The 4th edition of George G Bennett's

Complete On-Board

CELESTIAL NAVIGATION

Nautical Almanac and Sight Reduction tables

2011 to 2015

PDF format

to save on printing costs

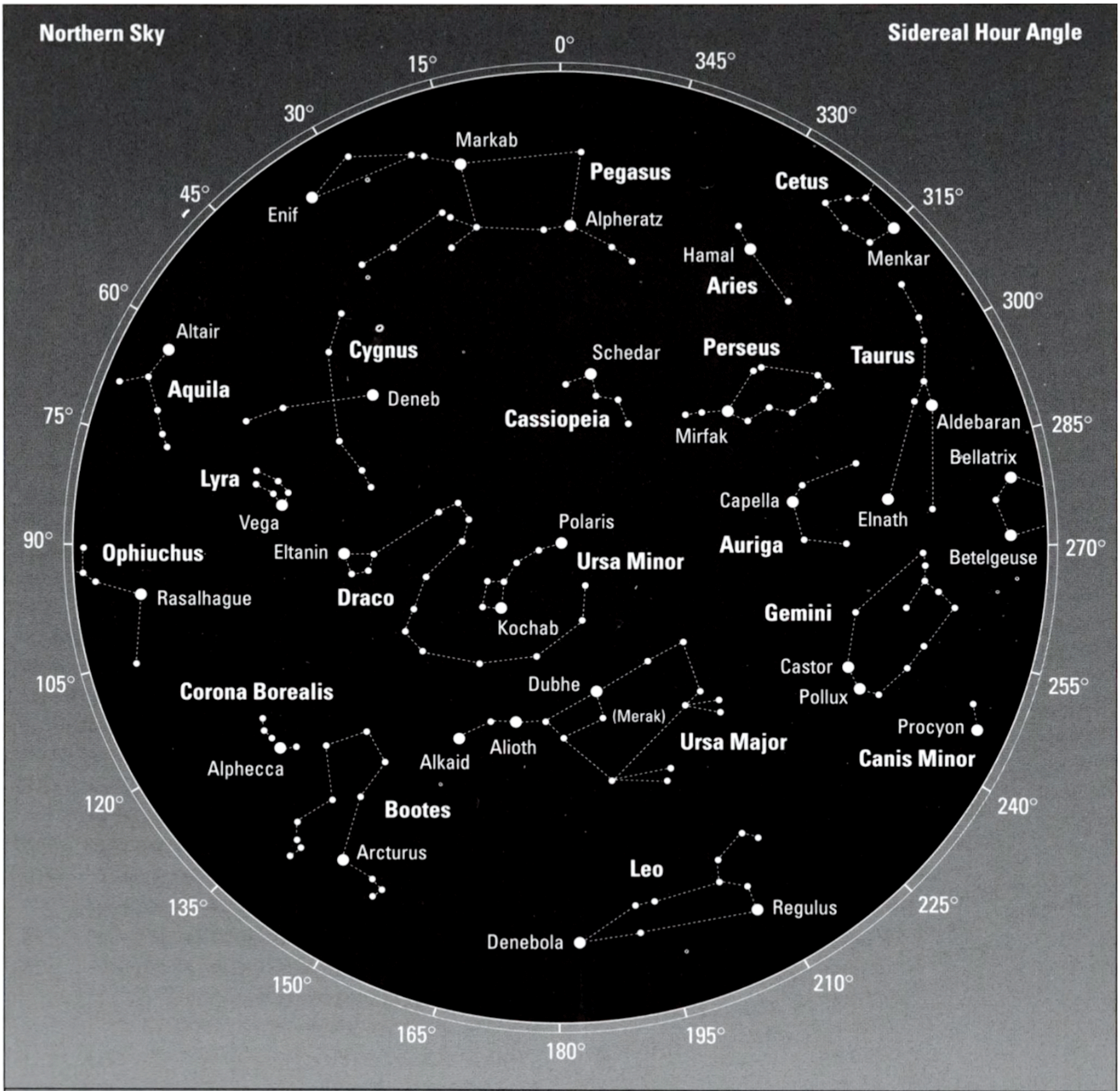
"A practical, convenient, and economical solution for the mariner who wants a backup system to GPS that contains all the essential instructions and data."

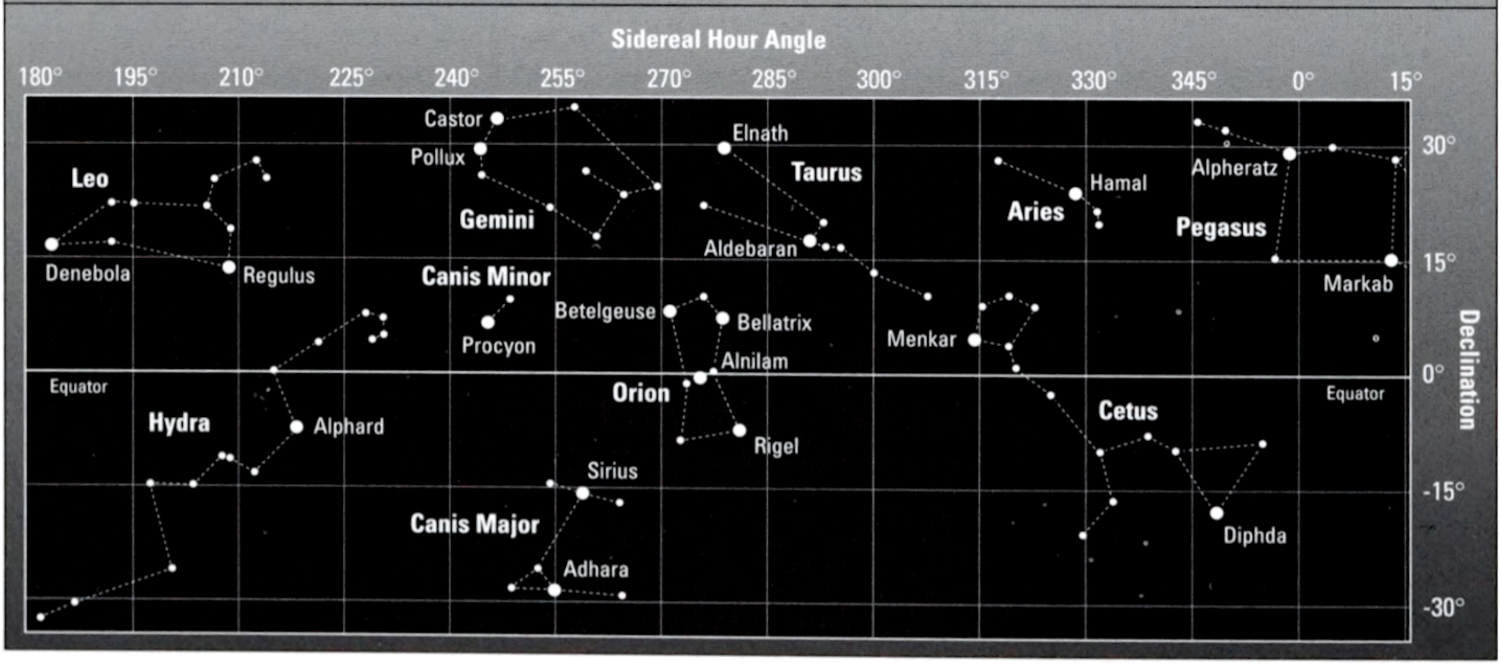
—FOUNDATION FOR THE ART OF NAVIGATION

5 years Nautical Almanac (Sun, Moon, Planets and Navigational Stars)

5 Years Star and Planet Prediction and Identification

Sight Reduction for Latitudes 60°N to 60°S





(FOR SHA 0° TO 180°, SEE INSIDE BACK COVER)

The 4th edition of George G Bennett's

Complete On-Board CELESTIAL NAVIGATION

Nautical Almanac and Sight Reduction tables 2011 to 2015

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The web reference contains some background material, an in depth review and test of the data and methodology, and some additional material in answer to correspondence.

Glossary of navigational stars on pages 170 to 171 courtesy of Ocean Navigator.
Used by permission.

Recommended use:

- **Print on paper that will survive damp or wet finger use, ie 80g/sqm or better;**
- **Print double sided;**
- **Bind in ringbinder or spiral bind to enable the book to lay flat when opened**
- **Consider printing the Sight Reduction Form and Universal Plotting Sheet on heavy duty Mylar or similar re-usable material, and print a few spare copies.**
- **Please provide feedback on how we may improve the next edition – it may help others too.**

CONTENTS

PART ONE: HOW TO WORK A SIGHT

- An Overview

The Note Numbers refer also to the Line Numbers on the Sight Reduction Form (see page 164). You will find it more efficient if for most of the work, you proceed across the Sight Reduction Form rather than work column by column. In order to keep interpolation errors to a minimum many of the tables are arranged in critical form. If you find your data entry coincides with a tabulated value then take the upper (up the page) value of the correction.

1 Indicate the day of the week as an additional check on the date.
2 The name of the body as identified.
3 It is preferable to use a digital rather than an analogue watch; there is less chance of making a reading mistake.
4 Determine the watch correction by comparing the watch with another timepiece whose error is known or with a Radio Time Signal, e.g., WWV (Colorado) & WWV (H) (Hawaii) U.S.
5 Standard Time or Zone Time, i.e., time referred to a given Time Zone.
6 Time Zones, with a few exceptions, are an integral number of hours.
7 The date of this GMT will change from that given in line 1 under the following circumstances,
1 In eastern Time Zones if the Time Zone is greater than the Standard Time, add 24 hours to the Standard Time on line 5 and then proceed. The date changes to the previous day.
2 In western Time Zones if after the addition of the Time Zone, the GMT is greater than 24 hours, subtract 24 hours from the GMT. The date changes to the next day.
8 **ALL BODIES.** Convert all GMTs from Time to Arc using the table on page 101 or 170.
9 **STARS.** From pages 26 to 35 look up the GHA of Aries at GMT 0hrs for the given date and add the Aries Correction given at the side and record the tabulated values of SHA and Declination on lines 10 and 15 respectively.
SUN and PLANETS. From pages 36 to 65 look up the GHA and Declination for the given date and note the changes v and d. From the interpolation tables on pages 66 and 67 determine the proportional parts of v and d and correct the tabulated values of GHA and Declination. Note that the change in Declination d is not signed so be careful how you apply the correction. Record the corrected values of GHA and Declination on lines 9 and 15 respectively.
MOON. For the Moon the process is identical to that for the Sun and Planets except that the tabulated values of (GHA-GMT) and Declination on pages 68 to 97 are given at every 6 hours of GMT. The interpolation tables are on pages 98 to 100. Record the value of Horizontal Parallax (HP, given daily) for use on line 23.
10 See note 9.
11 Add lines 8, 9 and 10 together (do not subtract 360˚ if the sum exceeds 360˚) to obtain the GHA of the body.
12 Enter the DR value of Longitude and heed the sign convention shown in the notes in the left-hand margin.

DATA FOR SIGHT REDUCTION

13 Add or subtract the DR Longitude to obtain the LHA of the body. You may have to add 360˚ to the GHA to effect the subtraction or subtract 360˚ from the LHA if it is greater than 360˚.
14 Enter the DR value of Latitude.
15 See note 9.
16 See under “Sight Reduction” below.
17 Form the Latitude ~ Declination difference (L twiddle D). If the Latitude and Declination have the same name (i.e. both North or both South), take their difference, otherwise take their sum. This quantity has no sign.

SIGHT REDUCTION

13, 14, 15, and 17. Extract the appropriate tabulated quantities under the headings LHA, LAT, DEC, and L~D in the Sight Reduction tables on pages 132 to 151. Note when using these tables, use the minutes column on the left side when entering from the top of the page, but when entering from the bottom use the minutes column on the right-hand side.

16 Add the tabulated quantities on lines 13, 14, and 15. Re-enter the tables and find a value of SUM as near as possible to that sum and write down the tabulated value next to it under the heading RES (Result). Do not attempt to interpolate the tables.
18 Add the values in lines 16 and 17 and look up this sum in the tables from the bottom under the heading ALT (Computed Altitude). Your point of entry in the tables for this quantity is simplified because you know the value of the observed altitude.

ALTITUDE CORRECTIONS AND AZIMUTH

19 Record the observed sextant altitude reading.
20 For the Dip Correction note the height of eye (meters or feet). For convenience the correction, always negative, has been tabulated for the stars on pages 26 to 35, for the Sun and Planets on page 66 and 67, and for the Moon on pages 102 and 103.
21 Record the sextant (Index) correction noting its sign: negative if read on the arc or positive if off the arc.
22 The corrections on lines 20 and 21 are combined and applied to the sextant altitude. The result is the apparent altitude.
23 A single altitude correction for the Stars is given on pages 26 to 35, for the Sun or Planets on page 66 and for the Moon on pages 101 and 102.
24 The observed altitude is obtained after the above correction is applied to the apparent altitude from line 22.
25 The Intercept is the difference between the Observed Altitude (line 24) and the Computed Altitude (line 18). A useful mnemonic is GOAT, meaning (G)reater (O)bserved (A)ltitude (T)oward. If the reverse is true then the Intercept is said to be (A)way.
26 Azimuth, to the nearest few degrees, is more than adequate for plotting lines of position from the DR position and can be obtained from one of the following sources:
1 Azimuths found from the Weir diagrams on pages 152 to 155 with explanation in Section 7.2.
2 Azimuths obtained from the Prediction and Identification tables on pages 104 to 129 with explanation in Section 5.1.
3 Azimuths found from the Azimuth tables on pages 156 to 159 with explanation in Section 7.2.
4 Near to the time of observation, bearings taken with a magnetic compass, corrected for compass error.

27 Use the Universal Plotting Sheet provided on page 165 to plot the Lines of Position, and find the Fix.
28 Adjust the DR Lat and Long by delta Lat and Long of the fix.
29 Record the Fixed position, and plan the next part of the voyage from this point.

1 INTRODUCTION

This book provides, in a compact form, all the essential instructions, almanac data, and tables for finding the latitude and longitude of a ship by celestial navigation and also the means for making a compass check, for a five-year period. Many numerical examples that illustrate the use of its methods and tables are provided as well. This is especially helpful for the navigator who uses celestial methods infrequently.

The difference between this and most other standard works on this subject is that it is entirely self-contained and yet remarkably compact. With the information supplied here, the navigator is independent of any other individual or agency. No longer will it be necessary to purchase separately a book on astronomical navigation, a nautical almanac, a set of tables for reducing sights, and a star and planet identifier.

This has been achieved in part by reducing the accuracy of the almanac data from one-tenth of a minute to one minute of arc. This reduction can be readily tolerated when one considers that now and in the future, astronomical methods will not be the basis for navigation; satellite systems will be the navigator's mainstay for position fixing. The prudent navigator, however, will not rely entirely on satellite systems and electronic devices, which may not be always available, but will choose as well independent methods such as are described here.

