship in Lat. 46° 00′ N., Long. 47° 20′ W. Find the true course and distance to steam and the G.M.T. of arrival at your maximum speed of 17½ knots.

BOW AND BEAM BEARINGS WITH CURRENT.

At 10 P.M. a point in Lat. 43° 10′ N., Long. 9° 13′ W., bore 4 points on the port bow, and at 11 P.M. it was abeam, ship steaming 15 knots. Compass course 231°, wind N.W., leeway 4°, variation 19° W., deviation 6° E., current 110° T. at 3 knots Required the true bearing, distance off when abeam, and the ship's position.

1. Correct the compass course for deviation and variation to get the true direction of ship's head from which to get the directions of the bow and beam bearings.
2. Resolve a two course traverse to find the course and distance made good during the interval between the bearings, viz., the compass course corrected for deviation, variation and leeway, if any, and the set and drift of current.
3. The question now resolves itself into solving a running fix either by calculation, projection on a chart or on squared paper.

Refer to figure and note that—

A is the point of land.
B the position of ship at first bearing.
B A the bow bearing and *A C* the beam bearing.
B C the true direction ship is heading.
B D the true course adjusted for leeway.
B F the course and distance made good between the bearings.
F is the ship's position relatively to *A*.

To Find the Bow and Beam Bearings.

Course 231° C. (deviation 6° E., variation 19° W.) gives ship's head 218° T.

Apply 45° and 90° to the left of 218° T. to get the bearings *A B* and *A C*, viz., 173° and 128°, to be laid off on the chart.

To Find the Course and Distance made Good between the Bearings.

Ship's head 218° T., leeway 4°, 214° T.

		Distance	D. Lat.	Dep.
B D course	214° T.	15 miles	12·4′ S.	8·4′ W.
D F current	110° T.	3 ,,	1·0 S.	2·8 E.
Course made good	203° T.	14·5 miles	13·4 S.	5·6 W.

The above work need not be shown either on the chart or on squared paper unless asked for.

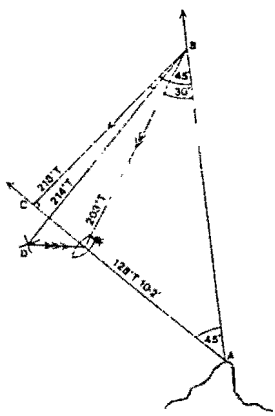
The Question now Reads.—A point of land bore 173° T. and after making good 203° T., 14·5 miles, the point bore 128° T. Find the ship's distance from the point and her latitude and longitude.

The heavy lines on the figure represent the actual charting to be laid off as a running fix. *A F* is the distance from the point, 10·2 miles by measurement. It is now required to transfer position *A* to *F*.

	Lat.		Long.	
Position *A*	43° 10′ N.		9° 13′ W.	
308° T. 10·2′ mls. = D. Lat.	6·3 N.	D. Long.	11 W.	Dep. 8·0
Position *F*	43 16·3 N.		9 24 W.	

When a chart is not available the triangle $A\ B\ F$ being oblique may be solved as follows:—

Given $B\ F = 14{\cdot}5$ miles, $\angle A = 45°$, $\angle F\ B\ A = 30°$, find side $A\ F$.



$$\frac{A\ F}{\sin B} = \frac{B\ F}{\sin A} \quad \therefore A\ F = B\ F \sin B \operatorname{cosec} A$$

$$= 14{\cdot}5 \sin 30° \operatorname{cosec} 45°$$

14·5	log	1·161368
30°	sin	9·698970
45°	cosec	10·150515
$A\ F$ 10·2	= log	1·010853

The ship is therefore 10·2 miles, 308° T. from A.

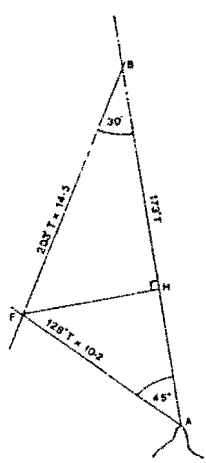
		Lat.	Long.
308° T., 10·2′	A	43° 10′ N.	9° 13′ W.
D. Lat. 6·3′ N.		6·3 N.	11 W.
Dep. 8·0′ W.			
D. Long. 11′ W.	F	43 16·3 N.	9 24 W

Some students may prefer to find the distance $A\ F$ by inspection from the Traverse Tables by dropping $F\ H$ perpendicular to $A\ B$.

In $\triangle\ F\ B\ H$, $B\ F = 14{\cdot}5$ (dist) $\angle B = 30°$ (course), $F\ H$ = dep (7·25).

In $\triangle\ A\ H\ F$, $\angle A = 45°$ (course), $H\ F = 7{\cdot}25$ (dep), $A\ F$ = dist (10·2).

Note.—The problem may be set giving the leeway in knots as in Examples 5 and 6, in which case it will be applied as if it were a course dead before the wind. There would then be a three course traverse to solve to get the course and distance made good, viz., true course steered and speed, set and drift due to leeway and the set and drift due to current. When leeway is left out the case is simplified to that extent.



Examples for Exercise.

1. At 1625 hrs. Dungeness lighthouse (Lat. 50° 54·9′ N., Long. 00° 58·4′ E.), bore 4 points on the starboard bow and at 1713 hrs. it was abeam. Course 230° C. (deviation 4° E., variation 14° W.), speed 10 knots, wind West, leeway 8°, tidal stream 250° T., 3 knots. Find the distance off when lighthouse was abeam and the ship's position on the beam bearing.
2. Dungeness lighthouse (Lat. 50° 54·9′ N., Long. 00° 58·4′ E.) bore 45° on the port bow at 0820 hrs., log 37, and at 0920 hrs. it was abeam, log 48. The ship steamed East by compass (deviation 6° W., variation 14° W.), wind N.E., leeway 5°, tidal stream 222° T., 4 knots. Find the ship's position on the beam bearing.

3. Beachy Head lighthouse (Lat. 50° 44′ N., Long. 00° 15′ E.) bore 4 points on the port bow at 2220 hrs. and at 2327½ hrs. it was abeam. Course 086° C. (deviation 20° E., variation 14° W.), speed 8 knots, wind North, leeway 4°, tidal stream West (magnetic), 2½ knots. Find the distance off on the beam bearing and the ship's position.
4. Cape Gris Nez (Lat. 50° 52·2′ N., Long. 01° 35′ E.) bore 45° on the port bow and after steaming 7 miles it was abeam. Course 195° C. (deviation 14° E., variation 14° W.), wind N.W., leeway 5°, tide set 300° M., 2·5 miles during the interval. Find the beam distance and ship's position.
5. South Foreland light (Lat. 51° 08½′ N., Long. 01° 22½′ E.) bore 45° on the starboard bow and after steaming for one hour at 9 knots it was abeam. Course 207° C. (deviation 7° E., variation 14° W.), wind West, leeway 2 knots, current 050° T., 3 knots. Find the ship's position. (See Note on p. 9.)
6. North Foreland light (Lat. 51° 22½′ N., Long. 01° 26·8′ E.) bore 4 points on the port bow, log 17, and after 30 minutes steaming it was abeam, log 21. Course 324° C. (deviation 10° E., variation 14° W.), wind S.W., leeway 2 knots, tide North (magnetic), 5 knots. Find ship's position.
7. Flamborough Head (Lat. 54° 7′ N., Long. 0° 4·6′ W.) bore 310° T., and after steaming 340° T., at 9 knots for 40 minutes it bore 240° T. Find the ship's position allowing for a tidal stream setting 010° T., 3 knots.
8. Needles light (Lat. 50° 39·7′ N., Long. 1° 35·4′ W.) bore 328° C., and after steaming 275° C. (deviation 12° E., variation 17° W.) for 3 hours at 6 knots, it bore 043° C. by the same compass; current setting 107° Magnetic, 2 knots. Find the ship's position on the second bearing.
9. From an observation of the sun, the position line was 120°—300° T., and it was drawn through Lat. 46° 28′ N., Long. 179° 58′ W. The ship then steered 292° T. for 20 hours at 10 knots through a current setting 180° T. at 2 knots when a point of land in 47° 03′ N., 176° 13′ E., bore 050° T. Find the ship's position.
10. Ship *A*, in Lat. 17° S., Long. 0°; ship *B* in Lat. 18° S., Long. 1° W. *A* steers due west at 17 knots. Find *B*'s course and speed to meet *A* in 4 hours.
11. Ship in position *A* Lat. 31° 40′ N., Long. 31° 41′ E., at apparent noon arrives at *B*, Lat. 33° 20′ N., Long. 24° 12′ E., at apparent noon next day. Find true course and average speed noon to noon.
12. At noon A.T.S. Jan. 31, Lat. 30° 15′ N., Long. 162° 47′ E.
    At noon A.T.S. Feb. 1, Lat. 30° 20′ N., Long. 168° 32′ E.
    Find steaming distance and average speed from noon to noon.
13. In D.R. Lat. 51° 10′ N., obs. Long. was 10° 14′ W., the Sun bearing 220° T. The ship then ran 090° for 24 miles when a point in Lat. 51° 23′ N., Long. 9° 36′ W., bore 070° T. Find the ship's position.

CHAPTER II.

THE MAGNETIC COMPASS—VARIATION AND DEVIATION.

THE error which can affect a magnetic compass can be divided into two parts, (*a*) Variation and (*b*) Deviation.

Variation varies with location and time. The earth's magnetic field is not the simple pattern shown in experiments using a bar magnet. However, if this type of field is compared with the actual earth's field, it will be found that the differences have a definite geographical distribution which coincides with currents within the earth. To find variation, charts showing curves of equal variation (isogonals), or the nearest information on the navigational chart, should be used and up-dated for the current year. On standard charts details of variation are included either in the compass rose or on printed isogonals.

Deviation varies essentially with the ship's head but also to some extent with time and location. The earth's field induces magnetism within the ship which in turn creates a secondary field. The ship's aspect with respect to the earth's magnetic field determines the amount of deviation. That is, deviation varies with the course. Deviation is made up of two main components—permanent magnetism associated with "hard" iron and temporary magnetism associated with "soft" iron. In the case of permanent magnetism, some parts of the ship's structure retain their magnetic characteristics for a very long time. In the case of temporary magnetism, the deviation will change, at least in theory, every time the ship changes course.

Changes in the "permanent" magnetism do take place slowly but the process can be accelerated by such factors as large structural alterations or completely change if the ship is struck by lightning. Permanent deviation is corrected by permanent compensating magnets. However, the strength of the earth's field varies with latitude and this alters the directive force of the compass which, in turn, affects the compensation of the permanent magnets.

The temporary component of magnetism results in a time lag between altering course and the "soft" iron adjusting to the change in the field. The time to adjust may range from a few minutes to a week. In the latter case the ship has probably been on a long straight course presenting the same aspect to the earth's field for a considerable time, e.g. two weeks.

The compasses are normally swung approximately once a year by a professional 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 be recorded in a 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 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 of a Distant Object.

Worked Example.

Having taken the following bearings of a distant object by the standard compass, find the magnetic bearing of the object and thence the deviations.

Ship's head by Standard Compass.	Bearing of object by Standard Compass.	Deviation.	Ship's head by Standard Compass.	Bearing of object by Standard Compass.	Deviation.
000°	128°	10° E.	180°	146°	8° W.
010°	130°	8° E.	190°	144½°	6½° W.
020°	132°	6° E.	200°	143°	5° W.
030°	134½°	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.

The sum of the bearings of the distance object = 4968.

The average bearing = 4968 ÷ 36 = 138°.

Therefore, the magnetic bearing is 138° and the deviations are then inserted in column three.

Note if the bearings of the distant object lie both sides of North add 360° for those in the North-East quadrant, e.g. 010° write as 370°. Then sum the bearings to obtain the average bearing and, if necessary, subtract 360°.

Use of the Deviation Card and Deviation Curve.

Deviations can be presented either on a Deviation Card, in tabular form or on a Deviation Curve, in graphical form. In both cases the ship's head by compass is normally shown at intervals of ten degrees.

When using a deviation card to obtain the deviation for an intermediate heading it becomes necessary to interpolate between the two values which lie either side of the required value. Interpolation is effected by linear ratios.

When using a deviation curve, the deviation for a particular compass heading can be picked off directly 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 D.o.T. Examinations, deviation cards are more generally used.

When using deviation cards it is good practice to construct a third column of magnetic headings which are listed opposite their corresponding deviations. Thus, when reading from left to right, we have the compass heading, deviation and magnetic heading shown alongside one another. The card can now be used to quickly convert courses from either compass to magnetic or from magnetic to compass.

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 D.o.T. Examination answers.

EXAMPLE 1. (Using deviation card No. 1)

Find the magnetic course for a course of 228° C.

From the card.

Ship's Head by Compass.	Dev.	
220°	8° E.	$\frac{x°}{2°} = \frac{2°}{10°}$ so $x = \frac{4}{10} = 0{\cdot}4° \simeq \frac{1}{2}°$
10°		
228°	y°	10° E. — $\frac{1}{2}°$ = $9\frac{1}{2}°$ E.
2°	x°	
230°	10° E.	228° C. + $9\frac{1}{2}°$ E. = $237\frac{1}{2}°$ M. *Answer.*

EXAMPLE 2.

Find the compass course for a course of $237\frac{1}{2}°$ M.

Ship's Head by Compass.	Dev.	Mag.
220°	8° E.	228°
	2°	
	y	$237\frac{1}{2}°$
	x°	$2\frac{1}{2}°$ 12°
230°	10° E.	240°

$\frac{2\frac{1}{2}°}{12°} = \frac{x°}{2°}$ so $x = \frac{5}{12} \simeq \frac{1}{2}°$

10° E. — $\frac{1}{2}°$ = $9\frac{1}{2}°$ E.

$237\frac{1}{2}°$ M. — $9\frac{1}{2}°$ E. = 228° C. *Answer.*

Using Sun Azimuths to Construct a Table of Deviations.

When a vessel is "swung" using sun azimuths to find the deviation, the procedure is much the same as when using a distant object. In this case, however, 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 and 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 the error, and the difference between the error and the variation is the deviation for the direction of the ship's head at the time.

Worked Example.

On 8th May in Lat. 49° N., Long. 5° W., the variation being 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.

Latitude 49° N., Sun Declination 17° N. Refer to ABC Tables.

Head by Compass	8th May G.M.T.	Bearing by Compass	True Az. from Tables	Error of Compass	Var.	Dev.
000° C.	0920 hrs.	128° C.	115·2° T.	12·8° W.	16° W.	3·2° E.
045°	0928	125°	117·3°	7·7° W.	,,	8·3° E.
090°	0936	122°	119·4°	2·6° W.	,,	13·4° E.
135°	0944	132°	121·5°	10·5° W.	,,	5·5° E.
180°	0952	141°	123·8°	17·2° W.	,,	1·2° W.
225°	0900	150°	126·0°	24·0° W.	,,	8·0° W.
270°	0908	159°	128·4°	30·6° W.	,,	14·6° W.
315°	0912	154°	130·9°	23·1° W.	,,	7·1° W.

Examples for Exercise.

(1) You have taken the following compass bearings of a distant object. Find its magnetic bearing, and thence the deviation on those points on which the bearings were observed.

Ship's head by Standard Compass.	Bearing of object by Standard Compass.	Deviation required.	Ship's head by Standard Compass.	Bearing of object by Standard Compass.	Deviation required.
000°	265°		180°	214°	
045°	244°		225°	211°	
090°	236°		270°	249°	
135°	230°		315°	251°	

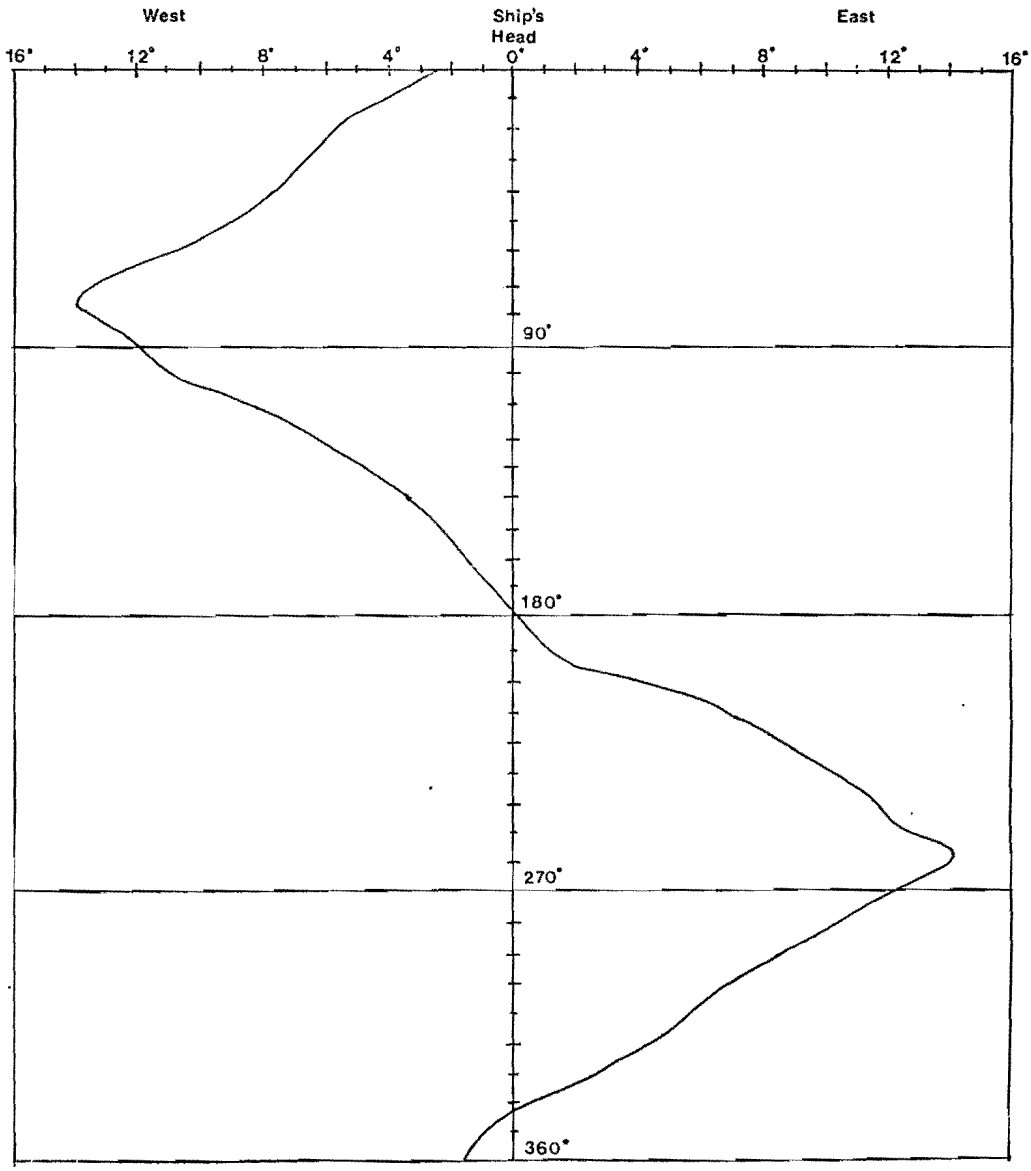
Required: (*a*) The Magnetic Bearings, (*b*) the Table of Deviations, and

(*c*) the Compass Courses to steer in order to make the following magnetic courses: 298° M, 158° M, 292° M, 139° M, and

(*d*) Use the Table of Deviations to find the Magnetic Courses corresponding to the following Compass Courses:

022° C 067° C 203° C 247° C.

Deviation Card No. 1

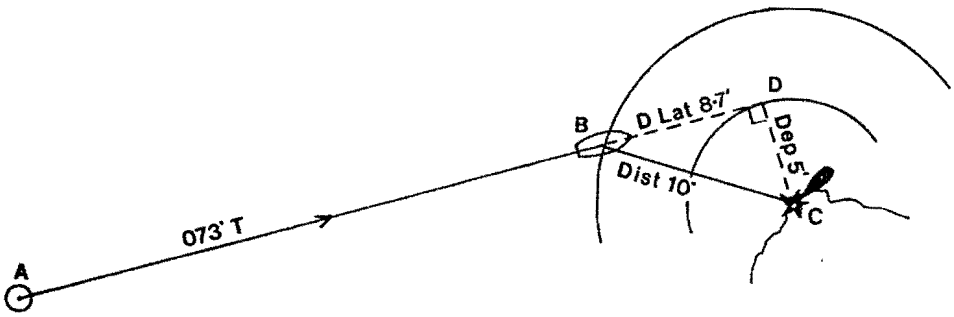


[To Face Page 17

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.

TO FIND THE COURSE TO STEER TO BRING A POINT A GIVEN DISTANCE OFF AT A GIVEN ANGLE ON THE BOW.



ENGLISH CHANNEL CHART.

Example.—Find the course to steer from (*A*) Lat. 49° 37′ N., Long. 3° 22′ W., to fetch the Casquets light (*C*) 30° on the starboard bow when 10 miles off. Find also the distance off when it comes abeam and the distance to go to bring it on the bow bearing.

1. With centre Casquets (*C*) and radius 10 miles (*C B*) describe a circle.
2. Enter Traverse Table with 30° as course, 10 miles as distance and we get 5 miles in Departure Column.
3. With centre Casquets and radius 5 miles (*C D*) describe a circle.
4. From *A* draw (*AD*) a tangent to the 5 mile circle cutting the 10 mile circle at *B*. Angle *C B D* will be 30°.

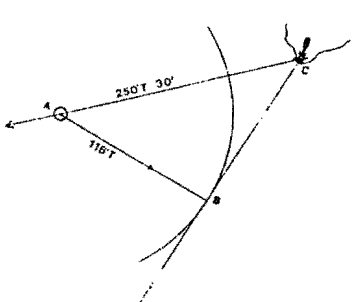
Answers.—*A B* is the course to steer, 073° T, *C D* the beam distance 5 miles, *A B* the distance to go 55½ miles. The Traverse Table gives *D B* in difference of latitude column, 8·7 miles, should this distance be required.

Example.—Bristol Channel. Find the course from Breaksea Lightvessel to bring Bull Point 7 miles off when it is 40° on the port bow. Give also the distance to go to bring Bull Point on this bearing and the distance off when light comes abeam.

Answer.—Course 263° T, Distance to go 31 miles, Beam distance 4·5 miles.

TO FIND THE COURSE TO STEER TO BRING A POINT ABEAM USING THE SHIP'S RADIUS OF ACTION.

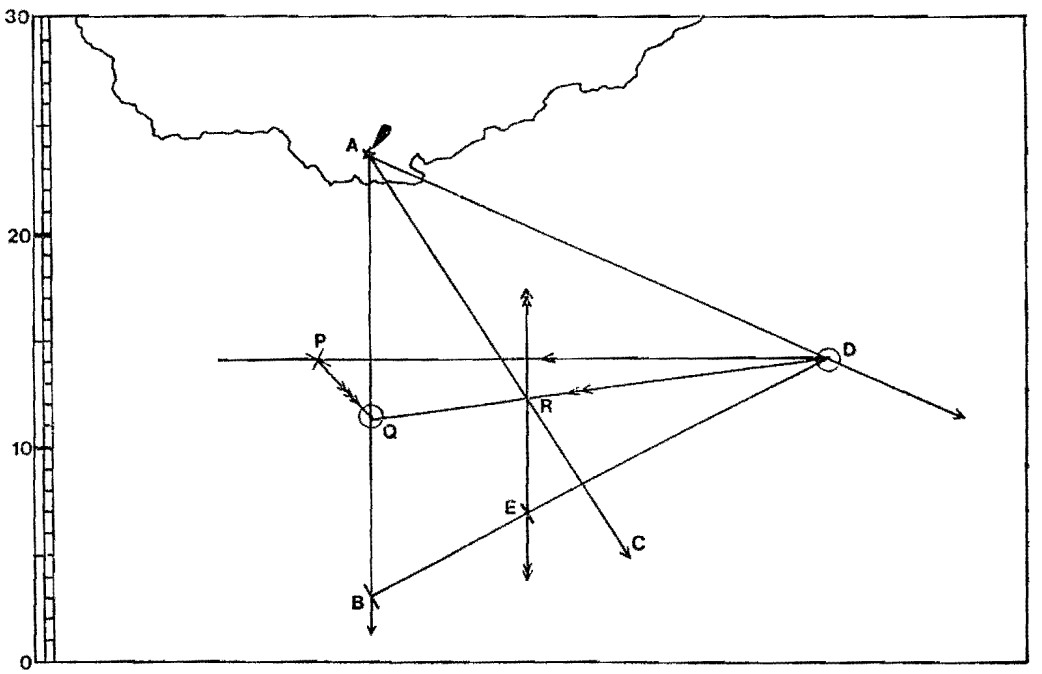
Example.—A ship steaming at 14 knots is at position *A*, 250° T, 30 miles from Lizard Head Point. Find the course to steer to bring the Point on the port beam in 1½ hours.



1. Plot position *A*.
2. The ship's radius of action in 1½ hours is 21 miles. With centre *A* and radius 21 miles describe a circle.
3. Draw a tangent to the circle from the Lizard (*C B*).
4. Join *A B* which is the required course of 116° T.

Given three true bearings of a point, the true course steered and the distance steamed between each bearing, and the ship's position on the first bearing.

To find the ship's position on the third bearing, the true course made good, and the set and drift since the first bearing was taken.



Example.—A vessel was steering 270° T. when she picked up a light *A* dipping on the horizon, distance off 23·8 miles, and bearing 295° T. After running 16 miles on her course it bore 328° T, and after running another 8 miles it bore 000° T.

Find the ship's position when abeam, the course and distance made good, and the set and drift since the light was first sighted.

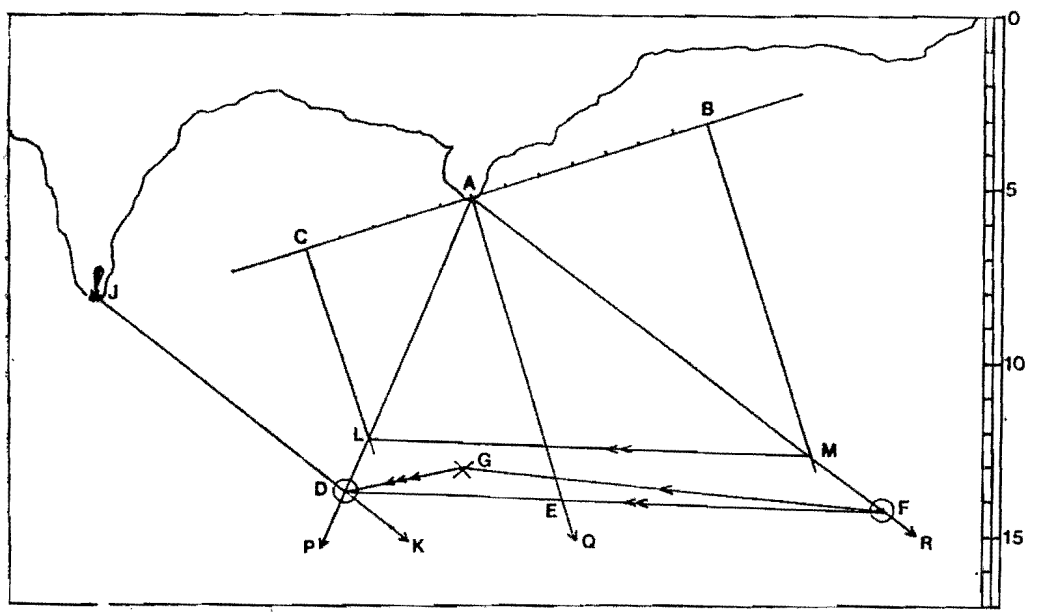
Lay off all the true bearings from *A*, and on the first bearing make $AD=23{\cdot}8$ miles, then *D* is the position of the ship on the first bearing, as she is 23·8 miles from the light. The ship steamed 24 miles between the first and third bearings, therefore with 24 miles on the compasses and the point of the compasses on *D* describe an arc cutting the third bearing at *B*. The distance steamed between second and third bearing was 8 miles, therefore from *B* make $B\,E=8$ miles. Draw a line parallel to the third bearing through *E*, and where this meets the second bearing at *R* is the ship's position on the second bearing. Join *D R* and extend it to *Q* on the third bearing. Then D *R Q* is the course the ship has made good, and *Q* her position on the third bearing, that is when abeam.

To find the set and drift of the current since the vessel was at *D*, lay off the true course and distance steamed from *D* by making *D P* 270° T. × 24 miles, then *P*

is the ship's D.R. position and Q is where she actually is. $P\ Q$ is, therefore, the set and drift since her position was ascertained at D.

Course made good 263° T.
Distance 21·7 miles.
Set 137° T.
Drift 3·5 miles.

Example.—A ship steering 275° T. observes point A to be bearing 307° T. After running 7 miles it bears 342° T. and after having done another 5 miles on the same course it bears 023° T. At the time of taking the third bearing point J was observed to bear 308° T. Required the ship's position when the third bearing was taken, the course and distance made good between the bearings, and the set and drift of the current.



Lay off the three bearings of point A, which will be RA, QA and PA, and KJ which is the bearing of point J.

The ship's position at the time of taking the third bearing is at D, which position is fixed by the intersection of that bearing by the cross bearing of point J.

Draw the line CAB through point A at right angles to the middle bearing QA.

From A lay off AB along this line to represent the distance steamed between the time of taking the first and second bearings, which is 7 miles. (*N.B.*—Use the latitude scale on which 5 miles is represented by approximately 1 inch).

From A lay off AC along this line in the other direction. This represents the distance steamed between the time of taking the second and third bearings, which is 5 miles (1 inch).

~~Draw the lines BM and CL~~ parallel to AQ.

These lines intersect the first and third bearings at *M* and *L* respectively.

Then *ML* represents the course which the ship is making good over the ground, though not necessarily the actual distance. In this case it certainly cannot be the distance, because the ship was somewhere on the first bearing *RA* at the start, and was at position *D* when the third bearing was taken at the finish.

Draw *FD* parallel to *ML*.

FD represents the actual track and distance made good over the ground between the times of taking the first and third bearings. This is about 272° T, 16 miles (3·2 inches).

Knowing that the ship was at *D* when the third bearing was taken she must have been at *E* when the second bearing was taken, and at *F* at the time of taking the first one.

Now, by laying off from *F* the course and distance **which she has steamed,** this will be 12 miles along the line *AB*, we should expect to find her at D.R. position *G*.

Having found that **her real position is at** *D*, the line *GD* must represent the set and drift of the current which is 259° T., 4 miles (0·8 inch).

Worked Example I.

(Worked on the St. George's Channel chart inset.)

Question 1.—**A vessel steering 187° C. observed Bailey Head light, height 81 feet, to be dipping on the starboard beam. Height of eye 22 feet. Required the true course, also the ship's position and her distance from Bailey Head light.** (Use Dev. Card No. 1).

Instructions for Working.—The extreme range (or dipping distance) at which a light is just visible is found by adding the distance of the sea horizon from the light to the distance of the sea horizon from the observer. In both cases it is either the height of light or height of eye which determines the distance of the respective sea horizons.

This method applies only to lights of adequate power and ignores meteorological conditions which affect visibility. Accuracy may also be affected by the fact that charted heights ignore fractions.

Distance of the sea horizon can be found using the formula $1{\cdot}17\sqrt{h}$ where h is the height of eye. In practice, extreme range is found by inspection of Distance of Sea Horizon Tables as follows:—

From tables:

Distance of Sea Horizon for Light 81 ft.	10·55 miles
,, ,, ,, ,, ,, Height of Eye 22 ft.	5·59 ,,
Dipping Distance (off Bailey Head Lt.)	16·05 ,,

With this distance as radius and Bailey Head Light as centre describe the circle *B P C*, the circumference of this circle will then be a **position line**—*i.e.*, the ship must be somewhere on this line. As Bailey Head Light was abeam on the starboard side we can get its true bearing by applying 90° to the right of the true course. Thus we have two position lines, the circle of equal distance and the true bearing, and as the vessel is on both of these lines, she must be at their point of intersection at *P*.

The ship's course being given by compass, it must be turned into a true one by applying the deviation (taken from the card), and the variation.

Compass course	- -	187° C.	
Dev. from card	- -	+¾ E.	
Magnetic course	- -	187¾° M.	Ship's position { Lat., 53° 24′ N.
Corrected variation	- -	—17 W.	{ Long., 5° 41½′ W.
True course	- - -	170¾° T. → 171° T.	

From the ship's position at *P*, project the course line *P H* in a 171° T. direction.

How to apply the Half Convergency.

Make a thumbnail sketch showing the ship and D.F. station in their relative position. The straight line joining them represents the rhumb line, or mercatorial bearing. Draw a curve between the two points to represent the great circle, or D.F. bearing, being careful to draw the bulge of the curve on that side of the rhumb line next to the pole of the hemisphere. It is then obvious from the figure whether the correction should be added or subtracted. It is plus in this case because the mercatorial bearing is more clockwise than the D.F. bearing.

For the Cape Grim bearing we have—

	Lat.	Long.		
Station	40° 42′ S.	144° 43′ E.	D.F. bearing	092·5°
Ship	40 40 S.	143 40 E.	½ convergency	— ·3
	2)81 22	1 03	Mercatorial bearing	092·2
Mn Lat.	40 41	D. Long 63′		or 092° T.

Convergency may also be found from the Traverse Tables as follows:—

Convergency = D. Long. × sin Mn. Lat.

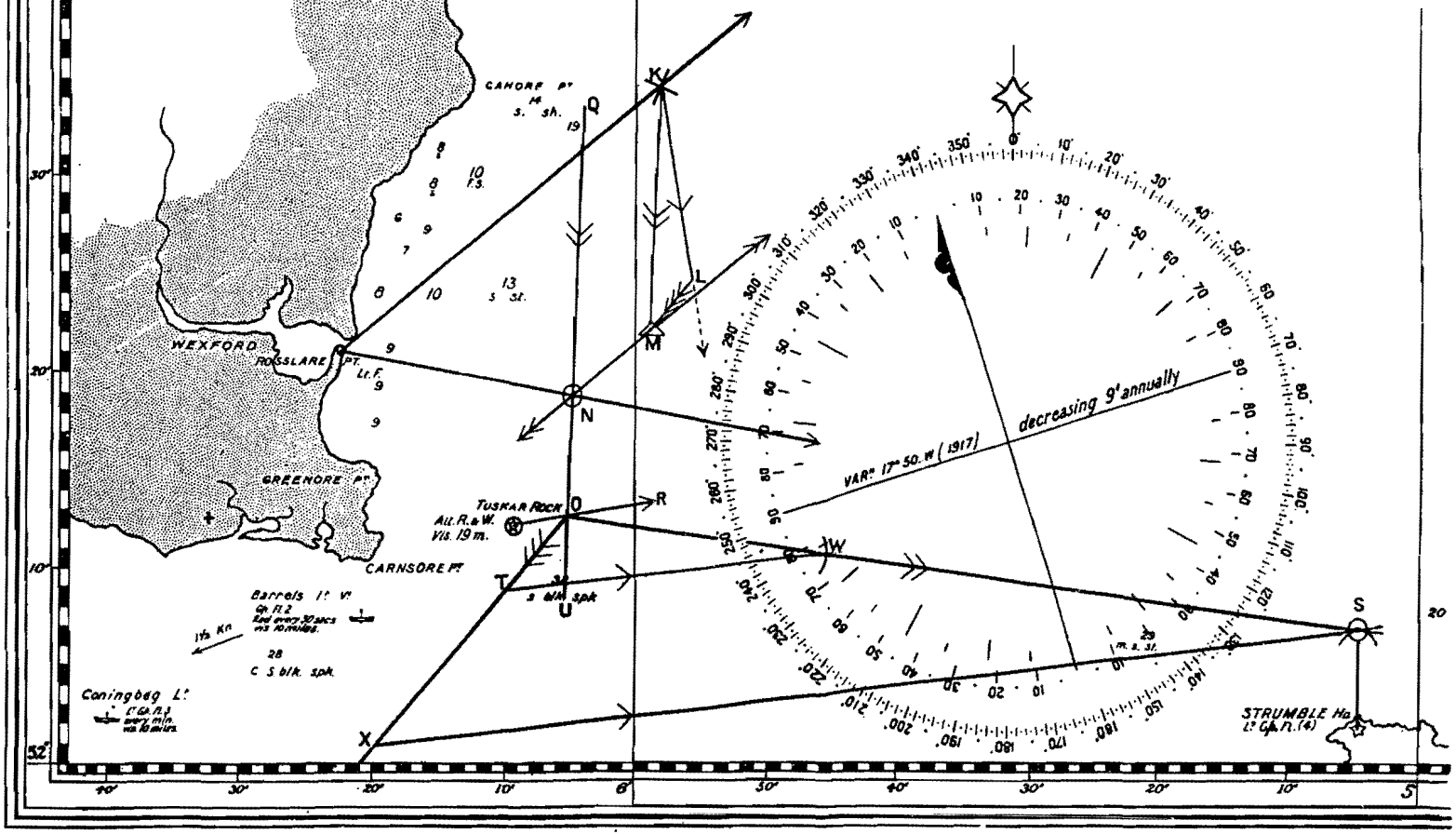
and Dep. = Dist. × sin Course

so by substitution we get

Lat. as Course - - - -	40° 41′
D. Long. in Dist. Col. - - -	63′
Convergency in Dep. Col. - -	41·3′

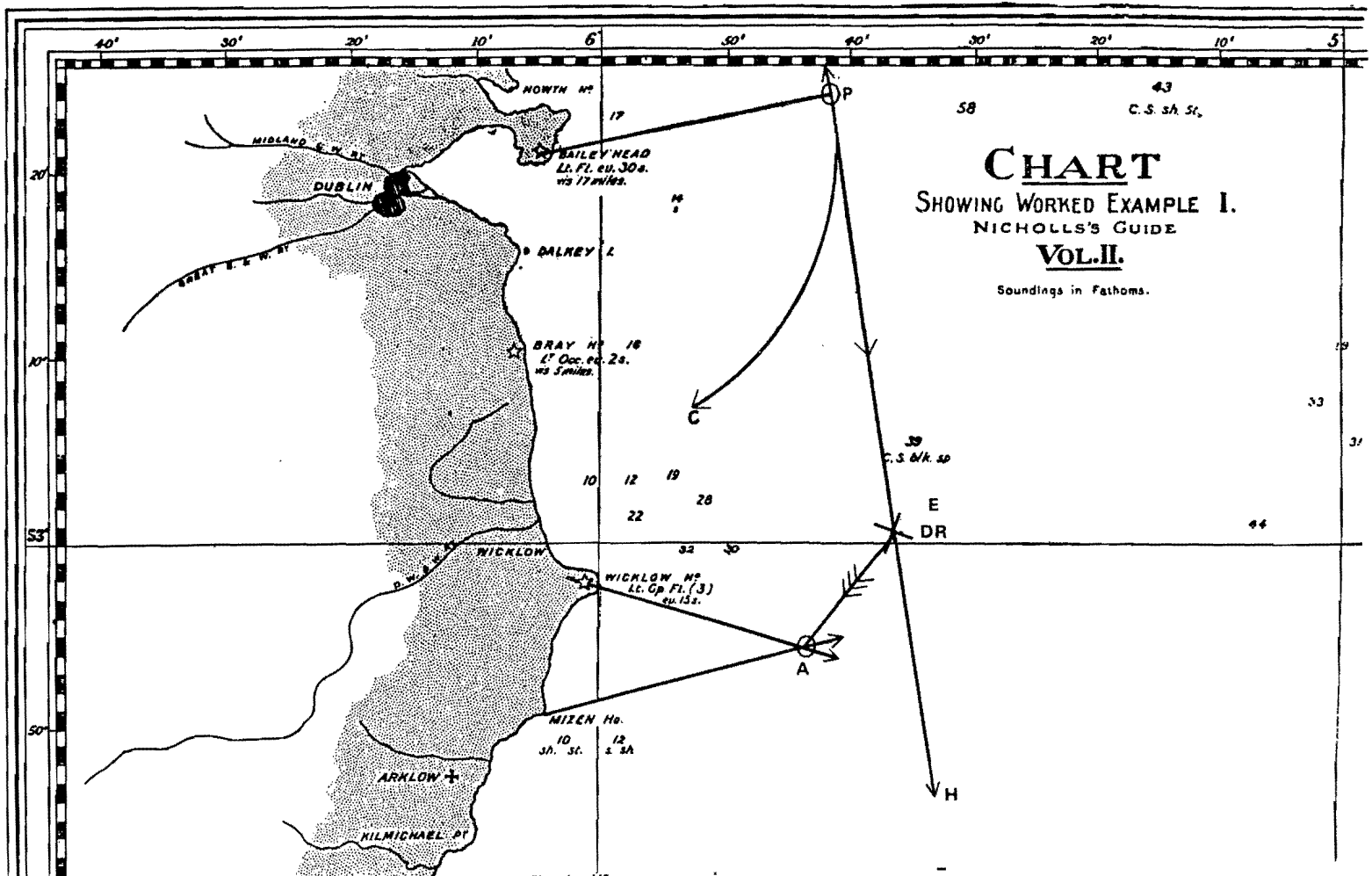
$\therefore \frac{1}{2}$ convergency = + 20·6′ = 0·3°

The position of the ship is fixed by the intersection of these two lines drawn from the D.F. stations (point *J* on the chart).



Printed by Brown, Son & Ferguson, Ltd., Glasgow, and inserted in "Nicholls's Concise Guide."

To face page 22



CHART

SHOWING WORKED EXAMPLE I.

NICHOLLS'S GUIDE

VOL. II.

Soundings in Fathoms.

WORKED EXAMPLE I. (*Continued*).

Question 2.—**Three hours after fixing the position of the ship in the last question, a steady speed of 8 knots being maintained; Mizen Head was observed to be bearing 85° on the starboard bow and at the same time Wicklow Head Lt. bore 25° abaft the starboard beam. Find the ship's position and the set and drift of the current experienced since the ship was abeam of Bailey Head Lt.**

INSTRUCTIONS FOR WORKING.—From *P* measure off along the course line the distance run since this position was obtained, which was 24 miles; this gives the D.R. position *E*. The bearings of Wicklow Head Lt. and Mizen Head can be laid off with graduated parallel rulers by treating the course line *P H* as a meridian and the angle of the bearing from the bow as a course; or they can be obtained from the true course as follows:—

True course - - - - - - -	171° T.
Angle of Mizen Head on bow - -	85 (+)
True bearing of Mizen Head - - -	256° T.
True course - - - - - - -	171° T.
Angle of Wicklow Head Lt. on bow -	115 (+)
True Bearing of Wicklow Head Lt. -	286° T.

The point of intersection of these two bearings at *A* is the Observed Position of the ship, the set and drift is, therefore, *E A*, which is reckoned from the D.R. to the Observed Position of the ship.

Ship's position - -	Lat. 52° 54½′ N.
	Long. 5° 43½′ W.
Set of current - -	219° T.
Drift - - - -	8 miles.
Rate - - - -	2·75 knots.

WORKED EXAMPLE I. (*Continued*).

Question 3.—**Whilst on the last-mentioned course Rosslare Point Lt. bore 60° on the starboard bow, and after running for 1h 15m at 8 knots the same light bore 20° abaft the starboard beam. Find the ship's position and her distance from Rosslare Point Lt. when the second bearing was taken, allowing for a current as ascertained in Question 2. Required also the distance from Tuskar Rock Lt. when abeam.**

Position of Rosslare Point Lt.: Lat. 52° 21′ N., Long. 6° 22·7′ W. Put it on the chart if it is not marked on your copy.

INSTRUCTIONS FOR WORKING.—Lay off the two bearings of Rosslare Point Lt. as explained when laying them off in Question 2. From any position (*K*) on the first bearing draw a line parallel to the ship's true course, and on it measure off from *K* to *L* the distance steamed in 1¼ hours, which is 10 miles.

From *L* lay off the current ascertained in the preceding question. This was 219° T. at 2·75 knots, which in 1¼ hours will be 3·45 miles. This will reach the mark *M*. Through *M* draw a line parallel to the first bearing. The point where this line intersects the second bearing at *N* is the ship's position at the time of taking that bearing. Now, *K M* is the course and distance **made good** between the time of taking the two bearings, and is the result of the course and distance steamed and the current experienced during that time. If we draw a line parallel to *K M* through *N* (the ship's position when the second bearing was taken) it will represent the vessel's **actual track** over the ground. This is the line *Q N O U*. The beam bearing of an object is always at right angles to the **direction of the ship's head,** which is represented by the line *K L*. We, therefore, draw a line at right angles to *K L*, and the point where this line (*O R* on chart) meets the actual track of the vessel at *O* will be the ship's position when abeam of Tuskar Light.

True course - - -	171° T.
Angle on bow - - -	60 (+)
First true bg. of Rosslare pt.	231° T.

True course - - -	171° T.
Angle on bow - -	110 (+)
	281° T.
Second true bg. Rosslare pt.	281° T.

Ship's position on second bearing Lat. 52° 19′ N.
Long. 6° 05′ W.

Distance from Rosslare Point, 12½ miles.

Distance from Tuskar Rock when abeam, 3 miles.

WORKED EXAMPLE I. (*Continued*).

Question 4.—**Find the course to steer by compass from the last position with Tuskar Rock Lt. abeam' to reach a position 000° T. from Strumble Head Lt. distant 5 miles. Make proper allowance to counteract the effect of a current setting 238° M. at 2½ knots' and allow 5° leeway for a N.E. wind, the ship's speed being 8½ knots. Give the distance steamed and the time taken to reach the destination.** (Deviation Card No. 1.)

INSTRUCTIONS FOR WORKING.—Mark off the position of the destination at a distance of 5 miles due North (true) from Strumble Head Lt. Call it *S*. Join *O S* with a straight line. If there was not any current, *O S* would be the true course.

To find the course to steer to counteract the effect of a current setting 238° (magnetic), lay off a line in a 238° magnetic direction from *O* to represent the set of the current.

No time being specified in the question, we must choose some convenient interval of time on which to base our calculations, let us say two hours. Now, in two hours the current will set 5 miles, so we measure off 5 miles along the current line from *O* and make the mark *T*. *O T*, then, represents the set of the current in two hours.

The ship's speed being 8½ knots, in two hours she will do 17 miles. With this distance in the compasses, place one leg on *T* and mark the position where the other leg meets the line *O S*. Name this mark *W*. Join *T W*, then *T W* is the course to steer to counteract the current *O T*. As the vessel will have to steer this course until she reaches her destination, draw a line parallel to *T W* through *S*. This line meets *O T* (extended) at *X*, and *XS* represents the distance which the ship will have to steam to reach *S*. The time occupied is found by proportion, as shown below.

The correction for leeway is not projected on the chart, but is applied to the true course *after* it has been taken from the chart. Remember that it must be allowed **to windward**—in other words, **towards the wind**—in order to counteract the effect of the ship being set to leeward or away from the wind.

It is important that the leeway should be applied before the deviation is taken from the card, as the deviation changes with the direction of the ship's head.

True course - -	083°
Leeway (N.N.E. wind)	—5
	078°
Variation - - -	+17° W.
Magnetic course -	095°
Deviation - - -	+10° W.
Compass course - -	105°
Distance steamed -	51·75 miles
Time occupied - -	6 hrs. 05·4 mins.

TO FIND THE TIME TAKEN TO REACH DESTINATION

As $8\frac{1}{2}$: : $51\frac{3}{4}$: : 1 hr. to time.

8·50)51·75(6·09 hours.
51·00

7500
7650

·09 hours
60

5·40 minutes

Worked Example II.

(To be worked on the practice chart of Tasmania.)
Working inset.

Question 1.—**The ship's D.R. position was Latitude 40° 40′ S.′ Longitude 143° 40′ E. D.F. bearing of the ship from Hobart RC Station in Lat. 42° 54′ S., Long. 147° 15′ E. was 132·5° T. and D.F. bearing of the ship from Cape Grim RC Station in Lat. 40° 42′ S., Long. 144° 43′ E. was 092·5° T. Required the position of the ship by these D.F. bearings.**

Important Note:—In practice D.F. bearings should **never** be taken across land.

The D.F. bearings are great circle bearings and have to be converted into their equivalent mercatorial bearings before laying them off on the chart. This is done by applying the half convergency correction. Convergency can be calculated using the formula

$$\text{Convergency} = \text{D. Long.} \times \cos \text{Mn. Lat.}$$

but, in practice, Half Convergency Correction Tables are generally used.

The tables are entered with the Mean Latitude and Difference of Longitude between the ship and the RC station. Care must be exercised to apply the correction the right way; this is best decided by making a sketch.

Hobart R.C. station	42° 54′ S.		147° 15′ E.	
D.R. ship	40 40 S.		143 40 E.	
	2)83 34 S.	D. Long	3 35′ W.	= 3·6°
Mean Lat.	41 47 S.			
,, ,,	= 41·8°			

From Half Convergency Tables:

		D. Long. 2°	D. Long. 4°
Mean Lat.	39°	0·6°	1·3°
	42°	0·7°	1·4°

Use corrections for Mean Lat. 42° as follows:—

D. Long		Half Convergency
2°	→	0·7°
1·6°		x° 0·7°
2° 3·6		C
4°	→	1·4°

To Interpolate for D. Long 3·6°:

$3{\cdot}6° \sim 2° = 1{\cdot}6°$

$$\frac{1{\cdot}6}{2} = \frac{x}{0{\cdot}7}$$

$$\frac{1{\cdot}6 \times 0{\cdot}7}{2} = x \qquad = 0{\cdot}56°$$

Half Convergency for 2°	0·7
,, ,, ,, 3·6°	1·26°
D.F. Bearing	132·50°
Half Convergency	— 1·26
Mercatorial Bearing	131·24°
	or 131° T.

How to apply the Half Convergency.

Make a thumbnail sketch showing the ship and D.F. station in their relative position. The straight line joining them represents the rhumb line, or mercatorial bearing. Draw a curve between the two points to represent the great circle, or D.F. bearing, being careful to draw the bulge of the curve on that side of the rhumb line next to the pole of the hemisphere. It is then obvious from the figure whether the correction should be added or subtracted. It is plus in this case because the mercatorial bearing is more clockwise than the D.F. bearing.

For the Cape Grim bearing we have—

	Lat.	Long.		
Station	40° 42′ S.	144° 43′ E.	D.F. bearing	092·5°
Ship	40 40 S.	143 40 E.	½ convergency	— ·3
	2)81 22	1 03	Mercatorial bearing	092·2
Mn Lat.	40 41	D. Long 63′		or 092° T.

Convergency may also be found from the Traverse Tables as follows:—

Convergency = D. Long. × sin Mn. Lat.

and Dep. = Dist. × sin Course

so by substitution we get

Lat. as Course - - - -	40° 41′
D. Long. in Dist. Col. - - -	63′
Convergency in Dep. Col. - -	41·3′

$\therefore$ ½ convergency = + 20·6′ = 0·3°

The position of the ship is fixed by the intersection of these two lines drawn from the D.F. stations (point *J* on the chart).

WORKED EXAMPLE II. (*Continued*).

Question 2.—**From this position obtained by the D.F. bearings, a course was set to pass 15 miles off Cape Sorell Lt. when abeam. Using Deviation Card No. 1, find the course to steer by compass and also the distance to steam to bring the light abeam.**

INSTRUCTIONS.—Take, from the latitude scale abreast of Cape Sorell Lt., 15 miles on your compasses, and describe an arc round the light. From the point of departure *J* draw a tangent to this arc. Now draw a line at right angles to this tangent on to the light, and obtain the beam bearing of the light (*K* on the chart). The tangent to the arc is the course, which must be corrected, and turned into a compass course. The distance to bring Cape Sorell Lt. abeam (*J K*) measured on the latitude scale is found to be 106·5 miles.

True Course - -	155° T.		140° C.
Variation - - -	—8 E.	Dev.	—3½ W.
Magnetic course -	147° M.		136½ M.
Deviation - - -	+2½ W.		
Compass Course -	149½° C.		150° C.
		Dev.	—2½ W.
			147½° M.

Distance to bring light abeam, 106½ miles.

Question 3.—**While on this course Cape Sorell Lt. bore 105° C. and after continuing for 1½ hours at 12 knots, the light was found to be exactly abeam. Required the ship·s position when abeam' and her distance from Cape Sorell Light.**

INSTRUCTIONS.—Correct the compass bearing of Cape Sorell Light, using the deviation found in the preceding question. There is no need to correct the second bearing of the light because it is abeam, or at right angles to the course. Plot these lines, and from where the first bearing intersects the course line, measure along the course line 18 miles (the distance steamed between the bearings) and through this point draw a line parallel to the first bearing of the light. Where it crosses the second or beam bearing is the position of the ship when the light is abeam (*L* on chart).

CAPE SORELL LT.		CAPE SORRELL LT.	
Compass Bearing -	105° C.	Abeam, requires no correction.	
Deviation - - -	—2½° W.		
Magnetic Bearing -	102° M.	Lat. - - -	42° 18½′ S.
Variation - - -	+8 E.	Long. - - -	144° 48′ E.
True Bearing - -	110½° T.		

Distance from Cape Sorell Light, 18 miles.

WORKED EXAMPLE II. (*Continued*).

Question 4.—**Proceeding on this course for a further 3 hours at the same speed, the western extremity of Point Hibbs was observed to be bearing 355° C., and at the same instant the Signal Staff on Rocky Point bore 109° C. Find the position of the ship and the set and drift experienced since determining the position by the running fix off Cape Sorell Light.**

INSTRUCTIONS.—As we are still continuing on the same course as in the last question, we draw a line parallel to the original course line from *L*. From *L*, measure along this course line a distance of 36 miles (3 hours' steaming), this gives us the D.R. position *M*. After applying the same compass error to the given compass bearings of Point Hibbs and Rocky Point Signal Staff, to turn them into true bearings, we plot them and their point of intersection *N* gives us the vessel's Observed Position. Joining up the D.R. *M* with the Observed Position *N*, we obtain the set and drift of the current during the previous three hours.

WESTERN EXTREMITY OF POINT HIBBS.			ROCKY POINT SIGNAL STAFF.	
Compass Bearing	355° C.		Compass Bearing	109° C.
Deviation	—2½ W.		Deviation	—2½ W.
Magnetic Bearing	352½° M.		Magnetic Bearing	106½° M.
Variation	+8 E.		Variation	+8 E.
True Bearing	360°	000½° T.	True Bearing	114½° T.

Lat. 42° 54½′ S. Long. 145° 15′ E.
Set, 128·5° T. Drift, 6 miles.
Rate 2 knots.

Question 5.—**From the position thus found by cross-bearings, reset the course by compass (Deviation Card No. 1) to a position 9 miles, 264° T. from South-west Cape, to counteract the effect of the current ascertained in the previous questions, and also find what distance will be made good in 3 hours towards the destination, and the distance from South-west Cape at the end of that time.**

INSTRUCTIONS.—To reset the course to the position 9 miles, 264° from South-west Cape, we plot this position on the chart (*O*) and draw a line from the Observed Position, *N*, found by cross-bearings in the previous question, to *O*. This gives us the course to be made good *N O*. Now, from the position by cross-bearings (*N*) lay off the current similar to that found in the last question; this will be a continuation of the line *M N*.

From *N* measure in the direction *M N* (continued) the distance the ship will be set in 3 hours; this is 6 miles, and reaches the point *P*. Take the distance steamed in 3 hours—that is, 36 miles—in the compasses, and with one leg on *P* mark the point *Q* on the line *N O*. A line from *P* to *Q* indicates the true course to steer which must be converted to a compass course. *N Q* represents the distance made good in 3 hours.

True Course	151° T.	Compass Course	140° C.
Variation	—8 E.	Deviation	—3½ W.
Magnetic Course	143° M.	Magnetic Course	136½° M.
Deviation	+3 W.	Compass Course	150° C.
Compass Course	146° C.	Deviation	—2½° W.
		Magnetic Course	147½° M.

Distance made good in 3 hours, 42 miles.
Distance from South-west Cape, 13 miles.

Worked Example III.

Question 1.—**Approaching the south-west coast of Tasmania on a compass course of 112½° C. a Lt. Gp. Fl. (2) ev. 30 secs. was observed to be bearing 087° C. 1·2 hours later it bore 060° C.′ and 48 minutes later still it was abeam. Required the position of the ship when abeam, also the rate of the current, the set being estimated to be 203° T. and the speed of the ship 10 knots by revolutions.** (Use Deviation Card No. 1.)

Instructions.—As the course by compass is given (112½° C.), we take the deviation direct from the card for that point and apply it to same, together with the variation, and obtain the true course. This same error is also applied to the three bearings taken of the Lt. Gp. Fl. (2) ev. 30 secs. to turn them into true bearings. It is a coincidence that the variation and deviation are equal in amount but opposite in name, thus making no compass error, and the compass bearings are, therefore, true ones.

Draw these three bearings on to the light, and through the light draw a line at right angles to the middle of the three bearings. Now take the distance steamed between the first and second bearings; in 1 hour 12 minutes this will be 12 miles, and measure it along this line to the left of the light, reaching point *R*, also take the distance steamed between the second and third bearings; in 48 minutes this will be 8 miles, and measure it along this line to the right of the light, reaching point *S*. From *R* and *S* lay off two lines parallel to the middle bearing, and let them intersect the first and third bearings in points *T* and *U*. These two points joined together will give the actual direction in which the ship is moving over the ground.

Draw from the point *T* on the first bearing the true course being steamed 113° and measure along it the distance steamed in the two given times, 1h 12m + 0h 48m = 2 hours, which at 10 knots = 20 miles. Name this point *V*. From *V* draw the given set of the current 203° T. on to the course being made good, reaching the point *W*. You will thus obtain the amount the tide has set you during the two hours (*V W*) and also the actual distance made good (*T W*). We then draw through the point *W* a line parallel to the first bearing, and the point where this parallel line meets the third bearing is the actual position of the ship at the time of taking the third bearing or when abeam (*X*).

Compass Course	112·5° C.	
Deviation	—8·0 W.	Dev. and var. practically the same value, therefore the error is assumed to be nil.
Magnetic Course	104·5° M.	
Variation	+8·5 E.	The three bearings of the light are, therefore, both compass and true.
True Course	113° T.	

First bearing 087° T., second bearing 060° T., third bearing 023° T. or abeam.
Position of the ship, Lat. 43° 50½′ S., Long. 146° 11′ E.
Drift 2 miles. Rate, 1 knot.

WORKED EXAMPLE III. (*Continued*).

Question 2.—**When abeam of this light (Lt. Gp. Fl. (2) ev. 30 secs.) the course was reset to pass 6 miles off Whale Head when abeam, and after proceeding for 2·5 hours at 10 knots, cross bearings were taken to fix the ship's position as follows :—Piedra Blanca 115° C. and Whale Head 022° C., both by the same compass. Required the course to steer by compass, the position of the ship by the cross bearings, and the set and drift of the current affecting the ship since the course was reset.** (Deviation Card No. 1.)

INSTRUCTIONS.—From the position (X) the course is reset to pass 6 miles off Whale Head. Draw a circle of 6 miles radius round Whale Head, and draw a tangent to it; measure 25 miles (distance steamed in 2·5 hours) from X along it, and obtain the expected position (Y). Correct the true course and obtain the compass error, and apply same to the compass bearings of Piedra Blanca and Whale Head to turn them into true bearings. Plot them on the chart, and where they intersect at Z is the Observed Position. The line Y Z is the set and drift experienced in the 2·5 hours.

True Course	079° T.		080° C.
Variation	—8·5° E.	Dev.	–13·5° W.
Magnetic Course	070·5° M.		066·5° M.
Deviation	+13° W.		
			090° C.
Compass Course	083·5° C.	Dev.	–12° W.
			078° M.

Piedra Blanca.		Whale Hd.	
Compass Bearing	115° C.	Compass Bearing	022° C.
Error	—4·5° W.	Error	—4·5° W.
True Bearing	110·5° T.	True Bearing	017·5° T.

Lat. 43° 45½′ S. Long. 146° 50′ E.
Set 133° T. Drift 4 miles. Rate 1·6 knots.

WORKED EXAMPLE III. (*Continued*).

Question 3.—**Reset the course again to maintain a distance of 5·5 miles from Tasman Head to counteract the effect of a current similar to that determined in the previous question, and when Tasman Head bears 270° T. alter the course to an anchorage with Iron Pot Lt. dead ahead and distant 2 miles.**

Using Dev. Card No. 1, give the course to steer and the distance to steam to the position where Tasman Head bears 270° T., and also give the course to steer to the anchorage (both by compass). If on the final course the tide is dead astern and the anchorage is made in exactly 2 hours, required the rate of the current, the speed of the ship being 10 knots throughout.

INSTRUCTIONS.—Draw a circle round Tasman Head 5·5 miles in radius, and from the "fix" by cross bearings in the previous question (*Z*) a tangent is drawn to this circle. As the course requires to be carried on until Tasman Head bears 270° T., we produce it to intersect a line drawn 090° T. from Tasman Head (*A*). This will obtain for us the real course and distance to be made good (*ZA*) to arrive at that position. As the tide found in the previous question must be counteracted, the direction is laid off from the starting point (*Z*). It should be observed that no specified time is given in the question, therefore any interval of time may be assumed. To save the time taken in calculating by proportion and to reduce the possibility of a mistake being made, it is usual to assume the same time used in determining the amount of the current. Extend the line *Y Z*, measure along it from *Z*, 4 miles, the distance set in 2·5 hours (*Z B*), and from *B*, 25 miles is fitted on to the course line to be made good (*Z A*) at point *C*. *B C* connected together gives the true course to be steered, and a parallel line to it (shown dotted) from the extended current line to the position (*A*) off Tasman Head gives the distance to be steamed to reach that position.

From the position of the ship (*A*) when Tasman Head bears 270° T., draw a line to Iron Pot Lt., measure 2 miles from it, and mark the point *D*. This will be the anchorage, or destination. Correct this true course to obtain the compass course, and measure the distance along it; this will be found to be 26·5 miles. As the ship makes the anchorage in 2 hours, steaming at 10 knots, she must have experienced 6·5 miles of fair tide or at the rate of 3·25 knots.

True Course	054° T.		050° C.
Variation	—9 E.	Dev.	—8·5° W.
Magnetic Course	045° M.		041·5° M.
Deviation	+9·75° W.		
			060° C.
Compass Course	054·75° C.	Dev.	—11° W.
or	055° C.		
			049° M.

Distance to steam to the position off Tasman Head, 37·5 miles.

True Course	344° T.		330° C.
Variation	—9° E.	Dev.	+2·5° E.
Magnetic Course	335° M.		332·5° M.
Deviation	—1·75° E.		
Compass Course	333·25° C.		340° C.
or	333° C.	Dev.	+0·5° E.
			340·5° M.

Distance on last course, 26·5 miles.
Distance in 2 hours at 10 knots, 20 miles.
Favourable Set. Drift, 6·5 miles. Rate, 3·25 knots.

Example for Exercise I.
(To be worked on the Chart of Tasmania.)

Proceeding through Bass Strait to the Eastward in hazy weather, soundings were taken at intervals of one hour, the ship steaming at a reduced speed of 6 knots. At 1800 hrs. 44 fathoms, mud ; at 1900 hrs. 41 fathoms ; 2000 hrs. 38 fathoms ; at 2100 hrs. 27 fathoms, coarse sand and shells. (All corrected soundings.)

The course being made good was estimated to be 102° T.

Soon after obtaining the cast at 2100 hrs. the fog lifted, and Goose Island light was observed to be bearing 49° from ahead on the port bow. Speed was increased to 11 knots, and at 2200 hrs. the light was found to be abeam. From the position thus obtained set a course by compass (using Deviation Card No. 1) to pass Swan Is. light at a distance of 5 miles, and state how long you will take and how far you will have to steam to bring it abeam. The tide may be assumed to be ebbing at 2 knots in approximately the same direction as the course of the ship.

Still steering on the same course and at the same speed, some time later Swan Is. light was observed to be bearing 276° C., and at the same time Eddystone Point light bore 204° C. Required the position of the ship at that time, and her distance from Swan Is. light.

From the position obtained by these cross bearings, reset the course by compass to pass Cape Forestier light 10 miles distant when abeam on the approaching course. Proper allowance to be made to counteract the effect of a current estimated to be setting 135° T. at 1·5 knots. Required also the time you will take to reach the position abeam of Cape Forestier light, the ship steaming at 12 knots by revolutions.

Answers.

Course 114° T. (variation 9° E., deviation 8° W.) 113° C.

Distance over the ground to bring Swan Is. light abeam is 21·5 miles.

As the ship is steaming at 11 knots, but making 13 knots over the ground, the time she will take to bring the light abeam will be $\frac{21{\cdot}5}{13}$, which is 1·65 hours, or 1h. 39m.

As she is doing 11 knots through the water, the distance she will steam will be $11 \times 1{\cdot}65$, which is 18·15 miles.

Lat. 40° 46′ S., Long. 148° 29½′ E., distance 16½ miles.

Course 181° T. (variation 9·5 E., deviation ¾° W.), compass course 172¼° C. or 172° C.

Example for Exercise II.

(To be worked on the Chart of Tasmania.)

Using D.R. latitude 40° 50′ S., the longitude obtained by an observation of a celestial object on the prime vertical was 143° 47′ E., and at the same time a cast of the deep-sea lead gave 70 fathoms (corrected), sand and shells. The course was set to pass 20 miles outside Cape Sorell light allowing for 5° leeway, wind S.W., and a current estimated to be setting 060° T. at 2 knots. Required the course to steer by compass and the approximate distance that will be made good in 8 hours, ship steaming at 10 knots. (Use Deviation Card No. 1.)

Cape Sorell light was observed dipping bearing 119° C. with height of eye 42 feet, at which time the course was reset to 162° C. Required the position of the ship and her distance from Point Hibbs when abeam. No leeway to be allowed, the wind having decreased considerably in strength. The current was considered to be setting 140° T. at rate 2 knots, and the ship to be making 10 knots, as in the previous question.

From this position reset the course to pass 3 miles off South West Cape to a position with Maatsuyker Is. light bearing 070° T. Give the compass course to steer and the distance. After running on this course for 3 hours at 10 knots, Rocky Point was found to be abeam, and at the same time Hill 2445 (De Witt Range) bore 100° C. Required the position of the ship and also the set and drift of the current since the course was reset off Point Hibbs.

From this position obtained by the cross bearings find the course to steer and also the distance to steam to reach the final point off Maatsuyker Is. light making due allowance for a similar set and drift to that just ascertained.

Answers.

True course to counteract the current, 165° T.

True course to counteract current and leeway, 170° T.

Course 170° T. (variation 8° E., deviation 1·5° W.), 163·5° C. Distance approximately 77 miles.

Course 162° C. (deviation 1·5° W., variation 8° E.), 168·5° T.

Lat. 42° 40·2′ S., Long. 144° 59·5′ E., beam distance from Point Hibbs 12 miles.

Course 142° T. (variation 8° E., deviation $3\frac{3}{4}$° W.), $137\frac{3}{4}$° C. or 138° C., distance 80 miles.

Lat. 43° 04·5′ S., Long. 145° 22·5′ E.

Set 248° T., Drift 2 miles, Rate 0·66 knots.

Course 136° T. (variation 8° E., deviation $4\frac{1}{2}$° W.), $132\frac{1}{2}$° C. or 133° C. Distance to steam 51·5 miles.

Examples for Exercise III.

(To be worked on the Chart of Tasmania.)

From a position in Lat. 41° 25′ S., Long. 149° 4′ E., set a course by compass (using Deviation Card No. 1) to bring Tasman Is. light abeam, distant 3 miles. Whilst on this course C. Forestier light was observed to be bearing 227° C., after proceeding for 9 miles it bore 254° C., and after doing another 6 miles it bore 280° C., whilst at the same moment the southern extremity of Schouten Is. bore 247° C., all these bearings being taken by the same compass.

Find the position of the ship at the time of taking the cross-bearings, and also find the set and drift of the current experienced since taking the first bearing of Cape Forestier light, the ship having been steaming for 1·25 hours at 12 knots until fixing her position by cross-bearings. Give also the distance made good from the initial point of departure.

Reset the course to pass 3 miles off Tasman Is. light as before, to counteract the effect of the current determined in the previous question.

Give the compass course to steer, the distance to steam, and the time occupied in bringing the light abeam, ship steaming at rate 12 knots.

When abeam of Tasman Is. light reset the course to pass 2 miles off C. Raoul, and when Wedge Is. opens just clear of Tasman Peninsula, alter course to reach an anchorage in Trumpeter Bay, N. Bruny Is.

Give the courses to steer by compass, making due allowance for a current setting 200° T. at 2 knots on the first course, and 160° T. at 2 knots on the second course.

Give, also, the time occupied in reaching the anchorage since resetting the course off Tasman Is., the ship maintaining a speed of 12 knots.

Answers.

Course 201·5° T. (variation 9·5° E., deviation $1\frac{1}{4}$° E.), $190\frac{3}{4}$° C. or 191° C.

Lat. 42° $16\frac{3}{4}$′ S., Long. 148° 42′ E., set 169° T., drift $3\frac{1}{4}$ miles, distance made good 54 miles.

Course 212° T. (variation $9\frac{1}{2}$° E., deviation $3\frac{1}{2}$° E.), 199° C., distance 56 miles at 12 knots→4h 40m.

Course 275° T. (variation $9\frac{1}{2}$° E., deviation 13° E.), 252·5° C., distance 14 miles at 12 knots→1h 10m.

Course 302° T. (variation $9\frac{1}{2}$° E., deviation 10° E.), $282\frac{1}{2}$° C., distance 20 miles at 12 knots→1h 40m.

Steaming time on last two courses, 2h 50m.

Example for Exercise IV.

(To be worked on the English Channel Chart.)
(Deviation Card No. 1, page 23.)

Ques. 1.—D.R. Lat. 50° 23′ N., Long. by observation of a star was 6° 41′ W., bearing 240° T. At the same time, which was one hour after high water at Dover, a corrected sounding gave 54 fathoms, gravel and shells. Set a compass course from this position to bring Lundy Island South light bearing 000° T., distant 3 miles. Make allowance for the tide as indicated by the chart, and for 5° leeway, wind N.N.W. force 7.

Find, also, the distance to steam and the time to reach destination, ship steaming at 14 knots.

Ques. 2.—From a position with Morte Point bearing 150° T., distant 5 miles, set the course by compass to make Flatholm Island light dead ahead distant 3 miles. No leeway, but the ebb tide was estimated to be setting 280° T. at 3 knots.

Find time required to reach the destination when steaming at 14 knots.

Answers.

1. Tidal stream as estimated from chart 042° T., 3 knots. Course 060° T. (leeway 5°, var. 20° W., dev. 12½° W.). Course 087½° C., distance to steam 74 miles, time occupied 5h 17m.

2. Course 084° T. (var. 20° W., dev. 8° W.). Course 112° C., distance to steam 52 miles, time occupied 3h 43m.

Exercise V.

Ques. 1.—Making the Channel, D.R. position 48° 55′ N., 6° 17′ W. Sights of a star gave intercept 5′ towards, and azimuth 340° T. Steered 092° C. (var. 16° W., dev. 4° E.) for 3 hours at 10 knots, Ushant W/T D.F. gave bearing of ship 350° T.

Find position.

Ques. 2.—After steaming 8 miles on the same course Ushant gave a second bearing 000° T., and after steaming another 8 miles gave a third bearing 010° T. A Pole Star latitude then gave 49° 11′ N.

Find the longitude and the course made good.

Ques. 3.—Altered course to 071° C. (var. 15° W., dev. 3° E.) and after logging 120 miles on this course, got a glimpse of Portland Bill light dipping, bearing 330° T. (H.E. 15 ft.). Continued on same course for 7 miles; Anvil Point light then bore 018° T. Find position.

Ques. 4.—Set course from above position to sight Beachy Head light 30° on port bow when on range at 16 miles. Give also the distance Beachy Head should be when it comes abeam, if ship maintains the same course.

Answers.

1. Lat. 49° 07·5′ N., Long. 5° 20′ W.
2. Long. 4° 56′ W.; Course 085° T.
3. Lat. 50° 21′ N., Long. 2° 05·5′ W.
4. 080° T.; beam distance 8 miles.

DAY'S WORK.

(Answers at end of Book.)

1.—At noon, a point in Lat. 47° 00′ N., Long. 178° 35′ W., bore 115° C., distant 12 miles, dev. 6° W. Ship then sailed the following compass courses :—

273° C.	70 miles.	Dev. 2° W.
317° C.	45 miles.	Dev. 5° E.
286° C.	20 miles.	Dev. 9° E.
335° C.	82 miles.	Dev. 4° E.

The var. throughout was 19° W. and a current set 025° T. at 1·5 knots during the day.

Find the position at the end of the run and the course and distance made good during the 24 hours.

2.—At noon in Lat. 32° 24′ N., Long. 53° 12′ W., course was set 260° C. Var. 18° W., Dev. 1° E., Speed 12 knots to counteract the effect of a current estimated to set 297° T. at 2 knots. After 18 hours steaming, stellar observations fixed the ship's position in Lat. 31° 22′ N., Long. 57° 32′ W.

Find the compass course to steer and the speed required in order to reach the position Lat. 31° 00′ N., Long. 59° 00′ W., in 6 hours, allowing for a similar set and drift to that experienced between noon and star sights. Var. 15° W., Dev. 0°.

3.—At 1330 hours a point of land in Lat. 49° 18′ N., Long. 4° 20′ W., bore 348° T., distant 10 miles, log 15, ship steering 210° C., var. 7° W., dev. 10° W. The following extracts were taken from the log :—

Log 45 altered course 230° C., dev. 12° W.

Log 46 a/c 240° C., dev. 7° W., log 79 a/c 245° C., dev. 7° W., this course being maintained until 2200 hours when log read 98. Current set 180° T., at 2 knots from 1330 until 1600 hours and 060° T., at 1·5 knots from 1800 until 2200 hours. Var. 7° W.

Find the ship's position at the end of the run.

4.—May 1st, at 0130 hours, log 142, in Lat. 49° 30′ N., Long. 4° 50′ W., course set 220° C., dev. 10° E., var. 15° W. At 0400 hours, log 162, a/c to 000° C., dev. 7° W. At 0730 hours, log 180, a/c to 220° C., dev. 10° E., this course being maintained till noon, log 216. Allow 5° leeway throughout for a westerly wind. Current from 0130 hrs. to 0600 hrs., 080° T., 2 knots, and thereafter till noon 260° T., 2·5 knots.

Find D.R. position at noon.

5.—Thursday at noon, point in Lat. 47° 30′ N., Long. 179° 25′ W., bearing 322° T., distant 12 miles. During the next 24 hours ship steered 210° C., dev. nil, at 11 knots. Var. during first 10h was 12° E. and for the remainder of the day 10° E. At 0800 hours on Friday the Observed Position was 44° 40′ N., 177° 00′ E.

Find the set, drift experienced to 0800 and, assuming the current remains unchanged, find the E.P. at noon on Friday.

6.—From Lat. 55° 43·3′ N., Long. 4° 58·9′ W., at 1600 hours a vessel steered 198° C. error 14° W., at 1650 hrs., with log 30, a point in Lat. 55° 15·2′ N., Long. 5° 6·2′ W., was 4 points on the starboard bow. At 1710 hrs. this point was abeam, log 33. Between the bearings a current set 223° T.; at 3 knots; var. 17° W.

Find the beam position and the bearing and distance of the ship from the point.

7.—At noon a point in Lat. 34° 50′ S., Long. 20° 01′ E., bore 060° T., 8 miles off, ship's head 114° C., dev. 6° E., var. 27° W., log zero. 1800 hrs. a/c to 249° C., dev. 6° E., log 42; 2400 hrs. a/c 105° C., dev. 5° E., log 82; 0600 hrs. a/c to 103° C., dev. 5° E., log 122. At noon, position by observation was 34° 59′ S., 22° 20′ E., log 164.

Find set and drift of current; and course and distance made good in 24 hours.

8.—In a D.R. position of Lat. 20° 10′ S., Long. 50° 37′ W., the Sun bore 070° T., intercept 5·7′ towards. Ship steered 310° T. for 44 miles when Lat. by ex-mer. alt. was 19° 45′ S. Ship continued on her course for 4 miles more till noon.

Find noon position.

9.—At an assumed position of Lat. 30° 3′ S., Long. 24° 17′ W., Sun bore 060° T., intercept 11·5 towards. Ship steamed 090° T., 41 miles, when the latitude by ex-meridian was found to be 29° 53′ S.

Find position at second observation and if ship continued on same course for another 3 miles till noon, find her position at noon.

10.—At noon D.R. Lat. 25° 00′ S., Long. 3° 00′ E., the ship then sailed as follows:

Time	Comp. Co.	Var.	Dev.	Wind	Leeway	Distance
1200–1600 hrs.	095° C.	25 W.	10° E.	East	0	43 miles
1600–2000	064°	,,	3° E.	,,	0	50 ,,
2000–2400	032°	,,	8° W.	,,	4	48 ,,
2400–0400	057°	,,	Nil	,,	2	44 ,,
0400–0800	005°	,,	15° W.	,,	5	53 ,,
0800–1200	082°	,,	5° E.	,,	2	40 ,,

At 2000 hrs. the obs. position was 24° 30′ S., Long. 4° 18′ E. Find the set and drift experienced till 2000 hrs. and allow a similar set and drift throughout the remainder of the day.

Find the E.P. the following noon, the course and distance made good and the average speed.

THE CAUSES AND EFFECTS OF THE TRADE WINDS, MONSOONS, ETC.

If all parts of the globe had the same temperature the atmospheric pressure would be practically uniform all over the world, and the result would be calm, fine weather. Such is not the case, however, and those parts that come more directly beneath the sun's rays—*i.e.* the tropics—have a much higher temperature than the temperate zones, where the sun shines more obliquely on the earth's surface. The atmosphere, being composed mainly of nitrogen, oxygen, and water vapour, is very elastic, and in common with other gases expands when heated and contracts when cooled. Cold air is thus comparatively heavier and so causes a greater pressure, whilst warm air is lighter and causes a lower pressure. Expansion and contraction which occurs is in the same ratio as the Absolute temperature.

From this we have two effects: the air at the equator expands, whilst the air in the colder regions contracts. This upsets the equilibrium of the atmosphere, with the result that between 20° N. and 20° S. we have a low pressure, between Latitudes 20° and 40° N. and S. we have a comparatively high pressure, whilst from Latitude 40° the pressure decreases towards the poles in both hemispheres. The air in the tropics rises and at the same time it expands, and in consequence of this the upper strata of air move from the equator towards the poles, whilst the lower strata at the earth's surface move from about Latitude 30°, where the pressure is greatest, towards the equator. A current of air in moving from Latitude 30° to the equator would be meeting the earth where it is rotating at greater speed, thus impressing these winds with North-easterly and South-easterly directions. They are indicated in Plates I. and II. by the blue and red colouring, and constitute the N.E. and S.E. trade winds. From these plates we see that they blow in all the oceans with the exception of the Indian Ocean, North of the equator, when they are substituted by the monsoons.

The general tendency of the atmosphere is to move from localities of high pressure to those of lower pressure, but in doing this it is influenced by the different speeds in rotation of the earth's surface. In the N. hemisphere currents of air are always deflected to the right, and in the S. hemisphere to the left. Given a high pressure at any particular place, the air moving outwards and turning to the right in the N. hemisphere sets up a circular clockwise motion. In the S. hemisphere, being deflected to the left, its circular motion would be anti-clockwise. This system of wind is called Anticyclonic. If now on Plates I. and II. we take Latitude 30° N. and S. to be the high pressure, we find that the wind is acting in conformity with the above. To the Eastward of these areas of high pressure we have the N.E. and S.E. trades, and to the Northward and Southward of Latitude 30° we have Westerly winds.

These winds are consistent in all the oceans with the exception of the Indian Ocean, where the great continent of Asia so closely approaches the equatorial region as to upset the system. When the sun is North the land directly under the sun's rays in Northern India gets much hotter than the sea at the equator. The mean barometric pressure in this locality falls to about 1000 millibars—*i.e.* about 11 millibars lower than the mean equatorial pressure. The wind, instead of blowing towards the equator, now blows from the equator, and with considerable violence; this is known as the S.W. monsoon, shown on Plate II.

When the sun is South there is a high pressure over Asia in about Latitude 30°, and well to the Eastward of that continent. This sets up an anticyclonic system similar to that in the Atlantic and Pacific, but the high pressure being exceptionally

high and to the Eastward we get very strong N.E. winds in the China Sea and moderate winds in the Indian Ocean.

The sun being South at the same time creates a low-pressure area in about Latitude 10° to 15° S., which is also affected by the Northern part of Australia, where the low-pressure area extends still further South. The N.E. monsoon, as this wind is called, blows therefore right across the equator to about 10° S. On crossing the equator, however, it is deflected to the left, as all winds are, so that it blows from the N.W., and is now called the N.W. monsoon (see Plate I.).

The approximate limits of the trade winds are as follows:

North Atlantic	6° N. to 28° N.
South Atlantic	2½° N. to 27° S.
North Pacific	10° N. to 27° N.
South Pacific	6° N. to 27° S.
South Indian Ocean	January, 15° S. to 30° S.; July, 0° S. to 25° S.

In the Atlantic and Pacific these limits move slightly with the sun, the polar limits about 5° and the equatorial limits about 3°, the above latitudes being taken as the mean.

Between the N.E. and S.E. trades we have an area of light variable winds and calms, with heavy rain squalls. This is called the Inter Tropical Convergence Zone (ITCZ). They are very similar in the Atlantic and the Pacific, and fairly consistent in both oceans. In the Indian Ocean they are both irregular and inconsistent on account of the monsoons; there is generally, however, an area of variable winds between the S.E. trades and the N.W. monsoons in about Latitude 10° S., and a similar area between the S.E. trade and the S.W. monsoon in about Latitude 2° S.

The student is advised to study carefully these two plates, I. and II., which have been reproduced from the *Admiralty Manual of Navigation*, by kind permission of the Controller of His Majesty's Stationery Office.

The various meteorological instruments are described and illustrated in *Nicholls's Seamanship and Nautical Knowledge*, and in *Meteorology for Masters and Mates*.

SUMMARY OF TRADE WINDS AND MONSOONS.

Name or Direction of Wind.	Average Limits of Locality.	Season.	Remarks.
	Atlantic Ocean.		
N.E. Trade,	27° N. to 8° N.		Polar limits vary 3° or 4° N. or S., and equatorial limits 5° or 6°, according as the Sun is N. or S.
S.E. Trade,	6° N. to a line joining Cape of Good Hope and Martin Vaz and Trinidad Islands.		
Anti-Trades (W'ly Winds)	Between 35° and 60° N. and S.		
E'ly Winds,	English Channel.	Spring.	
	Pacific Ocean.		
N.E. Trade,	27° N. to 7° N., and as far W. as the Mariana Islands.		Limits vary, like those in the Atlantic.
S.E. Trade,	5° N. to 27° S.		
Anti-Trades,	Between 35° and 60° N. and S.		Similar to Atlantic.
	Indian Ocean and China Seas.		
S.E. Trade,	7° S. to 27° S. in Indian Ocean.		Limits vary, as in the other oceans.
N.W. Monsoon,	Equator to 10° S. in Indian Ocean, and extending in the Pacific as far as the New Hebrides.	Nov. to March.	Not a steady monsoon, but varies between N.W. and W.S.W.
N.E. Monsoon,	East Coast of Africa, Arabian Sea, Bay of Bengal, and China Sea.	Oct. to April.	Stronger in China Seas. Is steadier in Dec., Jan. and Feb.
S.W. Monsoon,	China Seas.	April to Oct.	Stronger in East Indies. Least liable to change in June, July and August, when it blows fiercely over the East Indian Seas.
Anti-Trades,	35° to 60° S.		Similar to Atlantic.

OCEAN CURRENTS.

Whilst inshore currents are mainly generated by tidal effects, those in the open ocean are caused mainly by the prevailing winds. In consequence, they follow the general circulation around the mid-ocean permanent high pressure area. In Northern Oceans the general current circulation is clockwise and in the Southern Oceans it is anti-clockwise.

Due to the earth's rotation the direction of a current will be subject to Coriolis effect. In the Northern hemisphere the current will take up a direction to the right of that of the wind. In the Southern hemisphere the current will take up a direction to the left of the wind.

A body of water impinging on a coast takes the path of least resistance, and, therefore, follows the contours of the coastline, flowing through openings between islands and continents, sometimes with great velocity when a channel is comparatively small and a large volume of water is being impelled through it, such, for example, as the Straits of Florida, where it attains a speed of 4 to 5 knots. Ocean currents, however, vary from ½ to 2 knots, although in some congested localities they may be accelerated to 3 or 4 knots by pressure of water in the rear, or by seasonal winds increasing the drift of the upper layers, but it is the surface current, of course, that directly affects the ship.

Refer to Map II. and trace out the general circulation in each of the oceans.

North Atlantic.—We have to describe a right-handed circulation. Beginning at the equator the current flows westward into the Gulf of Mexico, follows the coastline, flows rapidly through the Straits of Florida and up the East coast of the United States, then broadens out and bends to the Eastward, now known as the Gulf Stream. Midway across the Atlantic the waters broaden out still more, and part flows Northward towards the British Isles and Iceland, the other part bending to the South-East and Southward, down the African coast, when it is now called the N.E. Trade or African drift, and joins the equatorial set to the Westward again.

Cold-water currents flow Southward down the East coast of Greenland and the West side of Davis Straits, along the coast of Labrador and Newfoundland. The cold Arctic current meets the warmer waters of the Gulf Stream and gets sandwiched between it and the coast and eventually loses itself by sinking out of sight.

Westerly winds bank up the water in the Bay of Biscay, with the result that a variable N.W. offshoot flows across the chops of the English Channel and is known as the Rennel current.

It will be noticed that a South equatorial current flows obliquely across the equator from the South Atlantic and connects up with the West-going North equatorial current. They leave in their rear a triangular-shaped area off the Guinea Coast, where counter-currents prevail. The Guinea current flows South and Eastward into the Gulf, and a counter-current setting Eastward is sometimes experienced in the region of the doldrums, between 5° and 9° North of the equator.

South Atlantic.—The equatorial current setting Westerly bends to the S.W. and Southward down the coast of Brazil, then turns more and more to the Eastward when off the River Plate. This East-going water is joined by the cold Cape Horn current and together they flow towards the Cape ; part of the water continues to

flow Eastward and part flows Northward up the African coast, forming a S.E. trade drift, and eventually forms the equatorial current again.

North Pacific.—The equatorial current flows to the West between the parallels of 10° and 20° N. and is deflected to the N.W. and Northward on reaching the Philippine Islands, then North and North-Eastward up the China coast towards Japan. It is then called the Kuro Siwo current, which is similar in character to the Gulf Stream of the North Atlantic. The water flows Eastward across the Pacific towards the coast of North America, then bends sharply to the Southward and is then called the California current; thereafter it runs S.W. and West and rejoins the equatorial current.

A counter-current flows Eastward between the equator and 10° N. until it is deflected by Central America, part of it bending to the N.E. and part to the S.E.

A cold-water current flows Southerly towards Japan and gets lost between the warmer waters of the Kuro Siwo and the coast.

South Pacific.—We note that the South equatorial current flows West and divides on approaching the Australian coast, part flowing to the N.W. past New Guinea and part flowing S.W. and South down the East coast of Australia, then bending sharply to the Eastward flowing part New Zealand and across the Pacific to South America, where it again divides into an East-going current round Cape Horn and a North-going set up the coast of Chile, when it is called the Humbolt or Peruvian current, before it eventually joins up again with the equatorial set to the West.

Indian Ocean.—The equatorial current flows West between the parallels of 5° and 20° S. and splits on Madagascar; part flows round the North end of the island and South through the Mozambique Channel and joins the other part, which, meantime, has flowed down the East coast towards the South end of the island. The current flows down the coast of Natal and West round the Cape, when it is called the Algulhas current. This current extends from the coast to about 100 miles off, and is deflected on meeting the East-going waters of the South Atlantic, part of the water slipping into the Atlantic and the remainder bending to the South and S.E. to join the general East-going set in the Southern Ocean.

The currents in the Northern area of the Indian Ocean and in the Bay of Bengal and Arabian Sea are greatly influenced by the monsoons. A portion of the West-going equatorial current which passed the North end of Madagascar flows North up the African coast and eddies to the Eastward, forming a counter-current just South of the equator. The strength and the existence of this current is controlled by the prevailing monsoon. During the S.W. monsoon it is more pronounced than during the N.E. monsoon, as, in the former case, it is assisted by the S.W. wind, and in the latter case it is retarded by the N.E. wind. Currents due to the wind are called drift currents and are confined to the surface layers of the water. In the Bay of Bengal and Arabian Sea the currents set to the S.W. during the N.E. monsoon from October to March and to the N.E. during the S.W. monsoon from April to September.

OCEAN PASSAGES AND SHIPS' ROUTEING.

General Information, References and International Requirements.

Full information relating to ocean passages may be found in British Admiralty publication, NP 136, *Ocean Passages for the World*, Third Edition, 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 on 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 IMCO are set out in the IMCO publication, *Ships' Routeing*, 4th Edition with Amendments, and in subsequent IMCO 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 IMCO. This rule is repeated at the end of this section.

Further information about ships routeing is contained at 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.

Ocean Passages for the World—NP 136.

NP 136 specifies that the recommended routes are intended for vessels with sea-going speeds of 15 knots and moderate draughts. Such routes should also be considered by all ships, particularly those operating in high latitudes. Special requirements of vessels drawing more than 12 metres are not covered.

Ocean passages for the World bears much the same relationship to Ocean Charts as the *Sailing Directions* bear to Coastal Charts. The volume is divided into two parts of which Part 1 covers Power Vessel Routes and Part 2, Sailing Vessel Routes.

Part 1 contains:

Chapter 1. Planning a passage.
2. North Atlantic Ocean.
3. South Atlantic Ocean.
4. Gulf of Mexico and Caribbean Sea.
5. Mediterranean Sea and Black Sea.
6. Red Sea, Indian Ocean and Persian Gulf.
7. Pacific Ocean, China and Japan Seas and Eastern Archipelago.
8. Miscellaneous information for power vessels.

Climatic and Weather Routeing.

As a result of higher fuel costs and the consequent greater emphasis placed on Weather Routeing, ships frequently follow routes which differ from the climatic routes recommended in NP 136. The need to modify the climatic route for variations in weather and other factors such as owners' requirements, fuel consumption, risk of damage and sensitive cargoes, is brought out in the supplementary pages on Passage Planning and in the following extract on General Planning from NP 136 : --

General Planning.

The best track.—The art of passage planning has been practised from time immemorial. The selection of the best track for an individual voyage demands skilled evaluation of all the factors controlling the voyage and modification of the shortest route accordingly.

In the past, most passage planning has been done with the aid of statistics on weather, currents, and climate which, together with the experience of previous voyages, have enabled the publication of suggested routes for a wide variety of passages. These statistic-based or "climatic" routes, usually depending on factors which can vary seasonally, serve the mariner's purpose up to a point, but they do not take into account short-term variations in the statistical pattern, which can be detected and even forecast by modern methods, and can therefore be incorporated in the plan or transmitted to the vessel at sea with great benefit to the immediate conduct of the voyage.

Each chapter of routes for power vessels contains a review, based on all available statistics and experience, of the usual climatic and other conditions affecting the area concerned. Having made a first study of the projected passage with the aid of the routes recommended as a result, the required route should be adjusted to meet such factors as urgency, risk of damage, and fuel consumption. In addition, the growing availability of shore-based routeing advice, together with forecasts of weather, currents, swell, and ice movements should be taken into account. A great deal of information is thus available to the shipmaster in most parts of the world, for application in aid of the successful prosecution of the voyage.

Exercises.

The climatic routeing exercises which follow are intended to familiarise the student in the use of NP 136, *Ocean Passages of the World, Main Ocean Route Chart,* 5307, *World Climatic Charts,* 5301 and 5302, (or similar charts showing wind and current direction) and, if required, with the *Load Line Rules—Zones, Areas and Seasonal Periods,* BA Chart, D 6083.

Example.—Describe the route to be followed on a passage from New York to Fastnet. State the winds and currents likely to be experienced, and comment on any special considerations which should be taken into account. List your references.

(*a*) **Atlantic Ocean**—General.

Regulation 8(e) of Chapter V. of the *International Convention for on Safety of Life at Sea,* 1974 (IMCO) directed that all ships proceeding on voyages in the vicinity of the Grand Banks of Newfoundland avoid, as far as possible, the fishing banks of Newfoundland north of latitude 43° N. and pass outside regions known or believed to be endangered by ice.

Diagram 18 of NP 136 shows Standard Alter-Course Positions and Approach Routes for Transatlantic Voyages. There are three such positions: CR (Cape Race) May–Nov.; BN (Banks North) April–May and Nov.–Feb.; and BS (Banks South) Feb.–April. Westbound tracks are slightly to the North of their corresponding Eastbound tracks.

(*b*) **New York to Fastnet** (NP 136, 2.61—2.67)

Follow the rhumb line tracks to Alter-Course Positions BN or BS, according to season, then the great circle to the English Channel.

Current: SW—variable at first, North Atlantic current (NE'ly) remainder.
Wind: SW becoming W'ly.
Ref: NP 136, 2.61—2.67.

EXAMPLES FOR EXERCISE.

In each of the following questions refer to the relevant chartlets provided and to the charts and volumes previously mentioned.

For each passage give a brief general description of any special considerations, state the route to be followed, the currents and winds likely to be experienced and the relevant references with which to enter NP 136.

Summary answers are provided at the end of these exercises.

Atlantic Ocean.

1. New York to Fastnet.
2. Cape Race to Malin.
3. U.K. to the Gulf of Mexico.
4. U.K. to Valparaiso via the Panama Canal.
5. U.K. to the Cape of Good Hope.

Indian Ocean.

6. Suez to Bombay.
7. Bombay to Hong Kong (NE Monsoon).
8. Hong Kong to Aden (SW Monsoon).
9. Bombay to Aden (SW Monsoon).
10. Cape Town to Java.
11. Cape Town to Fremantle.
12. Chittagong to Colombo (SW Monsoon).
13. Fremantle to Sunda Straits.

Pacific Ocean.

14. Yokohama to San Francisco.
15. Yokohama to Honolulu.
16. Philippines to Honolulu.
17. Fiji to Wellington.
18. Honolulu to the Panama Canal.

China Sea.

19. Singapore to Shanghai.
20. Singapore to Yokohama (NE Monsoon).

ANSWERS.

Atlantic Ocean.

1. New York to Fastnet.
As per the example previously given.

2. Cape Race to Malin Head.
   Current: N. Atlantic current (NE'ly).
   Wind: SW–Westerly.
   Ref.: NP 136 no reference. Great Circle track.
3. U.K. to the Gulf of Mexico.
   Current: Gulf stream setting Easterly, North Equatorial setting NW, Mexican currents various.
   Wind: Westerlies, Variables, NE Trades and Variables.
   Ref.: NP 136 2.81, 2.86, 8.11.
4. U.K. to Valparaiso via the Panama Canal.
   Current: As for (3) above. From Panama the Peruvian current will be against the ship.
   Wind: As for (3) above thence winds light and southerly.
   Ref.: NP 136, 8.02, 7.195.
5. U.K. to the Cape of Good Hope.
   Current: Rennel current (NW); Portuguese current (S); Canary current (S); Guinea current (ESE); Equatorial current (W); and South Atlantic current (NW).
   Wind: Westerlies; Variables, 35° N to 30° N; NE Trades; ITCZ; SE Trades, then Variables to the Cape.
   Ref.: Chart 5307.

Indian Ocean.

6. Suez to Bombay.
   Current: In the Red Sea currents are influenced by the prevailing monsoon. The general set is Southerly, but stronger during the SW monsoon than during the NE monsoon and in the Southern part of the Red Sea than in the Northern part, the drift varying from 20 to 30 miles per day. The current sets NNW in the Straits of Bab-el-Mandeb during the NE monsoon.
   Wind: According to Monsoon.
   Ref.: NP 136, 6.52, 6.76.
7. Bombay to Hong Kong (NE Monsoon).
   Ref.: NP 136, 6.81, 6.156, 7.116.
8. Hong Kong to Aden (SW Monsoon).
   Ref.: NP 136, 7.116, 6.154.
9. Bombay to Aden (SW Monsoon).
   Ref.: NP 136, 6.77.
10. Cape Town to Java.
    Current: Agulhas current, then, in crossing the Indian Ocean circulation, a Southerly current will be experienced, and afterwards, on reaching the parallel of about 20° S, a Westerly current.
    Wind: Variable when rounding the Cape, then the SE Trades.
    Ref.: NP 136, 6.150.
11. Cape Town to Fremantle.
    Current: Easterly.
    Wind: Westerly.
    Ref.: NP 136, 6.161.

12. Chittagong to Colombo (SW Monsoon).
Current: NE'ly and variable.
Ref.: NP 136, 6.71.

13. Fremantle to Sunda Straits.
Current: Northerly up the coast and Westerly after clearing NW Cape.
Wind: Variable, then SE Trades.
Ref.: None.

Pacific Ocean.

14. Yokohama to San Francisco.
Current: Easterly.
Wind: Westerly.
Ref.: NP 136, 7.305.

15. Yokohama to Honolulu.
Current: Kuro Shio (NE), variable later.
Wind: NE Trades.
Ref.: NP 136, 7.213.

16. Philippines to Honolulu.
Current: NW, more Westerly later.
Wind: NE Trades.
Ref.: NP 136, 7.210.

17. Fiji to Wellington.
Current: South sub tropical (Westerly), variable then northerly.
Wind: Seasonal.
Ref.: NP 136, 7.92.

18. Honolulu to the Panama Canal.
Current: Westerly, changing southerly, then easterly on approaching the land.
Wind: NE Trades.
Ref.: NP 136, 7.218, 7.265.

China Sea.

19. Singapore to Shanghai.
Current: Kuro Shio (NNE).
Wind: Monsoon.
Ref.: NP 136, 7.119.

20. Singapore to Yokohama (NE Monsoon).
Current: Kuro Shio (NNE).
Wind: NE.
Ref.: NP 136, 7.122.

COLLISION AVOIDANCE RULE WHICH REFERS TO THE USE OF 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 Organization.

(*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 practicable 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.

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*"—Dept. of Trade.
M Notices Nos. 756 and 854—Dept. of Trade.
"*Bridge Procedures Guide*"—International Chamber of Shipping.

These publications refer mainly to coastal passages, where the safety aspect is paramount. It will be convenient, therefore, to consider Ocean Passages under a separate heading.

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.

The 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.

(*N.B.*—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.**
   IMCO or local. 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 communication.
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—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 conspicuous 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.

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.

Plymouth towards Swansea—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, 12½ 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
Latest time at 16 knots—14 hours (allowing for slowing down)

Latest time at Pilot	1000	on 18th
Clear Breakwater	2000	on 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.

An Example of Passage Planning (cont.)

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° 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 allowance for cross tides on the next track.

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.

Also to be prepared are the Pilotage Plans for departure and arrival.

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.

PASSAGE PLANNING (OCEAN)—NOTES.

1. Objectives.

Your aim could be :—

1. The least time
2. The least damage
3. Maintaining schedule
4. The most economical speed
5. A constant speed as per the charter party.

A compromise is often desirable—put the most important objective first.

2. Appraisal.

In making a general decision about the route, the following factors may have to be considered. Some may have an overriding importance so that the choice of an alternative is forced; on other occasions their relative merits must be assessed.

3. ETA and Owners Requirements.

The owners or operator should indicate any urgency regarding the ETA, and the required speed. They should also indicate if there is any cargo offering en route.

4. Canals.

The use of canals involves an economic decision regarding dues and delays.

5. Bunkers.

Consider the quantity of bunkers on board; requirements and reserves; prices and availability and the relative distances to bunkering ports; ship s stability in the worst condition should also be considered.

6. Delays.

Delays and stoppages may be caused by political or industrial action and natural disasters.

7. Limits.

The insurance policy and articles of agreement should be checked for high latitude limits. Take account of war risk zones.

8. Load Line Zones.

Select the most advantageous zone if likely to be fully laden.

9. Draft.

Check the depths of water en route.

10. Sensitive Cargoes.

Cargoes which include passengers, live-stock, deck cargo and noxious substances may be considered sensitive. In such cases it is even more important to avoid heavy weather areas.

11. Bulk Liquid Cargoes.

Warm sea temperatures are desirable for economy of tank heating.

12. Seasonal Influences.

Consider alternative routes which take account of: monsoons, ice, fog, gales or the high incidence of tropical storms.

13. Weather, Currents and Climatic Routeing.

Take advantage of favourable weather and currents and minimise what is unfavourable. Make reference to NP 136, *Ocean Passages for the World,* and the preceding pages (44-49) which deal with ocean passages and ships routeing.

14. Weather Routeing (Shore-Based).

After considering the factors above you can now decide on the broad outlines of your route, and at this point weigh up the possible economic advantages of shore-based routeing, providing that it is covered by the owner's rules and that it is suitable to the area. In general such schemes are more appropriate to temperate zones where the weather may change from day to day than to tropical latitudes where conditions are more predictable.

INFORMATION RELATING TO CHARTS.

The publications issued by the Hydrographic Department, Admiralty, give a tremendous amount of information in detail 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 must manifestly depend 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 the information given in the *Notices to Mariners* as issued by the Hydrographic Department, Taunton. The degree of dependence 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. A wide berth should therefore be given to every rocky shore or patch and this rule should be followed, viz., 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.

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 (P.P.I.). 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 in its path 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 P.P.I. 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 P.P.I. 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 also 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. The Relative Plot does not, however, give the target's true course and speed without further plotting—this is demonstrated in Example 1 (a).

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 1 (b).

As will be appreciated, both methods have certain advantages.

Example 1(*a*).

TO DETERMINE CPA AND RISK OF COLLISION BY RELATIVE PLOT

(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 :

$$\frac{7{\cdot}7}{2} \times 6 = 23{\cdot}1 \text{ minutes}$$

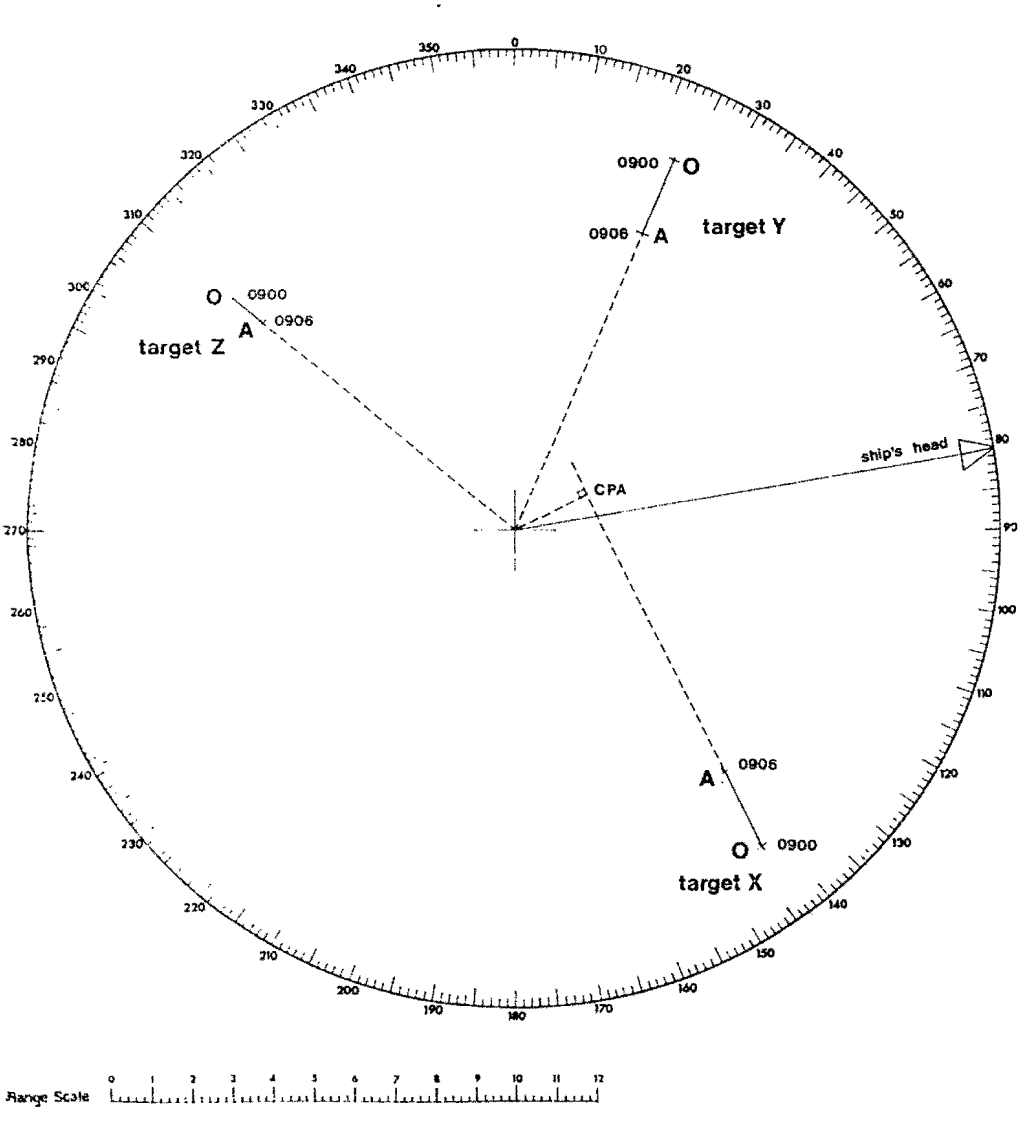
Target '*Y*' is on a steady bearing and CPA is a collision which will occur in :

$$\frac{8}{2} \times 6 = 24 \text{ minutes}$$

Target '*Z*' is on a steady bearing and CPA is a collision which will occur in :

$$\frac{8}{1} \times 6 = 48 \text{ minutes}$$

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.


Radar Plot 1
(Relative Motion)
0900
O
0906
A
target Y
O
0900
A
0906
target Z
ship's head
CPA
A
0906
O
0900
target X
Range Scale
0 1 2 3 4 5 6 7 8 9 10 11 12

Example 1(*b*).

TO FIND THE TARGET'S TRUE COURSE AND SPEED BY TRUE MOTION PLOT

(Refer to Radar Plot 2)

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

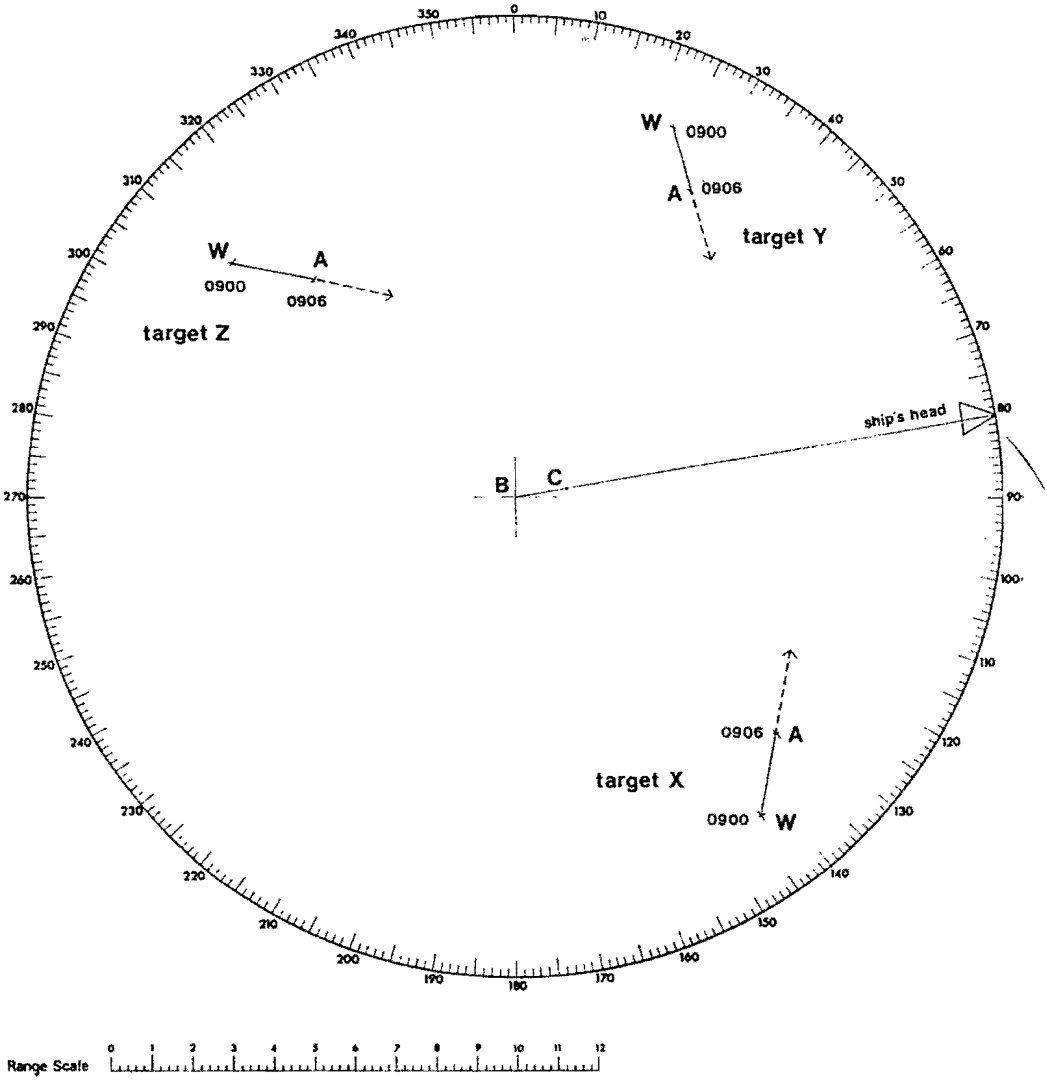
A minimum of 3 radar bearings and ranges, with suitable intervals between them, are necessary before reliable information can be obtained from a radar plot.

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 2.

Radar Plot 2
(True Motion)



Example 2.

TO FIND THE TARGET'S TRUE COURSE, SPEED, ASPECT, CPA AND THE OBSERVER'S RELATIVE BEARING OF THE TARGET AT CPA

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

Required: (*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 (*a*) Relative Plot, Ship's Head Up.
,, (*b*) Relative Plot, North Up.
,, (*c*) True Plot, North Up.

Example 2, *Method* (*a*)

RELATIVE PLOT, SHIP'S HEAD UP

(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 :

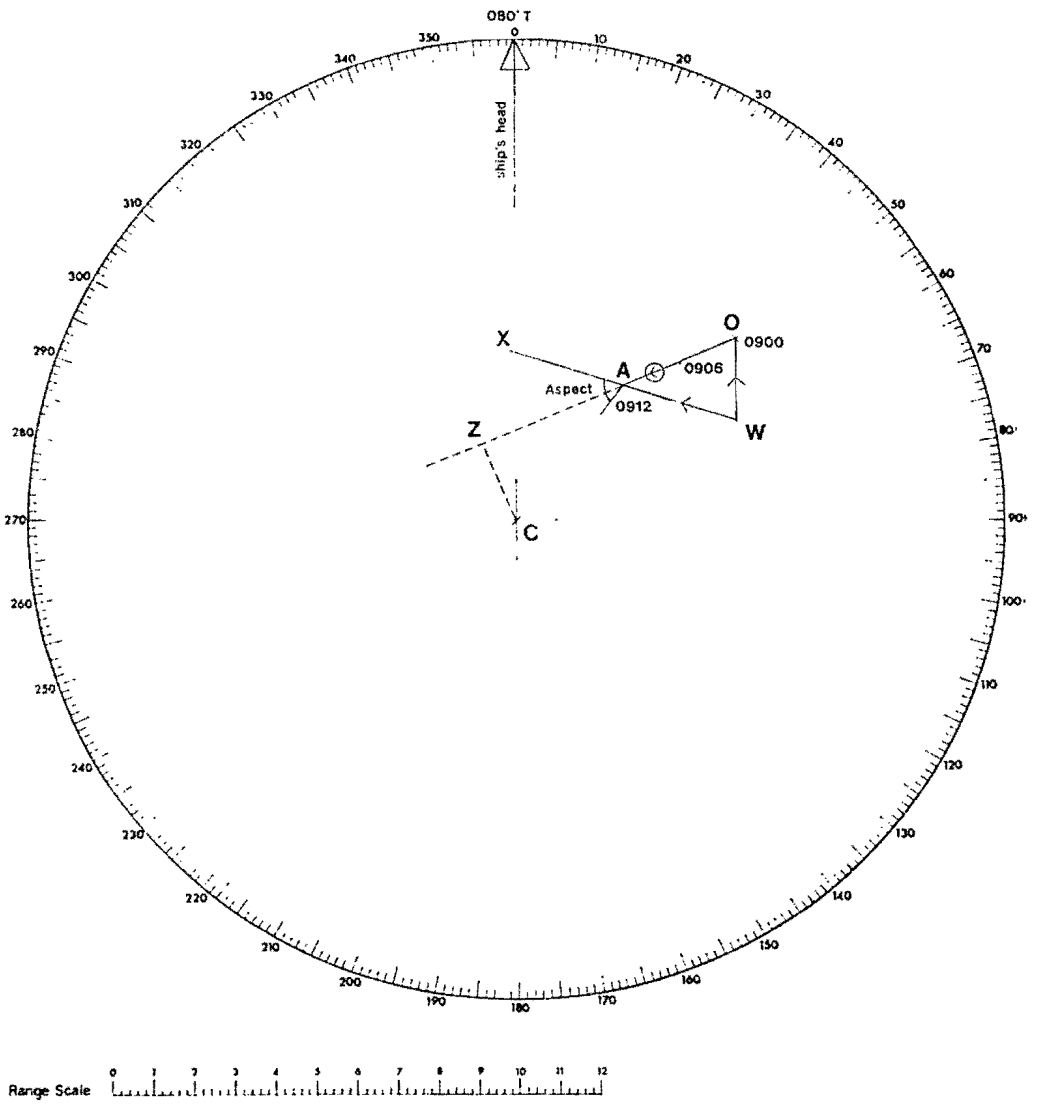
$$\frac{AZ}{OA} \times 12 \text{ minutes}$$

$$\frac{3{\cdot}7}{3{\cdot}0} \times 12 = 15 \text{ minutes (approx)}$$

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)



Example 2, Method (b)

RELATIVE PLOT, NORTH UP

(Refer to Radar Plot 4)

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:

$$\frac{AZ}{OA} \times 12 \text{ minutes}$$

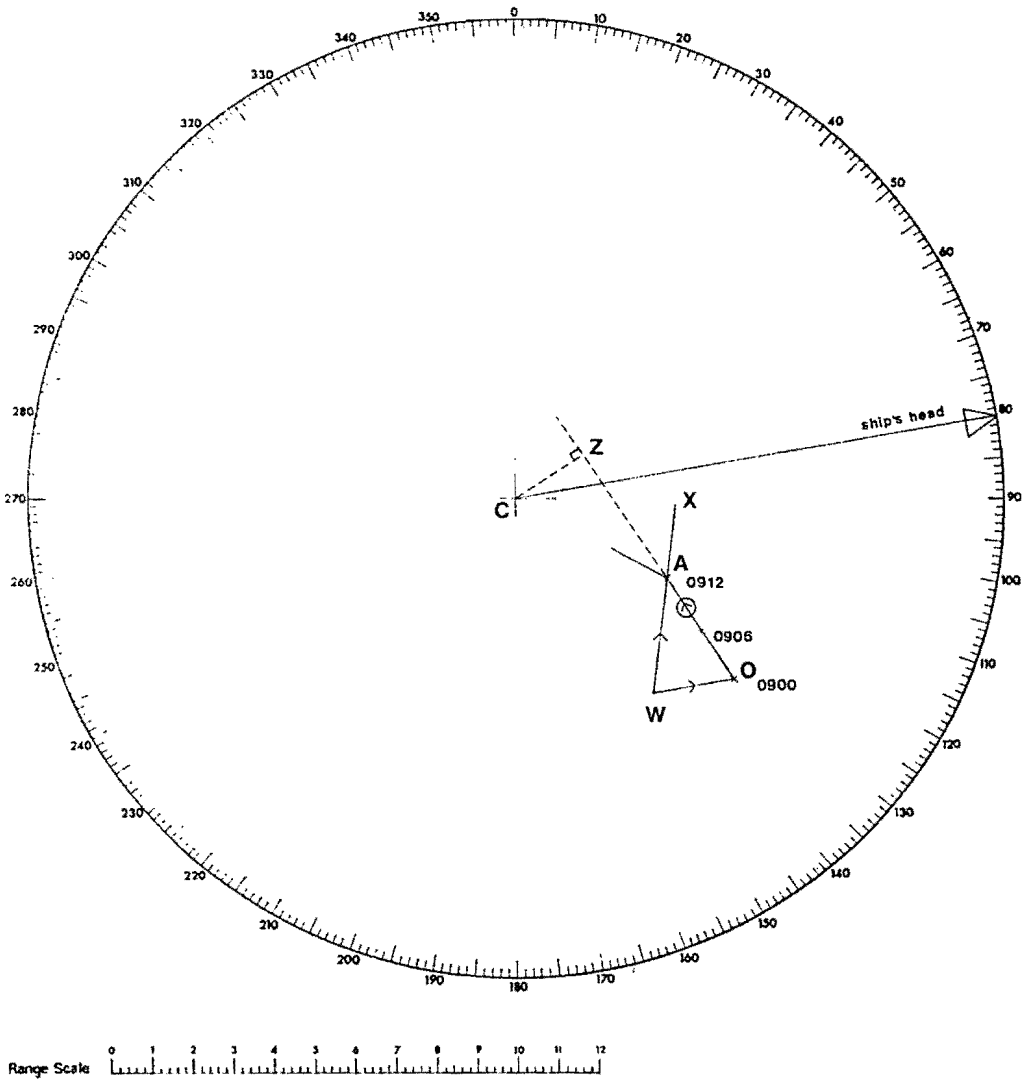
$$\frac{3{\cdot}7}{3{\cdot}0} \times 12 = 15 \text{ minutes (approx)}$$

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 2(*a*) 9. *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)



Example 2, Method (c).

TRUE MOTION PLOT, NORTH UP

(Refer to Radar Plot 5)

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 the 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°.

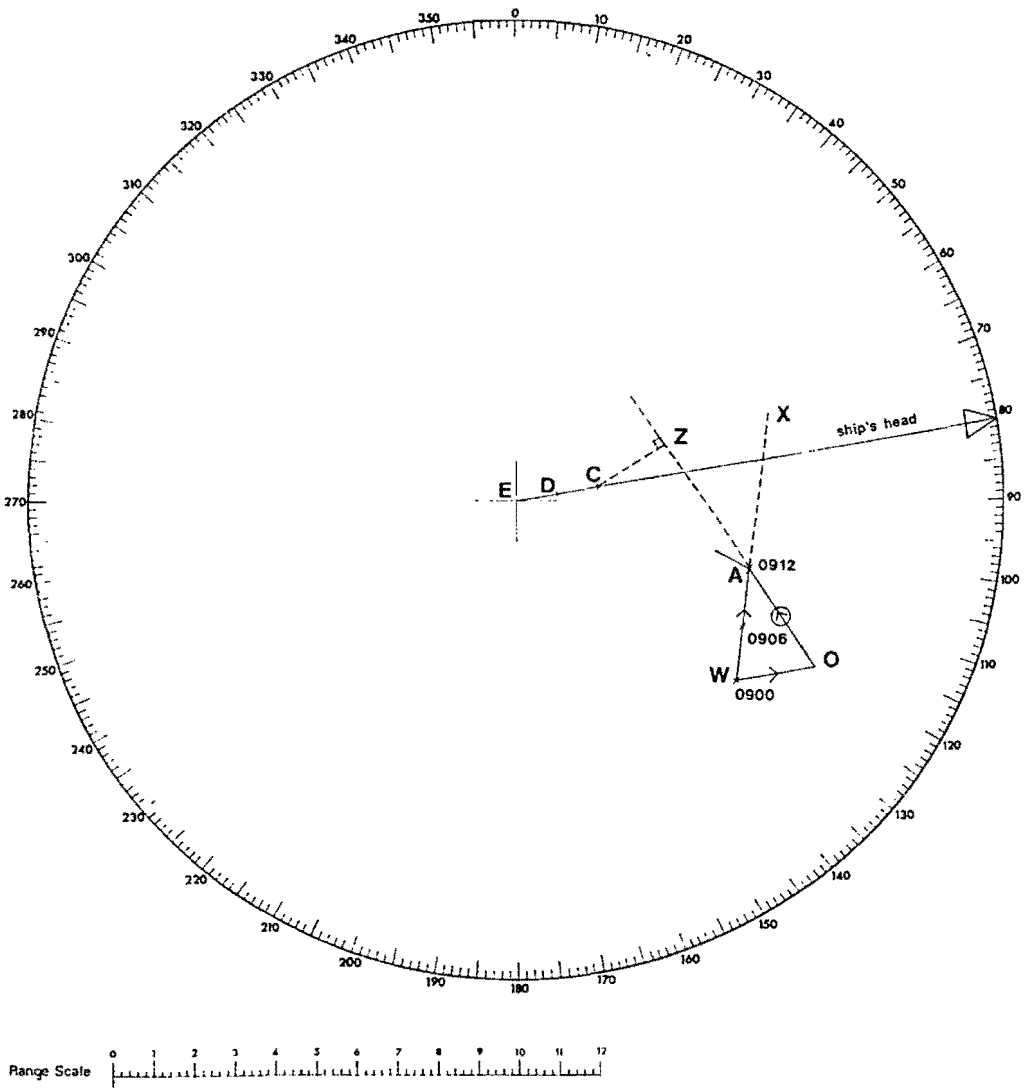
AVOIDING A CLOSE QUARTERS SITUATION—THE FORECAST PLOT

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)



Example 3.

TO FIND THE COURSE OR SPEED ALTERATION NECESSARY TO INCREASE THE DISTANCE OFF AT CPA

(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

1. By Relative Motion, North Up Plot, as in Radar Plot 6, the assessment† of the situation is as follows:
   (*a*) The target is on a steady bearing, 55° on the starboard bow.
   (*b*) CPA will be a collision in
   $$\frac{5}{2} \times 12 \text{ minutes} = 30 \text{ minutes}$$
   and will occur at 0442 hrs. (0412 + 30).
   (*c*) The target's course is 280°T at 9·5 knots.
   (*d*) Aspect is Red 65°.

†Students should verify this assessment by working through all stages of Radar Plot 6, as previously explained at Example 2 Method (*b*).

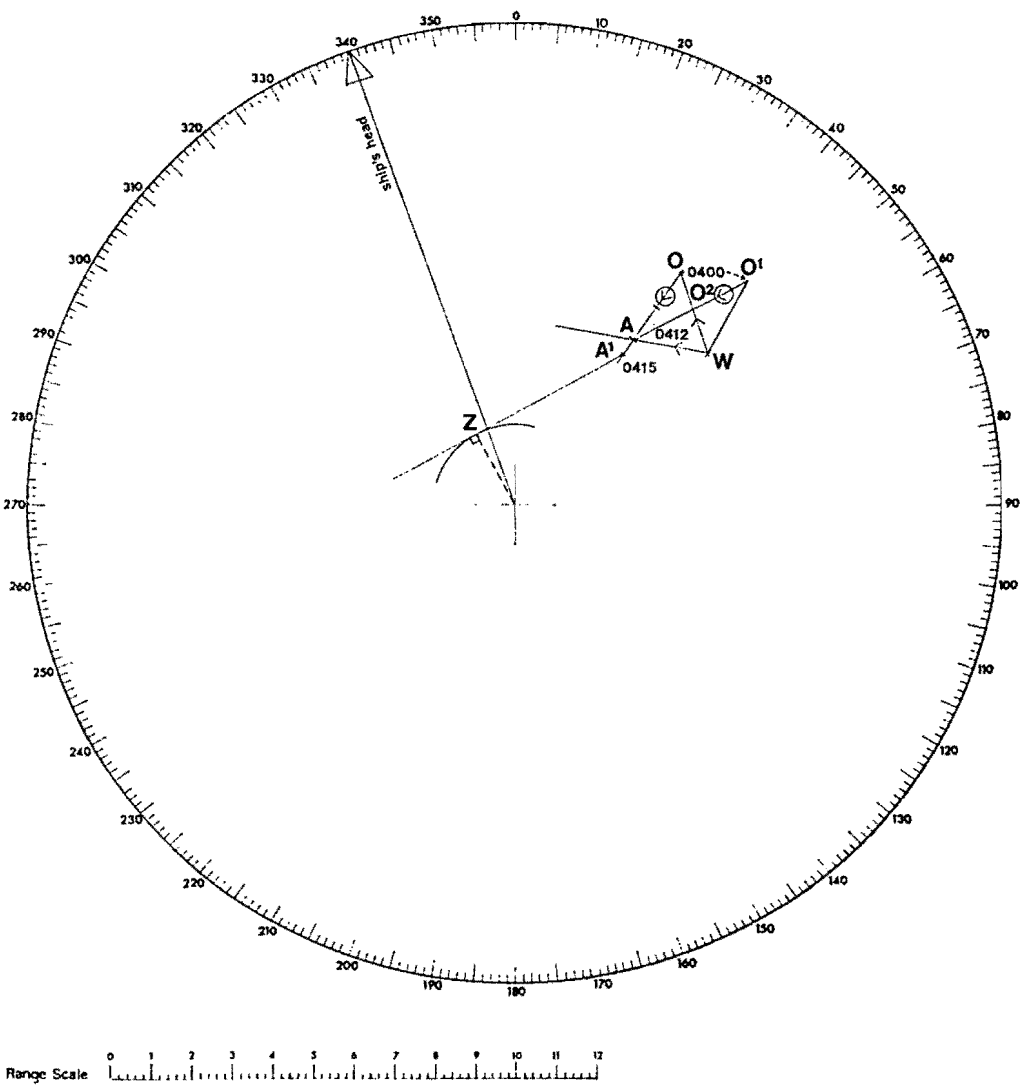
TO ACHIEVE A NEW CPA (2 MILES) BY A SINGLE ALTERATION OF COURSE

(Refer to Radar Plot 6)

2. Plot the target's 0415 position, on OA produced. Label this position 'A'. AA^1 is the distance made good along the relative track in 3 minutes.
3. From A^1 draw a tangent to the 2 mile circle and transfer this tangent back through 'A'.
4. 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.
5. The new CPA will occur in
   $$\frac{A^1Z}{O^1A} \times 12 \text{ minutes}$$
   $$\frac{4}{3} \times 12 \text{ minutes} = 16 \text{ minutes}$$
   CPA will occur at 0431 hrs.

Radar Plot 6

(Relative-North up)



TO ACHIEVE A NEW CPA (2 MILES) BY SPEED REDUCTION ONLY
(Refer to Radar Plot 6)

6. 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.
7. 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.

Example 4.

TO FIND THE SET AND RATE OF CURRENT FROM A STATIONARY TARGET AND THENCE THE COURSE TO STEER TO PASS A CHOSEN POINT AT A CHOSEN DISTANCE OFF
(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

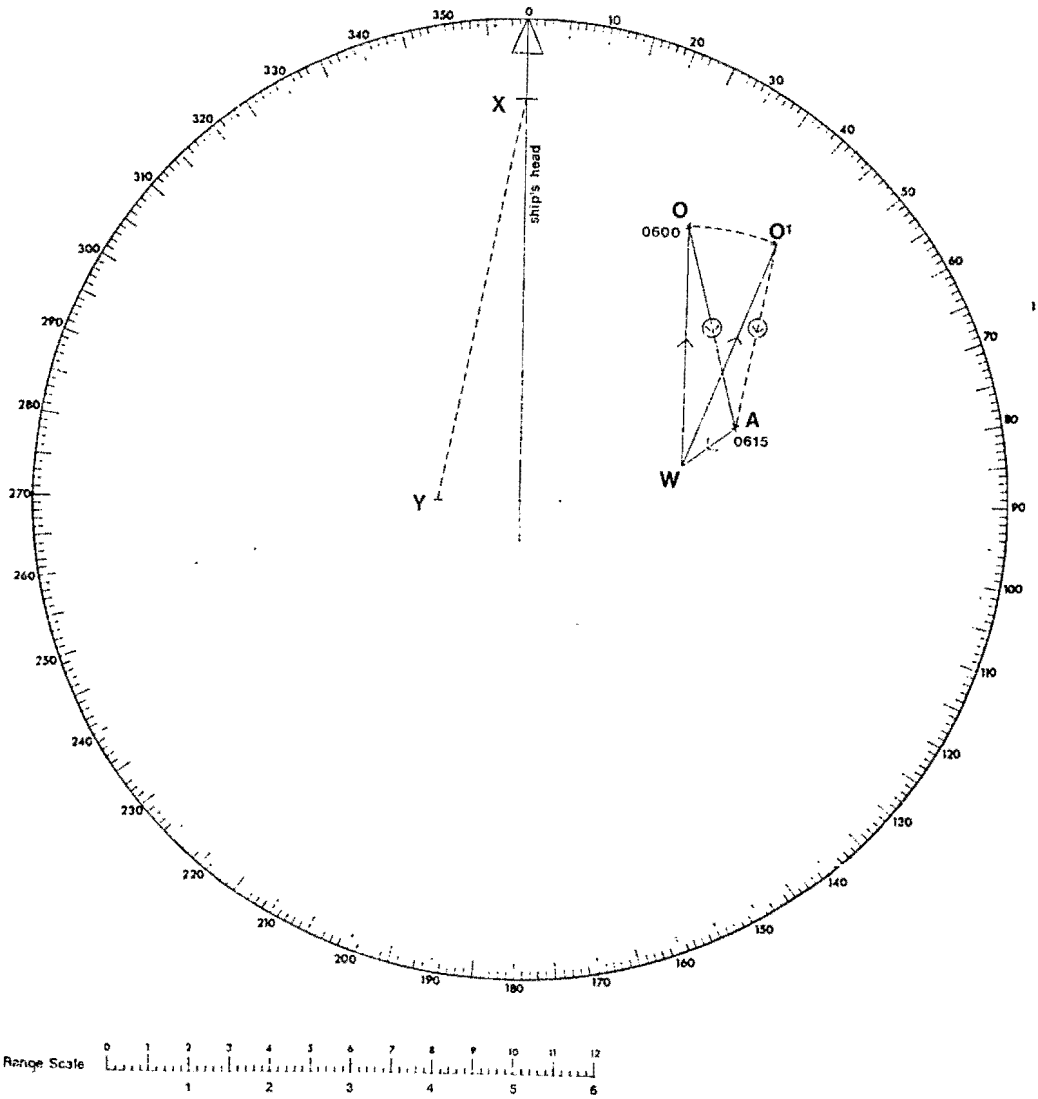
At 0615, a second light vessel was observed right ahead at a range of 5 miles.

Required: (*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.

Radar Plot 7
(Relative–North up)



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.
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 water 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.

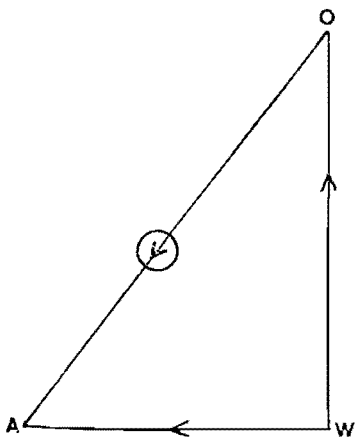
Tracking.

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



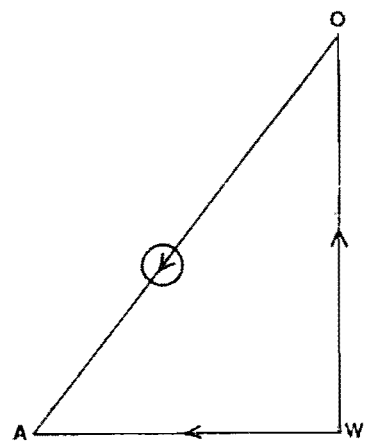
O = Initial position of target on plot at appropriate range and bearing from own ship.

O ⟶ A = target's relative track/speed vector.

W ⟶ O = own ship's course/speed vector over time increment *OA*.

W ⟶ A = target's true track/speed vector over time increment *OA*.

TRUE PLOT



W = Initial position of target on plot at appropriate range and bearing from own ship.

W ⟶ A = target's true track/speed vector.

W ⟶ O = own ship's course/speed vector over time increment *WA*.

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 visibility 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

(Answers on page 378)

EXAMPLES FOR 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. 3 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 miles		045°	7 miles
0004	331°	3 ,,		046°	6 ,,
0008	320°	2 ,,		047°	5 ,,
0012	293°	1·4 ,,		058°	3·7 ,,

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 miles
1203	030°	6·5 ,,
1206	030°	6 ,,
1209	030°	5·5 ,,

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 ,,		050°	6 ,,
1806	317°	4 ,,		049°	5 ,,

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 miles
2203	310°	6·3 ,,
2206	310°	5·6 ,,
2209	303°	4·7 ,,
2212	294°	4 ,,

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 miles
0003	290°	5 ,,
0006	290°	4 ,,
0009	284°	3·4 ,,
0012	277°	2·9 ,,

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 miles		045°	8 miles
0103	316°	4·4 ,,		045°	7·2 ,,
0106	317°	4 ,,		046°	6·6 ,,
0109	318°	3·4 ,,		046°	5·9 ,,

What report should be made to the O.O.W. at 0109? What are the courses and speeds of target vessels "*X*" and "*Y*"? At 0112 speed was reduced 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 ,,
1521	221° T	6 ,,
1524	220° T	5 ,,

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, also 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 miles	085° T.	5·5 miles	145° T.	7 miles
022° T.	4·2	091° T.	4·3	145° T.	6·4
024° T.	3·4	101° T.	3·3	145° T.	5·8
023° T.	2·9	120° T.	2·4	141° T.	6·1
020° T.	2·6	152° T.	2·0	137° T.	6·4

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. 12 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 miles
0005	204° T. 7·3	270° T. 6·8
0010	204° T. 6·2	270° T. 5·6
0015	203° T. 5·1	270° T. 4·4

"*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.

CHAPTER III.

GREAT CIRCLE SAILING.

GREAT circle sailing is the method used for making long ocean passages between two positions which are widely separated on the earth's surface. More specifically, it is used to find the courses which a ship must steer and the track which must be followed when sailing along the lesser arc of a great circle between the two positions.

The lesser arc of the great circle contained between any two places is the shortest possible distance between them; it is, in fact, the track that would be followed if steering straight for a destination as if it were in sight. If a vessel were steering exactly on the great circle course she would be heading directly towards her destination for the whole of the time, and would be a mile nearer to her port for every mile that she made good.

It is, however, not practicable to keep a vessel *exactly* on the great circle track, because to do so would involve continually changing course. A vessel may, however, save considerable distance on a passage by keeping as nearly as practicable on the track of the great circle, and this is the usual procedure.

The position of a suitable number of points, separated by regular intervals of longitude along the great circle, are calculated by means of right-angled spherical trigonometry. The vessel is then steered direct from point to point, and thus very nearly attains her object of sailing or steaming the shortest possible distance. The great circle course from any one place to another is calculated by means of spherical trigonometry and may also be taken out by inspection from ABC Tables, Alt-Azimuth Tables, Weir's Azimuth Diagram or any Sight Reduction Tables such as NP 401/HD 605.

The advantages obtained from the use of great circle sailing as compared with Mercator's sailing are greatest in high latitudes, when there is a large difference of longitude between the points of departure and destination. The advantages are least, and the differences between the great circle and mercatorial courses are least, when the places of departure and destination are in low latitudes, or when the ship's course is near North or South in any latitude. The equator and all meridians are great circles, so that if the ship is steering true North or South it is already on a great circle and the same applies when steering true East or West along the equator.

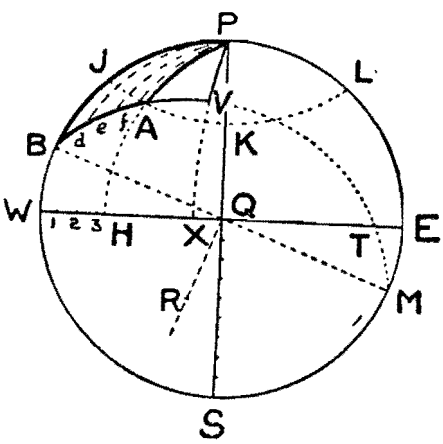
Unless there is a definite reason for not following it, the great circle track is the proper one to use, and is the best, because it is the shortest. There are cases, however, when it is necessary or advisable to depart from it. It may pass through higher latitudes than are desirable for the ship to go to; it may pass over an island or other land, when, of course, it would be necessary to depart from it; also, it might pass through regions where ice may be expected or where head winds are prevalent. In the latter case the distance saved might be more than counterbalanced by the extra strain put on the ship and by the loss of time and speed caused by heading into strong winds and heavy seas.

The statement that a ship when on the great circle course is always heading direct for her destination, yet continually changing her course, sounds contrary, but is nevertheless quite correct.

A great circle drawn between any two places on a globe will show clearly that the great circle track cuts each successive meridian at a different angle; the ship is, therefore, steering on different true courses though heading in one and the same direction all the time.

Worked Example I.

Find the initial and final courses, also the distance on the great circle, from Honolulu in Lat. 21° 18′ N., Long. 157° 52′ W., to a point off Vancouver Island in Lat. 48° 34′ N., Long. 126° 4′ W. Required also the latitude and longitude of the vertex and the latitude of the points where the great circle cuts the meridian of 150° W., and thence every 10° of longitude to destination.



In figure:

P E S W represents the globe.
P and *S* the poles.
W Q E the equator.
B Honolulu, *A* Vancouver.
P B the co-latitude of *B*.
P A the co-latitude of *A*.
$\angle$ *B P A* the D. Longitude *B* to *A*.
Arc *B A* the G.C. track and distance.
$\angle$ *P B A* the initial course.
$\angle$ *P A V* the final course.
d, *e* and *f* the successive points asked for.
V the vertex of the great circle.

Construction of Figure.

It is desirable to draw a fairly accurate figure for great circle problems in order to see clearly the relative positions of the various points.

The simplest method of drawing an approximate figure on the equidistant projection is to take nine equal parts on the compasses from any convenient scale (we have used the equidistant marks on *Q S*) and describe a circle with this radius to represent the globe: then draw in *W Q E* the equator, *P Q S* a central meridian, and proceed as follows:—

1. Mark the spot *B*, the place of lesser latitude, on the circumference by placing the centre of a protractor at *Q* and making $\angle$ *W Q B*=Latitude *B*=21° 18′ N.
P B W then becomes the meridian of Honolulu, Long. 157° 52′ W.

2. Measure *W H*=D. Longitude=31° 48′ from the scale and draw in the meridian *P H*. The centre of all the meridian circles is on the equator, produced if necessary. *P H* is now the meridian of Longitude 126° 04′ W. passing through *A*, the destination.

3. Run in the parallel of Latitude 48° 34′ N., passing through *A* by making *Q K* =48½° from the scale of equal parts, and laying off $\angle$ *W Q J* and $\angle$ *E Q L*=48½° with the protractor. By trial, find on *Q P*, produced if required, the centre of the parallel *J K L* and draw it in. It cuts meridian *P H* at *A* and fixes the point of destination.

4. To draw in *B A* the great circle. Join *B Q* with the straight edge of the protractor and produce to *M*. Make $\angle$ *B Q R*=90°, then on *Q R* find, by trial, the centre of the great circle passing through *B* and *A*, and produce it to *M*. It will be found that *B Q M* is a diameter of the circle *P E S W*, as all great circles cut the circumference of the primitive at diametrically opposite points.

