CHAPTER 20

SIGHT REDUCTION

BASIC PROCEDURES

2000. Computer Sight Reduction

The purely mathematical process of sight reduction is an ideal candidate for computerization, and a number of different hand-held calculators and computer programs have been developed to relieve the tedium of working out sights by tabular or mathematical methods. The civilian navigator can choose from a wide variety of hand-held calculators and computer programs which require only the entry of the DR position, altitude and azimuth of the body, and GMT. It is not even necessary to know the name of the body because the computer can figure out what it must be based on the entered data. Calculators and computers provide more accurate solutions than tabular and mathematical methods because they can be based on actual values rather than theoretical assumptions and do not have inherent rounding errors.

U.S. Naval navigators have access to a program called **STELLA** (System To Estimate Latitude and Longitude Astronomically; do not confuse with a commercial astronomy program with the same name). STELLA was developed by the Astronomical Applications Department of the U.S. Naval Observatory based on a Navy requirement. The algorithms used in STELLA provide an accuracy of one arc-second on the Earth's surface, a distance of about 30 meters. While this accuracy is far better than can be obtained using a sextant, it does support possible naval needs for automated navigation systems based on celestial objects. These algorithms take into account the oblateness of the Earth, movement of the vessel during sight-taking, and other factors not fully addressed by traditional methods.

STELLA can perform almanac functions, position updating/DR estimations, celestial body rise/set/transit calculations, compass error calculations, sight planning, and sight reduction. On-line help and user's guide are included, and it is a component of the Block III NAVSSI. Because STELLA logs all entered data for future reference, it is authorized to replace the Navy Navigation Workbook. STELLA is now an allowance list requirement for Naval ships, and is available from:

Superintendent
U.S. Naval Observatory
Code: AA/STELLA
3450 Massachusetts Ave. NW
Washington, DC, 20392-5420

or on the Navigator of the Navy Web site at

http://www.navigator.navy.mil/navigator/surface.html.

2001. Tabular Sight Reduction

The remainder of this chapter concentrates on sight reduction using the *Nautical Almanac* and *Pub. No. 229, Sight Reduction Tables for Marine Navigation*. The method explained here is only one of many methods of reducing a sight. The *Nautical Almanac* contains directions for solving sights using its own concise sight reduction tables or calculators, along with examples for the current year

Reducing a celestial sight to obtain a line of position using the tables consists of six steps:

1. Correct the sextant altitude (hs) to obtain observed altitude (ho).
2. Determine the body's GHA and declination (dec.).
3. Select an assumed position (AP) and find its local hour angle (LHA).
4. Compute altitude and azimuth for the AP.
5. Compare the computed and observed altitudes.
6. Plot the line of position.

The introduction to each volume of *Pub. 229* contains information: (1) discussing use of the publication for a variety of special celestial navigation techniques; (2) discussing interpolation, explaining the double second difference interpolation required in some sight reductions, and providing tables to facilitate the interpolation process; and (3) discussing the publication's use in solving problems of great circle sailings. Prior to using *Pub. 229*, carefully read this introductory material.

Celestial navigation involves determining a circular line of position based on an observer's distance from a celestial body's geographic position (GP). Should the observer determine both a body's GP and his distance from the GP, he would have enough information to plot a line of position; he would be somewhere on a circle whose center was the GP and whose radius equaled his distance from that GP. That circle, from all points on which a body's measured altitude would be equal, is a **circle of equal altitude**. There is a direct proportionality between a body's altitude as measured by an observer and the distance of its GP from that observer; the lower the altitude, the farther away the GP.

Therefore, when an observer measures a body's altitude he obtains an indirect measure of the distance between himself and the body's GP. Sight reduction is the process of converting that indirect measurement into a line of position.

Sight reduction reduces the problem of scale to manageable size. Depending on a body's altitude, its GP could be thousands of miles from the observer's position. The size of a chart required to plot this large distance would be impractical. To eliminate this problem, the navigator does not plot this line of position directly. Indeed, he does not plot the GP at all. Rather, he chooses an **assumed position (AP)** near, but usually not coincident with, his DR position. The navigator chooses the AP's latitude and longitude to correspond to the entering arguments of LHA and latitude used in *Pub. 229*. From *Pub. 229*, the navigator computes what the body's altitude would have been had it been measured from the AP. This yields the **computed altitude (h_c)**. He then compares this computed value with the **observed altitude (h_o)** obtained at his actual position. The difference between the computed and observed altitudes is directly proportional to the distance between the circles of equal altitude for the assumed position and the actual position. *Pub. 229* also gives the direction from the GP to the AP. Having selected the assumed position, calculated the distance between the circles of equal altitude for that AP and his actual position, and determined the direction from the assumed position to the body's GP, the navigator has enough information to plot a line of position (LOP).

To plot an LOP, plot the assumed position on either a chart or a plotting sheet. From the *Sight Reduction Tables*, determine: 1) the altitude of the body for a sight taken at the AP and 2) the direction from the AP to the GP. Then, determine the difference between the body's calculated altitude at this AP and the body's measured altitude. This difference represents the difference in radii between the equal altitude circle passing through the AP and the equal altitude circle passing through the actual position. Plot this difference from the AP either towards or away from the GP along the axis between the AP and the GP. Finally, draw the circle of equal altitude representing the circle with the body's GP at the center and with a radius equal to the distance between the GP and the navigator's actual position.

One final consideration simplifies the plotting of the equal altitude circle. Recall that the GP is usually thousands of miles away from the navigator's position. The equal altitude circle's radius, therefore, can be extremely large. Since this radius is so large, the navigator can approximate the section close to his position with a straight line drawn perpendicular to the line connecting the AP and the GP. This straight line approximation is good only for sights at relatively low altitudes. The higher the altitude, the shorter the distance between the GP and the actual position, and the smaller the circle of equal altitude. The shorter this distance, the greater the inaccuracy introduced by this approximation.

2002. Selection of the Assumed Position (AP)

Use the following arguments when entering *Pub. 229* to compute altitude (h_c) and azimuth:

1. Latitude (L)
2. Declination (d or Dec.)
3. Local hour angle (LHA)

Latitude and LHA are functions of the assumed position. Select an AP longitude resulting in a whole degree of LHA and an AP latitude equal to that whole degree of latitude closest to the DR position. Selecting the AP in this manner eliminates interpolation for LHA and latitude in *Pub. 229*.

2003. Comparison of Computed and Observed Altitudes

The difference between the computed altitude (h_c) and the observed altitude (h_o) is the **altitude intercept** (a).

The altitude intercept is the difference in the length of the radii of the circles of equal altitude passing through the AP and the observer's actual position. The position having the greater altitude is on the circle of smaller radius and is closer to the observed body's GP. In Figure 2004, the AP is shown on the inner circle. Therefore, h_c is greater than h_o.

Express the altitude intercept in nautical miles and label it T or A to indicate whether the line of position is toward or away from the GP, as measured from the AP.

A useful aid in remembering the relation between h_o, h_c, and the altitude intercept is: $\underline{H}_o$ $\underline{M}_o$ $\underline{T}_o$ for H_o More Toward. Another is C-G-A: Computed Greater Away, remembered as Coast Guard Academy. In other words, if h_o is greater than h_c, the line of position intersects a point measured from the AP towards the GP a distance equal to the altitude intercept. Draw the LOP through this intersection point perpendicular to the axis between the AP and GP.

2004. Plotting the Line of Position

Plot the line of position as shown in Figure 2004. Plot the AP first; then plot the azimuth line from the AP toward or away from the GP. Then, measure the altitude intercept along this line. At the point on the azimuth line equal to the intercept distance, draw a line perpendicular to the azimuth line. This perpendicular represents that section of the circle of equal altitude passing through the navigator's actual position. This is the line of position.

A navigator often takes sights of more than one celestial body when determining a celestial fix. After plotting the lines of position from these several sights, advance the resulting LOP's along the track to the time of the last sight and label the resulting fix with the time of this last sight.

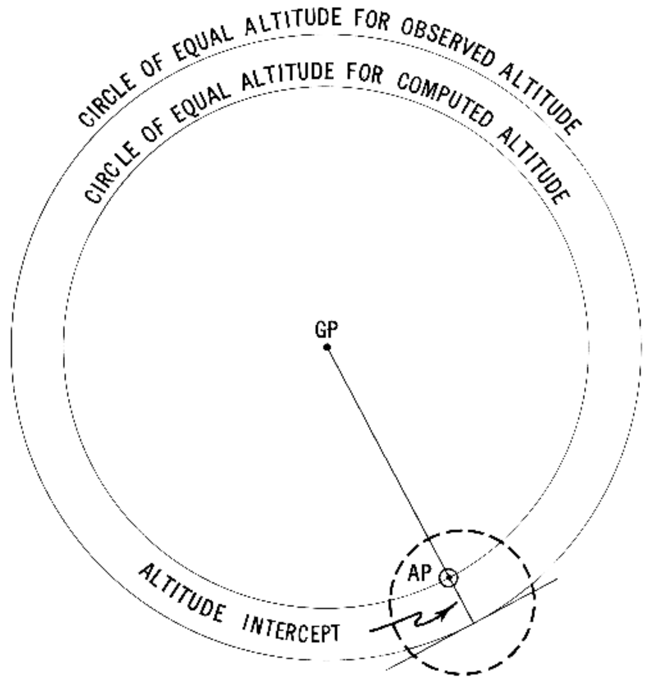

Figure 2004. The basis for the line of position from a celestial observation.

2005. Sight Reduction Procedures

Just as it is important to understand the theory of sight reduction, it is also important to develop a practical procedure to reduce celestial sights consistently and accurately. Sight reduction involves several consecutive steps, the accuracy of each completely dependent on the accuracy of the steps that went before. *Sight reduction tables* have, for the most part, reduced the mathematics involved to simple addition and subtraction. However, careless errors will render even the most skillfully measured sights inaccurate. The navigator using tabular or mathematical techniques must work methodically to reduce careless errors.

Naval navigators will most likely use OPNAV 3530, U.S. Navy Navigation Workbook, which contains pre-formatted pages with “strip forms” to guide the navigator through sight reduction. A variety of commercially-produced forms are also available. Pick a form and learn its method thoroughly. With familiarity will come increasing understanding, speed and accuracy.

Figure 2005 represents a functional and complete worksheet designed to ensure a methodical approach to any sight reduction problem. The recommended procedure discussed below is not the only one available; however, the navigator who uses it can be assured that he has considered every correction required to obtain an accurate fix.

SECTION ONE consists of two parts: (1) Correcting sextant altitude to obtain apparent altitude; and (2) Correcting the apparent altitude to obtain the observed altitude.

Body: Enter the name of the body whose altitude you have measured. If using the Sun or the Moon, indicate which limb was measured.

Index Correction: This is determined by the characteristics of the individual sextant used. Chapter 16 discusses determining its magnitude and algebraic sign.

Dip: The dip correction is a function of the height of eye of the observer. It is always negative; its magnitude is determined from the Dip Table on the inside front cover of the *Nautical Almanac*.

Sum: Enter the algebraic sum of the dip correction and the index correction.

Sextant Altitude: Enter the altitude of the body measured by the sextant.

Apparent Altitude: Apply the correction determined above to the measured altitude and enter the result as the apparent altitude.

Altitude Correction: Every observation requires an altitude correction. This correction is a function of the apparent altitude of the body. The *Almanac* contains tables for determin-

SECTION ONE: OBSERVED ALTITUDE

Body		
Index Correction		
Dip (height of eye)		
Sum		
Sextant Altitude (h_s)		
Apparent Altitude (h_a)		
Altitude Correction		
Mars or Venus Additional Correction		
Additional Correction		
Horizontal Parallax Correction		
Moon Upper Limb Correction		
Correction to Apparent Altitude (h_a)		
Observed Altitude (h_o)		

SECTION TWO: GMT TIME AND DATE

Date		
DR Latitude		
DR Longitude		
Observation Time		
Watch Error		
Zone Time		
Zone Description		
Greenwich Mean Time		
Date GMT		

SECTION THREE: LOCAL HOUR ANGLE AND DECLINATION

Tabulated GHA and *v* Correction Factor		
GHA Increment		
Sidereal Hour Angle (SHA) or *v* Correction		
GHA		
+ or - 360° if needed		
Assumed Longitude (-W, +E)		
Local Hour Angle (LHA)		
Tabulated Declination and *d* Correction Factor		
d Correction		
True Declination		
Assumed Latitude		

SECTION FOUR: ALTITUDE INTERCEPT AND AZIMUTH

Declination Increment and *d* Interpolation Factor		
Computed Altitude (Tabulated)		
Double Second Difference Correction		
Total Correction		
Computed Altitude (h_c)		
Observed Altitude (h_o)		
Altitude Intercept		
Azimuth Angle		
True Azimuth		

Figure 2005. Complete sight reduction form.

ing these corrections. For the Sun, planets, and stars, these tables are located on the inside front cover and facing page. For the Moon, these tables are located on the back inside cover and preceding page.

