

PRACTICAL NAVIGATION FOR SECOND MATES

Including chartwork to cover the

practical navigation and

chartwork papers for

D.O.T. certificates

Class V, Class IV, and Class III

Practical Navigation for Second Mates

Including chartwork to cover the practical navigation and chartwork papers for D.O.T. certificatesClass V, Class IV, and Class III

BY

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GLASGOW

BROWN, SON & FERGUSON LTD. NAUTICAL PUBLISHERS
4-10 D ARNLEY STREET

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First Edition - - 1955

Second Edition - - 1969

Third Edition - - 1974

Fourth Edition - - 1977

Fifth Edition - -. - 1981

Reprinted - - 1985

Reprinted - - 1991

Reprinted- - - 1994

Reprinted- - - - 2001

ISBN 0 85714 3978

ISBN 0 85174 300 5 (Fourth Edition)

ISBN 0 85174 22\ 4 (Third Edition)

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Printed and Made in Great Britain

FOREWORD TO THE FIFTH EDDITION

In this revision 'Practical Navigation for Second Mates' has been extended to include chartwork and tidal calculations. The intention in doing this was to provide a text for candidates preparing for the chartwork and practical navigation of the Department of Trade Class V and Class IV certificates. Worked examples of all problems and calculations encountered in these papers together with ample exercises for self examination, are included, and specimen papers similar to Class V 'Chartwork and Practical Navigation', Class IV 'Chartwork', and Class IV 'Practical Navigation' are provided.

All practical navigation problems and tidal calculations used may be worked with the extracts from the Nautical Almanac, and the extracts from the Admiralty Tide Tables included. Chartwork exercises however, inevitably require the use of a chart. Such exercises have been set on Admiralty charts 1179, 5050 or 5051, as these particular charts are published as inexpensive instructional charts, which, although not suitable for navigation, are full size and authentic and entirely adequate for practice purposes.

CARDIFF JUNE 1980

A. FROST

ACKNOWLEDGEMENTS

Extracts from the 1980 Nautical Almanac are published by permission of the Controller of Her Majesty's Stationery Office.

Extracts from the Admiralty Tide Tables 1980, Avonmouth, De~onport and Milford Haven, are published with permission of the Hydrographer of the Navy.

CONTENTS

Introduction

Section 1

CHAPTER 1-THE MEASUREMENT OF POSTION AND DISTANCE ON THE EARTH'S SURFACE

Latitude and longitude. Difference of latitude, difference of longitude. The sea mile. The nautical mile.

CHAPTER 2-THE MEASUREMENT OF DIRECTION. THE EFFECT OF WIND AND TIDE.

The three figure notation. The gyro compass. The magnetic compass. Variation and deviation. Compass error. The three norths. Relative bearing. The deviation table and its use. The effect of tide. Course made good. Counteracting the tide. To reach a position in a required time while counteracting a tide. To find the set and drift between two observed positions.

To find the course to steer to pick up a point of land at a required angle on the bow.

The effect of wind. Leeway. Counteracting the leeway.

CHAPTER 3-POSITION LINES

The position line defined. Great circle. bearings. Mercator bearings. The half convergency correction.

The position circle. Vertical sextant angles. Horizontal sextant angles. Rising and dipping distances:-Ranges of lights.

The transit bearing. Danger angles.

the hyperbolic position line.

CHAPTER 4-THE SAILINGS.

Parallel sailing. Plane sailing. The middle latitude. Mercator sailing.

CHAPTER 5-THE TRAVERSE TABLE. THE TRANSFERRED POSITION LINE.

The traverse table and its use. Running up the D. R. position. Transferring the position line. The running fix.

The running fix with tide.

Transferring the position circle.

Transferring the position line by traverse table.

Doubling the angle on the bow.

CHAPTER 6-- TIDES AND TIDAL STREAMS.

Tidal streams and currents. Tidal stream information on Admiralty charts. Tidal stream atlases.

Tides. Prediction of tidal times and heights.

To find the times and heights of high and low waters at a standard port. To find the height of tide at times between high and low water at a standard port. To find the time at which there will be a given depth of water at a standard port. Secondary ports. To find the times and heights of high and low water at a secondary port. To find the height of tide at times between high and low water at a secondary port. To find the time when there will be a given depth of water at a secondary port. Drying heights. Heights of terrestrial objects.

CHAPTER 7-THE CELESTIAL SPHERE AND THE NAUTICAL ALMANAC.

The celestial sphere. Definition of position on the celestial sphere. The geographical position. Definition of a celestial bodies G.P. on the terrestrial sphere.

The Nautical Almanac. To extract the declination and GHA. To find the times of meridian passage. To find the times of sunrise and sunset, and moonrise and moonset.

CHAPTER 8-COMPASS ERROR BY ASTRONOMICAL OBSERVATION.

The azimuth problem and the amplitude problem.

Specimen papers for Class V chartwork and practical navigation, and for Class IV chartwork.

Section 2

CHAPTER 9-POSTION CIRCLES AND POSTION LINES.

The Marcq St. Hilaire method.

Plotting of position lines. To plot the position from two simultaneous position lines by Marcq St. Hilaire. To plot the position from two position lines by Marcq St. Hilaire with a run between.

The Longitude by Chronometer method. To plot the position from two simultaneous position lines by longitude by chronometer.

To plot the position from two position lines by longitude by chronometer with a run between.

Position line by meridian altitude observation. Plotting the noon position from a forenoon observation and meridian observation.

Plotting the position by celestial observation combined with a terrestrial observation.

CHAPTER 10---CORRECTION OF ALTITUDES.

The individual corrections. Correction of altitudes by individual corrections. Total correction tables. Correction of altitudes by total correction.

CHAPTER 11-LATITUDE BY MERIDIAN ALTITUDE.

Calculation of the latitude by observation of a body on the observer's meridian. To find the altitude to set on a sextant to observe the meridian passage.

Lower meridian passage. Calculation of the latitude by observation of a body on the observer's lower meridian.

CHAPTER 12-CALCULA TION OF POSITION LINES BY OBSERVATION OF BODIES OUT OF THE MERIDIAN.

The PZX triangle. The Marcq St. Hilaire method. Calculation of intercept and bearing. The Longitude by Chronometer method. Noon position by forenoon observation and meridian observation. Use of the 'c' correction to find the noon longitude.

CHAPTER 13- THE EX MERIDIAN PROBLEM.

Calculation of position lines by observation of bodies near the meridian. Ex meridian tables.

CHAPTER 14 THEPOLESTARPROBLEM.

Calculation of the latitude by observation of the pole star.

CHAPTER 15-GREAT CIRCLE SAILING.

Calculation of courses and distance by great circle sailing. Calculation of courses and distance by composite great circle sailing.

Specimen papers in practical navigation for Class IV.

Answers to exercises.

Extracts from the Nautical Almanac 1980.

Extracts from the Admiralty Tide Tables 1980.

Index

SECTION 1

The work contained in this section is required for the 'Chartwork and Practical Navigation' paper for Department of Trade Class V certificate.

CHAPTER I

THE MEASUREMENT OF POSITION AND DISTANCE ON THE EARTH'S SURFACE

Definition of terms used in the measurement of position

Great Circle. A circle drawn on the surface of a sphere, whose plane passes through the centre of the sphere. It is the largest circle that can be drawn on a sphere, and given any two points on the sphere, there is only one great circle that can be drawn through those points. The shortest distance between those two points will lie along the shorter arc of that great circle. The exception is if the two points are at opposite ends of the same diameter, and in this case an infinite number of great circles can be drawn passing through the two points.

Small Circle. Any circle drawn on the surface of a sphere, whose plane does not pass through the centre of the sphere.

Geographical poles of the earth

Those points at which the axis of the earth's rotation cuts the earth's surface.

The measurement of position

To define a position on any surface we require two axes of reference, usually at right angles to each other. The definition of a point is obtained by stating the distance of the point from each of these axes. Thus in the construction of a mathematical graph, we draw an x-axis and a y-axis at right angles to each other and the co-ordinates of any position on the graph give us the distance of that position from the x-axis and from the y-axis. So defined, the position is unambiguous. On the earth's surface we use two great circles as the axes of reference, and we use angular distances instead of linear distances.

The great circles used are:

The Equator. A great circle on the earth's surface, the plane of which is at right angles to the axis of rotation of the earth. Every point on the equator is at an angular distance of 90° from each pole.

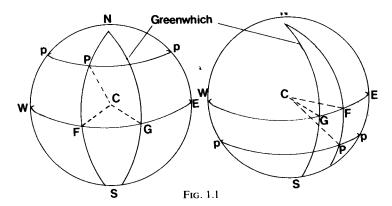
The Prime Meridian. This is a semi great circle on the earth's surface which runs between the two geographical poles, and passes through an arbitrary point in Greenwich. Any semi great circle which runs between the poles is called a meridian. All meridians cut the equator at their mid point at right angles, and all meridians intersect at the poles.

The position of any point on the earth is defined as an angular distance from these two circles, the two co-ordinates being called Latitude and Longitude.

Parallel of Latitude. A small circle on the earth's surface, the plane of which is parallel to that of the equator.

The Latitude of any point is the arc of any meridian contained between the equator and the parallel of latitude through the point. Thus all positions on the same parallel of latitude have the same latitude. The latitude of the equator is 0° and that of each pole is 90° . Latitude is named North or South of the equator.

The Longitude of any point is the lesser arc of the equator contained between the prime meridian and the meridian which passes through the point. It is measured from 0° to 180° on either side of the prime meridian and named East or West.



Latitude North, Longitude West

Latitude South, Longitude East

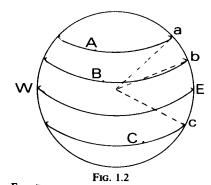
NGS =Prime Meridian NPFS =Meridian through P

WFGE=Equator Angle PCF or arc PF = Latitude of P

pp = Parallel of latitude through P Angle FCG or arc FG = Longitude of P

When sailing between any two positions on the earth's surface, a knowledge of the necessary change in latitude and change in longitude between the two positions is essential.

The Difference of Latitude (d. lat.) between any two positions is the arc of a meridian which is contained between the two parallels of latitude through the positions. From figure 1.2, if the two positions are on the same side of the equator (latitudes same name), then the d. lat. will be the numerical difference between the two latitudes. If they are on opposite sides of the equator (latitudes different names), then the d. lat. will be the sum of the two latitudes.



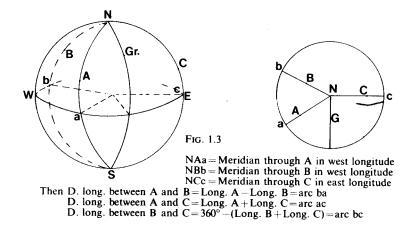
WE=Equator
Aa, Bb, Cc=Parallels of latitude through A, B and C

Then D. lat. between A and B=Lat A-Lat B=arc ab
D. lat. between A and C=Lat A+Lat C=arc ac
D. lat. between B and C=Lat B+Lat C=arc be

D. lat. is named according to the direction travelled. North or South.

The Difference of Longitude (d. long.) between any two positions is the lesser arc of the equator contained between the two meridians which pass through the positions. If the longitudes of the points lie on the same side of the prime meridian as each other then the d. long. will be the numerical difference between the longitudes (longitudes same name). If they lie on opposite sides of the prime meridian the d. long. will be the sum of the two longitudes (longitudes opposite name). If, however, the d. long. found thus is greater than 180°, as the d. long. is the LESSER arc of the equator between the two positions, then the d. long. is found

by subtracting this sum from 360° (see examples). The d.long. is named according to the direction travelled East or West.



Note

D. lats. and d. longs. are usually required in minutes of arc.

They are therefore expressed thus in the following examples.

Examples

1. Find the d. lat. and d. long. between lat. 25° 46' N., long. 15^{0} 28' W. and lat. 52^{U} 56' N., long. 39° 47' W.

A long. = $15^{\circ} 28' \text{ W}$.

The degrees are multiplied by 60 to change them into minutes and the odd minutes are added on.

2. Find the d. lat. and d. long. between lat. 44° 25' N., long. 75° 46' W., and lat. 36° 19' S., long. 09° 26' W.

A lat. =44° 25' N .. *A* long. =75° 46' W.

A lat. = $25^{\circ} 46'$ N.

Blat. =36° 19' S.
$$B \text{ long.} =09^{\circ} 26' \text{ W}.$$

d.lat. =80
$$^{\circ}$$
 44' S. d. long. =66 $^{\circ}$ 20' E.

3. Required the d. lat. and d. long. made good by a vessel which sails from position $A~22^{\circ}$ 10' S., $09^{\circ}~15'$ W., to a position B, $15^{\circ}~30'$ N., $29^{\circ}~30'$ E.

Notes

- 1. The latitudes being of different names, they are added to obtain the d. lat.
- 2. The longitudes being of different names, they are added to obtain the d. long.
- 4. A vessel steams from position P 18° 40′ S., 136° 40·6′ W., to position Q 31° 15·2′ S., 126° 35′8′ E. Find the d. lat. and the d. long.

Plat. =
$$18^{\circ} 40'0' \text{ S}$$
. long. = $136^{\circ} 40'6' \text{ W}$.

 $Q \text{ lat.} = 31^{\circ} 15 \cdot 2' \text{ S}$. long. = $126^{\circ} 35'8' \text{ E}$.

d. lat. = $12^{\circ} 35 \cdot 2' \text{ S}$. d. long. = $263^{\circ} 16'4'$

= $755 \cdot 2' \text{ S}$. 360°

Notes

- 1. The vessel is steaming from a West longitude across the 180° meridian to a position in East longitude, and is therefore proceeding in a westerly direction.
- 2. The d . long. could have been obtained by adding the differences of each longitude from 180° .
- 5. A vessel steams on a course which lies between North and East, and makes a d. lat. of 925'8' N., and a d. long. of $1392 \cdot 6$ ' E. The initial position was 25° 20-7' N., 46° 45·2' W. Find the D.R. position.

lat. =
$$25^{\circ} 20-7' \text{ N}$$
. long. = $46^{\circ} 45 \cdot 2' \text{ W}$.

d.lat.
$$= 15^{\circ} 25,8'$$
 N. d. long. $= 23^{\circ} 12'6'$ E.

D.R.lat. = $\frac{40^{\circ} \ 46'5'}{N}$. long. = $\frac{23^{\circ} \ 32 \cdot 6'}{W}$.

Note

The d. lat., having the same name as the latitude, is added to it, while the d. long. being of opposite name to the longitude, is subtracted from it.

EXERCISE IA

Find the d. lat. and d. long between the following positions

	Latitude	Longitude	Latitude	Longitude
1.	P 40° 10' N.	9° 25' W.	Q 47° 15' N.	21° 14′ W.
2.	A 35° 15' N.	22° 12' W.	B 50° 25' N.	11° 37′W.
3.	X 10° 12' N.	5° 03' E.	Y 5° 18' S.	7° 18' W.
4.	L 20° 40′ S.	170° 09' E.	M 13° 06' N.	178° 51' E.
5.	A 30° 03' N.	152° 43' W.	B 42° 24' N.	174° 01' W.
6.	F 11° 31' N.	178° 00' E.	K 5° 14' S.	177° 00' W.
7.	A 8° 42' S.	162° 41' W.	Z 7° 53' N.	135 ⁰ 27{ E.
8.	B 15° 20' S.	130° 35' E.	K 33° 10' N.	155° 40' W.
9.	V 52° 10' S.	171° 08' E.	W 27° 02' S.	34° 02' E.
10.	L 60° 40' S.	151° 23' W.	M 10° 57' S.	92° 47' W.

EXERCISE 1B

1. The initial longitude is 4° 30' W. and the d. long. is 104' E.

Find the final longitude.

- 2. Initiallat.= 20° 50' S., long. = 178° 49' E., d.lat.= 33° 14' N., d.long.= 15° 37' E. Find the final position.
- 3. Initiallat.=39° 40′ N., long. =9° 21′ W., d. lat.=3° 57′ N.,
- d.long. = 27° 07' E. Find the final position.
- 4. Final position lat. = 30° 10,6' S., long. = 4° 40,3' E., d. lat. was 72° 18·8' S., and d. long. was 38° 54,7' E. What was the initial position?
- 5. A ship steered a course between N. and E. making a d.lat. of 38° 55,5' and a d. long. of 20° 41,8'. If the final position was lat. 21° 10-4' N., long. 168° 18-7' W., what was the initial position?

The measurement of distance

The measurements and calculations required to find position on the earth's surface are in units of angular measure. Position on the celestial sphere and on the earth's surface is defined in the same units of angular measure. It is convenient therefore, at sea, to use as a unit of linear distance, the length of one minute of arc of a great circle on the surface of the earth. The great circles used are the terrestrial meridians so that the latitude scale of a navigator's chart becomes his scale of distance, one minute of latitude being equal to one mile.

The exact length of the mile however varies due to the fact that the earth is not a true sphere but an oblate spheroid. The earth is flattened at the poles and bulges at the equator due to the forces of its own rotation. A meridian and its opposite meridian form therefore an approximate ellipse rather than a circle.

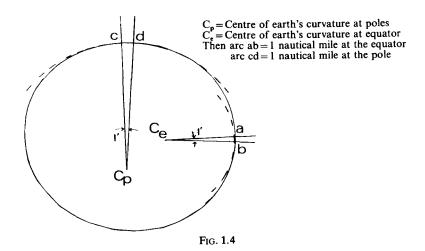
The nautical mile or 'sea mile' is defined as the length of a meridian which subtends an angle of one minute at the centre of curvature of that part of the meridian being considered. Figure 1.4 shows that because of the flattening at the poles, the radius of curvature of the polar regions is greater than that at the equatorial regions. The linear distance represented by an arc of one minute is therefore greater at the poles than at the equator.

The length of a sea mile at the equator is approximately 1842.9 metres.

The length of a sea mile at the poles is approximately 1861.7 metres.

This variation is of little or no significance in practical navigation at sea and a standard length close to the mean value is adopted. The International Nautical Mile is an adopted value of 1852 metres.

In practical navigation any unit of d'iat is taken as a nautical mile,



so that the difference of latitude between two places on the same meridian is, when expressed in minutes of arc, equal to the distance between them in nautical miles. Units of d'lat and distance are consistent units and may be used as such in any navigational formula.

The unit of speed at sea is the nautical mile per hour. This unit is called a knot.

The equator is the one great circle on the earth's surface which is actually a true circle. One minute of arc of the equator is therefore of constant length, about 1855·3 metres. This unit is called a geographical mile.

CHAPTER 2

THE MEASUREMENT OF DIRECTION

The three figure notation

The observer is imagined to be at the centre of his compass and the direction of the north geographical pole is taken to be 000°. The observer's horizon is divided into 360°, and any direction from the observer is expressed as a number of degrees measured clockwise from the direction of north.

Three figure notation is used to express:

- 1. Course. The direction of movement of the observer.
- 2. Bearing. The direction of an object from the observer.

Any instrument designed for the measurement of direction is called a compass. To measure direction correctly the zero mark of the compass must point towards the zero of direction, i.e. the direction of the north pole.

This is not always the case. If it is not then the direction that the compass zero points in must be ascertained in order to apply the necessary correction.

The Gyro Compass

Gyroscopic compasses are liable to small variable errors, which should never exceed one or two degrees.

If the zero mark, or north point of the compass card points to the left (to the West) of true North then all indications of direction taken from the card will be greater than the true value.

In this case the gyro is said to be reading high, and any compass error will be negative to the compass reading to obtain the true reading.

If the north point of the compass card is pointing to the right,

or East, of the true North direction, then all readings taken from the compass card will be less than the true value.

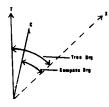


Fig. 2.2

In this case the gyro is said to be reading low, and any compass error will be additive to compass reading to obtain true reading.

Methods of calculating the value of the error will be explained in a later chapter. (See 'The

Azimuth Problem'.)

The Magnetic Compass

Variation

The magnetic poles of the earth are not coincident with the geographical poles. The north point of the>-compass therefore will not point towards the true direction of North.

The direction in which the compass needle aligns itself can be thought of as the magnetic meridian. The angle between the true meridian and the magnetic meridian is called the VARIATION, and this angle varies with position on the earth's surface. It is named WEST if the compass needle points to the left of true North, and EAST if the compass needle points to the right of true North.

Deviation

The compass needle will only align itself with the magnetic meridian if it is free from all other influences except the magnetic field of the earth.

This is rarely so, particularly on a ship which is constructed of steel. The magnetism induced in the steel by the earth's magnetic field causes the compass needle to deviate from the magnetic meridian, by an amount which is called the deviation. This will vary for any particular vessel for a number of reasons such as course, angle of heel, position on the earth's surface. Deviation is named WEST if the compass needle points to the left of the magnetic meridian, and EAST if the compass needle points to the right of the magnetic meridian. The direction of the magnetic meridian is called Magnetic North. The direction indicated by the compass needle is called Compass North.

Compass Error

The actual error of the compass at any time will be the combination of the variation and the deviation. If they are of the same name then the error will be the sum of the two and it will be named as they are. If they are of different names the compass error will be the difference between the two and 'will be named as the greater of the two.

Example 1

Variation 10° E.

Deviation 5° E.

Compass error 15° E.



Variation 9° W.

Deviation 3° E.

Compass error 6° W.

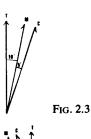




Fig. 2.4

EXERCISE 2A

Find the compass error given

1.Dev. 15° W., Var. 30° E.

6. Dev. 10° W., Var. 5° W.

2.Dev. 14° E., Var. 5° E.

7. Dev. 21° W., Var. 4° E.

3.Dev. 3° W., Var. 30° W.

8. Dev. 8° E., Var. 8° W.

4.Dev. 5° W., Var. 25° W.

9. Dev. 5° W., Var. 50° W.

5. Dev. 6° W., Var. 20° E.

10. Dev. 3° E., Var. 35° E.

We have defined three directions which we can call north.

True North. The direction of the north geographical pole. *Magnetic North.* The direction of the magnetic meridian at any place .

Compass North. The direction indicated by the north point of the compass.

The difference between True North and Magnetic North is the variation.

The difference between Magnetic North and Compass North is the deviation.

The difference between True North and Compass North is the compass error.

Any course or bearing can be denoted using any of these three directions of north.

True Course or Bearing. The angle at the observer between the direction of True North and

the direction being measured, measured clockwise from North.

Magnetic Course or Bearing. The angle at the observer between the direction of magnetic meridian and the direction being measured, measured clockwise from North.

Compass Course or Bearing. The angle at the observer between the direction of compass north and the direction being measured, measured clockwise from North.

The angle indicated by the compass is the compass course or bearing and this must be corrected to true course or bearing, before use.

If the compass error is west the compass course or bearing will be greater than the true course or bearing.

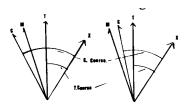


FIG. 2.5

If the compass error is east the compass course or bearing will be less than the true course or bearing.

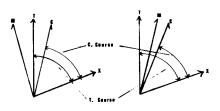


FIG. 2.6

From which may be deduced the mnemonic:

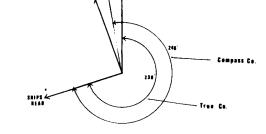
Error WEST, compass BEST Error EAST, compass LEAST

Note

Deviation is dependent upon course, or ship's head. For any particular ship's head the deviation will be the same for ALL BEARINGS.

Example 1

A vessel is steering 240° by compass. Deviation for the ship's head is 10° E. Variation for the place is 20° W. Find the true course.



Compass course 240° or Variation 20° W.

Deviation 10° E. Deviation 10° E.

Magnetic course 250° Compass error 10° W.

Variation 20° W. Compass course 240°

--- FIG. 2.7

True course 230° True course 230°

Example 2

Find the compass course to steer to make good a True Course of 130° if the variation is 20° W., and the deviation is 10° E.

True course	130°	or	Variation	20° W.
-------------	------	----	-----------	--------

Variation 20° W. Deviation 10° E.

Magnetic course 150° Compass error 10° W

Deviation 10° E. True course 130°

--- ---

Compass course 140° Compass course 140°

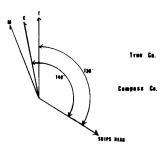


FIG. 2.8

Variation for any particular place is found either from the centre of the compass rose on the Admiralty chart of the area, or from the Admiralty variation charts.

Deviation is obtained from a deviation card compiled for a particular compass by the compass adjuster, or by direct observation as explained in a later chapter.

EXERCISE 2B

Find the true course

	Course	Dev.	Var.
1.	226° C.	3°W.	16° W.
2.	010°C.	lOW.	18° W.

3.	358° C.	2° E.	15° W.
4.	267° C.	4°W.	20° E.
5.	034° C.	3° E.	15° W.
6.	332° C.	4°W.	10° W.
7.	116° C.	2°W.	8°W.
8.	218° C.	3° W.	11° W.
9.	084° C.	5°W.	17° E.
10.	178° C.	6° E.	11° E.

EXERCISE 2C

Find the compass course

	Course	Dev.	Var.
1.	222° T.	4° E.	15° E.
2.	356° T.	5°W.	20^{0} W.
3.	172° T.	3° E.	18° W.
4.	200° T.	2° E.	1° W.
5.	005° T.	1° E.	5° E.
6.	086° T.	1° W.	Nil
7.	106° T.	2° W.	10° W.
8.	173° T.	3° E.	8°W.
9.	306° T.	2° W.	11° W.
10.	185° T.	3° W.	10° W.

Given the error and the variation to find the deviation

If, when the error and variation are given, it is desired to find the deviation, then the variation must be subtracted from the error as the error is the sum of the two. The variation may be subtracted by reversing its name. The deviation is then named according to the greater.

The following examples indicate the method:

Examples

EXERCISE 2D

Find the deviation given

1.error 3° E., var. 21° W. 6. error 34° W., var. 39° W.

2.error 15° W'o var. 24° W. 7. error 2° W., var. 12° W.

3.error 37° E., var. 34° E. 8. error 7° E., var. 9° W.

4.error 11° W., var. 7° W. 9. error 24° W., var. 30° W.

5. error 23° E., var. 25° E. O 10. error Nil var. 5° E.

Given the true bearing and the compass bearing of a body, also the variation, to find the deviation

Remember that if the error is East, it is added to a compass direction to obtain the true direction; it will be noted that the latter must be numerically greater than the former. Therefore, if the error is to be found, the rule is:

True greater than Compass-Error is East Compass greater than True-Error is West

Example 1

The sun bore 120° T. and 110° C., find the compass error, and if the variation was 10° W., find the deviation.

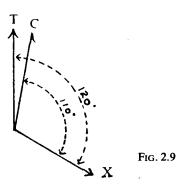
obearing = 110° C. bearing = 120° T.

Error = 10° E.

Var. $= 10^{\circ}$ W.

Dev. $= 20^{\circ} E$.

Note. Compass LeastError East



Example 2

The sun's true amplitude is W. 10° 20' S. and the observed amplitude W. 20° N. Find the compass error, and if the variation is 25° W., find the deviation.

W. 10° 20' S.=259° 40'

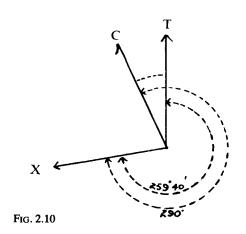
obearing = $290^{\circ} 00' \text{ C. bearing} = 259^{\circ} 40' \text{ T.}$

Error = $30^{\circ} 20' \text{ W}$.

Var. $= \underline{25^{\circ} 0'} W$.

Dev. $= 5^{\circ} 20' \text{ W}.$

Note. Compass BestError West



EXERCISE 2E

Find the deviation

	Compass	True	
	bearing	bearing	Variation
1.	050° C.	060° T.	12° E.
2.	010° C.	005° T.	11°W.
3.	075° C.	060° T.	19°W.
4.	140° C.	115° T.	24°W.
5.	242° C.	248° T.	13° E.
6.	201 ° C.	201° T.	8° E.
7.	309° C.	322° T.	8° E.
8.	037° C.	022° T.	12° W.

9.	341 ° C.	320° T.	23°W.
10.	289° C.	310° T.	33° E.
11.	260° C.	294° T.	49° E.

12. 134° C. 120° T. 21° W.

13.	163° C.	200° T.	62° E.
14.	219° C.	175° T.	40^{0} W.
15.	278° C.	262° T.	110W.

Relative bearing

Bearings measured by pelorus, which is a 'dummy' compass card whose zero mark is aligned with the vessel's fore and aft line, are said to be relative bearings, that is, relative to the ship's head.

The relative bearing may be defined as the angle at the observer measured clockwise from the direction of the ship's head, to the direction of the point observed.

A relative bearing is also obtained from measurements by radio direction finder. (see Chapter 3).

To convert a relative bearing to a true bearing

In order to obtain a true bearing from a relative measurement, the vessel's true heading at the time of the observation must be applied. It is not suffici~nt to aPRly the ship's course steered, as at tlie moment of observatIon the vessel may be one or more degrees off course. The heading should be observed at the instant of the observation.

True bearing=True ship's head+ Relative bearing

Example 1

A relative bearing of 105° , (object 105° on the starboard bow), was observed on a ship whose heading at that time was 085° T. Find the true bearing.

Relative bearing	105 ⁰
True ship's head	_085 ⁰ T
True bearing	$190^{0} \mathrm{T}$

Example 2

A relative bearing of 248^0 was observed from a vessel whose true

heading at the time was 176~. Find the true bearing.

Relative bearing True ship's head True bearing
$$248^{0}$$

$$-17_{-}6_{-}T_{-}$$

$$424^{0}$$

$$-360^{0}$$

$$---$$

$$=064 {}^{0}T$$

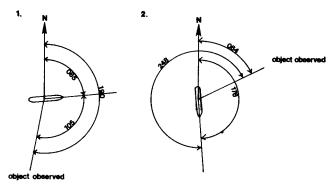


Fig. 2.11

EXERCISE 2F

Fill in the blanks

	Compass Course or		Magnetic Course or		True Course or
	bearing	Dev.	bearing	Var.	bearing
I.	050° C.	-	056° M.	-	036° T.
2.	-	3° E.	220° M.		225° T.
3.		4° W.	280° M.	18° W.	-
4.	⁰⁰³⁰ C.	-	358^0 M.	-	013° T.
5.	-	4" W.	$241^{0} M.$	llo W.	-
6.	169° C.	3° E.	-	-	184° T.
7.	-	2° E.		20° E.	008° T.
8.28	86 ⁰ C.	6° W.		5' W.	-
9.	088° C.	-	091° M.	-	066° T.
10.	-	4° E.	205° M	30° W	-
11.	332^{0} C.		332 M.		$014~^{0}$ T.
12.	180° C.	_	178° M.		178° T.

The deviation table

A deviation table and deviation curve is compiled, after correction of the compass, by direct observation of the residual errors and deviations. In subsequent use of the deviation table it should be remembered that it was compiled for a particular condition of the ship with respect to moveable structures, condition

of loading, draft, etc., and may not be accurate for other conditions. It should be used only when the deviation is not available by direct observation.

A deviation table is provided with the chartwork paper in Department of Trade examinations on which a deviation is given against compass heading at intervals of 10°. Deviations should be extracted using the compass heading as argument, interpolating between tabulated values. A sample deviation card is given which is used in examples and exercises to follow. The values included in the deviation column are rather large to be acceptable in practice but these values are used the better to illustrate the principles of interpolation required in examinations.

To extract a deviation given the compass heading of the vessel Enter the deviation table with the given compass heading and extract the deviation, interpolating between tabulated values.

Example

A vessel is steering 113° C. Find the true course if the variation is 8°W.

From deviation table;

compass course deviation
$$110^{\circ} \text{ C.} \qquad 15^{\circ} \text{ W.}$$
difference $3^{\circ} 113^{\circ} \text{ C.} \qquad \text{difference } 3^{\circ}$

$$120^{\circ} \text{C.} \qquad 12^{\circ} \text{W.}$$
deviation for $113^{\circ} \text{ C} = 15^{\circ} - \frac{3 - X - 3}{10}$

$$= 15^{\circ} \qquad -1^{\circ} \text{ almost}$$

$$= 14^{\circ} \text{ W}$$
Compass course 113° C.
deviation 14° W.
Magnetic course 099° M.
variation 8° W.
True course 091° T.

To find the deviation from a deviation table given the true course and the variation

Again the argument used in the deviation table must be the compass course. As yet however this is not known so that the following procedure should be adopted.

1. Apply the variation to the true course to obtain the magnetic course.

- 2. Extract from the deviation table the two values of compass course and of deviation which when combined will give two values of magnetic heading which 'straddle' the ship's magnetic course found 10 (1).
- 3. Interpolate between the two values of deviation according to the value of the ship's magnetic course as compared with the two values, either side of this magnetic course. See example.
- 4. Apply the deviation obtained to the magnetic course to give the compass course. By entering the deviation table with this compass course obtained, a value of deviation should be extracted which is the same as that used in (3).

Example

A vessel requires to make good a true course of 213° T. Using the deviation table provided find the compass course to steer if the variation is $91/2^{\circ}$ W.

(1) True course 213° T.

variation 91/2° W.

Magnetic course 222¹12° M.

(2) From deviation table; Compass

course Deviation Mag. Co.
$$210^{\circ} \text{ C.} \quad 6^{\circ} \text{ E.} = 216^{\circ} \text{ M.} \\ 222_{1/2}^{\circ} \text{M} \\ \text{diff. } 3^{\circ} \\ 220^{\circ} \text{ C.} \quad 9^{\circ} \text{ E.} = 229^{\circ} \text{ M.}$$
 diff. 13°

(3) Interpolating between 216 and 229 magnetic for a magnetic course of 222 1/2°, gives;

deviation =6° E.
$$\pm 3x6_{1/2}$$

13
=6° ± 1.5 ° ± 7.5 ° E.

(4) Magnetic course 222 1/2° M.

deviation $\frac{7 \text{ 1/2} \circ \text{E.}}{\text{compass course}}$ 215° C.

EXERCISE 2G

In the following cases, given the true course and the variation, using the specimen deviation table provided, find the compass course to steer.

- 1.True course 100" variation 6° W.
- 2.True course 024° variation 9° W.
- 3.True course 352° variation 2° E.
- 4.True course 262° variation 5° E. 5. True course 148° variation 12° W.

Specimen deviation table

Ship's head		Ship's head	
by compass	Deviation	by compass	Deviatio
000°	2°W.	180"	lOW.
010°	$4^{\circ}\mathrm{W}.$	1WO	2°E.
020"	6°W.	200°	4°E.
030°	7°W.	210°	6°E.
040"	8°W.	220°	9°E.
050°	10"W.	230°	11°E.
060°	13°W.	240"	13°E.
070°	15°W.	250°	15° E.
080°	16°W.	260"	17°E.
090"	19°W;	270"	20° E.
100°	17°W.	280°	18°E.
110"	15°W.	290°	15°E.
120"	12°W.	300°	12°E.
130°	10" W.	310°	9^0 E.
140°	8°W.	320°	7°E.
150°	6°w.	330"	5°E.
160^{0}	$4^{\circ}\mathrm{W}.$	340"	3°E.
170^{0}	3°W.	350"	nil

Wind and tide

The direction in which a vessel progresses may differ from that in which the vessel is heading, due to the effects of wind and tide.

The vessel may be assumed to move through the water in the direction in which it is steered, but a tidal stream, which is a horizontal movement of water due to differences in tidal height at different geographical positions, will carry the ship with it, and the resultant ship's motion will be that ofthe ship through the water and that of the water itself relative to the sea bed. It is necessary therefore to differentiate between the course steered and the course made good.

Course steered

This is the heading indicated by the lubber line of the compass, this being the direction in which the vessel is heading. Note that this is the course to which all relative bearings must be applied in order to convert to true bearings, irrespective of the direction in which the

vessel is moving. Lines drawn on a chart to represent a course steered should be marked with a single arrow.

Course made good

This is the true direction of the ship's movement relative to the sea bottom. It may be found by the vectorial addition of the velocity of the ship through the water, and the velocity of the tidal stream. Lines drawn on a chart to represent a course made good should be marked with a double arrow.

Rate of the tide

This is the speed of the tide in nautical miles per hour or knots.

Drift of the tide

This is the distance moved by the tide in nautical miles, in a specified time interval.

Thus rate oftide= drift of tide time interval

To find the course and speed made good given the ship's course IIteered and speed and the set and rate of the tidal stream

Example

Find the course and speed made good by a vessel steering 035° T. at 12 knots through a tidal stream setting 110° T. at 2.5 knots.

Procedure (refer to figure 2.12)

- 1. Layoff from a departure position the course steered (035°) , IInd mark off a distance along this line equal to the vessel's speed. (It is often convenient to use an interval of one hour, but if appropriate IIn interval of half an hour or any other convenient interval may be used. The distance to be marked off along the course line will then he the distance steamed in that interval.) Mark this line with a single \mathbf{II} rrow.
- 2. From the position reached in (1), layoff the direction of the \mathbf{I} idal stream or current, and mark off a distance equal to the rate of Ihe tide. (Or if the chosen interval is not one hour then mark off a distance equal to the drift of the tide in the chosen interval.)
- 3. Join the position reached in (2), to the original departure position to represent the track along which the vessel will progress, **I.** c. the course made good. The length of this line will give the distance made good in the interval and hence the vessel's speed.

Counteracting the tide

The course steered may be adjusted for the effect of the tide in

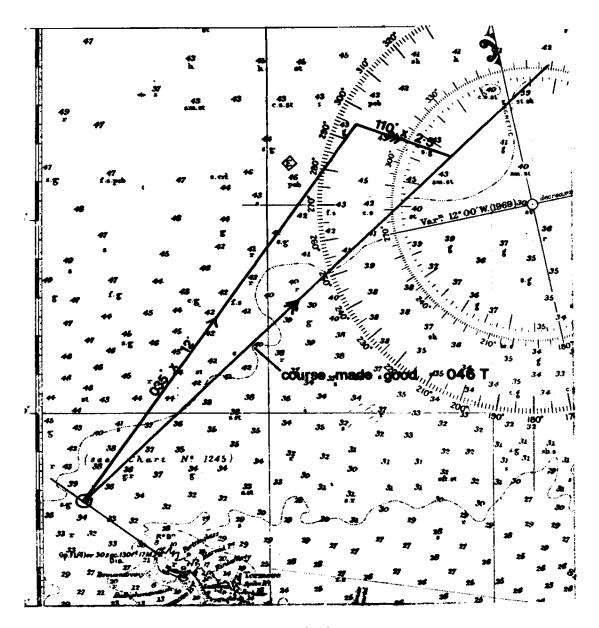


Fig. 2.12

order that the vessel progresses in a required direction. To counteract a tide the vessel must adjust its course up into the tide so that the tide will carry the vessel back down onto its required course line again.

To find the course to steer to counteract a given current, to make good a required course

Example

Find the course to steer to make good a course of 035° T, when steaming through a current setting 110^{0} T at 2.5 knots, if the ship's speed is 12 knots.

Procedure (refer to figure 2.13)

- 1. Layoff the course which it is required to make good from the ship's departure position to the destination. Mark this line with double arrow.
- 2. From the departure position layoff the direction of the tide or current and mark off the drift of the tide for any convenient chosen interval. (One hour is usually convenient.) Mark this line with a treble arrow.
- 3. From the position at the end of the tide found in (2), with compasses, describe an arc of radius the distance steamed by the ship in the chosen interval (the ship's speed if the interval used is one hour), to cut the course to be made good.

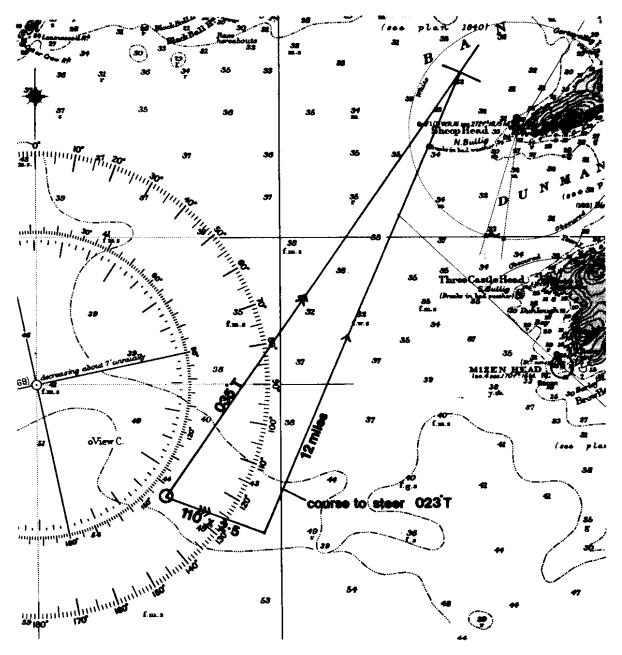


Fig. 2.13

- 4. Join the position where the arc cuts the course to be made good with the end of the tide. The direction of this line will give the course to be steered. Mark this line with a single arrow.
- 5. Measure the speed which will be made good. This will be given by the length of the line which represents the course to be made good, from the departure position to the position where the arc described cuts this line.

Note

Although the vessel will progress along the course to be made good, the ship's head will be that of the course steered, so that any relative bearing will be with respect to the course steered. Particular note should be taken of this when finding the position where a point of land will be abeam. The ship will be on the course line made good but the beam bearing will be at right angles to the course steered, or ship's head.

To find the distance and time at which the vessel will pass a point of land when abeam

Example

At 1000 hrs Lizard Point Lt. bore 000" T by 2.5 miles. Find the course to steer to make good a course of 050^0 T in order to counteract a current setting 2800 T at 2 knots. Ship's speed 10 knots. Find the distance off Black Head when abeam and the time when abeam.

Figure 2.14 shows the construction to counteract the current. The course to steer is 059⁰ T, and therefore the beam bearing of Black Head will be 329⁰ T. This will not be at right angles to the course made good, that is the track along which the vessel progresses. The beam distance will therefore not be the least distance.

```
From figure 2.14;

distance when abeam =1.5 miles.

speed made good =8.4 knots.

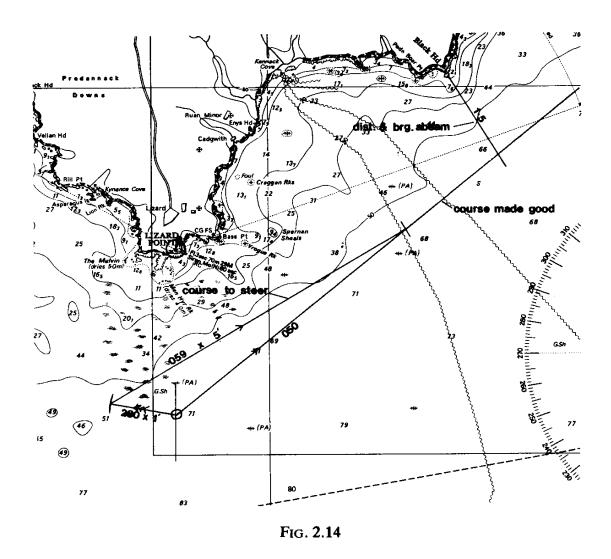
distance to beam bearing=5 miles

time when abeam =1000+-:-.4- hrs.

=1000+0.6 =1036 hrs.
```

To reach a position at a required time while counteracting a current To arrive at a position at a given time the vessel's speed must be adjusted so that;

```
speed= distance to steam to required position required time interval
```



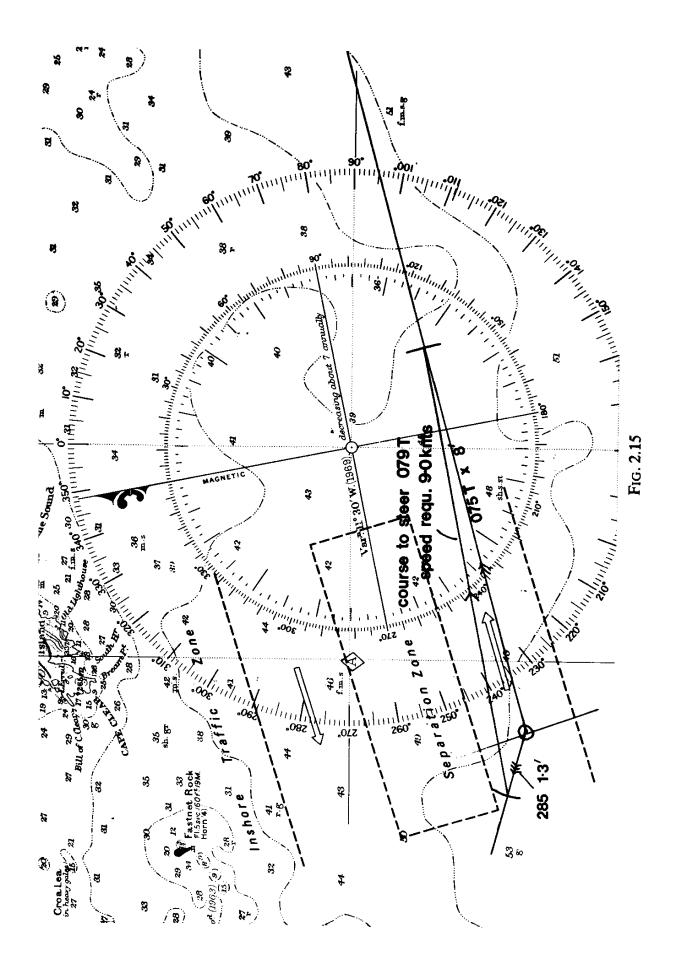
This will give the speed which must be made good over the ground. If there is a current or tidal stream, the vessel's log speed or speed through the water may be more or less than the speed made good. As the speed through the water will be determined by the engine revolutions, it is this speed which must be found.

Example

A vessel observes Fastnet Rock to bear 3400 T. by 7 miles. She wishes to arrive off Cork, a distance of 48 miles, in 6 hours. A tidal stream is estimated to set 285^0 T. at an average rate of $1 \cdot 3$ knots over the next 6 hours. Find the course to steer to make good a required course of 075^0 T., and the speed necessary to cover the 48 miles in six hours.

Procedure (refer to figure 2.15)

1. Having laid off the required course of 075^{0} T. and measured



the distance to go to be 48 miles, the speed to make good can be calculated to be

$$\frac{48}{6}$$
 =8 knots.

- 2. From the departure position layoff the current in the direction given (285° T.) and mark off the rate $(1 \cdot 3 \text{ miles})$.
- 3. From the departure position mark off the speed to make good, along the course to be made good.
- 4. Join the end of the tide found in (2), to the end of the speed made good found in (3). The direction of this line will give the course to steer, and its length will give the speed to make good through the water, that is the speed to use when determining the engine revolutions to order.

To find the set and drift of the tide between two observed positions

The set and drift, or rate, of the tidal stream or current may be found if two observed positions are available, and the courses and distances steamed between the two observations are known. The difference between the D.R. position at the time of the second observation, and the actual position as observed, is due to the tide.

Example

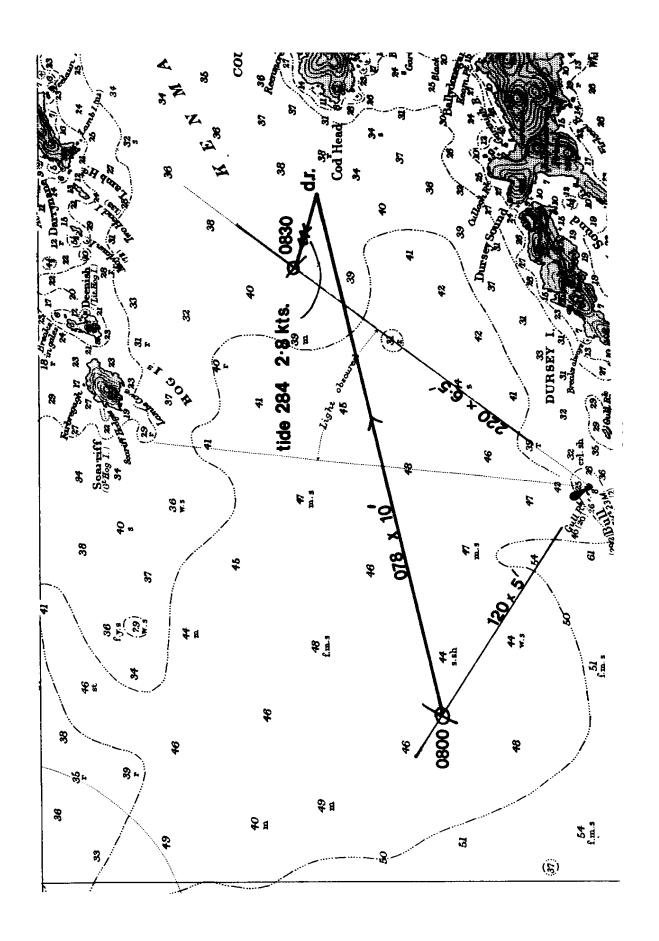
At 0800 a point of land is observed to bear 120^{0} T. by 5 miles. At 0830 the same point of land was observed to bear 220^{0} T. by 6.5 miles. Find the set and rate of the current, if the course steered in the interval was 078^{0} T. speed 20 knots.

Procedure (refer to figure 2.16)

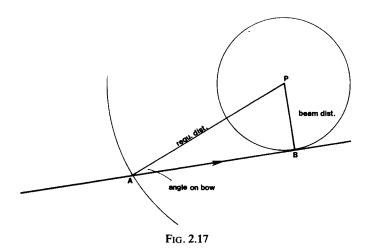
- 1. Layoff the two observed positions and label with their respective times.
- 2. From the first observed position layoff the course steered, and the distance steamed in the interval between the observations, to find the D. R. position for the time of the second observation. Mark this line with a single arrow.
- 3. Join the D.R. position found in (2) to the second observed position and mark the line with a treble arrow. Measure the direction to give the set of the current and the length to give the drift.

To find the course to steer to pick up a point of land at a required angle on the bow at a given distance.

This may be done by solving the right angled triangle P AB in figure 2.17 to find the beam distance PB. The angle PAB is the required angle on the bow and the side PAis the required distance.



When the beam distance is found the required course can be drawn tangential to a circle of that radius centred upon the point of land. The solution of the triangle may be done by traverse table.



Procedure

- 1. Calculate the beam distance. If traverse tables are used, the tables are entered with the angle on the bow as the course angle, and the required distance off as the distance (hypotenuse). The beam distance is extracted from the departure (opposite) column.
- 2. Draw a circle centred upon the point of land, of radius the beam distance found in (1).
- 3. Draw the course line to steer from the departure position, tangential to the beam distance circle.
- 4. Draw an arc of radius the given distance off, and centred upon the point of land, to cut the course line drawn. The intersection will give the position at which the point of land will be at the given distance and at the required angle on the bow.

Effect of the wind. Leeway

A vessel may be deviated from her course steered, or from her course made good due to the effect of the tide, by the wind. The change in a vessel's course angle due to the effect of a wind is called the leeway. The course made good due to the wind may be found by applying the leeway to the course steered in the direction in which the wind is causing the vessel to drift, that is down wind. The effect of the wind may be counteracted by applying the leeway to the course steered up into the wind.

To find the effect of a tide and a wind, the leeway is applied to the courses steered before laying them on the chart.

To allow for a tide and for the effect of leeway, the leeway is applied to the course to be steered, after allowing for the tide.

Example 1

Given a vessel's course is 135° T., wind S.W., leeway 5°, find the

track.

```
Course = 135^{\circ} T.

Leeway = 5^{\circ} (wind on the starboard side, subtract)

Track = 130^{0}T.
```

Example 2 (refer to figure 2.18)

Find the course to steer to counteract a current setting 085° T at 1.5 knots, and a S.W.'ly wind causing a leeway of 4° , in order to make good a course of 1200 T. Ship's speed 10 knots.

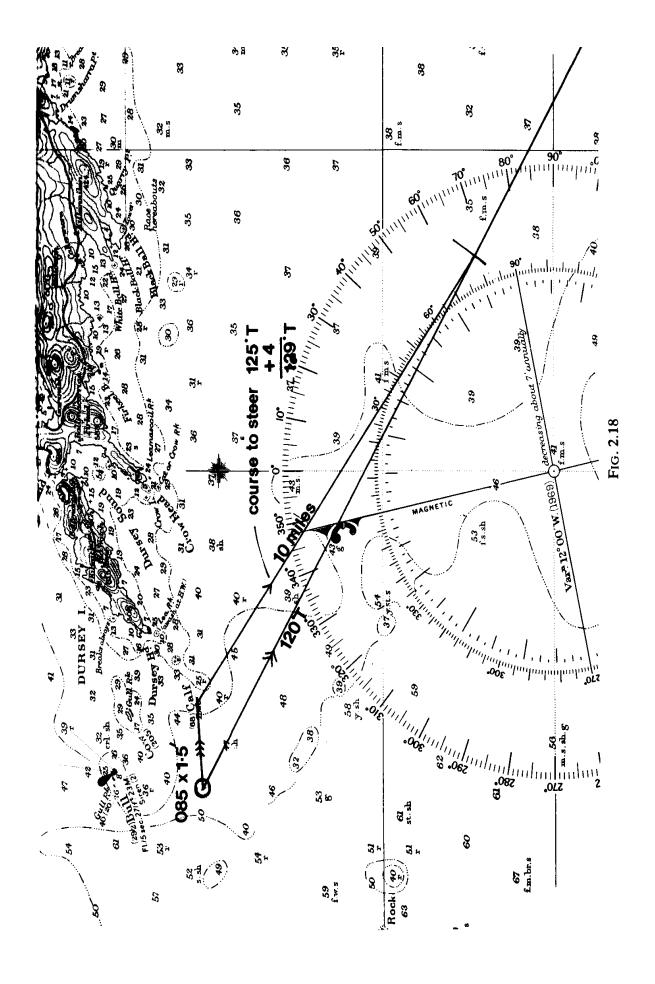
EXERCISE 2H

Find the track

	Course	Dev.	Var.	Leeway	Wind
1.	055° C.	3° E.	13° W.	4°	N.N.W.
2.	140° C.	4°W.	$10 {}^{\rm o}{ m W}$.	5°	S.W.
3.	246° C.	2° E.	15° E.	4°	N.W.
4.	330° C.	3°W.	8°W.	3°	S.W.
5.	104° C.	6° E.	12° W.	7°	N.E.
6.	084° C.	2°W.	20° E.	5°	North
7.	354° C.	5° W.	18° E.	6°	West
8.	190° C.	Nil	22° W.	10°	E.S.E.
9.	240° C.	3° E.	5° E.	8°	W.N.W.
10.	280° C.	1° W.	25°W.	4°	N.N.W.

EXERCISE 21

- 1. Find the course to steer to make good a course of 160" T. on a vessel of speed 18 knots, steaming through a current setting 215° T. at 3 knots. What will be the speed made good in the direction 1600 T.?
- 2. Find the course and speed made good if a vessel steams 305° T. at 12 knots through a current setting 243° T. at 2.5 knots.



- 3. Find the set and rate of the current if a point of land is observed to bear 025° T. by 6 miles and 45 minutes later is observed to bear 300° T. by 12 miles, if in the interval the vessel was steering 095° T. at 20 knots.
- 4. Find the true course to steer to make good a course of 350° T. on a vessel of speed 15 knots, steaming through a current setting 005° T. at 2 knots, if a westerly wind is causing a leeway of 5° .
- 5. Find the course and speed made good if a vessel steaming 176° at 17 knots through a current setting 020° T. at 3 knots, is experiencing a leeway of 5° due to an easterly wind.

CHAPTER 3

POSITION LINES

A position line is a line on the earth's surface which represents the locus of an observer who moves such that some item of observed information remains of constant value. Position lines generally used may take the form of part of a great circle, small circle, or hyperbola, depending upon the nature ofthe information observed, but in general, that part of the position line which lies near to the ship's O.R. position may be considered as, and represented on a chart as a straight line without any considerable error. If such a line is drawn on a chart, the observer may be assumed to be on that line. To fix the observer's position two, non coincident position lines must be drawn to intersect, the point of intersection defining the observer's position.

Position lines obtained from bearings

The most commonly used method of obtaining a position line at sea is to observe the bearing of a known and charted position. The most commonly used fix is that produced from two such position lines. This is not inherently the most accurate method of fixing but bearing information is in general the easiest to obtain. This may be done visually with a compass or by observing the direction from which radio waves radiated from a shore beacon, reach the observer by means of an aerial which has directional properties. In both cases the bearing measured will be the direction of the great circle which passes through the observer and the observed position, at the observer. Both a visual line of sight and a radio wave, follow a great circle path along the earth's surface.

In the case of the visual bearing this measured bearing, corrected for any compass error, may be laid off on a mercator chart from the charted position of the point observed, as a straight line, and this line can be assumed to represent the position line. The error incurred in doing this is negligible over the short distances over which visual bearings are taken.

In the case of a bearing observed by radio direction finder, errors may be considerable if this is done due to the longer path length of the radio wave, and to the longer distances on the chart over which the bearing is laid off. To maintain errors within tolerable limits radio OfF bearings are corrected for the half convergency, which may be considered to be the difference between the great circle

bearing of a point, and the mercator or rhumb line bearing which is produced on the chart by laying off a straight line. This is illustrated In figure 3.1

The half convergency may be found by the approximate formula;

half convergency =
$$\frac{\text{d'longx sine mean latitude}}{2}$$

Alternatively it may be obtained from a half convergency table provided in Burton's or Nories' nautical tables.

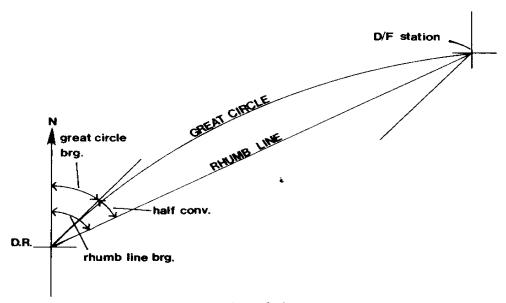


Fig. 3.1

Direction of the half convergency correction

The appearance of a great circle on a mercator chart is a curve which is concave towards the equator. The mercator bearing always lies on the equatorial side of the great circle bearing therefore, and the correction to the great circle bearing is always applied towards the equator. This is illustrated in figure 3.2 which shows the four possible cases of;

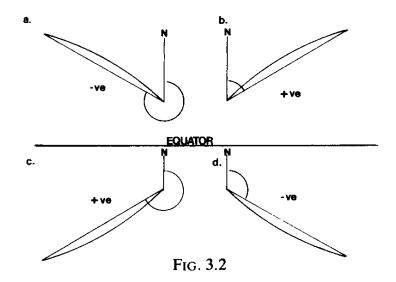
a.westerly bearing in north latitude,

b.easterly bearing in north latitude,

c.westerly bearing in south latitude, d. easterly bearing in south latitude.

Example

From a ship in O.R. position 44° 10' S. 144° 50' E., a OfF station bore 055° . If the position of the OfF station is 42° 53' S. 147° 14' E., find the rhumb line bearing.



D.R. position 44° 10′ S. 144° 50′ E. Mean lat. =43° 31′ S.

D/F station 42° 53' S. 147° 14' E.

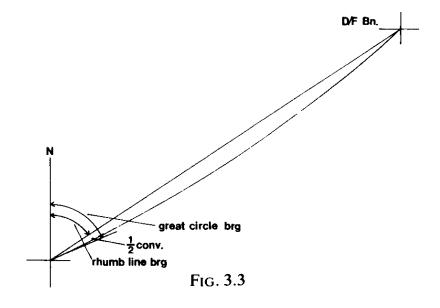
d'lat. =
$$1^{\circ}$$
 17' N. 2° 24' E. = d'long.

half convergency =
$$\frac{144x \sin 43^{\circ} 31'}{2}$$

$$=49.6' = \frac{3}{4}^{\circ}$$
 approx.

great circle bearing 055°

rhumb line bearing 054 1/4°

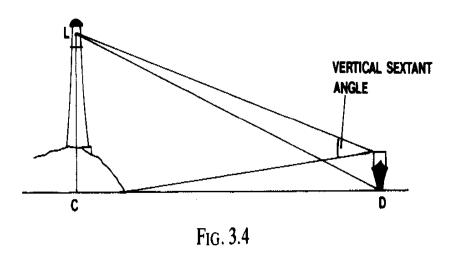


The position circle

If the information observed is that of distance from a known and charted object or point of land then the position line will take the form of a small circle centred upon the position of the object observed and of radius the distance measured. Such information may be readily obtained by radar observation. Position lines obtained by this method are inherently more accurate than those obtained from bearing information. This is due to the limitations of the instruments used for taking bearings, be they visual or by radar, and also to the fact that whereas the effect of an error in bearing, measured in terms of a distance error, increases as the position line diverges from the position observed, an error in range is constant, and does not increase with distance from the object observed.

The vertical sextant angle

Distance information may be obtained by observing the angle subtended by the top of a vertical structure or land formation of known height, and the sea foreshore at its base. The marine sextant is generally used for such an observation. The vertical angle subtended varies as the distance- of the observer from the object, which can be readily found.



The vertical sextant angled observed is illustrated in figure 3.4.

This is considered to be equal to angle LCD without undue error. The trian~le LCD, which is right angled at C can then be solved to find the distance CD.

By plane trigonometry CD=CL Tan vertical angle.

Note that the distance must be measured on the chart from the position of the highest point observed, that is in figure 3.4 from the position of the lighthouse, and not from the foreshore. Solutions for the distance off, tabulated against vertical angle and the height of the object observed, are given in nautical tables.

Heights of lights and topographical features given on Admiralty charts are expressed above Mean High Water Springs. For accurate

distances by this method these heights should be adjusted for the height of the tide as shown in Chapter 15, before entering vertical angle tables. In practice the uncorrected heights are used as the unknown error will always put the vessel closer to the position observed than its true position. This will in most cases fix the vessel closer to the danger and leave the navigator with a margin of safety. This will not be the case however if the danger lies on the side of the vessel away from the position observed.

The accuracy of this method depends upon the base of the object at sea level being visible. At distances greater than that of the sea horizon for the observer's height of eye, the base will not be visible and the angle measured will be that subtended by the top of the object and the sea horizon. If this is the case vertical sextant angle tables will not be valid.

Horizontal sextant angles

A position circle is obtained if the angular distance between two known and charted objects is measured by an observer. This information may be obtained with a marine sextant but is also readily obtained to acceptable accuracy by taking the difference between the compass bearings of the two objects. The advantage of using compass bearings in this way rather than to produce a fix by cross bearings, is that any unknown compass error will have no effect on the position line obtained. A fix may be produced by two horizontal angles obtained from compass bearings of three objects, independent of compass error, and the true bearings obtained from the chart after the fix is determined will, on comparison with the compass bearings observed, give the error of the compass.

The angle subtended by the chord of a circle at the circumference of the circle is the same at all points on the circumference. A circle may therefore be drawn a chord of which is formed by the straight

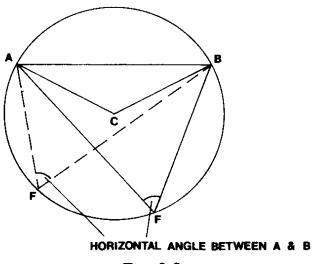


Fig. 3.5

line between the two points whose horizontal angle is known. The observer will lie somewhere on that circle.

In figure 3.5 angle ACB=2 x angle AFB

=2x measured horizontal angle.

(the angle on a chord at the centre of a circle is twice that at the circumference.)

Also in triangle ACB, angle CAB=angle CBA

$$= \frac{180^{\circ} - ACB}{2}$$

$$= \frac{180^{\circ} - (2 \times AFB)}{2}$$

$$= \frac{90^{\circ} - AFB}{2}$$

Thus to find the angles LCBA and LCAB, the measured horizontal angle is subtracted from 90°. (If the measured angle is less than 90°.)

Procedure (refer to figure 3.5). To be followed if the measured angle is less than 90°.

- 1. Join the charted positions of the two points between which the horizontal angle has been obtained, with a straight line. (AB)
- 2. Construct the angles LCBA and LCAB at the positions observed on the side of the line on which the observer lies. The values of LACB and LCAB have been shown to be 90°-horizontal angle observed. The point of intersection of the two lines AC and BC so formed will be the centre of the required circle.
- 3. Draw a circle centred on C to pass through the two positions between which the horizontal angle is known, A and B. This circle is the position circle.
- 4. Repeat for a second horizontal angle to produce an intersection of two position circles.
- 5. If required, measure the true bearings of the points observed, from the chart and compare with the compass bearings to find the compass error.

Example

The following compass bearings were observed. Find the ship's

position and also the error of the compass.

Great SkeUig lighthouse 304° C. Bolus Head 029° C.

Great Hog Island (Scarriff) 074° C. Highest point (829) observed.

Refer to figure 3.6 and to the procedure outlined above for the construction.

Ship's position= $5\underline{1}^{\circ}4\underline{1}\cdot\underline{8}'$ N. $10^{\circ}2\underline{4}\cdot\underline{8}'$ w.

	Great Skellig Lt.	Bolus Hd.	Scarriff
True bearing	310° T.	035° T.	080° T.
Compass bearing	304° C.	029° C.	074° C.
Compass error	6° E.	6° E.	6° E.

Note

By checking the compass error with the three bearings a check is provided that the construction has been done correctly.

Horizontal angle measured greater than 90°

In this case the observer lies on the circumference of the circle on the opposite side of the chord of the circle to the circles' centre.

In figure 3.7

angle *LACB*=3600- *LAFB* (the horizontal angle)

and angle LCBA=angle LCAB=180°-(3600- LAFB)

2

 $=90^{\circ}-180^{\circ}+LAFB$

 $= LAFB-90^{\circ}$

Thus the angles LCBA and LCAB are found by subtracting 90° from the horizontal angle measured.

Procedure

This is the same as for the case of the horizontal angle less than 90° except that the angles LCBA and LCAB are laid off on the straight line joining the two positions, on the opposite side of the line to the observer's position. See example in figure 3.8.

Example

The following compass bearings were observed. Draw a position

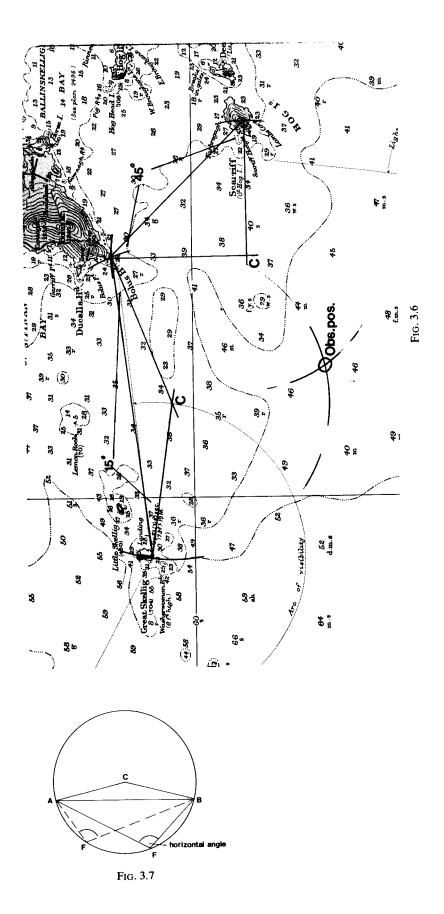
line by horizontal angles.

Galley Head. Lt. 050° C.

Castle Haven Lt. 295° C.

Horizontal angle 115°

Construction angles 115° - 90° = 25° See figure 3.8 for construction.



Notes

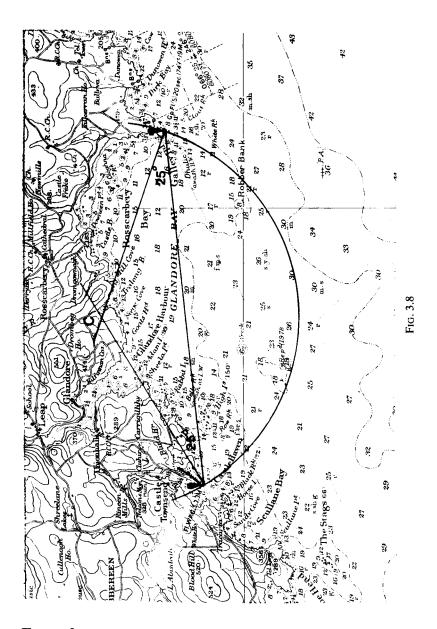
If the observed horizontal angle is 90° , then the centre of the circle lies on the straight line

which joins the two positions between which the angle has been measured. The chord of the circle is in fact a diameter of the circle.

A poor angle of cut will result if the two position circles almost coincide. If all the observed positions and the vessel's position also, lie on the circumference of the same circle, then the two position circles constructed will coincide and a fix cannot be obtained. When choosing features to observe for horizontal angles the vessel's D.R. position should be compared with the positions to be observed to check for this condition.

The transit bearing

One of the most useful and easily obtained position lines is that from observation of two known and charted objects which lie on the same bearing from the observer. Such objects are said to be in transit. A straight line drawn on the chart through the two positions will represent the charted position line. Observation of a transit does not require a compass but if the compass bearing is noted as the two objects come into line, a compass error may be readily obtained by comparison with the true bearing of the transit taken from the chart. If a compass bearing of some other prominent object is observed at the same time as the transit, then the accurate compass error obtained from the transit may be used to correct this compass bearing. An accurate fix may be obtained in this way very quickly, and with practice this method of fixing can be used to good effect in confined navigational waters where plenty of coastal features and beacons are available.



Example

From a vessel entering Bantry Bay, Sheep Head Lighthouse was observed to be in transit with Three Castle Head bearing 168⁰ by compass. At the same time Black Ball Head was observed to bear 264%0 by compass. Find the ship's position.

Procedure (refer to figure 3.9)

- 1. Draw a straight line through Sheep Head Lighthouse and Three Castle Head, and produce it into Bantry Bay. Measure the true direction of this bearing from the chart compass rose.
- 2. Compare the true bearing of the transit with the compass bearing to obtain the compass error.
- 3. Using the compass error obtained in (2) correct the compass bearing of Black Ball Head to true $. \bullet$
- 4. Layoff the true bearing of Black Ball Head to cross the transit bearing at the ship's position.

Note

A compass error obtained at the time of observation by this means or by any other means should always be used in preference to one taken from a deviation card and compass rose, or to one taken at some earlier time.

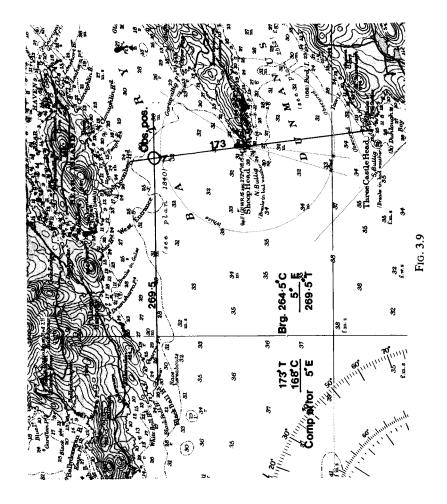
The use of the transit bearing for leading marks

The transit bearing is used to mark the direction of approach through a navigable channel. Beacons erected to provide a transit bearing are called leading marks or leading lights. A vessel navigating in the channel maintains the leading marks in line to keep herself in the channel and on the correct approach.

Very often this technique may be used by the navigator in close waters even though leading marks are not provided, by selecting natural prominent features or charted buildings. The technique is also very useful when keeping a check on anchor bearings. At anchor there are invariably enough natural topographical features to choose transits, which tell at a glance whether the vessel is dragging or not. The swing of the vessel around her anchor should not be mistaken for a dragging.

Position circle by rising and dipping distance

When making a landfall at night a first position may very often be obtained by observing a light which just appears above the horizon. In clear weather the loom of a light may very often be seen long before the actual light itself is seen. If a bearing is then taken when the actual light just appears or rises, then a position may be obtained by crossing this bearing with a position circle obtained



from a distance off. The height of the light must be obtained from the chart. The accuracy of such a position is acceptable as a first landfall position, but the distance may be approximate for a number of reasons.

The distance of the sea horizon is given by the formula 2.08J'11, where h is the height of the observer's eye in metres. The formula gives the distance in nautical miles. The constant 2.08 includes allowance for an estimated refraction for normal atmospheric conditions. Abnormal refraction however may cause inaccuracy.

Figure 3.10 shows that the distance at which a light will first rise above the horizon will be given by:

2.08 Jh+2'08 JH where h ::::;height of eye in metres.

H ::::; height of light above sea level in metres.



The solution of this formula may be obtained from nautical tables, from the table giving the distance of the sea horizon against height of eye. The distance is taken out in two parts, one

for the observer's height of eye and one for the height of the light.

It should be remembered that the heights of lights on charts are given above mean high water springs, and unless this height is adjusted for the height oftide, the distance obtained will be usually too small.

Ranges of lights

Nominal range-This is the range given against the light on Admiralty charts, and also in Admiralty Lists of Lights. It is the visible range based upon its intensity, which is measured in candelas, and upon a meteorological visibility of 10 nautical miles.

Geographical range-This is the maximum range at which it is possible to see the light as dictated by the curvature of the earth. This will depend upon the observer's height of eye and upon the height of the light above sea level. A formula for the geographical range was given when discussing the rising and dipping of lights.

The actual range at which the light may be seen may be more or

less than the nominal range depending upon the prevailing atmospheric conditions and the meteorological visibility. The range at which the light may be seen under any particular meteorological visibility is called the luminous range. This may be obtained from a luminous range diagram which is given in the introduction to each volume of the Admiralty List of Lights. This is reproduced in figure 3.11.

The nominal range obtained from the chart is entered at the top margin of the diagram. Going vertically down from this point until the cross curve which is labelled with the estimated meteorological visibility is reached, and then across to the left hand border scale gives the expected luminous range.

Example

A light of nominal range 25 miles is estimated meteorolgical visibility of 20 miles would be seen at a luminous range of 42 miles.

The light will only be seen at the luminous range if the observer has sufficient height of eye. It will be seen at the luminous range if the geographical range is greater than the luminous range. If the luminous ran~e is greater than the geographical range then the light will be seen rIsing or dipping at the geographical range.

Note

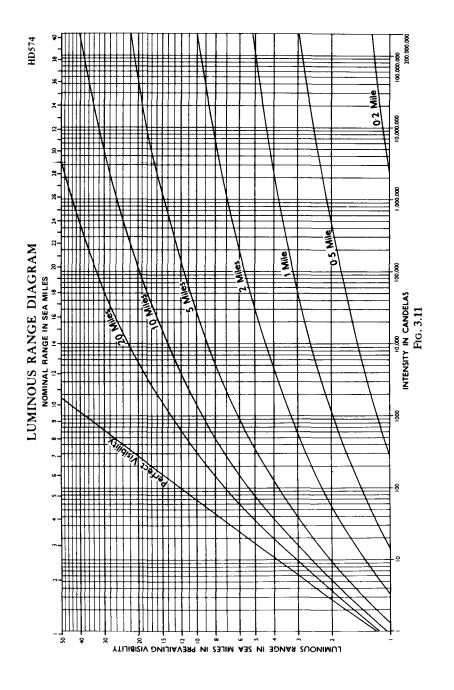
The luminous range obtained from the diagram in this way is only approximate and may vary with different atmospheric conditions and conditions of background lighting from shore etc. The luminous range should only be used as a guide to when a light may be expected to be seen, and not to establish a position circle when it is seen. This may only be done when the light is seen rising or dipping.

Danger angles

The vertical sextant angle or the horizontal sextant angle may be used as a danger angle to enable the navigator to maintain a required distance off a navigational hazard.

The vertical sextant angle of an elevated point increases as the observer's distance from it decreases. If the distance inside which the observer does not wish to go is used to enter the distance by vertical sextant angle tables, then the vertical sextant angle corresponding to that distance may be extracted. Monitoring of the vertical sextant angle of the elevated point as the vessel passes, to ensure that it does not attain a greater value than that extracted for the minimum distance, will ensure that the vessel does not go closer than desired to the danger.

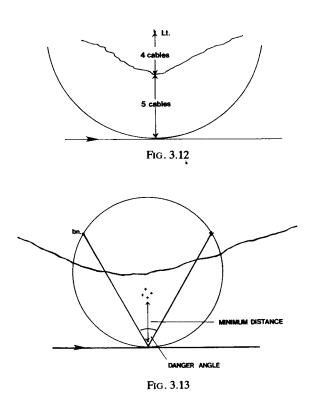
This technique may be used to advantage when rounding or passing a point which is suitable for observation of vertical sextant angle, at a small distance off. The time required to fix the ship by



other methods to monitor the distance off may take too long to give adequate warning when navigating close to.

Example

It is required to pass the point of land shown in figure 3.12, at a distance not less than 5 cables. A lighthouse of height 35 metres lies 4 cables inland from the outlying danger. Find the danger angle to set on a sextant to observe the vertical angle subtended by the light.



A horizontal angle may be used in the same way if there are beacons or charted buildings available which are suitable for horizontal angle observation. Figure 3.13 shows an outlying danger with two suitable marks, one on either side of the danger. A minimum distance may be chosen, and a point marked on the chart offshore from the outlying danger by this distance. The horizontal angle can then be measured from the chart by drawing lines from this point to the two objects to be observed, and measuring the

angle between them. Monitoring of this angle as the vessel passes the danger will ensure that the vessel does not go inside the circle shown in figure 3.13.

Hyperbolic position lines

A hyperbolic position line is obtained from measurement of the difference in the distances from the observer to two fixed points. Invariably this information is obtained by means of radio navigational aids, and the fixed points are the positions of the radio transmitters. The operator may make the necessary measurements with the receiving equipment without being aware of the underlying principles, and furthermore the position lines must be overprinted on navigational charts, as the hyperbolic shape is not easily drawn by the navigator. A series of charts is produced for each hyperbolic navigational system which are overprinted with hyperbolae which are representative of the position line at suitable intervals, between which

the navigator must interpolate to find his particular position line. The charted hyperbolae are labelled with values in the same units which are displayed by the receiving equipment. Navigational aids which give hyperbolic position lines include the Decca Navigator, Loran, Omega, and Consol.

In order to qualify for a Department of Trade Class V, Class IV or Class III certificate the candidate must hold an Electronic Navigational Aids certificate which covers the use of all radio navigational aids. A description of the principles and operation of these aids is therefore not appropriate here. Candidates will however be expected to be able to plot position lines from information derived from these navigation I aids, in particular the Decca Navigator, which is the only one ofthe aids mentioned which give accuracy consistent with all coastal navigation requirements.

CHAPTER 4 mE SAILINGS

In this chapter the problems of calculating the course and distance between two positions on the earth's surface are considered.

Parallel salling

To be used when finding the distance to steam between two positions which are in the same latitude.

The distance measured along a parallel of latitude between any two given meridians decreases as the meridians converge towards the poles, being maximum at the equator. This distance, i.e. the distance measured along a parallel of latitude between two given meridians, is called the departure, and is expressed in nautical miles. There is therefore' a relationship between departure, difference of longitude, and latitude.

The exact relationship can be seen as follows:

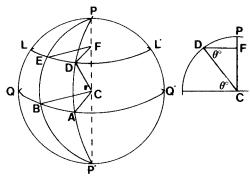


Fig. 4.1

In the figure let the circle represent the earth, C its centre, QQ' the equator, LL' a parallel of latitude (}0, PP' the earth's axis and F the centre of the small circle LL'.