5. The meridian passing through the vertex of a great circle is always 90° from the longitude of the spot where it cuts the equator at *T*. Measure *T X*=D. Longitude

90°, and draw in the meridian $P X$; it cuts the great circle at V, the vertex, which is the turning point, and represents the maximum latitude reached on this track. The great circle course at the vertex is always due East or due West.

6. Make $W1$ equal to 8° to represent the D. Longitude between B 157° 52′ W. and 150° W.; then 1 to 2=D. Longitude 10°; 2 to 3=D. Longitude 10°. Draw in the meridians through those numbered spots 1, 2 and 3, cutting the great circle at d, e and f respectively. It is required to find the latitudes and longitudes of those points for laying off on a Mercator chart.

In triangle $P B A$:

1. Given $P B$, $P A$ and $\angle B P A$, find side $B A$.

2. Given $P B$, $P A$ and $B A$, find 1st $\angle B$, 2nd $\angle P A B$, to be subtracted from 180° to give $\angle P A V$.

In triangle $P A V$:

3. Given $\angle V = 90°$, side $P A$ and $\angle P A V$, find 1st $P V$ the co-latitude of vertex; 2nd $\angle A P V$ the D. Longitude between A and vertex to be applied to Longitude A.

Lat. A 48° 34′ N., co-lat. 41° 26′ ($P A$)
Lat. B 21 18 N., co-lat. 68 42 ($P B$)
($P A \sim P B$) 27° 16′

Long. A, 126° 4′ W.
Long. B, 157 52 W.
D. Long. 31° 48′ (P)

1. To find the Distance.

Hav $B A$ = Hav P sin $P A$ sin $P B$ + hav ($P A \sim P B$)

P	31° 48′	log hav	8·87537
$P A$	41 26	log sin	9·82069
$P B$	68 42	log sin	9·96927
		log hav	8·66533
		nat hav	0·04627
($P A \sim P B$)	27° 16′	nat hav	0·05556
$B A$	37° 13·2′	nat hav	0·10183
	60		
Distance	2233·2 miles		

2. 1st To find angle B (the initial course)

$$\text{Hav } B = \frac{\text{hav } P A - \text{hav } (B A \sim B P)}{\sin B A \sin B P}$$

$P A$	41° 26′	nat hav	0·12514
($B A \sim B P$)	31 28·8	nat hav	0·07359
		nat hav	0·05155
		log hav	8·71221
$B A$	37° 13·2′	log cosec	0·21833
$B P$	68 42	log cosec	0·03073
B	35° 12·5′	log hav	8·96127

Initial course, N. 35° 12·5′ E.
or 035° 12·5′ T.

2nd To find angle A (the final course)

$$\text{Hav } A = \frac{\text{hav } P B - \text{hav } (A B \sim A P)}{\sin A B \sin A P}$$

$P B$	68° 42′	nat hav	0·31837
($A B \sim A P$)	4 12·8	nat hav	0·00135
		nat hav	0·31702
		log hav	9·50109
$A B$	37° 13·2′	log cosec	0·21833
$A P$	41 26	log cosec	0·17931
A	125 44	log hav	9·89873

Final course, S. 125° 44′ E.
or 054° 16′ T.

If angles A and B are both acute—that is, both less than 90°—the vertex of the great circle will be inside the triangle, but if either of them be over 90° it will be outside the triangle. In this case angle A is over 90°, and, therefore, V is on the great circle outside the triangle $P A B$, as shown in the diagram.

8. To find the Latitude and Longitude of the Vertex.

In triangle P A V. By Napier's Rules:—

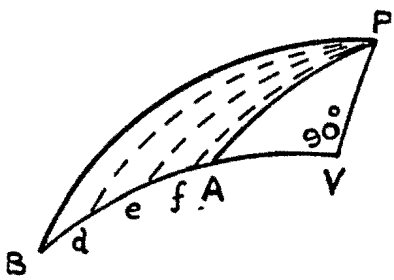
1st Sin $P V$ = cos *comp* $P A$ cos *comp* A
Sin $P V$ = sin $P A$ sin A

$P A$	41° 26′	sin	9·82069
A	54 16	sin	9·90942
$P V$	32° 29·5′	sin	9·73011
	90 00		
Lat. vertex	57° 30·5′ N.		

2nd Sin *comp* $P A$ = tan *comp* A tan *comp* $A P V$
Cos $P A$ = cot A cot $A P V$
Cos $P A \times$ tan A = cot $A P V$

$P A$	41° 26′	cos	9·87490
A	54 16	tan	0·14300
$A P V$	43° 49′	cot	10·01790
Long. A	126 04 W.		
Long. vertex	82° 15′ W.		

4. To find the Latitude of Points 10° of Longitude apart for laying off on Mercator's Chart.



Let d be the first point in Long. 150° W.

Then in triangle $P d V$, given side $P V$ and angle $d P V$.'

Required to find side $P d$ = co-lat. of d.

By Napier's Rules:—

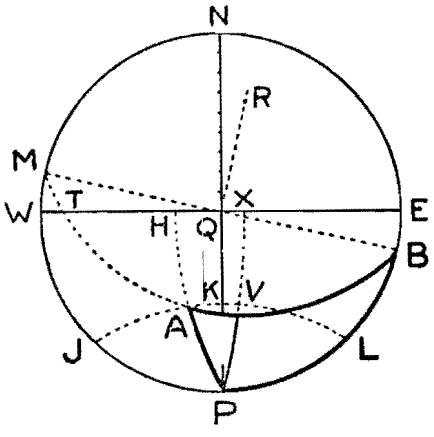
Sin *comp* $d P V$ = tan $P V$ tan *comp* $P d$
∴ cos $d P V$ = tan $P V$ cot $P d$
i.e. cos $d P V \times$ cot $P V$ = cot $P d$
or cos $d P V \times$ tan lat. V = tan lat. d
similarly cos $e P V \times$ tan lat. V = tan lat. e
and cos $f P V \times$ tan lat. V = tan lat f

Long. of vertex	Long. of successive points	Polar angle of points	Latitudes as calculated
82° 15′ W.	150° W. (d)	67° 45′ ($d P V$)	30° 44′ N.
,,	140 W. (e)	57 45 ($e P V$)	39 57·5 N.
,,	130 W. (f)	47 45 ($f P V$)	46 33 N.

	$d P V$	67° 45′	cos 9·57824	$e P V$	57° 45′	cos 9·72723	$f P V$	47° 45′	cos 9·82761
Lat.	V	57 30·5	tan 0·19595	V	57 30·5	tan 0·19595	V	57 30·5	tan 0·19595
Lat	d	30° 44′ N.	tan 9·77419	e	39° 57·5′ N.	tan 9·92318	f	46° 33′ N.	tan 10·02356

Worked Example II.

Find the initial and final courses and the distance on the great circle from Otago harbour, Tairoa Head, in Lat. 45° 47′ S., Long. 170° 45′ E., to Callao, in Lat 12° 4′ S., Long. 77° 14′ W. Required also the latitude and longitude of the vertex and the position of a succession of points along the great circle at a distance of 10° of longitude apart, beginning with a point in Long. 172° 54′ E.



Construction of figure:

The geometrical construction of the figure is the same as in the previous example.

$P\,B$ represents the meridian of Callao, the place of lesser latitude marked on the circumference of the circle.

Lay off $E\,H$, the D. Long. and draw in the meridian of Otago, $P\,H$.

$J\,K\,L$ is the parallel of Lat. 45° 47′ S. and A represents the position of Otago.

$X\,R$ is a locus perpendicular to the diameter $B\,X\,M$, and spot R, found by trial, is the centre of the great circle $M\,A\,B$ which cuts the equator at T. $T\,X$ is D. Long. 90°, giving the position of $P\,X$ the meridian through vertex V.

The initial and terminal courses may be found by the sine formula with a considerable saving of labour, but care must be taken when the angles are near 90° as neither the figure nor the formula will indicate whether the angles fall below or above 90°.

In triangle $P\,A\,B$.

(i) Given $P\,A$, $P\,B$ and included angle P, find $A\,B$ by haversine formula.

(ii) Given $\angle P$, $A\,B$ and $P\,B$, find $\angle A$ by sine formula.

(iii) Given $\angle P$, $A\,B$ and $P\,A$, find $\angle B$ by sine formula.

In triangle $P\,A\,V$.

(iv) Given $P\,A$, $\angle A$ and $\angle V = 90°$, find first $P\,V$ the co-lat of vertex; second, $\angle A\,P\,V$ the D. long between A and vertex.

A Lat. 45° 47′ S.	co-lat. 44° 13′	$(P\,A)$	A Long. 170° 45′ E.		
B Lat. 12 04 S.	co-lat. 77 56	$(P\,B)$	B Long. 77 14 W.		
			247 59 E.		
$(P\,A \sim P\,B)$	33° 43′		360 00		
			$\angle A\,P\,B$ 112 01 W.		

(i) Hav $A\,B$ = hav P sin $P\,A$ sin $P\,B$ + hav $(P\,A \sim P\,B)$
(ii) Sin A = sin P sin $B\,P$ cosec $A\,B$
(iii) Sin B = sin P sin $A\,P$ cosec $A\,B$

P	112° 01′	log hav	9·83723	sin	9·96711	sin	9·96711
$P\,A$	44 13	log sin	9·84347			sin	9·84347
$P\,B$	77 56	log sin	0·99030	sin	9·99030		
		log hav	9·67100				
		nat hav	0·46881				
$(P\,A \sim P\,B)$	33° 43′	nat hav	0·08410				
$A\,B$	96 4·4	nat hav	0·55291	cosec	0·00244	cosec	0·00244
	60						
Distance	5764·4 miles			sin	9·95985	sin	9·81302
				A	65° 44·5′	B	40° 33·2′

Initial course S. 65° 44·5′ E. Final course N. 40° 33·2′ E. Distance 5764·4 miles.

The initial and final courses may be found simultaneously by means of the tangent formula from the two given sides and their included angle. Although this means introducing another formula, yet it has the advantage of using the quantities given in the question and not the calculated side $A\,B$.

$$\text{Tan } \tfrac{1}{2}(A+B) = \frac{\cos \tfrac{1}{2}(P\,A \sim P\,B)}{\cos \tfrac{1}{2}(P\,A - P\,B)} \cot \frac{P}{2}$$

$$\text{Tan } \tfrac{1}{2}(A \sim B) = \frac{\sin \tfrac{1}{2}(P\,A \sim P\,B)}{\sin \tfrac{1}{2}(P\,A + P\,B)} \cot \frac{P}{2}$$

then $\tfrac{1}{2}(A+B) \pm \tfrac{1}{2}(A \sim B) = A$ and B.

$\frac{1}{2}(PA \sim PB)$	16° 51·5′	cos	9·98092	sin	9·46241	
$\frac{1}{2}(PA + PB)$	61 04·5	sec	0·31546	cosec	0·05787	
$\frac{P}{2}$	56 00·5	cot	9·82885	cot	9·82885	
$\frac{1}{2}(A+B)$	53 08·9	tan	10·12523	tan	9·34913	
$\frac{1}{2}(A \sim B)$	12 35·6					
A	65 44·5	Initial course	S. 65° 44·5′ E.	or	114° 15·5′ T.	
B	40 33·3	Final „	N. 40 33·3′ E.	or	040° 33·3′ T.	

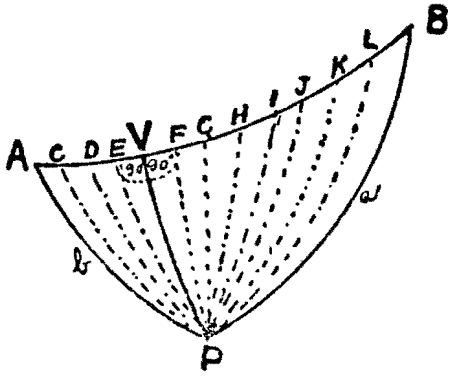
To find the Latitude and Longitude of the Vertex. By Napier's Rules:—

Sin $P\,V$ = cos *comp* $P\,A$ cos *comp* A
Sin $P\,V$ = sin $P\,A$ sin A

$P\,A$	44° 13′	sin	9·84347	
A	65 45	sin	9·95988	
$P\,V$	39 29	sin	9·80335	
	90 00			
	50° 31′ S. Lat. of vertex.			

sin *comp* $P\,A$ = tan *comp* A tan *comp* $A\,P\,V$
cos $P\,A$ = cot A cot $A\,P\,V$
cos $P\,A \times$ tan A = cot $A\,P\,V$

$P\,A$	44° 13′	cos	9·85534	
A	65 45	tan	0·34634	
$A\,P\,V$	32 09	cot	0·20168	
Long. A	170 45 E.			
	202° 54′ E.			
	360 00			
	Long. of vertex 157° 6′ W.			



To find the Latitude of Points 10° of Longitude apart.

Let C be the first point in Long. 172° 54′ E. Then in triangle $P\,C\,V$, given side $P\,V$, angle $V\,P\,C$, and $\angle V = 90°$.

Required to find side $P\,C$ = co-lat. of C.

By Napier's Rules:—

Sin *comp* P = tan $P\,V$ tan *comp* $P\,C$
∴ cos P = tan $P\,V$ cot $P\,C$
i.e., cos $P \times$ cot $P\,V$ = cot $P\,C$
or cos $P \times$ tan lat V = tan lat C

The same investigation applies to the other triangles to get the latitudes of the successive points.

Long. of vertex	Long. of successive points	Polar angle of points	Latitudes as calculated below
157° 06′ W.	172° 54′ E. ((*C*)	30° *V P C*	40° 26′ S.
,,	177 06 W. (*D*)	20 *V P D*	48 45½ S.
,,	167 06 W. (*E*)	10 *V P E*	50 05 S.
,,	157 06 W. (*V*)	0 Vertex	50 31 S.
,,	147 06 W. (*F*)	10 *V P F*	50 05 S.
,,	137 06 W. (*G*)	20 *V P G*	48 45½ S.
,,	127 06 W. (*H*)	30 *V P H*	46 26 S.
,,	117 06 W. (*I*)	40 *V P I*	42 55 S.
,,	107 06 W. (*J*)	50 *V P J*	37 58 S.
,,	97 06 W. (*K*)	60 *V P K*	31 15 S.
,,	87 06 W. (*L*)	70 *V P L*	22 33 S.

V P C	30° 00′	cos	9·937531	*V P D*	20° 00′	cos	9·972986	*V P E*	10° 00′	cos	9·99335 1
Lat. *V*	50 31	tan	10·084153	*V*	50 31	tan	10·084153	*V*	50 31	tan	10·08415 3
Lat. *C*	46° 26′	tan	10·021684	*D*	48° 45½′	tan	10·057139	*E*	50° 5′ S.	tan	10·077504

Points *F*, *G*, and *H* have the same latitudes as *E*, *D* and *C* respectively, because their polar angles are the same but on the other side of the vertex. The latitudes of *I*, *J*, *K* and *L* are given above and the student may work them out in verification.

GNOMONIC CHART.

The adjoining illustration represents a section of a chart drawn on the gnomonic projection to facilitate laying off great circle tracks. The meridians are straight lines radiating from the pole, the parallels of latitude are conic sections, the great circle is a straight line.

Example.—Required to lay off the great circle track from Rathlin Island (55° 18′ N., 6° 10′ W.) to Belle Isle (51° 58′ N., 55° 30′ W.).

Join the two places on the chart by a straight line. It will be noted that the great circle track crosses successive meridians at a different angle, and that the latitudes and longitudes of points along the great circle taken from the gnomonic chart may be transferred to the Mercator chart on which the track will appear as a curve.

We have marked four points on the track and have read off their positions from the gnomonic chart as follows: *A*, 56° 18′ N., 15° W.; *B*, 56° 33′ N., 25° W.; *C*, 56° 00′ N., 35° W.; *D*, 54° 35′ N., 45° W., the respective Mercator courses being *A*, N. 87° W.; *B*, S. 84° W.; *C*, S. 76° W.; *D*, S. 67° W.

Another track is shown from Sable Island to Brest, the position of its vertex from the chart being Lat. 49° 56′ N., Long. 24° 20′ W.

GREAT CIRCLE SAILING.

In the following examples find the initial, or the final, course; the great circle distance; the latitude and longitude of vertex and of successive points as stated:

1. *Lizard to Barbados.*—(*A*) Lat. 49° 50′ N., Long. 5° 12′ W.; (*B*) Lat. 13° 06′ N., Long. 59° 20′ W. Points every 10° apart, commencing with a point in Long. 15° 12′ W.
2. From (*B*) Lat. 36° 55′ N., Long. 140° W. to (*A*) Lat. 51° 40′ N., Long. 170° E. Points every 10° apart, commencing at the meridian of Long. 150° W.

3. *Algoa Bay to Cape Comorin.*—(*A*) Lat. 34° 02′ S., Long. 25° 30′ E.; (*B*) Lat. 8° 09′ N., Long. 78° 06′ E. Points every 10° apart, commencing at a point in Long. 35° 30′ E.
4. *Cape of Good Hope to Straits of Sunda.*—(*A*) Lat. 34° 22′ S., Long. 18° 29′ E; (*B*) Lat. 6° 40′ S., Long. 104° 29′ E. Points every 10° apart, beginning with a point 10° of Longitude eastward of vertex, and thence to destination.
5. *Bermuda to English Channel.*—(*A*) Lat. 32° 15′ N., Long. 64° 45′ W.; (*B*) Lat. 49° 45′ N., Long. 5° 12′ W. Points every 10° from Long. 55° W.
6. *Vancouver to Hawaii.*—(*A*) Lat. 48° 25′ N., Long. 123° 15′ W.; (*B*) Lat. 21° 20′ N., Long. 157° 48′ W. Points every 10° from Long. 135° W.
7. *Hawaiian Islands to Chile.*—(*A*) Lat. 20° N., Long. 160° W.; (*B*) Lat. 32° 30′ S., Long. 72° W. Points every 20° from 140° W.
8. *Sandy Hook to Straits of Gibraltar.*—(*A*) Lat. 40° 26′ N., Long. 73° 58′ W.; (*B*) Lat. 36° 00′ N., Long. 5° 33′ W. Points every 10° from 60° W.
9. *From A to B.*—(*A*) Lat. 36° 56′ N., Long. 76° 00′ W.; (*B*) Lat. 36° 56′ N., Long. 9° 00′ W. Points every 12½° from 67° 30′ W.
10. *From A to B.*—(*A*) Lat. 10° 37′ N., Long. 89° 56′ E.; (*B*) Lat. 40° 33′ S., Long. 55° 22′ E. Points every 5° from 85° E.

COMPOSITE GREAT CIRCLE SAILING.

Composite great circle sailing is the art of sailing a vessel on a composite track which is the shortest possible distance between any two places when a maximum latitude has been fixed upon, and it has been decided that the ship shall not go beyond that latitude.

Should a vessel, after considering the great circle track from one place to another, find that it would take her into too high a latitude, and therefore decide not to follow it, she should fix on what is to be her maximum latitude, and calculate and lay out a composite track.

This consists of the arcs of two separate great circles, and between them the arc of the parallel of latitude decided upon, which is the arc of a small circle, the three arcs together forming the composite track.

The great circle track from the point of departure to the maximum latitude is calculated, and the ship is sailed along it until she reaches the point where it touches the maximum latitude decided upon, which point is the vertex of the great circle on which she has been sailing. She then leaves the great circle, and sails along the parallel of maximum latitude until she reaches the vertex of another great circle (previously calculated), touching the maximum latitude and passing through the point of destination. She then leaves the parallel of latitude and sails along the arc of the second great circle to her destination.

Composite sailing is not a case of calculating a great circle direct from departure to destination, sailing along it until the maximum latitude is reached, then proceeding along that parallel of latitude, and picking up and following the arc of the same great circle at its other end. The arcs of the two great circles (one at each end of the track) are not in any way connected with one another, except by the arc of the small circle between them.

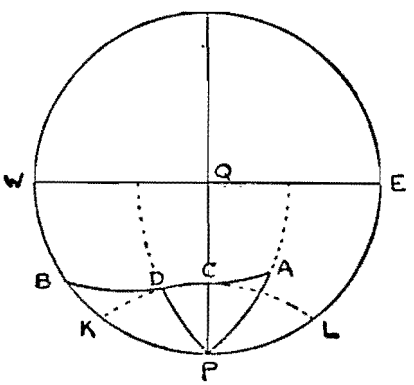
A composite track could be used with advantage by a vessel bound from, say, the River Plate to Melbourne, in which case the ordinary great circle track would pass through too high a latitude.

Worked Example I.

Required the composite route from Tristan da Cunha in Lat. 37° 3′ S., Long. 12° 18′ W., to Tasmania in Lat. 44° S., Long. 145° E., the maximum lat. to be 52° S. Find the longitudes at which the ship must meet and leave that latitude, also the initial and final great circle courses and the total distance along the composite track. Required also the longitude from vertex and the latitudes at which the track crosses the meridian of 20° E. and thence every 10° of longitude to destination.

Construction of figure:

A figure (in pencil) should be drawn in order to keep in view the relative positions of the points of departure and destination, the given parallel of maximum latitude and the two distinct great circles each having its vertex on the parallel of the latitude.



W P E represents the South Hemisphere and *K D C L* the parallel of maximum latitude, 52° S.
P W the meridian of Tristan da Cunha (*B*), 12° 18′ W.
P A the meridian of Tasmania (*A*), 145° E.
D the vertex of the 1st G.C., arc *B D*.
C the vertex of the 2nd G.C., arc *C A*.
D C an arc of the parallel *K L*.
These three arcs together form the composite route, viz., *B D*, *D C* and *C A*.

The calculation resolves itself into the solution of two right angled spherical triangles by Napier's Rules, and the conversion of a D. Long. into its corresponding departure by parallel sailing as follows.

In triangle P B D:

Given *P B* the co-latitude of *B*, *P D* the co-latitude of *D*, $\angle D = 90°$. Find (i) $\angle B$ the initial course, (ii) *B D* the great circle distance, (iii) $\angle B P D$ the D. Long. between *B* and *D*.

(i)

Sin *P D* = cos *comp P B* cos *comp B*
Sin *P D* = sin *P B* sin *B*
Sin *P D* × cosec *P B* = sin *B*
or, cos lat. *D* sec lat. *B* = sin *B*
cos 52° sec 37° 3′ = sin *B*

(ii)

Sin *comp P B* cos *P D* cos *B D*
Cos *P B* × sec *P D* = cos *B D*
or, sin lat. *B* cosec lat. *D* = cos *B D*
sin 37° 3′ cosec 52° = cos *B D*

(iii)

Sin *comp B P D* = tan *comp P B* tan *P D*
cos *B P D* = cot *P B* tan *P D*
or, cos *B P D* = tan lat. *B* cot lat *D*
cos *B P D* = tan 37° 3′ cot 52°

(i)

Lat. *D*	52° 00′	cos	9·789342
Lat. *B*	37 03	sec	0·097937
$\angle B$	50 28·8	sin	9·887279

Initial course S. 50° 28·8′ E. or 129° 31·2′ T.

Similarly in triangle *P C A* given *P C* the co-lat. of *C*, *P A* the co-lat of *A*, $\angle C = 90°$.

Find (i) $\angle A$ the final course, (ii) *C A* the great circle distance, (iii) $\angle C P A$ the D. Long. between *C* and *A*. The investigation is the same as in triangle *P B D* and we get

(i) Cos 52° sec 44° = sin *A*
(ii) Cosec 52° sin 44° = cos *C A*
(iii) Cot 52° tan 44° = cos *C P A*

(ii)

cosec	0·103468
sin	9·779966
cos	9·883434
B D	40° 7′ 43″
	60
Dist.	2407·7 miles

(iii)

cot	9·892810
tan	9·877903
cos	9·770713
$\angle B P D$	53° 51′ 23″
Long. *B*	12 18 00 W.
Long. *D*	41 33 23 E.

		(i)		(ii)		(iii)
Lat. *C*	52° 00′	cos	9·789342	cosec	0·103468	cot	9·892810
Lat. *A*	44 00	sec.	0·143066	sin	9·841771	tan	9·984837
∠ *A*	58 51·3	sin	9·932408	cos	9·945239	cos	9·877647
Final course		N. 58° 51·3′ E.		*C A*	28° 10′ 19″	∠ *A P C*	41° 1′ 12″
		or 058° 51·3′ T.			60		145 0 0 E.
				Dist.	1690·3 miles	Long *C*	103 58 48 E.

To find distance along parallel of maximum latitude.

Long. *B*	41° 33′ 23″ E.		
Long. *C*	103 58 48 E.		
	62 25 25		
	60		
D. Long.	3745·4		

D C = *D.* Long. × cos lat.

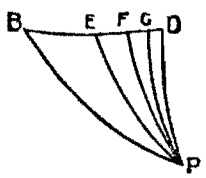
Lat.	52° 0′	cos 9·789342
D. Long	3745·4	log 3·573498
D C	2305·9	log 3·362840

To find the total distance.

Total distance = *B D* + *D C* + *C A*

B D	2407·7 miles
D C	2305·9 ,,
C A	1690·3 ,,
	6403·9 miles

To find the latitudes of the points along the track.



If *E* be the first point in Long. 20° E., then in triangle *E P D*, given side *P D*, ∠*E P D*, ∠*D*=90°, find side *P E* the co-lat. of *E*.

Sin *comp E P D* = tan *P D* tan *comp P E*

cos *E P D* = tan *P D* cot *P E*

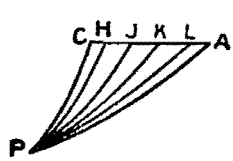
cos *E P D* cot *P D* = cot *P E*

or, cos D. Long. tan lat *D* = tan lat *E*.

The same formula applies to the other points by substituting the proper values of the successive polar angles.

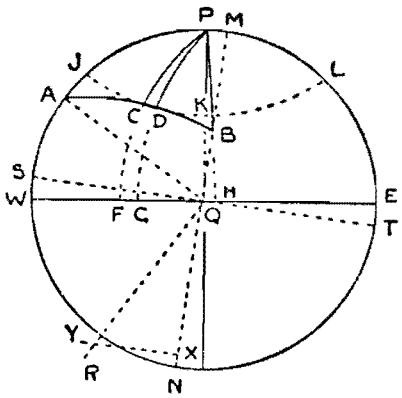
Longitude of vertex	Longitudes of points	Polar angles of points	Latitudes as calculated
(*D*) 41° 33′ 23″ E.	20° E. (*E*)	21° 33′ 32″ (*E P D*)	49° 58′ 06″ S.
,,	30 E. (*F*)	11 33 23 (*F P D*)	51 25 46 S.
,,	40 E. (*G*)	1 33 23 (*G P D*)	51 59 23 S.
	The points in Long. 50°, 60°, 70°, 80°, 90° and 100° E. are all in 52° 00′ 00″ S.		
(*C*) 103 58 48 E.	110° E. (*H*)	6° 01′ 12″ (*H P C*)	51° 50′ 46″ S.
,,	120 E. (*J*)	16 01 12 (*J P C*)	50 53 38 S.
,,	130 E. (*K*)	26 01 12 (*K P C*)	48 59 46 S.
,,	140 E. (*L*)	36 01 12 (*L P C*)	45 59 30 S.

	° ′ ″			° ′ ″				° ′ ″					
∠ *E P D*	21 33 23	cos	9·968509	*F P D*	11 33 23	cos	9·991106	*G P D*	1 33 23	cos	9·999839		
Lat. (*B*)	52 0 0	tan	0·107190		52 0 0	tan	0·107190		52 0 0	tan	0·107190		
Lat. (*E*)	49 58 6	tan	0·075699	(*F*)	51 25 46	tan	10·098296	(*G*)	51 59 23	tan	10·107029		



	° ′ ″					° ′ ″							
∠ *H P C*	6 1 12	cos	9·997598	*J P C*		16 1 12	cos	9·982798					
Lat. (*C*)	52 0 0	tan	0·107190			52 0 0	tan	0·107190					
Lat. (*H*)	51 50 46 S.	tan	10·104788	(*J*)		50 53 38 S.	tan	10·089988					
	° ′ ″					° ′ ″							
∠ *K P C*	26 1 12	cos	9·953587	*L P C*		36 1 12	cos	9·907848					
Lat. (*C*)	52 0 0	tan	0·107190			52 0 0	tan	0·107190					
Lat. (*K*)	48 59 46	tan	10·060777	(*L*)		45 59 30	tan	10·015038					

Construct a figure for the composite great circle route from a point in Japan (*A*) Lat. 35° 40′ N., Long. 141° E., to a point off San Francisco (*B*) Lat. 37° 48′ N., Long. 122° 40′ W., the maximum latitude to be 45° N. as given in exercise 2.



1. Describe a circle with nine equal parts as radius.

2. Draw in the parallel of maximum latitude *J K L*, 45° N.

3. Assume *P W* to be the meridian of *A*, 141° E., and make $\angle W Q A$=Lat. 35° 40′ N.

4. Lay off arc of the equator *W H*, the D. Long. between *A* and *B*=96° 20′, and draw in the meridian *P H*.

5. Lay off the parallel of latitude of *B*, 37° 48′ N., (not shown on figure) cutting meridian *P H* at *B*.

6. After having calculated the D. Long. of vertex *C* from *A*, viz., 44° 9′, and of vertex *D* from *B*, viz., 39° 8′, the meridians of *C* and *D* can be drawn by making arc *W f*=44° 9′ and arc *H G*=39° 8′, and drawing in the meridians *P C F* and *P D G*, cutting the maximum parallel at *C* and *D* respectively.

7. Join *A Q* and draw *Q R* at right angles to *A Q*, then find, by trial, point *R* the centre of the great circle arc *A C*.

8. To draw in the great circle arc *B D* proceed as follows:—

Join *B Q* and produce it to meet the circumference of the circle at *M* and *N*. Draw in the diameter *S Q T* at right angles to *M Q*. Then, by trial, find on *B N* the point *X* which is the centre of a circle passing through *B*, *S* and *T*. A line drawn through *X* at right angles to *B N* provides a locus on which the centre *Y* of the great circle arc *B D* can be found by trial.

9. Harden in the arc *C D* of the small circle *J L*. The composite track is then *A C*+*C D*+*D B*.

COMPOSITE GREAT CIRCLE SAILING.

EXAMPLES FOR EXERCISE.

(1) Required the initial and final courses and the distance along the composite great circle route from Wellington Isle (Lat. 49° 7′ S., Long. 75° 50′ W.) to New Zealand (Lat. 45° 54′ S., Long. 170° 46′ E.), the maximum latitude to be 55° S. Find the longitude of the points where the track meets and leaves the maximum latitude, also the longitude from vertex and the latitudes of the points where the track crosses the meridian of 80° W. and thence every 10° of longitude to destination.

2. Required the initial and final courses and the distance along the composite route from the East Coast of Japan (Lat. 35° 40′ N., Long. 141° E.) to a point off San Francisco (Lat. 37° 48′ N., Long. 122° 40′ W.), the ship not to go higher than Lat. 45° N. Find the longitude of the points where the track meets and leaves the maximum latitude, also the longitude from vertex and the latitudes of the point where the track intersects the meridians passing through the 150th degree of East longitude and every 10° of longitude in succession until arriving off San Francisco.

3. *New Zealand to Cape Horn.*—(*A*) Lat. 40° 20′ S., Long. 180°; (*B*) Lat. 56° 10′ S., Long. 67° 10′ W.; maximum Lat. 56° 10′ S. Points every 10° from 170° W.

4. *New Zealand to Chile.*—(*A*) Lat. 45° 30′ S., Long. 170° 13′ E.; (*B*) Lat. 33° 01′ S., Long. 71° 40′ W.; maximum Lat. 50° S. Points every 10° from 180°.

GNOMONIC CHART.

Lay off on the gnomonic chart (see inset) the following exercises:—

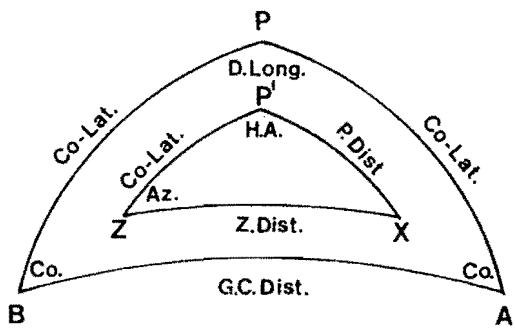
1. *Composite Great Circle Track.*—Belle Isle (Lat. 52° N., Long. 55½° W.) to the Naze (Lat. 58° N., Long. 7° E.), 1st vertex, Lat. 60° N., Long. 25° W., 2nd vertex, Lat. 60° N., Long. 8° W. Plot the track on the chart and lift as closely as the smallness of the scale will permit the latitudes corresponding to the following longitudes to obtain points along the great circles for plotting on a Mercator chart. Long. 50° W., 45° W., 40° W., 35° W., 30° W., 5° W., 0°, 5° E.

2. *Great Circle.*—Lay off on the gnomonic chart the great circle from Sable Isle to Lisbon, and with a protractor find the respective courses where the great circle crosses the meridians of 50° W., 40° W., 30° W., 20° W., 10° W.

See page 82 for more examples in Great Circle Sailing.

ABC TABLES AND GREAT CIRCLE SAILING.

It has been remarked that great circle sailing depends on the solution of an oblique spherical triangle having two of its sides and their included angle given, which is analogous to the time azimuth problem in the $P\,Z\,X$ triangle of nautical astronomy, so that ABC and other tables may be adapted to the solution by inspection of great circle questions as follows :



The inner triangle represents a $P\,Z\,X$ triangle and the outer one a great circle triangle similar in all respects so that in $\triangle\ XP'Z$:

Z	Azimuth	$= \angle B$	the initial GC course	in $\triangle\ A\,P\,B$
P'	Hour Angle	$= \angle P$	the D. Long.	,, ,, ,,
$P'Z$	Co. Lat. Z	$= PB$	the Co. Lat. of B	,, ,, ,,
$P'X$	Polar Dist. X	$= PA$	the Co. Lat. of A	,, ,, ,,
X	Angle of Posn.	$= \angle A$	the Final GC course	,, ,, ,,
ZX	Zenith Dist. X	$= AB$	the GC distance	,, ,, ,,

To Find Great Circle Courses by ABC Tables

The ABC Tables are entered with the arguments :

Lat. and Hour Angle in Table A
Dec. ,, Hour Angle ,, Table B
Lat. ,, (A $\pm$ B) ,, Table C

By substituting :

Initial GC Lat.	for	Lat.	in	Tables A & C
Final GC Lat.	,,	Dec.	,,	Table B, and
GC D. Long.	,,	Hour Angle		Table A & B

We can obtain :

The Initial GC Course in the Azimuth Column of Table C.

Conversely, to obtain the Final GC Course we substitute :

Final GC Lat.	for	Lat.	in	Tables A & C
Initial GC Lat.	,,	Dec.	,,	Table B, and
GC D. Long.	,,	Hour Angle		Table A & B

The following example is worked using the same data as for the great circle courses calculated in Example 1 on page 83.

Worked Example.

Find the initial and final great circle courses from
Initial position in Lat. 21° 18′ N. Long. 157° 52′ W to
Final „ „ „ 48° 34′ N. „ 126° 04′ W.

Enter the ABC Tables with:

Initial Lat.	21·3° N.	as	Lat.
Final Lat.	48·6° N.	as	Dec.
D. Long.	31·8° E.	as	Hour Angle.

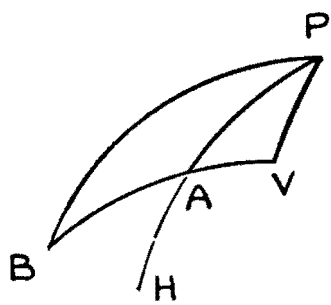
Lat.	21·3° N & HA 31·8°	A	0·63 S	(change name)
Dec.	48·6° N & HA 31·8°	B	2·15 N	(same name)
	A ± B =	C	1·52 N	

Lat. 21·3° N & C 1·52 N gives Azimuth N 35·3 E , or
Initial Course 035·3° T (035° 12·5′ T by calculation)

Now enter the ABC Tables with:

Final Lat.	48·6° N	as	Lat., and
Initial Lat.	21·3° N	as	Dec.

Lat.	48·6° N & HA 31·8°	A	1·83 S	
Dec.	21·3° N & HA 31·8°	B	0·74 N	
	A ± B =	C	1·09 S	



Lat. 48·6° N B C 1·09 S gives Azimuth S54·2° W
(∠HAB in the diagram), so
Final Course N 54·2° E or 054·2° T
(∠PAV in the diagram)
(054° 16′ T by calculation)

Great circle courses can also be found using Weir's Azimuth Diagram, Alt-Azimuth Tables or any Sight Reduction Tables such as HD 605/NP401.

Methods to Find Great Circle Distances by Tables

Alt-Azimuth and Sight Reduction Tables give both the azimuth and altitude. Since the great circle distance is equivalent to corresponding zenith distance (*ZX*), which is 90°-Altitude, these tables can also be used to find the great circle distance as well as the initial and final course.

It should be noted that Sight Reduction Tables are normally used in conjunction with an assumed or Chosen Position. The difference between *DR* and the assumed or Chosen Position (CP) is normally allowed for either in the plotting or by special corrections. In consequence, when obtaining a great circle distance by these methods a similar adjustment should be made for the difference in minutes between the initial GC position and the CP Lat. and the D. Long. between the initial position and the CP Longitude. Plotting is probably the most reliable method.

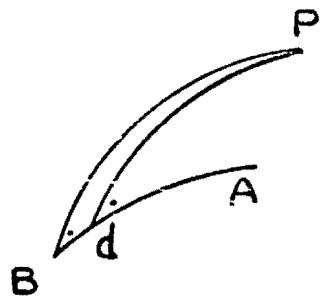
In practice, rhumb, great circle and composite great circle tracks are well charted for the ocean routes most commonly followed. Distances are also charted and included in a variety of distance tables. For further information the reader is referred to the section on Ocean Passages which is included at page 44 of this volume and which includes details of Admiralty publication, NP 136, "*Ocean Passages for the World*".

DOT Examination Requirements

D.o.T. Examination requirements are that great circle courses and distances are obtained by calculation but it is quite permissible, even desirable, to check the accuracy of results by other methods. The ABC Tables provide a quick and reliable method for checking courses.

Convergency.

The meridians on a globe converge on leaving the equator and intersect at the poles, so that the angles between successive meridians and a great circle crossing them are either progressively increasing or decreasing. The difference between the great circle courses at two points is called the angle of convergency. For example, in Figure, *BA* is a great circle and $\angle P\,d\,A - \angle P\,B\,A$ = convergency of meridians *P d* and *P B*.



Reference is made to convergency in Volume I, regarding the conversion of radio DF bearings into mercatorial bearings suitable for laying off on a chart, viz., Convergency = D. Long. × cos Mn. Lat., half the correction (Half Convergency) being added to DF bearings under 180°, and subtracted from DF bearings over 180° in the North hemisphere; the rule being reversed in the South hemisphere.

The radio DF convergency formula is modified to meet the case of great circle courses by introducing

$$\text{D. Long} = \frac{\text{Dep.}}{\cos \text{Mn. Lat.}} \text{ as in parallel sailing}$$

and Dep. = Dist. × sin Co as in plane sailing,

so that convergency $= \text{D. Long.} \times \sin \text{Mn. Lat.}$

$$= \frac{\text{Dep.}}{\cos \text{Mn. Lat.}} \times \sin \text{Mn. Lat.}$$

$$= \text{Dep.} \times \tan \text{Mn. Lat.}$$

$$= \text{Dist.} \times \sin \text{Co} \times \tan \text{Mn. Lat.}$$

Example.—Between Lat. 30° N. and 32° N. the distance along the great circle was 300 miles and the course 050° T, required the convergency.

Convergency = Dist. sin Co. tan Mn. Lat.

" = 300 sin 50° tan 31°

" = 138′ = 2° 18′

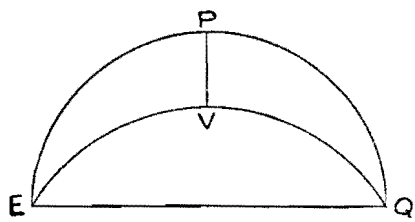
Example.—Calculate the convergency between the two following points on a great circle.

A Lat.	54° 20′ N.	Long. 50° W.
B ,,	56 00 N.	,, 45 W.
D. Lat.	1 40	D. Long. 300′

Convergency = D. long. nat sin Mn. lat. = 300′ sin 55° 10′.
= 300′ × ·8208 = 246·2′ = 4° 06·2′ *Ans.*

THE RELATIONSHIP OF VERTEX TO GREAT CIRCLE ARCS.

(1) The vertex is 90° removed from the point where the great circle crosses the equator, and (2) the course on crossing the equator is equal to the co-latitude of vertex.



(1) In Figure, $E\,Q$ is the equator, P the pole, $E\,V\,Q$ is half a great circle cutting the equator at E and Q.

Let V be the vertex of the great circle, then

$\triangle P\,V\,E = \triangle P\,V\,Q$

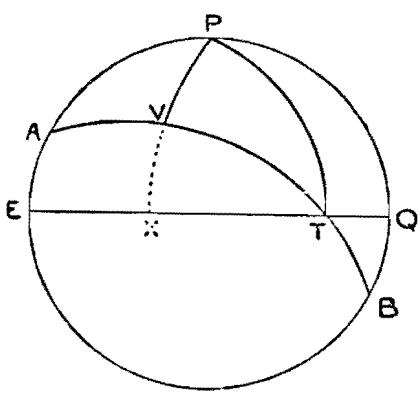
because $P\,E = P\,Q = 90°$

$\angle P\,V\,E = \angle P\,V\,Q = 90°$

$P\,V = P\,V$ (common)

$\therefore$ $E\,V = V\,Q$

But the two great circles $E\,P\,Q$ and $E\,V\,Q$ intersect at E and Q and so bisect each other, and as $E\,V\,Q = 180°$ $\therefore$ $E\,V = V\,Q = 90°$, thus vertex is 90° removed from the great circle crossing point on the equator.



(2) In Figure, $A\,B$ is a great circle cutting the equator at T

$P\,T$ the meridian of T

$\angle P\,T\,V$ the course on crossing the equator

$P\,V$ the meridian of vertex

It is required to prove that arc $P\,V = \angle P\,T\,V$.

Because $P\,T = 90°$, and $T\,V = 90°$, just proved, then T is the pole of the great circle $P\,V$, therefore $P\,V = \angle P\,T\,V$, that is to say, the co-lat. vertex = great circle course at the equator.

The pole of a great circle is a point in a sphere 90° removed from every part of the great circle. The student, for example, recognises that the earth's geographical pole is the pole of the equator and that it is 90° removed from every point on the equator, so that in $\triangle P\,T\,X$, $P\,T = 90°$, and $P\,X$ 90°, therefore P is the pole of the great circle $E\,Q$ and arc $T\,X$ the D. Long. $= \angle T\,P\,X$ the angle at the pole which it subtends. So for similar reasons the arc $P\,V$ subtends, and is equal to, its polar angle $P\,T\,V$.

QUESTIONS.

1. State the advantages of great circle sailing and the disadvantages if any.
2. Describe how a great circle track is plotted on a Mercator chart.
3. How may the difference between the great circle and the rhumb line joining two places in the same latitude be illustrated on a globe?
4. Why do vessels not always follow the great circle track in regions where it is theoretically more advantageous to do so?
5. What modification may be made when it is not advisable to follow strictly the great circle track?
6. Explain the procedure of plotting a composite great circle track.
7. What is a gnomonic chart and how is it applied to the purposes of practical navigation?
8. Show by a figure the similarity in principle of great circle sailing and time azimuth problems, and state how ABC Tables may be adapted to the solution of the former.
9. What is "convergency"? In what way is it associated with great circle courses?
10. What association exists between radio bearings and great circle courses?
11. A great circle course on crossing the equator in Long. 138° W. was S. 35° E. Draw a suitable figure and write down the latitude and longitude of both vertex.
12. Under what conditions will the course along the great circle (*a*) Change from a NE'ly to a SE'ly (or NW'ly to SW'ly) direction and (*b*) Maintain a NE'ly (or NW'ly) direction?

GREAT CIRCLE SAILING.

(Answers on page 380)

1. From Lat. 33° 50′ S., Long. 18° 10′ E., to Lat. 5° 10′ S., Long. 33° 50′ W., find initial co., dist., vertex and points every 10° from 10° E.

2. From Lat. 46° 30′ N., Long. 45° 00′ W., to Lat. 51° 23′ N., Long. 9° 36′ W., find initial co., dist., vertex and points every 5° from 40° W.

3. From Lat. 36° 06′ N., Long. 5° 21′ W., to Lat. 36° 56′ N., Long. 76° 00′ W., find initial co., final co. and dist.

4. From Lat. 36° 15′ S., Long. 56° 35′ W., to Lat. 15° 57′ S., Long. 5° 40′ W., find initial co., dist. and vertex.

5. From Lat. 48° 26′ N., Long. 161° 24′ E., to Lat. 37° 54′ N., Long. 142° 46′ W., find initial and final courses, dist., vertex and points every 10° from 170° E.

6. From Lat. 34° 10′ S., Long. 25° 47′ E., to Lat. 20° 00′ S., Long. 105° 10′ E., find initial co., dist. and vertex.

7. From Lat. 45° 47′ S., Long. 170° 45′ E., to Lat. 12° 04′ S., Long. 77° 15′ W., find initial co., dist., vertex and points every 20° from 180°.

8. From Lat. 56° 30′ S., Long. 67° 30′ W., to Lat. 37° 00′ S., Long. 20° 00′ E., find initial co., dist. and vertex.

9. From Lat. 25° 48′ S., Long. 45° 05′ E., to Lat. 32° 00′ S., Long. 115° 31′ E., find initial co., dist., vertex and points every 20° from 55° E.

10. From Lat. 49° 50′ N., Long. 6° 30′ W., to Lat. 51° 50′ N., Long. 55° 30′ W., given initial co. N. 67° 04′ W., final co. S. 74° 00′ W., dist. 1825½ mls, find vertex and points every 12° from 12° W.

11. From Lat. 6° 47′ S., Long. 105° 10′ E., to Lat. 34° 55′ S., Long. 20° E., find initial co., dist., vertex and lat. of point where meridian of 80° E. crosses the track.

12. From Lat. 35° 55′ N., Long. 6° 30′ W., to Lat. 40° 05′ N., Long. 70° 00′ W., find initial and final courses, dist., vertex and points every 10° from 10° W.

13. From Lat. 45° 30′ S., Long. 170° 13′ E., to Lat. 33° 01′ S., Long. 71° 40′ W., max. Lat. 50° S., find initial and final courses and total dist. and lat. of points every 10° from 180°.

14. From Lat. 40° 20′ S., Long. 180°, to Lat. 56° 10′ S., Long. 67° 10′ W., max. Lat. 56° 10′ S., find initial and final courses and the dist.

15. From Lat. 39° 10′ S., Long. 180°, to Lat. 57° 00′ S., Long. 70° 00′ W., max. Lat. 60° S., find initial and final courses, dist., and posn. of vertices.

16. From Lat. 35° 00′ S., Long. 180°, to Lat. 57° 10′ S., Long. 70° 00′ W., max. Lat. 60° S., find initial and final courses, dist. and long. of vertices.

CHAPTER IV.

TIDES

THE moon exerts a gravitational attraction on all the portions of the earth. This attractive force depends on the distance between the moon and the point of the earth's surface. In Fig 1 the attractive force at *C*, the point nearest to the Moon will be greater than that at point *A*, the point furthest from the Moon. If the attractive force at the centre of the earth (*P*) is taken as the average attractive force then the difference between this and the force at any point on the earth's surface is the Tide Generating Force due to the Moon.

This force can be resolved into vertical and horizontal components. The vertical component has little effect upon the sea level. However the horizontal component acting along the earth's surface is the Tractive Force which produces the tidal movements. There is a similar Tractive Force due to the sun but this is about 0·46 of the lunar force.

The tide raising forces at a point on the earth's surface change as the earth revolves on its axis, and as the relative position of the earth, moon and sun change. The extent to which the tides respond to the external forces vary in all parts of the world and frictional forces in water of varying depths moving around the land set up internal forces, which further complicate matters.

In a simple case the moon and the sun each produce a high water at the point on the earth nearest them and at the opposite point, with two low waters about midway between them. It follows that the angular distance separating high water from low water is about 90° of longitude.

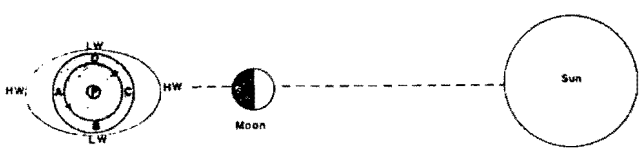


FIG 1 New Moon, Spring Tides

In Fig 1 the earth's centre is at *P* looking down on the pole, the sun and moon are supposed to be over the equator, in conjunction at new moon and the earth revolves in the direction indicated within the surrounding water.

An observer having HW at *A* will be carried round and experience in succession, LW at *B*, HW at *C*, LW at *D*, and HW again at *A*. This daily alternating rise and fall of tide is called a half-day or semidiurnal tide. The constituent due to the moon alone is called the Mean Lunar Semidiurnal Tide which is expressed as (M_2—M) for the moon. The Suffix 2 indicates two high waters per lunar day. The constituent due to the sun alone is called the Mean Solar Semidiurnal Tide, abbreviated to S_2 indicating two high waters per solar day.

SPRINGS AND NEAPS

The maximum time raising force occurs when the moon and sun are on the observer's meridian.

At new moon, Fig 1, the forces of the moon and sun are combined and give rise to a Spring Tide; the same occurs again about $14\frac{1}{2}$ days later at the period of full moon, when moon and sun are in opposition and the forces are again in the same straight line as shown in Fig 2. The range at springs is expressed as (M_2+S_2).

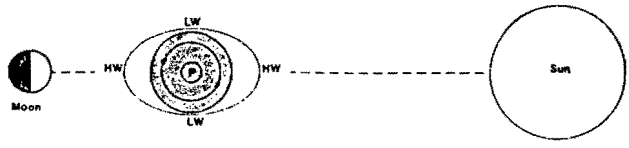


FIG 2 Full Moon, Spring Tides

Neap Tides occur about seven days after spring tides when the moon is in quadrature (Fig 3), at which time the HW due to M_2 coincides with the LW due to S_2 and the result is a tide having a smaller range. The range at neaps is expressed as (M_2-S_2).

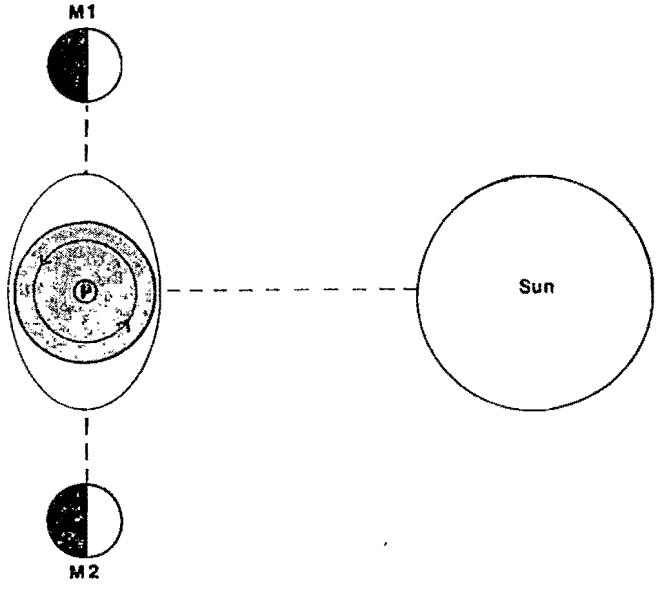


FIG 3 Quadrature, Neap Tides

The mean lunar day is about 50 minutes longer than the solar day, so that normally, an interval of about 24 hrs. 50 mins. separates the high water of one day from the corresponding high water of the next day at a given place, the average interval between high water and the next low water is, therefore, about 6 hrs. 12 mins.

PRIMING AND LAGGING

During the changes from springs to neaps when the interval between high waters mentioned above exceeds the average of 24 hrs 50 min the tide is said to LAG, and when the interval is less than 24 hrs 50 min the tide is said to PRIME.

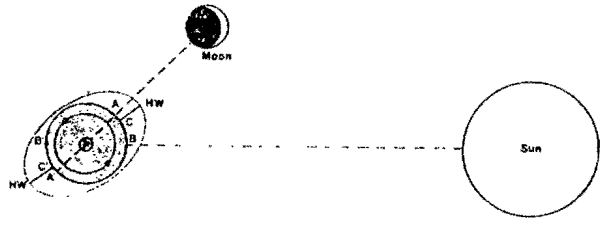


FIG 4 Priming

In Fig 4 the lunar HW during the first quarter would tend to be in the direction AA' and the solar HW along BB', but the actual HW is likely to be in the direction CC', which is a meridian nearer to that of the moon than to the sun's meridian. A place at C or C' will experience high water before the moon's meridian passage, and the tide is said to be priming. Generally the tide will also prime in the third quarter.

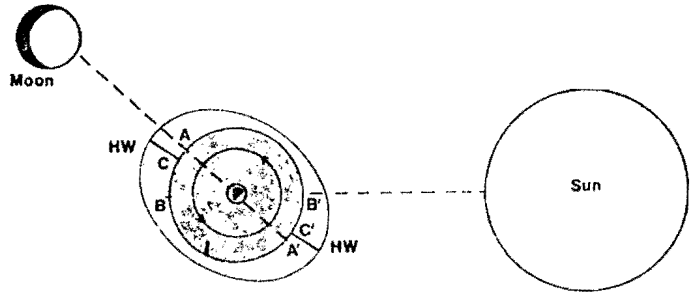


FIG 5 Lagging

When the moon is in the second quarter (Fig 5), the lunar HW would tend to appear at A and A' under the moon but due to the solar forces acting on the water the actual HW is likely to occur in the direction CC' so that a place will transit the moon's meridian before high water is experienced, and the tide is said to be lagging. This effect is also likely to occur in the fourth quarter.

The declination of the moon changes over a period of approximately one month and the sun's declination changes over a period of one year. These variable factors set up tide raising forces which sometimes act together and sometimes in opposition.

If the moon remained stationary over the equator there would tend to be a permanent low water at the poles and high waters on the upper and lower meridians

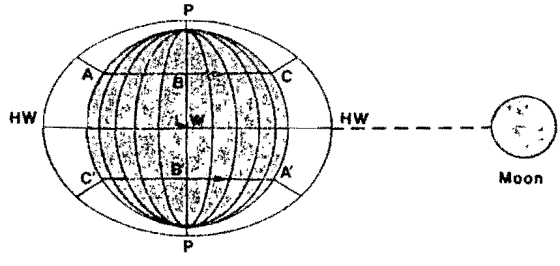


FIG 6 Moon on Equator

of the moon, with corresponding low waters 90° of longitude East and West of those meridians (Fig 6) where HW represents high water at the equator with the trough of low water PP' extending from pole to pole. ABC and $A'B'C'$ are two parallels of latitude. The figure represents high water at A, low water at B and high water at C. Similarly for $C'B'$ and A', but these tide heights are obviously not so great as at places on the equator where the maximum range of tide from low water to high water is experienced.

Declination is mainly responsible for a difference in the heights of the two daily high waters (Fig 7), where latitude C equals moon's declination. The tide shown is a higher high water at C, where the moon is over the upper meridian, than at A on the lower meridian. At position A it is a lower high water, and this place, on being carried round by the earth's rotation, gets low water on reaching B, which is on the low water trough BB', and, later gets the higher high water on reaching C. The same applies to the parallel $C'B'A'$. This gives a diurnal component of the tide due to the moon's declination. The declination of the sun produces a similar diurnal force effecting the tide and the average component of the combined forces is called constituent K_1.

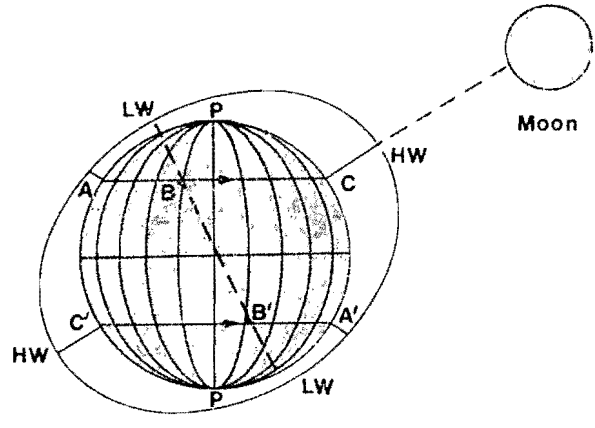


FIG 7 Moon in North Declination

The variable tide raising factors sometimes act together, and sometimes in opposition, and at every stage during their respective cycles, different lunar and solar components of a tide are formed. A composite tide may be built up and plotted on a graph, by computing the response of the water to each constituent, for a specified place and time. This is the Admiralty Method of Tidal Prediction.

ADMIRALTY TIDE TABLES

Admiralty Tide Tables (ATT) are published in three volumes namely:—

Vol. 1 EUROPEAN WATERS (including the 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 contains daily predictions for Standard Ports and Part II lists the time and height differences from Standard Ports together with harmonic constants for predicting the tide at Secondary Ports.

Admiralty Tide Tables—Extract Pages included in this Volume.

Throughout this chapter reference is made to particular parts of the *Admiralty Tide Tables.* Extracts from these tables are included in the Appendix at the end of this volume. These extracts include all necessary data to work through the examples and exercises included in this chapter.

In order to gain familiarity with the contents and layout of ATT, reference should also be made to recent editions of the 3 volumes.

TIDAL LEVELS

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.

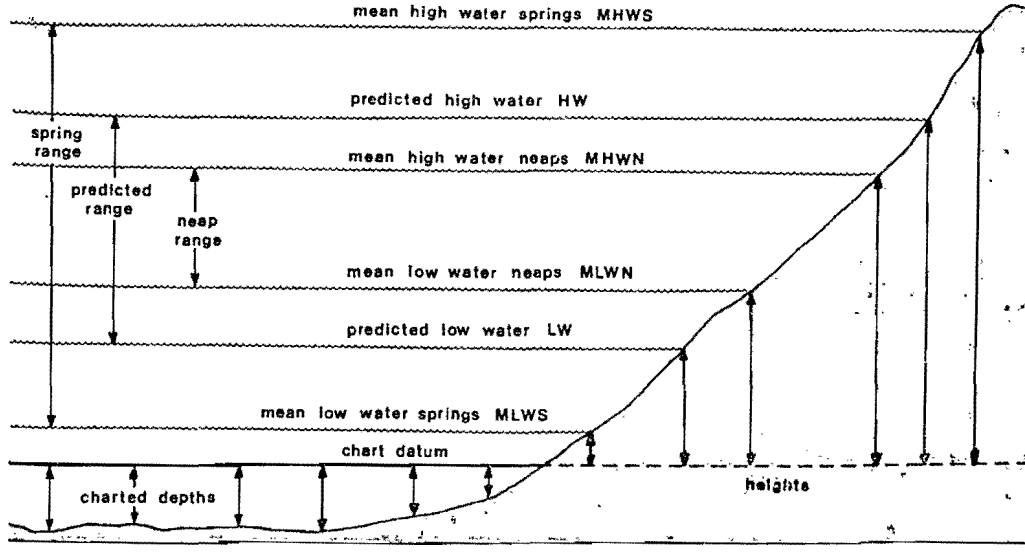


FIG 8 Tidal Levels

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.

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.

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.

Charted Height, Drying Height and Correction to Leadline (Reduction to Soundings).

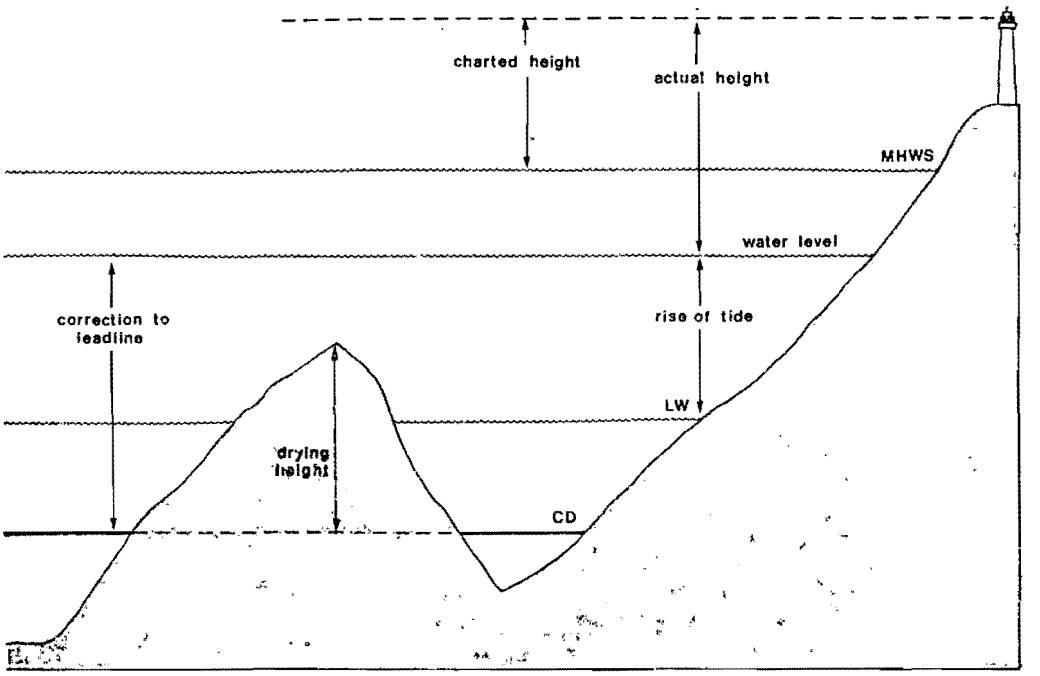


FIG 9 Charted Height and Drying Height

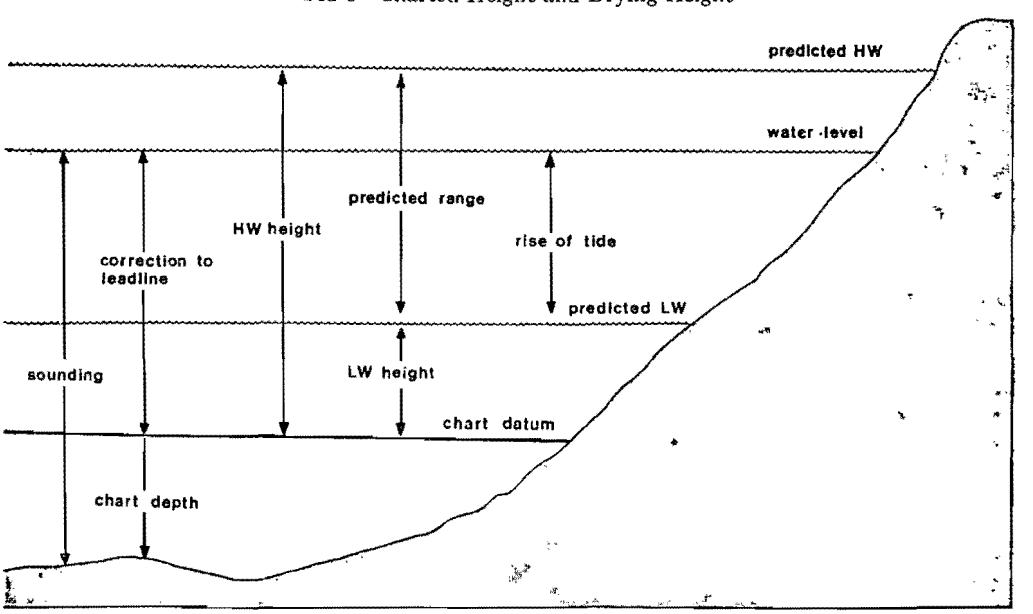


FIG 10 Soundings and Reduction to Soundings (Correction to Leadline)

SECONDARY PORT TIDE CALCULATIONS

European Secondary Ports—ATT Vol. 1

The method of finding the times and heights of high and low water 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.

The following examples illustrate the need for a methodical approach. Try to establish a consistent layout. To assist tidal prediction the Admiralty have produced Admiralty Tidal Prediction Form, NP 204, which is included in the Appendix.

TO FIND HW AND LW TIMES AND HEIGHTS
(European Secondary Ports)

1. Find the Secondary Port in the Index. Note its number.
2. Refer to Part II with the Secondary Port number and note the relevant Standard Port.
3. Refer to Part I and find the HW and LW times and heights at the Standard Port for the required day.
4. Refer back to Part II and note the time and height differences for the Secondary Port.
5. Apply the interpolated time and height differences of the Secondary Port to the HW and LW times and heights at the Standard Port.

Example 1.

Find the times and heights of HW and LW at Selsey Bill, AM on June 15th.

Secondary Port: Selsey Bill, Index No. 69 *Step* 1

Standard Port: Portsmouth *Step* 2

	Times		*Heights* (m)		
	HW	LW	HW	LW	
Standard Port	0449	1014	3·8	1·4	*Step* 3
Differences	−0005	+0035	+0·6	0·0	*Steps 4 and 5*
Secondary Port	0444	1049	4·4	1·4	*Selsey Bill Predictions*

HEIGHT OF TIDE AT INTERMEDIATE TIMES

At intermediate times between HW and LW the Height of Tide above chart datum is found, for a Standard Port, by multiplying the tide's Predicted Range by a factor taken from the tidal curve for that port and adding this result to the Height of LW predicted for the day.

The process of finding the Height of Tide for an intermediate time at a European Secondary Port is to obtain the predicted times, heights and ranges at the Secondary Port which are then used in conjunction with the factor obtained from the Standard Port tidal curve. This gives a fair degree of accuracy because Standard Ports are specially selected for the similarity of their tidal curve to that of the Secondary Port.

Special instructions apply to places between Swanage and Selsey owing to the rapid change of tidal characteristics and distortion of the tidal curve in this area. For these places two or three tidal curves are given and times are referred to the time of LW rather than to HW as in all other cases.

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.

Interpolation.

In most cases direct interpolation for a given time, using the range of tide in question as argument, will give an answer of sufficient accuracy. But where there is an appreciable change in duration between Spring and Neap tides, the factor obtained in this manner may have a slight error. Such error is greatest near LW.

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 Height of Tide at an Intermediate Time Between HW and LW.[1] (European Secondary Port)

1. Find Secondary Port in the Index. Note its number.
2. Refer to Part II with this number and note the relevant Standard Port.
3. Refer to Part I and find the HW and LW times and heights at the Standard Port.
4. Obtain the Secondary Port time and height differences from Part II and apply interpolated differences to Standard Port HW and LW to obtain Secondary Port HW and LW.
5. Find the Time Interval between HW at Secondary Port and the Required Time.
6. Find Predicted Range at Secondary Port.
7. Find Predicted Range at Standard Port.
8. Find Standard Port Spring and Neap Ranges from the box shown in the Tidal Curves.
9. Compare Standard Port Range found at (7) with Standard Port Spring and Neap ranges found at (8).
   If equal to or greater than Spring Range—use Spring Curve.
   If equal to or less than Neap Range—use Neap Curve.
   In other cases INTERPOLATE.

10. Use the Time Interval found at (5) to find the Factor (or Factors) from the Standard Port Curve(s) and if necessary interpolate to find the Predicted Factor.[2]
11. Multiply Secondary Port Range (6) by Predicted Factor to find Rise of Tide above LW.
12. Add Rise of Tide (11) to Secondary LW to find Height of Tide above Chart Datum. Make a sketch to determine Reduction to Soundings (Correction to Leadline).

NOTE [1]—This method ONLY to be used when:

(*a*) Adjacent Standard Port tidal curves are similar and where

(*b*) HW and LW time differences are nearly the same.

In other cases (indicated in Part II by the letter "c") use NP 159—see previous page for further details of these conditions and subsequent pages regarding the use of NP 159.

NOTE [2]—Interpolation is carried out as follows:

$$\frac{(\text{Spring}\sim\text{Neap Factor}) \times (\text{Standard Pred Range}\sim\text{Neap Range})}{\text{Spring}\sim\text{Neap Range}}$$

= Adjustment to Neap Factor.

Example 2.

Find the Height of Tide at Ardrossan at 0330 GMT on May 1st.

Secondary Port: Ardrossan Index No. 410 *step* 1
Standard Port: Greenock *step* 2

	Times		*Heights* (*m*)		
	HW	LW	HW	LW	
Standard Port	0525	2345 (30th)	3·2	0·9	*step* 3
Time Differences	−0020	−0029	−0·2	−0·1	*step* 4
Secondary Port	0505	2316 (30th)	3·0	0·8	

Time Interval

Secondary HW	0505
Required Time	0330
Interval from HW	0135 (−) *step* 5

Ranges (*m*)

Secondary HW	3·0	Standard HW	3·2	Spring Range	3·0	
LW	0·8	LW	0·9	Neap	1·9	
Secondary Range	2·2	Standard Range	2·3	Spring∼Neap	1·1	*step* 6, 7 *and* 8

Standard Range	2·3
Neap Range	1·9
Standard∼Neap	0·4

Standard Port Range lies $\frac{0{\cdot}4}{1{\cdot}1}$ from Neaps towards Springs—Interpolate. *step* 9

	Factors	*Interpolation*	
Factor from Spring Curve	0·83		
Neap	0·87		
Spring~Neap Factor	0·04	$\text{Adjustment} = \frac{0{\cdot}04 \times 0{\cdot}4}{1{\cdot}1} \simeq 0{\cdot}01$	
Neap Factor	0·87		
Adjustment	0·01		
Predicted Factor	0·86		*step* 10

	Rise of Tide (*m*)	
Secondary Range	2·2	
Predicted Factor (×)	0·86	*step* 11
Rise of Tide	1·9	
Secondary LW (+)	0·8	*step* 12
Height of Tide	2·7 metres at 0330 GMT	

NOTE:—A blank Tidal Prediction Form of this type has been included in the Appendix.

To Find the Time when the Tide Reaches a Required Height. (European Secondary Port)

1. Follow the previous instructions and obtain the times and heights of HW and LW at the Secondary Port. (*Steps* 1–4 *in Example* 2) and the Ranges (*steps* 6–8).
2. Subtract the Height of LW at the Secondary Port from the Required Height to obtain the Required Rise of Tide.
3. Divide the Required Rise by the Secondary Port Range to obtain the Factor.
4. Enter the Standard Port tidal curve(s) with the Factor obtained above and extract the predicted Time Interval(s) from HW. If necessary, interpolate between the Spring and Neap time intervals.
5. Apply the predicted Time Interval, obtained above, to the Time of HW at the Secondary Port to obtain the Time of the Required Height.

Example 3.

Find the time, AM, before HW at Ardrossan when the Height of Tide is 2·1 m. above chart datum on May 1st.

Secondary HW 0505 3·0 m LW 2316 (30th) 0·8 m Range 2·2 m *step* 1

Heights (*m*)	
Required Height	2·1
Secondary LW	0·8
Required Rise	1·3 *step* 2

$$\text{Factor} = \frac{\text{Rise}}{\text{Secondary Range}} = \frac{1{\cdot}3}{2{\cdot}2} = 0{\cdot}59 \quad \textit{step 3}$$

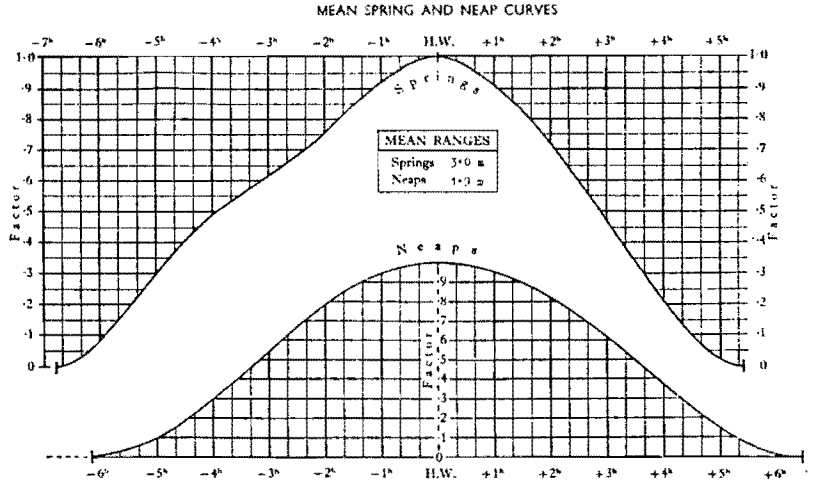
Time Interval(*s*)		*Standard Port Ranges* (*m*)			
Spring Interval	−0312	Spring Range	3·0	Predicted Range	2·3
Neap Interval	−0249	Neap Range	1·9	Neap Range	1·9
Spring∼Neap	23	Spring∼Neap	1·1	Pred∼Neap	0·4 *step* 1

$$\text{Adjustment} = \frac{23 \times 0{\cdot}4}{1{\cdot}1}$$

$$= 8 \text{ mins.}$$

Predicted Interval = 0249 + 8 = (−) 0257 *step* 4

Secondary HW	0505
Predicted Interval	−0257 *step* 5
Time	0208 at which the Required Height of Tide is 2·1 m.



Reproduced by kind permission of the Hydrographer of the Navy.

ATLANTIC AND INDIAN OCEAN SECONDARY PORTS — ATT Vol. 2

Admiralty Tide Tables for the Atlantic and Indian Oceans include Standard Curves which show the factor of the range attained at a given time interval relative to HW. The Standard Curves Diagram (see Appendix) shows five Standard Curves which correspond to durations of tide of 5, 5½, 6, 6½ and 7 hours. They are based on the assumption that the Standard Port tidal curve approximates to that of a cosine.

After any necessary interpolation between adjacent curves, these curves will give acceptable results for obtaining Intermediate Times and Heights at the Standard Port providing that:

(*a*) The duration of tide is between 5 and 7 hours, and

(*b*) There is no shallow water correction.

If either of these conditions is not met Intermediate Times and Heights at a Standard Port *must* be predicted by use of the Admiralty Method of Tidal Prediction, NP 159. This also applies to Pacific ports in ATT Vol. 3.

HW and LW at Secondary Ports.

The method of finding the Times and Heights of HW and LW at all Secondary Ports is by means of applying simple differences in times and heights from the predictions for the most suitable (not necessarily the closest) Standard Port. For certain ports, indicated by the letter "p", no Time Differences are listed in Part II of the ATT. Predictions for these ports can *only* be made by using NP 159.

Intermediate Times and Heights at Secondary Ports—NP 159.

Intermediate Times and Heights at Atlantic and Indian Oceans (and Pacific) Secondary Ports *must* be calculated by use of the Admiralty Method of Tidal Prediction, NP 159, which is dealt with later in this section.

To Find HW and LW Times and Heights.
(Atlantic and Indian Ocean Secondary Ports)

1. Find the Secondary Port in the Index to ATT Vol. 2. Note its number.
2. Refer to Part II with the Secondary Port number and note the relevant Standard Port and its number.
3. Refer to Part I and find the HW and LW times and heights at the Standard Port for the required day.
4. Refer back to Part II and apply the Seasonal Change in Mean Level (ML) to the Standard Port heights. (N.B.—The Standard Port height quoted in ATT already includes this Seasonal Correction which must be **subtracted algebraically** so that subsequent interpolation is carried out on the unadjusted tidal heights—see preliminary pages ATT).
5. Note the time and height differences for the Secondary Port (in Part II).
6. Apply the interpolated time and height differences of the Secondary Port to the HW and LW times and heights at the Standard Port.
7. Apply the Seasonal Change in Mean Level for the Secondary Port.

Example 4.

Find the times and heights of HW and LW at Akyab on 28th September.

Secondary Port: Akyab, Vol 2 Index No 4520 *step* 1

Standard Port: Bassein River Entrance, Index No 4539 *step* 2

	Times				
	HW	HW	LW	LW	
Standard Port	0655	1928	0008	1337	*step* 3
Time Differences	+0004	+0004	+0001	+0001	*step* 5 *and* 6
Secondary Port	0659	1932	0009	1338	*Akyab Time Predictions*
	Heights (*m*)				
Standard Port	2·0	1·8	1·3	1·2	*step* 3
Seasonal Change ML (−)+0·1	+0·1	+0·1	+0·1	+0·1	*step* 4
	1·9	1·7	1·2	1·1	
Height Differences	−0·1	−0·1	−0·3	−0·3	*step* 5 *and* 6
Secondary Port (uncorrected)	1·8	1·6	0·9	0·8	
Seasonal Change ML	+0·1	+0·1	+0·1	+0·1	*step* 7
Secondary Port	1·9	1·7	1·0	0·9	*Akyab Height Predictions*

NB.—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.

PACIFIC OCEAN SECONDARY PORTS — ATT Vol. 3

(Reference should also be made to the preceding pages dealing with Atlantic and Indian Ocean Secondary Ports and the Preliminary pages of ATT Vol. 3)

Admiralty Tide Tables for the Pacific Ocean and Adjacent Seas include the Standard Curves which have been explained in the preceding pages. The curve nearest the duration of the required tide must be used and the method of working the problem is the same as for European Standard Ports. Intermediate times and heights at Pacific Standard Ports are predicted with the aid of these Standard Curves which are included in the Appendix.

HW and LW at Secondary Ports.

As is the case for Secondary Ports in the Atlantic and Indian Oceans (ATT Vol 2) HW and LW Times and Heights at Pacific Secondary Ports can be predicted by applying Time and Height differences to the relevant Standard Port. The heights of HW and LW in many Pacific Ports show irregularities (due to a predominant diurnal effect) which should be taken into account in the calculations according to the ATT Footnotes for the ports affected.

Where time differences are not included in Part II, predictions must be made using the Admiralty Method of Tidal Prediction, NP 159.

Intermediate Times and Heights at Secondary Ports.

Intermediate Times and Heights at Pacific Secondary Ports *must* be made using NP 159, which is dealt with later in this section.

TO FIND HW AND LW TIMES AND HEIGHTS
(Pacific Ocean Secondary Port)

1. Find the Secondary Port in the Index to ATT Vol. 3. Note its number.
2. Refer to Part II with the Secondary Port number and note the relevant Standard Port and its number.
3. Refer to Part I and find the HW and LW times and heights at the Standard Port for the required day.
4. Refer back to Part II and apply the Seasonal Change in Mean Level (ML) to the Standard Port heights. (N.B.—The Standard Port height quoted in ATT already includes this Seasonal Correction which must be **subtracted algebraically** so that subsequent interpolation is carried out on the unadjusted tidal heights—see preliminary pages ATT).
5. Note the time and height differences for the Secondary Port (in Part II).
6. Apply the interpolated time and height differences of the Secondary Port to the HW and LW times and heights at the Standard Port.
7. Apply the Seasonal Change in Mean Level for the Secondary Port.

Example 5.

Find the times and heights of HW and LW at Port Hardy on May 1st.

Secondary Port: Port Hardy, ATT Vol 3 Index No 9020 *step* 1
Standard Port: Prince Rupert. Zone + 0800. *step* 2

	Times					
	HW	HW	LW	LW		
Standard Port	0755	2110	0150	1430		*step* 3
Time Differences	−0025	−0025	−0030	−0030		*step* 5 *and* 6
Secondary Port	0730	2045	0120	1400	*Port Hardy Time Predictions*	
	Heights (m)					
Standard Port	5·5	5·4	2·8	1·7		*step* 3
Seasonal Change ML	(−) 0·0	0·0	0·0	0·0		*step* 4
Standard Port (uncorrected)	5·5	5·4	2·8	1·7		
Height Differences	−1·5	−1·5	−0·4	−0·1		*step* 5 *and* 6
Secondary Port (uncorrected)	4·0	3·9	2·4	1·6		
Seaosnal Change ML	−0·1	−0·1	−0·1	−0·1		*step* 7
Secondary Port	3·9	3·8	2·3	1·5	*Port Hardy Height Predictions*	

NOTE—If the corrected Heights at the Standard Port happen to be the same as tabulated in Part II under MHWS, MHWN, MLWS and MLWN, then the Secondary Port Height Differences do not require interpolation or extrapolation. If only one HW and one LW is tabulated in Part II, interpolate between these two values for either HW or LW.

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.

This method can also be computed on a calculator.

A knowledge of the method is required in Class 1 examinations but not the full calculation and the plot of the tidal prediction.

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 A.T.T. 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 A.T.T. table VII, for the date, enter Tidal Angle (A) and Factor (F) for M_2, S_2, K_1 and O_1.
From A.T.T. part II, enter Seasonal Correction to M.L.

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 the 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]

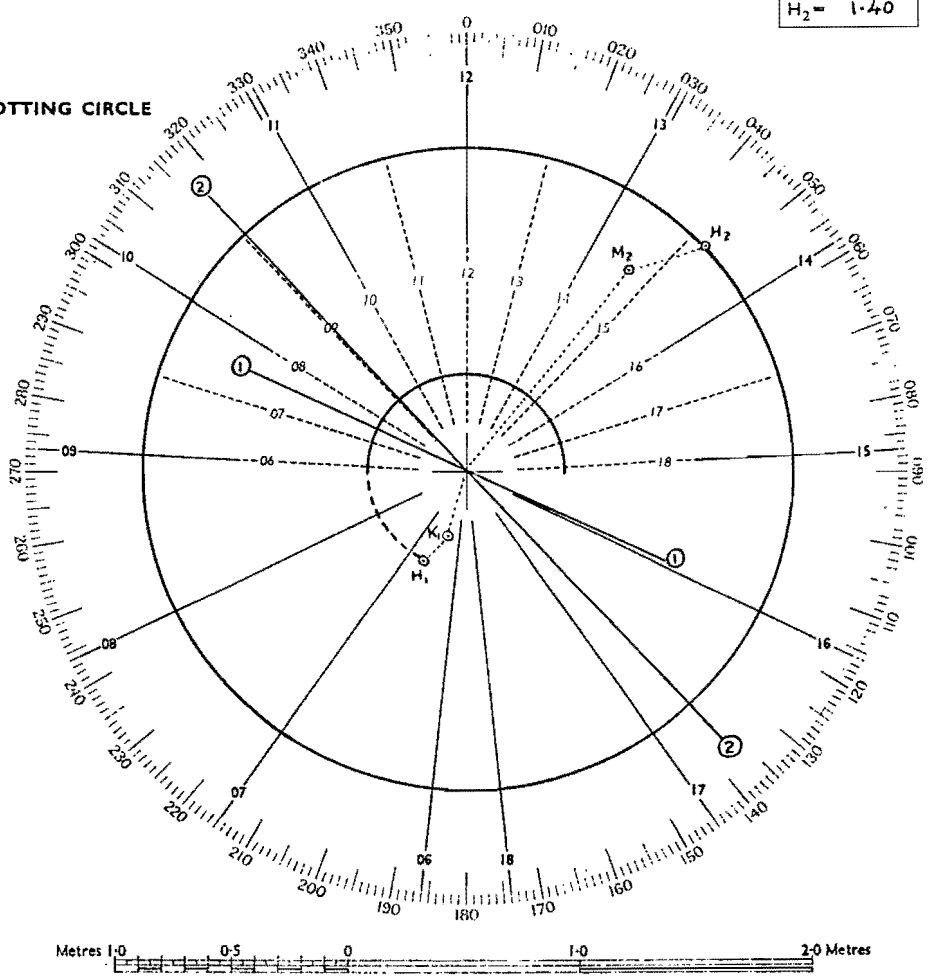
Lat 31° 24' N Long 121° 30' E Zone Time −0800

TABLE

			M_2		S_2		K_1		O_1		M.L.	
	$\alpha°$		012		000		180		192			
from A.T.T., part II	$\varepsilon°$	H	008	0·94	060	0·42	215	0·23	162	0·14	2·35	Mean level (Zo)
from A.T.T., table VII	$A°$	F	019	1·17	012	0·82	161	1·28	229	1·05	+0·2	Seasonal correction
	$\alpha+\varepsilon+A$	H×F	039 = m°	1·100 = M	072 = s°	0·344 = S	196 = k°	0·294 = K	223 = o°	0·147 = O	2·55 = A_0	ADD
	logs:		$\bar{1}$·9731		$\bar{1}$·6232		$\bar{1}$·3617		$\bar{1}$·1461			
			0·0682		$\bar{1}$·9138		0·1072		0·0212			
			0·0413		$\bar{1}$·5370		$\bar{1}$·4689		$\bar{1}$·1673			

h_2 =	047
H_2 =	1·40

PLOTTING CIRCLE



ADMIRALTY METHOD OF TIDAL PREDICTION

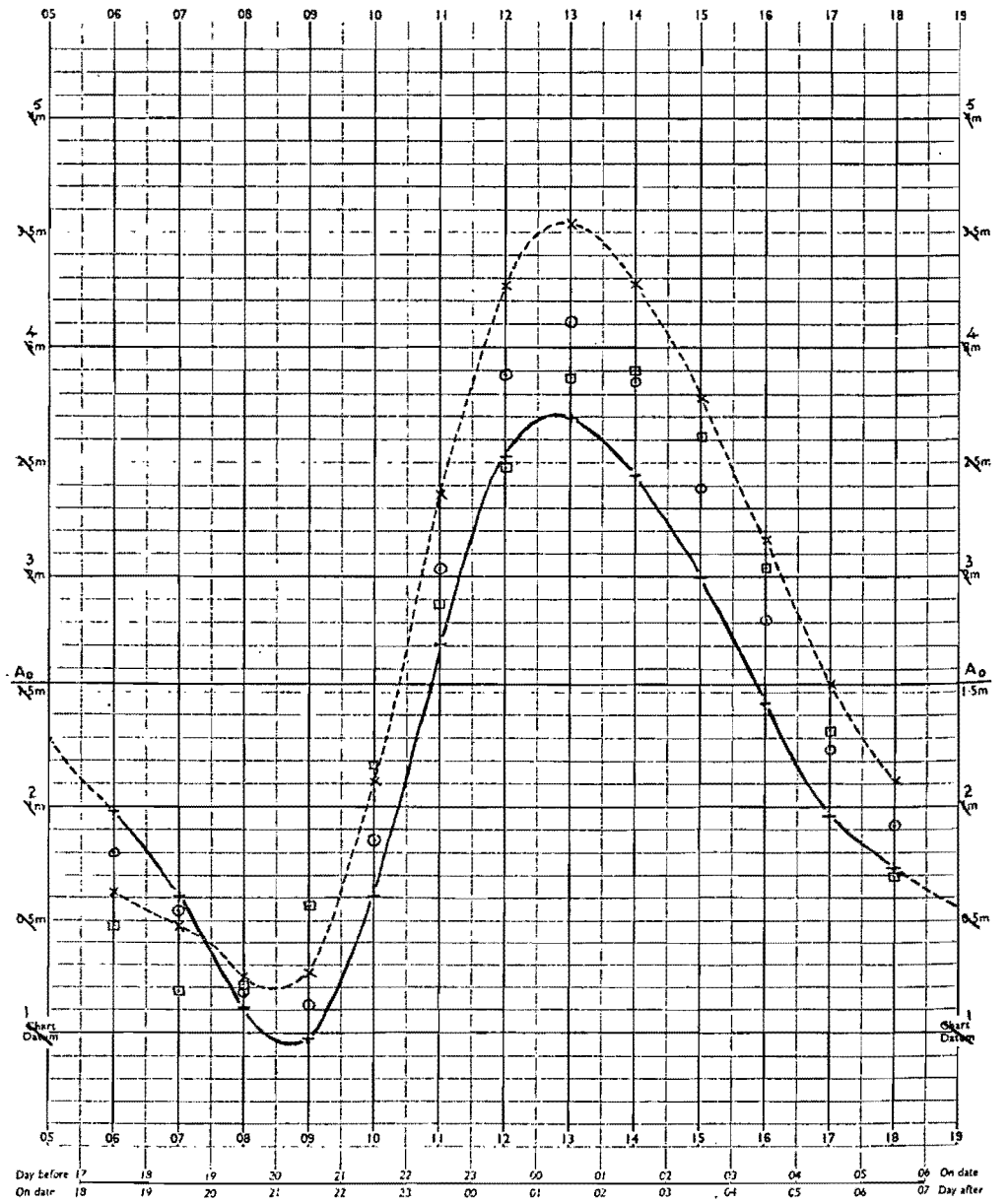
FORM B — instructions (refer to example Form B across).

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 for 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 8.

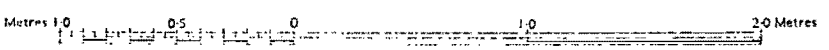
FORM B
[Example]

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 sample 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 A.T.T. 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 ⊙.

FORM C
[Example]

Place EXAMPLE PORT Date 10 JULY 1975

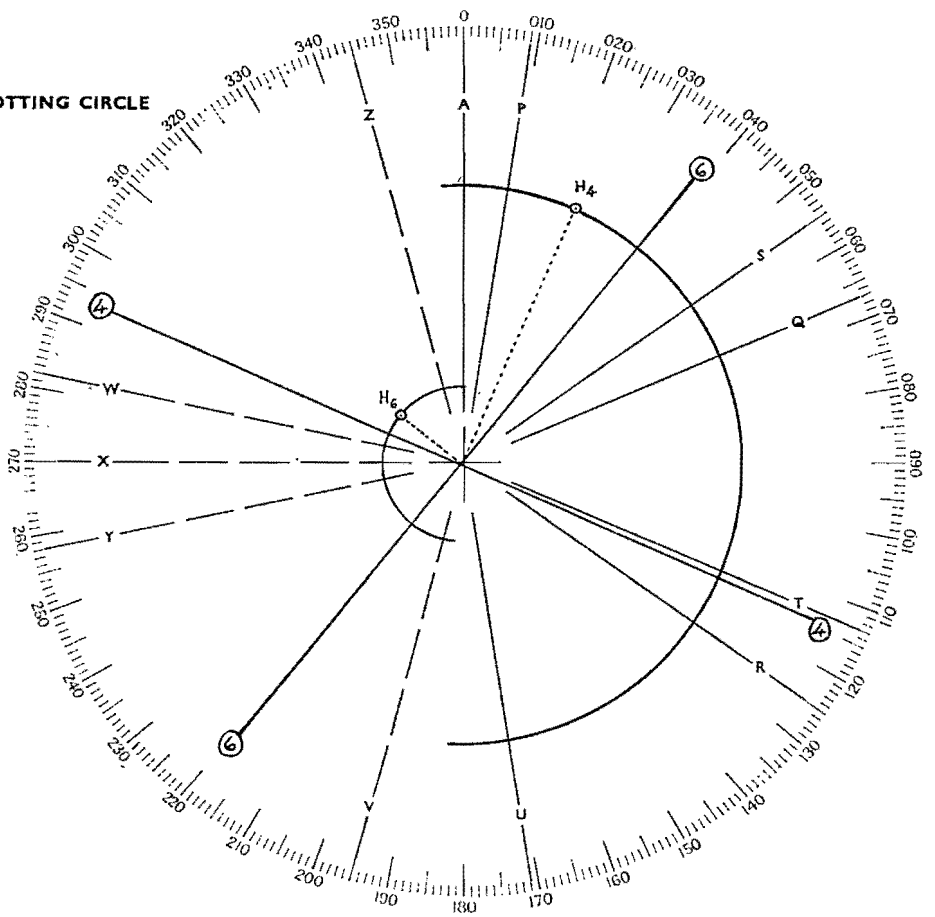
Lat 31° 24′ N Long 121° 30′ E Zone Time −0800

TABLE

h_2 = 047	$2h_2$ = 094	f_4 = 290	$h_4 = f_4 + 2h_2$ = 024	$3h_2$ = 141	f_6 = 168	$h_6 = f_6 + 3h_2$ = 309
H_2 = 1·40	H_2^2 = 1·960	F_4 = 0·185	$H_4 = F_4 \times H_2^2$ = 0·363	H_2^3 = 2·744	F_6 = 0·038	$H_6 = F_6 \times H_2^3$ = 0·104

log: 0·1461 0·2922 T·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	$P^{+}_{\cdot 350}$	$Q^{+}_{\cdot 266}$	$R^{-}_{\cdot 068}$	$-P^{-}_{\cdot 350}$	$-Q^{-}_{\cdot 266}$	$-R^{+}_{\cdot 068}$	$A^{+}_{\cdot 336}$	$S^{+}_{\cdot 314}$	$T^{+}_{\cdot 010}$	$U^{-}_{\cdot 304}$	$-S^{-}_{\cdot 314}$	$-T^{-}_{\cdot 010}$	$-U^{+}_{\cdot 304}$
6-D	$V^{-}_{\cdot 042}$	$W^{+}_{\cdot 088}$	$-V^{+}_{\cdot 042}$	$-W^{-}_{\cdot 088}$	$-X^{-}_{\cdot 062}$	$X^{+}_{\cdot 080}$	$A^{+}_{\cdot 062}$	$-X^{-}_{\cdot 080}$	$-A^{-}_{\cdot 062}$	$Y^{+}_{\cdot 062}$	$Z^{+}_{\cdot 082}$	$-Y^{-}_{\cdot 062}$	$-Z^{-}_{\cdot 082}$
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 12½ 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 cruve 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 1½ 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.

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

Pages 114-122—Reproduced by kind permission of the Hydrographer of the Navy.

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 this 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 Kong.

Admiralty Tidal Stream Atlases are published in 16 Volumes. NP 209–337 for NW Europe and NP 217 for 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.

A Co-Tidal Atlas for SE Asia, NP 215, is also published.

Other 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. Reference should be made to these publications for further information.

SECONDARY PORT TIDE CALCULATIONS

Exercise 1 — European Waters, Atlantic and Indian Oceans

Find the times of high and low water at :—

1. Sandown — June 15.
2. Moville — July 24.
3. Tilbury — March 10.
4. Bowling — May 1.
5. Barry — November 27.
6. Akyab — September 9.
7. Lubec (U.S.A.) — February 8.

(Standard Tidal Curves are included in the Appendix)

Exercise 2 — European Waters

From the predictions found in the first five examples of Exercise 1 find the height of tide :

1. At Sandown on June 15, at 2000 hours GMT.
2. At Moville on July 24, at 1400 hours GMT.
3. At Tilbury on March 10, at 0600 hours GMT.
4. When will the tide be 2·5 m above datum at Bowling on May 1?
5. When will the tide be 6·0 m above datum at Barry on November 27?

Exercise 3 — Pacific Ocean and Adjacent Seas

1. Find the times and heights of HW and LW at Kildala (No 8947) on May 1, 1982. (Standard Port Prince Rupert, No 8850)
2. Find the times and heights of HW and LW at Namu (No 8943) on May 1, 1982. (Standard Port Prince Rupert, No 8850)

Exercise 4 — Atlantic, Indian 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 on February 8. The ship grounded at 0815, when will she refloat?
2. Find the times and heights of HW and LW at Elephant Point on March 13.
3. Find the times and heights of HW and LW at Quebec on May 16.
4. Find the times and heights of HW and LW at Port Hedland on July 25.
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 24.

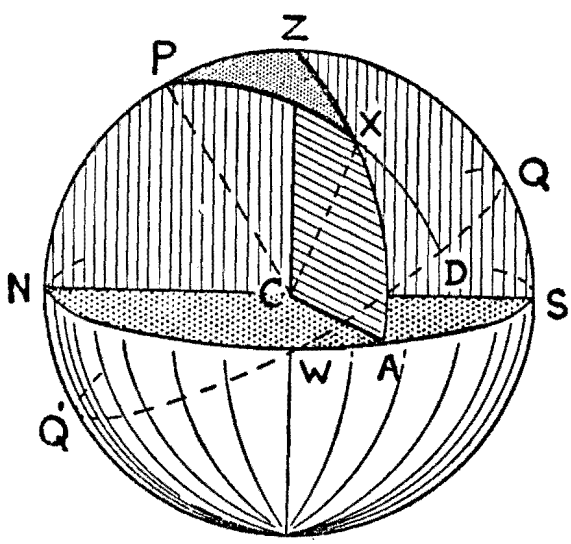
Answers on Page 381

ATT extracts included in the Appendix on Page 391

CHAPTER V.

FORMULAE, TIME EQUATIONS AND SOME THEORY.

It is assumed that the reader is conversant with the earlier work of Volume I, but before proceeding with further navigation problems it might be as well to again record the accepted trigonometrical formulae. This also seems a convenient place to refer to some of the special Tables used in solving some of the problems, such as the ABC Tables and Norie's Ex-meridian Tables.



This figure is a diagram drawn on the plane of a meridian with the zenith on top.

$N\,W\,S$ is the horizon, Z the zenith, P the pole, X a star, $Q^1W\,Q$ the equator.

Referring to the body X we have,

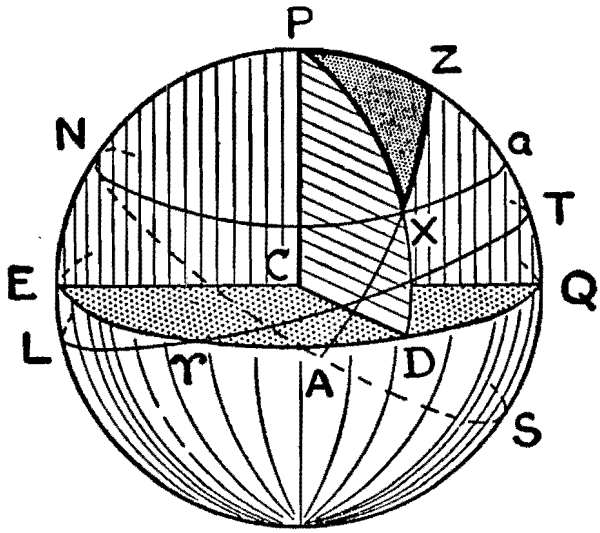
$A\,X$ its altitude $= \angle A\,C\,X$ $\quad$ $Z\,X$ its zenith distance $= \angle Z\,C\,X$

$D\,X$ its declination $\quad$ $P\,X$ its polar distance $= \angle P\,C\,X$

$P\,Z$ the co-latitude of observer $= \angle Z\,C\,P$

$\angle Z\,P\,X$ the hour angle of X = arc of equator $Q\,D$

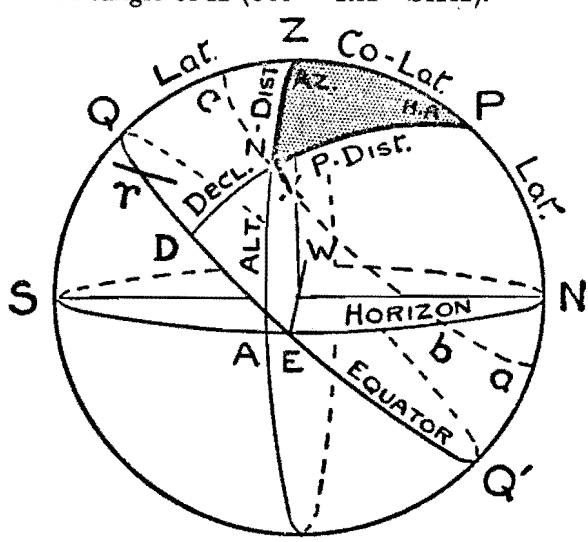
$\angle P\,Z\,X$ the azimuth of X = arc of horizon $N\,A$



This diagram is also drawn on the plane of the meridian but turned round a little to bring the pole on top.

$E\,D\,Q$ is the equator, $N\,A\,S$ the horizon, $L\ \gamma\ T$ the ecliptic, P the pole, Z the zenith, X a star moving along its diurnal arc $a\,X$

$A\,X$ = altitude of X — $Z\,X$ the zenith distance
$D\,X$ the declination — $P\,X$ the polar distance
$P\,Z$ the co-latitude of observer — $Q\,Z$ the latitude
$\angle Z\,P\,X$ the hour angle = arc of equator $Q\,D$
$\angle P\,Z\,X$ the azimuth = arc of horizon $N\,A$
$\gamma\,D$ is the right ascension of X and $\gamma\,D$ (measured westwards from γ) is the Sidereal Hour Angle of X ($360° - RA = SHA$).



A diagram drawn on the plane of the meridian.
$N\,E\,S\,W$ is the horizon.

$N\ S$ the projection of the meridian on to the horizon, $W\ E$ the projection of the prime vertical on to the horizon. $Q\ E\ Q'$ the equator, γ First Point of Aries, Z the zenith, P the pole, X a star.

$a\ b\ X\ c$ is the diurnal path of X parallel to the equator $Q\ E\ Q'$. The star crosses the lower meridian below the horizon at a, rises at b, and Eb is then its rising amplitude; the star is shown in altitude at X before culminating at c. When it is on the upper meridian at c, arc Qc is its declination, arc Zc its meridian zenith distance, so that $Qc+cZ=Z\ Q$ the latitude of observer.

The position of X relative to the equator is defined by means of its siderial hour angle (γD, measured westward from γ) and declination ($D\ X$); and relatively to the observer by (i) its zenith distance ($Z\ X$) and azimuth ($\angle P\ Z\ X$); or, (ii) its hour angle ($\angle Z\ P\ X$) and zenith distance; or, (iii) its polar distance ($P\ X$) and hour angle; or (iv) its azimuth and polar distance.

SOLUTION OF RIGHT-ANGLED SPHERICAL TRIANGLES. NAPIER'S RULES FOR CIRCULAR PARTS.

The rules are briefly as follows:

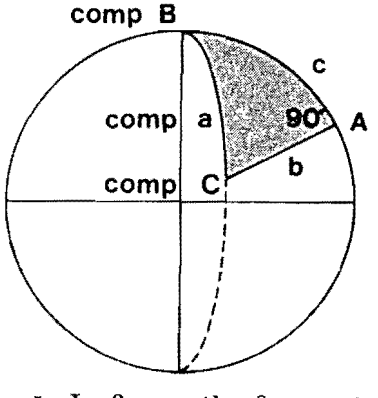
1. Let the triangle consist of five parts, viz., the three sides and two angles, the 90° being always **omitted.**
2. The **complements** of the hypotenuse and the two angles are used.
3. Adjacent part means the one next. Opposite part means the one past adjacent.
4. By selecting **any** one of three 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:—

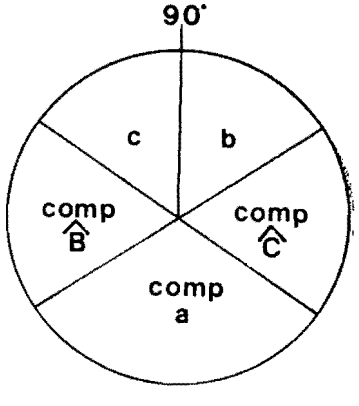
$$\textbf{sine of middle part} = \begin{cases} \text{product of } \textbf{tangents} \text{ of } \textbf{adjacent parts.} \\ \text{product of } \textbf{cosines} \text{ of } \textbf{opposite parts.} \end{cases}$$

which may be abbreviated to

I. sine mid part = tan adj × tan adj.

II. sine mid part = cos opp × cos opp.





1. In figure, the five parts of the triangle $A\ B\ C$ 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.

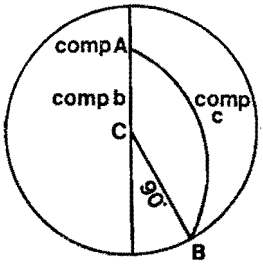
Some beginners draw a circle and divide it off into five sectors as shown above, then by writing in the successive sectors the names of the parts in the order just given they are able to spot more readily the relative position of the adjacent, the opposite and the middle parts.

Napier's Rules are also applicable to quadrantal triangles, the only modification being that the 90° side is omitted, the complements of the remaining two sides are used and the complement of the angle opposite to the quadrant side. The investigation is similar to that of right-angled triangles.

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.

Example.—In quadrantal triangle $A\ B\ C$, given $a=90°$, $A=60°$, $B=50°$, find sides c and b and angle C.



(i) *To find side c.*

c = mid part, A and B = adjacents

comp sin c = *comp* tan A tan B

$+$ $+$ $+$

$(-)$ cos c = cot A tan B

$-$

cos c = cot A tan B

NOTE:—The two adjacent parts are two angles, so put a $(-)$ sign on the left side. The two $+$ signs on the right side would make cos c a plus, but when combined with the additional $(-)$ sign it comes out minus, that is, side c is greater than 90°.

(ii) *To find* $\angle C$

A=mid part, B and C=opposites.

comp sin A = cos B cos C

$+$ $+$ $+$

$(-)$ cos A = cos B cos C.

cos C = cos A sec B.

NOTE:—Angles B and C are under 90° and the product of their cosines makes cos $A+$, but the opposites are both angles so that the additional $(-)$ added to the left side indicates that $\angle C$ is over 90°.

(iii) *To find side b.*

B = mid part, A and b = opposites

Sin B = *comp* cos A *comp* cos b

Sin B = Sin A sin b

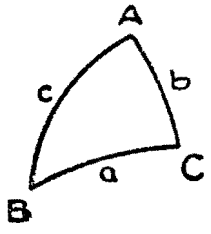
Sin b = Sin B cosec A.

The rule of signs fails in this case as sine and cosec are + up to 180°. But $\angle B$ is less than 90°, therefore side b is less than 90°.

		(i)		(ii)		(iii)	
A	60° cot	9·76144	cos	9·69897	cosec	0·06247	
B	50° tan	0·07619	sec	0·19193	sin	9·88425	
	cos	9·83763	cos	9·89090	sin	9·94672	
		46° 31½′		38° 56′	side b	62° 12′	
		180 00		180 00			
	side c		$\angle C$	141 04			
		133 28½					

OBLIQUE SPHERICAL TRIANGLES.

(i) Given three sides to find an angle.



$$\text{hav } A = \frac{\text{hav } a - \text{hav } (b \sim c)}{\sin b \sin c}$$

When given two sides and included angle to find the third side, the above formula is modified to

hav a = hav A sin b sin c + hav $(b \sim c)$

(ii) Of two angles and two sides opposite to each other, given any three to find the fourth.

$$\frac{\sin A}{\sin a} = \frac{\sin B}{\sin b} = \frac{\sin C}{\sin c}$$

(iii) Given two sides and the included angle to find the other two angles.

$$\tan \tfrac{1}{2}(B+C) = \frac{\cos \tfrac{1}{2}(b \sim c)}{\cos \tfrac{1}{2}(b+c)} \cot \tfrac{1}{2} A$$

$$\tan \tfrac{1}{2}(B \sim C) = \frac{\sin \tfrac{1}{2}(b \sim c)}{\sin \tfrac{1}{2}(b+c)} \cot \tfrac{1}{2} A$$

(iv) The connection between any four adjacent parts is given by

$$\cot c \sin b - \cos A \cos b = \cot C \sin A$$

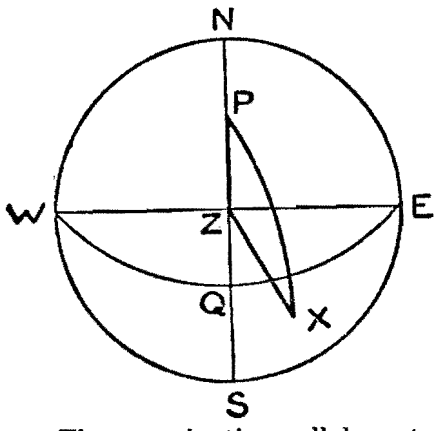
It is convenient to refer to these spherical formulae as the haversine formula, the sine formula, the tangent formula and the four adjacent parts formula respectively. See Chapter X for proofs.

(i) The haversine formula has been discussed in Volume I., Chapter VI., Trigonometry, page 120, and the method of its application in solving practical examples in navigation is presented throughout the text book. The formula satisfies nearly all the requirements of the $P\,Z\,X$ triangle of nautical astronomy.

(ii) Passing reference is made to the sine formula in Volume I., page 449. It will be noted that the shape and application of this formula is similar to the corresponding one for plane triangles; it is useful, sometimes, in finding the azimuth of a body in ex-meridian and position line questions when Tables are not available.

(iii) This compound formula is one of "Napier's Analogies". It applies to any spherical triangle in which two sides with the angle included between them is given and the remaining two angles are required, as in great circle sailing.

(iv) This formula connects any four adjacent parts of the spherical triangle and is introduced into the calculation of the A B C Azimuth Tables, which we shall describe directly in connection with the $P\,Z\,X$ triangle.



(ii) *Example.*—Given hour angle 30°, polar distance 110°, zenith distance 66° 12′, body East of meridian, calculate its azimuth. Latitude of ship 40° N.

$$\frac{\sin Z}{\sin PX} = \frac{\sin P}{\sin ZX}$$

P	30°	sin	9·69897	
PX	110°	sin	9·97299	
ZX	66° 12′	cosec	0·03860	
Z	30 54	sin	9·71056	Az. S. 30° 54′ E.

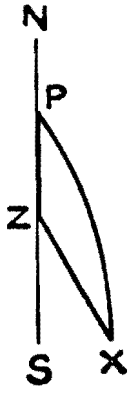
NOTE.—The formula gives us the smaller of the two angles at Z, viz., $\angle SZX$.

The examination syllabus states that candidates may use short method tables and, if so, they will be expected to know something of the principle on which they are constructed. We give here the formula from which the following have been compiled in case the question should arise at the examinations.

A B C Tables and *Norie's Ex-Meridian Tables.*

A B C TABLES.

(iv) Given hour angle 30°, decl. 20° S., Lat. 40° N., calculate the quantities given in the A B C Tables.



In the PZX triangle we have under consideration the adjacent parts—PX the polar distance, P the hour angle, PZ the co-latitude, and Z the azimuth—in their order round the triangle. Given the first three parts, find Z the fourth part.

$$\underset{B}{\cot PX \sin PZ} - \underset{A}{\cos P \cos PZ} = \underset{C}{\sin P \cot Z}$$

The Tables contain, respectively, the natural numbers corresponding to each part of the equation, but due regard must be paid to algebraic signs when combining the values. The above formula is camouflaged in *Norie's Nautical Tables* by dividing throughout by sin P sin PZ as follows: *see* also page 238.

$$\frac{\cot PX \sin PZ}{\sin P \sin PZ} - \frac{\cos P \cos PZ}{\sin P \sin PZ} = \frac{\sin P \cot Z}{\sin P \sin PZ}$$

$$\cot PX \operatorname{cosec} P - \cot P \cot PZ = \cot Z \operatorname{cosec} PZ$$

or, tan decl. cosec hour angle—cot hour angle tan lat. = cot az. sec. lat.

	± Table B	—	Table A	=	Table C
Table C = $(A \pm B)$ cos lat. = cot az.					
Hour angle 30°		cosec	0·30103	cot	0·23856
Decl. 20° S.		tan	9·56107		
Lat. 40° N.		.....		tan	9·92381
		log	9·86210	log	0·16237
Table	B	—	·728		
Table	A	—	1·453	A	1·453
Table C = $(A+B)$		—	2·181	log	0·33865
	Lat.		40°	cos	9·88425
	Az. S.		30° 54′ E.	cot	10·22290

The quantity from Table B is give the sign + when the latitude and declination are of the same name, and — when of contrary name. In this example B is — ·728.

EX-MERIDIAN TABLES.

The altitude of a body changes most rapidly when it is on the prime vertical and, to an observer on the equator, a body whose declination is 0° rises, culminates and sets on his prime vertical and it changes its altitude 1′ in 4 seconds of time. In other latitudes and for other declinations, the rates at which the altitudes of heavenly bodies change depends on their position with regard to the observer. When near the meridian, for example, the change of altitude varies as the square of the hour angle. See Chapter XII for investigation of formula.

Table I. in Norie's Ex-Meridian Tables contains a factor (A) which is the rate of change of altitude in one minute of time. The quantity is computed from the formula

$$A = 1{\cdot}9635'' \times \cos \text{lat.} \times \cos \text{decl} \times \text{cosec (lat.} \pm \text{decl.)}$$

latitude + declination when they are contrary names and minus when they are of the same name.

Table II. gives the reduction to be subtracted from the true zenith distance of the body to get its meridian zenith distance. It is derived from the formula

$$\text{Reduction} = A \times \text{hour angle}^2$$

Example.—Calculate the reduction to the meridian as given in Norie's or in Burton's Tables for Lat. 33° 07′ N., Decl. 29° 52·3′ S. Hour angle 6° 28′.

$A = 1{\cdot}9635 \cos \text{lat.} \cos \text{dec} \operatorname{cosec} (L + D)$

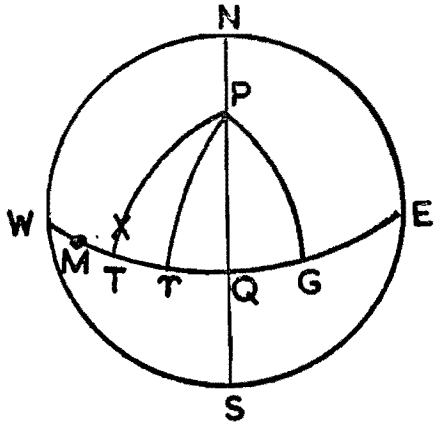
Constant	1·9635	log	0·29303
Lat.	33° 07′ N.	cos	9·92302
Decl.	29 52·3 S.	cos	9·93810
$(L+D)$	62 59·3	cosec	0·05017
A	1·601″	log	0·20432

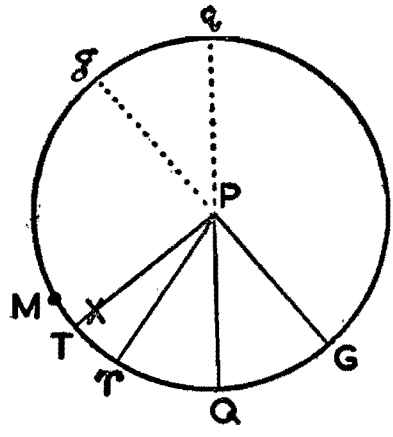
Reduction $= A \times$ Hour angle^2

H.A.	6° 28′	log	1·412460
			2
$(\text{H.A.})^2$	.....		2·824920
A	1·601	log	0·204450
	6′0)107′0″	log	3·029370
Reduction	17·8′		

Table I.	Lat. 33° 07′ N., Decl. 29° 52′ S. gives A		1·5
Table II.	H.A. 6° 28′ and A 1·0 gives		11·2′
Table II.	H.A. 6° 28′ and A 0·6 gives		6·6
	Reduction		17·8
From worked example, Chap. VII Fomalhaut true Z.D.		63	19·5
	M.Z.D.	63	01·7

HOUR ANGLE EQUATIONS.





In this general figure, *NESW* represents the rational horizon, *WQE* the celestial equator, *P* the pole, *Z* the zenith. ♈ the First Point of Aries, *M* the mean sun.

PG the meridian of Greenwich
PQ ,, ,, ,, Observer
P♈ ,, ,, ,, Aries
PT ,, ,, ,, a celestial body, true sun, star, moon or planet.
Arc *GQ* = Longitude of observer West of Greenwich (Greenwich hour angle of observer).
,, *G*♈ = Greenwich hour angle of Aries (Greenwich sidereal time).
,, *GT* = Greenwich hour angle of body (geographical longitude of body).
,, *QT* = Local hour angle of body.
,, *Q*♈ = Local hour angle of Aries (local sidereal time).

If the body is a star, then

Arc ♈*T* = sidereal hour angle.

If the body is the true sun, then

Arc *GT* = G.H.A. Sun.
,, *GT* + 12 hours = Greenwich apparent time.
,, *GM* + 12 hours = Greenwich Mean time.
,, *QT* + 12 hours = Local apparent time.
,, *QM* + 12 hours = Local Mean time.
,, *MT* = Equation of time (plus to apparent time in fig.)

The student can verify the following equations by referring to Volume I., or to the respective arcs of the equator in the general figure keeping in mind always that time is 12 hours + the hour angle of the sun, and that 360° may be added to, or rejected from, hour angles as desired.

1. L.M.T. = G.M.T. — West Longitude
   (*QM*+12h) = (*GM*+12h) — *GQ*
   QM = *QM*

2. Eq. Time	=	L.M.T.	—	L.A.T.
MT	=	(*QM*+12h)	—	(*QT*+12h)
	=	*MT*		
3. G.H.A. Star	=	G.H.A. Aries	+	S.H.A. Star
GT	=	*G*♈	+	♈*T*
	=	*GT*		
4. L.H.A. Body	=	G.H.A. Body	—	West Longitude
QT	=	*GT*	—	*GQ*
	=	*QT*		

The arc *GT* (G.H.A.) is tabulated at hourly intervals of G.M.T., for the Sun, Moon and planets, and the arc *G*♈ is also given for the same interval, in the daily pages of the *Nautical Almanac*. The arc ♈*T* (S.H.A. of Star) is given is the star list for the middle of each month and requires no correction for the day of the month. The arc *MT* (Equation of time) is given at intervals of 12 hours.

CHAPTER VI.

MERIDIAN PASSAGE

TIME OF MERIDIAN PASSAGE STAR

The times of the meridian passage of the sun, moon, planets and the First Point at Aries (♈) are listed in the daily pages of the *Nautical Almanac*. Times of meridian passage for individual stars are not included.

There are several methods for finding the time of a star's meridian passage:—

1. The Inspection Method using GHA Star at Meridian Passage.
2. Time of Meridian Passage Aries.
3. The Planet Diagram in the *Nautical Almanac*.

The first method, which involves inspection of the *Nautical Almanac* using the observer's west longitude as GHA star, has been used for example and the alternative approach using LHA star is also explained.

The second method, which involves use of the Time of Meridian Passage Aries, is less convenient than inspection methods but where a high degree of accuracy is not required, quick, approximate results can be obtained.

Use of the Planet Diagram contained in the *Nautical Almanac* is explained in the next section of this volume which deals with "Stars near the Meridian".

Method of Inspection Using the Observer's West Longitude to Obtain the Time of Meridian Passage Star.

The method of inspection relies on the following facts :—

1. GHA is measured Westwards from Greenwich.
2. At meridian passage :—
   (*a*) the star must lie on the Observer's meridian and
   (*b*) the star's GHA must equal the Observer's West longitude.
   (N.B.—An East longitude can be subtracted from 360° and expressed as a West longitude which exceeds 180°).
3. At Meridian Passage :—

GHA*		= Observer's West Longitude
GHA*		= GHA ♈ + SHA*
Observer's West longitude		= GHA ♈ + SHA*
Observer's West longitude	−SHA*	= GHA ♈

In the *Nautical Almanac* it can be seen that a star's SHA remains constant over a period of several days. So, by subtracting the SHA star from the Observer's West Longitude we can obtain the GHA♈ at the time of meridian passage.

Now, at any particular moment in time, GHA Aries is made up of its value for a whole number of hours plus the increment for the remaining minutes and seconds. By subtracting the next lowest GHA value for hours we obtain the increment which can be converted into time using the incremental tables at the rear of the *Almanac*. The resulting GMT is then adjusted for longitude to give the LMT of meridian passage.

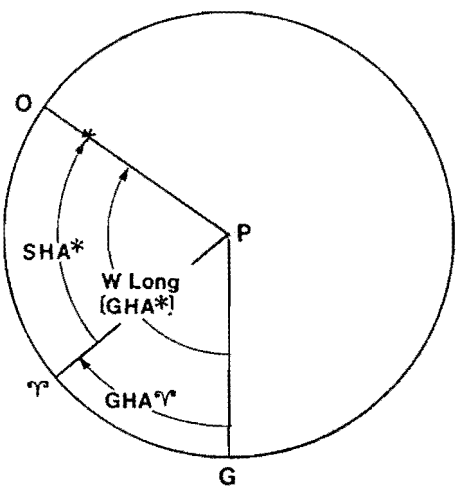


Fig.1 West Longitude

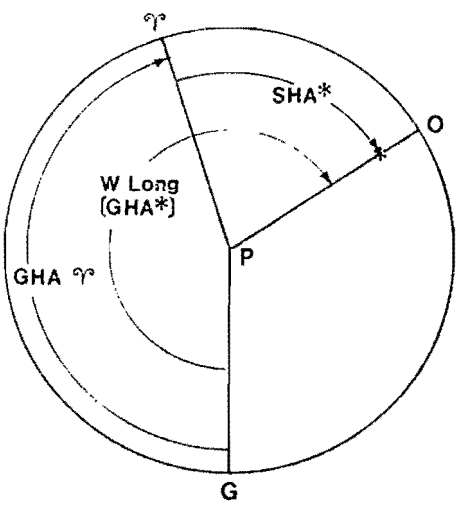


Fig.2 East Longitude

Alternative Method of Inspection Using the Star's LHA at Meridian Passage.

At Meridian Passage	LHA*	= 360°
	LHA*	= LHA♈ + SHA*
	360°	= LHA♈ + SHA*
	360° − SHA*	= LHA♈
Now	LHA♈ ± Long	= GHA♈
So	(360° − SHA*) ± Long	= GHA♈

From the above, it can be seen that by applying the Observer's Longitude to LHA Aries we obtain the GHA Aries for which the corresponding GMT can be extracted from the *Almanac* as previously explained.

This method gives precisely the same degree of accuracy as obtained by the longitude method and, for additional exercise, students may care to re-work the examples using this method.

TO FIND THE TIME OF MERIDIAN PASSAGE STAR—WEST LONGITUDE

Example 1 (W Long > SHA *)

Find the LMT of meridian passage for the star Vega on January 11th in DR 5° 00′ N, 90° 00′ W. Refer to Figure 3.

Observer's West Longitude − SHA * = GHA ♈ at Meridian Passage.

W Long	90°	00′					
SHA Vega	81	07·6					
GHA ♈	8	52·4					
From *Almanac* GHA ♈	5	41·7	gives	11d	17h		
,, ,, Increment	3°	10·7′	,,			12m	41s
			GMT	11	17	12	41
			W Long		6	—	—
Meridian Passage Vega			LMT	11d	11h	12m	41s
					11h	13m	(approx.)

In Example 1 the Observer's West longitude was greater than the SHA star. When the West longitude is less than the star's SHA it becomes necessary to add 360° to the Observer's longitude. Alternatively, Longitude ~ SHA can be subtracted from 360°. Both methods are demonstrated in the following example:—

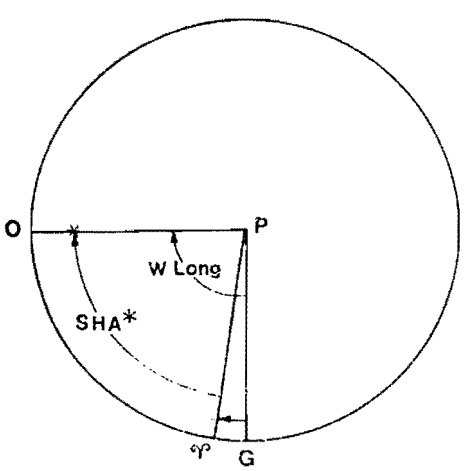


Fig.3 Example 1

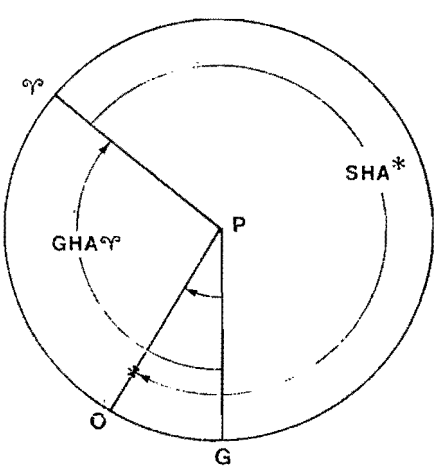


Fig.4 Example 2

Example 2 (W Long < SHA *)

Find the LMT of meridian passage for the star Sirius, am at ship, on October 11th in DR 40° 00′ N. 30° 00′ W. Refer to Figure 4.

Observer's West Long − SHA * = GHA ♈ at Meridian Passage.

	360°						
W Long	30°						
	390°	00′					
SHA Sirius	259°	09·9					
GHA ♈	130°	50·1					
From *Almanac* GHA ♈	124°	21·9	gives	11d	07h		
,, ,, Increment	6°	28·2′	,,			25m	48s
			GMT	11	07	25	48
			W Long		2	—	—
Meridian Passage Sirius			LMT	11d	05h	25m	48s
					05h	26m	(approx.)

Alternatively, GHA♈ can be found by subtracting longitude ~SHA from 360° as follows:—

W Long	30°	00′
SHA Sirius	259°	09·9′
W Long ~ SHA	229°	09·9′
	360°	
GHA ♈	130°	50·1′

TO FIND THE TIME OF MERIDIAN PASSAGE STAR—EAST LONGITUDE

When the Observer is in East longitude it becomes necessary to express the East longitude as West longitude. To express East longitude as West longitude subtract East longitude from 360°—this is demonstrated in the following example:—

Example 3 (East Longitude)

Find the LMT of meridian passage for the star Acrux, pm at ship, on June 16th in DR 40° 00′ S. 155° 00′ E. Refer to Figure 5.

Observer's West Long — SHA * = GHA ♈ at meridian passage *.

	360°						
E Long	155°	00′					
W Long	205°	00′					
SHA Acrux	173°	55·3′					
GHA ♈	31	04·7′					
From *Almanac* GHA ♈	24	05·1′	gives	16d	08h		
,, ,, Increment	6	59·6	,,			27m	58s
			GMT	16	08	27	58
			E Long		10	20	—
Meridian Passage Acrux			LMT	16d	18h	47m	58s
					18h	48m	(approx.)

In this example the resulting West longitude was greater than the SHA. Had the SHA exceeded the West longitude it would have been necessary to add 360° as explained at Example 2.

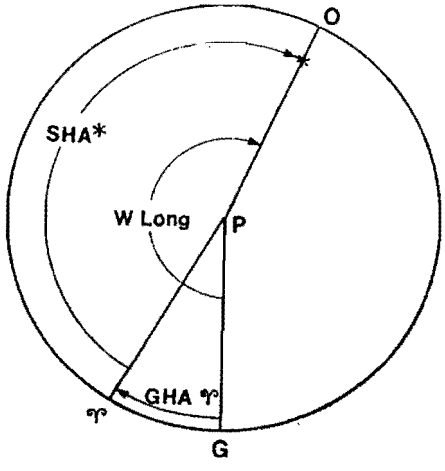


Fig.5 Example 3

FINDING A STAR WHOSE MERIDIAN PASSAGE OCCURS AT A SUITABLE TIME FOR SIGHTS

(Further information on this subject is included at page 148).

A star sight can only be taken when both the star and the horizon are clearly visible. This normally occurs only during twilight hours. In consequence, when deciding on a suitable star for a meridian observation it is generally necessary to limit the choice to that star whose meridian passage occurs during twilight hours. Nautical twilight occurs when the sun is between 6° and 12° below the horizon and during this period bright stars are visible and the horizon is sufficiently clear for star sights.

The times of twilight can be found in the daily pages of the *Nautical Almanac.* A study of these times will quickly show that the duration of twilight is dependent on the latitude of the observer. This, together with the fact that the clarity of the horizon depends heavily on atmospheric and sea conditions, results in situations where it is possible to obtain good star sights at times both earlier and later than those falling within nautical twilight, but in the following examples it has been assumed that nautical twilight is the correct period to be used in calculation.

TO FIND A STAR SUITABLE FOR MERIDIAN ALTITUDE AT TWILIGHT

1. Obtain GMT of nautical twilight.
2. Obtain DR longitude for this GMT.
3. Calculate LHA Aries for the GMT and longitude found above.
4. Subtract LHA Aries from 360° to obtain the SHA of an imaginary star whose meridian passage occurs precisely at this time.
   At meridian passage:

$$\begin{aligned} \text{LHA } * &= 360°, \\ \text{LHA } \Upsilon + \text{SHA } * &= \text{LHA } *, \\ \text{LHA } \Upsilon + \text{SHA } * &= 360°, \\ \text{SHA } * &= 360° - \text{LHA } \Upsilon \end{aligned}$$

5. Inspect the list of stars in the *Nautical Almanac* and select a star (or stars) of similar SHA to that of the imaginary star found at 4. (Magnitude and altitude should be taken into account in making the final selection).
6. Find the LMT of meridian passage for the selected star and compare this time with the time and duration of twilight found at 2.
7. Decide if a meridian or ex-meridian sight is possible.
8. Prepare for sights by pre-calculating the meridian altitude of the selected star and note the time and altitude of meridian passage.

Example 4 (Refer also to Example 3 and Figure 5)

Find the LMT of meridian passage of a star suitable for a latitude sight during evening twilight on the 16th June.

DR 40° 00′ S. 155° 00′ E.

Nautical twilight	LMT	16d 17h 45m	
E Long		10h 20m	
	GMT	16d 07h 25m	(step 1)
	Long	155° 00′ E. (given)	(step 2)
GHA ♈ 16d 07h		9° 02·6′	
Increment 25m		6° 16·0′	
GHA ♈		15° 18·6′	
E Long		155° 00·0′	
LHA ♈		170° 18·6′	(step 3)
		360°	
SHA (of a suitable star)		189° 41·4′	(step 4)

From the *Nautical Almanac*:

	SHA	*Declination*	*Magnitude*	
Acrux	173° 55·3′	S 62° 52·5′	1·1	
Denebola	193 15·8	N 14 48·3	2·2	(step 5)
Gagrux	172 46·8	S 56 53·2	1·6	
Gienah	176 34·8	S 17 18·8	2·8	

Denebola, SHA 183° 15·8′, is the most suitable star for a meridian altitude. Calculate the LMT at meridian passage Denebola, pm at ship, on 16th June.

Observer's West Longitude − SHA* = GHA ♈ at meridian passage.

	360°						
E Long	155° 00′ E						
W Long	205°						
SHA Denebola	183° 15·8′						
GHA ♈	21° 44·2′						
From *Almanac* GHA	9° 02·6′	gives	16d	07h	—	—	
,, ,, Inc.	12° 41·6′	,,			50m	38s	
		GMT	16	07	50	38	
		E long		10	20	—	
Meridian Passage Denebola		LMT	16d	18h	10m	38s	(step 6)
				18h	11m	(approx.)	
Nautical Twilight				17h	45m		
					26m		

Meridian passage occurs 26m after the start of Nautical Twilight.

Depending on the horizon available, either a meridian altitude or good ex-meridian altitude should be obtained. (step 7)

The meridian altitude should now be calculated or found by inspection from suitable tables. (step 8)

TIME OF MERIDIAN PASSAGE ARIES

The meridian passage of Aries is listed in the daily pages of the *Nautical Almanac* and the time quoted is for the middle day of the 3 days quoted. As each star is related to Aries by its sidereal hour angle the time of a star's meridian passage can be found by converting its SHA into time and applying this time to the time of meridian passage Aries:

Meridian passage * = Meridian passage ♈ + (360° − SHA *)

The rate at which the earth turns relative to the fixed stars is 23h 56·1m of Mean Solar Time. This means that Aries will reach the Greenwich meridian nearly 4 minutes earlier each day. In consequence, when converting SHA into time, the conversion should be made at the rate of 23h 56m to 360°.

Accurate results can be obtained by this method but the correction necessary for longitude and the 4 minute time difference is somewhat inconvenient.

Where speed and accuracy are required it is preferable to use inspection methods.

The approximate LMT of a star's meridian passage is frequently required in order to check the corresponding date at Greenwich. It is also used to check if an individual star will be on, or near, the meridian during twilight hours when a suitable horizon is available. For approximate purposes the 4 minute time correction can be safely ignored providing the limits of accuracy are appreciated.

TO FIND THE APPROXIMATE TIME AND DATE OF MERIDIAN PASSAGE STAR USING THE TIME OF MERIDIAN PASSAGE ARIES

In the previous examples it should be noted that no change has occurred between the GMT date and the LMT date, but when taking a sight it is always good practice to check that no such change has occurred. Failure to make this check can result in extracting *Almanac* data for the wrong day.

In question papers an indication of the LMT, or approximate time, of sights is often given, whilst in practice the approximate LMT of sights should be known. By carefully applying the longitude correction to the LMT and date at ship, the corresponding GMT and Greenwich date are easily found.

In solving problems where there is no such indication of LMT, or the approximate time of the observation, it is first necessary to obtain the corresponding time and date at Greenwich. In other cases a quick method for finding the approximate time of meridian passage star is sometimes useful.

As already mentioned, the *Nautical Almanac* lists the meridian passage Aries for the second of the three days listed on the daily pages.

If we neglect the small time difference between the Sidereal and Mean Solar Day:

Time of meridian passage * = Time of meridian passage ♈ + (360° − SHA *)

[The quantity (360° − SHA *) is known as Right Ascension (RA) and is expressed in hours and minutes.]

Providing this method is carefully used and providing careful corrections are made for longitude and the difference between the Sidereal and Mean Solar Day, this method can achieve results of similar accuracy to those achieved by the inspection method. In practice, such corrections are inconvenient and introduce unnecessary complications. But for approximate results, where such corrections are ignored, the method is quick and convenient.

Example 5

Find the approximate time of meridian passage Acrux on June 16th in DR 40° 00′ S. 155° 00′ E.

Meridian passage * = Meridian passage ♈ + (360° − SHA *)

Meridian passage ♈ from *Almanac*		16d	06h	24m	(approx.)
	360°				
SHA Acrux	173° 55·3				
(360° − SHA *)	186° 04·7	expressed as time		12h	24m ,,
		LMT	16d	18h	48m ,,
		E Long		10h	20m ,,
		GMT	16d	08h	28m (approx.)
The result by inspection (see Example 3) was		GMT	16d	08h	27m 48s

To achieve a result comparable to that achieved by inspection would have required considerable more work and increased the chances of error.

Whenever consulting the Nautical Almanac always check the approximate Time and Date at Greenwich.

Circumpolar Stars—Upper and Lower Meridian Passage.

The apparent motion of a star (and all celestial bodies) is to describe a circle around the pole once in a sidereal day. During this period the star will cross (or transit) the observer's meridian and will also cross the observer's anti-meridian which is 180° removed from his meridian. The time interval between the two transits is equal to half a sidereal day.

It will be recalled that the latitude of the observer is equal to the altitude of the elevated pole so that when latitude is greater than polar distance (90° − Dec) a body will be continuously above the horizon. Under these conditions a star will cross the observer's meridian and anti-meridian and, in consequence, will have two meridian altitudes (though these will only be visible if occurring during the hours of twilight or darkness).

When the star is at its Higher Meridian Altitude it is said to be, "Above the Pole" or at, "Upper Meridian Passage".

When the star is at its Lower Meridian Altitude it is said to be, "Below the Pole" or at, "Lower Meridian Passage".

The terms "Upper (or Lower) Meridian Transit and, "On the Meridian Above (or Below) the Pole", are also used.

Stars which are continuously above the observer's horizon during a diurnal revolution (and which hence transit the observer's meridian "above" and "below" the pole) are referred to as "Circumpolar Stars".

It should be noted that circumpolar stars do not rise or set and have no amplitude.

Conditions Necessary for Circumpolarity.

Refer to Figures 9 and 10 and verify the following conditions which are necessary for circumpolarity:

Latitude of Observer must be greater than Polar Distance Star

Lat > (90° − Dec)

Time of Meridian Passage Across Any Specified Meridian.

The time of a star's upper and lower meridian passage across any specified meridian will be the same for all latitudes. This fact is quite independent of whether, or not, the star is visible at the time of lower meridian passage. It should be noted that when a star is visible at lower meridian passage it will cross the observer's meridian from West to East between the horizon and the elevated pole.

To Find the Latitude at Lower Meridian Passage.

Refer to Figures 9 and 10 and verify that:

Latitude at Lower Meridian Passage equals True Altitude plus Polar Distance Star.

$$\text{Lat} = \text{True Alt} + (90° - \text{Dec})$$

To Find the Time of Lower Meridian Passage.

The interval of time between the upper and lower meridian passage of a star is half a Sidereal Day or 11h 58m 02s of Mean Solar Time. It follows that the lower Meridian passage of a star (whether visible or not at the time of its passage below the pole) will be found as follows:—

LMT Lower Mer Passage = LMT Upper Mer Passage ± 11h 58m 02s.

An alternative method is as follows:—

LMT Lower Mer Passage = LMT when LHA * is 180°.

As previously explained, at meridian passage LHA star is equal to 360°. Similarly when a star is on the observer's anti-meridian LHA star is equal to 180°.

At Lower Meridian Passage	LHA *	= 180°
	LHA *	= LHA ♈ + SHA *
	180°	= LHA ♈ + SHA *
	180° − SHA *	= LHA ♈
Now	LHA ♈ ± Long	= GHA ♈
So	(180° − SHA *) ± Long	= GHA ♈

From the above it can be seen that by applying the longitude to LHA Aries we obtain the GHA Aries for which the corresponding GMT can be extracted from the *Almanac* as previously demonstrated.

Example 6

Find (*a*) The LMT of the Upper and Lower Meridian passage of the star Capella on December 24th in DR 56° 30′ N. 38° 18′ W., and

(*b*) The observer's latitude if the Sextant Meridian Altitude of Capella (below the pole) was 12° 30′ N. IE 2′ off the arc. HE 9m.

(*a*) *Check Greenwich Date*:

Meridian Passage * = Meridian Passage ♈ + (360° − SHA *)

Mer Pass ♈ from *Almanac*	360°	LMT	24d	17h	49m	(approx.)
SHA Capella	281° 34·5′					
(360° − SHA *)	78° 25·0′ in time			5h	14m	(approx.)
	Meridian Passage *	LMT	24d	23h	03m	
		W Long		2h	33m	
		GMT	25d	01h	36m	(approx.)

N.B.—Use Data for 25th and refer to Figures 6 & 7.

December 25th at Greenwich

Observer's West Longitude — SHA * = GHA ♈ at Meridian Passage

W Long	38°	18′					
	360°						
	398	18					
SHA Capella	281	34·5					
GHA ♈	116	43.5					
from *Almanac*	108	02·5	gives	25d	01h		
Increment	8	41	,,			34m	38s
Meridian Passage Capella			GMT	25	01	34	38
			W Long		2	33	12
Upper Meridian Passage			LMT	24	23	01	26
½ Sidereal Day (−)					11	58	02
Lower Meridian Passage			LMT	24d	11h	03m	24s

In this case the half sidereal day was subtracted because had it been added it would have given the LMT of Lower Meridian Passage on the 25th instead of the 24th which was the date required.

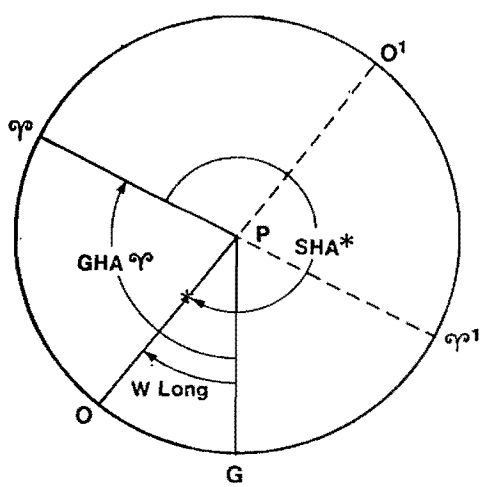


Fig.6 Upper Meridian Passage

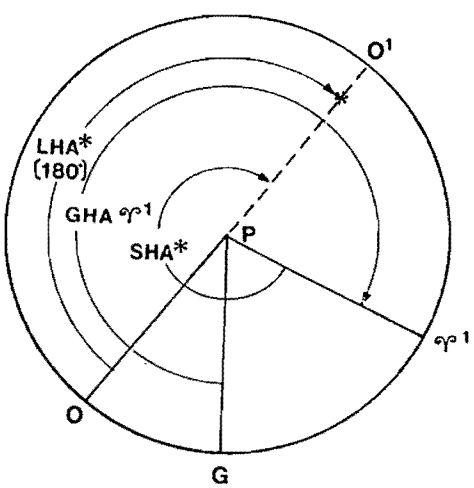


Fig.7 Lower Meridian Passage

(*b*) Latitude at Lower Meridian Passage = True Alt + (90° − Dec)
= X^1N + X^1P
= NP (the altitude of the elevated pole)
= QZ (the Observer's Latitude)

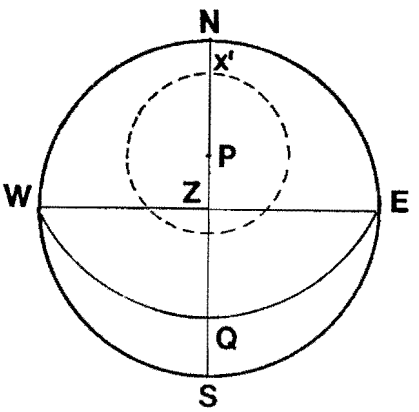


Fig.8

Dec Capella		45° 57·4′ N	(QX)
		90	
Polar Dist		44° 02·6′ N	(PX^1)
Sext Alt		12° 30′ N	
I.E	(+)	02	
Obs Alt		12 32	
Dip	(−)	05·3′	
App Alt		12 26·7	
Main Corrn	(−)	4·3	
True Alt		12 22·4 N	(X^1N)
Polar Dist		44 02·6 N	(PX^1)
Lat at Lower Mer Passage		56° 25·0′ N	(QZ)

To Find Latitude Using an Unknown Circumpolar Star.