Mars or Venus Additional Correction: As the name implies, this correction is applied to sights of Mars and Venus. The correction is a function of the planet measured, the time of year, and the apparent altitude. The inside front cover of the *Almanac* lists these corrections.

Additional Correction: Enter this additional correction from Table A-4 located at the front of the *Nautical Almanac* when obtaining a sight under non-standard atmospheric temperature and pressure conditions. This correction is a function of atmospheric pressure, temperature, and apparent altitude.

Horizontal Parallax Correction: This correction is unique to reducing Moon sights. Obtain the H.P. correction value from the daily pages of the *Almanac*. Enter the H.P correction table at the back of the *Almanac* with this value. The H.P correction is a function of the limb of the Moon used (upper or lower), the apparent altitude, and the H.P. correction factor. The H.P. correction is always added to the apparent altitude.

Moon Upper Limb Correction: Enter -30' for this correction if the sight was of the upper limb of the Moon.

Correction to Apparent Altitude: Sum the altitude correction, the Mars or Venus additional correction, the additional correction, the horizontal parallax correction, and the Moon's upper limb correction. Be careful to determine and carry the algebraic sign of the corrections and their sum correctly. Enter this sum as the correction to the apparent altitude.

Observed Altitude: Apply the Correction to Apparent Altitude algebraically to the apparent altitude. The result is the observed altitude.

SECTION TWO determines the Greenwich Mean Time (GMT; referred to in the *Almanac*s as Universal time or UT) and GMT date of the sight.

Date: Enter the local time zone date of the sight.

DR Latitude: Enter the dead reckoning latitude of the vessel.

DR Longitude: Enter the dead reckoning longitude of the vessel.

Observation Time: Enter the local time of the sight as recorded on the ship's chronometer or other timepiece.

Watch Error: Enter a correction for any known watch error.

Zone Time: Correct the observation time with watch error to determine zone time.

Zone Description: Enter the zone description of the time zone indicated by the DR longitude. If the longitude is west of the Greenwich Meridian, the zone description is positive. Conversely, if the longitude is east of the Greenwich Meridian, the zone description is negative. The zone description represents the correction necessary to convert local time to Greenwich Mean Time.

Greenwich Mean Time: Add to the zone description the zone time to determine Greenwich Mean Time.

Date: Carefully evaluate the time correction applied above and determine if the correction has changed the date. Enter the GMT date.

SECTION THREE determines two of the three arguments required to enter *Pub. 229*: Local Hour Angle (LHA) and Declination. This section employs the principle that a celestial body's LHA is the algebraic sum of its Greenwich Hour Angle (GHA) and the observer's longitude. Therefore, the basic method employed in this section is: (1) Determine the body's GHA; (2) Determine an assumed longitude; (3) Algebraically combine the two quantities, remembering to subtract a western assumed longitude from GHA and to add an eastern longitude to GHA; and (4) Extract the declination of the body from the appropriate *Almanac* table, correcting the tabular value if required.

Tabulated GHA and (2) *v* Correction Factor:

For the Sun, the Moon, or a planet, extract the value for the whole hour of GHA corresponding to the sight. For example, if the sight was obtained at 13-50-45 GMT, extract the GHA value for 1300. For a star sight reduction, extract the value of the GHA of Aries (GHA ♈), again using the value corresponding to the whole hour of the time of the sight.

For a planet or Moon sight reduction, enter the *v* correction value. This quantity is not applicable to a Sun or star sight. The *v* correction for a planet sight is found at the bottom of the column for each particular planet. The *v* correction factor for the Moon is located directly beside the tabulated hourly GHA values. The *v* correction factor for the Moon is always positive. If a planet's *v* correction factor is listed without sign, it is positive. If listed with a negative sign, the planet's *v* correction factor is negative. This *v* correction factor is not the magnitude of the *v* correction; it is used later to enter the Increments and Correction table to determine the magnitude of the correction.

GHA Increment: The GHA increment serves as an interpolation factor, correcting for the time that the sight differed from the whole hour. For example, in the sight at 13-50-45 discussed above, this increment correction accounts for the 50 minutes and 45 seconds after the whole hour at which the sight was taken. Obtain this correction value from the Increments and Corrections tables in the *Almanac*. The entering arguments for these tables are the minutes and seconds after the hour at which the sight was taken and the body sighted. Extract the proper correction from the applicable table and enter the correction.

Sidereal Hour Angle or *v* Correction: If reducing a star sight, enter the star's Sidereal Hour Angle (SHA). The SHA is found in the star column of the daily pages of the *Almanac*. The SHA combined with the GHA of Aries results in the star's GHA. The SHA entry is applicable only to a star. If reducing a planet or Moon sight, obtain the *v* correction from the Increments and Corrections Table. The correction is a function of only the *v* correction factor; its magnitude is the same for both the Moon and the planets.

GHA: A star's GHA equals the sum of the Tabulated GHA of Aries, the GHA Increment, and the star's SHA. The Sun's GHA equals the sum of the Tabulated GHA and the GHA Increment. The GHA of the Moon or a planet equals the sum of the Tabulated GHA, the GHA Increment, and the *v* correction.

+ or – 360° (if needed): Since the LHA will be determined from subtracting or adding the assumed longitude to the GHA, adjust the GHA by 360° if needed to facilitate the addition or subtraction.

Assumed Longitude: If the vessel is west of the prime meridian, the assumed longitude will be subtracted from the GHA to determine LHA. If the vessel is east of the prime meridian, the assumed longitude will be added to the GHA to determine the LHA. Select the assumed longitude to meet the following two criteria: (1) When added or subtracted (as applicable) to the GHA determined above, a whole degree of LHA will result; and (2) It is the longitude closest to that DR longitude that meets criterion (1).

Local Hour Angle (LHA): Combine the body's GHA with the assumed longitude as discussed above to determine the body's LHA.

Tabulated Declination and *d* Correction factor: (1) Obtain the tabulated declination for the Sun, the Moon, the stars, or the planets from the daily pages of the *Almanac*. The declination values for the stars are given for the entire three day period covered by the daily page of the *Almanac*. The values for the Sun, Moon, and planets are listed in hourly increments. For these bodies, enter the declination value for the whole hour of the sight. For example, if the sight is at 12-58-40, enter the tabulated declination for 1200. (2) There is no *d* correction factor for a star sight. There are *d* correction factors for Sun, Moon, and planet sights. Similar to the v correction factor discussed above, the *d* correction factor does not equal the magnitude of the *d* correction; it provides the argument to enter the Increments and Corrections tables in the *Almanac*. The sign of the *d* correction factor, which determines the sign of the *d* correction, is determined by the trend of declination values, not the trend of *d* values. The *d* correction factor is simply an interpolation factor; therefore, to determine its sign, look at the declination values for the hours that frame the time of the sight. For example, suppose the sight was taken on a certain date at 12-30-00. Compare the declination value for 1200 and 1300 and determine if the declination has increased or decreased. If it has increased, the *d* correction factor is positive. If it has decreased, the *d* correction factor is negative.

***d* correction:** Enter the Increments and Corrections table with the *d* correction factor discussed above. Extract the proper correction, being careful to retain the proper sign.

True Declination: Combine the tabulated declination and the *d* correction to obtain the true declination.

Assumed Latitude: Choose as the assumed latitude that whole value of latitude closest to the vessel's DR latitude. If the assumed latitude and declination are both north or both south, label the assumed latitude "Same." If one is north and the other is south, label the assumed latitude "Contrary."

SECTION FOUR uses the arguments of assumed latitude, LHA, and declination determined in Section Three to enter *Pub. 229* to determine azimuth and computed altitude. Then, Section Four compares computed and observed altitudes to calculate the altitude intercept. From this the LOP is plotted.

Declination Increment and *d* Interpolation Factor: Note that two of the three arguments used to enter *Pub. 229*, LHA and latitude, are whole degree values. Section Three does not determine the third argument, declination, as a whole degree. Therefore, the navigator must interpolate in *Pub. 229* for declination, given whole degrees of LHA and latitude. The first steps of Section Four involve this interpolation for declination. Since declination values are tabulated every whole degree in *Pub. 229*, the declination increment is the minutes and tenths of the true declination. For example, if the true declination is 13° 15.6', then the declination increment is 15.6'.

Pub. 229 also lists a *d* Interpolation Factor. This is the magnitude of the difference between the two successive tabulated values for declination that frame the true declination. Therefore, for the hypothetical declination listed above, the tabulated *d* interpolation factor listed in the table would be the difference between declination values given for 13° and 14°. If the declination increases between these two values, *d* is positive. If the declination decreases between these two values, *d* is negative.

Computed Altitude (Tabulated): Enter *Pub. 229* with the following arguments: (1) LHA from Section Three; (2) assumed latitude from Section Three; (3) the whole degree value of the true declination. For example, if the true declination were 13° 15.6', then enter *Pub. 229* with 13° as the value for declination. Record the tabulated computed altitude.

Double Second Difference Correction: Use this correction when linear interpolation of declination for computed altitude is not sufficiently accurate due to the non-linear change in the computed altitude as a function of declination. The need for double second difference interpolation is indicated by the *d* interpolation factor appearing in italic type followed by a small dot. When this procedure must be employed, refer to detailed instructions in the introduction to *Pub. 229*.

Total Correction: The total correction is the sum of the double second difference (if required) and the interpolation corrections. Calculate the interpolation correction by dividing the declination increment by 60' and multiply the resulting quotient by the *d* interpolation factor.

Computed Altitude (h_c): Apply the total correction, being careful to carry the correct sign, to the tabulated computed altitude. This yields the computed altitude.

Observed Altitude (h_o): Enter the observed altitude from Section One.

Altitude Intercept: Compare h_c and h_o. Subtract the smaller from the larger. The resulting difference is the magnitude of the altitude intercept. If h_o is greater than h_c, then label the altitude intercept "Toward." If h_c is greater than h_o, then label the altitude intercept "Away."

Azimuth Angle: Obtain the azimuth angle (Z) from *Pub. 229*, using the same arguments which determined tabulated computed altitude. Visual interpolation is sufficiently accurate.

True Azimuth: Calculate the true azimuth (Z_n) from the azimuth angle (Z) as follows:

a) If in northern latitudes:

$$LHA > 180°, \text{ then } Z_n = Z$$
$$LHA < 180°, \text{ then } Z_n = 360° - Z$$

b) If in southern latitudes:

$$LHA > 180°, \text{ then } Z_n = 180° - Z$$
$$LHA < 180°, \text{ then } Z_n = 180° + Z$$

SIGHT REDUCTION

The section above discussed the basic theory of sight reduction and presented a method to be followed when reducing sights. This section puts that method into practice in reducing sights of a star, the Sun, the Moon, and planets.

2006. Reducing Star Sights to a Fix

On May 16, 1995, at the times indicated, the navigator takes and records the following sights:

Star	Sextant Altitude	Zone Time
Kochab	47° 19.1'	20-07-43
Spica	32° 34.8'	20-11-26

Height of eye is 48 feet and index correction (IC) is +2.1'. The DR latitude for both sights is 39° N. The DR longitude for the Spica sight is 157° 10'W. The DR longitude for the Kochab sight is 157° 08.0'W. Determine the intercept and azimuth for both sights. See Figure 2006.

First, convert the sextant altitudes to observed altitudes. Reduce the Spica sight first:

Body	Spica
Index Correction	+2.1'
Dip (height 48 ft)	-6.7'
Sum	-4.6'
Sextant Altitude (h_s)	32° 34.8'
Apparent Altitude (h_a)	32° 30.2'
Altitude Correction	-1.5'
Additional Correction	0
Horizontal Parallax	0
Correction to h_a	-1.5'
Observed Altitude (h_o)	32° 28.7'

Determine the sum of the index correction and the dip correction. Go to the inside front cover of the *Nautical Almanac* to the table entitled "DIP." This table lists dip corrections as a function of height of eye measured in either feet or meters. In the above problem, the observer's height of eye is 48 feet. The heights of eye are tabulated in intervals, with the correction corresponding to each interval listed between the interval's endpoints. In this case, 48 feet lies between the tabulated 46.9 to 48.4 feet interval; the corresponding correction for this interval is -6.7'. Add the IC and the dip correction, being careful to carry the correct sign. The sum of the corrections here is -4.6'. Apply this correction to the sextant altitude to obtain the apparent altitude (h_a).