D and E are two positions on the parallel LL' with PAP' and PBP' the meridians through these two places. CA, CB and CD are radii of the earth.

By circular measure, the length of an are, which subtends any given angle at its centre, is proportional to its radius.

Thus -g_~=_~A_C where DE is the departure and BA is the d.long. Therefore _D_E=_D_F

BA AC

and as DC and AC are both radii of the earth:

DE DF-BA---D-C

Thus -~A E=cosine *LFDC*

Thus <u>Departure - Cosine Latitude</u>.

D. !,png.

The finding of distance between any two positions on the same parallel is, merely the application of this formula.

Example 1

Find the distance to steam between the two positions:

A 51° 20' N. 48° 30' W. and B 51 ° 20' N. $\underline{38^{\circ}\ 10'\ W}$.

d. long.
$$= 10^{\circ} 20' \text{ E.}=620'$$

and Departure = d. long. x coso latitude

Departure= $620x\cos. 51^{\circ} 20' = 3.87.4$

Distance = 387.4 miles

Example 2

Number	Log
620	2.79239
coso 51 ° 20'	1.79573
	2.58812

In what latitude will a d. long. of 3° 40' correspond to a departure

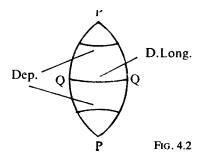
of 120 nautical miles?

sec. lat. = d. long .. in mins. dep. 10 M.

_220

-12-0

= 1.8333 Latitude= 56° 56!' N. or S.



Example 3

A vessel steams 090^{0} T. from long. 35° 25' W. to long. 28° 53' W.

How far did she steam if the latitude was 41° 20.5' N.?

Initial long. =3Y 25' W.

Final long ~280 53' W

d. long. = 6° 32' E.

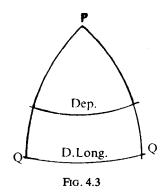
=392' E.

dep. in M.

= d. long. in mins. x coso lat. = $392 \times \cos 41^{\circ} 20.5^{\circ}$

= 294 · 3

Dist. steamed = $294 \cdot 3 \text{ M}$.



Number	Log
392	2.59329
coso 41 20·5'	9.87552
	2.46881

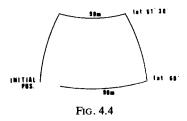
Example 4

A vessel steams from a position in latitude 60° , in a direction 000° T. for a distance of 90 miles. She then steams 90 miles 090° T., 90 miles 180^{0} T. and 90 miles 270° T. How far is she from her initial position?

Note

The distance steamed in a northerly direction gIves a d. lat. or 90' N. or 1 30' N. She will arrive therefore in latitude 61 Q 30' N. at the end of the first leg. The same d. lat. is made

good on the southerly leg. She will therefore arrive back in the same latitude of 60° N. A distance of 90 miles in the higher latitude will, however, give a larger d. long. than 90 miles in the lower latitude, and she will not reach her initial longitude when sailing on the westerly leg. Her distance from her initial position will be the difference in the departures for the two latitudes corresponding to the d. long. made good when sailing east.



Thus in latitude 61 ° 30'

dep. =d. long. coso lat.

90 =d.long.xcos. 61° 30'

d.long.=90xsec. $61^{\circ} 30'$. = 188.62

Thus in latitude 60°

dep. $= 188.62 \times \cos 60^{\circ}$

= 94.31

Thus distance from initial position = 94.31 - 90 = 4.31 miles

Number	Log
90	1.95424
sec. 61 ° 30'	0.32134
	2.27558
coso 60°	1.69897
	1.97455

Example 5

Two vessels 45 nautical miles apart on the parallel of 40° 30' N. steam 180° T., at equal speeds, until the distance between them is 55 nautical miles. How far did each steam?

d.long. in mins.

= dep. in M. x sec. lat. = $45 \text{ x sec. } 40^{\circ} 30'$

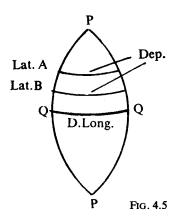
As both vessels steam 180° T., their d. long. is the same on both parallels.

sec. lat. d. long .. in mins. dep. 10 M.

_45 x sec. 40° 30' 55

<u>9 x sec. 40° 30' 11</u>

New Lat.=21° 39·6' N.



Example 6 At what rate in knots is a place in latitude 50° 56' N. being carried around by the earth's rotation?

In 24 hours any place is carried round through 360° . This can be thought of as the d. long. Thus in one hour the d. long is 15° .

Thus distance in miles moved in one hour=departure

and dep. =
$$15 \times 60 \times \cos 50^{\circ} 56' = 900 \times \cos .50'' 56'$$

$$= 567.2$$

Thus speed = $567 \cdot 2$ knots

Number	_ Log
900	2.95424
coso 50° 56'	1.79950
	2.75374

EXERCISE 4A

- 1. In what latitude will a departure of 300 nautical miles correspond to a d. long. of 6° 40'?
- 2. On a certain parallel the distance between two meridians is 250 M., while the d. long. between the meridians is 12° 30'. What is the latitude?
- 3. In latitude 50° 10' N. the departure between two meridians is 360 nautical miles. What is the d. long.?
- 4. A vessel steams on a course of 090° T. from *P* in lat. 23° 30' N., long. 59° 10' E. to *A* in lat. 23° 30' N., long. 65° 30' E. How far did she steam?
- 5. From lat. XC N. a vessel steams 000° T. 50 M., and then 090° T. 100 M. If the difference of longitude is 185', find lat. X.
- 6. From lat. 44° 15' N., long. 10° 20' W. a vessel steamed 270° T. for 550 nautical miles, and then 180° T. for 753 nautical miles. Find her final position.
- 7. On a certain parallel, the distance between two meridians is 150 nautical miles. On the Equator, the distance between the same two meridians is 235 nautical miles. What is the latitude of the parallel?
- 8. The distance between two meridians in lat. 48° 12' N. is 250 M. What is the angle at the pole?
- 9. A vessel steams 470 nautical miles along the parallel of XC N. from long. 15° 35' W. to the meridian of 27° 20' W. What is the latitude of X?
- 10. From lat. 39° 00' N., 33° 10' W. a vessel steamed 270° T. at 10 knots for 3 days 8 hours. In what D.R. position did she arrive?

EXERCISE 4B

1. The distance between two meridians is 427 nautical miles in lat. 50° 20' N. What is the angle at the pole?

- 2. Two ships on the parallel of 17° S. are 55 nautical miles apart. What would be their distance apart if they were on the parallel of 40° N.?
- 3. Two ports, *A* and *B* are in the Northern Hemisphere. On the parallel of *A*, the distance between their meridians is 250 M., on the parallel of *B* it is 350 M., and on the Equator it is 400 M. What are the latitudes of the ports?
- 4. At what rate does an observer in lat. 50° 20' rotate? (Answer to be in knots.)
- 5. A vessel in latitude 48° 30' N. steams 270° T. at 10 knots for 24 hours. By how much is the longitude changed?
- 6. In lat. 50° 20' N. a vessel steams from long. 15° 46' W. to long. 31° 18' W. What distance was made good?
- 7. A ship steams 090° T. for 200 nautical miles in lat. 49° 10' N.

By how much will her clocks have to be advanced?

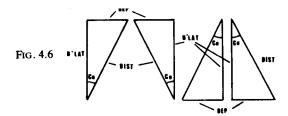
- 8. The distance between two meridians in the Northern Hemisphere is 240 M. On the Equator it is 400 M., and in the Southern Hemisphere it is 360 M. What is the d. lat. between the two parallels?
- 9. In what latitude is the departure in nautical miles fivesevenths the d. long. in minutes?
- 10. In lat. 48° 30' N. a vessel is in long. 34° 30' W.; at noon L.A.T. the course is set 270⁰T., and the following day at noon L.A.T. she is in long. 40° 30' W. What was the vessel's average speed? 11. Two vessels 200 nautical miles apart on the same parallel steam 180° T. to the parallel of 20° N., where their d. long. is found to be 5° 10'. How far did each steam?
- 12. A vessel leaves lat. 52° 21' N., long. 30° 20' W., and by steering 270° T. at 10 knots for 24 hours, arrives in lat. 52° 21' N., long. 36° 00' W. Find the set and drift.

Plane sailing (Mean Lat Sailing)

To be used to find the course and distance between two positions which are not in the same latitude, and when the distance is small.

Given the latitude and longitude of the two positions we can obtain the d. lat. and the d. long. between these positions.

The factors d. lat. and distance are measured in the same units and can be graphically represented as the two adjacent sides of a right-angled triangle. The angle between them can be made to represent the course, thus: ...



The appropriate one of the above triangles to be used will be decided by the direction of the d. lat. and the d. long., and hence the quadrant in which the course lies.

To solve this triangle for course and distance, we need to know two other arguments of the triangle. We know d. lat., but we also need to know the length of the third side.

The length of the third side can be thought of as the departure between the two positions, and there will be one value of length which will give, when used to solve the triangle, the correct values of course and distance. We can calculate a value for departure by the parallel sailing formula:

dep.=d. long. x cosine latitude.

But which latitude do we use in this formula. There is no readily apparent choice as the two positions are in different latitudes. The correct latitude to use would be that latitude which will give the required correct value of departure, but as yet we have no way of knowing this latitude, and as an approximation to it we use the numerical mean latitude between the two positions. (Hence the name Mean Lat. Sailing.)

Noh:

The inaccuracy due to the use of the mean latitude means that this method is only suitable for problems in which the d. lat. and therefore the distance is fairly small.

Procedure

1. From the two positions given calculate the d. lat. and the

d.long., and also the value of mean latitude.

- 2. Using the mean latitude in the parallel sailing formula, find the departure.
- 3. Solve the plane sailing triangle, using departure and d. lat. to find course and distance, thus:



Fig. 4.7

From the triangle, $\underline{dde_1^P}$ = tan. course . at.

and distance=d. lat. x sec. course

Example 1

Find the course and distance between the following positions.

A 37°01'N. 9°00'W.

t d. lat. 25'

d.lat. 50' S. d. long. 2 58' E.

dep. =d. long. x coso lat. = $178 \times \cos 36^{\circ} 36' = 142.9$

~ t

d. lat. = an co.

142.9

tan co. = -5-0-

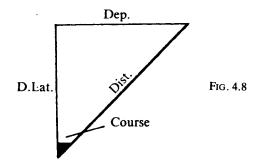
= 70° 43'

dist.=d.lat.xsec. co. =50xsec. 70° 43' =151-4

Number	Log
178	2.25042
coso 36° 36'	1 .90462
	2.15504
Number	Log
142.9	2.15504
50	1.69897
	0.45607
Number	Log
sec. 70° 43'	0.48114
50	1.69897
	2·180II

Answer: course=S. 70i E., distance = 151-4 miles. **Example 2**

The course and distance from A to B is 055° T. 720 nautical miles. Find the d. lat. and departure made good.



d. lat. =dist. x coso (course) = $720 \times \cos .55^{\circ} = 412.96 = 6^{\circ} 53' \text{ N}.$

dep. =dist. x sin. (course) =720 x sin. 55° = 589,8 M.

D. lat.= 6° 53' N., dep.=589.8 nautical miles

Log
2.85733
9,75859
2.61592

Number	Log
720	2.85733
sin. 55°	9.91337
	2.77070

Example 3

From lat. $50^{\circ}~28'~N$., a vessel 'steamed $156^{\circ}~T$. 1550 nautical miles. Find the latitude in which she arrived.

d. lat. =dist. x coso (course) = $1550 \text{ x coso } 24^{\circ}$

= 1416'

=23° 36' S.

Initiallat. = 50° 28,0' N. d. lat. = 23° 36,0' S.

Finallat. = $26^{\circ} 52.0'$ N.

[Numb«	Log
1550	3.19033
coso 24°	9.96073
	3.15106

Example 4

A vessel steers 327° T. and makes a departure of 396,7 nautical miles. How far did she steam?

Dist. =dep. x cosec. (course) = $396.7 \text{ x cosec. } 33^{\circ} = 728.4 \text{ M}.$

Dist. steamed = 728-4 nautical miles

Number	Log
396.7	2· 59846
cosec.	10·2638 9
	2.86235

EXERCISE 4C

1. Find the course and distance between the following positions; A 35° 12' N. 178° 12' W.

B 37° 06' N. 17r 00° E.

2. A vessel leaves position 45°12' N. 161° 12'W. and steams 213°

T.for 406 miles. Find the position arrived at.

3. Find the course and distance between the following positions.

P 5°21' N. 168° 17'E. Q 16° 38'S. 153°48'W.

- 4. From position $40^{\circ}30'$ S. 175° 45'E. a vessel steams 050^{\sim} . for 506 miles. Find the arrival position.
- 5. Find the course and distance between the following positions.

Y 41°00' S. 178°15'E.

The middle latitude

The plane sailing gives inaccurate results due to the uncertainty in the value of the departure used to solve the plane sailing triangle. The inaccuracy is acceptable over short distances of up to a few hundred miles.

The correct value of departure to use in the plane sailing triangle is that value which will give the correct value for the course between the two positions being considered. As an approximation the departure used was obtained from the parallel sailing formula, using the numerical mean latitude, thus;

departure=d'longxcosine mean latitude

. It can be shown that the correct value of departure is obtained if the latitude used in this formula is the middle latitude given by the formula;

sec. mid. lat. =
$$\frac{1}{d'$$
lat. $\int_{1^5}^{1^n}$ sec. l.dl.

where I'' and 1^5 are the latitudes of the positions concerned.

In practice this middle latitude may be found by applying a correction to the numerical mean latitude, the correction being obtained from nautical tables. Thus the correct departure is given by;

departure=d'longx cosine middle latitude.

If this departure is used to solve the plane sailing triangle then more accurate values of course and distance are obtained. These

methods are not often used however because there is an alternative method of finding course and distance which involves less calculation than plane sailing or middle latitude sailing, but gives the same accurate results as middle latitude sailing. This alternative method is called Mercator Sailing.

Mercator sailing

To be used when finding course and distance between two positions which are in different latitudes. It is accurate for large d. lats. and distances and is in practice employed in preference to the alternative methods as it involves less calculation.

If we draw a right-angled triangle on a mercator chart, such that the hypotenuse represents the rhumb line distance between the two positions on the chart, and one side represents the meridian through one of the positions, then the third side will lie along the parallel of latitude through the other position. The angle between the meridian and the hypotenuse will represent the course. The longitude scale on a mercator chart is a constant scale, so if we express the two sides opposite and ~djacent the course in units of this scale, then we can find the course by:

d. - an. co.

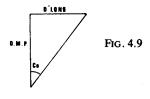
a J.

The side opposite the course, i.e. the side lying along the parallel of latitude, will be the d. long.

To express the adjacent side, i.e. the side along the meridian, a value called the meridional parts for the latitude is tabulated in nautical tables.

Meridional parts for any latitude is the length along a meridian, on a mercator chart, measured in units of the longitude scale, between the Equator and the parallel of latitude in question.

If we extract the meridional parts for each of the latitudes concerned and take the difference between them, then this 'difference of meridional parts' (d.m.p.) will be the length of the side of the triangle which lies along a meridian, adjacent to the course angle, and measured in units of the longitude scale.



ν

In the triangle $\sim long$ tan. course .m.p.

We have thus found the course without using the factor departure and have avoided the inaccuracy whicQ. was encountered in plane sailing.

We can now revert to the plane sailing triangle with a knowledge of course and solve for distance by

dist. = d. lat. x sec. course.

Procedure

I. Write down the latitude and longitude of the positions, and against each latitude the meridional parts for that latitude from the nautical tables. Calculate d. lat., d. long., and the d.m.p.

Note

The rule for finding d.m.p. is the same as that for finding d. lat., i.e. same name take the difference and different name take the sum.

2. Calculate the course by <u>dd long.</u> tan. course.

.m.p.

3. Calculate the distance by dist.=d. lat. x sec. course.

Example 1

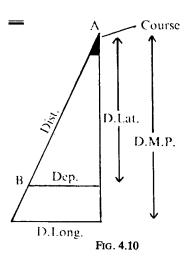
By Mercator Sailing find the true course and distance from A, lat. 49° 10' N., long. 12° 30' W., to B, lat. 25° 15' N., long. 26° 50' W.

A, lat.= 49° 10' N. M.P. =3379'6 long. = 12° 30'W.

B, lat.= $25^{\circ} 15' \text{ N}$. M.P. = 1556.6 long. = $26^{\circ} 50' \text{W}$.

d.lat. = $23^{\circ} 55'$ S. D.M.P. = 1823.0 d.long. = $14^{\circ} 20'$ W.

=1435' S. -- =860' W.



t() --- d. long. an. course -- D.M.P.

860

-182-3

Course = $S.25^{\circ} 15.3'$ W.

distance=d. lat. x sec. (course) =1435xsec. 25° $15 \cdot 3' = 1586 \cdot 7$ M.

Number	Log
860	2.93450
1823	3.26079
	9.67371
Number	Log
Number 1435	Log 3'1568~

Course=205° 15·3′ T., Oist.= 1586·7 M.

Example 2

A vessel steams 040° T. for 2300 miles from position 39° 37' S. 47° 28' W. Find the arrival position.

d. lat. =dist. x coso course (from the plane sailing triangle)

$$= 2300 \text{ x cOS}. 40^{\circ} = 1761.9$$

Number	Log
2300	3.36173
coso 40°	1,88425
	3.24598

initiallat. 39° 37' S. m.p. 2577.82

d. lat. 29° 21,9' N.

arrivallat. 10° 15·1' S. m.p. 614·25

d.m.p. 1963.57

d. long. = d.m. p. x tan. course (from mercator sailing triangle) = 1963.57 x tan. 40°

= 1647.6

 $= 27^{\circ} 27,6' E.$

Number	Log
1963.57	3.29305
tan. 40°	1,92381
	3.21686

initial long. 47° 28.0′ W.

d. long. 27° 27,6' E.

final long. 20° 00'4' W.

final position 10° 15·1′ S. 20° 00'4′ W.

EXERCISE 40

I. Find the O.M.P. between the following pairs of latitudes:

540° 00' N. 5 20° 10' N. 553° 15' S. 5 22° 18' S.

- (a) **I** 50° 00' N. (b) **I** 10° 35' S. (c) **I** 24° 47' S. (d) **I** 39° 53' N.
- 2. Find the true course and distance from lat. 20° 14' N., long. 22° 17' W., to lat. 11° 35' S., long 41° 05' W.
- 3. Calculate by mercator sailing method the true course and distance from A, lat. 40° 10' N., long. 09° 45' W., to B, lat. 10° 15' N., long. 18° II' W.
- 4. By using mercator sailing calculate the true course and distance from P, lat. 4-1 ° 13' N., long. 173° 50' W., to Q, lat. 07° 50' S., long. 79° 55' W.
- 5. A vessel steams 210° T. 750 nautical miles from 29° 30' N., 162° 20' E. In what position did she arrive?
- 6. From lat. 10° 12' S., long. 35° 05' W., a vessel steers 017° T. and arrives in long. 28° 29' W. What was the distance steamed and the latitude reached?
- 7. A vessel steams 225° T. 800 M., and then 135° T. 800 M. from lat. 10° 00' S., long. 00° 00'. In what position did she arrive?
- 8. A vessel steams 065° T. 1850 M. from lat. 20° 12' N., long. 178° 40' E. Find the latitude and longitude of the position in which she arrives.
- 9. Calculate the true course and distance from 05° 20' N., 79° 05' E., to 24° 20' S., 112° 03' E.

10. Calculate the true course and distance from 37° 03' N., 13° 20' E., to 31 ° 20' N., 29° 55' E.

EXERCISE 4E

The following problems are typical of those encountered in Class V Practical papers

1. From the following information find the O.R. position by

mercator sailing.

initial position 50" 33' N. 7 "25' W. course $237^0\ T.$

distance steamed 1008 miles.

- 2. Find by mercator sailing the true course and distance from 48° 11' S. $169^{\circ}50$ 'E. to $23^{\circ}36$ ' S. $161^{\circ}42$ 'W.
- 3. Find the course and distance to steam by plane sailing from a position off Ushant (48°20'N. 5° 12'W.) to a position off San Sebastian (42° 30' N. 2° 00' W.).
- 4. Find by plane sailing the course and distance from a position offUshant (48° 20' N. 5° 12' W.), to a position off Cork (51°44' N. 8° 10'W.).
- 5. Find by plane sailing the D.R. position if a vessel steams from a position off Esbjerg (55° 28 'N. 7° 50' E.), on a course of 248° T. for 95 miles.
- 6. Find by plane sailing the D.R. position if a vessel steams 355°T. from a position off Cape Villano (43° 10' N. 9°30' W.), for 18 hours 36 minutes at 9 knots.
- 7. Find the course and distance by mercator sailing between the following positions.

a 52° 35' N. 2°38' E.

b 59°15' N. 4° 30' E .•

- 8. A vessel leaves a position 43° 50' N. 9° 00' W. and steams 328° T. for 440 miles. Find by mercator sailing the D.R. position at the end of the run.
- 9. Initial position 60° 40' N. 0° 30' W. Course 160° T. Distance steamed by log 150 miles. Find by mercator sailing the D.R. position at the end of the run.
- 10. A vessel steams a course of 090^0 T. for 145 miles from an initial position 57° 50' N. 3° 30' W. Find the D. R. position at the end of the run.

CHAPTER 5

ME TRAVERSE TABLE AND ME TRANSFERRED

POSMON LINE

The traverse tables are tabulated solutions of plane right angled triangles. A table is provided for each value of the acute angles from 1° to 89° at 1° intervals, each table giving values of the three sides for a hypotenuse value from 1 unit to 600 units. By interpolation and extrapolation any right angled triangle may be solved with the traverse tables.

Traverse tables in nautical tables are specifically designed to solve the formulae associated with the parallel sailing and plane sailing problems, and columns are headed accordingly.

Description of tables

There is one table for each whole number of degrees of the acute angles in the right angled triangle from 1° to 45°. To avoid unnecessary repetition, values of angles between 45° and 89° are listed at the foot of the table which is given for the angles complement. Separate column headings are given at the foot of each column to be used when the angle required is listed at the bottom of the page. Three columns are given with each table these being headed, hypotenuse, adjacent, and opposite. The length of the adjacent and opposite sides of the

triangle are given for each value of the hypotenuse between 1 and 600. To facilitate the solution of the parallel sailing formula to solve the right angled triangle shown in figure 5.1 which corresponds to the parallel sailing formula;

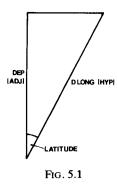
departure ...

<u>d'l</u>-cosme latitude.

ong

Alternative coulmn headings are given for the hypotenuse and the adjacent columns. The hypotenuse column is also headed d'long, and the adjacent column is also headed departure. In this case the table degree headings will represent degrees of latitude.

To facilitate the solution of the plane sailing problem the alternative headings distance, d'lat. and departure are given to the hypotenuse, adjacent and opposite columns respectively. In this case the table degree headings will represent the course angle in the plane sailing triangle.



Solution of the paraDel sailing formula departure

d'l cosine latitude.

ong.

Procedure

- 1. Locate the table which is headed with the whole number of degrees of the latitude given.
- 2. In the column headed d'long_ (hypotenuse column), locate the value of the d'long. given.
- 3. Read off the value of departure against the required value of d'long. from the column headed departure (adjacent column).
- 4. If the latitude given is not a whole number of degrees, repeat for the next highest value of whole number of latitude and interpolate between the two results according to the number of minutes in the latitude.

Example 1. Find the departure for a d'iong. of 138' in latitude 38°.

- 1.Enter table 38°.
- 2.Go down the d'long. column to locate 138. 3. Against 138 extract a departure of 108 · 7'.

Example 2. Find the departure in latitude 65° 40' for a d'iong. of 39.4'.

- 1.Enter the table headed 65° (at foot of the page).
- 2.Locate a d'long. of 39·4' in the column headed d'long.
- 3. Against 39.4, interpolating between 39 and 40, extract a de£arture of 16.6. (Interpolation may be facilitated by mentally shifting the decimal place and locating a d'long. of 394. This gives a departure of 166. The decimal place can now be replaced to give departure 16-6).
- 4.Repeat for a latitude of 66° . This gives a departure of $16 \cdot 0$.
- 5. Interpolate between 16.6 and 16.0 for a latitude of 65° 40'answer must lie two thirds of the way from 16.6 towards 16.0. The required departure is therefore 16.2'.

To solve the plane sailing triangle

The headings distance, d'lat. and departure are used, and the table degree headings are used as the course angle. The course should be expressed in quadrantal notation. In practice the problem is usually required to be solved with the course and distance known, in order to find a D.R. position. In this case the d'lat. and departure are easily extracted against the distance steamed. The tables are a little more difficult to use if the d'lat. and departure are known and it is requir8d to find the course and distal1,j::e. In practice this problem is usually done by calculation for accuracy, but it is possible to ~et a quick solution by the traverse table by finding the table in which the values of d'lat. and departure appear against each other. The distance can then be taken against these values and the course from the table heading. If interpolation is required, this may take some practice. (See example 3.)

Example 1

Given course 148° T., distance 520 miles. Find the d. lat. and dep.

Course 148° becomes S. 32° E. in quadrantal notation.

Steps

- 1. Find the page headed 32°.
- 2. Move down the page in the dist. column to 520.
- 3. Take out the d. lat. and dep. from the appropriate columns. *Answer*. Course S. 32° E. and dist. 520 M., d. lat.=441' S.,

dep.=275·6 M. E.

The course being in the S. E. quadrant indicates that the d. lat. is named S. and the departure is named E.

Example 2

Given course S. 62° W., dist. 47.4 M., find the d. lat. and dep.

Steps

- 1. Note that the angle is greater than 45° and will therefore be at the bottom of the page.
- 2. The dist. column is the same whether we are dealing with the top or bottom of the page, but the columns headed d. lat. and dep. are reversed, since we are concerned with complementary angles.

- 3. Turn to the page where the angle is 62° .
- 4. Shift the decimal point on the distance given, and look up 474 in the dist. column. This makes the task easier.
- 5. The d. lat. is 222.5 and the dep. is 418.5. Having multiplied the distance by 10, it will be necessary to divide these by 10 to arrive at the correct relationships for a distance of 47-4 miles.

Answer. Course S. 62° W. and distance 47-4 M. give d. lat. 22·25' S. and dep. 41·85 M. W.

Example 3

Given d. lat. = 339-6' N., dep. = $295\cdot2$ M. W., to find the course

and distance.

Steps

- 1. Note that the d. lat. being greater than the dep. the angle will be less than 45° , and will therefore be found at the top of the page. Also, the values are near one another, so that the angle is approaching 45° .
- 2. Open the table at about 35 \sim , and look down the d. lat. and dep. columns. The given values are found to be widely separated, so turn over a few pages, to 39 $^{\circ}$, and again look up the values. Here they are much closer, so continue to turn over the pages until they are found as near together as possible-this will be on the page headed 41 $^{\circ}$.

Answer. With d. lat. 339·6' N. and dep. 295·2 M., W., course= N. 41° W. Dist=450 M.

The values may not always be found so easily as in the examples shown. It may be necessary to (1) interpolate or (2) use aliquot parts. Interpolation for the factors dist., d. lat. and dep. can be quite accurate, since we are dealing with similar triangles; but for angles, the interpolation, though not exact, is within practical limits.

To change d. long. into departure and vice versa

Example

Find the departure corresponding to a d. long. of 58,5' in latitude 50° 24' N.

Under angle 50°, look up 585 in the dist. column, and this gives

376.0 in the d. lat. column.

Similarly, angle 51 $^{\circ}$ and dist. 585 give 368·2 in the d. lat.

column.

The dep. corresponding to the d. long. of 58.5 will therefore lie between 37,6 and 36,82. The interpolation is carried out thus, and, with practice it can be done mentally.

for angle 50° and dist. 585, d. lat. = 376.0 for angle 51° and dist. 585, d.lat.=368.2

diff. for 1 $^{\circ}$ = 7.8

multiplied by
$$0.4$$
 0-4

diff. for
$$0.4^{\circ}$$
 3.12

:. angle 50.4° and dist. 585 give d. lat. 376.0-3.12=372,9. *Answer*. In lat. 50° 24' N., d. long. 58.5', dep.=37.29 M.

To solve the plane sailing problem Example

A vessel steering 240° T. at 15 knots leaves a position 30° N. 179° 15' W. Find the position of the vessel after 24 hours.

Course
$$240^{\circ} = S.\ 60^{\circ} W.$$
, distance = $24 \times 15 = 360 \text{ m}$.

Procedure

- 1. Turn up the page in the traverse table headed 60°.
- 2. Using the column names at the foot of the columns, move up the distance column to 360.
- 3. Extract the d. lat. and the departure from the appropriate columns named so (d.lat.=180·O' dep.=311·8).
- 4. Apply the d. lat. to the initial latitude and calculate the mean la t.
- 5. Enter the page headed with the mean lat., and using the headings d. long. and dep. go down the dep. column to 311.8 and extract the d. long.
- 6. Apply d. long. to the initial longitude.

mean lat. 28° 30'0' N.

Note

Direction of d. lat. and d. long taken from the name of the course F

position left 30° 00·0' N. 179° 15,0' W.

arrival position 27° 00·0' N. 174° 46·3' E.

The solution of the mid lat. problem is exactly the same except that the correction to mean lat. is applied before taking out d. long.

Example

Find by use of traverse table the course and distance from A lat. 46° 30' N., long. 15° 45' W. to Blat. 43° 50' N., long. 25° 28' W.

A lat. 46° 30' N. long. 15° 45' W. A lat. 46° 30' N.

Blat. 43° 50' N. long. 25° 28' W. Blat. 43° 50' N.

d.lat. <u>160' S</u>. d. long. <u>583' W</u>. 2)<u>90° 20' N</u>.

mean lat. 45° 10′ N.

M. lat. 45° 00', d. long. 583' gives dep. $412\cdot2$ M. lat. 46° 00', d. long. 583' gives dep. $405\cdot0$

diff. 7·2 ... For M. lat. 45° 10', d. long. 583' dep.=411·0. From traverse table, with d. lat. 160' S., dep. 411' W. (By inspection) co. S. 68io W. dist. 441 miles.

.I

Note

If the mid lat. had been used the distance would have been 442 miles.

If set and drift is required, this will be found by calculating the course and distance between the position by dead reckoning and the position by observation. The method is, therefore, the same as shown in the example.

Note

If the solution of any triangle is required where the length of one of the sides is greater than the range of lengths given in the tables, then a solution can be found by dividing each known side by some convenient factor, usually 2. Then the length of any side found must be multiplied by the same factor.

EXERCISE SA

Traverse table

1.True co.=N. 25° E. dist. =238 M. Find the d.lat. and the dep.

2.True co. = S. 100 E. dist. = 333 M. Find the d. lat. and the dep.

3.True co.=N. 40^{0} W. dist. =505 M. Find the d. lat. and the dep.

4.True co.=S. 70^{0} W. dist. =214 M. Find the d. lat. and the dep.

5.True co.= 306° dist. = 176 M. Find the d. lat. and the dep.

6.True co.= 065° dep. = 173.3 M. Find the d. lat. and the dist.

7. True co. = 148° d. lat. = 386-7' Find the dep. and the dist.

8.Dist. =436 M. dep. =262-4 M. Find the course and the d. lat.

9.d.lat. =447.6' N. dep. = 198.3 M.E. Find the course and the dist.

10.d. lat. =351'1' S. dep. =229.3 M.W. Find the course and the dist.

11.d. lat. = 44.6' N. dep. = 14.5 M.E. Find the course and the dist.

12.d.lat. $=312\cdot3'$ S. dep. $=231\cdot1$ M.W. Find the course and the dist.

13.d. lat. =308·5' N. dep. =367·7 M.W. Find the course and the dist.

14.d. lat. $=855 \cdot 0'$ S. dep. $=380 \cdot 8$ M.E. Find the course and the dist. 15. True co. $=036^{\circ}$ dep. $=723 \cdot 0$ M. Find the dist. and the d.lat.

EXERCISE 5B To change dep. into d. long. by inspection Find the d. long, given

1.dep. = 354.8 M. lat. = $50^{\circ} 00' \text{ N}$.

2.dep. = 261.8M. lat. = 35° oo'N.

3.dep. =246.0 M. lat. = $42^{\circ} 30' \text{ N}$.

4.dep. = 197.0 M. lat. = $38^{\circ} 12' \text{ N}$.

5.dep. =348-4 M. lat. = 27° 00' N.

6.dep. $=361 \cdot 2$ M. lat. $=75^{\circ} 00'$ N.

7.dep. =294·6 M. lat. =52° 00' N.

8.dep. = 326.9M. lat. = $36^{\circ}30$ 'N.

9.dep. =444-4 M. lat. = 19° 15' N.

10. dep. =258.7 M. lat. = $50^{\circ} 45' \text{ N}$.

EXERCISE 5C To change d. long. into dep. by inspection Find the dep., given

1.d. long. =260-4' lat. $=40^{\circ} 00'$

2.d. long. =351,3' lat. =48° 15'

3. d. long. =
$$58 \cdot 1'$$

lat. =
$$56^{\circ} 00'$$

4. d. long. =
$$37.6$$
'

lat. =
$$25^{\circ} 00'$$

5. d. long.
$$=667.0$$
'

lat. =
$$47^{\circ} 30'$$

6. d.
$$long. = 44,4'$$

lat. =
$$35^{\circ} 15'$$

7. d. long. =
$$518.5$$
'

lat. =
$$36^{\circ} 30'$$

lat. =
$$58^{\circ} 30'$$

lat. =
$$67^{\circ} 30'$$

lat. =
$$17^{\circ} 30'$$

EXERCISE 5D To find the course and distance

By inspection of the traverse table, find the course and distance

From

Th

long. 177° 50′ W.

5. L lat.

10° 10' N.

M lat. 09° 00' N.

long. 34° 40′ W.

long. 29° 10′ W.

6. Find the set and drift, given

D.R. pos. lat. 50° 13' N., long. 15° 15' W. Pos. by obsn. lat. 50° 28' N., long. 14° 44' W.

- 7. Given initial position, lat. 40° 40' N., long. 4° 04' W.; course 214° T., dist. 100 M., find the D.R. position.
- 8. Find the true course and distance from 47° 06' N., 39° 10' W., to 48° 53·5' N., 27° 04' W.
- 9. Find the true course and distance from lat. 22° 33′ S., long. 96° 48′ E., to lat. 19° 43′ S.,

long. 92° 46′ E.

10. Find by inspection of the traverse table the course and distance from 18° 35-7' N., 39° 53' E. to 22° 45,5' N., 37° 15,5' E.

Running up a D.R.

The traverse tables are used to find the D.R. position when more than one course and distance has been steamed since the last observed position. This problem is very quickly solved if the

intermediate alter course positions are not required, by tabulating the d'lats. and departures for the individual courses and distances. These are then added (or subtracted if of opposite name), to find the total d'lat. and departure. The d'lat. is then applied to the initial latitude and the mean latitude found. The total departure is then converted to d'long. and applied to the initial longitude.

Example 1

A vessel observes her position to be 40° 30' N. 35° 15' W. She

then steams the following courses and distances:

 056° T. distance 45 miles 020° T. distance 20 miles 335° T. distance 35 miles 300° T. distance 50 miles

Find the D.R. position.

		D. fat.		Departure			
Course	Distance						
		N.	S.	E.	W.		
N. 56° E.	45	25.2		37.3			
N. 20° E.	20	18.8		6,8			
N. 25° W.	35	31.7			14.8		
N. 60° W.	50	25.0			43.3		
		100· 7		44.1	58-1		
		,		•	44.1		

d.lat.=
$$100.7$$
 N. dep.= 14.0 W.

initial latitude 40° 30.0' N.

d.lat. 1 ° 40,7' N.

arrival latitude 42° 10-7' N.

mean latitude =41° 20,3' N. dep.14·Ogivesd.long.=18·6'W. initial position 40° 30·0' N. 35° 15' W.

1 ° 40,7' N. 18·6' W.

arrival position 42° 10-7' N. 35° 33,6' W.

If during the steaming of the courses a current is estimated to be setting this can be treated as just another course with the drift as the distance, and the d. lat. and departure found summated with the other courses.

Example 2

A vessel steamed the following courses and distances:

165° distance 50 miles

072° distance 63 miles

112° distance 84 miles

256° distance 58 miles

A current set 300° T., drift 10 miles. If the initial position was 46° 19' N. 37° 47' W., find the final position and the course and distance made good.

		D. lat.		Dep.				
Course	Distance							
		N.	S.	E.	W.			
S. 15° E.	50		48.3	12.9				
N. 72° E.	63	19.5		59.9				
S. 68° E.	84		31.5	77.9				
S. 76° W.	58		14.0		56· 3			
N. 60° W.	10	5.0			8,7			
		24.5	93.8	150.7	65.0			
			24.5	65.0				

Resultant d. lat. and dep. 69,3 S. 85.7 E.

Initial latitude 46° 19,0′ N.

D.lat.
$$69.3'$$
 S. Mean lat. $=45^{\circ} 44.3'$ N.

D. long.
$$= 121,7'$$
 E.

Arrivallatitude 45° 09-7' N.

Initial position 46° 19.0' N. 37° 47,0' W.

Arrival position 45° 09,7' N. 35° 45,3' W.

From tables with d. lat. 69.3' S. dep. 85,7' E.

course=S. 51° E. dist.=llOmiles

Information required may vary somewhat, and each problem must be carefully considered. In some problems the set and drift of the current is asked for. To find this an observed position at the end of the traverse must be given and this should be compared with the D.R. calculated.

EXERCISE 5E

1. Find by traverse table the vessel's position at the end of the

fourth course:

Initial position $46^{\circ} 45'$ N. $45^{\circ} 30'$ W.

First course 202° T. by 72 miles Second course 272° T. by 72 miles Third course 33r T. by 36 miles Fourth course 050° T. by 36 miles

2. Find by traverse table the vessel's position at the end of the

third course;

Initial position 60° 30' N. 16° 45' W.

First course 213° T. by 64 miles Second course 306° T. by 72 miles Third course 082° T. by 80 miles

3. Find by traverse table the ship's position at the end of the third

course;

Initial position 39° 25' N. 9° 38·5' W. First course 262° T. by 9 miles Second course 169° T. by 146 miles Third course 109° T. by 144 miles

4. Find by traverse table the position at the end of the third

course;

Initial position 12° 12′ S. 50° 58′ E. First course 296°T. by 60 miles Second course 237°T. by 55 miles Third course 215°T. by 101 miles

- 5. A vessel observes a noon position 37° 54' N. 178° 29' E. The course is then 230°T. at 15 knots until 1800 hrs when an SOS is received from a position 37° 15' N. 179° 35' W. If speed is increased to 16 knots what is the course to be steered to the distress and what will be the ETA.
- 6. Find by traverse table the course and distance between the following positions.

A 51°30'N.176°42'W. B 50° 19' N. 179° 35' E.

7. Find by traverse table the course and distance between the following positions.

A 54°30' N. 37° 30'W. B 52°15' N. 42° 15'W.

8. A vessel obtained a noon position 34° 06' S. 172° 09' E. She then steamed the following courses and distances;

First course 321°T. by 75 miles Second course 037°T. by 52 miles

Third course 137°T. by 110 miles

A current was estimated to have set 260°T. by 20 miles in the interval. Find the EP at the end of the third course.

TRANSFERRING THE PosmON LINE

If a position line is observed at some initial time, a position line valid for some later time may be found by moving the observed line in the direction made good by the vessel and by the amount of the distance steamed. The position line so found is referred to as a transferred position line and a fix may be produced by crossing it with another position line observed at the later time. The accuracy of the transferred position line depends upon the reliability of the course and distance used for running up.

Transferring the position line may be done by taking any point on the original position line and using it as a departure position. The course and distance may then be applied to this position (a) by laying off the course and distance on the chart from this point, or (b) by applying the course and distance by traverse table. The transferred position line is then drawn through the position obtained by running up, in the same direction as the original position line. The first method is normally used when coasting and navigating by the methods of chartwork, when the time intervals involved are small. The second method is normally used when out of sight of land and navigating by astronomical methods. The time intervals involved are usually longer, of the order of a few hours.

The mooing fix

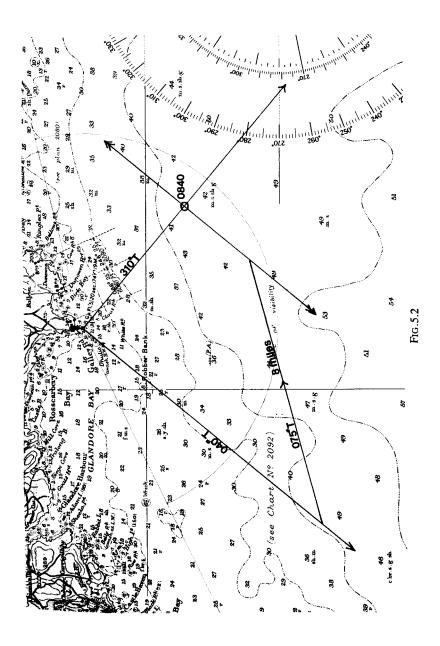
This is the name given to the fix produced by crossing an observed position line with a position line transferred or run up from an earlier observation.

Example

At 0800 hrs Galley Head was observed to bear MooT. At 0840 it was observed to bear 310° T. Find the position of the vessel at 0840 if the course and distance made good in the interval was estimated to be 075° T., 8 miles.

Procedure (refer to figure 5.2)

- 1. Layoff the two position lines given by the two bearings at $0800 (040^{\circ})$ and $0840 (310^{\circ})$, from the charted position of the point observed. Mark the lines with single arrows.
- 2. From any convenient point on the first position line, layoff the course and distance made good (075° by 8 miles).



- 3. Draw the transferred position line through the position reached in (2), parallel to the first position line (040), to cut the second position line (310). Mark the transferred position line with double arrows. This point of intersection gives the position of the ship at the time of the second bearing.
- 4. The position at the time of the first bearing may be found if required by transferrin~ the course and distance made good, through the second position, to cut the first bearing.

The mooing fix with tide

Any tide estimated to set in the duration of the running fix may be allowed for by laying off the set and drift from the end of the course and distance, before transferring the position line.

Example

At 1300 hrs Old Head of Kinsale Lt. Hse. was observed to bear 030° T. and at 1330 hrs the same lighthouse was observed to bear 295° T. Find the position at 1330 if the vessel steered 080^{0} T. at 16 knots in the interval and a tide was estimated to set 1000T. at 3 knots.

Procedure (refer to figure 5.3)

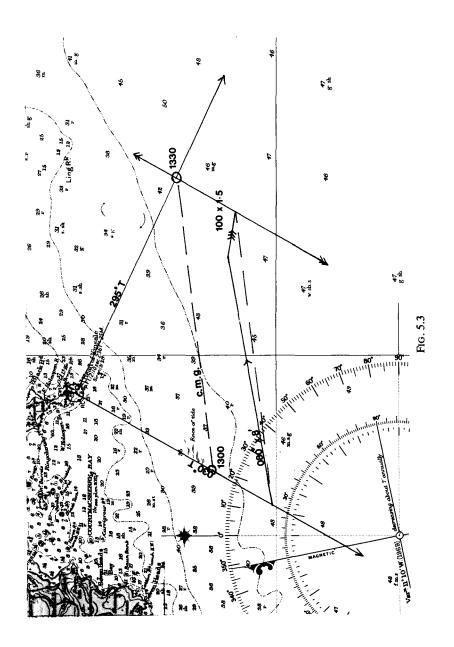
- 1. Layoff the two position lines given by the bearings at 1300 and 1330.
- 2. From any convenient position on the first bearing line layoff the course steered and the distance steamed.
- 3. From the end of the course and distance layed off in (2), layoff the direction of the tidal set and the amount of the drift (1000T. by 1'5').
- 4. Layoff the transferred position line through the end of the tide, parallel to the first position line (0300), to cut the second position line (295°). This intersection gives the vessel's position at the time of the second observation.

Note

The course and distance made good in the interval is given by the line joining the original departure position selected, and the end of the tide. To find the position at the time of the first observation, this course should be transferred through the position at the time of the second observation, to cut the first position line.

The running fix with leeway

If the vessel is making leeway during the interval of the running fix, this should be applied to the course steered before laying off from the first bearing.



Transferring a position circle

The general principles of the running fix apply, irrespective of the form that the position lines take. To transfer a position circle however it is easiest to transfer the centre of the circle, that is the position whose distance has been observed. The transferred position circle is then drawn centred upon this transferred position obtained.

Example

The distance from Wolf Rock Lt. Hse., bearing approximately north west, was observed by vertical sextant angle to be 3.0 miles. Forty-five minutes later the distance by vertical sextant angle of the same lighthouse was observed to be 3.4 miles. Find the position at the time of the second observation if the vessel was steering mOoT. in the interval and made good 4 miles by log.

Procedure (refer to figure 5.4)

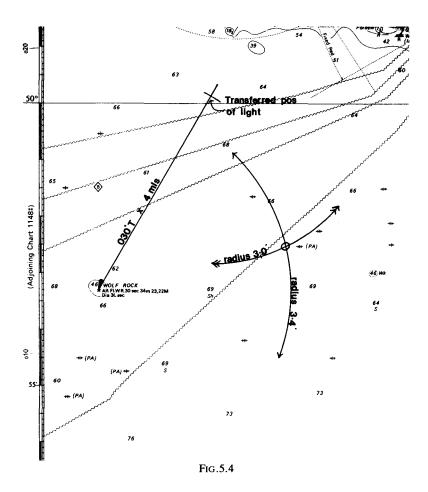
- 1. Layoff the course and distance made good in the interval (030 by 4 miles), from the position of the pQint observed (Wolf Rock). 2. Draw the transferred position circle, radius 3.0 miles, centred upon this transferred position.
- 3. Draw the second position circle, of radius 3.4 miles, centred upon the position of Wolf Rock itself, to cut the transferred position cIrcle. The intersection will give the position at the time of the second observation.

Running up the position line by traverse table

When navigating out of sight of land, position lines are obtained by astronomical observation. The time intervals between observed position lines when using the running fix method may be as long as two or three hours. The small scale charts used for ocean navigation are not suitable for transferring the position line by plotting so that in practice the traverse table is used. The method is the same as that described for solving the plane sailing problem, that is applying the course and distance steamed to an initial position to find a D.R. position at the end of the run. The position line may be transferred by using any position on the line to which the course and distance is applied. The position obtained gives a position through which the transferred position line may be drawn.

Example

At 0930 an astronomical observation gave a position line running $025^{\circ}/205^{\circ}$ passing through position 42° 30' N. 32° 08' W. Find a position through which to draw the transferred position line at 1200 hrs if in the interval the vessel steered 075° T. and made good 35 miles.



Procedure

- 1. Enter the traverse tables with the course and distance, and extract the d'lat. and departure.
- 2. Apply the d'lat. to the initial latitude to obtain the latitude at 1200 hrs.
- 3. Calculate the mean latitude and convert departure into d'long.
- 4. Apply the d'long. to the initial longitude to give the longitude at 1200 hrs.

Initial pos. 42° 30·0′ N. 32° 08′ W. mean lat.=42° 34·5′ N.

d'lat.
$$9.1$$
'N. 45.9 'E. = d'long. (departure= 33.8 ')

hrspos. 42°39·1'N. 31°22.1'W.

Transferred position line runs 025°/205° through 42° 39·1 N. 31° 22·1'W.

This problem is discussed further in the chapter devoted to plotting the astronomical position line.

Doubling the angle on the bow

This problem is a special case of the running fix method, which enables a fix to be obtained with a minimum of construction and plotting. It requires the time at which a point of land or beacon has a certain relative bearing expressed as an angle on either bow, and also the time when the same point is twice that angle on the bow, to be observed. It also requires a knowledge of the course steered and the distance run in the interval between the observations and a negligible effect from tide or wind ..

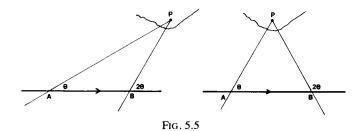
In figure 5.5, () and 2 () are the relative bearings observed.

and angle BAP+angle APB=2 ()(external angle of a triangle is equal to the two internal and-opposite angles).

thus angle APB= ()and the triangle is isosceles.

thus AB=PB

We can conclude therefore that the distance of the vessel from the point of land observed at the second observation, is equal to the distance run in the interval between the two observations.



Procedure

- 1. Note the time when a point of land or beacon is at any convenient angle on the bow.
- 2. Note the time when the same point of land or beacon is at twice the angle on the bow.
- 3. Calculate the distance run between the observations.
- 4. Layoff the bearing of the second observation after converting to a true bearing by application of the ship's head. Mark off the observed position at a distance from the point

observed equal to the distance run calculated in (3). This gives the vessel's position at the me of the second observation.

EXERCISE 5F

- 1. A point of land is observed to bear 205°T. from a vessel steering 248°T. at 15 knots. Forty-eight minutes later the same point of land was observed to bear 147°T. Find the distance off the point at the time of the second observation.
- 2. A lighthouse was observed bearing 050°T. from a vessel steering 100°T. After running for 7 miles by log the lighthouse was observed to bear 000°T. Find the distance off the lighthouse at the time of the second observation.
- 3. A vertical sextant angle observation of a lighthouse gave a distance off of 6.8 miles. After steaming 174° T. for 40 minutes at 11 knots the vertical sextant angle was observed to be the same as at the first observation, while the lighthouse 054° by compass. Find the true bearing and distance from the lighthouse at the time of the second observation.

The following questions are set on the Admiralty Instructional chart No. 5051 (Lands End to Falmouth).

- 4. At 0800 Wolf Rock Light was observed to bear 048°T. from a vessel steering 085°T. at 16 knots. Twelve minutes later Wolf Rock was observed to bear 337°T. If a tide was estimated to set 155°T. at 3.5 knots in the interval, find the latitude and longitude of the vessel at the time of the second observation.
- 5. At 2000 hrs. Tater-Du light was observed to bear 338° T. from a vessel steering 250^{0} T. at 18 knots. Thirty minutes later Wolf Rock was observed to bear 260° T. If a tide was estimated tD set 145° T. at 2.5 knots in the interval, find the ship's position at 2030.
- 6. Lizard Pt. Light was observed to bear OISOT. from a vessel steering 270⁰T. at 16 knots and making 5° leeway due to a northerly wind. 1 h 18m later Wolf Rock was observed to bear 335°T. If a tide was estimated to set 11 O°T. at 1·0 knot in the interval, find the ship's position at the time of the observation of Wolf Rock.
- 7. At 1200 hrs. a vessel observes Bishop Rock Lt. Hse. (position 49° 52·2' N. 6°26·5' W.), to bear035°T. The vessel then steams 278° for 3 hours at 15 knots. Find by traverse table a position through which to draw the transferred position line at 1500 hrs., and its direction, in order to cross it with an observation of the sun.

CHAPTER 6 TIDES

Tides and tidal streams are the result of gravitational attractions of astronomical bodies, mainly the sun and the moon. The tide raising forces of these bodies causes a horizontal movement of water such that tidal waves are produced directly underneath the tide raising body, and also on the opposite side ofthe earth to the body. Vanation in the height of water at any place on the earth will occur as the earth rotates with respect to these tidal waves, producing two high waters in each rotation. The hi~hest high waters will occur when the sun and the moon are in line wIth the earth, that is at new moon and at full moon. The solar tide then reinforces the lunar tide. Such tides are called spring tides occurring approximately once in two weeks. At first and third quarters the solar

tide decreases the height ofthe lunar tide. Such tides are called neap tides.

The magnitude of tidal effects are relatively small unless they are

increased by resonance in ocean basins or by the modifying effects of land and sea bed formations. This occurs to a marked extent in the North Atlantic which responds to semi diurnal components of the tide raising forces, and in which large tides are produced by the funneling effect of coastline shapes.

Tidal streams

Tidal streams are the horizontal movements of water due to the tide raising forces. In European waters they are of a semi diurnal nature directly related to the vertical tIdal variations. Their directions and rates can therefore be predicted with reference to times of high water at chosen locations. These predictions are made available to the navigator by:

a. Tidal information on Admiralty charts. b. Tidal stream atlases.

Currents

These are horizontal movements of water caused by meteorological conditions, or by flow of water from river estuaries. They' are not periodic as are tlie tidal streams and those currents which are due to local meteorologial conditions are not included in tidal predictions. Consistent strong winds may therefore modify the streams predicted to a marked extent. The largely permanent effect of the flow of water from rivers is included in tidal stream

predictions.

84

Tidal information on Admiralty charts

Selected positions on Admiralty charts are chosen for which to give tidal stream information. These positions are marked by a magenta diamond with an identifying letter inside. At some convenient place on the chart a table is given for each tidal diamond, each table being headed by its appropriate identifying letter. The tables give the direction, and the spring and neap rates for each hour of the tidal cycle. The hours are referred to the time of high water at some standard port which mayor may not appear on the chart. Many charts are referred to high water Dover. Information is given from 6 hours before H.W. to 6 hours after H. W. at hourly intervals. In order to relate the information to the ship's zone time the zone time of high water

at the chosen standard port must be obtained from Admiralty tide tables.

To find the direction and rate at points between the tidal diamonds some interpolation between the tables is necessary together with some personal judgement as to the likely effect of the coastline shape on the direction of the stream. In this respect it should be remembered that tidal streams tend to flow parallel to coastlines and into and out of estuaries, although this may not be the case especially near the turn of the tide. To facilitate this tidal arrows are shown on charts showing the approximate mean direction of the flood (an arrow with feathers), and the ebb (an arrow without feathers), or a current (a wavy arrow). (See chart booklet 5011 for abbreviations and symbols on Admiralty charts.

Tidal stream atlases

These are published by the Hydrographer to the Navy in a series of 11 booklets to cover the coastal waters of the British Isles. Each booklet contains chartlets of the covered area for hourly intervals from 6 hours before H. W. Dover to 6 hours after H. W. Dover. The times of high water Dover may be obtained from Admiralty Tide Tables Vol. I (N.P.200). On each chart let the direction of the tidal stream for that hour is shown by arrows, the length and the boldness of the arrows indicating approximately the strength of the stream. Figures are given against some arrows which show the mean neap and spring rates at that place. These are shown thus:

11,24

meaning that the mean neap rate is 1.1 knot and the mean spring rate is 2.4 knots. Interpolation or extrapolation between these figures can be done by taking the range at Dover for that day and comparing it with the neap and spring ranges. An interpolation diagram is included with fun instructions to facilitate this.

Tides

The term tide refers to the variation in the level of the water

Datum and remarks Fidal Levels referred to Datum of Soundings MLWS Heights in metres above datum MHWS MHWN MLWN MLWN Long 50°04′ 50°06′ 50°06′ 50°05′ 50°05′ 50°05′ 50°05′ ž z

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	ä	5	217	232	777	349	2	8	8	8	10,	212	224		217
	Rate	2	ò	0.5		Ö	0.7	60	1:1	800	Ö		0.7	8	60 Ö
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50°08'0N 4 52'3W		8	9		Slack		9	9	0.7 (0.5	Slack	0.5	9	0.7	0.5
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Fig. 6.1

Reproduced from British Admiralty Tide Tables with the sanction of the Controller, H.M. Stationery Office and of the Hydrographer of the Navy.

After HW

0 4 8 4 ± 5 ± 4 8 4 8 6

Before HW

surface due to the tide raising forces. The following terms will be used with reference to tidal prediction.

Chart datum

This is an arbitrary level below which charted soundings are expressed.

Height of tide

This is the height of the water surface at any instant above the level of chart datum. Thus the actual depth of water is given by the sum of the charted sounding and the height of tide above chart datum. Note that it is possible to have a negative height of tide although in general chart datums are chosen such that they rarely occur.

Mean high water springs (M.H. W.S.)

This is the height above chart datum, which is an average of the heights of all the two successive high waters at spring tides, throughout the year. This will vary from year to year as the maximum declination of the moon varies over an 18.6 year cycle. The value of M.H.W.S. is therefore averaged over the 18.6 year cycle. The average maximum declination of the moon over this 18.6 year cycle is 23%°.

Mean low water springs (M.L.W.S.)

This is the height, which is an average of the two successive low waters at sRring tides throu~hout a year when the average declination of the moon is 231/2.

Mean high water neaps (M.H.W.N.)

This is the height above chart datum which is an average of the two successive low waters at neaR tides, throughout a year when the average declination of the moon is 231/2°.

Mean low waterneaps(M.L.W.N.)

This is the height above chart datum which is an average of the two successive low waters at neaR tides, throughout a year when the average declination of the moon is 23%°.

Height of tide above low water

This is the height of the water surface at any instant, above the level of the nearest low water. This height can be found from the tide tables. The height of the low water is added to the height above low water to give the height of tide above chart datum.

Drying height

This is the height of a point on the sea bed which lies above the level of chart datum. Such a point will dry out when the hei~ht of tide above chart datum on a falling tide is equal to its drying heIght.

Highest astronomical tide. Lowest astronomical tide (H.A.T. L.A.T.)

These are the highest and the lowest levels which can be predicted to occur under any combination of astronomical conditions, under normal meterological conditions.

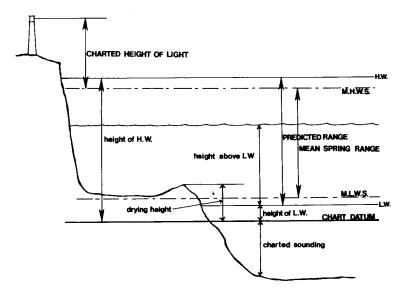


Fig. 6.2 shows the relationship between the terms defined above.

Prediction of tidal times and heights

Soundings on Admiralty charts are expressed below chart datum.

This is an arbitrary reference level chosen such that there will rarely be less water than is indicated on the chart. The level of chart datum may differ between charts, but are at present being standardised to approximate to lowest astronomical tide, which is the lowest level which can be predicted to occur under any combination of astronomical conditions under normal meteorological conditions. The relationship between chart datums at various places and the L.A.T. are shown in Table V in the front of the Admiralty Tide Tables Vol. 1. For comparison of chart datums between charts of different areas Table III in the tide tables is consulted. This gives the height of chart datums at various places relative to the ordnance

datum (Newlyn) which is the datum for the land levelling system of England, Scotland and Wales. For chart datums at places outside these countries the reference is the datum used in the respective countries. Because of differences in chart datums there may be differences in soundings on different charts of the same area. The level of the chart datum is shown on Admiralty charts in the titles .

. In all cases however tidal predictions for ports are referred to the chart datum established at that port and whIch is used on the largest scale chart of it. The total depth of water at any point is therefore the sum of the sounding shown on the chart, and the tidal height above chart datum predIcted from the tide tables.

Tidal calculations

Candidates for Class V and Class IV certificates are required to be able to use the Admiralty tide tables Volume I (European Waters), in order to predict times and heights of high and low waters, and to predict the height of tide at times between high and low water.

The tides of European waters are of a semi diurnal nature, that is there are two high and two low waters each lunar day. Part I of A IT Vol. I gives the predictions of the times and heights above chart datum of these hIgh and low waters for a number of selected ports which are called Standard Ports. For each standard port there is also a tidal curve plotting the tidal height between higo and low water, against the interval of time from the nearest high water. Part II of toe tide tables gives tidal predictions for a large number of ports which lie between the chosen standard ports. These are called secondary ports as their tidal information is given in the form of time and beight differences between the seconoary port and one of the standard ports.

To find times and heights of high and low water at a standard port

These may be extracted directly from Part I of A IT Vol. I for the regl!ired standard port, and for toe required date (see extracts from A IT Vol. I). Note that the times given are in the zone time for that area in which the port lies. The difference between the zone time used and G.M.T. is given at the top of each page. The sign attached to this time difference is appropriate to correct the tabulated zone times to G.M.T. Thus iftfie time zone is~iven as -0100, then the times tabulated are 1 hour ahead of G.M.T. The time zone used for the British Isles is G.M.T., but care must be taken when British Summer Time is being kept. Similarly care must be taken that the time kept in any other country is in fact the time zone used in the tables.

Example (refer to extract from A IT Vol. I)

Find the times of high and low water at Avonmouth on the morning of 29th January 1980, and the depth of water at these times at a place off A vonmouth where the charted sounding is $4 \cdot 2$ metres.

FromAIT H.W.0505 Ht.U-4m

L.W.1140 Ht. 2.0m

Depth of water= charted sounding+ height of tide depthatH.W. = $11 \cdot 4 + 4 \cdot 2 = 15 \cdot 6m$ depthatL.W. = $2 \cdot 0 + 4 \cdot 2 = 6 \cdot 2m$

To find the height of tide at times between high and low water (Standard Port)

This is done with the aid of the tidal curves given with each standard port. There is one curve for neap tides and one for springs. For times between springs and neaps mterpolation between the curves must be done (see examples).

Procedure

- 1. Extract from A IT Vol. I Part 1 the times and heights of the high and low waters that 'straddle' the time for which the prediction is required. This time should be exp,ressed in the same zone time as the tidal predictions for the standard port.
- 2. SUDtract the height of low water from the height of high water to obtain the predictea range.
- 3. Take the difference between the time required for prediction and the time of high water. This is the interval from high water. Note whether the interval is positive (falling tide) or negative (rising tide).
- 4. Compare the predicted ran~ with the mean spring and neap ranges given on the tidal curve. -This will determine wl1ether the spnng curve or the neap curve should be used or whether inteTP-olation between the two is necessary.
- 5. Enter tidal curve or curves with the interval from high water along the horizontal axis and go vertically to meet the tidal curve. From this point go across to oBtain the factor.
- 6. Multiply toe factor by the predicted range found in (2). If the predicted range is between the spring and neap ranges the factor is found by interpolating between the spring and neap factors. If the predicted range is above the spring range then Hie spring factor should be used. If the predicted range is Delow the neap range then the neap factor should be used. The factor multiplied by predicted range gives the height above low water.
- 7~ Add on the height of the low water to obtain the height of tide above chart datum.

Example

Find the height of tide at Avonmouth at 1530 G.M.T. on 9th April 1980, and hence the depth of water at a place \\-IIt:re the rh<ortpr! "nl1nr!ina i" ?() mptrp"

From AITH.W.1245 Ht.1O·0m

time H.W.1245 reqUired time _5_3_0

From tidal curve Spring range=12.3m

Neap range= 6.5m

Predicted range= $6 \cdot 5m$ (use neap curve) .4

From neap curve factor=0'59 (see tidal curve for Avonmouth) .. 5

Height above L. W. = $0.59x \ 6.5 = 3.8 \dots 6$

L. W. =3.5

Charted sounding $= 2 \cdot 0$

Depth of water =9.3 metres

To find the time at which there will be a given del?th of water between high and low waters at a standard port, on a given tide

With this problem it is first necessary to determine the height of tide which corresponds to the given depth of water. This will require consideration of the charted sounding. The problem is often given in the form of a required clearance under a vessels keel. In this case the ship's draft must be given. The draft and the clearance will be the required depth of water.

Procedure

- 1. Extract the times of high and low waters for the tide specified, and the heights.
- 2. Subtract the height of low water from the height of high water to obtain the predicted range.
- 3. Ascertam the height of tide above chart datum required to produce the given depth of water (subtract the charted sounding).
- 4. Subtract the height of L.W. to give the height above L.W. 5. Find the factor from:

height above L. W. factor= -----predicted range

- 6. Compare the predicted range with the spring and neap ranges to determine whicll curve to use or whether interpolation between both curves is necessary.
- 7. Enter appropriate curve or curves with the factor and extract the interval from H.W. by the reverse process to that described in the previous example.
- 8. If necessary interpolate between the intervals from H.W. from spring and neap curves, as indicated by the comparison between the predicted range and the spring and neap ranges.

9. Apply interval from H.W. to the time of high water found in (1). Example Find the time when a vessel of draft 6.5 metres will have a clearance of 1.0 metre over a shoal of charted depth 1.0 metre off A vonmouth, on the rising tide of the morning of 23rd February 1980. From A IT 23rd Feb. H. W. 1219 Htl1·0m, L.W.0611 Ht. 2·2m 1 pr. range 8.8m2 Draft 6.5m Clearance 1.0m Required depth 7.5m Sounding _1·_0m_ Height of L.W. 2. 2m

Height above L.W. 4·3m4

F ht. above L. W. actor = ----

pdctd. range

4.3

Spring range 12.3

predicted range 8.86

Neap range 6. 5

From spring curve interval from H.W. =-2h 50m

From neap curve interval from H.W. =-3h20m7

interpolating between springs and neaps for a predicted range of

8-8m interval from H.W.=-3h 09m8

Time of H.W. 12hl.9m

Interval from H.W. -03h 09m

Time required 09h 10m9

Secondary ports

Part II of A IT Vol. I gives tidal information for a large number of secondary ports. This information is given as time and height differences between the secondary port and some convenient standard port.

High and low water time dift'erences

The time differences between high or low water at the secondary port and high or low water at the standard port varies between springs and neaps. There are two values given which should be taken as the maximum and minimum differences. These are tabulated against the time of high or low water at the standard port which will depend mainly on the neap-spring cycle. If the time of high or low water at the standard port falls between the times tabulated then the time differences must be interpolated.

Figure 6.3 shows an extract from Part II of AIT Vol. I. The standard port is Milford Haven.

Example

Find the time of high water at Ilfracombe if the time of high water at Milford Haven is 0330.

496	MILFORD HAV	EN		(see	pag	ge 110)	0100 and 1300	0700 and 1900	e100 and 1300	0700 and 1900	7.0	5.2	2.5	0.7
535	Ilfracombe .			51	13	4 07	-0030	-0015	-0035	-0055	+2.2	+1.7	+0.5	0.0
536 537 538 539	Rivers Taw and T Appledore Yelland Marsh Fremington Barnstaple	orridge	:	51 6 51 6 51 6	04 05	4 10	-0010	-0015 -0015	+0015 +0100 +0030 -0155	-0015 -0030	+0·5 -0·4 -0·5 -2·9	0·0 -0·9 -1·2 -3·8	-0·9 -1·7 -1·6 -2·2	-0·5 -1·1 +0·1
540	Bideford .			51 0	01	4 12	-0020	-0025	0000	0000	-1.1	- ı ·6	-2·5	-o·7
							Fı	G. 6.3	3					

Produced from British Admiralty Tide tables with the sanction of the Controller, H.M. Stationery Office and of the Hydrographer of the Navy.

T~me diffe~ence for 0100} 2.5 hrs. -0030}

Time reqUIred 0330 15 mins.

Time difference for 0700 -0015

Thus for 0330 the time difference is: $-(0030 - 2.5_6 \times 15) = -(0030 - 6)$

= -0024 mins.

Time H. W. Milford Haven 0330

Time difference -0024

Time H.W. Ilfracombe 0306

Height differences

Differences in tidal height between secondary port and standard port are tabulated for M.H.W.S., M.H.W.N., M.L.W.S., and

M.L.W.N. The differences between the mean spring and mean neap levels should be assumed to vary linearly and can be found by interpolation. For levels outside the mean range the height differences are found by extrapolation. The level of the required tide at the standard port should be compared with the mean spring and neap levels gIVen for the standard port in Part II for interpolation purposes.

Example (refer to figure 6.3)

The height of H.W. at Milford Haven is 6.0 metres. Find the height of H.W. at Ilfracombe.

Difference for M.H.W.S.

RequiredH.W.6·0 1·8 0·5

M.H.W.N.leveI5·2 difference +1·7

$$1 \cdot 0 \times 0 \cdot 5$$
dIfference =+(2'~ $\underline{1.8}$)

$$=+(2\cdot 2-0\cdot 3)=+1\cdot 9$$

H.W. Milford Haven 6.0 metres

Example

Find the times and height of high and low waters at Watchet (A IT 531) on 12th February 1980.

Standard Port	H.W.	L.W.	H.W.	L.W.
(Avon mouth)	0242	0859	1524	2148
dffferences	-0037	-0049	-0039	-0057
Secondary Port				
(Watchet)	0205	0810	1445	2051
Standard Port				
heights	9.8	3.5	10.3	3.2
differences	-1.5	+0.1	-1.5	+0.1

Note

Care should be taken in problems like this that a high or low water at the standard port on the preceding or the following day does not produce a high or low water at the secondary port on the day in question, after the differences are applied.

To find the height of tide at a secondary port at a time between high and low water

Unless indicated otherwise in the tide tables the tidal movements at a secondary port are similar enough to those at the standard port for the tidal curve given for the standard port to be used for the secondary port also. After finding the times and heights of the high and low waters at the secondary port the problem is similar to that for a standard port. The spring and neap ranges for the secondary port must be found to compare with the predicted range to determine which curve to use.

Procedure

- 1. Extract the times of the high and low water on either side of the required time for the standard port, and the heights.
- 2. Apply the time differences to obtain the times of high and low water at the secondary port. Apply the height differences, interpolating between spring and neap ranges, by comparing the heights at the standard port with the mean spring and neap heights given in Part II for the standard port, as explained previously. This gives the heights at the secondary port.
- 3. Subtract the height of low water at the secondary port from the height of high water to obtain the predicted range.
- 4. Take the difference between the required time and the time of the high water to find the interval from H. W.
- 5. Apply the secondary port spring and neap height differences to the heIghtsofM.H.W.S., M.H.W.N., M.L.W.N andM.L.W.S. for the standard port to obtain these values for the secondary port.
- 6. Subtract the height of M.L.W.N. from that of M.H.W.N. to obtain the neap range, and subtract the height of M.L.W.S from that of M.H.W.S. to obtain the spring range. Compare these with the predicted range to determine whether to use the spring curve or the neap curve or whether interpolation is necessary between the two.
- 7. Enter the tidal curve given for the standard port with the interval from high water and extract the factor. Interpolate if necessary between the spring and neap factors.
- 8. Multiply the factor by the predicted range to obtain the height above L. W.
- 9. Add on the height of low water to the height above L. W. to obtain the height above chart datum.

Example

Find the heightoftide atClevedon(ATT 528) at1000G.M.T. on 16th March 1980. What will be the under keel clearance of a vessel of draft 8·1. metres, when passing over a shoal of charted

depth 3.4 metres?

Standard port	H.W.	. Height	L.W.	Height
(Avonmouth)	0654	13.9	141	17 0.41
Differences	-0018	-0.4	-002	4 -0.0 2
Clevedon	-06-3	8-6 -1-3·-5	-13-5-3	3 -04
0.4				
		13.1 =	predicted	l range3
High Water Cle	evedon 063	6 Require	d time _1	000_
Interval from H	I.W.+ 0324		•••••	4
M.H.W.S. M.H	.W.N. M.L	W.N. M.	L.W.S.	
A vonmouth				
mean levels	13.2	10.0	3.5	0.9
Cleve don				
differences	-0.4	-0.2	+0.2	0.0
Clevedon				
mean levels	12.8	9.8	3.7	0.95
	0.9	3.7		
Spring range	=11.9	6·1=nea	ap range	6
Predicted range	=13·1 use	spring cur	ve	
From spring cu	rve for A v	onmouth	factor =0	467
Height above L	W.=0·46x	:13.1	=6.0	8
HeightofL.W.		=_0·_4	=_04	
Height oftide al	bove chart	= 6.4	= 6.49	
Charted soundi	ng	=_3·_4	ļ.	
Depth of water	at 1000 G.	=9.8		
Vessel's draft			=8·1	
Underkeel clear	rance		=1.7 m	netres

To find the time between high and low water at a secondary port, when there will be a given depth of water on a given tide

Procedure

- 1. Extract the times and heights of the high and low water of the given tide for the standard port.
- 2. Apply the time and height differences to obtain the times and heights of the high and low water at the secondary port. Find the predicted range.
- 3. Apply the secondary port spring and neap height differences to the helghtsofM.H.W.S., M.H.W.N., M.L.W.N. andM.L.W.S. for the standard port to obtain these values for the secondary port. 4. Subtract the height of M.L. W.N from that of M.H. W.N. to

obtain the mean neap range, and subtract the height of M.L. W.S. from that of M.H.W.S. to obtain the mean spring range for the secondary port. Compare these with the predicted range at the secondary port to determine which tidal curve to use or whether to interpolate between the two.

- 5. Ascertain the required height of tide above chart datum.
- 6.Subtract the height of L.W. to obtain the height above L.W.
- 8. Enter the tidal curves for the standard port and extract the interval from H. W. Interpolate if necessary between the spring interval and the near interval.
- 9. Apply interva from H.W. to the time of high water at the secondary port to obtain the required time.

Drying heights

A drying height is a 'sounding' on a chart of a point which lies above the level of chart datum. The height of the point above chart datum will give the height of tide above chart datum when the point dries on a falling tide or covers on a rising tide.

Example

A vessel is berthed at Watchet alongside a quay with a drying height of 1.5 metres. Find the time when the vessel wil\ take the ground on the falling P.M. tide on 28th January 1980 if the vessels draft is 3.8 metres.

	H.W.	Height	L.W.	Height
Standard port				
(Avonmouth)	1638	11.1	2301.	2.21
Differences	-0042	-1.6	-01.08 -	-0.1
Watchet	1556	9.5	2153	2.32

-7 ·-2= predicted range2

M.H.W.S. M.H.W.N. M.L.W.N. M.L.W.S.

Α	vonmoutl	a

mean levels 13.2 10.0 3.5 0.9

Watchet

differences -1.9 -1.5 +0.1+0.1

Watchet -- -- --

mean levels 11·3 8·5 3·6 1·03

1.0 3.6

__ __

Spring range 10.3 4.9= neap range

Predicted range= 7.2 interpolation necessary4

Vessel's draft 3.8 metres (depth of water when taking

ground)

Drying height 1.5

Ht. above chart datum -5-·35

Ht. of L. W. 2.3

Ht. of tide above L.W. 3·06

3.0

7.2

From spring curve interval from H.W. =+ 3h 37m

From neap curve interval from H.W. =+ 3h 30m reqd. interval

Required interval from H.W. + 3h 33m8

Time of high water <u>15h 56m9</u>

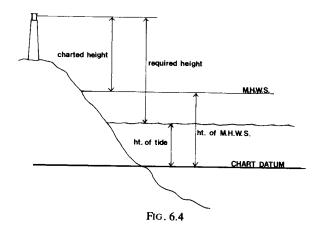
Time when vessel will take the ground 19h 29m G.M.T.

Charted heights

Heights of terrestrial objects such as lighthouses and topographical features are expres.sed above Mean High Water Springs. If these heights are required accurately above the water level, such as for observation of accurate distance by vertical sextant angle, then a correction must be applied equal to the height of M.H.W.S. above or below the water surface.

Example

Find the correction to apply to the charted height of a lighthouse at a place where the level of M.H. W.S. is 13·2, and the height of tide above chart datum is found to be 9·5 metres.



From figure 6.4 the correction may be seen to be the height of M.H.W.S. minus the height of tide.

Thus:

Actual height=Charted height+ M.H. W.S. - Height of tide.

If the height of tide is greater than the height of M.H. W.S then Actual height=Charted height-(Height of tide- M.H. W.S.)

EXERCISE 6A (Standard Port)

- 1. Find the times (G .M. T.) and heights of high and low waters at A van mouth on 27th February 1980.
- 2. Find the height of tide above chart datum at a place off Avonmouth at 0924 B.S.T. on 31st March 1980.
- 3. Find the depth of water beneath the keel < If a vessel of draft 5.8 metres when passing over a shoal of charted depth 2 metres, at 1 715
- B.S. T. on 29th April 1980 off A vonmouth.
- 4. Find the depth of water over a rock of drying height 1·5 metres at the P.M. high water on 26th January 1980. Will this rock dry during the following tide?
- 5. Find the earliest time (B.S.T.) that a vessel of draft 6.5 metres can pass over a shoal of charted depth 2.5 metres with a clearance of 2.0 metres on the rising tide of the morning of 20th April 1980.
- 6. A vessel is aground off A van mouth with her for'd section on a sandbank of charted drying height 1·0 metre. At what time (G.M.T.) can she expect to float off on the P.M. rising tide of 9th March 1980 if the for'd draft is 8·0 metres?
- 7. Find the height of a lighthouse near Avonmouth, above the water surface, at 0800 G .M. T. on 11 th January 1980, if the charted height of the light is 48 metres.

EXERCISE 6B (Secondary Ports)

- 1. Find the times and heights of all high and low waters at Sharpness Dock on 29th January 1980.
- 2. Find the depth of water at a place off Sharpness Dock where the charted defth is 2.5 metres, at the high water on the afternoon of 12th March 980, and the time G.M.T.
- 3. Find the clearance under the keel of a vessel at anchor off Watchet at 0830 (G.M.T.) on 27th April 1980 if the charted depth is 3.2 metres, and the vessel's draft is 5.5 metres.
- 4. Find the correction to charted soundings at a place off Weston-super-Mare at 1200 G.M.T. on 1st February 1980.
- 5. Find the time (B.S.T.) when there will be 13.0 metres of water

over a place where the charted depth is 5 metres, at Beachley on the rising tide on the morning of 19th April 1980.

- 6. Find the latest time that a vessel can pass over a shoal off Watchet of charted depth 1 metre on the falling tide of the evening ofl st January 1980, if the vessel's draft is 6 metres and a clearance of 0.5 metres is required.
- 7. Find the height of tide above chart datum at Bristol (Sea Mills) at 1500 G.M.T. on 15th January 1980. What would be the charted sounding at a place which was just drying at this time?

CHAPTER 7

THE CELESTIAL SPHERE AND THE NAUTICAL ALMANAC

The celestial sphere

The concept of the celestial sphere is one in which all astronomical bodies are considered to lie on the surface of a sphere of infinite radius, which is concentric with the terrestrial sphere. This concept is acceptable to the navigator as he is concerned only with the measurement of angles subtended at the centre of the sphere, and the fact that astronomical bodies lie at different distances from the earth is of little consequence in the measurement of these angles. The motion of the closer bodies and the motion of the earth will cause these bodies to exhibit a movement on the celestial sphere relative to the bodies which can be considered to lie at infinitely great distances, that is the stars.

An astronomical body may have its position defined with reference to the celestial sphere, or with reference to the terrestrial sphere. The latter is required in order to use the body for observation to find an observer's terrestrial position. The terrestrial position of the body is defined by the latitude and longitude of the point on the earth's surface where a line joining the body to the earth's centre cuts the surface. This point is called the body's Geographical Position (G.P.). The position of a G.P. changes rapidly with the rotation of the earth so that it is convenient to define position on the celestial sphere by coordinates which change relatively slowly.

Definition of position on the celestial sphere Equinoctial

This is the great circle on the celestial sphere which lies in the same plane as the earth's equator. It may sometimes be referred to as the celestial equator.

Celestial poles

These are the points on the celestial sphere at which the earth's axis of rotation when produced, meet the celestial sphere. The north and south celestial poles will be 90° removed from all points on the equinoctial.

Celestial meridians

These are semi great circles which terminate at the celestial poles, cuttin~ the equinoctial in a right angle in the manner of terrestrial meridlans. They are sometimes referred to as Hour Circles.

Declination

This defines the position of a celestial body with respect to the equinoctial. It may be defined as the arc of the celestial meridian which passes through the body, contained between the equinoctial and the body. It is measured north or south of the equinoctial in the manner of the terrestrial latitude. The declination of a celestial body will be equal to the latitude of its geographical position at all times.