The latitude of a place on land can be found by taking the mean of the true meridian altitudes above and below the pole of any unknown circumpolar star.

Figures 9 and 10 show the upper and lower transits of a star at X and X^1. Figure 9 is drawn on the plane of the observer's rational horizon and Figure 10 on the plane of the observer's meridian.

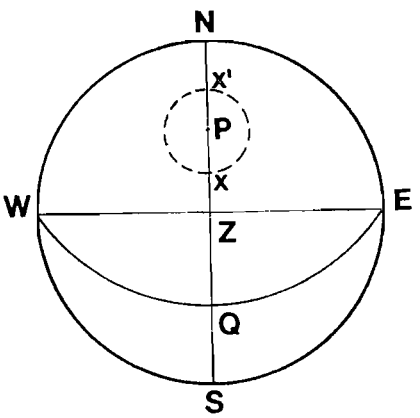


Fig.9

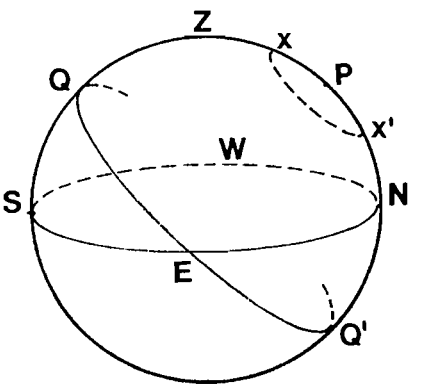


Fig.10

X	Star at Upper Meridian Passage
X^1	Star at Lower Meridian Passage
NX	Meridian altitude Above the Pole
NX^1	Meridian altitude Below the Pole
NP	Altitude of the elevated pole
QZ	Latitude of the observer
PZ	Co. Lat. of the observer
WQE	Equator
SZN	Observer's meridian
NESW	Observer's rational horizon

Refer to Figure 9 and the Legend above:

Now $NP + PZ = 90°$

$QZ + PZ = 90°$

$NP = QZ = \text{Lat}$

$NX + NX^1 = (NP + PX) + (NP - PX^1)$

$= 2\,NP$

$= 2 \times \text{Lat}$

So $\dfrac{NX + NX^1}{2} = \text{Latitude}$

or $\text{Latitude of Observer} = \dfrac{\text{Meridian Alt above Pole} + \text{Meridian Alt Below Pole}}{2}$

Examples and Questions for Exercise.

In examples 1–6 calculate the LMT of upper and lower meridian passage of the star in question. State if the star is visible at lower transit and if so calculate the approximate lower meridian altitude for the given latitude.

1.	Acrux, January 8th at ship in D.R.	52° 00′ S	163° 40′ E
2.	Regulus, December 22nd at ship in D.R.	24° 30′ S	138° 46′ W
3.	Vega, September 20th at ship in D.R.	60° 00′ N	176° 49′ E
4.	Atria, June 22nd at ship in D.R.	38° 40′ S	17° 45′ W
5.	Antares, June 17th at ship in D.R.	38° 00′ N	177° 40′ E
6.	Aldebaran, September 19th at ship in D.R.	56° 30′ N	154° 20′ W

7. Re-calculate the time of upper meridian passage for questions 1–6 above using the Time of Meridian Passage Aries.
8. Explain the conditions necessary for circumpolarity and use diagrams to illustrate your answer.
9. Comment on the conditions necessary in order to obtain an acceptable meridian altitude of a star.
10. Prove that, $(180° - \text{SHA}^*) \pm \text{Long} = \text{GHA } \Upsilon$ at lower meridian passage.

TO DETERMINE WHAT STARS ARE NEAR THE MERIDIAN.

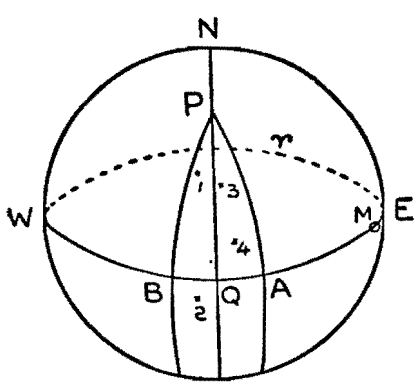
It may sometimes be required to find what stars are near the meridian so that those suitable for meridian altitude or ex-meridian sights may be selected. The Planet Diagram given in the Almanac can be used to find the Mean time of transit of any star for any date during the year, by simply reading the graph of Sidereal Hour Angle. Another method is to find the S.H.A. of the observer's meridian (360°—L.H.A. Aries) and compare this with the star list.

Star are tabulated in the main star list in the *Nautical Almanac* in the order of their sidereal hour angle which increases to the westward from zero at the First Point of Aries, so that stars having a greater S.H.A. than the S.H.A. of the observer are to the westward of the observer's upper meridian but to the eastward of his lower, or ante-meridian.

It will be remembered that stars are below the horizon when their meridian zenith distance exceeds 90°, that is, Latitude + Declination; also, that the brightness of a star is indicated by its magnitude. The brighter the star the smaller its magnitude number.

Example I.

Supposing you are not familiar with the stars, and wish to take an observation, find the names of the stars of magnitude 2·0 or brighter that are within one hour East and West of your meridian, above the pole and above the horizon, at 06h 30m Mean time at ship on January 9, the Latitude being 36° 30′ N., and the Longitude 48° 18′ W. Find also the approximate local hour angle of each of these stars and also whether to the North or South of your zenith when passing the meridian.



In figure:
N E S W the rational horizon
P the pole, Z the zenith
M the Mean sun
♈ the First Point of Aries
♈*EQ* the S.H.A. Observer's meridian.

The meridians *PA* and *PB* are 15° East and 15° West, and indicate respectively the limits of hour angle as prescribed in the question. The stars are represented within those meridians and are plotted approximately as numbered, according to their declinations.

S.H.A. Observer's meridian=360°—L.H.A. Aries.

	d	h	m
L.M.T.	9	06	30
Long. W. +		3	18
G.M.T.	9	09	48

G.H.A. Aries	243°	23·7′
Incre.	10	46·8
G.H.A. Aries	254	10·5
Long. W.	— 48	18
L.H.A. Aries	205	52·5
	360	00
S.H.A. Merid.	154	07·5

The required stars must have S.H.A's within 15° greater or less than the S.H.A. of observer. From the star list pick out the stars of the required magnitude whose S.H.A's come between 139° 07′ and 169° 07′ and write them down in the order in which they cross the meridian, as shown below.

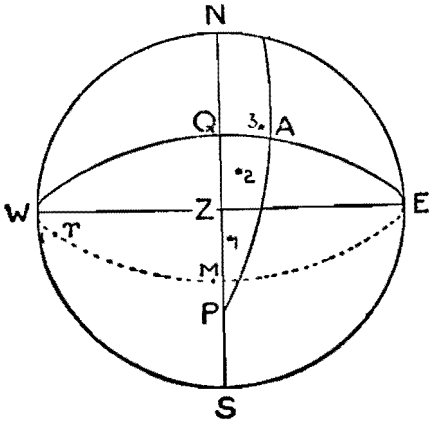
Name	1. *Alioth*	2. *Spica*	3. *Alkaid*	4. *Arcturus.*
Magnitude	1·7	1·2	1·9	0·2
Declination	56° N.	11° S.	50° N.	20° N.
S.H.A. Merid.	154° 07·5′	154° 07·5′	154° 07·5′	154° 07·5′
S.H.A. Star	166 57·1	159 15·1	153 31·7	146 33·7
L.H.A. Star	12 49·6 W.	5 07·6 W.	0 35·8 E.	7 33·8 E.
	Has crossed N.	Has crossed S.	Will cross N.	Will cross S.

The stars *Hadar* and *Rigil Kent* are omitted because their declination being of a different name to the latitude, and the sum in each case exceeding 90°, we know that they are below the horizon.

Example II.

On December 27, in Lat. 38° 42′ S., Long. 138° 15′ W., find the names of the stars not less bright than the first magnitude that are within 1½ hours East of the meridian above the pole and above the horizon. Time by chronometer 28d 09h 04m 00s which was correct G.M.T. Find the approximate local hour angle of these stars, and state if they cross the meridian to the North or South of the zenith.

S.H.A. Obs. Meridian=360°—L.H.A. Aries.



December		
G.H.A. 28d 09h	231°	19·6′
Incre. 04d 00h	1	00·2
G.H.A. Aries	232	19·8
Long. W.	—138	15
L.H.A. Aries	94	04·8
	360	00
S.H.A. Obs. Merid.	265	55·2
1½ hours East	— 22	30
East limit S.H.A.	243	25·2

} Limits of S.H.A.

	Canopus	*Sirius*	*Procyon*
Magnitude	—0·7	—1·6	0·5
Declination	53° S.	17° S.	5° N.
S.H.A. Obs.	265 55·2	265 55·2′	265 55·2
S.H.A. Star	264 13·8	259 09·5	245 42·3
L.H.A. Star	1 41·4 E.	6 45·7 E.	20 12·9 E.
	Will cross S.	Will cross N.	Will cross N.

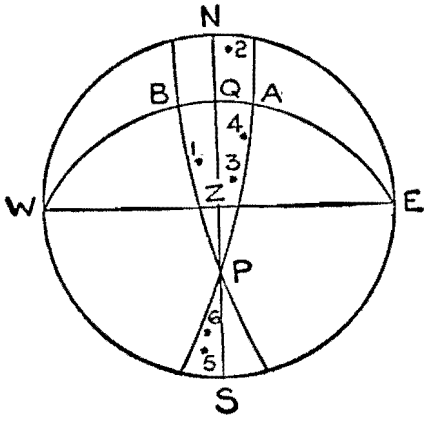
Notice the magnitudes of Canopus and Sirius. The minus sign prefixed to them indicates that they are brighter than magnitude 0, and, therefore, both are brighter than magnitude 1·0. These are the only two stars with a minus magnitude.

When the magnitude of a star is written 1·0—1·4 it means that its magnitude varies between 1·0 and 1·4. If the magnitude required in any example comes in between the two given magnitudes write the star down and mark it "magnitude variable 1·0—1·4," or whatever it may be.

Example III.

On June 24, at 05h 35m local Mean time, in Lat. 54° 30′ S., Long. 32° 10′ E., find the names of the stars up to magnitude of 2·5 that are within one hour East and West of the meridian above and below the pole and above the horizon. Find also the approximate local hour angle of each star, and state if to the North or South of the zenith at Transit.

S.H.A. Observer's meridian = 360° — L.H.A. Aries.



L.M.T.	24d	05h	35m
Long E.	—	2	09
G.M.T.	24	03	26
G.H.A. ♈	316°	45·9	
Incre	6	31·1	
G.H.A. ♈	323	17·0	
Long. E.	+ 32	10	
L.H.A. ♈	355	27	
	360	00	
S.H.A. Obs.	4	33	(upper)
	180	00	
S.H.A. Obs.	184	33	(lower)

"Upper Meridian" limits of S.H.A. 19° 33′ to 349° 33′.

Maximum declination to be visible 35° 30′ N. This is equal to the co-latitude but of opposite name to the latitude.

	1. *Fomalhaut*	2. *Alpheratz*	3. *Ankaa*	4. *Diphda*
	Mag. 1·3	Mag. 2·2	Mag. 2·4	Mag. 2·2
S.H.A. Obs.	4° 33′	364° 33′	364° 33′	364° 33′
S.H.A. Star	16 09·5	358 26·3	353 56·6	349 37
L.H.A. Star	11 36·5 W.	6 06·7 E.	10 36·4 E.	14 56 E.

All crossing North of Observer.

"Lower Meridian" limits of S.H.A. 199° 33′ to 169° 33′.

Minimum declination 35° 30′ S.=maximum Polar distance (*PS*) to be visible. The minimum declination is also equal to the co-latitude but of the same name as the latitude.

	5. *Acrux* (Mag. 1·1)	6. *Gacrux* (Mag. 1·6)
S.H.A. (lower)	184° 33′	184° 33′
S.H.A. Star	173 55·3	172 46·8
L.H.A. Star	10 37·7 W.	11 46·2 W.

Both crossing South of Observer.

Note.—Although stars (5) and (6) have sidereal hour angles less than the S.H.A. of the observer's lower meridian they bear South and West from the observer and have yet to come to the ante-meridian as their apparent daily motion, due to the earth's rotation, is counter clockwise round the South pole of the figure and their lower passage is from West to East.

Examples for Exercise.

Supposing you are not familiar with the stars and wish to take an observation, find, the names from the *Nautical Almanac* of the stars above, and below the pole if any, but above the horizon; give also the approximate local hour angle of each of the stars in the following examples, and state also whether they will be to the North or South of your zenith when passing the meridian.

	Date	Time	Lat.	Long.	Mag. up to	Limits of L.H.A.
1.	January 10	L.M.T. 03h 50m	40° 00′ S.	43° 20′ W.	2·5	1½hrs. E. and W.
2.	Sept. 19	G.M.T. 16h 24m	19 40 S.	0 30 E.	2·0	1h 45m E. and W.
3.	June 15	L.M.T. 02h 00m	54 00 S.	108 00 W.	2·1	1½ h. East
4.	June 18	G.M.T. 02h 35m	50 00 S.	38 05 E.	2·4	3h. East
5.	Sept. 23	L.M.T. 0h 30m	35 20 S.	155 00 W.	2·2	1h. E. and W.
6.	Sept. 20	G.M.T. 14h 40m	32 00 S.	135 00 W.	1·0	1½h East.

STAR IDENTIFICATION.

The easiest way for the star-gazer to begin is to ask someone who knows them to point out a few of the principal stars suitable for navigation, and, afterwards, to keep up a nodding acquaintanceship with them each night. Star identification at sea is then a simple matter.

The chief officer on the evening and morning watches night after night cannot fail to become familiar with the groups of suitable stars above the horizon and their position in the sky at dusk and dawn. The third officer will soon learn to know when and where to look for particular stars during the first watch, and the second officer will no doubt have a few in sight which he favours during the middle watch for position finding and azimuths. Allowance can readily be made each night for the slow automatic changes in the positions of the stars, relative to the horizon, and to the meridian, caused by the ship gradually changing her Latitude and to the fact that stars rise, culminate and set four minutes earlier each day.

The four diagrams given here are from *Brown's Nautical Almanac* and *Star Atlas*, to facilitate the recognition of stars. The maps are drawn on the gnomonic projection in which the meridians are straight lines radiating from the pole, spaced one hour or 15° apart to represent one hour of right ascension, and the parallels of declination are circles.

To read off the position of α Dubhe in the Great Bear, for example, we note that its right ascension is 11 hours and declination 62° N.

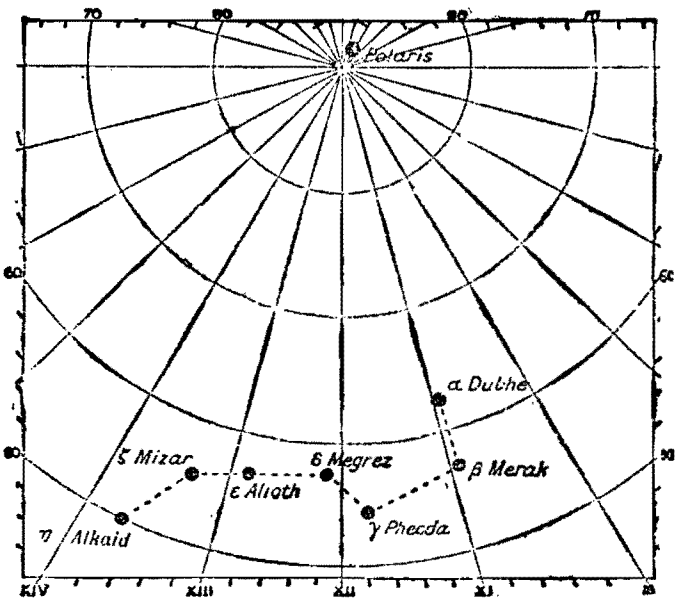


DIAGRAM 1.—Constellation of Ursæ Majoris.
Relative Positions of the Seven Principal Stars in the Constellation Ursæ Majoris, and of the Pole Star.

Amongst the most remarkable constellations which are the glory of our northern heavens, Ursæ Majoris, the Great Bear, is conspicuous (Diagram 1). The Great Bear

consists of seven principal stars not differing greatly in magnitude. These stars are of sufficient brightness to be of some use in navigation, but they have an even more important mission to fulfil in enabling us to identify α Ursæ Minoris, otherwise known as Polaris, or the Pole Star. This star is so near the North Pole that we may deduce the Latitude from its altitude at any time when the star is visible, without waiting for it to approach the meridian.

To Find Polaris.

Draw a line from β to α of the Great Bear (Diagram 1) and produce it. This line will lead to the Pole Star.

To Find the Constellation Cassiopeiæ.

Cassiopeiæ is on the opposite side of the pole to the Great Bear, so that when one bears East the other bears West. It is situated at about the same distance from the pole as the Great Bear, and is easily recognized from its resemblance to a chair, of which α, β, the two brightest stars, form the base of the seat, β being the western-most star when the constellation is above pole, and therefore the first to pass the meridian.

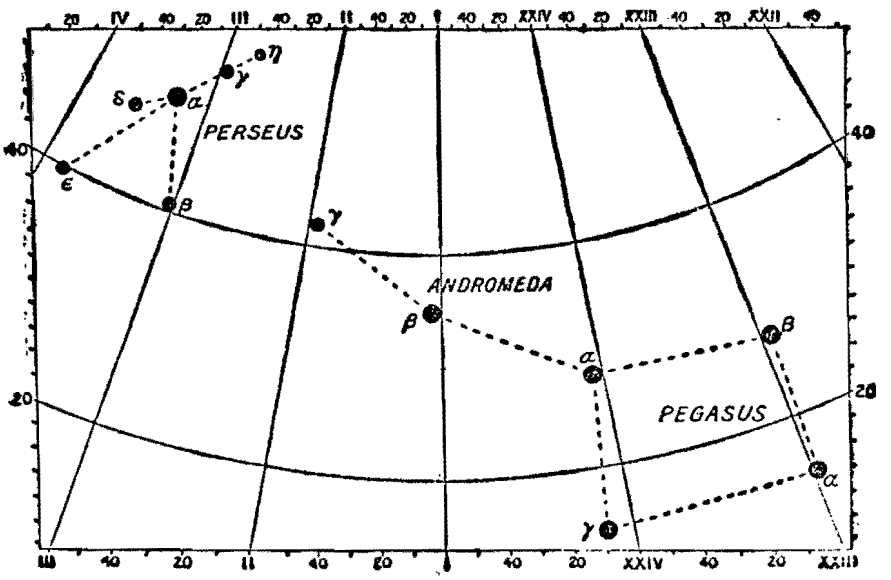


DIAGRAM 2.—The Constellations Perseus, Andromedæ and Pegasus.

To Find the Constellation Pegasus.

This constellation, with Perseus and Andromedæ, forms a configuration easy to remember (Diagram 2). A line from Polaris through β Cassiopeiæ, and produced about the same distance, terminates near the four stars which form "the great square of Pegasus." The stars α, β are those which form the outer side of the square, α, or Markab, being that which is nearer to the equator.

To Find Andromedæ.

The star at the angle of the square of Pegasus opposite to α Pegasi is sometimes called δ Pegasi, but it is known also as α Andromedæ, and if this diagonal is continued further it indicates β, γ, two of the principal stars in Andromedæ.

To Find Perseus.

The above line produced still further passes through the chief star in Perseus, situated in the middle of an arc formed by the stars β, δ, α, γ and η Persei.

To Find Capella (α Aurigæ).

From the bow of Perseus proceed two rows of small stars, one of which, curving to the East, extends to Aurigæ, which takes the shape of a large irregular pentagon. Capella, the brightest star (magnitude 0·2), is well marked by a small isosceles triangle, formed by three small stars in close proximity.

To Find the Pleiades.

The second row of stars proceeding from Perseus is directed towards the well-known group of small stars called the Pleiades.

To Find Arcturus (α Bootis).

Continue the curved tail of the Great Bear about twice the length of the constellation, and it will terminate near the bright star Arcturus (magnitude 0·2).

To Find Vega (α Lyræ).

A line from Capella, midway between Polaris and Cassiopeiæ, and continued something more than an equal distance beyond the Pole, leads to Vega (magnitude 0·1).

To Find Altair (α Aquilæ).

The Eagle lies to the southward of Lyra. It contains three bright stars in the same line, the centre one of which is Altair (magnitude 0·9).

To Find α Coronæ Borealis.

The Northern Crown lies between Vega and Arcturus. It is composed of several stars in the shape of a crown, the principal of which is known as α Coronæ or Alphacca. The brightness of this star has suffered some diminution in recent years and its magnitude is now 2·3. It lies upon a line drawn from Vega to Arcturus, about one-third of the length of the line from Arcturus.

To Find Hamal (α Arietis).

A line drawn from the neighbourhood of α Persei (Diagram 2) through β Persei, and produced twice their distance apart, points out α Arietis (magnitude 2·2).

To Find Aldebaran (α Tauri).

A line drawn from Polaris between Capella and α Persei passes no conspicuous star until it comes to Aldebaran (magnitude 1·1). This is a particularly easy star to determine since it is situated near the Pleiades, in a companion cluster called the Hyades, which have the shape of a well-marked V. Aldebaran is situated on the left, at the bottom of the cluster.

To Find Gemini (Castor and Pollux).

To the eastward of Aldebaran, about the distance of that star from Capella, are four stars in a line. These stars form the feet of the Twins. In the head are two bright stars, Castor (magnitude 1·6), and Pollux (magnitude 1·2).

Castor and Aldebaran form with Capella an isosceles triangle, which has Capella at the vertex. Pollux is a little to the South of Castor.

To Find Regulus (α Leonis).

A line drawn from α to β Ursæ Majoris, the Pointers, in the opposite direction to Polaris, and produced about twice the length of Ursæ Majoris will pass between Regulus and β Leonis. The magnitude of Regulus (1·2) will serve to distinguish it from β Leonis (magnitude 2·2).

To Find Cor Caroli (α Canum Venaticorum) and thence Spica, or α Virginis.

A line drawn from Dubhe (Diagram 1) through the opposite angle of the square, and produced nearly twice their distance apart, leads to Cor Caroli. The magnitude of this star (2·8) is not such as to give it any great importance in itself, but it is useful in helping to identify the bright star Spica (magnitude 1·2).

A line drawn from ε Ursæ Majoris, the star in the tail which is nearest to the square, through Cor Caroli, and produced about same distance, will terminate near Spica.

To Find α and β Libræ.

To the east of Spica are two stars, α Libræ (magnitude 2·9) and β Libræ (magnitude 2·8), β, the most distant from Spica, being about as far from Spica as is the latter from Arcturus.

To Find Antares (α Scorpii).

The Scorpion is to the South-East of Libra. In the head are five small stars, the centre one of which is β^1 Scorpii (magnitude 2·7); Antares (magnitude 1·3) forms, with Vega and Arcturus, a right-angled triangle, of which Vega is at the right angle.

To Find Fomalhaut (α Piscis Australis).

A line drawn from β to α Pegasi (Diagram 2), produced three times the distance, will terminate near Fomalhaut (magnitude 1·3).

To Find α Orionis (Betelguese) and β Orionis (Rigel).

The constellation Orion is one of great beauty, and its appearance should be familiar to every seaman (Diagram 3). The stars, α β, γ, κ, have the form of a great quadrilateral of which Betelguese (magnitude 1·0 to 1·4) is in the North-East angle. The star Rigel (magnitude 0·3) is in the opposite foot of the constellation. In the middle of the quadrilateral are three stars of the second magnitude, disposed in an oblique line. These are said to form the " belt of Orion."

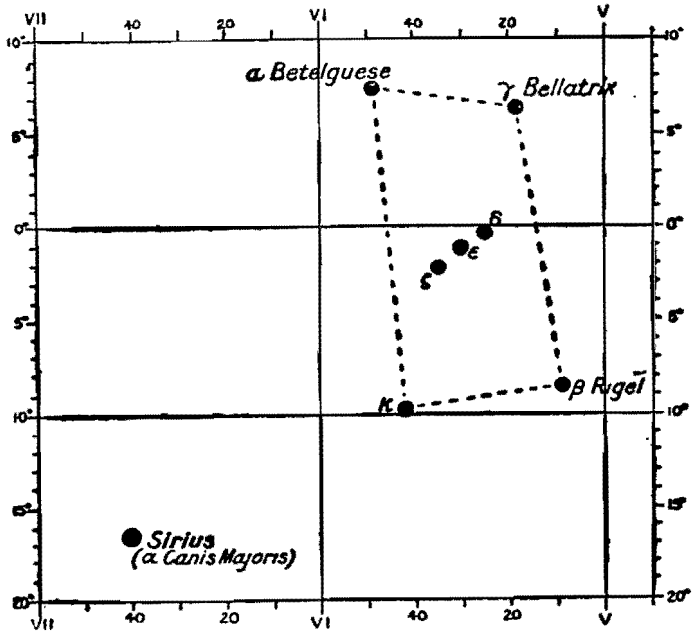


DIAGRAM 3.—Constellation of Orion.
Relative Position of the Seven Principal Stars in the Constellation Orion, showing also the Position of Sirius (α Canis Majoris).

To Find α Canis Majoris (Sirius).

A line drawn through the belt of Orion (Diagram 3) to the left, continued for about the distance which separates Rigel from Betelguese, will terminate near Sirius (magnitude −1·4).

To Find α Canis Minoris (Procyon).

Procyon (magnitude 0·5) lies midway between Gemini and Sirius. Or it may be regarded as forming the eastern angle of a triangle which has Sirius and Betelguese at the other angles.

To Find α Columbæ and thence Canopus (α Argus).

A line drawn from Procyon to Sirius and produced nearly the same distance passes near the first star (magnitude 2·7). Again a line drawn from Rigel through α Columbæ, and produced half the same distance, will terminate near Canopus (magnitude −1·0).

To Find the Centaur and the Cross.

These constellations lie to the South of Virgo and Libra. The various stars which compose them may easily be made out from Diagram 4 without any formal rule. The most southern star of the Cross is α (magnitude 1·0); the most northern is γ (magnitude 1·6). β Crucis (magnitude 1·5) and β Centauri (magnitude 0·8) are adjacent to each other.

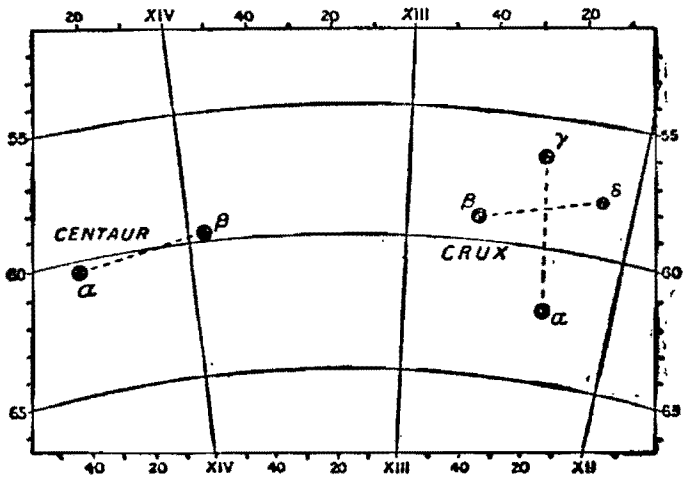


DIAGRAM 4.—The Constellations Centaur and Crux.

To Find Achernar (α Eridani).

A line drawn from Fomalhaut to Canopus is bisected by Achrenar (magnitude 0·5.)

Identification of Stars by Means of Azimuth Tables.

The foregoing directions will, it is hoped, enable the observer to locate the principal stars that are of service in navigation. Their use, however, is obviously limited to clear nights, when the outline of the various constellations can be made out, and are of little service in the case of an altitude "snapped during the momentary appearance of a star through a rift in the clouds, although it is in gloomy and overcast weather that star observations are often of paramount importance." A star may occasionally be identified by means of its altitude or azimuth, computed roughly.

For stars near the meridian the altitude, computed approximately in a few seconds from known values of Latitude and declination, is all that is required. A bright star bearing nearly due North or South, as the case may be, and having the altitude so obtained, may be accepted without much risk of error as the star required.

For stars observed on larger bearings it is necessary to know the altitude and azimuth of the star approximately before identification can be established.

The position of the observer's zenith is plotted on a star chart using declination for the latitude and right ascension equal to the local hour angle of Aries. From this position the star may be identified by laying off its zenith distance in the direction of its azimuth.

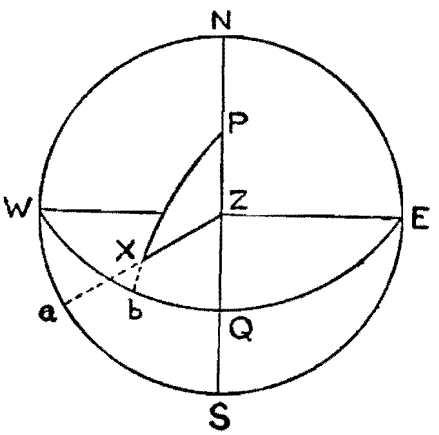
The following method of identifying a star by calculation and reference to the

star list in the *Nautical Almanac* may not be quite obsolete yet. In the *PZX* triangle of nautical astronomy, *PZ* the co-latitude is known, *ZX* is the complement of the altitude observed by sextant and angle *Z* is found from the compass bearing of the star. Using these three factors calculate *PX* the star's polar distance, and angle *P* the L.H.A. star as shown in the following example.

Example.—On January 10, D.R. Latitude 51° N., Longitude 30° 30′ W., the altitude of an "unknown" bright star was observed to be 42° 15′, bearing 239° (T) G.M.T. by chronometer 02h 02m 00s. What star was it?

Given: $PZ = 39° 00'$, $ZX = 47° 45'$, $Z = 121°$.

Find: PX thence the declination.



hav PX = hav Z sin PZ sin ZX + hav $(PZ \sim ZX)$

Z	121° 00′	log hav	9·87939	
PZ	39 00	log sin	9·79887	
ZX	47 45	log sin	9·86936	
		log hav	9·54762	
		nat hav	·35288	
$(PZ \sim ZX)$	8 45	nat hav	·00582	
PX	73 35	nat hav	·35870	
	90 00			
Decl.	16 25 N.			

(2) Find *P* and with the G.M.T. get G.H.A. Aries.

S.H.A. Star = G.H.A. Star − G.H.A. Aries.

$$\text{hav } P = \frac{\text{hav } ZX - \text{hav } (PZ \sim PX)}{\sin PZ \sin Px}$$

ZX	47° 45′	nat hav	·16382	G.M.T. 10d 02h 02m 00s
$(PZ \sim PX)$	34 45	nat hav	·08918	G.H.A. Aries 139° 33·4′
		nat hav	·07464	
		log hav	8·87298	
PZ	39 00	cosec	0·20113	
PX	73 45	cosec	0·01771	
L.H.A.	41 09·5	log hav	9·09182	
Long. W.	+30 30			
G.H.A. Star	71 39·5			
G.H.A. Aries	139 33·4			
S.H.A. Star	292 06·1	(Approx.)	The star whose S.H.A. and Decl. agree most closely with this will be the star required.	
Decl.	16 25 N.	(Approx.)	*Ans.*—*Aldebaran*	

LATITUDE BY MERIDIAN ALTITUDE (MOON).

The G.M.T. of moon's transit across the observer's meridian is required in order to find the moon's declination and horizontal parallax at the time of observation. The L.M.T. of transit of the moon over the meridian of Greenwich is given in the *Nautical Almanac* at the foot of the daily pages in the column headed "Moon, Mer. Pass. Upper". If the observer is not on the meridian of Greenwich, a correction for Longitude must be applied to the L.M.T. of transit at Green wich to findthe local time of the moon's meridian passage at ship.

The moon passes the meridian of Greenwich later each day by the number of minutes indicated by taking the difference of the times tabulated from one day to the next day. In the interval between two such transits the moon passes over 360° of Longitude, therefore, the Mean time of transit over any meridian of *West* Longitude is later than that over the meridian of Greenwich by $\frac{\text{Long. in time}}{24} \times \text{diff.}$ The Mean time of transit over any meridian of *East* Longitude is *earlier* than that over the meridian of Greenwich by $\frac{\text{Long. in time}}{24} \times \text{diff.}$ This is the correction to be applied to the tabulated time of meridian passage at Greenwich for the given date. Use the difference between the day in question and the following date when in West Longitude, but use the difference between the preceeding date when in East Longitude.

When the moon does not pass the upper meridian of Greenwich on the given date at ship, take the meridian passage for the preceeding day when in West Longitude, and for the following day when in East Longitude.

Example I.

On June 22, in D.R. Latitude 39° 40′ S., Longitude 60° 18′ W., the sextant meridian altitude of the moon's lower limb was 45° 22′. Index error 1′ off the arc, height of eye 34 feet. Required the Latitude.

	d	h	m
Mer. Pass. at Greenwich	22	16	32
Corr. for W. Long. +			8·5
L.M.T. Mer. Pass. ship	22	16	40·5
Long. in time		4	01·2
G.M.T. Mer. Pass. ship	22	20	41·7

diff. $51 \times \frac{4}{24} = 8{\cdot}5$ m.

Declination 22d 20h	4°	09·8′	N.
d correction (11·2) −		7·9	
Corr. Decl.	4	01·9	N.

Hor. Parlx. 58·9

Sext. alt.	45°	22′	
Index error +		1	
	45	23	
Dip. −		5·7	
	45	17·3	
Corr. +		50·2	
H.P. (58·9) +		6·1	
	46	13·6	
True alt.	90	00	
Zen. dist.	43	46·4	S.
Declination	4	01·9	N.
Latitude	39	44·5	S.

The altitude of the moon's lower limb has been corrected above using the correction tables given in the *Nautical Almanac.*

Example II.

On September 23, in D.R. Latitude 30° 12′ N., Longitude 100° 49·5′ E., the sextant meridian altitude of the moon's Upper Limb was 47° 00′. Index error 2′ off the arc; height of eye 25 feet. Required the Latitude.

	d	h	m
Mer. Pass. at Greenwich	23	20	56
Corr. for E. Long.	—		13·4
L.M.T. Mer. Pass. ship	23	20	42·6
Long. in time	—	6	43·3
G.M.T. Mer. Pass. ship	23	13	59·3

Declination	12°	32·1′ S.
Hor. Parlx.		55·7′

Diff. $48 \times \frac{6 \cdot 7}{24} = 13 \cdot 4$ mins.

Sext. alt.		47°	00′
Index error	+		2
		47	02
Dip	—		4·9
		46	57·1
Main corr.	+		49·1
H.P. (U) corr.	+		2·8
		47	49
Upper limb cor.	—		30
True alt.		47	19
		90	00
Zen. dist.		42	41 N.
Declination		12	32·1 S.
Latitude		30	08·9 N.

It should be noticed that the constant, 30′, is subtracted *after* the other corrections have been applied to the altitude of the moon's upper limb.

Examples for Exercise.

(1) On January 6, in D.R. Latitude 30° 20′ S., Longitude 47° 30′ E., the observed meridian altitude of the moon's upper limb was 41° 27′. Height of eye 35 feet. Required the Latitude.

(2) On December 21, in D.R. position 48° 00′ N., 43° 15′ W., the sextant meridian altitude of the moon's lower limb was 55° 10′. Index error the 1′ off arc; height of eye 30 feet. Find the Latitude.

(3) On June 23, in D.R. Lat. 28° 47′ S., Long. 84° 36′ E., the sextant meridian altitude of the moon's upper limb was 59° 50′. Index error 1′ on the arc; height of eye 35 feet. Required the Latitude.

(4) On September 19, in D.R. Lat. 41° 55′ N., Long. 52° 06′ W., the sextant meridian altitude of the moon's lower limb was 28° 24′. Index error 2′ off the arc; height of eye 28 feet. Required the Latitude.

(5) On June 24, in D.R. Lat. 50° 15′ N., Long. 45° 00′ W., the observed altitude of the moon's lower limb was 33° 35′. Height of eye 40 feet. Required the Latitude.

LATITUDE BY MERIDIAN ALTITUDE (PLANET).

The Mean time of transit of a planet over the meridian of Greenwich is given in the daily pages of the *Nautical Almanac* in the column headed Mer. Pass., opposite the name of the planet. The times are given for the middle day of the three days on each page, so if the date required does not happen to be the one tabulated, find the difference in time of meridian passage in one day and apply this to the time nearest the required date. The L.M.T. of transit of a planet over any other meridian is found by applying a correction for Longitude to the time of transit at Greenwich. If the Longitude is East, find the difference in times of transit between the date of the question and the preceding date, but the following date if the Longitude is West, and multiply this by the Longitude in time divided by 24. The correction is added if the time of transit increases between the date of the question and the second date, but subtracted if it decreases. To the L.M.T. of transit over the observer's meridian, apply the Longitude in time to get the G.M.T. at the time of observation.

Example I.

On June 16, in D.R. Lat. 27° 37′ S., Long. 167° 21′ W., the sextant meridian altitude of Venus was 47° 12′, index error 1′ on the arc, height of eye 35 feet. Required the Latitude.

June	d	h	m
Mer. Pass.	16	09	26
Corr. for W. Long. +			0·3
L.M.T. Mer. Pass.	16	09	26·3
Long. in time +		11	09·4
G.M.T. Mer. Pass.	16	20	35·7

Declination 15° 16·5′ N.

	h	m
Mer. Pass. 16th	9	26
,, ,, 19th	9	28
3)		2
Diff. in 1 day		0·6

Corr. $= 0{\cdot}6 \times \frac{11}{24}$
$= 0{\cdot}3$mins.

Sext. Alt.	47°	12
In ex error	—	1
Dip	—	5·7
Correction	—	0·9
True alt.	47	04·4
	90	00
Zen. dist.	42	55·6 S.
Declination	15	16·5 N.
Latitude	27	39·1 S.

Example II.

On January 10, in D.R. Lat. 44° 05′ N., Long. 130° 47′ E., compute the altitude to be set on the sextant for the meridian altitude observation of Venus, index error 1′ on the arc, height of eye 34 feet.

	d	h	m
Mer. Pass.	10	13	52·3
Corr. E. Long. +			1·5
L.M.T. Mer. Pass.	10	13	53·8
Long. in time —		8	43·1
G.M.T. Mer. Pass.	10	05	10·7

Declination 13° 11·3′ S.

	h	m
Mer. Pass. 11th	13	48
,, ,, 8th	14	01
3)		13
Diff. in 1 day		4·3
Diff. in 8·7h.		1·5

D.R. Lat.	44°	05′ N.
Decl.	13	11·3 S.
Zen. Dist.	57	16·3
	90	00
True alt.	32	43·7
Index error	+	1
Dip	+	5·7
Corr.	+	1·5
Sext. alt.	32	51·9

Examples for Exercise.

(1) On September 20, in D.R. Lat. 31° 25′ N., Long. 178° 37′ W., the observed meridian altitude of Saturn was 36° 51′, height of eye 36 feet. Required the Latitude.

(2) On January 10, in D.R. Lat. 39° 20′ N., Long. 157° 20′ W., the observed meridian altitude of Jupiter was 40° 37′, height of eye 30 feet. Required the Latitude.

(3) On June 20, in D.R. Lat. 26° 12′ S., Long. 71° 30′ E., index error 1′ on the arc, height of eye 35 feet, compute the altitude to be set on the sextant for the meridian altitude observation of Mars.

(4) On December 22, in D.R. Lat. 46° 25′ N., Long. 18° 12′ W., compute the sextant meridian altitude of Mars, index error 1′ on the arc, height of eye 36 feet.

(5) On January 8, in Longitude 132° 15′ E., the observed meridian altitude of Venus South of observer, was 58° 15′; height of eye 40 feet. Required the Latitude.

CHAPTER VII.

EX-MERIDIANS AND POSITION LINE METHODS.

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 56′ away from the pole and slowly approaching it, but the star describes such a small daily circle in the sky that the latitude can be computed from an altitude of the Pole Star at any time. Polaris changes its azimuth from about N.2° E. to N2° W. during its daily circuit round the pole of the heavens and bears true North on the two occasions, each day, when it crosses the meridian above and below the pole. See Pole Star Tables in Appendix.

Latitude = True altitude $-1° + a_0 + a_1 + a_2$.

The table is entered with the local hour angle Aries and the a° correction is interpolated mentally. The a_1 and a_2 corrections are taken from the tables nearest the L.H.A. Aries, abreast of the approximate Latitude and of the Month, respectively.

Example.

On September 20, at 22h 00m 00s local Mean time in Longitude 152° 30′ E., the sextant altitude of Polaris was 36° 44′, index error 1·5′ on the arc, height of eye 39 feet. Required the Latitude.

	d	h	m	s
L.M.T.	20	22	00	00
Long. E.	—	10	10	00
G.M.T.	20	11	50	00

L.H.A. ♈ = G.H.A. ♈ + E. Long.

G.H.A. ♈	20d 11h	163°	49·8′
Incre. 50m 00s		12	32·1
G.H.A. Aries		176	21·9
Long. E.		+152	30
L.H.A.		328	51·9

True Az. 001°
P.L. 091°—271° T.

Sext. alt.	36° 44′
Index error	— 1·5
Obs. alt.	36 42·5
Dip	— 6·1
	36 36·4
Corr.	— 1·3
True alt.	36 35·1
	−1
	35 35·1
a	+ 31·4
a	+ 0·5
a	+ 0·7
Latitude	36 07·7 N.

The Pole Star Tables are based on the formula:—

$$\text{Lat.} = \text{Alt.} - \overbrace{P.\ \text{dist}\cos \text{L.H.A. star}}^{\text{2nd term}} + \overbrace{\tfrac{1}{2}\ P\ \text{dist}^2 \sin^2 \text{L.H.A. star} \tan (\text{lat.})}^{\text{3rd term}}$$

The correction a_0 gives the value of the 2nd and 3rd terms, using a mean latitude of 50° and a mean S.H.A. and Declination of Polaris. A constant, 58·8′, is always added.

The corrections a_1 and a^2 are adjustments to the 3rd and 2nd terms, respectively when the ship's Latitude and the position of Polaris differ from the mean values, used. A constant (0·6′) is added to each to make them always positive, and to make the sum of the contants equal to one degree.

Examples for Exercise.

(1) On January 12, local Mean time 03h 16m at ship in Longitude 32° 00′ W., the sextant altitude of the Pole star (*α Ursae Minoris*) out of the meridian was 45° 19′, height of eye 35 feet, index error 1·5′ off the arc. Required the Latitude.

(2) On June 18, at 23h 39m Mean time at ship in Longitude 147° 20′ W., the sextant altitude of Polaris off the meridian was 34° 58′, index error 1·0′ on the arc, height of eye 27 feet. Required the Latitude.

(3) On June 23, in Longitude 165° 18′ E., the observed altitude of Polaris out of the meridian was 51° 15′, G.M.T. 22d 17h 02m 24s., height of eye 20 feet. Required the Latitude.

(4) On September 19, at G.M.T. 20d 00h 36m 31s in Longitude 30° 40′ W., the observed altitude of the Pole star out of the meridian was 61° 09′, height of eye 30 feet. Required the Latitude.

(5) On December 24 in Longitude 149° 30′ W., when a chronometer (corrected) indicated Mean time at Greenwich 15h 17m 40s, the sextant altitude of Polaris 42° 20′, index error 1·4′ off the arc, height of eye 26 feet. Required the Latitude.

(6) On January 10, in Longitude 20° 10′ E., when a chronometer (corrected) indicated Mean time at Greenwich January 9d 22h 53m 40s, the sextant altitude of the Pole star was 36° 02′, index error 1′ on the arc, height of eye 24 feet. Required the Latitude.

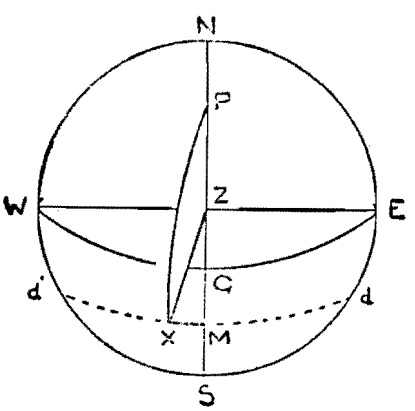
EX-MERIDIAN PROBLEMS.

The "Ex-Meridian" problem is given in Volume I., mainly in its application to the sun. We shall now proceed to give examples of all bodies worked by the "Ex-Meridian" and the "Intercept" methods, and show how to fix the ship's position by combining ex-meridian sights with position lines obtained from the observations of other bodies by the several methods described in Volume I.

EX-MERIDIAN (STAR).

Example I.

On June 15, DR position 33° 07′ N., 138° 30′ W., the observed altitude of the star *Fomalhaut* near the meridian was 26° 48·2′ South of the observer, height of eye 36 feet, time by chronometer 15h 13m 12s, which was 10m 08s fast of Mean time at Greenwich. Required the position line and the latitude where the position line crosses the DR longitude.



W Q E the equinoctial
W Z E the prime vertical
N Z S the observer's meridian
d M X d′ the parallel of declination
P the pole, *Z* the zenith, *X* the star at the time of observation, position exaggeration to show the *P Z X* triangle
M the position of the star when it was on the meridian
$\angle Z P X$ is the local hour angle of *X*
P Z the co-latitude
Z Q the latitude, which is the quantity required
P X the polar distance, which in this illustration is (90° +decl.)
Z X the zenith distance of the body at the time of observation
Z M the zenith distance of the body when it was on the meridian, that is its MZD.

Z Q the latitude is equal to (*Z M* − *Q M*), that is (MZD − decl.) and the purpose of the calculation is to find *Z M* 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 MZD 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 MZD 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 (*P M* − *P Z*) is equal to *Z M* then (*P X* − *P Z*) is assumed to be also equal to *Z M*, the meridian zenith distance, which we are out to find in triangle *P Z X*.

A D.R. latitude has to be introduced into the formula so that the latitude found by calculation must consequently be approximate, but when the body is suitably placed the result obtained is a very close approximation to the actual latitude.

If the calculated latitude should differ much from the D.R. latitude the triangle should be reworked, using the new latitude to obtain a nearer approximation, but a second working, however, should not be necessary.

Order of Work.

(1) Find the local hour angle of the body
(2) Correct the observed altitude.
(3) Apply the formula to find ($PZ \sim PX$) the meridian zenith distance, using PX, PZ, $\angle P$ and a D.R. co-latitude PZ.
(4) Apply the declination to the M.Z.D. and get the latitude at sights.
(5) Apply the sine formula in the PZX triangle and get the azimuth of the body for a position line.

	d	h	m	s
Chron.	15	15	13	12
Fast	—		10	08
G.M.T.	15	15	03	04

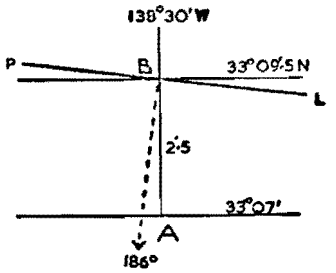
G.H.A. ♈ 15d 15h	128°	23·2′
Incre. 03m 04s	0	46·1
G.H.A. ♈	129	09·3
S.H.A.*	16	09·5
G.H.A.*	145	18·8
Long. W.	−138	30·0
L.H.A.*	6	48·8 (P)

Obs. Alt.	26°	48·2′
Dip	—	5·8
Corr.	—	1·9
True Alt.	26	40·5
	90	00
ZX	63	19·5 N.
Star's Decl.	29°	50·3′ S.
	90	00
Polar Dist.	119	50·3 (PX)
D.R. Lat.	33°	07′ N.
	90	00
Approx. co-lat.	56	53 (PZ)

Hav $(PZ \sim PX)$ = Hav ZX − Hav P Sin PZ Sin PX, for the M.Z.D.
Sin Z = Sin P Sin PX cosec ZX, for the azimuth.

P	6°	48·8′	log hav	7·54790	sin	9·07421
PZ	56	53	log sin	9·92302		
PX	119	50·3	log sin	9·93824	sin	9·93824
			log hav	7·40916		
			nat hav	0·00257		
ZX	63	19·5	nat hav	0·27554	cosec	0·04887
Mer. zen. dist.	62	59·8	nat hav	0·27297		
Declination	29	50·3				
					sin	9·06132
Latitude by obs.	33	09·5 N.				
Latitude by D.R.	33	07 N.			Azimuth S. 6° 37′ W.	
D. Lat.		2·5 N.			Position Line 096·6° − 276·3° T.	

The Position Line.



In the figure:

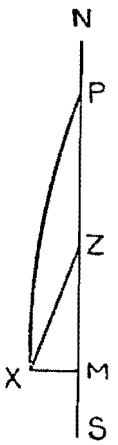
A is the D.R. position, Lat. 33° 07′ N., Long. 138° 30′ W.

AB is the D. Lat. 2·5′ N.

B is the amended D.R. position, 33° 09·5′ N. by observation, 138° 30′ W. by D.R., through which to draw the position line *PL*.

Another method of calculating the latitude by ex-meridian is by means of right angled spherical triangles. It was a popular method before the haversine formula was evolved and it possesses the merit of being independent of an estimated latitude which is an uncertain factor in the reduction formula.

PZMX shows the essential parts from the figure illustrating the foregoing example.



$\angle M = 90°$, we know the hour angle, the polar distance and the zenith distance of Fomalhaut from which to find *PZ* the co-latitude as follows.

In triangle PMX

(i) Sin *comp P* = tan *comp PX* tan *PM*
cos *P* = cot *PX* tan *PM*
tan *PM* = cos *P* tan *PX*—
tan *PM* = cos hour angle cot decl.

(ii) sin *XM* = cos *comp P* cos *comp PX*
sin *XM* = sin hour angle cos decl.

In triangle ZMX

(iii) sin *comp ZX* = cos *XM* cos *ZM*
sin alt sec *XM* = cos *ZM*
then arc *PM* — arc *ZM* = arc *PZ*, and 90° — *PZ* = latitude

Using the values given in the example we have

L.H.A.	6° 48·8′	cos	9·99693	sin	9·07421
Decl.	29 50·3	cot	10·24140	cos	9·93824
	59 59·2	Tan	10·23833	sin	9·01245
	180			*XM*	5° 54·5′
**PM*	120 00·8				
Alt·	26° 40·5			sin	9·65218
XM	5 54·5			sec	0.00231
ZM	63 10·3			cos	9·65449
PM	120 00·8				
Co-lat	56 50·5			Lat.	33° 09·5′ N.

*When the polar distance exceeds 90°, arc *PM* is also greater than 90° and, by the rule of signs, the arc taken from the Tables is then subtracted from 180° to yield arc *PM*.

EX-MERIDIAN (PLANET).

Example II.

On January 9, in DR 42° 20′ N., Long. 179° 30′ E., the sextant altitude of Jupiter near the meridian was 37° 22′, index error 1·2′ on the arc, height of eye 26 feet, time by chronometer which was correct Mean time at Greenwich 9d 18h 58m 57s. Required the latitude where the position line crosses the DR longitude. The vessel then steamed 075° T., for four hours at 10 knots, a current setting 130° T., at 2·5 knots. Required a position through which to draw the transferred position line.

LHA = GHA + E. Long.

GMT Jan. 9d 18h 58m 57s			Sext. alt.	37°	22·0′
GHA Jupiter 9d 18h	170°	46·2′	Index error	—	1·2
Incre. 58m 57s	14	44·3	Dip.	—	4·9
v corr. (2·2)		2·1	Corr.	—	1·3
GHA	185	32·6	True alt.	37	14·6
Long. E.	+ 179	30		90	00
LHA Jupiter	5	02·6 (P)	Zen. dist.	52	45·4

Decl. 10° 09·1′ S.

The formula

$$\text{hav}\,(PZ{\sim}PX)=\text{hav}\,ZX-\text{hav}\,P\sin PZ\sin PX$$

may be modified to

$$\text{hav}\,(PZ{\sim}PX)=\text{hav}\,ZX-\text{hav}\,P\cos\text{lat.}\cos\text{decl.}$$

thus saving two subtractions from 90°. When cos decl. is substituted the azimuth formula becomes sin Az=sin LHA cos decl cosec zen dist.

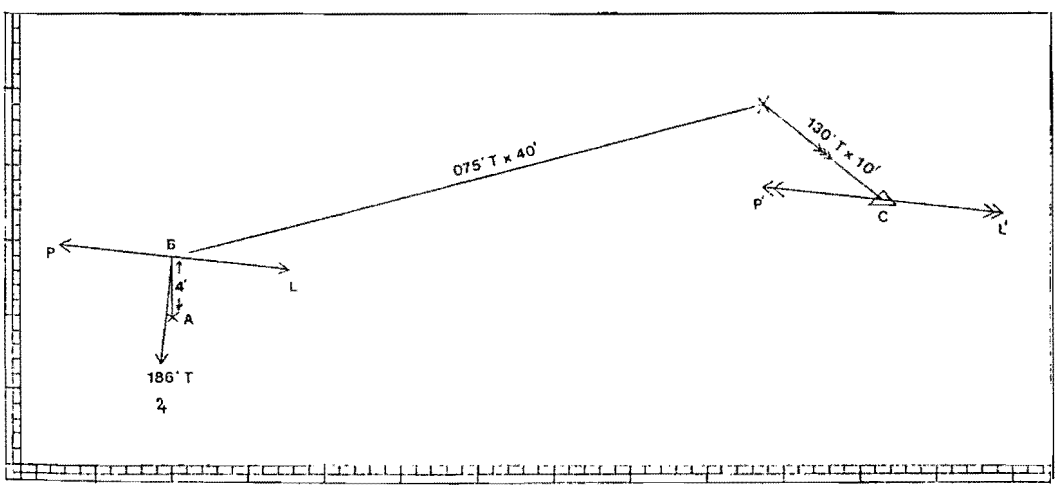
P	5°	02·6′		hav	7·28680	sin	8·94403
Lat.	42	20 N.		cos	9·86879		
Decl.	10	09·1 S.		cos	9·99315	cos	9·99315
				hav	7·14874		
			nat hav		0·00141		
ZX	52	45·4	nat hav		0·19739	cosec	10·09905
$(PZ{\sim}PX)$	52	33·1	nat hav		0·19598	sin	9·03623
M.Z.D.	52	33·1 N.					
Decl.	10	09·1 S.					
Obs. Lat.	42	24·0 N.					
D.R. Lat.	42	20·0 N.					
D. Lat.		4·0 N.					

Azimuth S. 6·1° W. or 186° T.
P.L. 096°—276° T.

Run *B* to *C*			D. Lat.		Dep.
Course	075° T.	40	10·4′ N.		38·6′ E.
Current	130° T.	10	6·4 S.		7·7 E.
			4·0 N.		46·3 E.
				D. Long.	60·5 E.

	Lat.	Long.
A	42° 20′ N.	179° 30′ E.
A to *B*	4 N.	0 00
B	42 24	179 30 E.
B to *C*	4 N.	1 00·5 E.
C	42 28 N.	180 30·5 E.
		360 00
		179 29·5 W.

Transfer the position line to Lat. 42° 28′ N., Long. 179° 29·5′ W.



In the figure:

A is the D.R. position.

A B the D. Lat. 4′ N. got from the ex-meridian of Jupiter.

B is a Latitude by observation, but a D.R. Longitude position through which to draw the position line *PL*.

C is the estimated point through which to draw the transferred position line *P′L′*, its accuracy being dependent on the correctness of the stated course and distance made good between *B* and *C*.

EX-MERIDIAN (MOON).

Example III.

(i) On December 21d 22h 01m 51s GMT, position by DR 39° 10′ N., 22° 30′ W., the observed altitude of the moon's upper limb was 64° 31′, height of eye 13·5 m. Required the Latitude and the position line.

(ii) At GMT 21d 22h 03m 02s DR Lat. 39° 10′ N. Long. 22° 30′ W., the observed altitude of Betelguese was 35° 28′ East of the meridian. Height of eye 13·5 m. Required the position line through the DR Long. and the ship's position as determined by combining both sights.

LHA = GHA − W. Long.

GMT Dec. 21d 22h 01m 51s

GHA Moon 21d 22h	19°	48·2′	Obs alt Moon UL	64°	31·0′
Incre 01m 51s	0	26·5	Dip	−	6·5
v corr (13·6)		0·3			
				64	24·5
GHA Moon	20	15·0	1st Corr.	+	35·1
Long W	−22	30	HP (U)	+	3·0
LHA Moon	357	45		65	02·6
				−	30
Decl 13° 37·0′ N.					
d (6·7) ·2			True Alt	64	32·6
Dec 13 37·2 N.			True Zen Dist	25	27·4

Hor Parlx 54·2

We might apply the "Ex-Meridian" formula in this example by way of a change.

Sin ½ red = hav LHA cos. Lat. ~ cos Decl. cosec *MZD*.

NOTE.—MZD = lat + decl when they are of opposite name, and lat ~ decl when the same name.

EHA	2° 15′	hav	6·58600
Lat.	39 10 N.	cos	9·88948
Decl.	13 37·2 N.	cos	9·98761
Approx. MZD	25 32·8	cosec	0·36527
½ red	2·3	sin	6·82836
Reduction	00° 04·6′		
Obs. Zen. Dist.	25 27·4		
MZD	25 22·8 N.		
Dec.	13 37·2 N.		
Lat.	39 00·0 N. by obs.		
Long.	22 30 W. by D.R.		

ABC Tables

A	20·6 S.
B	6·16 N.
C	14·44 S.

Azimuth 175° T.
P.L. 085°—265° T.

Example III.
(ii) Longitude by Betelguese.

G.M.T. Dec. 21d 22h 03m 02s.
G.H.A. Star=G.H.A. Aries+S.H.A. Star.

G.H.A. Aries	59°	57·7′	Obs. alt.	35°	28′
Incre.		45·6	Dip	—	6·5
S.H.A. Betelguese	271	45·3		35	21·5
G.H.A. ,,	332	28·6	Corr.	—	1·4
			True alt.	35	20·1
				90	
			True Zen. dist.	54	39·9

$$\text{hav } P = \frac{\text{hav } ZX - \text{hav } (L \sim D)}{\cos \text{Lat.} \cos \text{Decl.}}$$

ZX	54° 39·9′	nat hav	·21082	
(L—D)	31 46·1	nat hav	·07491	
		nat hav	·13591	
		log hav	9·13326	ABC Tables
Lat.	39 10 N.	log sec	10·11052	*A* ·68 S.
Decl.	7 23·9 N.	log sec	10·00363	*B* ·16 N.
P	49 43·5	log hav	9·24741	*C* ·52 S.
L.H.A.	310° 16·5′			Azimuth=S. 68° E.=112° T.
G.H.A.	332 28·6			P.L. 022°—202° T.
Obs. Long.	22 12·1 W.			
D.R. Long.	22 30 W.			
D. Long.	17·9 E.			
Dep.	13·9 E.			

Both Sights Combined.

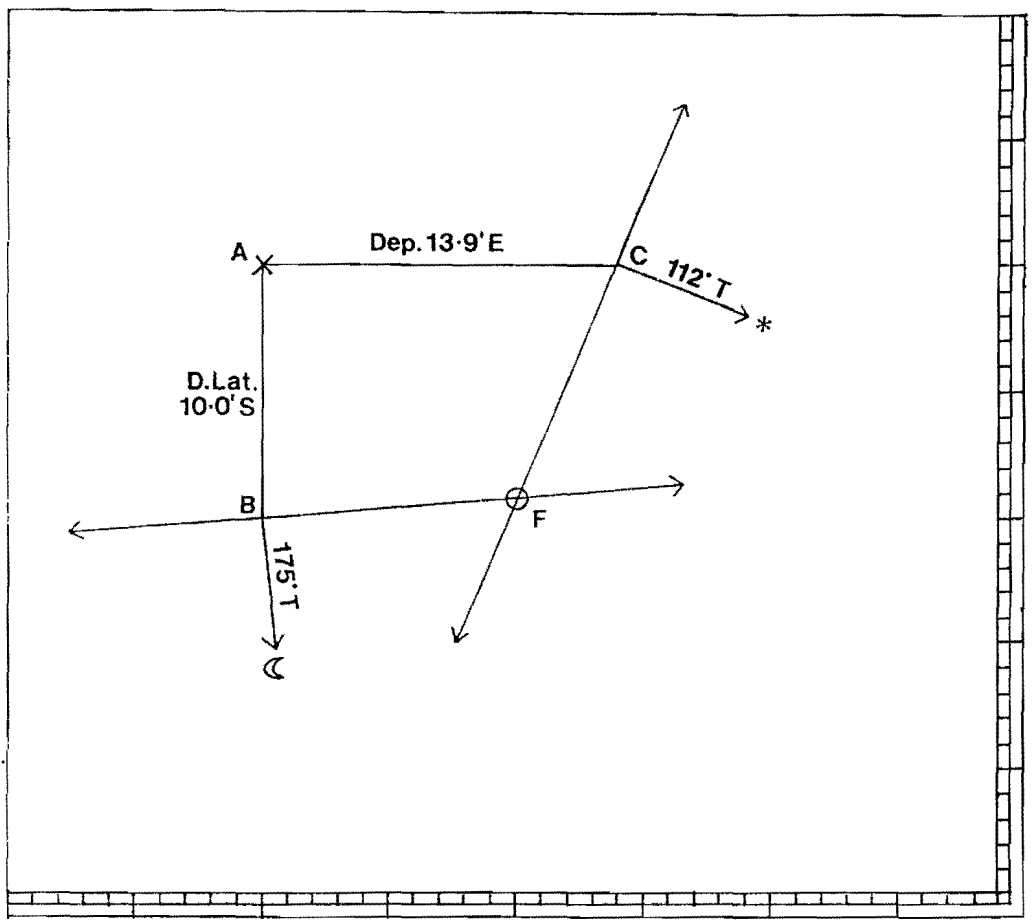
In the squared paper diagram:

A is an assumed position.
AB is D. Lat. 10′ S. from the moon's ex-meridian.
B is a Latitude by observation but a D.R. Longitude through which to draw position line *PL*.
AC is Dep. 13·9 miles East found by observation of Betelguese.
C is a Longitude by observation but a D.R. Latitude through which to draw position line *P′L′*.
F is the ship's position by observation.

To Transfer *A* to *F*.

	Lat.		Long.
A	39° 10′ N.		22° 30′ W.
A to *F*, D. Lat.	9·2 S.	(Dep. 10 miles)=D. Long.	12·8 E.
F	39 00·8 N.		22 17·2 W.

Ship's position Lat. 39° 00·8′ N., Long. 22° 17·2′ W.


A
Dep. 13·9'E
C
112°T
*
D.Lat.
10·0'S
B
F
175°T

EX-MERIDIAN POSITION LINE. INTERCEPT METHOD.

Example IV.

(i) December 28, about 2320 ship time, D.R. position Lat. 13° 50′ N., Long. 86° 36′ E., the sextant altitude of Canopus near the meridian was 23° 06′ South of the observer, eye 21 feet, index error 1·4 on arc. G.M.T. 28d 17h 34m 07s. Find the intercept and the position line.

(ii) At G.M.T. 28d 17h 34m 42s the same observer found the sextant altitude of Regulus to be 27° 29·5′. Find the intercept and the direction of the position line, also fix the ship's position by combining both sights.

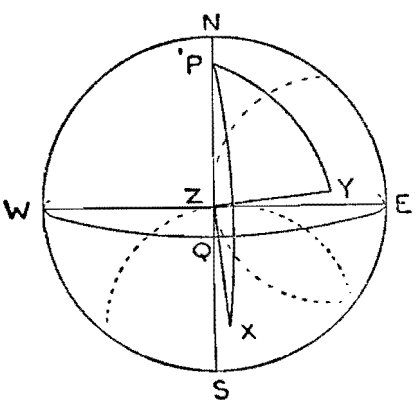
(i) Canopus.

L.H.A.=G.H.A. ♈ +S.H.A. +E. Long.

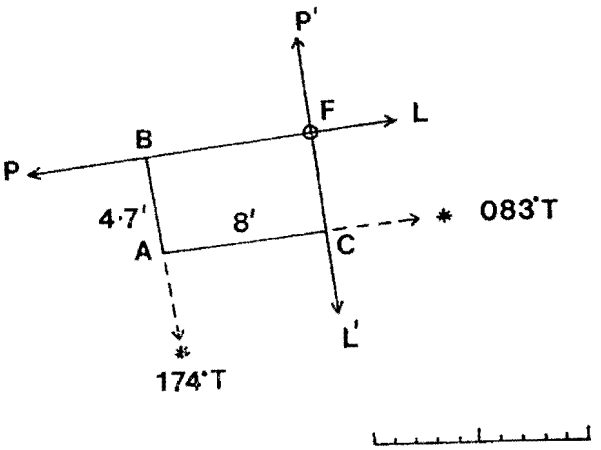
G.M.T. Dec. 28d 17h 34m 07s.

G.H.A. ♈ 28d 17h	351°	39·3′	Sext. Alt.	23°	06′
Incre. 34m 07s.	8	33·2	Index Error	—	1·4
G.H.A. ♈	000	12·5		23	04·6
S.H.A.*	264	13·8	Dip	—	4·4
G.H.A.*	264	26·3		23	00·2
Long. E.	+ 86	36	Corr.	—	2·3
L.H.A.*	351	02·3	True Alt.	22	57·9
				90	
Angle *P*	8	57·7	Zen. Dist. (Obs.)	67	02·1

Hav ZX=hav P sin PZ sin PZ +hav (PZ~PX)
or Hav ZX=hav P cos lat cos decl +hav (L +D)
and Sin az=sin P cos decl cosec ZX



P	8°	57·7′		hav	7·78558	sin	9·19250
Lat	13	50 N.		cos	9·93722		
Decl.	52	40·5 S.		cos	9·78271	cos	9·78271
				hav	7·55551		
				nat hav	0·00360		
(L+D)	66	30·5		nat hav	0·30069		
ZX	66	57·4		nat hav	0·30429	cosec	0·03617
Calc. zen. dist.			66°	57·4′		sin	9·01133
Obs. zen. dist.			67	02·1			
Intercept, away				4·7		Az. S. 5° 53·5′ E. P.L. 084°—264° T.	


P'
F
L
B
P
4·7'
8'
A
C
083°T
174°T
L'

(ii) The observation of Regulus when worked up gives calculated zenith distance 62° 46·2′, observed zenith distance 62° 38·2′, Intercept 8′ towards azimuth 083° T., P.L. 173°—353° T., which the student may verify for himself. The combined position lines are then plotted as shown on the squared paper diagram.

A is the D.R. position

AB the intercept 4·7′ away from Canopus and *PL* the position line drawn through *B* the intercept terminal point.

AC the intercept 8′ towards Regulus and *P′L′* the position line drawn through *C*, the intercept terminal point.

F is the ship's position—

A	13° 50′ N.		86 36′ E.
A to *F*, D. Lat.	5·5 N.	Dep. 7 miles=D. Long.	7·3 E.
F	13 55·5 N.		86 43·3 E.

Ship's position Lat. 13° 55·5′ N., Long. 86° 43·3′ E.

A Forenoon Position Line combined with an Ex-Meridian Position Line. (Sun).

Example V.

(i) On December 24, at 0838 at ship in D.R. position, Lat. 24° 43′ N., Long. 72° 57′ W., sights were taken for a position line. The sextant altitude of the sun's lower limb was 20° 46′, index error 1·5′ off the arc, eye 48 feet, G.M.T. 24d 13h 27m 55s. Required a position through which to draw the position line.

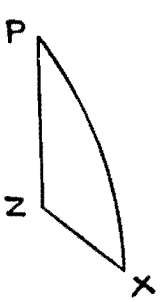
(ii) At 1138 hours on the same day an ex-meridian sight was taken, the ship's course being 330° T., speed 11 knots since 0838 when the position was assumed to be Lat. 24° 51′ N., Long. 73° 07′ W. Find the new position for working up the ex-meridian sight and also transfer the position line.

(iii) On December 24, at 1138 hours, position by D.R. Lat. 25° 19·5′ N., Long. 73° 25′ W., the observed altitude of the sun's lower limb was 40° 11·5′ South of observer, no index error, eye 48 feet, G.M.T. 24d 16h 15m 14s. Required the sun's true azimuth and the intercept, also the ship's position as determined by the position lines.

First work up the morning sights for a position line as follows:—

(i) L.H.A. Sun=G.H.A. Sun—W. Long.

G.M.T. Dec. 24d 13h 27m 55s.

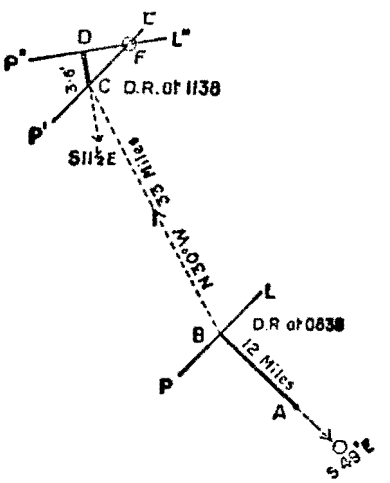


G.H.A. Sun 24d 13h	15° 07·6′	Sext. alt.	20° 46′
Incre. 27m 55s	6 58·8	Index error	+ 1·5
G.H.A.	22 06·4		20 47·5
Long. W.	— 72 57	Dip	— 6·7
L.H.A. Sun	309 09·4		20 40·8
		Corr.	+ 13·7
Angle *P*	50 50·6 E.	True Alt.	20 54·5
			90 00
		True zen. dist.	69 05·5

hav ZX = hav P cos lat cos decl + hav $(L \sim D)$

P	50°	50·6′	hav	9·26548	Azimuth from ABC Tables
Lat	24	43 N.	cos	9·95827	
Decl	23	25·4 S.	cos	9·96265	
			hav	9·18640	A ·37 S.
					B ·56 S.
			nat hav	0·15360	C ·93 S.
$(L+D)$	48	08·4	nat hav	0·16634	
Calc ZX	68	53·5	nat hav	0·31994	Azimuth S. 49° E.
True ZX	69	05·5			Position Line 041°—121° T.
Intercept		12·0 away			

Plotting the Position Line and Run.



(1) Plot the D.R. position at 0838 and name it A. Lay off the sun's true azimuth S. 49° E. from A and measure the intercept AB, 12 miles away. Through B draw the position line PL at right angles to the sun's bearing. The ship is somewhere on PL and B is the new D.R. position of which we have to find the latitude and longitude.

(2) Lay off the run BC N. 30° W., 33 miles, and transfer PL parallel to itself through C. Find the latitude and longitude of C. The ship is somewhere on the transferred position line $P'L'$ at the end of the run, not necessarily at C but somewhere near it.

(3) The ex-meridian sight is then worked up, using position C as D.R., and the intercept and sun's true azimuth found for a second position line.

Traverse Table.

INTERCEPT A B AWAY
N. 49° W., 12 miles.
D. Lat. 7·9 N.
Dep. 9·1 W., D. Long. 10′ W.

RUN B C
N. 30 W., 33 miles
D. Lat. 28·6 N.
Dep. 16·5 W., D. Long. 18·2′ W.

(i) and (ii)

	Lat.		Long.
D.R. Posn. A	24° 43′ N.		72° 57′ W.
D. Lat.	7·9 N.	D. Long.	10·0 W.
Posn. B	24 50·9 N.		73 07·0 W.
D. Lat.	28·6 N.	D. Long.	18·2 W.
Posn. C	25 19·5 N.		73 25·2 W.

(iii)

L.H.A. Sun = G.H.A. Sun − W. Long.

G.M.T. Dec. 24d 16h 15m 14s.

G.H.A. Sun 24d 16h	60°	06·6′	Obs. alt.	40°	11·5′
Incre. 15m 14s	3	48·5	Dip	−	6·7
G.H.A.	63	55·1		40	04·8
Long. W.	− 73	25·2	Corr.	+	15·1
L.H.A. Sun	350	29·9	True alt.	40	19·9
				90	00
Angle P	9	30·1 (E)	True zen. dist.	49	40·1

hav ZX = hav P cos lat cos decl + hav $(L \sim D)$

P	9° 30·1′	hav	7·83630
Lat.	25 19·5 N.	cos	9·95612
Decl.	23 25·3 S.	cos	9·96265
		hav	7·75507
		nat hav	0·00569
$(L+D)$	48 44·8	nat hav	0·17031
Calc. zen. dist.	49° 36·5		0·17600
True zen. dist.	49 40·1		
Intercept	3·6 away		

Azimuth from ABC Tables

A	2·83 S.
B	2·62 S.
C	5·45 S.

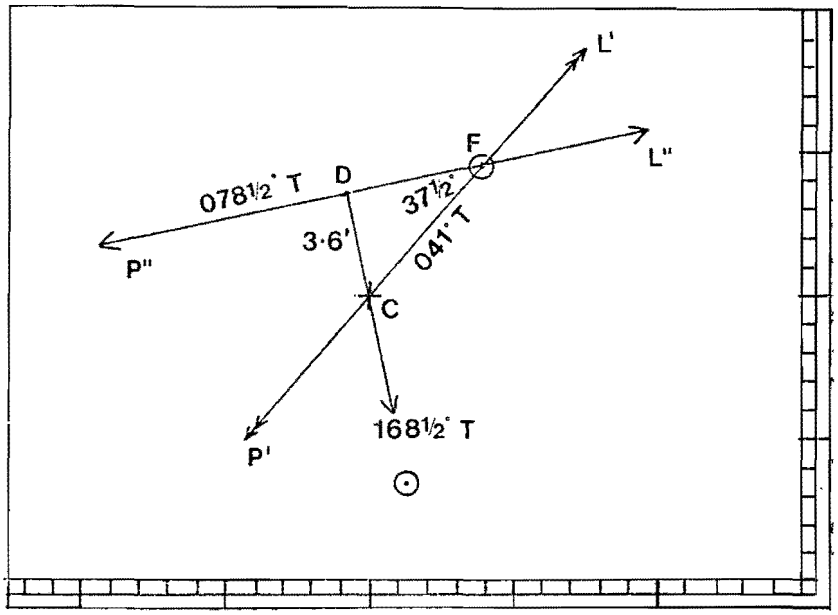
Position Line 078·5—258·5° T.

True Azimuth S. 11·5° E.

The above figure is on a reduced scale to illustrate the charting up to position C, but the triangle CDF is too small to enable us to measure the **D. Lat** and **Dep.** between C and F from the figure. Indeed, in practice, it is better to work up position C by the Traverse Table and leave only the transferred position line and the position line at second observation to be laid off on a scale large enough to transfer C to F by measurement. We shall now do so on squared paper.

(1) Mark a spot C and through it draw $P'L'$ the transferred position line N. 41° E., which is right angles to the azimuth S. 49° E. given in part (i).

(2) From C lay off the azimuth at ex-meridian observation, S. 11½° E., measure the intercept CD, 3·6 miles away, and draw the position line $P''L''$ which cuts $P'L'$ at F and gives us the position required.



(3) Count the number of squares (two to the mile) vertically between *C* and *F*. These are 4·5 ∴ D. Lat. is 4·5′ N. Count the number of squares horizontally between *C* and *F*. There are 4, which is 4 miles of departure to be turned into **D. Long.**

Lat. 25°, Dep 4 miles gives D. Long. 4·4′ E.

C Lat.	25° 19·5′ N.		Long.	73° 25·2′ W.
D. Lat.	4·5 N.		D. Long.	4·4 E.
F Lat.	25 24·0 N.		Long.	73 20·8 W.
		Lat.		Long.
Answers.—At 1138, position by D.R.		25° 19·5′ N.		73° 25·2′ W.
,, ,, obs.		25 24·0 N.		73 20·8 W.

To Shift Position C to F by Traverse Table.

In triangle *CDF* ∠*D*=90°, *CD*=3·6 miles. ∠*F* is the angle between the two position lines, which is always equal to the difference between the two azimuths: in this case the azimuths are S. 49° E. and S. 11½° E. so ∠*F*=37½°.

The length of *CF* is found by inspection from the Traverse Tables; angle 37¼°, *CD* 3·6 miles as **Dep.** gives *CF* as 5·9 miles in the **Dist.** column.

The direction from *C* to *F* is along the position line *P'L'* at right angles to the azimuth at 1st observation; the azimuth was S. 49° E., therefore *CF* is N. 41° E., distance 5·9 miles to be treated as a course and distance and applied to *C*.

Traverse Table.
C to *F*

∠*F* 37½°, *CD* 3·6 (Dep.)
Gives *CF* 5·9 (dist.)
CF is N. 41° E., 5·9 miles
D. Lat. 4·5 N.
Dep. 3·9 E., D. Long. 4·3 E.

	Lat.		Long.
C	25° 19·5′ N.		73° 25·2′ W.
CF, D. Lat.	4·5 N.	D. Long.	4·3 E.
F	25 24·0 N.		73 20·9 W.

At 1138, position by obs., Lat. 25° 24′ N., Long. 73° 21′ W.

DEGREE OF DEPENDENCE.

The position line at 1138 in the example we have worked is right. The transferred position line ($P'L'$) is at least right in direction but it is drawn N. 30° W., 33- miles from B and the ship may not have made that course and distance exactly so that $P'L'$ may be just a little ahead or behind where it should be. This however, is just one of the differences between theory and practice. The practical navigator learns to know from experience how much reliance to place upon the D.R., and during a three or four hour's straight run his reckoning is not likely to be more than a mile in error. The accuracy of the position by observation depends upon the ship making good the course and distance allowed between successive sights, and any error in this factor will probably be accentuated when the position lines cut each other at a small angle. The best "fix" is obtained when their angle of intersection is 90°, just as in a cross bearing "fix" of two shore objects.

Example VI.

(i) On June 15, at 1220 ship time, D.R. position Lat. 41° 21′ S., Long. 154° 16′E., the sextant altitude of sun's lower limb was 24° 49′ north of observer, index error 1′ off the arc, eye 32 feet, time by chronometer 2h 08m 16s which was 1m 10s fast on G.M.T. Required the position line and the Latitude and Longitude of the intercept terminal point.

(ii) On the same day at 1550 hours sights were taken for a position line, the ship having steamed 212° T., 10 knots during the 3½ hours since 1220 when the ship's position was assumed to be Lat. 41° 30·2′ S., Long. 154° 17·2′ E. Required the D.R. position for working the sights.

(iii) At 1550 hours, given D.R. position Lat. 41° 59·9′ S., Long. 153° 52·7′ E., the sun's azimuth 304° T., intercept 8′ towards. Required the ship's position, assuming the sun's azimuth for the transferred position line to be 354° T.

The ex-meridian sight in question (i) gives:—

June	d	h	m	s
Chron.	15	02	08	16
Fast	—		1	10
G.M.T.	15	02	07	06

G.H.A. sun 15d 02h	209°	57·4′
Incre. 07m 06s	1	46·5
G.H.A.	211	43·9
Long. E.	+154	16
L.H.A. Sun	5	59·9

Sext. Alt.	24°	49′
Index Error	+	1
	24	50
Dip	—	5·5
	24	44·5
Corr.	+	13·9
True alt.	24	58·4
	90	00
True zen dist	65	01·6

P	5°	59·9′	hav	7·43736
Lat.	41	21 S.	cos	9·87546
Decl.	23	16·9 N.	cos	9·96312
			hav	7·27594
			nat hav	0·00188
(*L*+*D*)	64	37·9	nat hav	0·28579
Calc. zen. dist.	64°	52·3′	nat hav	0·28767
True zen. dist.	65	01·6		
Intercept		9·3′ away		

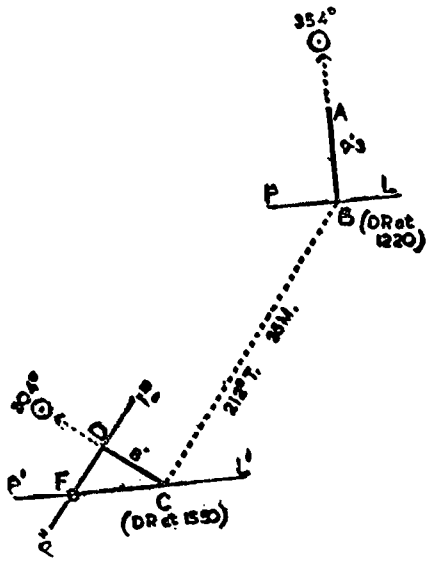
Azimuth Tables

A	8·37 N.
B	4·12 N.
C	12·49 N.

Azimuth N. 6·1° W. = 354° T.

P.L. 084°—264° T.

(i) In the figure, position A is the assumed position at the time of taking the ex-meridian sight at 1220; AB is the intercept 9·3 miles away, azimuth 354° T., and B is the D.R. position through which to draw the position line PL.

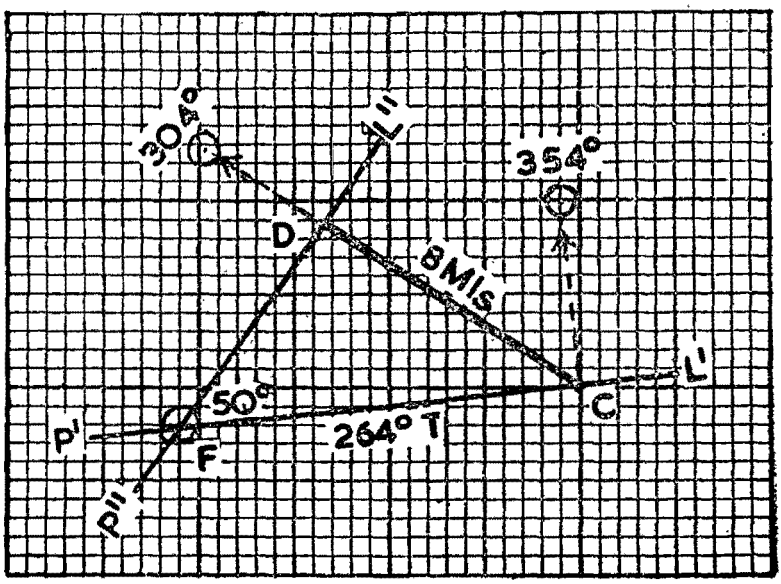


(ii) The run BC, 212° T., 35 miles, is laid off from B, and C now becomes the position at afternoon sights through which to draw the transferred position line $P'L'$. The ship is somewhere on this line at the end of the run.

Traverse Table.

		Lat.	Long.
(i) INTERCEPT A B			
174°, 9·3 miles	A	41° 21′ S.	154° 16′ E.
D. Lat. 9·2 S.	A B	9·2 S.	1·2E.
Dep. 1·0, D. Long. 1·3 E.			
	B	41 30·2 S.	154 17·2 E.
(ii) RUN B C	B C	29·7 S.	24·5 W.
212° W., 35 miles			
D. Lat. 29·7 S.	C	41 59·9 S.	153 52·7 E.
Dep. 18·5, D. Long. 24·5 W.			

(iii) The plotting of the position lines at *C* is best done on squared paper.



	Lat.		Long.
C	41° 59·9′ S.		153° 52·7′ E.
D. Lat.	1·1 S.	Dep. 10·5=D. Long.	14·0 W.
F	42 01 S.		153 38·7 E.

Answers—

(i) Azimuth 354° T., intercept 9·3 away, Lat. 41° 30·2′ S., Long. 154° 17·2′ E.
(ii) Lat. 41° 59·9′ S., Long. 153° 52·7′ E.
(iii) Lat. 42° 01′ S., Long. 153° 38·7′ E.

SUN

Examples for Exercise.

(1) A Forenoon Sight combined with an Ex-Meridian of the Sun.

(i) June 16, at 0935 ship's time, D.R. position 34° 48′ S., 163° 44′ E., sun's azimuth 036° T., intercept 10 miles towards. Required the position of the intercept terminal point for drawing in the position line.

(ii) On the same day at 1135 L.M.T. an ex-meridian sight was taken, ship's run 245° T., speed 12 knots since 0935. Required the latitude and longitude through which to draw the transferred position line.

(iii) June 16, about 1135 at ship, D.R. position 34° 50′ S., 163° 24·6′ E., sextant altitude of the sun's lower limb 31° 20′ North of observer, index error 1·4′ on the arc, eye 22 feet, time by chronometer 00h 42m 34s, which was fast 5m 21s on G.M.T. Required the sun's true azimuth and intercept, also the ship's position by observation as determined by position lines, assuming that the sun's true azimuth for the transferred position line to be 036° T.

(2) A Forenoon Position Line combined with an Ex-Meridian Position line.

(i) June 17, at 1000 L.M.T., D.R. position 48° 54′ N., 127° 52′ W., the azimuth of the sun was 127° T., intercept 10′ away. Required the latitude and longitude of the intercept terminal point through which to draw the position line.

(ii) On the same day about 1220 L.M.T., ex-meridian sights were taken, the ship having sailed 213° T., 40 miles since the morning sights were taken. Required the latitude and longitude through which to draw the transferred position line.

(iii) June 17, at 1220 ship's time, D.R. position 48° 26·5′ N., 128° 37·4′ W., observed altitude sun's lower limb 64° 23′, eye 24 feet, time by chronometer 20h 59m 44s which was 5m 16s fast on G.M.T. Required the intercept and the sun's true azimuth, also the position by observation, assuming the sun's azimuth for the transferred position line to be 127° T.

(3) An Ex-Meridian Position Line combined with an Afternoon Sight.

(i) June 22, about 1220 L.M.T., D.R. position 46° 01′ N., 35° 12′ E., sextant altitude sun's lower limb 66° 47′, index error 1·5′ off the arc, eye 30 feet, time by chronometer 22d 09h 50m 47s which was 12m 59s slow of G.M.T. Required the sun's true azimuth and intercept, also the latitude and longitude of the point through which to draw the position line.

(ii) On the same day at 1550 L.M.T., the ship having steamed 056° T., speed 12 knots since 1220, find the D.R. position for the transferred position line.

(iii) In the afternoon at 1550 the sun's azimuth was 265° T., intercept 5′ away, and D.R. position 46° 23·3′ N., 36° 01·7′ E. Required the ship's position by observation, assuming the sun's azimuth for the transferred position line to be 194° T.

(4) An Ex-Meridian Position Line combined with an Afternoon Position Line.

(i) January 7, about 10 minutes before the sun came to the meridian, D.R. position 56° 18′ S., 67° 22′ W., sextant altitude sun's lower limb 56° 01′ index error 1′ off the arc, eye 25 feet, G.M.T. 16h 25m 49s. Required the sun's true azimuth, intercept, and the latitude and longitude of the point through which to draw the position line.

(ii) From D.R. position 56° 07′ S., 67° 20·5′ W., ship steamed 145° T., 46 miles. Required the latitude and longitude for transferring the position line.

(iii) An afternoon sight worked for D.R. 56° 44·7′ S., 66° 32·4′ W., gave an intercept 8 miles away from sun's azimuth 296° T. Required the latitude and longitude of the observation position, assuming the azimuth of the sun for the transferred position line to be 004° T.

STARS, PLANETS, MOON.

Examples for Exercise

1. On January 10, D.R. position 14° 20′ S., 31° 22′ W., the observed altitude of the star Acrux near the meridian was 41° 34·5′, height of eye 26 feet, time by chronometer 07h 20m 10s which was 8m 06s slow of Mean time at Greenwich. Required the position line and the Latitude in which it crosses the D.R. Longitude.

2. (i) On June 17, D.R. position 48° 34′ N., 155° 30′ E., the observed altitude of the star Altair near the meridian was 50° 09′, height of eye 41 feet, G.M.T. 16d 16h 01m 26s. Required the position line and a position through which to draw it.

   (ii) If the ship steamed 035° T., 35 miles, find the Latitude and Longitude for the transferred position line.

3. (i) On October 12, D.R. position 36° 28′ N., 127° 41′ W., the sextant altitude of Sirius near the meridian was 36° 45′, index error 2′ on the arc, height of eye 45 feet, chronometer time 14h 06m 10s which was 11m 14s slow of G.M.T. Required the position line and the intercept terminal point.

   (ii) If the ship steamed 220° T. at 12 knots and current set 280° T., at 2 knots, find the position through which to draw the position line at the end of a 4 hours run.

4. June 19, D.R. position 38° 25′ S., 82° 16′ W., at G.M.T. 19d 11h 54m 09s the sextant altitude of Mars near the meridian was 50° 04′, index error 1′ off the arc, height of eye 40 feet. Find the latitude and the position line.

5. September 23, in D.R. Lat. 30° 20′ N., Long. 100° 50′ E., the sextant altitude of the moon's upper limb near the meridian was 46° 45′, index error 2′ off the arc, height of eye 30 feet, G.M.T. 23d 14h 14m 18s. Find the latitude in which the position line crosses the D.R. Longitude, also the position line.

6. January 8, in D.R. Lat. 36° 28′ S., Long. 127° 41′ W., the sextant altitude of the moon's lower limb was 42° 42′, index error 0·4′ on the arc, height of eye 52 feet, G.M.T. 8d 10h 25m 02s. Find the latitude in which the position line crosses the D.R. Longitude.

7. (i) June 16 at ship about 0650 hours L.M.T., D.R. Lat. 40° 06′ S., Long. 158° 11′ E., the observed altitude of Mars near the meridian was 49° 28′, height of eye 52 feet, when the chronometer which was 3m 12s fast of mean time at Greenwich showed 8h 10m 00s. Find the position line and a position through which it passes.

   (ii) The ship then steamed 140° C. (variation 14° E., deviation 6° E.) to counteract a current setting 090° M., drift 4 miles, the distance by log being 30 miles.

   (iii) At the end of the above run it was about 0840 hours L.M.T. on the 16th and the observed altitude of the sun's upper limb was then 11° 44′; and the same chronometer showed 10h 12m 12s. Find the ship's position at the time of the second observation.

8. (i) September 21, in D.R. Lat. 12° 18′ N., Long. 62° 12′ E., the sextant altitude of the moon's lower limb was 59° 41′, index error 1′ off the arc, height of eye 45 feet. G.M.T. 21d 15h 10m 10s. Find the position line and the latitude in which it crosses the D.R. Longitude.

(ii) If the ship then steamed 275° T., 45 miles, current setting 225° T., 6 miles, find a position through which to draw the transferred position line.

9. (i) September 23, D.R. position 30° 20′ N., 100° 50′ E., G.M.T. 23d 14h 14m 18s. the sextant altitude of the moon's upper limb near the meridian was 46° 45′, index error 2′ off the arc, height of eye 30 feet. Find the position line and the intercept terminal point.

(ii) Ship then ran 130° T., 48 miles, when the same sextant gave the altitude of the moon's upper limb 15° 13′, eye 30 feet, G.M.T. 23d 18h 20m 06s. Find the position at the time of taking the second observation.

10. (i) On September 23, G.M.T. 23d 03h 31m 50s, D.R. position 0° 24′ S., 26° 42′ W., the sextant altitude of star Achernar, near the meridian was 33° 05′, index error 1′ on the arc, height of eye 31 feet. Find the position line and a position through which to draw it.

(ii) At the same instant the observed altitude of Rigel was 39° 26′ (no index error), height of eye 31 feet. Find the intercept terminal point and plot the position lines to fix the ship's position.

11. (i) September 20, morning twilight at ship in D.R. position 56° 15′ N., 148° 25′ E., the observed altitude of Mars near the meridian was 51° 43′, height of eye 32 feet, a chronometer which had no error on mean time at Greenwich showed 6h 46m 40s. Find the position line and a position through which to draw it.

(ii) At the same instant the observed altitude of the star Pollux East of the meridian, was 43° 54′. Find the ship's position.

12. September 21, D.R. Lat. 36° 20′ N., Long. 18° 45′ W., G.M.T. 21d 19h 15m 09s, the observed altitude of Jupiter was 16° 47′, height of eye 60 feet.

At the same instant the observed altitude of the moon's upper limb was 33° 20′. Find the ship's position by combining both sights.

SIMULTANEOUS AND DOUBLE ALTITUDES
Examples for Exercise

1. January 9, in D.R. Lat. 32° 12′ S., Long. 80° 38′ E., G.M.T. 9d 14h 32m 12s, eye 35 feet, the observed altitude of Betelguese was 34° 34·5′ and Canopus was 50° 00′, both stars East of the meridian. Find the ship's position.

2. December 28, G.M.T. 20h 20m 06s, D.R. Lat. 11° 15′ N., Long. 32° 18′ W., height of eye 36 feet, the observed altitude of Fomalhaut was 42° 11·5′ and observed altitude of Deneb was 29° 26′, both stars West of the meridian. Find the ship's position.

3. June 15, about 0930 hrs. in D.R. Lat. 32° 04′ N., Long. 57° 18′ W., the observed altitude of Venus was 72° 45′ and the observed altitude of the Sun's lower limb was 55° 52′ when a chronometer which was slow 2m 06s on G.M.T. showed 1h 18m 01s. Height of eye 40 feet. Find the ship's position.

4. September 22, at ship, morning twilight, D.R. Lat. 42° 40′ N., Long. 171° 12′ E., chronometer showed 5h 53m 12s, no error, the observed altitude of Mars was 59° 48′, and when chronometer showed 5h 54m 20s the observed altitude of Procyon was 42° 01′, height of eye 55 feet. Find the ship's position.

5. September 26, about 0530 hrs. at ship in D.R. Lat. 13° 58′ N., Long. 78° 12′ W., the observed altitude of Sirius was 56° 33′ at G.M.T. 10h 42m 03s and the observed altitude of Mars was 62° 48′ at G.M.T. 10h 44m 00s, height of eye 30 feet. Find the ship's position.

6. December 21, at ship in D.R. Lat. 14° 03′ S., Long. 88° 05′ W., the observed altitude of the moon's L.L. was 61° 21′ and observed altitude of Adhara was 31° 21′, height of eye 45 feet G.M.T. 22d 02h 41m 43s. Find the ship's position.

7. September 23, G.M.T. 20h 07m 48s in D.R. Lat. 0° 24′ S., Long. 26° 42′ W., height of eye 39 feet, the observed altitude of Fomalhaut was 20° 34′ and the observed altitude of Saturn was 62° 05′. Find the ship's position.

8. December 28, at morning twilight, D.R. Lat. 35° 30′ S., Long. 80° 06′ W., a chronometer which was 2m 12s. slow on G.M.T. showed 9h 35m 50s., when the sextant altitude of Canopus was 42° 15′ and the sextant altitude of the moon's L.L. was 27° 50·5′. Index error 1′ off the arc, eye 40 feet. Find the ship's position.

9. January 8, in D.R. Lat. 25° 20′ N., Long. 155° 40′ E., the observed altitude of Capella was 47° 01′ at G.M.T. 08h 37m 04s, height of eye 28 feet. The ship then ran 100° T., 34 miles until G.M.T. 11h 37m 28s when the observed altitude of Capella was 69° 26′. Find the ship's position at second observation.

10. January 7, about 1400 hours at ship in D.R. Lat. 12° 04′ N., Long. 57° 18′ W., G.M.T. 7d 17h 54m 11s, the observed altitude of Venus was 64° 14′ and at the same time the observed altitude of the sun's L.L. was 44° 47′, eye 40 feet. Find the ship's position.

11. December 22, about 2015 hours at ship, D.R. Lat. 43° 08′ S., Long. 83° 25′ E., a chronometer showed 2h 49m 34s and was 8m 14s fast of G.M.T. when the observed altitude of Mars was 27° 53′ and at the same time Fomalhaut was observed to be 48° 05′, height of eye 30 feet. Find the ship's position.

12. September 20, in D.R. Lat. 24° 28′ S., Long. 156° 10′ E., about 1420 hours at ship, the observed altitude of Jupiter was 76° 27′, height of eye 45 feet, G.M.T. 20d 03h 58m 20.s Ship ran 060° T., 44 miles until G.M.T. 20d 07h 38m 06s when the observed altitude of Jupiter was 32° 33′. Find the ship's position at second observation.

13. June 24, in D.R. Lat. 46° 00′ N., Long. 22° 18′ W., the observed altitude of the moon's upper limb was 22° 02′, height of eye 60 feet, G.M.T. 24d 16h 15m 02s; the ship then ran 120° T., 48 miles until G.M.T. 24d 20h 49m 07s when the observed altitude of the moon's lower limb was 36° 28′. Find the ship's position at second observation.

14. January 10, in D.R. Lat. 35° 30′ N., Long. 151° 05′ W., the observed altitude of Spica was 41° 42′, G.M.T. 10d 15h 11m 27s, eye 65 feet; the ship then ran 230° T., 34 miles and the observed altitude of Regulus was then 28° 33′, G.M.T. 10d 17h 08m 56s. Find the ship's position at the second observation.

15. September 23, G.M.T. 23d 14h 10m 26s in D.R. Lat. 33° 40′ S., Long. 104° 12′ E., the observed altitude of the moon's L.L. was 67° 38′, near the meridian, height of eye 52 feet. At G.M.T. 23d 14h 10m 42s the observed altitude of Shaula was 45° 00′. Find the ship's position by combining the position lines.

CHAPTER VIII.

MISCELLANEOUS PROBLEMS ON PASSAGE FROM GLASGOW TO THE WEST INDIES

THE following series of examples for exercise have been made up for a vessel on passage from the Clyde to Mona Passage. The day to day navigation has been arranged progressively to include virtually all the questions of practical application that have been referred to in the text, the consecutive problems being set so as to be as independent of each other as possible, although, in some cases where one question runs into the next, it may be necessary to read the preceding one in order to get the sense of a question.

1. SWINGING SHIP FOR COMPASS DEVIATION.

September 15.—The ship was swung for deviation at the Tail of the Bank, Firth of Clyde, Lat. 55° 58′ N., Long. 4° 50′ W., and the following bearings of the sun were observed. GHA 30° 57·5′; Declination 3° 00′ N.; Variation 16° W.

Ship's Head Compass	Compass Bearing Sun	G M T
000° C	236° C	1436
045°	247°	1440
090°	251°	1444
135°	249·5	1448
180°	243°	1452
225°	234°	1456
270°	233·5	1500
315°	238·5	1504

Find the true azimuth of the sun from ABC Tables, thence the deviation for each direction on which the ship's head was steadied, then draw a curve of deviations on squared paper.

Ans.—Dev. 1·5° E ; 8·3° W ; 11·5° W ; 1·3° W ; 8·7° E ; 10·3° E ; 6·3° E.

2. A TRAVERSE.

September 15.

At 1230 hrs. GMT, dropped pilot and took departure from off Cloch Point (Lat. 55° 56½′ N., Long. 4° 52·6′ W.) bearing 098° T., distant 5 cables, set course 210° C. (variation 16° W., deviation 6° E.), log at zero.

At 1300 hrs., altered course 201° C. (Var. 16° W., Dev. 4° E.), log $4\frac{1}{2}$.

At 1359 hrs., Cumbrae Lighthouse (Lat. 55° 43·2′ N., Long. 4° 58′ W.) bore four points on the port bow, log $13\frac{1}{4}$, and at 1402 hrs. it was abeam, log $13\frac{3}{4}$.

Find the position on the beam bearing, the course and distance made good from the point of departure, and the set and drift, if any.

Ans.—Beam position Lat. 55° 43·3′ N., Long. 4° 58·9′ W.; course 193° T., distance 13·8 miles; set and drift nil.

3. BOW AND BEAM BEARING.

From the abeam position (Lat. 55° 43·3′ N., Long. 4° 58·9′ W.) off Cumbrae Lighthouse altered course 198° C. (error 14° W.) log $13\frac{3}{4}$.

At 1650 hrs. Ailsa Craig Lighthouse (Lat. 55° $15\frac{1}{4}$′ N., Long. 5° $06\frac{1}{4}$′ W.) was 45° on the starboard bow, log 39, and at 1710 hrs. it was abeam, log 42. Allow leeway 4° for a NW gale and a current setting 223° T. at 3 knots.

Find the beam position and the bearing and distance from Ailsa Craig at 1710 hrs.

Ans.—Beam position Lat. 55° 15′ N., Long. 5° 00·2′ W., bearing 094° T., distant 3·4 miles.

4. SET AND DRIFT OF CURRENT.

At 1710 hrs. in Lat. 55° 15′ N., Long. 5° $00\frac{1}{4}$′ W., with Ailsa Craig abeam, altered course 213° T., log 42, leeway 5°, wind N.W.

At 1857 hrs., altered course 185° T., log 58, ship making 5° leeway with wind on starboard beam.

At 2400 hrs., log 94.

Find the DR position and if the position by observation was Lat. 54° 19′ N., Long. 5° 06′ W.

Find the set and drift experienced since 1710 hrs.

Ans.—Set 144° T., drift 7·3 miles in 6·8 hrs. Rate 1·07 knots.

September 16.

5. D.R. POSITION AT NOON.

At 0000 hrs. (Lat. 54° 19′ N., Long. 5° 06′ W.) altered course 203° C. (Var. 18° W., Dev. 4° E.), log 94.

At noon, log 202.

Find the DR position at noon allowing for a current setting 144° T., 1·07 knots.

Ans.—Position at noon, Lat. 52° 21·7′ N., Long. 5° 21·6′ W.

6. POSITION BY BEARING.

At noon, log set at zero.

At 1600 hrs., log 40, Smalls Lighthouse (Lat. 51° 43′ N., Long. 5° 40′ W.) bore 110° T., distant 3 miles. Find the ship's position and the course and distance made good, and the average speed since noon.

Ans.—Position Lat. 51° 44′ N., 5° 44½′ W., course 201° T.; distance 40½ miles; speed 10·2 knots.

7. GREAT CIRCLE AND MERCATOR SAILINGS.

Find the initial course and distance on the great circle track from the position off the Smalls (Lat. 51° 44′ N., Long. 5° 44½′ W.) to Lat. 36° 00′ N., Long. 34° 33′ W. Find also the latitudes of points *C*, *D* and *E* every 10° along the track from Long. 10° W.

Find also the mercatorial courses and distances between these points along the track.

Ans.—Course 243° 44½′ T., distance 1546 miles; vertex Lat. 56° 15½′ N., Long. 26° 24′ E., Point *C*, Lat. 50° 18½′ N., Long. 10° W.; Point *D*, Lat. 45° 55′ N., Long. 20° W.; Point *E*, Lat. 39° 38½ N., Long. 30° W.

Mercator courses and distances 242° T., 182 miles; 237° T., 480 miles; 229·5° T., 580 miles; 224·5° T., 307 miles.

8. SETTING COURSE.

At 1600 hrs., in Lat. 51° 34′ N., Long. 5° 44½′ W., being of the Smalls, log. 40, course was set from chart 242° (Var. 18° W., Dev. 10° E.), allow 3° leeway for moderate N.W. gale. Find the compass course to steer.

Ans.—Course 253° C.

September 19.

9. FIX BY POSITION LINE AND RADIO BEARING.

At about 0745 hrs., ship time, log 198, having steered by compass 253° (error 8° W., allow leeway 3° for moderate N.W. gale) from Lat. 51° 44′ N., Long. 5° 44½′ W. when the log read 40, at 1600 hrs.

The observed altitude of the sun's lower limb was then 17° 42′, eye 50 feet. Chronometer showed 8h 19m 45s being fast 2m 30s on G.M.T. Required the position line.

At the same time Mizzen Head Ro D/F station (Lat. 51° 27′ N., Long. 9° 49·5′ W.) bore 330° (corrected). Find by plotting the ship's position by observation at 0745 hrs., and the set and drift of the current experienced since 1600 hrs. on the 18th, question 8.

(Chart S.W. Coast of Ireland No. 1123 used for plotting.)

Ans.—Fix at 0745 hrs., Lat. 50° 44′ N., Long. 9° 11′ W.; set 034° T., drift 17 miles. Intercept 4·2′ towards Az. 109·6° T.

10. STEAMING TIME AND SPEED.

Continued on the same course as above until noon the log then read 243. Find the D.R. position at noon allowing for a similar set and drift of current; find also the course and distance made good, the steaming time and the average speed since 1600 hrs.

Ans.—September 19 noon, D.R. Lat. 50° 26·8′ N., Long. 10° 09′ W.; Course 245° T.; distance 183 miles; steaming time 20h 17m; average speed 8·9 knots.

11. MERCATOR SAILING.

Find the mercatorial course and distance from the above noon position (Lat. 50° 27′ N., Long. 10° 09′ W.) to the next point *D* on the great circle track (Lat. 45° 55′ N., Long. 20° 00′ W.). Find also the compass course (Var. 19° W., Dev. 12° E.); log reset at noon to zero.

Ans.—Course 236° T., 243° C.; distance 480 miles.

12. A RUN AND FIX BY A.M. SIGHTS AND LATITUDE AT NOON.

About 0810 hrs. ship time, steered 245° C. (error 7° W., leeway 2° for N.W. wind), log 190 miles from noon position of the 19th (Lat. 50° 27′ N., Long. 10° 09′ W.).

The observed altitude of the sun's L.L. was then 21° 32′, eye 50 feet. Chronometer time 9h 01m 11s which was 2m 32s fast on G.M.T. Required the D.R. position, also the position by sights.

At noon, log 226. Observed meridian altitude of the sun's L.L. 42° 38′, eye 50 feet. Find the noon position combining both sights; the set and drift if any; the course and distance made good during the day, the steaming time and the average speed.

Ans.—D.R. at 0810, Lat. 48° 41′ N., Long. 14° 11·5′ W.; intercept terminal point Lat. 48° 37·6′ N., Long. 14° 00′ W., intercept 8·3′ towards. Position line 024°—204° T.

September 20, noon Lat. 48° 24·3′ N., Long. 14° 40·5′ W.

Course made good 235° T., distance 214 miles. Set 068° T., drift 10 miles= 0·42 knots; steaming time 24h 18m, average speed 8·8 knots. Log reset to zero.

13. RUN AND FIX BY STAR POSITION LINE.

Steering 244° C. (error 8° W.) from noon position Lat. 48° 24′ N., Long. 14° 40·5′ W.

At 1530 hrs. log 34, altered course 241° C. to allow 3° leeway for S.E. wind and sea.

About 1835 hrs. apparent time at ship, log 68, D.R. Lat. 47° 46′ N., Long. 16° 05′ W., the observed altitude of Altair was 47° 53·5′ East of meridian, eye 50 feet, G.M.T. 19h 38m 05s.

Almost simultaneously the observed altitude of Alphecca was 49° 47·5′ West of meridian, G.M.T. 19h 38m 12s. Find the ship's position and the set and drift experienced since noon.

Ans.—Lat. 47° 39′ N., Long. 15° 57·6′ W.; set 145° T., drift 8·6 miles=1·3 knots.

September 21.

14. FIX BY STAR POSITION LINES.

From Lat. 47° 39′ N., Long. 15° 57·6′ W., on September 20, at 1835 hrs., when log showed 68, steered 241° C. (error 10° W., allow 3° for S.E. wind and sea.)

About 0715 hrs. apparent time at ship, log 200, the observed altitude of Betelguese was 47° 30·5′ West of the meridian, G.M.T. 21d 08h 26m 24s, and the observed altitude of Mirfak was 52° 22′ West of meridian, G.M.T. 21d 08h 27m 08s, eye 50 feet.

Find the ship's position, the set and drift of current, the course and distance made good, the steaming time and the average speed between evening and morning star sights.

Ans.—D.R. Lat. 46° 21·4′ N., Long. 18° 34′ W.; Obs. Lat. 46° 30·7′ N., Long. 18° 21·5′ W.; course 235° T.; dist. 120 miles; set 044° T., drift 13 miles; steaming time 12h 49m; average speed 9·3 knots.

September 20.

15. POSITION LINE BY PLANET.

About 0715 hrs. altered course 256° C. (error 9° W.), log 200.

About 1000 hrs. log 224, D.R. Lat. 46° 21′ N., Long. 18° 53·5′ W., the observed altitude of Jupiter was 11° 00′ East of the meridian, G.M.T. 21d 11h 15m 28s, eye 50 feet. Find the position line and the intercept terminal point.

Ans.—Lat. 46° 15·4′ N., Long. 18° 38·8′ W.; P.L. 029°—209° T.

16. SUN MERIDIAN ALTITUDE' SET AND DRIFT.

At 1000 hrs. altered course 254° C. (error 7° W.) log 224; at noon log 240·5. The observed meridian altitude of the sun's lower limb was 44° 32′, eye 50 feet. Required the latitude by observation at noon and the longitude by combining the 1000 hrs. sight of Jupiter.

Required also, the course and distance made good, the set and drift of the current, and the steaming time and the average speed since noon on the 20th.

Ans.—Noon D.R. Lat. 46° 09′ N., Long. 19° 00·5′ W.; Obs. Lat. 46° 06·5′ N. Long. 19° 02·5′ W.; course 233° T.; 224 miles; set 105° T.; drift 23 miles steaming time 24h 17m; average speed 9·2 knots.

17. MERCATOR SAILING.

Find the course and distance by Mercator principle from the noon position on 21st, Lat. 46° 06·5′ N., Long. 19° 02·5′ W., to Point '*E*', Lat. 39° 39′ N., Long. 30° W., on the original great circle, as in Question 6.

Ans.—Course 231° 15′ T., distance 619 miles.

18. DAY'S WORK.

At noon (21st) course set 244° C. (error 12° W.), log reset at zero, noon position as above, Lat. 46° 06·5′ N., Long. 19° 02·5′ W.

September 22.

At noon (22nd), log 252. Find the estimated position allowing for a current estimated to have set East (mag.), Var. 20° W., drift 0·8 knots. Find also the estimated course and distance made good, the steaming time and the average speed.

Ans.—E.P. Lat. 43° 38′ N., Long. 23° 17·5′ W.; course 230·5° T.; distance 233·5 miles; steaming time 24h 17m; average speed 9·6 knots

September 23.

19. FIX BY STAR AND MARS.

At noon (22nd) the log was reset to zero. Continued on same course 244° C. (Error 12° W.) until 0400 hrs. on the 23rd, log 164. The observed altitude of Mars was 66° 19′ near the meridian, G.M.T. 23d 05h 45m 20s, eye 50 feet. At the same instant the observed altitude of Pollux was 44° 28′ East of meridian.

Find the ship's position and the set and drift experienced since the last observation at noon on 21st, Question 16, viz., Lat. 46° 06·5′ N., Long. 19° 02·5′ W.

Ans.—D.R. Lat. 41° 57′ N., Long. 26° 14′ W.; Obs. Lat. 42° 07′ N., Long. 26° 24′ W.; D.R. from 21st noon, Lat. 41° 50′ N., Long. 26° 38′ W.; set 031° T.; drift 19 miles in 40·5 hours.

20. FIX BY POSITION LINES OF SUN AND SATURN.

September 23, at 1600 hrs., having steamed 244° C. (Error 17° W.) for 130 miles from 0400 position (Lat. 42° 07′ N., Long. 26° 24′ W.) the observed altitude of the sun's L.L. was 22° 00′, G.M.T. 23d 17h 46m 56s, eye 50 feet.

About 1800 hours having steamed a further 22 miles on the same course, the observed altitude of Saturn was 26° 55′, G.M.T. 23d 19h 50m 42s. Find the ship's position at second observation.

Ans.—1st D.R. Lat. 40° 38·3′ N., Long. 28° 30′ W.; 2nd D.R. Lat. 40° 24′ N., Long. 28° 48′ W.; Sun azimuth 250° T., Intercept 2·7′ away. Saturn Azimuth 193° T., intercept 4·2′ towards Fix. Lat. 40° 19·5′ N., Long. 28° 46′ W.

September 24.

21. RIGEL AND SUN.

September 24, about 0612 hrs. in D.R. Lat. 38° 47′ N., Long. 30° 22′ W., the observed altitude of Rigel was 39° 42′, G.M.T. 24d 08h 22m 14s, height of eye 50 feet. The ship then steamed 232° T., for 31 miles through a current estimated to have set 130° T., at ¾ of a knot, until 0900 hrs. when the observed altitude of the sun's lower limb was 32° 51′, G.M.T. 24d 10h 53m 47s.

Find the ship's position at second observation.

Ans.—Obs. Lat. 38° 27·3′ N., Long. 30° 58·5′ W.

22. COURSE AND DISTANCE.

Find the true course and distance from Lat. 38° 27′ N., Long. 30° 58′ W., to Lat. 36° 00′ N., Long. 34° 33′ W.

Ans.—Course 229·5° T., distance 226 miles.

23. A GREAT CIRCLE.

Find the initial course and distance on the great circle track from Lat. 36° 00′ N., Long. 34° 33′ W., to a position in the Mona Passage, Lat. 18° 30′ N., Long. 67° 45′ W. Find also the position of the vertex and the latitudes of points every 10° from longitude 50° W.

Ans.—Course 248° T., distance 2043 miles; Vertex Lat. 41° 24′ N., Long. 00° 08′ W.; points 29° 34′ N., in 50° W.; 23° 49′ N. in 60° W.

September 25.

24. MARS AND SIRIUS.

September 25, about 0530 hrs., in D.R. Lat. 36° 00′ N., Long. 34° 33′ W., at G.M.T. 25d 07h 23m 48s the observed altitude of Mars West of the meridian was 61° 36′ and of Sirius 35° 24′ East of the meridian, eye 50 feet.

Required the position.

Ans.—Lat. 35° 56·5′ N., Long. 34° 39′ W.

25. VENUS—RUN—VENUS.

At 0530 hrs. on 25th in Lat. 35° 57′ N., Long. 34° 39′ W., altered course 281° C. (Var. 22° W., Dev. 11° W.) log 85.

At about 1110 hrs. on the same day log 147 G.M.T. 25d 13h 32m 55s the observed altitude of Venus was 59° 54′, eye 50 feet, and again about 1500 hours when log read 184 the observed altitude of Venus was 28° 09′, G.M.T. 25d 17h 23m 00s.

Required the ship's position at second observation.

Ans.—Mer. Alt. Lat. 35° 32·6′ N.; 2nd D.R. Lat. 35° 18·7′ N., Long. 36° 32′ W. Intercept 3·8′ away. Azimuth 254° T. Fix Lat. 35° 18·7′ N., Long. 36° 26′ W.

September 26.

26. ALTAIR AND MOON.

At about 1500 hrs. on 25th in Lat. 35° 19′ N., Long. 36° 26′ W., altered course 280° C. (Error 32° W.).

At about 1900 hrs. on 26th G.M.T. 26d 21h 36m 20s the observed altitude of Altair was 63° 47·5′ and at the same instant the observed altitude of the moon's lower limb was 19° 32′, eye 50 feet.

The distance by log from 1500 hrs. was 310 miles and the current was estimated to have set 150° T., 11 miles.

Find the ship's position.

Ans.—D.R. Lat. 33° 13·4′ N., Long. 42° 07′ W.; Obs. Lat. 33° 23·5′ N., Long. 42° 11′ W.

27. AN S.O.S. CALL.

At about 1900 hrs. L.M.T., September 26, in Lat. 33° 24′ N., Long. 42° 11′ W., altered course to 270° C. (Error 30° W.) log 90.

At G.M.T. 27d 03h 56m 38s log 185, an S.O.S. was picked up from a ship in Lat. 30° N., Long. 60° W., hove to in a hurricane moving north-easterly. Find the compass course to reach her, and if your maximum speed is 12·5 knots, find the L.A.T. of arrival (Var. 20° W., Dev. 8° E.).

Ans.—Course 271° C., distance 845 miles L.A.T. 29d 19h 40m.

September 27

28. POLE STAR.

At about 0105 hours L.M.T. In D.R. Lat. 32° 14′ N., Long. 43° 49′ W., G.M.T. 04h 00m 20s, the observed altitude of the Pole Star was 33° 16′, eye 50 feet. Find the latitude.

Ans.—Lat. 32° 12·2′ N., Long. 43° 49′ W., bearing North.

September 28.

29 MARS AND SIRIUS.

At about 0530 hours on September 28, having steamed 373 miles from last position (32° 12′ N., 43° 49′ W.) course 273° C. (Error 11° W.) G.M.T. 28d 08h 55m 56s. observed the altitude of Mars 68° 22′ West of meridian and of Sirius 40° 59′ East of meridian. Required the ship's position by D.R. and by observation.

Ans.—D.R. Lat. 31° 20′ N., Long. 51° 04′ W. Obs. Lat. 31° 16′ N., Long. 51° 09′ W.

30. D.R. POSITION AND MERCATOR SAILING.

Find the D.R, position at Noon on the 28th having steered 262° T., at speed 13 knots from 0530 position (31° 16′ N., 51° 09′ W.). Find also the course and distance from your noon position to the latest position of the vessel in distress (Lat. 30° 25′ N., Long. 59° 40′ W.) also the L.A.T. of arrival.

Ans.—Noon D.R. Lat. 31° 04·4′ N., Long. 52° 45′ W., 264° T., 360 miles; L.A.T. 29d 15h 13m.

31. RESETTING COURSE.

At G.M.T. 28d 22h 40m 00s, log 91, received radio message from disabled ship that no assistance would be required. Find the D.R. position and thence the course and distance to a position 310° T., 15 miles from Mona Island light (Lat. 18° 04′ N. Long. 67° 56′ W.), also the L.AT. of arrival assuming an average speed of 10·5 knots.

Ans.—D.R. Lat. 30° 55′ N., Long. 54° 31′ W.; course 225° T., distance 1081 miles, L.A.T. Oct. 3d 01h 13m.

September 29.

32. D.R. POSITIONS

At G.M.T. 28d 22h 50m, altered course 224° T., speed 10 knots, D.R. position Lat. 30° 55′ N., Long. 54° 33′ W.

About 0300 hours Sept. 29 at ship when G.M.T. was 29d 06h 55m, engines were stopped to effect repairs, wind East force 5, estimated leeway 1 knot, estimated

current setting 300° T., 2·5 knots, for the period under repair.

About 1340 hours, at G.M.T. 29d 17h 25m, repairs completed, find the estimated position. Resumed full speed 10 knots, course 224° T. (Variation 17° W., Deviation 10° E.) give the compass course.

Ans.—Lat. 30° 07′ N., Long. 56° 07′ W.; course 231° C.

September 29.

33. STAR POSITION LINE.

At about 1750 hours, G.M.T. 29d 21h 40m 10s, having steamed 224° T., 45 miles since getting under way at 1340 hours when the D.R. position was Lat. 30° 07′ N., Long. 56° 07′ W., the observed altitude of Antares was 27° 19′, height of eye 50 feet, and bearing 216° by compass. Find the Longitude in which the position line crosses the D.R. Latitude, and also the error of the compass.

Ans.—D.R. Lat. 29° 34·6′ N., Long. 56° 33·4′ W.; P/L 120-300° T., error 6° W.

34. STARS MERIDIAN PASSAGE.

Find the Mean time at ship to the nearest minute when Vega will be on the meridian, September 29 in Lat. 29° 35′ N., Long. 56° 45′ W., and find the altitude to set on the sextant, no index error, eye 50 feet.

Ans.—18h 03m, 80° 57′ north of observer.

EXAMINATION PAPERS

PAST EXAMINATION PAPERS SUITABLE FOR CLASS 4—CLASS 1 MASTER MARINER EXAMINATION CANDIDATES.

PRACTICAL NAVIGATION.

Paper 1. (*3 hours.*)

1. From the following data find the position of the ship:—Date at ship September 26, about 23h in DR Lat. 38° 10′ N, Long. 32° 20′ W.

   1st Obs.—Observed altitude Moon's lower limb 51° 04′, near the meridian, chronometer time 1h 35m 14s.

   2nd Obs.—Observed altitude star Aldebaran 24° 58′ when the same chronometer showed 1h 36m 08s. HE 12 m. Chronometer slow on GMT 1m 06s.

2. Find the initial course and the distance on the great circle track from Cape Clear (Lat. 51° 25′ N, Long. 9° 29′ W) to New York (Lat. 40° 43′ N, Long. 74° 07′ W) and the latitude and longitude of the vertex.

3. On Sept. 19, about 2010h at ship in DR Lat. 47° 00′ N, Long. 37° 00′ W, the sextant altitude of Polaris was 47° 04′ when a chronometer which was 2m 40s slow of GMT showed 10h 40m 00s. HE 9 m. Index error 1′ on the arc. Required the Latitude and position line.

4. On September 26, in Lat. 49° 50′ N, Long. 22° 00′ W, the star Bellatrix bore 091° C. at 23h 46m LMT. Required the true azimuth and error of the compass. If the variation is 20° W, what will be the deviation

5. Find the LMT on January 11 when the star Menkar will be on the meridian in Lat. 19° 15′ S, Long. 47° 15′ W. State whether the star will be N or S of the observer.

Paper 2. (*3 hours.*)

1. On December 25, about 1400h at ship in DR Lat. 46° 28′ N, Long. 179° 58′ W, the observed altitude of the sun's lower limb was 14° 32′, height of eye 14 m, GMT 2h 05m 54s.

   Ship then ran 292° T. at 10 knots through a current estimated to set 180° T at 2 knots until next day at GMT 22h 06m 00s when a point of land in Lat. 47° 03′ N, Long. 176° 13′ E bore 050° T. Find the position of the ship at the time of 2nd observation.

2. From the following data find the Latitude and position line:—GMT September 19d 00h 55m 00s, observed altitude of Polaris 51° 22′, height of eye 7·7 m. DR Lat. 50° 40′ N, Long. 28° 30′ W.

3. On September 26 in DR Lat. 45° 20′ S, Long. 132° 15′ W, required the LMT of meridian passage of the Moon.

The sextant meridian altitude of the moon's upper limb was 42° 48′. index error 2′ on the arc, height of eye 36 feet. Find the latitude and the position line.

4. The position of the vertex of the great circle from Port Jackson to Valparaiso is Lat. 60° 54′ S., Long. 140° 40′ W. Calculate the latitudes at which the great circle track crosses the meridian of 159° 20′ E., and thence every 10th degree to destination, and plot the points on a mercator's chart.

Port Jackson—Lat. 33° 52′ S., Long. 151° 16′ E.

Valparaiso—Lat. 33° 01′ S., Long. 71° 52′ W.

Paper 3. (*3 hours.*)

1. On September 27, about 1600h L.M.T. in D.R. position Lat. 52° 20′ N., Long. 5° 40′ W., the observed altitude of the sun's lower limb was 15° 09′, height of eye 50 feet, G.M.T. 16h 21m 50s. The ship then ran 359° T., for 16 miles until G.M.T. 27d 18h 41m 47s when the observed altitude Altair was 44° 22′. Find the ship's position at the time of the 2nd observation.

2. On November 27, at 0830h A.T.S., it was ascertained that the ship was on the position line 050°-230° T., passing through D.R. Lat. 50° 10′ N., Long. 27° 30′ W., the log registering 97.

At 1140h A.T.S. an ex-meridian observation of the sun gave Latitude 50° 35′ N., log 25.

In the interval the ship steered 322° T., to allow for a current estimated to set 090° T., at 1 knot.

Find by calculation, or by plotting, the position of the ship at 1140 hours.

3. The ship's head by compass being in turn on the eight principal points of the compass, and the compass bearing of a distant object on each course being as stated below, find the magnetic bearing of the object and construct, on squared paper, a deviation curve.

Compass Course	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
Compass bearing	255°C.	244°C.	236°C.	230°C.	214°C.	211°C.	229°C.	251°C.

From the curve ascertain the deviation for the following compass courses. N.N.E., E.N.E., N.N.W., and W.N.W.

4. On September 20, the sextant meridian altitude of the star Rigel, south of the observer, was 44° 53′. Index error 2′ on the arc, height of eye 87 feet. Required the latitude.

Paper 4. (*3 hours.*)

1. On September 26, about 1815h at ship in D.R. Lat. 35° 20′ N., Long. 36° 22′ W., the observed altitude of the moon's lower limb, east of the meridian, was 12° 48′, G.M.T. 26d 20h 40m 28s. Height of eye 35 feet. Find the position line and a position through which to draw it.

(*b*) At G.M.T. 26d 20h 41m 04s, the observed altitude of Nunki near the meridian was 28° 22′, height of eye 35 feet. Find the Latitude and position line and also the position by observation.

2. On September 16, at 0100h a point of land in Lat. 44° 20′ S., Long. 100° 08′ E., bore 4 points on the port bow and at 0200 it was abeam; variation 6° E., deviation 0°. Ship steamed the following courses during the day:—

   Noon to 2200: Course 160° C., Dev. 2° E., Speed 12·4 knots.
   2200 to 0600: Course 152° C., Dev. 0°, Speed 12·25 knots.
   0600 to Noon: Course 146° C., Dev. 2° E., Speed 13·5 knots.

   Find the course and distance made good during the 24 hours and the position of the ship at noon next day.

3. On January 7, at 05h 04m 15s G.M.T. in D.R. Lat. 34° 50′ N., Long. 24° 16′ E., the sextant altitude of Polaris was 34° 00′, index error 2′ on the arc, height of eye 28 feet. Required the latitude and position line.

4. Required the difference between the great circle distance and the Mercator distance from Lat. 48° 25′ N., Long. 123° 15′ W., to Lat. 21° 20′ N., Long. 157° 48′ W.

Paper 5. (3 *hours.*)

1. On January 25 at L.M.T. 0920, log 17, the ship was found to be on a position line 160-340° T., D.R. position Lat. 49° 25′ N., Long. 179° 50′ E. Ship steamed on course 080° T., till noon, during which time a current was estimated to set 125° T., at 1·5 knots. At noon, log 45, the latitude by meridian altitude was found to be 49° 34′ N. Find by calculation, or by plotting, the ship's position at noon.

2. The position of the vertex of the great circle from *A* Lat. 48° 26′ N., Long. 161° 24′ E. to *B*, Lat. 37° 54′ N., Long. 142° 46′ W., being Lat. 48° 46·4′ N., Long. 170° 14·7′ E. Calculate the latitudes at which the great circle track crosses the meridian of 170° E. and each 10th degree of longitude from it towards the destination and plot the track on the Mercator's chart provided.

3. On September 28 G.M.T. 27d 23h 17m 42s in D.R. Lat. 40° 56′ S., the observed altitude of Procyon, east of the meridian was 23° 09′, height of eye 42 feet. Find the longitude in which the position line crosses the D.R. Latitude.

4. On September 20 L.M.T. 05h 04m 00s at ship in Longitude 152° 30′ E., the sextant altitude of Polaris was 36° 46′, index error 2′ on the arc, height of eye 39 feet. Required the latitude and position line.

Paper 6. (3 *hours.*)

1. Find the initial and final courses and the distance on the great circle track from Sydney (Lat. 33° 52′ S., Long. 151° 18′ E.) to San Francisco (Lat. 37° 42′ N., Long. 123° W.) and the position of the vertex of the great circle.

2. Find the true course and distance by use of meridional parts between (*A*) Lat. 43° 08′ N., Long. 5° 56′ E., and (*B*) Lat. 39° 29′ N., Long. 0° 24′ W.

3. At midnight the ship bore 300° T., distant 20 miles from Lundy Island Light in Lat. 51° 10′ N., Long. 4° 40′ W. She then sailed 168° T., 35 miles, 230° T., 68 miles, and a current set 045° T., 15 miles. Find the position arrived at.

4. Cape Amber (Lat. 11° 57′ S., Long. 49° 18′ E.) bore 248° C., at 1800 hours, error 8° W., distant 20 miles. Stellar obs. at midnight placed the ship in Lat. 12° 34′ S., Long. 50° 12′ E.

   Noon to 2000: Course 101° C., Dev. 3° W., Var. 5° W., Speed 10 knots.
   2000 to noon: Course 156° C., Dev. 5° W., Var. 5° W., Speed 9·5 knots.

   Find the set and drift experienced between 1800 and midnight, and allowing for a similar set and drift throughout the day, find the course and distance made good from noon to noon, also the position at noon.

Paper 7. (3 *hours.*)

1. On January 8, D.R. Lat. 46° 20′ N., Long. 19° 15′ W., find the L.A.T. of meridian passage of Venus, and compute the altitude to set on the sextant, index error 1′ on the arc, height of eye 36 feet. If the sextant meridian altitude was observed to be 30° 18′, find the latitude.

2. On January 5, in D.R. Lat. 31° 35′ S., Long. 110° 08′ E., the obs. mer. alt, of the moon's upper limb was 89° 43′, height of eye 35 feet. Find the latitude and position line.

3. On September 19, at L.M.T. 05h 22m in D.R. Lat. 22° 00′ N., Long. 65° 48′ W., the sextant altitude of the Pole star was 22° 41′, index error 1′ off the arc, height of eye 36 feet. Required the latitude and position line.

4. On October 30, in D.R. Lat. 51° 10′ S., Long. 00° 20′ W., at 1510 A.T.S., log 83, the ship was found by observation to be on a position line 063°-243° T. At 21h 55m A.T.S. an ex-meridian observation of the moon gave Lat. 51° 50′ S., log 37. Ship steamed 130° T., between observations. Find by calculation or by plotting, the position of the ship at 21h 55m.

5. On December 24, in D.R. Lat. 12° 20′ S., Long. 45° 00′ W., the following observations were taken:

   (*a*) Observed altitude Jupiter 34° 08′ east of meridian, G.M.T. 24d 08h 20m 10s.

   (*b*) Observed altitude Denebola near the meridian 62° 38′, G.M.T. 24d 08h 21m 20s, height of eye 40 feet.

   Find the ship's position by means of position lines.

Paper 8. (3 *hours.*)

1. On September 25, in D.R. Lat. 16° 50′ N., Long. 113° 48′ E., the sextant meridian altitude of the moon's upper limb was 67° 31′, index error 2′ off the arc, height of eye 25 feet. Required the latitude.

2. On January 12, in D.R. Lat. 59° 18′ N., Long. 85° 30′ W., find the G.M.T. of transit of Betelguese, and compute the altitude to set on a sextant having an index error of 2′ off the arc; eye 40 feet.

3. On September 27, in D.R. Lat. 48° 52′ S., Long. 45° 10′ E., the observed altitude of the sun's upper limb was 28° 38′ when the chronometer, which was 5m 18s slow on G.M.T. showed 5h 39m 32s. The ship then ran 320° T., 46 miles until noon, when the observed altitude of the sun's lower limb was 43° 07′, height of eye 35 feet. Find the ship's position at noon.

4. Steering 107° C. (error 17° W.), Portland Bill (Lat. 50° 31′ N., Long. 2° 27′ W.) bore four points on the port bow and after steaming 9 miles the Bill was abeam. Find the position of the ship on the beam bearing making allowance for a current setting 225° T., 2 miles, and leeway for a N.W. gale 10°.

5. If the position of the vertex of the great circle from Tristan da Cunna to Java Head is Lat. 42° 37·3′ S., Long. 22° 38·6′ E., calculate the latitudes of the points where the great circle crosses the meridians of 10° W. and each 10th degree from it to the destination, and plot the points on a Mercator's chart.
Tristan da Cunha. Lat. 37° 02′ S., Long. 12° 17′ W.
Java Head. Lat. 6° 47′ S., Long. 105° 13′ E.

Paper 9.—Chartwork.

3 hours.

English Channel Practice Chart.

1. From a position with Bishop Rock bearing 300° T., and Lizard Light bearing 045° M., find the courses and distances to a position 180° T., 6 miles, from Helwick Shoal Lightvessel. Alter course when midway between Longships and Sevenstones Lightvessel, and pass 12 miles off Lundy Island North Light, the deviations being as follows:—Deviation on 1st course 3° E. On 2nd course Longships Light changed from white to red bearing 188° Compass. On 3rd course the Pole Star bore 353° C.

2. After steaming for 3 hours at 10 knots on the 2nd course the Longships Light changed from white to red and Trevose Head Light bore 103° C. Find the set and drift experienced and the Latitude and Longitude of both positions.

3. Lundy Island North Light bore 055° C., and after steaming 2½ hours at 10 knots it bore 121° C. Find the ship's position on the second bearing making allowance for the set and drift found in Question 2.

4. Find the course by compass to counteract the tide setting W.S.W. Magnetic, 3 knots, from a position 290° T., from Bishop Rock to a position 225° T. from the Smalls so as just to skirt the 50 fathom line. If the ship is logging 12 knots how long will she take to reach the final position? (Smalls Lt. 51° 43′ N., 5° 40′ W.)

Paper 10.—Practical Navigation.

3 hours.

1. On June 24, in D.R. Lat. 46° 22′ N., Long. 24° 20′ W., G.M.T. 24d 16h 16m 20s, the sextant altitude of the Moon's upper limb was 20° 48′ east of the meridian; index error 1′ on the arc; height of eye 55 feet. Following this observation

the ship ran 309° T., for 42 miles when a second altitude of the moon's lower limb was 36° 05′ west of the meridian at G.M.T. 24d 20h 50m 15s. Find the ship's position at the second observation.

2. Find the true course and distance by Mercator's Sailing from Cape Palmas, Lat. 4° 24′ N., Long. 7° 46′ W., to St. Paul de Loando, Lat. 8° 48′ S., Long. 13° 08′ E.

3. On January 11, in D.R. Lat. 42° 10′ N., Long. 157° 20′ W., find the local mean time of meridian passage of Jupiter and compute the sextant meridian altitude; index error 1·4′ on the arc; height of eye 30 feet. If the sextant meridian altitude was found to be 37° 47′ what was the latitude of the observer?

4. A lighthouse in Lat. 47° 19′ N., Long. 3° 14′ W., bore 45° on the port bow at 1735, log 24. At 1935 it was abeam, log 42. The course was 120° C., error 10° E., wind South force 7, leeway 5°, tide set 250° T., at 3 knots.

Find the ship's position on the beam bearings.

5. On December 27, in D.R. lat. 25° 20′ N., Long. 73° 26′ W., the sextant altitude of the sun's lower limb, near the meridian, was 40° 24′; index error 3′ off the arc; height of eye 38 feet; G.M.T. 27d 16h 21m 15s. Required the latitude and position line.

Paper 11.—Practical Navigation.

3 hours.

1. On September 19, in D.R. Lat. 10° 00′ S., Long. 60° 00′ E., required the time of transit of Capella to the nearest minute of G.M.T., also the sextant meridian altitude if index error is 1′ off the arc, and height of eye is 40 feet.

2. On September 29, Chronometer B was 2m 11s slow of A, and C was 4m 11s fast of A. Again on October 11, B was 2m 14s slow of A, and C was 4m 30s fast of A. If the latter's daily rate was 1·6s gaining, find the daily rates of B and C.

3. The ship took her departure from Lat. 47° 30′ N., Long. 179° 25′ W., at noon and steered the following courses: Noon to midnight—Course 176° C., 16·5 knots, Dev. 3° E., Var. 15° E. Midnight to noon—Course 202° C., 15·3 knots, Dev. 5° E., Var. 15° E.

At 2200 hours her position by observation was Lat. 44° 55′ N., Long. 180° E. Find the set and drift of the current. Find also the ship's position at noon the next day and the course and distance made good during the twenty-four hours, making due allowance for the current just found.

4. On January 10, in D.R. Lat. 11° 25′ N., Long. 37° 42′ W., the observed altitude of Fomalhaut, west of the meridian was 33° 46′, G.M.T. 20h 45m 48s; and the observed altitude of Deneb, west of the meridian was 19° 41′, G.M.T. 20h 46m 36s. Height of eye 40 feet. Required the position lines and the ship's position.

5. June 22, in Lat. 50° N., Long. 10° W., the following bearings were taken of the sun.

Ship's head Compass	Compass Bearing	A.T.S.	Ship's head Compass	Compass Bearing	A.T.S.
000° C	109°	0820	180° C	089°	0836
045°	104°	0824	225°	089°	0840
090°	102°	0828	270°	099°	0844
135°	096°	0832	315°	101°	0848

Variation 6° E. Draw a curve on squared paper and from it convert 040° T. into the equivalent compass course.

Paper 12.—Practical Navigation.

3 hours.

1. At 2000 hours, on February 17, Finisterre Light, in Lat. 42° 53′ N., Long. 9° 15′ W., was on the starboard beam distant 10 miles. Ship steamed 030° C. (Var. 20° W., Dev. 10° E.) until noon next day; speed 9 knots. Find the position of the ship at noon on February 18.
2. On September 23, in D.R. Lat. 42° 00′ N., Long. 52° 00′ W., the sextant meridian altitude of the moon's lower limb was 35° 53′; index error 2′ off the arc, height of eye 28 feet. Required the latitude.
3. Find the initial and final courses, also the distance from A, Lat. 36° 35′ N., Long. 160° W., to B, in Lat. 26° 25′ S., Long. 80° W. Give also the position of the vertex and of successive points every 10° on longitude apart from 150° W.
4. On January 7, in D.R. Lat. 45° 10′ N., Long. 20° 44′ W., the star Capella bore 100° C., G.M.T. 7d 21h 20m 00s. Required the true azimuth and the deviation for the direction of the ship's head if the variation was 18° W.
5. On September 24, in D.R. Lat. 42° 17′ S., Long. 76° 43′ E., the following observations were taken:

   (*a*) Sextant altitude of moon's lower limb, east of the meridian, 38° 30′; G.M.T. 24d 13h 23m 22s.

   (*b*) Sextant altitude of star Rasalhague, west of the meridian, 32° 55·5′; G.M.T. 24d 13h 24m 48s; index error 1·8′ on the arc; height of eye 37 feet.

   Find the ship's position by means of position lines.

Paper 13.—Practical Navigation.

3 hours.

1. On January 12, at evening twilight, D.R. Lat. 46° 00′ N., Long. 37° 26′ W., the sextant altitude of Polaris was 46° 57′; index error 1′ on the arc; height of eye 30 feet; the chronometer which was 1m 42s fast on G.M.T. showed 7h 43m 15s. Required the latitude and position line.

2. Thursday at noon, a point of land in Lat. 47° 30′ N., Long. 179° 25′ W., bore 322° T., distant 12 miles. During the next twenty-four hours ship steered 210° C. (Dev. nil): at 11 knots. Variation during the first 10 hours 12° E., and for the remainder of the day 10° E.

   Friday at 0800 position by observation Lat. 44° 40′ N., Long. 177° 00′ E. Find current for the 24 hours, the course and distance made good and the position at noon on Friday.

3. Find the G.M.T., to the nearest minute, when Dubhe will transit the observer's meridian on June 15, in Lat. 40° N., Long. 40° 10′ W.

4. On January 6, in D.R. Lat. 35° 20′ S., Long. 47° 30′ E., the observed meridian altitude of the moon's upper limb was 36° 24′, height of eye 50 feet. Required the latitude.

5. On January 10, in D.R. Lat. 26° 15′ N., Long. 37° 42′ W., the following observations were taken:

   (*a*) G.M.T. 10d 20h 43m 56s; observed altitude Capella 42° 29′.

   (*b*) G.M.T. 10d 20h 45m 48s; observed altitude Deneb 29° 40′.

   Height of eye 40 feet.

   Find the ship's position by means of position lines.

Paper 14.—Practical Navigation.

1. Having taken the following compass bearings of a distant object, find its magnetic bearing and thence the deviations on those points on which the bearings were observed.

Ship's head Compass	Compass Bearing	Ship's head Compass	Compass Bearing
000° C	270° C	180° C	248° C
045°	256°	225°	256°
090°	244°	270°	266°
135°	241°	315°	270°

   Find the magnetic bearing of the object and construct a curve of deviations on squared paper.