Next, apply the altitude correction. Find the altitude correction table on the inside front cover of the *Nautical Almanac* next to the dip table. The altitude correction varies as a function of both the type of body sighted (Sun, star, or planet) and the body's apparent altitude. For the problem above, enter the star altitude correction table. Again, the correction is given within an altitude interval; h_a in this case was 32° 30.2'. This value lies between the tabulated endpoints 32° 00.0' and 33° 45.0'. The correction corresponding to this interval is -1.5'. Applying this correction to h_a yields an observed altitude of 32° 28.7'.

Having calculated the observed altitude, determine the time and date of the sight in Greenwich Mean Time:

Date	16 May 1995
DR Latitude	39° N
DR Longitude	157° 10' W
Observation Time	20-11-26
Watch Error	0
Zone Time	20-11-26
Zone Description	+10
GMT	06-11-26
GMT Date	17 May 1995

Record the observation time and then apply any watch error to determine zone time. Then, use the DR longitude at the time of the sight to determine time zone description. In this case, the DR longitude indicates a zone description of +10 hours. Add the zone description to the zone time to obtain GMT. It is important to carry the correct date when applying this correction. In this case, the +10 correction made it 06-11-26 GMT on May 17, when the date in the local time zone was May 16.

After calculating both the observed altitude and the GMT time, enter the daily pages of the *Nautical Almanac* to calculate the star's Greenwich Hour Angle (GHA) and declination.

Tab GHA ♈	324° 28.4'
GHA Increment	2° 52.0'
SHA	158° 45.3'
GHA	486° 05.7'
+/- 360°	not required
Assumed Longitude	157° 05.7'
LHA	329°
Tabulated Dec/*d*	S 11° 08.4'/n.a.
d Correction	—
True Declination	S 11° 08.4'
Assumed Latitude	N 39° contrary

First, record the GHA of Aries from the May 17, 1995 daily page: 324° 28.4'.

Next, determine the incremental addition for the minutes and seconds after 0600 from the Increments and Corrections table in the back of the *Nautical Almanac*. The increment for 11 minutes and 26 seconds is 2° 52'.

Then, calculate the GHA of the star. Remember:

GHA (star) = GHA ♈ + SHA (star)

The *Nautical Almanac* lists the SHA of selected stars on each daily page. The SHA of Spica on May 17, 1995: 158° 45.3'.

Pub. 229's entering arguments are whole degrees of LHA and assumed latitude. Remember that LHA = GHA - west longitude or GHA + east longitude. Since in this example the vessel is in west longitude, subtract its assumed longitude from the GHA of the body to obtain the LHA. Assume a longitude meeting the criteria listed in Article 2005.

From those criteria, the assumed longitude must end in 05.7 minutes so that, when subtracted from the calculated GHA, a whole degree of LHA will result. Since the DR longitude was 157° 10.0', then the assumed longitude ending in 05.7' closest to the DR longitude is 157° 05.7'. Subtracting this assumed longitude from the calculated GHA of the star yields an LHA of 329°.

The next value of concern is the star's true declination. This value is found on the May 17th daily page next to the star's SHA. Spica's declination is S 11° 08.4'. There is no d correction for a star sight, so the star's true declination equals its tabulated declination. The assumed latitude is determined from the whole degree of latitude closest to the DR latitude at the time of the sight. In this case, the assumed latitude is N 39°. It is marked "contrary" because the DR latitude is north while the star's declination is south.

The following information is known: (1) the assumed position's LHA (329°) and assumed latitude (39°N contrary name); and (2) the body's declination (S11° 08.4').

Find the page in the *Sight Reduction Table* corresponding to an LHA of 329° and an assumed latitude of N 39°, with latitude contrary to declination. Enter this table with the body's whole degree of declination. In this case, the body's whole degree of declination is 11°. This declination corresponds to a tabulated altitude of 32° 15.9'. This value is for a declination of 11°; the true declination is 11° 08.4'. Therefore, interpolate to determine the correction to add to the tabulated altitude to obtain the computed altitude.

The difference between the tabulated altitudes for 11° and 12° is given in *Pub. 229* as the value d; in this case, d = -53.0. Express as a ratio the declination increment (in this case, 8.4') and the total interval between the tabulated declination values (in this case, 60') to obtain the percentage of the distance between the tabulated declination values represented by the declination increment. Next, multiply that percentage by the increment between the two values for computed altitude. In this case:

$$\frac{8.4}{60} \times (-53.0) = -7.4$$

Subtract 7.4' from the tabulated altitude to obtain the final computed altitude: H_c = 32° 08.5'.

Dec Inc / + or - d	8.4' / -53.0
h_c (tabulated)	32° 15.9'
Correction (+ or -)	-7.4'
h_c (computed)	32° 08.5'

It will be valuable here to review exactly what h_o and h_c represent. Recall the methodology of the altitude-intercept method. The navigator first measures and corrects an altitude for a celestial body. This corrected altitude, h_o, corresponds to a circle of equal altitude passing through the navigator's actual position whose center is the geographic position (GP) of the body. The navigator then determines an assumed position (AP) near, but not coincident with, his actual position; he then calculates an altitude for an observer at that assumed position (AP).The circle of equal altitude passing through this assumed position is concentric with the circle of equal altitude passing through the navigator's actual position. The difference between the body's altitude at the assumed position (h_c) and the body's observed altitude (h_o) is equal to the differences in radii length of the two corresponding circles of equal altitude. In the above problem, therefore, the navigator knows that the equal altitude circle passing through his actual position is:
away from the equal altitude circle passing through his assumed position. Since h_o is greater than h_c, the navigator knows that the radius of the equal altitude circle passing through his actual position is less than

$$\begin{aligned} h_o &= 32°28.7' \\ -h_c &= \underline{32°08.5'} \\ &\quad 20.2\ \text{NM} \end{aligned}$$

the radius of the equal altitude circle passing through the assumed position. The only remaining question is: in what direction from the assumed position is the body's actual GP. *Pub. 229* also provides this final piece of information. This is the value for Z tabulated with the h_c and d values discussed above. In this case, enter *Pub. 229* as before, with LHA, assumed latitude, and declination. Visual interpolation is sufficient. Extract the value Z = 143.3°. The relation between Z and Z_n, the true azimuth, is as follows:

In northern latitudes:

$$\text{LHA} > 180°, \text{ then } Z_n = Z$$
$$\text{LHA} < 180°, \text{ then } Z_n = 360° - Z$$

In southern latitudes:

$$\text{LHA} > 180°, \text{ then } Z_n = 180° - Z$$
$$\text{LHA} < 180°, \text{ then } Z_n = 180° + Z$$

In this case, LHA > 180° and the vessel is in northern latitude. Therefore, Z_n = Z = 143.3°T. The navigator now has enough information to plot a line of position.

The values for the reduction of the Kochab sight follow:

Body	Kochab
Index Correction	+2.1'
Dip Correction	-6.7'
Sum	-4.6'
h_s	47° 19.1'
h_a	47° 14.5'
Altitude Correction	-.9'
Additional Correction	not applicable
Horizontal Parallax	not applicable
Correction to h_a	-9'
h_o	47° 13.6'
Date	16 May 1995
DR latitude	39°N
DR longitude	157° 08.0' W
Observation Time	20-07-43
Watch Error	0
Zone Time	20-07-43
Zone Description	+10
GMT	06-07-43
GMT Date	17 May 1995
Tab GHA ♈	324° 28.4'
GHA Increment	1° 56.1'
SHA	137° 18.5'
GHA	463° 43.0'
+/- 360°	not applicable
Assumed Longitude	156° 43.0'
LHA	307°
Tab Dec / *d*	N74° 10.6' / n.a.
d Correction	not applicable
True Declination	N74° 10.6'
Assumed Latitude	39°N (same)
Dec Inc / + or - d	10.6' / -24.8
h_c	47° 12.6'
Total Correction	-4.2'
h_c (computed)	47° 08.4'
h_o	47° 13.6'
a (intercept)	5.2 towards
Z	018.9°
Z_n	018.9°

2007. Reducing a Sun Sight

The example below points out the similarities between reducing a Sun sight and reducing a star sight. It also demonstrates the additional corrections required for low altitude (<10°) sights and sights taken during non-standard temperature and pressure conditions.

On June 16, 1994, at 05-15-23 local time, at DR position L 30°N λ 45°W, a navigator takes a sight of the Sun's upper limb. The navigator has a height of eye of 18 feet, the temperature is 88° F, and the atmospheric pressure is 982 mb. The sextant altitude is 3° 20.2'. There is no index error. Determine the observed altitude. See Figure 2007.

Apply the index and dip corrections to h_s to obtain h_a. Because h_a is less than 10°, use the special altitude correction table for sights between 0° and 10° located on the right inside front page of the *Nautical Almanac*.

Enter the table with the apparent altitude, the limb of the Sun used for the sight, and the period of the year. Interpolation for the apparent altitude is not required. In this case, the table yields a correction of -29.4'. The correction's algebraic sign is found at the head of each group of entries and at every change of sign.

The additional correction is required because of the non-standard temperature and atmospheric pressure under which the sight was taken. The correction for these non-standard conditions is found in the *Additional Corrections* table located on page A4 in the front of the *Nautical Almanac*.

First, enter the *Additional Corrections* table with the temperature and pressure to determine the correct zone letter: in this case, zone L. Then, locate the correction in the L column corresponding to the apparent altitude of 3° 16.1'. Interpolate between the table arguments of 3° 00.0' and 3° 30.0' to determine the additional correction: +1.4'. The total correction to the apparent altitude is the sum of the altitude and additional corrections: -28.0'. This results in an h_o of 2° 48.1'.

Next, determine the Sun's GHA and declination.