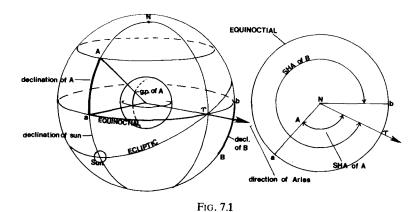
The declination of the sun varies between 23° 27' N. and 23° 27' S. approximately. The period of the variation is one year, the period of the earth's revolution around the sun. The variation is caused by the earth's axis of rotation being inclined to the plane of its annual orbit around the sun at an angle of 66° 33' approximately. The plane of the equator and equinoctial is ther~fore inclined to the plane of the earth's orbit by 23° 27'. The plane of the earth's orbit is called the ecliptic plane and the inclination of the equinoctial to the ecliptic plane is called the obliquity of the ecliptic. The intersection of the two planes, both of which are orientated in space in a constant plane (except for small long term changes), defines a constant direction in space. The point of their intersection which is occupied by the sun when going from south to north declination is called the First Point of Aries. The passage of the sun through the first point of Aries marks the beginning of the Spring season on earth.

Sidereal hour angle

This is the arc of the equinoctial measured westwards from the first point of Aries to the meridian which passes through the body being considered.

The declination and the sidereal hour angle (S.H.A.) define a position on the celestial sphere in the same way as latitude and longitude define a position on the terrestrial sphere. (Note that although the declination is equal to the latitude of the G.P., the S.H.A. is not equal to the longitude of the G.P. This is because, due to the earth's rotation within the celestial sphere, the meridian of Greenwich does not always coincide with the meridian of Aries, whereas the plane of the equinoctial is always coincidental with the plane of the equator by definition.)

If small long term movements of the first point of Aries are neglected the S.H.A. and declination of a fixed point on the celestial sphere remain constant. Stars lie at such vast distances that they almost constitute fixed directions in space. The S.H.A. and



declination of stars exhibit slow changes due to the stars own movement in space and due to the long term movements of Aries referred to previously. The changes are in the order of minutes of arc over a period of months.

The sun appears to move completely around the celestial sphere, relative to the stars and relative to the first point of Aries due to the earth's annual motion in orbit around the sun. This motion causes the S. H.A. of the sun to decrease by approximately 1 ° per day, that is by 360° per year. The inclination of the earth's axis causes the declination to vary from 23° 27' S. to 23° 27' N. and back again in the same period. The maximums are reached on December 22nd and June 21st respectively, and the sun's declination goes to zero on March 21st and September 23rd.

Planets exhibit movements on the celestial sphere relative to the stars due to their own orbital motion around the sun and also due to the earth's motion around the sun. Planets S.H.A. and declinations therefore have slow changes throughout the year.

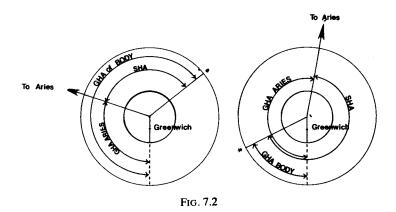
The moon, because of it proximity to the earth exhibits, a relatively rapid decrease in S.H.A. This is due to the moon's orbital motion around the earth in the same direction as the earth's orbital motion around the sun. This amounts to approximately 13° per day. The inclination of the moon's orbit to the equinoctial also produces a rapid change of declination. This varies between limits which are themselves variable, but may be as much as 28%OS. and 28%ON., and as little as 18%OS. to 18%ON. The declination will change between these limits in approximately two weeks.

Definition of a celestial body's position on the terrestrial sphere The longitude of the geographical position of a celestial body changes by 360° each day as the earth rotates. The longitude of the

G.P. is called the body's Greenwich Hour Angle (G.H.A.). This may be defined as the arc of the earth's equator measured westwards from the meridian of Greenwich to the meridian through the G. P. This is the same as the longitude except that whereas longitude is measured from 0^0 to 1800E. and W. of Greenwich, the G.H.A. is measured continually westwards from 0^0 to 360".

The G.H.A. may be found if the S.H.A. is known and the longitude of the first point of Aries is known (G .H.A. Aries). The G.H.A. of Aries will also change by 360^0 each time the earth rotates within the celestial sphere, and may be found at arty instant from the nautical almanac. The G .H.A. of a celestial body may therefore be found from the relationship:

G.H.A.=S.H.A.+G.H.A. Aries (see figure 7.2). (if greater than 360° subtract 360")



The Nautical Almanac

The Nautical Almanac is published by Her Majesty's Stationery Office as publication N.P. 314 and provides all astronomical data necessary for use in marine astronomical navigation.

The arrangement of the information in the almanac may be divided into sections as follows.

- 1. Altitude correction tables. These will be explained in full under the chapter heading of 'Correction of Altitudes'.
- 2. The list of selected navigational stars, giving the S.H.A. and declination of each star for each month of the year.
- 3. The Pole Star Tables. These will be described fully under the chapter heading 'The Pole Star Problem'.
- 4. The daily pages and increment tables. These are the most important pages of the almanac and allow the navigator to pick out

the G.H.A. and the declination of the sun, moon, four navigational planets, and each of the selected stars, for any second of Greenwich Mean Time throughout the year.

Arrangement of the daily pages

Each double page contains data for three days. This is arranged in columns headed Aries, Venus, Mars, Jupiter, Saturn, Sun and Moon. The column for each body contains the G.H.A.

and declination (except for Aries) for each hour of G. M. T. for the three days contained on the double page. The increment tables allow easy interpolation between the hourly figures to obtain the values for each second of G.M.T. These are found by adding an increment to the value ~iven for the hour of G.M.T. The increment is extracted from the Increment tables by entering the table headed with the number of minutes in the G.M.T., and extracting the increment from that table against the seconds of the G.M.T. down the page. There are three tables given, one for sun and planets, one for Aries and one for the moon. These are given because of slight variations in the rate of change of the G.H.A. Care should be taken to use the appropriate column.

Corrections to the increment. The 'v' correction

The mean rate of increase of G.H.A. of the sun is 15⁰ per hour, and it is upon this value that the sun's increment table is based. Variations from the mean rate of change are small and are allowed for in the hourly figures given in the daily pages. The sun's increment requires no correction.

The rate of increase of G.H.A. of the planets, is with the exception of Venus always greater than 15⁰ per hour. That of Venus may be slightly greater or slightly less. The sun's increment table is used however for the increment to planets G.H.A. The increment may be in error however if the hourly increase in G.H.A. is not exactly 15⁰ as assumed by the increment table figures. The difference is allowed for by the 'v' correction. The difference between the assumed value of 15⁰ per hour in the increment table and the actual hourly change as indicated by the hourly figures in the daily pages is given in the daily pages, at the foot of each of the planet's columns as 'v'. This is a mean figure for the three days. A more accurate figure may be obtained by noting the actual change in G.H.A. over the hour in which the requiredG.M.T.lies. The actual 'v' correction to apply is a proportion of this value depending upon the number of minutes in theG.M.T. (If the minutesofthe G.M.T. given is 30, then only half of the 'v' value is applied.) The 'v' correction may be found by entering the 'v' correction table given with each of the increment tables using that one which is given with the table headed with the minutes in the G.M.T. The 'v' value from

the daily pages is located and the correction is extracted against it. (Correction is in bold type.) This correction is added to the increment, unless in the case of Venus, the 'v' value from the daily pages is given a negative sign, in which case it is subtracted from the mcrement.

The rate of change of the moon's G .H.A. varies between 14° 19' and 14° 37' per hour. The moon's increment table is based upon the least value of 14° 19'. Any excess over this value is taken care of by a 'v' correction in the same manner as the planets. The correction is always positive for the moon. The variation in the hourly change of G.H.A. for the moon makes it necessary to give a 'v' value in the daily pages for each hour of G.M.T. This is given against each hourly value of G.H.A.

The rate of change of G.H.A. of Aries is constant of value 15° 02·46' per hour, and this is the value upon which the Aries increment table is based. There is therefore no 'v' correction required for Aries.

Declination

The declination for each body i~ given for each hour of G.M.T. against the value of G.H.A. The rate of change of declination is usually small enough to allow for mental interpolation between the hourly values. However this may be done by the interpolation tables (the same table as for interpolating the 'v' value). The difference between hourly values of declination is given as value 'd' in the daily pages. 'd' is given once for the three days for planets at the foot of each planet column, and once for the three days for the sun. These are mean values and a more accurate value may be obtained by inspecting successive hourly values of the declination. In the case of the moon the change of declination over one hour is large enough and variable enough to require a 'd' value for each hour of G.M.T. and this is given against the declination value in a column headed'd'.

The correction to apply to the hour value of declination is obtained by entering the increment interpolation tables ('v' or 'd') with the value from the daily pages and extracting the correction against it. The si~n of the 'd' correction must be inferred by noting whether the declination is increasing or decreasing over the hour in which the given G.M.T. lies.

Example

Required the G.H.A. and declination of the sun on 5th January

1980, at 18h45m 17sG.M.T.

G.H.A. at 18h	88°41'4'	dec.	22°38·7'S.
Incr.	<u>11° 19·3</u> '	'd' corr.	<u>-0·2'</u>
G.H.A.	100°00·7'	dec.	22° 38·5'S.

Notes

- 1. The G.H.A. for 18h 00m is obtained from the daily page for the date of G.M.T.
- 2. The declination is taken out at the same time.
- 3. The increment is for 45m 17s, and is taken from the Interpolation Tables. Turn to the page

headed 45m, and proceeding down the page to 17s, the increment will be found under the column headed Sun. The increment is always added.

4. The correction to the declination is found by proceeding down the column headed v or d correction to the value of d, as found at the foot of the column headed 'Sun' on the daily page and taking out the quantity abreast of it. Note from the values of the declination whether d is plus or minus.

To find the G.O.A. and declination of the moon

The method is similar to that for the sun, except that the ν correction must be applied to the G.H.A. Follow the steps in the example.

Example

Find the G.H.A. and declination of the moon on 7th January 1980 at 19h 34m 36s G.M.T.

G.H.A. for 19h 222°28'9' decfor 19h 6° 24·4' N. 'v' =15,2

Incr. $8^{\circ} 15.4' 'd' corr. -5.3' 'd' = 9.2$

'v'corr. <u>8.7</u> 6°19'1'

G.H.A. 230° 53.0'

Note

The v value of 15.2 is extracted against the G.H.A. value for 19h and the actual correction to apply is obtained. from the v or d interpolation table for 34m against 15.2. Similarly the increment to declination of -5.3 is obtained against 9.2.

(d correction is particularly important in the case of the moon as the declination is changing rapidly.)

To find the G.H.A. and declination of a planet

Follow the same steps as for the moon, but the increment for minutes and seconds of time is found in the interpolation tables by using the sun table.

Example

18th September 1980 at 21h 35m 45s G.M.T. Find the G.H.A. and declination of the planet Venus.

G.H.A.for21h 178°48'7' dec.for21h 16° 18·2'N. 'v' "'{} ·3

Incr. $8^{\circ} 56.3'$ "'{}.4 'd' 0.6

 $187^{\circ} 45.0' \text{ dec.}$ $16^{\circ} 17.8' \text{ N}$.

...{}.2'

G .H.A. 187° 44'8'

Note that the *v* is minus.

To find G.H.A. of a star

In order that G.H.A. information need not be given for every star a value of sidereal hour angle (S.HA.) is given for selected stars once on each three day page. This is the angular distance of the star west of the first point of Aries, and as the direction of the first point of Aries and the direction of the stars are, over short periods of time, constant then the S.HA. of a star is fairly constant.

The list of selected navigational stars down the right hand side of the left hand page contains the value for S.HA. If the star is not contained in this list it will be found in the fulllist at the back of the almanac, where a value is given for each month.

Now, if the S.H.A. of the star is the angular distance west of the first point of Aries, if we knew the angular distance of the first point of Aries west of Greenwich, then we could add them together and obtain the angular distance of the star west of Greenwich, i.e. the G.H.A. of the star.

Thus: S.HA.*+G.H.A.<r'=G.HA.*

The G.H.A. of the first point of Aries is given every hour in the extreme left hand column of the almanac and an interpolation table is given to find values at times between the hours exactly as for the sun.

Note

If the G.H.A.* as found exceeds 360° then this amount should be subtracted.

Example

Required the G.H.A. of the star *Canopus* 17, at 16h 50m 108 G.M.T. 7th January, 1980.

G.H.A. for 16h 346°22'9'

Incr. 12° 34.6′

G.H.A. 358° 57.5'

S.H.A. * 264° 06.9'

 $\sim 04.4'$ $\sim :\sim opus$ is listed on the daily

- _____ pages. The declination and the

G .H.A. * 263° 04.4′ S.H.A. are taken from that list.

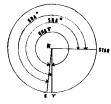


Fig. 7.3

Exercise

Find the G.H.A. and declination of the sun on:

- 1. 7th January, 1980, at IOh 50m OOs G.M.T.
- 2.18th September, 1980, at 15h 40m OOs G.M.T.
- 3.19th December, 1980, at 11h 58m 25s G.M.T.
- 4.26th June, 1980, at 17h 58m 34s G.M. T.
- 5. 30th September, 1980, at O4h 15m 47s G.M.T.

Answers

G.H.A. Dec.

1. 341°00'4' 22°26·7'S.

2. 56° 30·0' 1° 38·6' N.

3. 000° 17·5' 23° 25·3' S.

4. 88°55·8' 23°20·1'N.

5. 246° 26·7' 2° 50·4' S.

Exercise 1

Find the G.H.A. and declination of:

- 1. The moon, 8th January, 1980, at 02h 50m 208 G.M.T.
- 2. The moon, 19th September, 1980, at 08h 50m 408 G.M.T.
- 3. The moon, 19th December, 1980, at O6h 35m 42s G.M.T.
- 4. Venus, 18th September, 1980, at 11h 45m 108 G.M.T.
- 5.Mars, 18th September, 1980, at21h 51m20s G.M.T. 6. Jupiter, 8th January, 1980, at 20h, 31m 20s G.M.T.

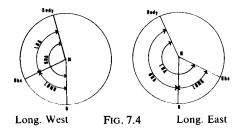
Answers

G.H.A.	Dec.	G.H.A.	Dec.	
1. 336° 41·8'	5° 11·8' N	. 4. 40° 09·3'	16° 23'3' N.	
2.202°06'1'	19°31·8'S	. 5. 104°41'3'	16°30.6'S.	
3. 134° 12·5'	13° 51.5'N	. 6. 253°26'7'	8° 54.6′N.	

LOCAL HOUR ANGLE (L.H.A.)

This is the arc of the equinoctial contained between the meridian of the observer and the meridian of the celestial body. It is always measured westwards from the observer to the body and expressed in degrees and minutes of arc.

Clearly the difference between the L.HA. and the G.HA. of any body will be the longitude of the observer.



Thus from the figure:

L.HA.=G.H.A.- W'ly longitude. L.H.A. = G.H.A. + E'ly longitude.

To find the Local Hour Angle (L.H.A.) of a body

First find the G.H.A. of the body, and then apply the longitude of the observer.

Note

If the longitude is west and the G.H.A. of the body is less than the longitude then 360° should be added to the G.HA. before subtracting the longitude.

Example

Find the L.H.A. of the sun at 23h 10m 48s G.M. T. on 7th January

1980, if the longitude of the observer is 153° 20' E.

G.H.A.23h 163°26·8'

Incr. 2° 42·0'

G.H.A. 166°08·8'

Long. E.+ve 153°20·0'

L.H.A. 319° 28·8'

Example 2

Find the L.H.A. of the moon on 1st October 1.980 at 15h 31m 29s G.M.T. to an observer in longitude 1500 42.0 W.

G.H.A.15h $130^{\circ} 04.4' \text{ 'v'} = 8.8$

Incr. 7° 30· 7'

'v' corr. $\underline{4.6'}$

G.H.A. 137° 39·7'

+360

497° 39.7'

Long. W.-ve <u>150°42·0'</u>

L.H.A. 346° 57·7'

Exercise

Find the L.H.A. in each ca.1Ie

-- - ~- ---

_

Date G.M.T. Body Longitude

1. 1.9th Dec. 198008h 35m 308 Sun 125°1O·0'E.

2. 1.8th Sept. 21h 58m 57s Sun 72°18·3'W.

3. 18th Sept. 198003h 50m 41.s Aries 14001O·2'W

4. 17th Dec. 1980 20h 1 Om Arcturus 1.64° 1.6-2' E.

5. 1.8th Dec. 198021h 10m 14s Kochab 38°20·2'W.

6. 19th Sept. 1980 18h 30m 408 Sun 1.62° 20.0' W.

7. 26th June 1980 20h OOm Aries 17° 33·0' W.

8. 30th Sept. $^{1}20h$ 31 m 208Betelgeuse $^{162^{\circ}}W$.

Answers

1. 74° 44·6' 2. 78° 57·4' 3. 274° 43·4' 4. 33go 50·8'

5.144°10'9' 6.296°56.0' 7.1.97°35.5' 8. 67°02.3'

TO FIND TIMES OF MERIDIAN PASSAGE

Meridian passage of a heavenly body occurs when the body, in its movement across the heavens due to the daily rotation of the earth, crosses the observer's meridian. At this point the

body bears due north or due south and the altitude reaches a maximum. Observation of the altitude at meridian passage provides a quick and easy method of finding the observer's latitude (see Chapter 11, The Meridian Altitude Problem). It is necessary to calculate the G.M.T. of the meridian passage in order to extract the declination from the almanac, and also to know approximately at what time to take the observation. The exact time is not necessary for observation as the practice is to watch the altitude with a sextant until it reaches a maximum and starts to decrease. The maximum altitude is then taken as the meridian altitude. The time is not required for the calculations. The accuracy to which the time is required in order to extract the declination will depend upon how

meridian passage on a day for which there is no passage at Greenwich, then the figure given for that day (the time of mer pass on the following day), should be used in the manner described. The longitude correction will bring the time back into the day in question.

Example

To find the G.M.T. of the moon's meridian passage

7th January, 1980. Find the G.M.T. of the moon's meridian passage to an observer in longitude ISO" 10' W.

L.M.T. mer. pass. 7th long. 0° 03h 44m

L.M.T. mer. pass. 8th long. 0° 04h 26m

difference 42m

corr. from table 11= 18m

L.M.T. mer. pass. 7th long. 0° . 03h Mm

Long. corr. <u>18m</u>

L.M.T. mer. pass. 7th long. 150° 10' W. 04h 02m

Long. in time 10h Olm

G.M.T. 14h 03m(7th)

Example

29th September, 1980, find the G.M.T. of the moon's meridian passage to an observer in longitude 94° 37' E.

L.M.T. mer. pass. 29th long. 0° 04h 09m

L.M.T. mer. pass. 28th long. 0° 03h 13m

difference 56m

corr. from table II = 15m

L.M.T. mer. pass. 29th long. 0° 04h 09m

Long. corr. <u>15m</u>

L.M.T. mer. pass. 29th long. 94° 37' 03h 54m

Long. in time <u>06h 18m</u>

G.M.T. 21h36m(28th)

To find the time of meridian passage of a planet

At the bottom right hand corner of the left hand page in the daily pages the L.M.T. of meridian passage of the four planets is given once for the three days. The figure refers to the middle day of the page. The difference in the times for successive days may be several minutes so that to obtain the time of meridian passage fOf any meridian other than the Greenwich meridian, to the nearest minute, a longitude correction must be applied in the same way as described for the moon. This correction will never amount to more than a few minutes. Inspection of the declination figures for the planets will show that the changes are slow and will never amount to any significance over a few minutes. In practice therefore it is sufficient to take the L.M.T. given for the day in question, interpolating between the three days on the page, and, ignoring the longitude correction, apply the longitude in time to obtain the G.M.T.

Example (with longitude correction)

Find the G.M.T. of meridian fassage of Saturn on 7th January,

1980 to an observer in longitude 79°W.

L.M.T. mer pass 8th 04h 45m

L.M.T. mer pass 5th 04h57m

By inspection

L.M.T. mer pass 7th 04h 49m

L.M.T. mer pass 8th 04h 45m

Difference 4m

L . d . 4x179°

ongltu e correctlon= --_ =2m

360°

L.M. T. mer pass 7th 04h 49m

Longitude correction 2m

L.M.T. mer pass 7th 179°W. 04h 471]1

Longitude in time 11 h 56m

G.M.T.7th 16h43m

(correction negative-west longitude with times becoming earlier. See instructions with Table II).

Example without longitude correction (same example is used) By inspection from almanac

L.M.T. mer pass 7th long. 0° 04h 49m

Longitude in time 11 h 56m

G.M.T.7th 16h45m

To find the time of meridian passage of a star

The method which is recommended here for finding the time of meridian passage of a star may also be used with any of the other bodies, if preferred.

At mendian passage the body concerned is on the same meridian as the observer. The G.H.A. of the body, which it will be remembered is the longitude of the body's geographical position, must therefore be equal to the longitude of the observer. As the G.H.A. is expressed from 0° to 360° westwards from Greenwich, then if the longitude is east it may be subtracted from 360° and then said to be equal to the G.H.A. It only remains to extract from the Nautical Almanac the exact G.M.T. at which that particular G.H.A. occurs, from the daily pages which list G.H.A. against G.M.T. In dealing with stars it will be necessary to apply the S.H.A. of the star to its G.H.A. to give the G.H.A. of the first point of Aries, which is listed in the daily pages. This is given by:

$$G.H.A. cy>=G.H.A.*-S.H.A.*$$

Note

When using this method a problem arises as to what will be the date at Greenwich when the required meridian passage occurs on the observer's meridian, on the date given in the question. The date given always refers to the date at the vessel. The Greenwich date may be the same, or it may be one day later if the observer is in west longitude, or one day earlier if in east longitude. When extracting the G .M. T. from the almanac for the appropriate value of G .H.A. at meridian passage, it must be extracted on such a date that when the longitude in time is applied to it to get the L.M.T., then the date at the observer is the date required by the problem. In practice this will not arise as the Greenwich date will be known, but in the context of an examination question this point should be given careful consideration (see Example 3).

Example 1

Find the G.M.T. and L.M.T. of meridian passage of the star Capella to an observer in longitude 45° 18'W. on 2nd October, 1980.

G.H.A. Capella 45°18'

S.H.A. Capella 281°11·1'

G.H.A. cy> 124°06.9'

G.H.A. cy>07h2nd 116°09·1' (by inspection of almanac)

Increment $7^{\circ} 57 \cdot 8' = 31 \text{m} 46 \text{s}$ (from Aries

increment tables)

G.M.T. mer pass 07h 31m 46s2nd

Longitude <u>03h 01m 12s</u>

L.M. T. 04h 30m 34s 2nd

Note

By inspection of the almanac the value of G.H.A. next less than the reqUIred G.H.A. should be extracted, mentally checking at this point that the application of the longitude in time will give a local date required by the question.

Example 2

Find the time of meridian passage of the moon over the meridian of 78° 45' E. on 18th December, 1980.

G.H.A. moon=E. Long.-36O° 281°15'

G.H.A. moon15h18th 269°01·0' (' I f d "I

°____,'v va ue rom aI y

!n,crement 12 14.0, pages 7.8 correction

v corr. -6.6 from increment table

Increment corrected $12^{\circ} 07.4'$ for 50 minutes=6.6)

From increment table for moon an increment of 12° 07.4' corresponds to 50m 49s.

G.M.T. 15h50m49s 18th

Long. <u>5h 15m</u>

L.M.T. 21h05m49s 18th

Note

Adequate accuracy is obtained by neglecting the 'v' correction. In this case the increment of 12° 14·0' would have given 51 m 16s. The G.M.T. would therefore have been 15h 51m 16s. In practice the error of a few seconds would be negligible. The other method described for the moon in fact only gives the times to the nearest minute.

Example 3

Find the G.M.T. and L.M.T. of meridian passage of the star

Antares to an observer in longitude 175°30' E. on 8th January 1980.

G.H.A. Antares 184°30'

S.H.A. Antares <u>112° 57·7'</u>

G.B.A. cy> 71 ° 32·3'

G.H.A. cy: 21h7th 61°35·3'

Increment $9^{\circ} 57.0' = 39 \text{m} 42 \text{s}$

G.M.T. 21h39m42s 7th Jan.

Long. <u>11 h 42m</u>

L.M.T. 33h21m 42s

= 9h21m42s 8th Jan.

Note

The date at Greenwich is one less than the date at ship in east longitude in this example. Had the G.H.A. for 21h on 8th been extracted, the L.M.T. would have fallen on the 9th. By extracting the G.H.A. for 21h on 7th the L.M. T. is on the required date.

EXERCISE

Find to the nearest second the G.M.T. of meridian passage in the

following examples.

- 1. Jupiter, 26th June, longitude SooW.
- 2. Canopus, 19th September, longitude 40° E.
- 3.Moon, 18th December, 10ngitudelOSoW. 4. Procyon, 28th June, longitude 169° SO' E. S. Spica, Sth January, longitude 124° 30' W.

Answers

- 1. 19h 30m 09s 26th June 2. 03h SOm 41s 19th Sept.
- 3. 04h 34m 17s 19th Dec. 4. 01 h S3m 38s 28th June
- S. 14h 44m 41s Sth Jan.

To find times of lower meridian passage (Lower transit or meridian passage below the pole)

If the body is visible above the horizon when it crosses the observer's lower meridian, latitude may be found readily by observation of altitude at this occurrence (see Chapter U). The declination is required and therefore the G.M. T. of lower meridian passage.

Sun and planets

It is sufficiently accurate for practical purposes to add 12 hours to the time of upper meridian passage given in the almanac, and to proceed as described for upper meridian passage.

Moon

The L.M.T. of lower meridian passage is extracted from the almanac and treated in the same way as described for upper meridian passage.

Stars

At lower meridian passage the G.H.A. of the body is 180° different from the observer's longitude. The G.M.T. when such G.H.A. occurs is extracted from the daily pages in the same way as for upper meridian passage.

TO FIND TIMES OF SUNRISE, SUNSET, MOONRISE AND MOONSET

The G. M. T. of sunrise and sunset, and moonrise and moonset is required to solve the amplitude problem in which the compass error is obtained by observation of the sun or moon at rising or setting. The declination is required in the problem hence the requirement for the G.M. T. (see Chapter 8, The Amplitude Problem).

To find times of sunrise or sunset

The time of sunrise and sunset is given on the right hand side of the right hand page in the daily pages. It is given once for the three days on the page, the figure referring to the middle day. In moderate latitudes the times will change little over three days, so that the figure given for the page may be used without interpolation. In higher latitudes the daily change may be such that interpolation between the three days may be necessary for accuracy. No significant error will be caused in practice if this is not done. The times vary with latitude so that the argument latitude must be used to extract the time, interpolating between the latitudes tabulated. The interpolation is not linear and may be done with the aid of Table 1 on the page immediately following the increment tables. Full instructions are given with this table. The change of the times with latitude are usually small and in practice no significant error will be caused by interpolation mentally assuming linear changes.

The times contained in these columns are local mean times (L.M.T.), and may be taken to be for any meridian. The longitude in time must be applied in order to obtain G.M.T. (see Times of Meridian Passage).

Example

Find the G.M.T. of sunrise on 19th September to an observer in

D.R. position SOON. 16So 24' W.

L.M.T. sunrise SOON. 19th OSh42m

Longitude in time (W) 11h 02m

G.M.T. 16h44m 19th

Example

Find the time of sunset on 26th June 1980 to an observer in position 55° S.172° 30' E.

L.M.T. sunset 55°N. 27th 17h 12m (interpolating between

L.M. T. sunset 55°N. 24th 17h 17m 54° and 56°)

L.M.T. sunset 55°N. 26th 17h 14m (interpolating between

Longitude in time (E.) 11 h 30m 27th and 24th)

G.M.T. 05h 44m 26th

To find times of moonrise and moonset

The times of moonrise and moonset are tabulated against latitude in the same manner as those for sunrise and sunset. The times are given for each day however due to the large differences between daily figures and the variations in the daily differences. For the same reasons the times, which are local mean times, cannot be taken as L.M.T. for any meridian, but only for the meridian for which they were calculated, the Greenwich meridian. In order to find the L.M.T. for any other meridian a.Jongitude correction must be applied as described for the time of meridian passage of the moon. Again this longitude correction is given by:

longitude

daily differencex 360

After correction for longitude, the longitude in time must be applied in order to give the G.M.T. Thus the procedure is:

- 1. Extract the L.M. T. tabulated for the date in question, interpolating for latitude using Table 1.
- 2. Extract the L.M. T. for the following day if in west longitude, or the preceding day if in east longitude, and thus find the daily difference.
- 3. Find the longitude correction from Table II or by the formula given above.
- 4. Apply the longitude correction to the L.M. T. extracted for the day in question as explained in (1). This is normally added if in west longitude and subtracted in east longitude. This only applies if the times are getting later each day, as is usually the case. If the times are getting earlier each day then this rule is reversed, and the correction subtracted if in west longitude an~ added if in east longitude. In all cases the result will lie between the times extracted in (1) and (2).
- 5. Apply longitude in time, +ve for west longitude and -ve for east longitude, to obtain the G.M.T.

Example

Find the G.M.T. of moonrise on 9th January to an observer in position 21 ° 30' S.100oE.

L.M.T. moonrise 9th Long. 0° 23h37m (interpolating for

L M T moonrise 8th Long 00 23h 01 m latitude between

.... 20° and 300)

Difference 36m

Longitude correction =36x -~-O = 10m

L.M.T. moonrise 9th Long. 0° 23h 37m

Longitude correction 10m

L.M.T. moonrise 9th Long.100oE. 23h 27m

Longitude in time (E.) <u>06h 40m</u>

G.M.T. 16h47m 9th

Example

Find the G.M.T. of moonset on 26th June 1980 to an observer in position 33°N.1700W.

L.M.T. moonset 26th Long. 0° 03h 24m (using Table Ifor

L. M. T. moonset 27th Long. 0° <u>04h 08m i</u>~~~ltng for

Difference 44m

Longitude correction =44x _17_0 = 21m

360

L.M.T. moonset 26th Long. 0° 03h24m

Longitude correction 21 m

L.M.T. moonset 26th Long.1700W. 03h 45m

Longitude in time (W.) 11h20m

G.M.T. 15h 05m 26th

CHAPTER 8

COMPASS ERROR BY ASTRONOMICAL OBSERVATION

(The Azimuth Problem and the Amplitude Problem)

The compass error may be found by observing the compass bearing of an astronomical body and comparing it with the true bearing found for the instant of observation, by calculation. The Azimuth problem may be used with any body which is visible above the horizon, except for bodies which are close to the zenith, when the observation of bearing is inaccurate. The Amplitude problem is used when the compass bearing of a body is observed at the moment of rising or setting.

The calculation of the true bearing requires the solution of the PZX triangle for the angle Z (see Chapter 12 for an explanation of the PZX triangle). The solution may be obtained quickly and easily with the use of the ABC tables contained in nautical tables (Nories' or Burton's). These are tables which can be used for the solution of any spherical triangle, just as the traverse tables may be used for the solution of any plane right angle triangle. The ABC tables are specifically designed however for the solution of the astronomical triangle for the angle Z, and are headed accordingly. The arguments are the known values of latitude declination and hour angle (L.H.A.).

The angle Z in the PZX triangle is the angle contained between the observer's meridian and the direction of the body. This is also a definition of the bearing (see Chapter 2). The angle Z however is called the azimuth and is measured from 0° to 1800 from the direction of the elevated pole (north if in north latitude and south if in south latitude), to the east or west depending upon whether the body is rising or setting. The azimuth therefore is merely the bearing of the body expressed and named according to a different set of rules.

Converting azimuth to bearing is therefore an easy matter. If the azimuth is named north then the bearing will be the same as the azimuth if named E, and 360° - azimuth if named west. If the azimuth is named south, the bearing will be 180° - azimuth if named E, or 180° + azimuth if named W.

Examples

North La	at.	South Lat.			
Azimuth	Bearing	Azimuth	Bearing		
N. 40° E.	040^{0}	S. 40° E.	140^{0}		
N. 140 ⁰ E.	140^{0}	S. 140^0 E.	040^{0}		
$N. 40^0 W.$	320°	S. 40° W.	220^{0}		
N. 140 ⁰ W.	220^{0}	S. 140^{0} W.	320^{0}		

When a body is on the observer's meridian the L.H.A. is 000° and when it lies to the west of the meridian the L.H.A. is between 000° and 180° . As the body passes to the eastwards of the meridian and commences to rise the L.HA. increases from 180° to 360° , when it is again on the observer's meridian.

Figure 8.1 shows a body with aN. declination and an observer in a higher N. latitude. As the body rises the azimuth or bearing of the body is N.E'ly and increases, bearing 090° when it crosses the Prime Vertical (WZE). It will pass to the south of the observer, bearing 180° when the L.H.A. is 360° (or 000°). Subsequently, as the body moves to the west, the bearing continues to increase, being 270° when it again crosses the Prime Vertical and finally it sets bearing N.W'ly.

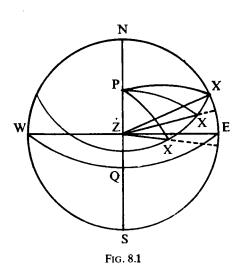


Figure 8.2 shows an observer in N. latitude and a body with a S. declination. It will be noted that the body rises, bearing S.E'ly and sets, bearing S. W'ly, so that the range of azimuth is less than in the previous case.

Figure 8.3 shows an observer in N. latitude and a body with a

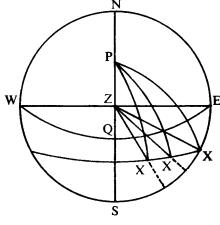


Fig. 8.2

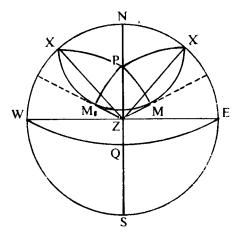


Fig. 8.3

higher N. declination. The body bears N.E'ly when rising and N. W'ly when setting, but in this case the body passes to the N. of the observer bearing 000° when the L.H.A. is 360° (or 000°). It will be noted that as the body rises it moves first to the right, reaching a maximum azimuth atM after which the bearing moves to the left until it reaches a maximum westerly azimuth at M1' It then moves to the right again before setting.

If a body has a declination of 0° , it will rise bearing due east and set, bearing due west. The L.H.A. on rising will be 270° and on setting the L.H.A. will be 90° .

Inspection of the figures will show, therefore, that when the latitude and declination are of the same name, the L.H.A. (E) of the body on rising and the L.H.A. on setting will be greater than 90° .

If the latitude and declination are of opposite names the L.H.A.(E) on rising and L.H.A. when setting will be less than 90°.

Steps in the problem

- 1. Ascertain the G.M.T. and date from the time given.
- 2. Take out the necessary elements from the *Nautical Almanac*: for the sun-the declination and G.H.A.

for a star-the declination, *S.H.A. and G.H.A. 'Y'

- 3. Using the appropriate time formula, derive the L.H.A. of the body. If the L.H.A. is greater than 180° it may be found more convenient to subtract this from 360° to obtain L.H.A.(E).
- 4. Using ABC tables, with L.H.A. and latitude take out the quantity.A, interpolating as necessary. If the L.H.A. is less than 90° name this opposite to the latitude. With L.H.A. and declination take out the quantity B interpolating as necessary. Name this the same as the declination.

Add the two quantities, A and B, if they are the same name. otherwise take the lesser from the greater to obtain the quantity C. Name this according to the greater.

From the C table against the latitude take out the azimuth.

Name this according to the quantity C and the L.H.A.

An example should make this clear.

L.H.A. 48° 45' Latitude of observer 40° 42/ N. Declination of body 16° 20/ S., to find the True Bearing.

L.H.A. 48°, lat. 40° 42/ N., A=0·774 L.H.A. 49°, lat. 40° 42/ N., A=0'751 :.L.H.A. 48° 45/, lat. 40° 42/ N.

L.H.A. 48° , dec. 16° 20/ S., B=0·396 L.H.A. 49° , dec. 16° 20/ S., B=0'390 :.L.H.A. 48° 45/, dec. 16° 20/ S., B=0·391

i.e. A 0,757 S. (named opposite to lat.) B 0.391 S. (named same as dec.)

C 1·148 S.

S.

	Dec.	Hour .	Angle
		48°	49°
В			
	16°	0.39	0.38
	17°	0-41	0-41

C 1,14, lat. 40° 42/, AZ.= $49 \cdot 2^{\circ}$ C 1,16, lat. 40° 42/, Az.= $48 \cdot 7^{\circ}$... C 1,148, lat. 40° 42/, AZ.= $49 \cdot 0^{\circ}$ i.e. True bearing S. 49° W.

or 229°

1.14 1.16

C Lat. Azimuth

40° 48.9° 48.4° 41° 49.3° 48.8°

Notes

- 1. Had the L.H.A. been greater than 90°, then A would have been named the same as the latitude. The B factor is always named the same as the declination.
- 2. With practice the interpolation can be done mentally.
- 3. When using *Burton's Tables* the method is exactly the same except that (a) + and signs are used instead of N. and S., (b) the factors A and B are given to 3 decimal places, (c) the azimuth is given for every full degree. This may make interpolation a little more awkward, but this can be overcome by using the interpolation table at the end of the ABC tables, and by following the concise instructions given there.

Example

30th September, 1980, in D.R. position lat. 45°22' N., long. 125° 10' E., where the variation was 24°E., the sun bore 229°C. at 07h 51m 06s G.M.T. Find the sun's true azimuth, and thence the deviation of the compass.

G.M.T. 30th 07h 51m 06s From N.A.

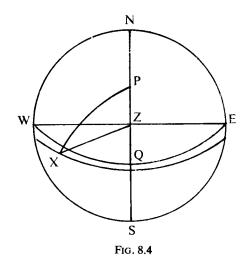
G.H.A. 287°30·5' Incr. 12° 46·5'

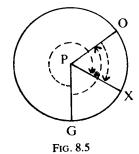
G.H.A. 300°17·0' Long. E. 125°10·0'

L.H.A. 425° 27·0'

360°

L.H.A. 65°27·0'





rig. o..

Dec. $2^{\circ} 53 \cdot 1' S$.

d. corr. $+ \underline{0.9}$

Dec. $2^{\circ} 54.0' \text{ S.}$

A 0-464 S. True bearing $250 \cdot 0^{\circ}$

B 0.054 S. Compo bearing 229'0°

C 0.518 S. Compo error 21.0° E.

-- Var. 24.0° E.

T. Az. S. 70,0° W. --

Dev. 3.0° W.

=----

EXERCISE 8A SUN AZIMUTHS

- 1. 19th September, 1980, in D.R. position lat. 42° 50'N., long. $46^{\circ}10'$ W. atllh40m19sG.M.T., the sun bore 149° C. Find the true azimuth and the deviation, the variation being $24 \cdot 5^{\circ}$ W.
- 2. 6th January, 1980, in E.P. $48^{\circ}20'$ S., $96^{\circ}30'$ W., at 20h40m30s G .M. T., the sun bore 286° C. Find the deviation, the variation being 23° E.

- 3. 19th December, 1980, in D.R. position $46^{\circ}15'$ N., $168^{\circ}35'$ W., the observed azimuth ofthe sun was 122° C. at 20h31ml0s G.M.T. Find the sun's true azimuth and the deviation, the variation being 12° E.
- 4. 27th June, 1980, in D.R. position, lat. 38° 10' S., long. 124° 10' E., a.m. at ship, when the chronometer showedllh 58mlOs, the observed azimuth of the sun was 057° C. Find the deviation, the variation being 2° W.
- 5. 19th September, 1980, at 15h 20m OOs L.M.T., the sun bore 262·5° to an observer in D.R. position lat. 19° 20'N., long. 14go 50' E., where the variation was 1°E. Find the deviation.

STAR AZIMUTHS Example

18th September, 1980, at 06h 14m O9s, G.M.T. in D.R. position 37° 36'N., 47° 50'W., the observed bearing of *Alpheratz* 1 was 289·5°C. Find the true azimuth and the deviation, the variation being $22 \cdot 5$ °W.

<u>G.M.T. 18th 06h 14m 09s</u> From N .A.

G.H.A. 'Y' 87°18.6'

Incr. $3^{\circ} 32 \cdot 8'$

G.H.A. 'Y' 90° 51.4'

*S.H.A. <u>358° 09·0'</u>

449° 00.4′ <u>360°</u>

*G.H.A. 89°00·4'

Long. W. 47° 50·0'

L.H.A. 41 °10·4'

*Dec. 28°59·1' N.

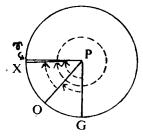


Fig. 8.5

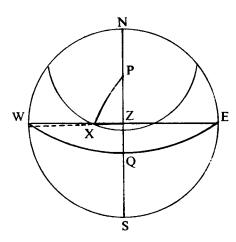


FIG. 8.6

A 0.88S. True bearing 267.1°

B O·84N. Compo bearing $289 \cdot 5^{\circ}$

C O·04S. Compo error 22·4°W.

Var. $22.5^{\circ}W$.

True Az. S. 87·1°W.

Dev. O·l°E.

EXERCISE 8B STAR AZIMUTHS

- 1. On 19th December, 1980, in position lat. 46°40′ N., long. 168° 20′W. the observed bearing of the star *Gienah* 29 was 134°C.at 15h 15m 27s G.M.T. If the magnetic variation in the locality wasI3°E., find the deviation for the ship's head.
- 2. On 26th June, 1980, at 02h 11m 43s G.M.T. the star *Rasalhague* 46 bore 247° C. to an observer in lat. 38° 20' N., long. 5° 40' E. If the variation was 6.5°E., find the deviation for the ship's head.
- 3. On1st October, 1980, a.m., at ship in lat. 41 °15' N., long. 145° 26'E., when the chronometer, which was correct on G.M.T., showed 5h 48m 19s, the star *Procyon* 20 was observed bearing 125°C. If the variation was 7°W., find the deviation for the ship's head.
- 4. On 6th January, 1980, at ship in lat. 46° 20'N., long. 47° 52' W., the star *Schedar3* bore 336° C. when the chronometer which was correct on G.M.T. indicated Olh 41m 28s. If the variation was 27°W., find the deviation for the ship's head.
- 5. On 19th Seftember, 1980, at about 03.30 at ship in lat. 32° 24′ S., long. 80° 5′ E. the star *Peacock* 52 was observed bearing 250°C. when the chronometer, which was correct on G.M.T., showed 10h 14m 20s. If the variation was 33°W., find the deviation for the ship's head.

THE AMPLITUDE PROBLEM Definition

The amplitude of a body is the angle between the direction of the body when rising or setting, and the direction of east or west respectively.

Thus the amplitude is merely another way of expressing the bearing of a body at the moment it rises or sets.

By observing the bearing of a body by compass (magnetic or gyro) when the centre is on the rational horizon and comparing

this with the calculated true bearing, the compass error, and if a magnetic compass, the deviation for the ship's head, are very simply found.

A body is on the rational horizon at theoretical rising or setting, and the true altitude at this instant is ()()O ()()'. Because of refraction and dip, etc., the visible rising or setting will occur earlier and later respectively. As a general rule of thumb, theoretical sunrise or sunset can be taken to occur when the sun's lower limb is about one semidiameter above the visible horizon. In lower and medium latitudes the bearing will be changing slowly at this time and any small error in time will not make any difference to the bearing calculated. In very high latitudes, however, when the bearing is changing quickly at sunrise and sunset more care must be taken.

The true amplitude can be calculated from the formula:

Sine amplitude = sine declination x secant latitude.

This is given in tabulated form in *Norie's*, *Burton's* and other nautical tables.

The amplitude is named east when rising, west. when setting and either north or south according to the name of the declination, e.g. a body with a declination of 20° N. will rise to an observer in latitude 30° N. with an amplitude of E. 23° 16' N. This can then be converted to the usual three figure notation of 066° 44'.

If the declination had been 20° S. then, in the same latitude, the amplitude would have been E. 23° 16' S. and this would have given a true bearing of 113° 16'.

Note

This problem usually involves the use of the sun. Sometimes the moon may be used, but stars and planets are rarely visible at their rising or setting due to horizon haze. If the moon is used care must be taken to obtain an accurate G.M.T. when taking out the declination, as this may be changing rapidly.

Procedure

1. Obtain the L.M.T. and hence the G.M.T. ofrising(orsetting)

from the almanac as explained in Chapter 7.

- 2. From the *Nautical Almanac* find the declination.
- 3.Obtain the true amplitude either by calculation or from tables. 4. Convert the true amplitude into a true bearing in thrl"l" figure

notation.

- 5. Compare the true bearing and the compass bearing and obtain the compass error.
- 6. If the variation is known, find the deviation for the ship's head.

Example

1st October, 1980, in D.R. position, lat. 36° lO'N., long. 28° 20' W., at05h57m22s L.M.T., the sun rose bearing 112°C. Find the true amplitude, and if the variation was 18°W., find the deviation for the direction of the ship's head.

L.M.T. sunrise 1st 05h55m Decl.07h 3°16·3'S.

Long. (W.) Olh53m 'd'corr. +0.8'

G.M.T. 07h48m Decl. 3°17·1'S.

Sin ampl.=sin3°17·1' sec. 36°10'

ampl.=4° 04·2'

True amp I. E. 4° 04·2' S. True brg. 094°T. Compo brg. _11_2°C.

Compo error 18°W.

Variation 18°W.

Deviation 0°

Example

On 8th January, 1980, at ship in lat. 30° 45' S., long. 166° 15' W., the sun set bearing 230° by compass. If the variation for the place was 16° E., find the deviation for the ship's head.

L.M.T. sunset, lat. 30° S. 8th 19h 06m

Diff. 12m Table I corr. + Olm

L.M.T. sunset, lat. 30° 45' S. 8th 19h 07m

Long. W. <u>Ilh 05m</u>

G.M.T.9th <u>06h 12m</u>

Dec. 9th 06h 22° 12.8′ S.

Corr. - 0.1'

Dec. 22° 12·7′ S.

Sin ampl. = $\sin 22^{\circ} 12 \cdot 7' \sec .30^{\circ} 45'$

 $=26^{\circ}05.7$ ' True ampl. $=W.26^{\circ}S$. True brg. $=244^{\circ}T$. Compo brg. $=_2230_{\circ}C$.

Compo error = $14^{\circ}E$.

Variation = 16° E.

Deviation 2°W.

EXERCISE 8C

- 1. 30th September, 1980, in D.R. position lat. 20° 52'N., long. 153°10' W., at06h 03m14sL.A.T., the sun rose bearing E. $11\cdot5^{\circ}$ N. by compass. Find the true amplitude and the deviation, the variation in the locality being 11° E.
- 2. 18th September, 1980, at 05h 52m 03s L.A.T., the observed amplitude of the sun to an observer in lat. 39° 53' N., long 51° 00' E., was E. 5° N. Find the true amplitude and the deviation. The variation was 5° E.
- 3. 27th June, 1980, at ship in D.R. positon, lat. 40° 20′ S., long. 00° OP′, the sun set bearing 301.5°C. Find the sun's true amplitude and the deviation, the magnetic variation being 26°W.
- 4. 18th December, 1980, at ship in D.R. position 37° 30' N., 32° 15' W. the sun ros~ bearing 138°C. Find the true amplitude and thence the deviation, the variation being 21°W.
- 5. 5th January, 1980, the sun set bearing 258° C. to an observer in E.P. lat 49° 10'S., long 98° 45'W., where the variation was 24°E. Find the deviation for the direction of the ship's head.
- 6. 26th June, 1980, the sun rose bearing 062° C. to an observer in D.R. position lat. 42° 30' N., long 142° 30' W .. Find the deviation of the compass, the variation in the locality being 20° E.

Revision papers

The following revision papers are similar in structure to the Department of Trade Class V (Chartwork and Practical Navigation) paper, and the Class IV (Chartwork) paper.

The chartwork papers are set on charts of British coastal waters in the hope that they will be available to navigators studying at sea. Those to whom the charts are not available may wish to obtain them from Admiralty chart agents. The charts used are published at minimal price as practice charts, which are full size charts containing the same information as navigational charts, but are printed on strong thin paper and may not be corrected to date. They must not be used for navigation but are entirely adequate for practice purposes. The following charts are used:

Lands End to Falmouth Chart No. 5051

Falmouth to Plymouth Chart No. 5050

Bristol Channel

(Worms Head to Watchet) Chart No. 1179

The practical navigation papers may be done with a set of nautical tables (Nories' or Burton's), and the extracts from the Nautical Almanac.

CLASS V CHARTWORK AND PRACTICAL NAVIGATION

PAPER 1 (3 hours)

Chartwork

Chart. Lands End to Falmouth No. 5051 Use variation 8°W. throughout.

Use deviation card given in Chapter 2

- L At a time 5 hours after H.W. Devonport (spring tides), a vessel was in a position with Lizard Lt. Hse. bearing ooooT. distant 5 miles. Find the compass course to steer to pass 3 miles to the south of Wolf Rock Lt., making allowance for any tide you may expect. Estimate the time of arrival off Wolf Rock. Vessel's log speed is 12 knots.
- 2. From a vessel leaving Falmouth steering 212°C. at 8 knots, Black Head was observed in transit with Lizard Lt. Hse. bearing 232°C. After maintaining this course for 1. hour Lizard Lt. Hse. bore 309°C. If a current set 230°T. at 1.⋅5 knots in the interval find the position of the vessel at the time of the second observation.
- 3. It is required to round Lizard Point maintaining a minimum distance off Men Hyr Rocks oft, 5 miles. What would be the vertical danger angle to set on a sextant to observe Lizard Pt. Lighthouse?
- 4. A vessel steering 125°C. at 10 knots observed Longships Lighthouse bearing 345°C. and Tater Du Lighthouse bearing 035° C. *Ph* hours later Lizard Pt. Lt. Hse. was bearing 065° C. while Mullion Island was bearing 029°C. Find the set and drift ofthe tide in the interval.

Practical navigation

1. Find by traverse table the vessel's position at the end of the

third course.

Initial position 49° 3D' N. 8° 00' W.

First course 261°T. distance steamed 7.0 miles Second course 210°T. distance steamed 72 miles Third course 166°T. distance steamed 65 miles

2. Find by J?lane sailing the course and distance between the following positions.

A5.0°15'N.5°25°W. B 52°10'N. 7°.05'W.

3. From the following information find the compass error and the deviation for the ship's head.

Date: June 26th 198.0 D.R. position 500 3D' N. 6° 3D' W.

Sun rose bearing .o53°C. Variation 8°W.

CLASS V CHARTWORK AND PRACTICAL NAVIGATION

PAPER 2 (3 hours)

Chartwork

Chart. Falmouth to Plymouth No. 5.05.0.

Use variation 8°W. throughout

Use deviation card provided in Chapter 2

- 1. From a position where Eddystone Rock Lt. bears 36.0°T. distant 3 miles find the compass course to steer to a position where Dodman Point bears3.07°T. distant2·4 miles, in order to counteract a tidal stream estimated to set 133°T. at 2 knots, and allowing for a 1.0° leeway due to a SW'ly wind. Ship's speed by log 8 knots.
- 2. The following compass bearings were obtained from a vessel:

Chapel Point 246°C.

Black Head 009°C.

Gribbin Hd. daymark 064°C.

Find the latitude and longitude of the vessel's position and the compass course to steer to arrive at a position where Rame Head chapel ruins is 3.0° on the port bow distant 3 miles.

3. A vessel steering 33.0°C. has the buoy (FI.R.1.0 sec.) in

fosition 5.0°.07' N. 4° 3D' W. approximately, bearing 015°C. distant ·2 miles. After steaming

for 4.0 minutes at 12 knots the vessel's position was fixed by three bearings:

Udder Rock buoy 015°C.

Cannis Rock buoy 326°C.

Yaw Rock buoy 273°C.

Find the set and rate of the current, the course made good and the speed made good.

4. Find the rising and dipping distance of Eddystone Light. Ht. of eye 12.5m.

Practical navigation

1. Find by mercator sailing the position at the end of the run.

Initial position 55°55'N. 7°18'E.

Course 257°C. Variation 8°W. Deviation 3°E. Distance run 12.0 miles.

2. Find by traverse table the vessel's position at the end of the

third course:

Initial position 49° 3D'. N. 8° 00' W.

First course 265°T. distance 132 miles

Second course 347°T. distance 97 miles Third course 18.0°T. distance 4.0 miles

3. From the following information find the compass error and the

deviation for the ship's head.

Time at ship 16.08 2nd October. D.R. 43° 3.0'N. 9° 4.0'W. Bearing of sun by compass 262° . Chronometer .05h .08m 02s. Chronometer error 2m 18s slow on G. M. T . Variation 12° W.

CLASS IV CHARTWORK PAPER 1

Chart. Bristol Channel Chart 1179.

Use variation 9°W. throughout

Use specimen deviation card Chapter 2

1. From a vessel the following simultaneous bearings were

taken:

Hartland Point Lt. Hse. 204°C.

Lundy Is. South Lt. 287°C.

Bull Point Lt. Hse. 067°C.

Find the ship's position, the compass error and the deviation for the ship's head.

- 2. At 1135 from a vessel steaming at 12 knots, a navigator observed St. Gowan Lt. V/L in transit with Warren Church spire, bearing 009°C. At the same time Caldy Is. Lt. Hse. bore 059°C. Find the latitude and longitude of this position and the course to steer by compass to a position with Worms Head bearing OOO°T. distant 9·9 miles in order to counteract a tide setting 115°T. at 3 knots, and allowing for 6° leeway due to a northerly wind. Estimate the distance off Helwick Lt. V/L when it is abeam and the time at this position.
- 3. At 0830 from a vessel steering259°C. at12 knots Breaksea Lt.

V/L was observed bearing 352°C. distant 1 mile. If 1 hour later Foreland Point Lt. Hse. and Selworthy Beacon bore 192°C. and 121°C. respectively find the set and rate of the tide. Assuming that the same tIdal conditions continue find also the course to steer by compass and the speed required to reach a position with Bull Point Lt. Hse. bearing 172°T. distant 5·4 miles in 50 minutes.

- 4. From a vessel in D.R. position 51 °20' N. 4°58'W. and steering 113°C. at 7 knots in reduced visibility, the relative bearing of Lundy Island radio beacon was 050°. Two hours later the relative bearing of Breaks~a Lt. V/L radio beacon was 357°. If during the interval the vessel was making 8° leeway due to a southerly wind, and the tidal stream set as indicated at position E. 3h before high water Swansea at Syring rate, find the latitude and longitude of the vessel at the time O the second bearing.
- 5. On 25th February 1980 at 1200 G.M.T. a vessel off Watchet passed over a shoal of charted depth 4 metres. If the vessel's draft was 1.0.5 metres what was her clearance underkeel?

CLASS IV CHARTWORK PAPER 2

Chart. Lands End to Falmouth No. 5051.

Use variation 9°W. throughout.

Use deviation card provided in Chapter 2

- 1. At 0800 hours in poor visibility, from a vessel steering 181 °G. at 5 knots, the Longships Lt. Hse. bore 148°G. Gyro error 1 ° High. The vessel continued on this course and at 0915 Wolf Rock Lt. was observed to bear 238°G. If a tide set 127°T. at 2 knots throughout, find the vessel's position at 0915.
- 2. From a position with Wolf Rock Lt. bearing 350° T. distant 2.4 miles, find the true course and distance to a position latitude 49° 46' N. longitude 5° 26.6' W. Find also the compass course to steer to counteract a tide setting 084° T. at 3 knots and 6° leeway due to a SW'ly wind, if the vessel's speed by log is 6 knots. What will be the E.T.A. at the position given?
- 3. On a vessel at anchor off Falmouth the following compass

bearings were taken;

Hil1 (102), (50° 02' N. 5° 05' W.) 226°C. Mawnan House (Conspic) (50° 06' N. 5° 05' W.) 280°C. St. Anthony Hd. Lt. 01 0° C.

Find the vessel's position and the compass error.

- 4. At 1000 hrs. the Runnel Stone buoy was observed in transit with Lon§:ship Lt. Hse. bearing318°C. At the same time Wolf Rock bore 251 C. Find the vessel's position. If course is now set 095° C., and 20 minutes later Tater Du Lt. bore 32ec. and St. Michael's Mount bore 028° c., estimate the set and drift of the tide if the distance run by log in the interval was 5 miles.
- 5. Find the times and heights of high and low waters at Sharpness Dock on 14th January 1980.

SECTION 2

The following section contains work required for Class IV Practical Navigation paper in addition to the work contained in Section 1.

CHAPTER 9

POSITION ORCLES AND POSITION LINES

If a distance off a charted point of land is obtained, either by radar or by vertical sextant angle, then a circle can be drawn centred on the point of land and with radius the distance off, and this circle will represent a line, any point on which the ship might be from the observed information. It is in fact a position circle. The intersection of two such circles will give an observed position, as will the intersection of two position lines.

We employ the same procedure when navigating with astronomical bodies. The charted point of land is replaced in this case with the geographical position of the heavenly body, i.e. the G.H.A. and the declination.

When we observe the altitude of a body, we correct it and subtract it from 90° and obtain the zenith distance. Now this zenith distance is the angular distance of the observer's zenith from the position of the body on the celestial sphere, and as the centres of the celestial sphere and the earth are coincident, this will be the same as the angular distance on the earth, of the observer from the geographical position of the body. Furthermore, when we measure an angular distance on the surface of the earth and express it in minutes of arc, it becomes, by definition of the nautical mile, a distance measured in those units.

Thus the zenith distance becomes the radius of our position circle which is centred on the geographical position of the body.

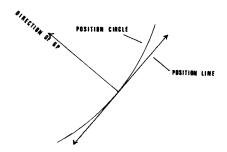
In this manner it would be possible to navigate by plotting the geographical positions of two or more bodies on a chart and drawing circles of radius the bodies' zenith distances and obtain a fix at the intersection of the circles. However, to do this we would need a chart of a very large area, and because of the large radii the plot would be on a very small scale. Far too small for the required accuracy. Moreover the circles would not appear on the mercator chart as true circles and would thus be difficult to plot.

To get around this problem we only draw that part of the position circle that passes near to the D.R. position, and because of the large radius of the circle such a small part of it can be taken as a straight line without material error. Thus our position circle now becomes a position line, which strictly speaking is a tangent

to the position circle.

The direction in which the line runs near to the D.R. position

is found by calculating the true bearing of the body. The line representing this bearing will be a radius of the position circle and therefore the position line, being a tangent to the circle is at right angles to this bearing.



The position line is marked at each end with an arrow

Fig. 9.1

Thus we can draw this position line on the chart without plotting the geographical position as long as we know some point through which to draw it. All methods of sight reduction are means of finding the direction of such a position line and a position through which it passes. The calculations involved in finding this information are dealt with in the following chapters, but first we will see how we obtain the fix once we have calculated the necessary position line information from two or more observations.

THE MARCQ ST. HILAIRE METHOD (INTERCEPT METHOD)

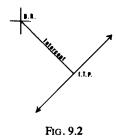
This is a universal method. Any sight can be worked this way. We assume a D.R. position and calculate a zenith distance using this position. The bearing is also calculated. Thus we could draw a position line through the D.R. position at right angles to the bearing. We could call this the calculated position line. We now take the observed altitude and find the TRUE zenith distance from it. We compare this true zenith distance with the calculated zenith distance and the difference between the two in minutes will be the distance in nautical miles between the calculated and the true position lines. This distance we call the INTERCEPT. It should be named 'towards' or 'away' depending upon whether the true position line is nearer the geographical position of the body than the D.R. position or farther away from it.

Note

True Z.D. less than Calc. Z.D.-towards. True Z.D. greater than Calc. Z.D.-away.

The true position should be close enough to the D.R. position to assume that the true bearing is the same as that which was calculated. The calculated and the true position lines are therefore parallel.

In practice we need only draw the true position line. This can be done by measuring the intercept from the D.R. position either towards or away from the direction of the bearing, as the intercept is named and drawing the position line at right angles to this direction through the intercept terminal point (I.T.P.). Thus the plot of one position line looks like this.



If this is plotted to scale for two or more observations we can take the observed position as being the intersection of the position lines and can measure the d. lat. and the departure between the D.R. and the observed position and thus find the latitude and longitude of the observed position.

To find the position by plotting the position lines from two simultaneous sights

Procedure

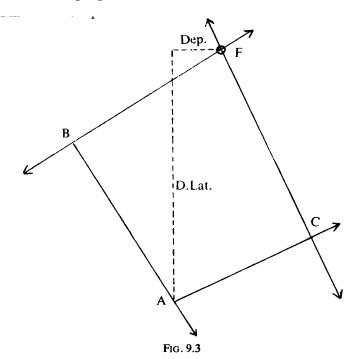
- 1.Plot a convenient point to represent the D.R. position.
- 2. From this point draw the dirt:ctions of the intercepts either towards the direction of the bearing of the body, or away from it depending on how the intercept is named.
- 3. Mark off to a scale of nautical miles the lengths of the intercepts from the D.R. position.
- 4. Through the intercept terminal points draw the position lines at right angles to the intercepts. Where the two position lines cross is the observed position.
- 5. Measure the d. lat. and the departure between the D.R. position and the observed position, and apply to the D.R. position after having converted departure into d. long.

Example 1

Using D.R. position, lat. 47° 56' N., long. 27° 50' W., simultaneous observations of two stars gave:

(1) bearing 148° T., intercept 5' away. (2) bearing 065° T., intercept 4' towards.

Find the ship's position.



By measurement from A to F

Description of plot

d.lat. = 6.7' N. dep. = 1.3' E. A-the D.R. position

A lat. 47° 56.0′ N. long. 27° 50,0′ W. B-the intercept terminal

d. lat. 6,7' N. d. long. 2,0' E. point for P.L. 058° T.

-238° T.

Flat. 48° 02·7' N. long. 27° 48·0' W. C-the I.T.P. for P.L.

F-Position by observation.

To find the position from two position lines by Marcq St. Hilaire, with a run in between them

A running fix using celestial position lines gives an observed position at the time of the second sight, by crossing the second

sight with an earlier observation, which position line is transferred up to the time of the second sight by applying the course and distance run.

Procedure

- I. Take the D.R. position at the time of the first sight and apply the course and distance run between the sights by the traverse table. This gives a D.R. position at the time of the second sight, which is used to calculate the second intercept and position line, and from which the two intercepts are plotted.
- 2. Plot the transferred position line and the second position line from this D.R. in the same manner as in the previous section.

Example 2

In D.R. position 23° 40′ S. 98° 50′ E. an observation of a star gave an intercept of 10′ towards with a bearing of 117° T. The ship then ran 254° for 27 miles, when a second observation gave an intercept 3,8′ away with a bearing of 226° T. Find the position at the time of the second sight.

D.R. at first sight $23^{\circ} 40,0' \text{ S. } 98^{\circ} 50.0' \text{ E.}$

Run 254°, 27m. 7·4' S. 28·3' W.

D.R. at second sight 23° 47·4′ S. 98° 21,7′ E.

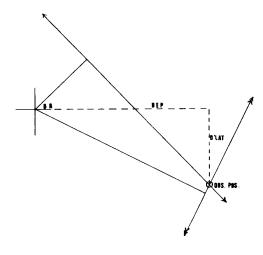


Fig. 9.4

Note that any transferred position line is marked with double arrows

By measurement:

d. lat.= $4\cdot2'$ S. departure=9'2' E.

D.R. at second sight 23° 47·4′ S. 98° 21·7 E.

4·2' S. 10·1' E.

Observed position $23^{\circ} 51.6' \text{ S. } 98^{\circ} 31.8' \text{ E.}$

Note

A D.R. for the second sight may be given that is different from the D.R. obtained from running up the first D.R. In this case each sight must be plotted from its own D.R. Thus the transferred position line is plotted from the first D.R. after the run is applied, and the second position line is plotted from the D.R. given, which will be the D.R. which has been used to calculate the intercept and bearing. (See example 4.)

The longitude by chronometer method

In this type of problem we assume only a D.R. latitude, and then calculate the longitude at which the position line crosses this latitude. It should be realised that if anyone observation is worked by two different methods of sight reduction then exactly the same position line should result. Only the position that we calculate, through which to draw the position line differs.

In the longitude by chronometer method we calculate the true bearing of the body to give us the direction of the position line and then draw the line through the position given by the D.R. latitude and the longitude found by calculation. Thus there is no intercept involved.

To find position by simultaneous position lines by longitude method

Procedure

- 1. Plot the TWO posItIons through which the posItIon lines pass. (There will be one position to be plotted for each observation, as, although probably the same D.R. latitude will have been used to work the sights, a different longitude will result from each. Note that the distance between the positions in an east-west direction on the plot should be the departure and not the d. long.)
- 2. Draw each position line through its respective plotted position.

The position where they cross is the observed position.

3. Measure the d. lat. and the departure between the observed position and one of the known positions, and apply to this position after having converted departure into d. long.

Example 3

By using D.R. latitude 25° 20' N., simultaneous observations of two stars gave:

(1) Longitude 36° 05' W., bearing 060° T. (2) Longitude 35° 57' W., bearing 300° T.

Find the ship's position.

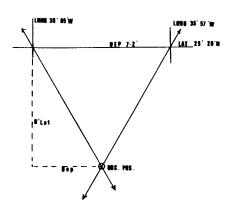


Fig. 9.5

By measurement from A to observed position d. lat.=6.2' S., dep.=3.6' E.

Pos. A lat. $25^{\circ} 20.0' \text{ N}$. long. $36^{\circ} 05' \text{ W}$.

d.lat. $\underline{6\cdot 2' S}$ d. long. $\underline{4\cdot 0' E}$

Obs. pos. lat. <u>25° 13-8' N</u>. long. <u>36° 01' W.</u>

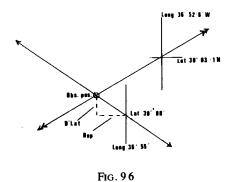
Example 4

At 1100 hours ship's time an observation of the sun by longitude by chronometer, using a D.R. latitude of 30° 14' N. gave a longitude of 36° 18' W., with the bearing of the sun 150° T. At 1300 hours ship's time, the sun was bearing 215° T., and a second observation gave a longitude of 36° 55' W.;using a D.R. latitude of 30° 00' N. If the ship's course and speed between the observations was 250° T., 16 knots, find the position at the time of the second observation.

D.R. at first sight $30^{\circ} 14.0' \text{ N. } 36^{\circ} 18.0' \text{ W.}$

Run 2500, 32m. <u>10,9' S. 34·8' W.</u>

D.R. to plot transferred PL. 30° 03·1' N. 36° 52·8' W.



By measurement

d.lat. between observed position and DR. of second sight=

 $1 \cdot 1'$ N. departure = $1 \cdot 6'$ W.

D.R. second sight 30° 00,0' N. 36° 55.0' W.

Observed position 30° 01·1' N. 36° 56·9' W.

Note

The east-west distance on your plot between the two D.R. positions should be the departure and not the d. long.

Latitude by meridian altitude method

The meridian altitude is the altitude when the body is on the same meridian as the observer. Under these circumstances the bearing of the body is either north or south, and therefore the position line will always run in an east-west direction. It therefore coincides with the parallel of latitude upon which the observer lies.

The standard method of finding the noon position at sea is to obtain a position line during the forenoon and transfer it up to the time of noon. The transferred position line can then be crossed with the noon latitude.

Example 5

In D.R. position 30° $15 \cdot 0'$ N. 26° $40 \cdot 0'$ W., an observation of the sun gave a bearing of 110° T. intercept 6,5' towards. The ship then steamed 245° T. 20 miles, when the latitude by meridian altitude of the sun was 30° $00 \cdot 0'$ N. Find the ship's position at noon.

A complete picture of the problem would look as follows. In fact only the part inside the dotted lines need be plotted.

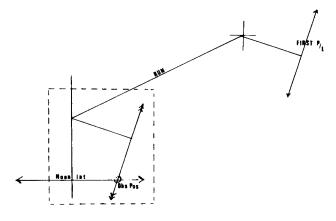


Fig. 9.7

The accuracy of the position obtained depends largely upon the length of the run up to noon. Hence this should be kept as short as possible consistent with a good angle of cut between the forenoon position line and the noon latitude.

The course and distance should be applied to the morning D.R. by use of the traverse table to find the position through which to draw the transferred position line.

Procedure

- 1. Apply the course and distance to the morning D.R. to give a noon D.R.
- 2. Plot this position and draw in the morning intercept and the transferred position line.
- 3. Take the difference between the noon D.R. and the observed latitude and hence plot the observed latitude, drawing in the position line running east-west.
- 4. The point where the transferred position line cuts the noon latitude is the position of the observer at noon.
- 5. Measure the departure between the observed position and the D.R. longitude, and convert it to d. long.
- 6. Apply this d. long. to the D.R. long. to get the observed

longitude.

D.R. at morning sight 30° 15,0′ N. 26° 40.0′ W.

Run 254° T. 20m. 8,5' S. 20.9' W.

D.R. at noon 30° 06,5' S. 27° 00.9' W.

L

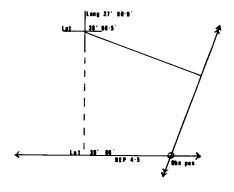


Fig. 9.8

By measurement departure between observed longitude and D.R. long.=4·S' E.

Longitude of D.R. noon 27° ()()·9' W.

D. long. $\underline{5\cdot 2' E}$.

Observed longitude 26° 55,7' W.

Observed position 30° ()()'O' N. 26° 55,7' W.

Example 6

An observation in D.R. latitude 42° 30' N. gave a longitude of 32° 08' W. bearing of the observed body 050° T. The ship then ran 075° T. for 35 miles when a meridian altitude gave a latitude of 42° 42' N. Find the ship's position at the time of the meridian altitude.

D.R. at first sight $42^{\circ} 30.0' \text{ N. } 32^{\circ} 08.0' \text{ W.}$

Run 075° T., 35m. 9·1' N. 45·9' E.

D.R. at time of meridian alt. $42^{\circ} 39 \cdot 1'$ N. $31^{\circ} 22 \cdot 1'$ W.

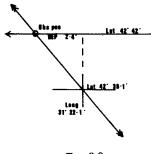


Fig. 9.9

By measurement departure between observed position and D.R.=2·4' W.

D.R.longitude 31° 22·1′ W.

D. long. $3 \cdot 3'$ W.

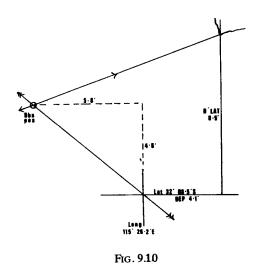
Observed long. 31 ° 25,4' W.

Observed position 42° 42·0′ N. 31° 25·4′ W.

Example 7

Position line from observation of a celestial body combined with the position line from observation of a shore object.

An observation of a celestial body gave bearing 220° T. and long. 115° 02' E., by using D.R. lat. 32° ()()' S. Later, a point of land (lat. 32° ()()' S., long. 115° 31' E.) bore 070° T. Between the observations the vessel steamed 145° T. for 17 nautical miles, and then 063° T. for 12 nautical miles. Find the vessel's position.



'Co. 145° dist. 17' d.lat. 13-9' S.

Dep. 9,8' E.

Co. 063° dist. 12' 5·4' N.

10,7' E.

D. lat. 8,5' S.

20·5' E.

Dep.

D.R. lat. 32° 00' S. Obs. long. 115° 02' E.

D. lat. <u>8'5' S.</u> D. long. <u>24·2' E.</u>

Run up pos. lat. $32^{\circ} 08.5'$ S. Long. $115^{\circ} 26.2'$ E.

Point of land lat. 32° 00'0' S. Long. 115° 31.0' E.

D.lat. 8.5' N. D. long. 4,8 E. Dep.

=====4.1'E.

From plot D. lat. 4'8' N. Dep. 5.8' W. D. long. 6'8' W.

Run up pos.lat. $32^{\circ} 08.5'$ S. Long. $115^{\circ} 26.2'$ E.

D.lat. <u>4'8' N.</u> D. long. <u>6'8' W</u>.

Ship's pos. lat. 32° 03'7' S. Long. 115° 19.4' E.

Procedure

1. Calculate the run up position from the D.R. lat. and the obs. long.

- 2. Plot the position of the point of land in relation to the run up position, converting the d. long. into departure, and draw in the line of bearing.
- 3. Measure the d. lat. and dep. from the ship's position to the run up position, convert the dep. into d. long. and thence find the lat. and long. of the ship's position.

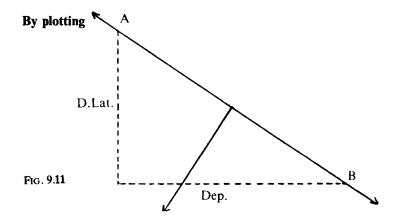
Example 10

On a vessel at anchor, an observation of the sun, during the afternoon, gave longitude 05° OS' W. by using lat. 50° 04' N. Vertical sextant angle observations taken later, put the ship 4 M. south and 6 M. east of this position. What was the sun's true bearing?

Description of figure:

A The point in lat. 50° 04' N., long. 05° OS' W.

B The point 4' S. and 6' E.



The position line must pass through position A and it must also pass through B since that was the ship's actual position. Therefore a line at right angles to the line joining A and B will give the sun's true bearing.

Sun's bearing=214° T.

By calculation

From a figure similar to the plot,

Tan
$$LA = \sim = 1'5$$

4

$$A=56^{\circ} 19'$$
 ... direction of $AB=S$. 56° 19' E.

Hence Sun's bearing=213° 41' T.

Note

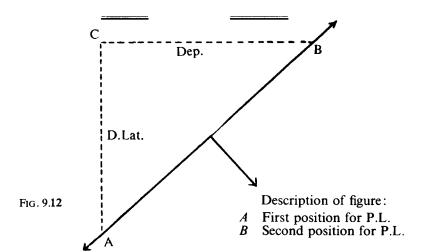
There are two possibilities for the bearing, i.e. either N. 34° E. or S. 34° W. As the body observed was the sun during the afternoon, it must therefore be west of the meridian. So S. 34° W. is the correct answer.

Example 11

A morning observation of the sun worked with lat. 42° 10' N. gave long. 35° 20' W. and when worked with lat. 42° 20' N. gave long. 35^{u} 05·1' W. What was the sun's bearing?

By plotting

d.lat. =
$$10'$$
 N. d. long. = $14.9'$ E.



The position line must pass through A and through B. Therefore by joining these two points, the position line is obtained, and the sun's bearing will be at right angles to this direction, and as the observation of the sun was taken during the morning then sun's bearing = 138° T.

By calculation

From a figure similar to the plot, and using the traverse table:

AC (d. lat.) 10, and CB (dep.) 11, give angle equal to 47° 44' :. PL. trends 047° 44' T.-227° 44' T., so that sun's bearing= 137° 44'

EXERCISE 9A

- 1. Given chosen position lat. 40° 20' N., long. 18° 30' W., T.ZX 38° $10\cdot0$ ', C.ZX 38° 20,0', azimuth 120° T. Plot the position line, using scale of 1 cm. to 1 nautical mile, and state the position of the intercept terminal. point.
- 2. D.R. position lat. 20° 20' S., long. 27° 30' W., true altitude 55° 28', C.zX 34° 26', azimuth 235° T. Plot the position line. State the position of the intercept tenninal point.
- 3. In D.R. position lat. 40° ()()' N., long. 30° ()()' W., an observation of the sun gave true altitude 45° 02'. The calculated zenith distance was 45° 04', and the azimuth was 140° T. Plot the position line and state the position of the intercept tenninal point.
- 4. From the following simultaneous observations, find the ship's position:

Sun -bearing 130° T. intercept 6,0' towards Venus-bearing 210° T. intercept 8.0' away

The selected position was lat. 50° 10′ N., long. 44° 20′ W.

5. In estimated position lat. 40° 20' N., long. 34° 20' W., simultaneous observations gave:

Sirius -bearing 136° T. intercept 10·0' away }Find ship's

Venus-bearing 286° T. intercept 8,0' towards position

6. In D.R. position lat. 48° 10' N., long. 500 14' W., simultaneous observations of two stars gave:

1.longitude 50° 08' W. azimuth 070° T. 2. longitude 50° 20' W. azimuth 330° T.

Find the ship's position.

7. By using D.R. lat. 25° 20′ N., simultaneous stellar observations gave:

1.longitude 36° IS' W. bearing 060° T. 2. longitude 35° 50' W. bearing 3()()O T.

Find the ship's position.

8. From a vessel steering 035° T. a point of land bore 330° T.

After the vessel had steamed 30 nautical miles, the point bere 250° T. Find the distance off the point at the second observation.

- 9. In D.R. position lat. 23° 40' N., long. 52° 30' W., a stellar observation gave intercept 4' towards, and bearing 040° T. The vessel steamed 090° T. at 12 knots through a current setting 000° T. at 2.5 knots. Two hours later, another observation gave the intercept 5' towards and bearing $120\sim$ T. Find the ship's position at the 2nd observation.
- 10. By using D.R. lat. 34° 11' N. the longitude by observation was 42° 25' W., bearing of the sun being 121° T., and log reading 40. The vessel steered 042° T. until noon, when the latitude by meridian altitude of the sun was 34° 11' N., and the log read 72. Find the position at noon.
- 11. An observation of the sun gave longitude 36° 58' W. and bearing 130° T., by using D.R.lat. 29° 32' S. The ship then steamed 3()()0 T. for 27 M. in a current setting 090° T. 5 M., when the latitude by meridian altitude of the sun was 29° 06' S. Find the ship's position at noon.
- 12. In D.R.lat. \cdot 34° 20' N. an observation of a star gave longitude 47° 58' W., and bearing of the star as 222° T. At the same time an observation of another star gave longitude 47° 46' W., and bearing 14r T. Find the ship's position.
- 13. By observation in D.R. position lat. 53° 47′ S., long. 178° 37′ W., the bearing of the sun was 076° T. intercept 11′ away. The ship then ran 284° T. for 47 M. through a current setting 256° T. for 7 M., when a second observation of the sun gave bearing 284° T., intercept 5′ towards. Find the ship's position at the second observation.
- 14. By using selected position lat. 16° 41′ S., long. 163° 29′ E., an observation of the sun gave intercept 18′ away, bearing 055° T. The ship then steamed 208° T. 33 M., when a second observation gave intercept 12′ towards, bearing 332° T. Find the ship's position at each observation.
- 15. An observation of the sun worked with lat. 42° 17' S. gave longitude 76° 43' E., bearing 123° T. The ship then steamed 23T T. 29 M. until noon, when the latitude by meridian altitude of the sun was 42° 27' S. Find the ship's position at noon.
- 16. In D.R. position lat. 39° 39' N., long. 130° 47' E., an observation of the sun gave intercept 4' towards, bearing 160° T. Later, a second observation, using lat. 39° 09' N. gave longitude 130° 47' E., bearing 200° T. Find the ship's position at the second observation, if during the interval the ship ran 196° T. 20 M. and 186° T. 18 M.
- 17. During the forenoon, the longitude was worked out on a vessel at anchor. Fog then set in. Later the fog cleared, and vertical

angle observations put the ship 6 M. north and 5 M. east of the observed position. What was the true bearing of the sun at sights?

- 18. An a.m. sight of the sun when worked with lat. 51° 55' N. gave longitude 20° 04' W., and when worked with lat. 52° 05' N. gave longitude 19° 54,5' W. What was the true bearing of the sun?
- 19. An observation worked with D.R. lat. 48° 20' N. gave long. 35° 17' W., and bearing 127° C. The vessel then steamed for 4 hours at 11 knots and a current set 090° T. at 3 knots. The course steered was 154° C., dev. 5° E., var. 12° W., wind N.E., and leeway 5°. A second observation then gave a star's bearing 252° c., intercept 10' towards. Find the ship's position.