   Ascertain from the curve the deviations on the following courses:

   Compass Courses 045° C, 098° C, 200° C, 312° C.

   Magnetic Courses 011° M, 087° M, 217° M, 337° M.

2. On September 21, in D.R. Lat. 33° 00′ N., Long. 24° 16′ E., the sextant altitude of Polaris was 33° 48′; index error 1·4′ on the arc; height of eye 8·3 m.; G.M.T. 21d 03h 43m 24s. Required the latitude.

3. On December 24, in D.R. Lat. 23° 50′ N., Long. 32° 20′ W., G.M.T. 24d 22h 26m 00s, the moon bore 106° C., variation 20° W. Required the true azimuth and the deviation for the direction of the ship's head.

4. Find by calculation on Mercator's principle the true course and distance from *A* 20° 00′ S., 178° 00′ W., to *B* 39° 52′ S., 147° 45′ E.

5. On January 12, in D.R. Lat. 30° 10′ S., Long. 17° 40′ W., height of eye 50 feet, the following observations were taken:—

   (*a*) G.M.T. 12d 05h 54m 12s. observed altitude Acrux near the meridian 57° 18′.

   (*b*) G.M.T. 12d 05h 55m 40s, observed altitude Antares east of the meridian 34° 14′.

   Find the ship's position.

Paper 15.—Practical Navigation.

3 hours.

1. May 1, at 0130 hours in Lat. 49° 30′ N., Long. 4° 50′ W., course set 220° C. (Dev. 10° E., Var. 15° W.) log reading 142. 0400 hrs. altered course to North (Dev. 7° W.) log 162. 0730 hrs. altered course to 220° C., log 180. Course maintained until 1200 hrs. log 216.

   Leeway 5° throughout for a westerly wind. Current from 0130 to 0600 hrs. 080° T., 2 knots, and thereafter till noon, 260° T., 2·5 knots. Find D.R. position at noon.

2. January 7, morning twilight at ship in D.R. Lat. 32° 46′ N., Long. 151° 12′ W., the observed altitude of Jupiter near the meridian was 46° 42′ when a chronometer which was correct on G.M.T. showed 5h 17m 10s; height of eye 45 feet. Required the position line and the latitude in which it crosses the D.R. longitude.

3. On October 20, Chronometer *A* was 32m 19s fast of G.M.T. and losing 2·5s daily. On the same date *B* was 1m 03s slow of *A*. If on November 30, *B* was 17s fast of *A*, find *B*'s daily rate.

4. June 15, at 0530 L.A.T., in D.R. Lat. 17° 25′ N., Long. 62° 42′ E., the sun rose bearing 070° C. Find the true amplitude and the deviation for the direction of the ship's head if the variation was 3° E.

5. January 7, D.R. Lat. 39° 03′ S., Long. 41° 45′ E., cloudy weather, at G.M.T. 7d 17h 39m 15s the obs, alt, of a bright star whose identity was unknown was 42° 52′, bearing 075·5° T. Height of eye 45 feet. Establish the identity of the star.

CHAPTER IX.

MARINE SURVEYING.

MARINE surveying is the art of portraying on paper in the form of a chart or plan the physical characteristics of any bay, harbour, or other locality of which the survey is to be made.

While the position and details of permanent land marks near the coastline form an important part of the work of marine surveying, it more particularly deals with the bed of the sea, shoal patches, islands, rocks, and any other features there may be, together with the set of the tides, depth of water, and nature of the bottom.

The first part of the work is the selection of the site and the laying off of a suitable base line on the land, by means of which the positions of other objects may be ascertained. The base line should be situated on a level surface if possible, and its two ends marked by definite fixed objects. If no desirable objects are already in position—that is, if the existing objects are not suitable—the purpose can be served by erecting two flag poles in convenient places, the distance between them being very accurately measured. In modern surveys this is usually carried out by Electronic Distance Measure (EDM). What that distance should be would depend on the area of the survey, but a length should be chosen with a view to saving labour in the future calculations which will have to be made. The true direction of this base line will also have to be found with great accuracy. The exact latitude and longitude of the marks at each end of it will have to be carefully calculated.

All the permanent landmarks which do not naturally offer a conspicuous point for observation should be marked, possibly with whitewash. The same process should also be adopted in the case of rocks and islands, a flag stuck firmly in the ground being useful on a level surface.

The high-water mark should then be carefully denoted by means of a succession of flags placed along it, or by otherwise marking it, the flags being most closely spaced where the greatest curvature or irregularity occurs in the beach or shore, this being done to facilitate the correct drawing in of the coastline.

Having marked (where necessary) all the objects which are to be shown on the chart or plan, it is advisable to give each one an appropriate name, as this will greatly assist the memory during the progress of the work.

The next thing to be done is to carefully ascertain the position of all these objects so that they may be denoted on the chart or plan in their correct places. This is done by a process called "triangulation". Each end of the base line is made a station for observations, and from these stations angles are measured between the base line and the objects to be fixed, the angles being very carefully recorded. These stations are called "triangulation stations". By means of the angles which have been measured triangles are formed, the base line forming one side of the triangle. As the position and true direction of the base line are known, also its exact length, the positions of the other objects can be easily deduced from it. Triangulation stations are also chosen in other known positions from which angles are measured and bearings taken to find the exact position of other objects and to verify the position

of objects which have been previously fixed. A new base line may be found when a new triangulation station is established.

Angles are also measured and bearings taken from the object whose position is required to be fixed.

Having obtained sets of triangles, the next performance is to calculate the length of the sides of the triangles where necessary, and lay off the exact position of the base line (or lines) on cartridge paper.

In modern surveys the lengths of the sides of the triangles are often measured direct by EDM and in these cases the process is known as, "trilateration".

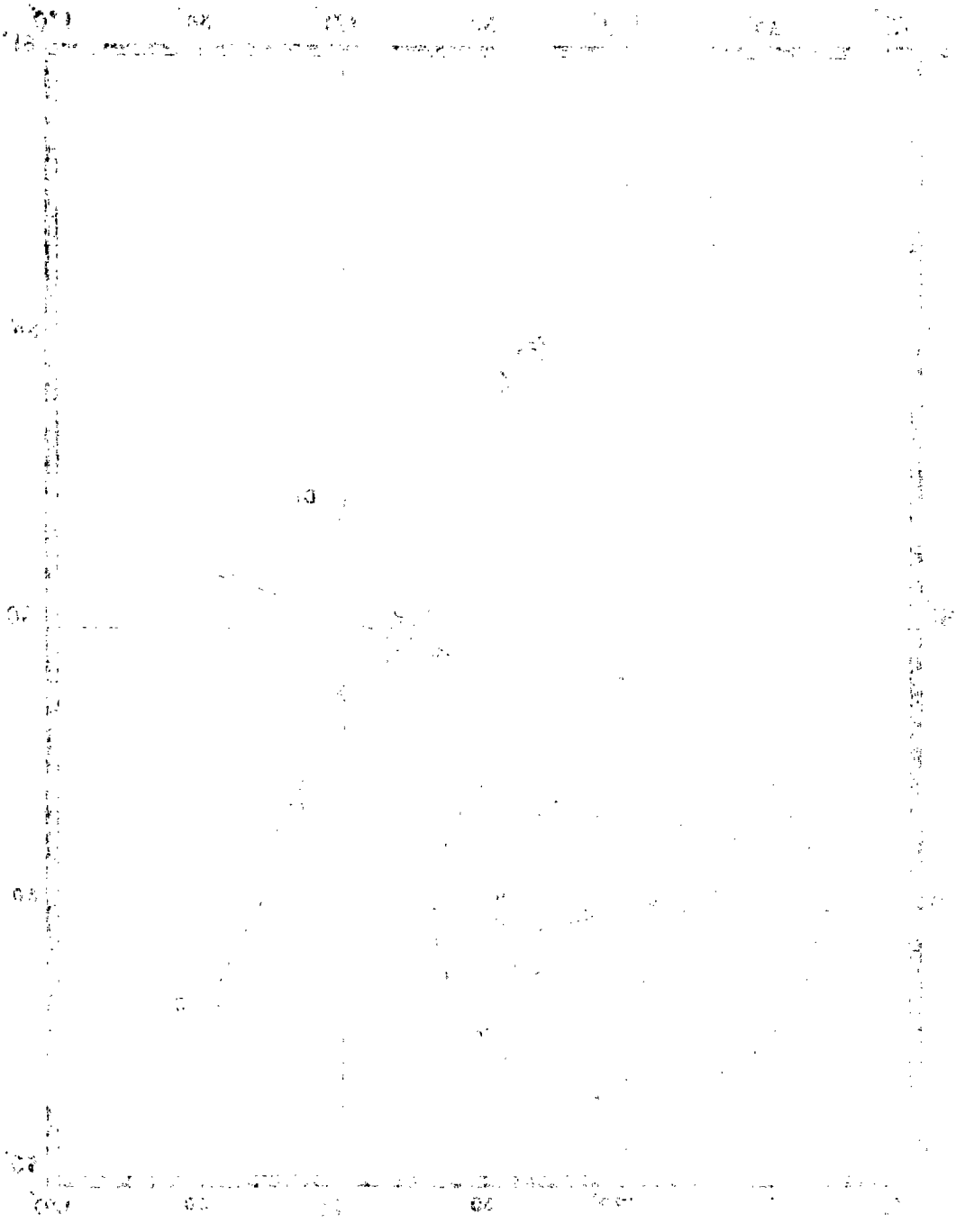
The first point chosen is then plotted off on its true bearings from both ends of the base line, its position being checked by means of the angles previously measured and recorded, also by the calculated length of the side of the triangle thus formed. The positions of other objects are then fixed by means of angles which have been measured between them and other known marks, the sides of the triangles which have been formed again providing a useful check. When all the triangles are laid off they should agree in fixing the position of each object as being in one definite place. If there are any discrepancies, an error has been made. It should be investigated and put right so that there shall be no doubt that the exact positions have been determined.

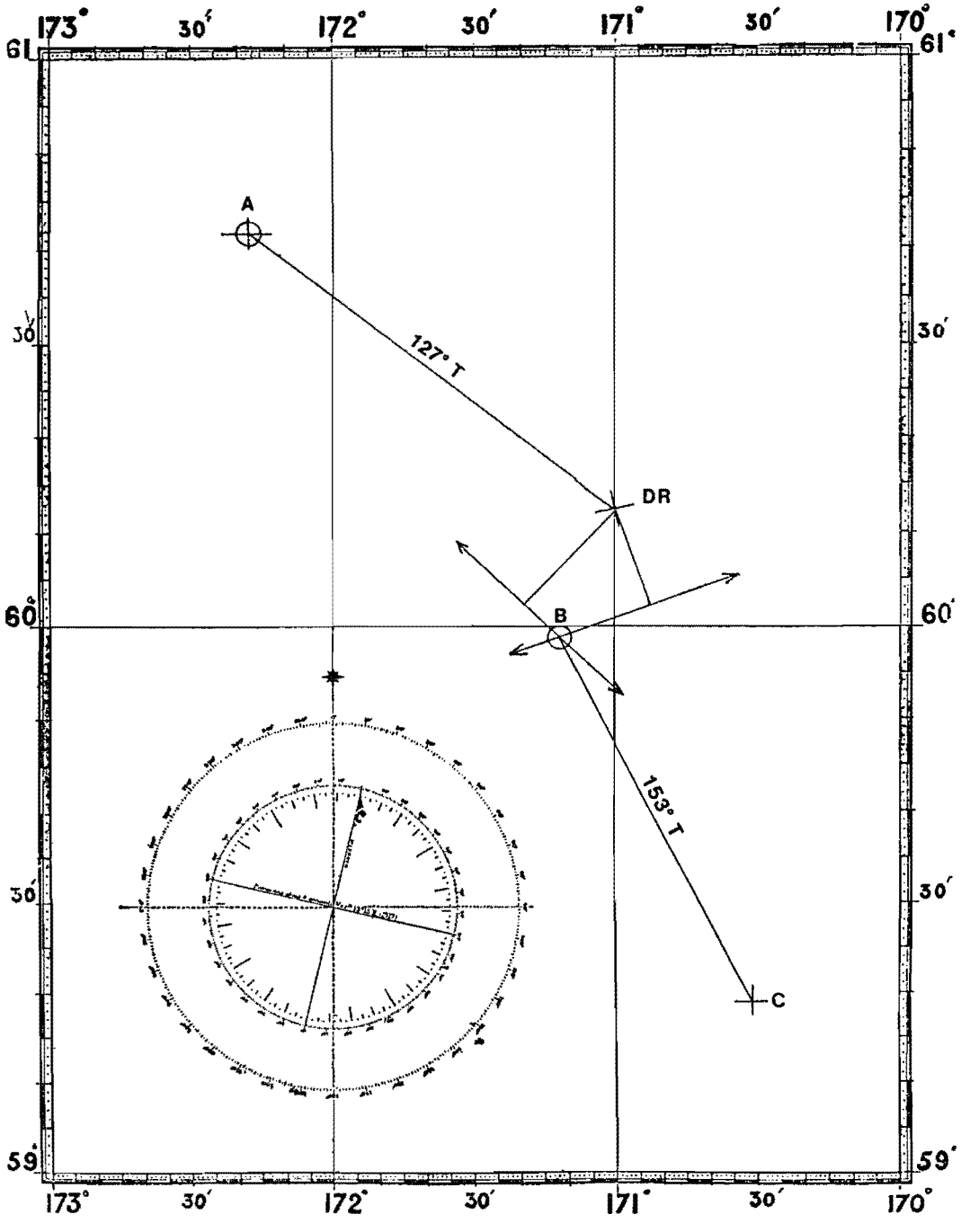
The coastline must be put in by means of plotting off the positions of the flags which were stuck in the ground along the high-water mark. A line drawn through them will be a good representation of it. The nature of the shore should be carefully noted, and sketches should be made of any important or unusual features. An aerial photographic survey would be helpful when drawing in the contour of the coast.

The set and drift of the tides, the depth of water, and the nature of the bottom form one of the most important parts of the survey, the value of the chart or plan depending greatly on their accuracy. Where echo sounders are not used the leadline must be carefully marked and, for the older non-metric charts, feet are the best unit of measurement up to the first five fathoms. The whole of the soundings being taken in feet if the water is not very deep. In the case of surveys for metric charts the metric leadline is used and soundings are taken in metres and decimetres. The soundings should be marked, as nearly as possible, in parallel straight lines, this being done by choosing or placing two fixed objects on shore and keeping the boat in line with them as the casts are taken. The exact time of each cast must also be taken so that the soundings may be reduced to chart datum when its level is decided upon. The distance between the position of one sounding and the next one to it will depend upon the locality of the place, the depth of water, the nature of the bottom, and the scale to which the chart or plan is to be constructed. Should a shoal patch be discovered, care must be taken to fix its position very accurately. This is best done by means of horizontal angles between objects ashore, which angles must be carefully observed from the boat.

Today most surveys are obtained by the use of echo sounders which, for accurate results, should first be calibrated by means of a "bar check" before survey commences. The other precautions and procedures as related to leadline surveys still apply.

A "tide pole" should be erected in a suitable and sheltered position which is always accessible to the sea, so that it may show the correct level of the water at all times. It should be graduated to spaces of, say, 1 decimetre, and very clearly marked




173°
30′
172°
30′
171°
30′
170°
61°
60°
59°
A
127° T
DR
B
153° T
C

so that the height of the water-level may be read without having to closely approach the pole. This height should be recorded at regular intervals of time, and special attention paid to the times of high and low water, most particularly on the dates of the new and full moon, so that the datum of the port" may be decided upon.

Allowance should be made for wind, atmospheric pressure, and other influences likely to affect the height of the tide. As the height of the water-level can be recorded at any time of the day by the above arrangements, it becomes a simple matter to reduce all the soundings to chart-datum level. On new editions of British Charts this is the level of the Lowest Astronomical Tide (LAT) which was chosen so as to ensure that the tide will rarely fall below this level and that the charted depth of water is the least the mariner can expect under normal conditions.

The height of all objects on the land should be marked on the chart or plan in feet above the level of mean high-water spring tides. These can generally be ascertained by means of the vertical angles which they subtend, allowance being made for the height of the tide. A compass should be engraved showing the variation.

CONSTRUCTION OF A MERCATOR CHART.

Example—Construct a chart on Mercator projection extending from Lat. 59° N. to 61° N. and from Long. 170° W. to 173° W. Scale 4 inches to 1 degree of longitude. Divide the scales of latitude and longitude into minutes. Insert a compass, Admiralty pattern, divided into degrees and showing variation 13° 15′ E.

Refer to the figure when reading the following explanation. The original drawing was drawn to a 4-inch scale, but has been reduced in size to fit the page of this book. Plot the following work on the chart:—

A ship at position *A*, Lat. 60° 42′ N., Long. 172° 17′ W., sailed 127°T, 48 miles. From this DR position, the azimuth of a star was 160°T, intercept 10·5 miles towards. Lay off the position line.

At the same time the azimuth of another star was 224°T, intercept 14 miles towards. Lay off the position line and find ship's position.

(*Ans.* Lat. 59° 59′ N., Long. 171° 11′ W.)

Find the course and distance from this position *B* to *C* in Lat. 59° 19′ N., Long. 170° 30′ W.

(*Ans.* Course 153°T, Dist. 45 miles).

Construction.—A horizontal line is drawn to represent the parallel of Latitude 59° N. and a perpendicular drawn to represent the meridian of 170° West Longitude. This meridian must be drawn exactly perpendicular by geometrical methods and then checked with a protractor.

Longitude Scale.—The parallel should then be divided into spaces for each degree of longitude; in this example 1 degree of longitude is 4 inches. Each degree should then be divided into 10′ spaces and subdivided into 5′ and finally into 1′ spaces. This must be done as accurately as possible because the accuracy of the whole chart depends upon the scale of longitude. The left hand marginal meridian may now be drawn exactly parallel to the right hand meridian.

Latitude Scale.—The spacing of the parallels of latitude depends on the meridional difference of latitude between each one, and increases with the latitude: the higher the latitude the greater the increase.

Write down each half degree of latitude and against each write its meridional parts taken from *Norie's Tables*. The D.M.P. will be the number of minutes of longitude separating each successive parellel as follows:—

Lat.	Mer. Parts	D.M.P.	Sphere
59°	4409·19		
59½	4467·82	58·57	between 59° and 59½°
60	4527·37	59·45	,, 59½ ,, 60
60½	4587·83	60·36	,, 60 ,, 60½
61	4649·23	61·29	,, 60½ ,, 61

Take 58·57 parts from the longitude scale and lay it off upwards on the meridian. This fixes the spot for 59½°. Then 59·45 parts from scale is laid off from 59½° to fix the spot for 60°, and 60·36 parts for 60° to 60½° and 61·29 parts for 60½° to 61°. The parallels of latitude may then be drawn. It is desirable, however, to lay off the D.M.P. on the marginal meridians on each side of the chart with the same opening of the compasses and to draw in the parallels with a straight edge, as parallel rulers are not likely to be accurate enough for the purpose. It will be obvious that great care should be taken when lining in the parallels and meridians (the graticule) so that they may be accurately parallel and perpendicular, otherwise, the chart will be twisted.

Another Method of determining by calculation the spacing between the parallels is—

D. Lat. scale = D. Long. scale × nat secant mid lat.

59° and 59½° = 2 × nat sec 59° 15′ = 2 × 1·956 = 3·912 inches
59½ ,, 60 = 2 ,, 59 45 = 2 × 1·975 = 3·970 ,,
60 ,, 60½ = 2 ,, 60 15 = 2 × 2·015 = 4·030 ,,
60½ ,, 61 = 2 ,, 60 45 = 2 × 2·047 = 4·094 ,,

The half degree spacing may then be divided off into minutes of latitude.

The Compass.—This may be drawn in with a protractor. The Admiralty pattern compass has the outer circle graduated true from 0° to 359° clockwise, and the inner circle graduated magnetic from 0° to 359°, with due allowance made for the angle of variation for the year, or, as given in the example.

1. Construct a chart on Mercator projection extending from Lat. 49° 55′ N. to Lat. 50° 45′ N., and from Long. 0° 00′ to Long. 2° 30′ W. Scale 6 ins. to 1 degree of longitude. Construct a compass, Admiralty pattern showing 12° W. variation. Divide margin scales to minutes.

	Lat.	Long.
St. Catherines	50° 34′ 30″ N.	1° 17′ 47″ W.
Portland Bill	50 31 18 N.	2 27 18 W.
Anvil Point	50 35 30 N.	1 57 30 W.

Portland Bill bore 291° T., and Anvil Point bore 047° T. Ship then steered 104° M. Find ship's position when St. Catherines is abeam and the distance off.

2. Construct a Mercator chart extending from Lat. 54° 40′ N., to Lat. 55° 40′ N. and from Long. 7° 40′ W. to Long. 9° 20′ W. Scale 7·5 ins. to 1 degree of longitude. Construct a compass showing 20° 40′ variation. Plot the following positions:—

A	Lat.	55°	17′	N.	Long.	8°	15′	W.
B	,,	55	13¾	N.	,,	7	59	W.
C	,,	55	08	N.	,,	8	15½	W.
D	,,	55	01	N.	,,	8	33	W.
E	,,	54	59	N.	,,	8	07	W.
F	,,	54	51	N.	,,	8	30	W.
G	,,	54	46	N.	,,	8	34	W.

When *A* and *B* were in transit the distance from *C* by vertical angle was 22 miles. Ship then sailed 230° M., 18 miles, when the distance from *C* was found to be 30 miles with *D* and *E* in transit. Find the set and drift of the current, also the course and distance made good by the ship.

Vessel stood to the south-east. The horizontal angle between *D* and *F* was 79° and at the same time the vertical angle of Hill *G* (1502 ft.) was 1° 18′ 40″ off the arc and 1° 23′ 00″ on the arc. Find the ship's position.

3. Construct a Mercator chart, scale 3½ ins. to 1 degree of longitude, extending from Lat. 53° 00′ N. to Lat. 54° 30′ N. and from Long. 3° W. to Long. 6° W. No variation. Plot the following positions:—

A	Lat.	54°	02′	N.	Long.	4°	50′	W.
B	,,	54	03	N.	,,	4	37	W.
C	,,	55	31	N.	,,	3	31	W.

At 02 p.m. *A* bore 311° M. and *B* bore 022° M. Set course 104° T., speed 15 knots. At 04·40 p.m., altered course to 172° T. At 05·50 p.m., *C* bore 126° M. and at 06·10 p.m. it bore 047° M. Find ship's position and the set and drift of current.

4. Construct a chart on Mercator's projection extending from Lat. 48° 20′ N. to Lat. 49° 10′ N and from Long 164° 20′ E. to Long. 165° 50′ E. Scale 8 ins. to 1 degree of longitude. Insert a true compass.

Project the following position lines and find the ship's position at the time of taking the 2nd observation:—

1st obs.—Position line 007°-187° T. drawn through Lat. 48° 55′ N., Long. 165° 35′ E.

2nd obs.—Position line 052°-232° T. drawn through Lat. 48° 25′ N., Long. 164° 38′ E.

Between 1st and 2nd observations the ship sailed 240° T., for 15 miles, 260° T., 13 miles, 310° T., 7 miles and 250° T., for 10 miles.

5. Construct a plan chart 4·8 equal to 1 mile of latitude. Divide latitude and Longitude scales to seconds.

An observation spot (Lat. 58° 11′ 00″ N., Long. 6° 19′ 22″ W.) bore 029° T., and 7 minutes later it bore 347° T., and 10 minutes later it bore 303° T. Required the course made good, and if the gyro course steered was 096°, speed 6 knots, find the set and drift of the tide experienced.

If a point in Lat. 58° 10′ 47″, Long. 6° 18′ 00″ N. then bore 081° T., find the course to bring the point 5 cables off when it comes abeam, and the distance to steam.

6. Construct a plan chart, scale of latitude 2·8 ins. to the mile, also show the scale of longitude, and a true compass divided into degrees.

Plot position *A* about 3 ins. from the bottom left hand corner of the paper.

Lighthouse	*A*	Lat.	50°	39′	42″	N.,	Long.	1°	35′	25″ W.
,,	*B*	,,	50	42	27	N.,	,,	1	32	56 W.

Find the course to steer and the distance from a position with *A*, 4 cables on starboard beam to a position with *B*, 3 cables on the port beam.

From the beam position of *B*, alter course to fetch an anchorage with *B* bearing 253½° and *C* (Lat. 50° 42′ 30″ N., Long. 1° 29′ 54″ W.) bearing 200° T. Required the distance of the anchorage from *B* and *C*.

7. Construct a chart extending from Lat. 60° 22′ N. to Lat. 60° 33′ N., and from Long. 27° 55′ E. to Long. 28° 25′ E., scale 1 mile of middle latitude equal to 4 ins. Divide margins to minutes, compass to degrees, variation 0° 40′ W.

Plot	*A*	Lat.	60°	24′	30″	N.,	Long.	27°	58′	40″	E.
,,	*B*	,,	60	28	40	N.,	,,	28	06	00	E.
,,	*C*	,,	60	26	50	N.,	,,	28	22	30	E.

Fix the centre of a shoal by sextant angles as follows:—*A* 54° *B* 96° *C*. Find this position, also its magnetic bearing from each of the points, *A*, *B* and *C*

8. Construct a chart, scale 7 ins. to 1 minute of longitude, variation 14° 15′ W., extending from Lat. 45° 30′ N., to Lat. 45° 44′ N., and from Long. 1° 00′ W. to Long. 1° 25′ W. A lighthouse in Lat. 45° 41′ 45″ N., Long. 1° 14′ 3″ W.

Showing a white sector between 309° M. and 297° M.
,, red ,, 297° M. ,, 245° M.
,, white ,, 245° M. ,, 236° M.

Another light in Lat. 45° 35′ 12″ N., Long. 1° 10′ 30″ W.

Showing white light between 338° M. and 332° M.
,, green ,, 332° M. ,, 312° M.
,, white ,, 312° M. ,, 208° M.
,, red ,, 338° M. ,, 025° M.

All bearings are from the light.

A buoy is moored at the intersection of the northern limits of the white lights. Find its latitude and longitude and its magnetic bearing and distance from the second light.

ANSWERS.

1. Lat. 50° 26′ N., Long. 1° 18′ W. Beam distance 8½ miles.

2. Set 262° M., drift 5 miles. Course 236° M., distance 22 miles. Position Lat. 54° 55′ N., Long. 8° 44′ W.

3. Lat. 53° 28½′ N., Long. 3° 35½′ W. Set 306° T., drift 4½ miles.

4. Lat. 48° 21′ N., Long. 164° 29′ E.

5. Course 085° T. Set 187° T. Drift 3·5 cables in 17 minutes. Course 111° T. Distance 8·3 cables.

6. Course 042° T. Distance 3 miles 1 cable. Distance 2 miles 1·5 cables from *B* and 6·6 cables from *C*.

7. Lat. 60° 24′ 20″ N., Long. 28° 11′ 45″ E. 094° M., 6·4 miles from *A*. 148° M. 5·3 miles from *B*. 244° M. 5·8 miles from *C*.

8. Lat. 45° 43′ 15″ N., Long. 1° 18′ 40″ W. Bearing 338° M. Distance 10 miles.

GNOMONIC CHART.

The eye, in the gnomonic projection, is conceived to be at the centre of the sphere and the area to be mapped out is projected on a tangent plane in contact with the sphere. Lines are drawn from the centre of the sphere through various points on its surface until they meet the tangent plane in spots which are projections of these points.

A simple case may illustrate the principle. Let *O*, in Fig. 1, represent the centre

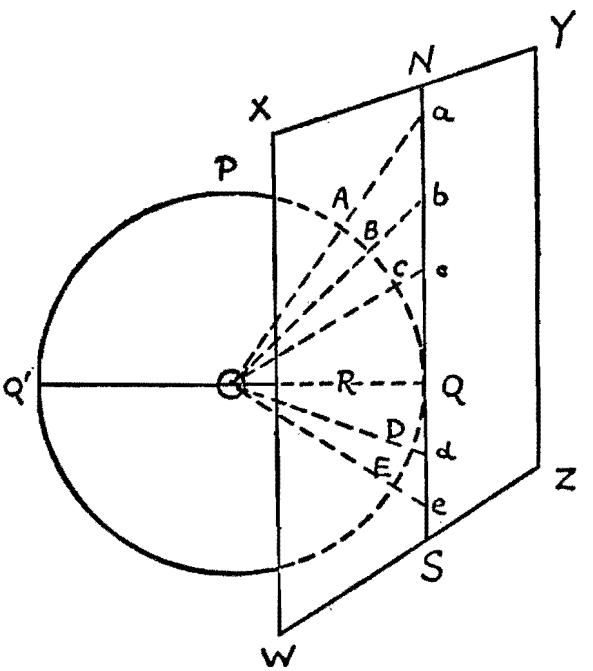


FIG. 1.

of the Earth and *QPQ'* be any meridian. *WXYZ* is a plane sheet of paper touching the sphere at *Q*. *Q* is called the tangential point. Let *A*, *B*, *C*, *D* and *E* be points on the meridian. Produce their respective radii *OA*, *OB*, *OC*, *OD* and *OE* until they meet the tangent plane at *a*, *b*, *c*, *d* and *e* respectively, then these spots will be projected along the line *NQS* which now represents the gnomonic projection of the meridian. But *QPQ'* is any meridian and all meridians, therefore, appear as straight lines on the chart.

The angles *QOA*, *QOB*, *QOC*., etc., represent the latitude of *A*, *B* and *C* respectively. *OQ* is the radius of the sphere = *R*, $\angle OQN = 90°$, therefore $Qa = R$ tan Lat. *A*, $Qb = R$ tan Lat. *B*, etc.

All Great Circles project as straight lines on the Gnomonic Chart.—A great circle is one whose plane passes through the centre of the sphere. Imagine, as in Fig. 2, a sphere resting on a plane surface at *A*. Let *ABC* and *ADE* be arcs of two great circles. The tangential point is projected on the plane at *A*, *OB* produced projects *B* at *b*, and, similarly, *C* is projected at *c*. Thus the projection of the great circle arc *ABC* is the straight line *Abc*.

Again, the points *A*, *D* and *E* on the great circle *ADA'* are similarly projected on

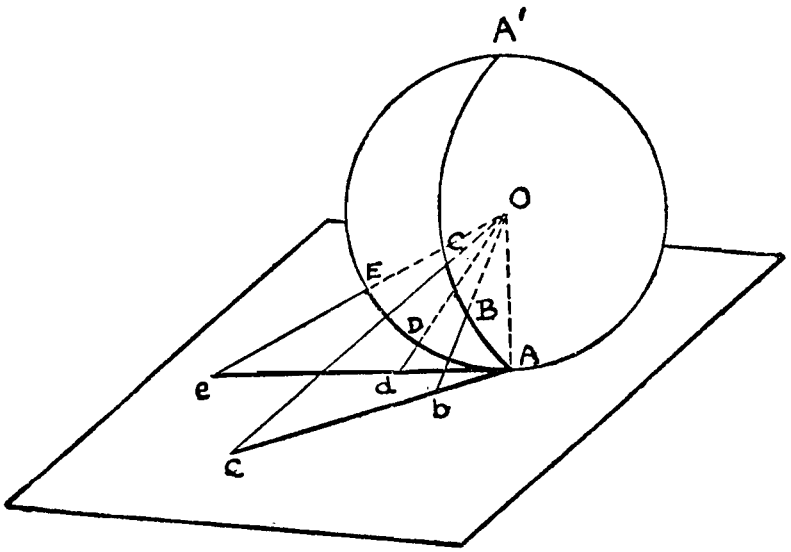


FIG. 2.

the tangent plane by producing their respective radii *OD* and *OE*. Now all the radii *OA*, *OD* and *OE* lie in the plane of the great circle and the points *A*, *d* and *e* lie on this plane and also on the tangent plane and they must, therefore, be on the line of intersection of the two planes.

Thus the projection of this great circle is a straight line, as indeed are all great circles on the gnomonic projection.

It may be noted that the spherical angle *CAE* on the sphere is equal to the plane angle *cAe* on the tangent plane.

Parallels of Latitude Project as Conic Sections.—Let *ABCDEFG*, in Fig. 3 be a parallel of latitude and *O* the centre of the sphere, then the projections of points on

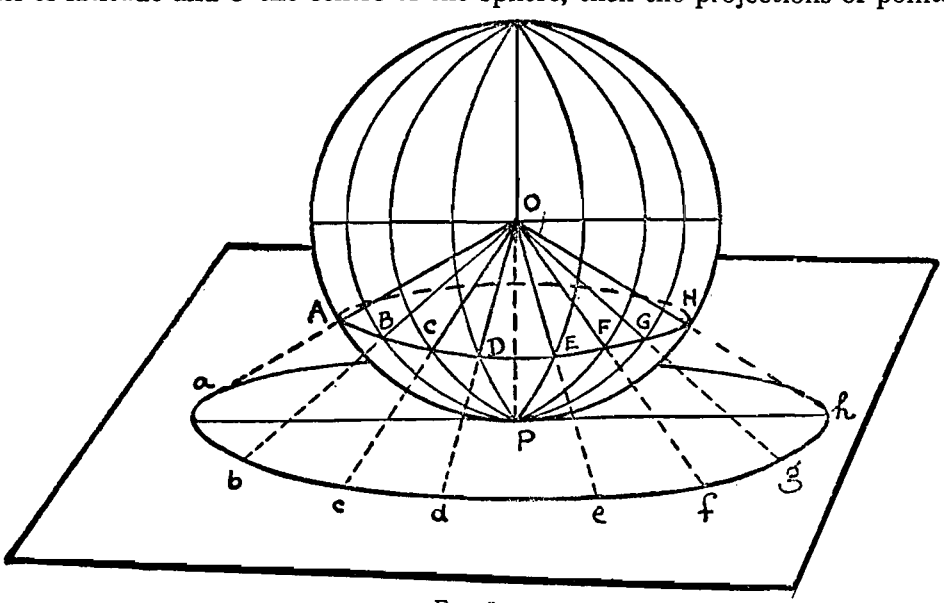


FIG. 3.

the parallel, such as *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H*, will trace out the curve *a*, *b*, *c*, *d*, *e*, *f*, *g* and *h* on the tangent plane.

But the radii *OA*, *OB*, *OC*, etc., lie on a right circular cone whose vertex is *O* and its base the parallel of latitude, hence this curve is a section of a cone projected on the tangent plane. This curve is usually a conic section and may be an ellipse, a parabola or hyperbola (see Fig. 4).

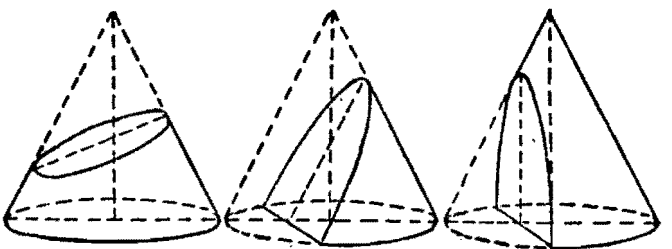


FIG. 4.

An ellipse is a conic section or curve made by a plane passing obliquely through the opposite sides of a cone.

A parabola is the curve formed by cutting the cone with the plane of the section parallel to the side of the cone.

A hyperbola is the curve formed by the intersecting plane making a greater angle with the base than the angle made by the side of the cone.

Should, however, the tangent plane be parallel to the base of the cone the section becomes a circle. This happens only when the plane touches the Earth sphere at the

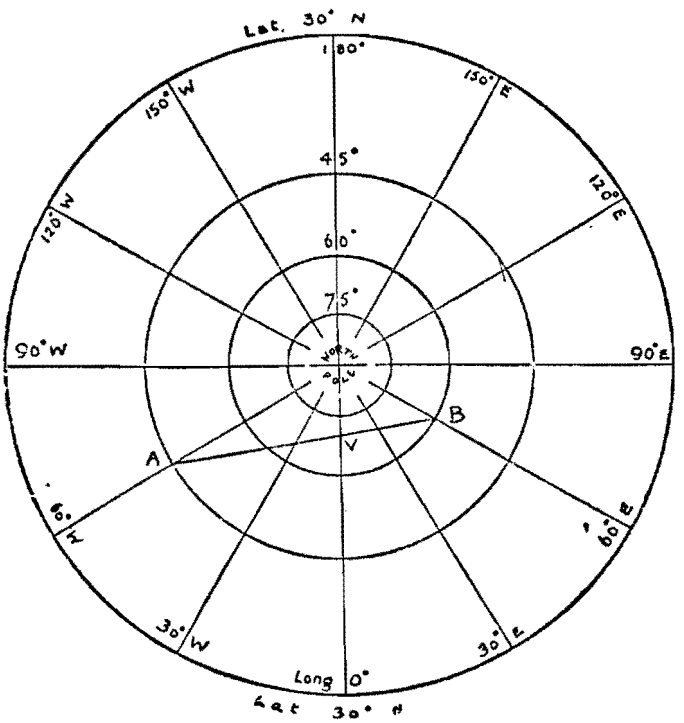


FIG. 5.

pole and, in this particular case called the "polar projection", the parallels of latitude are circles and the meridians are diameters, as in Fig. 5.

In triangle OPh we have P the pole, $\angle OPh = 90°$, OH the radius of earth $= R$, $\angle POH$ is the co-latitude of H, therefore, the radius of the parallel of latitude $= R$ tan $POH = R$ cot Lat. Thus the radii of the circles representing parallels of latitude on a polar gnomonic chart are proportional to the cotangent of their latitudes. But the cotangent increases quickly with decrease of the angle and finally becomes infinite, so that cot lat. $0° =$ infinity, and thus the polar chart fails to represent the tropical regions. Gnomonic charts cannot represent satisfactorily areas which are more than 75° from the tangential point, and consequently considerably less than a hemisphere can be shown on this projection. Refer back so Fig. 3.

The simplest gnomonic chart to construct is the polar projection (Fig. 5). The tangential point is the pole. The radius of latitude 45° is the unit of measure so that cot $45° = R$ units and the radii of the other parallels is R cot latitude respectively. The parallels of latitude are circles and the meridians are diameters.

In drawing this figure we made the radius of $45° = 2$ inches. Radius $75° = 2$ tan $75° = 2 \times \cdot 267 = \cdot 543$, similarly radius $60° = 1 \cdot 154$, radius $30° = 3 \cdot 46$. The meridians were laid off with a protractor.

The great circle from A Lat. 45° N., Long. 60° W. to B Lat. 60° N., Long. 60° E., is represented by the straight line AB. A perpendicular from the pole to AB gives the position of vertex. The positions of successive points can be read from the chart,

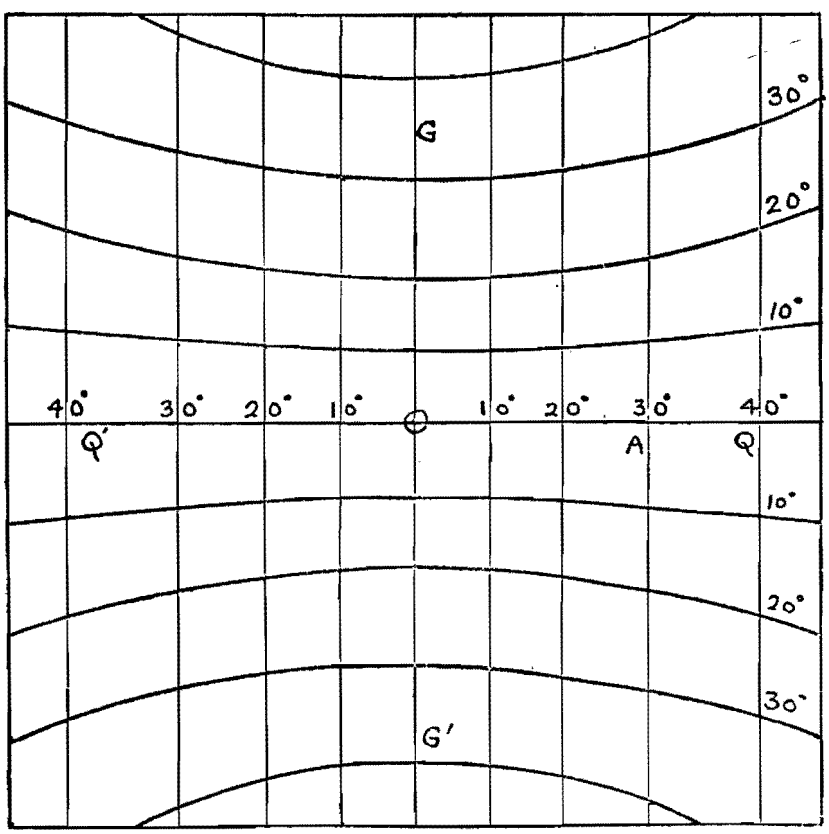


FIG. 6.

and courses measured with a protractor, the degree of accuracy being limited only by the scale of the chart.

Figure 6 represents an equatorial gnomonic projection the tangential point being at *O*. This network map is called a graticule. The parallels of latitude are conic sections, and the meridians are parallel straight lines but not equidistant from each other. If GOG^1 be the principal meridian and QOQ^1 the equator, the distance of each meridian from the principal meridian is given by, R tan difference of longitude, where R=the scale selected for a D. Long. of 45°. Thus, if D. Long. 45° were made equal to 3 ins., then OA (the D. Long. corresponding to 30°) equals 3 tan 30° = 3 × ·58 = 1·74 ins., and similarly for the spacing of the respective meridians having D. Long. 10°, 20°, etc. The parallels are not so easily drawn. Spots on each parallel corresponding to their latitudes, and their differences of longitude from the principal meridian, are calculated, the spots plotted and curves drawn through them. The equatorial projection is, however, of little use in navigation as the advantages of great circle sailing are confined to high latitudes.

When the tangential point is between the pole and the equator the projection of the meridians and parallels is somewhat complicated, and requires the calculation of a series of points through which to draw the respective meridians and the parallels of latitude. See gnomonic chart facing page 69.

Although hydrographic surveying is no longer included as a separate subject in the new Extra Master Examination, certain aspects of the subject are included in the Marine Environmental Studies Paper and also in maritime studies degree courses. The following questions, which include examples from past Extra Master examination papers, are here included for students wishing to acquire a deeper understanding of the subject either for examination or other purposes. The student is referred to the comprehensive chapter on "Surveying" contained in the *Admiralty Manual of Navigation* and the *Admiralty Manual of Hydrographic Surveying* for more detailed information.

Questions for Exercise

1. Regarding the use of echo sounding devices, what precautions would you take before making a survey?
2. Describe the buoyage system and lights around the British Isles giving distinctive features.
3. Give a brief description of the method adopted in the triangulation for a survey and explain with figure how you would extend the base line.
4. Describe the method of finding the true bearing of a triangulation station.
5. How would you make tidal observations when surveying a small bay?
6. What is meant by "running a line of soundings" and what are the precautions to be taken before plotting it?
7. Describe how soundings are plotted on a "field plan" and also the method adopted to indicate soundings in shallow water.
8. Describe a survey of a bay, or harbour, with special reference to hidden dangers and the system of observations.
9. What is put on a fair chart before sending it to the Hydrographer?
10. On which side of a river is the deepest water found when it curves? Why are shoals formed at river entrances?

11. Describe the tests you would make before using a station pointer for surveying.
12. Describe the methods of coast lining. Enumerate the instruments used and describe those which are not in general use in navigation.
13. Describe the theodolite and its adjustments.
14. Show that in surveying when obtaining distance by an angle of depression the correction for refraction is 100D/4 in seconds of arc, where D is the distance in miles.
15. The position of two stations and the distance between them has been established in a triangulation survey. Explain how the reliability of the position of the third station can be built up by: (*a*) intersection, (*b*) resection, and (*c*) trilateration.

CHAPTER X.

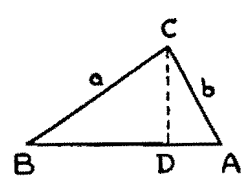
MATHEMATICAL FORMULAE AND THEIR APPLICATION TO SOME PROBLEMS. IN NAVIGATION, NAUTICAL AND SPHERICAL ASTRONOMY.

This chapter is devoted to recording very briefly, but in a more or less progressive order, proofs of the fundamental trigonometrical formulae usually employed in solving navigational problems, practical as well as academic. It is really a continuation of Chapter VI, Volume I, the contents of which the reader will, no doubt, be familiar with. But it is expected that students seeking after more comprehensive and elaborate investigations will also refer to standard works on the subject such as *Goodwin's Plane and Spherical Trigonometry, The Admiralty Manuals on Navigation,* and school textbooks on algebra and geometry, our purpose here being merely to lead up to the solution of some types of theoretical questions as indicated by the syllabus and the experience of extra masters' examinations.

PROOFS OF FORMULAE.

Prove $\frac{a}{b} = \frac{\sin A}{\sin B}$ . . . . . (1)

In figure $C\,D$ is perpendicular to $A\,B$



$$C\,D = a \sin B = b \sin A$$

$$\therefore \frac{a}{b} = \frac{\sin A}{\sin B}$$

Similarly, by moving the lettering A, B, C one place, we get

$$\frac{c}{b} = \frac{\sin C}{\sin B} \text{ and } \frac{a}{c} = \frac{\sin A}{\sin C} \quad . \; . \; . \; . \; . \; . \quad (1)$$

Prove $c = a \cos B + b \cos A$ . . . . . (2)

From above figure $c = B\,D + D\,A = a \cos B + b \cos A$

Similarly, it may be shown that

$$a = b \cos C + c \cos B \quad . \; . \; . \; . \; . \; . \; . \quad (2)$$

$$b = a \cos C + c \cos A \quad . \; . \; . \; . \; . \; . \; . \quad (2)$$

Prove $a^2 = b^2 + c^2 - 2bc \cos A$ . . . . . (3)

In ΔABC, CD is perpendicular to AB.

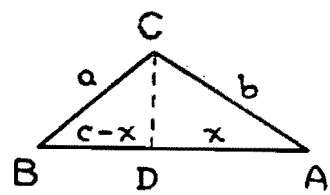
Let $AD = x$, then $BD = (c - x)$ in fig. (i) and $(c + x)$ in fig. (ii).

$$CD^2 = a^2 - (c - x)^2 = b^2 - x^2$$
$$a^2 - c^2 + 2cx - x^2 = b^2 - x^2$$
$$a^2 = b^2 + c^2 - 2cx$$
$$a^2 = b^2 + c^2 - 2cb \cos A \quad . . . . . (3)$$

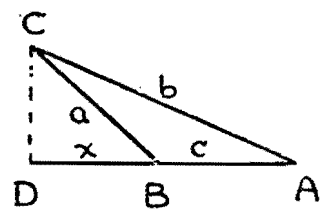
or, writing it in another form

$$\text{Cos } A = \frac{b^2 + c^2 - a^2}{2bc} \quad . . . . . (4)$$

(i)



(ii)



Similarly, it may be shown that

$$\text{Cos } B = \frac{a^2 + c^2 - b^2}{2ac} \quad . . . . . (4)$$

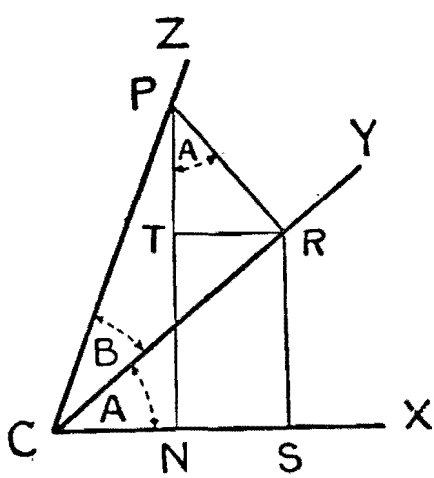
$$\text{Cos } C = \frac{a^2 + b^2 - c^2}{2ab} \quad . . . . . (4)$$

MULTIPLE ANGLES.

Prove $\sin (A + B) = \sin A, \cos B + \cos A, \sin B$ . . . . . (5)

„ $\cos (A + B) = \cos A \cos B - \sin A \sin B$ . . . . . (6)

„ $\tan (A + B) = \dfrac{\tan A + \tan B}{1 - \tan A \tan B}$ . . . . . (7)



Let $\angle YCX = A$ and $\angle ZCY = B$, then $\angle ZCX = (A + B)$.

On CZ (the line that includes the angle $(A + B)$), take any point P, and from this point drop a perpendicular on CY (PR), make PN and RS perpendicular to CX, and RT perpendicular to PN.

Because TR is parallel to CX, and CY cuts both at the same angle, therefore angle $TRC = RCX = A$.

As $\angle TPR$ and $\angle TRC$ are both complements of $\angle TRP$, we have

$$\angle TPR = \angle TRC = \angle A.$$

$$\sin (A + B) = \frac{NP}{CP} = \frac{NT + TP}{CP} = \frac{SR + TP}{CP} = \frac{SR}{CP} + \frac{TP}{CP}$$

By multiplying and dividing $\frac{SR}{CP}$ by CR, and $\frac{TP}{CP}$ by PR, we obtain

$$\sin(A+B) = \frac{SR \times CR}{CR \times CP} + \frac{TP \times PR}{PR \times CP}$$

$$\therefore \sin(A+B) = \sin A, \cos B + \cos A, \sin B \quad \ldots\ldots\ldots \quad (5)$$

$$\cos(A+B) = \frac{CN}{CP} = \frac{CS - NS}{CP} = \frac{CS - TR}{CP} = \frac{CS}{CP} - \frac{TR}{CP}$$

Multiplying and dividing by CR and PR as before, we obtain:—

$$\cos(A+B) = \frac{CS \times CR}{CR \times CP} - \frac{TR \times PR}{PR \times CP}$$

i.e., $$\cos(A+B) = \cos A, \cos B - \sin A, \sin B \quad \ldots\ldots\ldots \quad (6)$$

Triangles CRS and PTR are equiangular because

$$\angle RCS = \angle RPT = \angle A$$
$$\angle RSC = \angle PTR = 90°$$
$$\angle CRS = \angle PRT$$

and the corresponding sides are proportional ;

$\therefore$ $PT : PR = CS : CR$, which may be written as

$$\frac{PT}{CS} = \frac{PR}{CR} = \tan B, \text{ and from fig. } \frac{TR}{PT} = \tan A$$

$$\tan(A+B) = \frac{PN}{CN} = \frac{RS + PT}{CS - TR}. \text{ Dividing by } CS \text{ we get}$$

$$\tan(A+B) = \frac{\frac{RS}{CS} + \frac{PT}{CS}}{\frac{CS}{CS} - \frac{TR}{CS}} = \frac{\frac{RS}{CS} + \frac{PT}{CS}}{1 - \frac{TR}{PT} \times \frac{PT}{CS}} \quad \text{using } PT \text{ as a link line}$$

$$\tan(A+B) = \frac{\tan A + \tan B}{1 - \tan A \tan B} \quad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

Some may prefer to combine (5) and (6) to get (7), as follows :—

$$\tan(A+B) = \frac{\sin(A+B)}{\cos(A+B)} = \frac{\sin A \cos B + \cos A \sin B}{\cos A \cos B - \sin A \sin B}$$

Divide throughout by $\cos A \cos B$ to get tangents

$$\tan(A+B) = \frac{\frac{\sin A \cos B}{\cos A \cos B} + \frac{\cos A \sin B}{\cos A \cos B}}{\frac{\cos A \cos B}{\cos A \cos B} - \frac{\sin A \sin B}{\cos A \cos B}}$$

$$\tan(A+B) = \frac{\tan A + \tan B}{1 - \tan A \tan B} \quad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

If $\tan B = A$, we may write

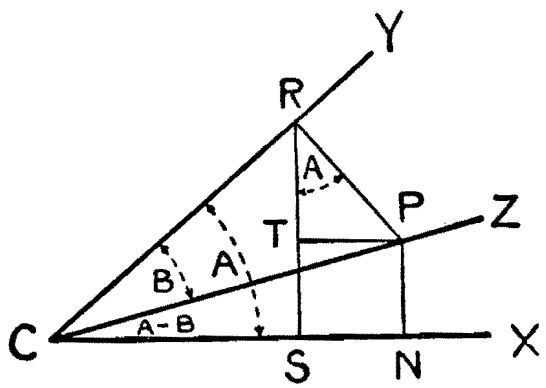
$$\tan(A+A) = \frac{\tan A + \tan A}{1 - \tan A \tan A}$$

$$\therefore \tan 2A = \frac{2 \tan A}{1 - \tan^2 A}$$

Prove $\sin (A - B) = \sin A \cos B - \cos A \sin B$ . . . . . (8)

,, $\cos (A - B) = \cos A \cos B + \sin A \sin B$ . . . . . (9)

,, $\tan (A - B) = \dfrac{\tan A - \tan B}{1 + \tan A \tan B}$ . . . . . (10)



Let $\angle XCY = A$ and $\angle ZCY = B$, then $\angle XCZ = (A - B)$.

From any point P on CZ the line that includes the angle $(A - B)$ make PR perpendicular to CY. Make RS and PN perpendicular to CX, and PT perpendicular to RS.

$\angle TRP$ and $\angle XCR$ are both complements of $\angle CRS$

$\therefore \quad \angle TRP = \angle XCR = \angle A.$

Now, $\sin (A - B) = \dfrac{NP}{CP} = \dfrac{SR - RT}{CP} = \dfrac{SR}{CP} - \dfrac{RT}{CP}$

By multiplying and dividing each fraction by CR and RP respectively we obtain :—

$$\sin (A - B) = \frac{SR \times CR}{CR \times CP} - \frac{RT \times RP}{RP \times CP}$$

$$\therefore \quad \sin (A - B) = \sin A \cos B - \cos A \sin B \quad . . . . . (8)$$

Also, $\cos (A - B) = \dfrac{CN}{CP} = \dfrac{CS + SN}{CP} = \dfrac{CS + TP}{CP} = \dfrac{CS}{CP} + \dfrac{TP}{CP}$

by introducing CR and PR as link lines

$$\cos (A - B) = \frac{CS \times CR}{CR \times CP} + \frac{TP \times RP}{RP \times CP}$$

$$\therefore \quad \cos (A - B) = \cos A \cos B + \sin A \sin B \quad . . . . . (9)$$

$$\tan (A - B) = \frac{PN}{CN} = \frac{RS - RT}{CS + PT}$$

$$= \frac{\dfrac{RS}{CS} - \dfrac{RT}{CS}}{\dfrac{CS}{CS} + \dfrac{PT}{RT} \times \dfrac{RT}{CS}}$$ dividing by CS and using RT as a link line

Remembering that in the similar triangles RPT and CRS

$\dfrac{RT}{RP} = \dfrac{CS}{RC}$ and by transposing we get

$\dfrac{RT}{CS} = \dfrac{RP}{RC} = \tan B$, so that the above becomes

$$\tan (A - B) = \frac{\tan A - \tan B}{1 + \tan A \tan B} \quad . . . . . (10)$$

or it may be deduced from (8) and (9)

$$\tan (A - B) = \frac{\sin (A - B)}{\cos (A - B)}$$

$$\text{,,} \qquad = \frac{\sin A \cos B - \cos A \sin B}{\cos A \cos B + \sin A \sin B}$$

Dividing by $\cos A \cos B$

$$\tan (A - B) = \frac{\dfrac{\sin A \cos B}{\cos A \cos B} - \dfrac{\cos A \sin B}{\cos A \cos B}}{\dfrac{\cos A \cos B}{\cos A \cos B} + \dfrac{\sin A \sin B}{\cos A \cos B}}$$

$$\tan (A - B) = \frac{\tan A - \tan B}{1 + \tan A \tan B} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

SUM AND DIFFERENCE OF TWO ANGLES.

From (5) and (8) the ratios of the sum and difference of angles may be established.

Prove $\sin A + \sin B = 2 \sin \frac{1}{2}(A + B) \cos \frac{1}{2}(A - B)$ . . . . . (11)

,, $\sin A - \sin B = 2 \cos \frac{1}{2}(A + B) \sin \frac{1}{2}(A - B)$ . . . . . (12)

By (5) $\sin (A + B) = \sin A \cos B + \cos A \sin B.$

By (8) $\sin (A - B) = \sin A \cos B - \cos A \sin B.$

By adding and subtracting we get

$$\sin (A + B) + \sin (A - B) = 2 \sin A \cos B$$
$$\sin (A + B) - \sin (A - B) = 2 \cos A \sin B.$$

Let $(A + B) = S$, and $(A - B) = D$

then $S + D = 2A$, and $A = \frac{1}{2}(S + D)$

$S - D = 2B$, and $B = \frac{1}{2}(S - D)$

and by substituting S and D in above we get

$$\sin S + \sin D = 2 \sin \tfrac{1}{2}(S + D) \cos \tfrac{1}{2}(S - D)$$
$$\sin A - \sin D = 2 \cos \tfrac{1}{2}(S + D) \sin \tfrac{1}{2}(S - D)$$

but S and D represent the sum and difference of any two angles so that the general expression may be written

$$\sin A + \sin B = 2 \sin \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B) \quad . \quad . \quad . \quad . \quad . \quad (11)$$
$$\sin A - \sin B = 2 \cos \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B) \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Prove $\cos A + \cos B = 2 \cos \frac{1}{2}(A + B) \cos \frac{1}{2}(A - B)$ . . . . . (13)

,, $\cos B - \cos A = 2 \sin \frac{1}{2}(A + B) \sin \frac{1}{2}(A - B)$ . . . . . (14)

by (6) $\cos (A + B) = \cos A \cos B - \sin A \sin B$

by (9) $\cos (A - B) = \cos A \cos B + \sin A \sin B$

add $\cos (A + B) + \cos (A - B) = 2 \cos A \cos B$

subtract $\cos (A - B) - \cos (A + B) = 2 \sin A \sin B$

If $(A + B) = S$ and $(A - B) = D$

then $\frac{1}{2}(S + D) = A$ and $\frac{1}{2}(S - D) = B$

and by substituting in above we get

$$\cos S + \cos D = 2 \cos \tfrac{1}{2}(S + D) \cos \tfrac{1}{2}(S - D)$$
$$\cos D - \cos S = 2 \sin \tfrac{1}{2}(S + D) \sin \tfrac{1}{2}(S - D)$$

or, by substituting A and B we get the general expression

$$\cos A + \cos B = 2 \cos \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B) \quad . \quad . \quad . \quad . \quad (13)$$
$$\cos B - \cos A = 2 \sin \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B) \quad . \quad . \quad . \quad . \quad (14)$$

Prove $\sin A = 2 \sin \frac{A}{2} \cos \frac{A}{2}$ . . . . . (15)

Substituting $\frac{A}{2}$ for A in (5) we may write

$$\sin\left(\frac{A}{2} + \frac{A}{2}\right) = \sin \frac{A}{2} \cos \frac{A}{2} + \cos \frac{A}{2} \sin \frac{A}{2}$$

$$\therefore \sin A = 2 \sin \frac{A}{2} \cos \frac{A}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

similarly $$\sin B = 2 \sin \frac{B}{2} \cos \frac{B}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

$$\sin C = 2 \sin \frac{C}{2} \cos \frac{C}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

or $$\sin 2A = 2 \sin A \cos A$$

When dealing with spherical triangles we may substitute $(A + B)$ for A, or $(a + b)$ for A and write for angles and sides respectively in (15) :—

for angles $\sin (A + B) = 2 \sin \frac{1}{2}(A + B) \cos \frac{1}{2}(A + B)$ . . . . . (16)
for sides $\sin (a + b) = 2 \sin \frac{1}{2}(a + b) \cos \frac{1}{2}(a + b)$ . . . . . (17)

Prove $\cos A = 1 - 2 \sin^2 \frac{A}{2}$ . . . . . (18)

by (6) $$\cos\left(\frac{A}{2} + \frac{A}{2}\right) = \cos \frac{A}{2} \cos \frac{A}{2} - \sin \frac{A}{2} \sin \frac{A}{2}$$

$$\text{,,} \qquad = \cos^2 \frac{A}{2} - \sin^2 \frac{A}{2}$$

$$\text{,,} \qquad = 1 - \sin^2 \frac{A}{2} - \sin^2 \frac{A}{2}$$

$$\therefore \cos A = 1 - 2 \sin^2 \frac{A}{2}$$

$$\text{or } 2 \sin^2 \frac{A}{2} = 1 - \cos A = \text{versine } A \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Prove $\cos A = 2 \cos^2 \frac{A}{2} - 1$ . . . . . (19)

by (6) $$\cos\left(\frac{A}{2} + \frac{A}{2}\right) = \cos \frac{A}{2} \cos \frac{A}{2} - \sin \frac{A}{2} \sin \frac{A}{2}$$

$$= \cos^2 \frac{A}{2} - \sin^2 \frac{A}{2}$$

$$= \cos^2 A - \left(1 - \cos^2 \frac{A}{2}\right)$$

$$\therefore \cos A = 2 \cos^2 \frac{A}{2} - 1$$

$$\text{or } 1 + \cos A = 2 \cos^2 \frac{A}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

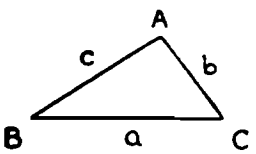
Similarly, $$\cos 2A = 2 \cos^2 A - 1$$

Prove $\cos\frac{A}{2} = \sqrt{\frac{s\,(s-a)}{bc}}$ where $s = \frac{a+b+c}{2}$ . . . . . (20)

by (19) $2\cos^2\frac{A}{2} = \cos A + 1$

by (4) $\quad = \frac{b^2+c^2-a^2}{2bc} + 1$

$\quad = \frac{b^2+2bc+c^2-a^2}{2bc}$



$\quad = \frac{(b+c)^2-a^2}{2bc}$

$\quad = \frac{(b+c+a)\,(b+c-a)}{2bc}$

But if $2s = a+b+c$
then $2\,(s-a) = b+c-a$ because $2s-2a = a+b+c-2a$
and $2\,(s-b) = a+c-b$,, $2s-2b = a+b+c-2b$
and $2\,(s-c) = a+b-c$,, $2s-2c = a+b+c-2c$

$\therefore 2\cos^2\frac{A}{2} = \frac{2s\,.\,2(s-a)}{2bc}$ the 2's cancel,

and $\cos\frac{A}{2} = \sqrt{\frac{s\,.\,(s-a)}{bc}}$ . . . . . (20)

Prove $\sin\frac{A}{2} = \sqrt{\frac{(s-b)\,(s-c)}{bc}}$ where $s = \frac{a+b+c}{2}$ . . . . . (21)

by (18) $2\sin^2\frac{A}{2} = 1 - \cos A$

by (4) $\quad = 1 - \frac{b^2+c^2-a^2}{2bc}$

$\quad = \frac{2bc-b^2-c^2+a^2}{2bc}$

$\quad = \frac{a^2-(b^2-2bc+c^2)}{2bc}$

$\quad = \frac{a^2-(b-c)^2}{2bc}$

$\quad = \frac{(a+b-c)\,(a-b+c)}{2bc}$

$\therefore 2\sin^2\frac{A}{2} = \frac{2\,(s-c)\,2\,(s-b)}{2bc}$

$\therefore \sin\frac{A}{2} = \sqrt{\frac{(s-b)\,(s-c)}{bc}}$ . . . . . (21)

But $2\sin^2\frac{A}{2} = 1 - \cos A = \text{vers } A$

$\therefore \sin^2\frac{A}{2} = \frac{\text{vers } A}{2} =$ haversine A, so the above expression may be written.

$$\text{Havs. } A = \frac{(s-b)\,(s-c)}{bc} \quad . \ . \ . \ . \ . \ . \ . \ . \ . \quad (22)$$

Prove $\dfrac{a+b}{a-b} = \dfrac{\tan \frac{1}{2}(A+B)}{\tan \frac{1}{2}(A-B)}$ . . . . . (23)

by (1) $\dfrac{a}{b} = \dfrac{\sin A}{\sin B}$ and by $\dfrac{\text{Componendo}}{\text{Dividendo}}$

$\therefore \dfrac{a+b}{a-b} = \dfrac{\sin A + \sin B}{\sin A - \sin B}$

by (11) $= \dfrac{2 \sin \frac{1}{2}(A+B) \cos \frac{1}{2}(A-B)}{2 \cos \frac{1}{2}(A+B) \sin \frac{1}{2}(A-B)}$

by (12) $= \tan \frac{1}{2}(A+B) \cot \frac{1}{2}(A-B)$

or $\dfrac{a+b}{a-b} = \dfrac{\tan \frac{1}{2}(A+B)}{\tan \frac{1}{2}(A-B)}$ . . . . . (23)

Prove $\sin^2 A - \sin^2 B = \sin (A+B) \sin (A-B)$ . . . . . (24)

$\text{Sin}^2 A - \sin^2 B = (\sin A + \sin B)(\sin A - \sin B)$ . . . . difference of squares.

$= 2 \sin \frac{1}{2}(A+B) \cos \frac{1}{2}(A-B) \cdot 2 \cos \frac{1}{2}(A+B) \sin \frac{1}{2}(A-B)$ by (11)(12)

$= 2 \sin \frac{1}{2}(A+B) \cos \frac{1}{2}(A+B) \cdot 2 \sin \frac{1}{2}(A-B) \cos \frac{1}{2}(A-B)$ rearrange

$= \sin (A+B) \sin (A-B)$ . . . . by (16) . . . . (24)

Various other expressions may be deduced from the foregoing, for example—

$\cos 3A = \cos (2A + A)$

by (6) $= \cos 2A \cos A - \sin 2A \sin A$

by (19) and (15) $= (2 \cos^2 A - 1) \cos A - (2 \sin A \cos A) \sin A$

$= 2 \cos^3 A - \cos A - 2 \sin^2 A \cos A$

$= 2 \cos^3 A - \cos A - 2(1 - \cos^2 A) \cos A$

$= 2 \cos^3 A - \cos A - 2 \cos A + 2 \cos^3 A$

$\cos 3A = 4 \cos^3 A - 3 \cos A$ . . . . . (25)

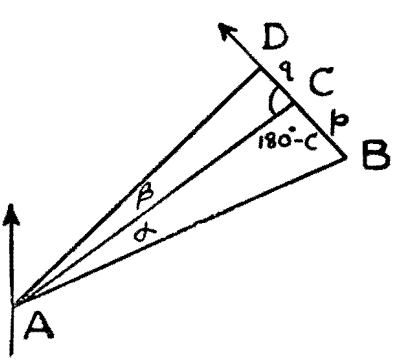
In a similar way it can be proved that $\sin 3A = 3 \sin A - 4 \sin^3 A$ . . (26)

A THREE BEARING FORMULA.

Given three bearings from a fixed point to find the angle at which a given ratio line will cross them.

In figure, let A be a fixed point, AB, AC and AD three lines of bearings drawn from it, α and β the angles between the bearings, BCD a line drawn across the bearings the ratio of BC to CD being as p is to q, expressed either in units of distance or of time.

It is required to find $\angle C$, which will give the angle between the ratio line and the middle bearing.



In $\triangle BAC$ $\dfrac{AC}{\sin B} = \dfrac{p}{\sin \alpha}$ $\therefore AC = p \dfrac{\sin B}{\sin \alpha}$

In $\triangle DAC$ $\dfrac{AC}{\sin D} = \dfrac{q}{\sin \beta}$ $\therefore AC = q \dfrac{\sin D}{\sin \beta}$.

$\therefore p \dfrac{\sin B}{\sin \alpha} = q \dfrac{\sin D}{\sin \beta}$

From figure, $\angle B = C - a \therefore \sin B = \sin (C-a)$

„ $\angle D = 180° - C - \beta = 180° - (C + \beta) \therefore \sin D = \sin (C + \beta)$

$$A C = \frac{p \sin B}{\sin a} = \frac{q \sin D}{\sin \beta}$$

$$\therefore \frac{p \sin (C-a)}{\sin a} = \frac{q \sin (C + \beta)}{\sin \beta}$$

$$p \frac{\sin C \cos a - \cos C \sin a}{\sin a} = q \frac{\sin C \cos \beta + \cos C \sin \beta}{\sin \beta}$$

$p (\sin C \cot a - \cos C) = q (\sin C \cot \beta + \cos C)$

divide both sides by $\sin C$.

$\therefore p (\cot a - \cot C) = q (\cot \beta + \cot C)$

$p \cot a - p \cot C = q \cot \beta + q \cot C$

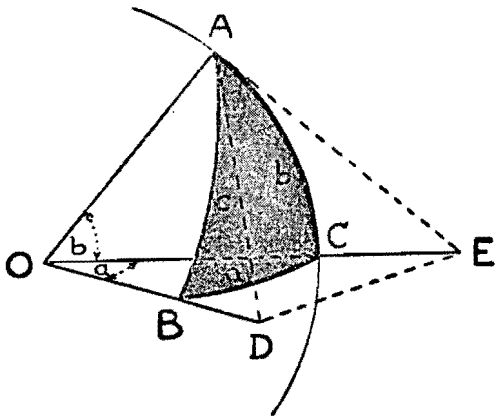
$p \cot a - q \cot \beta = (p + q) \cot C$

$$\text{or } \cot C = \frac{p \cot a - q \cot \beta}{p + q} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

NOTE. — $\angle C$ is on the opposite side to p and a, but should cot C come out negative take $\angle A C B$ instead of $\angle A C D$.

THE COSINE FORMULA.

Prove $\cos A = \dfrac{\cos a - \cos b \cos c}{\sin b \sin c}$ . . . . . (28)



In figure, let O be the centre of a sphere, and ABC a spherical triangle on its surface, so that the radii OB, OC and OA are equal.

AE is a tangent to the great circle AC at A.
AD „ „ „ AB „

and the plane $\angle DAE$ = spherical $\angle BAC$.

Produce OB and OC to meet the tangents at D and E. Join DE.

$\angle AOD$ measures the arc AB, side c.
$\angle DOE$ „ „ BC, side a.
$\angle AOE$ „ „ AC, side b.

by (8) In $\triangle ODE$ $\quad DE^2 = OD^2 + OE^2 - 2\,OD\,.\,OE \cos a$.
In $\triangle ADE$ $\quad DE^2 = AD^2 + AE^2 - 2\,AD\,.\,AE \cos A$.
Subtract, $O = \underbrace{OD^2 - AD^2} + \underbrace{OE^2 - AE^2} + 2\,AD\,.\,AE \cos A - 2\,OD.OE \cos a$

$O =$ $\quad OA^2 \quad +$ $\quad OA^2 \quad +$ do. $\quad -$ do.

AD being tangent to circle AB, of which OA is a radius
$\therefore \angle OAD = 90°$ and $AO^2 = OD^2 - AD^2$.
AE being tangent to circle AC of which OA is a radius
$\therefore \angle OAE = 90°$ and $AO^2 = OE^2 - AE^2$.

$$\therefore\ 2\,OD\,.\,OE \cos a = 2\,OA^2 + 2\,AD\,.\,AE \cos A$$

$$\cos a = \frac{OA}{OE} \cdot \frac{OA}{OD} + \frac{AD}{OD} \cdot \frac{AE}{OE} \cos A$$

$$\cos a = \cos b \cos c + \sin c \sin b \cos A$$

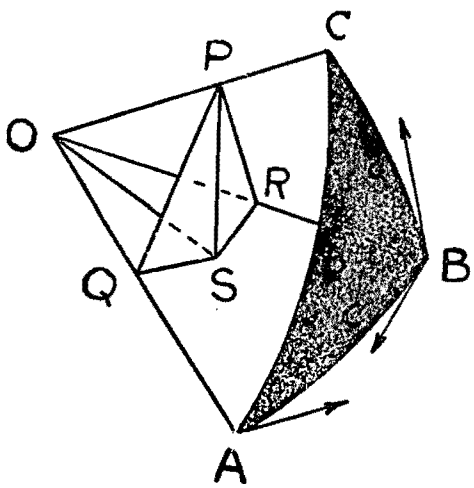
or, $$\cos A = \frac{\cos a - \cos b \cos c}{\sin b \sin c} \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ (28)$$

similarly, $$\cos B = \frac{\cos b - \cos c \cos a}{\sin c \sin a} \quad . \ . \ . \ . \ . \ . \ . \ . \ (28)$$

and $$\cos C = \frac{\cos c - \cos a \cos b}{\sin a \sin b} \quad . \ . \ . \ . \ . \ . \ . \ . \ (28)$$

THE SINE FORMULA.

Prove $\frac{\sin a}{\sin A} = \frac{\sin b}{\sin B}$ . . . . . (29)

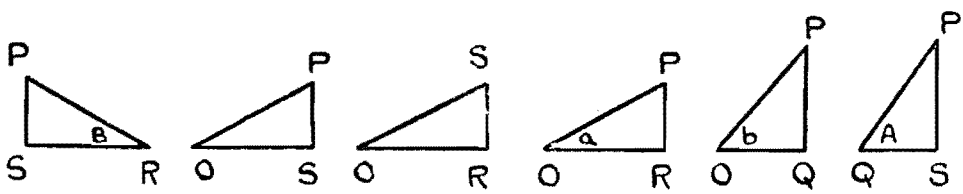


ABC is a spherical triangle, O the centre of the sphere, OA, OB and OC are radii forming the three inclined planes OCB, OCA and OBA.

$\angle COB$ measures the side a, $\angle COA$ the side b and $\angle BOA$ the side c.

Construction.—Take any point P in OC, draw PS perpendicular to the plane OAB and from S draw SR and SQ perpendicular to OB and OA respectively; join PR, PQ, OS.

Since PS is perpendicular to the plane OAB, it makes right angles with every straight line meeting it in that plane, hence angles PSR, PSO and PSQ are each 90°.



In triangles PSR, PSO, RSO and PRO in succession we have the following connections:—

$$PR^2 = PS^2 + SR^2 = PO^2 - OS^2 + SR^2 = PO^2 - OR^2 = PR^2 \quad \therefore \angle PRO = 90°$$

In $\triangle PRO$, $R=90°$, $PR=OP \sin POR=OP \sin a$

In $\triangle PSR$, $S=90°$, $PS=PR \sin PRS=PR \sin B$
$=OP \sin a \sin B$

In $\triangle PQO$, $Q=90°$, $PQ=OP \sin POQ=OP \sin b$ I

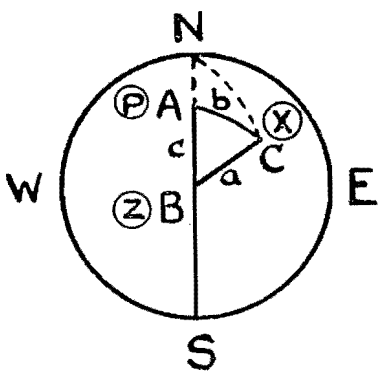
In $\triangle PSQ$, $S=90°$, $PS=PQ \sin PQS=PQ \sin A$
$=OP \sin b \sin A$ II

$\therefore OP \sin a \sin B=OP \sin b \sin A$

and $\frac{\sin a}{\sin A} = \frac{\sin b}{\sin B}$ . . . . . (29)

THE FOUR ADJACENT PARTS FORMULA.

Prove $\sin A \cot B = \sin c \cot b - \cos c \cos A$



In figure, given $\triangle ABC$. Draw in great circle NC

If $\angle BAC = A$, then $\angle NAC = 180° - A$
so that $\cos NAC = \cos (180° - A) = -\cos A$,
side $NB = 90°$ so NA and AB are complementary
and $\cos NA = \sin AB = \sin c$
and $\sin NA = \cos AB = \cos c$
In $\triangle NBC$, $NB = 90°$,
$\therefore \sin$ "comp" $NC = \cos B \cos$ "comp" a
$\cos NC = \cos B \sin a$ I

In $\triangle ABC$, $\dfrac{\sin a}{\sin A} = \dfrac{\sin b}{\sin B}$ $\therefore \sin a = \dfrac{\sin A \sin b}{\sin B}$ which

substitute in I so that

$$\cos NC = \cos B \times \frac{\sin A \sin b}{\sin B} = \cot B \sin A \sin b \quad . \quad . \quad . \quad . \quad \text{II}$$

$$\text{In } \triangle NAC, \cos NC = \cos NA \cos b + \sin NA \sin b \cos (180° - A) \quad . \quad \text{III}$$

Eq. II. = Eq. III.

$$\cot B \sin A \sin b = \cos NA \cos b + \sin NA \sin b (-\cos A)$$

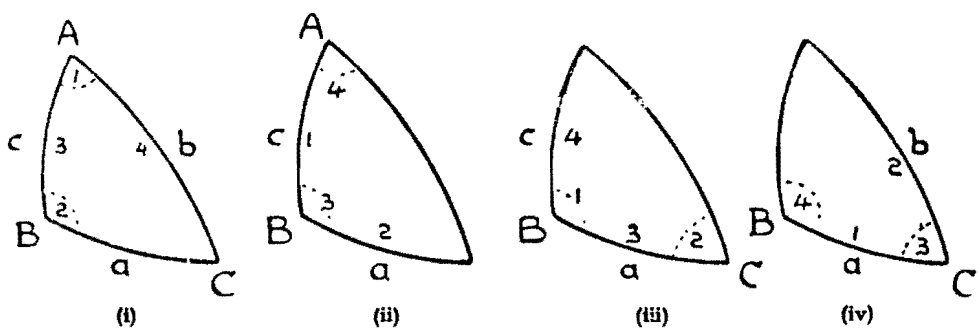
dividing by $\sin b$ we get

$$\cot B \sin A = \sin c \cot b - \cos c \cos A \quad . \quad . \quad . \quad . \quad . \quad (80)$$

It may be noticed that the $\triangle ABC$ is just the PZX triangle of nautical astronomy and that the four part formula is the basis of the ABC Azimuth Tables, so by substitution the formula

$$\cot B \sin A = \sin c \cot b - \cos c \cos A$$

becomes $\cot Z \sin P = \sin PZ \cot PX - \cos PZ \cos P$



This formula is rather difficult to remember, but it will be noted that the four parts occur in their order round the triangle and that there is a symmetry and sequence of the ratios and sides that help one to visualise the connection between them.

We have drawn four triangles leaving out the letters of the two parts not required, and have moved the given parts round one place to the left, as marked in the successive triangles, and have numbered the parts in the order in which they appear in the formula. If we can visualise and apply the formula in (i) we can write it down from symmetry in the other cases by simply moving our numbers round as shown in (ii), (iii) and (iv.)

$$\begin{array}{llllllll} & 1 & 2 & & 3 & 4 & 3 & 1 \\ \text{(i)} & \sin A & \cot B & = \sin c & \cot b & - \cos c & \cos A & \\ \text{(ii)} & \sin c & \cot a & = \sin B & \cot A & + \cos B & \cos c & \end{array}$$

Note that the sign is + when the left side of the formula contains two sides.

$$\begin{array}{llllllll} & 1 & 2 & & 3 & 4 & 3 & 1 \\ \text{(iii)} & \sin B & \cot C & = \sin a & \cot c & - \cos a & \cos B & \\ \text{(iv)} & \sin a & \cot b & = \sin C & \cot B & + \cos C & \cos a & \end{array}$$

Reference is made on page 119 to Norie's ABC Azimuth Table formula, but no special advantage seems to be gained in the modification of the direct formula by dividing each term by sin PZ sin P as previously shown.

The following example will show the application of the formula without the camouflage adopted in Norie's Tables.

Given L.H.A. 45°, Decl. 15° N., Lat. 40° N., required the Azimuth.

$$\cot Z \sin P = \sin PZ \cot PX - \cos PZ \cos P$$
$$A \quad - \quad B$$

PZ	50°	sin	9·88425			P 3h	cos	9·80807
PX	75°	cot	9·42804			- - -	cos	9·84949
		log	9·31230				log	9·65756
Nat No. A		+	·2053					
Nat No. B		−	·4545					
		+	·2492		log	9·39653		
P			3h		cosec	0·15052		
Z			70 35½		cot	9·54705		

Azimuth S. 70° 35½′ W.

The quantity A has a + sign when PX is less than 90°

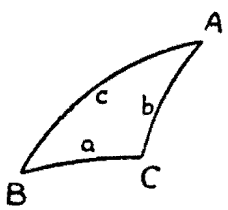
THE HAVERSINE FORMULA.

Prove $\text{hav } A = \dfrac{\text{hav } a - \text{hav } (b-c)}{\sin b \sin c}$ . . . . . (31)

by (28) $$\cos A = \frac{\cos a - \cos b \cos c}{\sin b \sin c}$$

$$1 - \cos A = 1 - \frac{\cos a - \cos b \cos c}{\sin b \sin c}$$

by (18) $$\text{vers } A = \frac{(\sin b \sin c + \cos b \cos c) - \cos a}{\sin b \sin c}$$



$\sin b \sin c \text{ vers } A = \cos (b-c) - \cos a$

add and subtract unity and rearrange.

„ $= 1 - \cos a - [1 - \cos (b-c)]$

„ $= \text{vers } a - \text{vers } (b-c)$

Divide throughout by 2.

$$\sin b \sin c \frac{\text{vers } A}{2} = \frac{\text{vers } a}{2} - \frac{\text{vers } (b-c)}{2}$$

$$\therefore \text{hav } A = \frac{\text{hav } a - \text{hav } (b-c)}{\sin b \sin c} \quad . \quad . \quad . \quad (31)$$

This form is used when three sides are given to find an angle but it may be rewritten in the form

$$\text{hav } a = \sin b \sin c \text{ hav } A + \text{hav } (b-c) \quad . \quad . \quad . \quad (31)$$

when given two sides and included angle, to find the third side, and proved as follows:

In (18) it was shown that $\cos A = 1 - 2 \text{ hav } A$ so by symmetry the angle $\cos (b-c) = 1 - 2 \text{ hav} (b-c)$

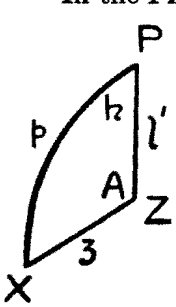
by (28)
$$\begin{aligned} \cos a &= \cos b \cos c + \sin b \sin c \cos A \\ \text{„} &= \cos b \cos c + \sin b \sin c (1 - 2 \text{ hav } A) \\ \text{„} &= (\cos b \cos c + \sin b \sin c) - 2 \sin b \sin c \text{ hav } A \\ \text{„} &= \cos (b-c) - 2 \sin b \sin c \text{ hav } A \end{aligned}$$

$$1 - 2 \text{ hav } a = 1 - 2 \text{ hav } (b-c) - 2 \sin b \sin c \text{ hav } A$$

$$\text{hav } a = \text{hav } (b-c) + \sin b \sin c \text{ hav } A$$

$$\text{or hav } A = \frac{\text{hav } a - \text{hav } (b-c)}{\sin b \sin c} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

In the PZX triangle of nautical astronomy,



where $\angle P$ = hour angle
$\angle A$ = azimuth
z = zenith distance
p = polar distance
l' = co-latitude

the formula would read

$$\text{hav } P = \frac{\text{hav } z - \text{hav } (p - l')}{\sin p \sin l'} \quad . \quad . \quad . \quad (31)$$

the steps of the proof being exactly as above.

ALL HAVERSINE FORMULA.

Prove $$\text{hav } A = \frac{\text{hav } a - \text{hav } (b-c)}{\text{hav } (b+c) - \text{hav } (b-c)} \quad . \quad . \quad . \quad . \quad (32)$$

by (28)
$$\cos a = \cos b \cos c + \sin b \sin c \cos A$$
$$\text{,,} = \cos b \cos c + \sin b \sin c (1 - 2 \text{ hav } A)$$
$$\text{,,} = (\cos b \cos c + \sin b \sin c) - 2 \sin b \sin c \text{ hav } A$$
$$\text{,,} = \cos (b-c) - 2 \sin b \sin c \text{ hav } A$$
$$1 - 2 \text{ hav } a = 1 - 2 \text{ hav } (b-c) - 2 \sin b \sin c \text{ hav } A$$
$$\text{hav } a = \text{hav } (b-c) + \sin b \sin c \text{ hav } A$$
$$\text{hav } a = \text{hav } (b-c) + [\text{hav } (b+c) - \text{hav } (b-c)] \text{ hav } A$$
$$\therefore \text{hav } A = \frac{\text{hav } a - \text{hav } (b-c)}{\text{hav } (b+c) - \text{hav } (b-c)} \quad . \quad . \quad . \quad . \quad . \quad (32)$$

It may be noted that the first five lines in the transformation are the same steps as in proof (31) and that it is left to convert $\sin b \sin c$ into haversines as follows:—

By proofs (13) and (14) 4th line we get

$$2 \sin A \sin B = \cos (A - B) - \cos (A + B)$$
$$\text{so that } \sin b \sin c = \tfrac{1}{2}\{\cos (b-c) - \cos (b+c)\}$$
$$\text{,,} = \tfrac{1}{2}\{1 - 2 \text{ hav } (b-c) - [1 - 2 \text{ hav } (b+c)]\}$$
$$\therefore \sin b \sin c = \text{hav } (b+c) - \text{hav } (b-c) \text{ as substituted above.}$$

In the *PZX* triangle the formula would be written

$$\text{hav } P = \frac{\text{hav } z - \text{hav } (p-l)}{\text{hav } (p+l) - \text{hav } (p-l)}$$

but if the complementary parts, latitude (L) and declination (D) be substituted for l and p respectively, due attention must be paid to the angle ($L \pm D$), viz., one named north and the other south use ($L + D$), but when they have the same names use ($L - D$). The formula is then modified to meet the condition $1 - \text{hav } A = \text{hav } (180° - A)$ into

$$\text{hav } P = \frac{\text{hav } z - \text{hav } (L \pm D)}{1 - \{\text{hav } (L+D) + \text{hav } (L-D)\}} \quad . \quad . \quad . \quad . \quad (32)$$

The transformation is as follows:—

$$1 - \text{hav } A = 1 - \frac{1 - \cos A}{2} = \frac{2 - (1 - \cos A)}{2} = \frac{1 + \cos A}{2}$$
$$= \frac{1 - \cos (180° - A)}{2} = \text{hav } (180° - A)$$

again
$$\text{hav } (p+l) = \text{hav } (90° - D + 90° - L)$$
$$\text{,,} = \text{hav } [180° - (L+D)] = 1 - \text{hav } (L+D)$$
$$\text{hav } (p-l) = \text{hav } (90° - D - 90° + L) = \text{hav } (L-D)$$
$$\therefore \text{hav } (p+l) - \text{hav } (p-l) = 1 - \text{hav } (L+D) - \text{hav } (L-D)$$
$$\text{,,} = 1 - [\text{hav } (L+D) + \text{hav } (L-D)] \text{ as substituted.}$$

A THREE SIDES FORMULA.

Prove hav $A = \dfrac{\sin(s-b)\sin(s-c)}{\sin b \sin c}$ where $s = \dfrac{a+b+c}{2}$ . . . . . (33)

by (28) $$1 - \cos A = 1 - \frac{\cos a - \cos b \cos c}{\sin b \sin c}$$

" $$= \frac{\cos b \cos c + \sin b \sin c - \cos a}{\sin b \sin c}$$

by (9) " $$= \frac{\cos(b-c) - \cos a}{\sin b \sin c}$$

by (14) $$\text{vers } A = \frac{2 \sin \frac{1}{2}(a+b-c) \sin \frac{1}{2}(a+c-b)}{\sin b \sin c}$$

If $2s = a+b+c$, then $2s - 2c = a+b+c-2c$

$2(s-c) = a+b-c$

$\therefore (s-c) = \frac{1}{2}(a+b-c)$

Similarly, $(s-b) = \frac{1}{2}(a+c-b)$

Substituting in above we get

$$\frac{\text{vers } A}{2} = \frac{\sin(s-c)\sin(s-b)}{\sin b \sin c}$$

$$\therefore \text{hav } A = \frac{\sin(s-b)\sin(s-c)}{\sin b \sin c} \quad . . . . . (33)$$

This may also be written as

$$\sin \frac{A}{2} = \sqrt{\frac{\sin(s-b)\sin(s-c)}{\sin b \sin c}} \quad . . . . . (33)$$

because $$\frac{\text{vers } A}{2} = \frac{1-\cos A}{2} = \frac{2\sin^2 A/2}{2} = \sin^2 \frac{A}{2}$$

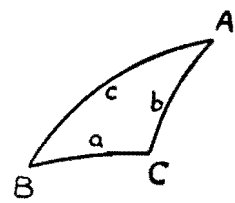
In the PZX triangle this would read

$$\text{hav } P = \frac{\sin(s-p)\sin(s-l')}{\sin p \sin l'} \quad . . . . . (33)$$

where $$s = \frac{z+p+l'}{2}$$

A THREE SIDES FORMULA.

Prove $\cos\frac{A}{2} = \sqrt{\frac{\sin s \sin(s-a)}{\sin b \sin c}}$ where $s = \frac{a+b+c}{2}$ . . . . . (34)



by (28) $$1 + \cos A = 1 + \frac{\cos a - \cos b \cos c}{\sin b \sin c}$$

" $$= \frac{\cos a - (\cos b \cos c - \sin b \sin c)}{\sin b \sin c}$$

by (6) " $$= \frac{\cos a - \cos(b+c)}{\sin b \sin c}$$

by (14) $$2\cos^2\frac{A}{2} = \frac{2\sin\frac{1}{2}(a+b+c)\sin\frac{1}{2}(b+c-a)}{\sin b \sin c}$$

$$\cos^2\frac{A}{2} = \frac{\sin s \sin(s-a)}{\sin b \sin c}$$

$$\therefore \cos\frac{A}{2} = \sqrt{\frac{\sin s \sin(s-a)}{\sin b \sin c}} \quad . . . . . (34)$$

This would read in the PZX triangle

$$\cos\frac{P}{2} = \sqrt{\frac{\sin s \sin(s-z)}{\sin p \sin l'}} \text{ where } s = \frac{p+l'+z}{2}$$

A THREE SIDES FORMULA.

Prove $\tan\frac{A}{2} = \sqrt{\frac{\sin(s-b)\sin(s-c)}{\sin s \sin(s-a)}}$ where $s = \frac{a+b+c}{2}$ . . . . (35)

by (33) and (34) $$\tan\frac{A}{2} = \frac{\sin\frac{A}{2}}{\cos\frac{A}{2}} = \frac{\sqrt{\frac{\sin(s-b)\sin(s-c)}{\sin b \sin c}}}{\sqrt{\frac{\sin s \sin(s-a)}{\sin b \sin c}}}$$

$$\therefore \tan\frac{A}{2} = \sqrt{\frac{\sin(s-b)\sin(s-c)}{\sin s \sin(s-a)}} \quad . . . . . (35)$$

Similarly, $$\cot\frac{A}{2} = \sqrt{\frac{\sin s \sin(s-a)}{\sin(s-b)\sin(s-c)}} \quad . . . . . (36)$$

THE SINE FORMULA.

Prove $\frac{\sin a}{\sin b} = \frac{\sin A}{\sin B}$ . . . . . (37)

by (15) $$\sin A = 2\sin\frac{A}{2}\cos\frac{A}{2}$$

by (33) and (34) $$\sin A = 2\sqrt{\frac{\sin(s-b)\sin(s-c)}{\sin b \sin c}}\sqrt{\frac{\sin s \sin(s-a)}{\sin b \sin c}}$$

(i.) $$\sin A = 2\frac{\sqrt{\sin s \sin(s-a)\sin(s-b)\sin(s-c)}}{\sin b \sin c}$$

Similarly, (ii.) $\sin B = 2\,\dfrac{\sqrt{\sin s \sin(s-a)\sin(s-b)\sin(s-c)}}{\sin a \sin c}$

Dividing (i.) by (ii.) we get

$$\frac{\sin A}{\sin B} = \frac{\sin a}{\sin b} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (37)$$

See also geometrical proof (29).

NAPIER'S ANALOGIES.

Prove $\tan \frac{1}{2}(A+B) = \dfrac{\cos \frac{1}{2}(a-b)}{\cos \frac{1}{2}(a+b)} \cot \dfrac{C}{2}$ $\ldots\ldots\ldots\ldots$ (38)

by (28) (i.) $\cos A = \dfrac{\cos a - \cos b \cos c}{\sin b \sin c}$

(ii.) $\cos c = \cos a \cos b + \sin a \sin b \cos C$

Substitute (ii.) for cos c in (i.)

$$\cos A = \frac{\cos a - \cos b(\cos a \cos b + \sin a \sin b \cos C)}{\sin b \sin c}$$

$$\text{,,} = \frac{\cos a - \cos a \cos^2 b + \sin a \sin b \cos b \cos C}{\sin b \sin c}$$

$$\text{,,} = \frac{\cos a(1 - \cos^2 b) - \sin a \sin b \cos b \cos C}{\sin b \sin c}$$

$$\text{,,} = \frac{\cos a \sin^2 b - \sin a \sin b \cos b \cos C}{\sin b \sin c}$$

$$\cos A = \frac{\cos a \sin b - \sin a \cos b \cos C}{\sin c}$$

By substituting B for A and b for a, we may write down from symmetry

$$\cos B = \frac{\cos b \sin a - \sin b \cos a \cos C}{\sin c}$$

then adding and grouping the quantities we get

$\cos A + \cos B = (\cos a \sin b, + \sin a \cos b) - \cos C\,(\sin a \cos b + \cos a \sin b)$

$$\cos A + \cos B = \frac{\sin(a+b) - \sin(a+b)\cos C}{\sin c}$$

$$\text{,,} = \frac{\sin(a+b)\,[1 - \cos C]}{\sin c}$$

by (18) $$\cos A + \cos B = \frac{\sin(a+b)\,2\sin^2 \frac{C}{2}}{\sin c} \quad \ldots\ldots\ldots\ldots \quad \text{(iii.)}$$

But by (29) $\dfrac{\sin A}{\sin C} = \dfrac{\sin a}{\sin c}$ $\quad \therefore \sin A = \dfrac{\sin a \sin C}{\sin c}$

and $\sin B = \dfrac{\sin b \sin C}{\sin c}$

Add, $$\sin A + \sin B = \frac{\sin C(\sin a + \sin b)}{\sin c} \quad \ldots\ldots\ldots \quad \text{(iv.)}$$

Divide (iv.) by (iii.).

$$\frac{\sin A + \sin B}{\cos A + \cos B} = \frac{\sin C\,(\sin a + \sin b)}{2\sin^2\frac{C}{2}\sin(a+b)}$$

by (11) $$= \frac{\sin C}{2\sin^2\frac{C}{2}} \times \frac{2\sin\frac{1}{2}(a+b)\cos\frac{1}{2}(a-b)}{\sin(a+b)}$$

by (15) $\sin C = 2\sin\frac{C}{2}\cos\frac{C}{2}$, and expanding $\sin(a+b)$ by (17) we get

$$\frac{\sin A + \sin B}{\cos A + \cos B} = \frac{2\sin\frac{C}{2}\cos\frac{C}{2}}{2\sin^2\frac{C}{2}} \times \frac{2\sin\frac{1}{2}(a+b)\cos\frac{1}{2}(a-b)}{2\sin\frac{1}{2}(a+b)\cos\frac{1}{2}(a+b)}$$

the right hand side cancels to

by (11) by (13) $$\frac{2\sin\frac{1}{2}(A+B)\cos\frac{1}{2}(A-B)}{2\cos\frac{1}{2}(A+B)\cos\frac{1}{2}(A-B)} = \frac{\cos\frac{C}{2}}{\sin\frac{C}{2}} \times \frac{\cos\frac{1}{2}(a-b)}{\cos\frac{1}{2}(a+b)}$$

$$\tan\tfrac{1}{2}(A+B) = \frac{\cos\frac{1}{2}(a-b)}{\cos\frac{1}{2}(a+b)}\cot\frac{C}{2} \quad \ldots\ldots \quad (38)$$

Prove $\tan\frac{1}{2}(A-B) = \frac{\sin\frac{1}{2}(a-b)}{\sin\frac{1}{2}(a+b)}\cot\frac{C}{2}$ . . . . . (39)

by (12) by (13) $$\frac{\sin A - \sin B}{\cos A + \cos B} = \frac{2\cos\frac{1}{2}(A+B)\sin\frac{1}{2}(A-B)}{2\cos\frac{1}{2}(A+B)\cos\frac{1}{2}(A-B)} = \tan\tfrac{1}{2}(A-B)$$

$$\therefore \tan\tfrac{1}{2}(A-B) = \frac{\sin A - \sin B}{\cos A + \cos B}$$

by (29)

$$\therefore \tan\tfrac{1}{2}(A-B) = \frac{\dfrac{\sin a\sin C}{\sin c} - \dfrac{\sin b\sin C}{\sin c}}{\dfrac{\sin(a+b)\,2\sin^2\frac{C}{2}}{\sin c}}$$

by (iii.) in (38)

$\sin c$ cancels and numerator becomes

$$\therefore \tan\tfrac{1}{2}(A-B) = \frac{\sin C\,(\sin a - \sin b)}{2\sin^2\frac{C}{2}\sin(a+b)}$$

by (15), (12) and (17)

$$\therefore \tan\tfrac{1}{2}(A-B) = \frac{2\sin\frac{C}{2}\cos\frac{C}{2}}{2\sin^2\frac{C}{2}} \times \frac{2\cos\frac{1}{2}(a+b)\sin\frac{1}{2}(a-b)}{2\cos\frac{1}{2}(a+b)\sin\frac{1}{2}(a+b)}$$

which cancels to

$$\tan \tfrac{1}{2}(A - B) = \frac{\sin \frac{1}{2}(a - b)}{\sin \frac{1}{2}(a + b)} \cot \frac{C}{2} \quad \ldots \quad (39)$$

$$\tan \tfrac{1}{2}(A + B) = \frac{\cos \frac{1}{2}(a - b)}{\cos \frac{1}{2}(a + b)} \cot \frac{C}{2} \quad \ldots \quad (38)$$

Napier's Analogies (38) and (39) when combined are applied to finding the two angles when given two sides with their included angle, as in great circle sailing to find the courses, and in time azimuth examples.

One of the following two analogies may be applied to find a side when the other two sides with their opposite angles are given.

$$\frac{\tan \frac{1}{2} c}{\tan \frac{1}{2}(a + b)} = \frac{\cos \frac{1}{2}(A + B)}{\cos \frac{1}{2}(A - B)} \quad \ldots \quad (40)$$

$$\frac{\tan \frac{1}{2} c}{\tan \frac{1}{2}(a - b)} = \frac{\sin \frac{1}{2}(A + B)}{\sin \frac{1}{2}(A - B)} \quad \ldots \quad (41)$$

Given three angles to find a side

$$\text{hav } a = \frac{\cos S \cos (S - A)}{\sin B \sin C} \quad \ldots \quad (42)$$

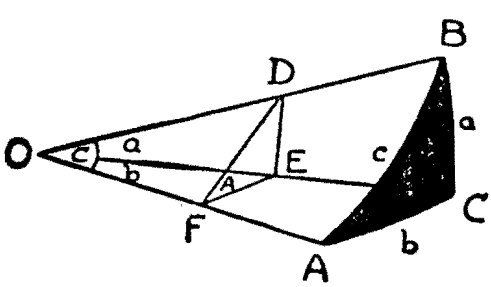
where S=half sum of the three angles.

RIGHT ANGLED SPHERICAL TRIANGLES.

ABC is a spherical triangle, O the centre of the sphere, $\angle ACB = 90°$ so the plane AOC is perpendicular to the plane BOC. $OA = OC = OB$ radii of the sphere.

Construction.—Make DE perpendicular to OC and EF perpendicular to OA $\angle DEF = 90°$ being at the intersection of two perpendicular planes, $\angle DEF = \angle C$.

Join DF and prove $\angle OFD = 90°$.



$\angle EFO = 90°$ $\therefore$ $OF^2 + FE^2 = OE^2$. Add DE^2

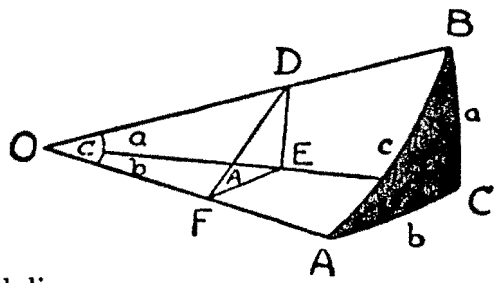
$OF^2 + (FE^2 + DE^2) = OE^2 + DE^2$

$OF^2 + DF^2 = OD^2$

$\therefore$ $\angle DFO = 90°$

$\angle BOC$	measures	side a
$\angle COA$	,,	,, b
$\angle AOB$	,,	,, c
$\angle EFD$	,,	$\angle A$
$\angle DEF$	,,	$\angle C$

The triangles referred to are as named in the following proofs, the middle letters being at the right angled corner, there being so many of them that one is easily confused.



(1) $\angle DFO,\ \angle EFO,\ \angle DEF = 90°$

$\frac{OF}{OD} = \frac{OF}{OE} \cdot \frac{OE}{OD}$, using OE as a link line

$\therefore \cos FOD = \cos EOF \cos DOE$

or $\cos c = \cos b \cos a$.

(2) $\angle DEO,\ \angle DEF,\ \angle DFO = 90°$

$\frac{DE}{OD} = \frac{DE}{DF} \cdot \frac{DF}{OD}$, using DF as a link line

$\sin a = \sin A \sin c$ . . . . . or $\sin A = \frac{\sin a}{\sin c}$

(3) Similarly it can be shown, by making FE and FD perpendicular to OC and OB respectively,

$\angle FDE = B$

$\sin b = \sin B \sin c$ . . . . . or $\sin B = \frac{\sin b}{\sin c}$

(4) $\angle EFO,\ \angle DEF,\ \angle DFO = 90°$

$\frac{EF}{OF} = \frac{EF}{DF} \cdot \frac{DF}{OF}$

$\therefore \tan b = \cos A \tan c$ . . . . . or $\cos A = \frac{\tan b}{\tan c}$

(5) Similarly $\tan a = \cos B \tan c$ . . . . . or $\cos B = \frac{\tan a}{\tan c}$

(6) $\angle DEF,\ \angle OFE,\ \angle DEO = 90°$

$\frac{ED}{EF} = \frac{OE}{EF} \cdot \frac{ED}{OE}$

$\therefore \tan A = \text{cosec } b \tan a$ . . . . . or $\tan A = \frac{\tan a}{\sin b}$

(7) Similarly $\tan B = \text{cosec } a \tan b$ . . . . . or $\tan B = \frac{\tan b}{\sin a}$

(8) By (2) $\sin a = \sin A \sin c$

By (5) $\tan a = \cos B \tan c$

Divide (2) by (5) $\cos a = \frac{\sin A \cos c}{\cos B}$

or $\cos B = \frac{\sin A \cos c}{\cos a}$ but by (1) $\cos b = \frac{\cos c}{\cos a}$

$\therefore \cos B = \sin A \cos b$ . . . . . or $\sin A = \frac{\cos B}{\cos b}$

(9) By (3) $\sin b = \sin B \sin c$

By (4) $\tan b = \cos A \tan c$

Divide (3) by (4) $\cos b = \dfrac{\sin B \cos c}{\cos A}$

$$\text{or } \cos A = \frac{\sin B \cos c}{\cos b} \text{ but by (1) } \cos a = \frac{\cos c}{\cos b}$$

$$\therefore \cos A = \sin B \cos a \text{ . . . . . or } \sin B = \frac{\cos A}{\cos a}$$

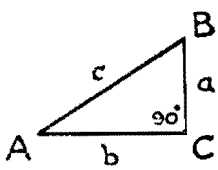
(10) Multiply (6) by (7).

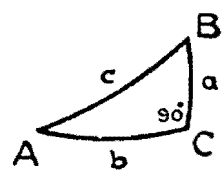
$$\tan A \tan B = \frac{\tan a}{\sin b} \cdot \frac{\tan b}{\sin a}$$

$$\text{,,} \qquad = \frac{1}{\cos a \cos b} = \frac{1}{\cos c,} \text{ . . . . . by (1)}$$

or $\cot A \cot B = \cos c$ by using reciprocals.

It is interesting to compare these formulæ with the corresponding ones for plane triangles and to note the similarity.





In plane right triangles.

$\sin A = \dfrac{a}{c}$ $\qquad$ $\sin B = \dfrac{b}{c}$

$\cos A = \dfrac{b}{c}$ $\qquad$ $\cos B = \dfrac{a}{c}$

$\tan A = \dfrac{a}{b}$ $\qquad$ $\tan B = \dfrac{b}{a}$

$\sin A = \cos B$ $\qquad$ $\sin B = \cos A$

$c^2 = a^2 + b^2$

$1 = \cot A \cot B$

In spherical right triangles.

(2) $\sin A = \dfrac{\sin a}{\sin c}$ $\qquad$ (3) $\sin B = \dfrac{\sin b}{\sin c}$

(4) $\cos A = \dfrac{\tan b}{\tan c}$ $\qquad$ (5) $\cos B = \dfrac{\tan a}{\tan c}$

(6) $\tan A = \dfrac{\tan a}{\sin b}$ $\qquad$ (7) $\tan B = \dfrac{\tan b}{\sin a}$

(8) $\sin A = \dfrac{\cos B}{\cos b}$ $\qquad$ (9) $\sin B = \dfrac{\cos A}{\cos a}$

(1) $\cos c = \cos a \cos b$

(10) $\cos c = \cot A \cot B$

These ten formulae for right angled triangles are grouped under the two rules referred to on page 112, as Napier's Rules for Circular Parts.

THE TRIGONOMETRICAL RATIOS FOR SMALL ANGLES.

If a small angle θ is expressed in circular measure, we have

$\sin\theta = \theta$ radians; $\cos\theta = 1$; $\tan\theta = \theta$ radians

1 radian $= 57° 17' 45'' = 3437{\cdot}75' = 206265''$

so that $\sin 1' = \frac{1}{3438}$ radian, $\sin 1'' = \frac{1}{206265}$ radian.

When angle θ is very small the chord and the subtended arc of the circle are very nearly equal, and if θ be indefinitely diminished we can make $\frac{\theta''}{\sin\theta''}$ differ from unity by less than any assignable quantity, however small, so that we may write

$$\sin\theta'' = \theta'' \sin 1''$$

$$\text{or } \sin\theta' = \theta' \sin 1' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (43)$$

This approximation is frequently made use of in spherical astronomy, remembering that angles are frequently expressed in terms of time,

$$24 \text{ hours} = 360°;\ 1\text{h} = 15°;\ 1\text{m} = 15';\ 1\text{s} = 15''$$

and approximately,

$$\sin 1\text{m} = \sin 15' = 15 \sin 1'$$

$$\text{or } \sin 1\text{s} = \sin 15'' = 15 \sin 1'' \quad . \quad . \quad . \quad . \quad (43)$$

THE POLAR TRIANGLE.

Every spherical triangle has its polar triangle formed by the great circles on the sphere joining the poles of its respective three sides. The pole of a great circle is that point on the sphere 90° removed from every part of the great circle.

In figure, given triangle ABC with A^1, B^1, C^1, the respective poles of the arcs CB AC, and BA. Then $A^1B^1C^1$ is the polar triangle of ABC, and A^1 is 90° from every spot on CB. Produce AC and AB to meet the polar arc C^1B^1 at x and y, then A is the pole of arc C^1B^1 and arc xy=angle A, because Ax and Ay=90°

B^1 is the pole of arc AC and is 90° removed from it.

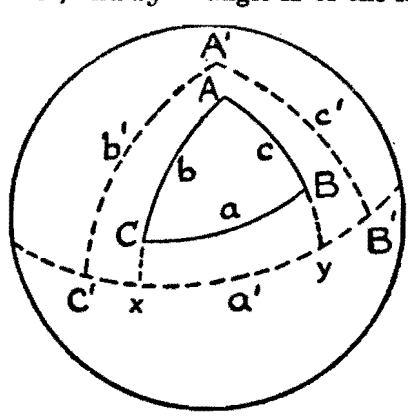
C^1 " AB

so that $B^1x = 90°$ and $C^1y = 90°$ $\therefore$ $B^1x + C^1y = 180°$

But $B^1C^1 = C^1y + yB^1$

and $xy = B^1x - yB^1$

add, $B^1C^1 + xy = B^1x + C^1y = 180°$ as above, but B^1C^1 is a^1, the side opposite angle A' of the polar triangle $A^1B^1C^1$, and xy = angle A of the ABC triangle



$\therefore B^1C^1 + xy = a^1 + A = 180°$. Similarly, if $A^1B^1C^1$ be the polar triangle of any spherical triangle ABC, with sides lettered $a^1b^1c^1$ correspondingly, we deduce that—

$180° - A$ of any triangle = side a^1 of its polar triangle
$180° - B$ „ = „ b^1 „
$180° - C$ „ = „ c^1 „

And conversely—

$180° - A^1$ of polar triangle = side a of the ABC triangle.
$180° - B^1$ „ = „ b „
$180° - C^1$ „ = „ c „

The formulae of a spherical triangle apply also to its polar triangle, for example, in the fundamental formula $\cos a = \cos b \cos c + \sin b \sin c \cos A$.

If $\pi = 180°$, then the polar equivalent is
$\cos(\pi - A^1) = \cos(\pi - B^1)\cos(\pi - C^1) + \sin(\pi - B^1)\sin(\pi - C^1)\cos(\pi - a^1)$
or, simply, $-\cos A^1 = \cos B^1 \cos C^1 - \sin B^1 \sin C^1 \cos a^1$.

Thus the angles and sides of the triangle may be converted into the corresponding sides and angles of its polar triangle, and the usual formulae applied to the solution of the triangle.

NOTE.—Cos of an angle = − cos of its supplement
Sin „ = + sin „ „

POLAR TRIANGLE.

Example.—In a spherical triangle ABC, $\angle A = 57° 26' 45''$, $\angle B = 94° 0' 45''$, $\angle C = 71° 51' 30''$. Find sides a and b.

Subtract each angle from 180° and name them a^1, b^1, c^1 respectively, then apply the appropriate spherical formula. The result will be the supplement of the side required. Suppose we apply the following established formula—

$$\text{hav } A^1 = \frac{\sin(s - b^1)\sin(s - c^1)}{\sin b^1 \sin c^1}$$

$$\text{hav } B^1 = \frac{\sin(s - a^1)\sin(s - c^1)}{\sin a^1 \sin c^1}$$

where $s = \frac{1}{2}(a^1 + b^1 + c^1)$

						(A^1)	(B^1)
$(180° - A)$	a^1	122°	33′	15″	cosec	. . .	. 0·07423
$(180° - B)$	b^1	85	59	15	cosec	0·00107	
$(180° - C)$	c^1	108	08	30	cosec	0·02214	0·02214
		2)316	41	00			
	s	158	20	30			
$(s - a^1)$		35	47	15	sin	. . .	. 9·76700
$(s - b^1)$		72	21	15	sin	9·97907	
$(s - c^1)$		50	12	00	sin	9·88552	9·88552
	A^1	129	00		hav	9·88780	9·74889
		180					
						B^1	96° 59′ 45″
	Side a	57	00				180
						side b	83 00 15

The triangle may be solved direct from the three given angles, and thus avoid supplementary parts, by the formula—

$$\text{hav } a = \frac{\cos S \times \cos (S - A)}{\sin B \sin C}$$

$$\text{hav } b = \frac{\cos S \times \cos (S - B^1)}{\sin A \sin C}$$

where $S = \frac{1}{2}(A + B + C)$

					(*a*)	(*b*)
A	57°	26′	45″	cosec	. .	0·07428
B	94	00	45	cosec	0·00112	. . .
C	71	51	30	cosec	0·02214	0·02214
	2)223	19	00			
S	111	39	30	cos	9·56711	9·56711
(*S* − *A*)	54°	12′	45″	cos	9·76698	. . .
(*S* − *B*)	17	38	45	cos	. . .	9·97907
Side *a*	57	00	00	hav	9·35735	9·64255
					side *b*	83° 00½′

1. Initial course of a great circle track in South hemisphere is N. 66° 13′ 45″ E., the final course is N. 43° 20′ 40″ E., the difference of longitude is 112°. Required the great circle distance between the two positions and their latitudes.

Ans. Lat. 42° 46¾′ S., Long. 11° 50¼′ S., Dist. 97° 27′ = 5847 miles.

2. In spherical triangle *ABC*, find the value of the sides, if $\angle A = 57° 26′ 45″$, $\angle B = 94° 00′ 45″$, $\angle C = 71° 51′ 30″$.

Ans. *a* 57° 00′, *b* 83° 00½′, *c* 71° 01′.

SPHERICAL EXCESS.

A geodetic survey is one which covers a considerable area of the Earth's surface and takes into account the curvature of the sphere.

The distances between observation stations in a geodetic survey may exceed 40 or 50 miles and the triangles are therefore spherical. The angles measured by theodolite at the triangulation stations are spherical angles and the sum of the three angles of the triangle will exceed 180 degrees. The excess of angles $A + B + C$ over 180° is called the *spherical excess* and is usually denoted by E, so that $E = A + B + C - 180°$.

The amount of spherical excess depends upon the area of the triangle and also upon the latitudes of the observation stations; it is approximately equal to 1 second of arc for each 75·5 square miles area of the triangle.

The quantity E may be computed more accurately from the formula—

$$E = \frac{\text{area of triangle}}{R^2 \sin 1''} = \frac{\frac{1}{2} b c \sin A}{R^2 \sin 1''}$$

where b and c are the sides of the plane triangle and A the included angle, R the mean radius of the Earth. The mean radius is accepted as being 20,889,000 feet and log $R = 7{\cdot}319917$.

Example.—If side $b = 20$ miles (105,600 ft.), side $c = 40$ miles (211,208 ft.). $\angle A = 60°$, the approximate method gives $E = 4{\cdot}5''$, and, by the accurate formula, $E = 4{\cdot}56''$.

The spherical excess varies as the area of the triangle, the area $= E r^2$ where r is the radius of the sphere.

The area of a spherical triangle varies as its spherical excess, so that for any two triangles $A\ B\ C$ and $A^1B^1C^1$ on the same sphere.

$$\frac{\text{area of } A\ B\ C}{\text{area of } A^1B^1C^1} = \frac{E}{E^1}$$

E is usually expressed in circular measure.

A radian $= 57°\ 17'\ 45'' = 3438' = 206265''$ so that, in circular measure, $1' = \frac{1}{3438}$ and $1'' = \frac{1}{206265}$

Example.—If the spherical excess be $1'$ and the radius of the sphere 9 inches, find the area of the triangle, and also of the sphere.

$$\text{Area of triangle} = E r^2 = \frac{1}{3438} \times 9^2 = {\cdot}0236 \text{ sq. ins.}$$

$$\text{Area of sphere} = 4\pi r^2 = \frac{4 \times 22 \times 9^2}{7} = 1018{\cdot}3 \text{ sq. inches.}$$

Example.—The surface area of a sphere is 4096 square feet. An equilateral spherical triangle whose angles are each $64°\ 51'\ 40''$ is described on the sphere. Find the area of the triangle.

$A + B + C = 3 \times 64°\ 51'\ 40'' = 194°\ 35'$

$E = 194°\ 35' - 180° = 14°\ 35'$

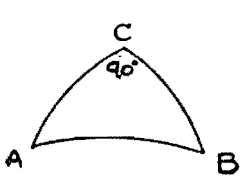
Area of sphere $= 4\pi r^2 = 4096$ sq. ft.

from which $r^2 = 325{\cdot}8$ ft.

$$E \text{ in circular measure} = \frac{14°\ 35'}{57°\ 18'} = \frac{875}{3438} \quad \text{in minutes of arc.}$$

$$\text{Area of triangle} = E r^2 = \frac{875 \times 325{\cdot}8}{3438} = 82{\cdot}96 \text{ sq. ft.}$$

A right-angled isosceles spherical triangle has an area equal to one-ninth the whole area of the sphere. Find the hypotenuse of the triangle.



Given $\angle A = \angle B$ and $\angle C = 90°$

$E = A + B + C - 180° = 2A + 90° - 180° = 2A - 90°$

Area of sphere $= 4\pi r^2$

$$\text{Area of triangle} = E r^2 = \frac{4}{9}\pi r^2$$

$$\therefore E = \frac{4\pi}{9} = \frac{4 \times 3{\cdot}1416}{9} = 1{\cdot}4 \text{ radians}$$

or $E = 1{\cdot}4 \times 57{\cdot}3° = 80{\cdot}22$

$E = 2A - 90 \therefore 2A = 90 + 80°\ 22' \therefore A = 85°\ 11'$

In triangle ABC—

$$\cos AB = \cot A \cot B = \cot^2 85° \ 11'$$

from which hypotenuse $AB = 89° \ 34\frac{1}{2}'$

Example.—In a spherical triangle the arc of spherical excess is 1″. What proportion does the area of the triangle bear to that of the sphere? If the radius of the sphere is 3960 miles, give also the area of the triangle.

$$\text{Here } E = 1'' = \frac{1}{206265}$$

$$\text{Ratio required} = \frac{\text{Area of triangle}}{\text{area of sphere}} = \frac{E r^2}{4 \pi r^2} = \frac{E}{4\pi}$$

$$\text{,,} = \frac{1}{206265 \times 4 \times 3{\cdot}1416} = \frac{1}{2592008}$$

Ratio is as 1 to 2592008

$$\text{Area of triangle} = E r^2 = \frac{3960^2}{206265} = 76{\cdot}01 \text{ sq. miles.}$$

SUMMARY OF FORMULAE FOR REFERENCE.

		page
1. Proofs of Formulae	$\frac{a}{b} = \frac{\sin A}{\sin B}$	225
2.	$c = a \cos B + b \cos A$	
3.	$a^2 = b^2 + c^2 - 2\,bc \cos A$	
4.	$\cos A = \frac{b^2 + c^2 - a^2}{2\,bc}$	
5. Multiple Angles	$\sin (A + B) = \sin A \cos B + \cos A \sin B$	226
6.	$\cos (A + B) = \cos A \cos B - \sin A \sin B$	
7.	$\tan (A + B) = \frac{\tan A + \tan B}{1 - \tan A \tan B}$	
8.	$\sin (A - B) = \sin A \cos B - \cos A \sin B$	
9.	$\cos (A - B) = \cos A \cos B + \sin A \sin B$	
10.	$\tan (A - B) = \frac{\tan A - \tan B}{1 + \tan A \tan B}$	
11. Sun and Difference of 2 Angles	$\sin A + \sin B = 2 \sin \frac{1}{2}(A + B) \cos \frac{1}{2}(A - B)$	229
12.	$\sin A - \sin B = 2 \cos \frac{1}{2}(A + B) \sin \frac{1}{2}(A - B)$	
13.	$\cos A + \cos B = 2 \cos \frac{1}{2}(A + B) \cos \frac{1}{2}(A - B)$	
14.	$\cos B - \cos A = 2 \sin \frac{1}{2}(A + B) \sin \frac{1}{2}(A - B)$	
15.	$\sin A = 2 \sin \frac{A}{2} \cos \frac{A}{2}$	
16.	$\sin (A + B) = 2 \sin \frac{1}{2}(A + B) \cos \frac{1}{2}(A + B)$	
17.	$\sin (a + b) = 2 \sin \frac{1}{2}(a + b) \cos \frac{1}{2}(a + b)$ (16) and (17) apply to spherical triangles.	
18.	$\cos A = 1 - 2 \sin^2 \frac{A}{2} = 1 - 2 \operatorname{hav} A$	
19.	$\cos A = 2 \cos^2 \frac{A}{2} - 1$, and $\cos 2A = 2 \cos^2 A - 1$	
20.	$\cos \frac{A}{2} = \sqrt{\frac{s(s-a)}{bc}}$, where $s = \frac{1}{2}(a + b + c)$	
21.	$\sin \frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{bc}}$	
22.	$\operatorname{hav} A = \frac{(s-b)(s-c)}{bc}$	
23.	$\frac{a+b}{a-b} = \frac{\tan \frac{1}{2}(A + B)}{\tan \frac{1}{2}(A - B)}$	
24.	$\sin^2 A - \sin^2 B = \sin (A + B) \sin (A - B)$	
25.	$\cos 3A = 4 \cos^3 A - 3 \cos A$	
26.	$\sin 3A = 3 \sin A - 4 \sin^3 A$	232

		page
27. Three Bearing Formula	$\cot C = \dfrac{p \cot a - q \cot \beta}{p + q}$	232
28. Cosine formula	$\cos A = \dfrac{\cos a - \cos b \cos c}{\sin b \sin c}$	235
29. Sine formula	$\dfrac{\sin a}{\sin A} = \dfrac{\sin b}{\sin B}$	236
30. Four Adealout Parts formula	$\cot B \sin A = \cot b \sin c - \cos c \cos A$ $\sin a \cot b = \sin C \cot B + \cos C \cos a$	237 238
31. Haversine Formula	$\text{hav } A = \dfrac{\text{hav } a - \text{hav } (b - c)}{\sin b \sin c}$	239
32. All Haversine Formula	$\text{hav } A = \dfrac{\text{hav } a - \text{hav } (b - c)}{\text{hav } (b + c) - \text{hav } (b - c)}$	240
33. Three Sides Formula	$\text{hav } A = \dfrac{\sin (s - b) \sin (s - c)}{\sin b \sin c}$	241
34.	$\cos \dfrac{A}{2} = \sqrt{\dfrac{\sin s \sin (s - a)}{\sin b \sin c}}$	242
35.	$\tan \dfrac{A}{2} = \sqrt{\dfrac{\sin (s - b) \sin (s - c)}{\sin s \sin (s - a)}}$	
36.	$\cot \dfrac{A}{2} = \sqrt{\dfrac{\sin s \sin (s - a)}{\sin (s - b) \sin (s - c)}}$	
37. Sine Formula	$\dfrac{\sin a}{\sin b} = \dfrac{\sin A}{\sin B}$	242
38. Napier's Analogies	$\tan \frac{1}{2} (A + B) = \dfrac{\cos \frac{1}{2} (a - b)}{\cos \frac{1}{2} (a + b)} \cot \dfrac{C}{2}$	243
39.	$\tan \frac{1}{2} (A - B) = \dfrac{\sin \frac{1}{2} (a - b)}{\sin \frac{1}{2} (a + b)} \cot \dfrac{C}{2}$	
40.	$\dfrac{\tan \frac{1}{2} c}{\tan \frac{1}{2} (a + b)} = \dfrac{\cos \frac{1}{2} (A + B)}{\cos \frac{1}{2} (A - B)}$	
41.	$\dfrac{\tan \frac{1}{2} c}{\tan \frac{1}{2} (a - b)} = \dfrac{\sin \frac{1}{2} (A + B)}{\sin \frac{1}{2} (A - B)}$	
	$\text{hav } a = \dfrac{\cos S \cos (S - A)}{\sin B \sin C}$. $S = \frac{1}{2}(A + B + C)$	
43. Small Angle Ratios	$\sin \ 0' = 0' \sin'$ $\sin \ 1^s = \sin 15'' = 15 \sin 1''$	248
44. Spherical Excess	Spherical excess $= A + B + C - 180 \ = E$	250
45. Area of Spherical Triangle	area of spherical triangle $= Er^2$	251
46. Polar Triangle	In Polar triangle $\cos a = \dfrac{\cos B^1 \cos C^1 + \cos A^1}{\sin B^1 \sin C^1}$	249

CHAPTER XI.

NUMEROUS examples, also exercises with hints as to their solution, are given in this chapter, many of which are similar in type to the questions set in the extra master's papers on mathematics and navigation.

There are five sections: I—Problems introducing algebraic equations. II—Plane triangles dealing with heights, distances and relative bearings. III—Speed and relative velocities. IV—Various examples. V—Theoretical problems in nautical astronomy.

It is suggested that the student should go through the worked examples, then re-work them without this assistance. When working the exercises he should read the question, draw an appropriate figure and attempt a solution before referring to the hint. It is to be understood that the methods adopted, or suggested, may not be the only way of solving particular problems and the student may probably be able to evolve more elegant solutions in some cases.

I.—ALGEBRA.

Quadratic Equations.

A quadratic equation is one which contains the square of the unknown quantity, and when it contains the first power as well as the second power of the unknown it is called an "adfected" quadratic.

A complete quadratic equation is solved in the following steps:—

(1) Arrange the quantities so that the terms involving the unknown quantity are on the left side and the known quantities to the right.

(2) Make the coefficient of x^2 unity and positive by dividing throughout by the coefficient of x^2.

(3) Add to each side of the equation the square of half the coefficient of x.

(4) Extract the square root of each side and solve the resulting simple equation.

Example (i.)

Solve the equation $\frac{5}{6}x^2 - \frac{1}{2}x + \frac{3}{4} = 8 - \frac{2}{3}x - x^2 + \frac{273}{12}$

clearing of fractions, common denominator 12.

$$10x^2 - 6x + 9 = 96 - 8x - 12x^2 + 273$$

Transposing and reducing we get $22x^2 + 2x = 360$

Dividing by 22.

$$x^2 + \frac{2}{22}x = \frac{360}{22}$$

adding $\left(\frac{1}{22}\right)^2$ to both sides $x^2 + \frac{2}{22}x + \left(\frac{1}{22}\right)^2 = \frac{360}{22} + \left(\frac{1}{22}\right)^2$

Extracting the square root

$$x + \frac{1}{22} = \pm\sqrt{\frac{360}{22} + \left(\frac{1}{22}\right)^2}$$

$$\text{,,} \quad = \pm\sqrt{\frac{7921}{(22)^2}} = \pm\frac{89}{22}$$

$$\therefore \quad x = -\frac{1}{22} + \frac{89}{22} \quad \text{or} \quad -\frac{1}{22} - \frac{89}{22}$$

$$x = \quad 4 \quad \text{or} \quad -\frac{45}{11}$$

Instead of going through the process of completing the square we may solve many quadratics by the general formula $x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$

where a is the coefficient of x^2, the first term,

,, b is the coefficient of the middle term,

,, c is the third term.

In the foregoing example we have

$$22x^2 + 2x = 360$$

$$\text{or } 22x^2 + 2x - 360 = 0.$$

$a = 22$, $b = 2$, $c = -360$, and introducing these values in the general formula we have

$$x = \frac{-2 \pm \sqrt{(4 - 4 \times 22(-360)}}{2 \times 22}$$

$$x = \frac{-2 \pm \sqrt{31684}}{44}$$

$$x = \frac{-2 \pm 178}{44} = \frac{176}{44} \quad \text{or} \quad -\frac{180}{44}$$

$$\therefore \quad x = 4 \text{ or } -\frac{45}{11}$$

Example (ii.)

A journey of 297 miles would be made by a train in 16 minutes less than the time actually taken, if the speed were increased by one mile per hour; find the speed in miles per hour.

Let x = original speed in m.p.h.

then $x + 1$ = increased speed in m.p.h.

$\therefore \frac{209}{x}$ = original time to perform journey

and $\frac{209}{x+1}$ = reduced time in hours to perform journey,

hence $\frac{209}{x} = \frac{209}{x+1} + \frac{16}{60}$

when reduced this gives the quadratic $4x^2 + 4x - 3135 = 0$

introducing the general formula $x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$,

we have $a = 4,\ b = 4,\ c = -3135$

$$\therefore x = \frac{-4 \pm \sqrt{(16 - 4 \times 4(-3135)}}{2 \times 4}$$

$$x = \frac{-4 \pm \sqrt{50176}}{8} = \frac{-4 \pm 224}{8}$$

$$\therefore x = \frac{220}{8} = 27\tfrac{1}{2} \text{ m.p.h.} \quad \text{Answer.}$$

It may be noticed that $4x^2 + 4x - 3135 = 0$

factorises into $(2x - 55)(2x + 57) = 0$

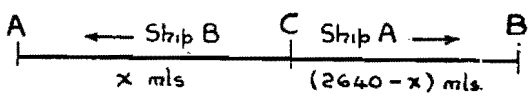
$$\therefore 2x = 55 \quad \text{or} \quad -57$$

$$x = 27\tfrac{1}{2} \quad \text{or} \quad -28\tfrac{1}{2}, \text{ which does not apply}$$

$$\therefore \text{speed } x = 27\tfrac{1}{2} \text{ m.p.h.}$$

Example (iii.)

A and *B* are two ports 2,640 miles apart. Two vessels start simultaneously from *A* and *B* and one reaches port 4 days 4 hours and the other 6 days after they meet each other en route. Find their respective speeds.



Let *A* and *B* be the ports and *C* the passing point of the ships x miles from *A*, then ship *B* goes x miles in 144 hours, and ship *A* goes $(2{,}640 - x)$ miles in 100 hours.

$$A\text{'s speed} = \frac{2640 - x}{100},\ B\text{'s speed} = \frac{x}{144}.$$

But the time taken by ship *A* in going from *A* to *C* is equal to the time taken by ship *B* in going from *B* to *C*, and time = distance ÷ speed.

$$\frac{\text{Distance}}{\text{Speed}} = \frac{x}{\frac{2640 - x}{100}} = \frac{2640 - x}{\frac{x}{144}}$$

$$i.e., \quad \frac{100x}{2640 - x} = \frac{144(2640 - x)}{x}$$

$$\therefore 25x^2 = 36(2640 - x)^2$$

Extract square root

$$5x = 6(2640 - x)$$

and $x = 1440$ miles.

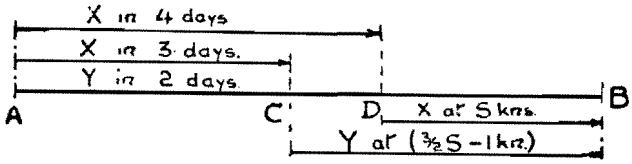
$$A\text{'s speed} = \frac{2640 - 1440}{100} = 12 \text{ knots}$$

$$B\text{'s speed} = \frac{1440}{144} = 10 \text{ knots}$$

Example (iv.)

Two ports A and B are 1,560 miles apart, steamer Y leaves A two days after steamer X and after 2 days passes a position that X passed 24 hours previously.

Y then reduced speed by 1 knot and arrived at B at the same time as X. Find the speeds of X and Y.



Let S knots be the speed of X.

X takes 3 days to go from A to C.

Y ,, 2 ,, ,, ,,

$\therefore$ Y's speed $= \frac{3}{2}S$ knots

and Y's reduced speed $= \left(\frac{3}{2}S - 1\right)$ knots

X does $24S$ miles per day.

X does $72S$ miles in 3 days from A to C

and X does $96S$ miles in 4 days from A to D

$\therefore$ $AC = 72S$ miles and $CB = (1560 - 72S)$ miles

$AD = 96S$,, ,, $DB = (1560 - 96S)$ miles

when ship X is at D ship Y is at C.

Time taken by X to go DB miles is equal to the time taken by Y to go CB miles at her reduced speed, and the time is distance $\div$ speed.

$$\therefore \frac{(1560 - 96S)}{S} = \frac{(1560 - 72S)}{\frac{3}{2}S - 1}$$

$$1560S - 72S^2 = 2340S - 144S^2 - 1560 + 96S$$

$$72S^2 - 876S + 1560 = 0$$

$$6S^2 - 73S + 130 = 0$$

$$(6S - 13)(S - 10) = 0$$

$$S = \frac{13}{6} \text{ or } 10$$

$\therefore$ X's speed $= 2\frac{1}{6}$ knots or 10 knots

Y's speed $= 3\frac{1}{4}$,, or 15 ,,

EXAMPLES FOR EXERCISE.

I. ALGEBRA.

Solve for x—

1. $12x - 210 = 205 - 3x^2 + 5$.

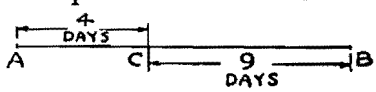
2. $2x^2 + 31 = 20x + 2$.

Solve for x and y—

3. $5x + y = 3$, $2x^2 - 3xy - y^2 = 1$.

4. $x^2 + xy = 15$, $y^2 + xy = 10$.

5. Two vessels leave ports A and B at the same time. One reaches B in 9 days and the other reaches A in 4 days after they meet. If the places A and B are 3000 miles apart, find the speed of each vessel.



If x = A's speed then

distance CB = $(9 \times 24\ x)$ miles

" $AC = AB - CB = 3000 - (9 \times 24\ x)$ miles

B's speed $= \dfrac{AC}{4 \times 24}$ knots.

The time taken to meet each other being the same

we get $\dfrac{CB}{B\text{'s speed}} = \dfrac{AC}{A\text{'s speed}}$

so put in the above values and solve for x.

6. The distance between two ports is 800 miles. A steamer outward bound goes half-way at full speed with a current. She then goes at reduced speed without a current. On the return journey the steamer does the first half at reduced speed and then, the current having turned against her, she completes the journey at full speed.

Outward she takes 3 days 11 hours, and homeward she takes 4 days 04 hours. If the vessel can steam the total distance in 3 days 18 hours without a current at full speed, find (a) the vessel's reduced speed, (b) speed of current, (c) her full speed.

1600 miles in 90 hours at full speed = 17·77 knots.

Let x = current, y = reduced speed.

Outward—400 miles at $(17{\cdot}77 + x)$ knots and 400 miles at y knots.

Time taken $\dfrac{400}{17{\cdot}77 + x} + \dfrac{400}{y} = 83$ hours . . . . . (1)

Homeward—400 miles at y knots and 400 miles at $(17{\cdot}77 - x)$ knots.

Time taken $\dfrac{400}{17{\cdot}77 - x} + \dfrac{400}{y} = 100$ hours . . . . . (2)

Subtract equation (1) from (2) and solve for x and y.

7. A convoy 1 mile in length is steaming at a uniform rate of $7\frac{1}{2}$ knots. A destroyer proceeds along the length of the convoy from rear to front and notes the time taken to do so. She then steams from front to rear again noting the time to do so. If the sum of the two times was 10 mins. 40 secs., find her speed.

Let S knots be the required speed of destroyer.

Distance = 1 mile.

Speed with convoy = $S - 7{\cdot}5$ knots.

" against " = $S + 7{\cdot}5$ "

$\therefore \quad \dfrac{1}{S - 7{\cdot}5} + \dfrac{1}{S + 7{\cdot}5} = 10\text{m } 40\text{s}$

Solve for S.

8. A steamer making a passage of 2000 miles, does half the distance at full speed, then owing to bad weather reduces to half speed. After covering quarter of the remaining distance she is able to increase speed by 3 knots. The passage takes 1 day 19 hrs. 45 mins. longer than at full speed. Find her full speed.

Let $2x$ knots = full speed, then x knots = half speed and $(x + 3)$ knots = final speed, then—

$$\frac{1000}{2x} + \frac{250}{x} + \frac{750}{x+3} = \frac{2000}{2x} + 43\tfrac{3}{4}$$

Solve for $2x$.

9. Two ships A and B leave ports 4320 miles apart at the same time and steam towards each other. A steams 60 miles more per day than B. They meet in a number of days equal to one-thirtieth of B's miles per day. Find the number of days.

10. A ship leaves port A at 0800 and is due at port B at 1800, distance between the ports being 120 miles. At 0900 another ship leaves B and is due at A at 1700. Show graphically, (a) when and where the two vessels will meet, (b) when they will be 10 miles apart.

(a) Draw a horizontal line AB = 120 miles to any convenient scale. Erect perpendiculars AC and BD, and divide them AC and BD into a scale of time from 0800 to 1800 hours.

Let A, at the bottom left-hand corner, be the point of origin, viz. 0 miles and 08 hours. Draw a line from A to 18 hours on BD.

Mark 09 hours on BD and 17 hours on AC, join the two points by a straight line. The graphs intersect at X, which indicates where and when they meet.

(b) With 10 miles from the scale of distance, fit dividers horizontal between the two graphs and read off the corresponding times.

11. Ship A leaves a port steaming at 10 knots. Three hours later B leaves at 15 knots on a course inclined to A's course at an angle $X°$ such that $\cos X = \frac{4}{5}$. If they are y miles apart after z hours from B's time of leaving, show that $y^2 = 900 + 85z^2 - 120z$; also find distance apart when they are closest to each other.

12. A ship going South at 12·75 knots has a current which adds 2·1 knots to her speed. If the current were reversed her speed would be reduced by 1·875 knots. Find rate and direction of current.

13. A and B are two stations 300 miles apart. Two trains start simultaneously from A and B, each to the opposite station. The train from A reaches B in 9 hours, and the train from B reaches A 4 hours after they pass. Find the rate at which each train travels.

14. A tank can be filled by two pipes running together in $22\frac{1}{2}$ minutes: the larger pipe would fill the tank in 24 minutes less than the smaller one. Find the time taken by each.

15. A tank is holed and will fill in 2 hours. One pump cannot keep the water under, so a second pump is started when the tank is three-quarters full. In an hour the tank is half full. If the second pump takes 70 minutes longer than the first pump to empty the tank under normal conditions, find time taken by each.

In 1 hour, 2 pumps empty $\frac{1}{2}$ tank + leak, but the leak fills $\frac{1}{4}$ tank in 1 hour, therefore the two pumps are capable of emptying $\frac{3}{4}$ tank in 1 hour with no leak.

Let 1st pump empty tank in x hours, *i.e.* $\frac{1}{x}$ tank per hour

∴ 2nd " " $(x + \frac{1}{4})$ hours *i.e.* $\frac{1}{x+\frac{1}{4}}$ tank per hour

$$\therefore \tfrac{3}{4} = \frac{1}{x} + \frac{1}{x+\frac{1}{4}}$$

Solve this equation for x.

16. Two pumps A and B are put on a ballast tank. A can empty the tank in 30 minutes less than B. The tank springs a leak which would fill it in 40 minutes. Pumps A and B were tried separately but could not reduce the water. At noon the tank was half full and both pumps were started; at 1 p.m. pump A broke down, but resumed work at 1h 30m p.m. and at 1h 40m p.m. the tank was a quarter full. Find how long each pump would take to empty the tank if there was no leak.

Into tank by leak	
at 12·00 - - -	$\frac{1}{2}$ tank
at 12·40 - - -	1 ,,
at 1·20 - - -	1 ,,
at 1·40 - - -	$\frac{1}{2}$,,
	3 tanks
Left in at 1·40 - -	$\frac{1}{4}$,,
Pumped out - - -	$2\frac{3}{4}$ tanks.

A pumps for 70 mins.
B ,, ,, 100 ,,

If x mins. = time for A to empty the tank and $x + 30$ mins. the time B takes, then together they would take

$$\frac{70}{x} + \frac{100}{x + 30} = 2\frac{3}{4} \text{ (tanks)}$$

17. Two pumps working together empty a ballast tank in 8 hours, pump A working at half speed during 30 mins. of the time. If B takes 30 mins. longer than A normally to empty the tank, find the time taken by each separately.

If A takes x hours alone at normal capacity
then B takes $(x + \frac{1}{2})$ hours at normal capacity

A empties $\frac{1}{x}$ tank per hour

B ,, $\frac{1}{x + \frac{1}{2}}$ tank per hour

A ,, $\frac{5}{2x}$ tank in $2\frac{1}{2}$ hours

and $\frac{1}{4x}$ tank in $\frac{1}{2}$ hour at $\frac{1}{2}$ speed

B empties $\frac{3}{x + \frac{1}{2}} = \frac{6}{2x + 1}$ tank in 3 hours

$$\therefore \frac{5}{2x} + \frac{1}{4x} + \frac{6}{2x + 1} = 1$$

Solve for x

18. When a flywheel of circumference $14\frac{2}{3}$ ft. takes 1 sec. more per revolution, a spot on the rim travels $2\frac{3}{4}$ miles less per hour. Find the circumferential speed of the flywheel.

Circumference $= \frac{44}{3}$ ft.

If t (secs.) = normal time per revolution
$t + 1$ (secs.) = new time per revolution

Circumferential speed $= \frac{44}{3} t$ (feet per sec.)

Revs. per hour $\frac{3600}{t}$ and $\frac{3600}{t + 1}$

I $\frac{44}{3} \times \frac{3600}{t}$ = speed in feet per hour

II $\frac{44}{3} \times \frac{3600}{t + 1}$ = new speed per hour

Eq. 1 − Eq. 2 = 14,520 ft. (2¾ miles)

Solve for t.

19. A ship steaming at 10 knots burns 30 tons of coal per day. In addition to her fuel bill her expenses are £25 per day, she has to make a voyage of 4800 miles. Find by any method her most economical speed for the voyage if the cost of coal is 10s. per ton.