1995 MAY 16, 17, 18 (TUES., WED., THURS.)

UT (GMT) d h	ARIES G.H.A.	VENUS −3.9 G.H.A.	VENUS Dec.	MARS +0.7 G.H.A.	MARS Dec.	JUPITER −2.5 G.H.A.	JUPITER Dec.	SATURN +1.3 G.H.A.	SATURN Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
16 00	233 14.4	205 51.6	N 9 30.5	84 34.3	N14 31.2	342 02.6	S21 28.7	239 13.9	S 4 40.8
01	248 16.9	220 51.2	31.6	99 35.8	30.8	357 05.3	28.7	254 16.2	40.7
02	263 19.4	235 50.8	32.7	114 37.3	30.3	12 08.1	28.7	269 18.5	40.6
03	278 21.8	250 50.4	· · 33.8	129 38.8	· · 29.9	27 10.9	· · 28.6	284 20.7	· · 40.6
04	293 24.3	265 50.0	34.9	144 40.3	29.5	42 13.7	28.6	299 23.0	40.5
05	308 26.8	280 49.6	36.0	159 41.7	29.1	57 16.4	28.5	314 25.3	40.4
06	323 29.2	295 49.2	N 9 37.1	174 43.2	N14 28.7	72 19.2	S21 28.5	329 27.6	S 4 40.4
07	338 31.7	310 48.8	38.2	189 44.7	28.3	87 22.0	28.5	344 29.9	40.3
T 08	353 34.2	325 48.4	39.2	204 46.2	27.9	102 24.7	28.4	359 32.1	40.2
U 09	8 36.6	340 48.0	· · 40.3	219 47.7	· · 27.5	117 27.5	· · 28.4	14 34.4	· · 40.2
E 10	23 39.1	355 47.6	41.4	234 49.2	27.1	132 30.3	28.4	29 36.7	40.1
S 11	38 41.5	10 47.1	42.5	249 50.6	26.6	147 33.1	28.3	44 39.0	40.0
D 12	53 44.0	25 46.7	N 9 43.6	264 52.1	N14 26.2	162 35.8	S21 28.3	59 41.3	S 4 40.0
A 13	68 46.5	40 46.3	44.7	279 53.6	25.8	177 38.6	28.3	74 43.6	39.9
Y 14	83 48.9	55 45.9	45.8	294 55.1	25.4	192 41.4	28.2	89 45.8	39.8
15	98 51.4	70 45.5	· · 46.9	309 56.6	· · 25.0	207 44.2	· · 28.2	104 48.1	· · 39.8
16	113 53.9	85 45.1	47.9	324 58.0	24.6	222 46.9	28.2	119 50.4	39.7
17	128 56.3	100 44.7	49.0	339 59.5	24.2	237 49.7	28.1	134 52.7	39.6
18	143 58.8	115 44.3	N 9 50.1	355 01.0	N14 23.8	252 52.5	S21 28.1	149 55.0	S 4 39.6
19	159 01.3	130 43.9	51.2	10 02.5	23.3	267 55.3	28.1	164 57.3	39.5
20	174 03.7	145 43.5	52.3	25 03.9	22.9	282 58.0	28.0	179 59.5	39.4
21	189 06.2	160 43.1	· · 53.4	40 05.4	· · 22.5	298 00.8	· · 28.0	195 01.8	· · 39.4
22	204 08.7	175 42.7	54.5	55 06.9	22.1	313 03.6	28.0	210 04.1	39.3
23	219 11.1	190 42.3	55.5	70 08.4	21.7	328 06.3	27.9	225 06.4	39.2
17 00	234 13.6	205 41.9	N 9 56.6	85 09.8	N14 21.3	343 09.1	S21 27.9	240 08.7	S 4 39.1
01	249 16.0	220 41.5	57.7	100 11.3	20.9	358 11.9	27.8	255 11.0	39.1
02	264 18.5	235 41.1	58.8	115 12.8	20.5	13 14.7	27.8	270 13.2	39.0
03	279 21.0	250 40.7	9 59.9	130 14.3	· · 20.0	28 17.4	· · 27.8	285 15.5	· · 38.9
04	294 23.4	265 40.3	10 01.0	145 15.7	19.6	43 20.2	27.7	300 17.8	38.9
05	309 25.9	280 39.8	02.0	160 17.2	19.2	58 23.0	27.7	315 20.1	38.8
06	324 28.4	295 39.4	N10 03.1	175 18.7	N14 18.8	73 25.8	S21 27.7	330 22.4	S 4 38.7
W 07	339 30.8	310 39.0	04.2	190 20.2	18.4	88 28.6	27.6	345 24.7	38.7
E 08	354 33.3	325 38.6	05.3	205 21.6	18.0	103 31.3	27.6	0 26.9	38.6
D 09	9 35.8	340 38.2	· · 06.4	220 23.1	· · 17.5	118 34.1	· · 27.6	15 29.2	· · 38.5
N 10	24 38.2	355 37.8	07.4	235 24.6	17.1	133 36.9	27.5	30 31.5	38.5
E 11	39 40.7	10 37.4	08.5	250 26.0	16.7	148 39.7	27.5	45 33.8	38.4
S 12	54 43.1	25 37.0	N10 09.6	265 27.5	N14 16.3	163 42.4	S21 27.5	60 36.1	S 4 38.3
D 13	69 45.6	40 36.6	10.7	280 29.0	15.9	178 45.2	27.4	75 38.4	38.3
A 14	84 48.1	55 36.2	11.8	295 30.5	15.5	193 48.0	27.4	90 40.7	38.2
Y 15	99 50.5	70 35.7	· · 12.8	310 31.9	· · 15.0	208 50.8	· · 27.4	105 42.9	· · 38.1
16	114 53.0	85 35.3	13.9	325 33.4	14.6	223 53.5	27.3	120 45.2	38.1
17	129 55.5	100 34.9	15.0	340 34.9	14.2	238 56.3	27.3	135 47.5	38.0
18	144 57.9	115 34.5	N10 16.1	355 36.3	N14 13.8	253 59.1	S21 27.2	150 49.8	S 4 37.9
19	160 00.4	130 34.1	17.2	10 37.8	13.4	269 01.9	27.2	165 52.1	37.9
20	175 02.9	145 33.7	18.2	25 39.3	13.0	284 04.6	27.2	180 54.4	37.8
21	190 05.3	160 33.3	· · 19.3	40 40.7	· · 12.5	299 07.4	· · 27.1	195 56.7	· · 37.7
22	205 07.8	175 32.8	20.4	55 42.2	12.1	314 10.2	27.1	210 58.9	37.7
23	220 10.3	190 32.4	21.5	70 43.7	11.7	329 13.0	27.1	226 01.2	37.6
18 00	235 12.7	205 32.0	N10 22.5	85 45.1	N14 11.3	344 15.8	S21 27.0	241 03.5	S 4 37.5
01	250 15.2	220 31.6	23.6	100 46.6	10.9	359 18.5	27.0	256 05.8	37.5
02	265 17.6	235 31.2	24.7	115 48.1	10.5	14 21.3	27.0	271 08.1	37.4
03	280 20.1	250 30.8	· · 25.8	130 49.5	· · 10.0	29 24.1	· · 26.9	286 10.4	· · 37.3
04	295 22.6	265 30.4	26.8	145 51.0	09.6	44 26.9	26.9	301 12.7	37.3
05	310 25.0	280 29.9	27.9	160 52.5	09.2	59 29.6	26.9	316 15.0	37.2
06	325 27.5	295 29.5	N10 29.0	175 53.9	N14 08.8	74 32.4	S21 26.8	331 17.2	S 4 37.1
07	340 30.0	310 29.1	30.0	190 55.4	08.4	89 35.2	26.8	346 19.5	37.1
T 08	355 32.4	325 28.7	31.1	205 56.9	07.9	104 38.0	26.8	1 21.8	37.0
H 09	10 34.9	340 28.3	· · 32.2	220 58.3	· · 07.5	119 40.8	· · 26.7	16 24.1	· · 36.9
U 10	25 37.4	355 27.9	33.3	235 59.8	07.1	134 43.5	26.7	31 26.4	36.9
R 11	40 39.8	10 27.4	34.3	251 01.2	06.7	149 46.3	26.6	46 28.7	36.8
S 12	55 42.3	25 27.0	N10 35.4	266 02.7	N14 06.3	164 49.1	S21 26.6	61 31.0	S 4 36.8
D 13	70 44.8	40 26.6	36.5	281 04.2	05.8	179 51.9	26.6	76 33.3	36.7
A 14	85 47.2	55 26.2	37.5	296 05.6	05.4	194 54.7	26.5	91 35.6	36.6
Y 15	100 49.7	70 25.8	· · 38.6	311 07.1	· · 05.0	209 57.4	· · 26.5	106 37.8	· · 36.6
16	115 52.1	85 25.3	39.7	326 08.6	04.6	225 00.2	26.5	121 40.1	36.5
17	130 54.6	100 24.9	40.7	341 10.0	04.2	240 03.0	26.4	136 42.4	36.4
18	145 57.1	115 24.5	N10 41.8	356 11.5	N14 03.7	255 05.8	S21 26.4	151 44.7	S 4 36.4
19	160 59.5	130 24.1	42.9	11 12.9	03.3	270 08.6	26.4	166 47.0	36.3
20	176 02.0	145 23.6	44.0	26 14.4	02.9	285 11.3	26.3	181 49.3	36.2
21	191 04.5	160 23.2	· · 45.0	41 15.9	· · 02.5	300 14.1	· · 26.3	196 51.6	· · 36.2
22	206 06.9	175 22.8	46.1	56 17.3	02.0	315 16.9	26.2	211 53.9	36.1
23	221 09.4	190 22.4	47.2	71 18.8	01.6	330 19.7	26.2	226 56.2	36.0
Mer. Pass. (h m)	8 21.7	v −0.4	d 1.1	v 1.5	d 0.4	v 2.8	d 0.0	v 2.3	d 0.1

STARS

Name	S.H.A.	Dec.
	° ′	° ′
Acamar	315 29.1	S40 19.4
Achernar	335 37.4	S57 15.5
Acrux	173 24.0	S63 04.7
Adhara	255 23.5	S28 58.3
Aldebaran	291 05.3	N16 29.9
Alioth	166 32.3	N55 59.2
Alkaid	153 09.2	N49 20.3
Al Na'ir	28 00.8	S46 58.7
Alnilam	276 00.5	S 1 12.5
Alphard	218 09.5	S 8 38.6
Alphecca	126 22.2	N26 43.8
Alpheratz	357 57.8	N29 03.8
Altair	62 21.3	N 8 51.4
Ankaa	353 29.4	S42 19.7
Antares	112 42.6	S26 25.3
Arcturus	146 07.8	N19 12.4
Atria	107 56.1	S69 01.0
Avior	234 23.8	S59 30.1
Bellatrix	278 46.9	N 6 20.6
Betelgeuse	271 16.3	N 7 24.2
Canopus	264 02.6	S52 41.9
Capella	280 55.0	N45 59.5
Deneb	49 40.6	N45 15.7
Denebola	182 47.4	N14 35.8
Diphda	349 09.8	S18 00.7
Dubhe	194 08.2	N61 46.7
Elnath	278 30.2	N28 36.1
Eltanin	90 52.0	N51 29.3
Enif	34 00.5	N 9 51.2
Fomalhaut	15 39.1	S29 38.6
Gacrux	172 15.6	S57 05.5
Gienah	176 06.1	S17 31.2
Hadar	149 06.6	S60 21.2
Hamal	328 16.4	N23 26.3
Kaus Aust.	84 01.5	S34 23.0
Kochab	137 18.5	N74 10.6
Markab	13 52.0	N15 10.8
Menkar	314 29.6	N 4 04.2
Menkent	148 23.3	S36 21.0
Miaplacidus	221 42.6	S69 42.4
Mirfak	309 00.4	N49 50.6
Nunki	76 14.9	S26 18.0
Peacock	53 40.4	S56 44.7
Pollux	243 44.6	N28 02.2
Procyon	245 14.1	N 5 14.0
Rasalhague	96 18.8	N12 33.8
Regulus	207 58.0	N11 59.3
Rigel	281 25.5	S 8 12.6
Rigil Kent.	140 09.6	S60 49.0
Sabik	102 27.8	S15 43.1
Schedar	349 56.4	N56 30.5
Shaula	96 40.0	S37 05.9
Sirius	258 45.9	S16 42.8
Spica	158 45.3	S11 08.4
Suhail	223 02.5	S43 25.2
Vega	80 47.8	N38 46.7
Zuben'ubi	137 20.2	S16 01.4

	S.H.A.	Mer. Pass.
	° ′	h m
Venus	331 28.3	10 17
Mars	210 56.3	18 18
Jupiter	108 55.5	1 07
Saturn	5 55.1	7 58

Figure 2006. Left hand daily page of the Nautical Almanac for May 17, 1995.

Body	Sun UL
Index Correction	0
Dip Correction (18 ft)	-4.1'
Sum	-4.1'
h_s	3° 20.2'
h_a	3° 16.1'
Altitude Correction	-29.4'
Additional Correction	+1.4'
Horizontal Parallax	0
Correction to h_a	-28.0'
h_o	2° 48.1'

Date	June 16, 1994
DR Latitude	N30° 00.0'
DR Longitude	W045° 00.0'
Observation Time	05-15-23
Watch Error	0
Zone Time	05-15-23
Zone Description	+03
GMT	08-15-23
Date GMT	June 16, 1994
Tab GHA / *v*	299° 51.3' / n.a.
GHA Increment	3° 50.8'
SHA or *v* correction	not applicable
GHA	303°42.1'
Assumed Longitude	44° 42.1' W
LHA	259°
Tab Declination / *d*	N23° 20.5' / +0.1'
d Correction	0.0
True Declination	N23° 20.5'
Assumed Latitude	N30° (same)

Again, this process is similar to the star sights reduced above. Notice, however, that SHA, a quantity unique to star sight reduction, is not used in Sun sight reduction.

Determining the Sun's GHA is less complicated than determining a star's GHA. The Nautical Almanac's daily pages list the Sun's GHA in hourly increments. In this case, the Sun's GHA at 0800 GMT on June 16, 1994 is 299° 51.3'. The *v* correction is not applicable for a Sun sight; therefore, applying the increment correction yields the Sun's GHA. In this case, the GHA is 303° 42.1'.

Determining the Sun's LHA is similar to determining a star's LHA. In determining the Sun's declination, however, an additional correction not encountered in the star sight, the *d* correction, must be considered. The bottom of the Sun column on the daily pages of the *Nautical Almanac* lists the *d* value. This is an interpolation factor for the Sun's declination. The sign of the *d* factor is not given; it must be determined by noting from the *Almanac* if the Sun's declination is increasing or decreasing throughout the day. If it is increasing, the factor is positive; if it is decreasing, the factor is negative. In the above problem, the Sun's declination is increasing throughout the day. Therefore, the *d* factor is +0.1.

Having obtained the *d* factor, enter the 15 minute increment and correction table. Under the column labeled "*v* or *d* $corr^n$," find the value for *d* in the left hand column. The corresponding number in the right hand column is the correction; apply it to the tabulated declination. In this case, the correction corresponding to a *d* value of +0.1 is 0.0'.

Correction (+ or -)	+10.8'
Computed Altitude (h_c)	2° 39.6'
Observed Altitude (h_o)	2° 48.1'
Intercept	8.5 NM (towards)
Z	064.7°
Z_n	064.7°

The final step will be to determine h_c and Z_n. Enter *Pub. 229* with an LHA of 259°, a declination of N23° 20.5', and an assumed latitude of 30°N.