The skills required by the celestial navigator can be divided broadly into three areas:

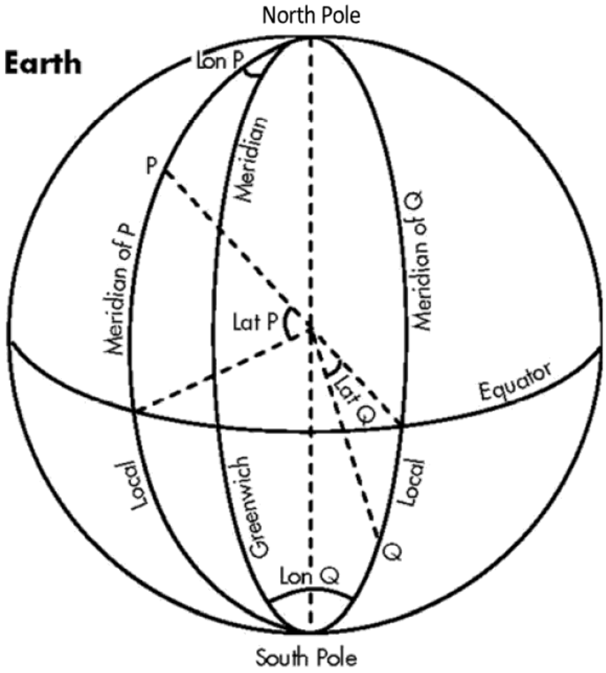
1 An ability to make reliable instrumental observations.
2 An understanding of how astronomical coordinates and other data can be extracted from the almanac section.
3 A proficiency in combining astronomical and terrestrial coordinates with sextant and compass observations to derive data for position fixing and azimuth (true bearing).

2 SCOPE AND CONTENTS

The Complete On-Board Celestial Navigator contains the following:

1 Explanations of the equipment used and practical methods for predicting, observing, calculating, and plotting celestial observations.
2 The coordinates of the Sun, Moon, navigational planets and 58 selected stars, and other astronomical data useful for navigation for five years.
3 Tables for interpolating the above coordinates and for correcting sextant observations.
4 Tables and graphs for sight reduction that will enable a navigator to fix position by the Marcq St. Hilaire method and to find the azimuth of any of the principal celestial bodies.
5 Tables for predicting the position in the sky of the Sun, Moon, planets, and 58 stars from which an optimum observing routine can be compiled. These tables can be used in reverse to identify bodies that, in difficult observing conditions, may not have been located or were mistakenly identified.
6 Examples of calculation and plotting that illustrate the use of the almanac and tables.

To keep the interpolation of data and the application of corrections simple and accurate, critical tables have been widely used.



This has the advantage that no errors greater than half a unit in the value of the quantity extracted can be incurred, and the average error will be a quarter of a unit. If when entering such a table one finds the point of entry is the same as that given in the table, the upper (that is, moving up the page) value of the two possible data values is chosen.

Before studying celestial navigation, the reader must be conversant with such basic navigational quantities as latitude, longitude, azimuth, etc., and be able to plot the passage of a vessel and fix its position in a coastal situation.

The figure at left shows the position (latitude and longitude) of two points, P and Q, on the surface of the Earth, considered to be spherical. Latitude is measured north or south (0˚–90˚) from the equator, and longitude east or west (0˚–180˚) from the Greenwich meridian. P has a north latitude and west longitude, while Q has a south latitude and an east longitude.

3 EQUIPMENT

In addition to this book and basic navigation equipment such as charts, plotting aids, and a hand-bearing compass, the navigator should possess a sextant, a timepiece, and a shortwave radio receiver.

3.1 Sextant

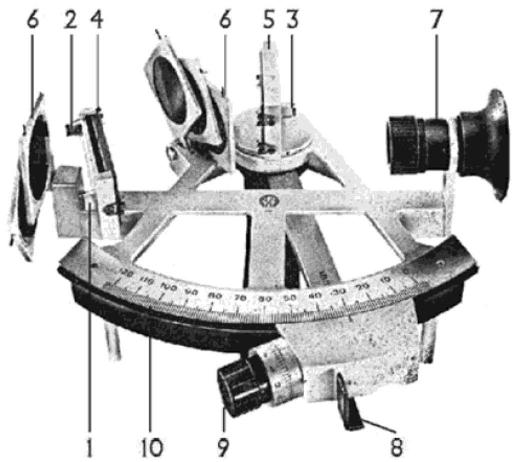
The sextant is one of the most delicate pieces of equipment on a vessel and should be treated with utmost care. Before stowing the sextant in its box, wash salt spray off with freshwater and carefully dry the instrument. If the sextant will not be used in the near future, remove the lighting batteries to prevent corrosion. Periodically check it for adjustment, especially if it may have been subjected to rough handling.

Sextants vary slightly in their arrangement of adjusting screws, and if the handbook for the instrument is missing, try to obtain a copy from the manufacturer.

The following errors are listed in the order in which they should be corrected.

Perpendicularity Error

When in adjustment, the index mirror—the mirror that rotates at the center of the instrument—should be perpendicular to the plane of the sextant. To check this, set the instrument to read near the middle of the graduated arc (about 60˚). Then look along the edge of the index mirror so you can see both the direct and reflected images of the graduated arc. These images should coincide. If not, then use the adjusting screw(s) on the back of the mirror to perfect coincidence.



Adjusting screws for 1) index error, 2) side error, 3) perpendicularity error, 4) horizon glass, 5) index mirror, 6) shades, 7) telescope, 8) clamp, 9) micrometer drum, 10) graduated arc.

If you have a choice when buying a sextant, then a metal one should be preferred over plastic. Plastic sextants are not as robust as the metal types and can deform and develop errors if allowed to heat up. Second hand sextants should be checked by an instrument technician before purchase. Large sextants, although they look magnificent, may not be ideal on a small craft. Observations in rough weather with the navigator standing on a heaving deck clinging to a stay are best made with a light sextant. Beginners will also find that observations without a telescope (the telescope may become misted over with salt spray) with both eyes open will give surprisingly good results. Practice using this technique—it is well worthwhile. The unaided human eye is capable of very accurate observations.

Side Error

When in adjustment, the horizon glass should be perpendicular to the plane of the sextant. For this test, select and sight a well-defined distant object; a star is ideal for this purpose. The direct and reflected images of the object should pass over one another as you move the sextant setting across the zero of the graduated arc. If they appear side by side, then use the adjusting screw(s), usually farthest from the graduated arc, on the horizon glass to correct the error.

Index Error

Before observations, and preferably afterward as well, the sextant should be checked for index error. To do this, set the sextant reading to approximately zero, aim at the sea horizon or at a clear horizontal line a mile or so distant, and bring the direct and reflected images into coincidence by operating the micrometer drum, which acts as a slow-motion screw.

If the sextant reading is not zero, this amount is the index error. Provided it is not more than a few minutes of arc, do not attempt to adjust it. If the reading is greater than zero (on the arc), then subtract this amount from all subsequent readings. If the reading is below zero (off the arc), then add this amount.

To correct for a large index error, set the reading to zero and use the adjusting screw at the rear of the horizon glass (fixed mirror) close to the graduated arc to make the two images coincide as nearly as possible.

Each of the above tests and adjustments is designed to be independent of the others. Unavoidable errors do arise and therefore it must be stressed that if any of the above adjustments are made, it is imperative that *all* be checked before one attempts any observations.

3.2 Clocks

An accuracy to a second or so is required for celestial observations. (an error of one second of time will lead to an error of a quarter of a mile in longitude at the equator, less as the latitude increases).

The worth of a clock is not necessarily its ability to keep time exactly but that the time it keeps can be predicted accurately over many days, provided that it has been subjected to reasonable changes in temperature and motion. If over a test period the clock gains or loses at a steady rate, then it is a simple matter to find a reliable clock correction some days after the last clock correction has been made. Clocks that perform erratically should be rejected. Note that it costs little, and it is a good safeguard, to have two or more clocks on a vessel.

To test a clock's performance, it should be compared with another timepiece of known accuracy or against a radio time signal. The latter method is convenient because continuous time signals are broadcast from many countries. Perhaps the best known are the signals that originate from WWV (Fort Collins) and WWV(H) (Hawaii) on 2.5, 5, 10, 15, and 20 (Fort Collins only) MHz in the USA. Provided ionospheric conditions are not abnormal and depending on the time of day, the signals can be heard throughout the world.

Although it will be necessary to find the Greenwich Mean Time (GMT or UTC or Zulu) of celestial observations, it is not necessary that the clock keep GMT. If the clock is set to keep standard time (zone time), it is a simple matter to add or subtract the time zone, usually expressed in hours, to obtain GMT. (There are a few exceptions to whole hours of half and quarter hours.)

A change of date occurs if, when applying the time zone to obtain GMT, one passes through midnight into the next or previous day. To avoid these problems, some navigators therefore prefer to carry a digital watch set to GMT that also shows the Greenwich date.

Gone are the days when it was necessary to maintain accurate time using an expensive chronometer. A budget-priced digital watch is adequate. A digital timepiece, rather than an analogue type with hour, minute, and second hands, is preferred for timing observations. When timing with the latter, the incorrect minute may be inadvertently recorded when the time is near the whole minute.

There is a danger if time is kept in GMT, without a date display, that the date may be confused, but when working with standard time the date is known without ambiguity because the appearance of the day (daylight and night) correspond approximately with the clock reading; for example, if the clock reading is about 12 hours and it is daylight, then it is near noon on the date for this day—a fact that would not necessarily be obvious if the clock were keeping GMT.

4 ALMANAC DATA

The astronomical coordinates of celestial bodies at their times of observation will need to be extracted from the almanac data for the various calculations described in later sections of this book.

Astronomical coordinates can be depicted on the surface of an imaginary sphere of infinite radius, called the celestial sphere, which has the Earth for its center.

The positions of the stars are given by Declination (**Dec**) and Sidereal Hour Angle (**SHA**), being the celestial counterparts of latitude and longitude respectively. Declinations are measured (0˚–90˚) north or south from the celestial equator. SHAs are measured (0˚–360˚) not from a terrestrial meridian containing Greenwich but west from a celestial meridian containing "the first point of Aries," often denoted by the zodiacal symbol ♈.

The Greenwich Hour Angle (GHA) is a measure of how far a celestial body has progressed since it passed the meridian of Greenwich. For a star the GHA is found by adding its SHA to the GHA of Aries, a quantity tabulated throughout the year. The declination of stars can be assumed constant.

Unlike stars, which maintain their relative positions on the celestial sphere, the Sun, Moon, and planets appear to move, sometimes in an irregular way, through the patterns (constellations)* of stars, and are therefore assigned individual coordinates of GHA and declination.

4.1 Stars and Aries

The GHA of Aries, and the SHA, declination, and magnitude** of 57 bright stars and Polaris are tabulated for each year on pages 26 to 35. The stars are listed in both alphabetical order and in reverse order of SHA. No interpolation is required to extract the data.

To find the GHA of Aries at any instant of GMT, convert the GMT from time to arc using the table on page 170.

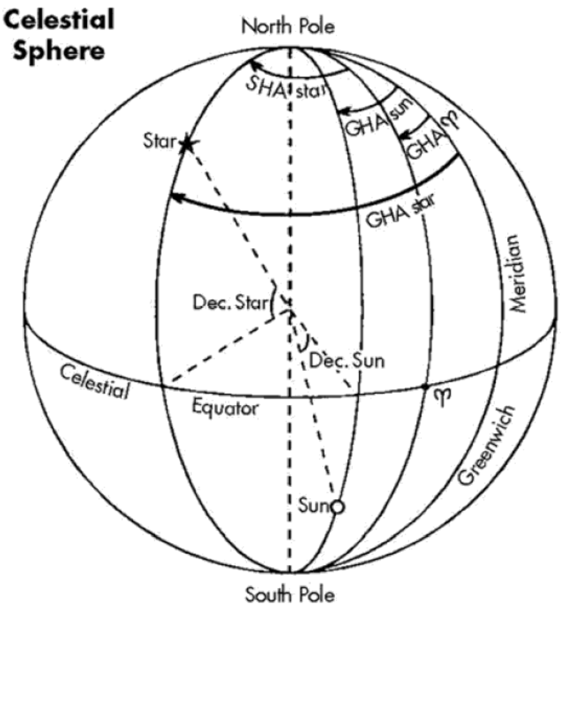
To this add the GHA of Aries tabulated at GMT0hrs on the given Greenwich date, together with the Aries Correction found at the side of the table. Then

GHA Aries = GMT (arc)
+ GHA Aries at GMT0hrs
+ Aries Correction.

For any star, GHA(star) is the sum of GHA Aries as found above, and the SHA:

GHA (star) = GHA Aries
+ SHA(star)

The declination of a star is the value tabulated.



4.2 Sun and Planets

The GHA and declination of the Sun, Venus, Mars, Jupiter and Saturn are tabulated at GMT0hrs for every day of the year on pages 36 to 65.

Each page lists two months of data. The magnitudes of the planets are quoted for the middle of the month. The daily differences at GMT0hrs of GHA (v), and declination (d), are also listed. The difference (v) is given a sign to show the direction of change, but the difference (d) is unsigned because declination is marked N or S. Therefore, when interpolating declination the user must note the direction of change. To find the GHA at any instant of GMT:

1. Convert the GMT from time to arc using the table on page 170.
2. Extract the listed GHA at GMT0hrs and (v) of the body on the date.
3. Using the given value of GMT and (v), look up the correction to GHA at GMT0hrs in the interpolation tables on pages 66 and 67 .If (v) is greater than 60′, the correction is found by adding the correction for hours to that for minutes in the table.

The required GHA is:

GHA Sun/planet = GMT(arc)
+ GHA at GMT0hrs
+ (v) Corrn.

**For convenience in identification, constellations have been named from their appearance. In some cases there is some justification for the name—e.g., the Scorpion, the Southern Cross—but in many others the name bears only a fanciful relationship to the constellation's appearance.*

***"Magnitude" is an indicator of the brightness of a celestial body. In order that the magnitudes of bright and dim bodies can be represented by small numbers, a logarithmic scale for magnitudes has been chosen. The brighter the body, the lower the magnitude number. The brightest stars are said to be of the first magnitude. We can just see a star of the sixth magnitude with the naked eye. Bright bodies may even have a negative value, e.g., Sirius m = –1.6, or show a variable magnitude, e.g., Betelgeuse m = 0.1 to 1.2.*

The figure at left, in contrast to that on page 8 which may be considered as static with respect to the Earth, can be thought of as dynamic. Apart from the stationary Greenwich meridian, the rest of the above figure can be imagined as rotating from east to west around an axis (dotted line) through the north and south celestial poles. A complete rotation of 360˚ is the same as 24 hours, i.e., 15˚ = 1 hour.

To find the declination at the same instant of GMT, use the same technique as described before, but use (d) instead of (v).

The required value of declination is:

Decl'n Sun/planet = Decl'n at GMT0hrs ± (d) Corrn.

4.3 Moon

The GHA-GMT and declination of the Moon are tabulated at every six hours of GMT for every day of the year on pages 68 to 97. Each page lists two months of data. The horizontal parallax (HP), see explanation in Sections 6.4 and 6.5, is given daily.

The times of the phases of the Moon (new, first quarter, full, and last quarter) are summarized at the end of each month. The process of interpolation using the differences of (GHA-GMT) (v) and declination (d) is similar to that used for the Sun and planets except that the data is given at every six hours of GMT.

To find the GHA at any instant of GMT:

1. Convert the GMT from time to arc using the table on page 170.
2. Extract the listed (GHA-GMT) at the nearest preceding six hours of GMT(0/6/12/18)hrs and (v) on the date.
3. Using the values of GMT and (v), look up the correction to (GHA-GMT) at GMT(0/6/12/18)hrs in the interpolation tables on pages 98 to 100. The correction is found by adding the correction for hours to that for minutes.