Let x = the economical speed.

Then $\frac{4800 \text{ miles}}{24\,x} = \frac{200}{x}$ = number of days.

Consumption varies as the cube of the speed, therefore new consumption at x knots is $\frac{30\,x^3}{10^3}$

Cost of coal for the voyage at x knots

$= £\left(\frac{30\,x^3}{10^3} \times \frac{1}{2}\right) \times \frac{200}{x} = £3\,x^2$

Other expenses at £25 per day $= 25 \times \frac{200}{x} = \frac{£5000}{x}$

Total cost $= 3\,x^2 + \frac{5000}{x} = y$, it is required to find the minimum value of y which we can do by means of a graph.

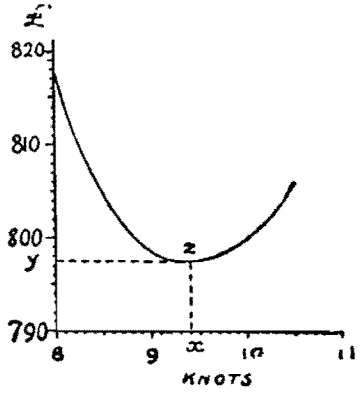
If x = knots	8	8½	9	9½	10	10½
then $3\,x^2$ =	192	216·7	243	270·7	300	330·7
and $\frac{5000}{x}$ =	625	588·2	555·5	527·3	500	476·5
$\therefore 3x^2 + \frac{5000}{x}$ =	£817	804·9	798·5	798	800	807·2

From graph, x = 9·4 knots, y = £797·5

How to draw the graph.—Write down some values of x on each side of the 10 knots and under each write the corresponding values of $3x^2$, $\frac{5000}{x}$ and $3x^2 + \frac{5000}{x}$.

On graph paper (use page 153) mark off the base line from 8 to 10½ knots (abscissa) say 10 spaces per knot, and on the vertical line (ordinate) the values of y on each side of the approximate minimum value, say, from £790 to £820, one space per pound.

Mark the spots corresponding to the x's and y's and draw a smooth curve through them. The turn of the curve gives the minimum value, £797·5, and the corresponding speed, 9·4 knots.



The speed may be found by means of the calculus. In this case the consumption x, and the cost y, vary together, but the cost is to be a minimum and equates to zero.

$$\text{thus } y = 3x^2 + \frac{5000}{x} = 0$$

$$\text{or } 3x^2 + 5000\ x^{-1} = 0$$

$$\text{differentiate } x,\ 3 \times 2x + 5000\ (-1\ x^{-2}) = 0$$

$$6x - 5000\ x^{-2} = 0$$

$$\text{or } 6x - \frac{5000}{x^2} = 0$$

$$\therefore\ 6x^3 = 5000$$

$$x = \sqrt[3]{\frac{5000}{6}} = 9{\cdot}4 \text{ knots.}$$

The process of differentiating is to diminish the power of x by 1 and at the same time multiplying x by its power. Thus if y and x vary together and $y = x^2$, then $\frac{dy}{dx} = 2x$. We might tabulate some examples to see how they appear. Put them in two columns, the values y in one and the corresponding values for $\frac{dy}{dx}$ in the other.

y	$\frac{dy}{dx}$
x^3	$3x^2$
$5x^4$	$5 \times 4x^3 = 20x^3$
x^{-1}	$-1 \times x^{-2} = \frac{-1}{x^2}$
$3x^{-2}$	$3 \times -2x^{-3} = \frac{-6}{x^3}$

Here are two similar examples for practice in the calculus as in previous question.

1. Consumption 30 tons per day at 10 knots, coal at £1 per ton; other expenses £86 per day, distance to go 5000 miles, find the most economical speed. *Ans.*—8·44 kns.

2. Consumption 40 tons per day at 12 knots, coal at 15s. per ton; other expenses £50 per day, distance to go 3600 miles, required the most economical speed. *Ans.*—11·29 kns.

TRIGONOMETRICAL EQUATIONS.

Find the value of angle A when

$$\frac{1}{1 - \sin^2 A} - \frac{1}{2}\sqrt{1 + \frac{\sin^2 A}{\cos^2 A}} = 8{\cdot}06$$

The first step is to express the equation in terms of one function.

$$\frac{1}{\cos^2 A} - \frac{1}{2}\sqrt{1 + \tan^2 A} = 8{\cdot}06$$

$$\sec^2 A - \tfrac{1}{2} \sec A = 8{\cdot}06$$

Complete the square by adding to each side of the equation the square of half the coefficient of sec. A.

$$\sec^2 A - \tfrac{1}{2}\sec A + (\tfrac{1}{4})^2 = 8{\cdot}06 + \tfrac{1}{4}^2$$
$$(\sec A - {\cdot}25)^2 = 8{\cdot}1225$$

Extract the square root of both sides

$$\sec A - {\cdot}25 = \pm 2{\cdot}85$$
$$\sec A = 3{\cdot}10 \text{ or } -2{\cdot}6$$

Referring to a table of natural secants, we find

when $\sec A = 3{\cdot}10$, $\angle A = 71^\circ\ 11'$ or $288^\circ\ 49'$
„ $\sec A = -2{\cdot}6$, $\angle A = 67^\circ\ 23'$

but having a negative sign the angle must be in the second or third quadrants, that is

$(180^\circ - 67^\circ\ 23') = 112^\circ\ 37'$
$(180^\circ + 67^\circ\ 23') = 247^\circ\ 23'$.

Find the values of the angles in the following equations:—

1. $\sin^2 A + \dfrac{1}{\sqrt{1 + \cot^2 A}} + \dfrac{1}{1 + \cot^2 A} = {\cdot}837$

2. $\cot^2 A - \dfrac{\cos A}{\sin A} = 17$

3. $\dfrac{1}{\operatorname{cosec}^2 A} - \sqrt{1 - \dfrac{1}{1 + \tan^2 A}} = {\cdot}8525$

NOTE.—In this example sin A has two values, 1·55 and − ·55, but sin A cannot exceed unity as the value 1·55 does not apply trigonometrically and − ·55 indicates that the angle is in the 3rd or 4th quadrants.

4. $\tan^2 A + \dfrac{4 \sin A}{\sqrt{1 - \sin^2 A}} - \dfrac{2}{\cot A} = 179$
5. $2 \cos \theta = 8 \sec \theta - 2$
6. $4\sqrt{3} \cot \theta = 7 \operatorname{cosec} \theta - 4 \sin \theta$
7. $\tan^2 \theta - \sin^2 \theta = 2{\cdot}25$
8. Find value of cos 15° from the expression cos $4A = \frac{1}{2}$
9. Find the greatest angle in a plane triangle whose sides are $x^2 + x + 1$, $2x + 1$, and $x^2 - 1$.

IDENTITIES.

Identities differ from equations in that they hold good for any angle whereas an equation can only be satisfied by introducing certain values for the angle.

Prove the following identities:—

1. $\text{Sin}^4 A + \cos^4 A = 1 - \frac{1}{2}\sin^2 2A$.
2. $\sin 3A = 4 \sin A \sin (60^\circ + A) \sin (60^\circ - A)$
3. $\tan 2A - \sin A \sec A = \tan A \sec 2A$
4. $\tan A \tan 2A = \sec 2A - 1$
5. $\tan^2 A + \cot^2 A = 2 + 4 \cot^2 2A$
6. $(\sin A - \sin B)^2 + (\cos A - \cos B)^2 = 2 \text{ vers } (A - B)$

AN ARTIFICE FOR SOLVING AN AWKWARD EQUATION.

Given an equation in the form of $3 \cos B + 4 \sin B = 4$, to find $\angle B$.

i. Let $R \sin (A + B) = 4$, then $\sin (A + B) = \frac{4}{R}$ Expanding we get $R \sin A \cos B + R \cos A \sin B = 4$.

ii. Note that $R \sin A =$ coeff. 3 $\quad \therefore \sin A = \frac{3}{R}$

iii. Note that $R \cos A =$ coeff. 4 $\quad \therefore \cos A = \frac{4}{R}$

Square and add ii and iii and we get $R^2 (\sin^2 A + \cos^2 A) = 9 + 16$.

$$R^2 \times 1 = 25 \quad \therefore R = 5$$

From i. $\sin (A + B) = \frac{4}{R} = \frac{4}{5} = \cdot 8$. $\therefore A + B = 53^\circ \ 8'$

From ii. $\sin A = \frac{3}{R} = \frac{3}{5} = \cdot 6$. $\therefore A = 36 \ 52$

$\angle B = 16 \ 16$

Verification from Tables

3 nat cos 16° 16′ = ·96 × 3 = 2·88
4 nat sin 16 16 = ·28 × 4 = 1·12

$\therefore$ 3 cos 16° 16′ + 4 sin 16° 16′ = 4

$\therefore B = 16^\circ \ 16'$ satisfies the equation.

Examples for Exercise—

10. $5 \cos x + 2 \sin x = 2$, find $\angle x$
11. $2 \cos B + 3 \sin B = 3$, find $\angle B$
12. $\sqrt{8} \sin \theta - \cos \theta = \sqrt{2}$, finds $\angle \theta$

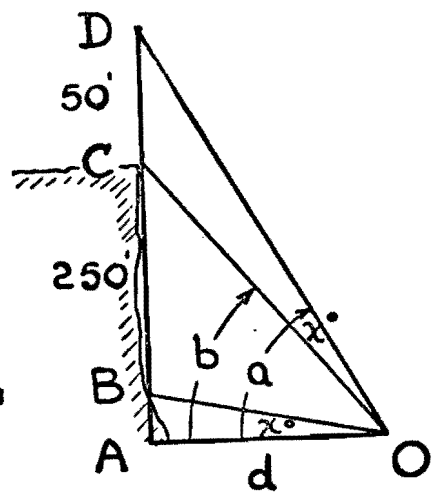
II.—TRIANGLES.

DEALING WITH HEIGHTS, DISTANCES AND BEARINGS.

Example 1.

A cliff 250 feet high has a flagstaff 50 feet high on top of it. To an observer on the same plane as the base of the cliff the flagstaff subtends an angle the same as at a point 10 feet up from the base of the cliff. Find the distance of the observer from the base of the cliff.

In figure, $AB = 10$ feet, $AC = 250$ feet, $AD = 300$ feet, $\angle AOB = DOC = x$. Let $AO = d$ the distance. Let $\angle AOD = a$, and $\angle AOC = b$, then $\angle DOC = (a - b) = x$.



$$\text{By (10)} \quad \tan x = \tan (a-b) = \frac{\tan a - \tan b}{1 + \tan a \tan b}$$

$$\text{,,} \qquad \text{,,} \qquad = \frac{\frac{300}{d} - \frac{250}{d}}{1 + \frac{300 \times 250}{d^2}}$$

$$\text{but } \tan x = \frac{10}{d} = \frac{50\,d}{d^2 + 75{,}000}$$

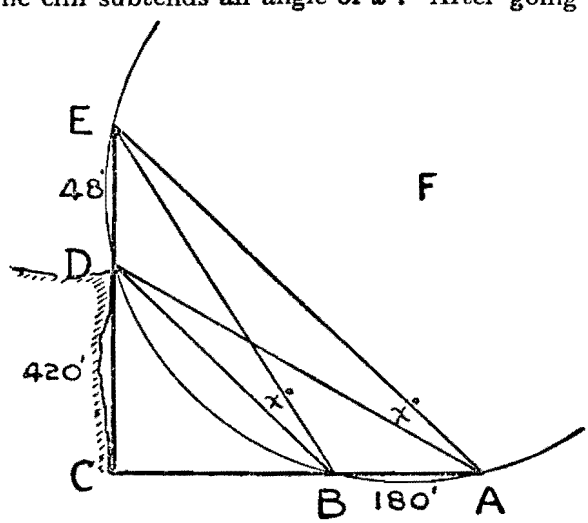
$$\text{from which } 5d^2 = d^2 + 75{,}000$$

$$\therefore \quad d = \sqrt{\frac{75{,}000}{4}} = 136{\cdot}93$$

Answer. Distance 136·93 feet.

Example 2.

A cliff is 420 feet high. From a boat a conspicuous object 48 feet high on top of the cliff subtends an angle of $x°$. After going 180 feet towards the cliff the object subtends the same angle x. Find distance of observer from the base of the cliff at each observation.



In figure, let A and B be the two positions of the boat. $AB =$ 180 feet, CD the cliff 420 feet, $D\,E$ the object 48 feet, F is the centre of the circle passing through A, B, D, and E.

$\angle EAD = \angle EBD = x°$.

It is required to find CB and CA.

$$CD \times CE = CB \times CA$$
$$468 \times 420 = CB\,(CB + 180 \text{ ft.})$$
$$196560 = CB^2 + 180\,CB.$$

Complete the square and solve for CB

$$CB^2 + 180\ CB + (90)^2 = 196560 + 90^2$$

$$CB + 90 = \pm\sqrt{204660} = \pm 452{\cdot}4$$

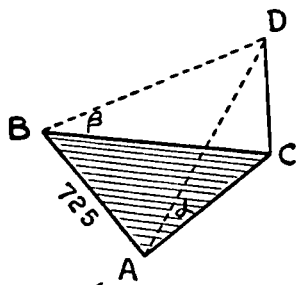
$$CB = \pm 452{\cdot}4 - 90 = 362{\cdot}4 \text{ ft.}$$

$$AC = (CB + 180) = (362{\cdot}4 + 180) = 542{\cdot}4 \text{ ft.}$$

Answer. 362·4 ft. and 542·4 ft.

Example 8.

The angle of elevation of a balloon from a station due South of it is 45° 35′ and from another station 725 feet due West of the former, the elevation is 40° 22′. Find the height of the balloon.



In figure, D is the balloon, CD its height above the ground at C. Station A is due south from C, $\angle DAC$ is the vertical angle at $A = \alpha = 45°\ 35'$. Station B is due west of A, so that $\angle CAB$ is 90° and $AB = 725$ feet. The vertical angle at B is $\angle DBC = \beta = 40°\ 22'$. BCD is a vertical triangle, right angled at C. BCA is a horizontal, or ground triangle, right angled at A.

From figure:—

$$CD = CA \tan \alpha = CB \tan \beta$$

$$\therefore \frac{\tan \alpha}{\tan \beta} = \frac{CB}{CA} = \text{cosec } CBA = \frac{\tan 45° 35'}{\tan 40° 22'} = \begin{matrix} \log 0{\cdot}008844 \\ \log 9{\cdot}929452 \end{matrix}$$

$$\angle CBA = 56°\ 24' \text{ cosec } \overline{10{\cdot}079392}$$

$$DC = BC \tan \beta$$

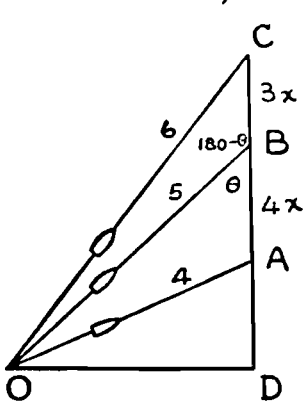
$$\text{,,} = AB \sec CBA \tan \beta$$

$$\text{,,} = 725 \text{ sec. } 56°\ 24' \tan 40°\ 22'$$

$$\text{,,} = 1113 \text{ feet, the height of the balloon.} \quad \textit{Ans.}$$

Example 4.

Three ships start from the same point steering in a north-easterly direction. A steams 8 knots, B 10 knots, C 12 knots. After 2 hours steaming they arrive on the same meridian, B to the North of A and to the South of C; B's distance from A and C is in the ratio of 4 to 3. Find the courses steered.



The distances steamed by ships A, B and C are, respectively 16, 20 and 24 miles, or, in the ratio of 4, 5 and 6. If $AB = 4x$ then, from question, $BC = 3x$. It is required to find the value of x and then solve the triangles to find angles A, B and C, the respective courses of the ships.

Call $\angle OBA$, θ, then $\angle OBC = (180° - \theta)$

Apply the general formula (3) for two sides and included angle in triangles OBA and OBC.

In $\triangle OBA$ by (3) $OA^2 = BO^2 + BA^2 - 2BO \cdot BA \cos\theta$

$$4^2 = 5^2 + (4x)^2 - 2 \times 5 \times 4x \times \cos\theta$$
$$16 = 25 + 16x^2 - 40x \cos\theta$$
$$\cos\theta = \frac{16x^2 + 9}{40x} \quad \ldots\ldots\ldots\ldots\ldots \text{(i.)}$$

In $\triangle OBC$ by (3) $OC^2 = BO^2 + BC^2 - 2BO.BC \cos(180° - \theta)$

$$6^2 = 5^2 + (3x)^2 - 2 \times 5 \times 3x \cos(180° - \theta)$$
$$36 = 25 + 9x^2 - 30x \times -\cos\theta$$
$$36 = 25 + 9x^2 + 30x \cos\theta$$
$$\cos\theta = \frac{-9x^2 + 11}{30x} \quad \ldots\ldots\ldots\ldots\ldots \text{(ii.)}$$

Eq. i = Eq. ii, and multiplying each side by $10x$ we get

$$\frac{16x^2 + 9}{4} = \frac{-9x^2 + 11}{3} \text{ from which}$$

$84x^2 = 17$ and $x = \sqrt{\frac{17}{84}} = \cdot4498 \quad \therefore 3x = 1\cdot3494$ and $4x = 1\cdot7992.$

In $\triangle COB$ the sides being in the ratio of 6, 5 and 1·3494 to find $\angle C$

by (22) hav $C = \dfrac{(s-6)(s-1\cdot349)}{6 \times 1\cdot349} \quad \ldots\ldots\ldots s = 6\cdot174$

$$\text{,,} \qquad = \frac{\cdot174 \times 4\cdot825}{8\cdot094}$$

From which $\angle C$ is 37° 34′ 30″.

$\triangle OCD$, $OD = 6$ nat sin 37° 34½′ $= 6 \times \cdot6098 = 3\cdot6588$

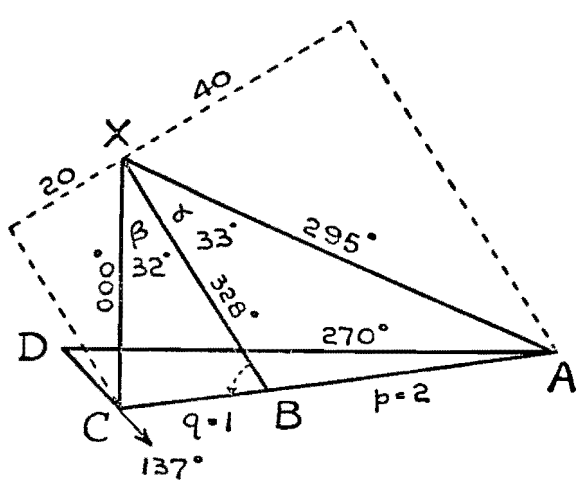
$\triangle OBD$, $\sin\theta = \dfrac{3\cdot6588}{5} = \cdot73174 \therefore \theta = 47° 2'$

$\triangle OAD$, $\sin A = \dfrac{3\cdot6588}{4} = \cdot9147 \therefore A = 66° 10'$

Answer. Courses, A N 66° 10′ E.
B N 47° 02′ E.
C N 37° 34½′ E.

Example 5.

A ship steering 270°, speed 24 knots, sights a light bearing 295°. After an interval of 40 minutes it bears 328° and after another interval of 20 minutes it bears 360°, a current of unknown strength was setting 137°. Find the course made good and the speed of the current.



XA, XB and XC are the three bearings. The dotted lines are constructional as described on page 21, chap. II, $p = 40$ minutes, $q = 20$ minutes or in

the ratio of 2 to 1, $\alpha = 33°$, $\beta = 32°$. ABC is the course made good. Find $\angle B$.

by (27) $\quad \text{nat cot } B = \dfrac{p \cot \alpha - q \cot \beta}{p + q}$

$$\text{,,} \quad = \frac{2 \cot 33° - 1 \cot 32°}{3}$$

$$\text{,,} \quad = \cdot 4932$$

$$\therefore \angle B = 63° \ 45'$$

Direction of $XB = 328° \ 00'$

$\angle B = \ 63 \ \ 45$ to the left

ABC the course $= 264 \ \ 15$

or S. $84° \ 15'$ W.

AD is the course and distance steered, 270°, 24 miles, DC the direction of current 137°, $\angle D = 47°$ $\angle A = 5° \ 45'$, $\angle C = 127° \ 15'$. In triangle ACD find DC the drift of the current in one hour.

$$\frac{DC}{\sin A} = \frac{DA}{\sin C} \therefore DC = 24 \sin 5° \ 45' \operatorname{cosec} 127° \ 15'$$

$$DC = 3{\cdot}02 \text{ knots.}$$

Answer. Course S. 84° 15′ W., current 3·02 knots.

II. Plane Triangles.

Examples 1 to 11 are exercises in vertical angles somewhat similar to Worked Examples 1 and 2.

1. From a boat on the same horizontal plane as the base of a cliff 360 ft. high, the angle subtended by a tower 50 feet high on the top of the cliff is 2° 54′ 27″. Find the distance of the boat from the base of the cliff.

2. A flagstaff 60 ft. high on top of a cliff subtends the same angle at an observer 200 ft. from the base of the cliff as a tree 12 ft. high at the base of the cliff. Find height of the cliff.

3. An observer on a vessel's bridge, height of eye 40 ft., observes the vertical angle of B's mast, 120 ft. from truck to water-line, to be 11° 18′ 36″. Find the distance between the two vessels.

4. A tower 80 ft. high stands on top of a cliff 600 ft. high. From a boat the tower subtends the same angle as a house 20 ft. high at the foot of the cliff. Find distance of the boat from the foot of the cliff.

See Example 1.

5. From the bridge of a vessel the vertical angle subtended by a cliff 100 ft. high is 9° 30′. If the angle subtended between the cliff top and its reflection is 18° 54′, how far off is the cliff?

Draw a figure such that $B\,C\,(q) = C\,D\,(p) = 100$ ft.
$\angle D\,A\,C = 9° \ 30'\ (\alpha)$, $\angle C\,A\,B = 9° \ 24'\ (\beta)$

Apply (27) $\cot C = \dfrac{p \cot \alpha - q \cot \beta}{p + q}$, $C = 88° \ 8\frac{1}{2}'$

In triangle $B\,A\,C$, having found C as above, find $A\,C$ by formula (1), then make $A\,E$ perpendicular to $B\,C\,D$ and find $A\,E$ the horizontal distance of the bridge from the cliff

6. An observer, whose height of eye was 42 ft., found the vertical angle of the upper half of a flagpole to be 30° while the lower half subtended 33°. Find the distance of the observer from the pole.

NOTE.—Construct a figure so that $A\,B = 42$ ft., the height of eye, and $C\,E$ the flagpole, then $\angle D\,B\,C = 33°$ (β), $D\,B\,E = 30°$ (α), D being halfway up the flagstaff, $C\,D = D\,E = x$, $\angle C\,D\,B = \theta$.

$$\cot\theta = \frac{x\cot\alpha - x\cot\beta}{x + x} = \frac{\cot 30° - \cot 33°}{2}$$

and $A\,C$ the distance $= 42 \tan B\,C\,A$.

7. A ship's deck cargo is 9 ft. high. A 6 ft. man standing on the main deck finds the angle of elevation to be $2d$ when the top of the cargo is in line with the masthead. He moves back until the angle is d and he then sees the upper one-third of the mast. Bottom of deck cargo and heel of mast are in the same horizontal plane.

If $\cos 2d = \frac{3}{5}$ find the height of the mast.

NOTE.—Construct a figure so that $A\,B = 6$ ft. $B\,C = 3$ ft. and D the masthead the height of which is h feet. $C\,D = (h - 9)$.

If $\angle E = 2d$ and $\angle F = d$, draw $C\,G$ parallel to the deck line $B\,E\,F$, to represent the top of the deck cargo. $\angle D\,G\,C = 2d$, $\angle H\,G\,C = d$ and as $H\,C$ is unknown call it a ft.

The mast $h = \frac{1}{3}h + a + 9$ ft. $\therefore a = (\frac{2}{3}h - 9)$, $H\,D = \frac{1}{3}h$.

Given $\cos 2d = \frac{3}{5} = \frac{\text{adj}}{\text{hyp}}$ therefore the opposite side is 4, from which $\cot 2d = \frac{3}{4} = 53° 8'$

$d = 26° 34'$, nat $\cot d = 2$

$\triangle G\,D\,C$, $C\,G = (h - 9)\cot 2d$

$\triangle H\,G\,C$, $C\,G = (\frac{2}{3}h - 9)\cot d$

from which $(h - 9)\frac{3}{4} = (\frac{2}{3}h - 9)\,2$

Solve for h.

8. An observer 20 ft. above the level of a lake observes the angle of elevation of a tower to be 45° and the angle of depression of its exact reflection to be 60°. Find the height of the tower.

NOTE.—Construct a figure so that A is the observer, $A\,B$ the level of eye, $C\,D$ the level of lake. $C\,A = D\,B = 20$ ft. $\angle B\,A\,E = 45°$, $\angle B\,A\,F = 60°$

If h be the height of tower and $A\,B = C\,D = d$, then $d = (h - 20)\cot 45° = (h + 20)\cot 60°$.

Solve for h.

9. An observer 7 ft. above the deck observes the angles subtended between the deck and the top of a conning tower 28 ft. and between the conning tower and the masthead 30 ft. to be equal, tower and mast in same plane perpendicular to the deck. Find distance of observer from the tower.

NOTE.—Make a rough figure such that A is the observer, $D\,B = 28$ ft. (q), $B\,C = 30$ ft. (p), the vertical angles $D\,A\,B$ and $B\,A\,C$ are equal (θ).

Apply (27) $\cot A\,B\,D = \dfrac{p\cot\theta - q\cot\theta}{p + q}$

from which $\tan B = 29\tan\theta$.

If x be the length of base line on deck and also drawn as $A\,E$ 7 ft. higher, then $\tan B = \frac{x}{21}$ and $\tan d = \frac{21}{x}$ where d is $\angle B\,A\,E$ and $(\theta - d)$ is $\angle E\,A\,D$, $\tan(\theta - d) = 7/x$.

Apply (10) $\tan(\theta - d) = \dfrac{\tan\theta - \tan d}{1 + \tan\theta\tan d}$

And solve the resulting equation.

10. An observer on deck observes the vertical sextant angle of masthead to derrick table to be 26° 33′ 26″. Another observer 36 ft. above the first finds the angle to be 28° 00′ 35″. The eye of first observer is on a level with the derrick table and the mast is perpendicular to the deck. Required distance of observer from the mast.

NOTE.—Draw a rough figure. Draw a horizontal line through the upper observer so that his angle is $(\alpha + \beta)$. Call the lower angle θ and total height of mast H, then the bit above the table is $(H - 36)$. Let d be the length of base line so that $\tan \alpha = \frac{36}{d}$ and $\tan \beta = \frac{H - 36}{d}$

Apply (7) $\tan (\alpha + \beta) = \frac{\tan \alpha + \tan \beta}{1 - \tan \alpha \tan \beta} = \frac{H d}{d^2 - 36 H + 36^2}$

when the right hand side is cleared up.

Now substitute $d \tan \theta$ for H and solve the resulting quadratic.

11. When steering East two buoys were observed in line bearing North. After going 1 cable the horizontal angle subtended by the two buoys is $\theta°$, and after going a further 3 cables the horizontal angle is again $\theta°$. Find the course from a point 3 cables beyond where the second angle was observed to pass midway between the two buoys. The distance between the buoys is twice the distance between the yacht and the nearest buoy when they were in transit.

This problem may be treated as a vertical angle problem similar to Example 2, page 247, by assuming C to be 1st position of yacht, D and E the two buoys, so that $C D = d$, the unknown distance and $D E = 2 d$.

$\angle D B E = \angle D A E = \theta$, $C B = 1$ cable, $B A = A F = 3$ cables.

Join F to G midway between D and E then $C D \times C E = C B \times C A$ or $d \times 3 d = 1 \times 4$

$\therefore d = 1{\cdot}1547 \tan F = \frac{2 d}{7}$

12. The angles of elevation of the top and bottom of a flagstaff on the top of a tower are A and B respectively. Prove that the height of the tower is equal to $\frac{x \cos A \sin B}{\sin (A - B)}$ where x is the height of the flagstaff.

13. Three stations P, M and O in same horizontal plane. P and O subtended an angle of 90° at M. R is a point midway between P and O and on a line joining them. There is a flagstaff at M. If x, y and z be the vertical angles subtended by the flagstaff at P, R and O respectively, show that $\tan^2 y = 2 \tan x \tan z \sin 2 P$, where P is the angle $M P O$ in the $M P O$ triangle.

Exercises 14 to 17 are in two planes similar in type to Worked Example 3.

14. A balloon is observed from two stations A and B 7560 ft. apart, B being due North of A. The angle of elevation at B was 27° 13′ and at A 46° 48′, the balloon bearing due East from A, find its distance from B.

15. At two stations A and B the following simultaneous observations were got. At A a balloon bore N. 3° E., alt. 47° 39′. At B it bore N. 76° E. Suppose B to be N. 40° W., 9120 ft. from A, find the height of the balloon and its distance in feet from A.

16. Two observers A and B are 1200 ft. apart. A observes the vertical sextant angle of the top of a tower to be 8° 17′, and the horizontal angle between B and the tower to be 67° 30′. B observes the horizontal angle between A and the tower to be 49° 15′. Find the height of the tower.

17. From a ship a mountain bore 000° and its vertical angle was 15° 20′. The ship then steamed due East for 5 miles and its vertical angle was now 11° 25′. Find the height of the mountain.

18. An observer finds that the angle between the mastheads of two masts of equal height is 120° from a point midway between the masts and on a line joining them. Walking 60 ft. backwards and perpendicular to the line joining the two masts the angle is now 81° 35′ 16″. Find the distance between the masts.

Construct a figure such that $A\ D$ and $A^1\ D^1$ represent the masts and B is midway between A and A^1. $\angle D\ B\ D^1 = 120°$. Join $D\ D^1$ with E midway between. Let $D\ E = d$ the half distance required, and h the height of the masts. $\angle D\ B\ E = 60°$, $\angle D\ E\ B = 90°$.

Make $B\ C = 60$ ft., so that $\angle A\ B\ C = 90°$, then $A\ B\ A^1\ C$ is a ground triangle. Join $D\ C$ and D^1C. $\angle D\ C\ D^1 = 81°\ 35'\ 16''$.

$B\ E$ is a vertical line and $B\ E\ D$ is a vertical triangle.

$B\ C$ is a horizontal line, and $C\ E\ D$ is a slant triangle in which $\angle E\ C\ D = 40°\ 47'\ 38''$, $\angle D\ E\ C = 90°$

Let $\angle E\ C\ D = \theta$, side $A\ C = a$, and $C\ D = b$.

1. $\triangle\ B\ A\ D$. $h = d \tan 30°$. $h^2 = d^2 \tan^2 30°$.
2. $\triangle\ C\ E\ D$. $b = d \operatorname{cosec} \theta$. $b^2 = d^2 \operatorname{cosec}^2 \theta$.
3. $\triangle\ D\ C\ A$. $\angle D\ A\ C = 90°$. $a^2 = b^2 - h^2$.
4. $\triangle\ A\ B\ C$. $d^2 = a^2 - 60^2 = b^2 - h^2 - 3600$ and by submitting 1 and 2 for b^2 and h^2 we get $d^2 = d^2 \operatorname{cosec}^2 \theta - d^2 \tan 30° - 3600$ which simplifies to $d^2 (\operatorname{cosec}^2 \theta - 1 - \tan^2 30°) = 3600$, but $\operatorname{cosec}^2 \theta - 1 = \cot^2 \theta$ $\therefore d^2 (\cot^2 \theta - \tan^2 30) = 3600$

Solve for d.

Exercises 19 to 33 are examples of running fixes involved with an unknown quantity which has either to be found or eliminated as in Worked Example 4.

19. Three ships A, B, and C leave the same point steering to the eastwards, A and C at equal speeds and B at 12 knots. Find the courses they must steer so that after one hour A is 3 miles due North of B, and B is 5 miles due North of C.

20. Three ships start simultaneously from the same position steering in a north-westerly direction, A steams 8 knots, B at 10 knots, C at 14 knots. After one hour steaming the ships are on the same meridian, B being midway between A and C. Find the courses steered.

21. A vessel observes a point of land abeam and at the same time the horizontal angle between it and a lighthouse is 42°. After steaming 3 miles the horizontal angle is still 42°, and after steaming another 4 miles the lighthouse is abeam. Find the distance between the point and the lighthouse.

22. A ship steering 000° sees a lighthouse ahead and a beacon on the starboard bow, the horizontal angle between them being $\theta°$. After 54 minutes the angle is 2θ and 34 minutes later it is $(90° - \theta)$, speed 10 knots. Find the distances off the beacon when it is abeam.

If A, C, D and E be the successive positions of ship, B the beacon and the angles named in terms of θ, then $A = \theta°$, $C = 2\theta°$, $D = 90° - 3$, $E = 90°$, $\angle E\ B\ D = \theta$, $\angle D\ B\ A = (90° - 2\theta)$, $\angle E\ B\ A = (90° - \theta)$, $\angle C\ B\ A = \theta$ $\angle D\ B\ C = (90° - 3\theta)$

Given $D\ C = 5{\cdot}67$ miles, $A\ C = C\ B = 9$ miles.

$B\ E = 9 \sin 2\theta = 9\ (2 \sin \theta \cos \theta) = 18 \sin \theta \cos \theta$

$$\triangle\ D\ B\ C \quad \frac{5{\cdot}67}{9} = \frac{\sin (90 - 3\theta)}{\sin (90 + \theta)} = \frac{\cos 3\theta}{\cos \theta} = \frac{4\cos^3 \theta - 3\cos \theta}{\cos \theta} = 4\cos^2 \theta - 3^*$$

from which $\theta = 17°\ 42\frac{1}{2}'$ and $B\ E = 9 \sin 2\theta$.

* (See Eq. (25) for this transformation.)

23. A ship observes a beacon on the starboard bow and after making good 6 miles observes the bearing to have trebled.

After making good another 2 miles the beacon was abeam. Find distance off when abeam.

If A, B and C be the three successive positions of the ship and D the beacon, the $\angle A = \theta$, $\angle B = 3\theta$, $\angle C = 90°$, $BC = 2$ miles.
$AB = 6$ miles, $CD = 2\tan 3\theta = 8\tan\theta$ $\therefore \tan 3\theta = 4\tan\theta$.

Apply Eq. (7) $\tan(2\theta + \theta) = \dfrac{\tan 2\theta + \tan\theta}{1 - \tan 2\theta \tan\theta}$ which resolves itself into $\tan\theta = \sqrt{\dfrac{1}{11}}$

24. A vessel steering 270° sights a point of land A bearing 000°. After two hours on the same course a point P (29·985 miles due West of A) bore 311°. After another 2 hours on the same course P bore 030°. Find ship's distance from P at nearest approach.

Construct a figure so that B, C and D are the three successive positions of the ship from point of land P, then $AP = 29{\cdot}985$ miles.

Let $\angle BPC = \alpha$, $\angle CPD = \beta = 79°$, $\angle C = 41°$, $BC = p$, $CD = q$, $p = q$.

Apply (27) $\cot C = \dfrac{p\cot\alpha - q\cot\beta}{p + q}$

$$\cot 41° = \frac{\cot\alpha - \cot 79°}{2}$$

from which $\alpha = 21°\ 50'$

Make PE perpendicular to DC. E is the point of nearest approach.

25. Two beacons are on same meridian. A ship steaming 290° sights the North beacon right ahead distant 12 miles and the horizontal angle between the beacons to be $A°$. After proceeding 6 miles the angle is $d°$ and after another 3 miles it is $2d°$. Find angle A.

If X and Y be the beacons, X to North of Y, A the ship's 1st position where the horizontal angle is $A°$, B the 2nd position where the angle is d and C the 3rd position where the angle is $2d$. C is the centre of a circle passing through X, Y and B.

$CY = CB = 3$ miles. $\angle X = \angle Y = 70°$.
$\triangle CYA$, given CY, CA, $\angle C$ Find $\angle A$.

26. Ship steering North, a light bearing 100° T. After sailing 2 miles the light bore 120° T. Ship then increased speed and after 20 minutes the light bore 140° T. Find vessel's speed between the second and third bearings.

NOTE.—Draw figure so that A, B, and C are the three successive positions of the ship and D the position of the light.

In $\triangle ABD$ all the angles are known and side AB. Find side BD.

In $\triangle BDC$ all the angles are known and now side BD. Find BC the distance ship has sailed in 20 minutes.

27. When steering North the maximum horizontal angle between two buoys was 44°, and after steaming 2 miles the buoys are in line bearing 158°. Find distance between the buoys.

Construct a figure such that A is the position when the hor. angle $XAY = 44°$, X and Y being the buoys. Make AB due North, 2 miles and $\angle ABY$ 22°.

The hor. angle being maximum a circle passes through X, Y, and A of which AB is a tangent and XY a chord.

The angle between the tangent and chord is equal to the angle in the opposite segment.

i.e. $\angle BAX = \angle XYA = \theta$.

In $\triangle ABX$, $\angle\ \theta + (\theta + 44) + 22° = 180$. $\therefore\ \theta = 57°$.

The solution is now obvious.

28. Two points of land in transit bearing 320° T. from a ship. After making 9·5 miles on a westerly course the horizontal angle becomes a maximum at 22°. If the two points are 4 miles apart, find the course made good by the ship.

Construct a figure. Make angles at X and Y equal to the complement of 22° the horizontal angle, the lines intersect at C which is the centre of the circle of position passing through X, Y and the ship. Join CY and CX and make CD perpendicular to XY, $DX = DY = 2$ miles. Draw tangent from A meeting circle at E. Join EY, EX and EC $\angle XEY = 22°$, $\angle XCY = 44°$, $\angle DCX = 22°$.

Calculate $CX = r$ the radius of the circle.

$\tan CAE = r/AE$, $CA = AE$ Sec. CAE.

Because AE is a tangent and AXY a secant to the circle, $AE^2 = AX(AX + XY)$ by Geometry, from which $AX = 7{\cdot}71$.

In triangle ACD, given three sides, find $\angle CAD$. The course required may now be found.

29. A vessel steering to the westward sights two beacons 8 miles apart and in transit bearing 008° T. She steams 6 miles and the maximum horizontal angle subtended by the two beacons is then 29° 18′. Find the course steered.

30. From a vessel steering north-easterly a beacon bears 000° and after 40 minutes it bears 315°; shortly afterwards it bears 270° and again in another 20 minutes it bears 225° T. Find the ship's course.

Draw figure. Let A, B, C and D be the respective positions of the ship when the bearings are 000°, 315°, 270° and 225°, the difference between each bearing being 45°. If P be the point then $\angle$s $APB = BPC = CPD = NPD = 45°$. $\angle PBD = (45° + A)$, $AB = 2$ units, $BC = x$ units, $CD = 1$ unit of time intervals.

By Geometry— $\dfrac{CP}{PA} = \dfrac{CB}{BA} = \dfrac{x}{2} = \tan A$ in $\triangle APC$

and $\dfrac{PD}{PB} = \dfrac{DC}{CB} = \dfrac{1}{x} = \tan(45° + A)$ in $\triangle PBD$

By (7) $\tan(45 + A) = \dfrac{\tan 45 + \tan A}{1 - \tan 45 \tan A} = \dfrac{1 + \frac{x}{2}}{1 - \frac{x}{2}} = \dfrac{2 + x}{2 - x} = \dfrac{1}{x}$

on solving the quadratic equation, $x = {\cdot}5615$, from which $\angle A$ is found.

31. Three buoys, A, B, C are in line, B being midway between A and C. A ship sails 6 miles from B and the angle between A and B is then 20°, and between B and C 30°. Find distance from A to C.

Draw a figure. If D be the ship, then $\angle ADB = 20°$, $\angle BDC = 30°$, $AB = BC = x$.

$x = c \sin 20 \operatorname{cosec} ABD = a \sin 30 \operatorname{cosec} CBD$

$$\therefore \frac{c}{a} = \frac{\sin 30}{\sin 20} = \frac{5}{3{\cdot}42}$$ call side c 5 and side a 3·42

Substitute this ratio for sides, use tan formula to find $\angle$s A and C, thence find X, the half distance

32. A, B and C are three buoys in line on a bearing 087° T. AB is 4 miles BC is 2 miles. A ship steams from A northwards 8 miles so as to subtend equal angles between AB and BC. Find the ship's distance from each buoy.

If S be the ship's position, then SB bisects $\angle ASC$ and $\dfrac{AB}{BC} = \dfrac{AS}{SC} = \dfrac{4}{2} = \dfrac{2}{1}$ $\therefore 2SC = AS$, $SC = 4$

$\triangle ASC$ three sides given. Find $\angle A$ and $\angle S$.

In $\triangle ABS$, with $\angle$s A and ASB and side AB. Find SB.

33. Three buoys A, B and C are in line bearing 080° T. A ship steams 5 miles to the northward from B and A, and C are then distant 8 and 6 miles respectively, and the sextant angles between A and B and B and C are equal. Find the distance between the buoys.

If S be the ship distant from A, B and C, 8, 5 and 6 miles respectively, and $AB = x$ miles, $BC = y$ miles then $\frac{x}{y} = \frac{8}{6}$ and $x = \frac{4y}{3}$. $\angle ASC$ is bisected $= 2\theta$,

$$\cos\theta = \frac{AS^2 + BS^2 - x^2}{2\,AS\,.\,BS} = \frac{CS^2 + BS^2 - y^2}{2\,CS\,.\,BS}$$

Substitute values and get $\frac{89 - x^2}{80} = \frac{61 - y^2}{60}$, solve this quadratic for x and y.

Exercises 34 to 37 are of similar type to Worked Example 4 which is sometimes referred to in chartwork as the three bearing problem.

34. A ship steering East through a current setting 204°, of unknown strength, sights a lighthouse bearing 030°; after sailing 4 miles it bore 000°; and after sailing another 4 miles it bore 340°. Find the course made good, also the drift of the current.

35. A ship steers north-easterly from a position A, then alters course 120° to port, finishing 3 miles, 270° from A; she steams altogether $4\frac{1}{2}$ miles. Find the distance on each course.

36. A vessel steaming at a uniform speed is observed from the shore to bear 025° T.; after an interval of 15 minutes she bears 350° T.; and after a further interval of 20 minutes she bears 280° T. Find her course.

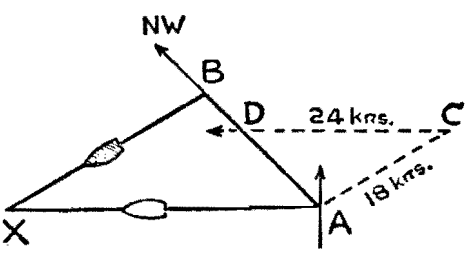
37. Steering 100° T. through a current of unknown strength, setting 315° T., a lighthouse is sighted bearing 036° T., and after sailing 30 minutes it bore 010° T, and after sailing another 20 minutes it bore 348° T. Ship's speed 10 knots. Find course and distance made good, also drift of current.

38. A ship heading East observes a buoy B right ahead and another buoy C on her port bow subtending an angle θ° with B. Ship proceeds x miles due East and is then 3 miles due South of C and x miles from B. At the same time from a vessel at anchor due South of C the buoys B and C subtend an angle 2θ°. If the distance AC be 5 miles, find the distance between C and the anchored ship.

III.—RELATIVE VELOCITIES.

Example 6.

A cruiser receives information that a vessel is bearing N.W. from her, distant 36 miles and steering 240° T., speed 18 knots. How must the cruiser steer to intercept the vessel in shortest possible time at 24 knots, and how long will she take to do so?



In relative velocity problems it usually simplifies the work if we assume the other ship to be stopped and treat her speed and course (reversed) as if it were the set and drift of a current.

In figure, let A be the cruiser and B the vessel, N.W. 36 miles from A. From A, lay off AC 060° T., 18 knots. With centre C and radius 24 knots describe an arc cutting AB at D. Then CD is the direction A must steer to reach B, and AD is the closing speed. Actually, ship A steams along AX which is parallel to CD, and B along BX, 240° T., the ships meeting at X. ACD is a triangle of velocity—given AC, CD and $\angle A = 105°$. Find $\angle D$, also AD.

by (1) $$\frac{\sin D}{18 \text{ kns.}} = \frac{\sin 105°}{24 \text{ kns.}} \text{ from which } D = 46° 26' 16''$$

A to B is N.	45°	00′	00″ W.
or	315	00	00
$\angle D = \angle A$	46	26	16
A to X	268	33	44
$\angle C$ =	28°	33′	44″

$$\frac{AD}{\sin C} = \frac{24}{\sin 105°} \text{ from which } AD = 11{\cdot}88 \text{ kns.}$$

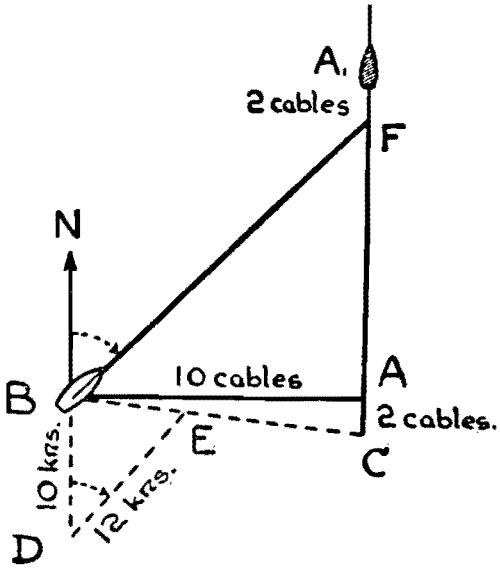
But the distance from A to B is 36 miles.

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}} = \frac{36 \text{ mls.}}{11{\cdot}88 \text{ kns.}} = 3\text{h } 1{\cdot}8\text{m.}$$

Answer.—Course 268° 33′ 44″, time 3h 1·8m.

Example 7.

Two ships A and B on patrol steering North, speed 10 knots. Ship B one mile on A's port beam is ordered to increase speed to 12 knots and take station 2 cables astern of A. Find B's course and time to get into position.



In figure, A and B are the two ships, B has to cross over to C. $AB = 10$ cables, $AC = 2$ cables.

Assume ship A to be stopped and apply his course (reversed), and speed, to ship B and read the question as follows:—Find the course B must steer to reach C *in order to counteract a current setting South*, 10 *knots*, B's speed being 12 knots.

Construction:—Join BC. Lay off BD from B, South 10 knots, and with centre D and radius 12 knots describe an arc cutting BC at E. Join DE.

Then BDE is a triangle of velocity in which DE is the direction B must steer to get into station and BE is the effective or closing speed.

First find the distance from B to C.

$$\cot B = \frac{10}{2} = 5$$

$$\therefore B = 11^\circ\ 19'$$

$$\angle DBE = 78^\circ\ 41'$$

$$BC = AB \sec B$$

$$\text{,,} = 10 \sec 11^\circ\ 19'$$

$$\text{,,} = 10{\cdot}2 \text{ cables.}$$

In $\triangle BDE$.

By (1) $\dfrac{\sin E}{10} = \dfrac{\sin 78^\circ\ 41'}{12}$ from which $E = 54^\circ\ 48\frac{1}{2}'$, $\angle D = 46^\circ\ 30\frac{1}{2}'$,

but BF is parallel to DE $\therefore$ $\angle NBF = \angle D = 046^\circ\ 30\frac{1}{2}'$ course.

Again, $\dfrac{BE}{\sin D} = \dfrac{12}{\sin 78^\circ\ 41'}$, from which $BE = 8{\cdot}88$ knots.

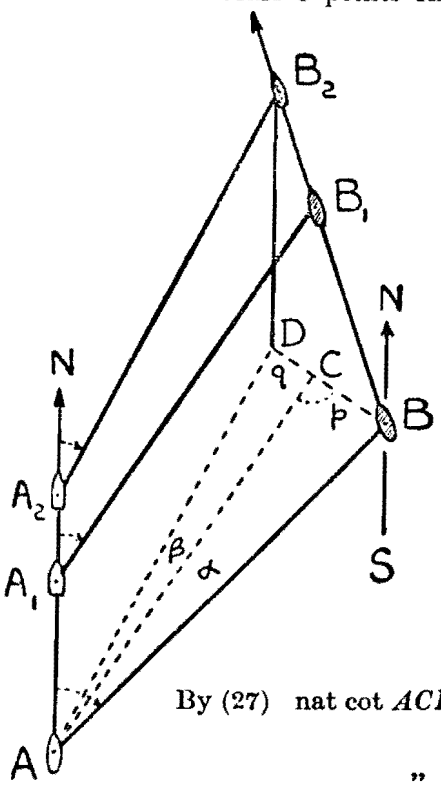
$$\text{Time} = \frac{\text{Distance}}{\text{Speed}} = \frac{BC}{BE} = \frac{1{\cdot}02 \text{ mls.}}{8{\cdot}88 \text{ kns.}} = 7 \text{ minutes.}$$

Answer. B's course is $046^\circ\ 30\frac{1}{2}'$, time to take station, 7 minutes.

When B reaches F, ship A is at A_1.

Example 8.

Ship A steering North at 12 knots sees ship B 4 points on her starboard bow, 10 minutes later B bears 3 points on the same bow and 5 minutes later she is $2\frac{1}{2}$ points on the bow, if B's speed is 15 knots find her course.



It is obvious from the question that B is passing ahead of A. Assume ship A to be stopped at position A in figure and imagine her speed and course (reversed) to be transferred to ship B so that the relative bearings of the two ships will be maintained as indicated by the dotted constructional lines on the figure where AB, AC and AD would be the 4, 3, and $2\frac{1}{2}$ point bearings respectively, $a = 11° 15'$, $\beta = 5° 37{\cdot}5'$, $p = 10$ minutes, $q =$ 5 minutes, a ratio of 2 to 1. It is required to find $\angle C$, which is the angle between the middle bearing and the ratio line BCD. BCD would be the course steered by B if A were actually stopped, but at the moment it only serves as a line of direction as a step towards finding B's course.

By (27) $$\text{nat cot } ACD = \frac{p \cot a - q \cot \beta}{p + q}$$

„ $$= \frac{2 \cot 11° 15' - 1 \cot 5° 37{\cdot}5'}{3} = -{\cdot}0329$$

$\angle ACD = 88° 7'$

but this is really $\angle ACB$ the supplement of $\angle ACD$ as the sign is negative.

$\angle ABC = 180° - (88° 7' + 11° 15') = 80° 38'$

To find B's course.

From A lay off A's course North so that $AA_1 = 2$ miles, $A_1A_2 = 1$ mile. From A_1 lay off the 3 point bearing and from A_2 the $2\frac{1}{2}$ point bearing. From D lay off A's course North cutting the $2\frac{1}{2}$ bearing at B_2. Join B to B_2 and this will give the direction of B's track, the successive relative positions of the ships being A and B, A_1 and B_1, A_2 and B_2.

In triangle BDB_2 it is required to find $\angle DBB_2$.

We know $DB_2 = 15$ minutes at 12 kns. $= 3$ miles $= AA_2$

$BB_2 = 15$ minutes at 15 kns $= 3\frac{3}{4}$ „

and we can get $\angle B_2DB$ which is equal to $DBS = 80° 38' + 45° = 125° 38'$.

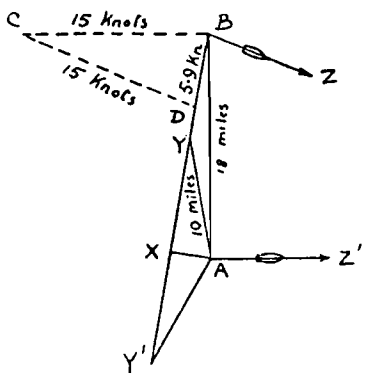
by (1) $$\frac{\sin B}{3} = \frac{\sin 125° 38'}{3{\cdot}75}$$ from which $\angle DBB_2 = 40° 33' 36''$.

$\angle B_2 = 180° - (40° 33' 36'' + 125° 38') = 13° 48' 24''$.

Answer. B's course N. 13° 48′ 24″ W. or 346° 11′ 36″ T.

Example 9.

Ship *B* is 18 miles North of *A* and steering E.S.E.; *A* is steering East and both are steaming at 15 knots. Find (1) speed of approach; (2) distance of nearest approach and time to reach it; (3) the interval of time they will be within 10 miles of each other.



Construction.—1. Let *A* and *B* be the relative positions of the two ships. *AB*= 18 miles from any convenient scale.

Lay off *BC*, West, 15 knots = *A*'s course (reversed) and speed.

Lay off *CD*, E.S.E., 15 knots = *B*'s course and speed.

Join *BD*, which indicates the relative bearing line, and the length of *BD* (5·9 knots) their speed of approach.

2. Drop *AX* perpendicular to *BD* produced, then *X* indicates the relative position of nearest approach but not the actual position. The length of *AX* gives the distance on the same scale as *AB* (3·5 miles) and *BX* gives the distance to go (17·5 miles) at approaching speed (5·9 knots).

$$\text{Time to reach } X = \frac{\text{Dist.}}{\text{Speed}} = \frac{17{\cdot}5}{5{\cdot}9} = 2{\cdot}97 \text{ hours.}$$

The distance each ship would have to go on their respective courses to reach *X* = 2·97 hrs. at 15 knots = 44·55 miles.

The actual position of *X* relatively to *A* and *B* may be found by laying off from *B*, *BZ*, E.S.E. 44·55 miles and from *A*, AZ^1 East 44·55 miles The distance ZZ^1 will measure 3·5 miles the distance of nearest approach.

3. Centre *A*, radius 10 miles, describe an arc cutting *BX* at *Y* and Y^1. Then YY^1 is the distance they cover (18·7 miles) when within 10 miles range of each other.

$$\text{Time} = \frac{\text{Dist.}}{\text{Speed}} = \frac{18{\cdot}7}{5{\cdot}9} = 3\text{h } 10\text{m.}$$

Relative velocity problems can be solved by constructing a figure to scale with compasses and protractor, the answers so found being near enough in practice as the data are only approximate, no allowance being made for the turning circle, delay in gaining speed, etc. The larger the scale of distances the more accurate will be the results. The facts can be laid off quickly on a prepared diagram, a manoeuvring board, which is just a compass rose, or protractor showing concentric circles spaced equally apart, the spaces being marked off in tenths for convenience of measurement. These spaces may be called miles, or knots, depending on whether distance, or speed, are the factors under consideration.

III. Relative Velocities.

1. A warship receives information that an enemy ship is bearing N.N.W. from him and distant 30 miles, steering W.S.W. at 20 knots. If the warship's maximum speed is 35 knots, how long will it take him to intercept the enemy, and what course must he steer to do so?

1. Lay off *AB*, N.N.W., the direction of enemy.
2. Lay off *AC*, E.N.E. 20 knots.
3. Centre *C*, radius 35 knots, describe an arc cutting *AB* at *D*. *CD* gives the direction warship must steer (302°) and *AD* (28·2 knots) his closing speed

2. A and B are two destroyers steaming North at 15 knots; B being on A's port beam distant 5 miles has orders to take up a position 2 miles astern of A, and to be in this position in 15 minutes. Find the course that B must steer and her speed to carry out the order.

1. Mark spot A. Lay off AB, 5 miles on A's port beam and AC 2 miles astern of A; BC measures 5·4 miles and this is the distance B has to go in 15 minutes. B's speed is therefore 21·6 knots.

2. Lay off BD, South 15 knots. Centre D and radius 21·6 knots cut BC, produced if need be, at E. DE is the course B must steer.

3. Two ships steering 338° T., at 12 knots, ship B is one mile on A's port quarter and is ordered to increase speed to 16 knots and take station one mile on A's starboard beam. Find B's course and closing speed.

4. Two ships A and B steering the same course; B 2 cables astern of A is ordered to increase speed to 12 knots and take station one mile on A's starboard beam, A's speed is 10 knots. Find B's alteration of course and the time she would take to get into position.

5. Two vessels patrolling steering 300° T., at 10 knots. Ship B is four points on A's starboard quarter distant one mile, and is ordered to increase to 15 knots and take station one mile on A's port beam. Required the course to steer and the time to get into position.

6. A and B are two steamers in a convoy steering N.N.W. at 10 knots. B being two miles on A's starboard beam is ordered to take a position 1 mile ahead of A and to increase speed to 12 knots. Find the course that B must steer and the time it will take to reach her new position ahead of A.

7. Two vessels A and B on the same meridian; B is 10 miles North of A. B steams S.E. at 10 knots and A steams East at 20 knots. Find how long it will be until they are within nearest approach of each other.
(See Worked Example 9).

8. A liner steering 180° at 20 knots to pass 2 miles due East of a lighthouse at 1600. At 1530 a 12-knot launch starts out from the lighthouse to intercept the liner in the shortest possible time. Find the course the launch must steer and give the time of intercepting.

1. Mark a spot B. Lay off BA due North, 10 miles. A gives the liner's position at 1530 and B is to be her position at 1600.

2. Lay off BC, due West, 2 miles. C is the lighthouse. Join CA; this gives the course and distance launch would have to go if liner were stopped at A.

3. Lay off CD, South, 20 knots. With centre C and radius 12 knots, describe the arc of a circle towards A. Through D draw a line parallel to CA cutting the 12 knot circle at E. Join CE; then CE is the direction launch must steer, viz. (031°) and DE is the closing speed (30·8 knots).

4. Where CE cuts BA is the meeting point. Call this spot X. By measurement AX is 6·6 miles and at 20 knots the liner will be there in 19·8 minutes, viz. at 15h 49·8m. CX is 4 miles by measurement and is the distance the launch has to go, viz. 4 miles at 12 knots = 20 minutes.

9. A and B are steering the same course 220° at same speed, 12 knots, B is one mile on A's starboard beam. Ship A sights a destroyer bearing 000°, distant 6 miles, and B alters course 22° to starboard. Find the course of the destroyer at 25 knots to pass midway between A and B.

1. Mark spot A, and spot B 1 mile on A's starboard beam, A heading 220°; mark also spot X the position of the destroyer bearing 000°, 6 miles from A.

2. Bisect AB at Y, being midway between A and B, the destroyer's objective if A and B were stopped.

3 Lay off YC = 231°, viz. 220° + half the alteration of B's course.

4. From X lay off XD, the mean course YC (reversed) and speed viz. 051°, 11·8 knots. With centre D and radius destroyer's speed, 25 knots describe an arc to cut XY at E. Join DE. DE gives the destroyer's course (205°) and XE her closing speed (14·8 knots) and XY (5·6 miles) the distance she has to go.

10. A vessel steering West, 10 knots, sights a cruiser bearing 020° T., distant 5·5 miles as measured by the flash and report of a gun fired from the cruiser. Half an hour later the cruiser bears 350° T., distant 2·5 miles as found by the same method. Find the course and speed of the cruiser.

1. Mark a spot A to represent the vessel and C the cruiser 020°, 5·5 miles from A.

2. Lay off AA^1, West 5 miles, and A^1C^1 350°, 2·5 miles. Join CC^1. CC^1 is the direction of the course (250°) and measures 7·85 miles in 30 minutes.

11. A's course 000°, speed 10 knots; B's speed 12 knots. At 1 p.m., B bore from A 066°; at 2 p.m.—046°, at 2.15 p.m.—025°. Find B's course.

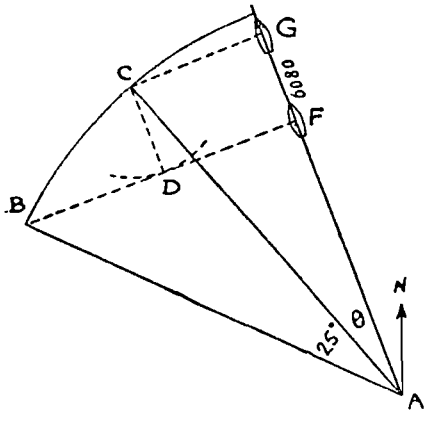
Similar to Worked Example 8.

12. A's course 180°, speed 12 knots; B's speed 16 knots. B bears from A 140°, and 30 minutes later B bears 160° and 15 minutes later 170°. Find B's course.

IV.—VARIOUS EXAMPLES.

Example 10.

A vessel sights a beacon 48 feet high bearing 295° and subtending a vertical angle of 0° 6′ 20″. At the same instant another beacon of the same height subtends the same vertical angle and bears 320. If the distance between the beam bearings to port is one mile, find the vessel's course.



Construction:—Let A be the position of the ship. $AB = AC$ the distance of the beacons B and $C = 48 \cot 0° 6' 20'' =$ 26046 feet.

With centre A and radius this distance from any convenient scale, describe an arc passing through the beacons B and C, lay off the bearing of B (295°) and of C (320°), $\angle BAC = 25°$. Join BC.

With centre C and radius 1 mile describe an arc. Draw BD a tangent to this arc and produce it.

Draw CD and AF perpendicular to the tangent BD, and make CG parallel to BD. $FG = 6080$ feet given, AF is the vessel's track.

In $\triangle AGC$ $\angle G = 90°$. $AG = AC \cos \theta$.

In $\triangle AFB$ $\angle F$ 90°. $AF = AB \cos (25° + \theta)$

Subtracting we get $GF = 26046 \{ \cos \theta - \cos (25° + \theta)\}$

By (14) $\cos \theta - \cos (25° + \theta) = 2 \sin \frac{1}{2} (25 + \theta + \theta) \sin \frac{1}{2} (25° + \theta - \theta)$

$\therefore$ $6080 = 26046 \times 2 \sin 12° 30' \times \sin (12° 30' + \theta)$.

$$\sin (12° 30' + \theta) = \frac{6080 \times \operatorname{cosec} 12° 30'}{2 \times 26046}$$

" $= 32° 38'$

$12 \quad 30$

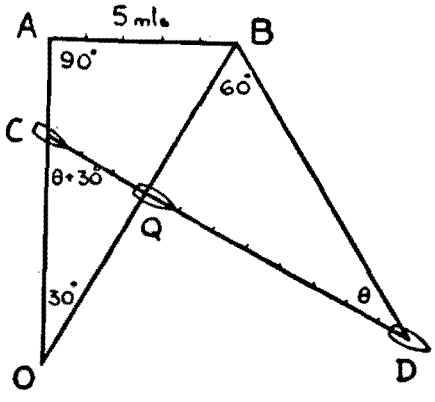
$\angle \theta = 20 \quad 08$

Bearing of C is $320 \quad 00$

A to F the course $340 \quad 08$ *Answer*

Example 11.

A and *B* are two points 5 miles apart, *B* being 090° from *A*. A vessel on an easterly course observes *A* bearing 000° and, after sailing 3 miles, observes *B* bearing 030° and after sailing a further 8 miles *B* was observed bearing 330°. Find the ship's course.



In figure, let *A* and *B* be the two points, $AB = 5$ miles, $CQ = 3$ miles, $QD = 8$ miles, $\angle O = 30°$, $\angle OBD = 60°$, $\angle A = 90°$, $\angle OCQ = (\theta + 30°)$, $\angle D = \theta$.

In △OAB.

$OB = 5 \text{ cosec } 30° = 5 \times 2 = 10$ miles.

$\therefore OQ + QB = OB = 10$ miles. . . (i.)

In △OCQ $\quad \dfrac{OQ}{\sin(\theta + 30)} = \dfrac{3}{\sin 30}$ by (1)

$\therefore OQ = \dfrac{3 \sin(\theta + 30)}{\sin 30} = 6 \sin(\theta + 30)$ (ii).

In △BQD. $\dfrac{QB}{\sin \theta} = \dfrac{8}{\sin 60}$

$\therefore QB = \dfrac{8 \sin \theta}{\sin 60} = \dfrac{16}{\sqrt{3}} \sin \theta$ . . (iii).

(i), (ii), (iii) $\quad OQ + QB = 10 = 6 \sin(\theta + 30) + \dfrac{16}{\sqrt{3}} \sin \theta$

by (5) $\quad \therefore 10 = 6(\sin \theta \cos 30 + \cos \theta \sin 30) + \dfrac{16}{\sqrt{3}} \sin \theta$

$$10 = 6\left(\frac{\sqrt{3}}{2} \sin \theta + \tfrac{1}{2} \cos \theta\right) + \frac{16}{\sqrt{3}} \sin \theta$$

$$10 = \frac{25}{\sqrt{3}} \sin \theta + 3 \cos \theta$$

We might adopt the artifice explained on page 245 to solve this equation for θ. Re-arranging the equation.

$$3 \cos \theta + \frac{25}{\sqrt{3}} \sin \theta = 10$$

Let $R \sin(A + \theta) = 10$, then $R \sin A \cos \theta + \cos A \sin \theta = 10$.

From which $R \sin A = 3$ and $R \cos A = \dfrac{25}{\sqrt{3}}$

Square and add, $R^2 = \dfrac{625}{3} + 9 = \dfrac{652}{3} = 217{\cdot}3$, $\therefore R = 14{\cdot}74$

$\text{Sin}(A+\theta) = \dfrac{10}{R} = \dfrac{10}{14{\cdot}74}$ or $\text{cosec}(A+\theta) = \dfrac{14{\cdot}74}{10} = 1{\cdot}474$, $A + \theta = 42°\ 43'$

$\text{Sin } A = \dfrac{3}{R} = \dfrac{3}{14{\cdot}74}$ or $\text{cosec } A = 4{\cdot}913$ . . $A = 11\ 44$

$\theta = 30\ 59$

The direction *B* to *D* is	150° 00′
$\angle\theta$	30 59
The course *C* to *D* is	119 01

Example 12.

The apparent wind is 260° to a vessel steering 220° at 10 knots. When she altered course to 260° the apparent wind was 15° on the starboard bow. Find the direction and velocity of the true wind.

In figure, AC is 260°, 10 miles and CD is the apparent wind 15° on the starboard bow. AB is 220°, 10 miles, and BD is the apparent wind from 260°, or 40° on the starboard bow. The apparent winds meet at D. Join AD which gives the direction of the true wind and its velocity per hour.

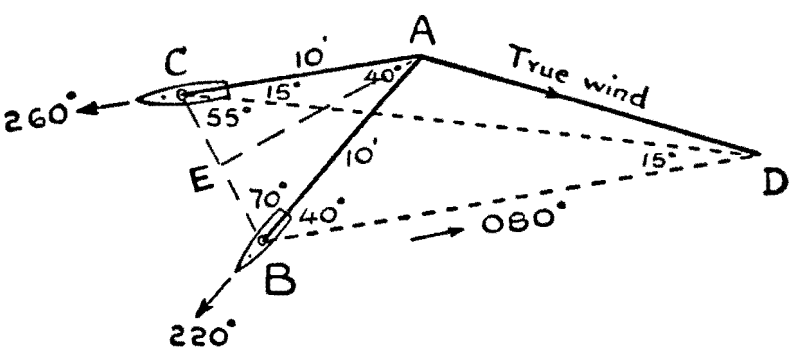
Join CB, then $\triangle ABC$ is isosceles and $\angle ACB = \angle ABC = 70°$
But $\angle ACD = 15°$, $\therefore \angle BCD = 55°$ and $\angle BDC = 15°$.

Make AE perpendicular to CB, then $CB = 2CE = 2\ (AC \sin 20°) = 20 \sin 20°$.

In $\triangle BCD$ by (1) $BD = CB \sin BCD \operatorname{cosec} BDC$

$= 20 \sin 20 \sin 55° \operatorname{cosec} 15°$

$= 21{\cdot}65$



In $\triangle ABD$ $\angle B = 40°$, $(A + D) = 140°$

by (23) $\dfrac{\tan \frac{1}{2}(A - D)}{\tan \frac{1}{2}(A + D)} = \dfrac{BD - BA}{DB + BA} = \dfrac{11{\cdot}65}{31{\cdot}65}$

$\therefore \tan \frac{1}{2}(A - D) = \dfrac{\tan 70° \times 11{\cdot}65}{31{\cdot}65}$

from which $\frac{1}{2}(A - D) = 45°\ 19\frac{1}{2}'$

$\frac{1}{2}(A + D) = 70\ \ 00$

$\angle BAD = 115\ \ 19\frac{1}{2}$

A to B is $220\ \ 00$

A to D is $104\ \ 40\frac{1}{2}$

$+\ 180\ \ 00$

$\therefore$ the direction of the true wind is from $284\ \ 40\frac{1}{2}$

In $\triangle DAB$ $\dfrac{AD}{AB} = \dfrac{\sin ABD}{\sin ADB}$

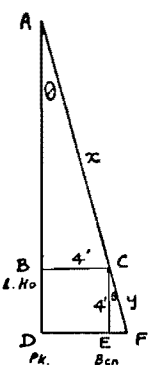
$\dfrac{AD}{10} = \dfrac{\sin 40°}{\sin 24° 40\frac{1}{2}'}$

$AD = 15{\cdot}4$ miles

Answer. True wind 284° 40′
Velocity 15·4 m.p.h.

Example 13.

At noon a vessel steaming south-easterly at 10 knots sights a lighthouse in transit with a peak bearing South true and, when the lighthouse bears 270°, sights a beacon bearing 180°. A cross bearing shows each to be 4 miles distant. At 2 p.m. after continuing on the same course, the vessel anchors with the beacon and peak in transit bearing 270°. Find the course made good during the two hours.



Given ABD a meridian, B the lighthouse, D the peak, $\angle A = \theta$ to be found. ACF the ship's track, such that $AC = x$, $CF = y$ and $x + y = 20$ miles. When ship is at C, B bears 270°, 4 miles, and beacon E bears 180°, 4 miles. When she reaches F, E and D are in transit. $\angle ECF = \theta$.

$\triangle ABC$ $\quad \frac{x}{4} = \operatorname{cosec}\theta = \frac{1}{\sin\theta}$ . . . . . (1)

$\triangle CEF$ $\quad \frac{y}{4} = \sec\theta = \frac{1}{\cos\theta}$ . . . . . (2)

(1) and (2) add $\frac{x+y}{4} = \frac{20}{4} = 5 = \frac{1}{\sin\theta} + \frac{1}{\cos\theta} = \frac{\cos\theta + \sin\theta}{\sin\theta\cos\theta}$

$$5\sin\theta\cos\theta = \sin\theta + \cos\theta$$

Square each side. $25\sin^2\theta\cos^2\theta = \sin^2\theta + \cos^2\theta + 2\sin\theta\cos\theta$

NOTE. * $\quad 25\frac{\sin^2 2\theta}{4} = 1 + \sin 2\theta$

$$\frac{25}{4}\sin^2 2\theta - \sin 2\theta = 1$$

Divide throughout by $\frac{25}{4}$, complete the square and solve for 2θ.

$$\sin^2 2\theta - \frac{4}{25}\sin 2\theta + \left(\frac{2}{25}\right)^2 = \frac{4}{25} + \frac{4}{625}$$

$$\therefore \sin 2\theta - \frac{2}{25} = \pm\sqrt{\frac{104}{625}}$$

$$\sin 2\theta = \pm\frac{10\cdot2}{25} + \frac{2}{25} = \frac{12\cdot2}{25} = +\cdot488$$

$2\theta = 29°\ 12'$, $\theta = 14°\ 36'$ Course S. 14° 36′ E. = 165° 24′.

NOTE.*—This transformation is derived from (15) $\sin 2\theta = 2\sin\theta\cos\theta$. Square both sides, $\sin^2 2\theta = 4\sin^2\theta\cos^2\theta$ $\therefore \sin^2\theta\cos^2\theta = \sin^2 2\theta/4$.

IV.—Various Examples.

1. From a vessel two towers, A and B, subtend a horizontal angle of 24° and A is distant 6 miles. After steaming a short distance the hor. angle was 36° and A is distant 4 miles. The distances from B to the points of observation are as 5 is to 6. Find the distance of B at the 1st and 2nd observations.

Construct a figure such that D is the 1st position of the vessel and $\angle ADB = 24°$ and $DA = 6$ miles. Make C the 2nd position and $\angle ACB = 36°$, $CA = 4$ miles. $DB = 5X$, $CB = 6X$. Join AB.

$BA^2 = AC^2 + BC^2 - 2\ AC{\cdot}CB \cos 36° = BD^2 + DA^2 - 2\ BD{\cdot}DA \cos 24°$

$\therefore\ 16 + 36X^2 - 48\ X \times {\cdot}809 = 25\ X^2 + 36 - 60X \times {\cdot}913$ from which $X = {\cdot}8055$ thence find distances BC and BD.

2. A ship observes the horizontal angle between a conspicuous object and a lighthouse bearing East to be 24°. She sails 132° T., 3 miles, and finds the lighthouse bearing North and the hor. angle the same as before. Find the distance between the object and the lighthouse.

Draw a figure so that A is the 1st position of ship, B the 2nd position and C the lighthouse, then $\triangle ACB$ is right angled at C. Bisect AB at D, then D is the centre of a circle passing through A, C and B, $DA = 1\frac{1}{2}$ miles.

If E be the object, then it is also on the circumference of the circle because $\angle CAE = \angle CBE = 24°$ Join DC and DE, radii of circle each being $1\frac{1}{2}$ miles. $\angle CDE = 48°$, double $\angle CAE$ which is 24° and stands on the same chord CE. Drop DF perpendicular to CE, it bisects $\angle CDE$ and also the chord CE, so that $CE = 2\ CF$ the distance required. $CF = CD \sin CDF$.

3. A survey vessel observes two points A and B the same distance off, subtending an angle of 86°, A bearing 310° T. After steaming due South for 7 cables the angle now subtended by A and B is 43°. Find bearing and distance from A to B.

4. A vessel steering East, 15 knots, has the apparent wind S.E., and when she alters course two points to starboard the apparent wind is S.E. by S. Find the direction and velocity of the true wind.

5. A ship steering 000° has the apparent wind 4 points on her starboard bow. She alters course to 045° and the apparent wind is now 20° on her starboard bow. Find the true direction of the wind and its velocity if the ship's speed were 12 knots.

See Worked Example 12.

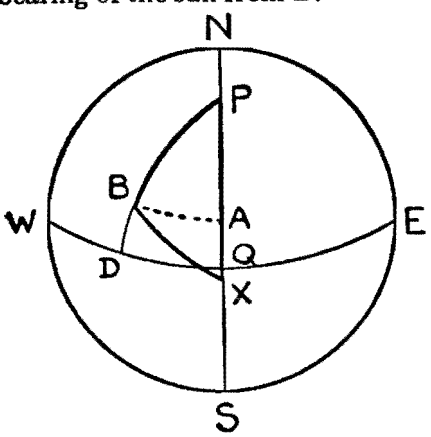
6. A cubical box of 4 feet sides is laid against a wall. A ladder is also laid against the wall just touching the edge of the box. The ladder is 16 feet long. Find the height of the wall.

Draw figure and note that the example is similar to Worked Example 13.

V. SPHERICAL TRIANGLES.

Example 14.

A and B are two observers 2640 miles apart in latitude 24° N., B being to the westward of A. The sun's zenith distance on A's meridian was 25° 16′. Find the bearing of the sun from B.



Let A be the zenith of observer A, and B that of observer B.

X the sun on the meridian of A so that AX is 25° 16′ and $PX = 91°\ 16'$. AB is the arc of the parallel of latitude, joining the two observers, 2640 miles; it is the departure between them and has to be converted into D Long. (QD) and transferred to $\angle P$.

D Long. $= 2640$ sec $24° = 2890' = 48°\ 10' = \angle P$. BX is a great circle between B and X.

In △PBX.

Given $PB = 66°$, $PX = 91°\ 16'$, $\angle P = 48°\ 10'$. Find $\angle X$.

by (38) $$\tan \tfrac{1}{2}(B + X) = \frac{\cos \frac{1}{2}(PB - PX)}{\cos \frac{1}{2}(PB + PX)} \cot \frac{P}{2}$$

by (39) $$\tan \tfrac{1}{2}(B - X) = \frac{\sin \frac{1}{2}(PB - PX)}{\sin \frac{1}{2}(PB + PX)} \cot \frac{P}{2}$$

from which $\frac{1}{2}(B + X) = 84°\ 50\frac{1}{2}'$

$\frac{1}{2}(B - X) = 26\ \ 31\frac{1}{2}$

$\angle PBX$. $111\ \ 22$

∴ Sun bears from B $111°\ 22'$ T. *Answer.*

Example 15.

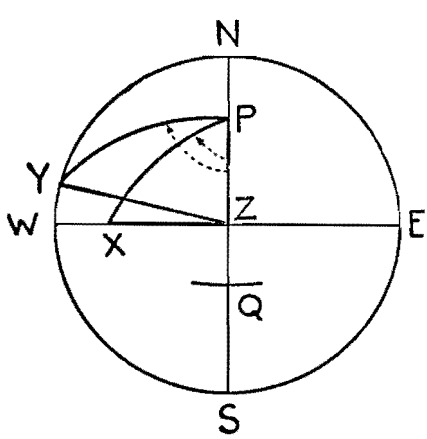
In north latitude a star is on the prime vertical $4^h\ 10^m$ after passing the meridian, and $2^h\ 32^m$ later it sets. Find the latitude.

In figure, $\angle ZPX = 4^h\ 10^m = P$

$\angle ZPY = 6\ \ 42 = P_1$

$\angle PZX = 90°$, side $ZY = 90°$

Find PZ.



In △PZX. $\cos P = \cot PX \tan PZ$

In △PZY. $-\cos P_1 = \cot PY \cot PZ$

but $PX = PY$ and dividing we get

$$\frac{\cos P}{-\cos P_1} = \tan^2 PZ$$

∴ cot lat. $= \sqrt{\cos P \sec P_1}$

P	$4^h\ \ 10^m$	cos	9·664406
P_1	6 42	− sec	10·739367
			2)20·403773
		cot	10·201886

Answer. Lat. $32°\ 8\frac{1}{2}'$ N.

Example 16.

Two stars have the same altitude at the same instant, A bears 060°, Decl 25° N., and B bears 090°, Decl 15° N. Find the latitude.

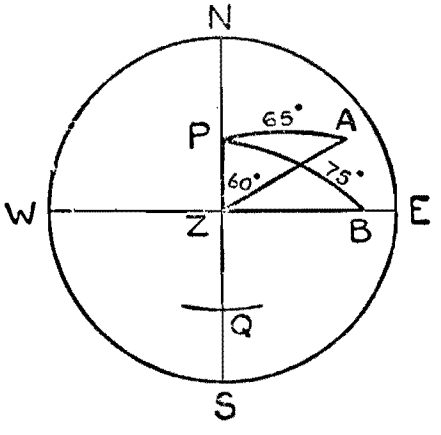
In figure. A and B are the two stars.

$$PA = 65°, \quad PB = 75°, \quad \angle PZA = 60°$$
$$\angle PZB = 90°, \quad ZA = ZB$$

In $\triangle PZB$. $\cos PB = \cos PZ \cos ZB = \cos 75°$ . . . . . (i.)

In $\triangle PZA$. by (28) $\cos 60° = \dfrac{\cos 65° - \cos PZ \cos ZA}{\sin PZ \sin ZA}$

$$\tfrac{1}{2} = \frac{\cos 65° - \cos 75°}{\sin PZ \sin ZA} \quad . . . . . \text{(ii.)}$$



From (ii.) $\sin PZ \sin ZA = 2 (\cos 65° - \cos 75°) = \quad ·327598$

,, (i.) $\cos PZ \cos ZA = \cos 75° \quad = \quad ·258819$

add $\cos PZ \cos ZA + \sin PZ \sin ZA = \cos (PZ - ZA) = \quad ·586417 \; (54° \; 06')$

subt. $\cos PZ \cos ZA - \sin PZ \sin ZA = \cos (PZ + ZA) = - \; ·068779 \; (93 \;\; 57)$

Nat cos — ·068779 = 86° 3′, but having a negative sign $(PZ + ZA) = 180° - 86° \; 3' = 93° \; 57'$

From which $(PZ - ZA)$ 54° 06′ 54° 06′

,, $(PZ + ZA)$ 93 57 93 57

2)148 03 2)39 51

PZ 74 1½ or PZ 19 55½

Answer. Lat. = 15° 58½′ N. or 70° 4½′ N.

Example 17.

In what latitude will a star of Decl 45° N. be on the prime vertical while having an hour angle of half that of another star on the prime vertical whose Decl is 20°N. ?

In figure, let x and y be the two stars bearing West, such that $\angle ZPY = \theta$ and $\angle ZPX = 2\theta$, $PX = 70°$, $PY = 45°$.

In $\triangle PZY$. $\cos \theta = \tan PZ \cot PY$ . . . . . (i.)

$\therefore$ $\tan PZ = \cos \theta \tan PY$

$\triangle PZX$. $\cos 2\theta = \tan PZ \cot PX$ . . . . . (ii.)

Dividing (ii.) by (i.) $\dfrac{\cos 2\theta}{\cos \theta} = \dfrac{\cot PX}{\cot PY} = \dfrac{\cot 70°}{\cot 45°} = ·364$

But $$\frac{\cos 2\theta}{\cos\theta} = \frac{2\cos^2\theta - 1}{\cos\theta} = \cdot 364$$

$$2\cos^2\theta - \cdot 364\cos\theta = 1$$

$$\cos^2\theta - \cdot 182\cos\theta = \cdot 5$$

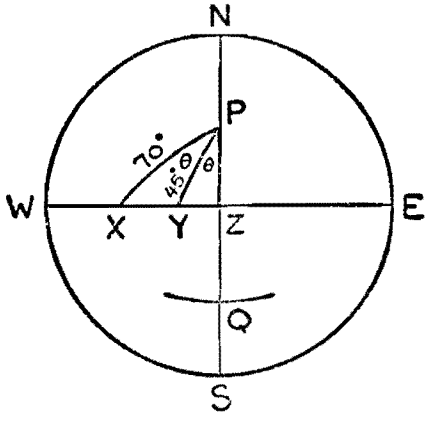
Complete the square by adding half the coefficient of cos θ to each side of the equation and we get

$$\cos^2\theta - \cdot 182\cos\theta + \cdot 091^2 = \cdot 5 + \cdot 091^2$$

$$(\cos\theta - \cdot 091)^2 = \cdot 5 + \cdot 091^2 = \cdot 5083$$

$$\cos\theta - \cdot 091 = \pm\sqrt{\cdot 5083} = \pm \cdot 7130$$

$$\cos\theta = + \cdot 7130 + \cdot 091 = + \cdot 804$$



From Eq. (i.)

$$\tan PZ = \cos\theta \tan PY$$

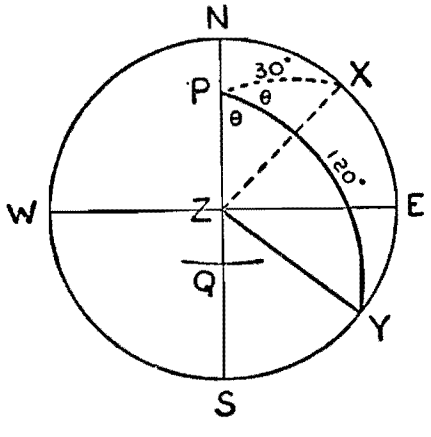
$$\text{nat cot Lat} = \cos\theta \tan 45$$

$$\text{,,} = \cdot 804 \times 1 = \cdot 804$$

$$\text{Lat} = 51°\ 12'\ \text{N.}\quad \textit{Answer.}$$

Example 18.

A star is above the horizon to an observer in 60° N. for twice the period it is to an observer in 30° S. Find the star's declination.



This problem is somewhat similar to Example 15 if we substitute declination for latitude in the question so that Lat 60° N. = Decl 60° N., making $PX = 30°$. Lat 30° S. = Decl 30° S., making $PY = 120°$ and hour angles θ and 2θ. Find PZ the colatitude which will be the polar distance of the star. It is merely a question of thinking of the observers as two stars X and Y, and the star as an observer Z.

In quadrantal $\triangle PZX$—$\cos 2\theta = \cot PX \cot PZ$

,, $\triangle PZY$—$\cos\theta = \cot PY \cot PZ$

$$\therefore \frac{\cos 2\theta}{\cos\theta} = \frac{\cot 30°}{\cot 120°}$$

$$= \cot 30° \tan 60° = \sqrt{3} \times -\sqrt{3} = -3$$

(Note that cot 120° is negative.)

By (19) we may write . . . $\cos 2\theta = 2\cos^2\theta - 1$

$$\text{so that} \quad \frac{\cos 2\theta}{\cos\theta} = \frac{2\cos^2\theta - 1}{\cos\theta} = -3$$

$$\therefore \quad 2\cos^2\theta + 3\cos\theta - 1 = 0$$

Applying the quadratic formula mentioned on page 286, viz.:—

$$x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

$$\cos\theta = \frac{-3 \pm \sqrt{(3^2 - 4 \times 2 \times (-1))}}{2 \times 2} = \frac{-3 \pm \sqrt{17}}{4} = \frac{-3 \pm 4{\cdot}12}{4}$$

$$\cos\theta = \frac{1{\cdot}12}{4} = {\cdot}28 \quad \therefore \theta = 73^\circ\ 41\tfrac{3}{4}'.$$

The negative value of $\cos\theta$ does not apply.

We already noted, $\cot PZ = \cos\theta \tan PY$

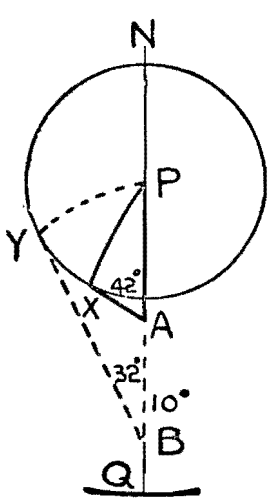
$$\text{,,} \quad = \cos 73^\circ\ 41\tfrac{3}{4}' \tan 120^\circ$$

from which $PZ = 64^\circ\ 04' =$ P. dist of star

Answer. Decl of star $= 25^\circ\ 56'$N.

Example 19.

A circumpolar star has maximum azimuth 42° from an observer A in North latitude. From another observer B, 10° South from A, the maximum azimuth is 32°. Find the latitude.



In figure, let A be the position of one observer and B that of the other, so that $AB = 10^\circ$.

X is the position of the star at maximum azimuth 42°.
Y is the position of the star at maximum azimuth 32°.
Angles X and $Y = 90^\circ$.

Required to find PA the co-latitude.

In $\triangle$PXA. $\sin PX = \sin PA \sin A$.
In $\triangle$PYB. $\sin PY = \sin PB \sin B$.
But $PX = PY$ and $PB = (PA + 10^\circ)$
$\therefore \sin PA \sin 42 = \sin 32 \sin (PA + 10^\circ)$
by (5)
$\sin PA \sin 42 = \sin 32 [\sin PA \cos 10 + \cos PA \sin 10]$

$$\frac{\sin 42}{\sin 32} = \frac{\sin PA \cos 10 + \cos PA \sin 10^\circ}{\sin PA}$$

$$\text{,,} \quad = \cos 10 + \cot PA \sin 10$$

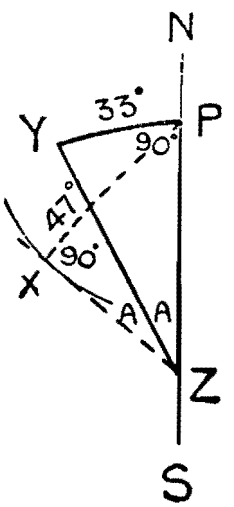
$$\therefore \cot PA = \frac{\sin 42}{\sin 32 \sin 10} - \frac{\cos 10}{\sin 10}$$

Nat cot $PA = 7{\cdot}271617 - 5{\cdot}671280 = 1{\cdot}600337$
$\therefore PA = 32^\circ$.

Answer. Lat of $A = 58^\circ$N.
Lat of $B = 48^\circ$N.

Example 20.

A star, declination 43° N., which crossed the meridian North of the observer and reached its maximum azimuth at the same time as another star, declination 57° N., has an hour angle of 6 hours West. The azimuth of the first star is twice that of the second. Find the observer's latitude.



In figure, Z is the zenith, P the pole, X the star having maximum azimuth, $\angle X = 90°$, $PX = 47°$, Y the star whose hour angle is 6^h, $\angle P = 90°$, and PY 33°.

Let $\angle PZY = A$, then $\angle PZX = 2A$.

Find angle A, thence the latitude.

In $\triangle$PZX. $\sin PX = \sin PZ \sin 2A$

$\therefore \sin PZ = \sin PX \operatorname{cosec} 2A$

In $\triangle$PZY. $\sin PZ = \tan PY \cot A$

$\therefore \sin PX \operatorname{cosec} 2A = \tan PY \cot A$

or, $\dfrac{\sin PX}{\tan PY} = \cot A \sin 2A$

$= \dfrac{\cos A \, 2 \sin A \cos A}{\sin A}$ . . by (15)

$\dfrac{\sin PX}{\tan PY} = 2\cos^2 A = \dfrac{\sin 47°}{\tan 33°}$

$\cos^2 A = \frac{1}{2}(\sin 47° \cot 33°)$ from which

$A = 41° \; 22\frac{1}{2}'$.

In $\triangle$PZY.

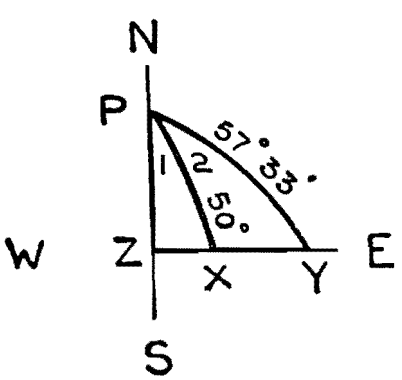
$\sin PZ = \tan PY \cot A$

$\cos \text{lat} = \tan 33 \cot 41° \; 22\frac{1}{2}'$

Answer. Lat $= 42° \; 30'$ N.

Example 21.

Two stars x and y are observed on the prime vertical at the same instant, x Decl 40°, y Decl 32° 27′, the hour angle of y is three times that of x. Find the latitude.



In figure, X and Y are the two stars. If $\angle ZPX = P$, then $\angle ZPY = 3P$, $PX = 50°$, $PY = 57° \; 33'$. Find angle P, thence PZ the co-latitude.

In $\triangle$ZPY. $\cos 3P = \cot PY \tan PZ$

In $\triangle$ZPX. $\cos P = \cot PX \tan PZ$

Divide $\dfrac{\cos 3P}{\cos P} = \dfrac{\cot PY}{\cot PX} = \dfrac{\cot 57° \, 33'}{\cot 50°} = \cdot 7578$

by (25) $\dfrac{\cos 3 \, P}{\cos P} = \dfrac{4\cos^3 P - 3 \cos P}{\cos P} = \cdot 7578$

$\cos P$ cancels, $4\cos^2 P - 3 = \cdot 7578$

$\cos P = \sqrt{\cdot 93945}$

and $P = 56^m \; 59^s$

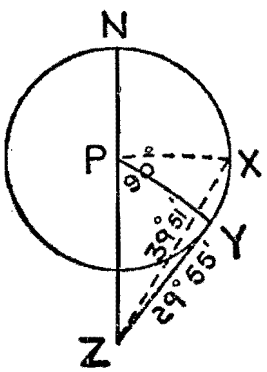
In $\triangle$PZX. $\cos P = \cot PX \tan PZ$

$\tan PZ = \cos 56^m \; 59^s \tan 50°$

Answer. Lat 40° 53′.

Example 22.

A circumpolar star with hour angle 6 hours East has an altitude of 50° 9′, and later on reaching its maximum azimuth for the same position of the observer it had an altitude of 60° 5′. Find the mean solar interval.



In figure, let X and Y be the two positions of the star, P the pole, Z the zenith.

$\triangle PZX$. Given $\angle ZPX = 90°$, $ZX = 39° 51'$

$\triangle PZY$. ,, $\angle ZYP = 90°$, $ZY = 29° 55'$

$PX = PY$, PZ common.

In $\triangle$PZX. $\cos ZX = \cos PZ \cos PX$

$\therefore \cos PZ = \cos ZX \sec PX$

In $\triangle$PZY. $\cos PZ = \cos ZY \cos PY$

equating, $\cos ZX \sec PX = \cos ZY \cos PY$

but $PX = PY$, $\sec^2 PX = \cos ZY \sec ZX$

$\sec PX = \sqrt{\cos 29° 55' \sec 39° 51'}$

from which $PX = 19° 45' 21'' = PY$

In $\triangle$PZY. $\sin PY = \cot P \tan ZY$

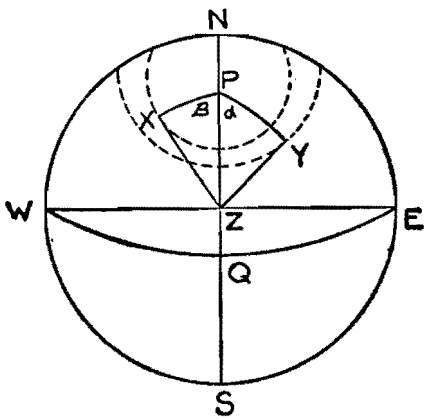
$\cot P = \sin PY \cot ZY$

,, $= \sin 19° 45' 21'' \cot 29° 55'$

		h.	m	s.
from which	$\angle ZPY =$	3	58	17
	$\angle ZPX =$	6	00	00
	$\angle ZPY =$	3	58	17
Sidereal interval,	$\angle XPY =$	2	01	43
Retardation from Tables			—	19·8
Answer. Mean solar interval		2	01	23·2

Example 23.

What is the latitude of an observer who observes that stars Alioth and Deneb are at their maximum azimuth on opposite sides of the meridian at the same instant?



In figure, Z is the observer.
PY = P. Dist. of Deneb Decl. 45° 1½′ N.
PX = P. Dist. of Alioth Decl. 56° 21′ N.
$\angle XPY = \theta$ = difference of star's right ascension, viz., Y 20h 39m 00s, X 12h 50m 55s $\therefore \theta$ = 7h 48m 5s.

If α be the H. ang. of Y and β the H. Ang. of X. then $\alpha + \beta = \theta$ and $\beta = \theta - \alpha$
Angles Y and $X = 90°$. Find value of α.

I. $\cos \alpha = \tan PY \cot PZ$
$\cos \beta = \cos (\theta - \alpha) = \tan PX \cot PZ$.

II. But $\cos (\theta - \alpha) = \cos \theta \cos \alpha + \sin \theta \sin \alpha = \tan P \times \cot PZ$.
Divide Eq. II. by Eq. I. and cancel and we get—

$$\cos \theta + \sin \theta \tan a = \tan PX \cot PY$$

$$\therefore \tan \alpha = \frac{\tan PX \cot PY - \cos \theta}{\sin \theta} \text{ from which}$$

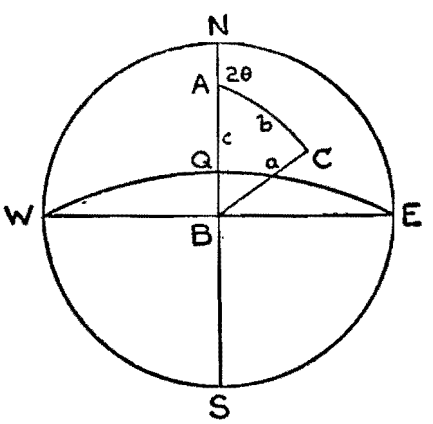
$$\alpha = 51° \ 31\tfrac{1}{2}', \quad \beta = 65° \ 29\tfrac{3}{14}'.$$

NOTE.—θ is over 90° so that $-\cos \theta$ becomes $+\cos \theta$ in the equation.
Solve one of the triangles for PZ.

Answer. Lat of observer 31° 48½′ N.

Example 24.

Two observers on the same meridian observed altitudes of the same star at the same instant. A's altitude was 41° 09′ and B's 30° 59′, and the azimuth of the star from the same pole was 2θ° at A and θ° at B. If B's latitude was 20° S., find A's latitude.



In figure, A and B are the two positions, and C the star, then side b is the zenith distance of star from A and side a its zenith distance from B, $b = 48° \ 51'$, $a = 59° \ 01'$.

$\angle NAC$ = azimuth of star from $A = 2\theta$
$\angle NBC$ = azimuth of star from $B = \theta$

Find value of θ.

$$\frac{\sin a}{\sin b} = \frac{\sin A}{\sin B} = \frac{\sin (180° - 2\theta)}{\sin \theta} = \frac{\sin 2\theta}{\sin \theta} = \frac{2 \sin \theta \cos \theta}{\sin \theta} = 2 \cos \theta \quad . \quad (15)$$

$$\therefore 2 \cos \theta = \frac{\sin a}{\sin b} = \frac{\sin 59° \ 01'}{\sin 48° \ 51'} \quad \therefore \ \underline{\theta = 55° \ 18'}$$

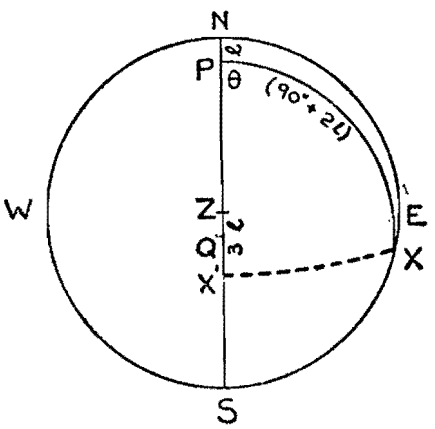
By Napier's Analogy (40).

$\tan \frac{c}{2} = \tan \frac{1}{2}(a + b) \cos \frac{1}{2}(A + B) \sec \frac{1}{2}(A - B)$ from which $c = 65° 24'$ and is the D. Lat. of A north of B.

Answers. B's Lat. 20° S.
A's Lat. 45° 24′ N.

Example 25.

If the meridian zenith distance of a body were three times the latitude, and the hour angle when rising were 5h 46m 16s, find the latitude and indicate the names of the latitude and declination.



Given NP the Lat. $= l$, and $ZX^1 = 3l$, $\theta = 5$h 46m 16s.

X the star at rising, X^1 when on meridian, $\angle N = 90°$ then $PX = PX^1 = (90° + 2l)$

$$\begin{aligned} \text{Cos } (180° - \theta) &= -\cos \theta \\ \text{,,} &= \tan l \cot (90° + 2l) \\ \text{,,} &= -\tan l \tan 2l \\ \text{but } \tan 2l &= \tan (l + l) \\ \text{,,} &= \frac{2 \tan l}{1 - \tan^2 l} \quad . \quad (7) \end{aligned}$$

$\therefore \cos \theta = \dfrac{2 \tan^2 l}{1 - \tan^2 l}$ or $\sec \theta = \dfrac{1 - \tan^2 l}{2 \tan^2 l}$ using reciprocal for convenience so that

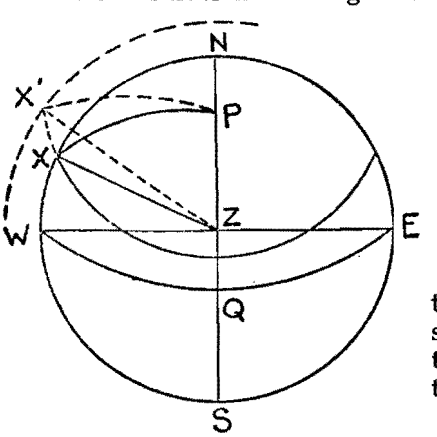
$$2 \sec \theta = \frac{1}{\tan^2 l} - \frac{\tan^2 l}{\tan^2 l} = \cot^2 l - 1$$

and $\cot l = \sqrt{2 \sec \theta + 1}$ from which $l = 9° 40\frac{1}{2}'$

Answer. Lat. 9° 40½′ N. when Decl. is S. but Lat. S. when Decl. is N.

Example 26.

Find the time of true sunset in Lat. 30° 40′ N., Long. 3° 30′ W., and from thence deduce the duration of twilight on the longest day.



In figure—

Given $PX = PX^1 =$ P. Dist. of Sun on longest day 66° 33′

$PZ =$ co-latitude

$ZX = 90°$. $ZX^1 = 108°$

Find $\angle ZPX$ the H. Ang.

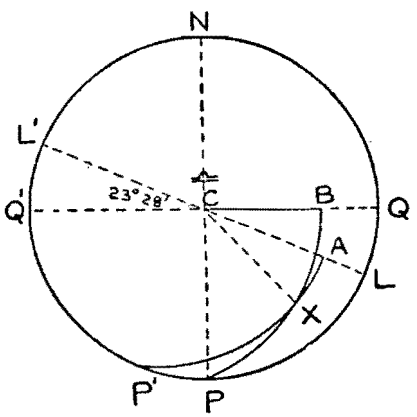
The dotted circle represents the 18° arc of twilight. Twilight lasts during the period the sun takes to travel from X to X^1 and $\angle ZPX^1$ is the hour angle at end of twilight, and $\angle ZPX$ is the hour angle at sunset.

In $\angle PZX^1$. Given PZ, ZX^1, PX^1. Find $\angle ZPX^1$ by haversine formula. In $\triangle PZX$ find $\angle ZPX$. Difference of the two hour angles is the duration of the setting twilight.

Hour angle of sunset	= 6h 59 38s
Hour angle at end of twilight	= 8 41 50
Duration of twilight	1 42 12

Example 27.

If the celestial position of a star is Lat. 4° 52′ 41″ S., Long. 246° 42′, and assuming the obliquity of ecliptic to be 23° 28′, find the star's right ascension and declination.



In figure—Q^1Q the equinoctial.
L^1L the ecliptic.
$\angle QCL$ the obliquity 23° 28′.
P the pole of equinoctial.
P^1 the pole of ecliptic.

If C be the point of Libra, the longitude of which is 180° from Aries, then the longitude of star X 246° 42′ is 180° + CA and CA = 66° 42′.

AX is the Lat. of X = 4° 52′ 41″ S. (position exaggerated to show up in figure).

BX the Decl. of X.

12h + CB is the R.A.'s of X. Join CX by a great circle.

In $\triangle CAX$ Given CA, AX and $\angle A = 90°$. Find CX and $\angle XCA$.
In $\triangle CBX$. Given CX, $\angle XCB$ and $\angle B = 90°$. Find CB and BX.
(12h + CB) = R.A. 16h 15m 44s. (BX) Decl. 26° 15.6′ S.

V.—Spherical Triangles.

1. In North latitude a star, Decl. 8° N., bears South, and another star, Decl. 19° N., bears West, the arc of the celestial concave between them is 47°. Find the latitude.

2. An observer in Lat. 23° 10′ N., Long. 20° W., observes the Sun on his meridian, Decl. 23 °10′ N. At the same time another observer, whose great circle distance is 1760 miles from the first observer, notes the Sun's bearing to be 045°. Find the latitude and longitude of the second observer.

Draw figure. Let A be observer whose latitude is known and equal to declination of Sun. B the other observer so that $\angle B = 45°$, AB his great circle distance from A, $\angle APB$ his D. Long. from A and PB his co-latitude. Find $\angle P$ by sine formula and thence PB by Napier's Analogy.

3. A and B are in the same North latitude. When the Sun is on A's meridian its bearing from B is 119° 30′, declination 4° S. The difference of longitude between A and B is equal to the true altitude of the Sun at B. Find the latitude.

This question is the same type as Example 14, the figures being somewhat similar. Refer to the figure and note that the question gives
$\angle B = 119° 30'$, $PX = 94°$, $\angle P = 0°$, side $BX = (90° - \theta)$ from which find value of θ.

In triangle PBX.

$$\frac{\sin\theta}{\sin(90^\circ-\theta)} = \frac{\sin\theta}{\cos\theta} = \tan\theta = \frac{\sin B}{\sin PX} = \frac{\sin 119^\circ 30'}{\sin 94^\circ} \text{ whence } \theta = 41^\circ\ 06'$$

Again by Napier's Analogy . . . . (40)

$\tan\frac{PB}{2} = \tan\frac{1}{2}(PX + BX)\cos\frac{1}{2}(\theta + B)\sec\frac{1}{2}(\theta - B)$ which gives PB the co-latitude of A and B.

4. If the hour angle of a body is 6h 30m at rising and 5h 16m when it reaches the prime vertical, find the latitude of observer and declination of the body.

See Example 15.

5. In North latitude a star was on the horizon at 22h 00m S.M.T., on the prime vertical at 0h 10m S.M.T., and on the meridian at 4h 0m S.M.T. Find the star's declination.

Convert the mean solar intervals into sidereal intervals. Construct figure. Let A be the star on the horizon, B on the prime vertical and C on the meridian.

In $\triangle ZPA$, $ZA = 90^\circ$, use $\angle ZPA$ and PZ and write the equation for PA.

In $\triangle ZPB$, $\angle Z = 90^\circ$, use $\angle ZPB$, and PZ and equate for PB. Divide one equation by the other, PZ cancels and $\frac{\sin ZPB}{\cos APZ} = \tan^2 PB$ the polar distance.

6. The difference between the longest and shortest days is 5h 5m 24s., the greatest declination of the Sun being 23° 27′; find the latitude.

See example on page 376 Vol. I.

Figure on plane of horizon. Let Z and Y be the Sun at setting on shortest and longest days respectively. Then $\angle XPY$ is half the difference of time = 2h 32m 42s. But $\angle ZPX + \angle XPY + \angle YPN = 12$h and $\angle ZPX = \angle YPN$ since X and Y are the positions of the Sun at extreme North and South declination. $\angle NPY$ is therefore 4h 43m 29s. Combine this angle with P. Dist. and find NP the latitude.

7. The rising amplitude of a star was E. 16° 53′ N. (true) and later its true altitude was 20° 25′ 35″ when bearing East (true). Find the latitude, North hemisphere.

Draw figure. Let X be the star on the horizon and Y when it is on the prime vertical.

In $\triangle ZXY$. Given ZY, $\angle Z$, side $ZX = 90^\circ$. Find XY.

In $\triangle PZX$. $\cos PX = \sin PZ \cos PZX$ I

In $\triangle PZY$. $\cos PY = \cos PZ \cos ZY$ II

$PX = PY$. Divide I by II $\tan PZ = \cos ZY \sec PZX$.

8. A star has maximum azimuth to an observer in Lat. 21° N., Long. 33° W. At the same time he finds that this star and another 15° W. of him and on the equinoctial differ in azimuth by 67° 6′. Required the declination of the first star and its altitude to an observer on the equator in Long. 48° W.

Construct figure. If B is the star on equator, and A the other star, then $\triangle PZB$ is quadrantal, $PB = 90^\circ$. Given PZ and $\angle P$ find $\angle Z$ and ZB.

In $\triangle PZA$ with $\angle A = 90^\circ$, PZ and $\angle PZA$ find PA and $\angle ZPA$.

In $\triangle PAB$ with PA, $\angle APB$, find BA the zenith distance of star A from observer B.

9. The altitude of a star when due South was 47° and when due West 18°, required the latitude.

Construct figure. If X be the star when on the meridian and Y when on the prime vertical, solve triangle ZXY for side XY. $\triangle PXY$ is isosceles. Draw PA perpendicular to XY. $\angle A = 90^\circ$

In $\triangle PAX$, given $AX = \frac{1}{2}XY$ also ZX, find PX, then $PX - 43^\circ$ = co-lat.

10. Betelgeuse R.A. 5h 51m 10s., Decl. 7° 23′ 30″ N.
Bellatrix R.A. 5 21 10, Decl. 6 16 54 N.
are both on the prime vertical to the westward at the same time, required the latitude.

If X and Y be the positions of the stars when on the prime vertical, then in $\triangle PXY$, given PX and PY their polar distances and $\angle XPY$ the difference of their right ascensions, calculate angles X and Y by tan formula.

In $\triangle PZY$, $Z = 90°$, find PZ the co-lat.

11. Given apparent time at ship 8h 52m a.m., Sun's Decl. 3° 10′ S., Alt. 29° 39′. Find the latitude.

Figure on plane of horizon.
Draw in XY perpendicular to meridian.
Solve $\triangle PXY$, for PY and XY.
Solve $\triangle ZXY$, for ZY.
$PY - ZY$ = co-lat.

12. Given Lat. 30° N., Alt. 22° 8·2′, Az. S. 76° 25′ E. Find the hour angle and declination of the body.

13. Given *R.A. 4h 31m 40s, *Decl. 16° 21·6′ N
*Az. 252° T., G.H.A. Aries 124° 26·5′.

If the star's meridian zenith distance when bearing South was 23° 13′ 28″, find the longitude.

In $\triangle PZX$, given PZ, PX, $\angle Z$, find X by the sine formula and ZX by Napier's Analogy (40), then $\angle P$ by sine formula, thence the longitude.

14. Given Vega R.A. 18h 34m 28s, Decl. 38° 42′ 09″ N. Az. N. 50° E.
Spica R.A. 13 21 18, Decl. 10 46 06 S. Az. S. 50° W.
Find the latitude of observer.

If X and Y be the respective stars, then in $\triangle PXY$, given PX, PY, $\angle XPY$ find $\angle$s X and Y.
In $\triangle PZX$, find PZ by the sine formula.

15. In North latitude, the difference of azimuth between Elnath and Betelgeuse was 20°, both stars to the eastward, the true altitude of Betelgeuse was 24°, find the altitude of Elnath.

Betelgeuse R.A. 5h 51m 28s, Decl. 7° 23′ 45″ N.
Elnath R.A. 5 21 56, Decl. 28 32 48 N.

Construct figure. If X be Betelgeuse and Y be Elnath, join XY by a great circle.
In $\triangle XPY$, given PX, PY, $\angle XPY$, find XY.
In $\triangle XZY$, given ZX, XY and $\angle Z$, find $\angle ZYX$ then find ZY by Napier's Analogy.

16. Find the celestial latitude and longitude of a star whose R.A. is 16h 25m 5s, and Decl. 26° 16·7′ S., obliquity 23° 27′.
See Example 25.

17. A star R.A. 2h 59m 36s., Decl. 21° 27′ 45″ N., find its celestial latitude and longitude.

CHAPTER XII.

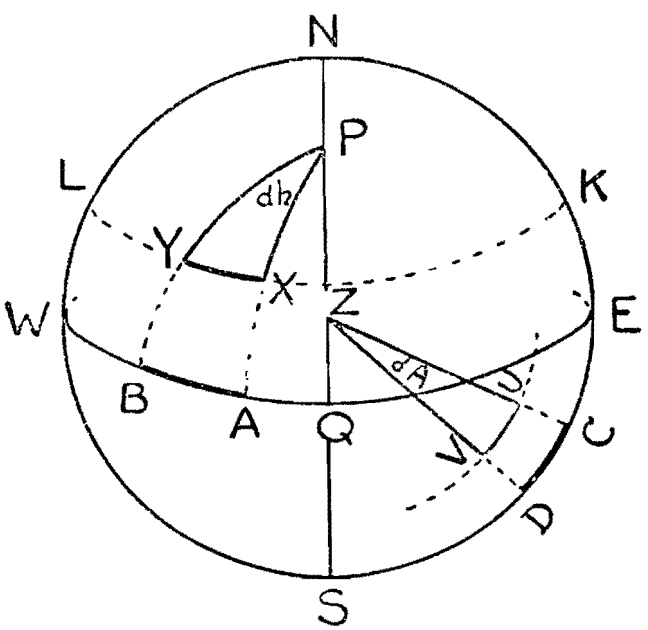
NAUTICAL AND SPHERICAL ASTRONOMY.

(I.) The arc of a small circle subtending a given angle at the pole is proportional to the cosine of the angular distance of the small circle from the parallel great circle.

This property will be recognised on referring to the figure, in which P is the pole of the great circle WQE, and XY the arc of a small circle KL parallel to it, then PA and PB are secondaries of the circle WQE and $KXYL$.

$$\therefore \text{ arc } XY = \text{arc } AB \cos AX$$
$$\text{or dep.} = d \text{ long} \cos \text{Lat.}$$

if WQE be the earth's equator. The student will recognise this as the formula for parallel sailing proved in Volume I., page 153.



If, however, we consider P to be the celestial pole, then WQE will be the equinoctial and the secondaries, or meridians, PA and PB are now hour circles and XY is an arc of a parallel of declination.

The time taken by a body to travel from X to Y is measured by the angle APB or arc AB, this interval of time, or difference in hour angle, is written as dh, and as before

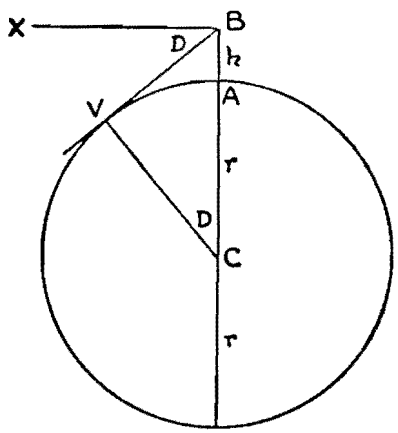
$$\text{arc } XY = \text{arc } AB \cos AX$$
$$\text{or } XY = dh \cos \text{Decl.}$$

Again, Z the zenith is the pole of the horizon $NESW$. With centre Z and radius ZU, describe a small circle of equal altitude of which UV is an arc, then $\angle UZV$ or arc CD measures the difference of azimuth, between U and V, written dA, and, as before, we may write

$$\text{arc } UV = \text{arc } CD \cos CU$$
$$UV = dA \cos \text{alt}$$

DIP.

(II.) To Find the Distance of the Sea Horizon.—



In figure:

BX is the plane of the sensible horizon
BV the tangent to the visible horizon
$\angle XBV$ the dip $= D$
AB the height of eye $= h$
AC the radius of the earth $= r = 3960$ miles.
h is small compared with r the earth's radius and therefore the arc AV is small and equals BV nearly.

$$\begin{aligned} BV^2 &= BC^2 - CV^2 \\ &= (r+h)^2 - r^2 \\ &= r^2 + 2rh + h^2 - r^2 \\ &= 2rh + h^2, \text{ but } h \text{ is small so that } h^2 \text{ may be neglected} \\ &= 2rh \text{ nearly. } h \text{ in mls.} = h/5280 \text{ ft.} \end{aligned}$$

$$BV = \sqrt{2rh} = \sqrt{\frac{2 \times 3960 \times h}{5280}} = \sqrt{1{\cdot}5h}$$

Example.—Calculate the distance of the sea horizon for height of eye 100 feet, and radius of the earth 3960 statute miles, or 3444 nautical miles.

Dist. $= \sqrt{2rh} = \sqrt{1{\cdot}5 \times 100} = 12{\cdot}2$ statute miles
$12{\cdot}2$ (statute) $\div 1{\cdot}15 = 10{\cdot}6$ nautical miles $= 1{\cdot}06\sqrt{h}$.

This calculated distance does not take into account the uncertain effect of refraction which increases the distance by an amount variously estimated at from $\frac{1}{10}$ to $\frac{1}{15}$ of itself, so if we add $\frac{1}{12}$ of $10{\cdot}6$ we get $\cdot 88 + 10{\cdot}6 = 11{\cdot}48$ miles as the distance of the sea horizon. This agrees closely with the approximate formula result given in Volume I, page 245, viz.

$$\text{Distance} = 1{\cdot}15\ \sqrt{\text{height of eye}} = 1{\cdot}15\ \sqrt{100} = 11{\cdot}5 \text{ miles.}$$

(III.) To Find the Angle of Dip, and Area of Visible Horizon.

In the figure, angle XBV the dip is equal to the angle BCV at the centre of the earth, because both angles are complements of $\angle VBC$. Find dip for 100 feet.

$$\tan D = \frac{BV}{CV} = \frac{\sqrt{2rh}}{r} = \sqrt{\frac{1{\cdot}5 \times 100}{3960}} = 10'\ 38''$$

About one-twelfth of the calculated amount should be deducted for the uncertain effect of refraction.

	D	$= 10'\ 38''$
Deduct for refraction		53
Dip for 100 feet		$= 9\ 45$

Nautical Tables give $9{\cdot}8'$ dip for 100 feet.

The angle of dip may be got approximately from the formula $\cdot 98\ \sqrt{\text{height of eye}}$.
In the above example the dip $= \cdot 98\ \sqrt{100} = 9{\cdot}8'$

Area within the Visible Horizon $= \frac{3\pi h}{2}$ **approximately.**

Example.—Find the area visible from a height of 100 feet.

Area $= \frac{3\pi h}{2} = \frac{3 \times 22 \times 100}{2 \times 7} = 471{\cdot}4$ sq. miles (statute) and 471·4 (statute) $\div 1{\cdot}15 = 410$ sq. miles (nautical).

Another approximate method is to assume the area within the visible horizon to be that of a plane circle, the radius of the circle being the distance of the sea horizon, thus:—

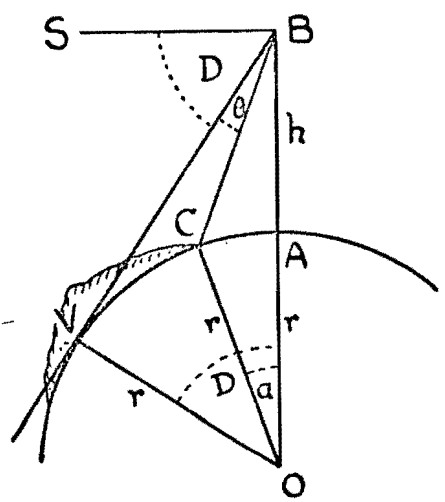
Distance $= 1{\cdot}15\sqrt{100}$ ft. $= 11{\cdot}5$ miles (nautical)

Area of circle $= \pi r^2 = \frac{22 \times 11{\cdot}5^2}{7} = 415$ sq. miles (nautical)

Example.—Find the area contained by the visible horizon when the eye is 64 feet above sea level.

Answer. 304 sq. miles (statute)
263 sq. miles (nautical)

(IV.) The Dip of a Shore Horizon.



In the figure BV represents the direction of the sea horizon for height of eye $AB = h$, and r = radius of the earth. Let the true dip $\angle SBV = D$, then, because $\angle SBV = \angle BOV$ both being complements of $\angle VBO$, $\angle BOV = D$. the apparent dip.

When land intervenes between the sea horizon and the observer the altitude of a body is measured from the waterline of the shore at C, and the dip of the shore horizon is $\angle SBC = (D + \theta)$, $\angle\theta$ being the correction to be added to the true dip as taken from the dip table.

The arc AC is the distance of the shore and, being very small compared with the radius of the earth, the arc $AC = \angle AOC = a$.

$$\angle BCO = 180° - (CBO + a) = 180° - CBO - a$$
$$\text{,,} \quad = 180° - (90° - D - \theta) - a$$
$$\text{,,} \quad = 180° - 90° + D + \theta - a$$
$$\angle BCO = 90° + (D + \theta - a) \text{ and } \angle CBO = 90° - (D + \theta)$$

In $\triangle BCO$. $\quad \frac{OB}{OC} = \frac{r + h}{r} = \frac{\sin BCO}{\sin CBO} = \frac{\sin\{90° + (D + \theta - a)\}}{\sin\{90° - (D + \theta)\}}$

$$= \frac{\cos(D + \theta - a)}{\cos(D + \theta)} \quad . \quad . \quad . \quad 1$$

From $\triangle BVO$. $\quad \frac{OB}{OV} = \frac{r + h}{r} = \sec D = \frac{1}{\cos D} \quad . \quad . \quad . \quad . \quad . \quad 2$

From 1 and 2. $\dfrac{\cos\{D+\theta-a\}}{\cos(D+\theta)} = \dfrac{1}{\cos D}$

$\therefore \cos(D+\theta-a) = \dfrac{\cos(D+\theta)}{\cos D} = \dfrac{\cos D\cos\theta - \sin D\sin\theta}{\cos D}$

or $\cos\{(D-a)+\theta\} = \cos\theta - \tan D\sin\theta$

$\cos(D-a)\cos\theta - \sin(D-a)\sin\theta = \cos\theta - \tan D\sin\theta$

See footnote for this transformation.

Dividing both sides by $\cos\theta$ we get

$\cos(D-a) - \sin(D-a)\tan\theta = 1 - \tan D\tan\theta.$

By re-arranging and multiplying both sides by -1 we get

$1 - \cos(D-a) = \tan D\tan\theta - \sin(D-a)\tan\theta = \tan\theta\{\tan D - \sin(D-a)\}$

$\therefore \tan\theta = \dfrac{1-\cos(D-a)}{\tan D - \sin(D-a)} = \dfrac{2\sin^2\left(\frac{D-a}{2}\right)}{\tan D - \sin(D-a)}$

But all these angles are small, therefore the equation may be reduced to

$$\theta = \frac{2\left(\frac{D-a}{2}\right)^2}{D-(D-a)} = \frac{(D-a)^2}{2a} = \frac{(\text{dip}-\text{dist.})^2}{2\text{ dist.}}$$

NOTE.—Let the compound angle $(D+\theta-a)$ be written $(D-a)+\theta$, then, if $(D-a)=A$ and $\theta=B$, it takes the form of the equation $\cos(A+B)=\cos A\cos B-\sin A\sin B$ from whence by substitution $\cos\{(D-a)+\theta\} = \cos(D-a)\cos\theta - \sin(D-a)\sin\theta$.

The *Admiralty Manual* formula for the dip of a shore horizon is $\cdot 565\frac{h}{a} + \cdot 423a$, where h is the height of eye in feet, and a is the offshore distance in miles.

Example.—Distance of shore horizon 3 miles, eye 49 feet, calculate the dip.

The distance of the sea horizon for 49 feet is $1\cdot15\sqrt{49} = 8$ miles (see *Norie's Table*). The offshore distance is only 2 miles so that the shore horizon is well within the range of the sea horizon.

Dip of sea horizon $= \cdot 98\sqrt{49} = 6\cdot9$ (see *Norie's Table*; Refr. allowed for).

The apparent dip is calculated from Eq. III, page 280.

$$\text{Tan } D^1 = \sqrt{\frac{1\cdot5\times49}{3960}} = \sqrt{\frac{49}{2640}}$$

	log 1·690196
	log 3·421604
	2)18·268592
	tan 9·134296

apparent dip $D = 7'\ 45''$ or $7\cdot7'$

$$\theta^1 = \frac{(D-a)^2}{2a} = \frac{(7\cdot7-3)^2}{2\times3} = \frac{4\cdot7\times4\cdot7}{6} = \frac{22}{6} = 3\cdot7'$$

True dip of sea horizon	6·9′	(from Dip Table)
Add θ as above	3·7	($\angle VBC$ in fig.)
Dip of shore horizon	10·6	($\angle SBC$ in fig.)

The above example by *Admiralty Manual* method.

$$\text{Dip of shore horizon} = \cdot565\times\frac{49\text{ ft.}}{3\text{ miles}} + \cdot423\times3\text{ miles}$$

$$= 9\cdot276+1\cdot269$$

$$= 10\cdot545'$$

Example.—

Distance of shore horizon 3 miles, eye 36 feet, calculate the dip.

Answers. *Guide* formula 8·1′
Admiralty „ 08·0′
Norie's Table „ 08·2′

Example.—

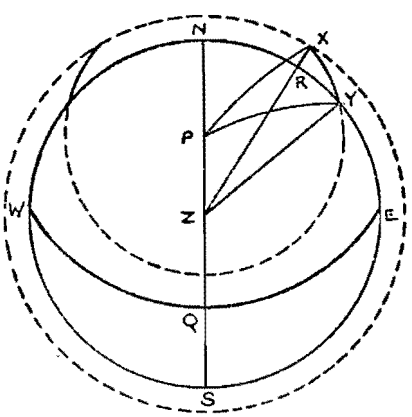
Offshore distance 1·5 miles, eye 25 feet, calculate the dip.

Answer. As per *Guide* 10·1′; *Admiralty* 10′; *Norie* 10′.

(V) Effect of Dip and Refraction on Times of Rising and Setting.

The effect of the height of eye is to depress the visible horizon and to cause celestial bodies to rise sooner, and set later, than they would if there were no dip.

Refraction raises the position of celestial bodies and, like dip, accelerates their times of rising and retards their times of setting.



In figure, *NESW* represents the rational horizon and the dotted circle the sea horizon.

If X be the position of a body at visible rising and Y its position at theoretical rising, then $\angle XPY$ is the interval of time taken by the body to travel along its diurnal path from X to Y, and $\angle XPY$ is the difference between the hour angles ZPY and ZPX.

In quadrantal triangle ZPY. PZ = co-lat. PY = P. dist. and ZX the zenith distance = 90°, so by Napier's Rules cos H. ang. = tan lat. tan decl., which gives the hour angle of theoretical rising without taking into account the effect of dip and refraction. These are the times given in *Norie's Tables.*

In triangle PZX, we have the same co-latitude and polar distance, PZ and PX, but ZX, the zenith distance, is equal to the arc ZR + arc RX, which is 90° plus the dip and refraction combined, or to each one separately if the effect of only one of the factors is being considered. The three sides of the triangle ZPX being known, the hour angle of the body when on the sea horizon is calculated from the formula

$$\text{hav } ZPX = \frac{\text{hav } ZX - \text{hav } (L - D)}{\cos L \cos D}$$

Example.—Find the acceleration of the rising of a celestial body, due to the effect of dip and refraction, in Lat. 50° N., from the top of a hill 900 feet above sea level, declination of body 20° N.

Dip $= \cdot 98\sqrt{900} = \cdot 98 \times 30 = 29{\cdot}4'$

Refr. $= 33'$ $\therefore$ $RX = 29{\cdot}4 + 33 = 62{\cdot}4'$, $ZX = 91°\ 02{\cdot}4'$

ZX	91°	2·4′	nat hav		·50905
$L-D$	30	00	,,		·06699
			,,		·44206
			hav		9·64548
Lat.	50	00	sec		0·19193
Decl.	20	00	sec		0·02701
$\angle ZPX$	7h	50·5m	hav		9·86442
$\angle ZPY$	7	43·0	(taken from Table)		
Interval		07·5			

Thus visible time of rising occurs 7·5 minutes earlier than the theoretical time.

This interval may be calculated by means of the "rate of change of altitude" formula (XX).

$dh = dz$ cosec azimuth sec. lat. where dh is the interval of time in minutes corresponding to a change of altitude dz in minutes of arc which, in this case, is 62·4′.

The azimuth at rising may be got from the Amplitude Table in *Norie*.

$$dh^{m} = \frac{62{\cdot}4'}{15} \text{ cosec } 57{\cdot}8° \text{ sec } 50°$$

dz	62·4′	log	1·79518
amp.	57·8°	cosec	0·07253
lat.	50°	sec	0·19193
			2·05964
	15′	log	1·17609 —
dh	7·6	log	0·88355

H. ang. from Table	7h 43m
Interval	+ 07·6
H. ang. of visible rising	7 50·6

Had dip (29·4′) and refraction (33′) been worked out separately, the interval for the height of eye (900 feet) would have been 3·6 minutes, and for refraction 4·0 minutes, the combined effect being 7·6m as above.

Exercises.

1. Given height of eye 400 feet, Lat. 56° N., Decl. 22° N., find acceleration of the rising of the body due to refraction and dip. (8·4 minutes)

2. In Lat. 56° N., eye 20 feet, Decl. of Sun 10° N., required the interval between visible and theoretical sunset. (6·7 minutes)

3. Lat. 30° N., Decl. 40°, eye 100 feet, required the interval between visible and theoretical rising of the body due to dip and refraction. (4·9 minutes)

(VI.) Visible and Theoretical Sunrise.

Visible sunrise and sunset is taken to be the moment when the Sun's upper limb is in contact with the sea horizon.

The time of theoretical sunrise and sunset is the instant when the Sun's centre is on the rational horizon. These are the times given in *Norie's Tables*, no allowance being made for dip, refraction and semi-diameter.

Example.—Find the time interval between visible and theoretical sunrise on the longest day in Lat. 45° N., eye 20 feet.

Lat. 45° N., Decl. 23° 27′ N. gives Amp. E. 34·3° N. = Az. N. 55·7° E.

Dip	—	4·4′	Obs. alt.	0°	00′
Ref.	—	33·0	Corr.	—	53·4
S. diam.	—	16·0	True alt.	— 0	53·4 (*RX* in fig.)
				90	00
Total corr.	—	53·4	Zen. dist.	90	53·4 (*ZX* in fig.)

Refer to the figure in previous section.

$$\text{hav } ZPX = \frac{\text{hav } ZX - \text{hav } (L - D)}{\cos L \cos D}$$

ZX	90°	53·4′	nat hav	·50778
L−*D*	21	33·0	,,	·03495
			,,	·47283
			hav	9·67469
Lat.	45	00 N.	sec	0·15051
Decl.	23	27 N.	sec	0·03744
∠*ZPX*	7h	49m	hav	9·86264
∠*ZPY*	7	43 (from Table)		
Interval		06		

Thus the Sun rises 6 minutes before, and sets 6 minutes after, the times of theoretical rising and setting.

The same result is got by using the formula, $dh = dz$ cosec az. sec. lat.

$$dh^{m} = \frac{53{\cdot}4'}{15} \text{ cosec } 55{\cdot}7° \text{ sec. } 45°$$

RX	53·4′	log	1·72754
Az.	55·7°	cosec	0·08297
Lat.	45·0°	sec	0·15051
			1·96102
	15	log	1·17609
Interval	6·1 min.	log	0·78493

Example.—Find the time taken at sunrise between contact of U.L. and L.L. with the sea horizon in Lat. 60° on March 21st.

$$dh = dz \text{ cosec az. sec lat}$$
$$\text{,,} = \frac{32'}{15} \text{ cosec } 90° \text{ sec } 60°$$
$$\text{,,} = \frac{32}{15} \times 1 \times 2$$
$$\text{,,} = \frac{64}{15} = 4{\cdot}26 \text{ minutes}$$

NOTE.—The average diameter of the Sun is about 32′. The declination is 0° on March 21 and the Sun rises bearing due East or azimuth N. 90° E., cosec 90° = 1, sec. 60° = 2.

A question, of the following type, associated with the rising and setting of the Sun, is sometimes given in examination papers.

In South latitude, S.M.T. of sunrise 6h 56m bearing by compass S. 78·5° E., S.M.T. of sunset 16h 34m., bearing by compass S.48·5 W., variation 10° E. Find the deviation of the compass, the Equation of Time, the declination of the Sun and the latitude of the observer.

1. The error of the compass is half the difference of the compass bearings at rising and setting.

Error in this case = 30°/2 = 15° E., named East because it has to be applied to the right of S. 78·5° E. to get the mean compass bearing.

Compass bearing	S. 78·5° E.
Error	15·0 E.
True bearing	S. 63·5 E.

Dev. = Error 15° E — Var. 10° E. = 5° E.

2. The equation of time is half the difference between the hour angles of the mean Sun at rising and setting.

H.A.M.S. rising	05h	04m
,, setting	04	34
Difference		30

Eq. of time is 15m 00s to be subtracted from apparent time.

Eq. of time is — from apparent time when it has to be subtracted from the H.A.M.S. at rising to get the mean of the hour angles.

L.M.T. sunset	16h	34m	00s
Eq. of Time +		15	00
L.A.T.	16	49	00

3. We now have azimuth 63·5° and hour angle 4h 49m 00s at rising or setting, and with these values in the quadrantal triangle *PZX* we have, by Napier's Rules—

Sin. lat. = cot H.A. tan az. and cos dec = cosec H.A. sin az. from which

Lat. = 39° 56½′ N. Decl. = 20° 00′ S.

Exercise.—In N. Latitude the Sun rose at 4h 37·6m S.M.T. bearing by compass N. 60° E., and set at 18h 51·6m S.M.T. bearing N. 80° W. by compass. If the variation is 20° W., find the deviation of the compass, the equation of time, the declination of the Sun and the latitude of the observer.

Answer. Dev. 30° E., Eq. time 15·4m—from App. time. Decl. 11° 5′ N., Lat. 56° 47′ N.

(VII.) Time of Moonrise and Moonset.

The remarks regarding the rising and setting of the Sun do not apply equally to the Moon owing to the larger parllax of the latter body. The effect of dip and refraction is to accelerate the time of visible sunrise or moonrise, whilst parallax retards the appearance of the bodies which in the case of the Moon averages about 57′ as against 1·5′ for the sun.

The effect of refraction minus parallax on the Sun is $+33'-1{\cdot}5'=+31{\cdot}5'$; so that the Sun's centre is a full diameter above the visible horizon when his centre is on the rational horizon. With the Moon, however, the combined effect is Refr. +33′ Parlx. $-57'=-24'$, so that the Moon's centre is about 24′ below the visible horizon at the time of theoretical moonrise, her upper limb would then be almost appearing to an observer whose eye is 40 or 50 feet above sea level.

Calculate the time of moonrise on January 4, in Lat. 40° N., Long. 45° W.

Mer. pass.	–	4d	23h	16m	diff. 57
Corr. for 3h Long.	+			7	
L.M.T. mer. pass		4	23	23	
Long. W.	–		03	00	
G.M.T. mer. pass.		5	02	23	
Approx. H.A.	–		7	07	
Approx. G.M.T. of moonrise	–	4	19	16	

Enter *Nautical Tables* (Times of Rising and Setting) with Lat. 40° N., Decl. 19° N. (approx.) and get H. ang. 7h 07m.

Decl. 19° 27′ N. (correct)

Again enter *Nautical Tables* with Lat. 40° N., and Decl. 19° 27′ N., and get

Hour angle	–	07h	09m
Diff. 57m × 7·1h ÷ 24h = correction	+		17
Intervals between moonrise and mer. pass.	–	07	26
G.M.T. of mer. pass. as above	–	26	23
G.M.T. of moonrise	–	18	57

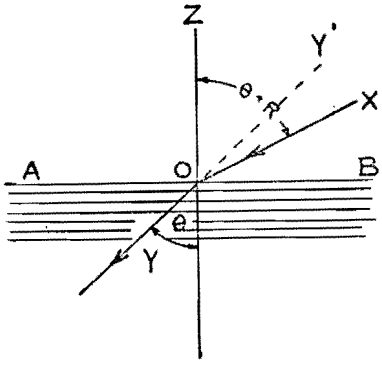
The first part of the work is the same as the moon's meridian passage. The first entry in Nautical Tables to get the hour angle of moonrise is an approximation because the declination at the time of transit is used. The second entry with the declination at moonrise is more correct. The acceleration of the solar interval due to the moon's proper motion is evident. The same operation is performed to get the time of moonset by adding the hour angle to the time of transit.

The above information can be obtained from the moonrise column in the daily pages of the *Nautical Almanac* and the Lat. and Long. correction tables for sunrise, moonrise, etc., as follows:—

Jan. 4—Lat. 40° N., L.M.T. of moonrise at Gr.		15h	50m
Correction for Long. (Diff. 1h 02m)	+		7
L.M.T. moonrise at ship	–	15	57
Long. in time	+	3	00
G.M.T. moonrise at ship	–	18	57

(VIII) THEORY OF REFRACTION.

Refraction depends upon two theorems in optics. (I) The angles of refraction and incidence are in the same plane, which plane passes through the normal to the refracting surfaces. (II.) The sine of the angle of incidence has to the sine of the angle of refraction a constant ratio for the same medium.



In figure: AB represents a surface separating two media of different density, OZ being the normal to that surface, XO a ray of light refracted in the direction of OY on entering the denser medium.

If R = mean refraction in seconds

θ = angle of refraction

then $(\theta + R) = \angle ZOX$ the angle of incidence; it is also the true zenith distance of the body X, and $\angle ZOY$, or θ, is its apparent zenith distance.

If μ be the relative index of refraction which is a constant ratio, then by theorem II.

$\mu \sin \theta = \sin (\theta + R)$

$= \sin \theta \cos R + \cos \theta \sin R$, but R is small so that $\cos R = 1$, and $\sin R$ may be written $R'' \sin 1''$ . . . . . by (43)

$\therefore \mu \sin \theta = \sin \theta + \cos \theta\, R'' \sin 1''$, or $R'' \cos \theta \sin 1'' = \mu \sin \theta - \sin \theta$

$= \sin \theta (\mu - 1)$

$$R'' = \frac{\sin \theta (\mu - 1)}{\cos \theta \sin 1''} = \tan \theta \frac{(\mu - 1)}{\sin 1''}$$

but $\dfrac{\mu - 1''}{\sin 1''}$ is a constant and for atmospheric refraction it is 57·538".

$\therefore$ Refraction in seconds = tan zen. dist. × 57·538"

Example.—Required the refraction for apparent altitude 37° 30'.

R'' = 57·538 cot alt = 57·538 cot 37° 30'

log 1·759954

cot 0·115020

R'' = log 1·874974 = 74·985"

Refraction = 1' 14·98" for alt 37° 30'. *Norie's Table* gives 1' 14"

Nicholls's Concise Guide Volume 2.

ERRATA

PAGE 309 5th line *should read*

X a body in the sensible horizon CX

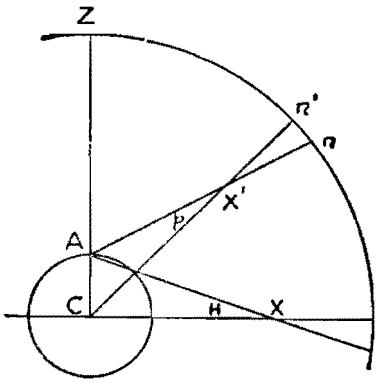
17th line *should read*

In triangle ACX $\dfrac{AC}{CX} = \sin H$

18th line *should read*

But $CX' = CX$ so that $\dfrac{AC}{CX'} = \dfrac{AC}{CX} = \dfrac{\sin p}{\cos \text{app alt}} = \sin H$

(IX.) DIURNAL PARALLAX OF THE MOON.



In figure:

C the centre of the Earth
A the observer, Z his zenith
X a body in the rational horizon CX
X' the body in altitude

From the observer at A the body X' would be projected on the celestial sphere at n, and from the centre of the Earth it would be projected at n'. The arc nn' is the parallax in altitude $= \angle nX'n' = \angle AX'C$ or simply p, which we want to find.

Let $\angle AXC = H$, the horizontal parallax as given in the *Nautical Almanac*.

In triangle ACX'

by (1) $$\frac{AC}{CX'} = \frac{\sin p}{\sin CAX'} = \frac{\sin p}{\sin ZAX'} = \frac{\sin p}{\cos \text{alt}}$$

In triangle ACX $$\frac{AC}{AX} = \sin H$$

But $CX' = AX$ nearly, so that $\frac{AC}{CX'} = \frac{AC}{AX} = \frac{\sin p}{\cos \text{alt}} = \sin H$

$$\therefore \sin p = \sin H \cos \text{alt}$$

The angles p and H being small we may write

by $$\sin p' = p' \sin 1' \text{ and } \sin h' = H' \sin 1'$$
$$\therefore p' \sin 1' = H' \sin 1' \cos \text{alt}$$
$$\text{or } p = H \cos \text{alt}$$

i.e., parallax in alt = hor parallax cos alt as in the case of correcting altitudes of the Moon.

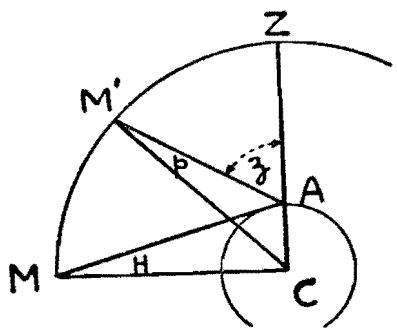
Example.—Calculate the parallax in altitude having given Earth's radius 3960 miles, Moon's distance 238,840 miles, Moon's altitude 34° 48′.

From figure: $\frac{\sin p}{AC} = \frac{\sin CAX'}{CX'}$

$$\therefore \sin p = \frac{AC \cos \text{alt}}{CX'}$$

AC	3960	log	3·59770
alt	34° 48′	cos	9·91442
			3·51212
CX'	238840	log	5·37810 —
p =	46′ 48″	sin	8·13402

(X.) AUGMENTATION OF THE MOON'S SEMI-DIAMETER.



In figure:

A the observer, Z the zenith

M the Moon in horizon for which the semi-diameter is tabulated in the *Nautical Almanac*.