Declination Increment / + or - *d*	20.5' / +31.5
Tabulated Altitude	2° 28.8'

2008. Reducing a Moon Sight

The Moon is easy to identify and is often visible during the day. However, the Moon's proximity to the Earth requires applying additional corrections to h_a to obtain h_o. This article will cover Moon sight reduction.

At 10-00-00 GMT, June 16, 1994, the navigator obtains a sight of the Moon's upper limb. H_s is 26° 06.7'. Height of eye is 18 feet; there is no index error. Determine h_o, the Moon's GHA, and the Moon's declination. See Figure 2008.

This example demonstrates the extra corrections required for obtaining h_o for a Moon sight. Apply the index and dip corrections in the same manner as for star and Sun sights. The altitude correction comes from tables located on the inside back covers of the *Nautical Almanac*.

In this case, the apparent altitude was 26° 02.6'. Enter the altitude correction table for the Moon with the above apparent altitude. Interpolation is not required. The correction is +60.5'. The additional correction in this case is not applicable because the sight was taken under standard temperature and pressure conditions.

The horizontal parallax correction is unique to Moon sights. The table for determining this HP correction is on the back inside cover of the *Nautical Almanac*. First, go to the daily page for June 16 at 10-00-00 GMT. In the column for the Moon, find the HP correction factor corresponding to 10-00-00. Its value is 58.4. Take this value to the HP correction table on the inside back cover of the *Almanac*. Notice that the HP correction columns line up vertically with the Moon altitude correction table columns. Find the HP correction column directly under the altitude correction table heading corresponding to the apparent altitude. Enter that column with the HP correction factor from the daily pages. The column has two sets of figures listed under "U" and "L" for upper and lower limb, respectively. In this case, trace down the "U" column until it intersects with the HP

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UT (GMT) d h	ARIES G.H.A. ° ′	VENUS −4.0 G.H.A. ° ′	VENUS Dec. ° ′	MARS +1.2 G.H.A. ° ′	MARS Dec. ° ′	JUPITER −2.3 G.H.A. ° ′	JUPITER Dec. ° ′	SATURN +1.0 G.H.A. ° ′	SATURN Dec. ° ′
15 00	263 03.0	140 48.0	N22 09.1	218 59.0	N16 08.6	49 42.0	S12 03.8	278 39.3	S 8 31.9
01	278 05.4	155 47.4	08.5	233 59.7	09.1	64 44.6	03.8	293 41.7	31.9
02	293 07.9	170 46.7	07.9	249 00.3	09.7	79 47.2	03.7	308 44.1	31.9
03	308 10.4	185 46.1	· · 07.3	264 01.0	· · 10.2	94 49.7	· · 03.7	323 46.6	· · 31.9
04	323 12.8	200 45.5	06.7	279 01.6	10.8	109 52.3	03.7	338 49.0	31.9
05	338 15.3	215 44.8	06.0	294 02.2	11.3	124 54.9	03.6	353 51.4	31.9
06	353 17.8	230 44.2	N22 05.4	309 02.9	N16 11.9	139 57.5	S12 03.6	8 53.9	S 8 31.9
W 07	8 20.2	245 43.6	04.8	324 03.5	12.4	155 00.1	03.6	23 56.3	31.9
E 08	23 22.7	260 42.9	04.2	339 04.2	13.0	170 02.7	03.5	38 58.7	31.9
D 09	38 25.2	275 42.3	· · 03.5	354 04.8	· · 13.5	185 05.3	· · 03.5	54 01.1	· · 31.9
N 10	53 27.6	290 41.7	02.9	9 05.5	14.0	200 07.9	03.5	69 03.6	31.9
E 11	68 30.1	305 41.0	02.3	24 06.1	14.6	215 10.4	03.4	84 06.0	31.9
S 12	83 32.6	320 40.4	N22 01.6	39 06.8	N16 15.1	230 13.0	S12 03.4	99 08.4	S 8 31.9
D 13	98 35.0	335 39.8	01.0	54 07.4	15.7	245 15.6	03.4	114 10.9	31.9
A 14	113 37.5	350 39.2	22 00.4	69 08.1	16.2	260 18.2	03.3	129 13.3	31.9
Y 15	128 39.9	5 38.5	21 59.7	84 08.7	· · 16.8	275 20.8	· · 03.3	144 15.7	· · 31.9
16	143 42.4	20 37.9	59.1	99 09.4	17.3	290 23.4	03.3	159 18.2	31.9
17	158 44.9	35 37.3	58.5	114 10.0	17.8	305 26.0	03.3	174 20.6	31.9
18	173 47.3	50 36.7	N21 57.8	129 10.7	N16 18.4	320 28.5	S12 03.2	189 23.0	S 8 31.9
19	188 49.8	65 36.0	57.2	144 11.3	18.9	335 31.1	03.2	204 25.5	31.9
20	203 52.3	80 35.4	56.6	159 12.0	19.5	350 33.7	03.2	219 27.9	31.9
21	218 54.7	95 34.8	· · 55.9	174 12.6	· · 20.0	5 36.3	· · 03.1	234 30.3	· · 31.9
22	233 57.2	110 34.2	55.3	189 13.3	20.6	20 38.9	03.1	249 32.8	31.9
23	248 59.7	125 33.5	54.6	204 13.9	21.1	35 41.5	03.1	264 35.2	31.9
16 00	264 02.1	140 32.9	N21 54.0	219 14.6	N16 21.6	50 44.1	S12 03.0	279 37.6	S 8 31.9
01	279 04.6	155 32.3	53.4	234 15.2	22.2	65 46.6	03.0	294 40.1	31.9
02	294 07.1	170 31.7	52.7	249 15.9	22.7	80 49.2	03.0	309 42.5	31.9
03	309 09.5	185 31.1	· · 52.1	264 16.5	· · 23.2	95 51.8	· · 03.0	324 44.9	· · 31.9
04	324 12.0	200 30.4	51.4	279 17.2	23.8	110 54.4	02.9	339 47.4	31.9
05	339 14.4	215 29.8	50.8	294 17.8	24.3	125 57.0	02.9	354 49.8	31.8
06	354 16.9	230 29.2	N21 50.1	309 18.5	N16 24.9	140 59.5	S12 02.9	9 52.2	S 8 31.8
07	9 19.4	245 28.6	49.5	324 19.1	25.4	156 02.1	02.8	24 54.7	31.8
T 08	24 21.8	260 28.0	48.8	339 19.8	25.9	171 04.7	02.8	39 57.1	31.8
H 09	39 24.3	275 27.4	· · 48.2	354 20.4	· · 26.5	186 07.3	· · 02.8	54 59.5	· · 31.8
U 10	54 26.8	290 26.8	47.5	9 21.1	27.0	201 09.9	02.7	70 02.0	31.8
R 11	69 29.2	305 26.1	46.9	24 21.7	27.6	216 12.5	02.7	85 04.4	31.8
S 12	84 31.7	320 25.5	N21 46.2	39 22.3	N16 28.1	231 15.0	S12 02.7	100 06.8	S 8 31.8
D 13	99 34.2	335 24.9	45.6	54 23.0	28.6	246 17.6	02.7	115 09.3	31.8
A 14	114 36.6	350 24.3	44.9	69 23.6	29.2	261 20.2	02.6	130 11.7	31.8
Y 15	129 39.1	5 23.7	· · 44.3	84 24.3	· · 29.7	276 22.8	· · 02.6	145 14.1	· · 31.8
16	144 41.5	20 23.1	43.6	99 24.9	30.2	291 25.3	02.6	160 16.6	31.8
17	159 44.0	35 22.5	42.9	114 25.6	30.8	306 27.9	02.5	175 19.0	31.8
18	174 46.5	50 21.9	N21 42.3	129 26.2	N16 31.3	321 30.5	S12 02.5	190 21.4	S 8 31.8
19	189 48.9	65 21.3	41.6	144 26.9	31.8	336 33.1	02.5	205 23.9	31.8
20	204 51.4	80 20.6	41.0	159 27.5	32.4	351 35.7	02.5	220 26.3	31.8
21	219 53.9	95 20.0	· · 40.3	174 28.2	· · 32.9	6 38.2	· · 02.4	235 28.7	· · 31.8
22	234 56.3	110 19.4	39.6	189 28.8	33.4	21 40.8	02.4	250 31.2	31.8
23	249 58.8	125 18.8	39.0	204 29.5	34.0	36 43.4	02.4	265 33.6	31.8
17 00	265 01.3	140 18.2	N21 38.3	219 30.1	N16 34.5	51 46.0	S12 02.4	280 36.0	S 8 31.8
01	280 03.7	155 17.6	37.6	234 30.8	35.0	66 48.5	02.3	295 38.5	31.8
02	295 06.2	170 17.0	37.0	249 31.4	35.6	81 51.1	02.3	310 40.9	31.8
03	310 08.7	185 16.4	· · 36.3	264 32.1	· · 36.1	96 53.7	· · 02.3	325 43.4	· · 31.8
04	325 11.1	200 15.8	35.6	279 32.7	36.6	111 56.3	02.2	340 45.8	31.8
05	340 13.6	215 15.2	35.0	294 33.3	37.2	126 58.8	02.2	355 48.2	31.8
06	355 16.0	230 14.6	N21 34.3	309 34.0	N16 37.7	142 01.4	S12 02.2	10 50.7	S 8 31.8
07	10 18.5	245 14.0	33.6	324 34.6	38.2	157 04.0	02.2	25 53.1	31.8
08	25 21.0	260 13.4	32.9	339 35.3	38.8	172 06.6	02.1	40 55.5	31.8
F 09	40 23.4	275 12.8	· · 32.3	354 35.9	· · 39.3	187 09.1	· · 02.1	55 58.0	· · 31.8
R 10	55 25.9	290 12.2	31.6	9 36.6	39.8	202 11.7	02.1	71 00.4	31.8
I 11	70 28.4	305 11.6	30.9	24 37.2	40.4	217 14.3	02.1	86 02.9	31.8
D 12	85 30.8	320 11.0	N21 30.2	39 37.9	N16 40.9	232 16.9	S12 02.0	101 05.3	S 8 31.8
A 13	100 33.3	335 10.4	29.6	54 38.5	41.4	247 19.4	02.0	116 07.7	31.8
Y 14	115 35.8	350 09.8	28.9	69 39.2	41.9	262 22.0	02.0	131 10.2	31.8
15	130 38.2	5 09.2	· · 28.2	84 39.8	· · 42.5	277 24.6	· · 02.0	146 12.6	· · 31.8
16	145 40.7	20 08.6	27.5	99 40.5	43.0	292 27.1	01.9	161 15.1	31.8
17	160 43.2	35 08.0	26.8	114 41.1	43.5	307 29.7	01.9	176 17.5	31.8
18	175 45.6	50 07.4	N21 26.2	129 41.7	N16 44.1	322 32.3	S12 01.9	191 19.9	S 8 31.8
19	190 48.1	65 06.8	25.5	144 42.4	44.6	337 34.9	01.9	206 22.4	31.8
20	205 50.5	80 06.2	24.8	159 43.0	45.1	352 37.4	01.8	221 24.8	31.8
21	220 53.0	95 05.6	· · 24.1	174 43.7	· · 45.6	7 40.0	· · 01.8	236 27.3	· · 31.8
22	235 55.5	110 05.1	23.4	189 44.3	46.2	22 42.6	01.8	251 29.7	31.8
23	250 57.9	125 04.5	22.7	204 45.0	46.7	37 45.1	01.8	266 32.1	31.8
Mer. Pass.	h m 6 22.8	v −0.6	d 0.7	v 0.6	d 0.5	v 2.6	d 0.0	v 2.4	d 0.0

STARS Name	S.H.A. ° ′	Dec. ° ′
Acamar	315 29.5	S40 19.5
Achernar	335 37.6	S57 15.6
Acrux	173 25.1	S63 04.5
Adhara	255 24.1	S28 58.0
Aldebaran	291 06.1	N16 29.8
Alioth	166 33.0	N55 59.6
Alkaid	153 09.8	N49 20.6
Al Na'ir	28 01.4	S46 58.9
Alnilam	276 01.2	S 1 12.4
Alphard	218 10.3	S 8 38.3
Alphecca	126 22.7	N26 44.1
Alpheratz	357 58.3	N29 03.5
Altair	62 21.8	N 8 51.3
Ankaa	353 29.8	S42 19.9
Antares	112 43.4	S26 25.2
Arcturus	146 08.5	N19 12.7
Atria	107 57.4	S69 01.1
Avior	234 24.3	S59 29.8
Bellatrix	278 47.6	N 6 20.6
Betelgeuse	271 17.0	N 7 24.3
Canopus	264 03.0	S52 41.7
Capella	280 56.0	N45 59.5
Deneb	49 40.8	N45 15.6
Denebola	182 48.1	N14 36.2
Diphda	349 10.3	S18 00.9
Dubhe	194 09.2	N61 47.0
Elnath	278 31.0	N28 36.1
Eltanin	90 52.2	N51 29.4
Enif	34 00.9	N 9 51.0
Fomalhaut	15 39.6	S29 38.8
Gacrux	172 16.6	S57 05.3
Gienah	176 06.9	S17 30.9
Hadar	149 07.7	S60 21.1
Hamal	328 17.1	N23 26.1
Kaus Aust.	84 02.3	S34 23.1
Kochab	137 18.6	N74 10.9
Markab	13 52.4	N15 10.5
Menkar	314 30.2	N 4 04.1
Menkent	148 24.1	S36 20.8
Miaplacidus	221 43.2	S69 42.1
Mirfak	309 01.2	N49 50.3
Nunki	76 15.6	S26 18.1
Peacock	53 41.1	S56 44.9
Pollux	243 45.4	N28 02.3
Procyon	245 14.9	N 5 14.2
Rasalhague	96 19.3	N12 33.9
Regulus	207 58.8	N11 59.6
Rigel	281 26.1	S 8 12.6
Rigil Kent.	140 10.7	S60 48.9
Sabik	102 28.5	S15 43.0
Schedar	349 56.9	N56 30.2
Shaula	96 40.8	S37 05.9
Sirius	258 46.6	S16 42.6
Spica	158 46.1	S11 08.1
Suhail	223 03.2	S43 24.9
Vega	80 48.2	N38 46.8
Zuben'ubi	137 20.9	S16 01.2

	S.H.A. ° ′	Mer. Pass. h m
Venus	236 30.8	14 38
Mars	315 12.5	9 23
Jupiter	146 41.9	20 34
Saturn	15 35.5	5 21

Figure 2007. Left hand daily page of the Nautical Almanac for June 16, 1994.