CHAPTER 10 CORRECTION OF ALTITUDES Definitions

Visible Horizon

The circle which bounds the observer's view of the earth's surface in a clear atmosphere.

Sensible Horizon

A plane which passes through the observer's eye and is at right angles to the vertical of the observer.

Rational Horizon

A plane which passes through the centre of the earth, and is at right angles to the observer's vertical. The rational horizon is therefore parallel to the sensible horizon.

The observed altitude of a heavenly body is the angle at the observer's eye between a line from the observer's eye to the point on the body observed, and a line from the observer's eye to the visible horizon. In figure 10.1 angle L LEV.

The altitude required for navigational computations is the true altitude. This is the angle at the centre of the earth between a line joining the earth's centre and the centre of the heavenly body, and the plane of the observer's rational horizon.

The following corrections must be applied to the observed altitude to obtain the true altitude.

Dip

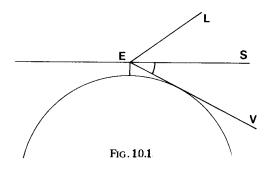
This is defined as the angle at the observer's eye between the plane of the sensible horizon and a line joining the observer's eye and the visible horizon. In figure 10.1 angle *L* SEV.

The application of dip to the observed altitude corrects the altitude above the visible horizon to an altitude above the sensible horizon. The altitude so corrected is called the Apparent altitude.

In the figure:

LLEV = Observed altitude L LES = Apparent altitude LSEV = Dip

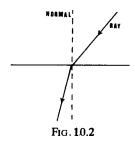
Thus Apparent altitude = Observed altitude- Dip.



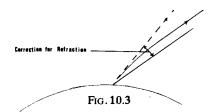
Thus dip is always negative. Values of dip are tabulated against height of eye in nautical tables and in the *Nautical Almanac*.

Refraction

A ray of light entering a medium of greater density than that in which it has been travelling is bent or refracted towards the normal. (The normal is the perpendicular to the surface of the interface between the two mediums at the point of entry of the ray of light.)



Light entering the earth's atmosphere from space therefore is so refracted, but as there is no definite interface between the atmosphere and space, but a gradual increase in density of the air, the refraction is not sudden as in figure 10.2, but the ray is bent gradually as it approaches the earth's surface. The true path of a ray therefore is as shown as a solid line in figure 10.3, but the apparent direction of the body to an observer will be as shown as a dotted line. The altitude will always appear to be greater than it really is, and therefore a correction must be subtracted to allow for it.



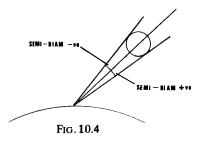
Refraction is greatest at low altitudes and is zero when the ray of light enters the atmosphere at right angles to the earth's surface, i.e. when the altitude is 90° Uncertainty in the value of refraction at low altitudes makes it advisable to avoid taking sights of bodies near the horizon, if possible.

Values of refraction for standard conditions of atmosphere are tabulated against altitude in nautical tables.

Semi-diameter

In the case of the sun and the moon, it is easier and more accurate to take the altitude of the upper or the lower edge or limb of the disc rather than estimate the position of the centre of the disc. A correction must in this case be applied to obtain the altitude of the centre of the body.

The amount of the correction will be the angle subtended at the observer's eye by the radius or semi-diameter of the body. From figure 10.4 it will be positive to an observation of the lower limb, and negative to an observation of the upper limb.



Semi-diameter varies with the distance of the body from the earth, and values are given in nautical tables. They are also given for each day in the daily pages of the almanac at the foot of the 'sun' and 'moon' columns.

Parallax

This is defined as the angle at the centre of the body, subtended by the line from the centre of the earth to the observer's eye. The application of this correction changes the altitude observed at the observer's position on the surface of the earth, to the altitude as it would be observed from the centre of the earth.

In the figure LELC is the angle of parallax.

L LES is the altitude uncorrected for parallax.

L LCR is the altitude after correction for parallax, i.e. the true altitude.

The external angle of a triangle is equal to the sum of the two internal and opposite angles.

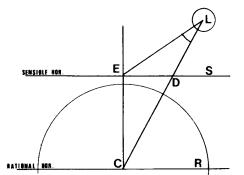


Fig. 10.5

Thus from figure to 5 L LDS = L LCR = True altitude

thus T. alt. = App. alt. + parallax

Thus the parallax correction is always positive to apparent altitude to give true altitude. The value of parallax will vary with the altitude, and will be maximum when the body is on the horizon, and zero when the altitude is 90°. Values for the sun are tabulated against altitude in nautical tables. For parallax of the moon, see 'Correction of Moon's Altitude'. The value of parallax for the stars, because of the vast distances of the stars, is negligible.

Note

The index error of the sextant should be applied before any correction of altitude is done, according to the rule:

Index error off the arc, error positive, Index error on the arc, error negative.

Summary

To correct an altitude of the sun we need to apply the following corrections.

Index error - ve, or + ve

dip - ve

refraction - ve

semi-diameter -ve (upper limb), +ve (lower limb)

parallax + ve

To correct an altitude of a star or planet, we need to apply the

following corrections.

Index error - ve. or + ve

dip - ve

CORRECTION OF THE SUN'S ALTITUDE Example

The sextant altitude of the sun's lower limb was 45° 20', index

error 1.2' on the arc; height of eye 15-4 metres; sun's semi-diameter 15,9'. Find the true altitude of the sun's centre.

Dip
$$-6.93'$$

45° 10,93'

S.D.
$$+ 15.90'$$

45° 26.83'

par.
$$+ 0.11'$$

Notes

- 1. The corrections for dip. refraction, and parallax-in-altitude are obtained from the appropriate tables in *Norie's*, *Burton's*, etc.
- 2. The sun's semi-diameter is obtained from the daily page for the given date in the *Nautical Almanac*.
- 3. The corrections should be made in the order shown.

Example 2

The sextant altitude of the sun's upper limb on 7th January, 1.980, at a certain instant was 53° 14.4'; index error 104' off the are, height of eye 18 metres. Find the true altitude.

Sext. alt.
$$53^{\circ} 14.4'$$
I.E. $+ \frac{1-4'}{}$
Observed alt. $53^{\circ} 15.8'$
dip $-\frac{7.5'}{}$

53° 08·3'

Apparent alt.

refraction - <u>0' 7'</u>

53° 07,6'

S.D. - <u>16·3'</u>

52° 51·3'

parallax $+ \underline{0.1}'$

True altitude 52° 51·4'

EXERCISE IOA CORRECTION OF THE SUN'S ALTITUDE

These examples are to be worked *fully* (as shown), i.e. using individual corrections.

Find the true altitude of the sun's centre, given:

- 1. The sextant altitude of the sun's lower limb was 52° 31,2'; index error $2 \cdot 2'$ on the arc; height of eye 8,3 metres; sun's semidiameter 16,1'.
- 2. The sextant altitude of the sun's L.L. 33° 10' 50"; I.E. $1\cdot0'$ off the arc; H.E. $12\cdot0$ metres; S.D. 15.9'.
- 3. Sextant altitude U.L. 71° 53' 30"; index error 1' 50" off. the arc; H.E. $11 \cdot 0$ metres; S.D. 16.0'.
- 4. The observed altitude of the sun's upper limb was 27° 46′ 40″; height of eye 7,7 metres; semi-diameter 15′8′.
- 5. Sextant all. L.L. 62° 34,3'; I.E. 2·2' off the arc; H.E. 9 metres; S.D. 16· I '.
- 6. Sextant altitude of the sun's upper limb was 55° 55' 50", index error l' 00" on the arc; height of eye 7,4 metres; semidiameter $16 \cdot 3$ '.
- 7. The sextant altitude of the sun by back angle, using the limb nearest the clear horizon, was 110° 51,6'; index error $2 \cdot 2'$ off the arc; H.E. $11 \cdot 5$ metres; semi-diameter $16 \cdot 2'$.
- 8. The sextant altitude of the sun by reverse horizon, using the limb farthest from the clear horizon, was 98° $24\cdot4'$; index error $1\cdot2'$ off the arc; height of eye 10,5 metres; semi-diameter 16,1'.

CORRECTION OF THE ALTITUDE OF A STAR OR A PLANET

Example

Find the true altitude of the star Rigel~11, the sextant altitude of the star being 29° 17,2', index error 1,8' off the are, and height of eye 14.0 metres.

Sext. all.	29° 17·2'
I.E.	+ <u>1,8'</u>
Obs. all.	29° 19·0'
dip	- <u>6,6'</u>

29° 12.4'

EXERCISE 10B

FIND THE TRUE ALTITUDE OF THE FOLLOWING BODIES

.&A

Ht. of eve

			""J"	J
	Sext. Alt.	Ind. Error	(metres)	Body
1.	47° 29,6'	1,0' on the arc	11.2	Altair
2.	32° 24,4'	0,8' on the arc	7.3	Canopus
3.	21° 13,6′	0-4' off the arc	11.6	Arcturus
4.	47° 15,8'	1.4' on the arc	15.3	Polaris
5.	37° 10,4′	1,8' on the arc	8,4	Dubhe
6.	12° 17,0'	2,0' off the arc	14.0	Sa turn
7.	53° 20·2'	0,6' on the arc	7,7	Venus
8.	23° 14·0'	$2 \cdot 2'$ off the arc	11.0	Jupiter
9.	51 ° 56·0'	0-4' on the arc	17.0	Mars
10	14° 38·2'	2,8' on the arc	9,9	Venus

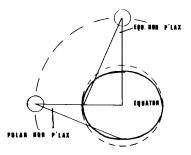
Correction of the moon's altitude

Because of the moon's proximity to the earth, the correction of its altitude presents special problems ..

Horizontal parallax

This is the angle of parallax of a body when it is on the sensible horizon, i.e. its maximum value of parallax (see definition of parallax). But even the value of horizontal parallax varies with latitude of the observer, being maximum when the observer is on the equator, and minimum when the observer is at the poles. The reason for this can be understood by considering the definition of parallax, i.e. the angle at the centre of the body subtended by a line from the observer's eye to the earth's centre. When the observer is "at the equator this line will be the equatorial radius of the earth. When the observer is at the poles it will be the polar radius. As the equatorial radius is greater then it will subtend a greater angle at the body's centre than the polar radius.





The parallax given in the almanac against each hourly G.M.T. is the equatorial horizontal parallax, and it must be reduced to find the horizontal parallax for the latitude. This correction is given in nautical tables under the name of 'Reduction to the Moon's Horizontal Parallax for Latitude'.

Once the horizontal parallax is found thus, the parallax in altitude is obtained by:

Parallax in alt=Hor. Pax. x Cosine altitude.

This figure is then added to the apparent altitude to obtain true altitude.

Augmentation of the moon's semi-diameter

Considering the distance of the moon from the earth's centre to be constant, the distance of the moon from an observer is greatest when the moon is on the rational hori~on, i.e. when the altitude is zero. It is least when the moon's altitude is 90°. The difference will be the earth's radius.

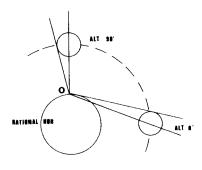


Fig.10.7

Hence the angular semi-diameter is greatest when the altitude is 90° and least when the altitude is zero.

The value given in the almanac is the least value when the altitude is zero, and must be increased or augmented for altitude. The value of the augmentation is given against altitude in nautical tables.

Hence to correct the moon's altitude the following corrections

must be applied.

Index error -ve or +ve.

dip -ve.

refraction - ve.

semi-diameter -ve or +ve after augmentation.

parallax in all. +ve obtained by reducing the equatorial

parallax and multiplying by cosine altitude

CORRECTION OF THE MOON'S ALTITUDE Example

The sextant altitude of the moon's lower limb was $]6^{\circ}$ 58,2', index error 0,8' off the arc, height of eye 5,4 m., semi-diameter $]5\cdot2'$, horizontal parallax 55·7', and latitude]20 50' N. Find the true altitude of the moon's centre.

	Sextant altitude]6°	58.2'	Semi-diameter]5·2'
	Index error		+ 0,8'	_augmentation	0.07'
	Observed alt.]6	° 59,0'	Augmented S.D.]5·27'
	dip	- <u>4,</u>]	<u>6</u> '		===
]6°	54,84'	Hor. par.	55,7'
	Semi-diameter	+	<u>15·27'</u>	reduction	Nil
	Apparent all.]7	0 10,]]'	Reduced H.P.	55,7'
	ref.	-	<u>3,05</u> '		
	App. all.] 7	° 07,06'	parin-alt.	
	parin-all.	+	53.23'	=H.P. x coso app.	alt.
=.	55,7' x cos.]7°07	,06'			
	True altitude	<u> 18</u>	° 00·29'	=53,23'	

Notes

-]. The corrections for augmentation of the moon's semidiameter, and the reduction for latitude to apply to the equatorial horizontal parallax, are taken from tables given in *Burton's*, *Norie's*, etc.
- 2. Working to the second place of decimals is not necessaryone place is quite sufficient. It is here shown solely for illustration.

EXERCISE toc CORRECTION OF THE MOON'S ALTITUDE

From the following information, find the true altitude of the moon's centre:

	Obs. limh		Index	: Erre	or	Height of eye	S.D.	HJ'.	Lat.
						(metre s)			
J.	L.L.	63° 12·8'	1·6' arc	off	the	7.3	15,3	56.0'	50° N.
2.	L.L.	34° 14·8'	2·2' arc	on	the	13.0	15- 1'	55-4'	39° S.
3.	V.L.	58° 16·2'	1,0' arc	on	the	10.4	16·1 '	59·2'	44° N.
4.	V.L.	77° 51·6'	1·2' arc	off	the	9,0	14.8	54·5'	22° N.
5.	L.L.	21° 38,8'	3·4' arc	on	the	11.5	15.8	58·1 '	00
6.	L.L.	38° 21,8'	2,4' arc	off	the	9.0	16- 3'	59,7'	41°IO'S.
7.	V.L.		1,6' arc	on	the	16.0	14,9	54·6'	37° 20' N.
8.	L.L.	43° 18,4'	Nil			13.7	16·6 '	61·0'	2SO 15' S.

Total correction tables

In practice correction of altitudes is simplified by the use of total correction tables. The most commonly used, and described here, are the convenient correction tables included in the *Nautical Almanac*. These are in three tables, for the sun, for stars and planets, and for the moon respectively. Each table is compiled with the apparent altitude as the argument so that the dip correction must first be applied to the observed altitude. A dip table is included with the total correction tables.

The dip table

The dip is tabulated against height of eye in metres or in feet. The table is based upon the formula:

$1.76\sqrt{\text{ht. of eye in metres.}}$

The table is arranged as a critical entry table which means that one value of the correction is given for an interval of the argument, height of eye. This means that no interpolation is

necessary, but it should be remembered that if the required height of eye corresponds to a tabulated value, then the upper of the two possible values of correction should be used. Thus the correction for a height of eye of 13·0 metres is -6·3 (see extracts of *Nautical Almanac*, correction tables).

Sun total correction table

The sun correction table, found on the first page of the almanac, corrects for mean refraction, semi-diameter and parallax. The argument is the apparent altitude, that is the observed altitude corrected for dip. Two separate tables are used, one for the spring and summer months from April to September, and one for the autumn and winter months, from October to March. This allows annual variations in the semi-diameter to be allowed for. Each table contains corrections for lower limb observations in bold type and corrections for upper limb observations in. feint type. The tables are arranged as critical tables which means that one value of the correction is given for an interval of the argument, apparent altitude. No interpolation is required but it should be remembered that if the required value of apparent altitude is a tabulated value then the correct correction is the upper of the two possible corrections. For example for an apparent altitude of 50° 46' in the October to March table a correction of + 15·4 (lower limb) should be used (see extracts from the *Nautical Almanac*).

Example

The sextant altitude of the sun's lower limb was 48° $56 \cdot 3'$. Index error $1 \cdot 2$ on the arc. Height of eye $7 \cdot 2$ metres. Date June 16th. Find the true altitude.

Sextant altitude 48° 56·3'

Index error $-1 \cdot 2'$

Observed altitude 48° 55·1'

Dip -4·7'

Apparent altitude 48° 50.4'

Correction $+15 \cdot 1.$ '

True altitude $49^{\circ} 05.5'$

Stars and planets

The correction table for stars and planets found on the first page of the almanac, corrects for a mean refraction only. The corrections are tabulated against apparent altitude (observed altitude corrected for dip), and are arranged as critical entry tables.

For Mars and Venus an additional correction may be applicable, depending upon the date. These are given down the right hand side of the refraction correction table. The additional correction for planets corrects for the effect of parallax and phase, but the correction for Venus is only applicable when the sun is below the horizon. The correction for daylight observations may be calculated from data given in the explanation in the back of the almanac, but the magnitude of the corrections is such that this is unnecessary and may be ignored.

Example

The sextant altitude of the star *Procyon* was 57° 18.9' Index error

1.0' off the arc. Height of eye 6.5 metres. Find the true altitude.

Sextant altitude 57° 18.9'

Index error + 1.0'

Observed altitude 57° 19.9'

Dip -4.5'

Apparent altitude 57°15.4'

Correction -0.6'

True altitudt: 57°14.8'

Example

The sextant altitude of Mars on 30th March 1980 was observed to be 38° 06.5'. Index error 0.5' off the arc. Height of eye 5.0 metres. Find the true altitude.

Sextant altitude 38° 06.5'

Index error +0.5'

Observed altitude 38° 07.0'

Dip -3.9'

Apparent altitude 38° 03·1.'

Correction $-1 \cdot 2'$

38° 01,·9'

Additional corr. + 0.2'

True altitude $38^{\circ} 02 \cdot 1.$

Moon

The moon's total correction table, found on the last pages of the almanac, is in two parts. The main correction, in the upper part of the table corrects for refraction, semi-diameter and parallax, using mean values. It is tabulated against apparent altitude, and some interpolation is necessary to obtain the accuracy to within one decimal place.

The second correction allows for variations in the semi-diameter and parallax, both of which depend upon the horizontal parallax. The arguments are therefore, apparent altitude and horizontal parallax. Two values are given one for lower limb, and one for upper limb

observations. These are arranged in columns, the correction being taken from the same column as that from which the main correction was extracted, and against H.P.

All corrections for the moon are additive to the apparent altitude, but those for upper limb observations have 30' added to maintain them positive. This 30' must therefore be subtracted from the final altitude.

Example

The sextant altitude of the moon's lower limb was 16° $58 \cdot 2'$. Index error $0 \cdot 8'$ off the arc. Height of eye $5 \cdot 4$ metres. The G.M.T. was 1400 on 27th June 1980. Find the true altitude.

From almanac H.P. =56.9

Sextant altitude 16° 58·2'

Index error ± 0.8

Observed altitude 16° 59.0'

Dip $-4\cdot1'$

Apparent altitude 16° 54.9'

Main correction +62.7'

Second corr. $\pm 4.0'$

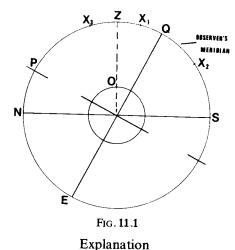
True altitude $18^{\circ} \ 01.6^{\circ}$

CHAPTER 11

LATITUDE BY MERIDIAN ALTITUDE

An observation of any body whilst on the meridian of the observer is of particular value to the navigator as it provides a quick and easy method of finding a position line which will be coincident with the observer's parallel of latitude. The latitude obtained from the sight is therefore the observer's latitude.

Let the following diagram represent the earth and the celestial sphere on the plane of the observer's meridian.



Explanation

o is the position of the observer in northerly latitude.

Z is the observer's zenith on the celestial sphere.

NS is the plane of the rational horizon.

If EQ represents the plane of the equinoctial then P will be the north celestial pole and arc ZQ will be the latitude of the observer.

Consider a body XI of declination same name as the latitude and less than the latitude, while on the observer's meridian. Then ZX_I is the angular distance of the body from the zenith, i.e. the zemth distance, and XI Q is the angular distance of the body from the equinoctial, i.e. the declination.

170

From the diagram:

$$ZQ = ZX_I + XIQ$$

Latitude = zenith distance + declination

Consider a body X_2 of declination opposite name to latitude. Then similarly:

$$ZQ = ZX_2 - QX_2$$

Latitude = zenith distance - declination'

Consider a body of X_3 of declination the same name as latitude and greater than latitude.

Then similarly:

$$ZQ = QX_3 - ZX.$$

Latitude = declina tion - zemth distance

These results can be memorised but preferably the appropriate one can be simply derived in each problem as is shown in the first example to follow.

Latitude by meridian altitude of a star Procedure

- I. Extract the declination of the star from the daily pages of the *Nautical Almanac* at the appropriate date. One value is given for each three day page in the list of stars. (If the star is not listed in the daily pages refer to the complete list of selected stars at the end of the almanac.)
- 2. Correct the sextant altitude for (i) Index error,
- (ii) Dip,
- (iii) Refraction (main correction from, the table on the inside cover of almanac).
- 3. Subtract the true altitude from 90° to obtain the zenith distance.
- 4. Draw a rough sketch on the plane of the rational horizon to

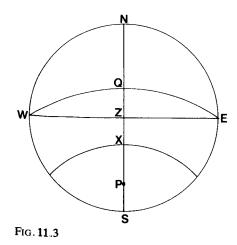
determine the appropriate rule, thus:

Insert the position of Z (the central point of the diagram). Mark on X the body, either to the north or to the south of Z according to the bearing of the body at meridian passage, and at a distance from Z to represent the zenith distance. Mark on Q, the point where the equinoctial cuts the observer's meridian, either to the north or to the south of X according to the name of the declination, and at a distance from X to represent the declination.

The relationship between ZX and QX should now be evident in order to find Z Q.

(See figure in example I for illustration.)

5. Apply the declination to the zenith distance accordillg to the rule derived, to give latitude.



_ -- -~""

Notes

The bearing of the body must either be 000° or 180°. The position line must therefore run along a parallel of latitude upon which the observer must lie.

If the bearing of the body is not given in the question it can be inferred by inspection of the latitude of the D.R. and the declination. If declination is greater north than a northerly latitude then the body must pass to the north of the observer at meridian passage. If they are of opposite names then the bearing must be the same as the name of the declination.

Note that the time of meridian passage is not required for the calculation. This is because the declination of a star is constant over relatively large periods of time, and the G.M.T. is not required therefore for extracting it. In practice the time will be required, however, in order to know when to take the sight.

Example 1

18th December, 1980, the sextant altitude of the star Diphda4 on the meridian, bearing 180^{0} T., was 46° 15'4', index error 1·4' on the arc, height of eye 12 metres, D.R. position lat. 25° 33' N., long. 330 52' W. Find the latitude and P.L.

Sext. alto 46° 15,4' S. Dec. 18°05.7S.

indo err. - <u>1'4'</u>

Obs. alto 46° 14'0'

dip - 6· **I** '

46° 07,9'

Main corr. - 0.9

True alt. $46^{\circ} 07,0' \text{ S}.$

<u>90°</u>

zen. dist. 43° 53,0' N.

dee. $18^{\circ}05.7'$ S.

lat. 25° 47·3′ N.

_

NESW Represents the plane of the observer's rational

horizon.

Z The observer's zenith. *dd* The parallel of declination.

P The elevated pole. X The body on the observer's

PZS The observer's m(Oridian. meridian.

WQE The equinoctial. ZX The true zenith distance.

WZE The prime vertical. QZ The observer's latitude.

P.L. trends 090° T.-270° T. through lat. 25° 47·3'N., long. 33° 52' W.

Example 2

On 5th January, 1980, the sextant altitude of the star *Fomalhaut* when on the meridian south of the observer was 77° 52·4'. I.n^{dex} error 3·0' off t~e a~c. Height of eye 11.0 metres. Find the latitude and state the dIrection of the position line.

Sext. alt. 77° 52-4' Declination 29° 43.9' S.

indo err. +3.0'

Obs. alto 77° 55-4'

dip - 5,8'

77° 49'6' Main Corr.- 0.2'

True alt. 77° 49,4'

Zen. dist. 12° 10'6'

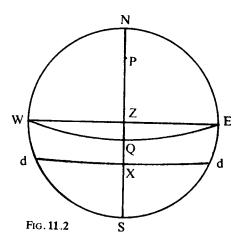
Decl. <u>29° 43·9′</u> S.

Latitude 17° 33·3′ S.

EXERCISE 11A

- 1. 19th September, 1980, to an observer in long. $,42^{\circ}$ 10' W., the sextant altitude of *Aldebaran* 10 on the meridian, was 71° 22,8', inde~ erro $_{0}^{r}$ 1-4' ~ff the arc, height of eye 14·5 metres, the star beanng 180 T. Find the latitude and P.L.
- 2. 19th December, 1980, the sextant altitude of *Dubhe* 27 on the meridian, and bearing 000° T. to an observer in long. 18° 30' W., w~s 28° 06,2', index error $1\cdot2$ ' off the arc, height of ~ye

- ~ 0.5 metres. Fmd the P.L. and latitude of the point through whIch It IS drawn.
- 3. 5th January, 1980, in D.R. yosition, lat. 49° 50' S., long. 42° 10' W. the sextant altitude of the star *Regulus* 26, on the meridian, was 28° 14'4', index error 0'6' on the arc, height of eye 15.3 metres. Find the latitude and the P.L.
- 4. 18th September, 1980, Rigel 11 was observed on the meridian bearing 000° (T.), sextant altitude 68° 10.9' index error 0.4' on the arc, height of eye 14'5 metres. Find the latitude and P.L.
- 5. 27th June, 1980. Find the latitude of an observer, given: sextant altitude of *Alioth* 32 on the meridian, was 34° 03'5', bearing 000° T., index error \mathbf{i} '8' off the arc, height of eye 12.0 metres.



Latitude by meridian altitude of the sun

The true or apparent sun is on the observer's meridian at apparent noon or 1200 Local Apparent Time each day. However, we require the mean time when this occurs, in order to extract the declination.

The L.M.T. of apparent noon may be earlier or later than 1200 hours by the value of the equation of time, and is given for each day at the foot of each right hand daily page in the *Nautical Almanac*, in the box labelled SUN under the heading 'mer. pass'. The longitude in time can then be applied to this figure to obtain the G. M. T. (See chapter 7 on finding times of meridian passages.) It is sufficient in this case to obtain the G.M.T. to the nearest minute.

Procedure

- 1.Take out the L.M.T. of meridian passage from the almanac. 2. Apply the longitude in time to obtain G.M.T. (longitude WEST, Greenwich BEST, longitude EAST, Greenwich LEAST).
- 2.Extract the declination for this G.M.T.
- 4. Correct the altitude and subtract from 90° to obtain zenith distance.
- 5. Apply the declination to the zenith distance as explained for the problem with a star.
- 6. State the direction of the position line, which will always be east/west.

Note

If it is preferred to remember rules of thumb to obtain the latitude, given the zenith distance and the declination, then the following may be helpful.

Put the bearin~ of the sun, i.e. N. or S., after the sextant altitude and the true altItude and apply the reverse name to the zenith distance.

Then:

la t. = zen. dist. + decl. (if the names are the same).

lat. = zen. dist. "" decl. (if the names are different, and name the lat. the same name as the greater).

Example

18th December, 1980, in D.R. position 22° OS' N., 154° 20' W., the sextant altitude of the sun's L.L. on the meridian was 44° 20,8', index error 0,4' off the are, height of eye $15\cdot3$ metres. Find the latitude and P.L.

L.M.T. mer. pass. 18th Ilh 57m

Long. W. <u>IOh 17m</u>

G.M.T. 18th 22h 14m

Sext. alt. 44° 20.8' S. Dec. 23° 24.6' S.

I.E. + 0.4'

obs. alt. 44° 21·2'

dip $-\underline{6.9'}$

App. alt. 44° 14·3'

main corr. + 15,3'

True alt. $44^{\circ} 29.6' \text{ S}$,

90°

zen. dist. 45° 30,4' N

dec. 23° 24.6′ S.

latitude $22^{\circ} 05.8' \text{ N}.$

P.L. trends 090°T.-2700T. through lat. 22° 05·8' N., long. 154° 20'W.

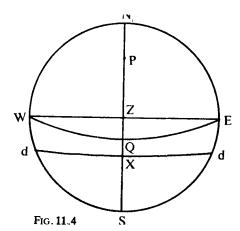
EXERCISE 11B

- 1. 18th December, 1980, in D.R. position lat. 00° 20'N., long. 162° 20' W., the sextant altitude of the sun's lower limb on the meridian was 66° 10,4' bearing south, index error 1·2' on the are, height of eye $13\cdot2$ metres. Find the latitude and P.L.
- 2. 26th June, 1980, the sextant altitude of the sun's lower limb when on the meridian was 41 $^{\circ}$ 26'4', index error 2,4' off the are, height of eye 7·3 metres. The D.R. position of the observer was lat. 25 $^{\circ}$ 10' S., long. 40 $^{\circ}$ 20' W. Find the latitude and P.L.
- 3. 6th January, 1980, an observation of the sun on the meridian by an observer 10 E.P. 51 $^{\circ}$ 30' S., 96 $^{\circ}$ 35' W., gave the sextant altitude of the sun's upper limb 61 $^{\circ}$ 25', index error was 1,4' on the are, height of eye 11.5 metres. Find the latitude and P.L.
- 4. From the following data, find the latitude and P.L.

Date at ship, 30th September, 1980.

Observer's E.P. lat. 36° 55' N., long. 165° 30' E.

Body observed: the sun on the meridian, bearing 180° T., sextant altitude of the lower limb 50° 11.8', index error 1.6' off the are, height of eye 14.0 metres.



5. 19th September, 1980, an observation of the sun on the meridian bearing 000° T. gave the sext. alto of the sun's lower limb as 37° $37 \cdot 6'$, index error $1 \cdot 6'$ off the arc, height of eye 13,0 metres. The D.R. long. was 141° $10 \cdot S'$ E.

Find the latitude and position line.

Latitude by meridian altitude of the moon

It is particularly important in the case of the moon to obtain an accurate G .M. T. for the time of meridian passage as the declination is usually changing rapidly. (See chapter 7 on finding time of meridian passage of the moon.)

Procedure

- 1. Extract the L.M.T: of meridian passage for the da;r' in question. These are given for each day at the foot of the right hand of each daily page in a box labelled MOON under the heading of 'Mer. Pass. Upper'.
- 2. Extract the time for the following day if in westerly longitude *or* the preceding day if in easterly longitude, and ~ke the difference between the two. Entering table II with this difference and the longitude, extract the correction for longitude ..
- 3. Apply this correctiOJ; i for longitude to the time of meridian passage for the required day, adding if in west longitude, or subtracting if in east longitude.
- 4. Apply the longitude in time to obtain the G.M.T. of meridian passage, and extract the declination from the almanac.
- 5. Correct the sextant altitude to true altitude and subtract from 90° to obtain the zenith distance.
- 6. Apply the declination to obtain latitude and state the direction of the position line.

Note

Particular care should be taken over the correction of the moon's altitude. Study chapter 1.0 on correction of altitudes.

Example

On 27th June in longitude 58° 45' W. the sextant meridian altitude of the moon's lower limb was 67° 4S·6' south of the observer. Index error 2·0' off the arc. Height of eye 9·5 metres.

L.M.T. mer. pass. 27th, long. 0° 23h42m L.M.T. mer. pass. 28th, long. 0° 24 h 3 7m

difference 55m

correction for longitude=9 i11 (from Table II)

L.M.T. mer. pass. 27th, long. 0° 23h42m

long. corr. ___9m

L.M.T. mer. pass. long. 58°45'W. 23h51m

longitude in tIme

_3_h_5_5m

G.M.T. mer. pass. long. 58° 45' W. 03h 46m 28th

declination 19° 36·1' S. H.P.57·2

'd' corr. +0.9'

declination 19° 37·0' S.

sextant alto 67° 48.6'

index error $\pm 2.0'$

obs. alt. 67° 50.6′

dip. -5.4

app. alto $67^{\circ} 45.2'$

main corr. $+32 \cdot 1'$

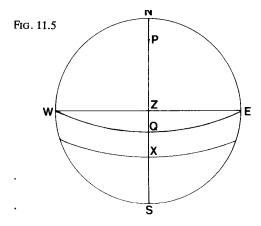
2nd corr. 4.6'

true alt. $68^{\circ} 21.9'$

Z.X. 21° 38·1'N

declination 19° 37.0' S.

latitude 2° 01·1' N



P/L runs $090^{\circ}/270^{\circ}$ through 2° $01 \cdot 1'$ N. 58° 45' W.

EXERCISE HC

- 1. On 5th January, 1980, in longitude 45° 20' E. the observed altitude of the moon's lower limb when on the meridian north of the observer was 40° IS·5'. Index error nil. Height of eye 5,5 metres. Find the latitude.
- 2. On 19th September, 1980, in longitude 16r 1S'W., the sextant meridian altitude of the

moon's upper limb was 30° 30'5' south of the observer. Index error 1,5' on the arc. Height of eye 10 metres. Find the latitude.

- 3. On 19th December, 1980, in longitude 130^{0} E. the observed altitude of the moon's upper limb when bearing south was 70° 30'0'. Height of eye 9.0 metres. Find the latitude.
- 4. On 30th September, 1980, in longitude 0° the observed altitude of the moon's lower limb when bearing 000° T. was 88° 18'6'. Height of eye 8.6 metres. Find the latitude.

To compute the altitude of a star on the meridian and find the time of the star's meridian passage

A practical problem arises when selecting suitable stars to observe in order to obtain a position. It is advantageous if a star can be found at its meridian passage at a time suitable for observation. The altitude can be computed, and this angle clamped on the sextant and the star found in the sextant telescope, and the accurate meridian altitude observed.

To enable this to be done we must first find the time when the star will be on our meridian, and this time must be at a time which is suitable for the observation of stars. In other words it must be during twilight.

In practice any stars which have their meridian passages during twilight can be found by extracting the time of nautical twilight from the almanac, and converting it to G.M.T. The S.H.A. of an imaginary star which has a G.H.A. equal to the longitude at this time can be computed, and the list of stars inspected to find stars which have S.H.A.s similar to this one.

Once a star is selected its exact time of meridian passage can be computed and this will give the navigator the time to observe. The D.R. latitude can then be used with the declination to find the zenith distance, from which the true altitude and hence the sextant altitude can be worked. The meridian altitude problem is worked in reverse to do this, all corrections being applied with the opposite sign to that in the normal way.

Example

19th September, 1980, compute the sextant altitude and find the L.M.T. when the star *Aldebaran* 10 is on the meridian to an observer in D.R. position lat. 55° 18' N., long. 142° 10' W. Height of eye 13,3 metres, index error 0.6' off the arc.

When a body is on the observer's meridian,

G.H.A. body=W.long. of observer.

Thus:

G.H.A. Aldebaran 142°10'

S.H.A. Aldebaran 291°17.9'

G.H.A. Aries 210° 52·1' (G.H.A.+3600-S.H.A.)

G.H.A.14hI9th $208^{\circ}37.5^{\circ}$

increment $2^{\circ}14.6' = 8m \ 57s$

G.M.T.mer. pass Aldebaran 19th 14h 8m57s 19th

longitude 9h 28m 40s

L.M.T. 04h 40m 17s 19th

(see chapter 7 for full explanation of this method).

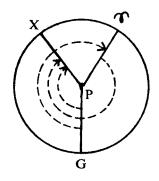


Fig. 11..6

It will be noted that this time occurs during a.m. twilight for the observer's latitude, see *Nautical Almanac*.

latitude 55° 18·0' N.

declination 16° 28 · 2' N.

Z.X. 38° 49·8'

True alt. 51°10.2'

correction ± 0.8 '

apparent alt. 51° 11.0'

dip. ± 6.4

obs. alt. 51~17·4'

index error -0.6'

sextant alt. 51° 16.8'

Computed altitude 51° 16.8' T.

EXERCISE 1iD

1. Compute the sextant altitude and find the L.M.T. of the star Vega 49 on the meridian to an observer in E.P. lat. 5° 50' N., long. 22° 30' W., index error 0,4' off the arc, height of eye 8·4 metres. Date at ship 19th September, 1980.

- 2. 6th January, 1980. Compute the altitude to set on a sextant and find the L.M. T. for observation of *Menkar* 8 on the meridian to an observer in lat. 35° 10' S., long. 32° 10' E., index error $1\cdot2$ ' off the are, height of eye $12\cdot0$ metres.
- 3. Compute the altitude of *Gienah* 29 for setting on the sextant and find the L.M.T. for observation when on the meridian, observer's D.R. position 39° 20'N., 35° 30'W., height of eye 13.2 metres, index error 0.6' off the are, gate at ship 19th December, 1980.
- 4. 27th June, 1980. Find the L.M.T. of meridian passage and compute the altitude of *Spica* 33 for seting on the sextant, index error 1.8 on the are, height of eye 16.2 metres, D.R. lat. $12^{\circ}18'$ N., long. 60° 35' E.
- 5. 20th September, 1980, E.P. lat. $36^{\circ}15$ 'N., long. $142^{\circ}04$ 'W., compute the sextant altitude of *Betelgeuse* 16 and find the L.M.T. when on the meridian, index error $2 \cdot 2$ ' off-the are, height of eye $17 \cdot 0$ metres.

Lower meridian passage

The daily apparent motion of all heavenly bodies is to describe a circle around the pole, .once in a sidereal day. Thus during this period as well as crossing the observer's meridian it must also cross the observer's antimeridian, i.e. the meridian 180° removed from the observer's meridian. Under certain circumstances the body will remain visible to an observer during the whole period, and will never set below the horizon. Such a body is called a circumpolar body. The conditions for circumpolarity are:

Latitude greater than polar distance or lat. $> (90^{\circ} - declination)$

A circumpolar body will, of course, be visible at the time when it crosses the observer's antimeridian. This occurrence is called the "'Lower Meridian Passage', 'Lower Meridian Transit', or 'on the meridian below the pole'.

The latitude can just as easily be found from an observation at lower meridian passage as at upper meridian passage.

At lower meridian passage, always:

Latitude = True altitude + $(90^{\circ}$ - declination) or lat. =T.A. + polar distance

Latitude by a star on the meridian below the pole *Procedure*

- **I.** Take out the star's declination from the *Nautical Almanac*.
- 2. Subtract the declination from 90° to obtain the polar distance.
- 3. Correct the altitude of the star.
- 4. Add the polar distance to the true altitude to obtain the latitude.
- 5. Name the latitude the same as the declination.

Example

18th September, 1980, the sextant altitude of Atria 43 on the meridian below the pole, was 19° 41,8', index error 0.8' on the are, height of eye 9,7 metres. Find the latitude.

Sext. alt. 19° 4] ·8' Dec. 68° 59.8' S.

I.E. 90° 0.8'

Obs. alt. 19° 41.0' Polar dist. 2e 00·2'

dip 5'5'

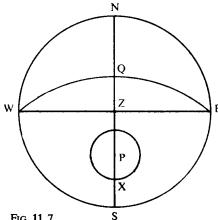
App. alt. 19° 35·S'

Corr. - <u>2,7'</u>

19° 32.8' T. alt.

Polar dist. 21° 00·2'

Latitude 40° 33·0′ S. True bearing 180° Position line 090° - 270°



Frg. 11.7

EXERCISE 11£

- 1. The sextant altitude of *Dubhe* 27 on the meridian below the pole on 18th December, 1980, was $22^{\circ} 19.5'$, index error 2.2' on the are, height of eye 12.8 metres. Find the latitude.
- 2. 19th December, 1.980, find the latitude by Alkaid 34, on the meridian below the pole, sextant altitude 12° 27.9', index error 2-4' on the are, height of eye 12.8 metres.
- 3. 7th January, 1980, the sextant altitude of Schedar 3 on the meridian below the pole was 21 ° 48.0', index error 0'8' off the are, height of eye 13.2 metres. Find the latitude.
- 4. 20th September, 1980, the star Avior 22 was observed at its lower transit, sextant altitude 19° 32-4', index error 1·2' off the are, height of eye 14 metres. Find the latitude.
- 5. 26th June, 1980, the sextant altitude of Achernar 5, on the meridian below the pole, was 13° 00·4', index error 1·4' on the are, height of eye 12·5 metres. Find the latitude.

CHAPTER 12

THE CALCULATION OF A POSITION LINE BY OBSERVATION OF A BODY OUT

OF THE MERIDIAN

A knowledge of the use of the spherical haversine formula is assumed. If necessary a text on spherical trigonometry should be consulted for its derivation and its use.

The solution of any navigational problem is basically the solution of a spherical triangle on the celestial sphere, the three points of which are: the elevated pole (P), the position of the body (X), and the position of the zenith (Z).

The three sides of the triangle will therefore be:

PX the angular distance of the body from the pole, i.e. the polar distance, i.e. 90°-declination.

PZ the angular distance of the observer from the pole, i.e. the

co-lat., i.e. 90° -latitude.

ZX the angular distance of the observer's zenith from the body, i.e. the zenith distance, i.e. 90°-altitude.

The angles of the triangle are:

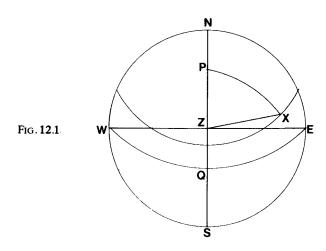
L P the angle between the observer's meridian and the meridian of the body (see definition of L.H.A.). Angle P is equal to the L.H.A. when the body is setting, and is equal to 360°-L.H.A. when the body is rising.

L Z the angle between the direction of the meridian and that of the body, i.e. the azimuth.

LX the parallactic angle. Is not used in the normal reduction of sights.

The triangle is usually represented by a figure on the plane of the rational horizon, i.e. looking down from above the observer's zenith.

182



To solve the triangle we need to know three of its elements.

The Marcq St. Hilaire (Intercept) Method

This is a popular method as any sight may be reduced by its use. The three elements used are:

- 1.An assumed latitude (D.R. lat.) to give a value for PZ.
- 2.Polar distance (PX) (90° declination).
- 3.An assumed longitude (D.R. long.), which is combined with the G.H.A. to give the L.H.A. and thus angle P.

With these arguments we solve the triangle for the side ZX, the zenith distance, by use of the haversine formula, thus:

Hav ZX=(Hav P. sin PZ. sin PX)+Hav(PZ",PX)

and as PZ=complement of latitude and PX=complement of declination

Hav ZX=(Hav P. cos lat. cos dec.)+Hav (lat.",dec.)

Having found this calculated zenith distance it can be compared with the true zenith distance, which is found by correcting the sextant altitude to a true altitude and subtracting it from 90° . The difference is the intercept (see chapter 9).

The true bearing can be calculated by the use of the ABC tables as described in chapter 8, and we are then in a position to plot a position line as described in chapter 9.

Procedure

1. From the chronometer reading, deduce the G.M.T. This is done by taking the approximate L.M.T. (ship's time indicated by clock is quite accurate enough), and applying the longitude in time to obtain the approximate G.M.T. From this can be decided:

- (a) Whether to add 12 hours to the chronometer time or not, i.e. 02h indicated on the chronometer may either be 02h or 14h.
- (b) The correct date at Greenwich. (Date given in the problem is the date at the ship. The date at Greenwich may be the day before or the day after, depending on the longitude.)
- 2. With the G.M.T. extract the G.H.A. and the declination of the body.
- 3. Apply the longitude to the G.H.A. and obtain the L.H.A. and thus deduce the angle P. (body setting L P= L.H.A., body rising L P = 360° L.H.A.).
- 4. Combine the latitude and the declination to obtain (PZ", PX).

If lat. and dec. are of the same name take (L",D). If of opposite name take (L+D).

- 5.Use the haversine formula to calculate the zenith distance.
- 6. Correct the altitude and subtract from 90° to obtain the

zenith distance.

7.Apply the C.Z.x. to the T.Z.x. and obtain the intercept. 8. Using ABC tables find the true bearing.

We now have information enough to plot a position line as explained in chapter 9.

Example 1. By an observation of the sun

On 30th September, 1.980, at about 0900 at ship in D.R. position, latitude 41° 15′ N., longitude 175° 30′ W., when the chronometer, which was correct on G.M.T., showed 8h 30m 15s, the sextant altitude of the sun's lower limb was 29° 24,6′, index error 0,4′ off the arc, height of eye 15·8 metres. Required the position line and a point through which it passes.

L i" D 44° 21· 2'

Approx. L.M.T. 30th 09h 00m Long. W. <u>Ilh 42m</u>

Approx. G.M.T. 30th 20h 42m G.M.T. 30th 20h 30m 15s

From N.A. G.H.A. 20h 122°33·1' declo 3°05·7'S.

490° 06.9'

Increment $7^{\circ} 33.8'$ 'd' 0.5'G.H.A. $1300\ 06.9'$ decl. $3^{\circ}\ 06.2'$ S. 360'' lat. $4e\ 15.0'$ N.

Longitude $175^{\circ} 30.0'$ W.

L.H.A. 314° 36·9' *Lp* 45°23·1'

Hav. ZX=Hav. P. cos lat. cos dec.+ hav(lat. ;t.dec.).

P.=45°23·1' loghav. 1·17269 Sext. alt. 29°24·6'

lat. =41°15' log. coso 1.87613 I.E. ± 0.4 '

dec.= $3^{\circ}06 \cdot 2' \log \cos f \cdot 99936$ Obs. alt. $29^{\circ}25 \cdot 0'$

<u>1.04818</u> dip. -7.0'

0.11173 App. alt. $2 \sim 18.0$ '

lat;t.dec. nat. hay. 0.14248 Corr. +14.3'

CZX= $160^{\circ} 33.3'$ 0.25421 True alt. $29^{\circ} 32.3'$

T.Z.X. 60" 27·7' C.Z.X. 60° 33·3'

5.6' Towards

A.0.865 S.

B.<u>0.076 S.</u>

C. 0.941 S.

Az. S. 54.7 E. orI25.3°

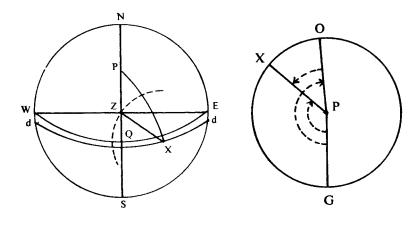
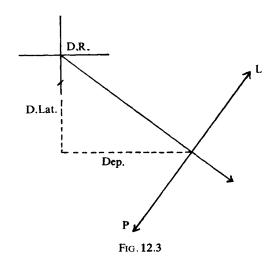


Fig. 12.2 (a)

Fig. 12.2 (b)



To calculate the position of the I.T.P.

D.R.lat. $41^{0}15.0$ N. Long. $175^{\circ}30.$ Q'W.

Co. $125 \cdot 3^{\circ}$ dist. $5 \cdot 6' = 3' = 2'8$. $6 \cdot 0' = E$. $(\text{dep.} = 4 \cdot 5')$

I.T.P. 4PII·8'N. 175°24·0'W.

Answer: Position line runs $035.3^{\circ}/215.3^{\circ}$ through position 41° 11.8'N.175°24.0'W.

EXERCISE 12A

BY OBSERVATION OF THE SUN

- 1. On 26th June, 1980, at about 0930, at ship in D.R. position, latitude 29° 30' S., longitude 12e 20' W., when the chronometer which was correct on G.M.T. showed 5h 45m 20s, the sextant altitude of sun's L.L. was 26° 52'2', index error 1.6' on the are, height of eye 12.0 metres. Find the direction of the position line and the position of a point through which it passes.
- 2. On 8th January, 1980, 1530 at ship in D.R. position, latitude 32° 15' S., longitude 48° 16' W., when the chronometer which was correct on G.M.T. indicated 18h 31m 24s, the sextant altitude of the sun's V.L. was 46° 58,0', index error 0-4' on the are, height of eye 11·0 m. Find the P.L. and the position of a point through which it passes.
- 3. On 19th September, 1980, at about 4 p.m., at ship in a estimated position, latitude $0^{\circ}00.0'$, longitude 160° 55' W., whe the chronometer which was correct on G.M.T. showed2h 30m 15: the sextant altitude of the sun's V.L. was $32^{\circ}12'9'$, index error $0\cdot'$ off the are, height of eye $12\cdot5$ m. Find the position line and th position of a point through which it passes.
- 4. On 18th December, 1980, at about 0900, at ship in D.F position, latitude 43° 12'N., longitude 38° 25'W., when th chronometer which was 2m 21s fast on G.M.T. showed 11h 51] 52s, the sextant altitude of the sun's L.L. was 13° 33·3', index err< 1·6' off the are, height of eye $11\cdot5$ m. Find the position line and t11 position of a point through which it passes.
- 5. On 30th September, 1980, at ship in D.R. position, latituc 44° 05'N., longitude $27^{\circ}41$ 'W. at 09h41m 02s G.M.T., the sextal altitude of the sun's L.L. was 18° 57·5, index error 1·4' on the

ar, height of eye 9.0 m. Find the direction of the position line and tt posItion of a point through which it passes.

Example 2. By an observation of a star

On 9th January 1980 at approximately 1900 at ship in OJ position 35° 10' S. 127° 50 E., the sextant altitude of the star *Siri*, was observed to be 36° 58·1'. Index error 0·4' on the arc. Height eye 15 metres. A chronometer which was correct on G.M: showed 11 h 15m 10s. Find the direction of the position line and t] I.T.P.

Approx. L.M.T. 1900 Chron. 11hl5mlOs

long. E. 0831 <u>G.M.T.11hI5ml0s9thJan.</u>

Approx. G.M.T. 1029 9th

FromN.A. G.H.A.'Y'l1h 273°08·9' Dec. 16°41·5'

incr. $3^{\circ} 48 \cdot 1'$ Lat. $35^{\circ} 10 \cdot 0'$

G.H.A.'Y' 276°57·0' Lat.-Dec. 18°28·5'

S.H.A.· <u>258° 55·8'</u>

G.H.A.· 535° 52·8'

360°

G .H.A. · 175° 52⋅8'

Long. E. <u>127° 50·0'</u>

L.H.A.· 303° 42·8'

L P. $56^{\circ}17.2^{\circ}$

Hav. ZX=Hav. P. coslat. cosdec.+hav(lat.-dec.)

P. 56°17.2' loghav. 1·34729 Sext. alt. 36°58.1'

Lat. 35°10.0' logcos 1.91248 I.E. -0.4'

Dec. 16° 41·5' log cos 1·98130

--- Obs. alt. 36° 57·7'

<u>1.24107</u> Dip. -6.8'

0·17421 App. alt. 36° 50·9'

Lat.-Dec. nat.hav. 0-02577 corr. $-1\cdot3'$

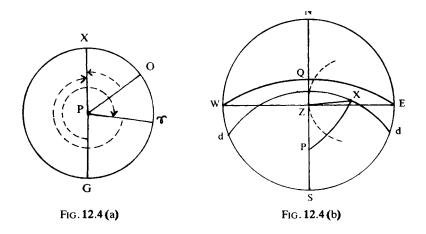
 $C.Z.X. = 53^{\circ}07.6'$ 0.19998 T. alt. 36°49.6'

A. 470N. T.Z.x. 53°10.4′

B. <u>·360N.</u> *C.Z.x.* <u>53°07.6′</u>

C. <u>·ltoN.</u> Intercept 2·8' Away

Az. N. 84.9'E.



To calculate the position of I.T.P.

D.R. lat. $35^{\circ}10.0$ 'S.

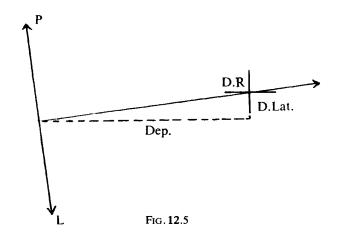
Co. 84.9° dist. 2.8' d. lat. 0.3' S.

I.T.P. 35°10.3' S.

Long. 127° 50·0' E.

d. long. 3.4 W.(dep. 2.8')

127° 46.6′ E.



Answer

P.L. trends 354'9T-174'9T through position latitude 35° 10·3'S.,longitudeI2'?°46·6'E.

EXERCISE 12B

BY OBSERVATION OF A STAR

- 1. On 18th September, 1980, at ship in D.R. position, latitude 24° 50' N., longitude 145° 10' E., at 08h 59m 50s G.M.T. the sextant altitude of the star *Arcturus* 37 was 31° 30·5', index error 0·8' on the are, height of eye 12 m. Find the direction of the position line and the position of a point through which it passes.
- 2. On 30th September, 1980, at ship in D.R. position, latitude $43^{\circ}05'N$., longitudel $77^{\circ}16'W$., atI7hOlm44sG.M.T. the sextant altitude of the star *Schedar* 3 was 41^{0} 04,2', index error 0·2' off the are, height of eye 13-2 m. Find the direction of the position line and the position of a point through which it passes.
- 3. On 19th September, 1980, at ship in estimated position, latitude 17° 53·6' N., longitude 4r 30' W., the sextant altitude of the star *Alphard* 25 during morning twilight was 18° 59·2', index error 0·5' on the are, height of eye $18\cdot6$ m. The chronometer, which was 04m 53s slow on G.M.T., showed 8h 10m 23s. Find the direction of the position line and the position of a point through which it passes.
- 4. On 18th December, 1980, in estimated position latitude 42° 40' N., longitude 172° 10' W., at 17h 59m 30s G.M.T. the sextant altitude of the star *Alphecca* 41 was 48° 05·9', index error 1·3' on the are, height of eye 17·5 m. Find the direction of the P.L. and the position of a point through which it passes.

5. On 26th June, 1980, at ship in D.R. position latitude 40° 59·5'S., longitude 56° 57'W., at 21h 26m OOs G.M.T. the sextant altitude of the star *Procyon* 20 was 15° 23,5', index error 0.6' off the are, height of eye 9.0 m. Find the direction of the P.L. and the position of a point through which it passes.

Example 3. By observation of the moon

An observer in D.R. position 14° 38' S. 154° 14' W. observes the altitude of the moon's lower limb to be 52° 07·5'. Index error nil, height of eye $12\cdot0$ metres. The chronometer showed 04h 45m 14s at the time and was correct on G.M.T. The approximate ship's time was 0639 on 30th September, 1980.

Find the direction of the position line and a position through which to draw it.

 $L \sim O 34^{\circ}17.8'$

App. L.M.T. 063930th

Long. W. 1017 Chron. 04h 45m 14s

- G.M.T. 16h45m14s30th

App. G.M.T.165630th Dec. 19° 38.7'N.

G.H.A.16h 157037.7' 'd' $+1\cdot1'$

!n,cr. 10° 47 ·6: Decl. 19° 39·8' N.

v (7·8) 5·9 Lat. 14° 38·0' S.

Long. $154^{\circ}14.0'W$. ",

168°31.2'

L.H.A. $14^{\circ}17.2'=LP$.

L P. $14^{\circ}17.2' \log \text{ hav. } 2.18931$ Sext. alt $52^{\circ} 07.5'$

Lat. 14° 38' log cos 1-98568 I.E.

Dec. 19° 39·8' log cos 1·97391 Obs. alt. 52° 07.5'

_ Dip. -6·1'

2.14890

G.H.A.

App. alt. 52° 01·4'

0.01409 M. corr. 45.4'

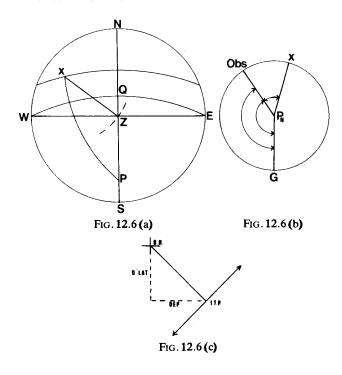
L. - D. nat. hav. 0.08693 2nd corr. 5.1'

 $CZX=37^{\circ} 03.9'$ 0.10102 T. alt. $52^{\circ} 51.9'$

A 1.025+ T.Z.X. $37^{\circ}08.1'$

B 1.448+ C. z.x. $37^{\circ} 03.9'$ C 2.473+ Intercept 4.2' away

Az. N. 22·7°W.



D.R. pos.lat. 14°38·0'S.

Course $22 \cdot 7^{\circ}$ dist. $4 \cdot 2'$ d. lat. $3 \cdot 9'$ S

I.T.P. $14^{\circ}41.9'S$.

Long. $154^{\circ}14\cdot0'W$.

D. long. $\underline{1.7' \text{ E. (dep.l.6')}}$

154° 12·3′ W.

Answer

Position line runs 067·3°/247·3° through 14° 41·9' S.154°12·3'W.

EXERCISE 12C

1. At approximately 1815 on 26th June at ship, in D.R. position 42° 50' S. 41° 30'W., the sextant altitude of the moon's lower limb was 29° $10\cdot8'$ Index error $2\cdot0'$ off the arc. Height of eye 1 0 metres. A chronometer which was correct on G.M.T. showed 09h 10m O2s at the time. Find the direction of the position line and a position through which it passes.

2. On 9th January 1980 at approximate L.M. T. 0900, in D.R. position 25° 30'N. 175° OO'E., the sextant altitude of the moon's upper limb was 27° 21·5'. Index error 2·0' on the arc. Height of eye 12·0 metres. A chronometer which was slow on G.M.T. by 1m 24s showed 09h 14m 21s at the time. Find the direction of the position line and the I.T.P.

The longitude by chronometer method

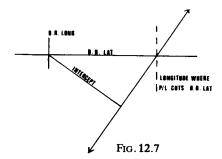
In this method only a D.R. latitude is assumed. This gives the side PZ in the triangle, and this is used with the polar distance and the observed zenith distance (ZX), in the haversine formula to calculate the angle P. From this the L.H.A. is deduced, and the G.H.A. applied to it to obtain the longitude.

Note that this longitude will only be the correct longitude, if the assumed latitude is correct. Thus the D.R. latitude and the longitude by calculation give a position through which to draw the position line. The true bearing must also be calculated as in other methods to find the direction of the position line.

Note

For one particular observation there can only be one position line. Whether the observation is worked by Marcq St. Hilaire or by longitude by chronometer, the same position line will result. The positions calculated through which to draw the position line will, however, differ.

Figure 12.7 shows one position line, and the information obtamed from each method.



Thus the arguments used to solve the triangle are:

- I. PZ, obtained from the D.R. latitude.
- 2.PX, obtained from the declination.
- 3. ZX, the true zenith distance obtained from the sextant altitude.

and by haversine formula:

Hav. P =(hav. ZX-hav. (PZ-PX» cosec PZ cosec PX =(hav. ZX-hav. (lat.-dec.» sec lat. sec dec.

Procedure

1. From the chronometer time deduce the G.M.T. as in the intercept method.

- 2. Using the G.M.T. extract the G.H.A. and the declination from the almanac.
- 3. Correct the sextant altitude and find the zenith distance.
- 4. By haversine formula, using lat. dec. and ZX find the angle P and hence L.H.A.
- 5. Apply L.H.A. to G.H.A. to obtain the longitude. 6. Calculate the true bearing.

We now have information for plotting a position line.

Note

This method of determining a position through which the position line passes is suitable provided the body is not too close to the observer's meridian. In this case there is a considerable change in longitude for a small change in azimuth, and in general it may be said that the longitude method can be used if the observed body is more than 2 hours from meridian passage. It should be noted that there is no such limitation for the Marcq St. Hilaire method.

Example 4. By an observation of the sun

(Using Example I worked by the longitude method).

On 30th September, 1980, at about 0900, at ship in D.R.latitude 41° 15'N., when the G.M.T. was 20h 30m 15s, the sextant altitude of the sun's L.L. was 29° 24,6', index error 0-4' off the arc, height of eye 15.8 m. Required the P.L. and the longitude in the D.R. latitude through which it passes.

G.M.T. 30th 20h 30m 15s

G.H.A.20h 122	2° 33·1'	Dec.	3° 05·7'
incr. $\underline{7^{\circ}}$	33.8'	corr.	+ <u>0' 5'</u>
G.H.A. 130°	06.9'	Dec.	3°06⋅2'S.
<u></u>			
Sextant alt. 29°	24.6:	Lat.	41° 15' N.
I.E. +	0,4	Dec.	3° 06.2' S.

Obs. alt. 29° 25.0′

App. alt. $29^{\circ} 18.0'$

Tot. corr. +
$$14 \cdot 3'$$

Hav. P.= $\{(hav. ZX- hay. (lat. -dec.))\}$ seclat. sec dec.

ZX60027·7' nat. hay. 0·25350

1-d44°21·2' nat. hay. <u>0·14248</u>

0.11102

1.04540 A .870S.

lat. 41 ° 15' log sec 0·12388 B ·076 S.

dec. 3° 06· 2' log sec 0·00064

C · 946S.

 $L P = 45^{\circ}13.9'$ 1.16992 Az. S. 54.6°E.

L.H.A.=314° 46·1'

G.H.A.=130° 06.9' (Long.=G.H.A.+360- L.H.A.)

Long. 175° 20.8' (see figure 12.2 (b»

Answer

Position line runs 035·4°/215·4° through position 41 ° 15' N. 175° 20·8'W.

Note

The position line is the same as that calculated in Example I and the only difference is in the position given through which it passes. Using the intercept and azimuth it is possible to find the longitude in the O.R. latitude through which the P.L. can be drawn.

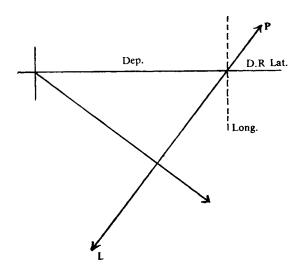


Fig. 12.8

In figure 12.8:

Intercept=5·6'T. Az.=S54·7E. (from example 1).

Longitude calculated by long. by Chron. is that shown by a dashed line. Thus by measurement departure=6.9.

D.long.=9·2'E. O.R.long 175°30·0'W.

O. long. $9 \cdot 2' E$.

Long. by chron. $175^{\circ}20.8$ 'W.

This was the longitude calculated in example 4 which shows that the same position line is obtained, whatever method of reduction is used.

EXERCISE 120

BY OBSERVATION OF THE SUN

- 1. On 26th June, 1980, at about 1600, at ship in O. R. latitude 100 25' N., when the chronometer, which was 4m 27s fast on G.M.T., indicated 11h 59m 53s, the sextant altitude of the sun's lower limb was 31° 33·3', index error1·2' on the are, height of eye17·0 m. Find the direction of the position line and the longitude in the O.R. latitude through which it passes.
- 2. On 19th September, 1980, at ship in O.R. position, latitude 18° 44' N., longitude 117° 12' W., the sextant altitude of the sun's upper limb was 24° 34·5', index error 0·6' off the arc, height of eye 18·0 m., at OOh Olm 42s G.M.T. Find the direction of the position line and the longitude in the O.R. latitude through which it passes.
- 3. On 20th December, 1980, a.m., at ship in O.R. position latitude 35° 24' S., longitude 171 ° 15' E., the sextant altitude of the sun's lower limb was 43° 09·7', index error 0·4' on the are, height of eye $14\cdot5$ m., when the chronometer, which was Olm 17s slow on G.M.T., showed 9h OOm 35s. Find the direction of the position line and the longitude in which it cuts the O.R. latitude.
- 4. On 5th January, 1980, a.m., at ship in O.R. latitude 0° 30' S., the sextant altitude of the sun's upper limb was 30° 27,1', index error 1,4' on the are, height of eye 19'5 m., at 08h 15m 35s G.M.T. Find the direction of the position line and the longitude in which it cuts the O.R. latitude.
- 5. On 30th September, 1980, at ship in O.R. position, latitude 44° 05' N., longitude 27° 41' W., at 09h 41m 02s G.MT., the sextant altitude of the sun's lower limb was 18° 57·5', index error 1,4' on the are, height of eye 9,0 m. Find the direction of the position line and the longitude in which it cuts the O.R. latitude.

(The answer to this problem may be verified from Exercise 12A, No.5.)

Example 5. By an observation of a star

(Using example 2 worked by the longitude method.)

On 9th January, 1980, p.m., at ship in D.R. position latitude 35° 10'S., longitude 127° 50' E., at llh 15m 10s G.M.T., the sextant altitude of the star *Sirius* to the east of the meridian was 36° 58·1', index error 0·4' on the are, height of eye 15·0 m. Find the direction of the position line and the longitude in which it cuts the D.R. latitude.

G.M.T.9thllh15m10s

FromN.A.G.H.A.'Y'llh 273°08·9' Dec. 16°41·5'S.

incr. $3^{\circ} 48.1'$

G .H.A. 'Y' 276° 57·0' S.H.A. · 258° 55·8'

G.H.A. 535° 52.8'

<u>360</u>

G.H.A. · 175° 52 · 8'

Sextant alt. $36^{\circ} 58 \cdot 1'$ Lat. $35^{\circ} \text{ to \cdot O' S}$.

I.E. -0.4' Dec. $16^{\circ}41.5'S$

Obs. alt. 36° 57·7' (Lat. - Dec.) 18°28·5'

Dip. -6.8'

App. alt. 36° 50.9'

Corr. -1·3'

T. alt. 36° 49.6'

T.Z.X. 53°to⋅4′

Hav. P={hav. ZX-hav. (lat. -dec.~sec lat. secdec.

ZX 53"10.4' nat. hay. 0.20030

(Iat. .dec.) $18^{\circ} 28.5'$ nat. hay. 0.02577

<u>0.17453</u> <u>1.24187</u>

lat. $35^{\circ}10'$ log see 0.08752

dec.16° 41.5' log see 0.01870

L P=56° 20·6' 1·34809

G.H.A.=
$$175^{\circ} 52.8'$$
 B .360-

Long. =
$$127^{\circ} 46.6' \text{ E}$$
. $C \cdot 109 +$

Az. N. 84·9°E. (longitude=L.H.A.-G.H.A. See figure 12.4 (a».

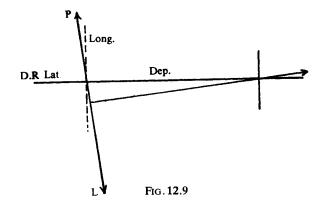
Answer

Position line runs 354·9°/174·9° through position 35° 10·0'S 127° 46·6'E.

A ·469+

From Example 2

Using intercept 2.8'away. Az. N. 84.9°E. to verify the above answer.



From figure dep.=2.8'

d. long. <u>3-4'</u>W.

D.R. lat. 35⁰ 10' S. long. 127⁰ 46,6' E

EXERCISE 12E

BY OBSERVATION OF A STAR

1. On 5th January, 1980, at ship in D.R. position, latitude $30 \sim 0$ 'N., longitude 44° 40'W. at 09h 15m 07s G.M.T. the sextant altitude of the star *Rasa/hague* 46 east of the meridian was 27° 56,5', index error $1 \cdot 3$ ' off the are, height of eye $16 \cdot 8$ m. Find the direction of the position line and the longitude in which it cuts the D.R. latitude.

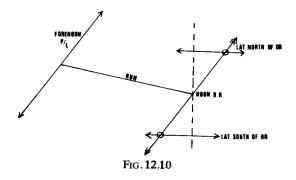
- 2. On 27th June, 1980, at ship in D.R. latitude 29° 40' S., the observed altitude of the star *Procyon* 20 at p.m. twilight was 14° 49·8', height of eye $13\cdot2$ m., west of the meridIan, when the chronometer, which was 3m 47s slow on G.M.T., indicated 02h 47m 24s. Find the direction of the position line and the longitude in which it cuts the D.R. latitude. D.R. long. 134° 55'W.
- 3. On 19th September, 1980, p.m., at ship in D.R. position, latitude 27°30' N., longitude178°10' E., at06h40m12sG.M.T. the sextant altitude of the star *Arcturus* 37 was 32° 21'4', index error 2-4' off the are, height of eye 15·8 m. Find the direction of the position line and the longitude in which it cuts the D.R. latitude.
- 4. On 1st October, 1980, at ship during morning twilight in D.R. position, latitude 32° 15' S., longitude 78° 33' E.; the sextant altitude of the star *Regulus* 26 was 13° 24,6', index error 0,8' on the are, height of eye II·5 m. The chronometer, which was 2m 16s fast on G.M.T., showed 1lh 53m 04s. Find the direction of the position line and the longitude in which it cuts the D.R. latitude.
- 5. On 26th June, 1980, at ship in D.R. position, latitude 40° 59·5' S., longitude 56° 57' W., at 21h 23m 42s G.M.T., the sextant altitude of the star *Procyon* 20 was 15° 23,5', index error 0,6' off the are, height of eye 9,0 m. Find the direction of the position line and the longitude in which it cuts the D.R. latitude.

Noon position by longitude by chronometer and meridian altitude

The most popular method of obtaining a noon position at sea is to transfer a position line obtained in the forenoon by observation of the sun, up to the time of noon, i.e. the time of meridian passage of the sun. It can then be crossed with a position line obtained from the meridian altitude which will run east-west (see chapter 9 for transferred position lines).

This problem can, however, be solved without resort to any plotting.

Let the figure represent a position line obtained by observation



of the sun and worked by longitude by chronometer, during the forenoon. This position line is then transferred to the time of noon by application of the course and distance steamed. The transferred position line is marked with double arrows.

We can say that at noon, if our D.R.latitude used in the forenoon sight was correct then our noon longitude is our D.R. longitude. However, the latitude obtained at noon will probably indicate that our true latitude is to the north or the south of our D.R. latitude, and therefore our longitude will be in error. The amount of the error in longitude can be found by taking the

difference in minutes of d. lat. between the D.R. latitude and the observed latitude, and multiplying this by the value of 'c' from the ABC table calculation when finding the azimuth for the forenoon sight.

The value of 'C' in this respect can be taken as the error in longitude caused by an error of I minute in the latitude when working the sight.

The direction of the longitude error must be found by inspection of the direction of the position line and the direction of the error in latitude. Thus in the figure 12·10, where the position line runs *SWINE* if the observed latitude is south of the D.R. latitude the true longitude must be to the west of the D.R. longitude. If the observed latitude is to the north, the observed longitude must be to the east.

If the position line runs NW jSE then the opposite will apply.

The appropriate case must be found from a rough sketch of the position line and the observed latitude.

Example

On 19th December, 1980, at 081.0 ship's time in D.R. position 25° 5.0' N. 57° 37' W. an observation of the sun's lower limb gave a sextant altitude of 15° 47,5'. Index error was 3,0' on the arc. Height of eye 13,6 metres. The chronometer showed Ilh 58m .04s and was 1m 03s slow on G.M.T. The ship then steamed 210° T. for 55 miles, when the meridian altitude of the sun's lower limb was 41° 19,8' south of the observer. Find the ship's position at the time of the meridian altitude.

Approx. ship's tim	e .0810	Chronometer lIh 58m 04s		
Longitude	.0349	Error	<u>1m 03s</u>	
Approx. G.M.T.	1159	G.M.T.	Ilh 59m .o7s	

G.H.A.llh $345^{\circ}41 \cdot 2'$ Dec. $23^{\circ}25:3'S$. iner. $14^{\circ} 46 \cdot 8'$ Lat. $25^{\circ} 50 \cdot 0'$ N.

G.H.A. 360°28·0' Lat. ~Dee. 49°15·3'

 $= 0^{\circ} 28.0'$

Sext. alt 15°47·5' ZX74°09·1' nat. hav.0·36345

I.E. -3.0' Lat. Dec. nat. hav. 0.17365

Obs. alt. 15° 44·5' 0·18980

Dip. -6·5' __---

1.27830

App. alt. $15^{\circ} 38.0'$ Lat. $25^{\circ} 50.0' \log \sec 0.04573$

Corr. + 12.9' Dec. 23° 25.3'log see 0.03734

True alt. $15^{\circ} 50.9'$ L P=57°17·4' 1·36137

T.Z.X. 74°09·1' L.H.A.=302°42·6' (Iong.=G.H.A.-

 $G.H.A.=360^{\circ} 28.0' L.H.A.)$

A ·311+ ---

B \cdot 515+ Long. =57° 45·4' W.

C ·826+ Az. S. 53·4°E.

D.R po~. ats,ights. 25° 50·0; N. 57°45.4; W. ~~~~ude

Run 210 T. dlst. 55 mIles 47.6 S. 30.5 W. II t d)

eacuae

D.R at noon 25° 02·4′ N. 58°15·9′W.

Meridian alt.

Sext. alt. **41** ° 19·8' Mer. pass. 1157

I.E. -3.0' Long. 0353

Obs. alt. **41°16.8'** G.M.T. 1550

Dip. -6.5' Decl. 23025.4'S.

App.alt. 41°10.3; D.Rlat. 25°02.4'N.

 Corr.
 +15·2
 Obs.lat.
 25009.1'N.

 True alt.
 41°25.5'
 D'ff
 6 7'N

 I erenee
 ...

 T. Z.x.
 48° 34.5'
 'c'
 x ·826

 Decl.
 23° 25·4' S. D I
 5.5' E

 ...
 ...
 ...

Lat. 25°09·1'N

Noon D.R. long. 58°15.9'W.

D. long. $\underline{5.5'}$ E.

Noon longitude 58°10·4′ W.

Noon position 25° 09·1' N. 58° 10·4' W.

EXERCISE 12F

1. On 30th Sertember 1980, in D.R. latitude 46° 17' S., the sextant altitude O the sun1s lower limb was observed to be 32° 15', during the forenoon when the G.M.T. was19h 34m 51son the 30th. The index error was $3\cdot0$ ' off the arc and height of eye $11\cdot0$ m.

The ship then steamed 300° T. for 45 miles when the sextant meridian altitude of the sun's lower limb was 46° 47 ·9' north of the observer. Find the ship's position at the time of the meridian altitude.

2. On 27th June, 1980, in D.R. position 38° 15' S. 169° 15' E.,

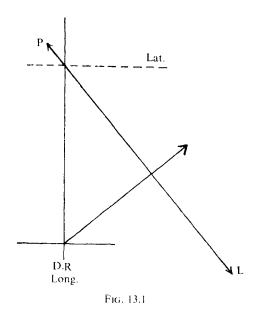
at approximate ship's time 0919 hrs., the sextant altitude of the sun's lower limb was)70 18'2'. Index error was 1'0' on the arc. Height of eye 8.0 m. The chronometer showed 10h 05m 17s at the time. The ship then steamed 045° T. for 40 miles until noon when the sextant meridian altitude of the sun's lower limb was 28° 39'4'. Find the ship's position at the time of the meridian altitude.

CHAPTER 13

LA TITUDE BY EX-MERIDIAN PROBLEM

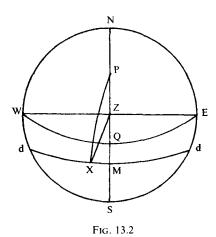
This is another method of finding a point-through which to draw the position line.

In this case if the longitude is assumed, the latitude in that longitude through which the position line passes can be calculated.



This method is limited to cases where the body observed is near the meridian, i.e., where the hour angle is small. The actual limits of hour angle before or after meridian passage will depend upon the rate of change of altitude.

If the declination of the body and the observer's latitude are the same name, the rate of change of altitude will be greater if the latitude and declination are of opposite names. This means that the limits of hour angle within which this method can be used will be less when the latitude and declination are the same name.



Description of figure:

NESW represents the plane of the observer's rational horizon.

NZS the observer's meridian.

P the elevated celestial pole.

Z the observer's zenith.

X the body.

WZE the prime vertical. WQE the equinoctial.

M the position of the body when on the observer's meridian.

dM X d the parallel of declina tion of the body.

From the figure QZ=ZM-QM:

i.e. Latitude = meridional zenith distance- declination.

and $ZM=PZ\sim PM$

and assuming that the declination remains constant between the time of sight and the time when the body is on the observer's meridian:

 $PM = PX = 90^{\circ} \pm declination$ Then $ZM = PZ \sim PX$

Thus meridional zenith distance = $(PZ \sim PX)$ From the haversine formula:

 $\operatorname{Ha} P \operatorname{hav} ZX \operatorname{-hav} (PZ \sim PX)$

v. $\sin PZ \sin PX$

:.Hav. $P \sin PZ \sin PX = hav$. ZX -hay. $(PZ \sim PX)$:.Hav. $(PZ \sim PX) = hav$. ZX-hav. $P \sin PZ \sin PX$ i.e. Hav. MZD = hav. ZX-hav. $P \sin PZ \sin PX$ This can be further simplified, so that:

Hav. MZD=hav. ZX - hay. $P \cos lat. \cos dec.$

The procedure is as follows:

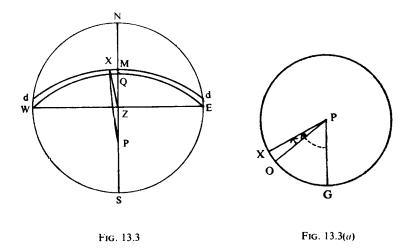
- 1. Using the G.M.T., find the G.H.A. of the body observed from the *Nautical Almanac*, and thence the L.HA.
- 2. Correct the sextant altitude to obtain the true altitude and thence the zenith distance.
- 3. From the formula find the MZD.
- 4. Apply the declination to the MZD to obtain the latitude of the point in the D.R. longitude through which the position line passes.
- 5. Find the azimuth of the body by any convenient method, and thence the position line.
- 6. Draw the position line on the chart, or state the position.

Note

Before deciding on the method to use, if the hour angle is small, it is advisable to verify that the ex-meridian method is appropriate. This can be found from a table in *Norie's* or *Burton's*, which gives the limits of time before and after meridian passage.

Example 1. By an observation of the sun

On 19th September, 1980, in D.R. position 45° 40' S. 52° 35' W., the sextant altitude of the sun's lower limb near the meridian was observed to be 41° 57.6'. Index error $2 \cdot 2$ ' off the arc. Height of eye $12 \cdot 0$ metres. A chronometer showed 04h 01 m 20s at the time. Find the direction of the position line and a position through which it passes.



Note

The fact that the sun is near the meridian means that the approximate local time can be taken as 1200.

Approx. L.M.T.19th 1200 Chron. 04h01m20s

Long. W. 0330

Approx. G.M.T.19th1530	G.M.T.19th 16h01m20s
G.H.A.16h 61°35·6'	Dec. 1°15·0'N.
Increment $0^{\circ} 20 \cdot 0'$	<u>'</u> d' <u>0.0'</u>
G.H.A. 61° 55·6'	Dec. 1°15·0'N.
Long. W. <u>52° 35·0'</u>	
L.H.A. 9° 20·6'	
Sext. alt. 41° 57·6'	0'-
I.E. +2.2'	L.H.A.9 20·6 log hav. J·82174
	Lat. 45° 40'log cos 1.84437
Obs. alt. 41 ° 59.8'	Dec. e $15.0' \log \cos \frac{1.99990}{}$
Dip. <u>-6·1'</u>	3.66601
App. alt. 41° 53· 7'	0.00463
Corr. $+14.9'$ T	<i>T.Z.X.</i> 47° 51⋅4 nat. hav. <u>0⋅16451</u>
True alt. <u>4ZO 08.6'</u>	<i>M. Z.x.</i> 47° 08·0' 0·15988
<i>T.Z.X.</i> 47° 51·4'	
Mer. zen. dist. 47°	08·3' A 6'22+
Dec. e	<u>15·0'</u> N. B <u>·13+</u>
Lat. 45° 5	3·3' S. C 6·35+

Az. N.12·7°W.

Answer

Position line runs 257·3%77·3° through position 45° 53·3' S. 52° 35'W.