M' the Moon in altitude

If S represents the semi-diameter for M, then $(S + a)$, will represent the augmented semi-diameter for M'

The semi-diameters are inversely proportional to the distances CM and AM'. and as AM' is always less than CM when the Moon is above the horizon the semi-diameter for M' is greater than for M.

p = parallax in alt. = $H \sin z$, as proved in (IX.).

$$\frac{S+a}{S} = \frac{M'C}{M'A} = \frac{\sin M'AC}{\sin M'CA} = \frac{\sin ZAM'}{\sin (ZAM' - p)} = \frac{\sin z}{\sin (z - p)}$$

$$\frac{S+a}{S} = 1 + \frac{a}{S} \quad \therefore \quad \frac{a}{S} = \frac{\sin z}{\sin (z-p)} - 1$$

$$,, = \frac{\sin z - \sin (z-p)}{\sin (z-p)}$$

$$,, = \frac{2 \cos \tfrac{1}{2}(z + z - p) \sin \tfrac{1}{2}(z - z + p)}{\sin (z-p)}$$

$$a = 2S \cos (z - \tfrac{1}{2}p) \sin \tfrac{1}{2}p \operatorname{cosec} (z - p).$$

Example.—Given Moon's Hor. Par. 58′ 57″ (H), App. Z. Dist. 48° (z), Semi-diam. 16′ 4″ (S), to find the augmentation.

by (IX.) $p = H \sin z$

$,, = 3537'' \times$ Nat. sin 48°

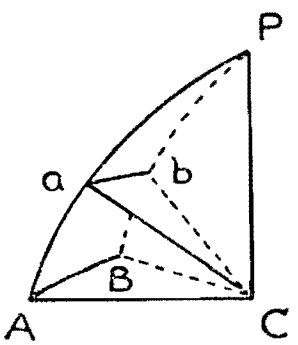
$,, = 3537 \times \cdot 7431 = 2629'' = 43'\ 49''$

$\therefore \quad \tfrac{1}{2}p = 21'\ 54'', (z - \tfrac{1}{2}p) = 47°\ 38'\ 06'', 2S = 1928''$

$2S$			$1928''$	log	3·285107
$(z - \frac{1}{2}p)$	47°	38′	06″	cos	9·828564
$\frac{1}{2}p$	0	21	54	sin	7·804173
$(z - p)$	47	16	11	cosec	0·133975
Augmentation, a =			11·27″	log	1·051819

(XI.) SEXTANT.

An error of collimation is caused when the axis of the telescope is not parallel to the plane of the sextant.



In figure, let C be the centre of a sphere, Aa the inclination of the telescope, greatly exaggerated to show up the figure, the inclination is always small.

$\angle aCb$ the true angular distance between two objects and $\angle ACB$ the measured distance between them.

$$\cos Aa = \frac{\text{arc } ab}{\text{arc } AB} = \frac{\text{chord } ab}{\text{chord } AB}$$

$$\cos Aa = \frac{2 \sin \frac{1}{2} aCb}{2 \sin \frac{1}{2} ACB}$$

$$\cos Aa = \frac{\sin \frac{1}{2} \text{ true dist.}}{\sin \frac{1}{2} \text{ measured dist.}}$$

The student may notice that $\cos Aa = \frac{ab}{AB}$ is equivalent to the parallel sailing formula $\cos \text{lat} = \frac{\text{dep.}}{\text{D. Long.}}$

Example.—If the line of collimation be inclined 42′ to the plane of the sextant, what is the error in an observed angle of 117° 22′ 50″?

$\sin \frac{1}{2}$ true dist. = $\cos Aa \sin \frac{1}{2}$ measured dist.

„ = $\cos 42' \sin 58° 41' 25''$

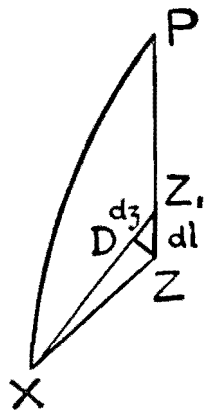
„ = $9{\cdot}999968 + 9{\cdot}931646 = 9{\cdot}931614$

$\frac{1}{2}$ true dist. = 58° 41′ 00″

True dist.	117	22	00
Obs. dist.	117	22	50
Error in sextant angle			50″

Example.—Calculate the error in an observed sextant angle of 90° if the line of collimation be inclined 1°. *Answer.* 1′ 4″.

(XII.) TO FIND THE ERROR OF LATITUDE DUE TO A SMALL ERROR IN ALTITUDE.



In figure, let Z be the correct zenith, Z_1 the faulty one, then ZZ_1 will be the error in latitude *dl*.

Make ZD perpendicular to Z_1X, then $DZ_1 = dz$ the error in zenith distance arising from *dl*.

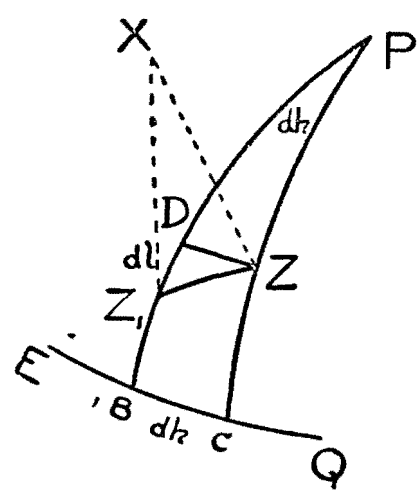
Triangle DZZ_1 being very small, is practically a right angled plane triangle.

$$\therefore \quad Z_1Z = DZ_1 \sec ZZ'D$$
$$dl = dz \sec \text{Az}$$

or, error in lat. = error in alt. × sec Az.

This indicates that observations for latitude should be taken near the meridian because the value of the secant increases with the azimuth from sec 0° = 1 to infinity.

(XIII.) TO FIND THE ERROR IN HOUR ANGLE DUE TO A SMALL ERROR IN LATITUDE.



In figure, let Z be the correct zenith, Z_1 the erroneous zenith. With centre P and radius PZ describe an arc ZD, then Z_1D = error in latitude (*dl*) and ZPZ_1 = error in hour angle (*dh*), DZ being an arc of a parallel, and BC the corresponding arc of equator, $BC = \angle ZPZ_1$ (*dh*), and $DZ = BC \cos CZ = dh \cos$ lat, by (I.)

$\angle PZD = 90°$ $\therefore$ $\angle PZX$ is the complement of $\angle DZX$

$\angle XZZ_1 = 90°$ $\therefore$ DZZ_1 is the complement of DZX

$\therefore$ $DZZ_1 = PZX$ the azimuth of X.

In $\triangle DZZ_1$ $DZ = DZ_1 \cot DZZ_1$

$dh \cos \text{lat.} = dl \cot Az$

$\therefore$ $dh = dl \sec \text{lat.} \cot Az$ (in arc).

Error in H. Ang. = $\frac{1}{15}$ Error in lat. sec lat. cot Az (in time).

Example.—Sights for hour angle were worked with Lat. 40° instead of 40° 10′, the azimuth of the body being 160°. Required the resulting error in the calculated hour angle.

dl	10′	log	1·000000
Lat.	40°	sec	0·115746
Az	20°	cot	0·438934
15	) 35·8′	log	1·554680
Error in H. Ang.	2m22·8s		

(XIV.) TO FIND THE ERROR IN HOUR ANGLE DUE TO A SMALL ERROR IN ALTITUDE.

The figure is drawn on the plane of the meridian, Z is the zenith, NWS the horizon, ZC and ZD are two vertical circles so that $\angle CZD = \text{arc } CD = dA$, the change of azimuth between X and Y.

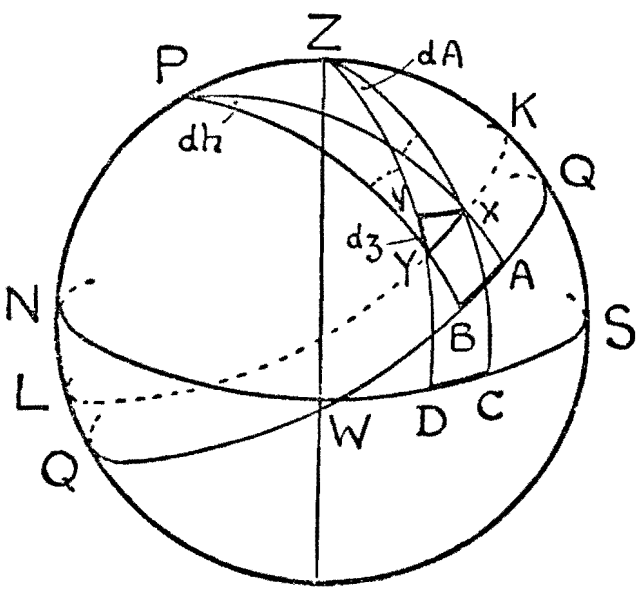
XV is the arc of a small circle of equal altitude

by (I.) $\therefore\ VX = DC \cos CX = dA \sin ZX$ . . . . . (a)

P is the pole, QWQ the equinoctial, X and Y are two successive positions of a body travelling along its diurnal arc KL. The secondaries PA and PB are meridians through X and Y, so that

arc $AB = \angle APB = dh$ the change of hour angle between X and Y.

by (I.) $\therefore\ XY = AB \cos AX = dh \sin PX$ . . . . . (b)



VY is the change of zenith distance, or of altitude, written dz, corresponding to the interval dh while the body moved from X to Y.

Triangle XVY being small may be considered to be plane, right angled at V, and X is very close to Y so that $\angle PXZ = \angle PYZ =$ complement of $\angle VYX$ as $\angle PYX = 90°$.

In $\triangle XVY$ $\quad VY = XY \cos VYX$

substitute (b) for XY, $\quad dz = dh \sin PX \sin PXZ.$

In $\triangle PZX$ $\quad \dfrac{\sin PXZ}{\sin PZ} = \dfrac{\sin PZX}{\sin PX}$

by (37)

$$\sin PX \sin PXZ = \sin PZ \sin PZX.$$

Substituting this in the above we get

$$dz = dh \sin PZ \sin PZX$$

expressed in arc $\quad dz' = dh' \cos \text{lat.} \sin \text{azimuth}$

or $\quad dh' = dz' \sec \text{lat.} \operatorname{cosec} \text{azimuth.}$

Divide the result by 15 to convert minutes of arc into minutes of time.

(XV.) MAXIMUM RATE OF CHANGE OF AZIMUTH.

Equation (*a*) and (*b*) in (XIV.) when combined give the maximum rate of change of azimuth of a body. This occurs when it is crossing the meridian, the zenith distance of the body being then its meridian zenith distance, that is (lat. ± decl.) by (*a*) and (*b*) where dA and dh vary together

$$dA \sin ZX = dh \sin PX$$

$$dA = \frac{dh^{m} \sin PX}{\sin ZX} = \frac{15' \cos \text{decl.}}{\sin (\text{Lat.} \pm \text{decl.})} \text{ per minute.}$$

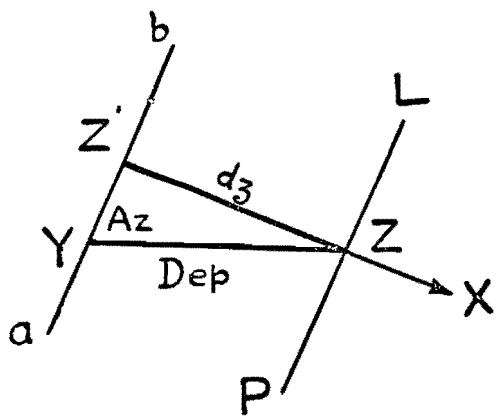
Example.—Calculate the maximum rate of change in azimuth of Vega in Lat. 50° N.

	15′	log	1·176091
decl.	38° 43′ N.	cos	9·892233
(L. — D.)	11 17	cosec	0·708496
dA	59·8′	log	1·776820

Rate of change 59·8′ per minute.

(XVI.) DISPLACEMENT IN LONGITUDE OF A POSITION LINE DUE TO AN ERROR IN HOUR ANGLE.

The equation $dz = dh$ cos lat. sin Az. enables us to show that an error in the G.M.T. used in computing the hour angle of a body when calculating the intercept produces an equal error in longitude when expressed in minutes of arc. In the figure (XIV.) ZX is the shorter zenith distance and ZY the longer one, VY being the dz,or intercept. If we were to project the information of the figure on to a chart the projection would appear as follows, the bearing of the body X being south-eastward,



Z the correct spot through which to draw the position line PL corresponding to the shorter zenith distance ZX, and Z' will be the wrong spot corresponding to the longer zenith distance, then the intercept ZZ' or VY in figure under (XIV.) = dz. In the projection it is the zenith we move towards or away from the body whereas, in the figure, it is the body that has moved away from the zenith, the difference, however, is merely a relative one.

ZY is the east-west displacement of the position line = departure.

$ZY = dz$ cosec $Y = dz$ cosec Az, because $Z'ZY$ is the complement of $\angle Y$ and also of the bearing of the body X. $\therefore$ $\angle Y$ = azimuth. But between Z and Y the

D. Long. = Dep. sec lat.
= ZY sec lat.
= dz cosec Az. sec lat.
= dh cos lat. sin Az. cosec Az. sec lat. = $dh \dfrac{\cos \text{lat.} \sin \text{Az.}}{\cos \text{lat.} \sin \text{Az.}}$

$\therefore$ D. Long.′ = dh'.

The reciprocals of the latitude and azimuth cancel out.

The displacement of the position line in longitude is, therefore, equal to the errors in hour angle in minutes of arc.

It is usually easier to rework, or replot, position lines, which have been laid off wrongly owing to an error in the course steered or in the distance run between sights, than to investigate a formula which will yield the resulting error. The student should refer to the *Admiralty Manuals of Navigation* for information regarding errors in position lines and fixes.

(XVII.) ERROR IN AZIMUTH OR HOUR ANGLE.

We may deduce from the figure in (XIV.) the error in azimuth resulting from a small error in hour angle.

Since $\angle PXY$ and $\angle ZXV$ are right angles and $\angle PXV$ is common to both, the angle $VXY = \angle PXZ$, which is known as the angle of position.

In $\triangle XVY$ $\quad VX = \cos VXY$

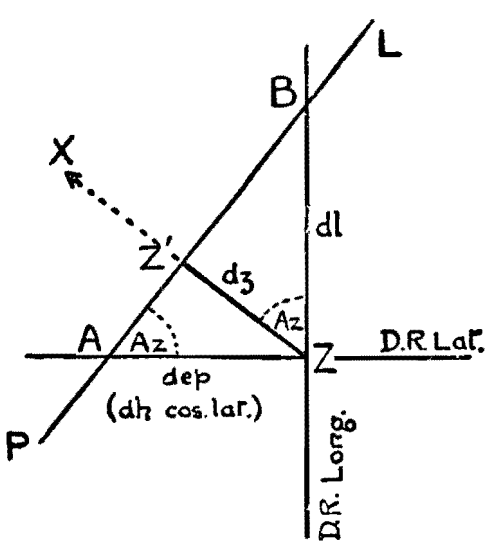
by (*a*) and (*b*) $\quad dA \sin ZX = dh \sin PX \cos PXZ$

$$dA = dh \sin PX \operatorname{cosec} ZX \cos PXZ$$

$$dA = dh \cos \text{decl.} \sec \text{alt.} \cos PXZ$$

(XVIII.) SMALL ERRORS IN LATITUDE, HOUR ANGLE AND ALTITUDE COMBINED.

Admiral Sir H. E. Purey-Cust, formerly Hydrographer to the Admiralty, has mentioned in the *Nautical Magazine* of August, 1933, that the reactions on each other of small errors of observation in altitude, hour angle and latitude can be very simply and clearly demonstrated by reference to the position line, as follows :—



In figure:

If Z be the D.R. position,

ZZ^1 an intercept or small error in altitude (dz),

PL a position line cutting the D.R. parallel of latitude at A, and the D.R. meridian of longitude at B, then

ZB is the error in latitude (dl) due to dz,

and ZA is the error of departure due to dz;

but dep. = D. long. cos lat.

or ZA = error in H. ang. cos lat.

but by (XVI.) D. Long. = dh

$ZA = dh$ cos lat.

$\angle BZZ'$ is the azimuth of body X, and $\angle BZZ' = \angle BAZ$, both being complements of $\angle B$.

In △AZZ'.

$$ZZ' = ZA \sin A$$
$$\text{or } dz = dh \cos \text{lat} \sin Az \quad \ldots\ldots\ldots (1)$$
$$\therefore \text{ error in alt.} = \text{error in H.A. cos lat sin Az.}$$

By transposing we have

$$\text{error in H.A.} = \text{error in alt. sec lat. cosec Az}$$
$$\text{or } dh = dz \text{ sec lat cosec Az} \quad \ldots\ldots\ldots (2)$$

In △ BZZ'.

$$ZZ' = ZB \cos BZZ'$$
$$\text{or } dz = dl \cos Az \quad \ldots\ldots\ldots (3)$$
$$\therefore \text{ error in alt.} = \text{error in lat. cos Az}$$

by transposing we have

$$\text{error in lat.} = \text{error in alt sec Az}$$
$$\text{or } dl = dz \text{ sec Az} \quad \ldots\ldots\ldots (4)$$

In △BZA.

$$ZB = ZA \tan A$$
$$\text{or } dl = dh \cos \text{lat tan Az} \quad \ldots\ldots\ldots (5)$$
$$\therefore \text{ error in lat.} = \text{error in H.A. cos lat. tan Az.}$$

By transposing we have

$$\text{error in H.A.} = \text{error in lat. sec lat. cot Az}$$
$$\text{or } dh = dl \text{ sec lat. cot. Az} \quad \ldots\ldots\ldots (6)$$

The Admiral points out that everything depends mainly on the size of the azimuth and has little to do with the size of the hour angle.

When calculating latitude from altitude (4), or from hour angle (5), the smaller the azimuth the better as in case (4), sec Az will be unity, and in case (5), tan Az will be zero when the body is on the meridan, that is azimuth 0° or 180°.

When calculating hour angle from altitude (2), and from latitude (6), the larger the azimuth the better, as, in case (2) cosec Az will be unity, and in case (6) cot Az will be zero when the body is on the prime vertical, that is azimuth 90° or 270°.

When calculating altitude from hour angle (1), and from latitude (3), it does not matter much whether the azimuth is large or small as in both cases (1) and (3) the sine and cosine of the azimuth are involved and the value of those functions is always less than unity.

While not laying down any strict rule as to what are small and what are large azimuths, it is convenient to consider azimuths under 45° as small and calculate latitude; azimuths over 45° as large and calculate hour angle.

(XIX.) TRIGONOMETRICAL DIFFERENTIAL COEFFICIENTS.

These coefficients are very convenient in determining the mathematical error in a quantity arising from a small error of observation in one of the factors used in a computation; thus, for example, an error in the altitude when working up longitude sights will produce a corresponding error in the resulting hour angle and it may save a long recalculation if we could determine readily the amount of this error.

We give here the standard forms of the six trigonometrical differential coefficients although those of the sine and cosine are the most commonly used in navigational problems.

Trigonometrical function.	Differential coefficient.	Differential
1. sin x	cos x	cos $x \,.\, dx$
2. cos x	$-$ sin x	$-$ sin $x \,.\, dx$
3. tan x	$\sec^2 x$	$\sec^2 x \,.\, dx$
4. cot x	$-$ $\operatorname{cosec}^2 x$	$-$ $\operatorname{cosec}^2 x \,.\, dx$
5. sec x	sec x tan x	(sec x tan x) dx
6. cosec x	$-$ cosec x cot x	$-$ (cosec x cot x) dx

It will be noted that the differentials of cos x, cot x, cosec x are negative because these functions decrease as x increases.

The symbol d does not represent a quantity but simply indicates that dx is a small "increment" or "increase" in the value of x. Note that the rate of change of sin x with x is cos x, etc.

When quantities attain maximum or minimum values their differential coefficient is zero, the values of x, etc., which give these maximum and minimum values are therefore obtained by equating the differential coefficient to zero.

We are really concerned only with the application of the differentials to navigation, but perhaps, we should give here the proofs of these rules for the benefit of those who may wish to know their origin.

(1) sin x.

If $y = \sin x$ then $y + \delta y = \sin (x + \delta x)$ and by subtraction

$$\delta y = \sin (x + \delta x) - \sin x$$

by (12) page 233

$$\delta y = 2 \cos \left(\frac{x + \delta x + x}{2}\right) \sin \left(\frac{x + \delta x - x}{2}\right)$$

$$\delta y = 2 \cos \left(x + \frac{\delta x}{2}\right) \sin \frac{\delta x}{2}$$

divide by δx so that

$$\frac{\delta y}{\delta x} = \frac{2 \cos \left(x + \frac{\delta x}{2}\right) \sin \frac{\delta x}{2}}{\delta x}$$

$$\frac{\delta y}{\delta x} = \cos \left(x + \frac{\delta x}{2}\right) \left(\sin \frac{\delta x}{2} \Big/ \frac{\delta x}{2}\right)$$

now let δx tend to zero, then $\frac{\delta y}{\delta x}$ tends to $\frac{dy}{dx}$, and $\sin \frac{\delta x}{2} \Big/ \frac{\delta x}{2}$ tends to **1**

and we have $\frac{dy}{dx} = \cos x$ but $y = \sin x$

$\therefore d \sin x = \cos x \,.\, d x$

(2) cos x.

If $y = \cos x$ then $y + \delta y = \cos (x + \delta x)$ and by subtraction

$$\delta y = \cos (x + \delta x) - \cos x$$

by (14) page 233

$$\delta y = 2 \sin \left(\frac{x + \delta x + x}{2}\right) \sin \left(\frac{x - \delta x - x}{2}\right)$$

$$\delta y = 2 \sin \left(x + \frac{\delta x}{2}\right) \sin \left(-\frac{\delta x}{2}\right)$$

then $$\frac{\delta y}{\delta x} = -\frac{2\sin\left(x+\frac{\delta x}{2}\right)\sin\frac{\delta x}{2}}{\delta x}$$ since $\text{Sin}(-A) = -\sin A$

$$\frac{\delta y}{\delta x} = -\sin\left(x+\frac{\delta x}{2}\right)\left(\sin\frac{\delta x}{2}\Big/\frac{\delta x}{2}\right)$$

now let δx tend to zero, etc., as in (1) and we have

$$\frac{dy}{dx} = -\sin x \qquad \text{but } y = \cos x$$

$$\therefore d\cos x = -\sin x \,.\, dx$$

(3) tan x.

If $y = \tan x$ then $y + \delta y = \tan(x+\delta x)$ and by subtraction

$$\delta y = \tan(x+\delta x) - \tan x$$

$$\delta y = \frac{\sin(x+\delta x)}{\cos(x+\delta x)} - \frac{\sin x}{\cos x}$$

$$\delta y = \frac{\sin(x+\delta x)\cos x - \cos(x+\delta x)\sin x}{\cos(x+\delta x)\cos x}$$

by (8) where $x+\delta x = A$, $x = B$

$$\delta y = \frac{\sin(x+\delta x - x)}{\cos(x+\delta x)\cos x}$$

$$\delta y = \frac{\sin\delta x}{\cos(x+\delta x)\cos x}$$

then $$\frac{\delta y}{\delta x} = \frac{\sin\delta x}{\delta x}\times\frac{1}{\cos(x+\delta x)}\times\frac{1}{\cos x}$$

now let δx tend to zero, etc., as in (1) then we have

$$\frac{dy}{dx} = 1\,.\,\frac{1}{\cos x}\,.\,\frac{1}{\cos x} = \frac{1}{\cos^2 x} = \sec^2 x, \text{ but } y = \tan x$$

$$\therefore d\tan x = \sec^2 x \,.\, dx$$

(6) cosec x.

If $y = \text{cosec } x$ then, $y + \delta y = \text{cosec}(x+\delta x)$ and by subtraction

$$\delta y = \text{cosec}(x+\delta x) - \text{cosec } x$$

$$\delta y = \frac{1}{\sin(x+\delta x)} - \frac{1}{\sin x}$$

$$\delta y = \frac{\sin x - \sin(x+\delta x)}{\sin(x+\delta x)\sin x}$$

by (12) where $x = A$, $(x+\delta x) = B$

$$\delta y = \frac{2\cos\left(\frac{x+x+\delta x}{2}\right)\sin\left(\frac{x-x-\delta x}{2}\right)}{\sin(x+\delta x)\sin x}$$

$$\delta y = \frac{2\cos\left(x+\frac{\delta x}{2}\right)\sin\left(-\frac{\delta x}{2}\right)}{\sin(x+\delta x)\sin x}$$

then $$\frac{\delta y}{\delta x} = -\frac{2\cos\left(x+\frac{\delta x}{2}\right)}{\sin(x+\delta x)\sin x}\,.\,\frac{\sin\frac{\delta x}{2}}{\delta x}$$

$$\frac{\delta y}{\delta x} = -\frac{\cos\left(x+\frac{\delta x}{2}\right)}{\sin(x+\delta x)} \times \frac{1}{\sin x} \times \left(\sin \frac{\delta x}{2} \Big/ \frac{\delta x}{2}\right)$$

Again let δx tend to zero, etc., as in (1),

then $\frac{dy}{dx} = -\frac{\cos x}{\sin x} \cdot \frac{1}{\sin x} \cdot 1 = -\cot x \operatorname{cosec} x$ but $y = \operatorname{cosec} x$

$\therefore d \operatorname{cosec} x = -\cot x \operatorname{cosec} x \, . \, dx$

The differential coefficients for cot x and sec x are obtained in the same way as those for tan x and cosec x respectively.

(XX.) RATE OF CHANGE OF ALTITUDE.

It is required to find the error in hour angle arising from a small error in altitude. The hour angle and zenith distance, that is h and z, are the two variable quantities, so we write down the fundamental formula and then re-write it, introducing the appropriate differential coefficient, remembering to write zero against any factor that does not contain a variable.

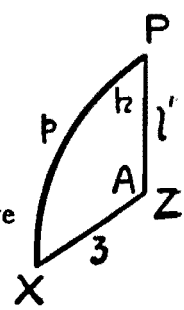
$$\cos z = \cos p \cos l' + \sin p \sin l' \cos h$$

differentials, $-\sin z \, . \, dz = o + \sin p \sin l' (-\sin h \, . \, dh)$

$$-\sin z \, . \, dz = -\sin p \sin l' \sin h \, . \, dh$$

$$dh = \frac{\sin z \, . \, dz}{\sin p \sin l' \sin h}$$

by (29) from figure, $\frac{\sin z}{\sin p} = \frac{\sin h}{\sin A}$ and by substitution in above we have



$$dh = \frac{\sin h \, . \, dz}{\sin A \sin l' \sin h}$$ but $\sin h$ cancels

$$\therefore \quad dh = \frac{dz}{\sin A \sin l'} = \frac{dz}{\sin \text{Az} \cos \text{lat.}}$$

Thus if $dz = 1'$ the resulting

$$dh = \frac{1'}{\sin \text{Az} \cos \text{lat.}} = \operatorname{cosec} \text{Az} \sec \text{lat.},$$

and if z be expressed in minutes of arc, h will also be in minutes of arc to be divided by 15′ to convert it into time, as otherwise proved in (XIV.).

Incidentally, the formula $dh = \frac{dz}{\cos \text{lat.} \sin \text{Az}}$ indicates that when the azimuth is greatest, that is $\sin 90° = 1$, its maximum value, the error in hour angle is least, so that sights for longitude should be taken when the body is near the prime vertical as a small error in altitude will then produce a comparatively small error in time.

By transposing the equation we get $dz = dh \sin \text{Az} \cos \text{lat.}$, and if $dh = 1^m = 15'$ we may write $dz = 15 \sin \text{Az} \cos \text{lat.}$, which expresses the rate of change of altitude of a body in 1 minute of time. Thus the rate of change of altitude depends on the azimuth for when the azimuth $= 0°$, $\sin 0° = 0$ and the rate of change of altitude disappears for the moment because the body is just crossing the meridian, but when the azimuth is 90°, $\sin 90° = 1$, its maximum value and so the equation tells us that a body changes in altitude most rapidly when on the prime vertical, whatever its declination may be.

(XXI.) MAXIMUM ALTITUDE.

The change of altitude of a star is due to the Earth's rotation on its axis. If the Earth did not rotate, and an observer remained in the same latitude, the fixed stars would retain their same altitudes but the Sun, Moon and planets would have a slow change of altitude depending on their rate of change of declination, an increasing altitude when they travel towards the observer and, obviously, a decreasing altitude when they move away from him.

Again, assuming the Earth and celestial bodies to be fixed in space but the observer moving along a meridian, then, as he travelled towards a body, his horizon would be falling from under it and its altitude would increase; and conversely, when travelling away from the body its altitude would decrease, or, one may think of it in terms of zenith distance, the geographical position of the body being fixed and the observer's zenith moving with him, either towards or away from the body.

When a body is moving rapidly in declination, as the Moon for instance, the maximum altitude may occur a little before or after the time the body is on the meridian, before when the body is moving away from the observer, that is polar distance increasing, and after its meridian passage when the polar distance is decreasing, that is when the body is travelling towards the observer.

This change in altitude continues until the rate of change of altitude due to the proper motion of the body is equal to the rate of change of altitude due to the Earth's rotation on her axis.

(XXII.) THE TIME INTERVAL IN MAXIMUM ALTITUDES.

$$\cos z = \cos p \cos l' + \sin p \sin l' \cos h$$

l' is the only constant, h is required and differentiating with respect to h we have

$$-\sin z \frac{dz}{dh} = -\sin p \frac{dp}{dh} \cos l' + \cos p \frac{dp}{dh} \sin l' \cos h - \sin p \sin l \sin h$$

but $dz/dh = 0$ since the zenith distance is to be a minimum, and $\cos h = \cos 0° = 1$; by substituting we get

$$0 = -\frac{dp}{dh} \sin p \cos l' + \frac{dp}{dh} \cos p \sin l' \times 1 - \sin p \sin l' \sin h$$

$$\sin p \sin l' \sin h = -(\sin p \cos l' - \cos p \sin l') \frac{dp}{dh}$$

$$\sin h = h'' \sin 1'' = -\frac{\sin (p - l')}{\sin p \sin l'} \frac{dp}{dh}$$

$$\therefore h \sec = -\frac{1}{15 \sin 1''} \times \frac{\sin (p - l')}{\sin p \sin l'} \times \frac{dp}{dh}$$

By substituting Lat. and Decl. we get

$$h = -\frac{1}{15 \sin 1''} \sin (L \pm D) \sec L \sec D \frac{dp}{dh}$$

$(L + D)$ when Lat and Decl. are of opposite names

$(L - D)$ when of same name.

$15 \sin 1'' = \log 5{\cdot}861666$, and $\frac{dp}{dh} = \frac{\text{change of decl. per hour}}{\text{rate of Earth's rotation per hour (15°)}}$

The maximum altitude may occur before, or after, the meridian passage of the body so that h seconds may have to be subtracted from, or added to, the time of meridian passage, but this can be decided algebraically by placing a plus, or minus, sign after dp/dh.

$\frac{dp}{dh}$ − when the body is approaching the observer

$\frac{dp}{dh}$ + when the body is receding from the observer

in other words, − when "closing" and + when "opening".

This sign when combined with the − sign which precedes the formula indicates whether h is to be added to, or subtracted from, the time of passage.

Example.—Dec. 22, Lat. 50° 22′ N., Long. 30° W. Required the interval before or after meridian passage when the moon will attain her maximum altitude.

Mer. Pass. Dec.		22d	21h	24m	Dec.	−	16° 05·2′ N.	diff. 5·1′ N. in 1h.
Corr. for Long. 30°		+		04	Cor.	−	2·4 N.	
L.M.T.	−	22	21	28	D.	−	16 07·6 N.	
Long. W.	−		2	00	L.	−	50 22 N.	
G.M.T.	−	22	23	28	(L.—D.)		34 14·4	

$$\frac{dp}{dh} = \frac{\text{change of decl. per hour}}{\text{minutes of arc per hour}} = \frac{5{\cdot}1}{900} = \frac{1}{176{\cdot}5}$$

and the foregoing formula may be written as

$$h \sec = \frac{-1}{15 \sin 1''} \sin (\text{L.}\sim\text{D.}) \sec \text{D.} \sec \text{L.} \frac{dp}{dh} -$$

where h=Hour angle, L. the Latitude, D. the Declination.

L.	50°	22′	N.	sec	0·19527
D.	16	07·6	N.	sec	0·01743
(L.∼D.)	34	14·4		sin	9·75025
					9·96295
$\frac{dp}{dh}$	1 / 176·5			log	2·24675
					7·71620
	15 sin 1″			log	5·86167
h	71·5s.			log	1·85453

The time interval is + 1m 11·1s.

The body is "closing", therefore $\frac{dp}{dh}$ is minus and this minus, combined with the minus sign which precedes the formula, makes the quantity plus to the time of meridian passage.

The maximum altitude occurs 1m 11·1s after the Moon's transit.

Example—Find the interval between the meridian passage and the maximum altitude of the Sun in Lat. 55° N. on March 23rd. Given Decl. 0° 56′ N., Sun going North at the rate of 1′ per hour; course 230°, speed 20 knots.

Answer: $\frac{dp}{dh} = \frac{13{\cdot}9}{873} = \frac{1}{62{\cdot}8} h = +3\text{m } 39\text{s}$

The time of maximum altitude, combined with equal altitudes of a body taken when the hour angles E and W are small (not more than about 40 minutes), provides a method of finding longitude.

Example.—Jan. 12, D.R. Lat. 10° 30′ N., Long. 32° 30′ E., the Sun had equal altitudes when the G.M. times by chronometer were 09h 27m 30s and 10h 26m 50s. The ship's course was 060°, and speed 15 knots during the interval between sights. Find the longitude.

1st G.M.T. – – –	09h	27m	30s
2nd „ – – –	10	26	50
Interval – – –	00	59	20
½ interval – – –	00	29	40
1st G.M.T. – – –	09	27	30
Middle G.M.T. of max. alt.	09	57	10

The quantity *dp* has to be adjusted for the course and speed of the ship, when the course is towards North or South the rate of change of altitude is due to the change in declination per hour plus or minus the ship's D. Lat. per hour.

Add them when ship and body are approaching each other, or "closing".
Subtract them when ship and body are receding from each other, or "opening".
In this example:—

Course 060°, 15 knots, D. Lat. 7·5′ N., Dep. 13·0 E., D. Long. 13·2′ E.
Decl. 21° 41·6′ S.—Sun going N. 0·4′ per hour
Ship going N. 7·5 „
Ship is leaving Sun at rate of 7·1 per hour = *dp*

To make sure whether the body and ship are opening or closing, it is desirable to make a rough sketch showing their relative positions.

In this case they are "opening", the ship is running away from the Sun, so that *dp*=(change of Decl.—D. Lat.) per hour.

The rate of change of altitude is also due to the Earth's rotation per hour (900′), plus or minus the ship's D. Long. per hour.

Add D. Long. when ship is making easting.
Subtract D. Long, when ship is making westing.

In this example the ship is making easting so that *dh*=(900′ +D. Long. 13·2′ E.) = 913·2′. These adjustments give $\frac{dp}{dh} = \frac{7{\cdot}1}{913{\cdot}2}$

$$h = -\frac{1}{15 \sin 1''} \sin (L+D) \sec L \sec D \frac{dp}{dh} +$$

A +sign should be placed after $\frac{dp}{dh}$ because the ship and body are "opening" out, or receding from each other.

L	10° 30′ N.	sec	10·00738	L.A.T. at noon	12h 00m 00
D	21 41·6 S.	sec	10·03191	*h*	— 1 02
L+*D*	32 11·6	sin	9·72655	L.A.T. at max. alt.	11 58 58
dp	7·1	log	0·85126	Eq. of time	+ 8 14
			0·61705	L.M.T. at max. alt.	12 07 12
dh	913·2	log	2·96057—	G.M.T. „	9 57 10
			7·65648	Longitude	2 10 02
15 sin	1″	log	5·86167—		32° 30·5′ E.
h=—	62·35s.	log	1·79481		

The *Admiralty Manual* formula for time of maximum altitude is

$$h \sec = 15{\cdot}28\ (\tan L \pm \tan D) \times \left(\frac{1 \pm 2X}{900}\right) Y$$

(tan $L \pm$ tan D) +for contrary names, —for like names

$\left(1 \pm \frac{2X}{900}\right)$, +for ship going West, —for ship going East

X=D. Long. of ship per hour.

$Y=dp$=decl. per hour combined with ship's D. Lat. per hour.

In the foregoing example, course 060°, speed 15 knots, D. Lat. 7·5′ N., Dep. 13·0 E., D. Long. 13·2′ E., change of Decl. 0·4′ per hour, Decl. 21° 41·6′ S., Lat. 10° 30′ N., X=13·2′ and Y=7·1′.

$$\left(1 - \frac{2X}{900}\right) Y = \left(\frac{900 - 26{\cdot}4}{900}\right) 6{\cdot}5 = \frac{874 \times 7{\cdot}1}{900} = 6{\cdot}8$$

15·28 tan L +15·28 tan D=8·911 as follows:—

Constant	15·28	log	1·18412		log	1·18412
L	10° 30′	tan	9·26797	D 21° 41·6′	tan	9·59968
	2·832	log	0·45209	6·079	log	0·78380
	6·079					
	8·911					

then h=8·91×6·9=61·5 sec.

The maximum altitude occurs 61·5s before the time of meridian passage because the ship and body are receding. The other formula gave 62·3 seconds.

Exercises

1. Sept. 20, D.R. Lat. 20° N., Long. 152° 30′ E. the Sun had equal altitudes when the G.M. times by chronometer were 01h 05m 02s and 02h 26m 00s, ship's course during the interval 190°, speed 20 knots, required the longitude.

Answer. $\frac{dp}{dh} = \frac{18{\cdot}8}{896{\cdot}3}$, $h = +98$s Long. 152° 27·5′ E.

2. Oct. 11, D.R. Lat. 2° 10′ N., Long. 66° 05′ E., Sun had equal altitudes when chronometer times were 06h 58m 53s and 07h 54m 57s, error on G.M.T. 5m 09s fast. Course during interval between sights, 325°, speed 18 knots, find the longitude.

Answer. $\frac{dp}{dh} = \frac{15{\cdot}6}{889{\cdot}7}$, $h = -3{\cdot}8$s, Long. 66° 08′ E.

3. Sept. 19, D.R. Lat. 30° 30′ N., Long. 31° 30′ W., G.M. times of Sun's equal altitudes, 13h 32m 30s and 14h 31m 50s, course during interval 200°, speed 20 knots, find the longitude.

Answer. $\frac{dp}{dh} = \frac{17{\cdot}8}{892}$, $h = +154$s, Long. 31° 25·5′ W.

4. A ship is steaming 180°, at 20 knots, in Lat. 50° N., Long. 0°. Find when the Sun will dip if the declination is 16° 4′ 30″ S. and travelling South at the rate of 45″ per hour.

Answer. 07m 15s past noon.

5. A ship steaming North at 16 knots in Lat. 37° N. If the Sun's declination is 4° 33·4′ N., and travelling North at the rate of 1′ per hour, at what time will the Sun dip?

Answer. 02m 34s before noon.

6. In Lat. 42° N., Decl. 10° 11′ N., the Sun to an observer on board a ship steaming on the meridian dipped 03m 21s before noon. Was the ship steaming North or South and what was her speed?

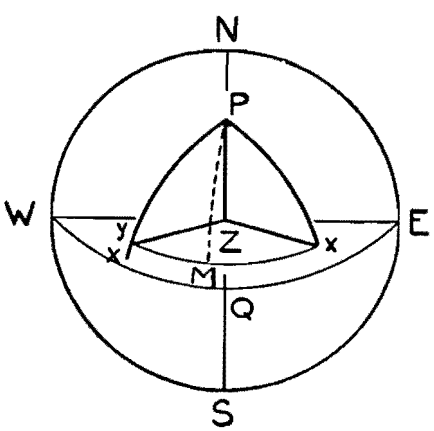
NOTE. $dp = \dfrac{dh\ 15 \sin 1'' \times h}{\sin (\text{L.} - \text{D.}) \sec \text{L} \sec \text{D}}$

Answer. Steaming North, 17·3 knots.

(XXIII.) EQUATION OF EQUAL ALTITUDES.

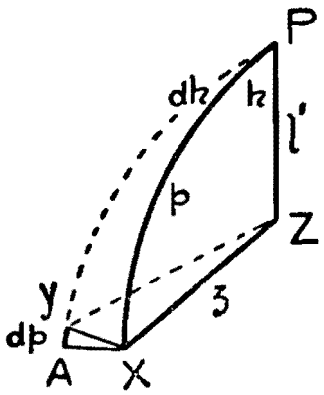
The frequent daily transmission by W.T. of G.M.T. ensures a greater degree of accuracy in determining the error of a ship's chronometer when at sea than was possible by means of time balls, or by delicate astronomical observations made either when in port or at sea, before the development of wireless telegraphy. The method of determining the error of chronometer by equal altitudes of the same body observed before and after it has crossed the meridian offers an example of the application of a fundamental principle in nautical astronomy and, as such, it may still be given as a test of theoretical knowledge.

If the Sun's declination did not alter, the mean of the chronometer times at which the Sun has the same altitude on opposite sides of the meridian would be the chronometer time of apparent noon. But the Sun's declination does alter, and, for the same altitude, the E.H.A. is not quite the same as the W.H.A., so a correction, called the "Equation of Equal Altitudes," must be applied to the mean of the chronometer times to get the correct middle time. The difference between the chronometer time of the apparent noon thus found, and the Greenwich time of apparent noon, is the error of chronometer on G.M.T.



In figure, X and Y are two positions of the Sun having equal altitudes east and west of the meridian so that $ZX = ZY$, but if the polar distance PY be shorter than PX, giving an hour angle west greater than the hour angle east for the same altitude due to the change of declination, then the middle meridian PM will be west of the observer's meridian, but if the polar distance were increasing PM would be to the eastward of the observer's meridian.

We can apply the differential calculus to determine an expression for the equation of equal altitudes.



In figure, let $ZX=ZY$

$AY=dp$ the change of declination during the time elapsed between observations.

$\angle XPA=dh$ the corresponding increment in hour angle.

Then in triangle PZX

$$\cos z=\cos p \cos l' +\sin p \sin l' \cos h$$

p and h are the variables.

$$0=-\sin p \,.\, dp \cos l' +\cos p \,.\, dp \sin l' \cos h +\sin p \sin l' (-\sin h \,.\, dh)$$

$$\sin p \sin l' \sin h \,.\, dh=dp (\cos p \sin l' \cos h-\sin p \cos l')$$

$$dh=\frac{dp (\cos p \sin l' \cos h - \sin p \cos l'}{\sin p \sin l' \sin h}$$

$$dh=-dp (\cot p \cot h \quad -\cot l' \operatorname{cosec} h)$$

$$dh=dp (\tan \text{lat.} \operatorname{cosec} h \quad -\tan \text{decl.} \cot h)$$

$$dh=dp (\quad A \quad - \quad B \quad)$$

The sign $-dp$ is introduced because the hour angle (h) and polar distance (p) vary inversely. Half the time elapsed between the observations gives h, and dp is the change of declination in the half elapsed time.

The parts A and B will be $-$ or $+$, depending on whether cot p is positive (less than 90°) or negative (greater than 90°). dh is the correction to apply to the mean chronometer time and is $+$ when polar distance is increasing and $-$ when it is decreasing.

Example.—September 22, Lat. 30° 30′ N., Long. 75° W., the sun had equal altitudes when the chronometer showed 12h 46m 57s and 20h 22m 45s, find the chronometer error on G.M.T.

		d	h	m	s
L.A.T.	–	22	12	00	00
Long.	–		5	00	00
G.A.T.	–	22	17	00	00

Eq. of time +7m 12s

Dec. 0° 19·6′ N. Hrly diff.=·9′

=54″

(change of decl. per hour × ½ interval)=dp=54″×3·8h=205″

	h	m	s
1st chron. time	12	46	57
2nd „ „ –	20	22	45
Interval – –	07	35	48
½ interval – –	03	47	54
1st chron. time	12	46	57
Mean chron. time	16	34	51

	h	m	s
L.A.T. (Noon) –	12	00	00
Eq. of time –	+	07	12
L.M.T. (Noon) –	12	07	12
Long. W. –	5	00	00
G.M.T. (Noon) –	17	07	12

$dh=dp$ tan lat. cosec $h-dp$ tan decl. cot h

dp	205″	log	2·31218		log	2·31218
Lat.	30° 30′	tan	9·77015	Dec. 0° 19·6′	tan	7·75488
h	3h 47m 54s	cosec	0·07653		cot	9·81293
A	144·2″	log	2·15886	0·8″	log	9·87991

B −0·8 ($-B$ because P. dist. is less than 90°)

15)143·4

dh 9·6s.

	h	m	s	
Mean chron. time – – –	16	34	51	
Eq. of eq. alts. – – –	+		10	(plus because P. dist. is increasing).
Chron. time (noon) – –	16	35	01	
G.M.T. (noon) – – –	17	7	12	
Chron. slow of G.M.T. – –		32	11	

Star.

Stars do not change their declination so that the mean of the chronometer times when they have equal altitudes E. and W. of the meridian will be the chronometer time of the star's meridian passage. The problem resolves itself into finding G.M.T. of the star's upper transit as in Chapter VI.

Example III, page 125, may be written as follows:—December 22, Lat. 43° 20′ S., Long. 175° 30′ E., Sirius had equal altitudes E. and W. of the meridian when the chronometer times were 10h 35m 12s and 15h 13m 20s, required the error of the chronometer.

The working up to G.M.T. of upper passage is exactly the same as in the worked examples, the additional work being:—

	h	m	s
1st chron. time –	10	35	12
2nd „ – –	15	13	20
Interval – –	4	38	08
½ elapsed time –	2	19	04
1st chron. time –	10	35	12
Middle chron. time of star's passage	12	54	16

	h	m	s
G.M.T. of star pass.	13	03	00
Chron. time of pass.	12	54	16
Chron. slow of G.M.T.		08	44

Given Lat. 27° 10′ N., Long. 56° 17′ E., chron. times when Sun had equal altitudes 04h 22m 17s and 12h 09m 52s, Sun's decl. 16° 48′ N., decreasing ·65′ per hour. eq. of time +5m 49s. Required the equation of equal altitude.

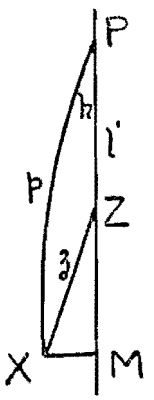
Answer. +04·2s.

Given Lat. 33° 02′ S., Long. 71° 42′ W., chron. times when Sun had equal altitudes 02h 16m 12s and 07h 20m 42s, Decl. 18° 02·7′ S. decreasing 39″ per hour, eq. of time +6m 11s, find the equation of equal altitudes.

Answer. +4·22s.

(XXIV.) EX-MERIDIAN—REDUCTION FORMULA.

The meridian zenith distance of a body is the least zenith distance possible and is smaller than the zenith distance obtained from observations taken a few minutes before, or after, the body has crossed the meridian by a small quantity called the reduction.



In figure: If z be the observed zenith distance (ZX)
R the reduction, then ZM the M.Z.D. $= (z - R)$

by (28) $$\cos h = \frac{\cos z - \cos p \cos l'}{\sin p \sin l'} = \frac{\cos z - \cos p \sin l}{\sin p \cos l} \quad . \quad . \quad \text{I.}$$

by substituting lat. for co-lat.

Now, when the body is on the meridian the hour angle $= 0$ and $\cos h = 1$.

$$1 = \frac{\cos (z - R) - \cos p \sin l}{\sin p \cos l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{II.}$$

Subtracting equation I. from II.

$$1 - \cos h = \frac{\cos (z - R) - \cos p \sin l - \cos z + \cos p \sin l}{\sin p \cos l}$$

$$1 - \cos h = \frac{\cos (z - R) - \cos z}{\sin p \cos l}$$

by (18) and (14)

$$2 \sin^2 \frac{h}{2} = \frac{2 \sin \tfrac{1}{2} (z + z - R) \sin \tfrac{1}{2} (z - z + R)}{\sin p \cos l}$$

$$\sin^2 \frac{h}{2} = \frac{\sin \left(z - \frac{R}{2}\right) \sin \frac{R}{2}}{\sin p \cos l}$$

but R is small so that $\left(z - \frac{R}{2}\right) = (z - R)$ nearly and by transposing we get

$$\sin \frac{R}{2} = \frac{\sin p \cos l \sin^2 \frac{h}{2}}{\sin (z - R)}$$

i.e., sin ½ Reduction = cos decl. cos lat. havs H. ang. cosec (M.Z.D.)
$(z - R)$ = M.Z.D. = (lat. ± decl.) nearly.

This expression involves the latitude, the quantity we wish to find, and as it is only known approximately, it may be necessary to repeat the calculation using the latitude last found.

Example, given D.R. Lat. 13° 50′ N., Decl. 52° 39·2′ S., H. ang. 37ᵐ 4ˢ, zen. dist. 67° 2·7′ N., calculate the reduction to the meridian.

Lat.	13°	50′ N.	cos	9·987217
Decl.	52	39·2 S.	cos	9·782930
M.Z.D.	66	29·2	cosec	0·037646
H. Ang.	37ᵐ	4ˢ	hav	7·814590
½ Red.		14·4′	sin	7·622383
Reduction		28·8		
Z. Dist.	67	02·7		
M.Z.D.	66	33·9 N.		
Decl.	52	39·2 S.		
Lat.	13	54·7 N.		

(XXV.) NORIE'S EX-MERIDIAN TABLES.

The reduction formula

$$\sin\frac{R}{2} = \frac{\sin p \cos l \sin^2\frac{h}{2}}{\sin(z - R)}$$

may be written as follows, and h being small, $\sin^2\frac{h}{2} = \frac{\sin^2 h}{4}$ nearly.

$$\frac{R''}{2}\sin 1'' = \frac{\cos d \cos l}{\sin(d \pm l)} \times \frac{\sin^2 h,}{4}$$

$$R = \frac{\cos d \cos l}{\sin(d \pm l)} \times \frac{2\sin^2 h}{4\sin 1''}$$

$$R = \frac{\cos d \cos l}{\sin(d \pm l)} \times \frac{\sin^2 15'}{2\sin 1''}, h^2$$

the quantity $\frac{\sin^2 15'}{2\sin 1''}$ is constant = 1·9635

15′ sin	7·639816		1″	sin	4·685575
sin² 15′	15·279632		2	log	0·301030
2 sin 1″	4·986605	. . . . .			4·986605
1·9635 log	0·293027				

The expression as given in Norie's Ex-Meridian Tables is

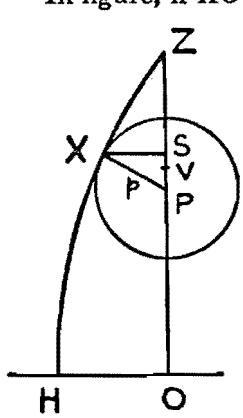
$$R = 1{\cdot}9635 \cos d \cos l \operatorname{cosec}(d \pm l) \times h^2$$
$$R = A \times h^2$$
$$R = \text{Table I.} \times \text{Table II.}$$

A is the first part of the above expression worked up for each degree of latitude and declination up to 60° and 63° respectively, it is also the change of altitude per minute when the body is near the meridian.

$R = A \times h^2 = A$ multiplied by the minutes in hour angle squared.

(XXVI.) POLE STAR.

In figure, if HO be the horizon, Z the zenith and X the pole star on its diurnal path round the pole, then PX = P. dist. (p), $\angle ZPX$ = H. ang. (h), ZX = zenith distance (z), ZP = co-latitude (l').



I.

Construction.—Make XS perpendicular to PZ. Centre Z and radius ZX, describe an arc cutting meridian at V, then $PZ = ZV - SV + PS$
and PS and SV are parts of corrections given in the Pole Star Tables.

In $\angle PXS$

$PS = p \cos h$ (1st part of correction)
$ZX = (ZS + SV)$
$\therefore \cos ZX = \cos(ZS + SV)$
$= \cos ZS \cos SV - \sin ZS \sin SV$ by (6)
but SV is small, $\therefore \cos SV = 1$ nearly
and $\sin SV = SV'' \sin 1''$ by (13)
so that $\cos ZX = \cos ZS - \sin ZS\,(SV'' \sin 1'')$.

II. In $\triangle ZXS$ $\quad \cos ZX = \cos ZS \cos SX$

I. = II. $\quad \cos ZS - \sin ZS\,(SV'' \sin 1'') = \cos ZS \cos SX$

$$\sin ZS\,(SV'' \sin 1'') = \cos ZS - \cos ZS \cos SX$$

$$,, \qquad = \cos ZS\,(1 - \cos SX)$$

$$SV'' \sin 1'' = \cot ZS \; 2 \sin^2 \frac{SX}{2} \text{ by (18)}$$

But $\quad \sin \frac{SX}{2} = \frac{SX''}{2} \sin 1''$

$$\sin^2 \frac{SX}{2} = \frac{SX^2}{4} \sin^2 1''$$

$$2 \sin^2 \frac{SX}{2} = \frac{SX^2}{2} \sin^2 1''$$

but $SX = p \sin h$

$$\therefore\ 2 \sin^2 \frac{SX}{2} = \frac{p^2 \sin^2 h}{2} \sin^2 1'' \quad \ldots\ldots\ldots\ (a)$$

$$\cot ZS = \tan SO = \tan HX = \text{tan alt.} \quad \ldots\ldots\ldots\ (b)$$

Substituting (a) and (b) in above, viz.

$$SV'' \sin 1'' = \cot ZS \,.\, 2 \sin^2 \frac{SX}{2}$$

$$\text{becomes } SV'' = \text{tan alt.} \frac{p^2 \sin^2 h}{2} \sin^2 1''$$

The Pole Star Tables were based on the formula:—

$$\text{Lat.} = \text{Alt.} - p \cos h + \tfrac{1}{2} p^2 \sin^2 h \tan \text{alt.} \sin^2 1''$$

but since 1952 the tables have been compiled using a mean Latitude of 50° in the first instance, and the formula for the correction is:—

$$\text{Lat.} = \text{True Alt.} - p \cos h + \tfrac{1}{2} p^2 \sin^2 h \tan \text{Lat.}$$

The value of correction a_0 is calculated from the formula using the assumed Latitude and mean position of the star, and a_1 and a_2 are the adjustments necessary when the observer and the star positions differ from the mean positions. The corrections are further adjusted to avoid negative values by adding constants 58·8′, 0·6′ and 0·6′ to a_0, a_1 and a_2 respectively.

SUMMARY OF FORMULAE, I TO XXVI.

I. **On any Sphere and between the same Secondaries.**

$$\frac{\text{Arc of a small circle}}{\text{Arc of parallel great circle}} = \cos\theta.$$

Where θ is the angular distance of the small circle from the great circle.

II. **Distance of sea horizon** $= \sqrt{2rh} = \sqrt{1{\cdot}5h}$ statute miles (no refraction):
" $= 1{\cdot}15\sqrt{h}$ in nautical miles including allowance for effect of refraction. h = height of eye, r = radius of earth.

III. **Angle of dip** $= \frac{\sqrt{2rh}}{r}$ without refraction.

" $= {\cdot}98\sqrt{h}$ allowing for refraction.

IV. **Dip of shore horizon** $= \frac{(D-a)^2}{2a}$

Where D = dip for height of eye.
a = distance of observer from the shore.

Admiralty Manual formula. ${\cdot}565\frac{h}{a} + {\cdot}423a$.

Where h = height of eye in feet and a = offshore distance in miles.

V. **Effect of Dip and Refraction on times of rising and setting.**

dh = Time in minutes $= \frac{RX}{15}$ cosec Az sec lat.

Where RX = dip and refraction in minutes of arc and dh is the interval between visible and theoretical times of rising.

VI. and VII. Sunrise and Moonrise.

VIII. **Refraction** $(R)'' = \tan\theta\frac{(\mu-1)}{\sin 1''}$

Where θ = zenith distance, R = refraction.

$\frac{\mu-1}{\sin 1''} = 57{\cdot}538'$ the constant of atmospheric refraction.

IX. **Diurnal parallax** = hor. parallax cos alt.

X. **Augmentation of Moon's Semi-diameter.**

Aug. $= 2s(\cos z - \frac{1}{2}p)\sin\frac{1}{2}p$ cosec $(z-p)$.
Where s = semi-diameter, z = zenith distance, p = parallax in altitude.

XI. **Sextant. Error of collimation** (Aa)

$$\cos Aa = \frac{\sin\frac{1}{2}\text{ true distance}}{\sin\frac{1}{2}\text{ apparent distance}}$$

XII., XIII., XIV., also XVI., XVII., XVIII.

Errors due to Small Errors in Azimuth, Latitude and Hour Angle.

1. $dz = dh$ cos lat sin Az.
2. $dl = dh$ cos lat tan Az.
3. $dz = dl$ cos Az.

Where dz = error in azimuth, dh = error in hour angle.
dl = error in latitude.

XV. **Maximum Rate of Change in Azimuth (dA)**

$$dA \text{ per minute} = \frac{15' \cos \text{decl.}}{\sin (\text{lat} \pm \text{decl.})}$$

XIX. **Trigonometrical Coefficients.**

XX. **Rate of change of Altitude (dh)**

$$dh = dz \operatorname{cosec} Az \sec \text{lat.}$$

XXI. **Maximum Altitude.**

XXII. **Time Interval in Maximum Meridian Altitude.**

$$h \sec = \frac{1}{15 \sin 1''} \sin (L \pm D) \sec L \sec D \frac{dp}{dh}$$

Where h = hour angle, L = Lat., D = Decl.

$$\frac{dp}{dh} = \frac{\text{change of decl. per hour}}{\text{minutes of arc per hour}}$$

$\frac{dp}{dh}$ has to be adjusted for course and speed of ship.

Admiralty Manual Formula.

$$h \sec = 15{\cdot}28 (\tan L \pm \tan D) \left(1 \pm \frac{2X}{900}\right) Y.$$

$(\tan L \pm \tan D)$, + for contrary names, − for like names.

$\left(1 \pm \frac{2X}{900}\right)$, + for ship going west, − for ship going east.

X = D. Long. of ship per hour.

Y = Decl. per hour combined with ship's D. Lat. per hour.

XXIII. **Equation of Equal Altitudes.**

$dh = dp (\cot L \operatorname{cosec} h \pm h \tan D \cot h)$.

\+ when polar distance greater than 90°

− „ „ less than 90°

+ dh „ „ is increasing

− dh „ „ is decreasing.

L = Lat., D = decl., $h = \frac{1}{2}$ interval between times of observatio

dp = change of decl. during the $\frac{1}{2}$ interval.

XXIV. **Reduction to Meridian (R).**

Sin $\frac{1}{2} R = \cos L \cos D \operatorname{hav} h \operatorname{cosec}$ (M.Z.D.)

M.Z.D. = $(L \pm D)$ nearly. L = Lat., D = decl., h = H. ang.

XXV. **Reduction to Meridian ("Norie's Table")**

$R = 1{\cdot}9635 \cos L \cos D \operatorname{cosec} (L \pm D) \times h^2$.

XXVI. **Pole Star.**

Lat. = $p \cos h + \frac{1}{2} \tan \text{alt} (p^2 \sin^2 h) \sin^2 1''$, where p = P. Dist., h = H. ang.

Lat. = True Alt. − $p \cos h + \frac{1}{2} p^2 \sin^2 h \tan$ (latitude).

CHAPTER XIII.

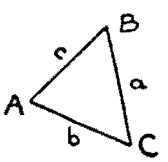
MENSURATION.

MENSURATION assumes a knowledge of algebra, geometry and a little trigonometry. We have assumed that knowledge. A brief reference is made in Volume I to the mensuration of a few simple figures and we now wish to extend the subject to include types of questions set in the extra master's examinations, such examples where given in this chapter being marked with an asterisk.

THE TRIANGLE.

Three sides given.

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



Two sides and included angle given.

$$Area = \tfrac{1}{2}bc \sin A$$

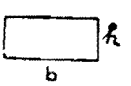
Three angles and a side given.

$$Area = \frac{a^2 \sin B \sin C}{2 \sin A}$$

I.—QUADRILATERALS.

A parallelogram is a quadrilateral whose pairs of opposite sides are parallel. It is particularised as a square, a rectangle, rhombus, rhomboid and trapezium according to the shape of the figure.

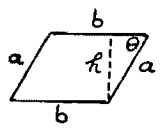
A rectangle has all its angles right angles, but its sides are not all equal.



$$Area = \text{length} \times \text{breadth} = bh$$

A rhombus has all its sides equal but angles oblique. Its diagonals bisect each other at right angles.

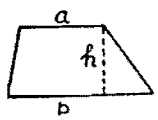
$Area = \frac{1}{2}d \times d_1$ where d and d_1 are the diagonals



A rhomboid is an oblique parallelogram.

(i) *Area* = base × height = bh.

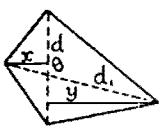
(ii) *Area* = $ab \sin \theta$, when two sides are given with the angle θ included between them. This will be obvious from the figure where $h = a \sin \theta$, and, substituting this in (i), we get area = $ab \sin \theta$.



A trapezium has two sides parallel.

$$Area = \tfrac{1}{2}(a + b)h$$

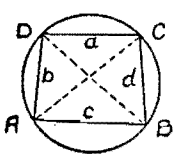
Any quadrilateral.—The offsets are the perpendiculars from two corners on to a diagonal, as x and y in figure.



(i) *Area* = the areas of the two triangles formed by the diagonal.

$Area = \tfrac{1}{2}dx + \tfrac{1}{2}dy = \tfrac{1}{2}d(x + y)$.

(ii) *Area* = $\tfrac{1}{2}dd_1 \sin \theta$, where θ is the angle at the intersection of the two diagonals d and d_1.



A quadrilateral having its opposite angles supplementary can be inscribed in a circle in which case its

(i) $Area^2 = (s - a)(s - b)(s - c)(s - d)$, where s is its semiperimeter and a, b, c, d its sides.

(ii) $Radius^2 = \dfrac{(ab + cd)(ad + bc)(ac + bd)}{16\ area^2}$

(iii) $Diagonal\ BD^2 = \dfrac{(ab + cd)(ac + bd)}{(ad + bc)}$

(iv) $Diagonal\ AC^2 = \dfrac{(ad + bc)(ac + bd)}{(ab + cd)}$

EXERCISES—QUADRILATERALS.

1. Find the number of square feet in a carpet 14 ft. 6 ins. long, 4 ft. 9 ins. broad.

2. Required the number of square yards in a floor $16\frac{1}{2}$ yds. long, $10\frac{1}{3}$ yds. broad.

3 Find the area of a rectangle base 21 ft., diagonal 35 ft.

4. Find the area of a rectangle of base 36 ft., and angle between the base and diagonal 32° 25′.

5. A rectangle, base 14·4 yds., angle between base and diagonal 35° 40′; required its area.

6. Given a parallelogram, length 45 ft., breadth 24 ft.; find its area.

7. Find the area of a rhombus whose sides are 42 ft. 6 ins. and acute angles 58° 20′.

8. In a rhomboid its adjacent sides are 18 ft. and 25 ft. 6 ins., and the angle contained by them is 58°; find its area.

9. The diagonals of a square courtyard measure 36 ft. 8 ins.; find its area.

10. How many square yards are contained in a rectangular field whose diagonals are each 96 ft. and contain an angle of 30°.

11. A rhombus, diagonals 75 ft. and 60 ft.; find its area.

12. Find the area of a trapezoid whose parallel sides are 41 ft. and 24·5 ft. and perpendicular height 43 ft.

13. A trapezoid whose parallel sides are 30 ft. and 40 ft. and area 525 sq. ft.; find its perpendicular breadth.

14. How many square yards are contained in a court, the diagonals of which are 180 ft. and 210 ft. and the angle contained between them is 30°?

15. The four sides of a trapezium inscribed in a circle are 40, 75, 55 and 60 ft.; find its area.

16. The diagonal of a quadrilateral is 60 yds. and the offsets 12·6 yds. and 11·4 yds.; find its area.

17. The diagonal of a trapezium is 40 units, and the offsets 21·6 units and 13 units; find its area.

* 18. $ABCD$ are four buoys, 6, 8, 7 and 9 miles apart respectively. A ship is anchored in a position such that she is equidistant from the buoys; find the distance.

(See note under quadrilateral.)

* 19. A circular area is marked by four buoys, A, B, C and D. A and B are the northern buoys two miles apart, C and D the southern, A and C are to the westward and one mile apart. At A, C and D subtend an angle of 37°. At B, A and D subtend an angle of 65°. If B bears 072° T. from A, find the bearing of C and D from A.

NOTE.—Draw a figure with the buoys in their relative positions as given in the question. The quadrilateral is cyclic, draw the diagonals and mark the angles that are equal to each other. In $\triangle ABC$, Given $\angle ABC = 28°$, $AB = 2$, $AC = 1$, find $\angle ACB$. $\angle ADB = \angle ACB$. All the angles are now known. Note that the opposite angles of a cyclic quadrilateral are supplementary so that $\angle C = (180° - \angle B)$.

* 20. Four beacons A, B, C and D mark a circular area, C and D being north of A and B. At A, C and D subtend a horizontal angle of 32° and the vertical angle of D (82 ft. high) is 0° 19′ 59″. The ship steams eastward to B; A and D then subtend an angle of 80° and the vertical angle of D is 0° 27′ 27″. Find distance between C and D.

NOTE.—Calculate the distances by vertical angle. $AD = 14{,}106$ ft., $DB = 10{,}269$ ft. The quadrilateral is cyclic. Draw in the diagonals. In $\triangle ADC$ given AD, $\angle DAC$, $\angle DCA$. Solve for DC.

21. Four buoys moored round the circumference of a circle; B is 12 cables to northward of A and 17 cables to north-westward of C; D is 10 cables northward of C and 16 cables north-eastward of A. Find distance from A to C.

NOTE.—Construct rough figure. $\angle ABC = \angle ADC = \theta$ on same arc AC. $AC^2 = AB^2 + BC^2 - 2\,AB\,.\,BC \cos\theta = AD^2 + DC^2 - 2\,AD\,.\,DC \cos.\,\theta$. Substitute the values of the sides and find $\theta = 28°\ 58'$. Then find AC.

II.—THE CIRCLE.

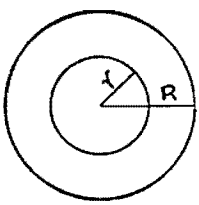
$$\textit{Circumference} = 2\pi r$$

$$\textit{Area} = \pi r^2$$

$$\textit{Area} = \frac{\text{circumference}^2}{4\pi}$$

ANNULUS.

To find the area of a circular annulus or ring.



Area of annulus = area of the outer circle of radius R, less the area of the inner ring of radius r.

$$\textit{Area of annulus} = \pi R^2 - \pi r^2 = \pi(R^2 - r^2) = \pi(R + r)(R - r).$$

If C be the circumference of the outer circle and c the circumference of the inner circle, then

$$\text{(ii) } \textit{Area of annulus} = \frac{(C + c)(C - c)}{4\pi}$$

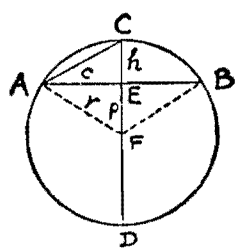
Exercises.

1. Find area of a circular annulus, the diameter of the containing circles being 80 and 40 ft.

2. The diameters of a ring are 12 and 10; find the area of the annulus.

3. The circumferences of the containing circles of an annulus are 30 and 40 units; find its area.

4. Find the area of a circular annulus the circumferences of which are 62·8 and 87·7.



In above figure, AEB is a chord, ACB an arc of the circle, both chord and arc subtend $\angle AFB$.

AC is the half chord of $\angle AFB$.

The area $ACBE$ enclosed by the arc and the chord is a segment of the circle and the area $AFBC$ is a sector.

Area of a segment = area of sector — area of triangle

thus area $AEBC$ = area $AFBC$ — area $AFBE$.

CE is the height (h) of the segment.

EF, or p, is the perpendicular, and r is the radius of the circle.

$AE^2 = \frac{1}{4}AB^2 = CE.ED = h(r + p)$

thus if radius = 9, $h = 2$, p = 7, then

$AE^2 = h(r + p) = 2(9 + 7) = 32$ and

$AC^2 = AE^2 + EC^2 = 32 + 4 = 36$.

If chord $AB = 2c$, then $AE = c$ and $p = r - h$.

From figure, $r^2 = c^2 + p^2 = c^2 + (r - h)^2$

$$r^2 = c^2 + r^2 - 2rh + h^2$$

$$\therefore 2rh = c^2 + h^2 \text{ and } r = \frac{c^2 + h^2}{2h} = \text{radius} \quad . \quad . \quad . \quad . \quad . \quad \text{(i)}$$

Half chord $AC^2 = c^2 + h^2 = 2rh$

$\therefore$ Half chord of angle $= \sqrt{2rh}$ . . . . . (ii)

Example.—Given chord = 20, perpendicular 12; find radius of circle.

$$r^2 = (c^2 + p^2) = (100 + 144) \quad \therefore r = \sqrt{244} = 15{\cdot}62.$$

Example.—Given height of segment 2, chord 15; find the diameter of the circle.

$$r = \frac{c^2 + h^2}{2h} = \frac{7{\cdot}5^2 + 2^2}{2 \times 2} = \frac{60{\cdot}25}{4} = 15{\cdot}06.$$

$$\text{Diameter} = 30{\cdot}12.$$

Example.—Given height 6, perpendicular 24; find the number of degrees in the arc of the segment.

In figure, $r = p + h = 30$.

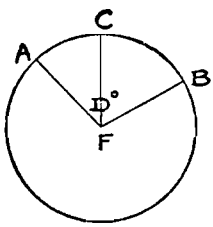
$$\text{Cos } AFE = \frac{p}{r} = \frac{24}{30} = {\cdot}8 \quad \therefore AFE = 36^\circ\ 52'.$$

$$\text{Angle } AFB = 73^\circ\ 44'.$$

Exercises.

5. Given chord 12, perpendicular 10; find radius of circle.
6. Chord 36, perpendicular 25; find radius.
7. Chord 24, height 10; find radius.
8. Chord 24, height 4; find radius.
9. Given chord 40, radius 60; required the number of degrees in the arc.
10. Chord 36, radius 54; find the arc of the segment.
11. Height 12, radius 56; find the angle subtended by the arc.
12. Chord 40, height 5; find the angle subtended by the arc.
13. Given the chord of half the angle of a segment to be 20, the height of which is 2; find the radius and thence the arc.

SECTORS.



In any circle

$$\frac{\text{length of arc}}{\text{length of circumference}} = \frac{D^\circ}{360^\circ}$$

where D° is the angle AFB at the centre of the circle subtended by the arc AB in figure; thus

$$\frac{\text{arc } AB}{2\pi r} = \frac{D^\circ}{360^\circ} \quad \therefore \text{ arc} = \frac{2\pi r D^\circ}{360^\circ}$$

AFC and CFB are sectors. The areas of sectors in the same circle are proportional to their angles, thus the

$$\frac{\text{area } AFC}{\text{area } CFB} = \frac{\text{angle } AFC}{\text{angle } CFB}$$

from which it follows

$$\frac{\text{area of sector}}{\text{area of circle}} = \frac{D^\circ}{360^\circ} = \frac{\text{arc}}{\text{circumference}}$$

as above, where D° is the angle of the sector.

(i) *Area of sector* $= \dfrac{\text{area of circle} \times D^\circ}{360^\circ} = \dfrac{\pi r^2 D^\circ}{360^\circ}$

again $\dfrac{\text{sector}}{\text{circle}} = \dfrac{\text{arc}}{\text{circumference}}$, or, $\dfrac{\text{sector}}{\pi r^2} = \dfrac{\text{arc}}{2\pi r}$

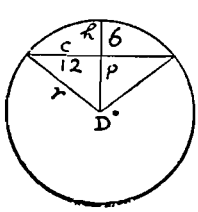
(ii) *Area of sector* $= \dfrac{\text{arc} \times r}{2}$

$\dfrac{\text{Area of sector}}{\text{Area of circle}} = \dfrac{\text{angle of sector}}{360^\circ}$, $\qquad \dfrac{\text{sector}}{\pi r^2} = \dfrac{\theta}{2\pi}$

where 2π is the radian measure of the circumference of the circle ($2\pi = 360^\circ$) and θ is the angle of the sector expressed in radian measure. ($R = 57{\cdot}3^\circ$) approximately, thus $\theta = \dfrac{D^\circ}{57{\cdot}3^\circ}$.

(iii) *Area of sector* $= \dfrac{r^2\theta}{2}$

SEGMENTS.



In figure,

Area of a segment = area of sector − area of triangle but area of sector $= \frac{1}{2}r^2\theta$, and area of triangle $= \frac{1}{2}r^2 \sin D^\circ$

Area of segment = sector − triangle
" $= \frac{1}{2}r^2\theta - \frac{1}{2}r^2 \sin D^\circ$
" $= \frac{1}{2}r^2(\theta - \text{nat sin } D^\circ)$

where $\theta = \dfrac{D^\circ}{57{\cdot}3^\circ}$

Example.—Given the chord of a segment = 24 and its height 6; find its area.

1st.—Find radius. $r = \frac{c^2 + h^2}{2h} = \frac{144 + 36}{2 \times 6} = \frac{180}{12} = 15$

$\therefore p = 15 - 6 = 9.$

2nd.—Find $D°$. $\text{Sin } \frac{D}{2} = \frac{c}{r} = \frac{12}{15} = \cdot 8.$

$\frac{D}{2} = 53° \ 8' \therefore D = 106° \ 16' = 106 \cdot 3°$ nearly.

3rd.—Area segment = area sector − area triangle; find area of sector.

By (i) sector $= \frac{\pi r^2 D°}{360°} = \frac{15^2 \times 22 \times 106 \cdot 3°}{7 \times 360°} = \underline{\underline{208 \cdot 7}}$ when worked out by logs.

or by (ii) sector $= \frac{r^2 D°}{2} = \frac{15^2}{2} \times \frac{106 \cdot 3°}{57 \cdot 3°} = \underline{\underline{208 \cdot 8}}$ when worked out by logs.

or by (iii) sector $= \frac{\text{length of arc} \times r}{2}$

To find the length of the arc

$$\frac{\text{arc}}{r} = \frac{\text{angle}}{57 \cdot 3°}, \ \text{arc} = \frac{15 \times 106 \cdot 3}{57 \cdot 3} = 27 \cdot 82$$

$$\text{sector} = \frac{27 \cdot 82 \times 15}{2} = \underline{\underline{208 \cdot 8}}.$$

The area of triangle $= \frac{1}{2}$ base $\times \perp^r$ height
$= \frac{1}{2} cp = 6 \times 9 = 54.$

Area of whole triangle $= 2 \times 54 = 108.$

Segment = sector − triangle $= 208 \cdot 8 - 108 = 100 \cdot 8$ sq. units.

The area of the sector has been worked out in three different ways to show the application of the formulæ. The area of the segment may be found direct, viz., area $= \frac{1}{2} r^2(\theta - \text{nat sin } D°)$; having found $r = 15$ and $D° = 106 \cdot 3°$ as above, then

$$\text{area} = \frac{15 \times 15}{2}\left(\frac{106 \cdot 3°}{57 \cdot 3} - \cdot 96\right) = 100 \cdot 7 \text{ when worked out by logs.}$$

Nat sine $106° \ 16' = \cdot 96$ from tables.

Exercises.

14. The chord of circle = 40, and height of the segment = 4; find area of segment.

15. Given chord 24, height of segment 9; find its area.

16. The diameter of a circle = 50, and a chord = 30; find the area of the segment.

17. Diameter 20, chord 16; find the area of this segment of the circle.

18. If the arc of a segment contains 90°, and the diameter of the circle is 12 ft., find area of the segment.

19. Diameter of circle = 50, height of the segment 18; find area of segment.

20. Diameter of circle 10 ft., arc of the segment 280°; find its area.

III.—SPECIFIC GRAVITY.

Frequently examination questions in mensuration involve the volumes and the weights of bodies, introducing their specific gravity.

The specific gravity of a body is the ratio of the weight of a given volume of it, to the weight of an equal volume of fresh water at 4° Centigrade. Fresh water is the standard, or unit, of specific gravity to which other bodies are referred.

One cubic foot of fresh water weighs 1,000 ounces (62½ lbs.).

If a cubic foot of a substance weighs 1,000 ounces, or 62½ lbs., then its specific gravity = 1.

If the weight of any given volume of a substance weighs the same as an equal volume of water, its specific gravity is 1, and its density, that is, its weight per cubic foot, is 1,000 ounces.

But should a cubic inch of the substance weigh five times more than a cubic inch of water, its specific gravity is 5. If a log of wood floats with half its volume immersed in fresh water, its specific gravity is half that of the water, viz., ·5.

If the average weight of a ship per cubic foot weighs less than a cubic foot of the water which supports her, she will float because her specific gravity is less than that of the water, the water, of course, may be sea water, having a specific gravity of 1·025. If weights be placed on board the ship her specific gravity will be increased until such time as her average weight per cubic foot will be equal to the weight of a cubic foot of the water, her specific gravity will then be the same as the water, she will have reached the limits of her buoyancy and, thereafter, if more weights be added, her specific gravity will be greater than that of the water and she will sink. Fresh water will support a weight of 62½ lbs. per cubic foot; average sea water supports 64 lbs. per cubic foot. When the density of the ship, that is her weight per cubic foot, exceeds these weights she will not float.

To find the Specific Gravity of a Substance.

The substance is weighed in air, and again in water, and the apparent loss of weight noted.

If S = the specific gravity of the substance,
s = ,, ,, ,, ,, ,, water,
W = weight of substance in air,
w = weight of an equal volume of fresh water,

then $W - w$ = the apparent loss of weight when the substance is weighed in water, and we get the equation.

$$\frac{S}{s} = \frac{W}{W - w}.$$

Example.—Find the specific gravity of a piece of steel which weighed 78·5 lbs in air and 68·5 lbs. in fresh water by means of a hydrostatic balance.

$$\frac{S}{s} = \frac{W}{W - w}. \qquad \text{Specific gravity of F.W.} = 1.$$

$$S = \frac{sW}{W - w} = \frac{1 \times 78{\cdot}5}{10} = \underline{7{\cdot}85} \text{ specific gravity of steel.}$$

Example.—Find specific gravity of a body which weighed 10 lbs. in air and 6 lbs. when suspended in sea water of specific gravity 1·025.

$$S = \frac{sW}{W - w} = \frac{1{\cdot}025 \times 10}{4} = \underline{\underline{2{\cdot}562}} \text{ specific gravity.}$$

1. Find specific gravity of a substance which weighed 20 lbs. in air and 13½ lbs. in fresh water.

2. A substance weighed 33 ounces in air and 29 ounces in water; find its specific gravity.

To find the Specific Gravity of a Body lighter than Water.

When a body is lighter than water it floats; it does not displace its own volume of water but only its own weight of water, *i.e.* its displacement.

To determine its specific gravity it has to be wholly submerged by attaching a weight to it, and then to eliminate the effect of the weight on the compound mass, that is, the substance and weight combined.

Let S = the specific gravity of the substance,
s = ,, ,, ,, ,, ,, water,
W = weight of the substance in air,
w_1 = weight of sinker in water,
W_1 = weight of sinker and substance together in water,

then $$\frac{S}{s} = \frac{W}{(W + w_1) - W_1}.$$

Example.—A piece of cork weighs 2·5 lbs. in air, a sinker weighs 9·1 lbs. in fresh water. The cork and sinker together weigh 1·2 lbs. in water. Find specific gravity of cork.

$$\frac{S}{s} = \frac{W}{(W + w_1) - W_1}. \qquad s = \text{specific gravity 1.}$$

$$S = \frac{25}{25 + 91 - 12} = \frac{25}{104} = \underline{\underline{{\cdot}243}} \text{ specific gravity.}$$

3. A substance in air weighs 10 gms.; a sinker in water weighs 91 gms. Substance and sinker together in water weigh 61 gms. Find specific gravity of the substance.

4. A piece of wood weighs 42·6 lbs. in air, a piece of iron weighs 40·7 lbs. in water; when tied together they weigh 33·3 lbs. in water. Find specific gravity of the wood.

Given the Volume and Specific Gravity of a Body to find its Weight.

V = volume of the body in cubic feet,
W = weight of the body,
S = specific gravity of the body,

then $W = VS \times 62\frac{1}{2}$ lbs. (one cubic foot of F.W. weighs 62½ lbs.).

Example.—Find the weight of a block of marble if specific gravity 2·7, length 6 ft., breadth 5 ft., thickness 18 inches.

$$W = VS \times 62\tfrac{1}{2}$$
$$= \frac{6 \times 5 \times 3 \times 27 \times 125}{2 \times 10 \times 2} = \frac{30375}{4} = \underline{\underline{7593{\cdot}75}} \text{ lbs.}$$

NOTE.—$2{\cdot}7 = \frac{27}{10}$, 18 ins. $= \frac{3}{2}$ ft.

5. Find weight of a log 24 ft. × 3 ft. × 1 ft., specific gravity ·925.

6. A square pillar of specific gravity 2·7 measures 63 ft. × 12 ft. × 12 ft.; find its weight.

7. The area of the end of a 10 ft. log is 93·582 sq. ins. and its specific gravity is ·8; find its weight.

To find the Volume of a Body of known Specific Gravity.

A re-arrangement of the preceding formula will suffice, viz.,

$$W = VS \times 62\tfrac{1}{2} \text{ lbs.} \quad \therefore \quad V = \frac{W}{62\tfrac{1}{2}S}.$$

Example.—Find the volume of a stone weighing 8 tons, specific gravity 2·52.

$$V = \frac{W}{62\tfrac{1}{2}S}$$
$$V = 8 \text{ tons} \times 2240 \text{ lbs.} \div (62\tfrac{1}{2} \times 2{\cdot}52) = 113{\cdot}7 \text{ cub. ft.}$$

8. How many cubic feet are in a ton of timber of specific gravity ·550?

9. A block of stone weighs 112 lbs. and its specific gravity is 2·52; find its volume.

* 10. A ring is 3 ins. in diameter, the internal radius is 10 ins., specific gravity of the iron is 7·5; find weight of the ring.

* 11. Find the weight of the greatest circular band 10 ins. wide that can be cut from a square iron sheet of 3 ft. 6 ins. side and 1 in. thick; specific gravity of iron is 7·75.

* 12. A hollow metal tube 6 ft. long, open at both ends, external diameter 2 ft., displaces 4 cubic ft. of fresh water when completely submerged; find thickness of the metal.

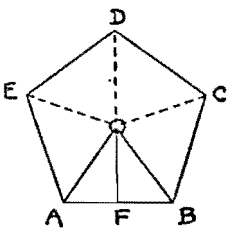
IV.—POLYGONS.

Rectilineal figures having several sides are named polygons and are distinguished by the number of their sides. They are called regular polygons when their sides and their angles are equal.

A triangle, for example, has 3 sides, a quadrilateral 4, a pentagon 5, a hexagon 6, heptagon 7, octagon 8, nonagon 9, decagon 10, undecagon 11, and a dodecagon 12.

The central angle of the figure is 360° divided by the number of sides.

Example.—Given a regular pentagon of side 6 ins. to find its area.



The pentagon is made up of five equal triangles, AOB, BOC, etc.

$$\angle AOB = \frac{360°}{5} = 72°.$$

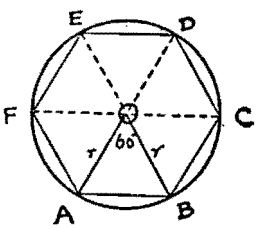
Make OF perpendicular to AB, it bisects $\angle AOB$, also side AB. Find OF.

$$OF = AF \cot AOF = 3 \cot 36° = 3 \times 1{\cdot}376 = 4{\cdot}128 \text{ ins.}$$

$$\text{Area } AOB = \tfrac{1}{2}AB \,.\, OF = 3 \times 4{\cdot}128 = 12{\cdot}384 \text{ sq. ins.}$$

$$\text{Area of pentagon} = 5 \times 12{\cdot}384 = \underline{\underline{61{\cdot}92}} \text{ sq. ins.}$$

Similarly with a hexagon or other regular polygonic figures.



If the radius of a circle be given as 6 inches and it is required to find the area of the inscribed hexagon, then the central angle $AOB = \dfrac{360°}{6} = 60°$, and $AO = OB = r$ the radius of the circle.

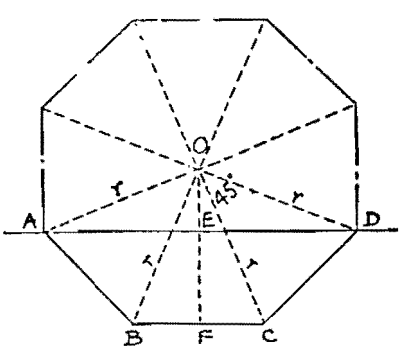
$$\text{Area of } AOB = \tfrac{1}{2}AO \,.\, OB \sin AOB$$

$$\text{,, ,,} = \tfrac{1}{2}r^2 \sin 60°$$

$$\text{,, ,,} = \tfrac{1}{2}\ 36 \times {\cdot}866 = 15{\cdot}588 \text{ sq. ins.}$$

$$\text{Area of hexagon} = 6 \times 15{\cdot}588 = \underline{\underline{93{\cdot}528}} \text{ sq. ins.}$$

*Example.**—An octagonal log of wood 16 ft. long, diagonal 18 ins., floats in fresh water with three sides immersed; find (*a*) depth of log in the water; (*b*) the volume of water displaced if floating in salt water of density 1020.



In figure the eight triangles are equal, $r = 9$ ins., central angle $= 45°$, $\angle AOD = 135°$.

$$\text{Area of one triangle} = \tfrac{1}{2}r \,.\, r \sin 45° = \tfrac{1}{2}\ 81 \times \frac{1}{\sqrt{2}} = \frac{81}{2\sqrt{2}}$$

$$\text{Area of triangle } AOD = \tfrac{1}{2}r \,.\, r \sin 135° = \tfrac{1}{2}\ 81 \times \frac{1}{\sqrt{2}} = \frac{81}{2\sqrt{2}}$$

The triangles are all of equal area and the figure $AODCB = 8$ triangles.

Immersed area $ABCD$ = fig. $AODCB$ — triangle $AODE$

" " = 8 triangles — 1 triangle

" " = 2 triangles $= \frac{2 \times 81}{2\sqrt{2}} = \frac{81\sqrt{2}}{2}$ sq. ins.

$= \frac{81\sqrt{2}}{2 \times 144}$ sq. ft.

Immersed volume = length of log × area of immersed end.

" " $= 16 \times \frac{81\sqrt{2}}{2 \times 144} = 6{\cdot}354$ cub. ft. in F.W.

The volume varies inversely as the density of the liquid, so that the immersed volume $= \frac{6{\cdot}354}{1{\cdot}020} = 6{\cdot}23$ cub. ft. in salt water.

The draught of water $= EF = OF - OE$

" $= 9 \cos 22\frac{1}{2}^\circ - 9 \cos 67\frac{1}{2}^\circ$

" $= 9 (\cos 22\frac{1}{2} - \cos 67\frac{1}{2})$*

" $= 18 \sin 45 \sin 22\frac{1}{2}$*

" $= 4{\cdot}86$ ins.

Answer (*a*) 4·86 ins.; (*b*) 6·23 cub. ft.

* See cos A — cos B, formula (14), page 233 for this transformation

Exercises.

1. Find the area of a regular pentagon whose side is 30 ft.

2. Find the area of a heptagon each side of which is 15 ft.

* 3. Find the area of a circle inscribed in a rhombus of 80·902 sq. ins. area, the angle at the base being 54°.

* 4. Find the perimeter of a hexagon circumscribing a circle of 2-inch radius.

* 5. A pentagonal log, each side 18 ins., is cut at an angle of 45°; find the area of the section.

(NOTE.—Area of section = area of end × secant angle of cut.)

* 6. Find the cross sectional area of a hexagonal log 20 ins. each side and cut at an angle of 50°.

* Find the weight of a coil of wire one-sixteenth inch in diameter, wound in the form of a screw having 12 turns, the pitch being one-fifth of an inch. The diameter of the coil is 2 ins. and the specific gravity of the metal is 7·6.

NOTE.—Diam. of helix = $2'' + \frac{1}{16} = 2\frac{1}{16}''$

Pitch $\frac{1}{5}''$.

The circumference, pitch and length of one turn of wire may be illustrated by a right-angled triangle from which—

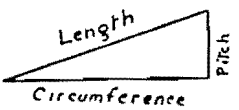
$$\text{Length}^2 = \text{pitch}^2 + \text{circumference}^2$$
$$= (\tfrac{1}{5})^2 + (\pi 2\tfrac{1}{16})^2$$

Length of one turn = 6·48

Length of 12 turns = 77·81

Weight of metal = vol. of wire × specific gravity

$= \pi r^2 l \times 7{\cdot}6 = 1{\cdot}05$ ozs.



* 7. Nine buoys are moored equidistant from each other round the circumference of a circle the area of which is 32 square miles; find the distance apart of the buoys.

* 8. Seven buoys equidistant from each other are moored round the circumference of a circle, the area of which is 23 square miles; find the distance between the buoys.

* 9. An octagonal log 12 ft. long, specific gravity ·87, greatest diagonal 16 ins. Find the volume of the immersed portion of the log when floating in sea water of density 1023.

* 10. Find the weight of the largest hexagonal log that can be cut from a cylindrical log 3 ft. in diameter, volume 85 cub. ft., specific gravity of the timber ·82.

* 11. Find the length of a helix having 64 turns, pitch $\frac{1}{8}$ in., diameter of helix 1 in.

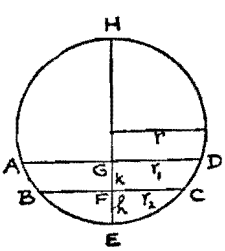
* 12. A metal plate 3 ins. × 8 ins. × 1 in. is made into a wire 200 ft. long; find diameter of the wire.

* 13. A light shown on a disc 10 ins. away, diameter of disc 24 ins., light in line with centre of the disc. Four inches further away from the disc is a second disc 48 ins. in diameter, the centres of the two discs being in line. Find the area of the annular of the second disc.

V.—THE SPHERE.

In figure, r is the radius of the sphere, $ABCD$ is a zone, r_1 and r_2 the radii of its two ends, GF its thickness (k in formula).

BEC is a segment or spherical cap, r_2 the radius of its base, FE its height (h). AHD is also a segment greater than a hemisphere, its height being HG, and r_1 the radius of its base.



Sphere.

$$\textit{Surface area} = 4\pi r^2 \text{ sq. units.}$$

$$\textit{Volume} = \frac{4\pi r^3}{3} \text{ cub. units.}$$

Segment.

Curved surface $= 2\pi rh$ sq. units, where r is the radius of the sphere.

Volume $= \pi h^2(r - \frac{1}{3}h)$ cub. units, where r is the radius of the sphere.

Volume $= \frac{\pi h}{6}(3r_1^2 + h^2)$, where r_1 is the radius of base of segment.

Zone.

Curved surface $= 2\pi rk$ sq. units, where r = radius of sphere, and k the thickness of the zone.

Volume $= \frac{\pi k}{6}\left\{3(r_1^2 + r_2^2) + k^2\right\}$ cub. units, where r_1 and r_2 are the radii of ends of zone.

Volume of a sphere having a hole bored through its centre.

$$\text{Volume} = \frac{4}{3}\pi(R^2 - r^2)^{\frac{3}{2}}$$

where R is the radius of the sphere and r the radius of the hole.

Example.—The surface area of a sphere is 616 sq. ft.; find its radius.

$$\text{Area} = 4\pi r^2 = 616 \therefore r^2 = \frac{616}{4\pi},\ r = \underline{\underline{7 \text{ ins.}}}$$

Example.—Find volume of a sphere of diameter 2 ft. 8 ins.

$$\text{Vol.} = \frac{4}{3}\pi r^3 = \frac{4}{3} \times \frac{22}{7} \times \frac{16^3}{1728} = \underline{\underline{9{\cdot}93}} \text{ cu. ft.}$$

Exercises.

1. Find the area and the volume of a sphere of 5 ins. diameter.

2. Find area and volume of a globe 12 ins. diameter, also area of its circumscribing square.

Example.—Find the diameter of the greatest possible sphere that can be turned out of a square block of wood, if the weight of wood removed after turning weighs 217·24 lbs. and 1 cub. ft. of the wood weighs 57 lbs.

Vol. of block $= L \times B \times D = (2r)^3 = 8r^3$.

Vol. of sphere $= \frac{4\pi r^3}{3}$.

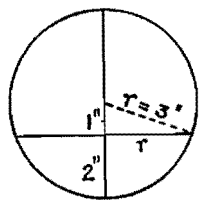
Wt. of turnings = Block − Sphere $= 8r^3 - \frac{4\pi r^3}{3} = \frac{217{\cdot}24}{57}$.

Solve for r and get 1 ft.

Diameter of sphere = 2 ft.

Segment of Sphere.

Example.—Find (*a*) the surface area, (*b*) the volume of a segment of a sphere of diameter 6 ins., height of segment 2 ins.



$$\text{Area of segment} = 2\pi rh = \frac{2 \times 22 \times 3 \times 2}{7} = 37{\cdot}7 \text{ sq. ins.}$$

$$\text{Volume of segment} = \frac{\pi h}{6}(3r_1^2 + h^2) = \frac{22 \times 2}{7 \times 6}(3 \times 8 + 4)$$

$$= \underline{\underline{29{\cdot}33}} \text{ cub. ins.}$$

Note.—$r_1^2 = 3^2 - 1^2 = 8$.

The other formula might be used, viz. :—

$$\text{Vol. of segment} = \pi h^2(r - \tfrac{1}{3}h) = \frac{22}{7} \times \frac{4}{1}\left(\frac{9-2}{3}\right) = 29{\cdot}33 \text{ cub. ins.}$$

The volume of the segment greater than a hemisphere when calculated is 83·31 cub. ins., its height being 4 ins. The volumes of the two segments together make up the volume of the whole sphere, viz. (29·33 + 83·81 = 113·14 cub. ins.) which is the same as found from $\frac{4\pi r^3}{3}$.

Exercises.

3. Find surface area of a segment, height 5 ins., diameter of sphere 25 ins.
4. Height of segment 3 ft. 6 ins., diameter of sphere 10 ft.; find area of segment.
5. Height of segment 8 ins., radius of base of segment 14 ins.; find its volume.
6. Diameter of sphere 5 ft., height of segment 2 ft.; find volume of segment.
7. Diameter of sphere 10 ft., height of segment 2 ft.; find volume of segment.

Zone.

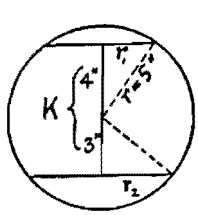
Example.—The radii of the circular ends of a zone on a sphere are 12 ins. and 5 ins.; find the volume of the zone if its thickness is 3 ins.

$$\text{Vol. of zone} = \frac{\pi k}{6}\left\{3(r_1^2 + r_2^2) + k^2\right\}$$ where k is its thickness and r_1 r_2 the radii of its ends.

$$\text{,, ,,} = \frac{22}{7} \times \frac{3}{6}\left\{3(144 + 25) + 9\right\}$$

$$\text{,, ,,} = \underline{\underline{132}} \text{ cub. ins.}$$

Example.—From a sphere of 10-in. diameter a parallel zone is cut, the ends of which are 4 ins. and 3 ins. on each side of the centre. Find the volume of the zone.



First find the radii of the ends of the zone.

$$r_1^2 = 5^2 - 4^2 = 9,\ r_2^2 = 5^2 - 3^2 = 16,\ k = 7.$$

$$\text{Vol.} = \frac{22}{7} \times \frac{7}{6}\left\{3(9 + 16) + 49\right\} = \underline{\underline{454\tfrac{2}{3}}} \text{ cub. ins.}$$

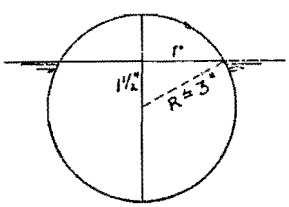
Exercises.

8. Find volume of a spherical zone, the diameters of its ends being 10 and 12 ins., and its height 2 ins.

9. Spherical zone, diameters 8 and 12 ins., thickness 10 ins.; find its volume.

10. Find volume of a middle zone of a sphere, its thickness being 8 ft. and the diameters of its ends 6 ft.

Volume and Density.



*Example.**—A sphere 6 ins. diameter floats in fresh water with three-quarters of its diameter immersed; find the density of this sphere.

1st. Find volume of segment.
2nd. ,, ,, ,, sphere.

Then vol. of segment ÷ vol. of sphere = specific gravity of sphere.

Given height of segment $h = 4\frac{1}{2}$ ins., radius of sphere $R = 3$ ins., radius of segment r_1.

So that $r_1^2 = 3^2 - 1\frac{1}{2}^2 = 6\frac{3}{4}$.

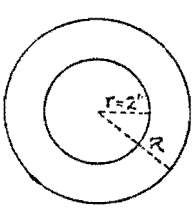
$$\text{Vol. of segment} = \frac{\pi h}{6}(3r_1^2 + h^2) = \pi\frac{4\frac{1}{2}}{6}(3 \times 6\tfrac{3}{4} + 20\tfrac{1}{4}) = \frac{243\pi}{8}$$

$$\text{Vol. of sphere} = \frac{4\pi R^3}{3} = \pi \times \frac{4 \times 3 \times 3 \times 3}{3} = 36\pi$$

$$\frac{\text{Vol. of segment}}{\text{Vol. of sphere}} = \frac{243\pi}{8} \times \frac{1}{36\pi} = \frac{27}{32} = \cdot 8437$$

Sp. gr. of sphere = ·8437, or density 843·7 oz. per cub. ft.

Example.—*A hollow iron sphere of internal diameter 4 ins. weighs 760 lbs., specific gravity of iron 7·6; find thickness of the iron.



NOTE.—A cub. ft. F.W. weighs 62·5 lbs. = $\frac{1000}{16}$ ozs.

1 cub. ft. = 1,728 cu. ins.

∴ A cub. inch of F.W. = $\frac{1000}{16 \times 1728}$ lbs. = w.

Let W represent the weight of substance (760 lbs.) and w the weight of unit volume of water $\left(\frac{1000}{16 \times 1728}\right)$ lbs., then as

Weight = vol. × sp. gr. × wt. of unit vol. of water

we have

$$\text{Vol.} = \frac{W}{\text{sp. gr.} \times w} = \frac{760 \times 1728 \times 16}{7{\cdot}6 \times 1000} = \frac{13824}{5} \text{ cub. ins.}$$

$$\text{Vol. of whole sphere} = \frac{4\pi R^3}{3}$$

$$\text{Vol. of hollow sphere} = \frac{4\pi r^3}{3}$$

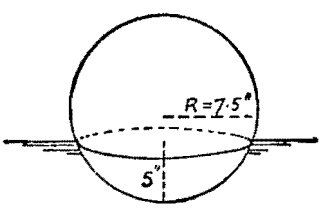
$$\text{Vol. of shell} = \frac{4\pi R^3}{3} - \frac{4\pi r^3}{3} = \frac{4\pi}{3}(R^3 - r^3) = \frac{W}{\text{sp. gr.} \times w} = \frac{13824}{5}$$

from which $$R^3 - 8 = \frac{13824 \times 3 \times 7}{5 \times 4 \times 22} = 659{\cdot}7$$

$$\therefore R = \sqrt[3]{667{\cdot}2} = 8{\cdot}73 \text{ ins.}$$

$$\text{Thickness of metal} = R - r = 6{\cdot}73 \text{ ins.}$$

*Example.**—A hollow aluminium sphere 15-in. diameter floats with one-third of its diameter immersed in liquid of density 932·5; specific gravity of metal 2·5. Find the thickness of the metal.



In figure $R = 7{\cdot}5$ ins., $h = 5$ ins.

(1) Vol. of sphere $= \frac{4\pi R^3}{3}$.

(2) Weight of liquid = volume × density $= \pi h^2(R - \frac{1}{3}h) \times 932{\cdot}5$.

(3) Vol. of shell $= \frac{4\pi}{3}(R^3 - r^3) = \frac{\text{Weight}}{\text{density}} = \frac{\pi h^2(R - \frac{1}{3}h)932{\cdot}5}{2500}$

Vol. of hollow part = vol. of sphere − vol. of shell

$$\frac{4\pi r^3}{3} = \frac{4\pi R^3}{3} - \frac{\pi h^2(R - \frac{1}{3}h)932{\cdot}5}{2500}$$

π cancels, divide throughout by $\frac{2}{3}$, rearrange and we get

$$R^3 - r^3 = \frac{25}{1} \times \frac{17{\cdot}5}{3} \times \frac{932{\cdot}5}{2500}$$

$$= 40{\cdot}8 \text{ by logs.}$$

$$r^3 = R^3 - 40{\cdot}8 = 421{\cdot}9 - 40{\cdot}8 = 381{\cdot}1$$

$$r = 7{\cdot}25$$

$$R = 7{\cdot}50$$

$$R - r = {\cdot}25 \text{ in. the thickness of metal.}$$

Exercises.

* 11. A hollow aluminium sphere has an external diameter of 16 ins. and floats at half its diameter in water weighing 1015 ounces per cub. ft. If specific gravity of the metal is 2·6, find the thickness of the shell.

* 12. A solid iron sphere of 6-in. diameter has a hole 1-in. diameter bored through its centre. Find the weight of the sphere after the hole is bored, specific gravity of the iron 7·8.

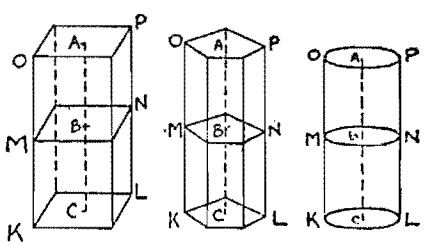
* 13. A hollow metal sphere, external diameter 14 ins., floats with upper edge just flush with the surface of the water of density 1023. If the specific gravity of the metal is 8·6, find its thickness.

* 14. A hollow metal sphere, external diameter 12 ins., internal diameter 10 ins., when full of water weighs 136 lbs. and when full of spirit it weighs 124 lbs. Find specific gravity of the sphere and of the spirit.

VI.—THE CONE AND PRISM.

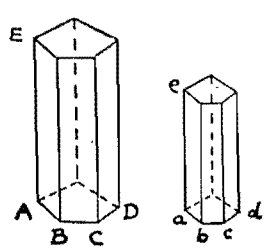
THEOREMS.

1. The solid content, or volume, of prisms, and cylinders, of the same base area and height, are equal to each other.



If ABC represent the height or length of the figures represented by l units in each case, and the base area KL are also equal, then the volume of each is equal to base times l.

2. Similar prisms and cylinders are to each other as the cubes of their heights, or of any other linear dimensions, like to like.

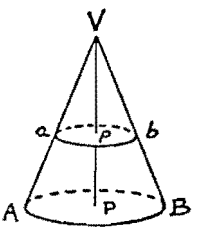


If the two pentagonal prisms in figure are similar, then

$$\frac{\text{Vol. } DE}{\text{Vol. } de} = \frac{AB^3}{ab^3} = \frac{AE^3}{ae^3}$$

3. The ends of the frustum of a right pyramid, or of a right cone, are to each other as the squares of their distances from the vertex.

Thus, $$\frac{\text{area } ab}{\text{area } AB} = \frac{Vp^2}{VP^2}$$



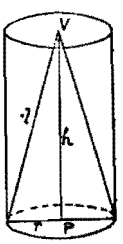
4. Every pyramid, whatever figure it may be, is the third part of a prism having the same base and height.

5. A right cone is the third part of a cylinder having the same base and height; it is also two-thirds of a hemisphere having the same radius.

6. All spheres are to each other as the cubes of their diameters.

7. The volume of a sphere is two-thirds of its circumscribing cylinder. If the volume of such a sphere be 320 cub. units, and x the volume of the cylinder, then

$$\frac{2x}{3} = 320. \quad x = 480 \text{ cub. units.}$$



The cylinder and cone are somewhat similar in character.

The figure represents a cone inside a cylinder, the height and base of each being the same.

VP or h = perpendicular height of cone and cylinder, l the slant height of cone and r the radius of the base.

Cylinder.

Curved area of cylinder $= 2\pi r \times h.$
Area of its ends $= 2\pi r^2.$
Area of whole surface $= 2\pi r(h + r)$ sq. units.

Cone.

Curved area of cone $= \pi rl.$
Area of its base $= \pi r^2.$
Area of whole surface $= \pi r(l + r)$ sq. units.
Vol. of cylinder $= \pi r^2 h$ cu. units.

The volume of a cone is one-third that of a cylinder on the same base and of the same height.

Vol. of cone $= \frac{\pi r^2 h}{3}.$

Example.—Required the surface area of a cylinder and also of a cone of the same height 20 ft., and same base of 5 ft. radius.

Cylinder.

Vol. $= \pi r^2 h = \frac{22}{7} \times 5^2 \times 20 = 1571{\cdot}43$ cub. ft.

Cone.

Vol. $= \frac{1}{3}$ of cylinder $= \frac{1571{\cdot}43}{3} = 523{\cdot}8$ cub. ft.

Cylinder.

$$\text{Area} = 2\pi r(h + r) = \frac{2 \times 22 \times 5 \times 25}{7} = 785{\cdot}77 \text{ sq. ft.}$$

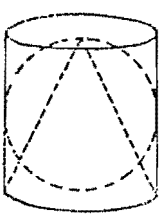
Cone.

Slant height of cone . $l = \sqrt{h^2 + r^2} = 20{\cdot}62.$

$$\text{Area} = \pi r(l + r) = \frac{22 \times 5 \times 25{\cdot}62}{7} = 402{\cdot}6 \text{ sq. ft.}$$

Show that the volume of a cone, a hemisphere and a cylinder of the same base and height are in the ratio of 1, 2 and 3.

In this case $r = l$ and πr^3 cancels and as it is common to each fraction it may be regarded as unity.

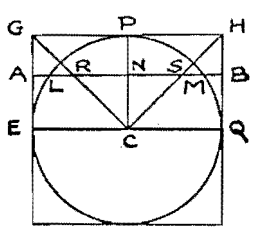


Vol. of cone: $\frac{\pi r^2 l}{3} = \frac{\pi r^3}{3} = \frac{1}{3} = 1$

Vol. of hemisphere: $\frac{2\pi r^3}{3} = \frac{2\pi r^3}{3} = \frac{2}{3} = 2$

Vol. of cylinder: $\pi r^2 l = \pi r^3 = \frac{1}{1} = 3$

Multiply each fraction by 3 and we have the ratio of 1, 2 and 3.



The figure represents a sphere within a cylinder, or cube, the diameter of the sphere being equal to the height of the cylinder.

Frustum $EQML$ = cylinder $EQBA$ — cone CRS, all having the same height NC.

Segment LPM = cylinder $AGHB$ — conic frustum $GRSH$, all having the same height PN.

Exercises.

1. Find the number of gallons of fresh water a cylindrical tank, height 10 ft., diameter of base 6 ft., would hold.

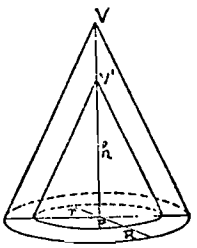
2. A conical vessel apex down measures 28 ins. across the top and is $4\frac{1}{2}$ ft. deep; find the weight of fresh water it would hold.

3. Find the volume of a cylinder, height 25 ins., diameter of base 15 ins.

4. Find volume of a cone, perpendicular height 30 ft., diameter of base 8 ft.

5. Cone of base diameter 3 ft. 4 ins. and slant side 16 ft.; find its volume.

Example.—Two similar cones, one 24 ins. in height, and volume 2772 cub. ins., the other 15 ins. high; find the diameter of the latter.



Similar cones are proportional to their heights and radii, thus, in figure, let h and H be the height of the two cones and r and R their radii, then $\frac{r}{R} = \frac{h}{H}$ $\therefore$ $r = \frac{hR}{H}$, but h and H are known, find R.

Vol. $= \frac{\pi R^2 H}{3} = 2772$ cub. ins., from which $R = \frac{\sqrt{441}}{2} = \frac{21}{2}$. Substitute this value for R, and $r = 6{\cdot}5625$. Diameter of smaller cone 13·125 ins.

Example.—Find the volume and surface area of a rod having hemispherical ends. The cylindrical part of the rod is 11 ins. long, and 2 ins. diameter.

Total vol. = vol. of cylinder + vol. of two hemispheres.

„ „ $= \pi r^2 h + \frac{4\pi r^3}{3}$.

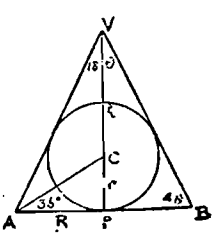
„ „ = 38·76 cub. ins. when worked out.

Total area = area of cylinder + area of sphere

„ „ $= 2\pi rh + 4\pi r^2$.

„ „ = 81·71 sq. ins. when worked out.

*Example.**—A right circular cone has the angle at the apex equal to half the angle at the base. A sphere is placed inside so that when it touches the sides of the cone it is resting on the base. The surface area of the sphere is 59·72 sq. ins.; find the volume of the space left vacant in the cone.



In figure, $h = VP$ the height of cone, R = radius of base of cone, r = radius of sphere.

Let $\angle A$ and $\angle B$ each = say 4θ, then $\angle V = 2\theta$.

but $V + A + B = 180° = 10\theta$, $\therefore$ $\theta = 18°$.

$\angle PVA = \theta = 18°$, $\angle VAP = 4\theta = 72°$,

$\angle CAP = 2\theta = 36°$.

Vol. of space = vol. of cone − vol. of sphere

„ „ $= \frac{\pi R^2 h}{3} - \frac{4\pi r^3}{3}$

„ „ $= \frac{1}{3}\pi(R^2 h - 4r^3)$.

We require to find a value for R^2h.

$R = r \cot 36°$, $\therefore R^2 = r^2 \cot^2 36°$.

$VP = h = R \cot 18° = r \cot 36° \cot 18°$.

$R^2h = (r^2 \cot^2 36°)(r \cot 36° \cot 18°) = r^3 \cot^3 36° \cot 18°$.

Substitute this value for R^2h in the above.

Vol. of space $= \frac{1}{3}\pi(r^3 \cot^3 36° \cot 18° - 4r^3)$

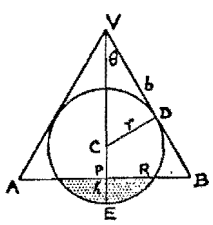
" " $= \frac{1}{3}\pi r^3(\cot^3 36 \cot 18 - 4)$

" " $= 43{\cdot}66$ cub. ins. when worked out by logs.

NOTE.—The vol. of sphere works out at 43·4 cub. ins. and vol. of cone works out at 87·06 cub. ins. when the two volumes are worked out separately.

Exercises.

* 6. A sphere whose radius is $3\frac{1}{2}$ ins. is placed inside a cone whose base radius is $4\frac{1}{2}$ ins. and slant height 12 ins.; find the volume of that part of the sphere projecting beyond the cone.



From figure. $CD = r = 3\frac{1}{2}$, $PB = R = 4\frac{1}{2}$, $VB = l = 12$, VP = height of cone, $PE = h$ = height of spherical cap.

In $\triangle VPB$, find $\angle\theta$ and VP.

In $\triangle VCD$, find VC and thence h.

Vol. of cap $= \pi h^2(r - \frac{1}{3}h)$.

Exercises.

* 7. A right cone whose base and height are equal to that of a hemisphere, has a volume of 28 cub. ins.; find the area of the hemisphere.

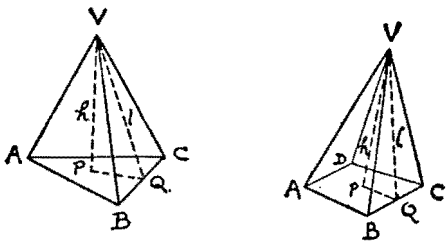
Draw a figure. Write down the formula for volume of cone and area of hemisphere. Note that radius of hemisphere = height of cone, that is $r = h$, and by substitution get area $= 2\sqrt[3]{9\pi V^2}$, where V = volume of cone.

* 8. Find the volume of the largest sphere which can be cut from a cone of volume 80 cub. ins., angle at apex 40°.

NOTE.—Refer to figure. $\angle AVP = 20°$, $\angle A = 70°$, $\angle CAP = 35°$. Note that $h = R \cot 20°$.
Vol. of cone $= \frac{1}{3}\pi R^2h$. Find R, then r in terms of R. Vol. of sphere $= \frac{4}{3}\pi r^3$.

* 9. A right cone, height 12 ins., base diameter 10 ins., find (*a*) diameter of sphere having the same volume, (*b*) and the same surface area as the cone.

PYRAMIDS.



(i) (ii)

The base of a pyramid may be any rectilineal figure. The sides, or faces, are triangles, the number of triangles depending upon the number of edges contained by the base.

Figure (i) represents a pyramid having a triangular base, and (ii) one having a rectilineal base of four sides. V is the vertex, VP is perpendicular to the base and is the height (h) of the pyramid. Bisect the edge BC at Q. Join VQ, then VQ is the slant height (l) of the face VBC and it bisects BC perpendicularly. $\angle VPQ = 90°$. Any line on the base drawn from P is at right angles to VP.

It will be obvious from the figure that the whole surface area of a pyramid is equal to the area of all the triangles plus area of the base.

A right pyramid is one standing on a regular base having any number of equal sides.

The slant surface area $= \triangle s\ BVC + BVA + AVC$ (fig. i).
" " " $= (\frac{1}{2}BC + \frac{1}{2}AC + \frac{1}{2}AB) \times$ slant height.
" " " $= \frac{1}{2}$ perimeter of base $\times$ slant height.

This applies to a right pyramid standing on a regular base, but in the case of an oblique pyramid the area of each triangle would need to be found separately.

The area of the base will depend upon its shape.

The volume $= \frac{1}{3}$(area of base) $\times$ (perp. height) for all pyramids.

Example.—Find the slant surface area of a pyramid the slant height of which is 10 ft., and each side of its triangular base is 18 ins.

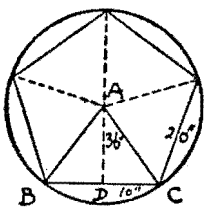
If s be the semi-perimeter of base and l the slant height, then the

$$\text{slant area} = s \times l = \frac{3 \times 1{\cdot}5 \text{ ft.}}{2} \times 10 \text{ ft.} = 22{\cdot}5 \text{ sq. ft.}$$

Example.—What is the surface of a square pyramid, a side of its base being 5 ft. and slant height 12 ft.?

Area of base $= 5 \times 5$	=	25 sq. ft.
$l = 12$, $s = 10$, . . slant area $s.l$	=	120 "
Whole area		145 "

Example.—A regular pentagonal pyramid, whose slant height is 10 ft., each side of base 1 ft. 8 ins.; find its surface area.



To find area of sides. Each side of the pentagon is 1 ft. 8 ins.

$$s = \tfrac{1}{2}(5 \times 1 \text{ ft. } 8 \text{ ins.}) = 4 \text{ ft. } 2 \text{ ins.}$$

Slant area $= s \times l = 4$ ft. 2 ins. $\times$ 10 ft. $= 41{\cdot}735$ sq. ft.

To find area of base. The figure shows the pentagonal base on which the pyramid stands. The area of the base will be equal to the sum of five triangles equal to ABC.

$\angle A = 72°$, AD bisects $\angle A$ and also BC perpendicularly, $DC = 10$ ins., $\angle DAC = 36°$.

$AD = 10 \cot 36° = 13{\cdot}7$ ins.

Area of $ABC = \frac{1}{2}$ base $\times$ perp. height $= 10 \times 13{\cdot}7 = 137$ sq. ins.

Area of base $= 5 \times 137$ . . .	$=$	4·76 sq. ft.
Area of sides as above	$=$	41·73 „
Area of whole pyramid . . .	$=$	46·49 „

Example.—Find volume of a regular triangular pyramid, sides of base 6 ft., height 60 ft.

Area of base $= \sqrt{s(s-a)(s-b)(s-c)}$

$= \sqrt{9 \times 3 \times 3 \times 3} = 9\sqrt{3} = 15{\cdot}588$ sq. ft.

Vol. of pyramid $=$ $\frac{1}{3}$ area of base $\times$ height

„ $= \frac{1}{3} \times 15{\cdot}588 \times 60 = 311{\cdot}76$ cub. ft.

Example.—A square pyramid, slant height 25 ft., side of base 30 ft.; find volume.

Refer to figure under pyramids. Note that in this question $BQ = QP = 15$ ft.; $l = 25$ ft.; find h.

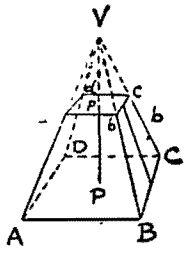
$$h = \sqrt{l^2 - PQ^2} = \sqrt{25^2 - 15^2} = \sqrt{400} = 20 \text{ ft.}$$

Vol. of pyramid $=$ $\frac{1}{3}$ area of base $\times$ height

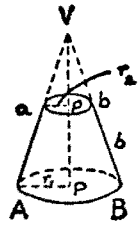
„ $= \frac{1}{3} \times 30 \times 30 \times 20 = 6000$ cub. ft.

FRUSTUMS.

A frustum is the lower part of a pyramid, or cone, sliced off parallel to the base.



(i)



(ii)

The solid lined parts in figures (i) and (ii) are the frustums of the pyramid and cone respectively.

The ends of a right pyramid frustum are similar figures and its sides, or faces, are trapeziums, and if the base be a regular polygon the trapeziums are all equal.

The ends of a cone frustum are circles of radius r_1 and r_2. In both cases pP represents the perpendicular distance between the base end and top end of the frustum, and is called its thickness, usually indicated in equations by letter k.

The areas of the ends of a frustum (pyramid or cone) are proportional to the squares of their heights, thus in the pyramid

$$\frac{\text{Area } abcd}{\text{Area } ABCD} = \frac{Vp}{\overline{VP}}$$

and in the cone

$$\frac{\text{Area } ab}{\text{Area } AB} = \frac{Vp}{\overline{VP}}$$

Pyramid.

The area of the slant surface of the frustum of a right pyramid in square units is n times the area of the figure $ABba$, where n is the number of equal sides, that is,

$$area = \frac{l}{2}(AB + ab)n,$$

or, in words,

$$area = \tfrac{1}{2}(\text{sum of perimeter of ends}) \times (\text{slant height}).$$

The volume of the frustum $= \frac{1}{3}k(E_1 + \sqrt{E_1E_2} + E_2)$ cub. units,

where k is the thickness of the frustum,

E_1 the area of one end,

E_2 the area of the other end.

CONE.

Area of frustum.

$$Curved\ area = \pi(r_1 + r_2)l \text{ sq. units,}$$

where r_1 and r_2 are the radii of the ends and l the slant height.

Volume of frustum.

$$Vol. = \tfrac{1}{3}k(E_1 + \sqrt{E_1E_2} + E_2) \text{ cub. units,}$$

where E_1 and E_2 are the area of its ends and k the thickness of the frustum.

This is the same as for a pyramid, but the ends of a cone frustum are circles, the areas of which are given by πr_1^2 and πr_2^2, so by substituting these symbols for E_1 and E_2 in the above equation we get

$$Vol. = \frac{\pi}{3}k(r_1^2 + r_1r_2 + r_2^2) \text{ cub. units.}$$

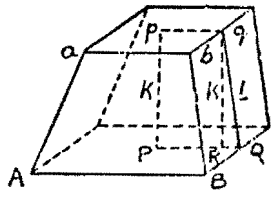
Example.—A square pyramid, the sides of a frustum are 20 ins. and 4 ins., thickness 15 ins.; find the area of its slant surface and its volume.

To find the volume of the frustum.

$$\text{Vol.} = \tfrac{1}{3}k(E_1 + \sqrt{E_1E_2} + E_2)$$
$$\text{Area of } E_1 = 20 \times 20 = 400 \text{ sq. ins.}$$
$$\text{Area of } E_2 = 4 \times 4 = 16 \text{ sq. ins.}$$
$$k = 15 \text{ ins.}$$
$$\text{Vol.} = \frac{15}{3}(400 + 16 + \sqrt{400 \times 16})$$
$$,, = 5(416 + 80)$$
$$,, = 2480 \text{ cu. ins. or } \underline{\underline{1{\cdot}43}} \text{ cub. ft.}$$

To find the area of the frustum.

The thickness (k) is given so we have first to find the slant height (l) or qQ.



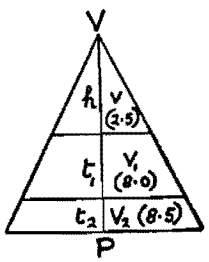
In figure

$$PQ = 10,$$
$$pq = 2 = PR,$$
$$qR = pP = 15 \text{ ins.} = k.$$
$$RQ = PQ - PR = 10 - 2 = 8 \text{ ins.}$$
$$qQ^2 = qR^2 + RQ^2 = 15^2 + 8^2 = 289. \quad \therefore\ qQ = 17.$$
$$\text{Area} = \frac{l}{2}(AB + ab)n = \frac{17}{2}(20 + 4)4 = 816 \text{ sq. ins.}$$

Area of slant surface = $\underline{\underline{5 \text{ sq. ft. } 96 \text{ sq. ins.}}}$

*Example.**—A cone of height 26 ins. is made up of three materials of specific gravity 2·5, 8·0 and 8·5 respectively. The weight of each material is the same, the lightest being on top and the heaviest below; find the thickness of each.

We have here a cone made up of two frustums surmounted by a cone, each of different density but of equal weight. The volume of the whole cone is made up of the volume of the top cone and the volumes of the two frustums, and their relative volumes must vary inversely as their densities because the weight of material is the same.



Let $VP = H$ (26 ins.), the height of the whole cone and V its volume.

h = height of the top cone and v (2·5) its volume.

t_1 and t_2 the thickness of the frustums and v_1 and v_2 their volumes, viz. (8·0) and (8·5).

There are really three similar cones of heights h, $(h + t_1)$ and H, to find h, t_1 and t_2.

$$\frac{v_1}{v} = \frac{25}{80} \quad \therefore v_1 = \frac{25v}{80} \qquad \frac{v_2}{v} = \frac{25}{85} \quad \therefore v_2 = \frac{25v}{85}$$

$$V = v + v_1 + v_2 = \frac{v}{1} + \frac{25v}{80} + \frac{25v}{85} = \frac{10925v}{6800} = 1{\cdot}607v.$$

The volumes of similar cones vary as the cube of their heights, so for the top cone

$$\frac{h^3}{H^3} = \frac{v}{V} \quad \therefore h^3 = \frac{H^3v}{V} = \frac{26^3v}{1{\cdot}607v} \quad \therefore h = \underline{22{\cdot}2} \text{ ins.}$$

For the top cone plus frustum t_1

$$\frac{(h + t_1)^3}{H^3} = \frac{v + v_1}{V} = \frac{v + \frac{25v}{80}}{1{\cdot}607v} = \frac{105}{80} \times \frac{1}{1{\cdot}607} = \frac{10500}{12856}$$

$$\therefore h + t_1 = 26\sqrt[3]{\frac{10500}{12856}} = 24{\cdot}3$$

$$\therefore \quad t_1 = 24{\cdot}3 - 22{\cdot}2 = \underline{2{\cdot}1} \text{ ins.}$$

$$t_2 = VP - (h + t_1) = 26 - 24{\cdot}3 = \underline{1{\cdot}7} \text{ ins.}$$

Answer:—

Height of top cone	22·2 ins.
Thickness of middle frustum . .	2·1 ,,
Thickness of bottom frustum . .	1·7 ,,

Exercises.

10. Find the slant surface area of an upright triangular pyramid, the slant height being 20 ft., and each side of the base 3 ft.

11. Find the area of the frustum of a square pyramid whose slant height is 10 ft., and each side of the base end 3 ft. 4 ins., and the top end 2 ft. 2 ins.

12. Required the number of cubic feet in a tapered log of timber the ends of which are square, one end being 15 ins. square, the other end 6 ins. square, and length of log 24 ft.

13. Find the volume of a pentagonal frustum, thickness 5 ft., sides of base 18 ins., sides of top 6 ins.

14. Given a square pyramid, slant height 2 ft. 3 ins., the sides of its ends being 24 and 14 ins.; find its surface area and its volume.

(NOTE.—The slant height has to be turned into the thickness h in order to get the volume.)

15. Required the surface area of a cone, slant height 50 ft., base diameter $8\frac{1}{2}$ ft.

16. The frustum of a cone, slant height $12\frac{1}{2}$ ft., circumferences of the two ends 6 ft. and 8·4 ft.; find its surface area.

17. A cone, of thickness $10\frac{1}{2}$ ft., circumference of base 9 ft.; find its volume.

18. Find the content of a conic frustum, thickness 18 units, greatest diameter 8 units, and least diameter 4 units.

19. Required the solid content of the frustum of a cone, thickness 25 ins., circumference of base 20 ins., and of top end 10 ins.

20. A cask which measured 40 ins. in length was cut across at the middle of its length, bung diameter 28 ins., head diameter 20 ins.; find how many gallons of fresh water the tub would hold. (NOTE.—Its shape is the frustum of a cone.)

* 21. A pyramid of square base having equilateral triangular sides of 12 ins. is placed in a lathe and the largest possible right cone made from it; find the weight of the turnings, the specific gravity of the wood being ·5.

* 22. A regular pentagonal prism of slant height 5 ft., bottom sides 20 ins., top sides 14 ins.; find its slant area.

* 23. The areas of the two ends of a frustum are 154 and 616 sq. ins. The area of the curved surface is equal to the surface area of a sphere of radius $10\frac{1}{2}$ ins.; find the slant height of the frustum.

* 24. A right cone is cut parallel to the base in such a way that the volume of the small cone so formed is half the volume of the remaining frustum; find the proportion of their heights.

* 25. A right cone is cut by a plane parallel to the base so that the volume of the cone cut off is half as large again as the remaining frustum; find the proportion in which the cutting plane divides the altitude of the original cone.

* 26. The frustum of a cone and a similar right cone each displace the same amount of water. Each is 30 ins. high and the cone has a base diameter of 12 ins., while the diameter of the frustum is 14 ins. If the specific gravity of the cone is 0·9, find the specific gravity of the frustum.

NOTE.—Find volume of cone and frustum.
Vol. of frustum × specific gravity = vol. of cone × specific gravity.
r_1 of frustum = 7", and r_2 = 1".

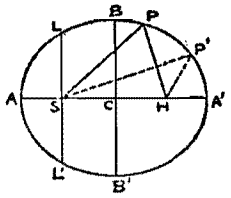
* 27. A conical buoy is floating apex up and weighs 3 tons, drawing 2 ft. of water. (35 cub. ft. water to 1 ton.) If the base radius of the buoy is 5 ft., find the radius of the waterplane and the height of the buoy above water.

VII.—THE ELLIPSE.

Definitions.

1. An ellipse is a closed curve such that, if lines be drawn from any point on the curve to two given points on the major axis, the sum of the two straight lines will always be the same.

2. **Foci.**—In figure, $SP + PH = SP^1 + P^1H = AA^1$ and this condition is constant for all positions of P on the curve. The fixed points S and H are called the foci.



3. **Eccentricity.**—The centre of the ellipse is at **C** midway between the foci so that $CS = CH$. The eccentricity of the ellipse, usually represented by e, $= \frac{CS}{CA}$.

4. **Axes.**—AA^1 is the major axis. BB^1 is the minor axis drawn through **C** at right angles to the axis major. $CA = CA^1$. The major axis is usually referred to as $2a$ and the minor axis as $2b$, so that $CA = a$ and $CB = b$.

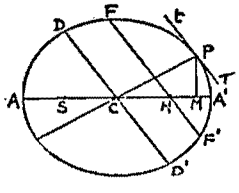
The simplest way to draw an ellipse is to make a loop of thread equal to the major axis desired. Slip the loop over two pins pushed into the paper. Hold the point of a pencil in the bight of the thread as at P and, keeping the thread tight, sweep in the circumference P, A^1, B^1, A, B. The pins mark the foci S and H.

5. **Ordinates.**—Any straight line drawn perpendicular to the major axis and terminated both ways by the curve is called an ordinate.

6. **Latus Rectum.**—The ordinate which passes through either foci, such as LSL^1 in figure is called the latus rectum, usually denoted by $2l$.

7. **Vertices.**—The points A and A^1 where the major axis meets the curve are named the principal vertices or apsides.

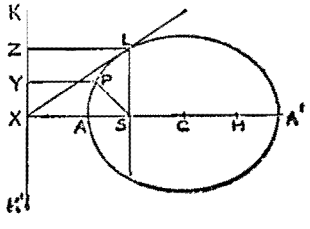
In figure, if PC continued be any diameter then P is its vertex, DCD^1 its conjugate diameter and FHF^1 its parameter.



8. **Conjugate Diameter.**—tT is a tangent at P. The diameter DCD^1 drawn through the centre of the ellipse and parallel to the tangent is known as the conjugate diameter.

9. **Parameter.**—The line drawn parallel to the tangent and through one of the foci, such as FHF^1, is called the parameter.

10. **Ordinates.**—A line drawn from a point on the curve and perpendicular to either axis is called the ordinate of that axis. Thus PM is the ordinate of P to the major axis, and the segments AM and A^1M are its abscissae.



11. **The Directrix** is a line outside the ellipse drawn perpendicular to the axis major. In figure the tangent LX meets the major axis produced at X and KXK^1 is the direction drawn through X perpendicular to CA.

THEOREMS.

Theorem 1.—The fixed line KK^1 is the directrix, and, in the foregoing figure, the property of the ellipse is such that if A and P and L be any points on the curve and AX, PY and LZ are drawn perpendicular to the directrix then the eccentricity $SC = \frac{SA}{AX} = \frac{SP}{PY} = \frac{SL}{LZ}$, the ratio of the distances being constant.

From the above we have $SA = e.AX$, $SP = e.PY$ and $SL = e.LZ$, but from figure, $SA = CA - CS$ and $AX = CX - CA$, from which $SA = e.AX$ becomes $CA - CS = e(CX - CA)$ I

Again $SA^1 = CA^1 + CS$ and $A^1X = CX + CA^1$ and so $SA^1 = e.A^1X$ becomes $CA^1 + CS = e(CX + CA^1)$ . . . II

bring down Eq. I . . . . . $CA - CS = e(CX - CA)$ . . I

and by subtraction . . . . . $CS = e.CA$ . . . . (1)

$$\therefore e = \frac{CS}{CA} \text{ and if } CA = 1, \text{ then } e = CS \quad . \quad . \quad . \quad (2)$$

By adding Eq. I and II we get $CA = e.CX$.

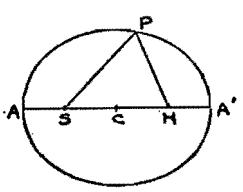
$$\therefore e = \frac{CA}{CX} = \frac{1}{CX} \text{ if } CA = 1.$$

From above—(1) $CS = e.CA$.

(2) $CA = e.CX$.

Combining (1) and (2) we get $CS.CX = CA^2$ . . . . . (3)

Theorem 2.—To prove $SP + PH = AA^1$ or $2a$



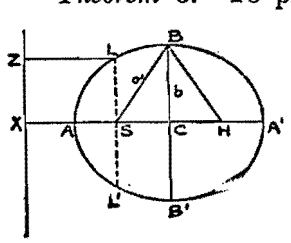
By Def. $SP + PH = AS + AH = AS + AS + SH = 2AS + SH$

$SP + PH = A^1S + A^1H = A^1H + HS + A^1H = 2A^1H + SH$

Add $2(SP + PH) = 2(AS + SH + A^1H) = 2AA^1$.

$\therefore SP + PH = AA^1$ or $2a$ the major axis.

Theorem 3.—To prove $CB^2 = AS.AH = b^2$.



If the point P coincides with B, which is the vertex of the minor axis, as in figure, then $SB + BH = AA^1$, but $SB = BH = CA = a$.

In triangle SCB,

$$CB^2 = SB^2 - SC^2 = CA^2 - SC^2 = (CA - SC)(CA + SC) = AS.AH.$$

Theorem 4.—The latus rectum is a third proportional to the major and minor axes.

By Theorem 1, $$e = \frac{SL}{LZ} = \frac{SL}{SX} = \frac{CS}{CA}$$

$$\therefore SL \,.\, CA = CS \,.\, SX = CS(CX - CS) = CS \,.\, CX - CS^2$$
$$= CA^2 - CS^2 = CB^2. \quad \text{(See Theorem I.)}$$
$$SL = \frac{CB^2}{CA} = \frac{b^2}{a} = l \text{ the semi latus rectum.}$$
$$\therefore \quad LSL^1 = 2l = 2\left(\frac{b^2}{a}\right).$$

Theorem 5.—The eccentricity of an ellipse is always less than unity. A circle is a particular form of ellipse, its axes being equal, so that $a = b$ and its eccentricity $e = o$.

By Def. 8, eccentricity $e = \frac{CS}{CA}$ $\therefore CS^2 = e^2 \,.\, CA^2 = e^2 \,.\, a^2$.

In figure, $SB = AC = a$ . . . Theorem 3.

$$b^2 = BC^2 = SB^2 - SC^2 = a^2 - e^2a^2 = a^2(1 - e^2) = b^2$$
$$1 - e^2 = \frac{b^2}{a^2} \quad \therefore \quad e^2 = 1 - \frac{b^2}{a^2} = \frac{a^2 - b^2}{a^2}.$$

again $$SA = CA - CS = a - ea = a(1 - e)$$

and $$SA^1 = CA^1 + CS = a + ea = a(1 + e)$$

The semi latus rectum $SL = l = \frac{b^2}{a}$ as in Theorem 4.

$$\text{,,} \qquad = \frac{a^2(1 - e^2)}{a} \text{ as above}$$
$$\text{,,} \qquad = a(1 - e^2).$$

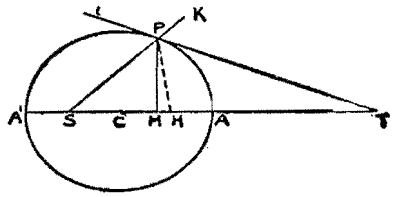
Theorem 6.—$SP(1 + e \cos ASP) = l$ and is constant for all positions of P on the curve

By Theorem 5 we have $1 - e^2 = \frac{b^2}{a}$.

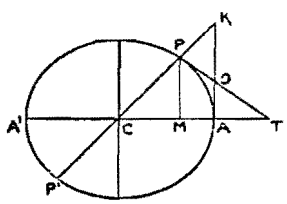
From figure, if P were at B then $SB = SP = a$, $SB = BH$

$\therefore SB + BH = SP + PH = 2SP = 2a$, which is constant for all positions of P.

$$\text{Cos } ASP = \cos BSA = \cos BSC = \frac{SC}{SB} = \frac{SC}{a} = e$$
$$\therefore (1 + e \cos ASP) = 1 + e^2 = \frac{b^2}{a}$$
$$\therefore SP(1 + e \cos ASP) = a \times \frac{b^2}{a^2} = \frac{b^2}{a} = l = \text{constant as in Theorem 4.}$$



Theorem 7.—In figure, if Tt be the tangent at P meeting the major axis produced at T, and PM a semi-ordinate, then $\frac{CT}{CA} = \frac{CA}{CM}$, thus CA is a mean proportional of CT and CM, and Tt bisects $\angle HPK$.



Theorem 8.—In figure, if P be any point, PT a tangent meeting the major axis produced at T, and AK be a tangent at the principal vertex meeting diameter P^1P produced at K, then $\triangle CAK = \triangle CPT$.

Take away the common part $CPOA$ and we have $\triangle PKO = \triangle OAT$; or, take away the common triangle CMP and the trapezium $PKAM = \triangle PMT$.

Mensuration of the Ellipse.

$$\textit{Surface area} = \pi a \,.\, b$$

$$\textit{Volume} = \pi ab \times \text{thickness}$$

$$\textit{Circumference} = 2\pi \sqrt{\frac{a^2 + b^2}{2}}$$

where a is the semi major axis
and b the semi minor axis.

Exercises.

Find the area of the following ellipses :—

1. Axes 5 and 10.
2. Axes 12 and 16.
3. Axes 6 and 7.

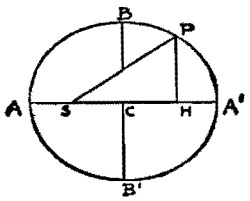
Example.—Required the length of the circumference of an ellipse whose axes are 10 and 12.

$$\text{Circumference} = \pi\sqrt{\frac{a^2 + b^2}{2}} = \frac{22}{7}\sqrt{\frac{244}{2}} = 34{\cdot}7 \text{ units.}$$

Find the circumference of the following ellipses :—

4. Axes 6 and 8.
5. Axes 4 and 6.
6. Find the weight of an elliptical steel plate 6 ft. by 4 ft. and 1 in. thick, specific gravity 7·8.
7. Find the weight of an elliptical steel plate $\frac{1}{2}$ in. thick, major axis 12 ft., minor axis 8 ft., specific gravity 7·6.

*Example.**—Given an ellipse, major axis 15 ft., minor axis 9 ft. The focal points S and H are joined by straight lines to P on the curve and PH is perpendicular to the major axis; find the area of triangle SPH.



In figure, find the sides of triangle SPH, thence its area.
Given AA^1 the major axis $= 2a = 15$ ft. $\therefore a = 7{\cdot}5$ ft.
Given BB^1 the minor axis $= 2b = 9$ ft. $\therefore b = 4{\cdot}5$ ft.

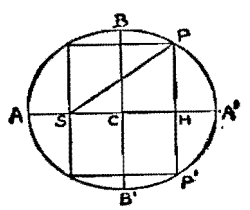
PH is half the latus rectum.

By Theorem 4. $PH = \dfrac{BC^2}{CA} = \dfrac{b^2}{a} \quad \dfrac{(4{\cdot}5)^2}{7{\cdot}5} = \dfrac{81}{30} = 2{\cdot}7$ ft.

By Theorem 2. $SP + PH = 2a = 15 \therefore SP = 15 - 2{\cdot}7 = 12{\cdot}3$ ft.
$\angle H = 90°$. $SH^2 = SP^2 - PH^2 = (12{\cdot}3)^2 - (2{\cdot}7)^2 = 144 \therefore SH = 12$ ft.
Area $\triangle SPH = \frac{1}{2}$ base $\times$ perp. ht. $= 6 \times 2{\cdot}7 = 16{\cdot}2$ sq. ft.

---

*Example.**—A square of 3 ins. has circumscribed about it an ellipse whose foci are in the sides of the square; find area of the ellipse.



The area of an ellipse $= \pi ab$; find a and b, given the sides of the square 3 ins.

$$PH = 1\tfrac{1}{2},\ PP^1 = 3,\ SH = 3.$$

$$SP^2 = PH^2 + SH^2 = \frac{9}{4} + 9 = \frac{45}{4} \therefore SP = 3{\cdot}354.$$

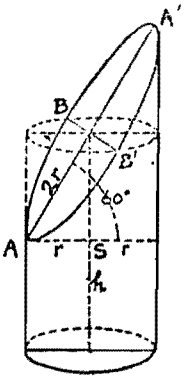
By Theorem 2. $AA^1 = 2a = SP + PH = 4{\cdot}854 \therefore a = 2{\cdot}427$.

PH is the semi latus rectum $= \dfrac{b^2}{a}$ by Theorem 4

$\therefore b^2 = a \times PH = 2{\cdot}427 \times 1{\cdot}5 = 3{\cdot}6405 \therefore b = 1{\cdot}908$.

Area $= \pi ab = \dfrac{22}{7} \times 2{\cdot}427 \times 1{\cdot}908 = 14{\cdot}55$ sq. ins.

*Example.**—The total surface area of a solid cylindrical frustum is 94·875 sq. ft. The axis is 6 ft., and the frustum is cut at an angle of 60° to the horizontal; find the diameter of the cylinder.