Body	Moon (UL)
Index Correction	0.0'
Dip (18 feet)	-4.1'
Sum	-4.1'
Sextant Altitude (h_s)	26° 06.7'
Apparent Altitude (h_a)	26° 02.6'
Altitude Correction	+60.5'
Additional Correction	0.0'
Horizontal Parallax (58.4)	+4.0'
Moon Upper Limb Correction	-30.0'
Correction to h_a	+34.5'
Observed Altitude (h_o)	26° 37.1'

correction factor of 58.4. Interpolating between 58.2 and 58.5 yields a value of +4.0' for the horizontal parallax correction.

The final correction is a constant -30.0' correction to h_a applied only to sights of the Moon's upper limb. This correction is always negative; apply it only to sights of the Moon's upper limb, not its lower limb. The total correction to h_a is the sum of all the corrections; in this case, this total correction is +34.5 minutes.

To obtain the Moon's GHA, enter the daily pages in the Moon column and extract the applicable data just as for a star or Sun sight. Determining the Moon's GHA requires an additional correction, the *v* correction.

GHA Moon and *v*	245° 45.1' and +11.3
GHA Increment	0° 00.0'
v Correction	+0.1'
GHA	245° 45.2'

First, record the GHA of the Moon for 10-00-00 on June 16, 1994, from the daily pages of the *Nautical Almanac*. Record also the *v* correction factor; in this case, it is +11.3. The *v* correction factor for the Moon is always positive. The increment correction is, in this case, zero because the sight was recorded on the even hour. To obtain the *v* correction, go to the tables of increments and corrections. In the 0 minute table in the *v* or *d* correction columns, find the correction that corresponds to a *v* = 11.3. The table yields a correction of +0.1'. Adding this correction to the tabulated GHA gives the final GHA as 245° 45.2'.

Finding the Moon's declination is similar to finding the declination for the Sun or stars. Go to the daily pages for June 16, 1994; extract the Moon's declination and *d* factor.

Tabulated Declination / *d*	S 00° 13.7' / +12.1
d Correction	+0.1'
True Declination	S 00° 13.8'

The tabulated declination and the *d* factor come from the *Nautical Almanac's* daily pages. Record the declination and *d* correction and go to the increment and correction pages to extract the proper correction for the given *d* factor. In this case, go to the correction page for 0 minutes. The correction corresponding to a *d* factor of +12.1 is +0.1. It is important to extract the correction with the correct algebraic sign. The *d* correction may be positive or negative depending on whether the Moon's declination is increasing or decreasing in the interval covered by the *d* factor. In this case, the Moon's declination at 10-00-00 GMT on 16 June was S 00° 13.7'; at 11-00-00 on the same date the Moon's declination was S 00° 25.8'. Therefore, since the declination was increasing over this period, the *d* correction is positive. Do not determine the sign of this correction by noting the trend in the *d* factor. In other words, had the *d* factor for 11-00-00 been a value less than 12.1, that would not indicate that the *d* correction should be negative. Remember that the *d* factor is analogous to an interpolation factor; it provides a correction to declination. Therefore, the trend in declination values, not the trend in *d* values, controls the sign of the *d* correction. Combine the tabulated declination and the *d* correction factor to determine the true declination. In this case, the Moon's true declination is S 00° 13.8'.

Having obtained the Moon's GHA and declination, calculate LHA and determine the assumed latitude. Enter the *Sight Reduction Table* with the LHA, assumed latitude, and calculated declination. Calculate the intercept and azimuth in the same manner used for star and Sun sights.

2009. Reducing a Planet Sight

There are four navigational planets: Venus, Mars, Jupiter, and Saturn. Reducing a planet sight is similar to reducing a Sun or star sight, but there are a few important differences. This Article will cover the procedure for determining h_o, the GHA and the declination for a planet sight.

On July 27, 1995, at 09-45-20 GMT, you take a sight of Mars. H_s is 33° 20.5'. The height of eye is 25 feet, and the index correction is +0.2'. Determine h_o, GHA, and declination. See Figure 2009.

The table above demonstrates the similarity between reducing planet sights and reducing sights of the Sun and stars. Calculate and apply the index and dip corrections exactly as for any other sight. Take the resulting apparent altitude and enter the altitude correction table for the stars and planets on the inside front cover of the *Nautical Almanac*.

In this case, the altitude correction for 33° 15.8' results in a correction of -1.5'. The additional correction is not applicable because the sight was taken at standard temperature and pressure; the horizontal parallax correction is not applicable to a planet sight. All that remains is the correction specific to Mars or Venus. The altitude correction table in the *Nautical Almanac* also contains this correction. Its magnitude is a function of the body sighted (Mars or Venus), the time of year, and the body's apparent altitude. Entering this table with the data for this problem yields a correction of +0.1'. Applying these cor-

1994 JUNE 15, 16, 17 (WED., THURS., FRI.)

UT (GMT) d h	SUN G.H.A. ° ′	SUN Dec. ° ′	MOON G.H.A. ° ′	v ′	MOON Dec. ° ′	d ′	H.P. ′
15 00 (WEDNESDAY)	179 55.6	N23 17.2	112 24.4	11.8	N 6 28.5	11.4	57.6
01	194 55.5	17.4	126 55.2	11.8	6 17.1	11.3	57.6
02	209 55.4	17.5	141 26.0	11.8	6 05.8	11.4	57.6
03	224 55.2	. . 17.6	155 56.8	11.7	5 54.4	11.4	57.7
04	239 55.1	17.7	170 27.5	11.8	5 43.0	11.5	57.7
05	254 55.0	17.8	184 58.3	11.8	5 31.5	11.5	57.7
06	269 54.8	N23 17.9	199 29.1	11.7	N 5 20.0	11.6	57.7
07	284 54.7	18.0	213 59.8	11.8	5 08.4	11.5	57.8
08	299 54.6	18.1	228 30.6	11.7	4 56.9	11.7	57.8
09	314 54.4	. . 18.2	243 01.3	11.8	4 45.2	11.6	57.8
10	329 54.3	18.3	257 32.1	11.7	4 33.6	11.7	57.8
11	344 54.2	18.5	272 02.8	11.7	4 21.9	11.7	57.9
12	359 54.0	N23 18.6	286 33.5	11.7	N 4 10.2	11.8	57.9
13	14 53.9	18.7	301 04.2	11.7	3 58.4	11.7	57.9
14	29 53.8	18.8	315 34.9	11.7	3 46.7	11.8	57.9
15	44 53.6	. . 18.9	330 05.6	11.7	3 34.9	11.9	58.0
16	59 53.5	19.0	344 36.3	11.6	3 23.0	11.8	58.0
17	74 53.4	19.1	359 06.9	11.6	3 11.2	11.9	58.0
18	89 53.2	N23 19.2	13 37.5	11.7	N 2 59.3	11.9	58.0
19	104 53.1	19.3	28 08.2	11.6	2 47.4	12.0	58.1
20	119 53.0	19.4	42 38.8	11.6	2 35.4	11.9	58.1
21	134 52.8	. . 19.5	57 09.4	11.5	2 23.5	12.0	58.1
22	149 52.7	19.6	71 39.9	11.6	2 11.5	12.0	58.1
23	164 52.6	19.7	86 10.5	11.5	1 59.5	12.0	58.2
16 00 (THURSDAY)	179 52.4	N23 19.8	100 41.0	11.5	N 1 47.5	12.1	58.2
01	194 52.3	19.9	115 11.5	11.5	1 35.4	12.0	58.2
02	209 52.2	20.0	129 42.0	11.5	1 23.4	12.1	58.2
03	224 52.0	. . 20.1	144 12.5	11.5	1 11.3	12.1	58.3
04	239 51.9	20.1	158 43.0	11.4	0 59.2	12.1	58.3
05	254 51.7	20.2	173 13.4	11.4	0 47.1	12.1	58.3
06	269 51.6	N23 20.3	187 43.8	11.4	N 0 35.0	12.2	58.3
07	284 51.5	20.4	202 14.2	11.3	0 22.8	12.1	58.4
08	299 51.3	20.5	216 44.5	11.3	N 0 10.7	12.2	58.4
09	314 51.2	. . 20.6	231 14.8	11.3	S 0 01.5	12.2	58.4
10	329 51.1	20.7	245 45.1	11.3	0 13.7	12.1	58.4
11	344 50.9	20.8	260 15.4	11.2	0 25.8	12.2	58.5
12	359 50.8	N23 20.9	274 45.6	11.3	S 0 38.0	12.2	58.5
13	14 50.7	21.0	289 15.9	11.1	0 50.2	12.2	58.5
14	29 50.5	21.1	303 46.0	11.2	1 02.4	12.2	58.5
15	44 50.4	. . 21.1	318 16.2	11.1	1 14.6	12.2	58.6
16	59 50.3	21.2	332 46.3	11.1	1 26.8	12.3	58.6
17	74 50.1	21.3	347 16.4	11.0	1 39.1	12.2	58.6
18	89 50.0	N23 21.4	1 46.4	11.0	S 1 51.3	12.2	58.6
19	104 49.9	21.5	16 16.4	11.0	2 03.5	12.2	58.7
20	119 49.7	21.6	30 46.4	10.9	2 15.7	12.2	58.7
21	134 49.6	. . 21.6	45 16.3	10.9	2 27.9	12.2	58.7
22	149 49.5	21.7	59 46.2	10.9	2 40.1	12.2	58.7
23	164 49.3	21.8	74 16.1	10.8	2 52.3	12.2	58.8
17 00 (FRIDAY)	179 49.2	N23 21.9	88 45.9	10.8	S 3 04.5	12.2	58.8
01	194 49.1	22.0	103 15.7	10.7	3 16.7	12.2	58.8
02	209 48.9	22.0	117 45.4	10.7	3 28.9	12.2	58.8
03	224 48.8	. . 22.1	132 15.1	10.7	3 41.1	12.2	58.9
04	239 48.6	22.2	146 44.8	10.6	3 53.3	12.1	58.9
05	254 48.5	22.3	161 14.4	10.6	4 05.4	12.2	58.9
06	269 48.4	N23 22.3	175 44.0	10.5	S 4 17.6	12.1	58.9
07	284 48.2	22.4	190 13.5	10.5	4 29.7	12.1	59.0
08	299 48.1	22.5	204 43.0	10.4	4 41.8	12.1	59.0
09	314 48.0	. . 22.6	219 12.4	10.4	4 53.9	12.1	59.0
10	329 47.8	22.6	233 41.8	10.3	5 06.0	12.1	59.0
11	344 47.7	22.7	248 11.1	10.3	5 18.1	12.1	59.1
12	359 47.6	N23 22.8	262 40.4	10.2	S 5 30.2	12.0	59.1
13	14 47.4	22.9	277 09.6	10.2	5 42.2	12.0	59.1
14	29 47.3	22.9	291 38.8	10.1	5 54.2	12.0	59.1
15	44 47.2	. . 23.0	306 07.9	10.1	6 06.2	11.9	59.2
16	59 47.0	23.1	320 37.0	10.0	6 18.1	12.0	59.2
17	74 46.9	23.1	335 06.0	10.0	6 30.1	11.9	59.2
18	89 46.8	N23 23.2	349 35.0	9.9	S 6 42.0	11.9	59.2
19	104 46.6	23.3	4 03.9	9.9	6 53.9	11.8	59.3
20	119 46.5	23.3	18 32.8	9.8	7 05.7	11.8	59.3
21	134 46.3	. . 23.4	33 01.6	9.7	7 17.5	11.8	59.3
22	149 46.2	23.5	47 30.3	9.7	7 29.3	11.8	59.3
23	164 46.1	23.5	61 59.0	9.6	7 41.1	11.7	59.4
	S.D. 15.8	d 0.1	S.D.	15.8	15.9		16.1