The required GHA is then:

GHA Moon = GMT(arc) +(GHA-GMT) at GMT(0/6/12/18)hrs +(v) Corrn.

To find the declination at the same instant of GMT, use the same technique as described before, but use (d) instead of (v) and the interpolation table on pages 98 to 100.

The required value of declination is:

Decl'n Moon = Decl'n at GMT(0/6/12/18)hrs ± (d) Corrn.

4.4 Summary

From the preceding text it becomes clear that the process of finding the GHA of Aries, stars, Sun, planets, and Moon is very similar.

The GMT is converted from time to arc, then the tabulated value of the GHA at GMT0hrs for Aries, Sun, and planets—or at a multiple of six hours for the Moon—is extracted and an interpolation correction applied. The sum of these components is then taken. For stars, the GHA is found by adding the SHA.

For declination, all that is required is an interpolation correction to be applied to the tabulated declination, except for stars, which do not need interpolation. In later sections we will often be required to find the local hour angle (**LHA**) of the body, which is a measure of how far the body has progressed since it passed the observer's meridian (north–south). This can be done by applying the longitude (usually the DR value) to the GHA.

The following examples illustrate the complete procedure for all bodies:

EXAMPLES

Find the LHAs and declinations for Arcturus, Sun, Moon, and planets in DR latitude N33°50', longitude W072°15' at standard time 4h 40m (time zone W5h) on 12 April 2015.

ARIES			
Standard Time		*4* h	*40* m
Time Zone (+W, -E)	W	*5* h	
GMT (time)		***9*** h	***40*** m
GMT (arc)		*145* °	*00* '
GHA Aries at GMT0hrs + Corr.		*200*	*17*
GHA Aries		***345***	***17***
Longitude (-W, +E)	W	*72*	*15*
LHA Aries		***273***	***02***

STARS - Arcturus			
GHA Aries		*345* °	*17* '
SHA Arcturus		*145*	*54*
GHA Arcturus (!Subtract 360°)		***131***	***11***
Longitude (-W, +E)	W	*72*	*15*
LHA Arcturus		***58***	***56***
Declination Arcturus	**N**	***19***	***06***

SUN MOON AND PLANETS

	Sun	Venus	Mars	Jupiter	Saturn	Moon
GMT(arc)	145° 00'	145° 00'	145° 00'	145° 00'	145° 00'	145° 00'
GHA *	179 45 (v): +4	141 58 (v)+ -14	163 55 (v): +17	64 32 (v): +58	317 10 (v): +62	265 58 (v): -198
Corrn	+ 2	- 6	+ 7	+ 24	+ 26	- 2 01 -121
GHA	**324 47**	**286 52**	**309 02**	**209 56**	**102 36**	**408 57**
Long**	W 72 15	W 72 15	W 72 15	W 72 15	W 72 15	W 72 15
LHA	**252 32**	**214 37**	**236 47**	**137 41**	**30 21**	**336 42**
Dec	N 8 29 (d): +22	N 21 42 (d): +18	N 14 17 (d): +14	N 17 56 (d): +0	N 18 52 (d): +0	S 16 22 (d): -31
Corrn	+ 9	+ 8	+ 6	+ 0	+ 0	- 19
Dec	**N 8 38**	**N 21 50**	**N 14 23**	**N 17 56**	**N 18 52**	**S 16 03**

* Listed values for the Sun and Planets at GMT0hrs on the date, or for the Moon the listed values at the nearest preceding GMT6hrs on the date.
** -W, +E

5 PLANNING AND OBSERVATIONS

5.1 Planning

An observation is a timed sextant altitude taken to a celestial body. The simplest of such observations are those made during the daylight hours when there are few restrictions on the visibility of the horizon and the identification of celestial bodies. However, observations at these times will generally be confined to the Sun and, for half of the month, the Moon.

With such a small choice of bodies, the navigational information that results, although valuable, will be limited. Nevertheless, the prudent navigator will, weather permitting, take observations throughout the day. Even though they may not be processed, they will form a valuable store of potentially useful information.

To take advantage of a wider choice of bodies will require some planning, and therefore—before making any celestial observations—it is advisable to check on what bodies can be seen. This may be done conveniently using the prediction and identification tables on pages 104 to 129, which give the altitudes and azimuths of 58 stars between the latitudes of N60˚ and S60˚ at 10˚ intervals for every 10˚ of LHA of Aries. A separate tabulation for use with the Sun, Moon, and planets is given at the bottom of each page, covering declinations N30˚ to S30˚ at 5˚ intervals.

To locate all the bodies that can be seen at a given instant of time, find the LHA of Aries and the LHA and declination of the Sun, Moon, and planets for the time of observation. If observations are planned for the time of civil twilight—that is, when stars, planets, and the horizon are visible (see Section 5.5)—you may wish to design an observation routine that optimizes the use of the restricted time available.

An example of the calculations involved is shown in detail in Section 4 and is summarized as follows:

Body	LHA		Declination	
Aries	273°	02'		
Sun	252	32	N 8°	38'
Moon	336	42	S 16	03
Venus	214	37	N 21	50
Mars	236	47	N 14	23
Jupiter	137	41	N 17	56
Saturn	30	21	N 18	52

Turn now to page 111 of the prediction and identification tables for latitude N30˚ (nearest 10˚ to DR Lat), and in the column for LHA of Aries equal to 270˚ (nearest 10˚ to DR Long) are listed the altitudes and azimuths to the nearest degree of those stars that are above the horizon at this time. The altitude is printed first, followed by a space and then the azimuth—a three-figure number in bold type. If a body is below the horizon, "# ###" will be shown, indicating that the body is not visible. The altitudes and azimuths of the Sun, Moon, and planets are found from the tables at the bottom of each page. Enter the table on the left with the value of declination (nearest 5˚) and from the top with the LHA of the body (nearest 10˚). The results of that search are as follows:

Body	LHA	Decl'n	Altidude	Azimuth
Sun	250°	N 10°	#°	###°
Moon	340	S 15	41	154
Venus	210	N 20	#	###
Mars	240	N 15	#	###
Jupiter	140	N 20	#	###
Saturn	30	N 20	61	257

In summary there are 25 stars, the Moon, and one planet available for observation.

As will be discussed later, however, many of the bodies may not be selected for observation because of other restrictions that the observer may wish to impose. In the first instance, bodies should be selected that are not at very low or high altitudes. At low altitudes the brightness of stars and planets is diminished because the light has to pass through more atmosphere than with those sights taken at high altitudes; there is a loss of about two magnitudes between the zenith and the horizon. In addition, because the light rays pass close to the sea's surface, the refraction correction (bending of the light path) is large and may be adversely affected by abnormal atmospheric conditions. At high altitudes, although the refraction correction (zero in the zenith) is small and of greater certainty, it will be difficult to estimate when the body and horizon are in proper coincidence.

From the bodies that satisfy the altitude restrictions, select those that will give a good fix. One observation to each of two bodies, not in line but preferably close to 90˚ apart in azimuth, will be the minimum requirement to obtain a fix. If time and opportunity permit, observations to a number of bodies are desirable to provide not only a check on the observations and calculations but an assessment of the quality of the observed position.

It is good practice also to select the bodies that are well distributed in azimuth because even if there is, say, a constant error in altitude—for example, a poor determination of the sextant index correction—the selected position should lie within the figure formed by the intersecting lines of position (see Section 7.3). For three well-spaced lines not intersecting at a point, the figure is called a "cocked hat."

All of the aforementioned attributes have been taken into account in selecting three stars (identified by their azimuths being underlined) in the columns of stars for each 10˚ of LHA Aries in the prediction and identification tables. Altitudes have been confined to a range of 15˚ to 65˚. Where possible the selected stars are bright — only 6% are dimmer than magnitude 2.2 with an average magnitude of 0.7 for all stars. In addition the three stars have been chosen such that they are well distributed in azimuth, i.e., as close as possible to the ideal of being 120˚ apart and never confined to an arc of less than 180˚ in azimuth.

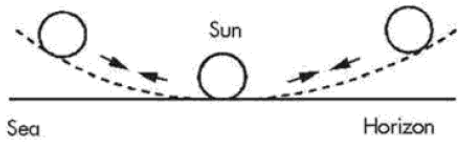
5.2 Sextant Observations

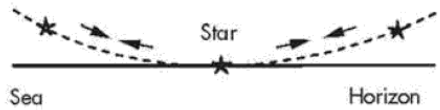
Observations to celestial bodies with a sextant are not difficult. However, good results can be achieved only if the observer has acquired skill and confidence in handling the instrument. Before attempting observations on the Sun, a suitable shade should be swung in front of the index mirror to guard against permanently damaging the eyes. Also, if there is glare on the sea, or the horizon is not sharp, a light shade in front of the horizon glass may be of assistance.

The following guidelines may be helpful:

1 Face the body to be observed and with the sextant set roughly on zero, sight the body in the index mirror. Unclamp and slowly bring this reflected image of the body down to the horizon while moving the index arm along the graduated scale. Clamp gently and then tilt the sextant from side to side like a pendulum and watch the body make an arc near the horizon; the lowest point of the arc is where the altitude is measured. Perfect the coincidence by operating the slow-motion screw until the body appears to touch the horizon. Call out "time" to the recorder or, if operating single-handed, start counting seconds until you can note a time on the watch. The watch reading minus the seconds count is the time of observation.

2 Read the degrees on the main scale and add the reading from the micrometer drum, which is graduated from 0 to 60 minutes.





This technique is suitable for stars and planets, but with the Sun or Moon the contact of the body with the horizon is made with either the upper or lower limb (edge). The figure above shows the appearance in the field of view of the path of the Sun's lower limb and a star as they touch the horizon at the time of observation.

3 If it is difficult to bring a dim body down to the horizon, the following technique may be employed. Turn the sextant upside down, and with the sextant set roughly on zero, point to the body. Bring the horizon up to the body by sliding the index arm along the graduated scale, then clamp and reverse the sextant. The body can now be relocated on the horizon below the body.

4 When the weather is fine, take observations from as high a vantage point as possible.

5 In fog or mist it may be necessary to find a low observation point in order to see the horizon clearly.

6 When there is broken cloud, the body may appear only fleetingly; under these circumstances the navigator should prepare a list of altitudes for setting the sextant and compass bearings to locate the bodies. The prediction and identification tables are invaluable for this purpose. As a precaution, if you are uncertain of the identity of any body, take a compass bearing to help in later identification.

7 When the vessel is rolling and pitching heavily, it is best to take observations amidships to limit the motion of the observer and the variability of the height of eye.

8 Get into the habit of making observations as early as possible at evening twilight and as late as possible at morning twilight, when the horizon will have its best definition. At morning twilight, however, it is all too easy to wait too long and see the stars disappear as you try to observe their altitudes.

5.3 Identification

Situations will sometimes arise when observations have been made to the wrong body or, because of partial cloud cover, the identity of the observed body is in doubt. For example, a few fleeting observations between clouds may be all that is possible in inclement weather, but nevertheless a good position fix may be possible. If there is a doubt about the body's identity at the time of observation, it is a sensible precaution to note the brightness and, if possible, take a compass bearing to the body. Even a rough direction may be of considerable value in deciding which body has been observed. The process of identification can best be illustrated with an example:

EXAMPLE

**Identify a body that has been observed at an altitude of 33˚ 15'
with a magnetic bearing of 115˚
(magnetic variation W10˚)
in the circumstances given in Section 4.**

When we examine the prediction and identification tables we find that eight bodies have altitudes within a few degrees of the observed altitude as follows:

Body	Altidude	Azimuth
Polaris	*30* °	*001* °
Aliot	*32*	*320*
Akaid	*39*	*311*
Arcturus	*38*	*272*
Kochab	*40*	*345*
Antares	*30*	*203*
Nunki	*32*	*165*
Enif	*34*	*099*

There is only one body, **Enif**, which has an azimuth (099˚) that is close to the observed value, i.e., 105˚ (115˚–10˚).

5.4 Observation Methods

There are two approaches to making observations:

Either

(a) make a single observation on a large number of bodies, or

(b) make multiple observations on each of a few bodies.

For (a) there is an advantage in that many lines of position (see Section 7.3) result from the calculations. These should all intersect closely together. If one or more lines cannot be plotted or is markedly distant from this network of lines, we should suspect that a mistake has been made in the observation or calculation, or the incorrect body has been observed. In the latter situation an examination of the prediction and identification tables as described in Section 5.3 may assist in identifying the correct body.

If calculations are not being made on a programmable calculator or computer but by tables, then observing a large number of bodies will lead to the burden of a large number of sight reductions.

For (b), multiple observations to a few bodies can be made quickly because the sextant does not have to be reset from one observation to the next on the same body. The large number of calculations can be avoided in (b) if one observation that best represents the whole series of observations on that body is selected.

First, one should notice that if the body lies to the east of the meridian, altitudes will increase with time, and decrease with time to the west. When a body is close to the meridian (north or south), altitudes change slowly with time. It is best to make a more detailed examination of the multiple observation data so that possible mistakes can be excluded and an assessment made of the quality of the data.

This may be done without any extra calculation as follows:

1 Take a piece of prepared squared paper, a sample of which is given on page 162,
2 mark off convenient vertical and horizontal scales for altitude and time, and
3 plot each observation point (see the example on page 163).

If the observations are error free, the observation points will follow a steady slope or trend (change of altitude with time). This slope can be found, using the diagram on page 161, where we see that approximate values of latitude and azimuth are required for its evaluation. The azimuth is usually known from a prediction or compass bearing or can be obtained from the prediction and identification tables. Now construct a line anywhere on the paper corresponding to this slope (dotted line) — positive upward, negative downward. Then draw a line parallel to it that best fits the observation points (full line). In the example given, it appears that the first observation deviates markedly from the general trend of the remaining observations, and for this reason it has been excluded. The navigator may have noted at the time that the observation was uncharacteristically poor or a mistake could have been made in reading the sextant or recording the time.

The best single representative observation is the mean of all the accepted observations, which can be found by taking the average of the times and the altitudes. Taking averages can be a source of arithmetical mistake, which can be avoided by taking instead a point on this line of best fit. *Any convenient point* will do, and this best estimate can be used in the calculations.

This technique should be used only if the time interval between the first and last observation is small, i.e., not greater than five minutes; otherwise, the observation points may follow a discernible curve instead of a straight line. The departure from a straight line (curvature) is at a maximum for bodies near the meridian (north–south) and a minimum near the prime vertical (east–west).

5.5 Sunrise, Sunset, and Twilight

A knowledge of the times of the rising and setting of the Sun is not only helpful for gauging the hours of darkness and light but also useful when determining azimuth by the method of amplitudes (see Section 8).

At the beginning of morning and the end of evening civil twilight, the Sun's center is 6° below the horizon, and in good conditions the bright stars and the horizon are visible. These are ideal times for making observations with a sextant, and they extend for some time between the beginning of morning twilight and sunrise and between sunset and the end of evening twilight. Note that in equatorial latitudes this period is short but becomes quite long in high latitudes.

The graphs on pages 130 and 131 give the LAT (local apparent time)—the local time kept by the apparent or real Sun—of sunrise, sunset, and twilight referred to the meridian of the observer.

An additional graph gives the correction (the equation of time with the sign reversed) to LAT to obtain LMT (local mean time)—the local time kept by the mean Sun*.