Ex-meridian tables

There are certain approximations inherent in the ex-meridian method which may be avoided if the sight were worked by the Marcq St. Hilaire method. The ex-meridian method by haversine formula is therefore rarely used in practice, but may be encountered in Department of Trade examinations. The ex-meridian method however is still of practical importance as it may be used to reduce a sight much more rapidly than by Marcq St. Hilaire if ex-meridian

tables are used. Examples of these may be found in nautical tables such as Nories' or Burton's.

In both these commonly used tables the tabulation is in two parts, Table I and Table II. Table I gives a factor (called A in Nories' and F in Burton's), which depends upon the latitude and the declination. The factor is extracted from Table I and used as an argument in Table II with the hour angle at the time of sight, to extract the 'reduction'. This is the amount by which the zenith distance at the time of the sight should be reduced to obtain the zenith distance at the time of meridian passage, assuming a stationary observer and a constant declination. The latitude is then found by the usual meridian observation formulae.

Procedure

- 1. Extract the G.H.A. from the almanac, apply longitude and hence find the L.H.A.
- 2. Correct the sextant altitude and obtain the observed zenith distance.
- 3. Enter Table I of the ex-meridian tables with D.R. latitude and declination and extract the factor (A or F). Take care to note whether latitude and declination are same name or opposite name and use the appropriate table.
- 4. With the factor and the hour angle (L.H.A.), enter Table II and extract the reduction.
- 5. Enter Table III of the ex-meridian tables with the reduction and the altitude and extract a second correction, which is a small correction to be subtracted from the reduction. In most cases this second correction is negligible.
- 6. Subtract the reduction (with second correction applied if necessary), from the zenith distance at the time of observation to obtain the meridional zenith distance (M.Z.X.).
- 7. Apply declination to the MZX to obtain latitude as for a meridian observation.

Example (using Example 1 as worked by haversine method)

From Example 1 L.H.A.=9° 20.6′. Deciination=P 15.0′N.

D.R. Lat.=45° 40' S. Zenith distance=47° 51.4.

From Table I (lat. and dec. contrary names)

Factor=I-88 (interpolating to second decimal place).

From Table II for hour angle 9° 20.6'

For factor of 0 reduction = $23 \cdot 2$

For factor of 0.8 reduction = 18.6

For factor of 0.08 reduction = 1.9

reduction= 43.7

From Table III second correction = .2

reduction 43.5

Zenith distance 47° 51.4'

Reduction 43.5'

M.Z.X. 47°07.9'

Declination 1 ° 15.0' N

Latitude $45^{\circ} 52.9' \text{ S}.$

Note

The azimuth must be calculated as in the haversine method.

Ex-meridian tables do not give the latitude, but only the latitude in which the position line cuts the D.R. longitude. The answer is therefore:

position line runs $257 \cdot 3\%77 \cdot 3^{\circ}$ through $45^{\circ} 52 \cdot 9'$ S. $52^{\circ} 35'$ W.

EXERCISE 13A

- 1. On 18th September, 1980, in D.R. position 49° OO'N. 35° 20' W., the sextant altitude of the sun's lower limb near the meridian was42°19·5'. Index errorl·2' off the arc. Height of eyelO·O metres. A chronometer showed 02h 40m 56s at the time and was correct on G.M.T. Find the direction of the position line and the latitude in which it cuts the D.R. longitude.
- 2. On 19th September, 1980, in D.R. position 4P 28'N. 28° 40'W., the sextant altitude of the sun's upper limb was observed to be 49° 28' when near the meridian. Inoex error 0.6' off the arc. Height of eye 12.6 metres. A chronometer showed Olh 15m 59s and was correct on G.M.T. Find the direction of the position line and the latitude in which it cuts the D.R. longitude.
- 3. On 19th December, 1980, in D.R. position 41° 04'N. 179° 30' E'₁ the sextant altitude of the sun's lower limb when near the meridIan was 24° 39·0'. Index error 1·2' on the arc. Height of eye $11\cdot0$ metres. A chronometer which was 3m 20s slow on G.M.T. showed 11h 10m 41s at the time. Find the direction of the position line and the latitude in which it cuts the D.R. longitude.

Example 2. By an observation of a star

On 26th June, 1980, at ship, in D.R. position, latitude $34^{\circ}40'$ N., longitude 40° 20' W., the sextant altitude of the star *Arcturus* 37 near the meridian during evening twilight was 74° 14· I', index error 0.8' off the .arc, height of eye 12.0 m. The chronometer, which was 1m 20s fast on G.M.T., showed IOh 55m 39s. Find the direction of the positIon line and the latitude in which it cuts the D.R. longitude.

Approx. L.M.T. 26th 20m OOs Chron. 22h ·55m 39.

Long. W. <u>02m 41s</u> Error - <u>1m 20.</u>

Approx. G.M.T. 26th <u>22m 41s</u> G.M.T. 26th <u>22h 54m 19</u>.

From N.A. 26th 22h G.H.A. 'Y' 245° 10.4' Arcturus

Incr. 13°37.0' S.H.A.* 146°18.5'

Dec. 19°17·3'N.

G.H.A. 'Y' 258° 47·4' S.H.A.* <u>146°18.5'</u>

G.H.A.* 405°05.9'

360

G.H.A.* 45° 05.9' Long. W. 40°20.0'

L.H.A. $4^{\circ} 45.9'$

Sext. alt. 74° 14·1' P 4° 45·9' log hav. 3·23754

I.E. $\pm 0.8'$ Lat. $34^{\circ} 40.0' \log \cos 1.91512$

Obs. alt. $74^{\circ}14.9'$ Dec. $19^{\circ}17.3' \log \cos \frac{1.97491}{1.97491}$

Dip. -6·1' 3.12757

App. alt. 74° 08·8' 0 00134

Corr. -0.3' T.Z.X.15° 51.5' nat. 0:01,903

True alt. $74^{\circ}08.5'$ M.Z.X.15°17.2' 0.01769

T.Z.X. 15° 51·5'

M.Z.X.15 $^{\circ}$ 17 \cdot 2' A 8 \cdot 30S.

Dec. 19°17.3' B 4·21N.

Lat. 34° 34.5'N. C 4.09S. Az. S.16.6°W.

Answer

Position line runs 286.6°/106.6° through 34° 34·5' N. 4QD 20' W.

By ex-meridian tables.

As above L.H.A.=4° 45.9', dec.=19° 17.3'N. D.R. lat.=34° 40' N. ZX=15° 51.5'.

From Table I (lat. and dec. same names) Factor=5.75

From Table II for hour angle 4° 45.9'

For factor of 5.0 reduction = 30.3

For factor of 0.7 reduction = 4.2

Forfactor of 0.05 reduction = 0.3

reduction =34.8

From Table III second correction =-0.6

reduction =34.2

Zenith distance 15° 51.5'

Reduction $34 \cdot 2'$

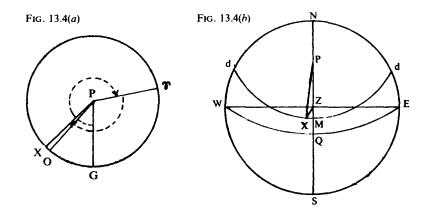
M.Z.X. 15°17.3'

Declination 19°17·3'

Latitude 34° 34.6′

Answer

Position line runs $286 \cdot 6^{\circ}/1,06 \cdot 6^{\circ}$ through $34^{\circ} 34 \cdot 6'$ N. $40^{\circ} 20'$ W.



EXERCISE 13B By an observation of a star

1. On 18th December, 1980, at ship, at about 0625 in D.R. position, latitude 45° 10'N., longitude 136° 02'W., the sextant altitude of the star *Denebola* 28 was 59° 02·5', index error 0·8' on the are, height of eye $11\cdot0$ m., when the chronometer, which was correct on G.M.T., showed 3h 31m 16s. Find the direction of the position line and the latitude in which it cuts the D.R. longitude.

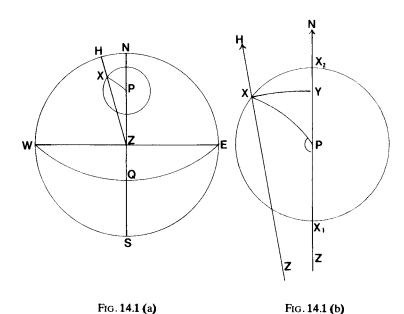
- 2. In D.R. position, latitude $36^{\circ}10'N$., longitude $40^{0}15'W$., on 26th June, 1980, an observation of the star *Fomalhaut* 56 near the meridian gave a sextant altitude of 23° $26\cdot4'$, index error $0\cdot4'$ off the are, height of eye $12\cdot0$ m. G.M. T. 06h 41m 03s. Find the direction of the posItion line and the latitude in which it cuts the D.R. longitude.
- 3. On 19th September, 1980, at ship, in D.R. latitude 25° 44' N., longitude $144^{\circ}25'$ E., the observed altitude of the star *Rigel* 11 near the meridian was 55° 28·3', height of eye $10\cdot5$ m., at 19h 26m 02s G.M.T. Find the direction of the position line and the latitude in which it cuts the D.R. longitude.
- 4. At ship, on 18th December, 1980, in D.R. position, latitude 30° 10'S., longitude 137° 50'W., the sextant altitude of the star *Alphard* 25 near the meridian was 67° 49'1', index error 0.8' on the are, height of eye 15.4 m. when the chronometer, which was 1m 1Os fast on G.M.T.; indicated 13h 12m 45s. Find the direction of the position line and the latitude in which it cuts the D.R. longitude.
- 5. On 18th September, 1980, at ship, in estimated position, latitude 18° 40' S., longitude 120° 25' W., at 13h 15m 28s G.M.T., the sextant altitude of the star *Capella* 12 near the meridian was 25° 29·1', index error 1·4' on the are, height of eye 17·7 m. Find the direction of the position line and the latitude in which it cuts the D.R. longitude.

CHAPTER 14

LATITUDE BY THE POLE STAR

Reference has already been made to the fact that the altitude of the Celestial Pole is equal to the latitude of the observer. If the Celestial Pole could be marked in some way, the latitude of an observer could be obtained at any time simply by finding the altitude.

The star *Polaris* has a declination in excess of 89° N., so that it moves around the Celestial Pole, describing a small circle with an angular radius of less than 1°. As it is so near, it is called the Pole Star, and the altitude can be adjusted by small corrections so that the latitude of the observer can be derived from it.



It is apparent from figure 14.1, which re Pole, that if the star is at position	represents the daily path of the star about the Celestial

x, the angular distance P XI must be subtracted from the altitude $!lx_l$ to obtain the latitude. Similarly if the star is at position X_2 ' then the polar distance must be added to the altitude. There will be two instants during the star's daily motion around the pole when the altitude of the pole star will be the same as that of the pole. At all other times the correction to apply will be the arc P Y, in figure 14.l(b), and this may be additive as shown, or negative. The solution to the triangle XP Y for P Y is tabulated in the 'Pole Star Tables' in the Nautical Almanac.

The solution is arranged in three separate quantities, rP, aI, and a²• To each is added a constant. The sum of the three constants is I degree. This is done to ensure that all values of the three quantities are positive. The I degree is subtracted from the final result.

Because the correction depends upon the L.H.A., and because the S.H.A. can be considered constant, the separate corrections are tabulated in the *Nautical Almanac* for values of L.H.A. 'Y'.

i.e.: L.H.A. * = L.H.A. 'Y' + a constant.

The procedure is as follows:

I. Obtain the G.M.T. and then find the L.H.A. 'Y' for the time of observation.

i.e. L:H.A. 'Y' = G.H.A. 'Y' + E. Long. - W. Long.

- 2. Correct the sextant altitude for index error, dip and star's total correction, to obtain the true altitude.
- 3. Using the L.H.A. 'Y', from the Pole Star Tables, find the column appropriate to its value. The three corrections and the azimuth will be found in the same column reading in sections down the page.
- 4. Find the corrections \sim , \sim and \sim and add these to the true altitude and subtract I \mathbf{v} from the total to obtain the observer's latitude.
- 5. From the tabulated azimuths find the bearing of the star. The position line will then lie at right angles to the bearing, passing through a position in the observed latitude and the D.R. longitude.

Note

It will be necessary to interpolate for correction cP, but unnecessary for corrections d and ci.

Example

18th September, 1980,in D.R. position 37° 58' N., 52° 30' E., at Olh 30m 24s G.M.T., an observation of *Polaris* gave sextant altitude 38° 40·4', *i.e.* 2·2' off the are, height of eye 11·7 m. Find the latitude and the direction of the position line.

G.M.T. 18th Olh 30m 24s

G.H.A. 'Y' 12° 06.3'

Incr. $7^{\circ} 37 \cdot 2'$

G.H.A.'Y' 19°43·5'

Long. E. <u>52° 30,0'</u>

L.H.A.'Y' <u>72°13·5'</u>

Sext. alt. 38° 40,4'

I.E. $+\underline{2\cdot 2'}$

Obs. alt. 38° 42.6'

Dip - <u>6·0'</u>

App. alt. 38° 36,6'

Tot. corr. - <u>1·2'</u>

T. alt. 38° 35,4'

~ 0° 20·5'

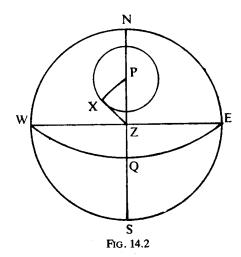
Q} 0.5'

<u>0.3'</u>

Total 38° 56⋅7'

_<u>1°</u>

Latitude $37^{\circ} 56.7$ 'N.



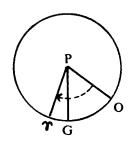


Fig. 14.3

T. Az. 359·3

P.L. 269·3-089·3

P.L. trends 269·3T.-089·3° T. through latitude 37° 56·7'N., long. 52° 30' E.

EXERCISE 14A

- L 8th January, 1980, at 1.9h 45m 22s G.M.T. in D.R. position 49° 10' N., 36° 20,4' W., the sextant altitude of *Polaris* was 50° 09-4', index error $1 \cdot 6'$ off the are, height of eye $12 \cdot 8$ m. Find the latitude and the direction of the position line.
- 2. 20th September, 1980, in D.R. lat. 35° 25'N., long. 36° 25' W., at 21h 15m 40s G.M.T., the sextant altitude of *Polaris* was 35° 15·8', index error 0·8' on the are, height of eye 11·5 m. Find the latitude and position line.

- 3. 26th June, 1.980, at ship in D.R. lat. $47^{\circ}15'N$., long. 158° 40' W., the sextant altitude of *Polaris* was 47° 42', index error 1.·4' off the are, height of eye 6·0 m., at 13h 26m 44s G.M.T. Find the latitude and position line.
- 4. 4th January, 1.980, p.m., at ship in D.R. position, lat. 22° 40' N., long. $163^{\circ}20$ 'W. at04h58m20sG.M.T., the sextant altitude of *Polaris* was 23° 40·4', index error 0·8' on the are, height of eye $13\cdot2$ m. Find the latitude and position line.
- 5. On 30th September, 1.980, at about 0520, at ship in D.R. lat. 50° 40' N., long. 162° 10.8' E. when the chronometer, which was 2m 08s slow on G.M.T., showed 6h 13m 17s, the sextant altitude of *Polaris* was 5r 10.8', index error 1.2' off the are, height of eye 14.0m. Find the latitude and position line.
- 6. 19th September, 1980, in D.R. position, lat. 32° 05'N., long. 31° 20' E., at 03h 00m 21s G.M.T., the sextant altitude of *Polaris* was 32° 44,2', index error 1,6' off the arc, height of eye 13-2 m. Find the latitude and position line.
- 7. 26th June, 1.980, in long. 57° 02'W. at 23h 51m 14s G.M.T., the sextant altitude O the star *Polaris* was 40° 35·4' index error 0·6' ~n the are, height of eye $10\cdot5$ m. Find the latitude and the position hne.

CHAPTER 15

GREAT CIRCLE SAILING

This method of sailing between two positions on the earth's surface is used over long ocean passages. Its use involves a knowledge of spherical trigonOIpetry, and this knowledge is assumed. If necessary a text on this subject should be consulted, for the use of the spherical haversine formula, and Napier's rules for the solution of right-angled and quadrantal spherical triangles.

Between any two positions on the surface of a sphere, unless the two positions are at opposite ends of a diameter, there is one only great circle that can be drawn through the two positions. The track along the shorter arc of this great circle is the shortest distance along the surface of the sphere between those two pasitions.

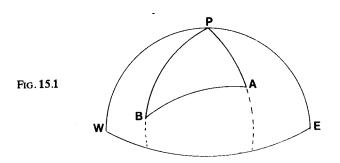
The main disadvantage in steaming such a track along the surface of the earth is that the course is constantly changing, and to attempt to make good a great circle a ship must steer a series of short mercator courses which correspond approximately to the curve of the great circle. The course must be altered at frequent intervals. The problem becomes initially to find the distance over a great circle track and then to find the course at the departur~ point, and the course at a series of positions along the track. These positions become the alter course positions.

To solve this problem a spherical triangle is formed by the

intersection of the three great circles: (i) The great circle track,

(ii) The meridian through the departure point, (iii) The meridian through the arrival point.

Thus the three points of the triangle are the two positions sailed between and one of the poles of the earth, usually the nearest pole.



In the figure PA = Colat. of $A = 90^{\circ}$ -lat. APB = Colat. of $B = 90^{\circ}$ -lat. B

LP = D. long. between the two positions WE = Equator

Thus using the haversine formula:

Hav. p=(hav. P. sin. PA. sin. PB)+hav. (PA-PB) Thus hav. dist. =(hav. d. long. coso lat. A. coso lat. B)+

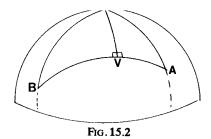
hav. d. la The initial course is then found from angle A:

Hav. $A = \{\text{hav. PB-hav. } (AB-PA)\}\ \text{x cosec. } ABcosec\ AP$ The final course may be found by calculating angle B.

The vertex of a great circle

This is the point on the great circle which is closest to the poll Thus every great circle will have a northerly vertex and a souther] vertex.

To **find** the position of the vertex



In figure 15.2 let V be the vertex of the great circle through A and B. At the vertex the great circle runs in a direction 090° { 270° . Thus it cuts the meridian through the vertex at right angles.

Thus $LPVA=LPVB=90^{\circ}$.

Solving the right-angled triangle by Napier's rules for *PV* and *LP* will give the latitude of the vertex and the d. long. between the vertex and position *A* respectively.

Given LA = initial course

PA = colat. of A

Sin. $PV = \sin PA \sin LA$

and Cot. $LP = \cos PA$. tan. LA

Having found the position of the vertex, a series of positions along the track can be found and the course of the great circle at each of these positions calculated, thus:

Assume longitudes at regular intervals of d. long. and solve a triangle PVX in figure 15.3.

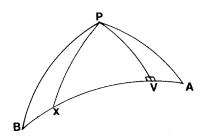


Fig. 15.3

Where *X* is the position where the meridian of the assumed longitude cuts the great circle track.

Thus given angle LP = d. long. between assumed longitude and the vertex

PV =colat. of the vertex

Cot. $PX = \cos \cdot PV$ and COSo $LX = \cos \cdot PV$. $\sin \cdot LP$

Solving for *PX* and *LX* will give the latitude corresponding to the assumed longitude, and the great circle course at that point respectively.

This can be done for a number of assumed longitudes as required, the working being tabulated as in the following example.

Note

The vertex of the great circle need not be between the two given positions. If it is not, then either the angle at A or that at B will be greater than 90° , and the course will lie in the same quadrant between the two positions. If the vertex lies between the two positions then the course will change quadrants at the vertex. After solving the angles at the positions then the course must be found by inspecting the triangle.

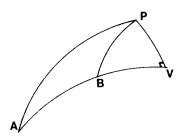
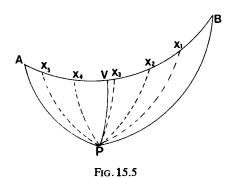


Fig. 15.4

J£xample

Find the total distance, the initial course, of the great circle track between:

Find also the latitudes at which the meridians of 90° W., 110° W., 130° W., 150° W., and 170° W. cut the great circle track, and the course at these points.



A 41 ° 00' S. *175* ° 00' E.

B 33° 00' S. 71° 30' W.

d.lat. $8^{\circ} 00'$ $113^{\circ} 30'$ =d.long.= LP

Hav. dist.=(hav. d. long. coso lat. A. coso lat. B)+hav. d. lat. Hav. dist.=(hav. 113° 30'. coso 41° . coso 33°)+hav. 8°

Number	Log		
hay. d. long.	1.84471		
coso 33°	1 .92359		
cos.41°	1.87778		

Dist.=83° 58.6'

 $= 5038.6 \text{ miles} \qquad \qquad \underline{1.64608}$

0.44267

nat. hay. 8° <u>0.00487</u>

0.44754

To find initial course

Hav. A={hav. PB-hav. (AB-PA)} cosec. AB cosec. PA Hav. $A = (hav. 57^{\circ}-hav. 34^{\circ} 58 \cdot 6')$ cosec. $83^{\circ} 58 \cdot 6'$. cosec. 49°

Number O

nat. hay. 57° 0·22768

34⁰ 58·6' 0·09031

$$A=50^{\circ} 39.5'$$
 0.13737

Course=S. 50.5° E.

1.13790

cosec. 49° 0·12222

cosec. 83° 58·6' <u>0·00240</u>

<u>1.26252</u>

To find the position of the vertex

In triangle APV

Sin. PV=sin. LA. sin. PA

$$=\sin. 50^{\circ} 39.5'$$
. $\sin. 49^{\circ}$ Number Log

 $PV = 35^{\circ} 42.6'$

Lat. of vertex =
$$54^{\circ} 17.4' \text{ S}$$
. Sin. $50^{\circ} 39.5' 1.88839$

Sin. 49° f.87778

1.76617

And cot. LP=cos. AP. Tan LA

=cos.
$$49^{\circ}$$
. tan. 50° $36.5'$ Number Log

 $P = 51^{\circ} 22.7'$

Long. of vertex = $133^{\circ} 37.3' \text{ W}$. Cos.49° 1.81694

Tan. 50° 36·5' 0·08557

1.90251

To find the latitude where the track cuts the given longitudes and the course at those points

In *VPX* Cot. *PX=cos*. *LP* cot. *PV*

Longitude ∠P	X, 90°W 43° 37·3′	X ₂ 110°W 23° 37·3′	<i>X</i> ₃ 130°W 3° 37⋅3′	<i>X</i> ₄ 150°W 16° 22⋅7′	<i>X</i> , 170°₩ 36° 22·7′
Cos ∠P Cot PV	T·85968 0·14337	T-96199 0-14337	T-99913 0-14337	T·98201 0·14337	T-90586 0-14337
Cot PX PX =	0·00305 44° 48′ 45° 12′ S	0·10536 38° 07′ 51° 53′ S	0·14250 35° 45·8′ 54° 14·2′ S	0·12538 36° 50·5′ 53° 09·5′	0·04923 41° 45·5′ 48° 14·5′
and Cos X = Sin ∠ P Cos PV	Cos PV Sin Z I·83878 I·90954	_P I-60282 I-90954	Ž·80050 Ĭ·90954	Ī·45022 Ī·90954	Ĭ·77314 Ĭ·90954
Cos ∠X ∠X	1.74832 55° 56' N 55° 56' E	1.51236 71° 01′ N 71° 01′ E	2·71004 87° 04′ N 87° 04′ E	1·35976 76° 46′ S 76° 46′ E	1.68268 61° 13′ S 61° 13′ E

Answer

Position on g.c.		Course
48° 14'5' S.	170° W.	S. 61.25° E.
53° 09·5' S.	150° W.	S. 76,75° E.
54° 14·2' S.	130° W.	N. 87° E.
51° 53·0' S.	110° W.	N. 71° E.
45° 12·0' S.	90° W.	N. 56° E.

Example 2

Find the distance, and the initial course and the position of the vertex between the following positions.

A
$$48^{\circ} 30.0' \text{ N.} 5^{\circ} 10'0' \text{ W.}$$

$$B = 22^{\circ} 00.0' \text{ S. } 40^{\circ} 40'0' \text{ W}.$$

Hav. dist.={hav. 35° 30'. coso 48° 30'<u>. coso 22°</u>)+hav. 70° 30'<u>.</u> Dist. =77° 18·8' Number Log =4638·8'

=4638·8 miles hay.
$$35^{\circ} 30' 2.96821$$
 $\cos 48^{\circ} 30' 1.82126$ $\cos .22^{\circ} 1.96717$

Figure will be 0,05710

similar to fig. 15.4 <u>0,33310</u>

O' 39020

Hav. $LA = \{\text{hay. PB-hav. } (AB-AP)\}$. cosec. AB. cosec. $AP = (\text{hav. } 112^{\circ}\text{-hav. } 35^{\circ} 48'8')$ cosec. $77^{\circ} 18.8'$

cosec 41 ° 30'

 $LA = 146^{\circ} 31'$ Number Log

Course=S. 33° 29' W.

hay. 112° 0.68730

hay. 35° 48·8' 0,09453

<u>0.59277</u> 1.77289

cosec. 77° 18·8' 0,01074

cosec. 41 ° 30' 0·17874

<u>1.96237</u>

To find the position of the vertex

In triangle PVA

 $LA = 33^{\circ} 29'$

 $PA = 41^{\circ} 30'$

and by Napier's rules

Sin. PV = sin. LA. sin. PA

=sin. 33° 29'. sin. 41 ° 30' Number Log

 $PV = 21^{\circ} 26.6$ '=co-lat. of vertex -----

Latitude=68° 33·4' N. Sin. 33° 29' 1·74170

Sin. 41 ° 30' r.82126

<u>1.56296</u>

and Coso PA=cot. LP. cot. LA

Cot. LP=cos. PA. tan. LA Number Log

=cos. 41° 30'. tan. 33° 29'

 $LP = 63^{\circ} 38.7'$ Coso 41 ° 30' 1.87446

Tan. 33° 29' 1·82051

1.69497 Longitude of vertex = 5° 10.0' W.

<u>63° 38⋅7' E</u>.

<u>58° 28'7' E.</u>

Position of vertex 68° 33'4' N. 58° 28-7' E.

EXERCISE 15A

1. Find the initial course, the final course and the distance by great circle sailing from:

to B 51° 12' N. 56° 10' W.

2. Find the great circle distance and the initial course, and the position of the vertex of the great circle from:

A 34° 55' S. 56° 10' W. to B 33° 55' S. 18° 25' E.

3. Find the saving in distance by steaming a great circle track as opposed to a mercator track from:

A 43° 36' S. 146° 02' E. to B 26° 12' S. 34° ()()' E.

4. Find the distance, the initial course, and the positions where the meridians of 140° W., 160° W., 180°, 160° E. cut the track, and the courses at these positions, on a great circle from:

A 48° 24' N. 124° 44' W. to B 34° 50' N. 139° 50' E.

Composite great circle sailing

If the vertex of a great circle lies between the two positions involved, then the great circle track will take the vessel into a higher latitude than either of the two positions. In some circumstances this may not be desirable. Due regard must be had to the weather conditions likely to be encountered.

In a composite great circle sailing a limit is put on the latitude to which a vessel goes, the limit being decided by the navigator. An example of the circumstances in which such a track might be employed is the voyage between Cape of Good Hope and Australia, in which case the great circle would reach very high southerly la ti tudes.

The track now becomes a great circle track from the departure position to the parallel of the limiting latitude, a parallel sailing along this parallel, and then another great circle track from the limiting latitude to the destination position.

The great circle to be taken from the departure position is that great circle which has its vertex in the limiting latitude. It will therefore form a right angle with the meridian through the vertex, and all triangles can be solved with Napier's rules. The same applies to the track from the limiting latitude to the arrival position.

Figure 15.6 represents such a track.

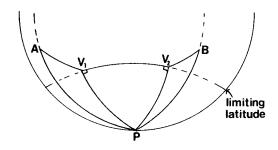


Fig. 15.6

Description of figure:

A = Departure position

B = Arrival position

AP = Co-lat. of A BP = Co-lat. of B

!') = Vertex of great circle A!J.

 $v \sim$ = Vertex of great circle BV_2

~ V_2 = Parallel of the. limiting latitude

VI $P = V_2 P = \text{Co-lat.}$ of limiting latitude

To find total· distance and initial course

The right-angled triangle A VI P can be solved using AP and VI P, to find A VI:

 $Coso AV_I = coso AP$. sec. VIP to find LA:

Sin. $LA = \sin VIP$. cosec. AP to find LP:

Coso LP = tan. VIP. cot. AP

The right-angled triangle BV1..P can be solved using V_2P , and BP, with the same formulae, to nnd v: B, and LP.

 $VI V_2$ can then be found by the parallel sailing formula; dep. (dist.) = d. long. x coso latitude

The d. long. being that between VI and V_2 which is found by d. long. between A and B- LAP V_I - $LBPV_2$

The problem of finding a series of positions along the two great circles AVI and V_2B , and the course of those positions is solved in the same way as in the normal great circle sailing problem.

Example

Find the initial course and the total distance along a composite great circle track from:

to B 43° 40' S. 146° 50' E.

It is required not to go south of latitude 48°. Give also the longitude of each vertex.

A 35° 00·0' S. 20° 00·0' E. *B* <u>43° 40·0' S. 146° 50·0'</u> E.

 $126^{\circ} 50.0' = d. long.$

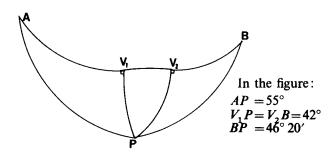


Fig. 15.7

In triangle AP J(By Napier's rules

1.88752

Sin.
$$LA = \sin . ViP \csc . AP$$
 Sin. 42° 1.82551
= $\sin . 4r \csc . 55^{\circ}$ Cosec. 55° 0,08664
 $LA = 54^{\circ} 46,3'$

<u>1.91215</u>

Coso
$$P = \cot AP \tan T\{P$$
 Cot. 55° 1.84523
= cot. 55° tan. 42° Tan. 42° 1.95444
 $LP = 50^{\circ}$ 54.9°

1.79967

In triangle BPV₂

Coso $BV_2 = \cos 46^\circ 20' \text{ sec. } 42^\circ$

$$BV_2 = 21^{\circ} 42'$$
 Number Log = 1302' ------

Coso 46° 20' 1.83914 Sec. 42° <u>0.12893</u>

1-96807

Coso
$$LP = \cot. 46^{\circ} 20' \tan. 42^{\circ}$$
 Cot. $46^{\circ} 20' 1.97978$

$$LP = 30^{\circ} 44.8'$$

Tan. 42° 1.95444

1.93422 Thus in triangle $T/V_2 P$

$$P = 126^{\circ} 50' - 50^{\circ} 54.9' - 30^{\circ} 44.8'$$

$$=45^{\circ} 10,3' = 2710,3'$$

and
$$J(V_2 = d. long. x coso lat.$$
 Number Log

$$= 2710.3 \text{ x coso } 48^{\circ}$$

$$= 1813.5$$

Coso 48° 1.82551

3.25853 Total distance = $AVI + VIV_2 + V_2B$

 $= 5484 \cdot 5$ miles

Initial course = $L VIAP = S. 54^{\circ} 46.3' E.$

Long. of
$$VI = 20^{\circ} 00' \text{ E.+ } LAPV_I$$

 $=70^{\circ} 54.9' E.$

Long. of
$$V_2 = 146^{\circ} 50' \text{ E.- } L V_2 PB$$

 $= 116^{\circ} 05.2' E.$

EXERCISE 15B

- 1. A composite great circle track from Montevideo (34° 55' S. 56° 10' W.) to Cape Town (33° 55' S. 18° 25' E.) is required with a limiting latitude of 38° S. Find the total distance to steam and the initial course.
- 2. Find the total distance, the initial course, and the longitudes where the track reaches and leaves the limiting latitude, on the composite great circle from:

to B 43° 36′ S. 146° 02′ E. Limiting latitude 45° S.

3. Find the total distance, and initial course on the composite great circle, with limiting latitude 49° S., from:

A 45° 30′ S. 71° 37′ W.

to B 46° 40' S. 168° 20' E.

SPECIMEN PAPERS

The following papers are typical of the practical navigation papers set for Department of Trade Class IV certificates. The time allowed is 2 hours and all questions must be attempted.

PAPER 1

1. From the following information find the direction of the position line and a position through which the position line passes.

Time at ship 0805 on 20th D.R. 5°

D.R. 5° 58'S. 126°03'E.

September 1980 Sextant altitude of Saturn 40° 49.5'

Index error 1.5' off the arc

Height of eye 14.5 metres

Chronometer showed Oh 27m 38s.

Chron. error nil.

2. Find the G.M.T. and L.M.T. of meridian passage of the star *Vega*, and the setting to put on a sextant to observe this passage.

Date at ship 19th September

D.R.13° 00' S.138° 55' E.

1980

Index errort·8' off the arc

Height of eye 17.0 metres

- 3. Find by mercator sailing the true course and distance from 48° 11' S.169° 50' E. to 23° 36' S.16e 42' W.
- 4. From the following information find the compass error and the deviation for the ship's head

Time at ship 1004 on 18th

D.R. 55° 08'N. 5°13' E.

December 1980

Sun bore 162° by compass Chronometer showed IOh 2m 17s error 1m 40s fast on G.M.T.

Variation 7°W.

PAPER 2

1. From the following information find the direction of the position line and a position through which it passes:

Time at ship 1930 on 26th June 1980 D.R.33°05'N.131°18'W. Sextant altitude of Regulus

35° 54.4'

Index error $1 \cdot 0'$ on the arc Height of eye $16 \cdot 7$ metres

Chronometer showed 4h 12m 13s and was fast on G.M.T. by1m 3s

2. From the following information find the direction of the position line and the latitude in which it cuts the D.R. longitude.

Time at ship 1210 on 7th January D.R. 26°17'N. 48°U'W. 1980

Sextant altitude of sun's lower limb near the meridian 41° 16.9'

Index error 2.0' on the arc Height of eye 13 metres

Chronometer showed 3h 18m 06s error 7m 14s fast on G.M.T.

3. From the following observation of *Polaris* during evening twilight find the latitude:

Date at ship 27th June 1980

D.R. 21° 03' N.153°16' W.

Sextant altitude 20° 15'

Index error $2 \cdot 0'$ on the arc

Height of eye 11.0 metres

Chronometer showed 5h 27m 42s.

Error 3m 29s slow on G.M.T.

4. From the following sights find the position of the ship at the time of the second observation:

E.P. 40° 12'S. 94° 30' E. Observed longitude 94° 33'E. Az. 079° T. Run 3.5 hours at 16 knots. Course 352° T. Current 260° T. at2 knots throughout. Using E.P. run up intercept 3.0' towards Az. 012° T.

PAPER 3

1. From the following information find the direction of the position line and a position through which it passes:

Time at ship 1429 on 2nd October D.R. 47°30'N. 45°20'W.

1980

Sextant altitude of sun's lower limb 27° 41.3'

Index error $2 \cdot 0'$ on the arc

Height of eye 6.0 metres

Chronometer showed 5h 31m 13s.

Error 1m 03s fast on G.M.T.

2. From the following meridian observation find the latitude and state the direction of the position line:

Date at ship 9th January 1980

D.R. 46°28' S.136°30'E.

Sextant altitude moon's lower limb

40°15.7'

Height of eye 16.5 metres

Index error nil

3. Find by traverse table the vessel's position at the end of the

fourth course.

Initial position 46°45' N

45° 00' W.

First course 202°T. distance 85 miles Second course 272° T distance 63 miles Third course 337°T. distance 40 miles Fourth course 0500T. distance 36 miles

4. From the following information find the error of the compass and the deviation for the ship's head:

Date at ship1.st October 1.980

D.R.100 50'N.

Sun bore 273° by compass at setting 157° 17' W.

Variation 4°E.

PAPER 4

1.. From the following information find the direction of the position line and a position through which it passes:

Time at ship 0850 on 9th January 1.980 D.R. 42°10'N.

Sextant altitude moon's upper 11mb 500 05' W.

28°09.6'

Index error 1.0' on the arc

Height of eye 8.2 metres

Chronometer showed 11h 59m 015.

Error Om 48s slow on G.M.T.

2. From the following observation find the direction of the position line and the latitude in which it cuts the D.R. longitude:

Time at ship 0508 on 19th September D.R. 38° 40'S.

1.980 138° 46'E.

Sextant altitude of *Bellatrix* near the meridian 44° 50'

Index error 3.0' off the arc

Height of eye 10 metres

Chronometer showed 8h 12m 1.9s.

Error 2m 18s fast on G.M.T.

3. From the following observation find the latitude and state the direction of the position line:

Date at ship 20th September 1.980 D.R. 26° OO'N. 116°

Sextant altitude of the sun's lower limb 37' W.

64°45'

Index error1..5'on the arc

Ht. of eye17.9 metres

4. From the following sights find the position of the ship at the time of the second observation:

Time 1300; E.P. 23° 57'N. 92°07'W.; Intercept 3·0' Towards, Az. 287°T.; Run 95 miles; Course 147°T.

Time 1830; Using E.P. run up, intercept 5.0' Away, Az. 030^{0} T.

PAPER 5

- L On 18th December, 1980, in D.R. position 29° 15' S. 134° 18' E. at approximatelyl950 L.M.T., the sextant altitude of the star *Aldebaran* was observed to be 28° 41·0'. Index error 1·O' on the arc. Height of eye 13·8 metres. A chronometer which was 1m O9s slow on G.M.T. showed IOh 57m 40s at the time. Find the direction of the position line and a position through which it passes.
- 2. On 8th January, 1980, in D.R. position 30° 58' S.15lo 46'W., an observation of the moon's lower limb when on the meridian gave sextant altitude 55° 04·4'. Index error 0·9' off the arc. Height of eye 15·0 metres. Find the latitude and state the direction of the position line.
- 3. A vessel steams at 15.5 knots for 24 hours on a course of $064 \sim T$. Ifth~ departure position is 20° 18.4' S, 175° 50.0'W., find the position arrIved at.
- 4. An observation in D.R. position 32° 30'N. $32^{\circ}15'$ W. gave a longitude of 32° 08' W. when worked by longitude by chronometer. Bearing of body' observed was 0600T. The vessel then steamed 070° T. for 40 mdes when a meridian observation gave a latitude of 32° 46·0' N. Find the vessel's position at the time of the meridian observation.

PAPER 6

1. From the following observation find the direction of the position line and the longitude in which it cuts the D.R. latitude:

Approximate time at ship 0840 on 28th September, 1980. D.R. posltton30 40 N.1.75 18 E.

Sextant altitude sun's lower limb, 33° 35.0.

Index error 1.0' off the arc. Height of eye 10.3 metres.

Chronometer 08h 50m 05s, correct on G.M.T.

2. From the following meridian observation find the latitude and state the direction of the position line.

Date at ship 6th January, 1980. D.R. long. 96° 35' W.

Sextant altitude sun's upper limb bearing north, 6l 25·0'.

Index error **104'** on the arc Height of eye 11.5 m

3. From the following observation of *Polaris* find the latitude and the direction of the position line:

Date at ship 27th June, 1980 Approx. L.M. T. 0500

D.R. positton47°15'N125°40'W.

Sextant altitude 47° 52'

I. E.l·4' off the arc

Height of eye 6·1 metres Chronometer O1h 20m 44s

error nil

4. From the following data find the position of the ship at the time of the third observation;

Course 07J.OT., speed 20 knots. D.R. 42°11.' S.16el7'E.

Time 1.73l, star A using D.R. given, intercept 5.8' Towards Az. 026° T.

Time 1737, star Busing D.R. given, intercept 2.9' Away, Az.

272°T.

Time 1746, star C using D.R. given, intercept 1.7' Towards, Az.

319°T.

ANSWERS

	ANSWERS			
Exercise IA				
I. 425' N. 709' W.	2. 910' N. 635' E	··	3. 930' S. 741' W.	
4. 2026' N. 522' E.	5. 741' N. 1278'	W. 6. 1005	3. 930' S. 741' W. ' S. 300' E. ' N. 8226' W.	
7. 995' N. 3712' W.	8. 2910' N. 4425	'E. 9. 1508	' N. 8226' W.	
10. 2983' N. 3516' E.				
Exercise 1B				
I. 2° 46' W.	2. 12° 24' N. 165	5° 34' W.		
3. 43° 37' N. 17° 46' E.	4. 42° 08·2' N. 3	4° 14,4' W.		
5. 17° 45·1' S. 170° 59'5' E.				
Exercise 2A				
I. 15° E. 2. 19° E.	3. 33° W.		4. 30° W.	5. 14°
E.				
6. 15° W. 7. 17" W.	8. Nil.		9. 55° W.	10.
38° E.				
Exercise 2B				
I. 207" 2. 351°	3. 345° 4. 283°		5. 022°	
6. 318° 7. 106°	8. 204° 9. 096°		10. 195°	
Exercise 2C				
I. 203° 2.021°	3. 187° 4. 199°		5. 359°	
6. 087° 7. 118°	8. 178° 9. 319°		10. 198°	
Exercise 2D				
I. 24° E. 2. 9° E.	3. 3° E.		4. 4° W.	5. 2°
W.				
6.5° E. 7. 10° E. 8. 16° E.	9. 6° E.		10. 5° W.	
Exercise 2E				
I. 2° W. 2. 6° E.	3. 4° E.		4. 1° W.	5. 7°
W.				
6. 8° W. 7. 5° E.	8. 3° W. 9. 2° E.		10. 12° W.	
II. 15° W. 12. 7° E. 13.25° W.	14.4° W.		15. 5° W.	
Exercise 2F				
I. 6° E., 20° W.	2. 217°, 5° E.		3. 284°,262°	4. 5°
W., 15° E.	,		,	
5. 245°,230°	6. 172°, 12° E.		7. 346°,348°	8.
280°,275°	,		,	
9. 3° E., 25° W.	10. 201°,175°		11. Nil., 42° E.	12. 2°
W., Nil.	,		,	
Exercise 2G				
1. 1181f2°C. 2. O41.1f.oC. 3. 3500	OC. 4. 2431f4	1"C.		
5. 163 ³ /. ⁰ C.				
Exercise H				
1. 049" 2. 121 °	3. 259"	4. 322°	5. 1050	
6. 107" 7. 013°	8. 178°	9. 2400	10. 2500	
· • • • • • • • • • • • • • • • • • • •	- / - · •		- × - = × ×	

ANSWERS

Exercise 21

1. 152°19·6 knots 4. 343°T.	2. 295112°13·36 knots 5. 177"14·2 knots Exercise 4A	3. 291"2·1. knots
I. Lat.41°24·6'N.orS. 3. D. long. 9° 22' E. or W. 5. Lat. 56° 26·75' N. 7. Lat. 50 ^U 20·1' N. or S. 9. Lat. 48° 11'3' N.	 Lat.70031·9'N.orS. Dist. 348-5' Lat. 31° 42' N., long. 23° 07·8' W. Angle at pole 6° 15·1' Lat. 39° 00' N., long. 50° 19-4' W Exercise 4B 	
I. Angle at pole II ° 08,9' 3. Lat. A 51° 19·1' N.	2. Dist. 44,06'4. Rate 574,5 knots	

Lat. B 28° 57,3' N. 5. D. long. 6° 02·2' 6. Dist. 594.9' 7. Clocks advanced 20m 23s 8. Lats. 53° 07,8' N., 25° 50,5' S., d. lat. 78° 58 · 3' 9. Lat. 44° 25' N. or S. 10. Speed 9,77 knots II. D. lat. 29° 49. 3', dist. 1789,3' 12. Set 090° T., drift 32· 3' Exercise 4C 1. CourseN. 63° 53'W. Distante259miles 2. 39°31·S'NI66°11·3'W. 3. Course S. 59° 46·S'E. Distance 2620·2 miles 4. 35°04·7S' S.176°04·S' W 5. Course S. 63°19·3' W. Distance 6514·6 miles Exercise 4D 1. (a) 848,9, (b) 1862,0, (c) 2244,1, (d) 3962.8 2. D. lat. 1909' S., D.M.P. 1927'1, d. long. 1128' W., course S. 30° 20,6' W., dist. 2212' 3. D. lat. 1795' S" D.M.P. 2006,5, d. long. 506' W., course S. 14° 09·2' W., dist. 1851·2' 4. D. lat. 2943' S., D.M.P. 3171,7, d. long. 5635' E., course S. 60° 37,6' E., dist. 6000' 5. D. lat. 649,5' S., D.M.P. 708,9', d. long. 409,3' W., lat. 18° 40-5' N., long. 155° 30,7' E. 6. D. lat. 1296·3' N., D.M.P. 1295·2', d. long. 396' E., lat. Ilo 24·2' N., dist. 1355-3' 7. (I) D. lat. 565.7' S., D.M.P. 581,89, d.long. 581.89' W. (2) D. lat. 565,7' S., D.M.P. 617,42, d. long. 617-42' E. Lat. 28° 51·4′ S., long. 0° 35·5′ E. 8. D. lat. 781·8' N., D.M.P. 873·3, d. long. 1872-9 E., lat. 33° 13-8' N., long. 150° 07·1' W. 9. D. lat. 1780' S., D.M.P. 1814,6, d. long. 1978' E., course S. 47° 28' E., dist. 2633' 10.D. lat. 343' S., D.M.P. 413,1, d. long. 995' E., course S. 67° 27·1' E., dist. 894·5' Exercise 4E 1. 41° 24·0'N. 27°41·5'W. 2. N.42°S0·3′E.(043°),2011·5miles 3. S. 21°03·6′E. (159″), 37S·1 miles 4. N. 29"16·2 W. 3303/.0), 233·8 miles 5. 54° 52·4'N. 5°15·7' E. 6. 4So 56·8' N. 9" SO·S' W. 7. N. 8° 54·6' E. (009°), 404·9 miles 8. SOOO3-1' N.14°40.9' W. 9.58°19·0'N.1°11·0'E. 10. S7"50·0'N.1"02·4'E. Exercise 5A 2. 327.9' 57,8' 3. 386.9' 324.6' 1. 215-7' 100-6' 4. 73.2' 201-1' 5. 103,5' 142-4' 6. 80,8' 191.2' 7. 241.6' 456.0' 8. 37" 348.2" 9; N. 24° E. 490·0' 10. S. 33° W. 421·0' II. N. 18° E. 46,9' 12. S. 36,5° W. 388-5' 13. N. 50° W. 480·0' 14. S. 24° E. 936,0 15. 1230' 995.1' Exercise 5B 4. 250,7' I. 552' 2. 319.6' 3. 333-7' 5.391.0' 6. 1395.0' 7. 478-5' 8. 406-7' 9.470-7' 10.408.9' Exercise 5C I. 199-5' 2. 234.0' 3. 32.49' 4. 34.08' 5. 450,6' 6. 36.26' 7.416.8' 8.59.98' 9. 204.6' 10. 314.2' Exercise 5D D. lat. Dist. D. long. M. lat. Dep. Course 1. 590·0' S. 590·0' W. 45.75° N. 411.7S. 34.9°W. 719-4' 2.160.0' N. 230.0' W. 36⋅5° N. 184.9 N. 49'1°W. 244.5' 172.7 3.148.0' N. 189'0' E. 24° S. N. 4H' E. 227-4' 4.17·0' N. 260·0' W. 38° N. 204.9 N. 85·3° W. 205.6' 9'5° N. 5.70,0' S. 325.4 S. 77-8° E. 332.9' 330·0' E. 50·33° N. 52·8° E., 6. 15,0' N. 31·0' E. 19'79 Set N. Drift 24.8' 7. 82·9' S. 73-0' W. 40° N. 55.9 Lat. 39° IH' N.,

21.1° S. 225·7 S. 53° W. 20·7" N. 147·3 N. 30·5° W.

N. 77-5° E. 497-6'

Long. 5° 17.0′ W.

282.6'

290.0'

Exercise 5E L 46°36·9'N.4T'34·6'W. 2.6O"29·7'N.17°1J.2'W. 3. 36°13·5'N. 6°22·0'W. 4. 13°38·4'S.48°15·0'E.

5. Course N. 83·3'K, distance 162·8 miles. E.T.A. 0410 following day.

485.8

6. 6. S. 63°12·4'W. (243°), 157·5 miles

10. 249'8' N. 157·5' W.

8.107,5' N. 726,0' E. 48° N.

9.170·0' S.

7.S. 5e 32·8' W. (23V12°), 21H miles 8.33°50·3'S.172°56·5'E.

242·0' W.

Exercise 5F

- L 9.6 miles 2.7.0 miles
- 3. 052°T., distant 6·8 miles 4. 49° 54·1' N. 5° 46·8' W. 5. 49°57·0'N. 5°45·3'W. 6. 49°50·6'N. 5°44·1'W.
- 7. 49°58·5'N. 7°35·7'W.

Exercise 6A

- 1. H. W. 0449,10.9 metres L. W.I119, 2.3 metres.
- H.W.1725, 11·3 metres. L.W. 2355,1·9 metres.
- 2. 11·2 metres 3. Ht. above C.D. 7·2 metres. Clearance 3·4 metres
- 4. 9.1 metres. Will not dry.
- 5. Ht. above C.D. 6.0m. Interval from H.W. -3hI6m. 0827 B.S.T.
- 6. Factor ·82, Interval from H.W. -lh43m, 2138 G.M.T.
- 7. Factor ·24, Ht. above C.D. 5·1, Ht. of light 56·1 metres.

Exercise 6B

- 1. L.W. 0202, 0.4 metresH.W. 0553, 7.3 metres.
- L.W.I443, 0.4 metres. H.W.1831, 7.8 metres.
- 2. 8.4 metres, 1532 G.M.T.
- 3. Factor ·39, ht. above C.D. 4·9 metres, clearance 2·6 metres.
- 4. Factor \cdot 19, correction to soundings (ht. above C.D.), $+3\cdot0$ metres.
- 5. Ht. above L.W. 7.6, factor '62, interval from H.W. -2h2Om. 0858B.S.T.

6.Ht. aboveL.W. 4·3, factor '44, interval fromH.W.(Sp.) +3h3Om,2128G.M.T. 7. Factor ·66, Ht. above C.D. 7·2 metres, sounding dries 7·2 metres.

Exercise 8A

- 1. A:z.. S. 6O·8°E., compass error 29·8°W., deviation 5·3°E.
- 2. Az. N. $56 \cdot 2^{\circ}$ W., compass error $17 \cdot 8^{\circ}$ E., deviation $5 \cdot 2^{\circ}$ W.
- 3. Az. S. $37 \cdot 1^{\circ}$ E., compass error $20 \cdot 9^{\circ}$ E., deviation $8 \cdot 9^{\circ}$ E.
- 4.Az. N. $51 \cdot 2^{\circ}$ E., compass error $5 \cdot 8^{\circ}$ W., deviation $3 \cdot 8^{\circ}$ W. 5. A:z.. S. $76 \cdot 9^{\circ}$ W., compass error $5 \cdot 6^{\circ}$ W., deviation $6 \cdot 6^{\circ}$ W.

Exercise 8B

- 1. A:z.. S. 35·1°E., compass error 10·9"E., deviation 2·1"W.
- 2. A:z.. S. 73;3°W., compass error 6·3°E., deviationO·2°W.
- 3. Az. S. 67·ZOE., compass errorI2·2°W., deviation 5·2°W.
- 4.Az. N. $49 \cdot 0^0$ W., compass error $45 \cdot 00$ W., deviation $18 \cdot 00$ W. 5. Az. S. $33 \cdot 8^\circ$ W., compass error $36 \cdot 2^\circ$ W., deviation $3 \cdot 20$ W.

Exercise 8C

- 1. Ampl. E. $3\cdot2^{\circ}$ S., compass error $14\cdot T'$ E., deviation $3\cdot7^{\circ}$ E.
- 2. Ampl. E. 2·4°N., compass error 2·6° E., deviationZ·4°W.
- 3. Ampl. W. 31·ZON., compasserrorO·3°W.,deviation25·T'E.
- 4. Ampl. E. 30.0° S., compass errorI8·OOW., deviation3·00E.
- 5.Ampl. W. 36·00S., compass error 24·00 W., deviation4S·00W. 6. Ampl. E. 32·5°N., compasserror4·5°W., deviationZ4·5°W.

CLASS V

Revision Paper I-Chartwork and Practical Navigation

- 1. Tide 247°T., 2·3 knots, compass course 266°C., E.T.A.lh 40m after departure.
- 2. Compass error 4° E., True course 216°, position 49" 55.9' N. 5°08.1' W.
- 3. Height of light 70m. Required distance off light 2.0 miles, vertical sextant angle $1^{\circ}05'$.
- 4. Compass error 19°W., tide JOOOT., drift 2·1 miles.

Practical navigation

- 1. Total d. lat. 136·4' s., total dep. 89·4' W., final position 47°13·6' N.10014·6' W.
- 2. Course N. 28° 34·8' W. (331%°), distance 131·0 miles.
- 3. Amplitude E. 38·6°N., compasserrorl·6°W., deviation6·2°E.

Revision Paper 2--Chartwork and Practical Navigation

- 1. Compass course 267³/4°.
- 2. Position 50016·2' N. 4° 44·7' W., compass course 110".
- 3. Compass error 3° W., set and rate of current 033° T. at 3· 3 knots, course and speed made good 3400 13·8 knots.
- 4. 20.7 miles.

Practical Navigation

- 1. 55°1.7·9' N. 3° 56·1' E.
- 2.Total d. lat. 43·0'N., total dep.153·3'W., position s0013·0' N.llo 57·8'W. 3. L.H.A. 700 37-1.', Az. S. 73·6°W., error 8·4°W., deviation 3·6' E.

CLASS IV

Revision Paper I-Chartwork

- 1.. Position 51,007·7'N. 4°27·3'W., compasserror2°W., deviation ~E.
- 2. Position 51,° 28·4' N. 4° 59·6' W., course 113°C., distance off Helwick abeam 5·8 miles, time 1302.
- 3. Tide 285°T. 4·1. knots, compass course 2521/2°, speed required 18 knots.
- 4. Brg. of Lundy 140" T., brg. of Breaksea 0871/2 $^{\circ}$ T., course made good 082 $^{\circ}$ T., tide 075 $^{\circ}$ T. 3·4 knots, position 51, $^{\circ}$ 18·0' N. 4 $^{\circ}$ 1.9.6' W.
- 5. Predicted range 5·1 m., interval from H.W. -0213, factor 0·72 (using neap curve), height above C.D. 7·1 m., clearance 0·6m.

Revision Paper 2---Chartwork

- 1.. 49"58·5'N.5°44·1'W.
- 2. Course 121° T., $16\cdot2$ miles, compass course $1581/4^{\circ}$, E.T.A. 2 hours after departure.
- 3. $50006 \cdot 3$ 'N $5^{\circ}00 \cdot 9$ 'W., compass error 11 ow.
- 4. Position 49" \$.6' N. 5° 37.8' W., setand drift091,1/2°T.1.·1 miles.
- 5. L.W. 0009, (1·2 metres, H.W. 0422, 6·1. metres, L.W. 1252, 0·2 metres, H.W. 1652, 6·7 metres.

Exercile 9A

- 1. I.T.P. lat. 40° 15' N., long. 18° 18.6' W.
- 2. I.T.P. lat. 20° 16·6' S., long. 27° 24·8' W. 3, I.T,P, lat. 39° 55-4' N., long. 29° 55' W.
- 4. Pos. lat. 50° 13·3′ N., long. 44° 03·7′ W.
- 5. POS. lat. 40° 28·1' N., long. 34° 27·9' W.
- 6. Pos.lat. 48° 13,8' N., long. 50° 10·1' W.
- 7. Pos. lat. 25° 00'4' N., long. 36° 02,5' W.
- 8. Dist.off 27.6 miles
- 9. Pos. lat. 23° 44·4′ N., long. 51° 56·7′ W.
- 10. Noon 1>0s. lat. 34° II' N., long. 42° 16· 3' W. II. Noon pos.lat. 29° 06' S., long. 37° 07·1' W.
- 12.Pos. lat. 34° 15·9' N., long. 47° 52·4' W.
- 13.Pos. lat. 53° 29·8' S., long. 179° 32·1' E.
- 14. (0) Pos. lat. 16° 41·4' S., long. 163° 07' E.
- (b) Pos. lat. 17° 10,5' S., long. 162" 50·2' E.
- 15. Noon pos. lat. 42° 27' S., long. 76° 15,2' E.
- 16.Pos. lat. 39° 04·7' N., long. 131° 02·3' E.
- 17. True bearing 129° 48'
- 18. True bearing 120° 20'
- 19.Pos. lat. 47" 30·6' N., long. 34° 37·2' W.

Exercise 10A

	Dip.	R.ef.	S.D.	Par.	True Alt.
I.	$-5\cdot 2^J$	-0.7'	+16'1'	+0'1'	52° 39· 3'
2.	-6'2'	-1-4'	+15.9'	+0'1'	33° 20·2'
3.	-5.9'	-0.3'	-16.0'	Nil	71 ° 33·2'
4.	-4.9'	-1'8'	-15'8'	+0'1'	27° 24·3'
5.	-5.6'	-0,5'	+16'1'	+0'1'	62° 46'8'
6.	-4.8'	-0.6'	-16'3'	+0'1'	55° 33·2'
7.	-6.0'	-0'4'	-16'2'	+0'1'	68° 55·7'
8.	-5'7'	-0'1'	+16'1'	Nil	81° 56·1'
9.	Nil	-0.8'	+16.0'	+0'1'	48° 33·2'
10.	Nil	-0.7'	-15.8'	+0'1'	51° 40·6'

Exercise 10B

1.	-5.96'	-0.87'	47° 21'77'
2.	-4,80'	-1-5'	32° 17,3'
3.	-6'04'	-2'44'	21° 05·52'
4.	-6.93'	-0.88'	47° 06·59'
5.	-5.19'	-1'27'	37° OH4'
6.	-6.65'	-4'32'	12" 08.03'
7.	-4.9'	-0.7'	53° 14·0'
8.	-5.88'	-2.22'	23° 08·1'
9.	-7.33'	-0.74'	51° 47·53'
10.	-5.54'	-3.63'	W 26·23′

Exercise10C

	Dip.	R.ef.	S.D.	Par.	True Alt.
I.	4'8'	-0.48'	+15.53'	+ 25.02'	63° 49·67'
2.	-6.35'	-1'38'	+15,23'	+45'70'	35° 05·80'
3.	5.71'	-0.58'	-16.33'	+ 31.43'	58° 24·01'
4.	-5'37'	-0.21'	-15.03'	+ 11.76'	77° 43·95'
5.	-6.04'	-2'36'	+15.90'	+ 53.98'	22° 36·88'
6.	-5.37'	-1'18'	+16'48'	+46'61'	39° 20· 74'
7.	-7.08'	-0.77'	-15'09'	+34.41'	W 26'87'
8.	-6.57'	-1.01'	+16.80'	+44'26'	44° 11·88'

Exercise 11A

- 1.. Lat. 35°11·0'N.,P/L0900/2700. 2. Lat.0009·1'S.,P/L09OO/2700.
- 3. Lat. 49" 51,·3' S., P/L09OO/27oo.
- 4. Lat. JOO09·9' S., P/L09OO/27oo.
- 5. Lat.0002·1'N.,P/L09OO/27OO.

Exercise 11B

- 1.. G.M.T. 224618th, lat. 0016·8'N. 2. G.M.T. lA4426th, lat. 25°00·7' S.
- 3. G.M.T. 18326th, lat. 51, °30·6' S. 4. G.M.T. OO483Oth,lat. 36° 51·0' N.
- 5. G.M.T. 02291.9th, lat. 50044·2' S.

Exercise 11C

- 1.. G.M.T. 23064th,lat. 33°28.5' S. 2. G.M.T. 07212Oth,lat. 40"41.·2'N.
- 3. G.M.T.13141.9th, lat. 34° $24\cdot7'$ N. 4. G.M.T. 0505 30th, lat. $1\sim45\cdot2'$ N.

Exercise 11D

- 1. Sextant altitude 57" 09·0', G.M. T. 20h 10m 46s 19th, L.M.T.18h 40m 46s 19th.
- 2. Sextant altitude 50055,1', G.M.T.17h 50m 41s6th, L.M.T.19h 59m21s 6th.
- 3. Sextant altitude 33°21.3', G.M.T. OSh44m24s19th, L.M.T. 06h 22m 24s 19th.
- 4.Sextant altitude $66^{\circ}47.8'$, G.M.T.14h58m20s27th, L.M.T.19h00m40s27th. 5. Sextant altitude $61^{\circ}14'9'$, G.M.T.15h23m42s2Oth, L.M.T. 05h 55m 26s 20th.

Exercise 11E

- 1. Lat. 50017·6' N. 2. Lat. 52° 50·5' N. 3. Lat. 55°14'1' N.
- 4. Lat. 49"57.7 S. 5. Lat. 45°28.6'S.

Exercise 12A

- 1. L.H.A. 324°17·3', C.Z.X. 63° 00·7', TZX 63° 01·4', Int. 0·7 A,Az. N. 37·0E., P/L *127·001317·00* through I.T.P. 29° 30·5' S. 121° 20·4' W.
- 2. L.H.A. 47" 56·7', C.Z.X. 43°24·4', TZX43°25·2', Int. 0·8' A., Az. N. 89'2°W., P/LOOO·8°/180·8" through I.T.P. 32"15·0' S. 48°15.1' W.
- 3. L.H.A. 58" 16,6', C.Z.X. 58° 17·0', T.Z.X. 58° 10·0', Int. 7·0'T., Az. N. 88·7"W., P/LOO1·3°/181·3° through I.T.P. 00 00·2'N. 161"02·0'W.
- 4. L.H.A. 319° 46·4', C.Z.X. 76° 10,6'. T.Z.X. 76° 18'8', Int. 8·2' A., Az. S. 37·6°E., P/L232·4°/052·4°through I.T.P. 43°18·5' N. 38°31·9'W.
- 5. L.H.A. 3000 05·4', C.Z.X. 71° 05·2', T.Z.X. 700 56·0', Int. 9·2'T., Az. S. 66·00 E., P/L204·OO/024·OO through I.T.P. 44°01·3' N. 27"29·3' W.

Exercise 12B

- 1. L.H.A. 63° 52·4', C.Z.X. 58° 56·4', T.Z.X. 58° 38·0', Int. 18·4' T., Az. N. 81·6°W., P/L188·4°/008·4° through I. T.P. 24° 52·7' N. 144° 49·9' E.
- 2. L.H.A. 77" 53·9' , C.Z.X. 49" $10\cdot 2$ T.Z.X. 49" OB' , Int. 7-1' T., Az. N. $45\cdot 6$ ° W., P/L 224.4°/044.4° through I.T.P. 43° $10\cdot 0$ ' N.177" $22\cdot 9$ ' W.
- 3. L.H.A. 293° 03·1', C.Z.X. 71° 10'6', T.Z.X. 71° 11·7', Int. 1-1' A., Az. S. 74·00 E., P/L196·OO/016·OO through I.T.P.17° 53·9' N. 47"31-1' W.
- 4.L.H.A. 311° 44·6', C.Z.X. 42° 03·7', T.Z.X. 42° 03·7', Int. Nil., Az. S.
- 8J·9"E., P/L186·1 °/006·1." through 42° 40·0' N.172°10·0' W.
- 5. L.H.A. 65° *OS*·4′ C.Z.X. 75° 11'2', T.Z.X. 74° 44·7', Int. 26·5"T., Az. N. 69·PW., P/L2oo·9"/020·9" through I.T.P. 400 SO·O' S. 57"29·8' W.

Exercise 12C

- 1. L.H.A. 294° 40,9'. C.Z.X. 59" 46,2', T.Z.X. 59" 50·0', Int. 3·8' A., Az. N. 87·3°E., P/Ll77-3°/357·3° through I.T.P. 42° 50·2' S. 41° 35·2'W.
- 2. L.H.A. 60011'5', C.Z.X. 62°15,7', T.Z.X. 62°15,1', Int. 0·6"T., Az. S. 78'4°W., P/L 168.4°/348.4° through I. T.P. 25° 29·9' N .174° 59·3' E.

Exercise 12D

- 1. G.H.A. 358" 09·5°, T.Z.X. 58" 20'8', L.H.A. 30" 18'5', longitude 61 ° 43·4' E., Az. N. 68·9"W., P/L201-1°.
- 2. G.H.A. 182° 02.9', T.Z.X. 65° 50.3', L.H.A. 64° 48.4' longitude 117" 14.5'W., Az. S. 67.00W., P/L157.00I337.00.
- 3. G.H.A.136°06·1', T.Z.X. 46°42·2', L.H.A. 307"30·9', longitude 171°24·8' E., Az. 090, P/L 0Q(f/180".
- 4. G.H.A. 302° 38·0', T.Z.X. 59" 59·8', L.H.A. 302° 34·4', longitude 00 03·6' W., Az. S. 63·9"E., P/L206·1 °/026.1 0.
- $5. \;\; G.H.A. \;\; 327" \;\; 46\cdot 4', \; T.Z.X. \;\; 700 \;\; 56\cdot 0', \; L.H.A. \;\; 300" 19,4', \; longitude \;\; 27" 27\cdot 0' \; W., \;\; Az. \cdot S. \;\; 65\cdot 8" E., \; P/L 204\cdot 2^{\circ}/024\cdot 2^{\circ}.$

Exercise 12E

- 1. G.H.A. 339°25'2', T.Z.X. 62° 11,2', L.H.A. 295°03,1', longitude 44°22·1'W., Az. S. 88·9"E., P/L181,·1°OOl·1°.
- 2. G.H.A 204° 35.6', T.Z.X. 75"20.2', L.H.A. 69" 48.5', longitude134° 47-1' W., Az. N. 75.1°W., P/L194.9"/014.9°.
- 3. G.H.A. 244° 41·3', T.Z.X. 57° 44·7', L.H.A. 62° 55·1', longitude 178° 13·8'E., Az. N. 83·6°W., P/LOO6·4°/186·4°.
- 4. G.H.A 215° 44·6', T.Z.X. 76° 46,2', L.H.A 294° 19·2', longitude 78" 33·6'E., Az. N. 66·3 °E., P/L156·3°/336·3°.
- 5. G.H.A.121°30·8', T.Z.X. 74°44·7', L.H.A. 64°30·7' longitude57"OO·1'W., Az.
- N. 76·7"W., P/L193·3°/013·3°.

Exercise 12F

- 1. G.H.A.116°15·7' T.Z.X. 57" 33·3', L.H.A. 316° OS·3', longitude 160007·4' W., Az. N. 55·1°E., 'C'1·01" P/L14Ho/325'1°, obs.latitude46°08·0' S., D.R.long, 161 ° 03·6' W., d. long. 13·6' E., noon position 46° OS'0' S. 1600 50·0' W.
- 2. G.H.A. *1500* 35·9' T.Z.X. 72° 34·9' L.H.A. 319° 01,9', longitude 168° 26·0' E., Az. N. 39·2°E., 'C'1·563, P/L309·2"/129·2°, obs.latitude3'f52·9'S.,D.R.long, 169"01·9' E., d.long. 9·7'E., noon position 37" 52·9'S. 169° 11·6'E.

Exercise 13A

- 1, L.H.A. 6° 23·8' T.Z.X. 47" 30·0', M.Z.X. 47" 10'9', latitude 4SO 50·5' N., Az. S. 33·00W., P/Ll23·OO/303·OO.
- 2. L.H.A. 351,° 54·7', T.Z.X. 400 54'2', M.Z.X. 4(f14·7', latitude 41 ° 32·3' N., Az.
- S. 12·4°E., P/L257·6°/077·6°.
- 3. L.H.A. 34SO 45·2', T.Z.X. 65°13'8', M.Z.X. 64°23.3', latitude 400 58·7' N., Az.
- S.11·4°E., P/L258·6°/078·6°.

Exercise 13B

- 1. L.H.A. 7" 09·7', T.Z.X. 31,° 04·7', M.Z.X. 30" 29'0', latitude 45° 09· 7' N., Az. S. 13·5°W., P/Ll03·5°/283·5°.
- 2. L.H.A. 350024-9' T.Z.X. 66°41.5', M.Z.X. 66°04.8', latitude36°21-4' N., Az. S. 9-1°E., P/L260-9"/080-9".
- 3. L.H.A. 355°23·3', T.Z.X. 34°38.1.', M.Z.X. 34°20·7', latitude26°07·4'N., Az.
- S. 8·1°E., P/L261,·9"/081,·9".
- 4. L.H.A. 5° 41·9', T.Z.X. 22° 19·0', M.Z.X. 21,° 40·3', latitude 30"14·8' S., Az. N. 15·00W., P/L255·OO/075·OO.
- 5. L.H.A. 357" 14· 7', T.Z.X. 64° 41· 7', M.Z.X. 64° 38·8', latitude 18" 40·3' S., Az.
- N. HOE., P/L272.1."/092-1 0.

Exercise 14A

- 1. L.H.A. 'Y' 7" 31.5', T. Alt. 50" 03.9' latitude 49"19.4' N. P/L 090.6°/270.6°.
- 2. L.H.A. 'Y' 282°24.5', T. Alt. 35°07.6', latitude.34°'25.7', P/L271°/091 0.
- 3. L.H.A. 'Y' 317" 50.4', T. Alt. 47"38.2', latitude 47"25.8' N., P/L271.3°/091.3°.
- 4. L.H.A. 'Y' 15°12.5', T. Alt. 23°31"0', latitude 22° 44·0' N., P/L09O·3°/270·3°.
- 5. L.H.A. 'Y' 85° 40.6', T. Alt. 51, °04'6', latitude 50" 34.5' N., P/L269"/089".
- 6. L.H.A. 'Y' 74°35.7', T. Alt. 32°37'9', latitude 32°00.6' N., P/L269.3°/089.3°.
- 7. L.H.A. 'Y' 216°01, 51, T. Alt. 40028·0', latitude41°17·8'N., P/L09OO/27OO.

Exercise 15A

- 1. Distance 1736.5 miles, initial course N. 77° 37.7' W., final course S. 62° 13.8' W.
- 2. Distance 3599 miles, initial course S. 67° 30·3' E., position of vertex 40° 44·8' \$. 20° 17·0' W.
- 3. Great circle distance 5190.4 miles, mercator distance 5594.1, saving 403.7 miles
- 4. Distance 4076.6 miles, initial course N. 61 ° 50.5' W., position of vertex 54° 10.4' N. 16()O 22.5' W.

Positions along track

Lat. 52°24·4'N. 54°10·3'N. 5*T31·3'N*. 46°49·9'N.

Long. 140° W. 160° W. 180° 160° E.

Course N. 59° 13·2' W. N. 74° 35·2' W. S. 89° 18' W. S.73° 13' W.

Exercise 15B

- I. Total distance 3613.4 miles (1296.6+816.8+1500.0), initial course S. 73° 56.6' E.
- 2. Total distance 5279.6 miles (3081.8+1431.5+766.3), initial course S. 5r 00.4 E.
- 3. Total distance 4803·8 miles (1144·8 +2731·0+928), initial course S. 69° 23·5′W.

Specimen Paper 1

- 1. L.H.A. 311° 21,·3" C.Z.X. 49"13·0', T.Z.X. 49" 16·8', intercept 3·8' A., Az. N. 82·2"E., P/L 352·2"/1,72·2" through I.T.P. 5° 5S·5' S.125° 59·2' E.
- 2. G.M.T. 09h26m52s1.9th, L.M.T.18h42m32s1.9th, ZX51~46·3', sextant alt. JSO 20·4'.
- 3. Course N. 42° 51·2' E., distance 2112·0 miles.
- 4. Az. S. 22·ooE, compass error4°W., deviation 3°E.

Specimen Paper 2

- 1. L.H.A. 55° 05·6′, C.Z.X. 54° 20·5′, T.Z.X. 54° 15·1′, intercept 5·4 T., Az. S.
- SO-8"W., P/L350-8"/170-8" through I.T.P. 33°04.1' N.I31°24-3' w.
- 2. L.H.A. 358" **II** '0', T.Z.X. 48" 36·2', M.Z.X. 48" 33·9', latitude 26° OS·5' N., Az.
- S. 2·4°E., P/L 267.6°/087.6°.
- 3.L.H.A. 'Y' 205° 59·S' ,latitude 200 54·1.' N., Az. 359·9". 4. Obs. pas. 39" 15·0' S 94° 13·2' E.

Specimen Paper 3

- 1. L.H.A. 39" 54·6', C.Z.X. 62° 06·4', T.Z.X. 6'J.O 10·6', intercept 4·2' A., Az. S.
- 46·4°W., P/LI36·4°1316·4° through I.T.P. *4T32·9'* N. 45°15·6' W. 2. G.M.T.I946Sth,latitude46°25·O' S., P/L09OO/27OO. 3.46°28·3'N.4Too·5'W.
- 4. G.M.T. 0419 2nd, amplitude W. 3·TS., compass error 6·TW., deviation to·TW.

Specimen Paper 4

- 1. L.H.A. 49" 51,·6', C.Z.X. 61° 31·6', T.Z.X. 61° 25·2', intercept 6·4' T., Az. S. 6O·4°W., P/LI50·4°133O·4° through I.T.P. 42°06·S' N 50012·6' W.
- 2. L.H.A. 358"OS'5', T.Z.X. 45°13'6', M.Z.X. 45°11'7', latitudeJS051'7' S., Az.
- N. 2·6°E., P/L 272·6°/092·6° through 38" 51,·7' S.138" 46·0' E.
- 3. G.M.T.I9392Oth, latitude 25°56·5'N., P/L09OO/27OO.
- 4. 22°33.9'N.91°15.1'W.

Specimen Paper 5

- 1.. L.H.A. 31,T3O·3', C.Z.X. 61,°25·1.', T.Z.X. 61,°28·3', intercept 3·2' A., Az. N.
- 47·5°E., P/L 137·5°131.7·5° through I.T.P. ~1.7·2' S.I34°15·3' E.
- 2. G.M.T.1451,Sth,latitudeJS05S·O'S., P/L09OO/27OO.
- 3.1.T35-3'SI69"58·6'W. 4. 32° 46·0'N. 31,025·0'W.

Specimen Paper 6

- 1. G.H.A. 134° O7·S', T.Z.X. 56°15'0', L.H.A. 309" 20·3' longitude 1.75° 12·5' E., Az. S. 59·1,D E., P/L $210\cdot9''/030\cdot9''$.
- 2. G .M. T. 1832 6th, latitude 51,° 30·6' s., P/L 0900/2700.
- 3. G.M.T. 13h 20m 44s 27th, L.H.A. ¥ 3500 19'3', latitude 4T 11.·7'N., PIL 270'8"/090·8".
- 4. 42° OJ·5' S.I61,o 25·0' E.