Lat. °	Twilight Naut. h m	Twilight Civil h m	Sunrise h m	Moonrise 15 h m	Moonrise 16 h m	Moonrise 17 h m	Moonrise 18 h m
N 72	□	□	□	09 54	11 50	13 49	15 56
N 70	□	□	□	10 01	11 49	13 40	15 36
68	□	□	□	10 06	11 48	13 33	15 21
66	□	□	□	10 11	11 47	13 26	15 09
64	////	////	01 33	10 14	11 47	13 21	14 59
62	////	////	02 10	10 18	11 46	13 17	14 50
60	////	00 52	02 36	10 20	11 46	13 13	14 43
N 58	////	01 41	02 56	10 23	11 45	13 10	14 37
56	////	02 11	03 13	10 25	11 45	13 07	14 31
54	00 48	02 33	03 27	10 27	11 45	13 04	14 26
52	01 33	02 51	03 39	10 29	11 44	13 02	14 21
50	02 00	03 06	03 50	10 30	11 44	13 00	14 17
45	02 46	03 35	04 13	10 34	11 44	12 55	14 08
N 40	03 16	03 58	04 31	10 37	11 43	12 51	14 01
35	03 39	04 16	04 46	10 39	11 43	12 48	13 54
30	03 58	04 31	04 59	10 42	11 42	12 45	13 49
20	04 27	04 56	05 20	10 45	11 42	12 40	13 39
N 10	04 49	05 16	05 39	10 49	11 41	12 35	13 31
0	05 08	05 34	05 57	10 52	11 41	12 31	13 23
S 10	05 25	05 51	06 14	10 55	11 40	12 27	13 16
20	05 41	06 09	06 33	10 59	11 40	12 23	13 07
30	05 58	06 28	06 54	11 03	11 40	12 18	12 58
35	06 06	06 38	07 06	11 05	11 39	12 15	12 53
40	06 16	06 50	07 20	11 07	11 39	12 12	12 47
45	06 26	07 03	07 37	11 10	11 39	12 08	12 40
S 50	06 38	07 19	07 58	11 14	11 38	12 04	12 32
52	06 43	07 27	08 08	11 15	11 38	12 02	12 28
54	06 49	07 35	08 19	11 17	11 38	12 00	12 24
56	06 55	07 44	08 31	11 19	11 38	11 58	12 19
58	07 02	07 54	08 46	11 21	11 38	11 55	12 14
S 60	07 09	08 06	09 03	11 24	11 37	11 52	12 09

Lat. °	Sunset h m	Twilight Civil h m	Twilight Naut. h m	Moonset 15 h m	Moonset 16 h m	Moonset 17 h m	Moonset 18 h m
N 72	□	□	□	23 38	23 25	23 12	22 54
N 70	□	□	□	23 35	23 29	23 23	23 16
68	□	□	□	23 34	23 33	23 32	23 32
66	□	□	□	23 32	23 36	23 40	23 46
64	22 29	////	////	23 31	23 38	23 47	23 57
62	21 52	////	////	23 29	23 40	23 52	24 07
60	21 26	23 10	////	23 28	23 42	23 57	24 15
N 58	21 05	22 21	////	23 27	23 44	24 02	00 02
56	20 49	21 51	////	23 26	23 45	24 06	00 06
54	20 34	21 29	23 15	23 26	23 47	24 09	00 09
52	20 22	21 11	22 29	23 25	23 48	24 13	00 13
50	20 11	20 56	22 01	23 24	23 49	24 15	00 15
45	19 49	20 26	21 16	23 23	23 52	24 22	00 22
N 40	19 31	20 04	20 45	23 22	23 54	24 27	00 27
35	19 16	19 45	20 22	23 21	23 55	24 32	00 32
30	19 03	19 30	20 04	23 20	23 57	24 36	00 36
20	18 41	19 05	19 35	23 18	24 00	00 00	00 43
N 10	18 22	18 45	19 12	23 17	24 02	00 02	00 50
0	18 04	18 27	18 53	23 15	24 05	00 05	00 55
S 10	17 47	18 10	18 36	23 14	24 07	00 07	01 01
20	17 28	17 52	18 20	23 12	24 09	00 09	01 08
30	17 07	17 34	18 03	23 10	24 12	00 12	01 15
35	16 55	17 23	17 55	23 09	24 13	00 13	01 19
40	16 41	17 11	17 45	23 08	24 15	00 15	01 24
45	16 24	16 58	17 35	23 07	24 17	00 17	01 29
S 50	16 03	16 42	17 23	23 05	24 20	00 20	01 36
52	15 53	16 34	17 18	23 04	24 21	00 21	01 39
54	15 42	16 26	17 12	23 04	24 22	00 22	01 42
56	15 30	16 17	17 06	23 03	24 23	00 23	01 46
58	15 15	16 07	16 59	23 02	24 25	00 25	01 50
S 60	14 58	15 55	16 52	23 00	24 27	00 27	01 55

Day	SUN Eqn. of Time 00ʰ m s	SUN Eqn. of Time 12ʰ m s	SUN Mer. Pass. h m	MOON Mer. Pass. Upper h m	MOON Mer. Pass. Lower h m	Age d	Phase
15	00 17	00 24	12 00	17 04	04 39	06	
16	00 30	00 37	12 01	17 53	05 28	07	◐
17	00 43	00 49	12 01	18 43	06 18	08	

Figure 2008. Right hand daily page of the Nautical Almanac for June 16, 1994.

Body	Mars
Index Correction	+0.2'
Dip Correction (25 feet)	-4.9'
Sum	-4.7'
h_s	33° 20.5'
h_a	33° 15.8'
Altitude Correction	-1.5'
Additional Correction	Not applicable
Horizontal Parallax	Not applicable
Additional Correction for Mars	+0.1'
Correction to h_a	-1.4'
h_o	33° 14.4'

rections to h_a results in an h_o of 33° 14.4'.

Tabulated GHA / *v*	256°10.6' / 1.1
GHA Increment	11° 20.0'
v correction	+0.8'
GHA	267°31.4'

The only difference between determining the Sun's GHA and a planet's GHA lies in applying the *v* correction. Calculate this correction from the *v* or *d* correction section of the Increments and Correction table in the *Nautical Almanac*.
Find the *v* factor at the bottom of the planets' GHA columns on the daily pages of the *Nautical Almanac*. For Mars on July 27, 1995, the *v* factor is 1.1. If no algebraic sign precedes the *v* factor, add the resulting correction to the tabulated GHA. Subtract the resulting correction only when a negative sign precedes the *v* factor. Entering the *v* or *d* correction table corresponding to 45 minutes yields a correction of 0.8'. Remember, because no sign preceded the *v* factor on the daily pages, add this correction to the tabulated GHA. The final GHA is 267°31.4'.

Tabulated Declination / *d*	S 01° 06.1' / 0.6
d Correction	+0.5'
True Declination	S 01° 06.6'

Read the tabulated declination directly from the daily pages of the *Nautical Almanac*. The *d* correction factor is listed at the bottom of the planet column; in this case, the factor is 0.6. Note the trend in the declination values for the planet; if they are increasing during the day, the correction factor is positive. If the planet's declination is decreasing during the day, the correction factor is negative. Next, enter the *v* or *d* correction table corresponding to 45 minutes and extract the correction for a *d* factor of 0.6. The correction in this case is +0.5'.

From this point, reducing a planet sight is exactly the same as reducing a Sun sight.

MERIDIAN PASSAGE

This section covers determining both latitude and longitude at the meridian passage of the Sun, or Local Apparent Noon (LAN). Determining a vessel's latitude at LAN requires calculating the Sun's zenith distance and declination and combining them according to the rules discussed below.

Latitude at LAN is a special case of the navigational triangle where the Sun is on the observer's meridian and the triangle becomes a straight north/south line. No "solution" is necessary, except to combine the Sun's zenith distance and its declination according to the rules discussed below.

Longitude at LAN is a function of the time elapsed since the Sun passed the Greenwich meridian. The navigator must determine the time of LAN and calculate the GHA of the Sun at that time. The following examples demonstrates these processes.

2010. Latitude at Meridian Passage

At 1056 ZT, May 16, 1995, a vessel's DR position is L 40° 04.3'N and λ 157° 18.5' W. The ship is on course 200°T at a speed of ten knots. (1) Calculate the first and second estimates of Local Apparent Noon. (2) The navigator actually observes LAN at 12-23-30 zone time. The sextant altitude at LAN is 69° 16.0'. The index correction is +2.1' and the height of eye is 45 feet. Determine the vessel's latitude.

First, determine the time of meridian passage from the daily pages of the *Nautical Almanac*. In this case, the meridian passage for May 16, 1995, is 1156. That is, the Sun crosses the central meridian of the time zone at 1156 ZT and the observer's local meridian at 1156 local time. Next, determine the vessel's DR longitude for the time of meridian passage. In this case, the vessel's 1156 DR longitude is 157° 23.0' W. Determine the time zone in which this DR longitude falls and record the longitude of that time zone's central meridian. In this case, the central meridian is 150° W. Enter the Conversion of Arc to Time table in the *Nautical Almanac* with the difference between the DR longitude and the central meridian longitude. The conversion for 7° of arc is 28^m of time, and the conversion for 23' of arc is 1^m32^s of time. Sum these two times. If the DR position is west of the central meridian (as it is in this case), add this time to the time of tabulated meridian passage. If the longitude difference is to the east of the central meridian, subtract this time from the tabulated meridian passage. In this case, the DR position is west of the central meridian. Therefore, add 29 minutes and 32 seconds to 1156, the tabulated time of meridian passage. The estimated time of LAN is 12-25-32 ZT.

This first estimate for LAN does not take into account the vessel's movement. To calculate the second estimate of LAN, first determine the DR longitude for the time of first estimate of LAN (12-25-32 ZT). In this case, that longitude would be 157° 25.2' W. Then, calculate the difference between the longitude of the 12-25-32 DR position and the central meridian longitude. This would be 7° 25.2'. Again, enter the arc to time conversion table and calculate the time difference corresponding to this