The following examples illustrate the use of these tables in finding the times of sunrise or sunset and the beginning or end of civil twilight:

EXAMPLE

Find the standard time (time zone W2h) of sunrise on 18 August 2015, in latitude N48° 40', longitude W033° 30' (W2h 14m, page 170).

STANDARD TIME OF SUNRISE			
Lat of Sunrise (from tables)		*4* h	*50* m
Correction (same Page)			+ *04*
LMT of sunrise		***4***	***54***
Longitude (+W, -E)	W	*2*	*14*
GMT		***7***	***08***
Time zone (-W, +E)	W	*2*	
Standard time of sunrise		***5***	***08***

EXAMPLE

Find the standard time (time zone E12h) of the end of evening civil twilight on 25 January 2015, in latitude S34° 20', longitude E170° 45' (E11h 23m, page 170).

CIVIL TWILIGHT			
LAT of civil twilight (from tables)		*19* h	*25* m
Correction (same page)			+ *12*
LMT of Civil Twilight		***19***	***37***
Longitude (+ W, –E)	E	*11*	*23*
GMT		***8***	***14***
Time zone (–W , +E)	E	*12*	
Standard time of civil twilight		***20***	***14***

Special Cases of Rising and Setting

In high latitudes and at certain times of the year, it may not be possible to find a point of interpolation in the diagrams on pages 130 and 131. These special situations are categorized as follows:

1. The Sun will remain continuously above the horizon if the latitude and declination are of the same name—that is, both north or both south—and their sum is greater than 89° 10'.
2. The Sun will remain continuously below the horizon if the latitude and declination are of opposite names and their sum is greater than 90° 50'.
3. Civil twilight will last all night if the latitude and declination are of the same name and their sum is greater than 84°.

**The "Mean Sun" is a fictitious body. If it were possible to view the apparent (real) and the mean Sun in the sky, we would see the mean Sun traveling at a constant rate along the celestial equator and the apparent Sun sometimes ahead or behind the mean Sun. The apparent Sun would be removed from the equator by a distance equal to its declination.*

6 Sextant Altitude Corrections

Corrections must be applied to observed sextant altitudes in the correct sequence. If a number of bodies have been observed, time will be saved if each correction is applied to all bodies in turn rather than treating each body separately, that is, work across the form sheet (see page 164). All of the altitude correction tables are set out in the form of critical tables. The complete process of correcting observed altitudes to obtain the true altitude is usually described as "clearing the altitude."

6.1 Dip Correction

The visible sea horizon lies slightly below a horizontal plane stretching out from the observer. Therefore, sextant altitude observations made using the sea horizon as a reference are too large and need to be corrected. The size of this correction, called dip, is always negative and depends upon how high the observer is above the sea surface (height of eye). For convenience, tables of dip for heights of eye in meters and feet are included throughout this book.

6.2 Index Correction

This is also known as sextant correction. The correction should be determined preferably before and after observations have been completed (see "Index Error" p. 9). It should be added to the sextant altitude if it is "off the arc" and subtracted if "on the arc." It is immaterial in which order the dip and sextant correction are made to the sextant altitude, but they must be applied before further corrections are made. The altitude corrected for dip and sextant correction is called the apparent altitude.

6.3 Star and Planet Corrections

Light coming from a celestial body toward an observer on the Earth travels in a straight line through the vacuum of outer space until it meets the Earth's atmosphere. Unless this light comes from directly overhead, upon entering the Earth's atmosphere the light bends in a vertical plane containing the observer and the body. The amount of bending, called astronomical refraction, reaches a maximum of about 34' near the horizon but reduces to about 10' at about 5˚ altitude and to zero in the zenith. Tables of astronomical refraction correction are given in many places throughout this work with the apparent altitude as argument. The correction is always negative.

6.4 Sun Correction

When the Sun and Moon are observed, it is not possible to make an accurate pointing on the center of the body, which is where the astronomical coordinates are referred. Instead, observations are made to the edges (limbs) of the body. Reducing an observation made to the upper or lower limb will require a correction equal to the radius (semidiameter, or s.d.) of the body.

In addition, another phenomenon called parallax in altitude, or just parallax, must be compensated for. This correction arises because of the simplifying assumption made in astronomical calculations that all celestial bodies lie at an infinite distance from the Earth. Allowance for this, for bodies other than stars, can be made by applying a correction, always positive, to the measured altitude. This parallax correction is extremely small for the Sun and planets but for the Moon it can be in excess of one degree. On page 66 is a table for correcting observations made to either the upper or lower limb of the Sun. This correction, using apparent altitude as argument, allows for refraction, parallax, and semidiameter and may be either positive or negative.

6.5 Moon Correction

These tables on pages 102 and 103 incorporate the same components as that for the Sun except that it is necessary to allow for the variable distance of the Moon from the Earth. The measure of this distance is horizontal parallax (HP), which is tabulated for every day of the year.

Because the Moon correction can have identical values for two different altitudes, the argument may be entered from either side of the columns of tabulated correction. It is also apparent from the tables that the correction is sensitive to altitude changes at low altitudes, and therefore the altitude argument is given in degrees and minutes up to about 10˚ or so when the correction reaches a maximum. Between about 10˚ and 20˚ the correction remains almost constant. At higher altitudes, the altitude argument is given only in degrees. The correction may be either positive or negative.

6.6 Summary

The process of applying the dip and sextant correction is common to all bodies. Only one further correction to altitude is necessary to complete the process. This is obtained directly from the tables appropriate to the body.

The following examples illustrate the procedures in a variety of situations:

EXAMPLES

SEXTANT ALTITUDE CORRECTIONS

Body:	Star	Sun (LL)
Sextant Altitude	18 ° 43 '	25 ° 17 '
Height of Eye	5.1m	15ft
Dip	- 4	- 4
Sextant Corrn.	+ 3	- 4
Apparent Altitude	18 42	25 09
Altitude Corrn.	- 3	+ 14
Observed Altitude	18 ° 39	25 23

Body:	Planet	Moon *
Sextant Altitude	36 ° 07 '	8 ° 54 '
Height of Eye	18.1m	6ft
Dip	- 7	- 2
Sextant Corrn.	- 8	- 2
Apparent Altitude	35 52	8 50
Altitude Corrn.	- 1	+ 67
Observed Altitude	35 51	9 57

*Moon LL HP=58'

7 The Marcq St. Hilaire Method

This method has been universally accepted as the simplest and most practical technique for position fixing. A line of position (LOP) for each observed body can be drawn on the chart using an "intercept" and "azimuth."

The intercept is the difference between the corrected observed sextant altitude, and the altitude obtained from calculation, using the celestial coordinates of the body and the best known position, usually the DR, of the observer. The intercept is marked off from the DR position in a direction (calculated azimuth) toward or away from the body.

The LOP is drawn from this point at right angles to this direction. The position of the vessel is somewhere along the LOP. Obviously two or more LOPs, which give a reasonable intersection, will resolve that uncertainty. The data required for this process, called sight reduction, are as follows:

1 The LHA obtained from the GHA of the body as described in Section 4, using the DR longitude.

LHA = GHA ± DR longitude (+east, –west)

2 The DR latitude.
3 The declination of the body as described in Section 4.

7.1 Intercept

From the LHA, DR latitude, and declination, an altitude is calculated (Hc). The observed altitude H(o) is obtained from the sextant altitude after those corrections described in Section 6 have been applied. The intercept is found from the difference "observed minus calculated altitude," expressed in minutes of arc (nautical miles).

The sight reduction tables on pages 132 to 151 are designed to provide the navigator with a simple, universal method of calculating the altitude, using a minimum number of steps. There are no decimal points, only one rule for the manipulation of data, no interpolation, and no special cases in which certain combinations of data lead to poor or even indeterminate solutions, as may happen with some other methods.

Because we can work with a DR position, plotting is simpler, and for most situations the intercepts are short. If a chosen position is adopted—that is, latitude is taken to the nearest whole degree and LHA rounded off to the nearest whole degree—the intercepts are often long. Sometimes it is not known until after plotting that a mistake may have been made in the sight reduction procedure.

The process of sight reduction, listed below, is best followed on a form sheet (see page 164), which can be followed in conjunction with the information in "How to Work a Sight—An Overview," page 6.

Step 1 Write down the values of the LHA, latitude, and declination. Form the difference between latitude and declination, L ~ D (called "L twiddle D"), where "twiddle D" (~D) means that if the latitude and declination have the same name, take their difference; but if they have opposite names, take their sum. Unlike most other sight reduction tables, this table requires only this one special rule.

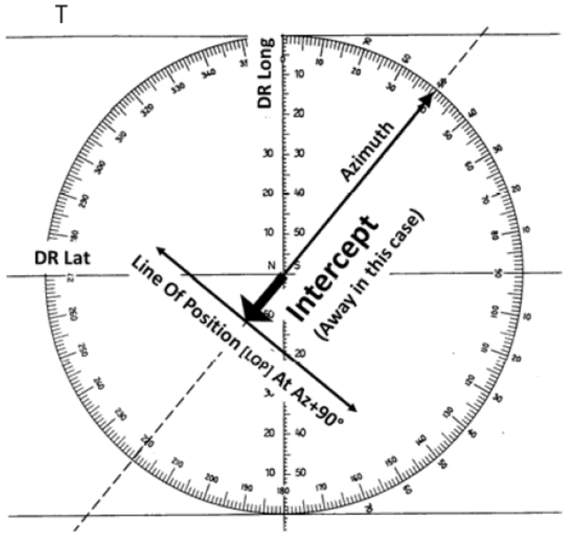
Step 2 Extract the appropriate quantities under the headings LHA (local hour angle), LAT (latitude), DEC (declination), and L ~ D from the sight reduction tables. Like standard trigonometrical tables, these tables are arranged to use the minutes column on the left-hand side when entering from the top of the page, but when entering from the bottom use the minutes column on the right-hand side.

Step 3 Add the tabulated quantities for LHA, LAT, and DEC. This is labeled SUM. Re-enter the tables and find under the heading SUM a value as near as possible to it. Write down the tabulated value next to it under the heading RES (Result). Do not attempt to interpolate the tables.

Step 4 Add the value of RES found from the tables to the tabulated value for L ~ D previously extracted and look up this sum in the tables from the bottom under the heading ALT. The search for this place in the tables is simplified because the value you seek is close to that tabulated for the sextant or observed altitude. See page 23 for very low altitudes.

EXAMPLE

INTERCEPT								
					from Sight Reduction Tables			
LHA		*356* °	*12* '		*38554*			
LAT	N	*48*	*31*		*2331*			
DEC	S	*21*	*39*		*414*			
				SUM	*41299*	›› **RES**		*136*
LAT~DEC		*70*	*10*					*66071*
ALT (Hc)		***19***	***45***	‹‹	‹‹	‹‹		***66207***
ALT (Ho)		*19*	*38*					
Intercept			*7*	Away				



The intercept is the difference between the above calculated altitude "H(c)" and the observed altitude "H(o)".

7.2 Azimuth

To construct LOPs, plotting the azimuth of celestial bodies is required. Provided the DR position is not too far removed from the true position, the intercepts will be short. Therefore azimuth accuracy within a few degrees should be sufficient for most work.

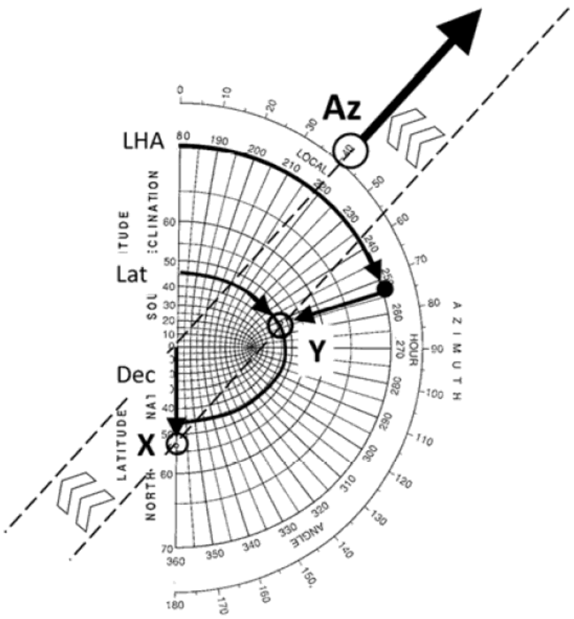
Weir Diagrams

Each diagram consists of a series of ovals (ellipses) that correspond to latitude and a series of radiating curves (hyperbolas) that correspond to the LHA of the body. Examples are given on the diagrams (pages 152 to 155). The steps are as follows:

1 Select the diagram appropriate to the latitude, north or south and LHA, east or west.
2 Mark a point on the vertical line (meridian) corresponding to the declination (north or south) of the body. Point X.
3 Locate a position on the LHA scale corresponding to the LHA of the body and follow this inward until it first cuts the required latitude ellipse. Point Y.

The direction of the line X–Y is the azimuth of the body, which may be measured either by

a. placing a protractor, oriented with respect to the vertical line, with the center on point X and reading off the azimuth on the protractor scale, or
b. transferring the direction X–Y to the center of the diagram with a parallel ruler and reading off the azimuth on the outer azimuth scale.



The original Weir diagram as used by the British Navy (Admiralty Chart No. 5000) has been redrawn on pages 152 to 155 so that it is not necessary to distinguish between colors and double graduated scales that were required in the original diagram to discriminate between north and south celestial and terrestrial hemispheres—a fruitful source of error.

Azimuth Tables

This method of finding the solution of azimuth (see pages 156 to 159), involves one table with different points of entry. No interpolation is required,* and it is one of the simplest techniques for finding azimuth with an accuracy of one or two degrees.

**In extreme cases, the table should be interpolated when observations have been made in the vicinity of the prime vertical and/or LHA, declination, and latitude require substantial rounding off before using the table. When in doubt, use the Weir diagrams. (see Section 7.2).*

Step 1 Enter the table at the top with the declination (ignore the N or S) and from the side with the value of LHA. Record the tabulated value (X).

Step 2 Enter the table again at the top with the altitude and find in the vertical column a value that most nearly corresponds to that of (X), found in Step 1. On the same line but on the side opposite that used in Step 1, record the two values of azimuth.

In most cases, it will be obvious which of the two values is correct, e.g., from prediction or a compass bearing. If you are not sure which of the two values of azimuth to select, mainly because the body is near to the east–west line (prime vertical), proceed as follows:

Step 3 (a) If the declination has the opposite name of the latitude, then the body lies in the southern sky in north latitudes, and in the northern sky in south latitudes. (b) If the declination has the same name (north or south—N or S) as the latitude and is greater than the latitude, then in northern latitudes the body lies in the northern sky and in southern latitudes in the southern sky. If the ambiguity has not been resolved in the previous steps—that is, the declination has the same name as the latitude but is numerically smaller—then proceed as follows:

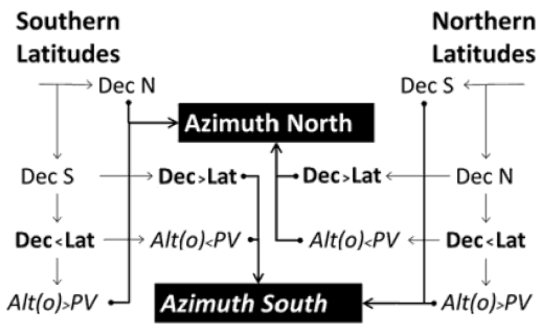
Step 4 Enter the table from the bottom with the declination and note the value immediately over the point of entry (Y). Enter the table again from the left-hand side with the latitude and find on the same line a value that most nearly corresponds to that of (Y). At the bottom of this column, read off the value of altitude, which is the prime vertical altitude—the altitude when the body lies directly east or west of the observer. A comparison between the values of the observed and prime vertical altitudes will resolve the ambiguity of whether the body lies to the north or south of the prime vertical.