In figure, the height of cylinder = 6 ft. (h). ABA^1B^1 represents the cylindrical cut, $\angle A^1AS = 60°$. If r = radius of the cylinder, then the semi minor axis $\frac{1}{2}(BB^1) = b = r$ the radius of cylinder, and the semi major axis $\frac{1}{2}(A^1A) = a = 2r$.

$$AA^1 = 2a = 2r \sec 60° = 2r \times 2 \quad \therefore a = 2r.$$

The total area of the frustum, 94·875 sq. ft., is made up of

area of bottom		πr^2
area of ellipse	πab	$= 2\pi r^2$
area of curved surface . .	$2\pi rh$	$= 12\pi r$

that is, $\pi r^2 + 2\pi r^2 + 12\pi r = 94{\cdot}875$

$$\pi(3r^2 + 12r) = \text{,,}$$

$$3\pi(r^2 + 4r) = \text{,,}$$

$$\therefore r^2 + 4r = \frac{94{\cdot}875 \times 7}{3 \times 22} = 10{\cdot}0625$$

$$r^2 + 4r - 10{\cdot}0625 = 0$$

On solving this quadratic equation we get

$$r = \frac{3{\cdot}5}{2} \quad \therefore \text{ diameter of cylinder is } \underline{\underline{3{\cdot}5}} \text{ ft.}$$

*Example.**—A ship is holed 9 ft. below the waterline; the hole is elliptical, its axes being 12 ins. and 8 ins. A pump takes the water away at the rate of 7 tons per minute. The ship's hold measures 30 ft. by 20 ft. Find how long it will take the water to reach a height of 6 ft. in the hold, the density of the water being 1024.

The volume of water entering through a hole at any depth below the waterline is given by the formula $V = A\sqrt{2gh}$ cub. ft. per sec., where V = volume, A = area of hole in sq. ft., $g = 32$, h = depth below waterline.

Inflow of water in feet per min. $= \dfrac{\pi ab\sqrt{2gh} \times 60}{144}$

,, ,, ,, ,, $= \dfrac{22}{7} \times 6 \times 4 \times \sqrt{2 \times 32 \times 9} \times \dfrac{60}{144}$

,, ,, ,, ,, $= \dfrac{22 \times 6 \times 4 \times 3 \times 8 \times 60}{7 \times 144}$

,, ,, ,, ,, $= 754{\cdot}3$ cub. ft. per minute.

Pump discharges 7 tons per min. $= 7 \times 35 = 245$ cub. ft. per minute.

Water gains on pump $754 - 245 = 509$ cub. ft. per min.

$$\text{Time} = \frac{\text{Vol. of hold}}{\text{Inflow of water}} = \frac{30 \times 20 \times 6}{509} = \underline{\underline{7{\cdot}1}} \text{ minutes.}$$

NOTE.—Sea water of density 1024 = 35 cub. ft. per ton.

Exercises.

*8. A tank measuring 28 ft. × 16 ft. × 12 ft. is filled through a pipe 10 ins. in diameter in 20 minutes; find the rate of flow in feet per second.

$$\frac{\text{Capacity of tank}}{\text{Time to fill}} = \text{cub. ft. per sec.} \quad \text{Rate of flow} = \frac{\text{cub. ft. per sec.}}{\text{area of pipe}}$$

*9. A vessel is holed 16 ft. below the waterline; the hole is a rhombus in shape, the diagonals being 12 and 18 ins. The hold measures 60 ft. × 48 ft. and the centre of buoyancy is ·75. The pumps are capable of discharging $20\frac{4}{7}$ tons per minute. How long will it take the water to rise 8 ft. in the hold? Density of water 1024.

*10. An elliptical tank is 9 ft. high, the axes of the base are 12 ft. and 8 ft., the axes of the top are 9 ft. and 6 ft.; find how many gallons of fresh water it can hold.

KEPLER'S LAWS.

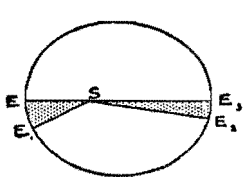
The only important application of the ellipse in nautical astronomy is the motion of the Sun in the ecliptic as enunciated in Kepler's Laws.

Assuming the Earth to travel in its orbit at a uniform speed, then it would be apparent to an observer on the Earth that he is passing the Sun faster in December when he is nearest to the Sun, than in June when he is furthest from it; that is, at an apparently decreasing speed during the first half of the year and at an increasing speed during the other half. Conversely, on reversing the relative conditions and assuming the theory that the Sun travels on the ecliptic with the Earth remaining fixed, then the Sun's motion in longitude appears to be faster in December than in June.

Kepler's First Law.—The Earth's orbit is an ellipse having the Sun in one focus.

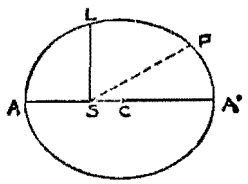
Kepler's Second Law.—The radius vector joining the Earth and Sun traces out equal areas in equal times about the Sun.

Kepler's Third Law.—If T is the sidereal period of a planet and d its distance from the Sun, then $T^2 \div d^3$ is the same for all planets.



If S be the Sun and E, E_1, E_2, E_3 successive positions of the Earth in its orbit, then area ESE_1 = area E_2SE_3 when the time taken by the Earth to travel from E to E_1 is equal to the time taken to travel from E_2 to E_3. But in nautical astronomy we assume the Sun and Earth to change places so that S becomes the Earth and E, E_1, E_2, E_3 successive positions of the Sun, in above figure.

Assume the ellipse in the following figure to represent the ecliptic, S the Earth, then CS is the eccentricity $= e = \frac{CS}{CA}$, using the same lettering as adopted throughout this chapter.



The eccentricity of the Earth's orbit may be verified approximately by a comparison of the measurable changes in the Sun's diameter. When the Sun is at A on 31st December, the angular diameter is greatest ($32' 36'' = 1956''$) because the Sun is then at its nearest distance (AS) to the Earth. The Sun is then in perigee and the Earth in perihelion. Again, when the Sun is at A^1 on 30th June, the angular diameter is least ($31' 32'' = 1892''$) for then the distance (A^1S) is greatest. The Sun is then in apogee and the Earth in aphelion.

$$\text{By Def. } e = \frac{CS}{CA} = \frac{CS}{a} \quad \therefore CS = a \,.\, e.$$

$$\text{Dist. } SA = CA - CS = a - a \,.\, e = a(1 - e)$$

$$\text{Dist. } SA^1 = CA^1 + CS = a + a \,.\, e = a(1 + e)$$

See also Theorem 5.

The diameter of the sun varies inversely as the distance, thus

$$\frac{\text{diam. at } A}{\text{diam. at } A_1} = \frac{SA^1}{SA} = \frac{a(1+e)}{a(1-e)} = \frac{1+e}{1-e} = \frac{1956}{1892} = \frac{489}{473}$$

$$\therefore e = \frac{489 - 473}{489 + 473} = \frac{16}{962} = \frac{8}{481} = \frac{1}{60}$$

which is approximately the eccentricity of the Earth and, e being very small, its orbit is almost circular.

Verification of Kepler's First Law.

In any ellipse it was shown by Theorem 6 that $SP(1 + e \cos ASP) = l$ = constant for all positions of P on the curve.

Suppose P to be at L, then $\angle ASP = 90°$, $\cos 90° = 0$, and SP then becomes SL because $e \cos 90° = 0$.

$\therefore SP(1 + e \cos ASP) = SP \times 1 = SL = l$. Theorem 6.

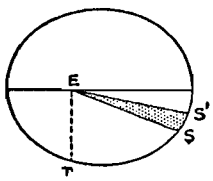
Suppose P to be at A, then $\angle ASP = 0°$, $\cos 0° = 1$, so that $e \cos ASP = e$ and $SP = SA = a(1 - e)$ as given previously.

$\therefore SP(1 + e \cos ASP) = a(1 - e)(1 - e) = a(1 - e^2) = l$. Theorem 5.

The truth of the equation being constant for all positions of P on the curve when $\angle ASP$ is known, it follows from the results of numerous observations, that if P represents the Sun travelling on the ecliptic and S the Earth at a focus, that the ecliptic is an ellipse and Kepler's First Law is confirmed.

Verification of Kepler's Second Law.

The result of observation indicates that the increase in the Sun's longitude in a day at different times of the year is inversely proportional to the square of its distance. This fact offers a method of verifying Kepler's Second Law.



If S and S^1 be positions of the Sun S on two successive days, then the arc SS^1 is the change of longitude in a day and the sector SES^1 is the area swept out in one day by the radius vector.

$$\text{Area } SES^1 = \tfrac{1}{2}\ ES\ .\ ES^1 \sin SES.$$

The angle SES^1 being small, about 1° per day, the sector SES^1 is practically equal to triangle SES^1, so we may assume $ES = ES^1$ and sin SES^1 = the angle SES^1 in circular measure without appreciably affecting the result, so the equation becomes

$$\text{Area } SES^1 = \tfrac{1}{2}\ ES^2 \times SES^1.$$

But, as stated, the change of longitude $\angle SES^1$ varies inversely as ES^2, thus $ES^2 \times SES^1$ is constant. It follows, therefore, that area SES^1 is also constant, which confirms Kepler's Second Law, viz., the area described by the radius vector in a day is constant. Also that the area swept out in any number of days is proportional to the number of days and, the general statement, that equal areas are traced out in equal times.

EXAMINATION PAPERS

PAST EXAMINATION PAPERS FOR THE EXTRA MASTER EXAMINATION.

Paper 1.—Mathematics.

4 hours.

1. Find the centre of gravity of a triangle and its perpendicular distance from the longest side, the length of the sides being 8, 7 and 5 yards.
2. A hexagonal log, sides 12 inches, is cut through at an angle of 45°. Find the area of the section.
3. Find angle A having given
$$\cot^2 A + \operatorname{cosec} A = 3.$$
4. An iron sphere 12″ in diameter and 1″ thick, find its weight in lbs., the specific gravity being 7·3.
5. The Sun rose at 7h a.m. apparent time, and its meridian zenith distance was twice the latitude; required the latitude.
6. A tank can be filled by two pipes running together in 22½ minutes; but when running separately the larger pipe would fill the tank in 24 minutes less than the smaller one; find the time taken by each.

Paper 2.—Mathematics.

1. Two ships on the same parallel of latitude are 20 miles apart. They are in touch by W/T and know they are on converging courses. A is steering S. 29° E. at 10 knots and B S. 40° W., at 9 knots. If the visibility is 5 miles, for how long will they be able to signal each other visually?
2. An elliptical tank 9 feet high and base 12 feet by 8 feet and top 9 feet by 6 feet; find the number of gallons of fresh water it can hold.
3. Solve the equation $3x + 7y = 27$, $5x + 2y = 16$.
4. Prove that if two circles intersect each other the angle subtended by any line which cuts the point of intersection and is terminated by the circumference is constant at the other point of intersection.
5. Prove that $\cos A = \dfrac{\cos a - \cos b \cos c}{\sin b \sin c}$
6. Find the length of a helix round a cylinder 12 inches in diameter and 10 feet long, there being 10 complete turns.

Paper 3.—Mathematics.

1. Find the value of ·378 to an infinite geometric progression.
2. Find the value of A which satisfies the equation
$$\operatorname{cosec}^2 A + \frac{1}{\sin A} + \frac{\sqrt{1 + \tan^2 A}}{\tan A} = 19$$

3. A ballast tank which is holed takes 2 hours to fill. A pump is put to work but fails to take effect. When the tank is three-quarters full a second pump is started, and the combined efforts of the pumps reduce the water to a half of the tank in one hour. If the second pump normally takes 70 minutes longer than the first to empty the tank, calculate how long each pump will take.

4. Find the weight of $13\frac{1}{2}$ fathoms of chain having a circular link. The outside diameter of the link is 4·5″, diameter of its cross section 1″, specific gravity of iron 7·8.

5. At a certain place, when the Sun's declination was 10° N., it rose an hour later than when it was 20° N., required the latitude.

6. Solve the equation

$$3x - 4y = 5$$
$$3x^2 - xy + 3y^2 = 27$$

Paper 4.—Mathematics.

1. (i) The sum of two numbers is 216. Find these numbers if $\frac{1}{4}$ of one number exceeds $\frac{1}{3}$ of the other by 5.

   (ii) Two ships A and B leave ports 4320 miles apart at the same instant. A does a certain number of miles daily and B this number + 60 miles daily. If the number of days before the ships meet is $\frac{1}{30}$ of the speed of B in miles per day, find the number of days until they meet.

2. What is an arithmetical mean? If the angles of a quadrilateral are in arithmetical progression and the larger and smaller angles are in the radio of 17 to 8, find the value of the angles.

3. What is the latitude of an observer who observes that the stars Alioth and Deneb are at their maximum azimuth, one east and one west of his meridian at the same instant?

4. In triangle ABC, if $C = 90°$ prove

   (i) $$\frac{\cos 2B - \cos 2A}{\sin 2A} = \tan A - \tan B$$

   (ii) Find value of θ if $4\sqrt{3} \cot \theta = 7 \operatorname{cosec} \theta - 4 \sin \theta$.

5. The surface area of a solid circular cylinder frustum is 100 sq. ft., its axis is 4 ft. and the angle of the cut section is 60° with the horizontal. Find diameter of the frustum.

Paper 5.—Mathematics.

1. A sphere 14″ in diameter is partially submerged in F.W. and displaces 1078 cubic inches. When a spherical sector (solid angle 39°) is removed and replaced by some other material the sphere just submerges. Find the specific gravity of the material.

2. If a fly-wheel, circumference $14\frac{2}{3}$ feet, takes one second more per revolution, a spot on the rim will do $2\frac{2}{3}$ miles less per hour. Find circumferential speed of the fly-wheel.

3. A vessel steers westwards on a G.C. from 25° N., 120° W., to 58° N. If the D. Long. = G.C. Dist., find Long. of arrival and the final course.

4. (i) Prove formula for arithmetical progression to the nth term.
   (ii) Two masts 120 ft. apart have a wire stay between them, secured at an equal height below each truck. From the mid-point the wire rises 1 inch in the 1st fathom, 2 more inches in the 2nd fathom, 3 more in the 3rd fathom, and so on. Find the height of wire on mast above the mid-point.

5. (i) Prove $\tan A \tan 2A = \sec 2A - 1$.
   (ii) $2 \cos \theta = 3 \sec \theta + 2$.

6. Celestial Lat. 4° 52′ 41·5″ S., celestial Long. 246° 42′, is the position of a star obliquity of ecliptic 23° 28′. Find star's R.A. and Decl.

Paper 6.—Mathematics.

1. In a right angled triangle ABC the hypotenuse is trisected at D and E. Prove that the sum of the squares on the sides of the triangle CDE is equal to two-thirds AB^2.

2. Draw figure showing a spherical triangle as it would appear on a sphere and also the polar triangle. Deduce their relationship and give an example of where used in spherical trigonometry.

3. Find the greatest angle in a plane triangle whose sides are $x^2 + x + 1$, $2x + 1$ and $x^2 - 1$.

4. (i) Prove $(\sin A - \sin B)^2 + (\cos A - \cos B)^2 = 2 \text{ vers } (A - B)$.
   (ii) Solve $\tan^2 A - \sin^2 A = 2{\cdot}25$.

5. Find the celestial Lat. and Long. of a star Decl. 26° 16·7′ S., R.A. 16h 25m 5s.

6. A ship sailing 270° sights a point bearing 000°. After steaming 2 hours a point B due west of A and distant 29·985 miles bore 311°, and after steaming another 2 hours B bore 030°. Find ship's speed.

Paper 7.—Navigation (Extra Master).

3 hours.

1. Calculate the maximum rate of change of azimuth of the star a Capella on June 21st in Lat. 55° 30′ N.

2. Explain the principle of the gyro compass and describe the errors.

3. What is meant by the equation of equal altitudes? Deduce the equation.

4. What are tides? Draw a figure showing the more important factors, neglecting the diurnal rotation of the earth.

5. In a certain place where the declination is twice the latitude, the Sun rose at 6h 15m a.m. What is the latitude?

6. Calculate the true angular distance between two bodies if the line of collimation be inclined 1° to the plane of the sextant and the observed angle were 150°.

Paper 8.—Navigation.

1. Prove the formula,
   Dip of sea horizon = $\cdot 98\sqrt{\text{height}}$ of eye in feet above sea level.
2. Prove the conclusion that an error in hour angle due to an error in altitude is least when the body is on the prime vertical.
3. Explain the principle of the sounding tube used in the Kelvin sounding machine. What precautions must be taken with the boxwood scale?
4. Find the time of visible moonrise on Jan. 9, in Lat. 34° N., Long. 144° W.
5. Write briefly what the Harmonic Tidal Constants are and what the letters and suffixes denote.
6. A point in Lat. 50° 44′ N., Long. 0° 15′ E., bore 45° on port bow at 22h 20m and at 23h 27½m it was abeam. Course 195°, speed 8 knots, wind north, leeway 4°, tidal stream west (magnetic) 2½ knots, var. 14° W. Find the distance off on beam bearing and the ship's position.

Paper 9.—Navigation.

1. Investigate the formula governing the rate of change of altitude of a heavenly body and show that such change is greatest when the body is on the prime vertical.
2. Explain the principle of the sextant vernier, and show how an arc cut to 10′ can be read to 10″.
3. Describe in detail the 1st correction in Norie's Ex-meridian Table.
4. Investigate the conclusion that the error in longitude of a position line is equal to the error in the intercept caused by an incorrect G.M.T.
5. What is "precession" in a gyro compass? Give the rules governing precession of a freely mounted gyro.
6. A ship steered 050° for 1000 miles from Lat. 50° S., Long. 70° E.; required the position reached.

Paper 10.—Navigation.

1. Sept. 24th, D.R. 10° 35′ S., 67° 15′ E., course 325°, speed 12 knots. The Sun had equal altitudes when the chronometer times were 06h 56m 20s, and 07h 46m 24s, but slow 02m 20s on G.M.T. Find the longitude.
2. At noon when the Sun's declination was 15° N. a post cast a shadow x feet long, and when the Sun was 15° S. the shadow was $4x$ feet in length. Find the latitude.
3. When observing simultaneous altitudes for position lines in Lat. 35° S. (approx.) the index error + 3′ was applied the wrong way to the first altitude. If the Sun's true bearing at 1st obs. was 160° and at 2nd obs. 220°, required the errors of latitude and longitude.

4. At what height above the earth's surface will the time of sunrise be accelerated by 4 minutes on March 21st in Lat. 64° 40′ N.
5. Give a brief description of wireless navigational instruments and methods.
6. Prove that the distance of the sea horizon is $1{\cdot}06\ \sqrt{h}$. Under what conditions will it be $1{\cdot}15\ \sqrt{h}$?

Paper 11.—Navigation.

1. Dec. 23rd, in Lat. 25° 40′ S., Long. 179° 10′ W., sext. alt. Vega 18° 14′, G.M.T. 24d 02h 41m 47s. Ship steamed 245° for 80 miles. Sext. alt. Aldebaran 20° 50′, G.M.T. 24d 06h 41m 41s. Index error 2′ off arc, eye 37 feet. Find ship's position.
2. Dec. 24th, at 03h 30m G.M.T. in Lat. 22° 40′ S., Long. 45° 10′ W. Eye 33 feet, index error 1′ on arc, variation 18° W., deviation 17° E. Calculate the sextant altitude and bearing by compass of Rigel.
3. June 16th, D.R. position Lat. 40° 10′ N., Long. 30° 40′ W., Altair had equal altitudes when chronometer showed 01h 50m 41s star East, and 07h 09m 49s star West. Find the error of chronometer.
4. Two stars have equal declinations but opposite names and differ by 12 hours right ascension. Show that at any instant at a given place the rates of change of altitude of the two stars is numerically equal.
5. Calculate the Moon's augmentation having given the apparent altitude of the Moon's centre 51°, horizontal parallax 54′ 36″ and semi-diameter 14′ 54″.

Paper 12.—Navigation.

1. Find the G.M.T. of astronomical sunset and duration of twilight in Lat. 30° 40′ N., Long. 3° 30′ W., on the longest day in the year.
2. A man cast away in the North Atlantic has no *Nautical Almanac*. His height above sea level is 6 feet and he observes a star rising. Later the star has an altitude of 20° 30′ 30″ and bears E.S.E. magnetic. If the star's amplitude was E. ½ S. magnetic and the variation was 22½ W., find the latitude of the observer.
3. South latitude, cloudy weather in a partial clearance two stars were seen on the same bearing west of the meridian. Star *X*, R.A. 20h 00m 00s, Decl. 24° 45′ 30″, true alt. 13° 45′. Star *Y*, R.A. 20h 45m 00s, Decl. 36° 53′ 00″, hour angle 6h 00m west of the meridian. Required the latitude.
4. Find the terrestrial positions of Jupiter (J.) and Saturn (S.) on Jan. 10th, 00h 00m G.M.T. Then find the great circle distance from J. to S., also the initial course. Find also the Mercator course from J. to S. Explain why these two courses differ.
5. The Sun rose at 04h 06m and set at 20h 04m ship mean time. Find the equation of time.
6. In North latitude, the semi-diameter 16′ was not applied to the Sun's lower limb at 1st observation, the azimuth being 065°. It was applied however, to the altitude at the 2nd observation when the azimuth was 140°. Find the resulting error in latitude.

[illegible]

[illegible]

[illegible]

ANSWERS

Plane; Parallel; Mercator and Traverse Sailings. Page 8.

1. 3725 miles to Lat. 18° 05′ N. or 1554 to Lat. 18° 05′ S.
2. Latitudes 34° 41·9′ and 34° 07·1 N. or S., distance 201 miles.
3. Latitude 61° 23′ N.
4. Latitude 51° 22′ S., distance 983·8 miles.
5. Latitude 20° 36·5′ S., distance 1427 miles.
6. Distance 421·7 miles.
7. Longitude 62° 30·3′ W.
8. Course 209° 45·4′ T., distance 400·8 miles.
9. Speed 10·29 knots.
10. Course 350° T., speed 15·25 knots.
11. Lat. 39° 46·8′ N., Long. 167° 37·2′ W.
12. Lat. 39° 17·2′ S., Long. 87° 57·5′ E.
13. Course 074° 56·3′ T., distance 2761 miles, time of arrival May 20d 04h 19m.
14. Course 161° T., distance 186 miles. Time of arrival G.M.T. 09h 30m on the 12th.

Answers to Four Point Bearings with Leeway and Current.

Bow and Beam Bearings with Current. Page 10

	Course and distance made good		Beam distance	Position				
1.	220° T.	10 miles	10 miles	50°	48·5′	N.	1° 10·5′	E.
2.	091·5	7·9 miles	10·2 miles	50	45·3	N.	1 04	E.
3.	104	6·5 miles	7·7 miles	50	36·3	N.	0 14·5	E.
4.	210	7·2 miles	8·8 miles	50	54·5	N.	1 21·5	E.
5.	169·5	6·7 miles	9·2 miles	51	05·3	N.	1 36·3	E.
6.	338	6·7 miles	8·5 miles	51	28	N.	1 37·2	E.
7.	Brg. 060	5 miles from Flamborough Head		54	09·5	N.	0 02·7	E.
8.	,, 218	9·9 miles from Needles Light		50	31·9	N.	1 44·9	W.
9.	46° 53·5′ N.	175° 56·6′ E.						
10.	349° 50′ T.	15·25 knots.						
11.	284° 48′ T.	24h 30m.	15·98 knots.					
12.	298 miles	12·67 knots.						
13.	51° 19′ N.	9° 53′ W.						

CHAPTER II.

Deviation Curves. Page 15.

1. Bearing 236° Magnetic.
   Deviations—21° W. 10° W. 2° W. 4° E. 20° E. 23° E. 5° E. 17° W.
   Courses—315° C. 149° C. 307° C. 135° C.
   Courses—007° M. 062° M. 225° M. 267° M.
   Bearings—137° M. 329° M.
2. Bearing 172° Magnetic.
   Deviations—12° E. 18° E. 10° E. 6° W. 10° W. 14° W. 9° W. 3° W.
   Courses—009½° C. 294½° C.
   Courses—072° M. 224° M. 326° M. 009° M.
   Bearings—036° M. 306° M.
3. Bearing—North Magnetic.
   Deviations—3° W. 17° E. 20° E. 15° E. 3° E. 9° W. 21° W. 22° W.
   Courses—097° M. 254° M.
4. Deviations—3·1° W. 9·6° W. 10·0° W. 5·5° W. 3·1° E. 9·6° E. 10·2° E. 2·9° E.

Day's Work. Page 37.

1. Lat. 48° 40½′ N., Long. 177° 07′ E. 302° T. 190 miles.
2. Current 320° T. 2·5 knots.
   Steer 243° T., 258° C.
   Speed 12·3 knots.
3. Lat. 48° 01·2′ N., Long. 5° 18′ W.
4. Lat. 48° 58′ N., Long. 5° 50′ W.
5. Lat. 44° 07′ N., Long. 176° 18′ E. D.R. position at noon. Course 224° T. 268·5 miles.
   Set and drift 292° T., 14 miles in 20 hrs. = 16·8 miles in 24 hrs.
6. Lat. 55° 15′ N., Long. 5° 01′ W. 094° 3 miles.
7. Set and drift 065° T., 30 miles Course 100° T. 95 miles.
8. Lat. 19° 42′ S., Long. 51° 08·3′ W.
9. Lat. 29° 53′ S., Long. 23° 21′ W. 2nd obs.
   Lat. 29° 53′ S., Long. 23° 17·6′ W., at noon.
10. D.R. at 8 p.m. Lat. 24° 15·3′ S., Long. 4° 23·3′ E.
    At noon. Lat. 22° 33′ S., Long. 4° 27·5′ E.
    Set and drift in 8 hrs. 198° T., 15·5 miles.
    Course 028·5° T. 167·5 miles. Speed 7·0 knots.

Radar Plotting. Page 77

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., spd. 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 mins.
   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 mins. 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 mins. 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., 4 knots.
    (*c*) Course 146° T., speed 10 knots, she will cross 1·6 miles ahead before I pass the Lt. Vessel.

CHAPTER III.

Great Circle Sailing. Page 87.

1. Initial course 249° 50′ T., final course 218° 26′ T., distance 3433·7 miles, latitude of vertex 52° 44′ N., longitude of vertex 20° 28′ E.
   Position of points on Great Circle:—Long. 15° 12′ W., Lat. 46° 53′ N. Long. 25° 12′ W., Lat. 42° 34′ N. Long. 35° 12′ W., Lat. 36° 33′ N. Long. 45° 12′ W., Lat. 28° 26′ N. Long. 55° 12′ W., Lat. 18° 1′ N.
2. Initial course 309° 12·7′ T., final course 272° 51·5′ T., distance 2269·4 miles, latitude of vertex 51° 43·5′ N., longitude of vertex 166° 21·5′ E.
   Position of points:—Long. 150° W., Lat. 42° 31·4′ N. Long. 160° W., Lat. 46° 32′ N. Long. 170° W., Lat. 49° 15·5′ N. Long. 180°, Lat. 50° 55·4′ N.
3. Initial course 060° 00′ T., final course 046° 28′ T., distance 3913·9 miles, latitude of vertex 44° 8′ S., longitude of vertex 20° 23′ W.
   Position of points:—Long. 35° 30′ E., Lat. 28° 33′ S. Long. 45° 30′ E., Lat. 21° 37′ S. Long. 55° 30′ E., Lat. 13° 19′ S. Long. 65° 30′ E., Lat. 3° 59′ S. Long. 75° 30′ E., Lat. 5° 41′ N.
4. Initial course 093° 16·5′ T., final course 056° 04·5′ T., distance 4975 miles, latitude of vertex 34° 30′ S., longitude of vertex 24° 16½′ E.
   Position of points:—Long. 34° 16½′ E., Lat. 34° 5½′ S. Long. 44° 16½′ E., Lat. 32° 51½′ S. Long. 54° 16½′ E., Lat. 30° 45½′ S. Long. 64° 16½′ E., Lat. 27° 46′ S. Long. 74° 16½′ E., Lat. 23° 50′ S. Long. 84° 16½′ E., Lat. 18° 58′ S. Long. 94° 16½′ E., Lat. 13° 13½′ S. Long. 104° 16½′ E., Lat. 6° 48½′ S.
5. 049° 48′ T., 091° 23′ T., 2809¾ miles. Vertex 49° 46′ N., 7° 00½′ W. Points 55° W., 38° 20½′ N., 45° W., 42° 58′ N.; 35° W., 46° 13½′ N.; 25° W., 48° 21′ N.; 15° W., 49° 29½′ N.
6. 237° 49′ T., 217° 05′ T., 2317 miles. Vertex 55° 49½′ N., 83° 11′ W. Points 135° W., 42° 19′ N.; 145° W., 34° 49½′ N.; 155° W., 24° 41′ N.
7. 121° 25·3′ T., 108° 03·3′ T., 5939 miles. Vertex 36° 41½′ S., 40° 45½′ W. Points 140° W., 6° 49½′ N.; 120° W., 7° 55½′ S.; 100° W., 20° 51½′ S.; 80° W., 29° 59½′ S.
8. 071° 19·5′ T., 116° 58′ T., 3154·5 miles. 43° 51½′ N., 46° 26′ W. Points 60° W., 43° 3′ N.; 50° W., 43° 48′ N.; 40° W., 43° 40½′ N.; 30° W., 42° 40′ N.; 20° W., 40° 42½′ N.; 10° W., 37° 42½′ N.
9. 068° 18·3′ T., 111° 41·7′ T., 3141½ miles. Vertex 42° 02′ N., 42° 30′ W. Points 67° 30′ W., 39° 15′ N.; 55° 00′ W., 41° 21′ N.; 30° 00′ W., 41° 21′ N.; 17° 30′ W., 39° 15′ N.
10. 209° 45′ T., 219° 56′ T., 3619 miles. Vertex 60° 48½′ S., 6° 05′ W. Points 85° 00′ E., 1° 56′ N.; 80° E., 6° 59′ S.; 75° E., 15° 31′ S.; 70° E., 23° 18′ S.; 65° E., 30° 08′ S.; 60° E., 35° 58′ S.

Composite Sailing. Page 92.

1. Initial course 241° 12·2′ T., final course 304° 29·5′ T., distance on first great circle 1358·25 miles' distance on second great circle 1725·42 miles, Longitude where track meets the maximum Latitude 111° 51′ 10″ W., Longitude where track leaves the maximum Latitude 145° 29′ 58″ W., distance along parallel of maximum Latitude 1157·94 miles, total distance 4241·61 miles.

First point in Long.	80°	W. is	31°	51′	10″	from vertex, and is in Lat.	50°	29′	58″ S.
Second point in Long.	90	W. is	21	51	10	from vertex, and is in Lat.	52	58	7 S.
Third point in Long.	100	W. is	11	51	10	from vertex, and is in Lat.	54	25	4 S.
Fourth point in Long.	110	W. is	1	51	10	from vertex, and is in Lat.	54	59	9 S.

The points in Longitudes 120°, 130° and 140° W. are on the parallel of maximum latitude.

Eighth point in Long.	150°	W. is	4°	30′	2″	from vertex, and is in Lat.	54°	55′	0″ S.
Ninth point in Long.	160	W. is	14	30	2	from vertex, and is in Lat.	54	7	26 S.
Tenth point in Long.	170	W. is	24	30	2	from vertex, and is in Lat.	52	25	19 S.
Eleventh point in Long.	180	W. is	34	30	2	from vertex, and is in Lat.	49	38	51 S.

2. Initial course 060° 30·1′ T., final course 116° 30·3′ T., distance on first great circle 2067·22 miles, distance on second great circle 1794·8 miles, longitude in which the track meets maximum Latitude 174° 51′ 51″ W., longitude in which the track leaves maximum Lat. 161° 48′ 00″ W., distance along parallel of maximum Latitude 554·27 miles, total distance 4416·29 miles.

First point in Long.	150°	E. is	35°	8′	9″	from vertex, and is in Lat.	39°	16′	34″ N.
Second point in Long.	160	E. is	25	8	9	from vertex, and is in Lat.	42	9	17 N.
Third point in Long.	170	E. is	15	8	8	from vertex, and is in Lat.	43	59	20 N.
Fourth point in Long.	180	E. is	5	8	9	from vertex, and is in Lat.	44	53	5 N.

The fifth point in Longitude 170° W. is on the parallel of maximum latitude.

Sixth point in Long.	160°	W. is	1°	48′	0″	from vertex, and is in Lat.	44°	59′	9″ N.
Seventh point in Long.	150	W. is	11	48	0	from vertex, and is in Lat.	44	23	17 N.
Eighth point in Long.	140	W. is	21	48	0	from vertex, and is in Lat.	42	52	4 N.
Ninth point in Long.	130	W. is	31	48	0	from vertex, and is in Lat.	40	21	39 N.

3. 133° 04·5′ T. East, 2329 mls.+1921 mls.=4250 mls. Vertex 56° 10′ S., 124° 41′ W. Pts. 170° W., 46° 22′ S.; 160° W., 50° 36′ S.; 150° W., 53° 26½′ S.; 140° W., 55° 12′ S.; 130° W., 56° 3′ S.; 120° W., 56° 10′ S.
4. 113° 29·5′ T., 050° 03′ T., 1284 mls.+2679½ mls.+1149 mls.=5112½ mls. Vertex 158° 25′ W. Vertex 128° 37′ W. Pts. 180°, 47° 56½′ S.; 170° W., 49° 25′ S.; 160° W., 49° 59½′ S.; 4th, 5th, 6th pts. in 50° S.; 120° W.; 49° 41′ S.; 110° W., 48° 28½′ S.; 100° W., 46° 17½′ S.; 90° W., 42° 57½′ S.; 80° W., 38° 14′ S.

Gnomonic Chart. Page 92.

1. Belle Isle to The Naze (Composite Track).

Long.			Lat.		
50°	W.		54°	20′	N.
,, 45	W.		,, 56	00	N.
,, 40	W.		,, 57	25	N.
,, 35	W.		,, 58	30	N.
,, 30	W.		,, 59	20	N.
,, 5	W.		,, 59	42	N.
,, 0	W.		,, 59	10	N.
,, 5	E.		,, 58	20	N.

2. Sable Island to Lisbon (Great Circle).

Long.		Course	
50°	W.	087°	T.
,, 40	W.	,, 093	T.
,, 30	W.	,, 100	T.
,, 20	W.	,, 107	T.
,, 10	W.	,, 115	T.

CHAPTER III.

Great Circle Sailing. Page 97.

No.	Initial Course	Final Course	Dist. miles	Vertex	Points
	° ′	° ′		° ′ ° ′	° ′ ° ′ ° ′
1	288 45·3 T.	307 50 T.	3359	38 08 S. 49 33 E.	31 11¼ S. 27 00 S. 21 42 S. 15 20½ S. 8 06½ S.
2	064 58	092 02·7	1411	51 25 N. 12 15 W.	47 57½ N. 49 08 N. 50 2½ N. 50 43 N. 51 09½ N. 51 23 N. 51 23¾ N.
3	293 36	247 52	3323	42 14 N. 41 54½ W.	
4	079 38	055 35	2962	37 30½ S. 73 47 W.	
5	083 21·7	123 22	2466	48 46 N. 170 16 E.	48 46 N. 48 21½ N. 47 03 N. 44 45 N. 41 17½ N.
6	101 12	059 41	4224	35 47 S. 45 29 E.	
7	114 15·5	040 33·2	5764	50 31 S. 157 5½ W.	48 11½ S. 50 29 S. 49 14½ S. 44 4½ S. 33 24 S. 15 10 S.
8	110 48·5	040 14·5	3516	58 56½ S. 43 00 W.	
9	113 52	076 08	3654	34 35 S. 90 33 E.	29 17 S. 33 35 S. 34 30 S. 32 6½ S.
10	292 56	254 00	1825	53 33½ N. 35 29 W.	51 10 N. 53 00 N. 53 33½ N. 52 54 N.
11	235 34	272 50	4930	35 1 S. 24 56 E.	21 52 S.
12	295 07·5	253 23·5	2948	42 50½ N. 45 8¾ W.	37 10 N. 40 01 N. 41 50 N. 42 43½ N. 42 44½ N. 41 52 N.
13	113 30	050 03	1284 2679½ 1149	158 25 W. 128 37 W.	47 56½ S. 49 25 S. 49 59½ S. 49 41 S. 48 28½ S. 46 17 S. 42 57½ S. 38 14 S.
14	133 04·5	090 00	2329 1921	56 10 S. 124 41 W.	46 22 S. 50 36 S. 53 26 S. 55 12 S. 56 03 S. 56 10 S.
15	139 50·5	066 38·5	2590½ 866½ 624	118 03 W. 97 15 W.	
16	142 23	067 14·5	2911½ 840½ 519½	113 50½ W. 96 32 W.	

CHAPTER IV.

SECONDARY PORT TIDE CALCULATIONS

EXERCISE 1. (p. 124)

	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 (US)	1140	6·9	0545	0·7
	—	—	1815	0·3

EXERCISE 2. (p. 124)

1. 3·1 m (2) 0·8 m (3) 0·6 m
4. 0235 0833 1641 2200
5. 0633 1154 1857

EXERCISE 3. (p. 124)

1. Kildala	HW	0708	3·6 m	HW	2023	3·5 m
	LW	0109	2·0 m	LW	1349	1·2 m
2. Namu Harbour	HW	0719	3·6 m	HW	2034	3·5 m
	LW	0114	1·9 m	LW	1354	1·1 m

EXERCISE 4. (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.	HW	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.

CHAPTER VI.

Stars on the Meridian. Page 147.

		Upper				Lower				Altitude
		d	h	m	s	d	h	m	s	
1.	L.M.T.	8	05	17	03	8	17	15	05	24° 52′
2.	,,	22	04	03	51	22	16	01	53	Not visible
3.	,,	20	18	40	54	20	06	42	52	8 45
4.	,,	22	22	41	44	22	10	43	42	17 37
5.	,,	17	22	50	17	17	10	52	15	Not visible
6.	,,	19	04	41	32	19	16	39	34	Not visible

Stars Near the Meridian. Page 151.

1.	S.H.A. Observer's Meridian 193° 13′				
	Regulus	has crossed meridian	North	L.H.A.	15° 15′
	Denebola	will cross meridian	North	E'ly H.A.	9° 57′
	Acrux	,, ,, ,,	South	,,	19° 18′
	Gacrux	,, ,, ,,	South	,,	20° 26′
2.	S.H.A. Meridian 115° 26′				
	Rigil Kent	has crossed	South	L.H.A.	25° 22·4′
	Antares	will cross meridian	South	E'ly H.A.	2° 09′
	Atria	,, ,, ,,	South	,,	6° 30′
	Shaula	,, ,, ,,	South	,,	18° 08′
3.	S.H.A. Meridian 67° 51′				
	Altair	will cross meridian	North	E'ly H.A.	5° 03′
	Peacock	,, ,, ,,	South	,,	13° 28′
	Canopus	crossed lower meridian	South	,,	16° 57′
4.	S.H.A. Meridian 17° 20′				
	Fomalhaut	will cross meridian	North	E'ly H.A.	1° 10′
	Ankaa	,, ,, ,,	North	,,	23° 23′
	Achernar	,, ,, ,,	South	,,	41° 22′
	Avior	crossed lower meridian	South	E'ly H.A.	37° 15′
	Suhail	,, ,, ,,	South	,,	26° 03′
	Miaplacidus	,, ,, ,,	South	,,	24° 29′
5.	S.H.A. Meridian 350° 43′				
	Alpheratz	has crossed meridian	North	L.H.A.	7° 43′
	Diphda	will cross meridian	North	E'ly H.A.	1° 06′
	Achernar	,, ,, ,,	South	,,	14° 46′
	Acrux	crossed lower meridian	South	,,	3° 13′
	Gacrux	,, ,, ,,	South	,,	2° 04′
6.	S.H.A. Meridian 276° 01′				
	Betelguese	will cross meridian	North	E'ly H.A.	4° 15′
	Canopus	,, ,, ,,	South	,,	11° 46′
	Sirius	,, ,, ,,	North	,,	16° 5′

Meridian Altitudes. Page 161.

MOON.

	G.M.T.	Decl.	Altitude	Latitude
1.	5d 20h 56m	17° 55·4′ N.	41° 48·3′	30° 16·3′ S.
2.	21 23 36·5	13 47·8 N.	55 50·9	47 56·9 N.
3.	23 11 32·6	1 12·9 N.	59 56·5	28 50·6 S.
4.	19 21 06	18 41·8 S.	29 26·1	41 52·1 N.
5.	24 21 22	5 15·4 S.	34 33	50 11·6 N.

PLANETS. Page 163.

	G.M.T.	Decl.	Altitude	Latitude
1.	21d 05h 11m	21° 53·7′ S.	36° 43·9′	31° 22·4′ S.
2.	10 17 03·3	10° 11·0′ S.	40° 30·6′	39° 18·4′ N.
3.	20 01 59·7	1° 33·2′ N.	62· 22′	—
4.	22 22 03·8	18° 28·1′ N.	62° 10·4′	—
5.	8 05 12	13° 37·6′ S.	58° 08·3′	18° 14·1′ N.

CHAPTER VII

Latitude by Pole Star. Page 165.

1.	Latitude 45° 50·9′ N.	Azimuth 359·1° T.	4.	Latitude 60° 29·6′ N.	Azimuth 001·5° T.
2.	,, 35° 24·3′ N.	,, 001° T.	5.	,, 43° 00·0′ N.	,, 359·3° T.
3.	,, 50° 40·0′ N.	,, 001·2° T.	6.	,, 35° 49·2′ N.	,, 358·8° T.

SUN. Position Lines and Ex-Meridian Sights. Page 182.

1. (i) At 0935 D.R. Lat. 34° 48′ S., Long. 163° 44′ E.
   (ii) At 1135 D.R. Lat. 34° 50′ S., Long. 163° 51·2′ E.
   (iii) L.H.A. 352° 37·4′. Decl. 23° 19·4′ N. Calc. *Z*. Dist. 58° 34·6′. True *Z*. Dist. 58° 31·5′. Intercept 3·1′ towards True Az. 008° T. *C* to *F* 306° T., 6·6 miles, Obs. Posn. 34° 46·1′ S., 163° 18·1′ E.
2. (i) At 1000, D.R. Lat. 49° 00′ N., Long. 128° 04·2′ W.
   (ii) At 1220, D.R. Lat. 48° 26·5′ N., Long. 128° 37·4′ W.
   (iii) L.H.A. 4° 50·6′. Decl. 23° 23·2′ N. Calc. *Z*. Dist. 25° 20·9′. True *Z*. Dist. 25° 26·3′, Intercept 5·4′ away. Az. 190·4° T., Obs. Posn. 48° 31·3′ N., 128° 32·0′ W.
3. (i) At 1220 L.H.A. 5° 42′. Decl. 23° 26·5′ N. Calc. *Z*. Dist. 23° 02·5′. True *Z*. Dist. 23° 01·3′. Intercept 1·2′ towards. Az. 193·5° T. Intercept Terminal Point 45° 54·8′ N., 35° 11·6′ E.
   (ii) At 1550 D.R. Lat. 46° 23·3′ N., Long. 36° 01·7′ E.
   (iii) *C* to *F* 104° T., 5·3 miles. Obs. Posn. 46° 22′ N., 39° 09·2′ E.
4. (i) At 1150 L.H.A. 357° 30·8′, Decl. 22° 22·6′ S., Calc. *Z*. Dist. 33° 58·3′. True *Z*. Dist. 33° 47·3′. Intercept 11′ towards. Azimuth 004° T. Int. Terminal Pt. Lat. 56° 07′ S., Long. 67° 20·5′ W.
   (ii) D.R. Position Lat. 56° 44·7′ S., Long. 66° 32·4′ W.
   (iii) *C* to *F* 096° T., 8·6 miles. Obs. Posn. Lat. 56° 45·3′ S., Long. 66° 16·6′ W.

Stars' Planets and Moon. Page 184.

1. Ex-meridian L.H.A. 3° 56·7′, M.Z.D. 48° 26·7′, Lat. 14° 25·1′ S., Azimuth 182·3° T., Posn. Line 092°-272° T.
2. Ex-meridian L.H.A. 003° 04·7′, M.Z.D. 39° 53′, Lat. 48° 36·6′ N., Azimuth 184·6° T., Posn. Line 094·6°-274·6° T. Intercept method 4·5′ away. (i) 48° 38·5′ N., 155° 30·6′ E. (ii) 49° 06·4′ N., 156° 00·6′ E.
3. Intercept 3·7 towards Azimuth 188° T. L.H.A. 6° 28·8′. Posn. Line 098°-278° T. (i) 36° 24·4′ N., 127° 41·5′ W. (ii) 35° 49′ N., 128° 29·5′ W.
4. Ex-meridian L.H.A. 354° 38·4′; M.Z.D. 39° 43·5′; Lat. 38° 19·7′ S., Azimuth 008° T., P.L. 098°-278° T.
5. Ex-meridian L.H.A. 3° 32·9′; M.Z.D. 42° 48′; Lat. 30° 17·7′ N. Azimuth 185° T. P.L. 095°-275° T.
6. L.H.A. 352° 54·2′; M.Z.D. 46° 26·2′; Lat. 36° 31·1′ S. Azimuth 010° T. P.L. 100°-280° T. or Intercept method 3·2′ away.
7. Intercept method L.H.A. Mars 357° 01·4′; Obs. Z.D. 40° 39·7′, Intercept 3·2′ away, Azimuth 004·5° T.; P.L. 094·5-274·5° T. L.H.A. Sun 310° 38·9′; Obs. Z.D. 78° 44·6′; Intercept 3·2′ away, Azimuth 04·5° T., P.L. 135°-315° T. 2nd D.R. position 40° 38·3′ S., 158° 29·2′ E. Fix 40° 38′ S., 158° 22·7′ E.
8. Intercept method; L.H.A. 2° 25·1′, Intercept 3·1′ away, Azimuth 185° T., P.L. 095°-275° T. (i) Lat. 12° 21′ N., Long. 62° 12·3′ E. (ii) Lat. 12° 20·7′ N., Long. 61° 22·3′ E.
9. Intercept method L.H.A. 3° 32·9′, T.Z.D. 42° 56·2′, Intercept 2·4′ towards, Az. 185° T. P.L. 095°-275° T. Int. Pt. 30° 17·7′ N., 100° 49·7′ E. 2nd D.R. Lat. 29° 47′ N., Long. 101° 32·2′ E. L.H.A. 63° 45·1′. T.Z.D. 74° 15·4′. Int. 3·5′ away. Azimuth 246° T. P.L. 156°-336° T. Fix 29° 46·5′ N., 101° 36·8′ E.
10. Intercept method L.H.A. 3° 41·2′. Int. 4·3′ towards. Az. 182° T. P.L. 092°-272° T. Int. Pt. 0° 28·2′ S., 26° 42·2′ W. (i) L.H.A. 309° 35·9′. Int. 8·3′ towards. Az. 100° T. P.L. 010°-190° T. Int. Pt. 0° 25·4′ S., 26° 34′ W. Fix 0° 28·6′ S., 26° 34·5′ W.
11. Intercept method Mars L.H.A. 5° 22·6′, T.Z.D. 38° 33·1′, Intercept 4·5′ away. Azimuth 188° T. P.L. 098°-278° T. Pollux L.H.A. 307° 33′, T.Z.D. 46° 12·5′, Intercept 7·0′ towards. Azimuth 105° T. P.L. 015°-195° T. Fix 56° 18·3′ N., 143° 40′ E.
12. Intercept method. Jupiter L.H.A. 59° 18·6′, T.Z.D. 73° 23·7′, Intercept 2·9′ towards, Azimuth 241° T. P.L. 151°-331° T., Moon L.H.A. 340° 35·2′, T.Z.D. 56° 17′. Intercept 3·3′ towards, Azimuth 157° T., P.L. 067°-247° T. Fix Lat. 36° 16′ N., Long. 18° 45·7′ W.

Simultaneous and Double Altitudes. Page 186.

		LHA	Intercept	Bearing	2nd DR and Fix	
1.	(*a*)	319° 04·3′	1·6 Towards	052° T		
	(*b*)	311° 32·4′	4·5 ,,	135°	32° 14·4′ S	80° 42·6′ E
2.	(*a*)	25° 40·3′	2·0 ,,	210·5°		
	(*b*)	59° 30·8′	1·0 ,,	315·5°	11° 14·1′ N	32° 20·4′ W
3.	(*a*)	001° 16′	4·9 Away	184°		
	(*b*)	322° 39·7′	2·7 Towards	095°	38° 08·7′ N	57° 14·2′ W
4.	(*a*)	21° 13·1′	3·0 Away	222°		
	(*b*)	325° 35·8′	2·4 Towards	134°	42° 40·5′ N	171° 17′ E
5.	(*a*)	346° 12·7′	2·0 Away	156°		
	(*b*)	28° 07·1′	3·7 Towards	283°	13° 58·6′ N	78° 15·7′ W
6.	(*a*)	0° 00·1′	3·5 ,,	000°		
	(*b*)	298° 14·3′	3·5 Away	116°	13° 59·5′ S	88° 07·3′ W
7.	(*a*)	293° 33·7′	2·9 Towards	122°		
	(*b*)	18° 21·3′	3·0 Away	218°	0° 23·2′ S	26° 38·2′ W
8.	(*a*)	64° 59·5′	2·6 Towards	228°		
	(*b*)	36° 50·9′	3·0 ,,	319°	35° 29·5′ S	80° 11′ W
9.	(*a*)	313° 55·1′	4·7 ,,	048°	2nd DR 25° 17·2′ N	156° 21′ E
	(*b*)	0° 51·5′	1·4 ,,	000°	Fix 25° 18·6′ N	156° 19·6′ E
10.	(*a*)	0° 00′	4·5 Away	180°		
	(*b*)	29° 40′	0·4 Towards	220°	12° 08·5′ N	57° 24′ W
11.	(*a*)	350° 46·3′	3·2 Away	010°		
	(*b*)	50° 33·1′	2·4 Towards	271°	43° 10·8′ S	83° 21·7′ E
12.	(*a*)	3° 43′	6·0 Away	344°	2nd DR 24° 11·6′ S	156° 53·5′ E
	(*b*)	59° 30·3′	5·6 Towards	272°	Fix 24° 13·4′ S	156° 43·3′ E
13.	(*a*)	308° 53·7′	6·8 ,,	123°	2nd DR 45° 32·3′ N	21° 10′ W
	(*b*)	16° 07·8′	4·7 ,,	200°	Fix 45° 28·3′ N	21° 13·7′ W
14.	(*a*)	345° 39·9′	3·1 Away	161°	2nd DR 35° 11′ N	151° 38·2′ W
	(*b*)	63° 46·2′	3·5 Towards	265°	Fix 35° 09·8′ N	151° 42·3′ W
15.	(*a*)	5° 58·8′	2·2 Away	344°		
	(*b*)	56° 05·4′	3·7 Towards	250°	33° 43′ S	104° 08·6′ E

EXAMINATION PAPERS CLASS 4—CLASS 1. Page 201.

Paper 1.

1. (*a*) Intercept 3·9′ towards. Azimuth 185° T. Lat. 38° 06′ N.
   (*b*) 2·3′ towards. 088° T. Long. 32° 17′ W.
2. Initial Co. 282° 35½′ T., Final Co. 233° 25½′ T. Distance 2674 miles. Vertex Lat. 52° 30½′ N., Long. 25° 26′ W.
3. Lat. 46° 54·4′ N. P.L. 091·4°-271·4° T.
4. Azimuth 094·5° T. Error 3·5° E. Dev. 23·5° E.
5. L.M.T. 19h 37m. North of observer.

Paper 2.

1. L.H.A. 31° 26·6′; T.Z.D. 75° 22′; Intercept 3·8′ towards; Azimuth 210° T. 2nd D.R. Lat. 47° 00′ N. Long. 175° 29′ E. Fix Lat. 46° 50·5′ N., Long. 175° 51′ E.
2. Lat. 50° 38′ N. P.L. 091°-271° T.
3. L.M.T. 26d 23h 21m; Lat. 45° 23·3′ S. P.L. 090-270° T.
4. Points C Long. 159° 20′ E. Lat. 41° 56′ S.
   ,, D ,, 169 20 E. ,, 49 07 S.
   ,, E ,, 179 20 E. ,, 54 00 S.
   ,, F ,, 170 40 W. ,, 57 16 S.
   ,, G ,, 160 40 W. ,, 59 22 S.
   ,, H ,, 150 40 W. ,, 60 32 S.

   There are other six points on other side of vertex, their polar angles are the same as the above, they must also be in, respectively, the same latitudes.

Paper 3.

1. Intercept 4·8′ away; Sun Az. 246° T. Lat. 52° 35′ N.
   ,, 3·4′ towards; Star Az. 157° T. Long. 5° 31′ W.
2. Lat. 50° 35·3′ N., Long. 27° 43·3′ W.
3. Bearing 233·7° M. Dev. 21·3° W., 10·3° W., 2·3° W., 3·7° E.
   ,, 19·7° E., 22·7° E., 4·7° E., 17·3° W.
   Compass courses deviations (i) 15·5° W. (ii) 6·5° W. (iii) 19° W. (iv) 6° W.
4. Lat. 37° 01′ N.

Paper 4.

1. (*a*) L.H.A. 287° 28·6′; Intercept 3·5′ towards; Az. 101° T.; Int. Terminal Pt. 35° 19·3′ N., 36° 18′ W.; P.L. 011°-191° T.
   (*b*) L.H.A. 355° 51·7′; Int. 2·0′ towards; Az. 176° T., P.L. 086°-266° T.
   Fix. Lat. 35° 18·5′ N., Long. 36° 18′ W.
2. Course 161° T., Dist. 301 miles. Lat. 46° 23′ S., Long. 101° 09·3′ E.
3. Lat. 34° 47·1′ N., P.L. 090°-270° T.
4. G.C. Dist. 2317 miles. Mercator (spheroid) 2335 miles, difference 18; Mercator (sphere) 2330 miles, difference 13 miles.

Paper 5.

1. Lat. 49° 34′ N., Long. 179° 26·5′ W.
2. Points A 170° E. Lat. 48° 46·5′ N.
   ,, B 180 E. ,, 48 21·5 N.
   ,, C 170 W. ,, 47 02·8 N.
   ,, D 160 W. ,, 44 44 N.
   ,, E 150 W. ,, 41 15·8 N.
3. Long. 65° 32·2′ E. P.L. 150°-330° T.
4. Lat. 35° 47·3′ N. P.L. 089°-269° T.

Paper 6.

1. Initial course 055° 34′ T. Final course 059° 57′ T. Dist. 6417 miles. Vertex Lat. 46° 46·5′ N., Long. 79° 35·5′ W.
2. Course 232° 38·8′ T. Distance 361·1 miles (spheroid).
   ,, 232° 27·5′ T. ,, 359·4 ,, (sphere).
3. Lat. 50° 12·7′ N., Long. 6° 01′ W.
4. Course 143° T. Dist. 236 miles; Set. 201° T., Drift 15·6 miles; Noon position Lat. 14° 38′ S., Long. 51° 06′ E.

Paper 7.

1. Mer. Pass. 8d 13h 54m L.A.T., Sextant Alt. 30° 16′; Lat. 46° 18′ N.
2. Lat. 31° 38·2′ S., P.L. 090°-270° T.
3. Lat. 21° 57·5′ N., P.L. 089°-269° T.
4. Lat. 51° 50′ S., Long. 00° 30′ E.
5. Jupiter L.H.A. 302° 01·6′; Int. 4·1′ towards; Az. 103° T. Denebola L.H.A. 355° 56·9′; Int. 2·8′ away; Az. 009° T. Lat. 12° 23·3′ S., Long. 44° 56·6′ W.

Paper 8.

1. 25d 14h 37m 12s Lat. 16° 52·4′ N.
2. G.M.T. 13d 04h 06·3m. Altitude 38° 11·2′.
3. Lat. 48° 13′ S., Long. 44° 29′ E.
4. Lat. 50° 20·5′ N., Long. 2° 27′ W.
5. Points C Long. 10° W. Lat. 37° 43·6′ S.
   ,, D ,, 0 E. ,, 40 20·5 S.
   ,, E ,, 10 E. ,, 41 55·3 S.
   ,, F ,, 20 E. ,, 42 35·5 S.
   ,, G ,, 30 E. ,, 42 23 S.
   ,, H ,, 40 E. ,, 41 17·5 S.
   ,, J ,, 50 E. ,, 39 15·5 S.
   ,, K ,, 60 E. ,, 36 11 S.
   ,, L ,, 70 E. ,, 31 56·3 S.
   ,, M ,, 80 E. ,, 26 24 S.
   ,, N ,, 90 E. ,, 19 30·5 S.
   ,, O ,, 100 E. ,, 11 23·3 S.

Paper 9. Chartwork.

1. Courses—350° C., 34 miles; 026° C., 90 miles; 080° C., 17 miles.
2. Lat. 50° 31′ N., Long. 5° 34′ W. Set 005° T., Drift 7·5 miles. Lat. 50° 38′ N., Long. 5° 37′ W.
3. Lat. 51° 23′ N., Long. 5° 06′ W.
4. Course 025° C. Effective speed 9·4 knots. Time 11½ hours.

Paper 10.

1. (*a*) Intercept 6·1′ towards; Azimuth 121° T.; 2nd D.R. position 46° 45·3′ N., 25° 00′ W.
   (*b*) Intercept 5·0′ towards; Azimuth 195° T.; Fix Lat. 46° 39′ N., Long. 24° 55′ W.
2. Course 122° 10·6′ T. Distance 1487·2 miles (spheroid). or Course 122° 21′ T. Distance 1480 miles (sphere).
3. Mer. Pass. 11d 06h 30m L.M.T.; Sext. alt. 37° 45′; Lat. 42° 08′ N.
4. Co. made good 144° T., dist. 15·4 miles. Beam dist. 18·6 miles. Lat. 47° 05′ N., Long. 3° 31′ W.
5. Lat. 25° 23·5′ N. P/L 080-260° T.

Paper 11.

1. G.M.T. 19d 01h 24m. Altitude 34° 09·3′.
2. B 1·35s gaining. C 3·18s gaining.
3. Current to 2200 hours 073° T., 17 miles; Course 203·5° T., distance 342 miles. Lat. 42° 13·6′ N., Long. 177° 29′ E.
4. (*a*) Intercept 3·6′ away; Azimuth 222° T.
   (*b*) Intercept 5·0′ towards; Azimuth 314° T.
   Fix: Lat. 11° 31′ N., Long. 27° 43·2′ W.
   Longitude method: Lat. 11° 30·8′ N. Long. 37° 43·3′ W.
5. Course 043° C.

Paper 12.

1. Lat. 45° 11·7′ N., Long. 8° 19·5′ W.
2. Lat. 42° 01·8′ N.
3. G.C. Initial Co. 117° 01¼′ T., Final Co. 126° 59¼′ T., Dist. 5883·8 miles. Vertex 44° 20′ N., 159° 26¼′ E. Lats. of points 31° 49¼′ N., 25° 39′ N., 18° 00¼′ N., 0° 33′ S., 10° 09¼′ S., 18° 56¼′ S.
4. Az. 076·5° T., Dev. 5·5′ W.
5. (*a*) Intercept 1·9′ towards Az. 063° T. } Lat. 42° 18·2′ S.
   (*b*) ,, 2·0′ away Az. 343° T. } Long. 76° 46·8′ E.
   or
   (*a*) Long. 76° 46′ E. P/L 153° 333° T. } Lat. 42° 18′ S.
   (*b*) Long. 76° 50·8′ E. P/L 075° 253° T. } Long. 76° 46·6′ E.

Paper 13.

1. Lat. 45° 57·3′ N. P/L 090·5°-270·5° T.
2. 0800 D.R. Lat. 44° 35·5′ N., Long. 177° 17·8′ E. Current 293° T., 12 miles in 20 hours. Noon Lat. 44° 07·4′ N., Long. 176° 17′ E. Course 224·5° T., distance 268·5 miles.
3. G.M.T. 15d 20h 07m 28s.
4. Lat. 35° 17·3′ S.
5. (*a*) Int. 2·9′ towards Az. 050° T. }
   (*b*) Int. 4·1′ towards Az. 309° T. } Lat. 26° 20·5′ N., Long. 37° 43′ W.
   or
   (*a*) Long. 37° 37·6′ W. P/L 140-320° T. }
   (*b*) Long. 37° 47·8′ W. P/L 039-219° T. } Lat. 26° 20·6′ N., Long. 37° 42·8′ W.

Paper 14.

1. Brg. 256° M., Dev. 14° W., 0°, 12° E., 15° E., 11° E., 0°, 10° W., 14° W. Compass courses dev. 0°, 14° E., 6° E., 14° W. Mag. courses dev. 8° W., 9° E., 3° E., 14·5° W.
2. Lat. 33° 04·7′ N.
3. Az. 090° T., Dev. 4° E.
4. Course 236° 07′ T., Distance 2138 miles (spheroid) or
   ,, 255° 59′ T., ,, 2131 ,, (sphere).
5. (*a*) Intercept 1·8′ away Az. 177° T. }
   (*b*) ,, 3·5′ towards Az. 103° T. } Lat. 30° 08′ S., 17° 35′ W.
   or
   (*a*) Ex.-Merid. Lat. 30° 08·3′ S., P.L. 087°-267° T. } Lat. 30° 08′ S.
   (*b*) Long. 17° 35·1′ W. P.L. 013°-193° T. } Long. 17° 34·7′ W.

Paper 15

1. Lat. 48° 58′ N., Long. 5° 50′ W.
2. Lat. 32° 49′ N., P.L. 100°-280° T.
3. B 55 secs. losing.
4. Amp. E. 4·5° N., Dea. 6·5° W.
5. Sirius.

CHAPTER XI.

I.—Algebra. Page 259.

1. $x=10$ or -14.
2. $x=8$ or 2.
3. $x=2$ or $\frac{5}{8}$, $y=7$ or $-\frac{1}{8}$.
4. $x=\pm 3$, $y=\pm 2$.
5. A's speed $8\frac{1}{3}$ knots, B's speed 12·5 knots.
6. Current 5·96 knots, reduced speed 6·05 knots, full speed 17·77 knots.
7. Destroyer's speed 15 knots.
8. Full speed 10 knots.
9. 8 days.
10. Meeting place halfway. Time 13·00. They are 10 miles apart at 12·38 and 13·22.
11. Closest distance 29·29 miles.
12. Current sets S. 39° 56′ E. or W., rate 2·615 knots.
13. 20 and 30 m.p.h.
14. 36 and 60 minutes.
15. First pump takes 2h 12·3m. Second pump takes 3h 22·3m.
16. Time 47·8 and 77·8 minutes.
17. Time $5\frac{1}{2}$ hours and 6 hours.
18. Speed 21·57 f.p.s.

Trigonometrical Equations. Page 264 and 265.

1. A = 26° 18′ or 153° 42′.
2. A = 12° 8′ or 192° 8′.
3. A = 213° 23′ or 326° 37′.
4. A = 85° 24′ or 265° 24′. 93° 58′ or 273° 58′.
5. θ = 34° 37′ or 325° 23′.
6. θ = 30° or 330°.
7. θ = 60° or 120°.
8. Cos 15° = ·966.
9. Angle 120°.
10. x = — 46° 24′ or 313° 30′.
11. B = 22° 37½′.
12. θ = 75° or 165°.

II.—Plane Triangles. Page 270.

1. Distance 820 feet or 180 feet.
2. Cliff 371 feet high.
3. Distance 605·3 feet.
4. Distance 369 feet.
5. Distance 600·2 feet.
6. Distance 80·62 feet.
7. Height of mast 19·3 feet.
8. Height of tower 74·62 feet.
9. Distance 131·15 feet.
10. Distance 176·4 or 121·8 feet.
11. Course N. 71° 44½′ W.
12. and 13. Theoretical proofs.
14. Distance 9705 feet, bearing from B, S. 28° 52½′ E.
15. Distance 12724 feet, height 9403 feet.
16. Height of tower 148·1 feet.
17. Height of mountain 1·493 miles.
18. Distance between masts 119·44 feet.

19. Courses A, N. 71° 31′ E.; B, N. 85° 13′ E.; C, S. 71° 31′ E.
20. ,, A, N. 86° 07′ W.; B, N. 52° 27′ W.; C, N. 34° 45′ W.
21. Distance 7·87 miles.
22. Distance 5·216 miles.
23. Distance 2·412 miles.
24. Distance 10·42 miles.
25. Angle A 9° 41′.
26. Speed 9·192 knots.
27. Distance ·632 miles.
28. Course S. 83° 33′ W., Angle 56° 27′.
29. Course N. 42° 26′ W.
30. Course N. 15° 41′ E.
31. Distance 6 miles.
32. Distance from B 4·9 miles; from C 4 miles.
33. Distance A B 5·537 miles; B C 4·153 miles.
34. Course 116·9°, drift 3·62 miles.
35. Distances 1·11 miles, 3·39 miles.
36. Course S. 58° W.
37. Course N. 86° 26½′ W., distance 6·376 miles, drift 2·61 miles in 50 minutes.
38. Distance 4·167 miles.

III.—Relative Velocities. Page 280.

1. Course N. 57° 21′ W., time 62·7 minutes.
2. Course N. 70° 21′ E., speed 21·2 knots.
3. Course N. 1° 38′ E., speed 6·95 knots.
4. Alter 23° 53′ to starboard, time 12·4 minutes.
5. Course N. 89½° W., time 13·9 minutes.
6. Course N. 37° 41′ W., time 38 minutes.
7. Speed of approach 14·8 knots. Distance to go 5 miles. Time to reach position 19·8 minutes.
8. Course N. 31° E., time 15h 49·8m.
9. Course 205°, time 22·8 minutes.
10. Course S. 70° W., speed 15·7 knots.
11. Ratio line ∠C 30° 49′. Direction of ratio line 257°. Course N. 49° W.
12. Ratio line 246½°. ∠C 93° 23′. Course S. 22° W.

IV.—Various Examples. Page 287.

1. Distances 4·02 and 4·82 miles.
2. Distance 1·22 miles.
3. Brg. N. 3° W., distance 9·548 cables.
4. True wind South, 15·27 m.p.h.
5. True wind 081·9°, 14·14 m.p.h.
6. Height 15·08 feet.

V.—Spherical Triangles. Page 296.

1. Lat. 26° 51′ 20″ N.
2. Lat. 3° 08′ N., Long. 42° 08′ W.
3. Lat. 24° 8½′ N.
4. Lat. 39° 35½′, Decl. 8° 58′.
5. Decl. 2° 44′ 27″.
6. Lat. 37° 01′ N.
7. Lat. 39° 46′ N.
8. Decl. 25° N., Alt. 58° 38′.
9. Lat. 58° 14′ N.
10. Lat. 10° 53½′ N.
11. Lat. 38° 57½′ N. or 48° 14½′ S.
12. Hour angle 4h 16m 50s, Decl. 0° 0′.
13. Long. 11° 58′ W.
14. Lat. 11° 20′ N.
15. Alt. 38° 23½′.
16. Lat. 4° 33′ 42″ S., Long. 248° 46′ 46″.
17. Lat. 4° 15′ 30″ N., Long. 48° 37′ 06″.

CHAPTER XII.

I.—Quadrilaterals. Page 334.

1. 68 feet 126 sq. inches.
2. 168·3 sq. yards.
3. 588 sq. feet.
4. 823 sq. feet.
5. 148·8 sq. yards.
6. 120 sq. yards.
7. 1448·8 sq. feet.
8. 389·3 sq. feet.
9. 74·69 sq. yards.
10. 256 sq. yards.
11. 2250 sq. feet.
12. 1408·2 sq. feet.
13. 15 feet.
14. 1050 sq. yards.
15. 3146·4 sq. feet.
16. 720 sq. yards.
17. 692 units.
18. 5·363 miles.
19. C bears S. 25° 52½′ E. from A.
    D bears S. 62° 52½′ E. from A.
20. 7417 feet.
21. 8·718 cables.

II.—Circle. Page 336.

1. 550 sq. feet.
2. 34·5 units.
3. 55·7 units.
4. 200·6 units.
5. 11·66 units.
6. 30·8 units.
7. 12·2 units.
8. 20 units.
9. 38° 56′.
10. 38° 56′.
11. 76° 25′.
12. 56° 08′.
13. 22° 57′.
14. 107·5 sq. units.
15. 159·1 sq. units.
16. 102·2 sq. units.
17. 44·7 sq. units.
18. 10·27 sq. units.
19. 636·4 units.
20. 73·4 sq. feet.

III.—Specific Gravity. Page 341.

1. Specific gravity 3·077.
2. Specific gravity 8·25.
3. Specific gravity ·25.
4. Specific gravity ·852.
5. 4162·5 lbs.
6. 683·2 tons.
7. 27·06 lbs.
8. 65·16 cub. feet.
9. ·71 cub. feet.
10. 138·55 lbs.
11. 281·8 lbs.
12. 1·356 inches.

IV.—Polygons. Page 344.

1. 1548·5 sq. feet.
2. 817·6 sq. feet.
3. 51·41 sq. inches.
4. 13·85 inches.
5. 788·3 sq. inches.
6. 1357 sq. inches.
7. 2·188 miles.
8. 2·348 miles.
9. 12·83 cub. feet.
10. Weight 1 ton, 12 cwt., 0 oz., 13 lbs.
11. 201·2 inches.
12. ·1128 inches.
13. Area 922·87 sq. inches.

V.—The Sphere. Page 346.

1. Area 78·54 sq. inches, vol. 65·45 cub. inches.
2. Area 452·4 sq. inches, vol. 905·1 cub. feet.
3. 392·7 sq. inches.
4. 110 sq. feet.
5. 2732 cub. feet.
6. 23·0384 cub. feet.
7. 54·45 cub. feet.
8. 195·8 cub. inches.
9. 1340·4 cub. inches.
10. 494·3 cub. inches.
11. ·56 inches.
12. 30·6 lbs.
13. ·29 inches.
14. Metal specific gravity 8·40, spirit ·366.

VI.—Cones. Page 352.

1. 1847·87 gallons.
2. 428 lbs.
3. 2·55 cub. feet.
4. 70·68 cub. feet.
5. 42·28 cub. feet.
6. 26·9 cub. inches.
7. 56·2 sq. inches.
8. 39·98 cub. inches.
9. Diameter (*a*) 8·434; (*b*) 9·486 inches.
10. 90 feet.
11. 110 feet.
12. 19·5 cub. feet.
13. 9·32 cub. feet.
14. 19·61 sq. feet, 6882 cub. inches.
15. 667·6 sq. feet.
16. 90 sq. feet.
17. 22·56 cub. feet.
18. 527·8 cub. units.
19. 464·2 cub. inches.
20. 5·31 cub. feet, 33·18 gallons.
21. 31·07 ounces.
22. 2700 sq. inches.
23. 21 inches.
24. $h = \text{'}6933\ H$.
25. As 721 is to 134.
26. Specific gravity ·57.
27. Radius 3·1 feet, height 3·26 feet above water.

VII.—Ellipse. Page 364.

1. 39·27.
2. 150·8.
3. 33·0.
4. 22·2.
5. 160.
6. 766·1 lbs.
7. 1492½ lbs.
8. 8·21 f.p.s.
9. 24 minutes.
10. Vol. 530·36 cub. ft., 3314·7 galls. F.W.

EXAMINATION PAPERS. EXTRA MASTER. Page 371.

Paper 1.

1. 1·44 yds. from longest side.
2. Area of end section 374·1 sq. ins.
   Area of slant section 529·1 sq. ins.
3. $A = 39° 52'$.
4. Weight 100·7 lbs.
5. Lat. 26° 58′.
6. 36m and 60m.

Paper 2.

1. 40·4 minutes.
2. 3270·5 gallons.
3. $x = 2$, $y = 3$.
6. 32·97 feet.

Paper 3.

1. $\frac{375}{990}$

   NOTE.—Sum to infinity $= \frac{a}{1-r}$. a = first term, r = common ratio. In this question ·3 does not recur and the progression is $\frac{78}{1000}$ as the 1st term, and $\frac{1}{100} = r$ ... the sum $S - \cdot 3 = \frac{a}{1-r}$.
2. $A = 16° 44'$ or $163° 16'$, $190° 32'$ or $349° 28'$.
3. 2h 12·3m and 3h 22·3m.
4. Weight of one link 2·438 lbs.
   Weight of chain 946 lbs.
5. Lat. 52° 27′ N.
6. $x = 3$, or $-\frac{137}{9}$; $y = 1$, or $-\frac{38}{3}$.

Paper 4.

1. (i) 132 and 84. (ii) 8 days.
2. 27°, 69°, 111°, 153°
3. Lat. 31° 48½′ N.
4. $\theta = 30°$ or $330°$.
5. Diameter 8·926 feet.

Paper 5.

1. Specific gravity 9·45.
2. One rev. 1·5 secs., speed 9·8 f.p.s.
3. Long. 166° 24′ W., Dist. 2784 mls.
4. 100 inches.
5. (ii) $\theta = 145° 30'$ or $325° 30'$.
6. R.A. 16h 22m 50s, Decl. 16° 38′ 36″ N.

Paper 6.

3. 120°—apply formula $\cos A = \frac{b^2 + c^2 - a^2}{2bc}$
4. (ii) $A = 60°$, 120°, 240° or 300°.
5. Lat. 47° 8′ 22″ S., Long. 237° 57′ 50″.
6. Speed 9 knots. Distance 10·43 miles.

Paper 7.

1. Rate of change 62·7′ per minute.
5. Lat. 10° 5½′ N., Decl. 20° 11′ S.
6. True dist. 149° 56′ 8″.

Paper 8.

4. Moonrise 14h 59m.
6. Lat. 50° 47·3′ N., Long. 00° 3·2′ W.,
   Dist. 12·16 miles.

Paper 9.

6. Lat. 39° 17·2′ S., Long. 78° 01′ E.

Paper 10.

1. dp/dh 10·8/893. Long. 67° 12¾′ E.
2. Lats. 61° 47′ N., or 28° 13′ N.
3. D. Lat. 4·44′ apply to North, D. Long. 6·45′ apply to the West.
4. 686 feet.

Paper 11.

1. Lat. 26° 11¼′ S., Long. 179° 26′ E.
2. Alt. 71° 28½′. Az. N. 74° 27′ E.
3. 4m 13·5s fast.
5. Augmentation 11·22″.

Paper 12.

1. G.M.T. 21d 19h 15m 14s. Duration 1h 42m 12s.
2. Lat. 39° 45½′ N.
3. Lat. 54° 26′ S.
4. G.C.Co. S. 71° 51′ E. Distance 3442·5 miles. Rhumb Co. S. 67° 49½′ E. Distance 3443·0 miles.
5. Eq. of time + 5m.
6. Error 10·67′ to add.

EXTRACTS FROM THE ADMIRALTY TIDE TABLES

INDEX

		page
Vol. I European Waters		
Part 1		
Portsmouth	Predictions and Curves	393
Sheerness	,, ,,	394
Greenock	,, ,,	395
Avonmouth	,, ,,	396
Londonderry	,, ,,	397
Part 2		
Secondary Ports	Time and Height Differences	398
Vol. II Atlantic and Indian Oceans		
Part 1		
Saint John N.B.	Predictions	399
Bassein River Entrance	,,	399
Part 2		
Secondary Ports	Time and Height Differences	400
	Seasonal Changes in Mean Level	400
	Harmonic Constants and Shallow Water Corrections	401
		401
Table VIa	Fortnightly Shallow Water Corrections	401
,, VII	Tidal Angles and Factors	402
,, V	Tidal Levels at Standard Ports	405
Vol. III Pacific Ocean and Adjacent Seas		
Part 1		
Prince Rupert	Predictions	407
Part 2		
Secondary Ports	Time and Height Differences	407
	Seasonal Changes in Mean Level	407
Pro Formas, Tidal Curve, Multiplication and Conversion Table		
NP 204	Admiralty Tidal Predictions Form Instructions	408
	Admiralty Tidal Predictions Form	409
	Secondary Port Height Difference Interpolation Graph	410
	Nicholls's Secondary Port Tidal Prediction Form	411
NP 159	Admiralty Method of Tidal Prediction using Harmonic Constants, Tidal Angles and Factors Form A	412
	Form B	413
	Form C	414
Table 1	Conversion Table: Metres to Feet	415
	Tidal Curve for Finding Height of Tide at Times Between High and Low Water	416
Table 11	Multiplication Table (Factor/Range)	418

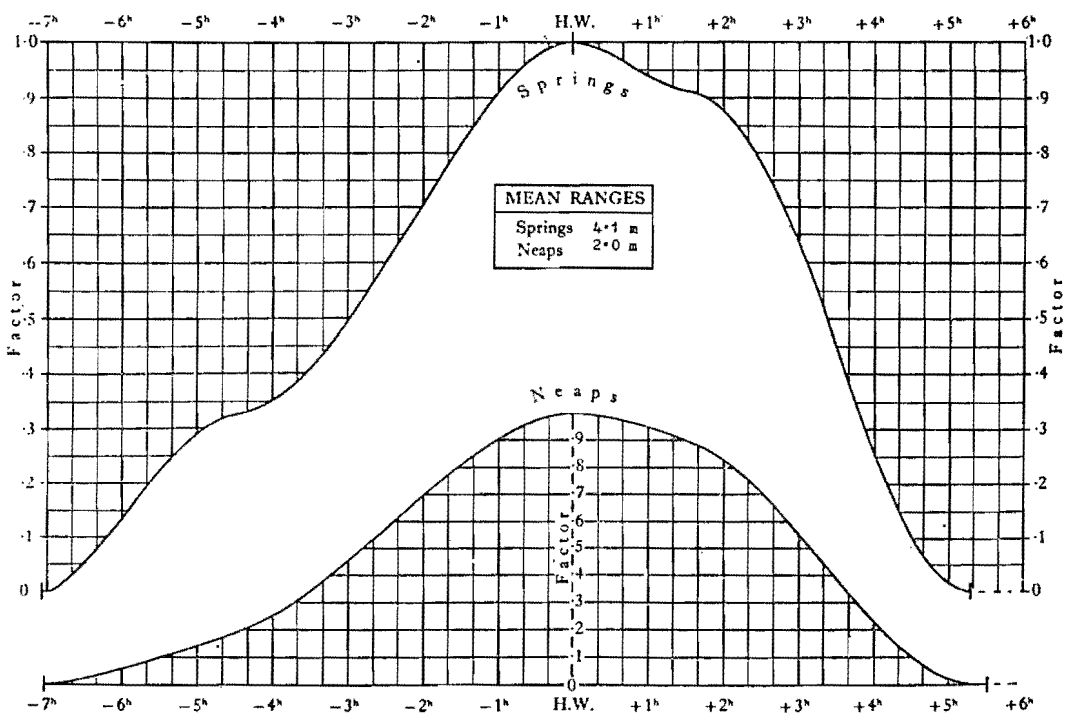
ENGLAND, SOUTH COAST - PORTSMOUTH

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	2143	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	2038	1.4								
29 SA	0345	4.2	0910	1.2	1640	4.3	2143	1.6								
30 SU	0453	4.0	1021	1.4	1753	4.1	2305	1.7								
13 SU	0303	3.9	0820	1.3	1546	4.0	2050	1.6								
14 M	0351	3.8	0912	1.4	1638	4.0	2149	1.7								
15 TU	0449	3.8	1014	1.4	1739	4.0	2255	1.7								
28 M	0423	4.1	0951	1.3	1715	4.3	2228	1.6								
29 TU	0530	4.0	1058	1.5	1820	4.2	2337	1.7								
30 W	0642	3.9	1207	1.5	1923	4.1										
13 TU	0326	4.1	0844	1.1	1608	4.2	2112	1.4								
14 W	0415	4.0	0937	1.2	1659	4.2	2210	1.5								
15 TH	0515	3.9	1040	1.4	1800	4.1	2318	1.5								
28 W	0445	4.1	1011	1.5	1727	4.2	2246	1.7								
29 TH	0551	3.8	1118	1.7	1829	4.0	2356	1.8								
30 F	0706	3.7	1230	1.8	1934	3.9										
13 F	0447	4.0	1009	1.4	1727	4.1	2246	1.6								
14 SA	0559	3.9	1127	1.6	1840	4.0										
15 SU	0008	1.6	0723	3.9	1249	1.6	1956	4.1								
28 SA	0615	3.6	1143	2.1	1845	3.7										
29 SU	0026	2.0	0740	3.6	1305	2.1	2001	3.8								
30 M	0140	1.9	0852	3.7	1411	1.9	2105	3.9								

MEAN SPRING AND NEAP CURVES



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

JANUARY

	TIME	M		TIME	M
7 TH	0325	1.2	**22** F	0433	1.3
	0952	5.3		1059	4.9
	1609	0.9		1648	1.1
	2237	5.5		2316	5.1
8 F	0440	1.0	**23** SA	0518	1.1
	1055	5.5		1142	5.1
	1720	0.8		1729	1.0
	2333	5.7		2356	5.3
9 SA	0550	0.8	**24** SU	0558	0.9
	1153	5.7		1219	5.3
	1819	0.7		1808	0.9
10 SU	0024	5.8	**25** M	0031	5.5
	0649	0.6		0638	0.8
	1245	5.9		1255	5.5
	1912	0.7		1849	0.8

FEBRUARY

	TIME	M		TIME	M
7 SU	0546	0.8	**22** M	0539	0.9
	1146	5.6		1200	5.3
	1810	0.8		1750	0.9
8 M	0012	5.7	**23** TU	0012	5.4
	0643	0.5		0622	0.8
	1239	5.8		1236	5.5
	1900	0.7		1832	0.8
9 TU	0100	5.8	**24** W	0050	5.6
	0733	0.3		0706	0.6
	1326	6.0		1314	5.7
	1942	0.7		1914	0.7
10 W	0145	5.9	**25** TH	0127	5.8
	0818	0.2		0748	0.5
	1411	6.0		1351	5.8
	2023	0.7		1955	0.6

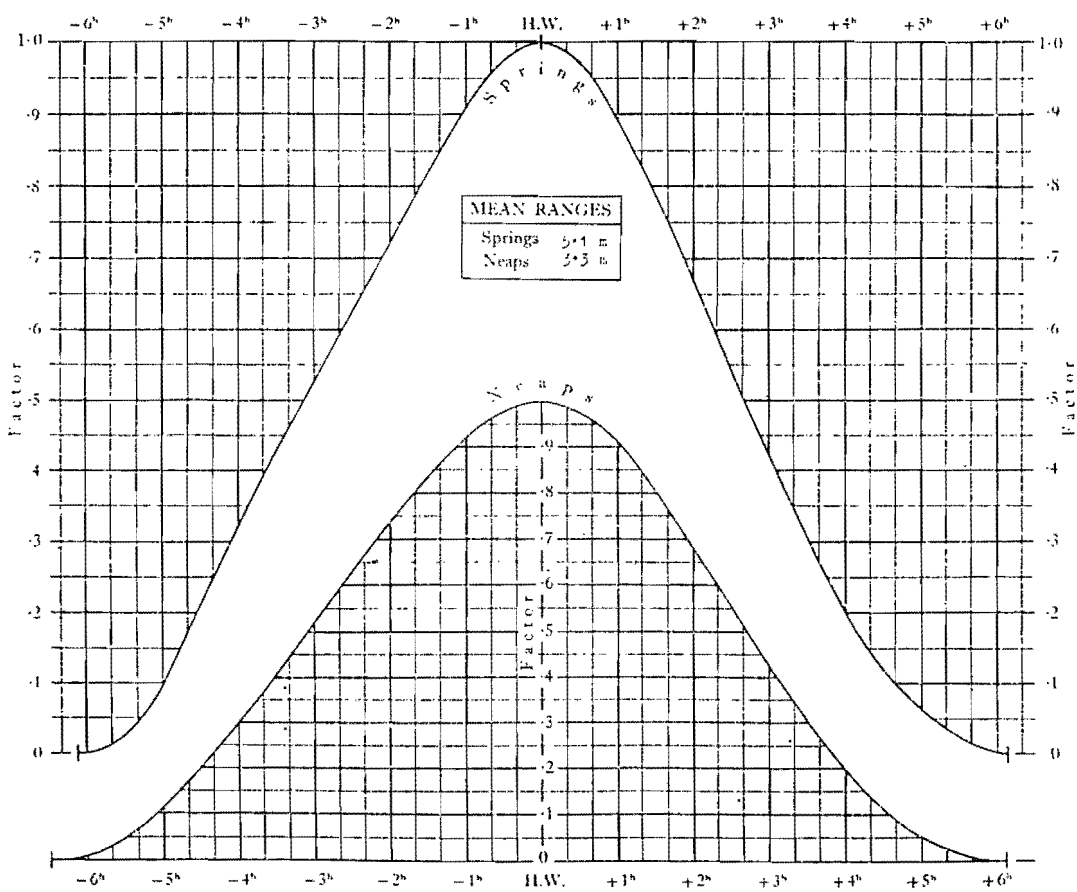
MARCH

	TIME	M		TIME	M
7 SU	0430	1.0	**22** M	0417	1.2
	1040	5.3		1048	5.0
	1701	1.1		1637	1.2
	2308	5.4		2302	5.1
8 M	0540	0.6	**23** TU	0509	0.9
	1139	5.6		1132	5.3
	1758	0.9		1725	0.9
				2344	5.4
9 TU	0000	5.6	**24** W	0557	0.7
	0634	0.4		1211	5.6
	1228	5.9		1811	0.8
	1845	0.7			
10 W	0046	5.8	**25** TH	0024	5.6
	0719	0.2		0643	0.5
	1312	6.0		1250	5.8
	1926	0.6		1855	0.7

APRIL

	TIME	M		TIME	M
7 W	0614	0.3	**22** TH	0523	0.6
	1211	5.9		1140	5.7
	1824	0.7		1740	0.8
				2353	5.6
8 TH	0027	5.7	**23** F	0614	0.5
	0655	0.3		1221	5.9
	1252	5.9		1828	0.7
	1902	0.6			
9 F	0106	5.8	**24** SA	0034	5.9
	0731	0.3		0700	0.4
	1328	5.9		1302	6.0
	1935	0.6		1913	0.6
10 SA	0141	5.8	**25** SU	0113	6.0
	0802	0.4		0744	0.4
	1402	5.9		1342	6.1
	2009	0.6		1957	0.5

MEAN SPRING AND NEAP CURVES



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

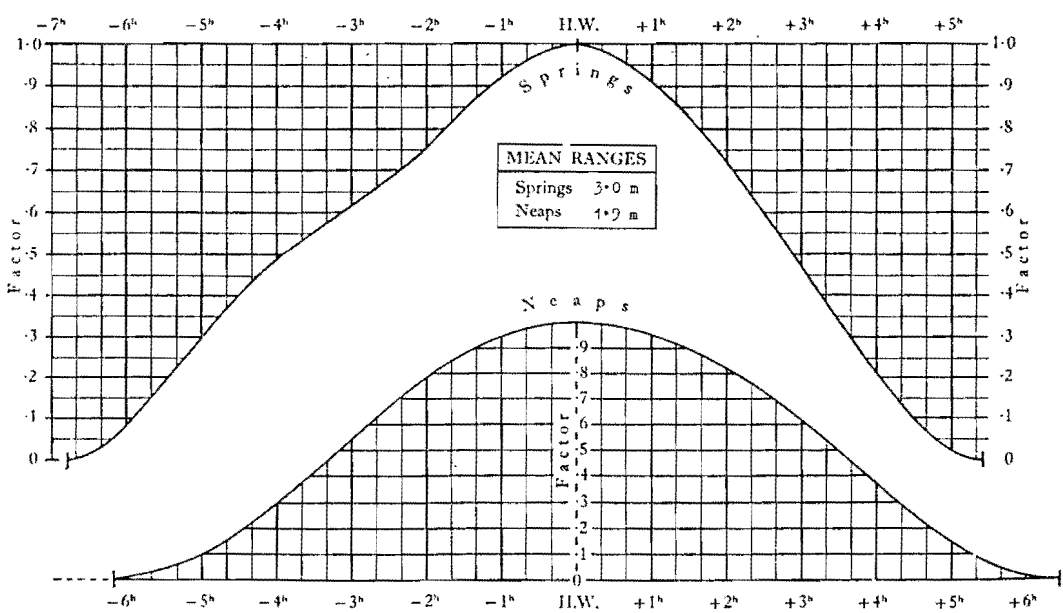
JULY

	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	0938	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

MEAN SPRING AND NEAP CURVES



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

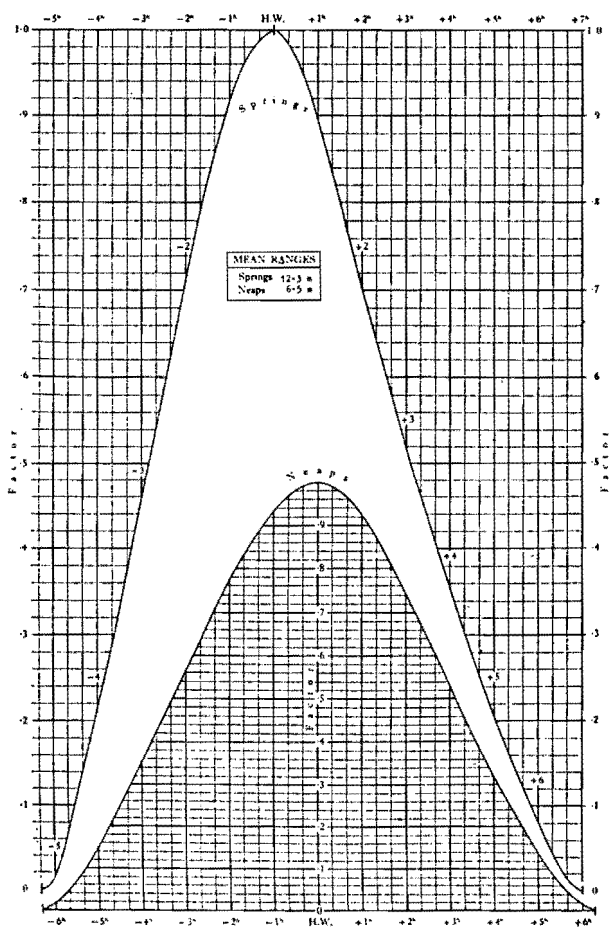
NOVEMBER

	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		0853	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

MEAN SPRING AND NEAP CURVES



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			

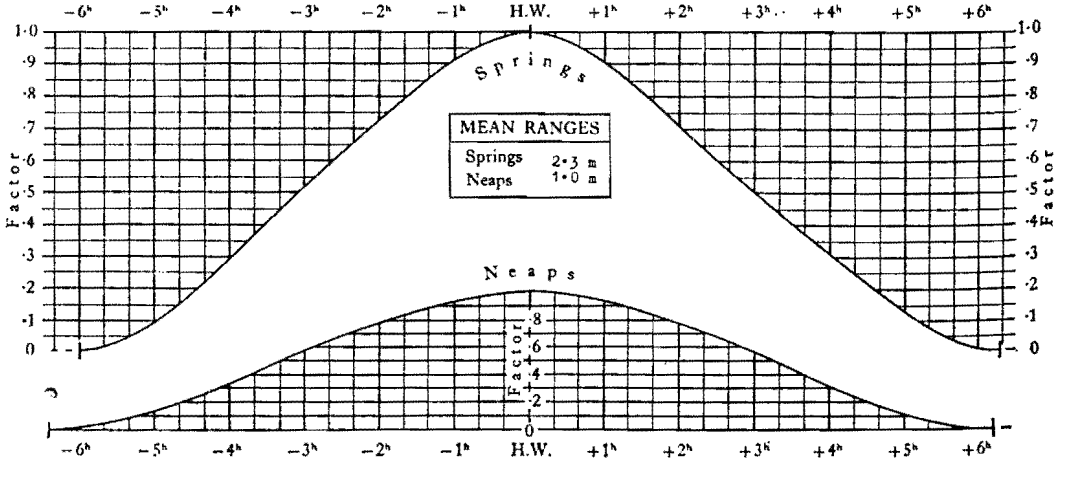
JULY

	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

MEAN SPRING AND NEAP CURVES



Vol. 1 — European Waters — Part II.

ENGLAND, SCOTLAND AND IRELAND

No.	PLACE	Lat. N.	Long. W.	TIME DIFFERENCES High Water	TIME DIFFERENCES Low Water	HEIGHT DIFFERENCES (IN METRES) MHWS	MHWN	MLWN	MLWS	M.L. Z_0 m.
				(Zone G.M.T.)						
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	⊙

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	1.4			
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	1805	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	1.8		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		0830	7.5		0745	7.1
TH	1250	1.5	F	13.	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	8.0		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		1159	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	1.8		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		0830	7.5		0745	7.1
TH	1250	1.5	F	13.	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	8.0		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		1159	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
	0830	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	8.0		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
	1159	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	0138	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

OCTOBER

	TIME	M		TIME	M		TIME	M		TIME	M
9	0120	2.4	24	0123	2.2	9	0348	2.1	24	0250	2.0
	0749	1.0		0749	1.2		1040	1.1		0945	1.2
SA	1337	2.1	SU	1335	1.8	TU	1702	1.9	W	1610	1.7
	1957	1.0		1947	1.2		2301	1.2		2156	1.3
10	0222	2.2	25	0220	2.0	10	0529	2.1	25	0420	1.9
	0910	1.1		0907	1.3		1207	1.0		1111	1.1
SU	1457	1.9	M	1503	1.7	W	1832	2.0	TH	1746	1.8
	2121	1.2		2111	1.3					2336	1.2
11	0357	2.1	26	0400	1.9	11	0034	1.1	26	0543	2.0
	1054	1.2		1104	1.3		0645	2.2		1218	1.0
M	1704	1.9	TU	1732	1.7	TH	1310	0.9	F	1846	2.0
	2311	1.2		2309	1.3		1928	2.2			
12	0556	2.1	27	0551	2.0	12	0135	1.0	27	0049	1.1
	1235	1.1		1238	1.2		0738	2.3		0643	2.1
TU	1849	2.0	W	1852	1.9	F	1357	0.7	SA	1307	0.8
							2011	2.4		1930	2.2
13	0049	1.1	28	0041	1.2	13	0223	0.8	28	0141	0.9
	0714	2.3		0655	2.1		0819	2.3		0731	2.2
W	1340	0.9	TH	1326	1.0	SA	1434	0.6	SU	1351	0.6
	1949	2.2		1934	2.1		2046	2.5		2009	2.4
14	0152	0.9	29	0134	1.0	14	0301	0.7	29	0226	0.7
	0805	2.4		0737	2.2		0854	2.3		0813	2.3
TH	1426	0.7	F	1401	0.8	SU	1507	0.6	M	1430	0.5
	2033	2.4		2009	2.3		2117	2.5		2049	2.6
15	0240	0.8	30	0216	0.9	15	0336	0.6	30	0310	0.6
	0846	2.5		0812	2.4		0927	2.3		0856	2.3
F	1504	0.6	SA	1433	0.7	M	1538	0.6	TU	1511	0.4
	2110	2.5		2042	2.4		2146	2.6		2128	2.7
			31	0253	0.7						
				0847	2.4						
			SU	1505	0.5						
				2115	2.6						

NOVEMBER

	TIME	M		TIME	M
9	0348	2.1	24	0250	2.0
	1040	1.1		0945	1.2
TU	1702	1.9	W	1610	1.7
	2301	1.2		2156	1.3
10	0529	2.1	25	0420	1.9
	1207	1.0		1111	1.1
W	1832	2.0	TH	1746	1.8
				2336	1.2
11	0034	1.1	26	0543	2.0
	0645	2.2		1218	1.0
TH	1310	0.9	F	1846	2.0
	1928	2.2			
12	0135	1.0	27	0049	1.1
	0738	2.3		0643	2.1
F	1357	0.7	SA	1307	0.8
	2011	2.4		1930	2.2
13	0223	0.8	28	0141	0.9
	0819	2.3		0731	2.2
SA	1434	0.6	SU	1351	0.6
	2046	2.5		2009	2.4
14	0301	0.7	29	0226	0.7
	0854	2.3		0813	2.3
SU	1507	0.6	M	1430	0.5
	2117	2.5		2049	2.6
15	0336	0.6	30	0310	0.6
	0927	2.3		0856	2.3
M	1538	0.6	TU	1511	0.4
	2146	2.6		2128	2.7

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
				1013	2.1
			F	1623	0.2
				2242	2.6

HEIGHTS IN METRES

Vol. 2 — Atlantic and Indian Oceans — Part II.

UNITED STATES: CANADA, BAY OF FUNDY

No.	PLACE		Lat. N.	Long. W.	TIME DIFFERENCES MHW (Zone + 0500)	MLW	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)	MLW	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	+0500	⊙	−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

Vol. 2 — Atlantic and Indian Oceans — Part II.

Vol. 3 — Pacific Ocean and Adjacent Seas — Part II.

No.	PLACE	M.L. Z_0 m.	HARMONIC CONSTANTS M_2 g°	H.m.	S_2 g°	H.m.	K_1 g°	H.m.	O_1 g°	H.m.	S.W. CORRECTIONS ¼-diurnal f_4	F_1	⅙-diurnal 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*
4547*	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.

Port No.	Average M.L.	At Springs	Corrected M.L. Days before or after 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.
,, ,, 4547 ,, ,, ,, ,, at Springs.

TABLE VII TIDAL ANGLES AND FACTORS YEAR 1982

JANUARY

DAY	M2 A	M2 F	S2 A	S2 F	K1 A	K1 F	O1 A	O1 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

DAY	M2 A	M2 F	S2 A	S2 F	K1 A	K1 F	O1 A	O1 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

DAY	M2 A	M2 F	S2 A	S2 F	K1 A	K1 F	O1 A	O1 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	0.88	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	008	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	006	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

DAY	M2 A	M2 F	S2 A	S2 F	K1 A	K1 F	O1 A	O1 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 TIDAL ANGLES AND FACTORS YEAR 1982

MAY

DAY	M2 A	M2 F	S2 A	S2 F	K1 A	K1 F	O1 A	O1 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

DAY	M2 A	M2 F	S2 A	S2 F	K1 A	K1 F	O1 A	O1 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

DAY	M2 A	M2 F	S2 A	S2 F	K1 A	K1 F	O1 A	O1 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	1.36	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

DAY	M2 A	M2 F	S2 A	S2 F	K1 A	K1 F	O1 A	O1 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 TIDAL ANGLES AND FACTORS YEAR 1982

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	062	0.95	001	1.24	107	0.67	339	0.93
22	105	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	0.79	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	1.49	011	1.25

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 tida predictions in all cases.

For Notes (*b*), (*c*) and (*d*) see p. 00.

TABLE V (*cont.*)

TIDAL LEVELS AT STANDARD PORTS

(with data concerning predictions, etc.)

Standard Port	L.A.T.	M.L.L.W.	M.H.L.W.	M.S.L.	M.L.H.W.	M.H.H.W.	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.

EXTRACTS FROM A.T.T.

Vol. 3 — Pacific Ocean and Adjacent Seas — Part I.

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				JUNE				JULY				AUGUST			
TIME	M	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M	TIME	M
1 0150 2.8	16 0110 3.1	1 0355 2.0	16 0250 2.3	1 0405 1.8	16 0310 1.8	1 0515 1.5	16 0510 1.0
0755 5.5	0655 4.8	0955 5.3	0850 4.9	1015 5.0	0930 4.9	1155 5.1	1140 5.5
SA 1430 1.7	SU 1335 2.0	TU 1555 2.0	W 1445 2.1	TH 1605 2.5	F 1510 2.5	SU 1720 2.7	M 1705 2.3
2110 5.4	2015 5.0	2215 6.0	2125 5.8	2225 5.9	2135 6.1	2325 5.9	2315 6.6
2 0310 2.6	17 0225 2.9	2 0440 1.7	17 0355 1.8	2 0505 1.6	17 0420 1.3	2 0615 1.3	17 0600 0.7
0900 5.5	0820 4.9	1055 5.4	0955 5.1	1125 5.1	1040 5.2	1230 5.3	1220 5.9
SU 1535 1.7	M 1450 2.0	W 1655 2.0	TH 1545 2.1	F 1705 2.5	SA 1625 2.4	M 1810 2.5	TU 1810 2.0
2210 5.7	2115 5.3	2310 6.1	2200 6.2	2305 6.0	2230 6.4		
3 0415 2.2	18 0335 2.5	3 0530 1.4	18 0445 1.3	3 0550 1.3	18 0520 0.9	3 0015 6.0	18 0005 6.9
1015 5.6	0930 5.1	1140 5.5	1100 5.4	1200 5.3	1145 5.5	0650 1.1	0655 0.3
M 1620 1.6	TU 1550 1.9	TH 1740 2.0	F 1650 2.1	SA 1750 2.5	SU 1725 2.3	TU 1310 5.5	W 1305 6.2
2300 6.0	2205 5.6	2345 6.2	2255 6.6	2345 6.1	2320 6.8	1845 2.3	1850 1.6

Part II.

				MHW	MLW	MHWS 6·5	MHWN 5·2	MLWN 2·5	MLWS 1·1	M.L. Z_0 m.
8850	**PRINCE RUPERT** . .	see page 207								
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

Box No.

Complete Heading.

1 to 4 Enter daily prediction data from ATT Part I.

5 and 6 Enter data from ATT Part II (not required for Standard Port or Vol. 1).

7 to 10 Enter Differences from ATT Part II (interpolation necessary for Vol. 1) (not required for Standard Port).

11 Enter sum of 1 and 7 (for Standard Port enter 1).

12 Enter sum of 2 and 8 (for Standard Port enter 2).

13 Enter sum of 3, 5, 6 and 9 (for Standard Port enter 3).

14 Enter sum of 4, 5, 6 and 10 (for Standard Port enter 4).

15 Enter Duration. Difference of times in 11 and 12 (not required for Vol. 1).

16(a) Enter Range at Standard Port. Difference of heights in 3 and 4.

16(b) Enter Range at Secondary Port. Difference of heights in 13 and 14.

*Delete Springs, Neaps, Interpolate as appropriate to Standard Port Range 16(a) (Vol. 1 only).

TO FIND HEIGHT AT GIVEN TIME

17 Enter required time.

18 Enter HW time from 11.

19 Enter Interval. Difference of 17 and 18.

20 *Enter Factor obtained from interpolation of appropriate curve entered with Interval 19.

21 Enter Rise=Factor 20 × Range 16(b) (for Standard Port use 16(a)).

22 Enter LW Height from 14.

23 Enter sum of Rise 21 and LW Height 22.

TO FIND TIME FOR A GIVEN HEIGHT (Start at bottom of column)

23 Enter required height.

22 Enter LW Height from 14.

21 Enter Rise=Height 23−LW Height 22.

20 Enter Factor=Rise 21/Range 16(b) (for Standard Ports use 16(a)).

19 *Enter Interval obtained from interpolation of appropriate curve entered with Factor 20.

18 Enter HW Time 11.

17 Enter Interval 19 applied to HW Time 18.

**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 16(a)) 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 or HEIGHT REQUIRED.....

SECONDARY PORT .....DATE.....TIME ZONE.....

	TIME		HEIGHT	
	HW	LW	HW	LW
STANDARD PORT	1	2	3	4
Seasonal Changes in ML	−Standard Port		5	
	+Secondary Port		6	
DIFFERENCES	7	8	9	10
SECONDARY PORT	11	12	13	14
DURATION	15	RANGE(a)St (b)Sec	16(a)	16(b)

***Springs/Neaps/Interpolate**

START— Height at Given Time ↓

REQUIRED TIME	17
TIME HW	18
INTERVAL	19

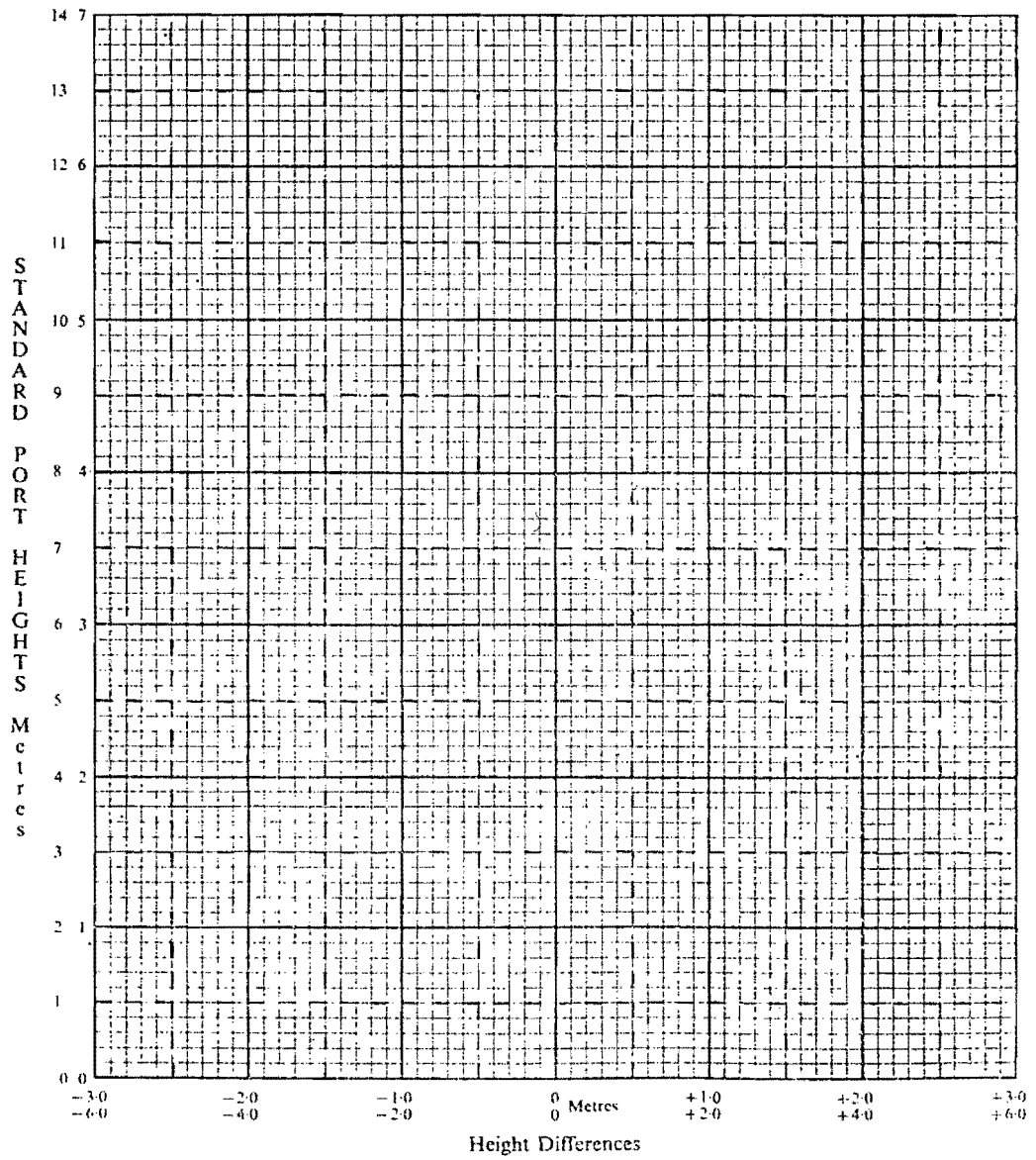
FACTOR	20

RISE	21
HEIGHT LW	22
HEIGHT REQUIRED	23

↑ START— Time for Given Height

*Delete as necessary

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 H.W. and one L.W. height value is tabulated in Part II, interpolation for both H.W. and L.W. must be made between these two values and extrapolating if necessary.

Pages 393—410 Reproduced by kind permission of the Hydrographer of the Navy.

Required the Height of Tide at at on

Secondary Port: Index No. *step* 1

Standard Port: *step* 2

	Times		*Heights* (*m*)		
	HW	LW	HW	LW	
Standard Port					*step* 3
Time Differences					*step* 4
Secondary Port					

Time Interval

Secondary HW
Required Time

Interval from HW *step* 5

Ranges (*m*)

Secondary HW		Standard HW		Spring Range		
LW		LW		Neap		
Secondary Range		Standard Range		Spring~Neap		*steps* 6, 7 & 8

Standard Range
Neap Range

Standard~Neap

Standard Port Range lies from Neaps towards Springs—Interpolate. *step* 9

Factors		*Interpolation*			
Factor from Spring Curve					
Neap					
Spring~Neap Factor		Adjustment =		×	≏
Neap Factor					
Adjustment					
Predicted Factor					*step* 10

Rise of Tide (*m*)

Secondary Range
Predicted Factor (×) *step* 11

Rise of Tide
Secondary LW (+) *step* 12

Height of Tide metres at

Forms A, B & C for Predictions using Harmonic Constants and the Table of Tidal Angles and Factors in ATT.

FORM A

Place _____ Date _____

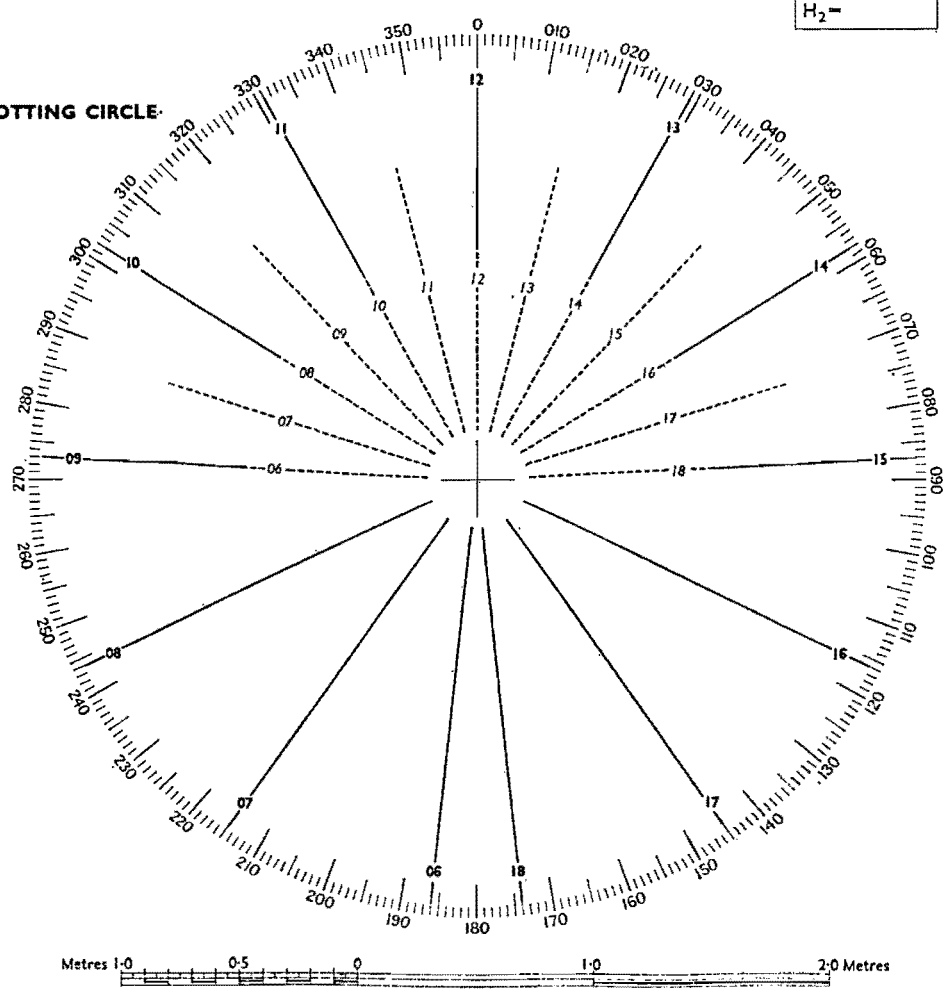
Lat _____ Long _____ Zone Time _____

TABLE

			M_2		S_2		K_1		O_1		M.L.	
	$\alpha°$		012		000		180		192			
from A.T.T., part II	$\beta°$	H										Mean level (Zo)
from A.T.T., table VII	$A°$	F										Seasonal correction
	$\alpha+\beta+A$	H×F	$-m°$	$-M$	$-s°$	$-S$	$-k°$	$-K$	$-o°$	$-O$	$-A_o$	ADD
	logs:											

h_2 =	
H_2 =	

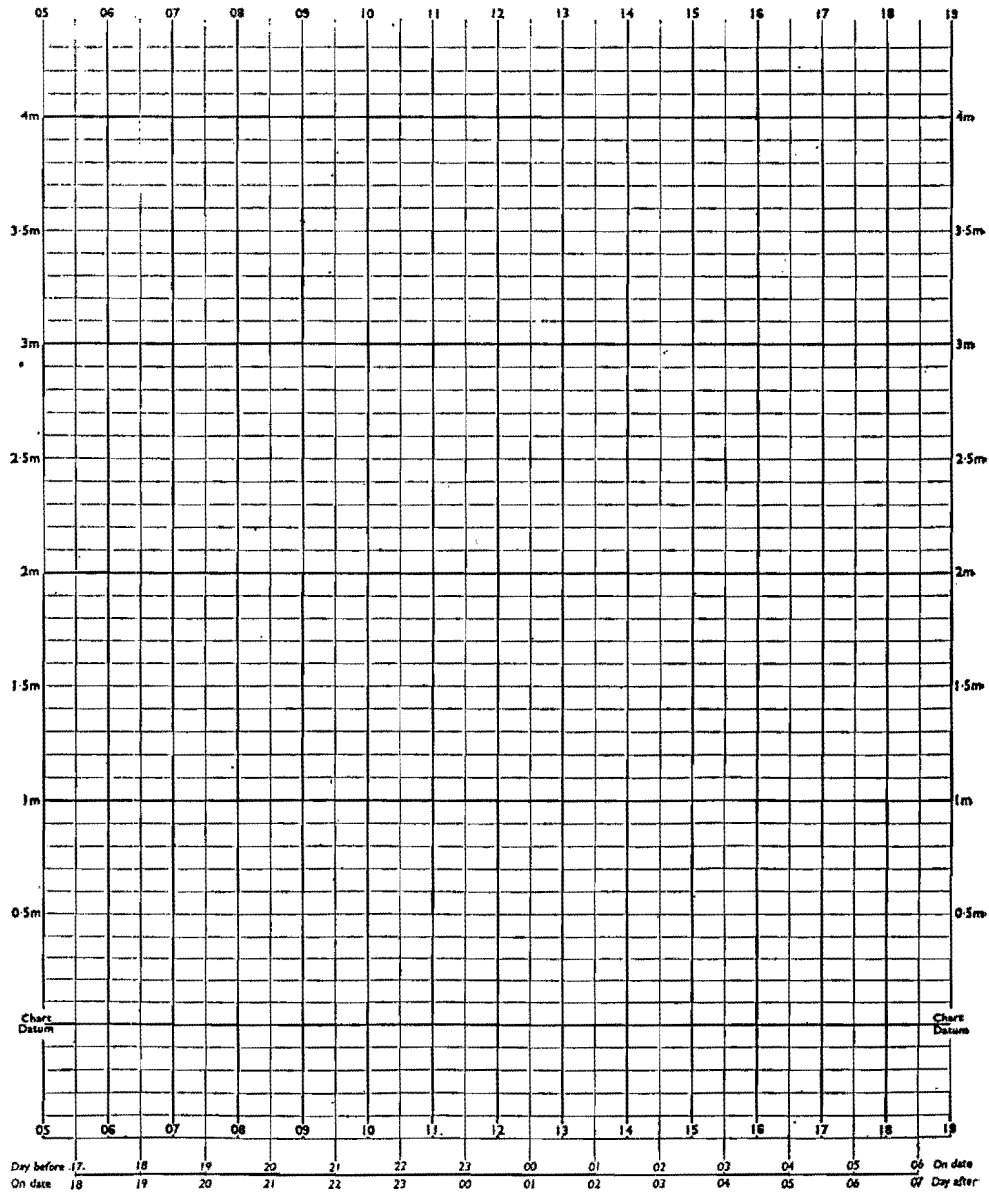
PLOTTING CIRCLE



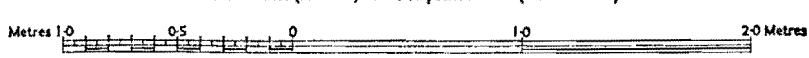
FORM B

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 packed curve (drawn second).



FORM C

Place _____ Date _____

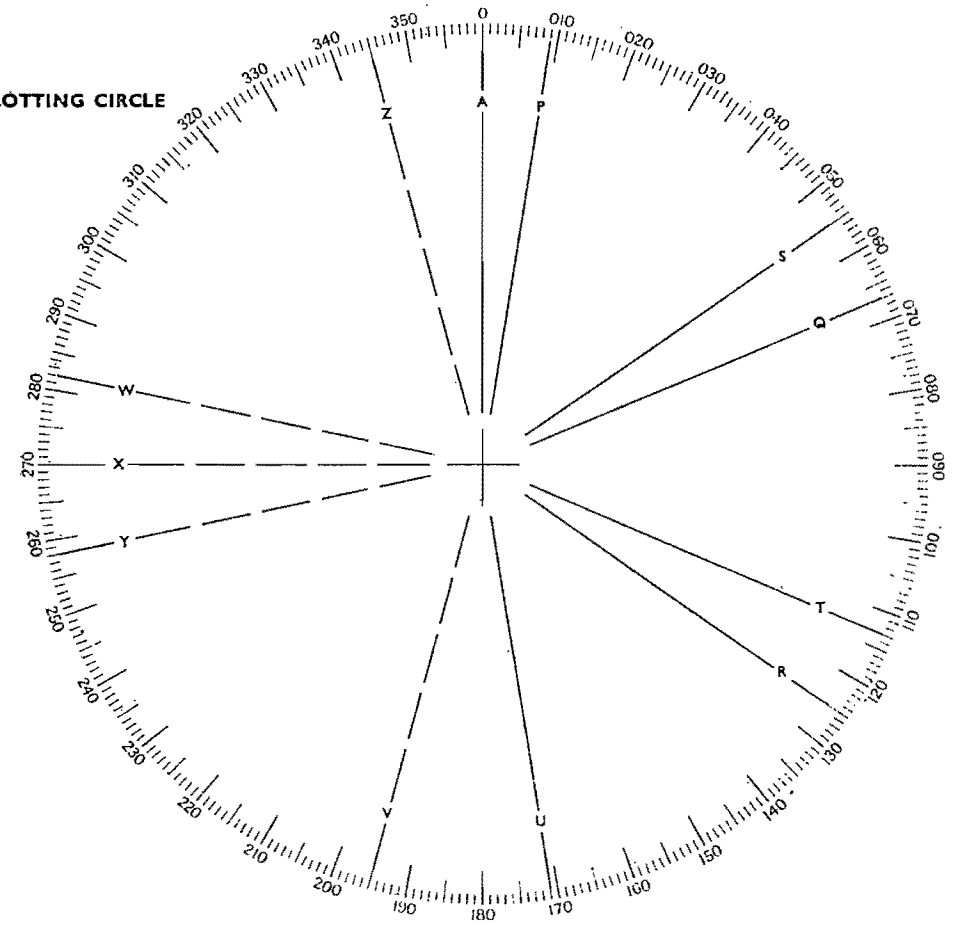
Lat _____ Long _____ Zone Time _____

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													

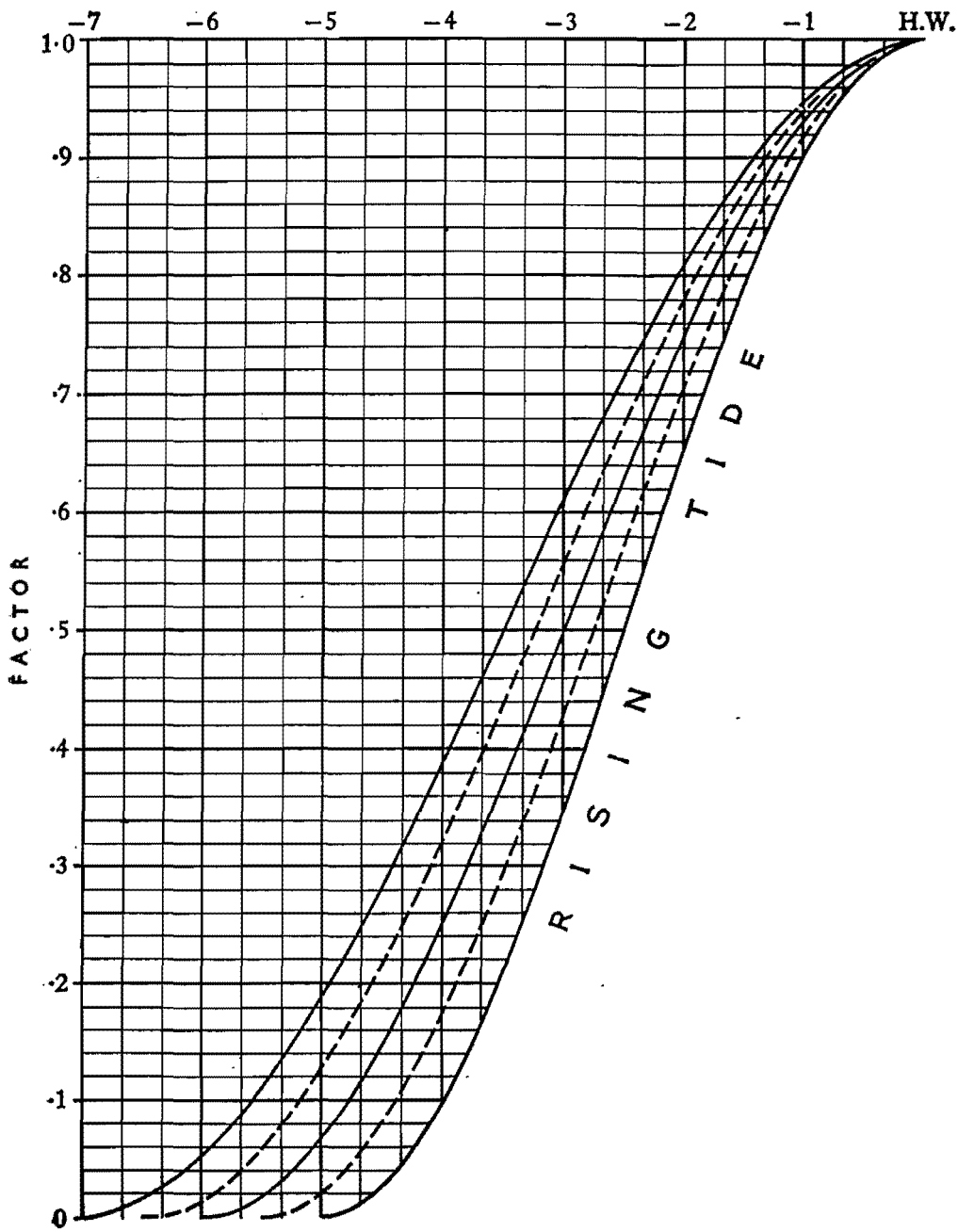
TABLE I

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	16·03	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
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	15·55	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

FOR FINDING THE HEIGHT OF THE TIDE AT TIMES BETWEEN HIGH AND LOW WATER



FOR FINDING THE HEIGHT OF THE TIDE AT TIMES BETWEEN HIGH AND LOW WATER

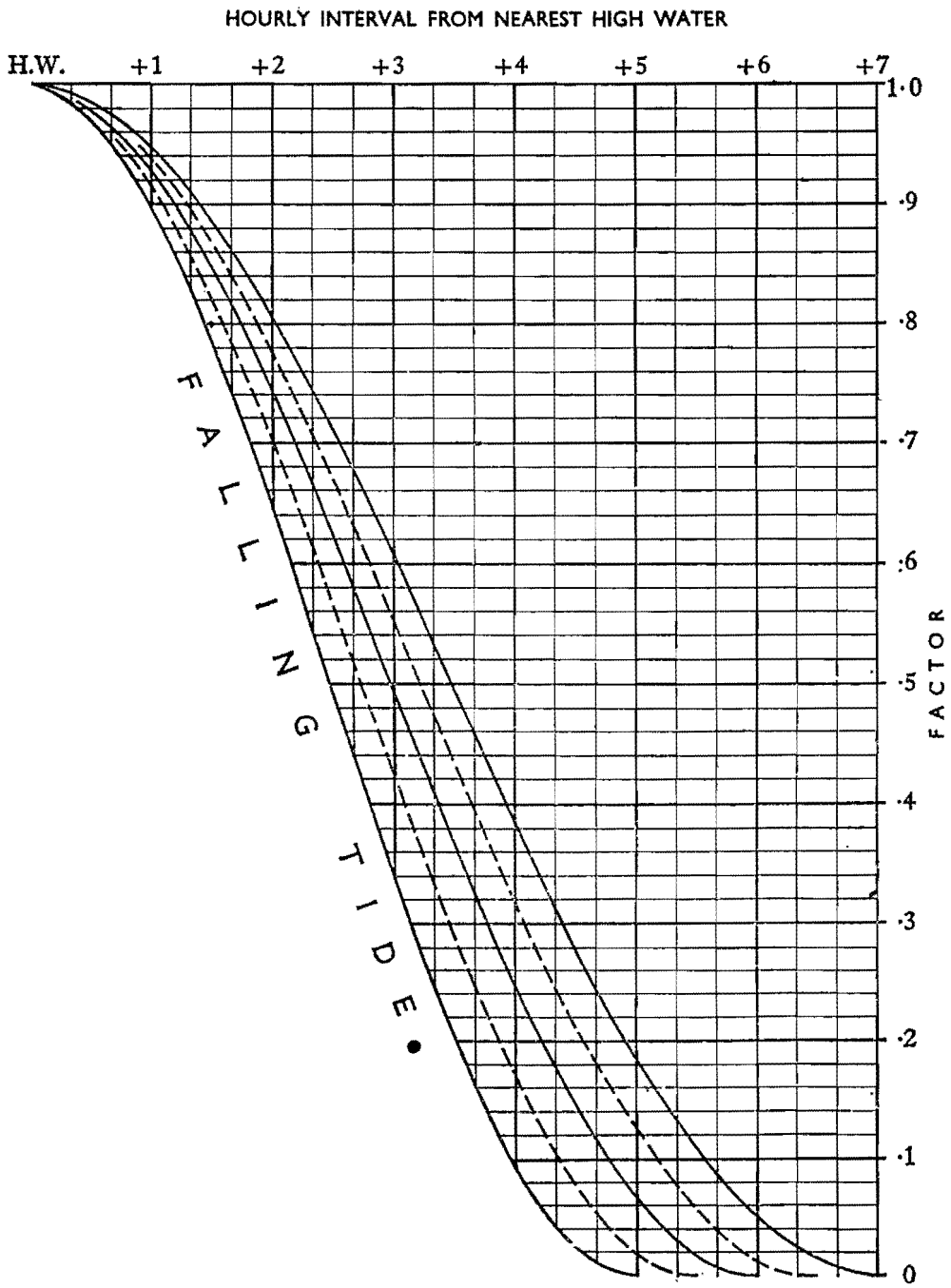


TABLE II

MULTIPLICATION TABLE

RANGE AT STANDARD PORT

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
·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	·98
·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	·96
·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	·94
·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	·92
·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	·90
·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	·88
·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	·86
·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	·84
·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	·82
·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	·80
·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	·78
·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	·76
·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	·74
·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	·72
·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	·70
·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	·68
·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	·66
·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	·64
·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	·62
·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	·60
·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	·58
·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	·56
·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	·54
·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	·52
·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	·50
·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	·48
·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	·46
·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	1·7	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	·44
·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	·42
·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	·40
·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	·38
·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	·36
·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	·34
·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	·32
·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	·30
·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	·28
·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	·26
·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	·24
·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	·22
·20	0·2	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	0·8	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	·20
·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	·18
·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	·16
·14	0·2	0·2	0·2	0·3	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	0·7	0·7	0·8	0·8	0·8	0·8	0·9	0·9	0·9	0·9	1·0	1·0	·14
·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	·12
·10	0·1	0·1	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·4	0·4	0·4	0·4	0·4	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·6	0·7	0·7	0·7	·10
·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	·08
·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	0·3	0·4	0·4	0·4	0·4	0·4	0·4	0·4	·06
·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	0·2	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	·04
·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	·02

FACTOR

FACTOR

TABLE II (*cont.*)

MULTIPLICATION TABLE

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
·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	·98
·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	·96
·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	13·2	13·2	14·1	15·0	16·0	·94
·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	·92
·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	·90
·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	·88
·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	·86
·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	·84
·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	·82
·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	·80
·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	·78
·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	·76
·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	·74
·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	·72
·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	·70
·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	·68
·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	·66
·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	·64
·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	·62
·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	·60
·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	·58
·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	·56
·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	·54
·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	·52
·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	·50
·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	·48
·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	·46
·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	·44
·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	·42
·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	·40
·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	·38
·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	·36
·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	·34
·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	·32
·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	·30
·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	·28
·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	·26
·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	3·9	4·1	·24
·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	·22
·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	·20
·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	·18
·16	1·2	1·2	1·2	1·2	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	2·0	2·1	2·2	2·4	2·6	2·7	·16
·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	·14
·12	0·9	0·9	0·9	0·9	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	1·4	1·6	1·7	1·8	1·9	2·0	·12
·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	·10
·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	0·8	0·9	0·9	0·9	0·9	0·9	0·9	1·0	1·0	1·1	1·2	1·3	1·4	·08
·06	0·4	0·4	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	0·6	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·8	0·9	1·0	1·0	1·0	1·0	·06
·04	0·3	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	·04
·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	·02

FACTOR

FACTOR

Pages 412-419—Reproduced by kind permission of the Hydrographer of the Navy.

ELEMENTS FROM THE

ADMIRALTY

NAUTICAL ALMANAC

JANUARY 4, 5, 6 (SAT., SUN., MON.)

G.M.T.	ARIES	VENUS −4·3		MARS +1·7		JUPITER −1·5		SATURN +0·7		STARS		
d h	G.H.A. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	Name	S.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	Acamar	315 49·7	S 40 28·6
01	118 08·3	160 10·0	38·6	231 33·9	39·0	270 46·0	56·4	219 08·6	43·1	Achernar	335 57·7	S 57 27·3
02	133 10·7	175 12·2	38·0	246 34·5	39·3	285 48·2	56·5	234 10·7	43·1	Acrux	173 55·7	S 62 51·8
03	148 13·2	190 14·4	.. 37·3	261 35·2	.. 39·6	300 50·4	.. 56·6	249 12·9	.. 43·1	Adhara	255 44·8	S 28 55·0
04	163 15·7	205 16·7	36·7	276 35·8	39·9	315 52·6	56·7	264 15·1	43·2	Aldebaran	291 36·9	N 16 25·5
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	Alioth	166 57·2	N 56 10·9
07	208 23·1	250 23·4	34·8	321 37·6	40·8	0 59·1	57·0	309 21·5	43·2	Alkaid	153 31·8	N 49 31·1
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	Al Na'ir	28 36·3	S 47 10·0
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	Alnilam	276 28·3	S 1 13·8
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	Alphard	218 36·7	S 8 28·7
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	Alphecca	126 46·5	N 26 51·2
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	Alpheratz	358 26·7	N 28 51·7
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	Altair	62 49·2	N 8 45·5
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	Ankaa	353 56·8	S 42 32·2
16	343 45·2	25 43·9	29·0	96 43·2	43·5	136 13·7	57·9	84 41·0	43·4	Antares	113 17·6	S 26 20·3
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	Arcturus	146 33·8	N 19 23·9
19	28 52·6	70 50·8	27·1	141 45·0	44·4	181 25·2	58·2	129 47·5	43·5	Atria	108 57·3	S 68 56·9
20	43 55·1	85 53·1	26·5	156 45·6	44·7	196 27·4	58·3	144 49·7	43·5	Avior	234 34·4	S 59 22·5
21	58 57·6	100 55·4	.. 25·9	171 46·2	. 44·9	211 29·6	. 58·4	159 51·9	.. 43·5	Bellatrix	279 16·3	N 6 18·7
22	74 00·0	115 57·8	25·2	186 46·9	45·2	226 31·8	58·5	174 54·0	43·6	Betelgeuse	271 46·0	N 7 23·9
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	Canopus	264 14·1	S 52 40·5
01	119 07·4	161 04·7	23·3	231 48·7	46·1	271 38·3	58·8	220 00·5	43·6	Capella	281 35·5	N 45 57·4
02	134 09·9	176 07·1	22·7	246 49·3	46·4	286 40·5	58·9	235 02·7	43·6	Deneb	50 00·2	N 45 08·0
03	149 12·3	191 09·4	.. 22·1	261 49·9	. 46·7	301 42·7	.. 58·9	250 04·8	. 43·7	Denebola	183 16·0	N 14 48·2
04	164 14·8	206 11·8	21·5	276 50·5	47·0	316 44·8	59·0	265 07·0	43·7	Diphda	349 37·7	S 18 13·1
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	Dubhe	194 42·4	N 61 58·3
07	209 22·2	251 18·8	19·6	321 52·4	47·9	1 51·4	59·3	310 13·5	43·8	Elnath	279 04·9	N 28 34·3
08	224 24·7	266 21·2	19·0	336 53·0	48·2	16 53·6	59·4	325 15·7	43·8	Eltanin	91 06·0	N 51 29·6
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	Enif	34 28·2	N 9 41·0
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	Fomalhaut	16 10·1	S 29 50·3
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	Gacrux	172 47·2	S 56 52·5
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	Gienah	176 35·1	S 17 18·5
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	Hadar	149 47·1	S 60 10·0
15	329 41·9	11 37·8	.. 14·6	81 57·3	.. 50·2	122 08·9	.. 00·1	70 30·8	. 43·9	Hamal	328 47·6	N 23 16·0
16	344 44·4	26 40·2	14·0	96 57·9	50·5	137 11·0	00·2	85 33·0	43·9	Kaus Aust.	84 39·4	S 34 24·2
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	Kochab	137 18·9	N 74 19·4
19	29 51·8	71 47·4	12·1	141 59·7	51·4	182 17·6	00·5	130 39·5	44·0	Markab	14 20·0	N 14 58·9
20	44 54·2	86 49·8	11·5	157 00·3	51·7	197 19·8	00·6	145 41·7	44·0	Menkar	314 58·4	N 3 55·5
21	59 56·7	101 52·2	. 10·9	172 00·9	. 52·0	212 22·0	.. 00·7	160 43·8	. 44·0	Menkent	148 56·8	S 36 09·7
22	74 59·2	116 54·6	10·3	187 01·5	52·3	227 24·2	00·8	175 46·0	44·1	Miaplacidus	221 47·7	S 69 32·6
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	Mirfak	309 39·7	N 49 42·9
01	120 06·6	162 01·9	08·4	232 03·4	53·1	272 30·7	01·0	220 52·5	44·1	Nunki	76 50·3	S 26 20·9
02	135 09·0	177 04·4	07·8	247 04·0	53·4	287 32·9	01·1	235 54·7	44·2	Peacock	54 25·4	S 56 52·3
03	150 11·5	192 06·8	.. 07·2	262 04·6	.. 53·7	302 35·1	. 01·2	250 56·8	.. 44·2	Pollux	244 18·2	N 28 07·5
04	165 13·9	207 09·2	06·6	277 05·2	54·0	317 37·3	01·3	265 59·0	44·2	Procyon	245 42·9	N 5 19·8
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	Rasalhague	96 45·4	N 12 35·4
07	210 21·3	252 16·6	04·8	322 07·0	54·8	2 43·8	01·6	311 05·5	44·3	Regulus	208 27·6	N 12 10·2
08	225 23·8	267 19·1	04·2	337 07·6	55·1	17 46·0	01·7	326 07·7	44·3	Rigel	281 51·8	S 8 15·1
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	Rigil Kent.	140 48·9	S 60 39·5
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	Sabik	103 00·6	S 15 40·4
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	Schedar	350 28·0	N 56 18·8
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	Shaula	97 18·8	S 37 04·3
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	Sirius	259 10·1	S 16 39·6
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	Spica	159 15·2	S 10 56·6
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	Suhail	223 22·7	S 43 15·8
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	Vega	81 07·6	N 38 44·7
19	30 50·9	72 46·4	57·6	142 14·3	58·2	183 10·1	02·7	131 31·5	44·5	Zuben'ubi	137 51·7	S 15 52·0
20	45 53·4	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		S.H.A.	Mer. Pass.
22	75 58·3	117 54·0	55·8	187 16·1	59·1	228 16·7	03·0	176 38·0	44·6		° ′	h m
23	91 00·8	132 56·5	55·2	202 16·7	59·4	243 18·9	03·1	191 40·2	44·6	Venus	41 57·4	14 14
										Mars	112 43·1	9 32
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 0·3	Jupiter	152 31·1	6 53
										Saturn	100 53·3	10 19

JANUARY 4, 5, 6 (SAT., SUN., MON.)

G.M.T.	SUN			MOON					
	G.H.A.		Dec.	G.H.A.	v	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	Sun-rise	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 35
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.	Sun-set	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 26
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	S 13 54·6	217 17·3	S 21 59·6	258 21·0	S 10 03·2	206 42·4	S 21 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	S 13 51·0	307 20·9	S 22 01·3	348 34·2	S 10 03·8	296 55·4	S 21 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	S 13 47·5	37 24·5	S 22 03·0	78 47·4	S 10 04·3	27 08·4	S 21 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	S 13 44·0	127 28·2	S 22 04·6	169 00·5	S 10 04·8	117 21·4	S 21 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	S 13 40·5	217 31·8	S 22 06·2	259 13·7	S 10 05·4	207 34·4	S 21 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	S 13 37·1	307 35·4	S 22 07·9	349 26·9	S 10 05·9	297 47·4	S 21 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	S 13 33·7	37 38·9	S 22 09·5	79 40·1	S 10 06·5	28 00·5	S 21 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	S 13 30·3	127 42·5	S 22 11·1	169 53·3	S 10 07·0	118 13·5	S 21 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	S 13 27·0	217 46·1	S 22 12·7	260 06·5	S 10 07·5	208 26·5	S 21 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	S 13 23·7	307 49·7	S 22 14·2	350 19·7	S 10 08·0	298 39·5	S 21 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	S 13 20·4	37 53·2	S 22 15·8	80 33·0	S 10 08·6	28 52·6	S 21 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	S 13 17·2	127 56·8	S 22 17·3	170 46·2	S 10 09·1	119 05·6	S 21 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 29 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	50 00·3	N 45 08·0
Denebola	183 16·0	N 14 48·2
Diphda	349 57·7	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
Gienah	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 13·8	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 16·8
Shaula	97 16·8	S 37 04·3
Sirius	259 10·1	S 16 39·6
Spica	159 15·2	S 10 56·6
Suhail	223 02·6	S 43 15·8
Vega	81 07·6	N 38 44·7
Zuben'ubi	137 51·7	S 15 52·6

	S.H.A. ° ′	Mer. Pass. h m
Venus	41 58·6	14 01
Mars	110 29·4	9 29
Jupiter	152 11·3	6 42
Saturn	139 32·9	10 08

JANUARY 7, 8, 9 (TUES., WED., THURS.)