EXTRACTS FROM THE NAUTICAL ALMANAC, 1980

A2 ALTITUDE CORRECTION TABLES 10°-90°—SUN, STARS, PLANETS

OCT.—N	IAR. S	UN APR.—SE	PT.	STARS A	ND PL	ANETS		DIP	
App. Low		App. Lower Alt. Limb		pp. Corrn	App. A	Additional Corr ⁿ	Ht. of Corr	Ht. of Eye	Ht. of Corrn
						1980	m	ft.	m,
0.24	, ,	0 30		9 56 _′_	1	INUS	2.4 -2.8	8.0	1.0- 1.8
9 34+10	·8 — 21·5	9 39 + 10.6	— 21·2 II	0 08 - 5.3	Ian. 1	-Feb. 26	2.6 _2.0	8.6	1.5 - 2.2
2 40	·9-21·4			0 20 -5.2	0		2.8 -3.0	9.2	2.0 - 2.5
10 08 + 11	·O 21·3	10 03 + 10 8		0 33 -5.0	42	+ 0.1	3.0 -3.1	9.8	215 - 2.8
	·I - 21·2	10 27 + 11 0	20·9 I	0 46 -4.9	Feb 2	7-Apr. 13	3.2 -3.2	10·5 11·2	3.0 - 3.0
10 34 + 11	·2 — 21·1	10 40 + 11.1	20·7	100	0	.,-11p1, 13	3.4 -3.3	11.9	See table ←
10 47 ± 11	·4 — 20·9	+11'2	2 20-6	$\frac{114}{120} - 4.8$	47	+ 0·2	3.8 -3.4	12.6	
(I OI ;	· •	II OO TILL			1	Man a	1.0 - 2.3	144	m , 20 — 7:9
II 15 ₊₁₁	·6 — 20·7	11 23+11	4 – 20:4 ;	1 45 2 01 -4.5	Apr.	14-May 9	$\frac{4.3}{4.5} - 3.6$		22 - 8.3
- + 1	·7 — 20·0	1 7 11	r — 20.2 ll	2 18 -4.4	46	+ oʻ3	4.5 - 3.8	14.9	24- 8.6
11 46 + 11 12 02 + 11	·8 — 20·5	11 54+11	5 20·2]	2 35 -4-3	40		4.7 - 3.9	/	26 - 9.0
12 19 + 1	19-20-4	o+11';	7-20-1			0-May 25	5.0 _4.0	, 10)	28 - 9.3
12 27 + 17	2.0 — 20.3	12 46	1 1 1 1		1 -	U·A	1 5.2 4.1	17.4	
12 EE T 1.	20.1	13.05 +11.3	. 11 4		1	+ 0.7	5.5 -4.2	18.3	30-9.6
13 14 ⁺¹	2 • 2 — 20 • 1	· · + 12·	7 — 19·7 '	3 34 - 3.8			5·8 -4·3	19·1 20·1	32 - 10.0
13 35 + 1	2·4 — 19·9	#3 #3 va.	تالتمميية	14 16 -3.7	May	26-June 3	6.3	21.0	34-10-3
13 56 T 1 14 18 + 1	2.5-19.1	14 07 +12 14 30		14 40 -3·7 14 40 -3·6	6	+ 0.2	6.6	22.0	36-10-6
14 18 + 1	2.6 – 19.1			15 04 -3.5 15 30 -3.5	20	+ 0.0	6.9 -4.6		30-10-6
14 42 _{+ 1}	2.7 - 19.	5 14 34 + 12·	S - 10:3	-3.4		+ 0.7	7.2 -4.	23.9	40-11-
15 06 + 1	2.8 19.	15 19 + 12	6 - ro 2 II	16 26 ^{- 5 5}	June	4-June 26	11 /2 40	, <i>-</i> +7	
	2·9 — 19·		7 - 10:1 II	16 56 ^{-3·2}			/ 9_5.6	200	44-11-
1D 7A	3.0 – 19.	16 14 + 12. 16 44	X — 10.0 H	17 28 - 31	1 4	+ 0.0	11 0 2	. ~/ ~	46-11
16 50 + 1	3.1 - 19.	17.15		18 02 -2.9	1 14	+ 0.8	8.5	5 29.1	40-12
17 32 + 1	3.2 - 19.		1 - 18.7	18 38 _2.8			IJ ~ ¯ − 5 ·	29·2 3 30·4	I II.
-0 AK+1	3·4 – 18· 3·3 – 19·	I8 24 _ , ,	.2 _ 18.6	19 17	Tune	27-July 6	9.2 -5.	4	1 2 1·
	3·4 - 18· 3·5 18·		. ¬ v Q. c	19 58 -2.6	; · ·	+ 0.5	9.5 - 5.	32.7	4-1
	3·6 – 18·			20 42 21 28 -2·5	20	+ 0.0	3.9 - 5.		0-2
20 03 + 1	3.7-18	6 + 13	·5 – 18·3			+ 0/	110.6 3	35.1	0-2
20 48	3.8 - 18	< + 13	·6 — 18·2	22 19 -2·3 23 13 -2·2	Inly	7-July 21	11.0 -5.	30.3	10 - 3
	3.9 - 18	. 22 00 12	.7 - 18.1	24 II —2·1	1 100	۰ .	11.4 _6.	37.0	
22 22 +1	4.0 - 18	124 74	.8 18.0	25 14 -2.0	1	0 + 0.4	11.8-6	ຸ 38∙9	_
24 21	4-1 - 18	2 24 53 +13	9-17-9	26 22 1.0	1 4	1 + 0.2	12.2 6	40·I	
	4.2 - 18	26 00 14	·I — 17·7	27 36		22-Aug. 1	126-6	3 41.5 3 42.8	
25 26 + 26 36 +	(4·3 – 18	9 27 13+14		28 56		ů′-	13.0 -6	4 44 2	
27 52		8 20 33 + 14	3-17-5	30 24	6 4	6 + o:3	13.4 13.8 -6	5 45.5	
29 15	14·6 – 17			32 00 .	ا ہ	3. 18-Oct. 2	14.2 _6	46.9	
+	14·7 — 17		115 - 17:2	33 43 <u> </u>	A	° ,	14.7 ₋₆	7 48.4	4 95 - 9
32 20 ₁	14.8 - 17	· e ~~ + 12	I D — 17 2 II	35 40 _ 1. 37 48 _ 1.	3 4	0 17 + 0·2	115.1 4	., 49	8
34 17 ₊ 36 20 ₊	14.9 – 17			40 08 -1	2 0~	 :. 3-Dec. 31	11 12.2	71	
		.a "' = " + 14		42 44	_	0	11 10.0		1
41 08	15.1 - 17	2 42 31 +14		45 30 ~		O + O·1			
43 59	15.2-17	45 31 + 1	5·1 — 16·7 l	40 47	. 0	-	11 14 7 7 4		-
43 59 47 10	15·3 — 1: 15·4 — 1:		5.2 - 16.6) 2 10 -o	7	MARS	11 4/4 -		
50 46	TE . E - 11	(.g) ~ ~ ~ + I	c - 2 - 16 - 5	50 11 -0	·6 Jar	1. 1-Apr. 28	17.9	5 60.	-
54 49 _±	15.6-1	3/ 02 _ + -	E-4 - 16.4	60 28 -0 65 08 -0	5	° ,	18.8		1 130-11
トラン ニラユ	T E - 7 - 1	5.6 T = T + I	F.F 16.3	70 11 -0	4	41 + 0.1	10.3	63	8 135-11
104 304	15.8 - 1			70 II _0 75 34 _0	1	73	19.8	7·8 65·	
76 26	15.9 - 1	4.4 / 2 - 1 4.8	5 7 — IO I I	81 13 -0	Apı	r. 29-Dec.	3 I 20 4 .	07	
170 20 4	- 19·1 — 1 - 19·0 — 1		5·8 — 16·0 5·9 — 15·9		. I	60 + 0'1	20.9	R.⊤ UG	
R2 05 '	-						21.4	° 70	.5 155 — 13

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

1980 JANUARY 4, 5, 6 (FRI., SAT., SUN.)

				OU JANUART	4, 5, 6 (FRI.,	3/11, 3014.7		
G.M.T.	ARIES	VENUS -	3.4	MARS +0.1	JUPITER -1.9	SATURN +1.1	SI	ARS
4 6	G.H.A.	G.H.A. D	ec.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	Name	S.H.A. Dec.
4 00 01 02 03 04	117 48.6 132 51.0 147 53.5 162 56.0	144 39.6 S18 159 39.0 18 174 38.3 17 189 37.7 ··	01.1 00.2 59.2 58.3 57.4	295 50.2 N 9 05.9 310 52.3 05.8 325 54.4 05.8 340 56.5 05.7 355 58.7 05.6	300 40.5 N 8 49.6 315 43.0 49.6 330 45.6 49.6 345 48.1 49.7 0 50.6 49.7	299 41.2 11.1 314 43.6 11.1 329 46.1 ·· 11.1	Achernar 3 Acrux 1 Adhara 2	37.4 S40 23.4 35 45.6 S57 20.7 73 37.6 S62 59.0 55 32.1 S28 56.8 91 18.3 N16 28.1
08 F 09 R 10	193 00.9 208 03.4 223 05.8 238 08.3 253 10.7	234 35.9 S17 249 35.3 264 34.6 279 34.0 · · · 294 33.4	54.6 53.6 52.7 51.8	11 00.8 05.6 26 02.9 N 9 05.5 41 05.0 05.5 56 07.1 05.4 71 09.2 - 05.3 86 11.3 05.3	15 53.1 49.8 30 55.7 N 8 49.8 45 58.2 49.8 61 00.7 49.9 76 03.2 49.9 91 05.8 49.9	359 51.0 11.1 14 53.4 N 3 11.1	Alioth 1 Alkaid 1 Al Na'ir Alnilam 2	.66 43.0 N56 03.9 .53 19.1 N49 24.6 .28 15.9 S47 03.7 .76 11.8 S 1 13.0 .18 20.8 S 8 34.3
	268 13.2 283 15.7 298 18.1 313 20.6 328 23.1 343 25.5 358 28.0	324 32.2 517 339 31.6 354 31.0 9 30.4 · · · 24 29.7	50.8 49.9 49.0 48.0 47.1 46.1	101 13.4 05.2 116 15.5 N 9 05.2 131 17.6 05.1 146 19.7 05.0 161 21.9 05.0 176 24.0 04.9 191 26.1 04.9	106 08.3 50.0 121 10.8 N 8 50.0 136 13.3 50.0 151 15.9 50.1 166 18.4 50.1 181 20.9 50.2 196 23.5 50.2	90 05.7 11.1 105 08.1 N 3 11.1 120 10.6 11.1 135 13.0 11.1 150 15.5 11.1 165 17.9 11.2 180 20.4 11.2	Alpheratz 3 Altair Ankaa 3	26 32.8 N26 46.9 58 09.9 N28 58.9 62 33.3 N 8 49.0 53 40.8 542 25.2 12 57.7 526 23.1
18 19 20 21 22 23	13 30.5 28 32.9 43 35.4 58 37.9 73 40.3 88 42.8	54 28.5 \$17 69 27.9 84 27.3 99 26.7 ··· 114 26.1	1	206 28.2 N 9 04.8 221 30.3 04.8 236 32.5 04.7 251 34.6 · 04.6 266 36.7 04.6 281 38.8 04.5	211 26.0 N 8 50.2 226 28.5 50.3 241 31.0 50.3 256 33.6 50.4 271 36.1 50.4 286 38.6 50.4	195 22.8 N 3 11.2 210 25.3 11.2 225 27.7 11.2	Atria 1 Avior 2 Bellatrix 2	46 19.1 N19 17.1 08 22.9 S68 59.3 34 27.7 S59 26.7 78 58.9 N 6 19.8 71 28.5 N 7 24.1
03	103 45.2 118 47.7 133 50.2 148 52.6 163 55.1 178 57.6	144 24.9 \$17 159 24.3 - 174 23.7 189 23.1 ·· 204 22.5	_	296 40.9 N 9 04.5 311 43.1 04.4 326 45.2 04.4 341 47.3 · 04.3 356 49.5 04.3 11 51.6 04.2	301 41.2 N 8 50.5 316 43.7 50.5 331 46.2 50.5 346 48.8 50.6 1 51.3 50.6 16 53.8 50.7	285 37.5 N 3 11.2 300 40.0 11.2 315 42.4 11.2 330 44.9 · 11.2	Capella 2 Deneb Denebola 1	64 06.9 S52 41.3 81 11.5 N45 58.7 49 49.2 N45 12.7 82 59.5 N14 41.0 49 21.4 S18 06.0
	194 00.0 209 02.5 224 05.0 239 07.4 254 09.9 269 12.3	264 20.1 279 19.5 294 18.9	32.9 31.9 31.0 30.0 29.1 28.1	26 53.7 N 9 04.2 41 55.9 04.1 56 58.0 04.1 72 00.1 - 04.0 87 02.3 04.0 102 04.4 03.9	31 56.4 N 8 50.7 46 58.9 50.7 62 01.4 50.8 77 04.0 50.8 92 06.5 50.9 107 09.0 50.9	30 54.7 11.3	Elnath 2 Eltanin Enif	94 22.5 N61 51.3 78 44.4 N28 35.4 90 58.5 N51 29.5 34 12.3 N 9 47.0 15 52.2 \$29 43.9
A 14	299 17.3 314 19.7 329 22.2 344 24.7	354 16.5 9 15.9 · · 24 15.3	26.2 25.3	117 06.5 N 9 03.9 132 08.7 03.8 147 10.8 03.8 162 12.9 ·· 03.7 177 15.1 03.7 192 17.2 03.6	122 11.6 N 8 50.9 137 14.1 51.0 152 16.6 51.0 167 19.2 51.1 182 21.7 51.1 197 24.2 51.2	106 06.9 N 3 11.3	Gienah 1 Hadar 1 Hamal 3	72 29.1 S56 59.7 76 18.4 S17 25.7 49 24.1 S60 16.3 28 29.3 N23 22.1 84 17.9 S34 23.6
18 19 20 21 22 23	14 29.6 29 32.1 44 34.5 59 37.0 74 39.5 89 41.9	84 12.9 99 12.3 · · 114 11.7	20.5 19.5	207 19.4 N 9 03.6 222 21.5 03.6 237 23.7 03.5 252 25.8 · · 03.5 267 28.0 03.4 282 30.1 03.4	212 26.8 N 8 51.2 227 29.3 51.2 242 31.8 51.3 257 34.4 51.3 272 36.9 51.4 287 39.5 51.4	196 21.7 N 3 11.4 211 24.1 11.4 226 26.6 11.4 241 29.0 11.4	Markab Menkar 3 Menkent 1	37 19.8 N74 14.1 14 03.8 N15 05.9 14 41.4 N 4 00.6 48 37.7 \$36 16.1 21 44.1 \$69 38.0
6 00 01 02 03 04 05	134 49.3 149 51.8	174 09.4 189 08.8 · · 204 08.2	14.7 13.7		302 42.0 N 8 51.4 317 44.5 51.5 332 47.1 51.5 347 49.6 · 51.6 2 52.1 51.6 17 54.7 51.7	301 38.8 11.4 316 41.3 11.4 331 43.8 ·· 11.4	Nunki Peacock Pollux 2	09 16.4 N49 47.5 76 30.2 \$26 19.3 53 59.8 \$56 48.1 43 58.4 N28 04.4 45 26.0 N 5 16.5
08 S 09 U 10 N 11	194 59.2 210 01.6 225 04.1 240 06.6 255 09.0 270 11.5	264 05.8 279 05.2 294 04.7	09.8 08.8 07.9 06.9 05.9 04.9	27 45.2 N 9 03.1 42 47.3 03.0 57 49.5 03.0 72 51.6 03.0 87 53.8 02.9 102 56.0 02.9	32 57.2 N 8 51.7 47 59.8 51.7 63 02.3 51.8 78 04.9 51.8 93 07.4 51.9 108 09.9 51.9	16 51.1 N 3 11.5 31 53.6 11.5 46 56.0 11.5 61 58.5 · · 11.5	Regulus 2 Rigel 2 Rigil Kent. 1	96 30.4 N12 34.5 108 10.3 N12 03.8 181 36.2 S B 13.6 140 26.7 S60 44.8 102 42.0 S15 41.9
15 16 17	300 16.4 315 18.9 330 21.3	354 02.3	03.0 02.0 01.0 00.1	148 02.4 02.8 163 04.6 · 02.7	168 20.1 · · 52.1	107 05.9 N 3 11.5 122 08.3 11.5 137 10.8 11.5 152 13.2 · · 11.6	Shaula Sirius 2 Spica 1	350 09.5 N56 25.9 96 56.8 \$37 05.2 258 55.8 \$16 41.5 158 58.1 \$11 03.3 223 10.7 \$43 21.0
18 19 20	15 28.7 30 31.2	54 00.0 516 68 59.4	57.1	208 11.1 N 9 02.6 223 13.3 02.6	213 27.7 N 8 52.2 228 30.3 52.3		Zuben'ubi :	80 56.6 N38 46.0 L37 33.7 S15 57.4
21 22 23	75 38.6 90 41.1	83 58.8 98 58.3 ·· 113 57.7 128 57.1	54.2	238 15.5 02.6 253 17.6 ·· 02.5 268 19.8 02.5 283 22.0 02.5			Venus	S.H.A. Mer. Pass. 40 39.6 14 23 192 55.7 4 13
Mer Pas	s. 17 02.2	v -0.6 d	1.0	v 2.1 d 0.0	v 2.5 d 0.0	v 2.5 d 0.0	Jupiter :	197 55.9 3 53 181 52.3 4 57

1980 JANUARY 4, 5, 6 (FRI., SAT., SUN.)

A 00 176 53.3 522 646. 39 263 31.2 M17 239 4.5 554 M 77 00 20 20 44 m 16 229 34 129 20 20 58 64 20 20 20 44 m 16 229 34 20 20 20 20 44 m 16 229 34 20 20 20 20 44 m 16 229 34 20 20 20 20 44 m 16 229 34 20 20 20 20 44 m 16 229 34 20 20 20 20 44 m 16 229 34 20 20 20 20 20 20 20 20 20 20 20 20 20		1700 3/110// 4,		э, о г	Twilight				Moon	ise	
OHA DET. OHA DE	c	SUN	MOON	Lat.		I	Sunrise				
A 15 33 46 6 46 31 46	4 00 1 01 02 03 04 05 06 07 08 F 09 R 10 1 11	GHA. Dec. 178 53.3 S22 49.6 193 53.0 49.3 208 52.7 49.1 223 52.5 48.8 253 51.9 48.3 268 51.6 S22 48.1 283 51.3 47.8 298 51.0 47.6 313 50.7 47.4 328 50.5 47.1 343 50.2 46.8	339 25.3 11.2 N17 23.9 4.5 55.4 353 55.5 11.2 17 19.4 4.5 55.4 8 25.7 11.2 17 14.9 4.6 55.4 22 55.9 11.3 17 10.3 4.7 55.4 37 26.2 11.3 17 05.6 4.8 55.3 51 56.5 11.4 17 00.8 4.9 55.3 66 26.9 11.5 N16 55.9 4.9 55.3 80 57.4 11.5 16 51.0 50 55.3 95 27.9 11.5 16 46.0 51. 55.3 10.9 58.4 11.6 16 40.9 5.2 55.2 124 29.0 11.7 16 35.7 5.2 55.2 138 59.7 11.7 16 30.5 5.3 55.2	N 70 68 66 64 62 60 N 58 56 54 52 50	08 21 08 02 07 48 07 36 07 25 07 16 07 09 07 02 06 55 06 49 06 44 06 39 06 28	h m 10 32 09 44 09 13 08 50 08 32 08 17 08 04 07 53 07 44 07 35 07 27 07 20 07 05	11 36 10 22 09 46 09 20 09 00 08 44 08 30 08 18 08 08 07 58 07 38	15 46 16 29 16 57 17 18 17 35 17 49 18 01 18 11 18 20 18 27 18 34 18 41 18 54	17 38 18 04 18 23 18 39 18 51 19 02 19 11 19 19 19 26 19 32 19 38 19 43 19 54	19 20 19 36 19 49 20 00 20 08 20 16 20 22 20 28 20 33 20 37 20 41 20 45 20 53	20 58 21 07 21 14 21 20 21 25 21 29 21 33 21 36 21 39 21 45 21 47 21 52
05 253 45.1 42.2 40 20.6 12.8 14 43.9 6.6 54.9 50 111 6 02 48 22 01 22 24 22 42 22 58 06 288 44.8 522 41.9 69 24.0 12.7 14 30.7 6.7 54.8 1.0 1.0 11 34.9 47.5 12.0 11 34.9 47.5 12.0 12.0 12.0 12.0 12.0 12.0 12.0 12.0	A 13 Y 14 15 16 17 18 19 20 21 22 23 5 00 01 02 03	13 49.6 46.3 28 49.3 46.1 45.8 45.8 48.7 45.6 45.3 88 48.2 \$22 45.1 103 47.9 44.8 118 47.0 44.0 163 46.8 43.8 178 46.5 \$22 43.5 178 46.5 \$22 43.5 193 46.2 208 45.9 43.0 223 45.6 42.7	168 01.1 11.9 16 19.8 5.5 55.2 182 32.0 11.8 16 14.3 5.5 55.1 197 02.8 11.9 16 08.8 5.6 55.1 1211 33.7 12.0 16 03.2 5.7 55.1 226 04.7 12.1 15 57.5 5.8 55.1 240 35.8 12.0 N15 51.7 5.8 55.1 255 06.8 12.2 15 45.9 5.9 55.1 269 38.0 12.2 15 40.0 6.0 55.0 284 09.2 12.2 15 34.0 6.0 55.0 298 40.4 12.3 15 28.0 6.1 55.0 313 11.7 12.3 15 21.9 6.2 55.0 327 43.0 12.4 N15 15.7 6.2 55.0 342 14.4 12.5 15 09.5 6.3 54.9 356 45.9 12.5 15 03.2 6.4 54.9 11 17.4 12.6 14 56.8 6.4 54.9	35 30 20 N 10 0 S 10 30 35 40 45 S 50 52 54 56	06 09 06 01 05 45 05 29 05 13 04 55 04 33 04 04 03 46 03 24 02 55 02 12 01 47 01 10	06 41 06 30 06 12 05 56 05 39 05 21 05 02 04 38 04 23 04 05 03 44 03 15 02 44 02 23	07 09 06 57 06 36 06 18 06 01 05 44 05 26 05 05 04 52 04 38 04 20 03 59 03 48 03 37 03 23	19 15 19 23 19 38 19 50 20 02 20 14 20 26 20 40 20 49 20 58 21 09 21 22 21 28 21 35 21 43	20 17 20 29 20 39 20 48 20 58 21 08 21 26 21 26 21 34 21 43 21 53 21 58 22 04 22 10	21 10 21 18 21 26 21 33 21 40 21 48 21 56 22 01 22 06 22 13 22 20 22 24 22 28 22 32	22 02 22 07 22 12 22 16 22 20 22 25 22 30 22 33 22 36 22 40 22 45 22 47 22 50 22 52
S 08 298 442 414 88 35.7 128 14 240 68 54.8 70 71 34.9 74 14 98 275 129 14 172 28 54.8 72 74 74 75 75 75 75 75 75	05	253 45.1 42.2	40 20.6 12.6 14 43.9 6.6 54.9 54 52.2 12.8 N14 37.3 66 54.9			01 16	02 48		22 24		22 58
T 10 328 43.7	s 08	298 44.2 41.4	83 55.7 12.8 14 24.0 6.8 54.8	Lat.	Sunset	Civil	Naut.				T
16 58 35.3 32.4 189 17.9 14.3 10 13.2 8.4 54.4 5 60 21 21 22 51 1111 05 24 06 34 07 45 08 56 18 88 34.7 522 31.8 218 24.5 14.4 N10 04.8 8.4 54.4 19 103 34.5 31.5 232 57.9 14.4 9 56.4 8.5 54.4 20 118 34.2 31.2 247 31.3 14.5 9 47.9 8.4 54.4 21 133 33.9 · 30.9 262 04.8 14.5 9 39.5 8.6 54.3 22 148 33.6 30.6 276 38.3 14.5 9 30.9 8.5 54.3 22 148 33.6 30.6 276 38.3 14.5 9 30.9 8.5 54.3 22 148 33.4 30.3 291 11.8 14.5 9 22.4 8.6 54.3 23 163 33.4 30.3 291 11.8 14.5 9 22.4 8.6 54.3 4 04 26 04 40 12 05 01 25 13 50 16 04 54 05 07 12 05 02 13 14 37 17	U 11 R 12 D 13 A 14 Y 15 16 17 18 19 20 21 22 23 600 01 02 03 04 05 06 07 08 S 09 U 10 N 11 D 12 A 13 Y 14	343 43.4 40.6 358 43.1 S22 40.3 13 42.8 40.0 28 42.5 39.8 43 42.2 39.5 58 42.0 39.2 73 41.7 38.9 88 41.4 S22 38.7 103 41.1 38.1 118 40.8 38.1 133 40.6 37.8 148 40.3 37.8 148 40.3 37.8 148 40.3 37.8 128 39.2 36. 223 38.9 36. 223 38.9 36. 223 38.9 36. 238 38.6 35.5 268 38.1 S22 35. 283 37.8 35. 268 38.1 S22 35. 283 37.8 35. 298 37.5 34. 313 37.2 34. 328 36.9 34. 343 36.7 33. 358 36.4 S22 33. 13 36.1 33. 28 35.8 35.8 33.	127 31.3 13.0 14 03.6 7.0 54.8 142 03.3 13.0 N13 56.6 6.9 54.8 156 35.3 13.1 13 49.7 7.1 54.7 185 39.5 13.2 13 35.5 7.1 54.7 185 39.5 13.2 13 35.5 7.1 54.7 185 39.5 13.2 13 35.5 7.1 54.7 185 39.5 13.2 13 35.5 7.1 54.7 185 39.5 13.2 13 28.4 7.2 54.7 185 39.5 13.3 13 21.2 7.3 54.7 185 200 11.7 13.2 13 28.4 7.2 54.7 185 20.9 13.4 12 59.2 7.4 54.6 18 272 53.3 13.5 12 51.8 7.5 54.6 18 287 25.8 13.5 12 44.3 7.5 54.6 18 287 25.8 13.5 12 36.8 7.6 54.6 18 30.1 58.3 13.5 12 36.8 7.6 54.6 18 30.1 58.3 13.5 12 36.8 7.6 54.6 18 30.1 58.3 13.5 12 36.8 7.6 54.6 18 30.8 13.7 N12 29.2 7.6 54.6 18 30.8 13.8 12 06.2 7.8 54.1 10 08.8 13.8 12 06.2 7.8 54.1 10 08.8 13.8 12 06.2 7.8 54.1 10 15.0 11 15.0 12 13.9 11 50.6 7.9 54.1 18 18 18 12 06.2 7.8 54.1 18 18 18 18 18 18 18 18 18 18 18 18 18	N 70 68 66 64 62 66 65 54 55 55 8 10 20 35 55 5 5 4 4 5 56 5 5 5 5 5 5 5 5 5 5 5	12 35 13 49 14 25 14 50 15 10 15 27 15 40 15 52 16 03 16 12 16 32 17 14 17 34 17 52 18 09 18 26 18 44 19 05 5 19 18 19 32 5 19 49 10 20 21 4 20 33 6 20 46	13 38 14 26 14 57 15 20 15 38 15 53 16 06 16 17 16 27 16 35 16 43 16 50 17 06 17 19 17 30 17 40 17 58 18 31 18 49 19 08 19 33 19 47 20 05 20 26 20 54 21 09 21 25 21 46	15 50 16 08 16 23 16 35 16 45 16 54 17 02 17 09 17 15 17 21 17 27 17 31 17 43 17 52 18 10 18 25 18 41 18 57 19 16 19 37 20 05 20 23 20 46 21 15 22 22 58	12 03 11 20 10 51 10 29 10 12 09 57 09 45 09 25 09 25 09 27 09 10 09 03 08 47 08 27 08 18 08 03 07 37 07 24 07 11 06 55 06 46 06 06 06 02 05 54	11 49 11 22 11 02 10 45 10 32 10 21 10 11 10 03 09 54 09 42 09 37 09 05 09 07 09 00 08 47 08 05 08 25 08 14 08 02 07 49 07 42 07 33 07 10 07 05 06 58 06 51	11 40 11 22 11 08 10 57 10 47 10 39 10 32 10 25 10 20 10 15 10 10 10 06 09 57 09 50 09 43 09 37 09 10 09 02 08 53 08 43 08 30 08 22 08 13 08 08 08 08 08 03 07 58	11 32 11 21 11 13 11 05 10 59 10 54 10 49 10 45 10 38 10 35 10 32 10 26 10 16 10 12 10 16 10 10 12 10 06 10 00 09 54 09 42 09 35 09 31 09 26 09 21 09 15 09 12 09 05
21 133 33.9 · · 30.9 262 04.8 14.5 9 39.5 8.6 54.3 22 148 33.6 30.6 276 38.3 14.5 9 30.9 8.5 54.3 23 163 33.4 30.3 291 11.8 14.5 9 22.4 8.6 54.3 4 04 26 04 40 12 05 01 25 13 50 16 05 07 12 05 02 13 14 37 17 17 18 18 18 18 18 18 18 18 18 18 18 18 18	17 18 19	7 73 35.0 32 3 88 34.7 522 31 9 103 34.5 31	.1 203 51.2 14.3 10 13.2 8.4 54 .8 218 24.5 14.4 N10 04.8 8.4 54 .5 232 57.9 14.4 9 56.4 8.5 54	4	Eqn.	SUN of Time	Mer.	Mer	Mi Pass.	NOC	
graph and the street of the st	21 27	1 133 33.9 · · 30 2 148 33.6 30 3 163 33.4 30	9 262 04.8 14.5 9 39.5 8.6 54 6 276 38.3 14.5 9 30.9 8.5 54 3 291 11.8 14.5 9 22.4 8.6 54	.3 .3 .3	4 04 26 5 04 54	04 40 05 0	12 05 7 12 05	01 25 02 13	13 50 14 37	16 17	•

1980 JANUARY 7, 8, 9 (MON., TUES., WED.)

	ARIES	VENUS -3.4	MARS 0.0	JUPITER -1.9	SATURN +1.1	STARS
G.M.T.	G.H.A.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	Name S.H.A. Dec.
7 00 01 02 03 04	105 43.5 120 46.0 135 48.4 150 50.9 165 53.4	143 56.5 S16 52.2 158 56.0 51.2 173 55.4 50.2 188 54.8 49.2 203 54.2 48.2	298 24.1 N 9 02.4 313 26.3 02.4 328 28.5 02.4 343 30.7 02.3 358 32.9 02.3	303 43.0 N 8 52.5 318 45.5 52.5 333 48.1 52.6 348 50.6 52.6 3 53.2 52.7	302 37.8 11.7 317 40.3 11.7 332 42.8 11.7 347 45.2 11.7	Acamar 315 37.4 S40 23.4 Achernar 335 45.6 S57 20.7 Acrux 173 37.5 S62 59.0 Adhara 255 32.1 S28 56.8 Aldebaran 291 18.3 N16 28.1
05 06 07 08 M 09 O 10 N 11	180 55.8 195 58.3 211 00.8 226 03.2 241 05.7 256 08.2 271 10.6	218 53.7 47.3 233 53.1 S16 46.3 248 52.5 45.3 263 52.0 44.3 278 51.4 43.3 293 50.8 42.3 308 50.2 41.3	13 35.0 02.3 28 37.2 N 9 02.3 43 39.4 02.2 58 41.6 02.2 73 43.8 02.2 88 46.0 02.1 103 48.1 02.1	18 55.7 52.7 33 58.3 N 8 52.8 49 00.8 52.8 64 03.4 52.8 79 05.9 52.9 94 08.5 52.9 109 11.0 53.0	2 47.7 11.7 17 50.1 N 3 11.7 32 52.6 11.7 47 55.1 11.7 62 57.5 11.8 78 00.0 11.8 93 02.4 11.8	Alioth 166 43.0 N56 03.9 Alkaid 153 19.0 N49 24.6 Al Na'ir 28 15.9 S47 03.7 Alnilam 276 11.8 S 1 13.0 Alphard 218 20.7 S 8 34.3
D 12 A 13 Y 14 15 16 17	286 13.1 301 15.6 316 18.0 331 20.5 346 22.9 1 25.4	323 49.7 516 40.3 338 49.1 39.3 353 48.5 38.3 8 48.0 37.3 23 47.4 36.3 38 46.8 35.3	118 50.3 N 9 02.1 133 52.5 02.1 148 54.7 02.0 163 56.9 02.0 178 59.1 02.0 194 01.3 02.0	124 13.6 N 8 53.0 139 16.1 53.1 154 18.7 53.1 169 21.2 53.2 184 23.8 53.2 199 26.3 53.3		Alphecca 126 32.8 N26 46.9 Alpheratz 358 09.9 N28 58.9 Altair 62 33.3 N 8 49.0 Ankoa 353 40.8 542 25.2 Antores 112 57.7 \$26 23.1
18 19 20 21 22 23	16 27.9 31 30.3 46 32.8 61 35.3 76 37.7 91 40.2	53 46,3 S16 34,3 68 45.7 33,3 83 45.1 32,3 98 44.6 31,3 113 44.0 30,3 128 43.5 29,3	209 03.5 N 9 01.9 224 05.7 01.9 239 07.9 01.9 254 10.1 01.9 269 12.3 01.8 284 14.5 01.8	214 28.9 N 8 53.3 229 31.4 53.4 244 34.0 53.4 259 36.5 53.5 274 39.1 53.5 289 41.6 53.6	198 19.7 N 3 11.9 213 22.1 11.9 228 24.6 11.9 243 27.1 11.9 258 29.5 11.9 273 32.0 11.9	Arcturus 146 19.0 N19 17.1 Atria 108 22.8 S68 59.3 Avior 234 27.7 S59 26.7 Bellatrix 278 58.9 N 6 19.8 Betelgeuse 271 28.5 N 7 24.1
03 04 05	106 42.7 121 45.1 136 47.6 151 50.1 166 52.5 181 55.0	143 42.9 \$16 28.3 158 42.3 27.3 173 41.8 26.3 188 41.2 25.3 203 40.7 24.3 218 40.1 23.3	299 16.7 N 9 01.8 314 18.9 01.8 329 21.1 01.8 344 23.3 ·· 01.7 359 25.5 01.7 14 27.7 01.7	304 44.2 N 8 53.6 319 46.7 53.6 334 49.3 53.7 349 51.9 53.7 4 54.4 53.8 19 57.0 53.8	288 34.5 N 3 11.9 303 36.9 11.9 318 39.4 12.0 333 41.8 ·· 12.0 348 44.3 12.0 3 46.8 12.0	Canopus 264 06.9 S52 41.3 Capella 281 11.6 N45 58.7 Deneb 49 49.2 N45 12.7 Denebola 182 59.4 N14 40.9 Diphda 349 21.4 S18 06.0
U 10 E 11 S 11	196 57.4 211 59.9 227 02.4 242 04.8 257 07.3 272 09.8	233 39.5 \$16 22.3 248 39.0 21.3 263 38.4 20.3 278 37.9 19.2 293 37.3 18.2 308 36.8 17.2	29 29.9 N 9 01.7 44 32.1 01.7 59 34.3 01.7 74 36.5 · 01.6 89 38.7 01.6 104 40.9 01.6	34 59.5 N 8 53.9 50 02.1 53.9 65 04.6 54.0 80 07.2 54.0 95 09.7 54.1 110 12.3 54.1	18 49.2 N 3 12.0 33 51.7 12.0 48 54.2 12.0 63 56.6 12.1 78 59.1 12.1 94 01.6 12.1	Dubhe 194 22.5 N61 51.3 Elnath 278 44.4 N28 35.4 Eltonin 90 58.5 N51 29.5 Enif 34 12.3 N 9 47.0 Famalhaut 15 52.2 S29 43.9
O 12 A 13 Y 14 Y 15 16 17	287 12.2 302 14.7 317 17.2 332 19.6 347 22.1 2 24.5	323 36.2 S16 16.2 338 35.7 15.2 353 35.1 14.2 8 34.6 ·· 13.2 23 34.0 12.2 38 33.5 11.1	119 43.2 N 9 01.6 134 45.4 01.6 149 47.6 01.6 164 49.8 01.5 179 52.0 01.5 194 54.2 01.5	125 14.8 N 8 54.2 140 17.4 54.2 155 20.0 54.3 170 22.5 54.3 185 25.1 54.4 200 27.6 54.4	109 04.0 N 3 12.1 124 06.5 12.1 139 09.0 12.1 154 11.4 · 12.1 169 13.9 12.1 184 16.4 12.2	Gacrux 172 29.1 S56 59.8 Gienah 176 18.4 S17 25.7 Hadar 149 24.1 S60 16.3 Hamol 328 29.3 N23 22.1 Kaus Aust. 84 17.9 S34 23.6
18 19 20 21 22 23	17 27.0 32 29.5 47 31.9 62 34.4 77 36.9 92 39.3	53 32.9 \$16 10.1 68 32.4 09.1 83 31.8 08.1 98 31.3 07.1 113 30.7 06.0 128 30.2 05.0	209 56.5 N 9 01.5 224 58.7 01.5 240 00.9 01.5 255 03.1 01.5 270 05.4 01.5 285 07.6 01.4	215 30.2 N 8 54.5 230 32.8 54.5 245 35.3 54.6 260 37.9 54.6 275 40.4 54.7 290 43.0 54.7	199 18.8 N 3 12.2 214 21.3 12.2 229 23.8 12.2 244 26.2 12.2 259 28.7 12.2 274 31.2 12.2	Kochab 137 19.7 N74 14.1 Markab 14 03.8 N15 05.9 Menkar 314 41.5 N 4 00.6 Menkent 148 37.6 S36 16.1 Miaplacidus 221 44.1 S69 38.0
01 02 03 04 05	107 41.8 122 44.3 137 46.7 152 49.2 167 51.7 182 54.1	143 29.6 516 04.0 158 29.1 03.0 173 28.5 01.9 188 28.0 16 00.9 203 27.4 15 59.9 218 26.9 58.9	300 09.8 N 9 01.4 315 12.0 01.4 330 14.3 01.4 345 16.5 01.4 0 18.7 01.4 15 21.0 01.4	305 45.6 N 8 54.8 320 48.1 54.8 335 50.7 54.9 350 53.2 54.9 5 55.8 55.0 20 58.4 55.0	319 38.6 12.3 334 41.0 · 12.3	Mirfak 309 16.4 N49 47.5 Nunki 76 30.1 S26 19.3 Peacock 53 59.8 S56 48.1 Pollux 243 58.4 N28 04.4 Procyon 245 25.9 N 5 16.5
W 08 E 09 D 10 N 11		233 26.3 \$15 57.8 248 25.8 56.8 263 25.3 55.8 278 24.7 54.8 293 24.2 53.7 308 23.6 52.7	30 23.2 N 9 01.4 45 25.4 01.4 60 27.7 01.4 75 29.9 · 01.4 90 32.1 01.4 105 34.4 01.4	36 00.9 N 8 55.1 51 03.5 55.1 66 06.0 55.2 81 08.6 55.2 96 11.2 55.3 111 13.7 55.4	95 00.8 12.4	Rasolhague 96 30.4 N12 34.5 Regulus 208 10.3 N12 03.8 Rigel 281 36.2 S 8 13.6 Rigil Kent. 140 26.7 S60 44.8 Sabik 102 42.0 S15 41.9
S 12 D 13 D 14 A 15 Y 16 17	288 11.4 303 13.8 318 16.3 333 18.8 348 21.2 3 23.7	323 23.1 \$15 51.7 338 22.6 50.6 353 22.0 49.6 8 21.5 48.6 23 21.0 47.5 38 20.4 46.5	150 41.1 01.3 165 43.3 · 01.3 180 45.6 01.3 195 47.8 01.3	126 16.3 N 8 55.4 141 18.9 55.5 156 21.4 55.5 171 24.0 55.6 186 26.6 55.6 201 29.1 55.7	140 08.2 12.5 155 10.7 ·· 12.5 170 13.2 12.5 185 15.6 12.5	Schedar 350. 09.5 N56 25.9 Shaula 96 56.8 S37 05.2 Sirius 258 55.8 S16 41.5 Spico 158 58.1 S11 03.3 Suhail 223 10.7 S43 21.1
18 19 20 21 22	18 26.2 33 28.6 48 31.1 63 33.5 78 36.0	53 19.9 S15 45.5 68 19.3 44.4 83 18.8 43.4 98 18.3 42.4 [113 17.7 41.3	255 56.8 • 01.3	216 31.7 N 8 55.7 231 34.3 55.8 246 36.8 55.8 261 39.4 55.9 276 42.0 55.9		Vega 80 56.6 N38 45.9 Zuben'ubi 137 33.7 S15 57.4 S.H.A. Mer. Pass. Venus 37 00.2 14 26
23	93 38.5 . 16 50.4	128 17.2 40.3 v -0.6 d 1.0		v 2.6 d 0.0	275 30.5 12.6	Mars 192 34.0 4 02 Jupiter 198 01.5 3 40 Saturn 181 51.8 4 45

1980 JANUARY 7, 8, 9 (MON., TUES., WED.)

-					Twili	ght	· • · · · · ·	Mooni		rise	
G.M.T.	SUN	MOON	_	Lat.	Naut.	Civil	Sunrise	7.	8	9 h m	10 h m
d h	G.H.A. Dec.		.P.	N 72 N 70	08 16 07 59	10 22 09 38	-	20 58 21 07	22 33 22 36	24 07 24 04	00 07
7 00	178 33.1 S22 30.0 193 32.8 29.7	320 18.9 14.7 9 05.1 8.7 54	1.3	68	07 45	09 09	11 14	21 14	22 38	24 02 24 00	00 02
02 03	208 32.5 29.4 223 32.3 ·· 29.1	334 52.6 14.6 8 56.4 8.7 54 349 26.2 14.7 8 47.7 8.7 54		66	07 33 07 23	08 47 08 29	10 15 09 41	21 20 21 25	22 40 22 41	23 58	25 16
04 05	238 32.0 28.8 253 31.7 28.5	3 59.9 14.8 8 39.0 8.8 54 18 33.7 14.7 B 30.2 8.8 54		62 60	07 15 07 07	08 15 08 03	09 17 08 58	21 29	22 43	23 56 23 55	25 11 25 07
06	268 31.4 \$22 28.2	33 07.4 14.8 N 8 21.4 8.8 54	1.3	N 58 56	07 00 06 54	07 52 07 42	08 42 08 28	21 36 21 39	22 45 22 46	23 54 23 53	25 04 25 01
07 08	283 31.2 27.9 298 30.9 27.6	62 15.0 14.9 8 03.7 8.9 54	\$.3	54	06 49	07 34	08 17	21 42	22 47	23 52 23 51	24 58 24 55
	313 30.6 ·· 27.3 328 30.4 27.0	76 48.9 14.9 7 54.8 8.9 54 91 22.8 14.9 7 45.9 8.9 54	1.2	52 50	06 43 06 39	07 26 07 20	08 06 07 57	21 45 21 47	22 48 22 48	23 50	24 53
N 11 D 12	343 30.1 26.7 358 29.8 \$22 26.4	105 56.7 14.9 7 37.0 9.0 54 120 30.6 15.0 N 7 28.0 9.0 54	- 1	45 N 40	06 28 06 18	07 05 06 52	07 38 07 22	21 52	22 50	23 49 23 47	24 48
A 13	13 29.5 26.1	135 04.6 15.0 7 19.0 9.1 54	4.2	35 30	06 09 06 01	06 41 06 31	07 09 06 57	21 59 22 02	22 53 22 54	23 46 23 45	24 41 24 37
15	28 29.3 25.8 43 29.0 ·· 25.5	164 12.6 15.0 7 00.9 9.1 5	4.2	20	05 46	06 13	06 37	22 07	22 55	23 43 23 42	24 32 24 28
16 17	58 28.7 25.1 73 28.4 24.8	178 46.6 15.1 6 51.8 9.1 54 193 20.7 15.1 6 42.7 9.2 54		N 10 0	05 30 05 14	05 57 05 40	06 19 06 03	22 12 22 16	22 57 22 58	23 40	24 23
18 19	88 28.2 S22 24.5 103 27.9 24.2	207 54.8 15.1 N 6 33.5 9.1 5 222 28.9 15.2 6 24.4 9.2 5		5 10 20	04 56 04 35	05 23 05 04	05 46 05 28	22 20 22 25	23 00 23 01	23 39 23 37	24 19 24 14
20	118 27.6 -23.9	237 03.1 15.1 6 15.2 9.2 5	4.2	30	04 07	04 40 04 25	05 07 04 55	22 30 22 33	23 03 23 04	23 36 23 35	24 09 24 06
21 22	133 27.4 ·· 23.6 148 27.1 23.3	251 37.2 15.2 6 06.0 9.3 5 266 11.4 15.2 5 56.7 9.2 5	4.2	35 40	03 49 03 28	04 08	04 41	22 36	23 05	23 34	24 03
8 00	163 26.8 22.9 178 26.6 522 22.6	280 45.6 15.3 5 47.5 9.3 5 295 19.9 15.2 N 5 38.2 9.3 5		45 S 50	02 59 02 18	03 47 03 19	04 24 04 02	22 40 22 45	23 07 23 08	23 32 23 31	1
01 02	193 26.3 22.3 208 26.0 22.0	309 54.1 15.3 5 28.9 9.3 5 324 28.4 15.2 5 19.6 9.3 5	4.2	52 54	01 54 01 20	03 05 02 49	03 52 03 41	22 47 22 50	23 09 23 10	23 30 23 30	
03	223 25.8 · · 21.7	339 02.6 15.3 5 10.3 9.4 5	4.2	56 58	1111 1111	02 29 02 04	03 28 03 12	22 52 22 55	23 11 23 12	23 29 23 28	
04 05	238 25.5 21.4 253 25.2 21.0	353 36.9 15.4 5 00.9 9.4 5 8 11.3 15.3 4 51.5 9.4 5		s 60	1111	01 27	02 54	22 58	23 13	23 27	
06 07	268 24.9 S22 20.7 283 24.7 20.4	22 45.6 15.3 N 4 42.1 9.4 5 37 19.9 15.4 4 32.7 9.4 5		Lat.	Sunset	Twi	light		Moo		
T 08	298 24.4 20.1 313 24.1 ·· 19.7	51 54.3 15.4 4 23.3 9.5 5 66 28.7 15.4 4 13.8 9.4 5			-	Civil	Naut.	7	8	9	10
U 10	328 23.9 19.4	81 03.1 15.4 4 04.4 9.5 5	4.2	N 72	h	13 52	15 57	h m	11 25	h m	
\$ 11 S 12	343 23.6 19.1 358 23.3 S22 18.8	110 11.9 15.4 N 3 45.4 9.5 5	4.2	N 70	-	14 35	16 15	11 21	11 20	11 18	11 16
A 13	13 23.1 18.4 28 22.8 18.1	124 46.3 15.5 3 35.9 9.5 5 139 20.8 15.4 3 26.4 9.5 5		68 66	12 59 13 59	15 04 15 26	16 29 16 40	11 13 11 05	11 16 11 12	11 18 11 18	11 24
Y 15 16	43 22.5 ·· 17.8 58 22.3 17.4	153 55.2 15.5 3 16.9 9.6 5 168 29.7 15.4 3 07.3 9.6 5	4.2 4.2	64 62	14 32 14 56	15 44 15 58	16 50 16 59	10 59 10 54	11 09 11 06	11 18 11 18	11 30
17	73 22.0 17.1	183 04.1 15.5 2 57.7 9.5 5	4.2	60	15 16 15 31	16 11 16 21	17 06 17 13	10 49 10 45	11 04 11 02	11 18 11 18	
18 19	88 21.7 \$22 16.8 103 21.5 16.5	212 13.1 15.4 2 38.6 9.6 5	4.2	N 58 56	15 45	16 31	17 19	10 41	11 00	11 18	11 37
20 21				54 52	15 56 16 07	16 39 16 47	17 25 17 30	10 38 10 35	10 58 10 57	11 18	11 40
22 23	148 20.7 15.5 163 20.4 15.1			50 45	16 16 16 35	16 54 17 09	17 35 17 45	10 32 10 26	10 56 10 53	11 18 11 18	11 44
9 00	178 20.1 S22 14.8	285 05.5 15.5 N 1 50.5 9.6 5		N 40 35	16 51 17 04	17 21 17 32	17 55 18 04	10 21 10 16	10 50 10 48	11 18 11 18	
02	193 19.9 14.4 208 19.6 14.1	314 14.5 15.5 1 31.2 9.6 5	4.2	30	17 16	17 42	18 12 18 27	10 12 10 06	10 46 10 42	11 18 11 19	11 51
03 04		343 23.5 15.5 1 11.9 9.7 5	4.2	N 10	17 36 17 54	18 00 18 16	18 42	10 00	10 39	11 19	11 58
05 06	253 18.8 13.1 268 18.6 S22 12.8	I .		5 10	18 10 18 27	18 32 18 50	18 58 19 16	09 54	10 36	11 19	12 04
w 07	283 18.3 12.4	27 06.9 15.5 0 42.9 9.7	54.3	20 30	18 45 19 06	19 09 19 33	19 38 20 05	09 42	10 30	11 18	
£ 09	313 17.8 · · 11.7	56 15.9 15.5 0 23.5 9.7	54.3	35 40	19 18	19 47 20 04	20 23 20 45	09 31 09 26	10 25 10 22	11 18	
Ņ ii	. 343 17.3 11.0	B5 24.8 15.5 N 0 04.1 9.7 5	54.3	. 45	19 49	20 25	21 13	09 51	10 20	11 16	3 12 17
5 12 5 13				S 50 52		20 53 21 07	21 54 22 17	09 15 09 12	10 16 10 15	11 18	B 12 22
A 14	28 16.5 10.0	129 08.2 15.4 0 25.0 9.7	54.3	54 56	20 31	21 23 21 43		09 08 09 05	10 13 10 11	11 10	
' 1 (58 15.9 09.3	158 17.1 15.4 0 44.4 9.7	54.3	58 5 60	20 59	22 08 22 43	HII	09 01 08 56	10 09 10 07	11 14	8 12 27
17 18	88 15.4 S22 08.6	187 25.9 15.4 S 1 03.8 9.7	54.3	-	1	SUN	1	1	<u></u>	NOC	
19	103 15.2 08.3 118 14.9 07.9	3 202 00.3 15.4 1 13.5 9.7 9 216 34.7 15.3 1 23.2 9.7	54.4	Day		of Time	Mer.	1	Pass.	Age	Phase
2	1 133 14.6 ·· 07.6 2 148 14.4 07.2	5 231 09.0 15.4 1 32.9 9.7		′	00,	12*		Upper h m	Lower h m	1 1	
2				7 8	05 47	06 00 06 26		03 44 04 26	16 05 16 47	19 20	
	S.D. 16.3 d o.	3 S.D. 14.8 14.8	14.8	9		06 52		05 08	17 29	21	

1980 JUNE 26, 27, 28 (THURS., FRI., SAT.)

	1980 JUNE 20, 27, 28 (THURS., FRI., SAT.)										
G.M.T.	ARIES	VENU\$ -3.6	MARS +1.1	JUPITER -1.4	SATURN +1.3	STARS					
G.M.1.	G.H.A.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	Name S.H.A. Dec.					
26 00 01 02 03 04	289 18.7	196 34.3 N19 34.2 211 37.8 33.6 226 41.4 33.1 241 44.9 32.6 256 48.4 32.1	101 18.5 N 3 45.0 116 19.8 44.4 131 21.1 43.9 146 22.3 43.3 161 23.6 42.7	116 46.5 N10 35.8 131 48.6 35.7 146 50.7 35.5 161 52.8 35.4 176 54.9 35.2	131 34.6 30.0 146 36.9 ·· 30.0	Acamar 315 37.7 S40 22.9 Achernar 335 45.7 S57 20.0 Acrux 173 37.3 S62 59.7 Adhara 255 32.6 S28 56.8 Aldebaran 291 18.5 N16 28.1					
05 06 07 7 08 H 09 U 10 R 11 S 12 D 13	349 28.5 4 31.0 19 33.5 34 35.9 49 38.4 64 40.9 79 43.3 94 45.8 109 48.3	271 52.0 31.6 286 55.5 N19 31.1 301 59.0 30.6 317 02.5 30.1 332 06.0 - 29.6 347 09.5 29.1 2 13.0 28.6 17 16.5 N19 28.1 32 20.0 27.6	176 24.9 42.2 191 26.2 N 3 41.6 206 27.5 41.1 221 28.8 40.5 236 30.1 39.9 251 31.4 39.4 266 32.6 38.8 281 33.9 N 3 38.3 296 35.2 37.7	191 57.0 35.1 206 59.1 N10 34.9 222 01.2 34.8 237 03.3 34.7 252 05.4 34.5 267 07.5 34.4 282 09.6 34.2 297 11.7 N10 34.1 312 13.9 33.9	206 46.3 29.7 221 48.6 29.7 236 51.0 29.6 251 53.3 29.5 266 55.6 29.5 281 58.0 N 5 29.4 297 00.3 29.3	Alioth 166 42.6 N56 04.3 Alkaid 153 18.5 N49 25.0 Al Na'ir 28 14.9 S47 03.1 Alnilam 276 12.2 S 1 12.9 Alphard 218 21.0 S 8 34.5 Alphecca 126 32.0 N26 47.0 Alpheratz 358 09.4 N28 58.7					
A 14; Y 15 16 17 18 19	139 53.2	47 23.5 27.2 62 27.0 · 26.7 77 30.5 26.2 92 34.0 25.7 107 37.4 N19 25.2 122 40.9 24.7	311 36.5 37.2 326 37.8 36.6 341 39.1 36.0 356 40.3 35.5 11 41.6 N 3 34.9 26 42.9 34.4	327 16.0 33.8 342 18.1 33.6 357 20.2 33.5 12 22.3 33.4 27 24.4 N10 33.2 42 26.5 33.1	327 05.0 29.2 342 07.3 29.1 357 09.6 29.1 12 12.0 N 5 29.0	Altair 62 32.4 N 8 49.0 Ankaa 353 40.5 542 24.6 Antares 112 56.7 526 23.3 Arcturus 146 18.5 N19 17.3 Atrio 108 20.5 568 59.6					
	215 05.5 230 08.0	137 44.4 24.2 152 47.8 ·· 23.7 167 51.3 23.2 182 54.8 22.8 197 58.2 N19 22.3	41 44.2 33.8 56 45.5 ·· 33.2 71 46.8 32.7 86 48.0 32.1 101 49.3 N 3 31.6	57 28.6 32.9 72 30.7 · 32.8 87 32.8 32.6 102 34.9 32.5 117 37.0 N10 32.3	42 16.6 28.9 57 19.0 · 28.8	Avior 234 28.8 S59 27.0 Bellatrix 278 59.3 N 6 19.8 Betelgeuse 271 28.8 N 7 24.1 Canopus 264 07.8 S52 41.2					
01 02 03 04 05	305 20.3	213 01.6 21.8 228 05.1 21.3 243 08.5 20.8 258 12.0 20.4 273 15.4 19.9 288 18.8 N19 19.4	116 50.6 31.0 131 51.9 30.4 146 53.2 29.9 161 54.5 29.3 176 55.7 28.8 191 57.0 N 3 28.2	132 39.1 32.2 147 41.2 32.1 162 43.3 31.9 177 45.4 31.8 192 47.5 31.6 207 49.6 N10 31.5	117 28.3 28.6 132 30.6 28.5 147 33.0 28.4 162 35.3 28.4 177 37.6 28.3 192 40.0 N 5 28.3	Diphdo 349 21.1 \$18 05.6					
07 08 F 09 R 10	20 32.6 35 35.1 50 37.5 65 40.0 80 42.5	303 22.2 18.9 318 25.7 18.5 333 29.1 - 18.0 348 32.5 17.5 3 35.9 17.1	206 58.3 27.6 221 59.6 27.1 237 00.9 26.5 252 02.1 25.9 267 03.4 25.4	222 51.7 31.3 237 53.8 31.2 252 55.9 31.0 267 58.0 30.9 283 00.2 30.7	207 42.3 28.2 222 44.6 28.1 237 47.0 28.1 252 49.3 28.0 267 51.6 27.9	Elnath 278 44.7 N28 35.4 Eltanin 90 57.3 N51 29.6 Enif 34 11.5 N 9 47.1 Fomalhaut 15 51.5 \$29 43.4					
D 12 A 13 Y 14 15 16 17	140 52.3 155 54.8 170 57.3	18 39.3 N19 16.6 33 42.7 16.1 48 46.1 15.7 63 49.5 15.2 78 52.9 14.7 93 56.3 14.3 108 59.6 N19 13.8	282 04.7 N 3 24.8 297 06.0 24.3 312 07.3 23.7 327 08.5 23.1 342 09.8 22.6 357 11.1 22.0 12 12.4 N 3 21.5	298 02.3 N10 30.6 313 04.4 30.5 328 06.5 30.3 343 08.6 30.2 358 10.7 30.0 13 12.8 29.9 28 14.9 N10 29.7	312 58.6 27.7 328 01.0 ·· 27.7 343 03.3 27.6 358 05.6 27.5	Gacrux 172 28.8 S57 00.4 Gienah 176 18.1 S17 26.0 Hadar 149 23.2 S60 16.9 Hamal 328 29.3 N23 22.0 Kaus Aust. 84 16.7 S34 23.6 Kochab 137 18.4 N74 14.5					
19 20 21 22 23	201 02.2 216 04.6 231 07.1	124 03.0 13.4 139 06.4 12.9 154 09.7 · 12.4 169 13.1 12.0 184 16.5 11.5	27 13.6 20.9 42 14.9 20.3 57 16.2 ·· 19.8 72 17.5 19.2 87 18.7 18.6	43 17.0 29.6 58 19.1 29.4 73 21.2 · · 29.3	28 10.3 27.4 43 12.6 27.4 58 15.0 27.3 73 17.3 27.2 88 19.6 27.2	Markob 14 03.2 N15 05.9 Menkar 314 41.5 N 4 00.7 Menkent 148 37.0 S36 16.5 Miaplacidus 221 45.6 S69 38.4					
01 02 03 04 05 06	291 17.0 306 19.4 321 21.9 336 24.4 351 26.8 6 29.3 21 31.8	214 23.2 10.6 229 26.5 10.2 244 29.9 · 09.7 259 33.2 09.3 274 36.5 08.8 289 39.9 N19 08.4 304 43.2 07.9	117 21.3 17.5 132 22.6 17.0 147 23.9 16.4 162 25.1 15.8 177 26.4 15.3 192 27.7 N 3 14.7 207 29.0 14.1	133 29.6 28.7 148 31.7 28.6 163 33.8 28.4 178 35.9 28.3 193 38.0 28.1 208 40.1 N10 28.0 223 42.2 27.8	118 24.3 27.0 133 26.6 27.0 148 28.9 26.9 163 31.3 26.8 178 33.6 26.8 193 35.9 N 5 26.7 208 38.3 26.6	Nunki 76 29.0 526 19.2 Peacock 53 58.2 556 47.7 Pollux 243 58.7 N28 04.4 Procyon 245 26.3 N 5 16.5					
S 08 A 09 T 10 U 11 R 12 D 13	51 36.7 66 39.1 81 41.6 96 44.1 111 46.5	334 49.8 · 07.1 349 53.1 · 06.6 4 56.4 · 06.2 19 59.7 N19 05.7 35 03.0 · 05.3	237 31.5 13.0 252 32.8 12.4 267 34.0 11.9 282 35.3 N 3 11.3 297 36.6 10.8	253 46.4 ··· 27.5 268 48.5 ··· 27.4 283 50.6 ··· 27.2 298 52.7 N10 27.1 313 54.8 ··· 26.9	238 42.9 ··· 26.5 253 45.3 ·· 26.4 268 47.6 ·· 26.4 283 49.9 N 5 26.3 298 52.2 ·· 26.2	Rigil Kent. 140 25.6 560 45.4 Sabik 102 41.0 515 42.0 Schedar 350 09.2 N56 25.5 Shaula 96 55.6 537 05.3					
	141 51.5 156 53.9 171 56.4 186 58.9	65 09.6 · · 04.6 80 12.9 04.0 95 16.2 03.6 110 19.5 N19 03.1	327 39.1 · 09.6 342 40.4 · 09.1 357 41.7 · 08.5 12 43.0 N 3 07.9	343 59.0 · 26.6 359 01.1 · 26.5 14 03.2 · 26.4 29 05.3 N10 26.2	328 56.9 26.1 343 59.2 26.0 359 01.6 26.0 14 03.9 N 5 25.9	Spica 158 57.6 S11 03.5 Suhoil 223 11.2 S43 21.4					
20 21 22 23	217 03.8 232 06.2 247 08.7 3 262 11.2	140 26.0 02.3 155 29.3 · 01.5 170 32.6 01.4 185 35.8 01.0	42 45.5 06.8 57 46.8 06.2 72 48.0 05.7 87 49.3 05.1	5 59 09.5 25.9 74 11.6 25.8 89 13.6 25.6 104 15.7 25.5	44 08.5 25.8 59 10.9 25.7 74 13.2 25.7 89 15.5 25.6	S.H.A. Mer. Pass. h m Venus 282 42.8 10 46					
Mer. Pa	ss 5 38.1	. J. J. 4 U U.	, , , , , , , , , , , , , , , , , , , ,	1							

1980 JUNE 26, 27, 28 (THURS., FRI., SAT.)

		1980 JUNE 20, 27	, 20) (INUKS., IKI., SAI.		· · · · · · · · · · · · · · · · · · ·				
C 11 7	SUN	MOON	Lat.	Twili Naut.	ight Ci <u>vil</u>	Sunrise	26	Moon 27	28	29
G.M.T.	G.H.A. Dec.	G.H.A. v Dec. d H.P.	N 72		, m		.	h m	h m	h m
	194 19.3 21.6 209 19.2 21.6 224 19.1 21.5 239 18.9 21.4 254 18.8 21.3 269 18.7 N23 21.2 284 18.6 21.1 299 18.4 21.0 314 18.3 21.0 314 18.3 21.0 329 18.2 20.9 344 18.0 20.8 359 17.9 N23 20.7 14 17.8 20.6 29 17.6 20.5 44 17.5 20.4 59 17.4 20.3 74 17.3 20.2 89 17.1 N23 20.1 104 17.0 20.0 119 16.9 19.9 134 16.7 19.8 149 16.6 19.7 164 16.5 19.6	29 28.7 11.0 516 22.9 6.1 55.9 43 58.7 10.9 16 29.0 5.9 55.5 58 28.6 10.9 16 34.9 5.9 56.0 72 58.5 10.8 16 40.8 5.9 56.0 87 28.3 10.8 16 46.7 5.7 56.0 10.5 58.1 10.7 16 52.4 5.7 56.0 116 27.8 10.6 516 58.1 5.5 56.1 130 57.4 10.6 17 03.6 5.5 56.1 130 57.4 10.6 17 03.6 5.5 56.1 130 57.4 10.6 17 09.1 5.4 56.1 174 26.0 10.3 17 19.9 5.2 56.0 174 26.0 10.3 17 19.9 5.2 56.0 188 55.3 10.3 17 25.1 51 56.0 20.3 24.6 10.3 517 30.2 51 56.0 20.3 24.6 10.3 517 30.2 51 56.0 20.3 24.6 10.3 517 30.2 51 56.0 20.3 24.6 50.3 517 30.2 51 56.0 20.3 24.6 50.3 517 30.2 51 56.0 20.3 24.6 50.3 517 30.2 51 56.0 20.3 24.6 50.3 517 30.2 51 56.0 20.3 24.6 50.3 517 30.2 51 56.0 20.3 24.6 50.3 51.7 30.2 51 56.0 20.3 24.6 50.2 10.1 17 40.3 4.9 56.0 20.3 24.6 50.2 10.1 17 45.2 48 56.0 20.3 24.6 50.2 10.1 17 45.2 48 56.0 30.4 48.1 9.8 18 03.9 4.6 56.4 31.9 16.9 9.7 18 08.3 4.3 56.4 31.9 16.9 9.7 18 08.3 4.3 56.4 31.9 16.9 9.7 18 08.3 4.3 56.4 31.9 16.9 9.7 18 16.9 4.1 56.5 24.3 0 9.6 18 21.0 4.1 56.5 17 11.6 9.5 518 25.1 4.0 56.5 55.5 18 25.1 4.0 56.5 56.5 18 11.6 11.6 11.6 11.6 11.6	N 70 68 66 64 62 60 N 58 55 45 N 405 30 20 N 10 S 10 30 35 45 55 55 55 55 55 55 55 55 55 55 55 55		00 55 01 44 02 13 02 35 02 53 03 08 03 38 04 00 04 18 04 34 04 58 05 19 05 54 06 11 06 30 06 40 06 52 07 06 07 22	01 35 02 12 02 38 02 59 03 15 03 30 03 42 03 53 04 15 04 23 05 42 05 42 05 42 05 59 06 17 06 35 06 56 07 09 07 23 07 39 08 00	21 08 20 23 19 54 19 32 19 14 19 00 18 47 18 36 18 27 18 19 18 11 17 55 17 42 17 31 17 21 17 21 16 50 16 36 16 23 16 08 15 52 15 43 15 32 15 19 15 04	22 54 21 45 21 09 20 43 20 23 20 06 19 52 19 40 19 30 19 21 19 12 18 55 18 40 18 18 18 00 17 44 17 29 17 14 16 59 16 41 16 30 16 18 16 04 15 47	23 56 22 43 22 07 21 40 21 20 21 20 21 03 20 49 20 37 20 17 20 09 19 51 19 36 19 13 18 55 18 39 17 53 17 34 17 24 17 11 16 57 16 39	24 01 23 15 22 45 22 22 22 24 21 49 21 36 21 25 21 15 21 07 20 59 20 42 20 28 20 17 20 06 19 49 19 34 19 19 19 05 18 32 18 22 18 10 17 57 17 57 17 40 17 32
01 02 03 04	194 16.2 19.4 209 16.1 19.3 224 16.0 · 19.2	31 40.1 9.4 18 29.1 3.8 56.4 46 08.5 9.4 18 32.9 3.8 56.4 60 36.9 9.4 18 36.7 3.7 56.4 75 05.3 9.3 18 40.4 3.6 56.4	54 56 58	06 45 06 51 06 57 07 04	07 29 07 37 07 46 07 56	08 10 08 21 08 33 08 48	14 57 14 49 14 40 14 30	15 39 15 30 15 20 15 09	16 31 16 22 16 11 15 59	17 23 17 13 17 02
05 06 07	•	89 33.6 9.2 18 44.0 3.4 56. 104 01.8 9.2 \$18 47.4 3.4 56. 118 30.0 9.1 18 50.8 3.3 56.	, 	07 11 Sunset	08 08 Twi	09 05 ilight	14 18	14 56 Moo		16 49
08 F 09	299 15.3 18.7 314 15.2 ·· 18.6	132 58.1 9.0 18 54.1 3.1 56. 147 26.1 9.0 18 57.2 3.1 56.	3		Civil	Naut.	26	27 h m	28 h m	29 h m
R 10 11 D 12	344 14.9 18.4	161 54.1 9.0 19 00.3 3.0 56. 176 22.1 8.9 19 03.3 2.8 56. 190 50.0 8.8 S19 06.1 2.8 56.	B N 72		,	, 0	00 24	00 23	00 27	01 21
A 13 Y 14 15 16 17 18 19 20 21	14 14.7 18.2 29 14.6 18.1 44 14.4 18.0 59 14.3 17.9 74 14.2 17.8 89 14.0 N23 17.7 104 13.9 17.5 119 13.8 17.4	205 17.8 8.8 19 08.9 2.6 56. 219 45.6 8.8 19 11.5 2.6 56. 234 13.4 8.7 19 14.1 2.4 56. 248 41.1 8.6 19 16.5 2.4 56. 263 08.7 8.6 19 18.9 2.2 57. 277 36.3 8.6 S19 21.1 2.1 57. 292 03.9 8.5 19 23.2 2.0 57. 306 31.4 85 19 25.2 1.9 57. 320 58.9 8.4 19 27.1 1.8 57. 335 26.3 8.3 19 28.9 1.6 57.	9 68 9 66 9 64 9 62 0 60 0 N 58 0 54 1 52	22 30 21 53 21 27 21 07 20 50 20 36 20 24 20 13	23 10 22 22 21 52 21 30 21 13 20 58 20 28		00 54 01 16 01 34 01 48 02 01 02 11 02 21 02 29 02 37 02 43 02 58	01 08 01 37 02 00 02 18 02 33 02 46 02 57 03 06 03 15 03 23 03 39	01 36 02 13 02 39 02 59 03 16 03 30 03 42 03 52 04 02 04 10 04 28	02 33 03 09 03 36 03 56 04 12 04 26 04 38 04 49 04 58 05 06 05 24
28 00 01 02 03 04 04 04	1 194 13.2 16.9 2 209 13.0 16.7 3 224 12.9 · 16.6 4 239 12.8 16.5 5 254 12.7 16.4 6 269 12.5 N23 16.3 7 284 12.4 16.1	18 48.2 8.3 19 33.6 1.3 57 33 15.5 8.2 19 34.9 1.2 57 47 42.7 8.1 19 36.1 1.1 57 62 09.8 8.2 19 37.2 1.0 57 76 37.0 8.1 19 38.2 0.9 57 91 04.1 8.0 \$19 39.1 0.8 57 105 31.1 8.0 19 39.9 0.7 57	2 3! 2 3(2 2(3 N 1(3 S 1(3 2(19 18 19 05 18 43 18 24 18 07 17 49 0 17 31	20 06 19 48 19 32 19 08 18 47 18 29 18 12 17 55	19 37 19 14 18 55 18 38 18 22	03 09 03 20 03 29 03 44 03 57 04 10 04 23 04 36	03 53 04 04 04 15 04 32 04 47 05 01 05 16 05 31	04 42 04 55 05 06 05 24 05 40 05 55 06 10 06 26	05 39 05 51 06 01 06 20 06 35 06 50 07 05 07 21 07 39
S 00	9 314 12.1 · 15.9	134 25.1 7.9 19 41.1 0.4 57	.4 3.	5 16 57	17 36 17 26 17 14	17 57	04 52 05 01 05 11	05 48 05 58 06 10	06 44 06 55 07 07	07 49 08 01
T 10 U 1 R 1: O 1 A 1 Y 1	1 344 11.9 15.7 2 359 11.8 N23 15.5 3 14 11.6 15.4 4 29 11.5 15.3	163 18.9 7.9 19 41.8 0.2 57 177 45.8 7.9 S19 42.0 0.1 57 192 12.7 7.8 19 42.1 0.0 57 206 39.5 7.8 19 42.1 0.2 57 221 06.3 7.7 19 41.9 0.3 57 235 33.0 7.7 19 41.6 0.3 5	.4 S 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	5 16 27 0 16 06 2 15 56 4 15 45 6 15 33 8 15 18	17 00 16 44 16 37 16 29 16 20 16 10	17 38 17 26 17 21 17 15 17 09 17 09	05 23 05 38 05 45 05 52 06 01 06 11 06 22	06 24 06 40 06 48 06 57 07 07 07 18 07 31	07 22 07 39 07 48 07 57 08 07 08 19 08 33	08 15 08 33 08 41 08 50 09 00 09 11 09 24
1 1 2	8 89 11.0 N23 14.8 9 104 10.9 14.6 0 119 10.8 14.1	3 264 26.4 7.7 \$19 40.7 0.6 5 5 278 53.1 7.7 19 40.1 0.7 5 5 293 19.8 7.6 19 39.4 0.9 5	.6 .6 Do	Eqn. 900°	SUN of Time 12*	Mer. Pass.	Mer Upper	. Poss.	Age	Phase
2	1 134 10.6 ·· 14.6 12 149 10.5 14.1 13 164 10.4 14e S.D. 15.8 d 0.	3 322 13.0 7.6 19 37.5 1.1 5 1 336 39.6 7.6 19 36.4 1.2 5	2.7 2	6 02 42 7 02 54 8 03 07	02 48 03 00	3 12 03 0 12 03	22 49 23 42	10 23 11 15	14 15	0
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1980 SEPTEMBER 18, 19, 20 (THURS., FRI., SAT.)