Choose the latitude, north or south that corresponds to your situation. Compare the declination or prime vertical altitude with those given in the table to decide whether the body lies in the northern or southern azimuth quadrants:

1. If the prime vertical altitude is greater than the observed altitude the body lies in the northern sky in north latitudes or in the southern sky in south latitudes.

2. If the prime vertical altitude is less than the observed altitude the body lies in the southern sky in north latitudes or in the northern sky in south latitudes.

A simple summary of the situation in steps 1 to 4 above is given below:



A number of examples to demonstrate the resolving of this ambiguity are given below:

EXAMPLES

AZIMUTH EXAMPLES (North Latitudes)							
Dec.	LHA	X	ALT (Obs.)	LAT	Y	ALT (P.V.)	Az.
N *16* °	*301* °	823	*4* °	S *53* °			***056*** °
S *54*	*109*	555	*24*	S *42*			***217***
S *17*	*88*	955	*11*	S *36*	292	*30* °	***257***
S *8*	*345*	256	*60*	S *35*	139	*14*	***031***

AZIMUTH EXAMPLES (South Latitudes)							
Dec.	LHA	X	ALT (Obs.)	LAT	Y	ALT (P.V.)	Az.
S *18* °	*325* °	545	*23* °	N *41* °			***144*** °
N *63*	*123*	380	*20*	N *37*			***336***
N *15*	*284*	936	*19*	N *27*	259	*35* °	***082***
N *23*	*62*	812	*34*	N *59*	390	*27*	***259***

If only an approximate azimuth is needed, two other techniques are available:
1. Close to the time of observation, take compass bearings to the various bodies. After correcting for compass error (magnetic variation and deviation), true bearings may be found. The reverse process of finding the compass error from an observed compass bearing and a calculated azimuth is also possible using one of the methods described under Azimuth Tables. The accuracy of azimuth derived from a compass bearing is only as good as the error of observation combined with the uncertainty of the compass error (magnetic deviation and variation).
2. Azimuths can be found directly from the prediction and identification tables on pages 104 to 129. Details of the way in which these tables can be used will be found in Section 5.1. The accuracy of azimuths found by this method may not be very high because we have chosen a latitude and LHA to the nearest 10° in order to enter the tables.

7.3 The Position Fix

Every timed altitude observation, be it a single observation or the representative of a set of observations on a body, will give an LOP. The LOP may be constructed on the chart from the intercept—which is the difference between the observed and computed altitudes—and the azimuth of the body.

The position of the observer would lie somewhere along this line. It is obvious that if we have made observations to two bodies at different azimuths, the intersection of the two LOPs would give a position for the observer.

Observations to more than two bodies are desirable because they will not only provide a check on the observations and calculations but also allow an assessment of the quality of the observed position.

If we would rather not clutter up the chart with a lot of construction lines, we can draw the LOPs and so forth on a plotting sheet (see example on page 169), and transfer the resulting position to the chart. In either case, the principles for plotting are the same.

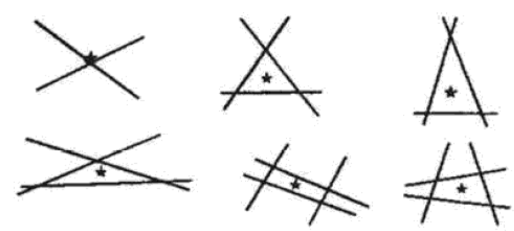
Proceed as follows:

1 Mark a point on the chart, or adopt the center of the protractor scale on the plotting sheet, corresponding to the DR position and draw radial lines (azimuth lines) from this point corresponding to the azimuths of the bodies.

2 Using the scale of latitude on the side of the chart, or on the central vertical line of the plotting sheet, mark off the intercepts along the azimuth lines, toward or away from the bodies. (One minute of altitude equals 1 minute of latitude equals 1 nautical mile.) Intercepts are said to be “toward” if the observed altitude is greater than the calculated altitude and “away” if otherwise. If the intercept is “away,” then the azimuth line must be produced backward from the DR position to mark off the intercept.

3 Draw lines, LOPs, at right angles to the azimuth lines—through these points— which were marked off in step 2. These lines should be made heavy, to distinguish them from the azimuth lines with arrowheads at the ends of the lines and the name of the body written against them.

4 If more than two bodies have been observed and the resulting LOPs do not intersect at a point but crisscross closely together, we must select a point that best fits this configuration. In so doing, try to keep the selected point as close as possible to all LOPs. Some simple configurations are shown below.



Fix *

5 Finally, read the latitude and longitude of the selected point. If using a plotting sheet, be sure to use the central vertical scale for changes in latitude; for changes in longitude, use the longitude scale selected for the DR latitude at the bottom right-hand corner of the sheet.

EXAMPLE OF A POSITION FIX

Timed sextant altitude observations were made to four bodies on the morning of 9 February 2015. Determine the vessel's position using the following additional data:

DR position N16° 30', W135° 50';
watch correction 15s fast;
time zone W9h;
height of eye 2.0m;
and index correction 5' off the arc.

POSITION FIX					
Body	Watch Time			Sextant Altitude	
Moon(UL)	6 h	9 m	35 s	50 °	40 '
Saturn	6	11	20	52	40
Altair	6	12	52	25	44
Regulus	6	14	7	12	44

Fix:			
Latitude	N	16 °	50 '
Longitude	W	135	22

See pages 168 and 169 for full details of extracting almanac data, altitude corrections, sight reduction, and plotting.

There have been many suggestions as to where this point of fix lies but—provided systematic errors are not suspected— the most probable position lies such that the sum of the squares of the distances (errors or residuals) from this point to each LOP is a minimum. We are applying the "principle of least squares," a universally accepted method of dealing with redundant data. Taking the average, or mean, of a set of numbers is a good illustration of this; for example, the average of 6, 7, 9, and 6 is 7 (sum divided by four); the differences, without regard to sign, from the average and the individual numbers are 1, 0, 2 , and 1, and the sum of the squares of these differences is 6. You will find that there is no number, other than 7, that will give a smaller sum of squares of differences. To become familiar with the technique of least squares, set yourself some examples of plots of LOPs at a large scale. Select the point of fix, measure off the distances (errors), and form the sum of their squares. Move the point of fix to another position and compare the new sum of squares with the previous value.

After a little practice, you will be able to choose the optimum point without taking any measurement. This process of selecting the point of fix could be called "eyeball least squares."

8 AMPLITUDES (Compass Check)

One of the simplest and most practical ways of checking a compass is to observe the Sun or Moon when near rising or setting. At these times their azimuths do not change very rapidly, especially in low to medium latitudes. This form of solution assumes that the altitude of the body at rising or setting is zero, which could only be the case if the observer's eye were situated at sea level and the Earth had no atmosphere. To observe the altitude close to zero, the Sun should be observed when the lower limb lies about a semi-diameter above the horizon, and the Moon when the upper limb touches the horizon—at the time of appearing and disappearing. The accuracy of this method is similar to that described under "Azimuth Tables," on page 19.

Given the latitude and the declination of the body, the amplitude (horizontal angle from the east or west points) can be derived from a formula or obtained from special tables. The azimuth tables on pages 156 to 159, although not intended for this purpose, can be used to derive amplitudes conveniently as follows:

Step 1 Enter the table at the bottom with the declination (N or S) and note the value immediately over the point of entry (P).

Step 2 Enter the table at the top with the latitude (ignore the N or S) and find in the vertical column where a value occurs that most nearly corresponds to (P) found in step 1. On the same line on the left-hand side, read off the amplitude on the latitude scale. Azimuth is given as follows:

At Rise

Azimuth = 090° ± amplitude

(+ for south declinations, –for north declinations)

At Set

Azimuth = 270° ± amplitude

(+ for north declinations, –for south declinations)

EXAMPLE

At rise.

Declination N19°, Latitude N29°

From the table P = 325 and Amplitude = 22°

Azimuth = 90°–22° = 068°

A number of examples to illustrate the use of the tables for finding amplitude are given below:

AMPLITUDE EXAMPLES (Sunrise)					
At Rize	Dec	Lat	P	Ampl	**Azimuth**
Az = 90°± Amplitude	S31°	N15°	515	32°	**122°**
(-for Dec N, +for Dec S)	N19	S11	325	19	**071**

AMPLITUDE EXAMPLES (Sunset)					
At Set	Dec	Lat	P	Ampl	**Azimuth**
Az = 270°± Amplitude	N14°	S28°	342	23°	**293°**
(+for Dec N, -for Dec S)	S23	N15	390	24	**246**

9 POLARIS

The proximity of Polaris (the "pole star," Ursae Minoris, magnitude 2.1) to the north celestial pole makes it a good object for determining azimuth and latitude even though the observer's position and the time of observation may not be known very accurately. First calculate the LHA of Aries using the procedure in Section 4.4.

9.1 Latitude

The sextant altitude given in Section 9.1 is corrected for index error, dip, and refraction, using the tables on page 160. Using the LHA of Aries, read off on the same page the altitude correction that when added to or subtracted from the apparent altitude will give the latitude of the observer.

POLARIS LATITUDE			
Sextant Altitude		38 °	05 '
Dip		-	5
Index Correction		-	5
Apparent Altitude		**37**	**55**
Refraction		-	1
Observed Altitude		**37**	**54**
Altitude Correction (page 160)			+ 24
Latitude	**N**	**38**	**18**

9.2 Azimuth

With the above value of LHA of Aries and an approximate latitude, the azimuth of Polaris may be read directly from the table on page 160.

EXAMPLE

Find the azimuth of Polaris
and the latitude
from a sextant altitude observation of 38° 05'
made on 12 April 2015,
at standard time 4h 51m (time zone W5h).
DR latitude N38° 20', longitude W072° 20',
height of eye 9.0m,
and index correction 5' on the arc.

POLARIS AZIMUTH			
Standard Time		4 h	51 m
Time Zone (+W, -E)	W	5	
GMT (time)		**9 h**	**51 m**
GMT (arc)		147 °	45 '
GHA Aries at GMT0hrs + Corr.		200	17
GHA Aries		**348**	**02**
DR Longitude (-W, +E)	W	72	20
LHA Aries		**275**	**42**
Azimuth (from table)		**000.8**	

10 SUN OBSERVATIONS

10.1 Running Fixes

The Sun is a most useful body for celestial navigation, being bright and available for observation throughout most of the day. Methods of calculating the azimuth of the Sun are given in Section 7.2.

If a body such as the Sun or Moon is observed on a number of occasions during the day, an LOP can be drawn from each DR position where those observations were taken. When at least two or more of these LOPs are combined, the position of the vessel can then be determined by either

(a) plotting the LOPs at any selected DR position on the vessel's run or

(b), as in coastal navigation, advancing previous LOPs by the course and distance run between the times of observation and fix. The result is called a running fix.

LOPs not plotted at the DR position from which they were calculated are called double sights, transferred sights, or simply transfers. To distinguish them from normal sights, the LOPs are usually marked with a double arrowhead on each end.

EXAMPLE

The following observations were taken to
the lower limb of the Sun
in the forenoon, near noon, and afternoon
of 15 July 2015.
Determine the vessel's position
at watch time 16h 50m (time zone E10h).
The watch was 1m 10s slow,
the height of eye 12ft,
and the index correction 2' on the arc.

SUN - RUNNING FIX														
DR Position														
Latitude			**Longitude**			**Watch Time**			**Sext. Alt.**					
S	33 °	15 '	E	155 °	24 '	8 h	8 m	30 s	14 °	35 '				
S	33	04	E	155	41	12	14	47	34	31				
S	32	52	E	156	03	15	57	14	8	12				
S	32	40	E	156	25	16	50							
Fix:														
Latitude			**S**	**32 °**	**48 '**									
Longitude			**E**	**156 °**	**04 '**									

See pages 166 and 167 for details of sight reduction and plotting.

The accuracy of these "running" fixes is dependent on the reliability of the estimates of the vessel's run (courses and distances) between the celestial observations. The method is flexible in that there are no special times when observations need to be made, and the point selected along the vessel's run for the plotting is irrelevant. Inclement weather or some other circumstance may prevent observation at a specific time, such as "noon" (see Section 10.2), and therefore the navigator should be circumspect about relying on making such observations. A plot of an LOP near the middle of the day is just as valuable as a "noon" sight, described in the next section.

10.2 Meridian Observations

The Sun will cross the observer's meridian (north–south line) twice each day, at upper and lower transit. The Sun at lower transit can be observed only at certain times of the year inside the Arctic or Antarctic Circles: an unusually high latitude for shipping. If the altitude of the Sun is observed as it makes its upper transit, it will be noticed that altitudes slowly increase to a maximum and then decrease. At the highest altitude, the Sun is said to be making its upper meridian passage at a time called local apparent noon (LAN). This will not occur at "12 hours" but will depend on the time of the year and the vessel's position with respect to the standard meridian adopted for timekeeping; see the following example.

If the longitude is known with reasonable certainty and the altitude is not too high, a compass bearing at upper transit will provide a useful compass check. The time of meridian passage can be calculated as follows:

EXAMPLE

Find the standard time (time zone W10h) of the meridian passage of the Sun on 24 September 2015, in longitude W149° 46' (W9h 59m).

The LMT (local mean time) of the meridian passage of the Sun is 12h ± the correction found on pages 130 or 131. See Section 5.5 for a discussion of the meanings of LAT and LMT.

STANDARD TIME OF MERIDIAN PASSAGE			
LAT of Meridian Passage		*12* h	*00* m
Correction (pages 130 or 131)		-	*8*
LMT of Meridian Passage		*11*	*52*
Longitude (+W, -E)	W	*9*	*59*
GMT		*21*	*51*
Time Zone (-W, +E)	W	*10*	
Standard Time		*11*	*51*

Historically the "noon sight" is deeply entrenched in maritime lore, its main attraction being the simple relationship that exists between the Sun's altitude and declination, and the observer's latitude. The method can best be illustrated with an example.

EXAMPLE

A navigator in DR position S55°, E155° observed the Sun (LL) toward the north at its meridian passage on 24 September 2015. Find the latitude if the sextant altitude was 35° 18', height of eye 2.5m, and index correction 2' on the arc.

Step 1 Clear (correct) the altitude and calculate the zenith distance, which is 90° minus the altitude (that is, an angle measured in a vertical plane from the zenith downward to the body).

ZENITH DISTANCE		
Sextant Altitude	*35* °	*18* '
Dip	-	*3*
Index Correction	-	*2*
Apparent Altitude	*35*	*13*
Altitude Correction	+	*15*
Observed Altitude	*35*	*28*
Zenith Distance = 90°00' - Alt(o)	***54***	***32***

Step 2 Calculate the declination. The GMT of observation may be found with sufficient precision for obtaining the value of declination from,

180° ± longitude (+W, –E)
= 180°– 155°
= 25°
= 1h 40m (time)

DECLINATION AT GMT 1h40m		
Declination at GM T 1h40m on 24 Sept	S *0* °	*15* '
Correction for 1h40m (d=+24')	+	*2*
Declination	**S** *0*	*17*

Step 3 The latitude is calculated from the numerical sum of, or difference between, the zenith distance and the declination using the following table:

LATITUDE		
	Direction of Observation	
	North	South
Declination North	Difference	Sum
Declination South	Sum	Difference

The Sun was observed to the north and the declination was south, therefore the latitude is found from the sum of the zenith distance and the declination:

$$
\begin{array}{lr}
 & 54^\circ\ 32' \\
+ & 0^\circ 17' \\
\hline
= & 54^\circ\ 49'
\end{array}
$$

Therefore the Latitude was S 54° 49'.