G.M.T.	SUN			MOON					Lat.	Twilight Naut.	Twilight Civil	Sun-rise	Moonrise 7	Moonrise 8	Moonrise 9	Moonrise 10
d h	G.H.A. ° ′		Dec. ° ′	G.H.A. ° ′	v ′	Dec. ° ′	d ′	H.P. ′	°	h m	h m	h m	h m	h m	h m	h m
7 00	178 29·8	S 22 27·7		343 22·1	7·3	N14 55·5	8·2	59·5	N 72	08 15	10 20		16 57	19 03	21 05	23 04
01	193 29·5	27·4		357 48·4	7·3	14 47·3	8·2	59·5	N 70	07 58	09 37		17 19	19 15	21 09	23 00
02	208 29·2	27·1		12 14·7	7·3	14 39·1	8·3	59·5	68	07 44	09 08	11 11	17 37	19 25	21 12	22 57
03	223 29·0	26·8		26 41·0	7·4	14 30·8	8·5	59·5	66	07 33	08 46	10 13	17 51	19 33	21 14	22 54
04	238 28·7	26·5		41 07·4	7·4	14 22·3	8·5	59·5	64	07 23	08 29	09 40	18 03	19 39	21 16	22 52
05	253 28·4	26·2		55 33·8	7·4	14 13·8	8·6	59·6	62	07 14	08 14	09 16	18 13	19 45	21 18	22 50
06	268 28·2	S 22 25·9		70 00·2	7·4	N14 05·2	8·7	59·6	60	07 07	08 02	08 57	18 21	19 50	21 20	22 49
07	283 27·9	25·5		84 26·6	7·5	13 56·5	8·8	59·6	N 58	07 00	07 51	08 42	18 28	19 55	21 21	22 47
08	298 27·6	25·2		98 53·1	7·5	13 47·7	8·9	59·6	56	06 54	07 42	08 28	18 35	19 58	21 23	22 46
T 09	313 27·3	24·9		113 19·6	7·6	13 38·8	9·0	59·6	54	06 48	07 34	08 16	18 40	20 02	21 24	22 45
U 10	328 27·1	24·6		127 46·2	7·5	13 29·8	9·0	59·6	52	06 43	07 26	08 06	18 46	20 05	21 25	22 44
E 11	343 26·8	24·3		142 12·7	7·6	13 20·8	9·2	59·6	50	06 38	07 19	07 57	18 50	20 08	21 26	22 43
S 12	358 26·5	S 22 24·0		156 39·3	7·7	N13 11·6	9·2	59·7	45	06 28	07 04	07 38	19 00	20 14	21 28	22 41
D 13	13 26·3	23·7		171 06·0	7·7	13 02·4	9·3	59·7	N 40	06 18	06 52	07 22	19 09	20 19	21 30	22 39
A 14	28 26·0	23·3		185 32·7	7·7	12 53·1	9·4	59·7	35	06 09	06 41	07 08	19 16	20 24	21 31	22 38
Y 15	43 25·7	23·0		199 59·4	7·7	12 43·7	9·5	59·7	30	06 01	06 31	06 57	19 22	20 28	21 32	22 37
16	58 25·5	22·7		214 26·1	7·8	12 34·2	9·6	59·7	20	05 46	06 13	06 37	19 33	20 34	21 35	22 34
17	73 25·2	22·4		228 52·9	7·8	12 24·6	9·6	59·7	N 10	05 31	05 57	06 19	19 43	20 40	21 37	22 33
18	88 24·9	S 22 22·1		243 19·7	7·8	N12 15·0	9·8	59·7	0	05 15	05 40	06 03	19 51	20 46	21 39	22 31
19	103 24·7	21·8		257 46·5	7·9	12 05·2	9·8	59·7	S 10	04 56	05 23	05 46	20 00	20 51	21 41	22 29
20	118 24·4	21·4		272 13·4	7·9	11 55·4	9·8	59·7	20	04 35	05 04	05 28	20 10	20 57	21 43	22 27
21	133 24·1	21·1		286 40·3	7·9	11 45·6	10·0	59·7	30	04 07	04 40	05 07	20 21	21 04	21 45	22 25
22	148 23·9	20·8		301 07·2	8·0	11 35·6	10·0	59·8	35	03 50	04 26	04 55	20 27	21 08	21 46	22 24
23	163 23·6	20·5		315 34·2	8·0	11 25·6	10·1	59·8	40	03 28	04 09	04 41	20 34	21 12	21 48	22 23
8 00	178 23·3	S 22 20·1		330 01·2	8·1	N11 15·5	10·2	59·8	45	03 00	03 47	04 24	20 42	21 17	21 50	22 21
01	193 23·1	19·8		344 28·3	8·1	11 05·3	10·3	59·8	S 50	02 18	03 20	04 03	20 52	21 23	21 52	22 20
02	208 22·8	19·5		358 55·4	8·1	10 55·0	10·3	59·8	52	01 55	03 06	03 53	20 56	21 26	21 53	22 19
03	223 22·5	19·2		13 22·5	8·1	10 44·7	10·4	59·8	54	01 21	02 50	03 41	21 01	21 29	21 54	22 18
04	238 22·3	18·8		27 49·6	8·2	10 34·3	10·4	59·8	56	////	02 30	03 28	21 07	21 32	21 55	22 17
05	253 22·0	18·5		42 16·8	8·2	10 23·9	10·5	59·8	58	////	02 04	03 13	21 13	21 36	21 57	22 16
06	268 21·7	S 22 18·2		56 44·0	8·3	N10 13·4	10·6	59·8	S 60	////	01 27	02 55	21 20	21 40	21 58	22 15
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									

Lat.	Sun-set	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	S 13 14·0	218 00·3	S 22 18·9	260 59·4	S 10 09·6	209 18·6	S 21 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	S 13 10·8	308 03·9	S 22 20·4	351 12·7	S 10 10·1	299 31·7	S 21 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	S 13 07·7	38 07·4	S 22 21·9	81 26·0	S 10 10·6	29 44·7	S 21 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	S 13 04·6	128 11·0	S 22 23·4	171 39·2	S 10 11·1	119 57·8	S 21 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	S 13 01·5	218 14·5	S 22 24·9	261 52·5	S 10 11·6	210 10·8	S 21 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	S 12 58·5	308 18·0	S 22 26·4	352 05·8	S 10 12·1	300 23·8	S 21 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 50·8
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	S 12 55·5	38 21·5	S 22 27·8	82 19·1	S 10 12·6	30 36·9	S 21 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	S 12 52·6	128 25·0	S 22 29·3	172 32·4	S 10 13·1	120 49·9	S 21 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	S 12 49·7	218 28·5	S 22 30·7	262 45·7	S 10 13·6	211 03·0	S 21 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	S 12 46·8	308 32·0	S 22 32·1	352 59·0	S 10 14·1	301 16·1	S 21 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	S 12 43·9	38 35·5	S 22 33·6	83 12·4	S 10 14·6	31 29·1	S 21 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 10·8	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 19·0	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	S 12 41·1	128 39·0	S 22 35·0	173 25·7	S 10 15·0	121 42·2	S 21 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	Venus	42 22·1	13 48
23	96 55·6	139 45·1	38·8	203 41·9	36·1	248 36·8	15·4	196 53·1	47·4	Mars	108 14·7	9 27
										Jupiter	151 52·7	6 31
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	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.	MOON v	MOON Dec.	MOON d	MOON 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
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 43
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	S 21 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	S 21 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	S 21 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	S 21 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	S 21 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	S 21 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	S 21 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	S 21 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	S 21 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	S 21 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	S 21 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	S 21 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
Gienah	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 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 27·8	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		Sun-rise	Moonrise			
		G.H.A.	Dec.	G.H.A.	v	Dec.	d	H.P.			Naut.	Civil		15	16	17	18
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	□	□	□				
	01	194 57·5	16·8	222 55·2	11·4	17 10·8	4·6	55·2		N 70	□	□	□	00 18	00 28	00 59	02 11
	02	209 57·4	16·9	237 25·6	11·4	17 15·4	4·5	55·3		68	□	□	□	00 50	01 13	01 53	02 57
	03	224 57·3	17·0	251 56·0	11·3	17 19·9	4·5	55·3		66	□	□	□	01 14	01 42	02 26	03 28
	04	239 57·1	17·1	266 26·3	11·2	17 24·4	4·4	55·3		64	////	////	01 33	01 33	02 05	02 50	03 50
	05	254 57·0	17·2	280 56·5	11·3	17 28·8	4·3	55·3		62	////	////	02 10	01 48	02 23	03 09	04 09
										60	////	00 52	02 36	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		N 58	////	01 41	02 56	02 12	02 50	03 38	04 36
	07	284 56·7	17·5	309 56·9	11·1	17 37·3	4·1	55·4		56	////	02 11	03 13	02 22	03 01	03 49	04 47
	08	299 56·6	17·6	324 27·0	11·1	17 41·4	4·0	55·4		54	00 48	02 33	03 27	02 31	03 11	03 59	04 57
S	09	314 56·5	17·7	338 57·1	11·0	17 45·4	4·0	55·4		52	01 33	02 51	03 39	02 38	03 19	04 08	05 05
U	10	329 56·3	17·8	353 27·1	11·0	17 49·4	3·8	55·4		50	02 00	03 06	03 50	02 45	03 27	04 16	05 13
N	11	344 56·2	17·9	7 57·1	10·9	17 53·2	3·8	55·4		45	02 46	03 35	04 13	03 00	03 43	04 33	05 29
D	12	359 56·1	N23 18·0	22 27·0	10·9	N17 57·0	3·7	55·5		N 40	03 16	03 58	04 30	03 13	03 57	04 47	05 43
A	13	14 55·9	18·1	36 56·9	10·8	18 00·7	3·6	55·5		35	03 39	04 16	04 45	03 23	04 09	04 59	05 54
Y	14	29 55·8	18·2	51 26·7	10·7	18 04·3	3·5	55·5		30	03 58	04 31	04 58	03 32	04 19	05 10	06 04
	15	44 55·7	18·4	65 56·4	10·8	18 07·8	3·5	55·5		20	04 27	04 56	05 20	03 48	04 36	05 27	06 22
	16	59 55·5	18·5	80 26·2	10·6	18 11·3	3·3	55·5		N 10	04 49	05 16	05 39	04 02	04 51	05 43	06 36
	17	74 55·4	18·6	94 55·8	10·6	18 14·6	3·2	55·6		0	05 08	05 34	05 57	04 15	05 05	05 58	06 51
	18	89 55·3	N23 18·7	109 25·4	10·6	N18 17·8	3·2	55·6		S 10	05 25	05 51	06 14	04 28	05 20	06 12	07 05
	19	104 55·1	18·8	123 55·0	10·6	18 21·0	3·1	55·6		20	05 41	06 09	06 33	04 43	05 35	06 28	07 19
	20	119 55·0	18·9	138 24·6	10·4	18 24·1	2·9	55·6		30	05 58	06 27	06 54	04 59	05 53	06 46	07 37
	21	134 54·9	19·0	152 54·0	10·5	18 27·0	2·9	55·7		35	06 06	06 38	07 06	05 08	06 03	06 56	07 47
	22	149 54·7	19·1	167 23·5	10·4	18 29·9	2·8	55·7		40	06 16	06 50	07 20	05 19	06 14	07 08	07 58
	23	164 54·6	19·2	181 52·9	10·3	18 32·7	2·7	55·7		45	06 26	07 03	07 37	05 32	06 28	07 22	08 11
16	00	179 54·5	N23 19·3	196 22·2	10·3	N18 35·4	2·6	55·7		S 50	06 38	07 19	07 58	05 47	06 45	07 39	08 28
	01	194 54·3	19·4	210 51·5	10·3	18 38·0	2·5	55·7		52	06 43	07 27	08 08	05 55	06 53	07 47	08 35
	02	209 54·2	19·5	225 20·8	10·2	18 40·5	2·4	55·8		54	06 48	07 35	08 19	06 03	07 02	07 56	08 44
	03	224 54·1	19·6	239 50·0	10·2	18 42·9	2·3	55·8		56	06 55	07 44	08 31	06 12	07 12	08 07	08 53
	04	239 53·9	19·7	254 19·2	10·1	18 45·2	2·3	55·8		58	07 01	07 54	08 46	06 22	07 23	08 18	09 04
	05	254 53·8	19·8	268 48·3	10·1	18 47·5	2·1	55·8		S 60	07 09	08 06	09 03	06 34	07 37	08 32	09 17
	06	269 53·7	N23 19·9	283 17·4	10·0	N18 49·6	2·0	55·9									
	07	284 53·5	20·0	297 46·4	10·0	18 51·6	2·0	55·9		Lat.	Sun-set	Twilight Civil	Twilight Naut.	Moonset 15	Moonset 16	Moonset 17	Moonset 18
	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		°	h m	h m	h m	h m	h m	h m	h m
O	10	329 53·1	20·3	341 13·3	9·9	18 57·1	1·7	55·9		N 72	□	□	□				
N	11	344 53·0	20·4	355 42·2	9·9	18 58·8	1·5	56·0		N 70	□	□	□	21 12	22 28	23 07	23·20
D	12	359 52·8	N23 20·5	10 11·1	9·8	N19 00·3	1·4	56·0		68	□	□	□	20 28	21 34	22 20	22 46
A	13	14 52·7	20·6	24 39·9	9·7	19 01·7	1·4	56·0		66	□	□	□	19 58	21 01	21 49	22 21
Y	14	29 52·6	20·7	39 08·6	9·8	19 03·1	1·2	56·0		64	22 29	////	////	19 36	20 37	21 26	22 02
	15	44 52·4	20·7	53 37·4	9·7	19 04·3	1·1	56·1		62	21 51	////	////	19 18	20 18	21 08	21 46
	16	59 52·3	20·8	68 06·1	9·7	19 05·4	1·0	56·1		60	21 25	23 10	////	19 04	20 03	20 53	21 33
	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		N 58	21 05	22 20	////	18 51	19 49	20 40	21 22
	19	104 51·9	21·1	111 32·0	9·5	19 08·2	0·7	56·1		56	20 48	21 51	////	18 40	19 38	20 29	21 12
	20	119 51·8	21·2	126 00·5	9·6	19 08·9	0·7	56·2		54	20 34	21 29	23 14	18 31	19 28	20 19	21 03
	21	134 51·6	21·3	140 29·1	9·5	19 09·6	0·5	56·2		52	20 22	21 11	22·29	18 22	19 19	20 10	20 55
	22	149 51·5	21·4	154 57·6	9·4	19 10·1	0·4	56·2		50	20 11	20 56	22 01	18 15	19 11	20 02	20 48
	23	164 51·4	21·4	169 26·0	9·5	19 10·5	0·3	56·2		45	19 49	20 26	21 16	17 59	18 54	19 46	20 33
17	00	179 51·2	N23 21·5	183 54·5	9·4	N19 10·8	0·2	56·3		N 40	19 31	20 03	20 45	17 46	18 40	19 32	20 20
	01	194 51·1	21·6	198 22·9	9·4	19 11·0	0·1	56·3		35	19 16	19 45	20 22	17 34	18 28	19 20	20 09
	02	209 51·0	21·7	212 51·3	9·3	19 11·1	0·0	56·3		30	19 03	19 30	20 03	17 25	18 18	19 10	20 00
	03	224 50·8	21·8	227 19·6	9·3	19 11·1	0·1	56·3		20	18 41	19 05	19 34	17 08	18 00	18 53	19 44
	04	239 50·7	21·9	241 47·9	9·3	19 11·0	0·2	56·3		N 10	18 22	18 45	19 12	16 53	17 45	18 37	19 29
	05	254 50·5	21·9	256 16·2	9·3	19 10·8	0·3	56·4		0	18 04	18 27	18 53	16 39	17 30	18 23	19 16
	06	269 50·4	N23 22·0	270 44·5	9·3	N19 10·5	0·4	56·4		S 10	17 47	18 10	18 36	16 25	17 16	18 08	19 03
	07	284 50·3	22·1	285 12·8	9·2	19 10·1	0·6	56·4		20	17 28	17 52	18 20	16 11	17 00	17 53	18 48
	08	299 50·1	22·2	299 41·0	9·2	19 09·5	0·6	56·4		30	17 07	17 34	18 03	15 54	16 42	17 35	18 32
T	09	314 50·0	22·3	314 09·2	9·2	19 08·9	0·7	56·5		35	16 55	17 23	17 55	15 44	16 32	17 25	18 22
U	10	329 49·9	22·3	328 37·4	9·1	19 08·2	0·9	56·5		40	16 41	17 11	17 45	15 33	16 20	17 13	18 11
E	11	344 49·7	22·4	343 05·5	9·2	19 07·3	0·9	56·5		45	16 24	16 58	17 35	15 20	16 06	16 59	17 58
S	12	359 49·6	N23 22·5	357 33·7	9·1	N19 06·4	1·1	56·5		S 50	16 03	16 42	17 23	15 04	15 49	16 42	17 42
D	13	14 49·5	22·6	12 01·8	9·1	19 05·3	1·1	56·6		52	15 53	16 34	17 18	14 56	15 41	16 34	17 35
A	14	29 49·3	22·6	26 29·9	9·0	19 04·2	1·3	56·6		54	15 42	16 26	17·12	14 48	15 32	16 25	17 26
Y	15	44 49·2	22·7	40 57·9	9·1	19 02·9	1·4	56·6		56	15 30	16 17	17 06	14 39	15 22	16 15	17 17
	16	59 49·1	22·8	55 26·0	9·0	19 01·5	1·5	56·6		58	15 15	16 07	16 59	14 28	15 10	16 03	17 07
	17	74 48·9	22·9	69 54·0	9·1	19 00·0	1·6	56·6		S 60	14 58	15 55	16 52	14 16	14 57	15 50	16 54
	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		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
	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			m s	m s	h m	h m	h m	d	
	22	149 48·2	23·2	142 14·0	9·0	18 51·0	2·1	56·8		15	00 09	00 15	12 00	10 27	22 52	28	
	23	164 48·1	23·3	156 42·0	8·9	18 48·9	2·3	56·8		16	00 22	00 28	12 00	11 18	23 44	29	●
		S.D. 15·8	d 0·1	S.D.	15·1		15·3	15·4		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	
d h	G.H.A. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. °
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
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
02	295 48·6	248 06·1	41·0	287 53·6	01·2	95 11·6	14·0	34 18·1	47·7
03	310 51·1	263 05·6	·· 41·8	302 54·4	·· 01·8	110 14·1	·· 14·0	49 20·7	·· 47·7
04	325 53·5	278 05·2	42·7	317 55·3	02·5	125 16·6	14·0	64 23·4	47·7
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
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
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
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
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
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
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
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
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
16	146 23·1	97 59·8	52·5	138 05·4	10·5	305 46·2	14·1	244 55·3	47·6
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
19	191 30·5	142 58·5	54·9	183 07·9	12·6	350 53·7	14·2	290 03·3	47·6
20	206 33·0	157 58·0	55·8	198 08·8	13·2	5 56·1	14·2	305 06·0	47·6
21	221 35·4	172 57·6	·· 56·6	213 09·6	·· 13·9	20 58·6	·· 14·2	320 08·6	·· 47·6
22	236 37·9	187 57·1	57·4	228 10·4	14·6	36 01·1	14·2	335 11·3	47·5
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
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
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
03	311 50·2	262 54·8	·· 01·4	303 14·7	·· 17·9	111 13·4	·· 14·2	50 24·6	·· 47·5
04	326 52·7	277 54·4	02·2	318 15·5	18·6	126 15·9	14·3	65 27·3	47·5
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
T 07	12 00·1	322 53·0	04·7	3 18·0	20·6	171 23·3	14·3	110 35·2	47·5
H 08	27 02·5	337 52·6	05·5	18 18·9	21·2	186 25·7	14·3	125 37·9	47·5
U 09	42 05·0	352 52·1	·· 06·3	33 19·7	·· 21·9	201 28·2	·· 14·3	140 40·6	·· 47·5
R 10	57 07·5	7 51·6	07·1	48 20·6	22·6	216 30·7	14·3	155 43·2	47·5
S 11	72 09·9	22 51·2	07·9	63 21·4	23·2	231 33·1	14·3	170 45·9	47·5
D 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
A 13	102 14·9	52 50·3	09·5	93 23·1	24·6	261 38·1	14·4	200 51·2	47·4
Y 14	117 17·3	67 49·8	10·3	108 24·0	25·2	276 40·5	14·4	215 53·9	47·4
15	132 19·8	82 49·3	·· 11·1	123 24·8	·· 25·9	291 43·0	·· 14·4	230 56·5	·· 47·4
16	147 22·2	97 48·9	11·9	138 25·7	26·6	306 45·5	14·4	245 59·2	47·4
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
19	192 29·6	142 47·5	14·3	183 28·2	28·6	351 52·9	14·4	291 07·2	47·4
20	207 32·1	157 47·0	15·1	198 29·0	29·2	6 55·3	14·4	306 09·8	47·4
21	222 34·6	172 46·6	·· 15·9	213 29·9	·· 29·9	21 57·8	·· 14·5	321 12·5	·· 47·4
22	237 37·0	187 46·1	16·7	228 30·7	30·6	37 00·3	14·5	336 15·2	47·4
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
01	282 44·4	232 44·7	19·1	273 33·3	32·6	82 07·6	14·5	21 23·1	47·4
02	297 46·9	247 44·2	19·9	288 34·1	33·2	97 10·1	14·5	36 25·8	47·3
03	312 49·4	262 43·8	·· 20·7	303 35·0	·· 33·9	112 12·6	·· 14·5	51 28·5	·· 47·3
04	327 51·8	277 43·3	21·5	318 35·8	34·6	127 15·0	14·6	66 31·1	47·3
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
07	12 59·2	322 41·9	23·9	3 38·4	36·6	172 22·4	14·6	111 39·1	47·3
08	28 01·7	337 41·4	24·7	18 39·2	37·2	187 24·9	14·6	126 41·8	47·3
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
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
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
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
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
15	133 18·9	82 38·1	·· 30·2	123 45·2	·· 41·9	292 42·1	·· 14·7	232 00·4	·· 47·3
16	148 21·4	97 37·6	31·0	138 46·0	42·5	307 44·5	14·7	247 03·1	47·2
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
19	193 28·8	142 36·2	33·4	183 48·6	44·5	352 51·9	14·8	292 11·0	47·2
20	208 31·2	157 35·7	34·1	198 49·4	45·2	7 54·4	14·8	307 13·7	47·2
21	223 33·7	172 35·3	·· 34·9	213 50·3	·· 45·9	22 56·8	·· 14·8	322 16·4	·· 47·2
22	238 36·2	187 34·8	35·7	228 51·1	46·5	37 59·3	14·8	337 19·0	47·2
23	253 38·6	202 34·3	36·5	243 52·0	47·2	53 01·7	14·8	352 21·7	47·2
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

STARS

Name	S.H.A. ° ′	Dec. ° ′
Acamar	315 50·0	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 51·6
Altair	62 48·2	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 22·8
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 59·3	N 45 07·8
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 09·5	S 29 50·3
Gacrux	172 46·8	S 56 53·2
Gienah	176 34·8	S 17 18·8
Hadar	149 46·1	S 60 10·6
Hamal	328 47·6	N 23 15·9
Kaus Aust.	84 38·2	S 34 24·2
Kochab	137 17·4	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 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 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 16·2
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	311 13·4	9 28
Mars	351 29·3	6 47
Jupiter	159 23·2	19 32
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
07	284 40·5	26·0	246 49·3	9·3	14 05·4	7·8	57·9
F 08	299 40·3	26·0	261 17·6	9·4	13 57·6	7·8	58·0
R 09	314 40·2	26·0	275 46·0	9·3	13 49·8	7·9	58·0
I 10	329 40·0	26·1	290 14·3	9·4	13 41·9	8·1	58·0
D 11	344 39·9	26·1	304 42·7	9·4	13 33·8	8·1	58·0
A 12	359 39·8	N23 26·1	319 11·1	9·5	N13 25·7	8·1	58·0
Y 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
N72	□	□	□	□	02 52	05 04	07 05
N70	□	□	□	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
N58	////	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
N40	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
N10	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
S10	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
S50	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
S60	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
N72	□	□	□	□	(20 17) (23 56)	23 45	23 36
N70	□	□	□	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
N58	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
N40	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
N10	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
S10	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
S50	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
S60	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		STARS		
d h	G.H.A. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	Name	S.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	Acamar	315 50·0	S 40 28·1
01	283 43·6	232 33·4	38·1	273 53·7	48·5	83 06·6	14·9	22 27·0	47·2	Achernar	335 57·8	S 57 26·6
02	298 46·0	247 32·9	38·8	288 54·5	49·2	98 09·1	14·9	37 29·7	47·2	Acrux	173 55·3	S 62 52·5
03	313 48·5	262 32·4	·· 39·6	303 55·4	·· 49·8	113 11·5	·· 14·9	52 32·3	·· 47·2	Adhara	255 45·4	S 28 55·1
04	328 51·0	277 31·9	40·4	318 56·2	50·5	128 14·0	14·9	67 35·0	47·2	Aldebaran	291 37·1	N 16 25·5
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	Alioth	166 56·9	N 56 11·4
07	13 58·3	322 30·5	42·7	3 58·8	52·5	173 21·4	15·0	112 43·0	47·1	Alkaid	153 31·2	N 49 31·5
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	Al Na'ir	28 35·4	S 47 09·4
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	Alnilam	276 28·6	S 1 13·8
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	Alphard	218 36·9	S 8 28·8
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	Alphecca	126 45·7	N 26 51·4
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	Alpheratz	358 26·3	N 28 51·6
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	Altair	62 48·2	N 8 45·6
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	Ankaa	353 56·5	S 42 31·6
16	149 20·5	97 26·1	49·7	139 06·4	58·4	308 43·4	15·1	248 06·9	47·1	Antares	113 16·6	S 26 20·4
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	Arcturus	146 33·2	N 19 24·0
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	Atria	108 55·0	S 68 57·2
20	209 30·4	157 24·2	52·8	199 09·8	01·1	8 53·2	15·2	308 17·5	47·0	Avior	234 35·4	S 59 22·8
21	224 32·8	172 23·7	·· 53·6	214 10·7	·· 01·8	23 55·7	·· 15·2	323 20·2	·· 47·0	Bellatrix	279 16·7	N 6 18·7
22	239 35·3	187 23·2	54·4	229 11·5	02·4	38 58·1	15·2	338 22·9	47·0	Betelgeuse	271 46·4	N 7 23·9
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	Canopus	264 15·0	S 52 40·5
01	284 42·7	232 21·7	56·7	274 14·1	04·4	84 05·5	15·3	23 30·8	47·0	Capella	281 36·0	N 45 57·3
02	299 45·2	247 21·2	57·4	289 15·0	05·1	99 07·9	15·3	38 33·5	47·0	Deneb	49 59·2	N 45 07·9
03	314 47·6	262 20·7	·· 58·2	304 15·8	·· 05·7	114 10·3	·· 15·3	53 36·2	·· 47·0	Denebola	183 15·8	N 14 48·3
04	329 50·1	277 20·3	59·0	319 16·7	06·4	129 12·8	15·3	68 38·8	47·0	Diphda	349 37·4	S 18 12·7
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	Dubhe	194 42·6	N 61 58·7
07	14 57·5	322 18·8	01·2	4 19·2	08·4	174 20·1	15·4	113 46·8	47·0	Elnath	279 05·3	N 28 34·3
08	29 59·9	337 18·3	02·0	19 20·1	09·0	189 22·6	15·4	128 49·5	47·0	Eltanin	91 04·8	N 51 29·7
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	Enif	34 27·5	N 9 41·1
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	Fomalhaut	16 09·4	S 29 50·3
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	Gacrux	172 46·8	S 56 53·2
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	Gienah	176 34·8	S 17 18·8
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	Hadar	149 46·2	S 60 10·6
15	135 17·2	82 14·8	·· 07·3	124 26·1	·· 13·6	294 39·7	·· 15·6	234 08·1	·· 46·9	Hamal	328 47·6	N 23 15·9
16	150 19·7	97 14·3	08·1	139 26·9	14·3	309 42·1	15·6	249 10·7	46·9	Kaus Aust.	84 38·2	S 34 24·2
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	Kochab	137 17·5	N 74 19·8
19	195 27·1	142 12·8	10·4	184 29·5	16·3	354 49·5	15·6	294 18·7	46·9	Markab	14 19·4	N 14 58·9
20	210 29·5	157 12·3	11·1	199 30·4	16·9	9 51·9	15·7	309 21·4	46·9	Menkar	314 58·5	N 3 55·6
21	225 32·0	172 11·8	·· 11·9	214 31·2	·· 17·6	24 54·3	·· 15·7	324 24·0	·· 46·9	Menkent	148 56·1	S 36 10·1
22	240 34·4	187 11·3	12·6	229 32·1	18·2	39 56·8	15·7	339 26·7	46·9	Miaplacidus	221 49·0	S 69 33·1
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	Mirfak	309 39·9	N 49 42·7
01	285 41·8	232 09·8	14·9	274 34·6	20·2	85 04·1	15·8	24 34·7	46·8	Nunki	76 49·1	S 26 20·8
02	300 44·3	247 09·3	15·6	289 35·5	20·9	100 06·5	15·8	39 37·3	46·8	Peacock	54 23·8	S 56 51·9
03	315 46·8	262 08·8	·· 16·4	304 36·4	·· 21·5	115 09·0	·· 15·8	54 40·0	·· 46·8	Pollux	244 18·6	N 28 07·6
04	330 49·2	277 08·3	17·1	319 37·2	22·2	130 11·4	15·8	69 42·6	46·8	Procyon	245 43·3	N 5 19·8
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	Rasalhague	96 44·5	N 12 35·5
07	15 56·6	322 06·8	19·4	4 39·8	24·2	175 18·7	15·9	114 50·6	46·8	Regulus	208 27·6	N 12 10·2
08	30 59·1	337 06·3	20·1	19 40·6	24·8	190 21·2	15·9	129 53·3	46·8	Rigel	281 52·1	S 8 15·0
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	Rigil Kent.	140 47·7	S 60 40·1
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	Sabik	102 59·6	S 15 40·4
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	Schedar	350 27·7	N 56 18·3
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	Shaula	97 17·6	S 37 04·4
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	Sirius	259 10·5	S 16 39·6
15	136 16·3	82 02·8	·· 25·3	124 46·6	·· 29·4	295 38·2	·· 16·1	235 11·9	·· 46·7	Spica	159 14·7	S 10 56·8
16	151 18·8	97 02·2	26·1	139 47·5	30·1	310 40·7	16·1	250 14·5	46·7	Suhail	223 23·1	S 43 16·1
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	Vega	81 06·5	N 38 44·8
19	196 26·2	142 00·7	28·3	184 50·1	32·1	355 48·0	16·2	295 22·5	46·7	Zuben'ubi	137 51·0	S 15 52·2
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		S.H.A. ° ′	Mer. Pass. h m
22	241 33·6	186 59·2	30·5	229 52·7	34·0	40 55·3	16·2	340 30·5	46·7	Venus	307 42·0	9 31
23	256 36·0	201 58·7	31·2	244 53·5	34·7	55 57·7	16·3	355 33·1	46·7	Mars	349 33·1	6 43
										Jupiter	159 22·8	19 21
										Saturn	98 48·0	23 22
Mer. Pass.	h m 6 00·3	v −0·5	d 0·8	v 0·9	d 0·7	v 2·4	d 0·0	v 2·7	d 0·0			

JUNE 21, 22, 23 (SAT., SUN., MON.)

G.M.T.	SUN			MOON						Lat.	Twilight		Sun-rise	Moonrise			
		G.H.A.	Dec.	G.H.A.	v	Dec.	d	H.P.		Naut.	Civil		21	22	23	24
d h		° ′	° ′	° ′	′	° ′	′	′		°	h m	h m	h m	h m	h m	h m	h m
										N 72	▭	▭	▭	07 05	09 01	10 55	12 51
21	00	179 38·1	N23 26·4	132 53·6	9·7	N11 42·5	9·0	58·2		N 70	▭	▭	▭	07 22	09 10	10 57	12 45
	01	194 38·0	26·4	147 22·3	9·7	11 33·5	9·2	58·3		68	▭	▭	▭	07 36	09 17	10 59	12 41
	02	209 37·9	26·4	161 51·0	9·7	11 24·3	9·2	58·3		66	▭	▭	▭	07 48	09 23	11 00	12 37
	03	224 37·7	26·4	176 19·7	9·7	11 15·1	9·3	58·3		64	////	////	01 31	07 57	09 28	11 01	12 34
	04	239 37·6	26·4	190 48·4	9·7	11 05·8	9·3	58·3		62	////	////	02 09	08 05	09 33	11 01	12 31
	05	254 37·5	26·4	205 17·1	9·8	10 56·5	9·4	58·3		60	////	00 49	02 36	08 12	09 37	11 02	12 29
	06	269 37·3	N23 26·4	219 45·9	9·8	N10 47·1	9·5	58·3		N 58	////	01 40	02 56	08 18	09 40	11 03	12 27
	07	284 37·2	26·4	234 14·7	9·8	10 37·6	9·6	58·4		56	////	02 10	03 13	08 24	09 43	11 04	12 25
S	08	299 37·0	26·5	248 43·5	9·8	10 28·0	9·6	58·4		54	00 45	02 33	03 27	08 29	09 46	11 04	12 23
A	09	314 36·9	26·5	263 12·3	9·9	10 18·4	9·6	58·4		52	01 32	02 51	03 40	08 33	09 48	11 05	12 22
T	10	329 36·8	26·5	277 41·2	9·8	10 08·8	9·8	58·4		50	02 00	03 06	03 51	08 37	09 50	11 05	12 20
U	11	344 36·6	26·5	292 10·0	9·9	9 59·0	9·8	58·4		45	02 46	03 36	04 13	08 45	09 55	11 06	12 17
R	12	359 36·5	N23 26·5	306 38·9	9·9	N 9 49·2	9·8	58·4		N 40	03 17	03 58	04 31	08 53	09 59	11 07	12 15
D	13	14 36·4	26·5	321 07·8	9·9	9 39·4	9·9	58·4		35	03 40	04 17	04 46	08 59	10 03	11 07	12 13
A	14	29 36·2	26·5	335 36·7	9·9	9 29·5	10·0	58·5		30	03 59	04 32	04 59	09 04	10 06	11 08	12 11
Y	15	44 36·1	26·5	350 05·6	10·0	9 19·5	10·0	58·5		20	04 28	04 57	05 22	09 13	10 11	11 09	12 08
	16	59 35·9	26·5	4 34·6	9·9	9 09·5	10·1	58·5		N 10	04 50	05 17	05 40	09 21	10 16	11 10	12 05
	17	74 35·8	26·5	19 03·5	10·0	8 59·4	10·1	58·5		0	05 09	05 36	05 58	09 29	10 20	11 11	12 02
	18	89 35·7	N23 26·5	33 32·5	10·0	N 8 49·3	10·2	58·5		S 10	05 26	05 53	06 16	09 36	10 24	11 12	12 00
	19	104 35·5	26·5	48 01·5	10·0	8 39·1	10·3	58·5		20	05 43	06 10	06 34	09 44	10 29	11 13	11 57
	20	119 35·4	26·5	62 30·5	10·0	8 28·8	10·2	58·6		30	05 59	06 29	06 55	09 54	10 34	11 14	11 54
	21	134 35·3	26·5	76 59·5	10·1	8 18·6	10·4	58·6		35	06 08	06 40	07 08	09 59	10 37	11 15	11 52
	22	149 35·1	26·5	91 28·6	10·0	8 08·2	10·4	58·6		40	06 17	06 51	07 22	10 05	10 41	11 16	11 50
	23	164 35·0	26·5	105 57·6	10·1	7 57·8	10·4	58·6		45	06 28	07 05	07 39	10 12	10 45	11 17	11 48
22	00	179 34·9	N23 26·5	120 26·7	10·1	N 7 47·4	10·5	58·6		S 50	06 40	07 21	08 00	10 20	10 50	11 18	11 46
	01	194 34·7	26·5	134 55·8	10·1	7 36·9	10·6	58·6		52	06 45	07 29	08 10	10 24	10 52	11 18	11 44
	02	209 34·6	26·5	149 24·9	10·1	7 26·3	10·5	58·6		54	06 50	07 37	08 21	10 28	10 54	11 19	11 43
	03	224 34·4	26·5	163 54·0	10·1	7 15·8	10·7	58·7		56	06 57	07 46	08 33	10 32	10 57	11 19	11 42
	04	239 34·3	26·5	178 23·1	10·1	7 05·1	10·6	58·7		58	07 03	07 56	08 48	10 38	11 00	11 20	11 40
	05	254 34·2	26·5	192 52·2	10·1	6 54·5	10·8	58·7		S 60	07 11	08 08	09 06	10 43	11 03	11 21	11 38
	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.	Sun-set	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 35·8	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 43·3	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 03·0	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 37·5	6 39
	h m									Jupiter	159 20·8	19 09
Mer. Pass.	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 29

JUNE 24, 25, 26 (TUES., WED., THURS.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	v	MOON 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. 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	◐

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 46·8	S 60 10·5
Hamal	328 47·9	N 23 16·1
Kaus Aust.	84 39·3	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 13·7
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			
									Naut.	Civil		19	20	21	22
	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
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 57
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								
D 13	16 36·8	10·2	281 40·7	8·2	18 30·4	1·7	57·7								
A 14	31 37·0	09·2	296 07·9	8·3	18 28·7	1·7	57·6								
Y 15	46 37·2	08·2	310 35·2	8·3	18 27·0	1·9	57·6								
16	61 37·4	07·3	325 02·5	8·4	18 25·1	1·9	57·6								
17	76 37·7	06·3	339 29·9	8·4	18 23·2	2·1	57·5								
18	91 37·9	N 1 05·3	353 57·3	8·5	S 18 21·1	2·2	57·5								
19	106 38·1	04·4	8 24·8	8·5	18 18·9	2·3	57·5								
20	121 38·3	03·4	22 52·3	8·6	18 16·6	2·3	57·5								
21	136 38·5	02·4	37 19·9	8·6	18 14·3	2·5	57·4								
22	151 38·8	01·4	51 47·5	8·7	18 11·8	2·6	57·4								
23	166 39·0	1 00·5	66 15·2	8·8	18 09·2	2·7	57·4								
21 00	181 39·2	N 0 59·5	80 43·0	8·8	S 18 06·5	2·8	57·3								
01	196 39·4	58·5	95 10·8	8·8	18 03·7	2·9	57·3								
02	211 39·6	57·6	109 38·6	8·9	18 00·8	2·9	57·3								
03	226 39·9	56·6	124 06·5	9·0	17 57·9	3·1	57·2								
04	241 40·1	55·6	138 34·5	9·0	17 54·8	3·2	57·2								
05	256 40·3	54·6	153 02·5	9·1	17 51·6	3·3	57·2								
06	271 40·5	N 0 53·7	167 30·6	9·1	S 17 48·3	3·3	57·1								
07	286 40·7	52·7	181 58·7	9·2	17 45·0	3·5	57·1								
08	301 41·0	51·7	196 26·9	9·2	17 41·5	3·6	57·1								
S 09	316 41·2	50·8	210 55·1	9·3	17 37·9	3·6	57·1								
U 10	331 41·4	49·8	225 23·4	9·4	17 34·3	3·8	57·0								
N 11	346 41·6	48·8	239 51·8	9·4	17 30·5	3·8	57·0								
D 12	1 41·8	N 0 47·8	254 20·2	9·5	S 17 26·7	4·0	57·0								
A 13	16 42·1	46·9	268 48·7	9·5	17 22·7	4·0	56·9								
Y 14	31 42·3	45·9	283 17·2	9·6	17 18·7	4·1	56·9								
15	46 42·5	44·9	297 45·8	9·6	17 14·6	4·2	56·9								
16	61 42·7	44·0	312 14·4	9·7	17 10·4	4·3	56·9								
17	76 43·0	43·0	326 43·1	9·8	17 06·1	4·4	56·8								
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		Moonset			
		Civil	Naut.	19	20	21	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		Mer. Pass.	MOON			
	Eqn. of Time			Mer. Pass.		Age	Phase
	00h	12h		Upper	Lower		
	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 23·7
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 55·3	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 15·2
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			
21	318 11·0	147 43·2	·· 39·0	259 05·1	·· 31·2	106 43·0	·· 41·9	59 04·3	·· 55·1		S.H.A.	Mer. Pass.
22	333 13·5	162 42·8	37·8	274 07·0	31·3	121 45·0	42·1	74 06·6	55·1		° ′	h m
23	348 15·9	177 42·4	36·6	289 09·0	31·5	136 47·0	42·3	89 08·9	55·1	Venus	191 42·0	11 08
	h m									Mars	301 19·1	3 49
Mer. Pass.	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	Jupiter	148 53·5	13 57
										Saturn	100 59·1	17 08

SEPTEMBER 22, 23, 24 (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	° ′	° ′	° ′	′	° ′	′	′
22 00	181 44·5	N 0 36·2	68 05·7	10·2	S 16 33·5	5·0	56·6
01	196 44·7	35·2	82 34·9	10·2	16 28·5	5·1	56·6
02	211 44·9	34·2	97 04·1	10·3	16 23·4	5·1	56·6
03	226 45·2	33·3	111 33·4	10·4	16 18·3	5·3	56·5
04	241 45·4	32·3	126 02·8	10·4	16 13·0	5·3	56·5
05	256 45·6	31·3	140 32·2	10·4	16 07·7	5·4	56·5
06	271 45·8	N 0 30·3	155 01·6	10·6	S 16 02·3	5·4	56·5
07	286 46·0	29·4	169 31·2	10·5	15 56·9	5·6	56·4
08	301 46·3	28·4	184 00·7	10·7	15 51·3	5·6	56·4
M 09	316 46·5	27·4	198 30·4	10·7	15 45·7	5·7	56·4
O 10	331 46·7	26·4	213 00·1	10·8	15 40·0	5·8	56·4
N 11	346 46·9	25·5	227 29·9	10·8	15 34·2	5·9	56·3
D 12	1 47·1	N 0 24·5	241 59·7	10·9	S 15 28·3	5·9	56·3
A 13	16 47·4	23·5	256 29·6	10·9	15 22·4	6·0	56·3
Y 14	31 47·6	22·6	270 59·5	11·0	15 16·4	6·1	56·3
15	46 47·8	21·6	285 29·5	11·1	15 10·3	6·2	56·2
16	61 48·0	20·6	299 59·6	11·1	15 04·1	6·2	56·2
17	76 48·2	19·6	314 29·7	11·1	14 57·9	6·3	56·2
18	91 48·5	N 0 18·7	328 59·8	11·3	S 14 51·6	6·4	56·2
19	106 48·7	17·7	343 30·1	11·3	14 45·2	6·4	56·1
20	121 48·9	16·7	358 00·4	11·3	14 38·8	6·5	56·1
21	136 49·1	15·7	12 30·7	11·4	14 32·3	6·6	56·1
22	151 49·3	14·8	27 01·1	11·5	14 25·7	6·6	56·1
23	166 49·6	13·8	41 31·6	11·5	14 19·1	6·7	56·0
23 00	181 49·8	N 0 12·8	56 02·1	11·6	S 14 12·4	6·8	56·0
01	196 50·0	11·8	70 32·7	11·6	14 05·6	6·8	56·0
02	211 50·2	10·9	85 03·3	11·7	13 58·8	6·9	56·0
03	226 50·4	09·9	99 34·0	11·7	13 51·9	7·0	55·9
04	241 50·7	08·9	114 04·7	11·8	13 44·9	7·0	55·9
05	256 50·9	08·0	128 35·5	11·9	13 37·9	7·1	55·9
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	55·5
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		15·1

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 22	Moonrise 23	Moonrise 24	Moonrise 25
°	h m	h m	h m	h m	h m	h m	h m
N 72	03 01	04 32	05 41	17 46	17 37	17 29	17 23
N 70	03 21	04 40	05 42	17 13	17 16	17 16	17 16
68	03 36	04 47	05 43	16 49	16 59	17 05	17 10
66	03 48	04 52	05 44	16 31	16 46	16 56	17 05
64	03 58	04 57	05 44	16 16	16 34	16 49	17 01
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
N 58	04 20	05 07	05 46	15 43	16 09	16 32	16 51
56	04 25	05 09	05 46	15 35	16 03	16 27	16 48
54	04 29	05 11	05 46	15 27	15 57	16 23	16 46
52	04 33	05 13	05 47	15 21	15 52	16 19	16 44
50	04 37	05 15	05 47	15 15	15 47	16 16	16 42
45	04 44	05 18	05 48	15 02	15 37	16 09	16 38
N 40	04 49	05 21	05 48	14 51	15 29	16 03	16 34
35	04 53	05 23	05 48	14 42	15 21	15 58	16 31
30	04 57	05 25	05 48	14 34	15 15	15 53	16 28
20	05 01	05 27	05 49	14 20	15 04	15 45	16 24
N 10	05 04	05 28	05 49	14 08	14 54	15 38	16 20
0	05 05	05 29	05 49	13 56	14 45	15 31	16 16
S 10	05 04	05 28	05 49	13 45	14 36	15 25	16 12
20	05 02	05 27	05 49	13 33	14 26	15 17	16 08
30	04 57	05 25	05 49	13 19	14 15	15 09	16 03
35	04 54	05 24	05 49	13 11	14 08	15 05	16 00
40	04 50	05 22	05 49	13 01	14 01	14 59	15 57
45	04 45	05 19	05 48	12 51	13 52	14 53	15 54
S 50	04 38	05 16	05 48	12 37	13 41	14 46	15 49
52	04 34	05 14	05 48	12 31	13 37	14 42	15 47
54	04 31	05 12	05 47	12 25	13 31	14 39	15 45
56	04 26	05 10	05 47	12 17	13 25	14 34	15 43
58	04 21	05 08	05 47	12 08	13 19	14 30	15 40
S 60	04 15	05 05	05 47	11 59	13 11	14 24	15 37

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 22	Moonset 23	Moonset 24	Moonset 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 02	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 59
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 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	
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		STARS		
d h	G.H.A. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	Name	S.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	Acamar	315 49·3	S 40 28·0
01	18 20·9	207 41·6	34·2	319 12·8	31·8	166 51·0	42·6	119 13·6	55·2	Achernar	335 56·9	S 57 26·6
02	33 23·3	222 41·2	33·0	334 14·8	32·0	181 52·9	42·8	134 15·9	55·2	Acrux	173 55·9	S 62 52·2
03	48 25·8	237 40·7	·· 31·8	349 16·7	·· 32·2	196 54·9	·· 43·0	149 18·2	·· 55·2	Adhara	255 44·9	S 28 54·8
04	63 28·3	252 40·3	30·6	4 18·7	32·3	211 56·9	43·1	164 20·6	55·2	Aldebaran	291 36·5	N 16 25·6
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	Alioth	166 57·4	N 56 11·1
07	108 35·7	297 39·1	27·0	49 24·5	32·8	257 02·9	43·7	209 27·6	55·3	Alkaid	153 31·8	N 49 31·3
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	Al Na'ir	28 35·0	S 47 09·6
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	Alnilam	276 28·1	S 1 13·6
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	Alphard	218 36·7	S 8 28·7
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	Alphecca	126 46·1	N 26 51·5
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	Alpheratz	358 25·7	N 28 51·9
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	Altair	62 48·2	N 8 45·8
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	Ankaa	353 55·9	S 42 31·6
16	243 57·8	72 35·4	16·2	184 42·1	34·3	32 20·7	45·2	344 48·5	55·4	Antares	113 16·9	S 26 20·4
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	Arcturus	146 33·6	N 19 24·0
19	289 05·2	117 34·1	12·6	229 48·0	34·8	77 26·7	45·8	29 55·5	55·5	Atria	108 55·8	S 68 57·4
20	304 07·7	132 33·7	11·3	244 49·9	34·9	92 28·6	45·9	44 57·8	55·5	Avior	234 35·1	S 59 22·4
21	319 10·1	147 33·3	·· 10·1	259 51·9	·· 35·1	107 30·6	·· 46·1	60 00·1	·· 55·5	Bellatrix	279 16·1	N 6 18·8
22	334 12·6	162 32·9	08·9	274 53·9	35·3	122 32·6	46·3	75 02·5	55·5	Betelgeuse	271 45·8	N 7 24·0
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	Canopus	264 14·4	S 52 40·2
01	19 20·0	207 31·7	05·3	319 59·8	35·7	167 38·6	46·8	120 09·4	55·6	Capella	281 35·2	N 45 57·2
02	34 22·5	222 31·3	04·1	335 01·8	35·9	182 40·5	47·0	135 11·8	55·6	Deneb	49 59·2	N 45 08·3
03	49 24·9	237 30·9	·· 02·9	350 03·7	·· 36·1	197 42·5	·· 47·2	150 14·1	·· 55·6	Denebola	183 15·9	N 14 48·2
04	64 27·4	252 30·5	01·7	5 05·7	36·2	212 44·5	47·3	165 16·4	55·6	Diphda	349 36·8	S 18 12·6
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	Dubhe	194 42·8	N 61 58·3
07	109 34·8	297 29·2	58·1	50 11·6	36·7	257 50·4	47·9	210 23·4	55·7	Elnath	279 04·6	N 28 34·3
08	124 37·3	312 28·8	56·9	65 13·6	36·9	272 52·4	48·0	225 25·7	55·7	Eltanin	91 05·3	N 51 30·0
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	Enif	34 27·3	N 9 41·4
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	Fomalhaut	16 09·0	S 29 50·3
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	Gacrux	172 47·3	S 56 52·9
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	Gienah	176 35·0	S 17 18·7
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	Hadar	149 46·8	S 60 10·5
15	229 54·5	57 26·0	·· 48·4	170 27·5	·· 38·0	18 06·3	·· 49·3	330 42·0	·· 55·8	Hamal	328 46·9	N 23 16·1
16	244 57·0	72 25·5	47·2	185 29·5	38·1	33 08·3	49·4	345 44·3	55·8	Kaus Aust.	84 38·4	S 34 24·3
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	Kochab	137 19·2	N 74 19·7
19	290 04·4	117 24·3	43·5	230 35·5	38·6	78 14·2	50·0	30 51·3	55·9	Markab	14 19·0	N 14 59·2
20	305 06·8	132 23·9	42·3	245 37·5	38·7	93 16·2	50·1	45 53·6	55·9	Menkar	314 57·9	N 3 55·8
21	320 09·3	147 23·5	·· 41·1	260 39·5	·· 38·9	108 18·2	·· 50·3	60 55·9	·· 55·9	Menkent	148 56·5	S 36 10·0
22	335 11·7	162 23·1	39·9	275 41·5	39·1	123 20·2	50·5	75 58·2	55·9	Miaplacidus	221 49·0	S 69 32·7
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	Mirfak	309 39·0	N 49 42·8
01	20 19·1	207 21·9	36·3	320 47·5	39·5	168 26·1	51·0	121 05·2	56·0	Nunki	76 49·2	S 26 20·9
02	35 21·6	222 21·5	35·1	335 49·5	39·7	183 28·1	51·2	136 07·5	56·0	Peacock	54 23·7	S 56 52·2
03	50 24·1	237 21·1	·· 33·8	350 51·5	·· 39·8	198 30·1	·· 51·4	151 09·9	·· 56·0	Pollux	244 18·2	N 28 07·5
04	65 26·5	252 20·7	32·6	5 53·5	40·0	213 32·0	51·5	166 12·2	56·0	Procyon	245 42·9	N 5 19·9
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	Rasalhague	96 44·7	N 12 35·6
07	110 33·9	297 19·4	29·0	50 59·5	40·5	258 38·0	52·1	211 19·1	56·1	Regulus	208 27·6	N 12 10·2
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	Rigel	281 51·5	S 8 14·8
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	Rigil Kent.	140 48·5	S 60 40·0
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	Sabik	102 59·8	S 15 40·4
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	Schedar	350 26·9	N 56 18·7
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	Shaula	97 17·9	S 37 04·5
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	Sirius	259 10·0	S 16 39·4
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	Spica	159 14·9	S 10 56·7
16	245 56·1	72 15·8	18·0	186 17·7	41·8	33 55·8	53·6	346 40·0	56·3	Suhail	223 23·0	S 43 15·8
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	Vega	81 06·8	N 38 45·1
19	291 03·5	117 14·6	14·4	231 23·8	42·3	79 01·7	54·2	31 47·0	56·3	Zuben'ubi	137 51·3	S 15 52·2
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		S.H.A.	Mer. Pass.
22	336 10·9	162 13·4	10·7	276 29·9	42·7	124 07·7	54·7	76 53·9	56·4		° ′	h m
23	351 13·4	177 12·9	09·5	291 31·9	42·9	139 09·6	54·9	91 56·3	56·4	Venus	188 14·6	11 10
										Mars	300 40·3	3 40
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	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		Sun-rise	Moonrise			
									Naut.	Civil		25	26	27	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
25 00	182 00·3	S 0 33·9	33 27·4	13·9	S 7 48·2	9·0	55·0	N 72	03 19	04 46	05 54	17 23	17 17	17 11	17 05
01	197 00·5	34·9	48 00·3	13·9	7 39·2	9·1	55·0	N 70	03 36	04 53	05 54	17 16	17 15	17 14	17 14
02	212 00·7	35·9	62 33·2	13·9	7 30·1	9·0	55·0	68	03 49	04 58	05 54	17 10	17 13	17 17	17 21
03	227 00·9	36·8	77 06·1	14·0	7 21·1	9·1	55·0	66	04 00	05 02	05 53	17 05	17 12	17 19	17 27
04	242 01·1	37·8	91 39·1	14·0	7 12·0	9·1	55·0	64	04 08	05 06	05 53	17 01	17 11	17 21	17 32
05	257 01·3	38·8	106 12·1	14·1	7 02·9	9·2	54·9	62	04 15	05 09	05 53	16 57	17 10	17 23	17 36
								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 51
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	Lat.	Sun-set	Twilight Civil	Twilight Naut.	Moonset 25	Moonset 26	Moonset 27	Moonset 28
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	°	h m	h m	h m	h m	h m	h m	h m
I 11	347 07·8	08·0	182 56·1	14·9	2 20·6	9·6	54·5	N 72	17 47	18 54	20 20	02 14	03 51	05 27	07 01
D 12	2 03·0	S 1 09·0	197 30·0	14·8	S 2 11·0	9·6	54·5	N 70	17 47	18 48	20 04	02 25	03 57	05 26	06 55
A 13	17 08·2	10·0	212 03·8	14·9	2 01·4	9·7	54·5	68	17 48	18 43	19 51	02 35	04 01	05 25	06 49
Y 14	32 08·5	10·9	226 37·7	14·9	1 51·7	9·6	54·5	66	17 48	18 39	19 41	02 42	04 04	05 25	06 45
15	47 08·7	11·9	241 11·6	14·9	1 42·1	9·6	54·5	64	17 49	18 36	19 33	02 49	04 07	05 24	06 41
16	62 08·9	12·9	255 45·5	14·9	1 32·5	9·6	54·5	62	17 49	18 33	19 26	02 54	04 10	05 24	06 38
17	77 09·1	13·9	270 19·4	14·9	1 22·9	9·6	54·4	60	17 49	18 31	19 20	02 59	04 12	05 24	06 35
18	92 09·3	S 1 14·8	284 53·3	14·9	S 1 13·3	9·6	54·4	N 58	17 50	18 29	19 15	03 03	04 14	05 23	06 33
19	107 09·5	15·8	299 27·2	15·0	1 03·7	9·6	54·4	56	17 50	18 27	19 11	03 07	04 15	05 23	06 30
20	122 09·7	16·8	314 01·2	14·9	0 54·1	9·7	54·4	54	17 50	18 25	19 07	03 10	04 17	05 23	06 28
21	137 10·0	17·8	328 35·1	15·0	0 44·4	9·6	54·4	52	17 50	18 24	19 03	03 14	04 18	05 23	06 26
22	152 10·2	18·7	343 09·1	15·0	0 34·8	9·6	54·4	50	17 51	18 23	19 00	03 16	04 20	05 22	06 25
23	167 10·4	19·7	357 43·1	15·0	0 25·2	9·6	54·4	45	17 51	18 20	18 54	03 22	04 23	05 22	06 21
27 00	182 10·6	S 1 20·7	12 17·1	15·0	S 0 15·6	9·6	54·4	N 40	17 51	18 18	18 50	03 27	04 25	05 22	06 18
01	197 10·8	21·6	26 51·1	15·1	S 0 06·0	9·6	54·4	35	17 52	18 17	18 47	03 32	04 27	05 21	06 15
02	212 11·0	22·6	41 25·2	15·0	N 0 03·6	9·7	54·3	30	17 52	18 16	18 44	03 35	04 29	05 21	06 13
03	227 11·2	23·6	55 59·2	15·0	0 13·3	9·6	54·3	20	17 53	18 15	18 41	03 42	04 32	05 21	06 09
04	242 11·5	24·6	70 33·2	15·1	0 22·9	9·6	54·3	N 10	17 54	18 15	18 39	03 47	04 34	05 20	06 06
05	257 11·7	25·5	85 07·3	15·0	0 32·5	9·6	54·3	0	17 55	18 15	18 39	03 53	04 37	05 20	06 02
06	272 11·9	S 1 26·5	99 41·3	15·1	N 0 42·1	9·5	54·3	S 10	17 56	18 17	18 41	03 58	04 39	05 19	05 59
07	287 12·1	27·5	114 15·4	15·1	0 51·6	9·6	54·3	20	17 57	18 19	18 44	04 04	04 42	05 19	05 56
S 08	302 12·3	28·5	128 49·5	15·1	1 01·2	9·6	54·3	30	17 58	18 22	18 50	04 10	04 45	05 18	05 52
A 09	317 12·5	29·4	143 23·6	15·0	1 10·8	9·6	54·3	35	17 59	18 24	18 54	04 14	04 46	05 18	05 49
T 10	332 12·7	30·4	157 57·6	15·1	1 20·4	9·5	54·3	40	18 00	18 27	18 59	04 18	04 48	05 18	05 47
U 11	347 12·9	31·4	172 31·7	15·1	1 29·9	9·6	54·3	45	18 01	18 31	19 05	04 22	04 50	05 17	05 44
R 12	2 13·2	S 1 32·4	187 05·8	15·1	N 1 39·5	9·5	54·3	S 50	18 03	18 35	19 13	04 28	04 53	05 17	05 40
D 13	17 13·4	33·3	201 39·9	15·1	1 49·0	9·5	54·2	52	18 03	18 37	19 17	04 31	04 54	05 16	05 39
A 14	32 13·6	34·3	216 14·0	15·1	1 58·5	9·5	54·2	54	18 04	18 40	19 22	04 33	04 55	05 16	05 37
Y 15	47 13·8	35·3	230 48·1	15·1	2 08·0	9·5	54·2	56	18 05	18 42	19 27	04 36	04 57	05 16	05 35
16	62 14·0	36·3	245 22·2	15·2	2 17·5	9·5	54·2	58	18 06	18 45	19 33	04 40	04 58	05 16	05 33
17	77 14·2	37·2	259 56·4	15·1	2 27·0	9·5	54·2	S 60	18 07	18 49	19 40	04 44	05 00	05 15	05 30
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								

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	

SEPTEMBER 28, 29, 30 (SUN., MON., TUES.)

G.M.T.	ARIES	VENUS −3·4		MARS −1·1		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	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
28 00	6 15·8	192 12·5	N 4 08·3	306 33·9	N 18 43·1	154 11·6	S 11 55·0	106 58·6	S 21 56·4	Acamar	315 49·3	S 40 28·0
01	21 18·3	207 12·1	07·1	321 36·0	43·2	169 13·6	55·2	122 00·9	56·4	Achernar	335 56·9	S 57 26·6
02	36 20·7	222 11·7	05·9	336 38·0	43·4	184 15·6	55·4	137 03·2	56·4	Acrux	173 55·9	S 62 52·2
03	51 23·2	237 11·3	· · 04·6	351 40·0	· · 43·5	199 17·5	· · 55·6	152 05·5	· · 56·4	Adhara	255 44·9	S 28 54·3
04	66 25·7	252 10·9	03·4	6 42·1	43·7	214 19·5	55·7	167 07·8	56·5	Aldebaran	291 36·5	N 16 25·6
05	81 28·1	267 10·5	02·2	21 44·1	43·8	229 21·5	55·9	182 10·2	56·5			
06	96 30·6	282 10·1	N 4 01·0	36 46·2	N 18 44·0	244 23·5	S 11 56·1	197 12·5	S 21 56·5	Alioth	166 57·4	N 56 11·1
07	111 33·1	297 09·7	3 59·8	51 48·2	44·1	259 25·4	56·3	212 14·8	56·5	Alkaid	153 31·8	N 49 31·3
08	126 35·5	312 09·3	58·5	66 50·3	44·2	274 27·4	56·4	227 17·1	56·5	Al Na'ir	28 35·0	S 47 09·6
09	141 38·0	327 08·9	· · 57·3	81 52·3	· · 44·4	289 29·4	· · 56·6	242 19·4	· · 56·5	Alnilam	276 28·1	S 1 13·6
10	156 40·5	342 08·5	56·1	96 54·3	44·5	304 31·4	56·8	257 21·7	56·6	Alphard	218 36·7	S 8 28·7
11	171 42·9	357 08·1	54·9	111 56·4	44·7	319 33·4	57·0	272 24·1	56·6			
12	186 45·4	12 07·7	N 3 53·7	126 58·4	N 18 44·8	334 35·3	S 11 57·1	287 26·4	S 21 56·6	Alphecca	126 46·1	N 26 51·5
13	201 47·8	27 07·3	52·4	142 00·5	45·0	349 37·3	57·3	302 28·7	56·6	Alpheratz	358 25·7	N 28 51·9
14	216 50·3	42 06·9	51·2	157 02·6	45·1	4 39·3	57·5	317 31·0	56·6	Altair	62 48·3	N 8 45·8
15	231 52·8	57 06·5	· · 50·0	172 04·6	· · 45·3	19 41·3	· · 57·7	332 33·3	· · 56·6	Ankaa	353 55·9	S 42 31·7
16	246 55·2	72 06·1	48·8	187 06·7	45·4	34 43·2	57·9	347 35·6	56·7	Antares	113 16·9	S 26 20·4
17	261 57·7	87 05·7	47·5	202 08·7	45·6	49 45·2	58·0	2 38·0	56·7			
18	277 00·2	102 05·3	N 3 46·3	217 10·8	N 18 45·7	64 47·2	S 11 58·2	17 40·3	S 21 56·7	Arcturus	146 33·6	N 19 24·0
19	292 02·6	117 04·9	45·1	232 12·8	45·9	79 49·2	58·4	32 42·6	56·7	Atria	108 55·9	S 68 57·4
20	307 05·1	132 04·5	43·9	247 14·9	46·0	94 51·1	58·6	47 44·9	56·7	Avior	234 35·1	S 59 22·4
21	322 07·6	147 04·1	· · 42·7	262 17·0	· · 46·2	109 53·1	· · 58·7	62 47·2	· · 56·8	Bellatrix	279 16·1	N 6 18·8
22	337 10·0	162 03·7	41·4	277 19·0	46·3	124 55·1	58·9	77 49·5	56·8	Betelgeuse	271 45·8	N 7 24·0
23	352 12·5	177 03·3	40·2	292 21·1	46·5	139 57·1	59·1	92 51·8	56·8			
29 00	7 15·0	192 02·9	N 3 39·0	307 23·2	N 18 46·6	154 59·0	S 11 59·3	107 54·2	S 21 56·8	Canopus	264 14·4	S 52 40·2
01	22 17·4	207 02·5	37·8	322 25·2	46·8	170 01·0	59·4	122 56·5	56·8	Capella	281 35·1	N 45 57·3
02	37 19·9	222 02·1	36·5	337 27·3	46·9	185 03·0	59·6	137 58·8	56·8	Deneb	49 59·3	N 45 08·3
03	52 22·3	237 01·7	· · 35·3	352 29·4	· · 47·0	200 05·0	11 59·8	153 01·1	· · 56·9	Denebola	183 15·9	N 14 48·2
04	67 24·8	252 01·3	34·1	7 31·4	47·2	215 06·9	12 00·0	168 03·4	56·9	Diphda	349 36·8	S 18 12·6
05	82 27·3	267 00·9	32·9	22 33·5	47·3	230 08·9	00·1	183 05·7	56·9			
06	97 29·7	282 00·5	N 3 31·6	37 35·6	N 18 47·5	245 10·9	S 12 00·3	198 08·0	S 21 56·9	Dubhe	194 42·8	N 61 58·3
07	112 32·2	297 00·1	30·4	52 37·7	47·6	260 12·9	00·5	213 10·4	56·9	Elnath	279 04·6	N 28 34·3
08	127 34·7	311 59·7	29·2	67 39·7	47·8	275 14·8	00·7	228 12·7	56·9	Eltanin	91 05·3	N 51 30·0
09	142 37·1	326 59·3	· · 28·0	82 41·8	· · 47·9	290 16·8	· · 00·8	243 15·0	· · 57·0	Enif	34 27·3	N 9 41·4
10	157 39·6	341 58·9	26·7	97 43·9	48·1	305 18·8	01·0	258 17·3	57·0	Fomalhaut	16 09·0	S 29 50·4
11	172 42·1	356 58·5	25·5	112 46·0	48·2	320 20·8	01·2	273 19·6	57·0			
12	187 44·5	11 58·1	N 3 24·3	127 48·1	N 18 48·3	335 22·7	S 12 01·4	288 21·9	S 21 57·0	Gacrux	172 47·3	S 56 52·9
13	202 47·0	26 57·7	23·0	142 50·1	48·5	350 24·7	01·5	303 24·2	57·0	Gienah	176 35·0	S 17 18·7
14	217 49·4	41 57·3	21·8	157 52·2	48·6	5 26·7	01·7	318 26·5	57·0	Hadar	149 46·8	S 60 10·5
15	232 51·9	56 56·9	· · 20·6	172 54·3	· · 48·8	20 28·7	· · 01·9	333 28·9	· · 57·1	Hamal	328 46·9	N 23 16·1
16	247 54·4	71 56·5	19·4	187 56·4	48·9	35 30·6	02·1	348 31·2	57·1	Kaus Aust.	84 38·4	S 34 24·3
17	262 56·8	86 56·1	18·1	202 58·5	49·1	50 32·6	02·3	3 33·5	57·1			
18	277 59·3	101 55·7	N 3 16·9	218 00·6	N 18 49·2	65 34·6	S 12 02·4	18 35·8	S 21 57·1	Kochab	137 19·2	N 74 19·7
19	293 01·8	116 55·3	15·7	233 02·7	49·3	80 36·6	02·6	33 38·1	57·1	Markab	14 19·0	N 14 59·2
20	308 04·2	131 54·9	14·5	248 04·8	49·5	95 38·5	02·8	48 40·4	57·2	Menkar	314 57·9	N 3 55·8
21	323 06·7	146 54·5	· · 13·2	263 06·9	· · 49·6	110 40·5	· · 03·0	63 42·7	· · 57·2	Menkent	148 56·5	S 36 10·0
22	338 09·2	161 54·1	12·0	278 09·0	49·8	125 42·5	03·1	78 45·0	57·2	Miaplacidus	221 49·0	S 69 32·7
23	353 11·6	176 53·7	10·8	293 11·1	49·9	140 44·4	03·3	93 47·4	57·2			
30 00	8 14·1	191 53·3	N 3 09·5	308 13·2	N 18 50·1	155 46·4	S 12 03·5	108 49·7	S 21 57·2	Mirfak	309 38·9	N 49 42·8
01	23 16·6	206 52·9	08·3	323 15·3	50·2	170 48·4	03·7	123 52·0	57·2	Nunki	76 49·3	S 26 20·9
02	38 19·0	221 52·5	07·1	338 17·4	50·3	185 50·4	03·8	138 54·3	57·3	Peacock	54 23·8	S 56 52·2
03	53 21·5	236 52·1	· · 05·9	353 19·5	· · 50·5	200 52·3	· · 04·0	153 56·6	· · 57·3	Pollux	244 18·1	N 28 07·5
04	68 23·9	251 51·7	04·6	8 21·6	50·6	215 54·3	04·2	168 58·9	57·3	Procyon	245 42·9	N 5 19·9
05	83 26·4	266 51·3	03·4	23 23·7	50·8	230 56·3	04·4	184 01·2	57·3			
06	98 28·9	281 50·9	N 3 02·2	38 25·8	N 18 50·9	245 58·3	S 12 04·5	199 03·5	S 21 57·3	Rasalhague	96 44·7	N 12 35·6
07	113 31·3	296 50·5	3 00·9	53 27·9	51·0	261 00·2	04·7	214 05·8	57·3	Regulus	208 27·5	N 12 10·2
08	128 33·8	311 50·1	2 59·7	68 30·0	51·2	276 02·2	04·9	229 08·1	57·4	Rigel	281 51·5	S 8 14·8
09	143 36·3	326 49·7	· · 58·5	83 32·1	· · 51·3	291 04·2	· · 05·1	244 10·5	· · 57·4	Rigil Kent.	140 48·5	S 60 40·0
10	158 38·7	341 49·3	57·2	98 34·2	51·5	306 06·1	05·2	259 12·8	57·4	Sabik	102 59·9	S 15 40·4
11	173 41·2	356 48·9	56·0	113 36·3	51·6	321 08·1	05·4	274 15·1	57·4			
12	188 43·7	11 48·5	N 2 54·8	128 38·5	N 18 51·7	336 10·1	S 12 05·6	289 17·4	S 21 57·4	Schedar	350 26·9	N 56 18·8
13	203 46·1	26 48·1	53·5	143 40·6	51·9	351 12·1	05·8	304 19·7	57·4	Shaula	97 17·9	S 37 04·5
14	218 48·6	41 47·7	52·3	158 42·7	52·0	6 14·0	05·9	319 22·0	57·5	Sirius	259 10·0	S 16 39·4
15	233 51·0	56 47·3	· · 51·1	173 44·8	· · 52·1	21 16·0	· · 06·1	334 24·3	· · 57·5	Spica	159 14·9	S 10 56·7
16	248 53·5	71 46·9	49·9	188 46·9	52·3	36 18·0	06·3	349 26·6	57·5	Suhail	223 23·0	S 43 15·0
17	263 56·0	86 46·5	48·6	203 49·1	52·4	51 19·9	06·5	4 28·9	57·5			
18	278 58·4	101 46·1	N 2 47·4	218 51·2	N 18 52·6	66 21·9	S 12 06·6	19 31·2	S 21 57·5	Vega	81 06·8	N 38 45·1
19	294 00·9	116 45·7	46·2	233 53·3	52·7	81 23·9	06·8	34 33·5	57·6	Zuben'ubi	137 51·3	S 15 52·2
20	309 03·4	131 45·3	44·9	248 55·4	52·8	96 25·9	07·0	49 35·8	57·6		S.H.A.	Mer. Pass.
21	324 05·8	146 44·9	· · 43·7	263 57·6	· · 53·0	111 27·8	· · 07·2	64 38·2	· · 57·6		° ′	h m
22	339 08·3	161 44·5	42·5	278 59·7	53·1	126 29·8	07·4	79 40·5	57·6	Venus	184 47·9	11 12
23	354 10·8	176 44·1	41·2	294 01·8	53·2	141 31·8	07·5	94 42·8	57·6	Mars	300 08·2	3 30
	h m									Jupiter	147 44·0	13 38
Mer. Pass.	23 27·2	v −0·4	d 1·2	v 2·1	d 0·1	v 2·3	d 0·2	v 2·3	d 0·0	Saturn	100 39·2	16 46

SEPTEMBER 28, 29, 30 (SUN., MON., TUES.)

G.M.T.	SUN		MOON					Lat.	Twilight		Sunrise	Moonrise			
									Naut.	Civil		28	29	30	1
	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
28 00	182 15·7	S 1 44·0	1 55·1	15·2	N 3 33·1	9·4	54·2	N 72	03 36	05 00	06 08	17 05	16 59	16 53	16 45
01	197 15·9	45·0	16 29·3	15·1	3 42·5	9·3	54·2	N 70	03 50	05 05	06 06	17 14	17 14	17 15	17 18
02	212 16·1	46·0	31 03·4	15·1	3 51·8	9·3	54·1	68	04 01	05 09	06 04	17 21	17 26	17 32	17 43
03	227 16·3	· · 47·0	45 37·5	15·1	4 01·1	9·4	54·1	66	04 10	05 12	06 03	17 27	17 35	17 46	18 01
04	242 16·5	47·9	60 11·6	15·1	4 10·5	9·3	54·1	64	04 18	05 14	06 02	17 32	17 44	17 58	18 17
05	257 16·8	48·9	74 45·7	15·0	4 19·8	9·2	54·1	62	04 24	05 16	06 01	17 36	17 51	18 08	18 29
								60	04 29	05 18	05 59	17 40	17 57	18 17	18 40
06	272 17·0	S 1 49·9	89 19·7	15·1	N 4 29·0	9·3	54·1	N 58	04 34	05 20	05 59	17 43	18 02	18 24	18 50
07	287 17·2	50·9	103 53·8	15·1	4 38·3	9·2	54·1	56	04 37	05 21	05 58	17 46	18 07	18 31	18 58
S 08	302 17·4	51·8	118 27·9	15·1	4 47·5	9·2	54·1	54	04 41	05 22	05 57	17 49	18 12	18 37	19 06
U 09	317 17·6	· · 52·8	133 02·0	15·0	4 56·7	9·2	54·1	52	04 44	05 23	05 57	17 51	18 15	18 42	19 12
N 10	332 17·8	53·8	147 36·0	15·1	5 05·9	9·2	54·1	50	04 46	05 24	05 56	17 54	18 19	18 47	19 18
D 11	347 18·0	54·7	162 10·1	15·1	5 15·1	9·1	54·1	45	04 51	05 26	05 55	17 59	18 27	18 57	19 31
A 12	2 18·2	S 1 55·7	176 44·2	15·0	N 5 24·2	9·2	54·1	N 40	04 55	05 27	05 54	18 03	18 33	19 06	19 42
Y 13	17 18·4	56·7	191 18·2	15·0	5 33·4	9·0	54·1	35	04 58	05 27	05 53	18 06	18 39	19 14	19 51
14	32 18·6	57·7	205 52·2	15·1	5 42·4	9·1	54·1	30	05 00	05 28	05 52	18 09	18 44	19 20	19 59
15	47 18·9	· · 58·6	220 26·3	15·0	5 51·5	9·1	54·1	20	05 03	05 28	05 50	18 15	18 53	19 32	20 13
16	62 19·1	1 59·6	235 00·3	15·0	6 00·6	9·0	54·1	N 10	05 03	05 28	05 49	18 20	19 00	19 42	20 25
17	77 19·3	2 00·6	249 34·3	15·0	6 09·6	9·0	54·1	0	05 03	05 27	05 47	18 25	19 08	19 52	20 37
18	92 19·5	S 2 01·6	264 08·3	15·0	N 6 18·6	8·9	54·1	S 10	05 00	05 25	05 46	18 29	19 15	20 01	20 49
19	107 19·7	02·5	278 42·3	14·9	6 27·5	9·0	54·0	20	04 56	05 22	05 44	18 34	19 23	20 12	21 01
20	122 19·9	03·5	293 16·2	15·0	6 36·5	8·9	54·0	30	04 50	05 18	05 42	18 40	19 32	20 24	21 15
21	137 20·1	· · 04·5	307 50·2	14·9	6 45·4	8·9	54·0	35	04 45	05 15	05 40	18 43	19 37	20 30	21 24
22	152 20·3	05·5	322 24·1	15·0	6 54·3	8·8	54·0	40	04 40	05 12	05 39	18 47	19 43	20 38	21 33
23	167 20·5	06·4	336 58·1	14·9	7 03·1	8·8	54·0	45	04 33	05 07	05 37	18 51	19 50	20 48	21 44
29 00	182 20·8	S 2 07·4	351 32·0	14·9	N 7 11·9	8·8	54·0	S 50	04 24	05 02	05 35	18 57	19 58	20 59	21 58
01	197 21·0	08·4	6 05·9	14·9	7 20·7	8·8	54·0	52	04 19	05 00	05 34	18 59	20 02	21 04	22 04
02	212 21·2	09·3	20 39·8	14·9	7 29·5	8·7	54·0	54	04 15	04 57	05 33	19 02	20 06	21 09	22 11
03	227 21·4	· · 10·3	35 13·7	14·9	7 38·2	8·7	54·0	56	04 09	04 54	05 31	19 05	20 11	21 16	22 19
04	242 21·6	11·3	49 47·6	14·8	7 46·9	8·6	54·0	58	04 03	04 50	05 30	19 08	20 16	21 23	22 28
05	257 21·8	12·3	64 21·4	14·8	7 55·5	8·6	54·0	S 60	03 55	04 46	05 28	19 12	20 22	21 31	22 38
06	272 22·0	S 2 13·2	78 55·2	14·9	N 8 04·1	8·6	54·0								
07	287 22·2	14·2	93 29·1	14·8	8 12·7	8·6	54·0								
M 08	302 22·4	15·2	108 02·9	14·8	8 21·3	8·5	54·0								
O 09	317 22·6	· · 16·2	122 36·7	14·7	8 29·8	8·5	54·0								
N 10	332 22·8	17·1	137 10·4	14·8	8 38·3	8·4	54·0								
D 11	347 23·0	18·1	151 44·2	14·7	8 46·7	8·4	54·0								
A 12	2 23·3	S 2 19·1	166 17·9	14·7	N 8 55·1	8·4	54·0								
Y 13	17 23·5	20·0	180 51·6	14·7	9 03·5	8·3	54·0								
14	32 23·7	21·0	195 25·3	14·7	9 11·8	8·3	54·0								
15	47 23·9	· · 22·0	209 59·0	14·6	9 20·1	8·3	54·0								
16	62 24·1	23·0	224 32·6	14·7	9 28·4	8·2	54·0								
17	77 24·3	23·9	239 06·3	14·6	9 36·6	8·1	54·0								
18	92 24·5	S 2 24·9	253 39·9	14·6	N 9 44·7	8·2	54·0								
19	107 24·7	25·9	268 13·5	14·5	9 52·9	8·0	54·0								
20	122 24·9	26·9	282 47·0	14·6	10 00·9	8·1	54·0								
21	137 25·1	· · 27·8	297 20·6	14·5	10 09·0	8·0	54·0								
22	152 25·3	28·8	311 54·1	14·5	10 17·0	7·9	54·0								
23	167 25·5	29·8	326 27·6	14·5	10 24·9	8·0	54·0								
30 00	182 25·7	S 2 30·7	341 01·1	14·5	N10 32·9	7·8	54·0	N 40	17 47	18 13	18 45	06 18	07 14	08 10	09 05
01	197 25·9	31·7	355 34·6	14·4	10 40·7	7·9	54·0	35	17 48	18 13	18 42	06 15	07 09	08 03	08 56
02	212 26·2	32·7	10 08·0	14·4	10 48·6	7·7	54·0	30	17 49	18 12	18 40	06 13	07 05	07 57	08 49
03	227 26·4	· 33·7	24 41·4	14·4	10 56·5	7·8	54·0	20	17 50	18 12	18 38	06 09	06 58	07 46	08 36
04	242 26·6	34·6	39 14·8	14·4	11 04·1	7·7	54·0	N 10	17 52	18 13	18 37	06 06	06 51	07 37	08 24
05	257 26·8	35·6	53 48·2	14·3	11 11·8	7·6	54·0	0	17 54	18 14	18 38	06 02	06 45	07 29	08 13
06	272 27·0	S 2 36·6	68 21·5	14·3	N11 19·4	7·6	54·0	S 10	17 55	18 17	18 41	05 59	06 39	07 20	08 03
07	287 27·2	37·5	82 54·8	14·3	11 27·0	7·5	54·0	20	17 57	18 20	18 45	05 56	06 33	07 11	07 51
T 08	302 27·4	38·5	97 28·1	14·2	11 34·5	7·5	54·0	30	18 00	18 24	18 52	05 52	06 26	07 01	07 39
U 09	317 27·6	· · 39·5	112 01·3	14·3	11 42·0	7·5	54·0	35	18 01	18 27	18 56	05 49	06 22	06 55	07 31
E 10	332 27·8	40·5	126 34·6	14·2	11 49·5	7·5	54·0	40	18 03	18 30	19 02	05 47	06 17	06 48	07 23
S 11	347 28·0	41·4	141 07·8	14·2	11 56·8	7·4	54·0	45	18 05	18 34	19 09	05 44	06 11	06 41	07 13
D 12	2 28·2	S 2 42·4	155 41·0	14·1	N12 04·2	7·3	54·0	S 50	18 07	18 40	19 18	05 40	06 05	06 31	07 01
A 13	17 28·4	43·4	170 14·1	14·1	12 11·5	7·2	54·0	52	18 08	18 42	19 23	05 39	06 02	06 27	06 55
Y 14	32 28·6	44·3	184 47·2	14·1	12 18·7	7·2	54·0	54	18 10	18 45	19 28	05 37	05 59	06 22	06 47
15	47 28·8	· · 45·3	199 20·3	14·1	12 25·9	7·2	54·0	56	18 11	18 48	19 34	05 35	05 55	06 17	06 42
16	62 29·0	46·3	213 53·4	14·0	12 33·1	7·0	54·0	58	18 12	18 52	19 41	05 33	05 51	06 11	06 35
17	77 29·2	47·3	228 26·4	14·1	12 40·1	7·1	54·0	S 60	18 14	18 56	19 48	05 30	05 46	06 05	06 26
18	92 29·4	S 2 48·2	242 59·5	13·9	N12 47·2	6·9	54·0								
19	107 29·6	49·2	257 32·4	14·0	12 54·1	7·0	54·0								
20	122 29·8	50·2	272 05·4	13·9	13 01·1	6·8	54·0								
21	137 30·0	· · 51·1	286 38·3	13·9	13 07·9	6·8	54·0								
22	152 30·3	52·1	301 11·2	13·9	13 14·7	6·8	54·0								
23	167 30·5	53·1	315 44·1	13·8	13 21·5	6·7	54·0								
	S.D. 16·0	d 1·0	S.D.	14·7	14·7		14·7								

Lat.	Sunset	Twilight		Moonset			
		Civil	Naut.	28	29	30	1
°	h m	h m	h m	h m	h m	h m	h m
N 72	17 31	18 38	20 02	07 01	08 36	10 14	11 54
N 70	17 34	18 34	19 48	06 55	08 23	09 53	11 22
68	17 35	18 31	19 37	06 49	08 13	09 36	10 58
66	17 37	18 28	19 29	06 45	08 04	09 23	10 40
64	17 38	18 25	19 22	06 41	07 57	09 12	10 26
62	17 39	18 23	19 16	06 38	07 51	09 03	10 13
60	17 40	18 22	19 11	06 35	07 45	08 55	10 03
N 58	17 41	18 20	19 06	06 32	07 41	08 48	09 54
56	17 42	18 19	19 03	06 30	07 36	08 42	09 46
54	17 43	18 18	18 59	06 28	07 33	08 37	09 39
52	17 43	18 17	18 56	06 26	07 29	08 32	09 33
50	17 44	18 16	18 54	06 25	07 26	08 27	09 27
45	17 46	18 15	18 49	06 21	07 20	08 18	09 15
N 40	17 47	18 13	18 45	06 18	07 14	08 10	09 05
35	17 48	18 13	18 42	06 15	07 09	08 03	08 56
30	17 49	18 12	18 40	06 13	07 05	07 57	08 49
20	17 50	18 12	18 38	06 09	06 58	07 46	08 36
N 10	17 52	18 13	18 37	06 06	06 51	07 37	08 24
0	17 54	18 14	18 38	06 02	06 45	07 29	08 13
S 10	17 55	18 17	18 41	05 59	06 39	07 20	08 03
20	17 57	18 20	18 45	05 56	06 33	07 11	07 51
30	18 00	18 24	18 52	05 52	06 26	07 01	07 39
35	18 01	18 27	18 56	05 49	06 22	06 55	07 31
40	18 03	18 30	19 02	05 47	06 17	06 48	07 23
45	18 05	18 34	19 09	05 44	06 11	06 41	07 13
S 50	18 07	18 40	19 18	05 40	06 05	06 31	07 01
52	18 08	18 42	19 23	05 39	06 02	06 27	06 55
54	18 10	18 45	19 28	05 37	05 59	06 22	06 47
56	18 11	18 48	19 34	05 35	05 55	06 17	06 42
58	18 12	18 52	19 41	05 33	05 51	06 11	06 35
S 60	18 14	18 56	19 48	05 30	05 46	06 05	06 26

Day	SUN		MOON			
	Eqn. of Time		Mer. Pass.	Mer. Pass.		Age	Phase
	00h	12h		Upper	Lower		
	m s	m s	h m	h m	h m	d	
28	09 02	09 13	11 51	24 35	12 13	15	
29	09 23	09 33	11 50	00 35	12 56	16	○
30	09 43	09 52	11 50	01 18	13 40	17	

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 20·6	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	Glenah	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			
2 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 16·8
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 09·7	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		S.H.A.	Mer. Pass.
21	335 55·5	144 50·6	·· 15·0	275 14·2	·· 23·8	120 52·1	·· 58·1	75 36·4	·· 02·9		° ′	h m
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
										Jupiter	145 19·7	13 01
										Saturn	99 49·8	16 02
	h m											
Mer. 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			

OCTOBER 10, 11, 12 (FRI., SAT., SUN.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
10 00	183 11·1	S 6 21·9	221 37·0	8·7	N 5 42·4	11·1	59·9
01	198 11·3	22·8	236 04·7	8·7	5 31·3	11·1	60·0
02	213 11·5	23·8	250 32·4	8·7	5 20·2	11·2	60·0
03	228 11·6	24·7	265 00·1	8·7	5 09·0	11·2	60·0
04	243 11·8	25·7	279 27·8	8·6	4 57·8	11·3	60·1
05	258 12·0	26·6	293 55·4	8·7	4 46·5	11·3	60·1
06	273 12·1	S 6 27·6	308 23·1	8·6	N 4 35·2	11·4	60·1
07	288 12·3	28·5	322 50·7	8·5	4 23·8	11·4	60·2
08	303 12·5	29·5	337 18·2	8·6	4 12·4	11·5	60·2
F 09	318 12·6	30·4	351 45·8	8·5	4 00·9	11·5	60·2
R 10	333 12·8	31·4	6 13·3	8·5	3 49·4	11·5	60·3
I 11	348 13·0	32·3	20 40·8	8·5	3 37·9	11·5	60·3
D 12	3 13·1	S 6 33·3	35 08·3	8·5	N 3 26·4	11·6	60·3
A 13	18 13·3	34·2	49 35·8	8·4	3 14·8	11·7	60·4
Y 14	33 13·5	35·2	64 03·2	8·4	3 03·1	11·6	60·4
15	48 13·6	36·1	78 30·6	8·4	2 51·5	11·7	60·4
16	63 13·8	37·1	92 58·0	8·3	2 39·8	11·7	60·5
17	78 14·0	38·0	107 25·3	8·4	2 28·1	11·8	60·5
18	93 14·1	S 6 39·0	121 52·7	8·3	N 2 16·3	11·7	60·5
19	108 14·3	39·9	136 20·0	8·2	2 04·6	11·8	60·5
20	123 14·5	40·9	150 47·2	8·3	1 52·8	11·8	60·6
21	138 14·6	41·8	165 14·5	8·2	1 41·0	11·9	60·6
22	153 14·8	42·8	179 41·7	8·2	1 29·1	11·8	60·6
23	168 15·0	43·7	194 08·9	8·2	1 17·3	11·9	60·7
11 00	183 15·1	S 6 44·7	208 36·1	8·1	N 1 05·4	11·9	60·7
01	198 15·3	45·6	223 03·2	8·1	0 53·5	11·9	60·7
02	213 15·4	46·5	237 30·3	8·1	0 41·6	12·0	60·7
03	228 15·6	47·5	251 57·4	8·0	0 29·6	11·9	60·8
04	243 15·8	48·4	266 24·4	8·0	0 17·7	12·0	60·8
05	258 15·9	49·4	280 51·4	8·0	N 0 05·7	11·9	60·8
06	273 16·1	S 6 50·3	295 18·4	8·0	S 0 06·2	12·0	60·8
S 07	288 16·3	51·3	309 45·4	7·9	0 18·2	12·0	60·9
A 08	303 16·4	52·2	324 12·3	7·9	0 30·2	12·0	60·9
T 09	318 16·6	53·2	338 39·2	7·8	0 42·2	12·0	60·9
U 10	333 16·7	54·1	353 06·0	7·9	0 54·2	12·0	60·9
R 11	348 16·9	55·1	7 32·9	7·8	1 06·2	12·0	61·0
12	3 17·1	S 6 56·0	21 59·7	7·7	S 1 18·2	12·0	6 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.	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	04 35	05 54	07 03	02 14	04 14	06 17	08 24
N 70	04 41	05 52	06 54	02 22	04 14	06 09	08 07
68	04 46	05 51	06 47	02 28	04 14	06 03	07 54
66	04 50	05 50	06 41	02 33	04 14	05 58	07 43
64	04 54	05 49	06 36	02 38	04 14	05 54	07 34
62	04 56	05 48	06 32	02 41	04 15	05 50	07 27
60	04 59	05 47	06 28	02 44	04 15	05 47	07 20
N 58	05 00	05 46	06 25	02 47	04 15	05 44	07 14
56	05 02	05 45	06 22	02 50	04 15	05 42	07 09
54	05 03	05 44	06 19	02 52	04 15	05 39	07 05
52	05 04	05 43	06 17	02 54	04 15	05 37	07 01
50	05 05	05 42	06 15	02 56	04 15	05 35	06 57
45	05 06	05 40	06 10	03 00	04 15	05 31	06 49
N 40	05 07	05 38	06 06	03 04	04 15	05 28	06 42
35	05 07	05 37	06 02	03 07	04 15	05 25	06 36
30	05 07	05 35	05 59	03 09	04 15	05 23	06 31
20	05 06	05 31	05 53	03 14	04 15	05 18	06 23
N 10	05 03	05 27	05 48	03 18	04 15	05 15	06 15
0	04 59	05 23	05 44	03 21	04 16	05 11	06 08
S 10	04 53	05 18	05 39	03 25	04 16	05 08	06 01
20	04 45	05 11	05 33	03 29	04 16	05 04	05 54
30	04 35	05 03	05 27	03 34	04 16	05 00	05 46
35	04 28	04 58	05 24	03 36	04 16	04 58	05 41
40	04 19	04 52	05 19	03 39	04 17	04 55	05 35
45	04 09	04 44	05 15	03 43	04 17	04 52	05 29
S 50	03 55	04 36	05 09	03 47	04 17	04 48	05 22
52	03 49	04 31	05 06	03 49	04 17	04 47	05 18
54	03 42	04 26	05 03	03 51	04 18	04 45	05 15
56	03 33	04 21	05 00	03 53	04 18	04 43	05 11
58	03 24	04 15	04 56	03 55	04 18	04 41	05 06
S 60	03 12	04 08	04 52	03 58	04 18	04 39	05 01

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 46	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 18 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	Alphecca	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	Glenah	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		S.H.A.	Mer. Pass.
21	46 53·5	123 56·1	51·1	3 13·4	29·8	176 36·7	28·7	138 29·9	28·4		° ′	h m
22	61 55·9	138 55·1	50·9	18 15·7	29·8	191 38·7	28·8	153 32·1	28·4	Venus	79 37·0	12 42
23	76 58·4	153 54·1	50·7	33 18·1	29·9	206 40·7	29·0	168 34·2	28·4	Mars	316 23·2	20 51
	h m									Jupiter	130 05·5	9 18
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	Saturn	91 50·8	11 51

DECEMBER 21, 22, 23 (SUN., MON., TUES.)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
21 00	180 34·0	S 23 26·1	59 40·8	14·4	N 10 57·0	7·8	54·1
01	195 33·7	26·1	74 14·2	14·4	11 04·8	7·8	54·1
02	210 33·3	26·1	88 47·6	14·3	11 12·6	7·6	54·1
03	225 33·0	26·2	103 20·9	14·3	11 20·2	7·7	54·2
04	240 32·7	26·2	117 54·2	14·3	11 27·9	7·6	54·2
05	255 32·4	26·2	132 27·5	14·2	11 35·5	7·5	54·2
06	270 32·1	S 23 26·2	147 00·7	14·3	N 11 43·0	7·5	54·2
07	285 31·8	26·3	161 34·0	14·2	11 50·5	7·5	54·2
08	300 31·5	26·3	176 07·2	14·1	11 58·0	7·4	54·2
S 09	315 31·2	26·3	190 40·3	14·1	12 05·4	7·4	54·2
U 10	330 30·9	26·3	205 13·4	14·1	12 12·8	7·3	54·2
N 11	345 30·5	26·3	219 46·5	14·1	12 20·1	7·2	54·2
D 12	0 30·2	S 23 26·4	234 19·6	14·0	N 12 27·3	7·2	54·2
A 13	15 29·9	26·4	248 52·6	14·0	12 34·5	7·2	54·2
Y 14	30 29·6	26·4	263 25·6	13·9	12 41·7	7·1	54·2
15	45 29·3	26·4	277 58·5	13·9	12 48·8	7·0	54·2
16	60 29·0	26·4	292 31·4	13·9	12 55·8	7·0	54·2
17	75 28·7	26·4	307 04·3	13·9	13 02·8	7·0	54·2
18	90 28·4	S 23 26·4	321 37·2	13·8	N 13 09·8	6·9	54·2
19	105 28·1	26·5	336 10·0	13·7	13 16·7	6·8	54·2
20	120 27·8	26·5	350 42·7	13·8	13 23·5	6·8	54·2
21	135 27·4	26·5	5 15·5	13·7	13 30·3	6·7	54·2
22	150 27·1	26·5	19 48·2	13·6	13 37·0	6·7	54·2
23	165 26·8	26·5	34 20·8	13·6	13 43·7	6·6	54·2
22 00	180 26·5	S 23 26·5	48 53·4	13·6	N 13 50·3	6·5	54·2
01	195 26·2	26·5	63 26·0	13·6	13 56·8	6·5	54·2
02	210 25·9	26·5	77 58·6	13·5	14 03·3	6·4	54·3
03	225 25·6	26·5	92 31·1	13·4	14 09·7	6·4	54·3
04	240 25·3	26·5	107 03·5	13·5	14 16·1	6·3	54·3
05	255 25·0	26·5	121 36·0	13·3	14 22·4	6·3	54·3
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	5·8	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.	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	08 26	10 57	▬	11 33	11 25	11 12	▭
N 70	08 06	09 54	▬	11 55	11 57	12 04	12 19
68	07 50	09 19	▬	12 11	12 21	12 36	13 02
66	07 36	08 54	10 35	12 25	12 39	13 00	13 30
64	07 25	08 34	09 52	12 36	12 54	13 18	13 52
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
N 58	07 00	07 52	08 45	13 02	13 27	13 58	14 36
56	06 53	07 42	08 30	13 08	13 35	14 07	14 47
54	06 47	07 33	08 17	13 14	13 42	14 16	14 56
52	06 41	07 25	08 06	13 19	13 49	14 24	15 05
50	06 36	07 18	07 56	13 24	13 55	14 31	15 12
45	06 24	07 02	07 35	13 34	14 08	14 45	15 28
N 40	06 14	06 48	07 18	13 43	14 18	14 58	15 42
35	06 04	06 36	07 04	13 50	14 27	15 08	15 53
30	05 56	06 26	06 52	13 57	14 35	15 17	16 03
20	05 39	06 07	06 31	14 08	14 49	15 33	16 20
N 10	05 23	05 49	06 12	14 18	15 01	15 47	16 35
0	05 06	05 32	05 55	14 28	15 13	16 00	16 49
S 10	04 47	05 14	05 37	14 37	15 24	16 13	17 03
20	04 24	04 53	05 18	14 47	15 37	16 27	17 18
30	03 55	04 28	04 56	14 59	15 51	16 43	17 35
35	03 37	04 13	04 43	15 05	15 59	16 53	17 45
40	03 13	03 55	04 28	15 13	16 09	17 03	17 57
45	02 43	03 32	04 10	15 22	16 20	17 16	18 10
S 50	01 57	03 03	03 47	15 33	16 33	17 31	18 27
52	01 29	02 47	03 36	15 38	16 39	17 39	18 35
54	00 41	02 29	03 24	15 44	16 46	17 47	18 43
56	////	02 07	03 10	15 50	16 54	17 55	18 53
58	////	01 37	02 53	15 57	17 03	18 06	19 04
S 60	////	00 47	02 32	16 05	17 13	18 18	19 17

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	▬	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 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	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 −0·3		JUPITER −1·3		SATURN +0·6		STARS		
d h	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
24 00	92 00·9	163 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	Acamar	315 49·2	S 40 28·3
01	107 03·3	183 52·2	50·2	63 22·8	30·1	236 44·6	29·2	198 38·5	28·4	Achernar	335 57·1	S 57 27·0
02	122 05·8	198 51·3	50·0	78 25·1	30·1	251 46·6	29·3	213 40·6	28·4	Acrux	173 55·1	S 62 52·0
03	137 08·3	213 50·3	49·8	93 27·5	30·2	266 48·6	29·5	228 42·8	28·4	Adhara	255 44·3	S 28 55·0
04	152 10·7	228 49·3	49·6	108 29·9	30·3	281 50·5	29·6	243 44·9	28·4	Aldebaran	291 36·1	N 16 25·6
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	Alioth	166 56·8	N 56 10·6
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	Alkaid	153 31·4	N 49 30·8
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	Al Na'ir	28 35·5	S 47 09·7
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	Alnilam	276 27·6	S 1 13·8
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	Alphard	218 36·1	S 8 28·9
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	Alphecca	126 46·0	N 26 51·1
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	Alpheratz	358 25·9	N 28 52·0
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	Altair	62 48·5	N 8 45·7
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	Ankaa	353 36·1	S 42 31·9
16	332 40·3	48 37·8	47·0	288 58·0	31·2	102 14·2	31·0	64 10·7	28·5	Antares	113 16·9	S 26 20·4
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	Arcturus	146 33·3	N 19 23·7
19	17 47·7	93 34·9	46·4	334 05·0	31·5	147 20·2	31·4	109 17·1	28·5	Atria	108 56·0	S 68 57·1
20	32 50·2	108 34·0	46·1	349 07·3	31·6	162 22·1	31·5	124 19·3	28·5	Avior	234 34·2	S 59 22·6
21	47 52·6	123 33·0	45·9	4 09·6	31·7	177 24·1	31·6	139 21·4	28·5	Bellatrix	279 15·6	N 6 18·7
22	62 55·1	138 32·1	45·7	19 11·9	31·7	192 26·1	31·8	154 23·5	28·5	Betelgeuse	271 45·3	N 7 23·9
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	Canopus	264 13·8	S 52 40·5
01	108 02·5	183 29·2	45·0	64 18·9	32·0	237 32·0	32·1	199 30·0	28·5	Capella	281 34·5	N 45 57·4
02	123 04·9	198 28·2	44·7	79 21·2	32·1	252 34·0	32·2	214 32·1	28·5	Deneb	49 59·7	N 45 08·3
03	138 07·4	213 27·3	44·5	94 23·6	32·1	267 36·0	32·4	229 34·3	28·5	Denebola	183 15·4	N 14 47·9
04	153 09·9	228 26·3	44·3	109 25·9	32·2	282 37·9	32·5	244 36·4	28·5	Diphda	349 37·0	S 18 12·8
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	Dubhe	194 41·8	N 61 58·0
07	198 17·3	273 23·5	43·5	154 32·8	32·5	327 43·9	32·8	289 42·9	28·5	Elnath	279 04·1	N 28 34·4
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	Eltanin	91 05·7	N 51 29·7
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	Enif	34 27·6	N 9 41·3
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	Fomalhaut	16 09·3	S 29 50·5
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	Gacrux	172 46·6	S 56 52·8
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	Glenah	176 34·5	S 17 18·8
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	Hadar	149 46·3	S 60 10·3
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	Hamal	328 46·8	N 23 16·2
16	333 39·4	48 14·9	41·3	289 53·6	33·3	103 01·7	33·9	65 02·2	28·6	Kaus Aust.	84 38·6	S 34 24·2
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	Kochab	137 19·2	N 74 19·2
19	18 46·8	93 12·0	40·5	335 00·5	33·5	148 07·6	34·3	110 08·6	28·6	Markab	14 19·3	N 14 59·2
20	33 49·3	108 11·1	40·3	350 02·8	33·6	163 09·6	34·4	125 10·8	28·6	Menkar	314 57·7	N 3 55·7
21	48 51·8	123 10·1	40·0	5 05·1	33·7	178 11·5	34·5	140 12·9	28·6	Menkent	148 56·1	S 36 09·9
22	63 54·2	138 09·1	39·8	20 07·4	33·8	193 13·5	34·6	155 15·0	28·6	Miaplacidus	221 47·6	S 69 32·8
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	Mirfak	309 38·6	N 49 43·1
01	109 01·6	183 06·3	39·0	65 14·3	34·1	238 19·5	35·0	200 21·5	28·6	Nunki	76 49·5	S 26 20·8
02	124 04·1	198 05·3	38·7	80 16·6	34·1	253 21·4	35·1	215 23·6	28·6	Peacock	54 24·3	S 56 52·1
03	139 06·5	213 04·4	38·4	95 18·9	34·2	268 23·4	35·2	230 25·8	28·6	Pollux	244 17·5	N 28 07·4
04	154 09·0	228 03·4	38·2	110 21·2	34·3	283 25·4	35·3	245 27·9	28·7	Procyon	245 42·3	N 5 19·7
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	Rasalhague	96 44·8	N 12 35·4
07	199 16·4	273 00·6	37·3	155 28·0	34·6	328 31·3	35·7	290 34·4	28·7	Regulus	208 26·9	N 12 09·9
08	214 18·9	287 59·6	37·1	170 30·3	34·7	343 33·3	35·8	305 36·5	29·7	Rigel	281 51·1	S 8 15·0
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	Rigil Kent.	140 48·1	S 60 39·7
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	Sabik	102 59·9	S 15 40·4
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	Schedar	350 27·1	N 56 19·1
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	Shaula	97 18·0	S 37 04·4
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	Sirius	259 09·5	S 16 39·7
15	319 36·1	32 53·0	35·1	275 46·2	35·3	88 47·2	36·6	50 51·5	28·7	Spica	159 14·6	S 10 56·8
16	334 38·6	47 52·1	34·8	290 48·5	35·4	103 49·1	36·8	65 53·7	28·7	Suhail	223 22·2	S 43 15·9
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	Vega	81 07·1	N 38 44·8
19	19 46·0	92 49·2	34·0	335 55·3	35·7	148 55·1	37·1	111 00·1	28·7	Zuben'ubi	137 51·0	S 15 52·2
20	34 48·4	107 48·3	33·7	350 57·6	35·8	163 57·1	37·2	126 02·2	28·7		S.H.A.	Mer. Pass.
21	49 50·9	122 47·3	33·4	5 59·9	35·9	178 59·1	37·3	141 04·4	28·7		° ′	h m
22	64 53·4	137 46·4	33·1	21 02·1	36·0	194 01·0	37·5	156 06·5	28·7	Venus	75 30·1	12 47
23	79 55·8	152 45·4	32·8	36 04·4	36·1	209 03·0	37·6	171 08·7	28·7	Mars	316 16·6	20 40
										Jupiter	129 30·0	9 09·
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	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	N17 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	N18 06·9	2·6	54·9
W 07	285 09·4	25·7	127 44·9	11·3	18 09·5	2·6	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	N18 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	N18 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	N18 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	N18 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	N18 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	N18 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	N18 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	N18 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	N18 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	N18 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	25	26	27
°	h m	h m	h m	h m	h m	h m	h m
N 72	08 27	10 57	[sun]	12 19	12 57	14 06	15 37
N 70	08 07	09 55	[sun]	13 02	13 44	14 47	16 07
68	07 51	09 20	[sun]	13 30	14 14	15 15	16 30
66	07 38	08 55	10 35	13 52	14 37	15 37	16 48
64	07 26	08 35	09 53	14 09	14 56	15 54	17 03
62	07 17	08 19	09 24	14 24	15 11	16 08	17 15
60	07 08	08 05	09 03				
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	25	26	27
°	h m	h m	h m	h m	h m	h m	h m
N 72	[sun]	13 02	15 33	08 49	09 56	10 32	10 48
N 70	[sun]	14 04	15 53	08 08	09 08	09 51	10 17
68	[sun]	14 39	16 09	07 39	08 38	09 22	09 53
66	13 24	15 05	16 22	07 18	08 15	09 01	09 35
64	14 06	15 24	16 33	07 00	07 57	08 43	09 20
62	14 35	15 41	16 42	06 46	07 42	08 29	09 07
60	14 57	15 54	16 51				
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	Glenah	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		S.H.A.	Mer. Pass.
21	52 48·3	121 40·0	·· 09·2	8 39·7	·· 43·5	181 22·0	·· 45·7	143 38·9	·· 29·1		° ′	h m
22	67 50·8	136 39·0	08·8	23 41·9	43·6	196 24·0	45·8	158 41·1	29·1	Venus	71 24·5	12 51
23	82 53·3	151 38·1	08·5	38 44·0	43·7	211 26·0	45·9	173 43·2	29·1	Mars	316 03·2	20 29
	h m									Jupiter	128 55·2	8 59
Mer. Pass.	17 33·3	v −0·9	d 0·1	v 2·2	d 0·1	v 2·0	d 0·1	v 2·1	d 0·0	Saturn	91 04·9	11 30

DECEMBER 27, 28, 29 (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	° ′	° ′	° ′	′	° ′	′	′
27 00	179 49·3	S 23 21·5	349 43·9	10·1	N 17 40·5	3·6	56·1
01	194 49·0	21·4	4 13·0	10·1	17 36·9	3·7	56·1
02	209 48·7	21·3	18 42·1	10·0	17 33·2	3·9	56·2
03	224 48·4	21·2	33 11·1	10·1	17 29·3	3·9	56·2
04	239 48·1	21·1	47 40·2	10·1	17 25·4	4·0	56·2
05	254 47·8	21·0	62 09·3	10·1	17 21·4	4·1	56·2
06	269 47·5	S 23 20·9	76 38·4	10·0	N 17 17·3	4·2	56·2
07	284 47·2	20·8	91 07·4	10·1	17 13·1	4·3	56·3
S 08	299 46·9	20·7	105 36·5	10·1	17 08·8	4·3	56·3
A 09	314 46·6	20·6	120 05·6	10·1	17 04·5	4·5	56·3
T 10	329 46·2	20·5	134 34·7	10·1	17 00·0	4·6	56·3
U 11	344 45·9	20·4	149 03·8	10·1	16 55·4	4·6	56·3
R 12	359 45·6	S 23 20·3	163 32·9	10·1	N 16 50·8	4·8	56·4
D 13	14 45·3	20·2	178 02·0	10·1	16 46·0	4·9	56·4
A 14	29 45·0	20·1	192 31·1	10·1	16 41·1	4·9	56·4
Y 15	44 44·7	20·0	207 00·2	10·1	16 36·2	5·0	56·4
16	59 44·4	19·9	221 29·3	10·2	16 31·2	5·1	56·4
17	74 44·1	19·8	235 58·5	10·1	16 26·1	5·3	56·5
18	89 43·8	S 23 19·7	250 27·6	10·1	N 16 20·8	5·3	56·5
19	104 43·5	19·6	264 56·7	10·2	16 15·5	5·4	56·5
20	119 43·2	19·5	279 25·9	10·2	16 10·1	5·4	56·5
21	134 42·9	19·4	293 55·1	10·1	16 04·7	5·6	56·5
22	149 42·6	19·3	308 24·2	10·2	15 59·1	5·7	56·6
23	164 42·3	19·2	322 53·4	10·2	15 53·4	5·7	56·6
28 00	179 41·9	S 23 19·1	337 22·6	10·2	N 15 47·7	5·9	56·6
01	194 41·6	18·9	351 51·8	10·2	15 41·8	5·9	56·6
02	209 41·3	18·8	6 21·0	10·2	15 35·9	6·0	56·6
03	224 41·0	18·7	20 50·2	10·2	15 29·9	6·1	56·7
04	239 40·7	18·6	35 19·4	10·3	15 23·8	6·2	56·7
05	254 40·4	18·5	49 48·7	10·2	15 17·6	6·2	56·7
06	269 40·1	S 23 18·4	64 17·9	10·3	N 15 11·4	6·4	56·7
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	N 14 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	N 13 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·
29 00	179 34·6	S 23 16·2	325 06·6	10·5	N 13 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	N 12 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	N 11 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	N 10 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.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 27	Moonrise 28	Moonrise 29	Moonrise 30
°	h m	h m	h m	h m	h m	h m	h m
N 72	08 26	10 53		14 48	16 47	18 41	20 32
N 70	08 07	09 54		15 37	17 16	18 58	20 41
68	07 51	09 20		16 07	17 38	19 12	20 49
66	07 38	08 55	10 33	16 30	17 54	19 23	20 55
64	07 27	08 35	09 52	16 48	18 08	19 33	21 00
62	07 17	08 19	09 24	17 03	18 19	19 41	21 04
60	07 09	08 06	09 03	17 15	18 29	19 47	21 08
N 58	07 02	07 54	08 46	17 26	18 37	19 54	21 12
56	06 55	07 44	08 32	17 35	18 45	19 59	21 15
54	06 49	07 35	08 19	17 43	18 51	20 04	21 18
52	06 44	07 27	08 08	17 51	18 57	20 08	21 20
50	06 38	07 20	07 58	17 57	19 03	20 12	21 22
45	06 27	07 04	07 38	18 11	19 14	20 20	21 27
N 40	06 16	06 50	07 21	18 23	19 24	20 27	21 31
35	06 07	06 39	07 07	18 33	19 32	20 33	21 35
30	05 58	06 28	06 54	18 41	19 39	20 38	21 38
20	05 42	06 09	06 33	18 56	19 52	20 47	21 43
N 10	05 26	05 52	06 15	19 09	20 02	20 55	21 48
0	05 09	05 35	05 58	19 22	20 12	21 03	21 53
S 10	04 50	05 17	05 40	19 34	20 23	21 10	21 57
20	04 28	04 57	05 21	19 47	20 33	21 18	22 02
30	03 59	04 32	04 59	20 02	20 46	21 27	22 07
35	03 40	04 17	04 46	20 10	20 53	21 32	22 10
40	03 17	03 59	04 31	20 20	21 01	21 38	22 14
45	02 47	03 36	04 13	20 31	21 10	21 45	22 18
S 50	02 01	03 07	03 51	20 45	21 21	21 53	22 22
52	01 34	02 52	03 40	20 52	21 26	21 57	22 25
54	00 49	02 34	03 28	20 59	21 32	22 01	22 27
56	////	02 12	03 14	21 07	21 38	22 06	22 30
58	////	01 42	02 57	21 16	21 46	22 11	22 33
S 60	////	00 54	02 37	21 26	21 53	22 16	22 36

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 13	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	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	
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	

POLARIS (POLE STAR) TABLES,

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 = corrected sextant altitude $-1° + a_0 + a_1 + a_2$

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*.

ELEMENTS FROM NAUTICAL ALMANAC

POLARIS (POLE STAR) TABLES,

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 48·9
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	Corr. Sext. Alt.	49°31′·6
Increment ($17^m\ 50^s$)	4 28·2	a_0 (argument 56° 49′)	0 09·7
Longitude (west)	−27 34	a_1 (lat. 50°-approx.)	·6
L.H.A. Aries	56 49	a_2 (January)	0·7
		Sum −1° = Lat. =	48 42·6

POLARIS (POLE STAR) TABLES,

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 = corrected sextant altitude $-1° + a_0 + a_1 + a_2$

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*.

INCREMENTS AND CORRECTIONS

0m INCREMENTS AND CORRECTIONS 1m

m 0	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

m 1	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

4m INCREMENTS AND CORRECTIONS 5m

4m	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

5m	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

6m INCREMENTS AND CORRECTIONS 7m

m 6 s	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
	° ′	° ′	° ′	′	′	′	′	′	′
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

m 7 s	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
	° ′	° ′	° ′	′	′	′	′	′	′
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

8	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
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

9	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
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

10m s	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
	° ′	° ′	° ′	′	′	′	′	′	′
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	14·9	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

11m s	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
	° ′	° ′	° ′	′	′	′	′	′	′
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

12m	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

13m	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 Corr^n d	v or Corr^n d	v or Corr^n d
	° ′	° ′	° ′	′ ′	′ ′	′ ′
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 Corr^n d	v or Corr^n d	v or Corr^n d
	° ′	° ′	° ′	′ ′	′ ′	′ ′
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

m 16	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
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	9·0	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

m 17	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
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	8·0	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 20·4	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 Corr^n d	v or Corr^n d	v or Corr^n d
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 Corr^n d	v or Corr^n d	v or Corr^n d
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	v or d	Corr	v or d	Corr
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	v or d	Corr	v or d	Corr
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	5·2	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	Corrn	v or d	Corrn	v or d	Corrn
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	Corrn	v or d	Corrn	v or d	Corrn
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 Corrn d	v or Corrn d	v or Corrn 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 Corrn d	v or Corrn d	v or Corrn d
s	° ′	° ′	° ′	′ ′	′ ′	′ ′
00	6 45·0	6 46·1	6 26·6	0·0 0·0	8·0 2·8	12·0 5·5
01	6 45·3	6 46·4	6 26·8	0·1 0·0	8·1 2·8	12·1 5·5
02	6 45·5	6 46·6	6 27·0	0·2 0·1	8·2 2·8	12·2 5·6
03	6 45·8	6 46·9	6 27·3	0·3 0·1	8·3 2·9	12·3 5·6
04	6 46·0	6 47·1	6 27·5	0·4 0·2	8·4 2·9	12·4 5·7
05	6 46·3	6 47·4	6 27·7	0·5 0·2	8·5 3·0	12·5 5·7
06	6 46·5	6 47·6	6 28·0	0·6 0·3	8·6 3·0	12·6 5·8
07	6 46·8	6 47·9	6 28·2	0·7 0·3	8·7 3·1	12·7 5·8
08	6 47·0	6 48·1	6 28·5	0·8 0·4	8·8 3·1	12·8 5·9
09	6 47·3	6 48·4	6 28·7	0·9 0·4	8·9 3·2	12·9 5·9
10	6 47·5	6 48·6	6 28·9	1·0 0·5	9·0 3·2	13·0 6·0
11	6 47·8	6 48·9	6 29·2	1·1 0·5	9·1 3·3	13·1 6·0
12	6 48·0	6 49·1	6 29·4	1·2 0·6	9·2 3·3	13·2 6·1
13	6 48·3	6 49·4	6 29·7	1·3 0·6	9·3 3·3	13·3 6·1
14	6 48·5	6 49·6	6 29·9	1·4 0·6	9·4 3·4	13·4 6·1
15	6 48·8	6 49·9	6 30·1	1·5 0·7	9·5 3·4	13·5 6·2
16	6 49·0	6 50·1	6 30·4	1·6 0·7	9·6 3·5	13·6 6·2
17	6 49·3	6 50·4	6 30·6	1·7 0·8	9·7 3·5	13·7 6·3
18	6 49·5	6 50·6	6 30·8	1·8 0·8	9·8 3·6	13·8 6·3
19	6 49·8	6 50·9	6 31·1	1·9 0·9	9·9 3·6	13·9 6·4
20	6 50·0	6 51·1	6 31·3	2·0 0·9	10·0 3·7	14·0 6·4
21	6 50·3	6 51·4	6 31·6	2·1 1·0	10·1 3·7	14·1 6·5
22	6 50·5	6 51·6	6 31·8	2·2 1·0	10·2 3·8	14·2 6·5
23	6 50·8	6 51·9	6 32·0	2·3 1·1	10·3 3·8	14·3 6·6
24	6 51·0	6 52·1	6 32·3	2·4 1·1	10·4 3·9	14·4 6·6
25	6 51·3	6 52·4	6 32·5	2·5 1·1	10·5 3·9	14·5 6·6
26	6 51·5	6 52·6	6 32·8	2·6 1·2	10·6 3·9	14·6 6·7
27	6 51·8	6 52·9	6 33·0	2·7 1·2	10·7 4·0	14·7 6·7
28	6 52·0	6 53·1	6 33·2	2·8 1·3	10·8 4·0	14·8 6·8
29	6 52·3	6 53·4	6 33·5	2·9 1·3	10·9 4·1	14·9 6·8
30	6 52·5	6 53·6	6 33·7	3·0 1·4	11·0 4·1	15·0 6·9
31	6 52·8	6 53·9	6 33·9	3·1 1·4	11·1 4·2	15·1 6·9
32	6 53·0	6 54·1	6 34·2	3·2 1·5	11·2 4·2	15·2 7·0
33	6 53·3	6 54·4	6 34·4	3·3 1·5	11·3 4·3	15·3 7·0
34	6 53·5	6 54·6	6 34·7	3·4 1·6	11·4 4·3	15·4 7·1
35	6 53·8	6 54·9	6 34·9	3·5 1·6	11·5 4·4	15·5 7·1
36	6 54·0	6 55·1	6 35·1	3·6 1·7	11·6 4·4	15·6 7·2
37	6 54·3	6 55·4	6 35·4	3·7 1·7	11·7 4·4	15·7 7·2
38	6 54·5	6 55·6	6 35·6	3·8 1·7	11·8 4·5	15·8 7·2
39	6 54·8	6 55·9	6 35·9	3·9 1·8	11·9 4·5	15·9 7·3
40	6 55·0	6 56·1	6 36·1	4·0 1·8	12·0 4·6	16·0 7·3
41	6 55·3	6 56·4	6 36·3	4·1 1·9	12·1 4·6	16·1 7·4
42	6 55·5	6 56·6	6 36·6	4·2 1·9	12·2 4·7	16·2 7·4
43	6 55·8	6 56·9	6 36·8	4·3 2·0	12·3 4·7	16·3 7·5
44	6 56·0	6 57·1	6 37·0	4·4 2·0	12·4 4·8	16·4 7·5
45	6 56·3	6 57·4	6 37·3	4·5 2·1	12·5 4·8	16·5 7·6
46	6 56·5	6 57·6	6 37·5	4·6 2·1	12·6 4·9	16·6 7·6
47	6 56·8	6 57·9	6 37·8	4·7 2·2	12·7 4·9	16·7 7·7
48	6 57·0	6 58·1	6 38·0	4·8 2·2	12·8 5·0	16·8 7·7
49	6 57·3	6 58·4	6 38·2	4·9 2·2	12·9 5·0	16·9 7·7
50	6 57·5	6 58·6	6 38·5	5·0 2·3	13·0 5·0	17·0 7·8
51	6 57·8	6 58·9	6 38·7	5·1 2·3	13·1 5·1	17·1 7·8
52	6 58·0	6 59·1	6 39·0	5·2 2·4	13·2 5·1	17·2 7·9
53	6 58·3	6 59·4	6 39·2	5·3 2·4	13·3 5·2	17·3 7·9
54	6 58·5	6 59·6	6 39·4	5·4 2·5	13·4 5·2	17·4 8·0
55	6 58·8	6 59·9	6 39·7	5·5 2·5	13·5 5·3	17·5 8·0
56	6 59·0	7 00·1	6 39·9	5·6 2·6	13·6 5·3	17·6 8·1
57	6 59·3	7 00·4	6 40·2	5·7 2·6	13·7 5·4	17·7 8·1
58	6 59·5	7 00·6	6 40·4	5·8 2·7	13·8 5·4	17·8 8·2
59	6 59·8	7 00·9	6 40·6	5·9 2·7	13·9 5·5	17·9 8·2
60	7 00·0	7 01·1	6 40·9	6·0 2·8	14·0 5·5	18·0 8·3

INCREMENTS AND CORRECTIONS

28m s	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
	° ′	° ′	° ′	′	′	′	′	′	′
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 s	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
	° ′	° ′	° ′	′	′	′	′	′	′
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

30m INCREMENTS AND CORRECTIONS 31m

30m	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

31m	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 d Corr	v or d Corr	v or d Corr
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 d Corr	v or d Corr	v or d Corr
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

34m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	8 30·0	8 31·4	8 06·3	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

35m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
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	0·0	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

m 38	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

m 39	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	Corrn	v or d	Corrn	v or d	Corrn
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	Corrn	v or d	Corrn	v or d	Corrn
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 50·9	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 s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corr^n ′	v or d ′	Corr^n ′	v or d ′	Corr^n ′
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 s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corr^n ′	v or d ′	Corr^n ′	v or d ′	Corr^n ′
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	v or d	Corr	v or d	Corr
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	v or d	Corr	v or d	Corr
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 Corr^n d	v or Corr^n d	v or Corr^n d
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 Corr^n d	v or Corr^n d	v or Corr^n d
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 51m

50m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
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^n	v or d	Corr^n	v or d	Corr^n
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	12·1	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 d	Corr^n	v or d	Corr^n	v or d	Corr^n
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 d	Corr^n	v or d	Corr^n	v or d	Corr^n
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

56m	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

57m	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 59m

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		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 44·8	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	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

Pages 421-485—Reproduced by kind permission of the Hydrographer of the Navy.

INDEX

A

PAGE

ABC Tables - - - - - - - 93, 130
Abbreviations - - - - - - - xxiv
„ - - - - - In Pocket
Aden to Hong Kong Passage - - - 46
Admiralty Publications—
Charts - - - - - - - - 56
Ocean Passages for the World - - 44
Method of Tidal Prediction - - 103-114
Tide Tables - - - - - 103, 391
Tidal Stream Atlas - - - - - 123
Agulhas Current - - - - - - - 43
Altitude and Azimuth - - - - - 299
„ Circum-meridian - - 142, 293, 296
„ Effect of Errors in - - - - 304
„ Equation of Equal - - - - 324
„ Ex-Meridian - - - - 131, 166, 327
„ Maximum - - - - - 320
„ Rate of Change of - - - - 319
„ of Pole Star - - - - 308, 328
„ and Time Interval - - - 300, 320
Altitudes, Simultaneous and Double - - 171
Angle of Dip - - - - - - - 300
Analogies, Napier's - - - - - 243
Answers—
Bow and Beam Bearings - - - - 377
Composite Sailing - - - - - 379
Day's Work - - - - - - 378
Double Altitudes - - - - 384, 385
Examination Papers - - - - 384
Gnomonic Chart - - - - - 380
Great Circle Sailing - - - 360, 380
Latitude by Pole Star - - - - 383
Napier's Diagram - - - - - 377
Plane, Parallel and Mercator Sailings - 377
Star Identification - - - - - 382
Stars on Meridian - - - - - 382
Stars, Planets and Moon - - - 383
Stars near Meridian - - - 362, 382
Sun Position Line and Ex-Meridian Sights - - - - - - 362, 382
Tides - - - - - - - 361, 381
Appendices - - - - - - - - 391
Apogee and Perigee - - - - - - 87
Arcs of Small Circles - - - - - 248
Astronomical Theory - - - - - 125
Atlantic Ocean, Winds, Currents and Passages 42, 44, 46
Atmospheric Refraction - - - - 308
Augmentation of Moon's Semi-diameter - 310
Azimuth - - - - - - - - 124
„ Error - - - - - - - 315
„ Rate of Change of - - - - 314
„ and Star Identification - - - 158
„ Pole Star - - - - - 164
„ Tables, Pole Star - - - - 453
„ Tables, A B C - - - - 93, 130

B

Bearings, Beam - - - - - - 9, 18
Bearing Problem, Three - - - - - 19
Bombay to Hongkong - - - - 46
Bow and Beam Bearings - - - - 9, 18
Brazil Current - - - - - - - 42

C

Calculations—
A B C Tables - - - - - - - 130
Augmentation of a Semi-Diameter - - 310
Bearings of Sun - - - - - - 288
Bow and Beam Bearings - - - 9, 18, 190
Collimation Error - - - - - 311
Composite G. C. Sailing - - - 18, 88
Course and Current - - 19, 20, 277
Course of Ship - - - - 278, 284
Course and Relative Speeds - - 276, 282
Declinations - - - - - 139, 289
Deviation Curves and Tables - - - 13
Dip - - - - - - - - 300
Distance of Horizon - - - 300, 301
Equation of Equal Altitudes - - - 324
Error in Hour Angle - - - 312-315
Ex-Meridian Tables - - - 129, 328
„ Latitude by - 131, 166-182
„ Intercept by - - 174
Fix by Position Lines - - - - 176
Great Circle Sailing - - - - 81
„ by ABC Tables - - - 93
Heights and Distances - - - - 275
Latitudes - - - - - 288, 294
Latitude by Pole Star - - - - 164
Maximum Altitude - - - - - 320
Moonrise - - - - - - 311
Oblique Spherical Triangles - - - 128
Plane and Parallel Sailing - - - 1
Positions on Great Circle - - 84, 86
Position Lines - - - - - 6
Quadratic Equations - - - 255-275
Radar Collision Avoidance Rules - - 75
„ Plotting - - - - - 57
„ Terms - - - - - - 73
„ Diagrams - - - - - 74
Rate of Change of Azimuth - - - 319
Reduction to Meridian - - 130, 166, 327
„ Soundings - - - - - 105
Refraction - - - - - - 308
Relative Velocities - - - - 277, 280
Rising and Setting - - - - 303, 304
Star's Meridian Passages - - - 134
Stars near Meridian - - - - 148
Three Bearing Problems - - - - 19-20
Traverse—Long Distance - - 5, 7, 189
True and Apparent Wind - - - 285
True and Magnetic Courses - - - 25, 29
Visibility of Lights - - - - - 22
Convergency - - - - - - 26
Cape Race to Malin Head - - - - 47
Cape to Java - - - - - - - 47
Cape to Fremantle - - - - - 47
Centrifugal Theory of Tides - - - - 100

	PAGE
Charts—	
Atlantic Ocean	In Pocket
English Channel	„
Indian Ocean	„
Pacific Ocean	„
Tasmania	„
Chart Abbreviations	„
„ Gnomomic	87
„ General Information	56
Chartwork, Examples	22
Convergency	26, 95
Current Sailing	31
Deviation Cards	14, 17
English Channel	36
St. George's Channel	22
Three Bearing Fixes	19
Tasmania	26-35
Visibility of Lights	22
China Sea	41, 48
Chronometer Error	325, 326
Circumpolar Stars	142, 146, 293
Circular Parts, Napier's	127-129
Collision Avoidance Rules (Traffic Separation)	49
„ (Radar)	75
Collimation Error	311
Climatic Routeing	44
Compass Courses and Bearings	13
Compass Deviation	12, 189
Composite G C Sailing	88
Constallations, Star	153
Cosine Formula	215, 235
Convergency	26, 95
Currents, Ocean	42-43
Currents, Agulhas	47
„ Arctic	42
„ Atlantic Ocean	42, 46
„ Californian	43
„ Equatorial	42
„ Guinea	42
„ Gulf Stream	42
„ Humbolt	43
„ Indian Ocean	47
„ Kuro Siwo	43, 48
„ Labrador	42
„ Pacific Ocean	43, 48
„ Peruvian	43
„ Rennel	47

D

Day's Work Problems	37
Datum Chart	211
Day, Solar and Sidereal	140
Declination	123, 125
Declination of Moon and Tides	103
„ Parallel of	299
„ Rate of Change of	319
Definitions	xxiv
Departure	1, 299
Deviation Tables	15
Difference of Latitude	1
„ Longitude	1
„ Meridional Parts	1
Differential Coefficients	316
Distance of Sea Horizon	22
Dip	300, 301
Double Altitudes	186
Diurnal Inequality of Tides	102
Diurnal Parallax	309
Tides	100

E

Electronic Distance Measure (EDM)	211
Equation of Time	132
Equatorial Current	43
Equation of Equal Altitudes	324
Examination Papers (Extra Master)	371
Examination Papers, Class 4-Class 1	201-209
Ex-Meridians—	
Moon	171
Planet	169
Star	166
Sun	176
Ex-Meridians and Longitude-Sights combined	172
„ Reduction Formula	327
„ Tables	131, 328
Examples for Exercise—	
Bow and Beam Bearings	9, 18
Chartwork	33
Double Altitudes	186
Equations, Algebraic	235-245, 255-265
„ Trigonometrical	265
Error of Chronometer	324
Error of Collimation	311
Great Circle Sailing	81
Latitude by Pole Star	164
„ by Ex-Meridian	131
Napier's Diagram	127
Plane, Parallel and Mercator Sailings	8
Sights for Position Line Fix	182
Star Identification	153
„ Meridian Passage	134
„ Near Meridian	148
Small Errors in Sights	315
U.K. to West Indies	189

F

Florida Straits	44
Formulae Proofs—Summary	253, 330
Compound Angles	226
Convergency	95
Cosine	235
Four Parts	237
Haversine	239
Latitude by Ex-Meridian	327
Latitude by Pole Star	329
Napier's Analogies	243-245
Polar Triangle	248
Right Angled Spherical Triangles	245
Sine	236
Small Angles	248
Tangent	227, 229
Three Sides	231, 241
Three Bearings	232
(*See also under* "Trigonometry")	
Fremantle to Sunda Straits	48

G

Geographical Position of Star	132
Gnomonic Chart	92, 219

PAGE

Great Circle Bearings - - - - - 95
Great Circle Graphic Method - - - 87
„ Sailing - - - - - 81
„ and ABC Tables - - - 93
„ Vertex - - - - - 96
Guinea Current - - - - - - 43
Gulf of Mexico - - - - - - 43
Gulf Stream - - - - - - - 43

H

Half Convergency - - - - - - 27
Harmonic Tidal Constants - - - - 114
„ Curve - - - - - - 114
Haversine Formulae - - - - 240, 241
Heavenly Bodies—
Geographical Position of- - - - 132
Identification of - - - - 153-158
Rising and Setting of - - - 303, 304
Height of Tide - - - - - 105, 108
High Water - - - - - - 100-114
Hongkong to Aden - - - - - 47
Honolulu to Panama - - - - - 48
Horizon, Dip of - - - - - - 300
Hour Angle - - - - - - - 125
„ Errors in - - - - - 305
„ and Position Line - - - 306

I

Identities, Trigonometrical - - - - 263
Identification of Stars - - - - 153-158
Indian Ocean - - - - 41, 43, 44, 46
Inequality of Tides - - - - - 103
Intercept for Position Line - 154, 156, 174, 176

K

Kepler's Laws - - - - - 367-389
Kuro Siwo Current - - - - - 43

L

Labrador Current - - - - - - 42
Lagging of Tides - - - - - - 102
Latitude Effect of Error in - - - 312, 313
„ by Meridian Altitudes - - - 142
„ Ex-Meridian - - - - - 166
„ Moon - - - - - - 160
„ Pole Star - - - - - - 164
„ Planet - - - - - - 162
„ Mean - - - - - - - 1
Level, Tide - - - - - - - 104
Lights—Extreme Range - - - - 22
Longitude, Geographical - - - - 132
„ Star - - - - - - - 172

M

Magnetic Courses - - - - - 13
Marine Surveying - - - - - - 211
Construction of Gnomonic Chart - - 219
Construction of Mercator Chart - - 215
Maximum Altitude - - - - - 320
Mean Latitude Sailing - - - - - 1, 2
Mensuration - - - - - - 333-367
Annulus - - - - - - - 336
Cone - - - - - - - 350-358
Ellipse - - - - - - - 361

PAGE

Mensuration—*cont.*
Frustums - - - - 337, 357
Kepler's Laws - - 347-349, 367-369
Polygons- - - - - - 342
Prism - - - - - - - 350
Pyramids - - - - - - 355
Quadrilaterals - - - - - 333
Sectors - - - - - - 318, 338
Segments - - - - - - 338
Specific Gravity of a Body - - - 340
Triangle - - - - - - 317, 327
Mercator Chart—Construction - - - 215
Mercator Sailing - - - - - - 1, 2
Meridional Parts - - - - - - 1-5
Meridian, Reduction to - - - - - 327
Meridian Passage Aries - - - - 134, 140
„ „ of Stars - - - 134-146
„ „ —Upper, Lower - - 143
Meridian Zenith Distance - - - - 166
Mean and Middle Latitude - - - - 2
Modified Distance Formula - - - - 2
Monsoons - - - - - - - 39-41
Moon, Diurnal Parallax of the Moon - - 209
„ Ex-Meridian of - - - - 171
„ Conjunction - - - - - 101
„ Parallax in Altitude - - - - 309
„ Semi-Diameter, Augmentation of - 310
Moonrise - - - - - - - 307
Motion, Apparent and Real - - - - 320
Multiple Angles - - - - - - 226

N

Napier's Analogies- - - - - - 243
Napier's Circular Rules - - - - 127-129
Napier's Diagram - - - - - 127
Nautical and Spherical Astronomy - 299-307
Nautical Almanac - - - - - - 401
Neap Tide - - - - - - - 101
New York to Fastnet - - - - - 46
North Atlantic Current, Winds - - 41, 42
North Pacific - - - - - - 41, 43

O

Oblique Spherical Triangles - - - - 129
Observations below the Pole - - - 142-145
„ Ex-Meridian - - - - 130
„ Pole Star - - - 144, 164
„ Position Line - - - 7, 167, 172
Ocean Currents - - - - - - 42
Ocean Passages—Ships Routeing - - - 44
Bombay to Aden - - - - - 47
Bombay to Hongkong - - - - 47
Cape Race to Main Head - - - 47
Cape to Java - - - - - - 47
Cape to Fremantle - - - - - 47
Fremantle to Sunda Straits - - - 48
Hongkong to Aden - - - - 47
Honolulu to Panama - - - - 48
New York to Fastnet - - - - 46
Philippines to Honolulu - - - - 48
Singapore to Shanghai - - - 48
Singapore to Yokohama - - - - 48
Suez to Bombay - - - - - 47
Yokohama to San Francisco - - - 48
Yokohama to Honolulu - - - - 48

P

PAGE

Pacific Ocean - - - - 41, 43, 46, 48
Parallax, Diurnal - - - - - 259, 309
Parallel Sailing - - - - - - 1
Passages - - - - - - - 46-48
Passage, Meridian - - - - - - 140
Passage Planning - - - - 50
„ Coastal - - - - 51
„ Ocean - - - - 54
Philippines to Honolulu - - - - 48
Plane Sailing - - - - - - - 1
Plane of Observer's Meridian - - 109, 129
Plane Triangles - - - - - 267-287
Planet Ex-Meridian - - - - - 169
Plotting Position Lines - 168, 173, 175, 177, 179, 180
Polar Distance - - - - - - 125
Polar Triangle - - - - - 248, 249
Pole Star Latitude - - - - - - 164
Pole Star Tables - - - - - - 453
Pole Star Formula - - - - - 328
Position Line - - - - 7, 168, 173
Prediction of Tides - - - 103, 106-122
Priming and Lagging of Tide - - - - 102
Proofs of Formulae - - - - - 225
Publications (*See* Admiralty) - - 391 *et seq.*

Q

Quadratic Equations - - - - 255, 275

R

Radar Plotting - - - - - - 57
„ Terms - - - - - 73
„ Symbols - - - - 74
Radius of Action - - - - - - 18
Range of Tide - - - - - - 105
Rate of Change of Altitude - - - 319, 320
Ratio of Small Angles - - - - - 248
Reduction to Meridian - - - - - 166
Reduction Formula - - - - - 327
Refraction and Dip - - - 300, 303, 304
Relative Motion (Radar Plot) - - - 58
Relative Velocity - - - - - 277
Rennel Current - - - - - - 42
Right Ascension - - - - - - 126
Right Angled Spherical Triangles - - - 245
Rise and Fall of Tide - - - - - 105
Rising and Setting of Bodies 283, 284, 303, 304
Routeing—Climatic and Weather - - - 44

S

Sailings - - - - - - - 1-4, 81
Sea Horizon, Dip of - - - - - 300
Setting of Celestial Bodies - - - - 304
Semi-Diameter, Augmentation of - - - 310
Set and Drift by Radar - - - - - 70
Sextant - - - - - - - - 311
Sextant, Error of Collimation - - - - 311
Shore Horizon, Dip of - - - - - 311
Sidereal Day - - - - - - 134
Simultaneous and Double Altitudes - - 186
Sine Formula - - - - - - 236
Small Circles, Arcs of - - - - - 299
Small Angles, Ratio of - - - - - 248
Small Errors of Observations, etc. - - 313-316
Soundings - - - - - - - - 56

PAGE

Spherical Excess - - - - - 250, 252
Spherical Triangles - - - - 278-288
Spring Tides - - - - - - 101
Stars, Circumpolar - - - - - 142, 293
Stars, Ex-Meridian - - - - - - 166
„ Geographical Position - - - - 132
„ Identification - - - - 153-159
„ Maps - - - - - - 153, 158
„ Meridian Passage - - - - 134
„ Near Meridian - - - - - 148
Suez to Bombay - - - - - - 47
Summary of Formulae - - - - - 330
Sum and Difference of Two Angles - - 229
Sunrise and Sunset - - - - 303, 305
Surveying, Marine - - - - - - 211
Swinging Ship for Deviation - - - - 189
Symbols and Abbreviations - - - xxiv
„ BA 5011 - - - In Pocket
„ (Radar Plotting) - - - - 74

T

Tables—
A B C Azimuth Tables - - - - 93, 130
Admiralty Tide Tables - - - 103, 391
Azimuth of Pole Star - - - - 408
Deviation - - - - - - - 15
Ex-Meridian - - - - - - 130
Great Circle Sailing - - - - 81
Nautical Almanac - - - - - 421
Pole Star - - - - - - 452
Tasmania Chart - - - In Pocket
Tides - - - - - - - - 391
Admiralty Method NP 159 100, 103, 107, 112
„ Tide Tables - - - - 103
Constituents $M_2S_2K_1O_1$ - - - - 114
Charted Height - - - - - 105
Co-Tidal Charts - - - - 107, 123
Declination—Moon - - - - 103
Diurnal Component - - - - 103
Drying Height - - - - - 105
Harmonic Constants - - - - 114
Harmonic Curve - - - - - 114
Methods of Predicting - - - - 114
Notation—Harmonic Method - - 104
Offshore Areas - - - - - 107
Predicting Machine - - - - 114
Priming and Lagging - - - - 101
Reduction to Soundings - - - - 105
Rise and Fall Range - - - - 105
Secondary Port Calculations—
European - - - - - 106
Atlantic and Indian Oceans - - 111
Pacific Ocean - - - - - 112
Shallow Water Effect - - - - 114
Spring and Neaps - - - - - 100
Standard Curves - - - - - 111
Tidal Levels - - - - - - 104
Tides Around U.K. - - - - 122
Tidal Stream Atlases - - - - 123
Tidal Extracts Index - - - - 421
Time Azimuth - - - - - - 130
Time Equations - - - - - 125, 132
Time Intervals in Altitudes - - - - 320
Time, Sidereal and Solar Intervals - - - 293

	PAGE
Trade Winds, Monsoons, etc., Causes and Effects of	39-41
Traffic Separation Schemes	44, 49
Traverse Sailing	5
Triangulation	211
Trigonometry—Proofs, etc.—	
Aximuth, Rate of Change	314
Angle of Dip	300
Dip. Effect on Rising	303
Dip of Sea Horizon	300
Dip of Shore Horizon	301
Diurnal Parallax	309
Differential Coefficients	316
Errors in Latitude, Altitude, Hour Angle and Azimuth	324
Equation of Equal Altitudes	315
Ex-Meridian Tables (Norie)	328
Ex-Meridian Formula	307
Four Parts Formula	237
Haversine Formulae	239, 249
Maximum Altitude	320
Multiple Angles	208
Napier's Analogies	86, 243
Polar Triangle	248
Pole Star Formula	329
Position Line and Error in Hour Angle	264
Quadratic Equations	255-265
Rate of Change of Altitude	319
Ratio of Small Angles	248
Right Angled Spherical Triangles	245
Refraction	304
Refraction, Effect on Sunrise	268
Sine Formula	242
Semi-diameter, Augmentation	310
Sunrise and Moonrise	305
Sextant Collimation	311
Summary of Formulae	330
Three Sides Formula	241
Time Interval and Maximum Altitude	320
Three Bearing Formula	232
Types of Examples	237
Transferring Position Lines	7, 170, 180
Trilateration	212
True and Apparent Wind	265
True Motion—Radar Plot	60
U	
United Kingdom to The Cape of Good Hope	47
„ to Valparaiso	47
V	
Vertex of Great Circle	96
Vertical Sextant Angles	237, 238
Visible Horizon	300, 301
Visibility of Lights	22
W	
Weather Routeing	44
Wind, True and Apparent	276
Winds, Trades and Monsoons	39-41
Y	
Yokohama to San Francisco	48
„ Honolulu	48
Z	
Zenith Distance	125