		1700	SEPTEMBER I	6, 19, 20 (1f1	UKS., IKI., SA	
6 11 7	ARIES	VENUS -3.8	MARS +1.5	JUPITER -1.2	SATURN +1.2	STARS
G.M.T.	G.H.A.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	Name S.H.A. Dec.
18 00 01 02 03 04	357 03.9 12 06.3 27 08.8 42 11.3 57 13.7	223 55.7 N16 29.9 238 55.4 29.3 253 55.0 28.8 268 54.7 28.2 283 54.4 27.7	136 34.2 S16 19.0 151 35.0 19.5 166 35.8 20.1 181 36.5 20.6 196 37.3 21.1	184 13.8 N 4 13.8 199 15.8 13.6 214 17.8 13.3 229 19.7 13.1 244 21.7 12.9	191 40.4 03.7 206 42.5 03.5 221 44.7 03.4	Acamar 315 37.0 \$40 22.8 Achernar 335 44.8 \$57 20.0 Acrux 173 37.9 \$62 59.4 Adhara 255 32.2 \$28 56.5 Aldebaran 291 17.9 N16 28.2
05 06 07 7 08 H 09 U 10 R 11 S 12 D 13	72 16.2 87 18.6 102 21.1 117 23.6 132 26.0 147 28.5 162 31.0 177 33.4 192 35.9	298 54.0 27.1 313 53.7 N16 26.6 328 53.4 26.0 343 53.0 25.5 358 52.7 24.9 13 52.4 24.4 28 52.0 23.8 43 51.7 N16 23.2 58 51.4 22.7	211 38.1 21.7 226 38.9 516 22.2 241 39.7 22.7 256 40.5 23.3 271 41.3 23.8 286 42.0 24.4 301 42.8 24.9 316 43.6 516 25.4 331 44.4 26.0	259 23.7 12.7 274 25.6 N 4 12.5 269 27.6 12.3 304 29.6 12.1 319 31.5 · 11.9 334 33.5 11.6 349 35.5 11.4 4 37.4 N 4 11.2 19 39.4 11.0 34 41.4 10.8	281 53.4 02.9 296 55.6 02.8 311 57.8 02.7 327 00.0 02.6 342 02.1 02.4 357 04.3 N 2 02.3 12 06.5 02.2	Alioth 166 43.1 N56 04.1 Alkaid 153 19.0 N49 24.9 Al Na'ir 28 14.6 S47 03.3 Alnilam 276 11.7 S 1 12.8 Alphard 218 20.8 S 8 34.3 Alphecco 126 32.3 N26 47.1 Alpheratz 358 09.0 N28 59.1 Altair 62 32.4 N 8 49.2
A 14 Y 15 16 17 18 19 20	207 38.4 222 40.8 237 43.3 252 45.8 267 48.2 282 50.7 297 53.1 312 55.6	73 51.0 22.1 88 50.7 ·· 21.6 103 50.4 21.0 118 50.0 20.4 133 49.7 N16 19.9 148 49.4 19.3 163 49.0 18.7 178 48.7 ·· 18.2	346 45.2 26.5 1 46.0 27.0 16 46.7 27.6 31 47.5 28.1 46 48.3 S16 28.6 61 49.1 29.2 16 49.9 29.7 91 50.6 30.2	49 43.3 · · 10.6 64 45.3 10.4 79 47.2 10.2 94 49.2 N 4 10.0 109 51.2 09.7 124 53.1 09.5 139 55.1 · · 09.3	42 10.9 · · · 02.0 57 13.0 · 01.8 72 15.2 · 01.7 87 17.4 N 2 01.6 102 19.6 · 01.5 117 21.8 · 01.3 132 23.9 · · 01.2	Ankaa 353 39.9 542 24.6 Antares 112 57.0 526 23.3 Arcturus 146 18.8 N19 17.3 Atria 108 21.3 568 59.8 Aviar 234 28.6 559 26.6 Bellotrix 278 58.7 N 6 20.0
22 23 19 00 01 02 03 04 05	327 58.1 343 00.5 358 03.0 13 05.5 28 07.9 43 10.4 58 12.9 73 15.3	193 48.4 17.6 208 48.0 17.0 223 47.7 N16 16.5 238 47.4 15.9 253 47.0 15.3 268 46.7 14.8 283 46.3 14.2 298 46.0 13.6	106 51.4 30.8 121 52.2 31.3 136 53.0 516 31.9 151 53.8 32.4 166 54.5 32.9 181 55.3 33.5 196 56.1 34.0 211 56.9 34.5	154 57.1 09.1 169 59.0 08.9 185 01.0 N 4 08.7 200 03.0 08.5 215 04.9 08.3 230 06.9 08.0 245 08.9 07.8 260 10.8 07.6	147 26.1 01.1 162 28.3 01.0 177 30.5 N 2 00.9 192 32.7 00.7 207 34.8 00.6 222 37.0 00.5 237 39.2 00.4 252 41.4 00.2	Betelgeuse 271 28.3 N 7 24.3 Canopus 264 07.3 552 40.9 Capella 281 11.2 N45 58.5 Deneb 49 48.1 N45 12.9 Denebola 182 59.4 N14 41.0 Diphda 349 20.6 S18 05.5
06 07 08 F 09 R 10 11 D 12	88 17.8 103 20.3 118 22.7 133 25.2 148 27.6 163 30.1 178 32.6	313 45.7 N16 13.0 328 45.3 12.5 343 45.0 11.9 358 44.7 · 11.3 13 44.3 10.7 28 44.0 10.2 43 43.7 N16 09.6	226 57.7 S16 35.1 241 58.4 35.6 256 59.2 36.1 272 00.0 36.7 287 00.8 37.2 302 01.5 37.7 317 02.3 S16 38.2	275 12.8 N 4 07.4 290 14.8 07.2 305 16.7 07.0 320 18.7 06.6 335 20.7 06.6 350 22.6 06.3 5 24.6 N 4 06.1	267 43.6 N 2 00.1 282 45.7 2 00.0 297 47.9 1 59.9 312 50.1 59.8 327 52.3 59.6 342 54.5 59.5 357 56.6 N 1 59.4	Dubhe 194 22.8 N61 51.4 Elnath 278 44.1 N28 35.4 Eltanin 90 57.7 N51 29.9 Enif 34 11.3 N 9 47.3 Fomalhaut 15 51.1 S29 43.4 Gacrux 172 29.3 S57 00.2
A 13 Y 14 15 16 17	193 35.0 208 37.5 223 40.0 238 42.4 253 44.9 268 47.4	58 43.3 09.0 73 43.0 08.4 88 42.7 - 07.8 103 42.3 07.3 118 42.0 06.7 133 41.6 N16 06.1	332 03.1 38.8 347 03.9 39.3 2 04.6 39.8 17 05.4 40.4 32 06.2 40.9 47 07.0 \$16 41.4	20 26.6 05.9 35 28.5 05.7 50 30.5 05.5 65 32.5 05.3 80 34.4 05.1 95 36.4 N 4 04.9	12 58.8 59.3 28 01.0 59.1 43 03.2 59.0 58 05.3 58.9 73 07.5 58.8 88 09.7 N 1 58.7	Gienah 176 18.3 S17 25.9 Hadar 149 23.8 S60 16.8 Hamal 328 28.6 N23 22.2 Kaus Aust 84 16.8 S34 23.7 Kochab 137 19.9 N74 14.4 Markab 14 02.9 N15 06.2
19 20 21 22 23 20 00	298 52.3 313 54.7 328 57.2 343 59.7 359 02.1	148 41.3 05.5 163 41.0 04.9 178 40.6 04.3 193 40.3 03.8 208 40.0 03.2 223 39.6 N16 02.6	77 08.5 42.5 92 09.3 43.0 107 10.1 43.6 122 10.8 44.1 137 11.6 516 44.6	110 38.4 04.7 125 40.3 04.4 140 42.3 04.2 155 44.2 04.0 170 46.2 03.8 185 48.2 N 4 03.6 200 50.1 03.4	103 11.9 58.5 118 14.1 58.4 133 16.2 58.3 148 18.4 58.2 163 20.6 58.0 178 22.8 N 1 57.9 193 25.0 57.8	Menkar 314 40.9 N 4 00.9 Menkent 148 37.3 S36 16.4 Miaplacidus 221 45.6 S69 38.0 Mirfak 309 15.8 N49 47.4
01 02 03 04 05 06	44 09.5 59 12.0 74 14.5 89 16.9 104 19.4	253 39.0 01.4 268 38.6 00.8 283 38.3 16 00.2 298 37.9 15 59.6 313 37.6 N15 59.0 328 37.3 58.4	167 13.1 45.7 182 13.9 46.2 197 14.7 46.7 212 15.5 47.3 227 16.2 516 47.8 242 17.0 48.3	215 52.1 03.2 230 54.1 03.0 245 56.0 02.7 260 58.0 02.5 276 00.0 N 4 02.3 291 01.9 02.1	208 27.1 57.7 223 29.3 - 57.6 238 31.5 57.4 253 33.7 57.3 268 35.9 N 1 57.2 283 38.0 57.1	Peacock 53 58.1 S56 48.0 Pollux 243 58.4 N28 04.4 Procyon 245 26.0 N 5 16.6 Rosalhague 96 29.6 N12 34.7 Regulus 208 10.3 N12 03.8
S 08 A 09 T 10 U 11 R 12 D 13	134 24.3 149 26.8 164 29.2 179 31.7 194 34.2	358 36.6 57.2 13 36.3 56.6 28 35.9 56.0 43 35.6 N15 55.5 58 35.2 54.9	272 18.5 49.4 287 19.3 49.9 302 20.1 50.4 317 20.8 516 51.0 332 21.6 51.5	321 05.9 01.7 336 07.8 01.5 351 09.8 01.3 6 11.8 N 4 01.1 21 13.7 00.8	313 42.4 · · · 56.8 328 44.6 · 56.7 343 46.8 · 56.6 358 48.9 N 1 56.5 13 51.1 · 56.3	Rigil Kent. 140 26.3 560 45.3 Sabik 102 41.2 515 42.0 Schedar 350 08.4 N56 25.8 Shaula 96 55.8 537 05.4
A 14 Y 15 16 17 18	224 39.1 239 41.6 254 44.0 269 46.5	88 34.6 53.7 103 34.2 53.1 118 33.9 52.4 133 33.5 N15 51.8	2 23.2 52.5 17 23.9 53.1 32 24.7 53.6 47 25.5 \$16 54.1	51 17.7 - 00.4 66 19.6 - 00.2 81 21.6 - 4 00.0 96 23.6 N 3 59.8 111 25.5 - 59.6	43 55.5 56.1 58 57.6 56.0 73 59.8 55.8 89 02.0 N 1 55.7 104 04.2 55.6	Spico 158 57.8 S11 03.4 Suhail 223 11.1 S43 21.0 Vego 80 55.8 N38 46.3 Zuben'ubi 137 33.3 S15 57.5
20 21 22	299 51.4 314 53.9 329 56.4 344 58.8	163 32.9 50.6 178 32.5 50.6 193 32.2 49.6 208 31.9 48.8	77 27.0 55.2 9 92 27.8 55.7 1 107 28.5 56.2 3 122 29.3 56.7	126 27.5 59.4 141 29.5 59.1 156 31.4 58.9 171 33.4 58.7	119 06.4 55.5 134 08.5 55.3 149 10.7 55.2 164 12.9 55.1	Venus 225 44.7 9 05

1980 SEPTEMBER 18, 19, 20 (THURS., FRI., SAT.)

				Twili	aht			Moon	rise	·
	SUN	MOON	Lat.	Naut.	Civil	Sunrise	18	19	20	21
G.M.T.	G.H.A. Dec.	G.H.A. V Dec. d H.P.	N 72	h m 02 39	h m 04 16	h m 05 25	h m	h m	19 42	19 07
1800	181 26.7 N 1 53.8	86 55.5 9.8 S19 29.0 1.8 56.2	N 70	03 03	04 26	05 28		18 40 17 43	18 39 18 03	18 36 18 14
- 01	196 26.9 52.8	101 24.3 9.8 19 30.8 1.7 56.2 115 53.1 9.7 19 32.5 1.5 56.3	68 66	03 21 03 35	04 34 04 41	05 31 05 33		17 43 17 09	17 38	17 56
02 03	226 27.4 · · 50.9	130 21.8 9.6 19 34.0 1.5 56.3	64	03 47	04 46 04 51	05 35 05 36	15 57 15 37	16 44 16 25	17 18 17 01	17 41 17 29
04 05	241 27.6 49.9 256 27.8 48.9	144 50.4 9.7 19 35.5 1.4 56.3 159 19.1 9.5 19 36.9 1.3 56.4	62 60	03 56 04 04	04 55	05 37	15 20	16 09	16 48	17 18
06	271 28.0 N 1 48.0	173 47.6 9.5 \$19 38.2 1.1 56.4	N 58 56	04 11 04 17	04 59 05 02	05 38 05 39	15 05 14 53	15 55 15 43	16 36 16 26	17 09 17 01
07 1 08	286 28.2 47.0 301 28.5 46.0	188 16.1 9.5 19 39.3 1.1 56.4 202 44.6 9.4 19 40.4 1.0 56.5	54	04 22	05 05	05 40	14 43	15 33	16 17	16 54 16 47
н 09	316 28.7 · 45.1	217 13.0 9.4 19 41.4 0.8 56.5 231 41.4 9.3 19 42.2 0.8 56.5	52 50	04 27 04 31	05 07 05 09	05 41 05 42	14 33 14 25	15 24 15 16	16 09 16 01	16 41
U 10 R 11	331 28.9 44.1 346 29.1 43.1	231 41.4 9.3 19 42.2 0.8 56.5 246 09.7 9.3 19 43.0 0.6 56.6	45	04 39	05 14	05 43	14 07	14 59	15 46	16 29 16 18
S 12	1 29.4 N 1 42.2 16 29.6 41.2	260 38.0 9.2 S19 43.6 0.5 56.6 275 06.2 9.1 19 44.1 0.5 56.6	N 40 35	04 46 04 51	05 18 05 20	05 45 05 46	13 52 13 40	14 44 14 32	15 33 15 22	16 09
D 13 A 14	31 29.8 40.2	289 34.3 9.2 19 44.6 0.3 56.7	30 20	04 55	05 23 05 26	05 47 05 48	13 29 13 11	14 22 14 04	15 13 14 56	16 01 15 47
Y 15 16	46 30.0 · 39.3 61 30.3 38.3	304 02.5 9.0 19 44.9 0.2 56.7 318 30.5 9.0 19 45.1 0.1 56.7	N 10	05 01 05 04	05 28	05 49	12 54	13 48	14 42	15 35 15 24
17	76 30.5 37.3	332 58.5 9.0 19 45.2 0.0 56.8	0 S 10	05 06 05 06	05 30 05 30	05 50 05 51	12 39	13 33	14 28 14 15	15 13
18 19	91 30.7 N 1 36.3 106 30.9 35.4	347 26.5 9.0 \$19 45.2 0.2 56.8 1 54.5 8.8 19 45.0 0.2 56.9	20	05 05	05 30	05 52	12 08	13 03	14 00	15 01 14 47
20	121 31.1 34.4	16 22.3 8.9 19 44.8 0.3 56.9 30 50.2 8.8 19 44.5 0.5 56.9	30	05 02 04 59	05 29 05 28	05 53 05 54	11 50 11 39	12 44 12 34	13 44 13 34	14 39
21 22		45 18.0 8.7 19 44.0 0.6 57.0	40	04 56	05 27 05 26	05 54 05 55	11 27 11 13	12 22 12 08	13 23 13 10	14 30 14 19
19 00		59 45.7 8.7 19 43.4 0.7.57.0 74 13.4 8.7 S19 42.7 0.7 57.0	5 50	04 51 04 45	05 23	05 55	10 55	11 50	12 54	14 06
01	, 196 32.3 29.6	88 41.1 8.6 19 42.0 10 57.1	52 54	04 43 04 39	05 22 05 21	05 56 05 56	10 47 10 37	11 42 11 33	12 47 12 39	14 00 13 53
02 03		117 36.3 8.6 19 40.0 1.1 57.2	56	04 36	05 19	05 56	10 27	11 23	12 29 12 19	13 46 13 37
04	241 32.9 26.6	132 03.9 8.5 19 38.9 1.3 57.2	58 5 60	04 31 04 26	05 18 05 16	05 57	10 15 10 01	11 11 10 57	12 07	13 28
0.	. 1	160 58.8 8.4 S19 36.3 1.5 57.3	-	 	Tw	/ilight		Mod	nset	
01			Lat.	Sunset	Civil	Naut.	18	19	20	21
F O	9 316 34.0 21.8	204 21.0 8.3 19 31.5 1.8 57.4		h m	, ,		, "	h m	h m	h m
R 1			N 72	18 19	19 29	21 03	=		21 52	24 25 24 54
D 1				18 17	19 19		19 20 20 42	20 58 21 55	23 30	25 16
A 1 Y 1		276 37.2 8.1 19 21.2 2.4 57.6	66	18 13	19 04 18 59		21 20 21 47	22 28	23 55 24 14	25 33 00 14
1	5 46 35.4 · 16.0 6 61 35.6 · 15.0			18 10	18 54	19 49	22 08	23 12	24 30 24 43	00 30 00 43
1	7 76 35.8 14.0	319 58.5 B.0 19 13.6 2.7 57.7		1	18 50		22 25	23 27	24 54	00 54
	8 91 36.0 N 1 13. 9 106 36.3 12.	1 348 52.5 8.0 19 08.0 3.0 57.8	B 54	18 07	18 44	19 29	22 51	23 52 24 02	25 04	01 04 01 13
2	0 121 36.5 11.	1 3 19.5 7.9 19 05.0 3.1 57.			18 4		23 02	24 11	00 11	01 20
2	2 151 36.9 09.	2 32 13.4 7.8 18 58.6 3.3 57.	9 5	18 05	18 3 18 3		23 20	24 19 24 36	00 19	01 27 01 42
	23 166 37.1 08. 00 181 37.4 N 1 07.			2.	18 2	9 19 01	23 52	24 50	00 50	01 54
)1 146 31.6 Uo.	3 75 33.9 7.8 18 48.2 3.7 58.	0 3	5 18 01 0 18 00			24 04 24 15	00 04	01 02	02 04
)2 211 37.8 05.)3 226 38.0 · · · 04.	3 104 27.5 7.8 18 40.7 3.9 58.	1 2	0 17 59	18 2	1 18 47	24 34 24 50	00 34	01 30 01 45	
(04 241 38.3 03 05 256 38.5 02			0 17 58 0 17 57			00 12	01 05	01 59	02 55
	06 271 38.7 N 1 01	4 147 47.7 7.7 518 28.5 4.3 58.	.2 5 1				00 27 00 43	01 20 01 36		
	07 286 38.9 1 00 08 301 39.1 0 59		.3 3	0 17 55 0 17 55	18 1	9 18 46	01 01	01 54	02 46	03 36
A	09 316 39.4 · 58	.5 191 07.7. 7.6 1B 15.3 4.6 58.		5 17 54 0 17 54				02 05	03 08	03 54
	10 331 39.6 57 11 346 39.8 56	6 220 00.9 7.6 18 05.9 4.9 58	.4 4	5 17 53	18 2			02 32	•	1
R	12 1 40.0 N 0 55 13 16 40.3 54			0 17 53 2 17 53				02 57	03 45	04 26
A	14 31 40.5 53	6 263 20.6 7.5 17 50.9 5.3 58	.6	4 17 52 6 17 52					1	
Y		7 292 13.6 7.5 17 40.3 5.5 58	.6	58 17 5	2 18 3	19 10	02 35	03 29		
	17 76 41.1 50),7 306 40.1 7.5 17 34.8 5.6 58		50 17 57	2 18 : SUI		02 49		AOON	-
		3.8 335 33.1 7.4 17 23.5 5.8 58	.8	Eqn.	of Time		Me	r. Pass.	Age	Phase
	20 121 41.8 4	7.8 349 59.5 7.5 17 17.7 5.9 58 6.8 4 26.0 7.4 17 11.8 6.1 58	3.8	3, <u>00,</u>	12	.h Pass	_		' 	
	22 151 42.2 4	5.9 18 52.4 7.4 17 05.7 6.1 58		m 18 05 4		57 11 5		06 2	6 09	
_			-	19 06 0 20 06 2	B 06	18 11 5				U
	S.D. 16.0 d	1.0 S.D. 15.4 15.7 1	,., <u>,</u>	-0 00 2	<u> </u>					

1980 SEPT. 30, OCT. 1, 2 (TUES., WED., THURS.)

	ARIES	VENUS -3.7	MARS +1.5	JUPITER -1.2	SATURN +1.2	STARS
G.M.T.	G.H.A.	G,H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	Name S.H.A. Dec.
30 00	8 53.5 23 56.0	222 17.4 N13 18.6 237 17.0 17.8	140 08.3 518 45.8 155 09.0 46.3	193 40.6 N 3 13.0 208 42.5 12.8 223 44.5 12.5	187 05.8 N 1 28.7 202 07.9 28.6 217 10.1 28.4	Acomar 315 36.9 S40 22.8 Achernar 335 44.7 S57 20.0 Acrux 173 37.9 S62 59.4
02 03 04	38 58.5 54 00.9 69 03.4	252 16.7 17.1 267 16.3 ·· 16.3 282 16.0 15.5	170 09.7 46.8 185 10.4 47.3 200 11.1 47.7	238 46.5 ·· 12.3 253 48.4 12.1	232 12.3 ·· 28.3 247 14.5 28.2 262 16.7 28.1	Adhara 255 32.1 S28 56.5 Aldebaran 291 17.8 N16 28.2
05 06 07	84 05.8 99 08.3 114 10.8	297 15.7 14.7 312 15.3 N13 14.0 327 15.0 13.2	215 11.8 48.2 230 12.5 518 48.7 245 13.2 49.2	283 52.4 N 3 11.7 298 54.4 11.5	277 18.8 N 1 28.0 292 21.0 27.8	Alioth 166 43.1 N56 04.0 Alkaid 153 19.0 N49 24.8 Al Na'ir 28 14.6 S47 03.4
7 08 7 09 U 10 E 11	129 13.2 144 15.7 159 18.2	342 14.6 12.4 357 14.3 11.6 12 13.9 10.8	260 13.9 49.7 275 14.6 · 50.1 290 15.3 50.6	313 56.3 11.3 328 58.3 ·· 11.1 344 00.3 10.9	307 23.2 27.7 322 25.4 ·· 27.6 337 27.6 27.5	Al Na'ir 28 14.6 547 03.4 Alnilam 276 11.6 5 1 12.8 Alphard 218 20.8 5 8 34.3
S 12 D 13	174 20.6 189 23.1 204 25.6	27 13.6 10.1 42 13.3 N13 09.3 57 12.9 08.5	305 16.0 51.1 320 16.7 518 51.6 335 17.4 52.0	359 02.2 10.7 14 04.2 N 3 10.5 29 06.2 10.2	7 31.9 N 1 27.2 22 34.1 27.1	Alphecca 126 32.4 N26 47.1 Alpheratz 358 08.9 N28 59.1
Y 14 Y 15 16	219 28.0 234 30.5 249 33.0	72 12.6 07.7 87 12.2 06.9 102 11.9 06.1	350 18.1 52.5 5 18.8 · 53.0 20 19.5 53.5	44 08.2 10.0 59 10.1 ·· 09.8 74 12.1 09.6	37 36.3 27.0 52 38.5 26.9 67 40.6 26.7	Altair 62 32.4 N B 49.2 Ankaa 353 39.8 S42 24.6 Antares 112 57.0 S26 23.3
17 18 19	264 35.4 279 37.9 294 40.3	117 11.5 05.3 132 11.2 N13+04.6 147 10.9 03.8	35 20.2 53.9 50 20.9 S18 54.4 65 21.6 54.9	89 14.1 09.4 104 16.0 N 3 09.2 119 18.0 09.0	82 42.8 26.6 97 45.0 N 1 26.5 112 47.2 26.4	Arcturus 146 18.8 N19 17.2 Atrio 108 21.5 568 59.7
20 21 22	309 42.8 324 45.3 339 47.7	162 10.5 03.0 177 10.2 02.2 192 09.8 01.4	80 22.2 55.4 95 22.9 55.8 110 23.6 56.3	134 20.0 08.8 149 22.0 · 08.6 164 23.9 08.4	127 49.4 26.3 142 51.5 ·· 26.1 157 53.7 26.0	Avior 234 28.4 S59 26.6 Bellotrix 278 58.6 N 6 20.0 Betelgeuse 271 28.2 N 7 24.3
100	354 50.2 9 52.7	207 09.5 13 00.6 222 09.1 N12 59.8	125 24.3 56.8 140 25.0 \$18 57.3	179 25.9 08.2 194 27.9 N 3 08.0 209 29.8 07.7	172 55.9 25.9 187 58.1 N 1 25.8 203 00.3 25.7	Canapus 264 07.2 552 40.8 Capella 281 11.1 N45 58.6
01 02 03	24 55.1 39 57.6 55 00.1	237 08.8 59.0 252 08.5 58.2 267 08.1 · 57.4	170 26.4 58.2 185 27.1 58.7	224 31.8 07.5 239 33.8 · 07.3 254 35.8 07.1	218 02.4 25.5 233 04.6 25.4 248 06.8 25.3	Deneb 49 48.2 N45 13.0 Denebolo 182 59.4 N14 41.0 Diphdo 349 20.5 518 05.5
04 05 06		282 07.8 56.7 297 07.4 55.9 312 07.1 N12 55.1	200 27.8 59.1 215 28.5 18 59.6 230 29.2 \$19 00.1	269 37.7 06.9 284 39.7 N 3 06.7	263 09.0 25.2 278 11.1 N 1 25.1	Dubhe 194 22.8 N61 51.3
W 08 E 09		327 06.7 54.3 342 06.4 53.5 357 06.1 · · 52.7	245 29.9 00.6 260 30.5 01.0 275 31.2 01.5	299 41.7 06.5 314 43.6 06.3 329 45.6 · 06.1		Eltanin 90 57.8 N51 29.9 Enif 34 11.3 N 9 47.3
D 10 N 11 E 12	175 19.8	12 05.7 51.9 27 05.4 51.1 42 05.0 N12 50.3	290 31.9 02.0 305 32.6 02.4 320 33.3 519 02.9	344 47.6 05.9 359 49.6 05.7 14 51.5 N 3 05.4	338 19.9 24.6 353 22.0 24.5 8 24.2 N 1 24.3	Fomalhaut 15 51.1 529 43.5 Gacrux 172 29.3 557 00.2
D 13 A 14 A 15	205 24.7 220 27.2	57 04.7 49.5 72 04.3 48.7 87 04.0 · 47.9	335 34.0 03.4 350 34.7 03.9 5 35.4 · 04.3	29 53.5 05.2 44 55.5 05.0 59 57.5 · 04.8		Gienah 176 18.3 S17 25.9 Hadar 149 23.9 S60 16.8 Hamal 328 28.6 N23 22.3
16 17	250 32.1 265 34.6	102 03.7 47.1 117 03.3 46.3 132 03.0 N12 45.5	20 36.0 04.8 35 36.7 05.3 50 37.4 S19 05.7	74 59.4 04.6 90 01.4 04.4 105 03.4 N 3 04.2	83 35.1 23.7	Kaus Aust. 84 16.9 534 23.7 Kachab 137 20.0 N74 14.4
18 19 20	295 39.5 310 41.9	147 02.6 44.7 162 02.3 43.9	65 38.1 06.2 80 38.8 06.7	120 05.3 04.0 135 07.3 03.8	113 39.5 23.5 128 41.7 23.4	Markob 14 02.9 N15 06.2 Menkor 314 40.9 N 4 00.9 Menkent 148 37.4 S36 16.4
21 22 23	340 46.9 355 49.3	192 01.6 42.2 207 01.3 41.4	110 40.2 07.6 125 40.8 08.1	165 11.3 03.4 180 13.2 03.2	158 46.0 23.1 173 48.2 23.0	Miaplacidus 221 45.5 569 38.0
2 00 01 02	25 54.3 40 56.7	237 00.6 39.8 252 00.2 39.0	155 42.2 09.0 170 42.9 09.5	210 17.2 02.7 225 19.2 02.5	203 52.6 22.8 218 54.7 22.7	
03 04 05	71 01.7	281 59.5 37.4 296 59.2 36.6	200 44.3 10.4 215 44.9 10.9	255 23.1 02.1 270 25.1 01.9	248 59.1 22.4 264 01.3 22.3	Procyon 245 25.9 N 5 16.6
	101 06.6 7 116 09.1 131 11.5	326 58.5 35.0 341 58.2 34.1	245 46.3 11.8 260 47.0 12.3	300 29.0 01.5 315 31.0 01.5	5 294 05.6 22.1 3 309 07.8 21.9	Regulus 208 10.3 N12 03.8 Rigel 281 35.9 S 8 13.3
U 10	146 14.0 161 16.4 176 18.9	11 57.5 32.	290 48.4 13.2	345 34.9 00.9 0 36.9 00.0	9 339 12.2 21.7 6 354 14.4 21.6	`
D 13	2 191 21.4 3 206 23.8 4 221 26.3	56 56.5 30.1	1 335 50.4 14.6 3 350 51.1 15.3	30 40.9 00.1 1 45 42.8 3 00.1	2 24 18.7 21.3 0 39 20.9 21.3	Shaula 96 55.9 \$37 05.4 Sirius 258 55.7 \$16 41.2
Y 19	5 236 28.6 6 251 31.2 7 266 33.7	3 86 55.8 ·· 28.4 2 101 55.4 27.0	5 51.8 ·· 15.5 5 20 52.4 16.0	75 46.8 59.4 90 48.8 59.	6 69 25.3 21.0 4 84 27.4 20.9	?
10	8 281 36.2 9 296 38.0 0 311 41.3	2 131 54.8 N12 26.6 6 146 54.4 25.3	2 65 54.5 17.4 3 80 55.2 17.8	4 120 52.7 59. 3 135 54.7 58.	0 114 31.8 20.6 B 129 34.0 20.5	S.H.A. Mer. Poss.
2	1 326 43.0 2 341 46.0 3 356 48	6 176 53.7 ·· 23.0 0 191 53.4 22.	5 95 55.8 ·· 18.3 7 110 56.5 18.1	8 165 58.6 58.	4 159 38.3 20.3	Venus 212 16.5 9 12 Mars 130 32.3 14 38
	oss. 23 16.			5 υ 2.0 d o	2 v 2.2 d 0.	Jupiter 184 35.2 11 01 1 Saturn 178 05.4 11 26

1980 SEPT. 30, OCT. 1, 2 (TUES., WED., THURS.)

		1980 SEPT. 30, OCT. 1	I, Z	(TUES.,	VVLD	.,				
\neg		MOON	Lat.	Twili	·	Sunrise	30	Moor 1	rise 2	3
.M.T.	SUN	d us	-	Naut.	Civil	h m	h m	h m	h	22 00
	G H.A. Dec.	G.H.A. U Dec. d H.P.	N 72	03 50	05 12 05 15	06 19 06 16	18 24	□ 19 21	21 01	22 44
ဂ္ဂိ ဝုဂ္ဂိ	182 29.1 S 2 46.3 197 29.3 47.2	286 32.7 7.4 N18 57.7 3.5 58.4 300 59.1 7.3 19 01.2 3.4 58.4	N 70	04 02 04 11	05 18	06 13	19 30	20 27 21 Q2	21 45 22 14	23 13 23 35
	212 29.5 48.2	315 25.4 7.5 19 04.6 3.2 58.3	66	04 19 04 25	05 20 05 22	06 11 06 09	20 06 20 32	21 28	22 36	23 52
	227 29.7 · · 49.2 242 29.9 · 50.2	344 18.3 7.5 19 10.9 3.0 58.3	62	04 31	05 23 05 24	06 07	20 52 21 08	21 48 22 04	22 54 23 09	24 07 24 19
05	257 30.1 51.1	358 44.8 7.5 19 13.9 2.8 58.2 13 11.3 7.5 N19 16.7 2.8 58.2	60 N 58	04 35	05 25	06 04	21 22	22 18	23 21 23 32	24 29 24 38
	272 30.3 \$ 2 52.1 287 30.5 53.1	27 37.8 7.5 19 19.5 2.6 58.1	56 54	04 43	05 26 05 27	06 03	21 34 21 45	22 30 22 40	23 41	24 46
	302 30.7 54.0 317 30.9 55.0	56 30.9 7.6 19 24.6 2.4 58.1	52	04 48	05 27 05 28	06 01	21 54 22 02	22 49	23 49 23 57	24 53 24 59
10	332 31.1 56.0	70 57.5 7.6 19 27.0 2.2 58.0 85 24.1 7.7 19 29.2 2.1 58.0	50 45	04 50	05 29	05 58	22 20	23 15	24 13	00 13
12	2 31.5 \$ 2 57.9	99 50.8 7.7 N19 31.3 21 58.0	N 40	04 58 05 00	05 29	05 56	22 35 22 47	23 29	24 37	00 37
13	17 31.7 58.9 32 31.9 2 59.9	128 44.2 7.7 19 35.3 1.7 57.9	30	05 02	05 29 05 29	05 53 05 51	22 58 23 16	23 52	24 47	00 47 01 04
15	47 32.1 3 00.8	143 10.9 78 19 37.0 1.7 57.8		05 03	05 28	05 49	23 32	24 26 24 41	00 26	01 19
16 17	77 32.5 02.8	172 04.5 7.9 19 40.2 1.5 57.8	S 10	1 .	05 26	05 46 05 44	23 47	00 02	00 56	01 46
18 19	92 32.7 \$ 3 03.7 107 32.9 04.7	1 1 200 583 79 19 430 11 2//	20	04 54	05 19	05 41 05 38	24 19 24 37	00 19	01 12	02 01 02 17
20	122 33.1 05.	215 25.2 8.0 19 44.1 1.1 57.7			05 14	05 36	24 48	00 48 01 00	01 40 01 53	02 27
21 22		244 19.2 8.0 19 46.2 0.8 57.6	49		05 07 05 02		00 02	01 15	02 07	02 51
23		1120 477 04 57	5 S 5	04 18	04 56	05 29	00 33 00 41	01 33 01 42	02 24	03 07
1 00	197 34.1 10.	5 287 40.4 8.1 19 48.3 0.5 57.5			04 54	05 26	00 50	01 51	02 42	03 23
02 03	212 34.3 11. 227 34.5 ·· 12.	5 316 34.7 83 19 49.1 0.3 57	4 5	6 04 01	04 47		01 00	02 02	03 04	03 42
	242 34.7 13.			3 L	1		01 25			03 54
06	272 35.1 \$ 3 15	4 359 56.5 8.4 N19 49.5 0.1 57.		Sunse	• I .	wilight	30	M:	oonset 2	3
w 07		3 28 51.3 8.5 19 49.2 0.3 57.	2	3030	Civil	Naut.	30	1	T -	T
E 09	317 35.7 · 18	3 57 46.2 86 19 48.5 0.6 57	.2	<u>. د. ا د.</u>	1	_		, \ , ·	`	18 29
N 13	1 347 36.1 20	2 72 13.8 8.6 19 47.9 0.6 57				2 19 34	16 39	17 30		
S 17		2 101 09.0 87 19 46.5 0.9 57	.i] (58 17 2 56 17 2					4 16 30	16 52
D Î	4 32 36.7 23	.1 130 04.4 8.8 19 44.6 1.1 57	.0	64 17 2	9 18 1	6 19 12				
'1	6 62 37.1 25	6.1 144 32.2 8.8 19 43.5 1.2 57		62 17 3 60 17 3	1	_	2 13 5	6 14 5	2 15 3	
	7 77 37.3 20 8 92 37.5 \$ 3 2	7.0 173 27.9 8.9 N19 41.0 1.5 56	5.9 N	58 17 3 56 17 3				0 14 2	6 15 1	1 15 46
1	19 107 37.7 2	3.0 187 55.8 8.9 19 39.5 1.5 56 8.9 202 23.7 9.1 19 38.0 1.7 56		54 17 3	6 18	11 18 5	2 13 2			
2	1 137 38.1 · · 2	9.9 216 51.8 9.0 19 36.3 1.7 30		52 17 3 50 17 3	8 18	10 18 4	8 13 0	2 13 5	8 14 4	
		1.9 245 48.0 9.1 19 32.7 2.0 5	6.7	45 17 4 40 17 4				-	6 14 1	5 14 5
20	00 182 38.7 S 3 3	2.8 260 16.1 9.3 N19 30.7 2.0 5 3.8 274 44.4 9.2 19 28.7 2.2 5		35 17	14 18	09 18 3	8 12	18 13		
(02 212 39.1 3	4.8 289 12.6 9.4 19 26.5 2.3 5		30 17 20 17		10 18 3	6 11	49 12	44 13	6 14 2
		6.7 318 09.3 9.5 19 21.8 2.5 5	6.6 N	10 17				- 1	13 13	06 13 5
	05 257 39.7	18 4 347 06.3 9.5 N19 16.7 2.7 5	6.5 S	10 17	55 18,	16 18 4				36 13 3
	07 287 40.1	39.6 1 34.8 96 19 14.0 2.8 5		20 17 30 18	01 18	25 18	53 10	29 11	23 12	
		11.5 30 32.1 9.7 19 08.3 2.9	56.4	35 18 40 18		29 18	05 10	07 11	00 11	56 12 5
u	10 332 40.7	42.5 45 00.8 9.7 19 05.4 3.1 5 43.5 59 29.5 9.9 19 02.3 3.2	56.4	45 18	08 18	38 19		1		
R S	12 2 41.1 5 3	44.4 73 58.4 9.9 N18 59.1 3.3		50 18 52 18	13 18	47 19	28 09	27 10	- 1	17 12
D A	13 17 41.3 14 32 41.5	46.4 102 56.2 10.0 18.52.4 3.5	56.3	-		50 19 54 19	40 09	07 09	59 10	58 12
Ÿ	15 47 41.7	48.3 131 54.2 10.1 18 45.3 3.7	56.2	58 18	18 18	58 19 03 19			46 10 32 10	
	17 77 42.1	49.3 146 23.3 102 18 41.6 3.7	56.2 56.2	5 60 18		UN TA			MOON	
	18 92 42.3 5 3 19 107 42.5	51.2 175 21.7 10.3 18 34.0 3.9	56.1		an, of Ti	me M		Mer. Pas	- rue	Phase
	20 122 42.7 21 137 42.8	52.2 189 51.0 10.3 18 30.1 4.1 53.1 204 20.3 10.4 18 26.0 4.1	56.1 56.1			 +-	m h			
	21 137 72.0	54.1 218 49.7 105 18 21.9 4.3	56.0					05 17	33 21	
	22 152 43.0 23 167 43.2	55.1 233 19.2 10.5 18 17.6 4.3	56.0				50 06	00 18	1 27 22	

1980 DECEMBER 17, 18, 19 (WED., THURS., FRI.)

	ARÍES	VENUS -3.4	MARS +1.4	JUPITER -1.5	SATURN +1.1	STARS
G.M.T.	G.H.A.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec	Name S.H.A. Dec.
02 03	85 46.4 100 48.8 115 51.3 130 53.7 145 56.2	209 15.7 S18 26.4 224 15.0 27.2 239 14.3 27.9 254 13.6 28.7 269 12.8 29.4	154 53.8 S23 11.2 169 54.2 10.9 184 54.6 10.7 199 54.9 10.4 214 55.3 10.1	257 49.8 S 2 04.4 272 52.0 04.5 287 54.2 04.6 302 56.4 04.7 317 58.6 04.8	256 45.3 5 1 24.1 271 47.6 24.2 286 49.9 24.2 301 52.3 · 24.3 316 54.6 24.3	Acamar 315 36.8 S40 23.1 Achernar 335 44.9 S57 20.4 Acrux 173 37.1 S62 59.2 Adhara 255 31.6 S28 56.8 Aldebaran 291 17.5 N16 28.2
05 06 07 W 08	160 58.7 176 01.1 191 03.6 206 06.1 221 08.5	284 12.1 30.2 299 11.4 518 30.9 314 10.7 31.7 329 10.0 32.4 344 09.2 33.2 359 08.5 33.9	229 55.7 09.8 244 56.1 S23 09.6 259 56.4 09.3 274 56.8 09.0 289 57.2 08.7 304 57.6 08.5	333 00.8 04.9 348 03.0 \$ 2 05.0 3 05.2 05.1 18 07.4 05.2 33 09.6 05.3 48 11.9 05.4	331 56.9 24.4 346 59.3 S 1 24.4 2 01.6 24.4 17 03.9 24.5 32 06.3 24.5 47 08.6 24.6	Alioth 166 42.6 N56 03.6 Alkoid 153 18.7 N49 24.4 Al No'ir 28 15.0 S47 03.5 Alnilam 276 11.2 S 1 12.9 Alphard 218 20.2 S 8 34.5
N 11 E 12 S 13 D 14 A 15	236 11.0 251 13.5 266 15.9 281 18.4 296 20.8 311 23.3	14 07.8 34.7 29 07.1 \$18 35.4 44 06.3 36.2 59 05.6 36.9 74 04.9 37.7	319 57.9 08.2 334 58.3 S23 07.9 349 58.7 07.6 4 59.0 07.4 19 59.4 07.1	63 14.1 05.5 78 16.3 S 2 05.6 93 18.5 05.7 108 20.7 05.8 123 22.9 05.9	62 10.9 24.6 77 13.3 \$ 1 24.7 92 15.6 24.7 107 17.9 24.8 122 20.3 24.8	Alphecca 126 32.3 N26 46.8 Alpheratz 358 09.1 N28 59.2 Altair 62 32.7 N 8 49.1 Ankaa 353 40.0 \$42 24.9
16 17 18 19 20 21	326 25.8 341 28.2 356 30.7 11 33.2 26 35.6 41 38.1	89 04.2 38.4 104 03.4 39.2 119 02.7 S18 39.9 134 02.0 40.6 149 01.3 41.4 164 00.5 42.1	34 59.8 06.8 50 00.2 06.5 65 00.5 S23 06.2 80 00.9 06.0 95 01.3 05.7 110 01.7 05.4	138 25.1 06.0 153 27.3 06.1 168 29.5 5 2 06.2 183 31.7 06.3 198 33.9 06.4 213 36.1 06.5	137 22.6 24.8 152 24.9 24.9 167 27.3 S 1 24.9 182 29.6 25.0 197 31.9 25.0 212 34.2 25.1	Arcturus 146 18.6 N19 16.9 Atria 108 21.7 S68 59.5 Avior 234 27.6 S59 26.7 Bellatrix 278 58.2 N 6 19.9
03	56 40.6 71 43.0 86 45.5 101 48.0 116 50.4 131 52.9	178 59.8 42.9 193 59.1 43.6 208 58.3 518 44.3 223 57.6 45.1 238 56.9 45.8 253 56.1 46.6	125 02.0 05.1 140 02.4 04.8 155 02.8 S23 04.5 170 03.2 04.3 185 03.5 04.0 200 03.9 03.7	228 38.3 06.6 243 40.5 06.7 258 42.7 S 2 06.8 273 45.0 06.9 288 47.2 07.0 303 49.4 07.1	227 36.6 25.1 242 38.9 25.2 257 41.2 5 1 25.2 272 43.6 25.2 287 45.9 25.3 302 48.2 25.3	Canopus 264 06.6 S52 41.1 Capella 281 10.6 N45 58.7 Deneb 49 48.7 N45 12.9 Denebola 182 58.9 N14 40.7
04 05 06 07 T 08 H 09 U 10	146 55.3 161 57.8 177 00.3 192 02.7 207 05.2 222 07.7 237 10.1	268 55.4 47.3 283 54.7 48.0 298 53.9 S18 48.8 313 53.2 49.5 328 52.5 50.2 343 51.7 51.0 358 51.0 51.7	215 04.3 03.4 230 04.7 03.1 245 05.1 523 02.8 260 05.4 02.6 275 05.8 02.3 290 06.2 02.0 305 06.6 01.7	318 51.6 07.2 333 53.8 07.3 348 56.0 S 2 07.4 3 58.2 07.5 19 00.4 07.6 34 02.6 07.7 49 04.8 07.8	317 50.6 25.4 332 52.9 25.4 347 55.3 S 1 25.5 2 57.6 25.5 17 59.9 25.6 33 02.3 25.6 48 04.6 25.6	Diphda 349 20.6 S18 05.7 Dubhe 194 21.9 N61 51.0 Elnath 278 43.6 N28 35.4 Eltanin 90 58.2 N51 29.6 Enif 34 11.6 N 9 47.3 Fomalhout 15 51.3 S29 43.6
R 11 S 12 D 13 A 14 Y 15	252 12.6 267 15.1 282 17.5 297 20.0 312 22.5 327 24.9	13 50.3 52.4 28 49.5 \$18 53.1 43 48.8 53.9 58 48.1 54.6 73 47.3 55.3 88 46.6 56.0	320 06.9 01.4 335 07.3 S23 01.1 350 07.7 00.8 5 08.1 00.5 20 08.4 ·· 00.3 35 08.8 23 00.0	64 07.0 07.9 79 09.3 S 2 08.0 94 11.5 08.1 109 13.7 08.2 124 15.9 08.3 139 18.1 08.4	63 06.9 25.7 78 09.3 \$ 1 25.7 93 11.6 25.8 108 13.9 25.8 123 16.3 25.9 138 18.6 25.9	Gacrux 172 28.6 S57 00.0 Gienah 176 17.8 S17 26.0 Hadar 149 23.5 S60 16.5 Hamal 328 28.5 N23 22.4 Kaus Aust. 84 17.1 S34 23.6
17 18 19 20 21 22	342 27.4 357 29.8 12 32.3 27 34.8 42 37.2 57 39.7	103 45.8 56.8 118 45.1 518 57.5 133 44.4 58.2 148 43.6 58.9 163 42.9 18 59.6 178 42.1 19 00.4	50 09.2 22 59.7 65 09.6 522 59.4 80 09.9 59.1 95 10.3 58.8 110 10.7 58.5 125 11.1 58.2	154 20.3 08.5 169 22.5 S 2 08.6 184 24.7 08.7 199 27.0 08.8 214 29.2 08.9 229 31.4 09.0	198 27.9 26.1 213 30.3 ·· 26.1 228 32.6 26.2	Kochob 137 20.0 N74 13.9 Morkob 14 03.1 N15 06.2 Menkar 314 40.7 N 4 00.8 Menkent 148 37.1 S36 16.3 Miaplacidus 221 44.2 569 38.1
03 04	102 47.1 117 49.6 132 52.0 147 54.5	238 39.2 03.2 253 38.4 03.9 268 37.7 04.7	140 11.5 57.9 155 11.8 522 57.6 170 12.2 57.3 185 12.6 57.0 200 13.0 56.7 215 13.3 56.5	289 40.2 09.4 304 42.4 09.5 319 44.7 09.6	288 42.0 26.3 303 44.3 · 26.4 318 46.6 26.4	Nunki 76 29.4 S26 19.2 Peacock 53 58.7 S56 48.0 Pollux 243 57.7 N28 04.3
06 07 08 f 09 R 10	193 01.9 208 04.3 223 06.8 238 09.3	298 36.2 S19 06.1 313 35.4 06.8 328 34.7 07.5 343 34.0 08.2 358 33.2 08.9	275 14.9 55.3 290 15.2 55.0 305 15.6 54.7	349 49.1 5 2 09.8 4 51.3 09.9 19 53.5 10.0 34 55.7 10.1 49 58.0 10.1	348 51.3 5 1 26.5 3 53.7 26.5 18 56.0 26.6 33 58.3 26.6 49 00.7 26.7	Regulus 208 09.7 N12 03.6 Rigel 281 35.5 5 8 13.5 Rigil Kent. 140 26.1 560 45.0 Sabik 102 41.3 515 42.0
	268 14.2 283 16.7 298 19.1 313 21.6 328 24.1	28 31.7 S19 10.3 43 31.0 11.0 58 30.2 11.7 73 29.5 · 12.4 88 28.7 13.1	5 17.1 53.5 20 17.5 53.2 35 17.9 52.9	80 02.4 S 2 10.3 95 04.6 10.4 110 06.8 10.5 125 09.0 10.6 140 11.3 10.7	79 05.3 \$ 1 26.7 94 07.7 26.8 109 10.0 26.8 124 12.4 26.9 139 14.7 26.9	Schedar 350 08.6 N56 26.2 Shaula 96 56.0 S37 05.3 Sirius 258 55.2 S16 41.5 Spica 158 57.5 S11 03.5 Suhail 223 10.3 S43 21.1
18 19 20 21 22	28 33.9 43 36.4 58 38.8	118 27.2 S19 14.6 133 26.5 15.2 148 25.7 15.9 163 25.0 · 16.6 178 24.2 17.3	65 18.6 S22 52.3 80 19.0 52.0 95 19.4 51.7 110 19.8 51.4 125 20.2 51.1	1 170 15.7 S 2 10.9 185 17.9 11.0 200 20.1 11.1 215 22.3 - 11.2 230 24.6 11.3	169 19.4 S 1 27.0 184 21.7 27.0 199 24.1 27.1 214 26.4 27.1 229 28.7 27.2	Vega 80 56.2 N38 46.1 Zuben'ubi 137 33.1 S15 57.6 S.H.A. Mer. Pass.
Mer. Pa	73 41.3 h m ss. 18 10.0				,	Jupiter 171 57.3 6 44

1980 DECEMBER 17, 18, 19 (WED., THURS., FRI.)

		1980 DECEMBER 17, 1	8, 1	9 (WE	D., 1H	UK5., I	FR1.)			_
	SUN	MOON	Lat.	Twil Naut.	ight Civil	Sunrise	17	Moon:	19	20
G.M.T.	G.H.A. Dec.	G.H.A. V Dec. d H.P.	N 72	08 24	h m	h **	h m 12 51	12 38	12 19	11 36
17 00	180 59.3 S23 21.2	64 58.1 9.6 N 3 35.9 12.3 59.7	N 70	08 04	09 52		13 00 13 07	12 55 13 08	12 49 13 12	12 43 13 20
- 01	195 59.0 21.3	79 26.7 9.5 3 48.2 12.3 59.7 93 55.2 9.5 4 00.5 12.3 59.8	68	07 48 07 35	09 17 08 52	10 32	13 12	13 19	13 30 13 44	13 46 14 07
02 ! 03	225 58.4 · · 21.5	108 23.7 9.5 4 12.8 12.3 59.8	64 62	07 24 07 14	08 32 08 16	09 50 09 22	13 17 13 22	13 29 13 37	13 56	14 23
04 05	240 58.1 23.5 255 57.8 21.6	122 52.2 9.5 4 25.1 12.2 59.8 137 20.7 9.4 4 37.3 12.3 59.8	60	07 06	08 02	09 00	13 25	13 44	14 07 14 16	14 37 14 49
06	270 57.5 S23 21.7	151 49.1 9.3 N 4 49.6 12.2 59.8 166 17.4 9.3 5 01.8 12.1 59.8	N 58	06 58	07 51	08 43 08 28	13 29 13 32	13 50 13 56	14 24	14 59
w 07	285 57.2 21.8 300 56.9 21.9	180 45.7 9.3 5 13.9 12.2 59.8	54 52	06 45 06 39	07 31 07 23	08 15 08 04	13 35 13 37	14 01 14 05	14 31 14 38	15 08 15 17
E 09	315 56.5 ·· 22.0 330 56.2 22.1	195 14.0 9.3 5 26.1 12.1 59.9 209 42.3 9.2 5 38.2 12.2 59.9	50	06 34	07 16	07 54 07 34	13 39 13 44	14 09 14 18	14 43 14 56	15 24 15 40
N 11	345 55.9 22.2	224 10.5 9.1 5 50.4 12.0 59.9 238 38.6 9.1 N 6 02.4 12.1 59.9	45 N 40	06 22	07 00 06 46	07 17	13 49	14 26	15 07	15 53
S 12	0 55.6 S23 22.2 15 55.3 22.3	253 06.7 9.1 6 14.5 12.0 59.9	35 30	06 03 05 54	06 34 06 24	07 03	13 52 13 55	14 32 14 38	15 16 15 24	16 04 16 14
A 15	30 55.0 22.4 45 54.7 22.5	267 34.8 9.0 6 26.5 12.0 59.9 282 02.8 9.0 6 38.5 11.9 59.9	20	05 37	06 05 05 48	06 29 06 10	14 01 14 06	14 48 14 56	15 37 15 50	16 31 16 45
Y 16 17	60 54.4 22.6	296 30.8 8.9 6 50.4 12.0 59.9 310 58.7 8.9 7 02.4 11.8 60.0	N 10	05 21	05 30	05 53	14 11	15 05	16 01	16 59
18	90 53.8 523 22.7	325 26.6 8.9 N 7 14.2 11.9 60.0	S 10	04 45	05 12 04 52	05 35	14 15 14 21	15 13 15 22	16 13 16 25	17 13 17 28
19 20		354 22.3 87 7 37.9 11.8 60.0	30	03 54	04 27	04 54 04 41	14 27 14 30	15 32 15 38	16 39 16 47	17 46 17 56
21 22	135 52.9 . 22.9		40		03 54	04 26	14 34	15 45 15 53	16 57 17 08	18 07 18 21
23	165 52.3 23.1	37 45.4 8.6 8 13.1 11.6 60.0		02 41	03 31	04 08	14 38	16 03	17 22	18 37
18 00	180 52.0 S23 23.2 195 51.6 23.2	66 40.6 8.5 8 36.3 11.5 60.0	52	01 28	02 46	03 35	14 46	16 07	17 28 17 35	18 45 18 54
02 03	2 210 51.3 23.3 3 225 51.0 · 23.4	1 95 35.5 8.4 8 59.3 11.5 60.1	56	III	02 06	03 08	14 52 14 56	16 18 16 24	17 43 17 52	19 04 19 15
04		110 02.9 8.4 9 10.8 11.3 60.1			00 46		15 00	16 31	18 02	19 28
0.	6 270 50.1 S23 23.6	138 57.6 BZ N 9 33.5 11.3 60.1				vilight			onset	20
0 τ 0		7 167 52.1 81 9 56.0 11.2 60.	ـــــا ١	Sunse	Civil	Naut.	17	18	T 19	70
н 0 u 1			1 _	. ,		, , , , , ,	02 35	04 40	06 55	09 39
R l	1 345 48.6 23.	9 211 13.4 8.0 10 29.3 11.0 60.			12 59		02 29	04 25	06 26	08 33
S 1 D 1		0 240 07.3 7.9 10 51.2 10.9 60.	1 6	8 -	14 36 15 07			04 13	06 05 05 48	07 57 07 32
A I	.4 30 47.6 24. 5 45 47.3 · 24.	2 269 01.0 7.8 11 12.9 10.7 60.	i 6	4 14 0	3 15 21	16 30	02 17		05 35 05 23	07 12
1	6 60 47.0 24.	2 283 27.8 7.8 11 23.6 10.6 60.	- T -	2 14 3 0 14 5			02 12	03 42	05 14	06 43
	.7	3 312 21.2 7.7 N11 44.8 10.5 60		8 15 1 6 15 2					05 05 04 58	
	19 105 46.1 24 20 120 45.8 24	5 341 14.4 7.6 12 05.8 10.3 60	.2	4 15 3	8 16 2	2 17 08	02 06			1
;	21 135 45.5 24	4 I 10 074 74 12 26.4 10.2 60	.2	52 15 4 50 15 5	9 16 3	8 17 19	02 03	3 03 21	04 40	05 58
	23 165 44.9 24	6 24 33.8 74 12 36.6 10.2 60	.2	15 16 2 10 16 3	1 .		1	` \	04 19	05 30
19	00 180 44.6 \$23 24 01 195 44.3 24	17 53 26.5 7.3 12 56.8 10.0 60	.2	35 16 5	1 17 1	9 17 5	1 01 5			
	02 210 44.0 24 03 225 43.6 · 24	18 67 52.8 7.2 13 06.8 9.9 60	2	30 17 (20 17 (5 17 4	9 18 1	6 01 4	9 02 50	03 5	2 04 55
	04 240 43.3 24	96 45.1 7.1 13 26.5 9.7 60		10 17 4 0 18 9				3 02 36	5 03 3	1 04 29
	05 255 43.0 24 06 270 42.7 523 2!	5.0 125 37.3 6.9 N13 45.8 9.6 60).2 S	10 18 1 20 18 1						1 04 02
	07 285 42.4 25	5.0 1140 03.2 7.0 13 55.4 9.4 60 5.1 154 29.2 6.9 14 04 8 9.4 60	0.2	30 18	59 19 2	27 20 0	0 01 3	4 02 1		
-	09 315 41.8 · · 2	5.1 168 55.1 6.8 14 14.2 9.2 6		35 19 40 19	27 20	00 20 4	2 01 2	9 02 0	5 02 4	4 03 27
R		5.2 197 46.7 6.7 14 32.6 91 6	0.2	45 19 50 20	1		1		1	3 03 01
D A	12 0 40.9 S23 2 13 15 40.6 2	5.3 226 38.1 6.7 14 50.7 8.8 6	0.2	52 20	19 21	08 22 2	6 01 2	2 01 4		3 02 46
Ŷ	14 30 40.2 2	5.3 241 03.8 6.6 14 59.5 88 6 5.4 255 29.4 6.5 15 08.3 8.7 6	0.2	54 20 56 20	45 21	48 1111	01 1	19 01 4	1 05 (7 02 38
	16 60 39.6 2	5.4 269 54.9 6.5 15 17.0 8.6 6	0.2	58 21 60 21					1	
	17 75 39.3 2 18 90 39.0 S23 2	5.5 298 45.8 6.4 N15 34.1 84 6	0.2		SU		\neg		MOON	
	19 105 38.7	15.5 313 11.2 6.4 15 42.5 82 6 15.6 327 36.6 6.3 15 50.7 8.2 6	0.1 C	``	in. of Tim O" 1	ne Me 2" Pas		ler. Pass. per Low	er Age	Phase
	21 135 38.1 · ·	25.6 342 01.9 6.3 15 58.9 8.1 6 25.6 356 27.2 6.2 16 07.0 7.9 6			,	3 6	m h	m h	m 6	
		25.7 10 52.4 6.2 16 14.9 7.9 6			28 03	43 11 14 11	57 21	18 08	50 11	\mathbf{O}
	S.D. 16.3 d	0.1 S.D 16.3 16.4	16.4			44 11	57 22	15 09	46 12	
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	Ö	SUN PLANETS	ARIES	MOON	or Corra	or Corra	or Corra	Ī	SUN PLANETS	ARIES	моом		or Corra	or Corre
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	02 03 04 05	0 00-5 0 00-8 0 01-0 0 01-3	0 00-8 0 01-0 0 01-3	0 00-7 0 01-0 0 01-2	0-3 0-0 0-4 0-0 0-5 0-0	6-3 0-1 6-4 0-1 6-5 0-1	12-3 D1 12-4 D1 12-5 D1	03 04 05	0 15-8 0 16-0 0 16-3	0 15-8 0 16-0 0 16-3	0 15-0 0 15-3 0 15-5	0-3 0-0 0-4 0-0 0-5 0-0	6-3 0-2 6-4 0-2 6-5 0-2	12·3 0·3 12·4 0·3 12·5 0·3
	06 07 08 09	0 01·5 0 01·8 0 02·0 0 02·3	0 01-5 0 01-8 0 02-0 0 02-3	0 01-4 0 01-7 0 01-9 0 02-1	0-6 0-0 0-7 0-0 0-8 0-0 0-9 200	6-6 0-1 6-7 0-1 6-8 0-1 6-9 0-1	12-6 O·l 12-7 O·l 12-8 O·l 12-9 O·l	06 07 08 09	0 16-5 0 16-8 0 17-0 0 17-3	0 165 0 168 0 170 0 173	0 15-7 0 16-0 0 16-2 0 16-5	0-6 0-0 0-7 0-0 0-8 0-0 0-9 0-0	6-6 0-2 6-7 0-2 6-8 0-2 6-9 0-2	12-6 0-3 12-7 0-3 12-8 0-3 12-9 0-3
	10 11 12	0 02·5 0 02·8 0 03·0	0 02·5 0 02·8 0 03·0	0 02-4 0 02-6 0 02-9 0 03-1	1-0 0-0 1-1 0-0 1-2 0-0 1-3 0-0	7-0 0-1 7-1 0-1 7-2 0-1 7-3 0-1	13-0 O·l 13-1 O·l 13-2 O·l 13-3 O·l	10 11 12 13	0 17-5 0 17-8 0 18-0 0 18-3	0 17·5 0 17·8 0 18·0 0 18·3	0 16-7 0 16-9 0 17-2 0 17-4	1·0 0·0 1·1 0·0 1·2 0·0 1·3 0·0	7·0 0·2 7·1 0·2 7·2 0·2 7·3 0·2	13-0 0-3 13-1 0-3 13-2 0-3 13-3 0-3
	13 14 15 16	0 03-3 0 03-5 0 03-8 0 04-0	0 03-3 0 03-5 0 03-8 0 04-0	0 03-3 0 03-6 0 03-8	1-4 0-0 1-5 0-0 1-6 0-0	74 01 75 01	13-4 0-1 13-5 0-1 13-6 0-1	14 15 16	0 18-5 0 18-8 0 19-0	0 186 0 188 0 191	0 17-7 0 17-9 0 18-1	1-4 0-0 1-5 0-0 1-6 0-0	7-4 0-2 7-5 0-2 7-6 0-2	13-4 0-3 13-5 0-3 13-6 0-3 13-7 0-3
	17 18 19	0 04-3 0 04-5 0 04-8 0 05-0	0 04-3 0 04-5 0 04-8	0 04-1 0 04-3 0 04-5	1-7 0-0 1-8 0-0 1-9 0-0 2-8 0-0	7-8 0-1 7-9 0-1	13-7 O·1 13-8 O·1 13-9 O·1 14-0 O·1	17 18 19 20	0 19-3 0 19-5 0 19-8 0 20-0	0 19-3 0 19-6 0 19-8 0 20-1	0 18-4 0 18-6 0 18-9 0 19-1	1.7 0.0 1.8 0.0 1.9 0.0	7-7 0-2 7-8 0-2 7-9 0-2 8-0 0-2	13-8 0-3 13-9 0-3 14-0 0-4
	20 21 22 23 24	0 05-3 0 05-5 0 05-8 0 06-0	0 05-3 0 05-5 0 05-8 0 06-0	0 05-0 0 05-2 0 05-5 0 05-7	2-1 0-0 2-2 0-0 2-3 0-0 2-4 0-0	8-1 0-1 8-2 0-1 8-3 0-1	14-1 0-1 14-2 0-1 14-3 0-1 14-4 0-1	21 22 23 24	0 20-3 0 20-5 0 20-8	0 20-3 0 20-6 0 20-8 0 21-1	0 19-3 0 19-6 0 19-8 0 20-0	2-1 0-1 2-2 0-1 2-3 0-1 2-4 0-1	8-1 0-2 8-2 0-2 8-3 0-2 8-4 0-2	14-1 0-4 14-2 0-4 14-3 0-4 14-4 0-4
	25 26 27	0 06-3 0 06-5 0 06-8	0 063 0 065 0 068	0 06-0 0 06-2 0 06-4	2-5 0-0 2-6 0-0 2-7 0-0	8-5 0-1 8-6 0-1 8-7 0-1	14-5 0-1 14-6 0-1 14-7 0-1	25 26 27	0 21-3 0 21-5 0 21-8	0 21·3 0 21·6 0 21·8 0 22·1	0 20-3 0 20-5 0 20-8 0 21-0	2-5 0·1 2-6 0·1 2-7 0·1 2-8 0·1	8-5 0-2 8-6 0-2 8-7 0-2 8-8 0-2	
	28 29 30 31	0 07·0 0 07·3 0 07·5 0 07·8	0 07-0 0 07-3 0 07-5 0 07-8	0 06-7 0 06-9 0 07-2 0 07-4	2-8 0-6 2-9 0-0 3-0 0-0 3-1 0-6	8-9 0-1 9-0 0-1	14-8 0-1 14-9 0-1 15-0 0-1 15-1 0-1	29 30	0 22-3	0 22-3 0 22-6 0 22-8	0 21·2 0 21·5 0 21·7	2-9 0-1 3-0 0-1	8-9 0-2 9-0 0-2 9-1 0-2	14·9 0·4 15·0 0·4 15·1 0·4
	32 33 34	0 08-0 0 08-3 0 08-5	0 08-0 0 08-3 0 08-5	0 07-6 0 07-9 0 08-1	3-2 0-0 3-3 0-0 3-4 0-0	9-2 0-1 9-3 0-1 9-4 0-1	15-2 0-1 15-3 0-1 15-4 0-1	33 34	0 23-3	0 23-1 0 23-3 0 23-6	0 22-0 0 22-2 0 22-4	3-3 0·1 3-4 0·1	9-2 0-2 9-3 0-2 9-4 0-2 9-5 0-2	15-3 0-4 15-4 0-4
	35 36 37 38	0 08-8 0 09-0 0 09-3 0 09-5	0 08-8 0 09-0 0 09-3 0 09-5	0 08-4 0 08-6 0 08-8 0 09-1	3-7 (3-1	9-6 0-1 9-7 0-1		36 37 38	0 24-0 0 24-3 0 24-5	0 24-3 0 24-6	0 22-7 0 22-9 0 23-1 0 23-4	3-6 0-1 3-7 0-1 3-8 0-1	9-6 0-2 9-7 0-2 9-8 0-2	15·6 0·4 15·7 0·4 15·8 0·4
	39 40 41	0 09-8 0 10-0 0 10-3	0 09-8 0 10-0 0 10-3 0 10-5	0 09-3 0 09-5 0 09-8 0 10-0	4-0 0- 4-1 0-	0 10-0 0-1 0 10-1 0-1	16-0 0-1 16-1 0-1	4 4 4	0 250 L 0 253	0 251	0 24-1	4-0 0-1 4-1 0-1	10-0 0-3 10-1 0-3	3 16-0 0-4 3 16-1 0-4
	42 43 44 45	0 10-5 0 10-8 0 11-0 0 11-3	0 10-8	0 10-3	4-3 D 4-4 D	0 10-3 0-1 0 10-4 0-1	16-3 0-1 16-4 0-1 16-5 0-1	1 4	0 25-8 0 26-0 5 0 26-3	0 25-8 0 26-1 0 26-3	0 24-6 0 24-8 0 25-1	4-4 01	10-4 0-3 10-5 0-3	3 16·4 D·4 3 16·5 D·4
	46 47 48 49	0 11-5 0 11-8 0 12-0	0 11·8 0 12·0	0 11-2	2 4-7 D 5 4-8 D	0 10-7 0-1	16-7 0-1 16-8 0-	1 4 1 4	7 0 26-8	3 0 26-8 3 0 27-1	0 25	5 4-7 0-1 8 4-8 0-1	10-7 O-1 10-8 O-1	3 16·7 0·4 3 16·8 0·4 3 16·9 0·4
	50 51 52 53	0 12-8	0 12-8	0 11-0 0 12-0 0 12-0	9 5-0 0- 2 5-1 0 4 5-2 0	0 11-0 0- 0 11-1 0- 0 11-2 0- 0 11-3 0-	1 17·1 0 1 17·2 0	1 5	0 0 27-1 1 0 27-1 2 0 28-1 3 0 28-2	8 0 274 0 0 28-3	3 0 26 1 0 26 3 0 27	5 5-1 0-1 7 5-2 0-1 0 5-3 0-1	1 11-1 0- 1 11-2 0- 1 11-3 0-	3 17·1 0·4 3 17·2 0·4 3 17·3 0·4
	54 55 56	0 13-5 0 13-6 0 14-6	0 13-5 0 13-8 0 0 14-0	0 12-	9 5-4 0 1 5-5 0 4 5-6 0	0 11-4 0- 0 11-5 0- 0 11-6 0-	1 17-4 0- 1 17-5 0- 1 17-6 0-	1 5	4 0 28 5 0 28 6 0 29	8 0 284 0 0 29	8 0 27- 1 0 27-	4 5-5 0-1 7 5-4 0-1	1 11-5 O- 1 11-6 O-	3 17-5 0-4 3 17-6 0-4
	57 56 59	0 14-	5 0 14-5 8 0 14-8	0 13-	8 5-8 0 1 5-9 0	-0 11-7 0- -0 11-8 0- -0 11-9 0- -1 12-8 0	1 17-8 0 1 17-9 0	1 1	57 0 29- 58 0 29- 59 0 29- 50 0 30-	5 0 29 8 0 29	6 0 28 8 0 28	2 5-8 0- 4 5-9 0-	1 11-8 0 1 11-9 0	3 17·8 04 3 17·9 04
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	04 05 06 07 08 09	2 31-0 2 31-3 2 31-5 2 31-8 2 32-0 2 32-3	2 31-4 2 31-7 2 31-9 2 32-2 2 32-4 2 32-7	2 24-1 2 24-6 2 24-6 2 24-8 2 25-1 2 25-3	0-4 0-1 0-5 0-1 0-6 0-1 0-7 0-1 0-8 0-1 0-9 0-2	6-4 1·1 6-5 ·1·1 6-6 1·2 6-7 1·2 6-8 1·2 6-9 1·2	12-4 2-2 12-5 2-2 12-6 2-2 12-7 2-2 12-8 2-2 12-9 2-3	04 05 06 07 08 09	2 460 2 463 2 465 2 468 2 47-0 2 47-3	2 46-5 2 46-7 2 47-0 2 47-2 2 47-5 2 47-7	2 38-7 2 38-9 2 39-2 2 39-4 2 39-6	0-5 0-1 0-6 0-1 0-7 0-1 0-8 0-2 0-9 0-2	6-5 1-2 6-6 1-3 6-7 1-3 6-8 1-3 6-9 1-3	12-5 2-4 12-6 2-4 12-7 2-4 12-8 2-5 12-9 2-5
	10 11 12 13 14	2 32·5 2 32·8 2 33·0 2 33·3 2 33·5	2 32-9 2 33-2 2 33-4 2 33-7 2 33-9	2 25-6 2 25-8 2 26-0 2 26-3 2 26-5	1·0 0·2 1·1 0·2 1·2 0·2 1·3 0·2 1·4 0·2	7-0 1-2 7-1 1-2 7-2 1-3 7-3 1-3 7-4 1-3	13-0 2-3 13-1 2-3 13-2 2-3 13-3 2-3 13-4 2-3	10 11 12 13 14	2 47-5 2 47-8 2 48-0 2 48-3 2 48-5	2 48-0 2 48-2 2 48-5 2 48-7 2 49-0	2 39-9 2 40-1 2 40-3 2 40-6 2 40-8	1-0 0-2 1-1 0-2 1-2 0-2 1-3 0-2 1-4 0-3	7-2 1-4 7-3 1-4 7-4 1-4	13-0 2-6 13-1 2-5 13-2 2-5 13-3 2-5 13-4 2-6
	15 16 17 18 19	2 33·8 2 34·0 2 34·3 2 34·5 2 34·8	2 34-2 2 34-4 2 34-7 2 34-9 2 35-2	2 26-7 2 27-0 2 27-2 2 27-5 2 27-7	1-5 0-3 1-6 0-3 1-7 0-3 1-8 0-3 1-9 0-3	7-5 1-3 7-6 1-3 7-7 1-3 7-8 1-4 7-9 1-4	13-5 2-4 13-6 2-4 13-7 2-4 13-8 2-4 13-9 2-4 14-0 2-5	15 16 17 18 19 20	2 488 2 490 2 493 2 495 2 498 2 500	2 492 2 495 2 497 2 500 2 502 2 505	2 41-1 2 41-3 2 41-5 2 41-8 2 42-0 2 42-3	1.5 0.3 1.6 0.3 1.7 0.3 1.8 0.3 1.9 0.4	7-6 1-5 7-7 1-5 7-8 1-5 7-9 1-5	13-5 2-6 13-6 2-6 13-7 2-6 13-8 2-6 13-9 2-7
	20 21 22 23 24 25	2 350 2 353 2 355 2 358 2 360 2 363	2 354 2 357 2 359 2 362 2 364 2 367	2 28-7 2 28-9	2-4 0-4	8-0 1-4 8-1 1-4 8-2 1-4 8-3 1-5 8-4 1-5 8-5 1-5	14-1 2-5 14-2 2-5 14-3 2-5 14-4 2-5	21 22 23 24 25	2 50-3 2 50-5 2 50-8 2 51-0	2 50-7 2 51-0 2 51-2 2 51-5 2 51-7	2 42·5 2 42·7 2 43·0 2 43·2 2 43·4	2-1 0-4 2-2 0-4 2-3 0-4 2-4 0-1	8-1 1-6 0-2 1-6 8-3 1-6 5 8-4 1-6	14-1 2-7 14-2 2-7 14-3 2-7 14-4 2-8
	26 27 28 29 30	2 365 2 368 2 37.0 2 37.3 2 37.5	2 36-9 2 37-2 2 37-4 2 37-7	2 294 2 296 2 298 2 301	2-6 0-5 2-7 0-5 2-8 0-5 2-9 0-5	8-6 1-5 8-7 1-5 8-8 1-5 8-9 1-6	14-6 2-6 14-7 2-6 14-8 2-6 14-9 2-6	26 27 28 29	2 51·5 2 51·8 2 52·0 2 52·3	2 52·0 2 52·2 2 52·5 2 52·7 2 53·0	2 44-4		5 8-7 1-7 5 8-8 1-7 6 8-9 1-7 6 9-0 1-7	7 14-7 2-8 7 14-8 2-8 7 14-9 2-9 7 15-0 2-9
	31 32 33 34 35	2 37-8 2 38-0 2 38-3 2 38-5 2 38-8	2 38-2 2 38-4 2 38-7 2 38-9	2 30-6 2 30-6 2 31-6 2 31-3	3-1 0-5 3-2 0-6 3-3 0-6 3-4 0-6	9-1 1-6 9-2 1-6 9-3 1-6 9-4 1-6	15-1 2-6 15-2 2-7 15-3 2-7 15-4 2-7	32 33 34	2 53-0 2 53-3 2 53-5	2 53-5 2 53-7 2 54-0	2 451 2 454 2 456 2 458	3-2 () 3-3 () 3-4 () 3-5 ()	6 9-2 1-1 6 9-3 1-1 7 9-4 1-1 7 9-5 1-	3 15-2 2-9 8 15-3 2-9 8 15-4 3-0 8 15-5 3-0
	36 37 38 39	2 390 2 393 2 395 2 396	2 394 2 395 2 396 3 2 406	2 31-1 7 2 32-1 9 2 32-1 2 2 32-1	3 3-6 0-6 0 3-7 0-6 2 3-8 0-5 5 3-9 0-	9.6 1. 9.7 1. 7 9.8 1.	7 15-7 2-7 7 15-8 2-8 7 15-9 2-8	37	7 2 54-3 B 2 54-5 9 2 54-8	2 54-7 2 55-0 2 55-2	2 463 2 466 2 466	3-7 0 3-8 0 3-9 0	·7 9·6 1· ·7 9·7 1· ·7 9·8 1· ·7 9·9 1· ·8 10·0 1·	9 15·7 3·0 9 15·8 3·0 9 15·9 3·0
	41 42 43 44	2 40: 2 40: 2 40: 2 41:	2 40- 5 2 40- 8 2 41- 0 2 41-	7 2 32- 9 2 33- 2 2 33- 4 2 33-	9 4-1 D 2 4-2 D 4 4-3 D 7 4-4 D	8 10-3 1- 8 10-4 1-	8 16-2 2-8 8 16-3 2-9 8 16-4 2-9	9 4	2 2 554 3 2 554	5 2 56 8 2 56 0 2 56	0 2 47·1 2 2 47·1 5 2 48·1	5 4-2 0 7 4-3 0 3 4-4 0	10-2 2- 18 10-3 2 10-4 2 10-5 2	0 16·2 3·1 ·0 16·3 3·1 ·0 16·4 3·1 ·0 16·5 3·2
	46 41 41 41 51	2 41- 7 2 41- 3 2 42- 2 42-	5 2 41- 8 2 42- 0 2 42- 3 2 42-	9 2 34 2 2 34 4 2 34 7 2 34	1 4-6 0 4 4-7 0 -6 4-8 0 -9 4-9 0	8 10-6 l	9 16-6 2- 9 16-7 2- 9 16-8 2- 9 16-9 3-	9 4 9 4 9 4	6 2 56 7 2 56 8 2 57 9 2 57 60 2 57	8 2 57- 0 2 57- 3 2 57-	2 2 48- 5 2 48- 7 2 49-	7 4-7 1 9 4-8 1 2 4-9 1	D-9 10-6 2 D-9 10-7 2 D-9 10-8 2 D-9 10-9 2	1 16-7 3-2 1-1 16-8 3-2 1-1 16-9 3-2 1-1 17-8 3-3
	5 5 5	1 2 42- 2 2 43- 3 2 43- 4 2 43-	8 2 43 0 2 43 3 2 43 5 2 43	2 2 35 4 2 35 -7 2 35 -9 2 36	5-1 0 -6 5-2 0 -8 5-3 0 -1 5-4 0	9 11-1 1 9 11-2 2 9 11-3 2 9 11-4 2	.9 17-1 3- .0 17-2 3- .0 17-3 3- .0 17-4 3	0	51 2 57- 52 2 58- 53 2 58- 54 2 58- 55 2 58-	8 2 58 0 2 58 3 2 58 5 2 59	2 2 49- 5 2 49- 7 2 50 60 2 50	7 5-1 1 9 5-2 1 1 5-3 4 5-4	1-0 11-1 2 1-0 11-2 2 1-0 11-3 2 1-0 11-4 2	2-2 17-3 3-3 2-2 17-4 3-3 2-2 17-5 3-4
	5 5	6 2 44 7 2 44 8 2 44 9 2 44	0 2 44 3 2 44 5 2 45 8 2 45	4 2 36 -7 2 36 -0 2 37 -2 2 3	55 5.6] 58 5.7] 70 5.8] 7-2 5.9]	0 11-6 2 0 11-7 2 0 11-8 2 0 11-9 2	2:0 17:6 3 2:0 17:7 3 2:1 17:8 3 2:1 17:9 3	1 1	56 2 59 57 2 59 58 2 59 59 2 59 60 3 00	0 2 59 3 2 59 5 3 00 8 3 00	5 2 50 7 2 51 90 2 51 92 2 51	·8 5·6 ·1 5·7 ·3 5·8 ·6 5·9	1-1 11-6 1-1 11-7 1-1 11-8 1-1 11-9 1-2 12-6	2-2 17-6 3-4 2-2 17-7 3-4 2-3 17-8 3-4 2-3 17-8 3-4
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14	SUN PLANETS	ARIES	моон	to or Corra d	or Corr*	or Corr*	15	SUN PLANETS	ARIES	MOON	or Corra	or Corra	or Corre
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04 05 06 07	3 31 0 3 31 3 3 31 5 3 31 8	3 31.6 3 31.8 3 32.1 3 32.3	3 21-4 3 21-6 3 21-9 3 22-1	0-4 O-1 0-5 O-1 0-6 O-1 0-7 O-2	6-4 1-5 6-5 1-6 6-6 1-6 6-7 1-6	12-4 3-0 12-5 3-0 12-6 3-0 12-7 3-1	04 05 06 07	3 460 3 463 3 465 3 468	3 466 3 469 3 47·1 3 47·4	3 357 3 359 3 362 3 364	0-4 0-1 0-5 0-1 0-6 0-2 0-7 0-2	6-4 1-7 6-5 1-7 6-6 1-7 6-7 1-7	12-4 3-2 12-5 3-2 12-6 3-3 12-7 3-3
08 09 10 11	3 32·0 3 32·3 3 32·5 3 32·8	3 32·6 3 32·8 3 33·1 3 33·3	3 22-3 3 22-6 3 22-8 3 23-1	0·8 0·2 0·9 0·2 1·0 0·2 1·1 0·3	6-8 1-6 6-9 1-7 7-0 1-7 7-1 1-7	12-8 3-1 12-9 3-1 13-0 3-1 13-1 3-2	08 09 10 11	3 47·0 3 47·3 3 47·5 3 47·8	3 47-6 3 47-9 3 48-1 3 48-4	3 367 3 369 3 371 3 374	0-8 0-2 0-9 0-2 1-0 0-3 1-1 0-3	6-8 1-8 6-9 1-8 7-0 1-8 7-1 1-8	12-8 3-3 12-9 3-3 13-6 3-4 13-1 3-4
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16 17 18 19	3 34-0 3 34-3 3 34-5 3 34-8	3 34-6 3 34-8 3 35-1 3 35-3	3 243 3 245 3 247 3 250	1-6 0-4 1-7 0-4 1-8 0-4 1-9 0-5	7-6 1-8 7-7 1-9 7-8 1-9 7-9 1-9	13·6 3·3 13·7 3·3 13·8 3·3 13·9 3·4	16 17 18 19	3 490 3 493 3 495 3 498	3 49-6 3 49-9 3 50-1 3 50-4	3 386 3 388 3 390 3 393 3 395	1-6 0-4 1-7 0-4 1-8 0-5 1-9 0-5	7-6 2-0 7-7 2-0 7-8 2-0 7-9 2-0 8-0 2-1	13-4 3-5 13-7 3-5 13-8 3-6 13-9 3-6 14-0 3-6
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01	6 303	6 31.3	6 12·5 6 12·7	0-1 0-0 0-2 0-1	1	12-1 5-3 12-2 5-4	02	6 455	6 46-6	6 27-0	0.2 0-1	· 1	12.2 56
02	6 30-5	6 31·6 6 31·8	6 12-9	0-3 0-1		12-3 5-4	03	6 458	6 469	6 27-3	0-3 G-	6-3 2-9	12.3 5-6
04	6 31.0	6 32-1	6 13-2	0-4 O-2	1	12-4 5-5	04	6 46-0	6 47-1	6 27-5	0-4 D-2	2 6-4 2-9	12-4 5-7
05	6 31-3	6 32-3	6 13-4	0-5 0-2	6-5 2-9	12-5 5-5	05	6 46-3	6 47-4	6 27-7	0-5 0-2	2 65 30	12-5 5-7
06	6 31-5	6 32-6	6 13-7	0-6 0-3	6-6 2-9	12-6 5-6	06	6 46-5	6 47-6	6 28-0	0.6 0.		12-6 5-8
07	6 31-8	6 32-8	6 13-9	0-7 D-3	1	12.7 5-6	07	6 468	6 47-9	6 28-2	0-7 0-		12-7 5-8 12-8 5-9
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111	6 32-8	6 34-1		1-2 0-		13-2 5-8	12	6 48-0	6 49-1	6 29-4	1·2 O		13-2 6-1
13	6 33-3	6 34-3	6 15-3	1-3 0-6		13-3 5-9	13	6 48-3	6 494	6 29-7	1·3 O		13-3 61
14	6 33-5	6 34-6	6 156	1-4 0-6	5 74 3-3	13-4 5-9	14	6 48-5	6 49 6	6 29-9	1-4 D-	6 7.4 3.4	13-4 6-1
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29	6 37-3	6 383	6 19-2	2.9 1				6 52-3	6 53-4	6 33-5	2.9 1	.3 8-9 4-3	14-9 6-8
30	6 37-5	6 38-6	6 194	3.0 1.	3 9-0 4-0	15-0 6-6	30	6 52-5	6 53-6	6 33-7	3-0 1	.4 9-0 4:	15.0 6.9
31	L	6 38-8	6 19-6	3-1 1-		15-1 6-7	31	6 52-8	6 53-9	6 33-9	11	-4 9-1 4-7	
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33		6 39-3	6 20-1	3-3 1-				6 53-3	6 54-4	6 34-4	11	·5 9·3 4·3 ·6 9·4 4·3	
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35		6 39-8	6 20-6	3.5 l		1			6 54.9	6 351	41	-7 9-6 4-	11 11 11 11
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38		6 40-6	6 21-3	3-8 l		L			6 55-6		41	-7 9-8 4-	
39	6 398	6 40-8	6 21.5	3.9 1	7 9.9 4	15-9 7-0	39	6 54-8	6 55-9	6 359	3-9	L-8 9-9 4·	5 15.9 7.3
40	6 40-0	6 41-1			8 10-9 4-							L-8 10-6 4·	1
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05 06 07 08 09	7 31-3 7 31-5 7 31-8 7 32-0 7 32-3	7 32-5 7 32-7 7 33-0 7 33-2 7 33-5	7 10-7 7 10-9 7 11-2 7 11-4 7 11-6	0-4 0-2 0-5 0-3 0-6 0-3 0-7 0-4 0-8 0-4 0-9 0-5	64 33 65 33 66 34 67 34 68 35 69 35	12-4 6-3 12-5 6-4 12-6 6-4 12-7 6-5 12-8 6-5 12-9 6-6	05 06 07 08 09	7 460 7 463 7 465 7 468 7 470 7 473	7 47-3 7 47-5 7 47-8 7 48-0 7 48-3 7 48-5	7 250 7 252 7 255 7 255 7 257 7 260	0-4 0-2 0-5 0-3 0-6 0-3 0-7 0-4 0-8 0-4 0-9 0-5	6-5 3-4 6-6 3-5 6-7 3-5 6-8 3-6 6-9 3-6	12-5 6-6 12-6 6-6 12-7 6-7 12-8 6-7 12-9 6-8
10 11 12 13 14	7 32-5 7 32-8 7 33-0 7 33-3 7 33-5	7 33-7 7 34-0 7 34-2 7 34-5 7 34-7	7 11-9 7 12-1 7 12-4 7 12-6 7 12-8	1-0 0-5 1-1 0-6 1-2 0-6 1-3 0-7 1-4 0-7	7-9 3-6 7-1 3-6 7-2 3-7 7-3 3-7 7-4 3-8	13-0 6-6 13-1 6-7 13-2 6-7 13-3 6-8 13-4 6-8	10 11 12 13 14	7 47-5 7 47-8 7 48-0 7 48-3 7 48-5	7 488 7 490 7 493 7 495 7 498	7 262 7 264 7 267 7 269 7 272	1-0 0-5 1-1 0-6 1-2 0-6 1-3 0-7 1-4 0-7	7-4 3-7 7-1 3-7 7-2 3-8 7-3 3-8 7-4 3-9	13-0 6-8 13-1 6-9 13-2 6-9 13-3 7-8 13-4 7-0
15 16 17 18 19	7 33-8 7 34-0 7 34-3 7 34-5 7 34-8	7 350 7 352 7 355 7 357 7 360	7 13-1 7 13-3 7 13-6 7 13-8 7 14-0	1-5 0-8 1-6 0-8 1-7 0-9 1-8 0-9 1-9 1-0	7-5 3-8 7-6 3-9 7-7 3-9 7-8 4-0 7-9 4-0	13-5 6-9 13-6 6-9 13-7 7-0 13-8 7-0 13-9 7-1	15 16 17 18 19	7 48-8 7 49-0 7 49-3 7 49-5 7 49-8	7 500 7 503 7 505 7 508 7 510	7 27-4 7 27-6 7 27-9 7 28-1 7 28-4	1-5 0-8 1-6 0-8 1-7 0-9 1-8 0-9 1-9 1-0	7-5 3-9 7-6 4-0 7-7 4-0 7-8 4-1 7-9 4-1	13-5 7-1 13-6 7-1 13-7 7-2 13-8 7-2 13-9 7-3
20 21 22 23 24	7 350 7 353 7 355 7 358 7 360	7 362 7 365 7 367 7 37-0 7 37-2	7 143 7 145 7 147 7 150 7 152	2-0 1-0 2-1 1-1 2-2 1-1 2-3 1-2 2-4 1-2	8-0 4-1 8-1 4-1 8-2 4-2 8-3 4-2 8-4 4-3	14-0 7-1 14-1 7-2 14-2 7-2 14-3 7-3 14-4 7-3	20 21 22 23 24	7 50-0 7 50-3 7 50-5 7 50-8 7 51-0	7 51·3 7 51·5 7 51·8 7 52·0 7 52·3	7 286 7 288 7 291 7 293 7 295	2-6 1-1 2-1 1-1 2-2 1-2 2-3 1-2 2-4 1-3	8-8 4-2 8-1 4-3 8-2 4-3 8-3 4-4 8-4 4-4	14-0 7-4 14-1 7-4 14-2 7-5 14-3 7-5 14-4 7-6
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35 36 37 38	10 09-5	10 10-7 10 10-9 10 11-2	9 41-0 9 41-3 9 41-5 9 41-7	н -	9-5 6-4 9-6 6-5 9-7 6-5 9-8 6-6	15-5 10-5 15-6 10-5 15-7 10-6 15-8 10-7	35 36 37 38	10 24-0 7 10 24-3 3 10 24-5	10 260 10 262	9 55-8 9 56-1	3-5 2-4 3-6 2-5 3-7 2-6 3-8 2-6	9-6 6-6 9-7 6-7 9-8 6-8	15-6 10-9
39 40 41 42 43	10 10-3 10 10-5	10 11-4 10 11-7 10 11-9 10 12-2 10 12-4	9 42-4 9 42-7	4-2 2-8	9-9 6-7 10-0 6-8 10-1 6-8 10-2 6-9 10-3 7-0	15-9 10-7 16-0 10-8 16-1 10-9 16-2 10-9 16-3 11-0	39 40 41 42 42	10 250 10 253 2 10 255	10 26-7 10 27-0	9 56-8	4-2 2-9		16-2 11-2
44 45 46 47	10 11-0 10 11-3 10 11-5	10 12-7 10 12-9 10 13-2 10 13-4	9 43-2 9 43-4 9 43-6 9 43-9	4-4 3-0 4-5 3-0 4-6 3-1	1	16-4 11-1 16-5 11-1 16-6 11-2 16-7 11-3	4! 4!	10 260 5 10 263 5 10 265	10 27-7	9 57-5 9 57-7 9 58-0	4-4 3-0 4-5 3-1 4-6 3-2	10-4 7-2	16-4 11-3 16-5 11-4 16-6 11-5
48 49 50	10 12-0 10 12-3	10 13-7 10 13-9 10 14-2	9 44-1 9 44-4 9 44-6		10-6 7-3 10-9 7-4	16-8 11-3 16-9 11-4 17-0 11-5	41	3 10 27·0 7 10 27·3	10 28-7 10 29-0 10 29-2	9 58-4 9 58-7		10-8 7-5 10-9 7-5	16-8 11-6 16-9 11-7 17-0 11-8
51 52 53 54	10 13-0 10 13-3	10 14-4 10 14-7 10 14-9 10 15-2	9 44-8 9 45-1 9 45-3 9 45-6	5.3 3-6	11-1 7-5 11-2 7-6 11-3 7-6 11-4 7-7	17-1 11-5 17-2 11-6 17-3 11-7 17-4 11-7	5 5	2 10 28-0 3 10 28-3	10 295 10 297 10 300 10 302	9 59-4	5-2 3-1 5-3 3-1	11-1 7-7 11-2 7-7 11-3 7-8 11-4 7-9	17-2 11-9 17-3 12-0
55 56 57 58	10 14-0 10 14-3	10 15-4 10 15-7 10 15-9 10 16-2	9 45-8 9 46-0 9 46-3 9 46-5	5-6 3-8 5-7 3-8	11-5 7-8 11-6 7-8 11-7 7-9 11-6 8-0	17-7 11-9	5	6 10 29 0 7 10 29 3	10 30-7 10 31-0	10 00-1 10 00-3 10 00-6 10 00-8	5-6 3-6	3 11-5 8-0 11-4 8-0 11-7 8-1 11-4 8-2	17·6 12·2 17·7 12·2
59 60	10 14-8	10 164	9 467	5-9 4-0	11-9 8-0	17-9 12-1	5	9 10 29-8	10 31-9	10 01-1	5-9 4	1 11-9 8-2 2 12-9 8-3	17-9 12-4