11 SIGHT REDUCTION AT VERY LOW ALTITUDES

Occasionally observations need to be made at a very low altitude. This is not recommended because of possible uncertainty in the light path of the body (see Section 5.1).

In the sight reduction procedure at very low altitudes, the calculated altitude may be less than zero, i.e., negative. In this situation the value used in the process of finding the altitude is greater than 99,999. Therefore, subtract this value from 200,000 and find the altitude in the tables in the normal way, noting that this altitude is negative, then proceed to find the intercept and azimuth.

The following example of the sun at its setting illustrates the technique.

OBSERVED ALTITUDE (Ho)	
Sextant Altitude	0 ° 00 '
Dip	- 2
Index Correction	0
Apparent Altitude	- 2
Altitude Correction (page66)	- 50
Observed Altitude	**- 52**

CALCULATED ALTITUDE (Hc)							
LHA		104 °	50 '		2633		
LAT	S	34	20		1083		
DEC	S	19	03		319		
				SUM	**4035**	>>RES	98021
LAT~DEC		15	17				3537
							101558
							200000
ALT Calculated		-	**54** '			<<	98442

INTERCEPT		
Ho	-	52 '
Hc	-	54
INTERCEPT	-	**2** (towards)

Note the observed altitude is greater (higher) than the calculated altitude, therefore the intercept is 2' Towards.

The navigator will find it convenient to make copies of some of the more frequently used forms and tables, e.g., pages 6, 162, 164, 165, and 175/6. In particular a copy of pages 175/6, covered in clear plastic film, will make an excellent bookmark.

CONSTANTS AND FORMULAS

LINEAR UNITS CONVERSIONS

1 International Nautical Mile = 1,852 metres
(Subtended by one minute of latitude)
1 statute mile = 5,280 feet
1 knot = 1 nautical mile per hour
1 cable = 1/10 nautical mile
1 foot = 0.3048 metres
1 fathom = 6 feet

SYMBOLS AND SIGN CONVENTIONS

A = Azimuth, clockwise 000º – 360º
d = declination, +N, –S
l = latitude, +N, –S;
t = local hour angle 000º – 360º
h = altitude

DIP (D) in minutes (always negative)

$$D = 1.76\sqrt{H_m}$$
$$D = 0.97\sqrt{H_f}$$

where:
H_m = height of eye in metres
H_f = height of eye in feet

REFRACTION (R) in minutes (always negative)

$$R = \cot\left(h + \frac{7.31}{h + 4.4}\right)$$

where: *h* = altitude in degrees

PARALLAX IN ALTITUDE (P) in minutes (always positive)

$$P = HP \cos h$$

where: HP = Horizontal Parallax (HP) in minutes

ALTITUDE

$$\sin h = \sin l \sin d + \cos l \cos d \cos t$$

AZIMUTH

$$\tan A' = \frac{-\sin t}{\tan d \cos l - \sin l \cos t}$$

Numerator	+	+	–	–
Denominator	+	–	–	+
Quadrant	000º – 090º	090º – 180º	180º – 270º	270º – 360º
A	A´	180º + A´	180º + A´	360º + A´

OR

$$\cos A' = \frac{\sin d - \sin l \sin h}{\cos l \cos h}$$

t	0º – 180º	180º – 360º
A	360º – A´	A´

OR

$$\sin A = \frac{-\cos d \sin t}{\cos h}$$

(A is ambiguous, see page 19 et seq)

PRIME VERTICAL ALTITUDE (h_{PV})

$$\sin h_{PV} = \frac{\sin d}{\sin l}$$

AMPLITUDE (Amp)

$$\sin Amp = \frac{\sin d}{\cos l}$$

At rise: Azimuth = 090º – Amp

At set: Azimuth = 270º + Amp

PART TWO: TABLES, EXAMPLES, AND FORMS

GHA ARIES AT GMT 0hrs 2011

Day	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	Day
1	SAT 100°18'	TUE 130°52'	TUE 158°27'	FRI 189°01'	SUN 218°35'	WED 249°08'	1
2	SUN 101 17	WED 131 51	WED 159 27	SAT 190 00	MON 219 34	THU 250 07	2
3	MON 102 16	THU 132 50	THU 160 26	SUN 190 59	TUE 220 33	FRI 251 06	3
4	TUE 103 16	FRI 133 49	FRI 161 25	MON 191 58	WED 221 32	SAT 252 06	4
5	WED 104 15	SAT 134 48	SAT 162 24	TUE 192 57	THU 222 31	SUN 253 05	5
6	THU 105 14	SUN 135 47	SUN 163 23	WED 193 56	FRI 223 31	MON 254 04	6
7	FRI 106 13	MON 136 46	MON 164 22	THU 194 55	SAT 224 30	TUE 255 03	7
8	SAT 107 12	TUE 137 45	TUE 165 21	FRI 195 55	SUN 225 29	WED 256 02	8
9	SUN 108 11	WED 138 45	WED 166 20	SAT 196 54	MON 226 28	THU 257 01	9
10	MON 109 10	THU 139 44	THU 167 20	SUN 197 53	TUE 227 27	FRI 258 00	10
11	TUE 110 10	FRI 140 43	FRI 168 19	MON 198 52	WED 228 26	SAT 259 00	11
12	WED 111 09	SAT 141 42	SAT 169 18	TUE 199 51	THU 229 25	SUN 259 59	12
13	THU 112 08	SUN 142 41	SUN 170 17	WED 200 50	FRI 230 24	MON 260 58	13
14	FRI 113 07	MON 143 40	MON 171 16	THU 201 49	SAT 231 24	TUE 261 57	14
15	SAT 114 06	TUE 144 39	TUE 172 15	FRI 202 49	SUN 232 23	WED 262 56	15
16	SUN 115 05	WED 145 39	WED 173 14	SAT 203 48	MON 233 22	THU 263 55	16
17	MON 116 04	THU 146 38	THU 174 14	SUN 204 47	TUE 234 21	FRI 264 54	17
18	TUE 117 04	FRI 147 37	FRI 175 13	MON 205 46	WED 235 20	SAT 265 53	18
19	WED 118 03	SAT 148 36	SAT 176 12	TUE 206 45	THU 236 19	SUN 266 53	19
20	THU 119 02	SUN 149 35	SUN 177 11	WED 207 44	FRI 237 18	MON 267 52	20
21	FRI 120 01	MON 150 34	MON 178 10	THU 208 43	SAT 238 18	TUE 268 51	21
22	SAT 121 00	TUE 151 33	TUE 179 09	FRI 209 43	SUN 239 17	WED 269 50	22
23	SUN 121 59	WED 152 33	WED 180 08	SAT 210 42	MON 240 16	THU 270 49	23
24	MON 122 58	THU 153 32	THU 181 08	SUN 211 41	TUE 241 15	FRI 271 48	24
25	TUE 123 58	FRI 154 31	FRI 182 07	MON 212 40	WED 242 14	SAT 272 47	25
26	WED 124 57	SAT 155 30	SAT 183 06	TUE 213 39	THU 243 13	SUN 273 47	26
27	THU 125 56	SUN 156 29	SUN 184 05	WED 214 38	FRI 244 12	MON 274 46	27
28	FRI 126 55	MON 157 28	MON 185 04	THU 215 37	SAT 245 12	TUE 275 45	28
29	SAT 127 54		TUE 186 03	FRI 216 37	SUN 246 11	WED 276 44	29
30	SUN 128 53		WED 187 02	SAT 217 36	MON 247 10	THU 277 43	30
31	MON 129 52		THU 188 02		TUE 248 09		31

Day	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	Day
1	FRI 278°42'	MON 309°16'	THU 339°49'	SAT 9°23'	TUE 39°56'	THU 69°31'	1
2	SAT 279 41	TUE 310 15	FRI 340 48	SUN 10 22	WED 40 55	FRI 70 30	2
3	SUN 280 41	WED 311 14	SAT 341 47	MON 11 21	THU 41 55	SAT 71 29	3
4	MON 281 40	THU 312 13	SUN 342 46	TUE 12 20	FRI 42 54	SUN 72 28	4
5	TUE 282 39	FRI 313 12	MON 343 45	WED 13 20	SAT 43 53	MON 73 27	5
6	WED 283 38	SAT 314 11	TUE 344 45	THU 14 19	SUN 44 52	TUE 74 26	6
7	THU 284 37	SUN 315 10	WED 345 44	FRI 15 18	MON 45 51	WED 75 25	7
8	FRI 285 36	MON 316 10	THU 346 43	SAT 16 17	TUE 46 50	THU 76 25	8
9	SAT 286 35	TUE 317 09	FRI 347 42	SUN 17 16	WED 47 49	FRI 77 24	9
10	SUN 287 35	WED 318 08	SAT 348 41	MON 18 15	THU 48 49	SAT 78 23	10
11	MON 288 34	THU 319 07	SUN 349 40	TUE 19 14	FRI 49 48	SUN 79 22	11
12	TUE 289 33	FRI 320 06	MON 350 39	WED 20 14	SAT 50 47	MON 80 21	12
13	WED 290 32	SAT 321 05	TUE 351 39	THU 21 13	SUN 51 46	TUE 81 20	13
14	THU 291 31	SUN 322 04	WED 352 38	FRI 22 12	MON 52 45	WED 82 19	14
15	FRI 292 30	MON 323 04	THU 353 37	SAT 23 11	TUE 53 44	THU 83 18	15
16	SAT 293 29	TUE 324 03	FRI 354 36	SUN 24 10	WED 54 43	FRI 84 18	16
17	SUN 294 29	WED 325 02	SAT 355 35	MON 25 09	THU 55 43	SAT 85 17	17
18	MON 295 28	THU 326 01	SUN 356 34	TUE 26 08	FRI 56 42	SUN 86 16	18
19	TUE 296 27	FRI 327 00	MON 357 33	WED 27 08	SAT 57 41	MON 87 15	19
20	WED 297 26	SAT 327 59	TUE 358 33	THU 28 07	SUN 58 40	TUE 88 14	20
21	THU 298 25	SUN 328 58	WED 359 32	FRI 29 06	MON 59 39	WED 89 13	21
22	FRI 299 24	MON 329 58	THU 0 31	SAT 30 05	TUE 60 38	THU 90 12	22
23	SAT 300 23	TUE 330 57	FRI 1 30	SUN 31 04	WED 61 37	FRI 91 12	23
24	SUN 301 23	WED 331 56	SAT 2 29	MON 32 03	THU 62 37	SAT 92 11	24
25	MON 302 22	THU 332 55	SUN 3 28	TUE 33 02	FRI 63 36	SUN 93 10	25
26	TUE 303 21	FRI 333 54	MON 4 27	WED 34 02	SAT 64 35	MON 94 09	26
27	WED 304 20	SAT 334 53	TUE 5 27	THU 35 01	SUN 65 34	TUE 95 08	27
28	THU 305 19	SUN 335 52	WED 6 26	FRI 36 00	MON 66 33	WED 96 07	28
29	FRI 306 18	MON 336 52	THU 7 25	SAT 36 59	TUE 67 32	THU 97 06	29
30	SAT 307 17	TUE 337 51	FRI 8 24	SUN 37 58	WED 68 31	FRI 98 06	30
31	SUN 308 16	WED 338 50		MON 38 57		SAT 99 05	31

ARIES Corrn

GMT h m	Corrn
	0'
0 12	
	+1
0 36	
	+2
1 00	
	+3
1 25	
	+4
1 49	
	+5
2 13	
	+6
2 38	
	+7
3 02	
	+8
3 26	
	+9
3 51	
	+10
4 15	
	+11
4 40	
	+12
5 04	
	+13
5 28	
	+14
5 53	
	+15
6 17	
	+16
6 41	
	+17
7 06	
	+18
7 30	
	+19
7 54	
	+20
8 19	
	+21
8 43	
	+22
9 07	
	+23
9 32	
	+24
9 56	
	+25
10 20	
	+26
10 45	
	+27
11 09	
	+28
11 33	
	+29
11 58	
	+30
12 22	
	+31
12 47	
	+32
13 11	
	+33
13 35	
	+34
14 00	
	+35
14 24	
	+36
14 48	
	+37
15 13	
	+38
15 37	
	+39
16 01	
	+40
16 26	
	+41
16 50	
	+42
17 14	
	+43
17 39	
	+44
18 03	
	+45
18 27	
	+46
18 52	
	+47
19 16	
	+48
19 40	
	+49
20 05	
	+50
20 29	
	+51
20 53	
	+52
21 18	
	+53
21 42	
	+54
22 07	
	+55
22 31	
	+56
22 55	
	+57
23 20	
	+58
23 44	
	+59
24 00	

INDEX OF BRIGHT STARS 2011

NAME	No.	Mag.	SHA	DEC	NAME	No.	Mag.	SHA	DEC
Acamar	1	3.1	315 20'	S40 15'	Alpheratz	12	2.2	357 45'	N29 09'
Achernar	2	0.6	335 28	S57 10	Ankaa	14	2.4	353 17	S42 14
Acrux	3	1.1	173 11	S63 10	Schedar	52	2.5	349 42	N56 36
Adhara	4	1.6	255 14	S28 59	Diphda	25	2.2	348 57	S17 55
Aldebaran	5	1.1	290 51	N16 32	Achernar	2	0.6	335 28	S57 10
Alioth	6	1.7	166 22	N55 54	Hamal	34	2.2	328 03	N23 31
Alkaid	7	1.9	153 00	N49 16	Polaris	44	2.1	318 43	N89 19
Al Na'ir	8	2.2	27 45	S46 54	Acamar	1	3.1	315 20	S40 15
Alnilam	9	1.8	275 48	S 1 12	Menkar	38	2.8	314 17	N 4 08
Alphard	10	2.2	217 58	S 8 43	Mirfak	41	1.9	308 43	N49 54
Alphecca	11	2.3	126 12	N26 41	Aldebaran	5	1.1	290 51	N16 32
Alpheratz	12	2.2	357 45	N29 09	Rigel	49	0.3	281 14	S 8 11
Altair	13	0.9	62 09	N 8 54	Capella	22	0.2	280 37	N46 00
Ankaa	14	2.4	353 17	S42 14	Bellatrix	19	1.7	278 34	N 6 22
Antares	15	1.2	112 28	S26 27	Elnath	27	1.8	278 15	N28 37
Arcturus	16	0.2	145 57	N19 07	Alnilam	9	1.8	275 59	S 1 12
Atria	17	1.9	107 30	S69 03	Betelgeuse	20	Var*	271 03	N 7 25
Avior	18	1.7	234 19	S59 33	Canopus	21	-0 9	263 57	S52 42
Bellatrix	19	1.7	278 34	N 6 22	Sirius	54	-1.6	258 35	S16 44
Betelgeuse	20	Var*	271 03	N 7 25	Adhara	4	1.6	255 14	S28 59
Canopus	21	-0.9	263 57	S52 42	Procyon	46	0.5	245 02	N 5 12
Capella	22	0.2	280 37	N46 00	Pollux	45	1.2	243 30	N28 00
Deneb	23	1.3	49 32	N45 19	Avior	18	1.7	234 19	S59 33
Denebola	24	2.2	182 35	N14 30	Suhail	56	2.2	222 54	S43 29
Diphda	25	2.2	348 57	S17 55	Miaplcidus	40	1.8	221 41	S69 46
Dubhe	26	2.0	193 54	N61 41	Alphard	10	2.2	217 58	S 8 43
Elnath	27	1.8	278 15	N28 37	Regulus	48	1.3	207 45	N11 55
Eltanin	28	2.4	90 46	N51 29	Dubhe	26	2.0	193 54	N61 41
Enif	29	2.5	33 48	N 9 56	Denebola	24	2.2	182 35	N14 30
Fomalhaut	30	1.3	15 25	S29 33	Gienah	32	2.8	175 54	S17 37
Gacrux	31	1.6	172 03	S57 11	Acrux	3	1.1	173 11	S63 10
Gienah	32	2.8	175 54	S17 37	Gacrux	31	1.6	172 03	S57 11
Hadar	33	0.9	148 50	S60 26	Alioth	6	1.7	166 22	N55 54
Hamal	34	2.2	328 03	N23 31	Spica	55	1.2	158 33	S11 13
Kaus Australis	35	2.0	83 45	S34 23	Alkaid	7	1.9	153 00	N49 16
Kochab	36	2.2	137 19	N74 07	Hadar	33	0.9	148 50	S60 26
Markab	37	2.6	13 40	N15 16	Menkent	39	2.3	148 09	S36 26
Menkar	38	2.8	314 17	N 4 08	Arcturus	16	0.2	145 57	N19 07
Menkent	39	2.3	148 09	S36 26	Rigil Kentaurus	50	0.1	139 53	S60 53
Miaplcidus	40	1.8	221 41	S69 46	Zubenelgenubi	58	2.9	137 07	S16 05
Mirfak	41	1.9	308 43	N49 54	Kochab	36	2.2	137 19	N74 07
Nunki	42	2.1	76 00	S26 17	Alphecca	11	2.3	126 12	N26 41
Peacock	43	2.1	53 21	S56 42	Antares	15	1.2	112 28	S26 27
Polaris	44	2.1	318 43	N89 19	Atria	17	1.9	107 30	S69 03
Pollux	45	1.2	243 30	N28 00	Sabik	51	2.6	102 14	S15 44
Procyon	46	0.5	245 02	N 5 12	Shaula	53	1.7	96 23	S37 07
Rasalhague	47	2.1	96 07	N12 33	Rasalhague	47	2.1	96 07	N12 33
Regulus	48	1.3	207 45	N11 55	Eltanin	28	2.4	90 46	N51 29
Rigel	49	0.3	281 14	S 8 11	Kaus Australis	35	2.0	83 45	S34 23
Rigil Kentaurus	50	0.1	139 53	S60 53	Vega	57	0.1	80 39	N38 48
Sabik	51	2.6	102 14	S15 44	Nunki	42	2.1	76 00	S26 17
Schedar	52	2.5	349 42	N56 36	Altair	13	0.9	62 09	N 8 54
Shaula	53	1.7	96 23	S37 07	Peacock	43	2.1	53 21	S56 42
Sirius	54	-1.6	258 35	S16 44	Deneb	23	1.3	49 32	N45 19
Spica	55	1.2	158 33	S11 13	Enif	29	2.5	33 52	N 9 54
Suhail	56	2.2	222 54	S43 29	Al Na'ir	8	2.2	27 45	S46 54
Vega	57	0.1	80 39	N38 48	Fomalhaut	30	1.3	15 25	S29 33
Zubenelgenubi	58	2.9	137 07	S16 05	Markab	37	2.6	13 40	N15 16

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9.7		32
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13.6		44
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18.1		59
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23.3		76
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29.1		95
	-10	

STARS REFN Corrn

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	-2
32 54	
	-1
62 22	
	0

SUN & PLANETS AT GMT 0hrs JANUARY 2011

	SUN SD 16'				VENUS Mag. -4.5				MARS Mag. +1.1				JUPITER Mag. -2.3				SATURN Mag. +0.7				
Day	GHA	v	Dec	d	GHA	v	Dec	d	GHA	v	Dec	d	GHA	v	Dec	d	GHA	v	Dec	d	Day
1 SAT	179° 12'	-7'	S23° 03'	5'	228° 14'	0'	S15° 16'	14'	170° 15'	10'	S23° 10'	7'	102° 58'	52'	S 2° 32'	4'	264° 02'	56'	S 4° 19'	1'	SAT 1
2 SUN	179 05	-7	S22 58	6	228 14	1	S15 30	13	170 25	9	S23 03	6	103 50	51	S 2 28	3	264 58	57	S 4 20	1	SUN 2
3 MON	178 58	-7	S22 52	5	228 15	-1	S15 43	14	170 34	9	S22 57	7	104 41	52	S 2 25	4	265 55	57	S 4 21	1	MON 3
4 TUE	178 51	-7	S22 47	7	228 14	-1	S15 57	13	170 43	9	S22 50	7	105 33	51	S 2 21	3	266 52	57	S 4 22	0	TUE 4
5 WED	178 44	-6	S22 40	6	228 13	-1	S16 10	14	170 52	9	S22 43	7	106 24	51	S 2 18	4	267 49	57	S 4 22	1	WED 5
6 THU	178 38	-7	S22 34	8	228 12	-2	S16 24	13	171 01	10	S22 36	8	107 15	51	S 2 14	4	268 46	57	S 4 23	0	THU 6
7 FRI	178 31	-6	S22 26	7	228 10	-3	S16 37	13	171 11	9	S22 28	7	108 06	51	S 2 10	3	269 43	57	S 4 23	1	FRI 7
8 SAT	178 25	-7	S22 19	8	228 07	-3	S16 50	13	171 20	9	S22 21	8	108 57	51	S 2 07	4	270 40	57	S 4 24	0	SAT 8
9 SUN	178 18	-6	S22 11	9	228 04	-3	S17 03	13	171 29	10	S22 13	9	109 48	51	S 2 03	4	271 37	57	S 4 24	1	SUN 9
10 MON	178 12	-6	S22 02	9	228 01	-5	S17 16	12	171 39	10	S22 04	8	110 39	51	S 1 59	4	272 34	58	S 4 25	0	MON 10
11 TUE	178 06	-6	S21 53	9	227 56	-4	S17 28	13	171 49	9	S21 56	9	111 30	50	S 1 55	4	273 32	58	S 4 25	0	TUE 11
12 WED	178 00	-6	S21 44	10	227 52	-5	S17 41	12	171 58	10	S21 47	9	112 20	50	S 1 51	4	274 30	57	S 4 25	1	WED 12
13 THU	177 54	-5	S21 34	10	227 47	-6	S17 53	12	172 08	10	S21 38	9	113 10	51	S 1 47	4	275 27	58	S 4 26	0	THU 13
14 FRI	177 49	-6	S21 24	11	227 41	-6	S18 05	12	172 18	9	S21 29	10	114 01	50	S 1 43	4	276 25	58	S 4 26	0	FRI 14
15 SAT	177 43	-5	S21 13	11	227 35	-7	S18 17	11	172 27	10	S21 19	9	114 51	50	S 1 39	4	277 23	58	S 4 26	0	SAT 15
16 SUN	177 38	-5	S21 02	11	227 28	-7	S18 28	11	172 37	10	S21 10	10	115 41	50	S 1 35	4	278 21	58	S 4 26	1	SUN 16
17 MON	177 33	-5	S20 51	12	227 21	-7	S18 39	11	172 47	11	S21 00	11	116 31	50	S 1 31	5	279 19	58	S 4 27	0	MON 17
18 TUE	177 28	-5	S20 39	12	227 14	-8	S18 50	11	172 58	10	S20 49	10	117 21	49	S 1 26	4	280 17	58	S 4 27	0	TUE 18
19 WED	177 23	-5	S20 27	13	227 06	-9	S19 01	10	173 08	10	S20 39	11	118 10	50	S 1 22	4	281 15	59	S 4 27	0	WED 19
20 THU	177 18	-4	S20 14	12	226 57	-8	S19 11	10	173 18	10	S20 28	11	119 00	49	S 1 18	5	282 14	58	S 4 27	0	THU 20
21 FRI	177 14	-4	S20 02	14	226 49	-10	S19 21	9	173 28	11	S20 17	11	119 49	50	S 1 13	4	283 12	59	S 4 27	0	FRI 21
22 SAT	177 10	-4	S19 48	14	226 39	-9	S19 30	10	173 39	10	S20 06	11	120 39	49	S 1 09	5	284 11	58	S 4 27	0	SAT 22
23 SUN	177 06	-4	S19 34	14	226 30	-10	S19 40	8	173 49	11	S19 55	12	121 28	49	S 1 04	4	285 09	59	S 4 27	1	SUN 23
24 MON	177 02	-4	S19 20	14	226 20	-11	S19 48	9	174 00	11	S19 43	11	122 17	49	S 1 00	5	286 08	59	S 4 26	0	MON 24
25 TUE	176 58	-3	S19 06	15	226 09	-10	S19 57	8	174 11	11	S19 32	12	123 06	49	S 0 55	4	287 07	59	S 4 26	0	TUE 25
26 WED	176 55	-3	S18 51	15	225 59	-12	S20 05	7	174 22	10	S19 20	13	123 55	49	S 0 51	5	288 06	59	S 4 26	0	WED 26
27 THU	176 52	-4	S18 36	15	225 47	-11	S20 12	8	174 32	11	S19 07	12	124 44	49	S 0 46	5	289 05	59	S 4 26	1	THU 27
28 FRI	176 48	-2	S18 21	16	225 36	-12	S20 20	6	174 43	12	S18 55	13	125 33	49	S 0 41	4	290 04	59	S 4 25	0	FRI 28
29 SAT	176 46	-3	S18 05	16	225 24	-12	S20 26	7	174 55	11	S18 42	12	126 22	48	S 0 37	5	291 03	60	S 4 25	0	SAT 29
30 SUN	176 43	-3	S17 49	17	225 12	-12	S20 33	5	175 06	11	S18 30	13	127 10	49	S 0 32	5	292 03	59	S 4 25	1	SUN 30
31 MON	176 40	-2	S17 32	16	225 00	-13	S20 38	6	175 17	11	S18 17	14	127 59	48	S 0 27	5	293 02	60	S 4 24	0	MON 31
32 TUE	176 38		S17 16		224 47		S20 44		175 28		S18 03		128 47		S 0 22		294 02		S 4 24		TUE 32

SUN & PLANETS AT GMT 0hrs FEBRUARY 2011

	SUN SD 16'				VENUS Mag. -4.3				MARS Mag. +1.1				JUPITER Mag. -2.1				SATURN Mag. +0.6				
Day	GHA	v	Dec	d	GHA	v	Dec	d	GHA	v	Dec	d	GHA	v	Dec	d	GHA	v	Dec	d	Day
1 TUE	176° 38'	-2'	S17° 16'	18'	224° 47'	-13'	S20° 44'	4'	175° 28'	12'	S18° 03'	13'	128° 47'	48'	S 0° 22'	4'	294° 02'	59'	S 4° 24'	1'	TUE 1
2 WED	176 36	-2	S16 58	17	224 34	-13	S20 48	5	175 40	12	S17 50	14	129 35	49	S 0 18	5	295 01	60	S 4 23	0	WED 2
3 THU	176 34	-1	S16 41	18	224 21	-14	S20 53	3	175 52	11	S17 36	13	130 24	48	S 0 13	5	296 01	60	S 4 23	1	THU 3
4 FRI	176 33	-2	S16 23	17	224 07	-13	S20 56	4	176 03	12	S17 23	14	131 12	48	S 0 08	5	297 01	60	S 4 22	1	FRI 4
5 SAT	176 31	-1	S16 06	19	223 54	-14	S21 00	3	176 15	12	S17 09	15	132 00	48	S 0 03	5	298 01	60	S 4 21	0	SAT 5
6 SUN	176 30	-1	S15 47	18	223 40	-14	S21 03	2	176 27	12	S16 54	14	132 48	48	N 0 02	5	299 01	60	S 4 21	1	SUN 6
7 MON	176 29	-1	S15 29	19	223 26	-15	S21 05	1	176 39	12	S16 40	14	133 36	48	N 0 07	5	300 01	60	S 4 20	1	MON 7
8 TUE	176 28	-1	S15 10	19	223 11	-14	S21 06	2	176 51	12	S16 26	15	134 24	48	N 0 12	5	301 01	61	S 4 19	0	TUE 8
9 WED	176 27	0	S14 51	19	222 57	-15	S21 08	0	177 03	13	S16 11	15	135 12	47	N 0 17	5	302 02	60	S 4 19	1	WED 9
10 THU	176 27	0	S14 32	20	222 42	-15	S21 08	0	177 16	12	S15 56	15	135 59	48	N 0 22	5	303 02	61	S 4 18	1	THU 10
11 FRI	176 27	0	S14 12	19	222 27	-14	S21 08	0	177 28	13	S15 41	15	136 47	48	N 0 27	6	304 03	60	S 4 17	1	FRI 11
12 SAT	176 27	0	S13 53	20	222 13	-15	S21 08	1	177 41	13	S15 26	16	137 35	47	N 0 33	5	305 03	61	S 4 16	1	SAT 12
13 SUN	176 27	0	S13 33	20	221 58	-16	S21 07	2	177 54	12	S15 10	15	138 22	47	N 0 38	5	306 04	61	S 4 15	1	SUN 13
14 MON	176 27	1	S13 13	21	221 42	-15	S21 05	2	178 06	13	S14 55	16	139 09	48	N 0 43	5	307 05	61	S 4 14	1	MON 14
15 TUE	176 28	0	S12 52	20	221 27	-15	S21 03	3	178 19	13	S14 39	15	139 57	47	N 0 48	5	308 06	61	S 4 13	1	TUE 15
16 WED	176 28	1	S12 32	21	221 12	-16	S21 00	3	178 32	13	S14 24	16	140 44	47	N 0 53	6	309 07	61	S 4 12	1	WED 16
17 THU	176 29	1	S12 11	21	220 56	-15	S20 57	4	178 45	14	S14 08	16	141 31	48	N 0 59	5	310 08	61	S 4 11	1	THU 17
18 FRI	176 30	2	S11 50	21	220 41	-16	S20 53	4	178 59	13	S13 52	17	142 19	47	N 1 04	5	311 09	61	S 4 10	1	FRI 18
19 SAT	176 32	1	S11 29	22	220 25	-15	S20 49	6	179 12	13	S13 35	16	143 06	47	N 1 09	6	312 10	61	S 4 09	1	SAT 19
20 SUN	176 33	2	S11 07	21	220 10	-16	S20 43	5	179 25	14	S13 19	17	143 53	47	N 1 15	5	313 11	62	S 4 08	2	SUN 20
21 MON	176 35	1	S10 46	22	219 54	-15	S20 38	6	179 39	13	S13 02	16	144 40	47	N 1 20	5	314 13	61	S 4 06	1	MON 21
22 TUE	176 36	2	S10 24	22	219 39	-16	S20 32	7	179 52	14	S12 46	17	145 27	47	N 1 25	6	315 14	62	S 4 05	1	TUE 22
23 WED	176 38	2	S10 02	22	219 23	-15	S20 25	7	180 06	14	S12 29	17	146 14	46	N 1 31	5	316 16	62	S 4 04	1	WED 23
24 THU	176 40	3	S 9 40	22	219 08	-16	S20 18	8	180 20	14	S12 12	17	147 00	47	N 1 36	6	317 18	61	S 4 03	2	THU 24
25 FRI	176 43	2	S 9 18	22	218 52	-15	S20 10	9	180 34	14	S11 55	17	147 47	47	N 1 42	5	318 19	62	S 4 01	1	FRI 25
26 SAT	176 45	2	S 8 56	23	218 37	-16	S20 01	9	180 48	14	S11 38	17	148 34	47	N 1 47	5	319 21	62	S 4 00	1	SAT 26
27 SUN	176 47	3	S 8 33	22	218 21	-15	S19 52	10	181 02	14	S11 21	17	149 21	46	N 1 52	6	320 23	62	S 3 59	2	SUN 27
28 MON	176 50	3	S 8 11	23	218 06	-15	S19 42	10	181 16	14	S11 04	18	150 07	47	N 1 58	5	321 25	62	S 3 57	1	MON 28
29 TUE	176 53		S 7 48		217 51		S19 32		181 30		S10 46		150 54		N 2 03		322 27		S 3 56		TUE 29

THE NAVIGATIONAL STARS

The following list contains basic information on 58 stars used for navigation during morning and evening twilight — that is, when it is dark enough to see the stars but light enough to see the horizon. Information includes the constellation in which the star is found, whether it is in the northern or southern sky, and its position relative to other stars.