44	SUN PLANETS	ARIES	MOON	or Corre	or Corra	or Corre	45	SUN PLANETS	ARIES	MOON	or Corre	or Corre	or Corra
00 01	11 00-0 11 00-3	11 01-8 11 02-1	10 29-9 10 30-2	0-0 0-0 0-1 0-1	6-0 4-5 6-1 4-5	12-0 8-9 12-1 9-0	00 01	11 153	11 168 11 171	10 44-5	6-0 0-0 0-1 0-1 0-2 0-2	6-0 4-6 6-1 4-6 6-2 4-7	12-0 9-1 12-1 9-2 12-2 9-3
02 03 04 05	11 00-5 11 00-8 11 01-0	11 02·6 11 02·8	10 30-4 10 30-6 10 30-9 10 31-1	0-2 0-1 0-3 0-2 0-4 0-3 0-5 0-4	6-2 4-6 6-3 4-7 6-4 4-7 6-5 4-8	12-2 90 12-3 9-1 12-4 9-2 12-5 9-3	02 03 04 05	11 15-8	11 17-6 11 17-9	10 45-2	0-2 0-2 0-3 0-2 0-4 0-3 0-5 0-4	6-3 4-8 6-4 4-9 6-5 4-9	12·3 9·3 12·4 9·4 12·5 9·5
06 07 08 09	11 01·5 11 01·8	11 03-3 11 03-6 11 03-8	10 31-4 10 31-6 10 31-8 10 32-1	0-6 0-4 0-7 0-5 0-8 0-6 0-9 0-7	6-6 4-9 6-7 5-0 6-8 5-0 6-9 5-1	12-6 9-3 12-7 9-4 12-8 9-5 12-9 9-6	06 07 08 09	11 165 11 168 11 17-0	11 184 11 186 11 189 11 191	10 45-7 10 45-9 10 46-2	0-6 0-5 0-7 0-5 0-8 0-6 0-9 0-7	64 50 67 51 64 52 64 52	12-6 9-6 12-7 9-6 12-8 9-7 12-9 9-8
10 11 12 13	11 03-0 11 03-3	11 04·6 11 04·8 11 05·1	10 32·8 10 33·0	1·1 3·7 1·1 0·8 1·2 0·9 1·3 1·0	7-0 5-2 7-1 5-3 7-2 5-3 7-3 5-4	13-0 9-6 13-1 9-7 13-2 9-8 13-3 9-9	10 11 12 13	11 17-8 11 18-0 11 18-3		10 46-9 10 47-1 10 47-4	1.0 0.8 1.1 0.8 1.2 0.9 1.3 1.0	74 53 74 54 72 55 73 55 74 56	13-0 9-9 13-1 9-9 13-2 10-0 13-3 10-1 13-4 10-2
14 15 16 17 18	11 04·0 11 04·3 11 04·5	11 05-6 11 05-8 11 06-1 11 06-3	10 33-5 10 33-8 10 34-0 10 34-2	1-4 1-0 1-5 1-1 1-6 1-2 1-7 1-3 1-8 1-3	74 55 75 56 76 56 77 57 78 58	13-4 9-9 13-5 10-0 13-6 10-1 13-7 10-2 13-4 10-2	14 15 16 17 18	11 19.3 11 19.5	11 20-6 11 20-9 11 21-1 11 21-4	10 48-1 10 48-3 10 48-5	14 14 15 14 16 12 17 13 14 14	75 5-7 7-6 5-8 7-7 5-8 7-4 5-9	13-5 10-2 13-6 10-3 13-7 10-4 13-8 10-5
19 20 21 22 23	11 05-0 11 05-3 11 05-5 11 05-8	11 07·1 11 07·3 11 07·6	10 35-2 10 35-4	1.9 1.4 2.0 1.5 2.1 1.6 2.2 1.6 2.3 1.7	8-2 6-1 8-3 6-2	13-9 10-3 14-0 10-4 14-1 10-5 14-2 10-5 14-3 10-6	19 20 21 22 23	11 198 11 200 11 203 11 205 11 208	11 21-9 11 22-1 11 22-4 11 22-6	10 49-0 10 49-3 10 49-5 10 49-7	1.9 1.4 2.0 1.5 2.1 1.6 2.2 1.7 2.3 1.7	74 60 80 61 81 61 82 62 83 63	13-9 10-5 14-0 10-6 14-1 10-7 14-2 10-8 14-3 10-8
24 25 26 27 28	11 06-8 11 07-0	11 08-1 11 08-3 11 08-6 11 08-8	10 366	2·4 1·8 2·5 1·9 2·6 1·9 2·7 2·0 2·0 2·1	8-6 64 8-7 6-5	14-4 10-7 14-5 10-8 14-6 10-8 14-7 10-9 14-8 11-0	24 25 26 27 28	11 21-3 11 21-5 11 21-8 11 22-0	11 23-4 11 23-6 11 23-9	10 50-5 10 50-7 10 50-9	2-4 1-8 2-5 1-9 2-6 2-0 2-7 2-0 2-8 2-1	84 64 85 64 86 65 87 66 88 67	14-4 10-9 14-5 11-0 14-6 11-1 14-7 11-1 14-8 11-2
30 31 32 33	11 07-5 11 07-8 11 08-0	11 091 11 093 11 096 11 098 11 101	10 369 10 37·1· 10 37·3 10 37·6 10 37·8	2-9 2-2 3-0 2-2 3-1 2-3 3-2 2-4 3-3 2-4	9-0 6-7 9-1 6-7 9-2 6-8	14-9 11-1 15-0 11-1 15-1 11-2 15-2 11-3 15-3 11-3	29 30 31 32 33	11 22-3 11 22-5 11 22-8 11 23-0 11 23-3	11 24-4 11 24-6 11 24-9	10 51-2 10 51-4 10 51-6 10 51-9 10 52-1	2-9 2-2 3-0 2-3 3-1 2-4 3-2 2-4 3-3 2-5		14-9 11-3 15-0 11-4 15-1 11-5 15-2 11-5 15-3 11-6
34 35 36 37 38	11 08-8 11 09-0 11 09-3	11 10-3 11 10-6 11 10-8 11 11-1 11 11-3	10 38-3 10 38-5 10 38-8	3-4 2-5 3-5 2-6 3-6 2-7 3-7 2-7 3-8 2-8	9-5 7-0 9-6 7-1 9-7 7-2	15-4 11-4 15-5 11-5 15-6 11-6 15-7 11-6 15-8 11-7	34 35 36 37 38	11 23-8 11 24-0 11 24-3	11 25·9 11 26·1	10 52·8 10 53·1	3-4 2-6 3-5 2-7 3-6 2-7 3-7 2-8 3-8 2-9	95 7.2 96 7.3 9.7 7.4	15-4 11-7 15-5 11-8 15-4 11-8 15-7 11-9 15-8 12-0
39 40 41 42 43	11 09-8 11 10-0 11 10-3 11 10-5	11 11-6 11 11-8 11 12-1 11 12-3 11 12-6	10 395 10 397 10 400	4-1 3-0	9-9-7-3 10-0-7-4 10-1-7-5 10-2-7-6 2 10-3-7-6	15-9 11-8 16-0 11-9 16-1 11-9 16-2 12-0 16-3 12-1	42	11 25-0 11 25-3 11 25-5	11 269 11 27-1 11 27-4	10 54-0 10 54-3	4-2 3-2	10-0 7-6 10-1 7-7 10-2 7-7 10-3 7-8	15-9 12-1 16-0 12-1 16-1 12-2 16-2 12-3 16-3 12-4
44 45 46 47 48	11 11 0 11 11 3 11 11 5 11 11 8	11 12-8 11 13-1 11 13-3 11 13-6 11 13-8	10 40-4 10 40-7 10 40-9 10 41-1	4-4 3-3 4-5 3-4 4-6 3-4 4-7 3-5	10-4 7·7 3 10-5 7·8	16-4 12-2 16-5 12-2 16-6 12-3 16-7 12-4 16-8 12-5	44 45 46 47	11 260 11 263 11 265 11 268	11 27-9 11 28-1 11 28-4 11 28-6	10 54-7 10 55-0 10 55-2 10 55-5 10 55-7	4-4 3-3 4-5 3-4 4-6 3-5 4-7 3-6	10-4 7-9 10-5 8-0 10-6 8-0 10-7 8-1 10-8 8-2	16-7 12-7
49 50 51 52	11 12·3 11 12·5 11 12·8 11 13·0	11 14-1 11 14-3 11 14-6 11 14-8	10 41-6 10 41-9 10 42-1 10 42-3	5-0 3-1 5-1 3-6 5-2 3-1	7 11-0 8-2 3 11-1 8-2 9 11-2 8-3	16-4 12-5 17-0 12-6 17-1 12-7 17-2 12-8	50 51 52	11 27-3 11 27-5 11 27-8 11 28-6	11 294 11 294 11 296 11 299	10 55-9 10 56-2 10 56-4 10 56-7	5-0 3-6 5-1 3-9 5-2 3-9	10-9 8-3 11-0 8-3 11-1 8-4 11-2 8-5	16-9 12-8 17-0 12-9 17-1 13-0 17-2 13-0
53 54 55 56	11 13-5 11 13-6 11 14-0	11 15-3 11 15-6 11 15-8	10 42-8 10 43-1 10 43-3	5-4 4-1 5-5 4-1 5-4 4-1	7 11-3 8-4 0 11-4 8-5 1 11-5 8-5 2 11-4 8-6	17-5 13-0 17-6 13-1	54 55 56	11 28: 11 28: 11 29:	11 304 11 304 11 304	10 57-4 10 57-6	5-4 4-2 5-5 4-2 5-6 4-2	1 11-4 8-6 2 11-5 8-7 2 11-6 8-8	174 132 175 133 174 133
57 58 59 60	11 14-5 11 14-6	11 161 11 163 11 166 11 168	10 43-8 10 44-0	5-8 4- 5-9 4-	2 11-7 8-7 3 11-8 8-8 4 11-9 8-8 5 12-0 8-9	17-8 13-2 17-9 13-3	58 59	11 29	11 31- 11 31-	1 10 57-9 1 10 58-1 5 10 58-3 9 10 58-6	5-8 4- 5-9 4-	3 11-4 8-9 5 11-4 9-0 6 12-6 9-1	174 135 174 136

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00 01 02 03 04	2 30-0 12 30-3 12 30-5 12 30-8 12 31-0	12 32-3		0-0 0-0 0-1 0-1 0-2 0-2 0-3 0-3 0-4 0-3	6·0 5 6·1 5 6·2 5	-1 12-0 10-1 -1 12-1 10-2 -2 12-2 10-3 -3 12-3 10-4 -4 12-4 10-4	00 01 02 03 04	. , 12 450 12 453 12 455 12 458 12 460	12 47-3 12 47-6	. , 12 10-2 12 10-4 12 10-6 12 10-9 12 11-1	0-0 0-0 0-1 0-1 0-2 0-2 0-3 0-3 0-4 0-3	6.0 5.2 6.1 5.2 6.2 5.3 6.3 5.4 6.4 5.5	12-0 10-3 12-1 10-4 12-2 10-5 12-3 10-6 12-4 10-6
05 06 07 08 09	12 31·8 12 32·0 12 32·3	12 33-6 12 33-8 12 34-1 12 34-3	11 57-5 11 57-7 11 58-0	0-5 O-4 0-6 O-5 0-7 O-6 0-8 O-7 0-9 O-8	6-6 6-7 6-8 6-9	5 12-5 10-5 6 12-6 10-6 16 12-7 10-7 12-8 10-8 12-9 10-9	05 06 07 08 09	12 463 12 465 12 468 12 47·0 12 47·3	12 49-1 12 49-4	12 12-3	0-5 0-4 0-6 0-5 0-7 0-6 0-8 0-7 0-9 0-8	6-5 5-6 6-6 5-7 6-7 5-8 6-8 5-8 6-9 5-9	12-5 10-7 12-6 10-8 12-7 10-9 12-8 11-0 12-9 11-1
10 11 12 13 14 15	12 33-3	12 34·8 12 35·1 12 35·3 12 35·6	11 58-7 11 58-9	1.0 0.8 1.1 0.9 1.2 1.0 1.3 1.1 1.4 1.2 1.5 1.3	7-1 (7-2 (7-3 (7-4 (-9 13-0 10-9 -0 13-1 11-0 -1 13-2 11-1 -1 13-3 11-2 -2 13-4 11-3 -3 13-5 11-4	10 11 12 13 14	12 47·8 12 48·0 12 48·3 12 48·5	12 49-6 12 49-9 12 50-1 12 50-4 12 50-6 12 50-9	12 13-3 12 13-5	1-0 0-9 1-1 0-9 1-2 1-0 1-3 1-1 1-4 1-2 1-5 1-3	7-0 6-0 7-1 6-1 7-2 6-2 7-3 6-3 7-4 6-4 7-5 6-4	13-0 11-2 13-1 11-2 13-2 11-3 13-3 11-4 13-4 11-5
16 17 18 19 20	12 34-0 12 34-3 12 34-5 12 34-8 12 35-0	12 361 12 363 12 366 12 368 12 371	11 59-7 11 59-9 12 00-1 12 00-4	1.6 1.3 1.7 1.4 1.8 1.5 1.9 1.6 2.0 1.7	7·6 (7·7 (7·8 (7·9 (8·0 (74 13-6 11-4 75 13-7 11-5 76 13-8 11-6 76 13-9 11-7 77 14-0 11-8	16 17 18 19 20	12 49-0 12 49-3 12 49-5 12 49-8 12 50-0	12 51-1 12 51-4 12 51-6 12 51-9 12 52-1	12 14-0 12 14-2 12 14-4 12 14-7 12 14-9	1.6 1.4 1.7 1.5 1.8 1.5 1.9 1.6 2.0 1.7	7.6 6.5 7.7 6.6 7.8 6.7 7.9 6.8 8-0 6.9	13-6 11-7 13-7 11-8 13-8 11-8 13-9 11-9 14-0 12-0
21 22 23 24 25 26	12 35-3 12 35-5 12 35-8 12 36-0 12 36-3 12 36-5	12 37·6 12 37·8 12 38·1 12 38·3	12 00-8 12 01-1 12 01-3 12 01-6 12 01-8 12 02-0	2-1 1-8 2-2 1-9 2-3 1-9 2-4 2-0 2-5 2-1 2-6 2-2	8-2 (8-3) 8-4)	78 14-1 11-9 79 14-2 12-0 70 14-3 12-0 7-1 14-4 12-1 7-2 14-5 12-2 7-2 14-6 12-3	22 23 24	12 50-5 12 50-8 12 51-0 12 51-3	12 52-4 12 52-6 12 52-9 12 53-1 12 53-4 12 53-6	12 15-6 12 15-9 12 16-1	2-1 1-8 2-2 1-9 2-3 2-0 2-4 2-1 2-5 2-1 2-6 2-2	8-2 7-0 8-3 7-1 8-4 7-2 8-5 7-3	
27 28 29 30 31	12 368 12 37-0 12 37-3 12 37-5 12 37-8	12 388 12 391 12 393 12 396 12 398	12 02-3 12 02-5 12 02-8 12 03-0 12 03-2	2-7 2-3 2-8 2-4 2-9 2-4 3-0 2-5 3-1 2-6	8-7 8-6 8-9 9-0 9-1	7-3 14-7 12-4 7-4 14-8 12-5 7-5 14-9 12-5 7-6 15-0 12-6 7-7 15-1 12-6	27 28 29 30 31	12 51-8 12 52-0 12 52-3 12 52-5 12 52-8	12 53-9 12 54-1 12 54-4 12 54-6 12 54-9	12 16-6 12 16-8 12 17-1 12 17-3 12 17-5	2-7 2-3 2-8 2-4 2-9 2-5 3-0 2-6 3-1 2-7	8-7 7-5 8-8 7-6 8-9 7-6 9-0 7-7 9-1 7-8	14-7 12-6 14-8 12-7 14-9 12-8 15-0 12-9 15-1 13-0
32 33 34 35 36 37	12 38-0 12 38-3 12 38-5 12 38-8 12 39-0 12 39-3	12 40-3 12 40-6 12 40-8 12 41-1	12 03-5 12 03-7 12 03-9 12 04-2 12 04-4 12 04-7	3-2 2-7 3-3 2-8 3-4 2-9 3-5 2-9 3-6 3-0 3-7 3-1	9-3 9-4 9-5 9-6	7.7 15-2 12-6 7.8 15-3 12-6 7.9 15-4 13-6 9.0 15-5 13-6 9.1 15-6 13-6 9.2 15-7 13-6	33 34 35 36	12 53-3 12 53-5 12 53-8 12 54-0	12 55-6 12 55-9 12 56-1	12 183 12 185 12 187	3·2 2·7 3·3 2·8 3·4 2·9 3·5 3·0 3·6 3·1 3·7 3·2	9-3 8-0 9-4 8-1 9-5 8-2 9-6 8-2	15-3 13-1 15-4 13-2 15-5 13-3 15-6 13-4
38 39 40 41 42 43	12 40-3 12 40-5		12 05-6 12 05-9	4-2 3-5 4-2 3-5	9-9 10-0 10-1 10-2	3-2 15-8 13-1 3-3 15-9 13-4 3-4 16-0 13-5 3-5 16-1 13-6 3-6 16-2 13-6 3-7 16-3 13-5	39 40 41 42	12 54·8 12 55·3 12 55·5	12 56-9 12 57-1 12 57-4 12 57-6	1	3-8 3-3 3-9 3-3 4-0 3-4 4-1 3-5 4-2 3-6 4-3 3-7	9-9 8-5 10-0 8-6 10-1 8-7 10-2 8-8	15-9 13-6 16-0 13-7 16-1 13-8 16-2 13-9
44 45 46 47 48	12 41.3 12 41.3 12 41.5 12 41.8 12 42.0	12 43-1 12 43-3 12 43-6 12 43-8 12 44-1	12 06-3 12 06-6 12 06-8 12 07-0 12 07-3	4-4 3-7 4-5 3-8 4-6 3-9 4-7 4-0 4-8 4-0	10-4 10-5 10-6 10-7 10-8	8-8 16-4 13-6 8-8 16-5 13-6 8-9 16-6 14-6 9-0 16-7 14-6 9-1 16-8 14-6	4: 4: 4: 4: 4: 4:	12 560 12 563 12 565 12 568 12 570	12 58-1 12 58-4 12 58-6 12 58-9 12 59-1	12 20-6 12 20-9 12 21-1 12 21-4 12 21-6	4-4 3-8 4-5 3-9 4-6 3-9 4-7 4-0 4-8 4-1	10-4 8-9 10-5 9-0 10-6 9-1 10-7 9-2 10-8 9-3	16-4 14-1 16-5 14-2 16-6 14-2 16-7 14-3 16-8 14-4
50 51 52 53 54	12 42-5 12 42-8 12 43-0 12 43-3	12 44-3 12 44-6 12 44-8 12 45-1 12 45-3 12 45-6	12 07-8 12 08-0 12 08-2 12 08-5	4-9 4-1 5-0 4-2 5-1 4-3 5-2 4-4 5-3 4-5 5-4 4-5	11-0 11-1 11-2 11-3	9-2 16-9 14- 9-3 17-0 14- 9-3 17-1 14- 9-4 17-2 14- 9-5 17-3 14- 9-6 17-4 14-	5(5) 5(5)	12 57-5 1 12 57-8 2 12 58-0 3 12 58-3	12 59-9 13 00-1 13 00-4	1		11-0 9-4 11-1 9-5 11-2 9-6 11-3 9-7	17-0 14-6 17-1 14-7 17-2 14-8 17-3 14-8
55 56 57 58 59	12 43-8 12 44-0 12 44-3 12 44-5	1 1	12 090 12 092 12 094 12 097	5-7 4-8 5-8 4-9	11-6 11-7	9-7 17-5 14- 9-8 17-6 14- 9-8 17-7 14- 9-9 17-6 15- D-0 17-9 15-	5 5 5	6 12 59 0 7 12 59 3 8 12 59 5	13 004 13 014 13 014 13 014	12 23-3 12 23-5 12 23-8 12 24-0 12 24-2	5-7 4-9 5-8 5-1	3 11-6 10-0 11-7 10-0 11-8 10-1	17-5 15-0 17-6 15-1 17-7 15-2 17-8 15-3 17-9 15-4
60	12 450	12 47-1	12 10-2	6-0 5-1	12-0 1	0-1 18-0 15-	<u> </u>	0 13 00-0	13 02-1	12 24-5	6-0 5	2 12-0 10-3	18-0 15-5

58	SUN	ARIES	MOON	v or Co	orr"	or C	orr ⁿ	or C	orr*	59		UN NETS	ARI	ES	MO	ON	_	orr	_	orr	or C	orr"
3	PLANETS			d	_	d		d			-			_			d	-	d,	- 	<u>d</u>	
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01	14 30-3				0-1	6-1	5-9	12.1		01		45-3	14 4		14 (- 1	0.1	01	6.1	6-0	12-1	
02	14 30-5				0-2	6-2	60	12.2		02		45-5 45-8	14 4		14 (14 (- 13	0-2	0.3	6·2 6·3		12•2 12•3	
03	14 30-8 14 31-0		13 51·1 13 51·3		03 04	6-3 6-4	6-1	12-3 12-4		03 04		450		I	14 (11	0-4	0-4	6-4	6-3	12-4	
05	14 31-3				0.5	6-5	6-3	12-5		05	14	463	14 4	8-7	14 (159	0+5	0-5	6-5	6-4	12-5	12-4
06	14 31.5	•	1 1		0-6	6.6	64	12.6		06	14	46-5	14 4	8-9	14 (ll ll	0.6	0-6	6-6	6-5	12-6	- 1
07	14 31.8		13 52-0	4	0-7	6.7	6-5	12.7		07		46-8	14 4 14 4	,			0.7	0-7 0-8	6·7	6-6 6-7	12•7 12•8	
08	14 32·0 14 32·3		13 52·3 13 52·5	1	0-8 0-9	6-8 6-9	6-6	12·B 12·9		08		47-0 47-3	14 4				0.9	0.9	6.9	6-8	12-9	
10	14 32-5	14 34-9	13 52-8	1-0	1.0	7.0	6-8	13-0	12.7	10	1 -	47-5	•		14 (13	1-0	1-0	7-0	69	13-0	
11	14 32-8		4 1		1-1	7-1	69	13-1		111		47·8 48·0		- 1	14 (1.1	1·1 : 1·2	7·1 7·2	7·0 7·1	13·1 13·2	
12 13	14 33-0 14 33-3	14 354 14 356	13 53-2 13 53-5	I	1·2 1·3	7-2 7-3	7·0 7·1	13·2 13·3		112		1 48-3		Ŀ			1.3	1.3	7-3	7.2	13.3	
14	14 33-5	14 35-9			1.4	7-4	7-2	13-4		14	1	48-5			14	08-0	1-4	1.4	7-4	7.3	13-4	13-3
15	14 33-8	14 361	13 53-9	1-5	1.5	7-5	7-3	13-5	13-2	15		48-8			14			1.5	7-5	7.4	13-5	
16	14 34-0	1	13 54-2	lf .	1.6	7-6	7.4	43.6		16	1	490 493	ŀ				1.6	1.6	7.7	7·5 7·6		13-5
17 18	14 34·3 14 34·5	14 366 14 369	13 54·4 13 54·7	10	1·7 1·8	7-7 7-8	7·5 7·6	13.7 13.8		17 18		1 4 7 5					1.8	1.8	7.8	7.7		13-7
19	14 34-8			ll .	1.9	7-9	7.7	13.9		19		49-8			14		1.9	1-9	7.9	7-8		13-8
20	14 350			ll .	2-0	8-0	7-8	14-0		20	1 -	50-0	1		14	1	2.0	2.0	8-0	7.9		13-9
21	14 35-3		1	H	2.0	8-1	7·9 8·0	14-1 14-2		21	_	1 50-3 1 50-5	I		14	09-7 ng-9	2-1	2·1 2·2	8·1 8·2	8-0 8-1		14-0
22	14 35-5 14 35-8	14 37·9 14 38·1		2.2		8-2 8-3	8-1	14-3		23	_	50-8		- 1		10-2		2-3	8.3	8-2		14-2
24	14 36-0	3	13 561	lì .	2-3	8-4	8-2	14-4	14.0	24	14	51.0	14 5	3-4	14	10-4	2-4	2-4	8-4	8-3		14-3
25	14 363	14 38-6	13 56-3	II .	2-4	8.5	8-3	14-5		25	_	51.3				10-6	2-5	2·5 2·6	8-5	8-4 8-5		14-4 14-5
26 27	14 365 14 368	14 389 14 392	1	II	2·5 2·6	8-6 8-7	8-4 8-5	14-6		26 27		\$ 51·5 \$ 51·8	1		14	10-9 11-1	2.6		8-7	8-6		14.6
28	14 37-0		13 57-0	II	2.7	8-8	8-6	14-8		28	1	52-0				11-4	2-8	2-8	8-8	8-7		14.7
29	14 37-3	14 39-7	13 57-3	2.9	2-8	8-9	8-7	14-9	14-5	29	14	1 52-3	14 5	4-7	14	11.6	2.9	2.9	8-9	8-8	14-9	14-8
30	14 37-5			**	2.9	9-0	8-8	15.0		30		52.5	14 5			11.8	3-0		9-0	8-9 9-0		14·9 15·0
31 32	14 37.8 14 38-0	I .	13 57-8 13 58-0	II '	3-0 3-1	9·1	8-9 9-0	15·1 15·2		31		\$ 52·8 \$ 53·0	1		14		3·1 3·2	3·1 3·2	9-1	9-1		151
33	14 38-3	14 40-7		11	3.2	9.3	9-1		14.9	33		4 53-3	14 5				3-3	3-3	9-3	9-2	F	15-2
34	14 38-5	14 40-9	13 58 5	3-4	3-3	9-4	9-2	15-4	150	34	14	53. 5	14 5	5-9	14	12-8	3-4		9-4	9-3	i	153
35	14 38-8		13 58-7)	3-4	9-5	93		15-1	35		4 53-8	14 5				3-5	3·5 3·6	9.5	9-4 9-5		15-4 15-5
36 37	14 390 14 393		13 590 13 592	1 1	3-5 3-6	9·6 9·7	9-4 9-5	15-6	152 153	36 37	_	4 54·0 4 54·3	14 5			13-3 13-5	3·6 3·7		9.7	9-6	I	156
38	1	14 41.9	1	11	3.7	9-8	9-6	15-8		38		4 54-5	14 5			13-8	3-8		9-8	9-7		15-7
39	14 39-8	14 42-2	13 59-7	3.9	3-8	9-9	9 -7	15.9	15-5	39		4 54-8	1		l	14-0	11	3-9	9-9	9-8	1	15-8
40			13 59-9			10-0		16-0		40	1	4 550 4 553	14 5	57.5	14	14.2	4-0	4.0	10-0	9-9 10-0	16.0	159
41 42			14 00-1 14 00-4	4-1		10-1	98 99	16.1	15-7 15-8	41 42	11	4 55-5 4 55-5	14 5	58-0	14	14-7	4-2		10-2			
43	14 408	14 43-2	14 00-6	4-3			100		15-9	43	1.	4 55-8	14 5	58-2	14	14-9	4-3	4-3	10-3	10-2	16-3	16-2
44	14 41.0	14 43-4	14 00-9	4-4	4-3	10-4	10-1	16-4	160	44	1	4 560	1		ı	15-2	ll .	4-4	1	10-3	1	163
45	_		14 01-1	11	4-4		10-2		161	45		4 563 4 565				154 157		4·5 4·6		104 105		164 165
46 47		E .	14 01·3 14 01·6	II		1	10-3 10-4		162 163	46 47		4 565 4 568										16-6
48	14 42-0	14 44-4	14 01-8	4-8	4.7		10-5	ſ		48	1	4 57-0	14 5	59-5	14	161	4.8	4-8	10-8	10-7	16-B	16-7
49	ł	i .	14 02-1	K .	4-8	i	10-6			49	Į.	4 57-3			ı		li .	4.9	1	108	1	168
50	14 42-5		14 02-3		4.9 5.0		10-7			50		4 57·5 4 57·8				166		5·0 5·1				16-9 17-0
51 52	14 42-8	1	14 02·5 14 02·8		5-0 5-1		10-8 10-9			51 52		4 57·8 4 58·0	15	00-5	14	17.1	5.2					17-1
53	14 43-3	14 45-7	14 03-0	5-3	5-2	11.3	11-0	17-3	169	53	· 1	4 58-3	15	00-7	14	17.3	5-3	5-3		11.2	1	17-2
54	14 43-5		14 03-3	11		ł	11.1	l	17-0	54		4 58-5	4				5-4		1	11.3	1	17-3
55			14 03-5 14 03-7	5·5 5·6	54 55		11·2 11·3			55 56		4 58-8 4 59-0	15 (01·2 01·5	14	1/-B	5-6			11·4 11·5		17-4 17-5
56 57			14 04-0	II .			11.4			57	1	4 59-3	15 (01.7	14	18-3	5•7	5-7	11.7	11-6	17-7	17-6
58	14 44-5	14 469	14 04-2	5-8	5-7	11-8	11.5	17-8	17-4	58	1	4 59-5	15	02-0	14	18-5	5-1	5-8				17.7
59	14 44-8	ł	14 04-4	5.9	5-8	ŀ	11.6	1		59		4 59-8	1				Ш	5-9	1	11.8	1	17-8
60	14 450	14 47-4	14 04-7	6-0	5-9	12-0	11-7	18-0	17-6	60	1	5 00-0	15	02-5	14	140	6.0	. 6-(1 12-0	11.7	14-4	17-9

POLARIS (POLE STAR) TABLES, 1980 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°-
	a,	a _e	a.	a,	a,	a,	a,	a ₀	a,	a.	a,	a _e
ô	0 17:5	0 72.2	o 10·6	0 00.4	° ~ ′-			° - ′ .				
1	0 17.5	0 13.3	10.4	0 09.4	0 09.7	0 11.5	0 14·7 15·1	0 19.4	0 25·2 25·8	32.8	0 39.7	0 48.0
2	16.2	12.7	10.7	09.3	09.9	12.0	15.5	19·9 20·4	26.5	33.5	40·5 41·3	48·8 49·7
3	16.1	12.4	10.1	09.3	10.0	12.3	16.0	21.0	27.1	34.3	42 I	50.2
4	15.7	12.1	09.9	09.3	10.2	12.6	16.4	21.5	27.8	35.0	43.0	51.4
5 6	0 15.2	0 11.8	0 09.8	0 09.3	0 10.4	0 12.9	0 16.9	O 22·I	0 28.5	0 35.8	0-43-8	0 52.2
6	14.8	11.5	09.7	09.4	10.6	13.3	17.3	22.7	29.2	36.6	44.6	23.1
7	14.4	11.3	09.6	09.4	10.8	13.6	17.8	23.3	29.9	37-3	45 4	53.9
8	14.1	11.0	09.5	09.5	11.0	14.0	18.3	23.9	30.6	38.1	46.3	54.8
9	13.7	10.8	09.4	09.6	11.2	14.3	18.8	24.6	31.3	38.9	47·I	55.7
10	0 13.3	0 10.6	0 09:4	0 09.7	0 11.5	0 14.7	0 19.4	0 25.2	0 32.0	0 39.7	0 48 0	0 56.5
Lat.	a ₁	a ₁	a ₁	<i>a</i> ₁	a ₁	<i>a</i> ,	a 1	a 1	a,	<i>a</i> ₁	a ₁	a ₁
ů	0.5	0.6	o.6	o.6	o.6	0.5	0.5	0.4	o´.3	o.3	0·2	0.2
10	·5	.6	·6	.6	-6	.5	.5	-4	•4	.3	.3	.2
20	•5	-6	-6	-6	-6	· 6	.5	-5	•4	•4	.3	-3
30	-6	-6	∙6	-6	-6	∙6	•5	•5	-5	-4	·4	·4
40	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.2	0.5	0.5	0.2	0.5
45	.6	.6	.6	-6	.6	-6	-6	.6	-6	·5	-5	·5
50	-6	.6	.6	-6	.6	-6	•6	.6	∙6	-6	-6	∙6
55 60	·6	·6	·6	·6	·6	·6 ·6	·6	·6	.7	.7	.7	.7
		ŀ					.7	-7	.7	-7	-8	-8
62	0.7	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.8
64 66	7	·6 ·6	-6	-6	•6	-6	.7	.7	-8	·8	.9	0.9
68	·7 0·7	0.6	-6 o-6	.6 o.6	.6 o.6	.7	.7	•8 o⋅8	8 0-9	I.O	0.9	1.0
						_ 0.7	0.7					1.0
Month	aı	a,	a,	a ₁	a,	a ₁	a,	a ₁	a,	a ₂	a ₁	a ₁
Jan.	0.7	0.7	0.7	oʻ.7	0.7	0.7	o.7	0.7	0.7	0.7	o.6	o.6
Feb.	-6	.7	.7	7	.7	-8	-8	-8	.8	-8	-8	.8
Mar.	-5	·5	∙6	.6	·7	·7	.8	-8	.8	.9	-9	.9
Apr.	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.0	0.9
May	∙2	•3	.3	⁻ 4	·4	•5	.2	-6	.7	-8	∙8	.9
June	•2	•2	.5	·2	-3	·3	⁻ 4	-5	-5	-6	.7	.7
July	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.3	0.4	0.2	0.5	0.6
Aug. Sept.	·4 ·5	·3 ·5	·3 ·4	·3 ·4	·2 ·3	·2 ·3	·3	·3	·3	·3	·4 ·3	·4 ·3
Oct.	0.7	0.7	0.6	0.5	0.2	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Nov.	0.9	0.8	.8	.7	.7	.6	-5	.5	•4	<i>i</i> ·4	.3	.3
Dec.	1.0	1.0	0.9	0.9	0-8	0.8	0.7	0∙6	0.6	0.5	0.4	0.4
Lat.						AZIM	UTH					
	ا م	0.3			350.8	260.5	250.6	350.4	350.4	350.3	350.3	
0 20	0·4 0·4	0·3	0·I	0.0	359·8 359·8	359·7 359·7	359·6 359·5	359·4 359·4	359·4 359·3	359·3 359·2	359·2 359·2	359·2 359·1
40	0.2	0.3	0.5	0.0	359.8	359·6	359·4	359·3	359·I	359·0	359·0	358.9
50	0.6	0.4	0.2	0-0	359.7	359.5	359.3	359·I	359.0	358.9	358.8	358-7
55	0.7	0.2	0.2	0.0	359.7	359.5	359.2	359.0	358.9	358.7	358.6	358.6
60	0.8	0.2	0.2	359.9	359.7	359.4	359·I	358.9	358.7	358 5	358-4	358.4
65	0.9	0.6	0.3	359.9	359.6	359.3	358-9	358.7	358.4	358 3	358∙1	358·I

Latitude = Apparent altitude (corrected for refraction) = $1^{\circ} + a_0 + a_1 + a_2$

The table is entered with L.H.A. Aries to determine the column to be used; each column refers to a range of 10°. a_0 is taken, with mental interpolation, from the upper table with the units of L.H.A. Aries in degrees as argument; a_1 , a_2 are taken, without interpolation, from the second and third tables with arguments latitude and month respectively. a_0 , a_1 , a_2 are always positive. The final table gives the azimuth of *Polaris*.

POLARIS (POLE STAR) TABLES, 1980 FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	120°-	130°-	140°-	150°-	160° 169°	170°-	180°- 189°	190°- 199°	200°- 209°	210°- 219°	220°- 229°	230°-
	129°	139°	149°	159°	109	17 9 °	109	199	209	219	229	239°
	a_{0}	a _o	a_0	a _o	a _o	a_0	a _e	a,	a _o	a _o	a _•	a,
ů	o 56·5	° 05.1	î 13.6	î 21·5	° 28.8	î 35·1	1 40.4	Î 44.4	i 47.0	1 48.2	1 48·o	1 46.2
1	57.4	06.0	14.4	22.3	29.4	35.7	40.8	44.7	47.2	48.3	47.8	46.0
2	58.2	06⋅8	15.2	23.0	30∙1	36.3	41.3	45.0	47.4	48.3	47.7	45.7
3	0 59.1	07.7	16.0	23.8	30⋅8	36∙8	41.7	45.3	47.5	48.3	47.6	45.4
4	I 00.0	08∙5	16.8	24.2	31.4	37.4	42·I	45.6	47.7	48.3	47.4	45·I
5 6	1 00·8	I 09·4 I0·2	1 17·6 18·4	1 25·2 26·0	1 32·1 32·7	1 37±9 38·4	1 42·5 42·9	1 45·9 46·1	1 47·8 47·9	1 48·3 48·2	I 47·3	1 44·8 44·5
7	02.6	11.1	19.2	26.7	33.3	38.9	43.3	46.4	48·o	48.2	46.9	44.1
8	03.4	11.9	20.0	27.4	33.9	39.4	43.7	46.6	48∙1	48-1	46.7	43.8
9	04.3	12.7	20.7	28.1	34.5	39.9	44.0	46.8	48.2	48.0	46.4	43 4
10	1 05.1	I 13·6	1 21.5	1 28·8	I 35·I	1. 40-4	I 44·4	1 47.0	1 48·2	1 48.0	I 46·2	I 43·0
Lat.	a _i	a_1	a_1	<i>a</i> ,	a ₁	a_1	a 1	a ₁	a 1	a ₁	a ₁	a,
o	ý 0·2	ý 0-2	ý 0·2	, 0·3	o.4	, 0.4	, 0·5	0.6	, o.6	0.6	0.6	0.5
10	.2	.3	.3	.3	•4	.5	.5	.6	.6	-6	.6	-5
20	.3	.3	·3	-4	4	.5	·ś	-6	-6	-6	-6	·ő
30	•4	·4	-4	-4	.5	.5	-6	-6	.6	-6	-6	-6
40	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6
45	•5	-5	.5	-6	-6	∙6	-6	∙6	-6	-6	.6	-6
50	∙6	-6	-6	-6	∙6	-6	٠6	-6	-6	-6	-6	-6
55	•7	.7	.7	·7	-6	۰6	-6	.6	·6	.6	-6	.6
60	-8	.8	-8	.7	.7	-7	·6	-6	·6	·6	.6	·6
62	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6
64	0.9	0.9	.9	-8	8	.7	7	·6	·6 ·6	·6 ·6	·6 ·6	·6
66 68	1 · I 1 · O	I.O	1.0	0.9	-8 0·9	·7 o·8	·7 0·7	0.6	0.6	0.6	0.6	·7 0·7
-				<u> </u>					· · · · · · · ·			
Month	a ₂	a,	a ₂	a ₁	a ₂	a ₂	a _s	a,	a,	a ₂	a ₂	a,
an.	o.6	0.6	o.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Feb.	-8	.7	-7	.7	-6	-6	-6	1 .5	.5	-5	•5	.4
Mar.	0.9	0.9	0.9	0.8	-8	-8	.7	.7	-6	-6	•5	·5
Apr.	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0⋅8	o⋅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	0.8	-8	.7
une	-8	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	.9
luly	0.7	0.7	0.8	0⋅8	0.9	0.9	1.0	1.0	1.0	1.0	1.0	0.9
Aug.	•5	-6	·6	.7	'7	-8	0.8	0.9	0.9	0.9	1.0	1.0
Sept.	·4	·4	·4	•5	.6	.6	-7	.7	.8	.8	0.9	0.9
Oct.	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	o.8 .6
Nov.	-2	.2	·2	.2.	0.2	.3	·3	0.2	0·3	0.3	·5 0·4	0.4
Dec.	0.3	0.3	0.2	0.2	1 0.2	AZIM	<u> </u>	1 0-2	03	1 03	<u> </u>	1 0 4
LAI.	۰	.			۱ .					1 .	•	•
0	359.2	359.2	359.2	359.3	359.4	359.5	359.6	359.7	359.9	0.0	0.2	0.3
20	359·I	359·1	359.2	359.3	359.3	359.5	359.6	359.7	359.9	0.0	0.2	0.3
40	358.9	358.9	359.0	359·I	359.2	359.3	359.5	359.7	359.8	0.0	0.2	0.4
50	358.7	358.7	358.8	358.9	359·I	359.2	359.4	359.6	359.8	0.0	0.3	0.5
55	358∙6	358-6	358.7	358.8	358-9	359∙1	359.3	359.6	359.8	0.0	0.3	0.5
60	358.4	358.4	358.5	358.6	358.8	359.0	359.2	359.5	359.8	O.I	0.3	0.6
65	358·I	358⋅1	358.2	358.4	358.6	358.8	359·I	359.4	359.7	0.1	0.4	0.7

ILLUSTRATION
On 1980 April 21 at G.M.T.
23^h 18^m 56^s in longitude
W. 37° 14' the apparent altitude
(corrected for refraction), Ho, of
Polaris was 49° 31'.6.

From the daily pages:

G.H.A. Aries (23h) 195 09.8

Increment (18m 56s) 4 44.8

Longitude (west) -37 14

L.H.A. Aries 162 41

Но	49	31.6
a. (argument 162° 41')	I	30.6
a ₁ (lat. 50° approx.)		0.6
a ₂ (April)		0.9
$Sum - 1^{\circ} = Lat. =$	50	03.7

POLARIS (POLE STAR) TABLES, 1980 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 _o	a ₀	a_0
ů	0 / 1 43·0	1 38·6	° , I 32.9	i 26·2	î 18.6	i 10·5	1 01.9	o 53·3	0 44 8	o 36·8	0 29 4	0 22 9
1	42.7	38.0	32.2	25.4	17.8	09.6	01.1	52.4	44.0	36.0	28.7	22.3
2	42.2	37.5	31.6	24.7	17.0	08⋅8	I 00·2	51.6	43.2	35.2	28∙0	21.7
3	41.8	37.0	31.0	24.0	16.2	07.9	0 59.3	50.7	42.4	34.5	27.3	21.1
4	41.4	36.4	30.3	23.2	15.4	07.1	58.5	49.9	41.5	33.7	26.7	20.6
5	1 41.0	I 35.9	1 29.6	1 22.5	1 14 6	1 06.2	0 57 6	0 49.0	0 40.7	0 33.0	0 26.0	0 20.0
6	40.5	35.3	29.0	21.7	13.8	05.4	56.7	48.2	39.9	32 2	25.4	19.5
7 8	40.0	34.7	28·3 27·6	20.9	12·9 12·1	04.5	55·9 55·0	47·3 46·5	39·1	30.8	24·7	19.0
9	39·1	34·I 33·5	26.9	19.4	11.3	02.8	54.2	45.7	37.5	30.1	23.5	18.0
10	1 38.6	1 32.9	1 26.2	1 18·6	1 10.5	1.01.9	0 53.3	_	o 36·8		0 22.9	0 17.5
Lat.	<i>a</i> ₁	a ₁	a_1	<i>a</i> ₁	aı	<i>a</i> ₁	<i>a</i> ₁	<i>a</i> ₁				
	,	0.4	0:3	,	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.4
0 10	0.5	0.4	0.3	0.3	.3	.2	.2	3	3	.3	.4	.5
20	·ś	.5	.4	1 .4	.3	-3	3	·3	.3	•4	-4	·š
30	.5	.5	.5	-4	-4	4	·4	·4	·4	·4	•5	.5
40	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6
45	-6	-6	-6	.5	•5	.5	.5	.5	.5	-6	-6	.6
50	.6	-6	•6	·6	-6	.6	.6	-6	6	·6	·6 ·6	·6 ·6
55 60	·6 ·7	·6 ·7	·7 ·7	7	.7	·7 ·8	.7	·7 ·8	·7 ·8	·7	-7	.7
	1	1							0.8	0.8	0.7	
62 64	0.7	0.7	o⋅8 8	0.8	0.8	0.3	0.8	0.8	9	.8	.8	0·7 ·7
66	·7	-8	-8	0.9	0.9	1.0	1.0	1.0	0.9	9	.8	.7
68	0.7	0.8	0.9	1.0	1.0	1.0	1.1	I.O	1.0	0.9	0.9	0.8
Month	a ₂	a ₂	a_2	a 2	a_{i}	a ₂	az	a ₂				
Ion	0.5	0.5	0,5	,	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7
Jan. Feb.	0.5	0.5	0·5 ·4	0·5 ·4	4	-4	.4	.5	.5	.5	.6	.6
Mar.	4	.4	4	-3	3	.3	.3	•3	·3	.4	•4	·4
Apr.	0.5	0.5	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3
May	.7	.6	.5	.4	.4	.3	-3	·2	·2	·2	·2	•2
June	-8	.7	.7	.6	.5	.5	.4	·3	.3	·2	.2	·2
July	0.9	0.9	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0.4	0.3	0.3
Aug.	.9	.9	.9	.9	-8	-8	.7	-6	-6	.5	.5	4
Sept.	.9	.9	.9	.9	'9	.9	.8	-8	·8	.7	.6	.6
Oct.	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8
Nov.	.7	:7	.8	-8	.9	.9	1.0	1.0	I.O	1.0	1.0	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.						AZIM	UTH	1	1	•	1	1
0	0.4	0.6	0.6	0.7	0.8	0.8	0.8	0.8	0.8	0.7	o.6	0.5
20	0.5	0.6	0.7	0.8	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.5
40	0.6	0.7	0.8	0.9	1.0	I · I	1.1	1.1	1.0	0.9	0.8	0.7
50	0.7	0.8	1.0	1.1	1.2	1.3	1.3	1.3	1.2	1.1	1.0	0.8
55	0.7	0.9	1.1	1.3	1.4	1.4	1.4	1.4	1.3	I · 2	1.1	0.9
60	0.9	I · I	1.3	I 4	1.6	1.6	1.7	1.6	1.5	1.4	1.2	1.0
65	1.0	1.3	1.2	1.7	1.8	1.9	2.0	1.9	1.8	1.7	1.5	1.2

Latitude = Apparent altitude (corrected for refraction) $-1^{\circ} + a_{0} + a_{1} + a_{2}$

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*.

TABLES FOR INTERPOLATING SUNRISE, MOONRISE, ETC.

TABLE I-FOR LATITUDE

Tat	oul	lar	Inte	rva	ıl					Ďif	feren	ce bet	ween	the '	times	for c	conse	cutive lati	tudes		
Io°		5	°	:	2°	5 ^m	IOm	15 ^m	20 ^m	25 ^m	30m	35 ^m	40 ^m	45 ^m	50m	55 ^m	60m	I ^h 05 ^m	Ip 10m	Ih 15m	Ih 20m
. ,		•	,	۰	,	m	70	m	m	m	m	m	m	m	m	m	m	h m	h ma	b m	h m
0 30		0	15	0	06	0	0	I	I	1	1	I	2	2	2	2	2	0 02	0 02	0 02	0 02
I 00	•	0	30	0	12	0	I	I	2	2	3	3	3	4	4	4	5	05	05	05	O5
I 30		0 .	45	0	18	I	I	2	3	3	4	4	5	5	6	7	7	97	07	07	07
2 00		1	00	0	24	I	2	3	4	5	5	6	7	7	8	9	10	10	IO	10	10
2 30		I	15	0	30	1	2	4	5	6	7	8	9	9	10	11	12	12	13	13	13
3 00		I	30	0	36	ı	3	4	6	7	8	9	10	11	12	13	14	0 15	0 15	0 16	0 16
3 30		1	_	0	42	2	3	5	7	8	10	11	12	13	14	16	17	18	18	19	19
4 00		2		0	48	2	4	6	8	9	11	13	14	15	16	18	19	20	21	22	22
4 30		2		0	54	2	4	7	9	ΙI	13	15	16	18	19	21	22	23	24	25	26
5 00		2	-	I	00	2	5	7	10	12	14	16	18	20	22	23	25	26	27	28	29
5 30		2	- 45	I	06	3	5	8	11	13	16	18	20	22	24	26	28	0 29	0 30	0 31	0 32
6 00		3		ī		3	6	9	12	14	17	20	22	24	26	29	31	32	33	34	36
		-		_		1 -	6	10	13	16	19	22	24	26	29	31	34	36	37	38	40
		_	15	I		3	_	10	1	17	20	23	26	29	31	34	37	39	41	42	44
7 00		-	30	I	24	3	7		14	18		1 -	28	-	1 -		•	43	44	46	48
7 30	•	3	45	I	30	4	7	11	15	10	22	25	20	31	34	37	40	45	4**	40	40
8 00)	4	00	I	36	4	8	12	16	20	23	27	30	34	37	41	44	0 47	0 48	0 51	0 53
8 30	•	4	15	I	42	4	8	13	17	21	25	29	33	36	40	44	48	0 51	0 53	0 56	0 58
9 00		-	30	1	48	4	9	13	18	22	27	31	35	39	43	47	52	0 55	0 58	101	1 04
9 30	,	-	45	1	-	5	9	14	19	24	28	33	38	42	47	51	56	1 00	1 04	1 08	I 12
10 00			00	2		5	10	15	20	25	30	35	40	45	50	55	60	1 05	1 10	1 15	1 20

Table I is for interpolating the L.M.T. of sunrise, twilight, moonrise, etc., for latitude. It is to be entered, in the appropriate column on the left, with the difference between true latitude and the nearest tabular latitude which is less than the true latitude; and with the argument at the top which is the nearest value of the difference between the times for the tabular latitude and the next higher one; the correction so obtained is applied to the time for the tabular latitude; the sign of the correction can be seen by inspection. It is to be noted that the interpolation is not linear, so that when using this table it is essential to take out the tabular phenomenon for the latitude less than the true latitude.

TABLE II-FOR LONGITUDE

Long. East			D	iffere	nce	betwe or	en th	ne ti iven	mes date	for g and f	iven follov	date ving	and date	prec (for	edi wes	ng da t lon	ite (gitu	for e de)	ast 1	longi	tude)	
or West	IOn	20 ^m	30 ^m	40 ^m	50 ^m	60m	r .	I ^h + 20 ^m	30 ^m		1 ^h +	60m	2 ^h	10 ^m	2 ^h	20 ^m	2 ^h	30 ^m	2 ^h	40 ^m	2 ^b	50 ^{.n}	3 ^h 00 ^m
•	I III	m	m	· m.	m	m	m	m	m	m	m	m	4	m	ь	m	Ь	100	þ	m	b	m	h =
0	0	0	0	0	0	0	0	0	0	0	0	0	°	00	0		0		0		°	00	0 00
10	0	I	1	I	I	2	2	2	2	3	3	3	1	04		04	1	04	ŀ	04	1	05	05
20	I	1	2	2	3	3	4	4	5	6	6	7		07		08		о8	İ	09	l	09	10
30	I	2	2	3	4	5	6	7	7	8	9	10	l	II	1	12		12		13	}	14	15
40	1	2	3	4	6	7	8	9	10	11	12	13		14	1	16		17	ļ	18	ľ	19	20
50	1	3	4	6	7	8	10	II	12	14	15	17	0	18	0	19	0	21	0	22	0	_,	0 25
60	2	3	5	7	8	10	12	13	15	17	18	20	1	22	1	23		25	1	27	l	28	30
70	2	4	6	8	10	12	14	16	17	19	21	23	1	25		27		29		31	l	33	35
80	2	4	7	9	11	13	16	18	20	22	24	27		29	1	31		33		36	ļ	38	40
90	2	5	7	10	12	15	17	20	22	25	27	30		32		35		37		40		42	45
100	3	6	8	11	14	17	19	22	25	28	31	33	0	36	0	39	0	42	0	44	0	47	0 50
IIO	3	6	9	12	15	18	21	24	27	31	34	37	1	40		43		46	1	49	0	52	0 55
120	3	7	10	13	17	20	23	27	30	33	37	40		43	1	47	1	50	i	53	0	57	I 00
130	4	7	11	14	18	22	25	29	32	36	40	43		47	1	51		54	0	58	ÌI	10	1 05
140	4	8	12	16	19	23	27	31	35	39	43	47		51		54	0	58	I	02	I	06	1 10
150	4	8	13	17	21	25	29	33	38	42	46	50	10	54	٥	58	1	03	1	07	I	II	1 15
160	4	9	13	18	22	-	31	36	_	44	-	-	0		1	-	1	_	1	ΙÏ	1	16	I 20
	5	9	14	19	24		33	38		47	52	57	1	-	1		r	11	1	16		20	I 25
170 180	12	10	15	. 20	25		35	40	•	50	_							15	1	20	1	25	1 30

Table II is for interpolating the L.M.T. of moonrise, moonset and the Moon's meridian passage for longitude. It is entered with longitude and with the difference between the times for the given date and for the preceding date (in east longitudes) or following date (in west longitudes). The correction is normally added for west longitudes and subtracted for east longitudes, but if, as occasionally happens, the times become earlier each day instead of later, the signs of the corrections must be reversed.

ALTITUDE CORRECTION TABLES 0°-35°-MOON

App.	o°-4°	5°-9°	10°-14°	15°-19°	20°-24°	25°-29°	30°-34°	App.
App. Alt.	Corr	Corra	Corra	Corr	Corra	Corra	Corr	Alt.
		• .	•	D	•		_ ° ,	
oó	° 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	¥ 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 50·6	⁷ 60·5	12 62·6	17 62·7	22 61·7	²⁷ 60·1	32 58·o	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·I	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
IO	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·I	61.9	62.8	62.3	61.1	59.2	56.9	20
30	57.4	61.9	62.8	62.3	61.0		56.8	30
40	57.7	62.0		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.	LU	L U	L U	LU	LU	LU	LU	H.P.
,	, ,	, ,	, ,	, ,	, ,			
54.0	0.3 0.9	0.3 0.9	0.4 1.0	0.2 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	I-I I-4	1.1 1.4	I-I I-4		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	2.0 2.0	1.8 1.9	2.2 2.2	54.9
55.2	1.8 1.8	1.8 1.8	1.9 1.9	1.9 1.9	2.0 2.0	2.12.1		55.2
55.5	2.2 2.0	2.2 2.0	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		55.8
56·I	3.0 2.4	3.0 2.5	3.0 2.5	3.0 2.5	3.1 2.6		3.2 2.7	56·I
56.4		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	57.0
57:3	4.5 3.3	4.5 3.3	4.5 3.3	4.5 3.3	4.5 3.3			57:3
57.6		4.9 3.5	1	4.9 3.5	4.9 3.5	1		57.6
57.9	5.3 3.8	5.3 3.8						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·I	58.5
58.8	6.4 4.4	6.4 4.4		6.3 4.4	6.3 4.3			58.8
59·I	6.8 4.6	6.8 4.6	6.7 4.6	6.7 4.6			1	59·I
59.4	7.2 4.8	7.1 4.8	1					11
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						60.3
60.6	8.7 5.7	8.7 5.7	1		8.5 5.5	8.4 5.4		60.6
60.9	9.1 5.9			8.9 5.8	8.8 5.7			1
				10.3 6.0			8.9 5.6	61.2
61·2 61·5	9.5 6.2							61.5

	D.	IP	
Ht. of Corra	Ht. of Eye	Ht. of Corru	Ht. of Eye
m	ft.	m	ft.
$^{2\cdot 4}$ -2·8	8.0	9.5 - 5.5	31.2
2.6	8.6	9·9 -5·6	32.7
2.8 -3.0	9.2	10.3	33.9
3.0 -3.1	9.8	10.6 -5.8	35.1
3.2 3.2	10.2	-5·9	36∙3
3.4 -3.3	I I ·2	11.4 -6.0	37.6
3.6 3.3	11.9	11.8 -0.1	38.9
3.8 3.4	12.6	12·2 -6·2	40·I
4.0 -3.6	13.3	12·6 -6·3	41.5
4.3 - 3.7	14·I	13.0 -6.4	42.8
4.5 -3.8	14.9	13·4 -6·5	44.2
4.7 -3.9	15.7	13·8 —6·6	45.5
5.0 -4.0	16.5	14.2 -6.7	46.9
5.2 4.1	17:4	14.7 -6.8	48-4
5.5 -4.2	18.3	15·1 -6·9	49.8
5.8 -4.3	19.1	15.5 - 7.0	<1.3
6·I 4·3	20·I	16.0 -7.1	52.8
6.3 -4.5	21.0	16.5 7.2	54.3
6.6 4.6	22.0	16.9	55.8
6.9 -4.7	22.9	17.4 -7.4	57:4
7.2 -4.8	23.9	17.9	- 58·o
7.5 -4.9	24.9	18·4 -7·6	60.5
7.9 -5.0	26.0	18 8	62·1
8·2 -5·I	27·I	19.3 -7.8	63.8
8.5 -5.2	28·I	198	65.4
8.8	29.2	20.4 -8.0	67.1
9.2 -5.3	30.4	20.9 -8.1	68-8
9.5 -5.4	31.5	21.4	70.5

MOON CORRECTION TABLE

The correction is in two parts; the first correction is taken from the upper part of the table with argument apparent altitude, and the second from the lower part, with argument H.P., in the same column as that from which the first correction was taken. Separate corrections are given in the lower part for lower (L) and upper (U) limbs. All corrections are to be added to apparent altitude, but 30' is to be subtracted from the altitude of the upper limb.

For corrections for pressure and temperature see page A4.

For bubble sextant observations ignore dip, take the mean of upper and lower limb corrections and subtract 15' from the altitude.

App. Alt. - Apparent altitude - Sextant altitude corrected for index error and dip.

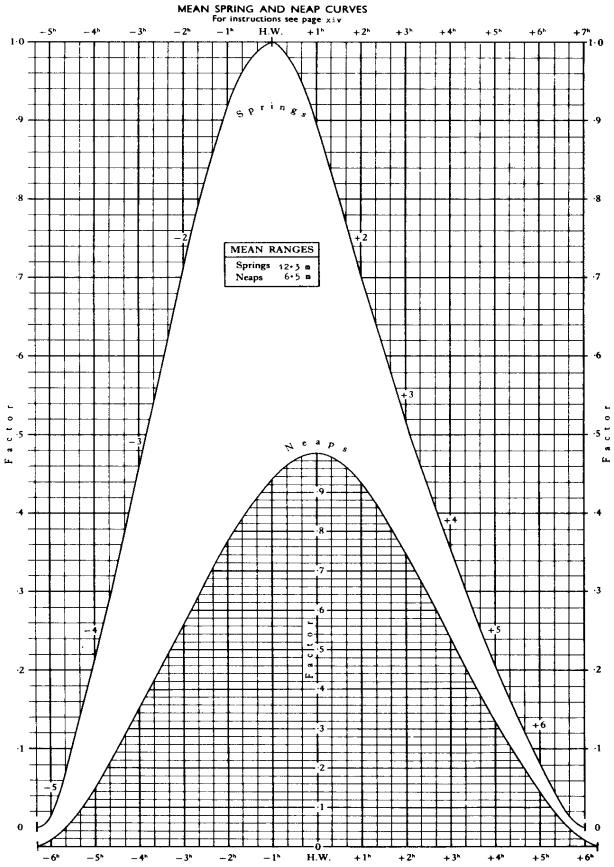
ALTITUDE CORRECTION TABLES 35°-90°-MOON

		ALII	TUDE	COM	w							
App.	35°-39°	40°-44°	45°-49°	50°-54°	55°-59°	60°-64°	65°- 6 9°	70°-74°	75°-79°			App. Alt.
Alt.	Corr	Corr	Corra	Corr	Corr	Corre	Corr	Corra	Corr	Corr	Corre	
,		40 ′_	45	50 46.0	55 43.1	60 _ 6'	65	70 20 T	75 _{25 3}	80 20.5	85 ₁₅ .6	00
00	35 56·5	53.7	45 50.5	40.9	43 -	38.9	34.0	30.1	25.2	20.4	15.5	10
10	50.4	53.6	50.4	46.8	42.9	38.8	34.4	29.9	25.0	20.2	15.3	20
20	56⋅3	53.5	50.2	46.7	42.8	38.7	34.3	29·7 29·6	24.9	20.0	15.1	30
30	56.2	53.4	50·I	46.5	42.7	38.5	34·I	29.4	1	h .	15.0	40
40	56.2	53.3	50.0	46.4	42.5	38.4	34.0	29.3	24.5	19.7	14.8	50
50	56.1	•		46.3	42.4	38.2	33·8 66			Q.	86	
00	36 56·0	4I 53·1	46 49.8	51 46.2	56 42·3.	61 38·1	33.7	71 29.1	24.4	19.6	14.0	90
10	55.9	53.0	1	46.0	42.1	37.9	33.5	29.0	24.2	19.4	14.5	10
20	55.8			45-9	42.0	37.8	33.4	28.8	ł .			20
30	55.7			45.8	41.8	37.7	33.2	28.7			1	30
40	55.6	1 - 2		45.7	41.7	37.5	33·1	28.5				40
50	55.5	1		45.5	41.6	37.4	32.9	28.3	23.6		1 -	50
_			49		57 41.4	62 37.2	67 32.8	72 28.2	77 23.4	82 18-6	87 13.7	00
00	37 _{55·4}	4ª 52·4					32.6	1 _	1 -	1 -		10
10	55-3				41.3	36.9	32.5	1		1 - 1		20
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40	55.0		_			1 -	32.0	,				1 *
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10	54-8			44-5	40.5					1		
20	54.1		6 48-1	44.4		1			. i			
30	54.0	- 1	5 48·C	44 2	1				- 1			
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50	54.	4 51·	2 47.8	3 44∙0	39.9	1 -		I	'	' e .	80	1 -
~~	39 ₅₄	3 44 ₅₁ .	I 49 47-6	5 54 43.9	59 39.8	3 64 35·5	69 31.0	74 26.	3 79 21 ·	5 04 16-	6 3 11.7	
00	54							3 26⋅:	[21 :		- 1	٠. ١
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		i		1		0 3.4 3.	2 3.6 3.	4 3.7 3	5 3.93	7 4.13	9 4.3 4.	
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56											·8 4·6 3·	
56			1		1			1			·8 4·7 3·	8 5
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57		·6 4·9 3	6 4.9 3								6 5.13	
57	9 5.23									- 1		
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			-	
58	.5 5.9 4	.0 5.8 4	.o 5⋅8 3	9 5.73	.9 5.6 3	8 5.63	8 5.53	.7 5.5 3			5 5 3 3	
58				1 -			8 5.73	7 563				
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59	_ 1			1.5 7.0 4		1 -	-					
			4.8 7.5 4	1.7 7.3 4	·5 7·1 4	ŀ3 6·9 4					- 1	
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59 60 60		5·I 7·9	5.0 7.7 4	1.8 7.6 4	·6 7·3 4							
59 60 60	7.8	5·I 7·9 5·3 8·2	5·0 7·7 4 5·1 8·0 4	1·8 7·6 4 1·9 7·8 4	·6	1.5 7.3 4	2 7.1 4	4.0 6.8	3.7 6.6	3.4 6.3	3.2 6.0 2	9 (
59 60 60 60	7·8 :	5·I 7·9 5·3 8·2	5·0 7·7 4 5·1 8·0 4 5·2 8·3	·8 7·6 4 ·9 7·8 4 ·0 8·1 4	·6		·2 7·1 4 ·3 7·3 4	4·0 6·8 4·0 7·0	3·7 6·6 3·7 6·7	3·4 6·3 3·4 6·4	3·2 6·0 2 3·1 6·1 2	.9

EXTRACTS FROM THE ADMIRALTY TIDE TABLES VOL. I 1980

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AVONMOUTH



ENGLAND, WEST COAST - PORT OF BRISTOL (AVONMOUTH)

LAT 51°30'N LONG 2°43'W

TIF	E ZON	E GMT						TIM	IES A	ND HE	IGHTS	OF	HIGH	AND L	0W W	ATERS					YE	AR	1980
JANUARY						FE	BRUA	RY				H	ARCH					A	PRIL				
	TIME	Ħ		TIME	M		TIME	M		TIME	M		TIME	M		TIME			TIME	M		TIME	M
	0038 0617 1307 1845	1.3	16	0548 1230 1811	12.2 1.6 12.4	F	0203 0726 1422 1949	1.1	SA	0154 0712 1428 1934	0.5	SA	1409 1930	1.1	SU	0141 0654 1417 1920	0.4 13.9	TU	0232 0748 1448 2009	1.1	W	1529 2025	0.0 14.2
2	0132 0703 1356 1929	1.1	17 TH	0102 0639 1334 1901	1.1	ŜΑ	0242 0801 1457 2024	1.2	SU	0251 0757 1519 2020	0.2	2 su	0227 0742 1442 2003	1.1	17 *	0239 0742 1510 2005	0.1	2	0302 0821 1518 2037	1.1	17 TH	0343 0851 1604 2102	0.1
3	0217 0743 1435 2008	1.1	18	0201 0725 1430 1947	0.7		0314 0836 1529 2059	1.3	M	0340 0841 1606 2104	0.1	3	0258 0814 1513 2036	1.1	ΤU	0329 0827 1554 2047	0.0		0332 0848 1544 2103	1.2		1630	0.3 13.8 0.5 13.3
4	1509			0253 0810 1520 2033	0.6	4	0348 0908 1602 2131	1.5	ŢU	0423 0926 1648 2146	0.2	4	0330 0845 1545 2105	1.2	19	0409 0909 1632 2126	0.0	4	0358 0914 1605 2126	1.4	19 sa	1650	0.7 12.9 1.0 12.4
5 sa	1540	1.2 13.0 1.5 12.7	20 su	0340 0854 1608 2118	0.5		0419 0937 1631 2157	1.7		0459 1009 1721 2225	0.5	W	1612 2130	1.4	TH	0443 0949 1700 2202	13.4	SA	0416 0937 1618 2150	1.6 12.2	SU	1708 2255	1.7
6	1612		21	0424 0940 1653 2202	0.6	6	0445 1005 1654 2221	2.0	21 TH	0526 1049 1746 2304	1.0	6 TH	0425 0937 1632 2151	1.6	21	0506 1026 1719 2238	1.0	SU	0429 1003 1629 2220	2.1 11.5	M	1735 2346	2.4 10.6
7	1643	1.8 12.3 2.1 11.9	22 TU	0504 1025 1732 2247	0.9 13.4 0.9 12.9	7	1709	2.1 11.8 2.3 11.4	22	0548 1131 1808 2346	1.8	F	1642 2212	1.9 11.8	SA	0522 1106 1735 2319	11.4	7	0443 1037 1650 2302	2.6	22 TU	0556 1223 1823	2.7 10.1 3.0
	1710		¥	0538 1111 1806 2330	1.2 12.8 1.3 12.1	8	0515 1056 1722 2315	2.6 11.1 2.9 10.6	23 SA	0611 1219 1837	2.2 11.0 2.5	SA	1650 2239	11.1	SU	0542 1151 1801	2.5	TŲ	0516 1128 1736	2.8 10.4 3.2	23	0050 0657 1337 1940	10.0 3.1 9.8 3.2
¥	1736 2325	2.8 10.7	TH	0608 1158 1837	1.9	SA	1746	3.4	SU	1324 1932	5.1	SU	1707 2321	3.0 10.3	M	0010 0618 1251 1851	10.0 3.1	W	1245 1901	10.0 3.5	TH	1504 2118	
10 TH	0549 1143 1806	3.1 10.6 3.3	25 _F	0019 0644 1253 1921	11.2 2.4 11.2 2.5	10 su	0000 0607 1228 1837	9.9 3.7 9.8 3.9	25	0155 0808 1450 2058	9.9 3.3 10.0 3.1	10	0526 1147 1751	3.2 10.0 3.6	25 Tu	9120 0727 1416 2018	9.8 3.3 9.7 3.2	10	0137 0806 1426 2056	10.1 3.2 10.2 3.1	25	1010	10.3 2.6 10.7 2.5
F	1230 1849	10.0 3.7	SA	0119 0739 1404 2022	10.6 2.8	M	1349 2006	9.7 3.8	TU	1617 2233	10.5	TU	1307 1920	9.7 3.8	¥	1548 2201	2.8	ŀ	2240	2.3	SA	2352	11.1 2.0 11.4 1.9
12 sa	0105 0718 1334 1953	9.8	SU	1523 2141	2.7	TU	2148	3.2	w	2355	1.9	W	2117	3.3	1 H	2330	2.1	34	1700	12.2	30	1134	11.7
SU	1452 2115	10.0	M	1638 2301	2.2	u	1645 2325	2.2	TH	1815	12.0	14	2303	2.3	. •	1/51	11.6	20	1806	13.1	-	1830	12.3
14	0338 0955 1607 2236	10.8	i iu	0505 1140 1741	11.4 2.0 11.8	14 TH	0522 1211 1751	12.0 1.7 12.3	29	1321	1.3 12.3 1.2 12.5	14	0500 1154 1731	11.9 1.7 12.3	29 SA	1304	1.5 12.0 1.3 12.3		(13)	0.8 13.7 0.4 13.8		رووا ا	1.3 2 12.3 1.3 1.3 12.5
	I 1714			0013 0602 1249 1831	1.7 12.1 1.5 12.3	F	1326	1.4 13.0 1.0 13.2)			15	1313	1.4 13.0 0.9 13.2	S U	1345	1.2 12.4 1.1 12.6	TU	1445	0.4 14.2 0.2 14.1		1 1412	1.2 3 12.5 2 1.2 3 12.8
			31	0648 1 1341	1.2 12.6 1.2 1.2										31	0201 0716 1416 1938	1.1 12.6 1.1 12.8						

ENGLAND, WEST COAST

No.	PLACE		Lat. N.	Long.		TIME DII Water (Zone		Water	HEIGH MHWS	T DIFFERE MHWN	nces (in i MLWN	METRES) MLWS	M.L. Z ₀ m.	g° M
523	PORT OF BRISTOL (AVONMOUTH)		(see pa	ige 122)	0000 and 1200	0600 and 1800	and	and	13.2	10.0	3.2	0.9		
	River Severn													
517	Sudbrook		51 35	2 43	+0010	+0010	+0025	+0015	+0.3	+0.1	-0.1	+0.1	0	0
518	Beachley (Aust)	•	51 36	2 38	+0010	+0015	+0040	+0025	-0.3	-0.5	-0.2	-0.3	6.6₄	211
519	Inward Rocks		51 39	2 37	+0020	+0020	+0105	+0045	-1.0	-1.1	I'4	~o·6	9	9
520	Narlwood Rocks .	•	51 39	2 36	+0025	+0025	+0120	+0100	-1.9	-2.0	-2.3	o·8	ě	٥
521	White House										•			•
522	Berkeley .	•	51 40	2 33	+0025	+0025	+0145	+0120	-3.0	-3.1	−3 ·6	-1.0	•	•
5228		•	51 42	2 30	+0030	+0045	+0245	+0220	-3.8	-3.9	-3.4	-0.2	•	•
522b		•	51 43 51 44	2 29	+ 0035	+0050	+0305	+0245	-3.9	-4.3	-3.3	-0.4	•	•
	THE STATE OF THE S		31 44	4 49	T 0040	+0055	+0320	+0305	-4.1	-4.4	-3.1	-0.5	⊚	•
523	PORT OF BRISTOL				0200	0800	0300	0800						
	(AVONMOUTH)		(see pa	ge 122)		and	and	and	13.2	10.0			66	
			•	- ,	1400	2000	1500	2000	-3 -	100	3.2	0.9	6.96	202
	Diam 4				•		•							
***	River Avon													
5232	Shirehampton .		51 29	2 41	0000		+0035		-0.7	-0.7	-o·8	0.0	0	0
523b 524	Sea Mills Bristol	•	51 29	2 39	+0005	+0005	+0102	+0030	-1.4	-1.5	- r·7	-0.1	ō	0
344	(Cumbosland Decks)						_			•	•		٠.	•
	(Cumberiand Basin)	٠	51 27	² 37	+0010	+0010	ş	§	-2.9	-3·o	§	ş	0	•
5248	Portishead		51 20	2.45			_							
525	Clevedon		51 27		-0002	0000	©	•	-0.1	-0.1	•	•	•	②
547	Weston-super-Mare		51 21	2 50	-0010	-0020 -0030	-0025	-0015	-0.4	-0.3	+0.2	0.0	•	③
		•	.1	- 39	0020	-0030	-0130	-0030	- I · 3	-1.0	-o.8	-0.3	6.14	195
	River Parrett													
528	Burnham		51 14	1 00	-0020	-0025	~-0020	0000					_	
529	Bridgwater		51 08	3 00	~-0015	-0030	+0105	+0455	-2·3 -8·6	-8·1 6·1	-ī.4	- i · I	9	0
			-	•	3	,-	, -3-3	1 2433	-0.0	-0.1	§	§	⊚	0
531	Watchet		51 11	3 20	-0035	-0050	-0145	-0040	- ı ·o	-1.5	+0.1	ت ما	ە00. س	
	Minchead		51 13	3 28	-0035	-0045	0	0	-26	-1.0	-0.I	0.1 +0.1	5 88	179
533	Porlock Bay		51 13		-0045		-0205	_	-3.0	-2.2	-0.1	-0.1	⊚ 6-	. ⊙
534	Lynmouth		51 14		-0055		0	0	-1.6	-2.7	-0·1 0	-0·1	5·62 ⊚	189 ©

	INDEX
A	Convergency 33,34
A.B.C. tables 112,183	Correction of altitudes 157
Admiralty list of lights 45	Course 8, 10
Almanac 105	Current 84
Altitude, correction of 157	Correction tables 104, 166
Amplitude problem 112, 129	
tables 130	D
Angle on the bow, doubling the 82	Danger angles 47
Aries, first point of 102	'd' correction 106
Augmentation 163	Declination 102
Azimuth 112	Departure 50
conversion to bearing 112	Deviation 9, 12
problem 112	Difference oflatitude 2
•	Difference of longitude 2, 50
	Diff<;rence of meridional parts 60
В	Dip, formula for 166
Bearing, 3 figure notation 8	.tabl~ 166
calculation of 112	Direction, abeam 24
compass 11	measurement of 8
magnetic 11	Distance, of sea horizon 45
position from 33	measurement of 6
relative 16	Doubling the angle on the bow 82
transit 41	Drift 21,27,70
	Drying height 87, 97
C	
'C' correction 199	
Celestial equator 101	E
meridian 102	Earth, the shape of 6
poles 101,211	Ecliptic 102
sphere 101	obliquity of 102
Chart datum 87 88	Equator 1
Co-lat 182 '	celestial 101
Compass 8	Ex-meridian problem 202
bearing 11	tables 205
errors 8, 10,43	
calculation of 37, 41, 122 gyro 8	
north 9,10	F
Composite great circle 222	First point of Aries 102

INDEX

INDE	$\mathbb{Z}\mathbf{X}$
G	Lights, height of 36, 98
Geographical mile 7	range of 45
poles 1, 8, 9	Local hour angle 110, 182
position 101	Longitude 2
range 45	by chronometer 146, 192
Great circle 33	correction 113
composite 222	difference of 2
sailing 215	Lower meridian passage 118, 180
Greenwich hour angle 104	Lowest astronomical tide 88
rate of change of 108	Luminous range 46
Gyro compass 8	diagram 46, 47
Cyro compass o	Lunar tide 84
Н	Lanar fide 04
Height, drying 97	M
of tide 87	Magnetic compass 9
Highest astronomical tide 88	meridian 9
Horizon, distance of 45	north 9, 10
rational 130, 157	variation 9
sensible 157	Marcq St. Hilaire method 142, 18
visible 157	205
Horizontal parallax 163	Mean high water neaps 87
Horizontal sextant angle 37	Mean high water springs 87, 98
Hour angle 110, 182	Mean latitude 59
Hour circles 102	sailing 60
Hyperbolic position line 33, 49	Mean low water neaps 87
Tryperbone position line 33, 49	Mean low water springs 87
I	Mercator sailing 60 Meridian 1
1	celestial 102
Increment tables 104	
	prime 1
Intercept 14~, 183	Meridian altitude, latitude by 148
termmal pomt 143	Meridian passage 111
International nautical mile 6	lower 118
times of 111 Meridional parts 60	Middle letitude 50
K Vant 7	Middle latitude 59
Knot 7	sailing 60
Moon 103	
correction of altitude 163	CIIA and dealined an effort
L Latituda 2	GHA and declination of 107
Latitude 2	rising and setting 119
byex-meridian 202	SHA of 103
by meridian altitude 148	times of meridian passage of 113
by pole star 211	Moonrise and moonset 119
difference of 2 mean 55	N
middle 59	N N
parallel of 2	Nautical almanac 104
Leading marks 43	Nautical mile 6, 141
Leeway 29	Neap tides 84

Nominal range 45	Set and drift 70
Noon position 198	Sextant angles 34,47
Sidereal hour angle 102	-
C	Small circle 1,33 Solar tide 84
Obliquity of the ecliptic 102	Speed 7
made good 25	•
P	through the water 25
Spring tides 84	8
Parallax 15~	Standard port 89
Parallelof.1?tltude 2	Star, correction of altitude 162
Parallel smhng 50	GHA and declination of 108
formula for 51,65	meridian passage of 116
Pelorus 16	Streams tidal 84
Plane sailing 55,65	tidal ;tlases 84 85
Planet, correction of altitude of 162	Sun change of declination of 102
GH~ and declination of 107	change of SHA of 103
mendlan passage of 115	correction of altitude of 160
Polar distan~e 182	GHA and declination of 106
Poles, celes~lal 211	
geographIcal 1,8,9	meridian passage of 112 Sunrise and sunset, times of 119
	Sumise and sunset, times of 119
Pole star problem 211	
tables 104,212 T	
Position circle 36,37,43,80, 141	Th 6:4-4: 0
hyperbola 49	Three figure notation 8
line 33 141	Tidal calculations 89
measure~ent of 1	information 85
transferred 65,72,76,80	streams 84
Prime meridian 1	Tide 20,84
PZX triangle 182	counteracting the 21
height of 87 rate of 21,27	
R	Tide tables 85
Radio direction finding 16,33	Time of meridian passage 113
Ranges of lights 45	Time zones 89
Rational horizon 129, 157	Total correction tables 116
Refraction 45,158	Transferred position line
65,72,76,80	
Relative bearing 16	Transit bearing 41
Rhumb line bearing 34	Transit, lower 118
Rising and dipping distance 43	Traverse table 65,80
Rising and setting 129	True bearing, calculation of 112
Running fix 76, 78, 82	
	V
S	Variation 9,12
Sailings, the 50	'v' correction 105
great circle 215	Vertex 216,222
Sea horizon, distance of 45	Vertical sextant angle 34,47
Sea mile 6	tables 37
Secondary port 89,92	Visible horizon 157
Selected stars 104	Z
Semi diameter 159	
Sensible horizon 157	Zenith distance 141,182
- ·	