Acamar One of two navigational stars in Eridanus (southern sky), Acamar is situated well to the west of Adhara, and lies halfway between Sirius (CMa) and Diphda (Cet).

Achernar One of two navigational stars in Eridanus (southern sky), Achernar lies about 70º west of Canopus (Car) about halfway between Canopus and Fomalhaut (PsA).

Acrux Acrux is the brightest and most southerly star in the Southern Cross, a constellation visible only south of latitude 20ºN.

Adhara The second-brightest star in Canis Major (southern equatorial zone), Adhara lies about 10º south of Sirius, the Dog Star.

Aldebaran Lying at one end of a conspicuous "V" pattern in Taurus (northern equatorial zone), just below the cluster of stars known as the Pleiades, Aldebaran can be found by tracing a line northward from the three stars of Orion's Belt.

Alioth Part of Ursa Major (northern sky), Alioth is the innermost star of the Big Dipper's handle—the one closest to the actual dipper.

Alkaid The second-magnitude star in Ursa Major (northern sky), Alkaid is the outermost star in the handle of the Big Dipper.

Al Na'ir A second magnitude star in Grus—the Crane (southern sky)—Al Na'ir lies about halfway between Fomalhaut (PsA) and Peacock (Pav).

Alnilam The middle of the three bright stars in Orion's belt (equatorial zone), Alnilam lies almost directly over the equator.

Alphard With a name meaning the lonely one, Alphard is the brightest star in Hydra (equatorial zone). It lies just below the equator about midway between Gienah (Cor) and Procyon (CMi).

Alphecca The brightest star in Corona Borealis (the Northern Crown). Alphecca is located at the southern end of a line drawn from Polaris and Kochab [UMi].

Alpheratz The brightest star in Pegasus (northern equatorial zone), Alpheratz lies about halfway between Markab (Peg) and Hamal (Ari). It is one of four bright stars (with Markab, Algenib, and Scheat) that form the Square of Pegasus.

Altair The brightest star in Aquila (northern equatorial zone), Altair is the southern apex of the "summer triangle" formed with Deneb (Cyg) and Vega (Lyr), prominent in the northern sky in summer.

Ankaa A second-magnitude star in Phoenix (southern sky), Ankaa lies just south of a line between Acamar (Eri) and Fomalhaut (PsA).

Antares The brightest star in Scorpius (southern equatorial zone), Antares lies on a line extending from Acrux (Southern Cross) and Hadar (Cen).

Arcturus The second-brightest star in the northern sky, Arcturus is located in Boötes and can be found at the end of a long curve starting at the Big Dipper's handle (including Alioth and Alkaid). "Follow the arc to Arcturus."

Atria Atria is the brightest of the three stars at the southeast apex of the Triangulum Australis (Southern Triangle), which lies between Rigil Kentaurus (Cen) and Peacock (Pav).

Avior One of three navigational stars in Carina (southern sky), it lies north of a line between Miaplacidus and Canopus.

Bellatrix One of four navigational stars in Orion (equatorial zone), Bellatrix lies in the northern sky slightly south of Betelgeuse, or about "10 o'clock" relative to the axis of Orion's Belt.

Betelgeuse The northernmost and brightest of the stars in Orion (equatorial zone), Betelgeuse is at about "9 o'clock" relative to the axis of Orion's Belt.

Canopus The second-brightest star in the night sky, Canopus is one of three navigational stars in Carina (southern sky), with Avior and Miaplacidus. It lies about 36º south of Sirius—the Dog Star—the brightest star.

Capella A bright star in Auriga (northern sky), Capella is at the end of a line drawn from Bellatrix through Elnath.

Deneb The brightest star in the constellation Cygnus (the Swan; northern sky), Deneb is one of three stars comprising the "Summer Triangle"; the others are Vega (Lyr) and Altair (Aql).

Denebola The second brightest star in Leo (northern equatorial zone), Denebola lies just south of a line between Regulus (Leo) and Arcturus (Boö).

Diphda One of two navigational stars in Cetus (equatorial zone), Diphda lies below the equator on a line between Menkar (at the northern end of Cetus) and Fomalhaut (PsA).

Dubhe The brighter and northernmost of the Big Dipper's two pointer stars showing the way to Polaris (UMi), Dubhe is at the far edge of the Big Dipper.

Elnath The second brightest star in Taurus (northern equatorial zone) after Aldebaran, Elnath lies about halfway between Bellatrix (Ori) and Capella (Aur).

Eltanin The brightest star in Draco (northern sky), Eltanin lies about one-third the distance from Vega (Lyr) and Kochab (UMi).

Enif One of two navigational stars in Pegasus (northern equatorial zone), Enif is located just below the midway point of a line halfway between Altair (Aql) and Markab (Peg).

Fomalhaut Found in relative isolation in Piscis Austrinus (southern equatorial zone), Fomalhaut is at one corner of a trapezoid formed by Al Na'ir (Gru), Ankaa (Pho), and Diphda (Cet).

Gacrux The dimmer of two navigational stars in the Crux (the Southern Cross), Gacrux is found opposite Acrux at the northern end of the cross.

Gienah The brightest star in Corvus (southern equatorial zone), Gienah is at the end of a curve that runs from Arcturus (Boö) and Spica (Vir).

Hadar One of three navigational stars in Centaurus (southern sky), Hadar lies near Rigil Kentaurus between that star and the Southern Cross.

Hamal Located in Aries (northern equatorial zone), Hamal lies halfway between Aldebaran (Tau) and Alpheratz (Peg).

Kaus Australis One of two navigational stars in Sagittarius (southern equatorial zone), Kaus Australis lies just south of a line from Nunki (Sag) to Shaula (Sco).

Kochab The brightest star in the Little Dipper (northern sky), Kochab is the nearest bright star to Polaris.

Markab One of two navigational stars in Pegasus (northern equatorial zone), Markab lies south of a line between Enif (Peg) and Alpheratz (Peg) and is in the southwest corner of the "Square of Pegasus" opposite Alpheratz (Peg).

Menkar One of two navigational stars in Cetus (equatorial zone), Menkar lies north of the equator at the end of a line drawn from Procyon (CMi) and Aldebaran (Tau).

Menkent One of three navigational stars in Centaurus (southern sky), Menkent lies well north of Hadar and Rigil Kentaurus.

Miaplacidus The southernmost of the three navigational stars (with Canopus and Avior) in Carina (southern sky), Miaplacidus lies about halfway between Canopus and Rigil Kentaurus (Cen).

Mirfak The brightest star in Perseus, Mirfak lies near the intersection of lines between Menkar (Cet) and Polaris (UMi), and Aldebaran (Tau) and Schedar (Cas).

Nunki The dimmer of the two navigational stars in Sagittarius (southern equatorial zone), Nunki lies north of Kaus Australis on a line between Antares (Sco) and Fomalhaut (PsA).

Peacock The brightest star in Pavo (the Peacock; southern sky), Peacock lies between Al Na'ir (Gru) and Atria (TriA).

Polaris The Pole Star, Polaris is at the end of the handle of the little dipper (Ursa Minor). It is easily found by tracing a line through the Big Dipper's pointer stars Merak and Dubhe (UMa). The altitude of Polaris is within one degree of the observer's latitude.

Pollux The brighter of the Gemini twins in the northern equatorial zone (the other is Castor), Pollux lies nearly halfway between the Big Dipper (UMa) and Orion.

Procyon Known as the Little Dog Star from its position in Canis Minor (northern equatorial zone), Procyon is located about halfway between Sirius—the Dog Star, in Canis Major—and Castor and Pollux (Gem).

Rasalhague The brightest star in Ophiuchus (the Serpent Bearer, northern equatorial zone), Rasalhague lies across the Milky Way from Altair (Aql).

Regulus The brighter of the two navigational stars in Leo (northern equatorial zone), Regulus lies between Denebola (Leo) and Procyon (CMi).

Rigel The most southerly of the four navigational stars in Orion (equatorial zone), Rigel lies diagonally across the belt from Betelgeuse.

Rigil Kentaurus One of three navigational stars (with Hadar and Menkent) in Centaurus, Rigil Kentaurus is the third-brightest star in the night sky. Rigil Kentaurus and Hadar are Southern Cross pointer stars.

Sabik One of two navigational stars in Ophiuchus (equatorial zone), Sabik lies in the southern sky on a line between Antares (Sco) and Rasalhague (Oph).

Schedar The brightest star in Cassiopeia (northern sky), Schedar lies on the far side of a line drawn from Alioth (UMa) and Polaris (UMi).

Shaula One of two navigational stars in Scorpius (southern sky), Shaula lies south of a line between Antares (Sco) and Kaus Australis (Sag).

Sirius Sirius—the Dog Star—is the brightest in the night sky. The three stars in Orion's belt point down to Sirius.

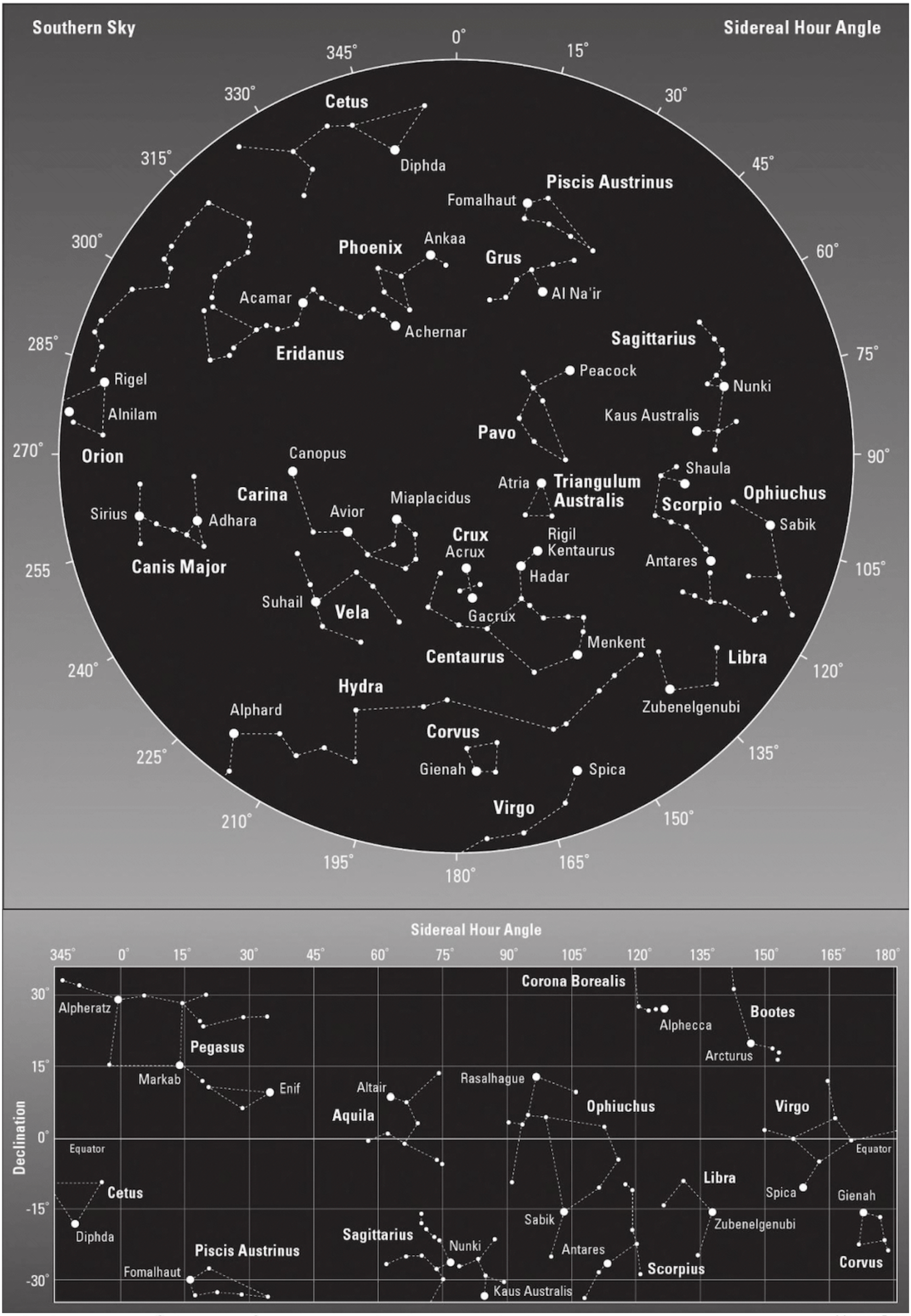
Spica The brightest star in Virgo (southern equatorial zone), Spica can be found by following the arc from the handle of the Big Dipper down through Arcturus (Boö).

Suhail The brightest star in Vela (southern sky), Suhail lies at the end of an arc drawn from Orion's Belt through Sirius (CMa).

Vega The brightest and most beautiful star in the northern summer sky, Vega (one of the stars in Lyra) forms the summer triangle with Altair (Aql) and Deneb (Cyg).

Zubenelgenubi The brightest star in Libra (southern equatorial zone), Zubenelgenubi lies on a line between Spica (Vir) and Antares (Sco).

INDEX



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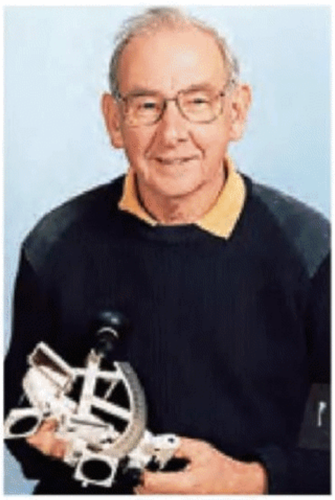

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