1995 JULY 27, 28, 29 (THURS., FRI., SAT.)

UT (GMT) d h		ARIES G.H.A. ° ′	VENUS −3.9 G.H.A. ° ′	VENUS Dec. ° ′	MARS +1.3 G.H.A. ° ′	MARS Dec. ° ′	JUPITER −2.3 G.H.A. ° ′	JUPITER Dec. ° ′	SATURN +1.0 G.H.A. ° ′	SATURN Dec. ° ′
27 00		304 12.4	185 23.5	N21 31.7	121 00.7	S 1 00.4	60 23.8	S20 36.7	308 27.9	S 4 15.6
01		319 14.9	200 22.7	31.2	136 01.8	01.0	75 26.3	36.7	323 30.4	15.7
02		334 17.3	215 21.9	30.7	151 02.9	01.7	90 28.8	36.7	338 33.0	15.7
03		349 19.8	230 21.1	· · 30.2	166 04.0	· · 02.3	105 31.3	· · 36.7	353 35.5	· · 15.8
04		4 22.3	245 20.4	29.7	181 05.1	02.9	120 33.8	36.7	8 38.1	15.8
05		19 24.7	260 19.6	29.2	196 06.2	03.6	135 36.4	36.7	23 40.6	15.8
06		34 27.2	275 18.8	N21 28.7	211 07.3	S 1 04.2	150 38.9	S20 36.7	38 43.1	S 4 15.9
07		49 29.7	290 18.0	28.2	226 08.4	04.8	165 41.4	36.7	53 45.7	15.9
08	T	64 32.1	305 17.2	27.7	241 09.5	05.4	180 43.9	36.7	68 48.2	16.0
09	H	79 34.6	320 16.4	· · 27.1	256 10.6	· · 06.1	195 46.4	· · 36.7	83 50.7	· · 16.0
10	U	94 37.1	335 15.6	26.6	271 11.7	06.7	210 48.9	36.7	98 53.3	16.1
11	R	109 39.5	350 14.8	26.1	286 12.8	07.3	225 51.5	36.7	113 55.8	16.1
12	S	124 42.0	5 14.0	N21 25.6	301 13.9	S 1 08.0	240 54.0	S20 36.7	128 58.4	S 4 16.1
13	D	139 44.4	20 13.2	25.1	316 15.0	08.6	255 56.5	36.7	144 00.9	16.2
14	A	154 46.9	35 12.4	24.5	331 16.1	09.2	270 59.0	36.7	159 03.4	16.2
15	Y	169 49.4	50 11.6	· · 24.0	346 17.2	· · 09.8	286 01.5	· · 36.7	174 06.0	· · 16.3
16		184 51.8	65 10.8	23.5	1 18.3	10.5	301 04.0	36.7	189 08.5	16.3
17		199 54.3	80 10.0	23.0	16 19.4	11.1	316 06.6	36.7	204 11.1	16.4
18		214 56.8	95 09.2	N21 22.5	31 20.6	S 1 11.7	331 09.1	S20 36.7	219 13.6	S 4 16.4
19		229 59.2	110 08.4	21.9	46 21.7	12.4	346 11.6	36.7	234 16.1	16.4
20		245 01.7	125 07.7	21.4	61 22.8	13.0	1 14.1	36.7	249 18.7	16.5
21		260 04.2	140 06.9	· · 20.9	76 23.9	· · 13.6	16 16.6	· · 36.7	264 21.2	· · 16.5
22		275 06.6	155 06.1	20.3	91 25.0	14.2	31 19.1	36.7	279 23.8	16.6
23		290 09.1	170 05.3	19.8	106 26.1	14.9	46 21.6	36.7	294 26.3	16.6
28 00		305 11.6	185 04.5	N21 19.3	121 27.2	S 1 15.5	61 24.1	S20 36.7	309 28.8	S 4 16.7
01		320 14.0	200 03.7	18.8	136 28.3	16.1	76 26.7	36.7	324 31.4	16.7
02		335 16.5	215 02.9	18.2	151 29.4	16.8	91 29.2	36.7	339 33.9	16.8
03		350 18.9	230 02.1	· · 17.7	166 30.5	· · 17.4	106 31.7	· · 36.7	354 36.5	· · 16.8
04		5 21.4	245 01.3	17.1	181 31.6	18.0	121 34.2	36.7	9 39.0	16.8
05		20 23.9	260 00.6	16.6	196 32.7	18.6	136 36.7	36.7	24 41.5	16.9
06		35 26.3	274 59.8	N21 16.1	211 33.8	S 1 19.3	151 39.2	S20 36.7	39 44.1	S 4 16.9
07		50 28.8	289 59.0	15.5	226 34.9	19.9	166 41.7	36.7	54 46.6	17.0
08		65 31.3	304 58.2	15.0	241 36.0	20.5	181 44.2	36.7	69 49.2	17.0
09	F	80 33.7	319 57.4	· · 14.5	256 37.1	· · 21.2	196 46.7	· · 36.7	84 51.7	· · 17.1
10	R	95 36.2	334 56.6	13.9	271 38.2	21.8	211 49.2	36.7	99 54.3	17.1
11	I	110 38.7	349 55.8	13.4	286 39.3	22.4	226 51.8	36.7	114 56.8	17.2
12	D	125 41.1	4 55.1	N21 12.8	301 40.4	S 1 23.0	241 54.3	S20 36.7	129 59.3	S 4 17.2
13	A	140 43.6	19 54.3	12.3	316 41.5	23.7	256 56.8	36.7	145 01.9	17.2
14	Y	155 46.1	34 53.5	11.7	331 42.6	24.3	271 59.3	36.7	160 04.4	17.3
15		170 48.5	49 52.7	· · 11.2	346 43.6	· · 24.9	287 01.8	· · 36.7	175 07.0	· · 17.3
16		185 51.0	64 51.9	10.6	1 44.7	25.6	302 04.3	36.7	190 09.5	17.4
17		200 53.4	79 51.1	10.1	16 45.8	26.2	317 06.8	36.7	205 12.1	17.4
18		215 55.9	94 50.4	N21 09.5	31 46.9	S 1 26.8	332 09.3	S20 36.7	220 14.6	S 4 17.5
19		230 58.4	109 49.6	09.0	46 48.0	27.5	347 11.8	36.7	235 17.1	17.5
20		246 00.8	124 48.8	08.4	61 49.1	28.1	2 14.3	36.7	250 19.7	17.6
21		261 03.3	139 48.0	· · 07.9	76 50.2	· · 28.7	17 16.8	· · 36.7	265 22.2	· · 17.6
22		276 05.8	154 47.2	07.3	91 51.3	29.3	32 19.3	36.7	280 24.8	17.6
23		291 08.2	169 46.4	06.8	106 52.4	30.0	47 21.8	36.7	295 27.3	17.7
29 00		306 10.7	184 45.7	N21 06.2	121 53.5	S 1 30.6	62 24.3	S20 36.8	310 29.9	S 4 17.7
01		321 13.2	199 44.9	05.7	136 54.6	31.2	77 26.8	36.8	325 32.4	17.8
02		336 15.6	214 44.1	05.1	151 55.7	31.9	92 29.3	36.8	340 34.9	17.8
03		351 18.1	229 43.3	· · 04.5	166 56.8	· · 32.5	107 31.8	· · 36.8	355 37.5	· · 17.9
04		6 20.5	244 42.5	04.0	181 57.9	33.1	122 34.3	36.8	10 40.0	17.9
05		21 23.0	259 41.8	03.4	196 59.0	33.8	137 36.8	36.8	25 42.6	18.0
06		36 25.5	274 41.0	N21 02.9	212 00.1	S 1 34.4	152 39.3	S20 36.8	40 45.1	S 4 18.0
07		51 27.9	289 40.2	02.3	227 01.2	35.0	167 41.8	36.8	55 47.7	18.1
08	S	66 30.4	304 39.4	01.7	242 02.3	35.6	182 44.4	36.8	70 50.2	18.1
09	A	81 32.9	319 38.7	· · 01.2	257 03.4	· · 36.3	197 46.9	· · 36.8	85 52.8	· · 18.1
10	T	96 35.3	334 37.9	00.6	272 04.5	36.9	212 49.4	36.8	100 55.3	18.2
11	U	111 37.8	349 37.1	21 00.0	287 05.6	37.5	227 51.9	36.8	115 57.9	18.2
12	R	126 40.3	4 36.3	N20 59.4	302 06.7	S 1 38.2	242 54.4	S20 36.8	131 00.4	S 4 18.3
13	D	141 42.7	19 35.6	58.9	317 07.8	38.8	257 56.9	36.8	146 02.9	18.3
14	A	156 45.2	34 34.8	58.3	332 08.9	39.4	272 59.4	36.8	161 05.5	18.4
15	Y	171 47.7	49 34.0	· · 57.7	347 10.0	· · 40.1	288 01.8	· · 36.8	176 08.0	· · 18.4
16		186 50.1	64 33.2	57.2	2 11.0	40.7	303 04.3	36.8	191 10.6	18.5
17		201 52.6	79 32.5	56.6	17 12.1	41.3	318 06.8	36.8	206 13.1	18.5
18		216 55.0	94 31.7	N20 56.0	32 13.2	S 1 42.0	333 09.3	S20 36.8	221 15.7	S 4 18.6
19		231 57.5	109 30.9	55.4	47 14.3	42.6	348 11.8	36.8	236 18.2	18.6
20		247 00.0	124 30.1	54.9	62 15.4	43.2	3 14.3	36.8	251 20.8	18.6
21		262 02.4	139 29.4	· · 54.3	77 16.5	· · 43.8	18 16.8	· · 36.8	266 23.3	· · 18.7
22		277 04.9	154 28.6	53.7	92 17.6	44.5	33 19.3	36.8	281 25.9	18.7
23		292 07.4	169 27.8	53.1	107 18.7	45.1	48 21.8	36.8	296 28.4	18.8
Mer. Pass.		h m 3 38.6	v −0.8	d 0.5	v 1.1	d 0.6	v 2.5	d 0.0	v 2.5	d 0.0

STARS Name	S.H.A. ° ′	Dec. ° ′
Acamar	315 28.7	S40 19.1
Achernar	335 36.7	S57 15.2
Acrux	173 24.6	S63 04.8
Adhara	255 23.4	S28 58.0
Aldebaran	291 05.0	N16 29.9
Alioth	166 32.7	N55 59.3
Alkaid	153 09.6	N49 20.4
Al Na'ir	28 00.2	S46 58.7
Alnilam	276 00.3	S 1 12.3
Alphard	218 09.6	S 8 38.4
Alphecca	126 22.3	N26 44.0
Alpheratz	357 57.2	N29 04.0
Altair	62 21.0	N 8 51.6
Ankaa	353 28.8	S42 19.5
Antares	112 42.5	S26 25.3
Arcturus	146 08.0	N19 12.5
Atria	107 56.1	S69 01.3
Avior	234 24.1	S59 29.8
Bellatrix	278 46.7	N 6 20.7
Betelgeuse	271 16.1	N 7 24.3
Canopus	264 02.6	S52 41.6
Capella	280 54.7	N45 59.4
Deneb	49 40.1	N45 16.0
Denebola	182 47.6	N14 35.9
Diphda	349 09.2	S18 00.4
Dubhe	194 08.7	N61 46.6
Elnath	278 29.9	N28 36.1
Eltanin	90 51.9	N51 29.7
Enif	34 00.0	N 9 51.5
Fomalhaut	15 38.5	S29 38.5
Gacrux	172 16.1	S57 05.6
Gienah	176 06.3	S17 31.1
Hadar	149 07.0	S60 21.3
Hamal	328 15.9	N23 26.4
Kaus Aust.	84 01.3	S34 23.1
Kochab	137 19.4	N74 10.8
Markab	13 51.5	N15 11.0
Menkar	314 29.2	N 4 04.4
Menkent	148 23.4	S36 21.0
Miaplacidus	221 43.3	S69 42.1
Mirfak	308 59.8	N49 50.5
Nunki	76 14.6	S26 18.0
Peacock	53 39.8	S56 44.8
Pollux	243 44.5	N28 02.1
Procyon	245 14.1	N 5 14.1
Rasalhague	96 18.7	N12 34.0
Regulus	207 58.1	N11 59.3
Rigel	281 25.2	S 8 12.4
Rigil Kent.	140 10.0	S60 49.2
Sabik	102 27.7	S15 43.1
Schedar	349 55.6	N56 30.6
Shaula	96 39.8	S37 06.0
Sirius	258 45.9	S16 42.6
Spica	158 45.5	S11 08.3
Suhail	223 02.7	S43 25.0
Vega	80 47.7	N38 47.1
Zuben'ubi	137 20.3	S16 01.4

	S.H.A. ° ′	Mer. Pass. h m
Venus	239 52.9	11 40
Mars	176 15.6	15 53
Jupiter	116 12.6	19 51
Saturn	4 17.3	3 22

Figure 2009. Left hand daily page of the Nautical Almanac for July 27, 1995.

Date	16 May 1995
DR Latitude (1156 ZT)	39° 55.0' N
DR Longitude (1156 ZT)	157° 23.0' W
Central Meridian	150° W
d Longitude (arc)	7° 23' W
d Longitude (time)	+29 min. 32 sec
Meridian Passage (LMT)	1156
ZT (first estimate)	12-25-32
DR Longitude (12-25-32)	157° 25.2'
d Longitude (arc)	7° 25.2'
d Longitude (time)	+29 min. 41 sec
Meridian Passage	1156
ZT (second estimate)	12-25-41
ZT (actual transit)	12-23-30 local
Zone Description	+10
GMT	22-23-30
Date (GMT)	16 May 1995
Tabulated Declination / *d*	N 19° 09.0' / +0.6
d correction	+0.2'
True Declination	N 19° 09.2'
Index Correction	+2.1'
Dip (48 ft)	-6.7'
Sum	-4.6'
h_s (at LAN)	69° 16.0'
h_a	69° 11.4'
Altitude Correction	+15.6'
89° 60'	89° 60.0'
h_o	69° 27.0'
Zenith Distance	N 20° 33.0'
True Declination	N 19° 09.2'
Latitude	39° 42.2'

longitude difference. The correction for 7° of arc is 28' of time, and the correction for 25.2' of arc is 1'41" of time. Finally, apply this time correction to the original tabulated time of meridian passage (1156 ZT). The resulting time, 12-25-41 ZT, is the second estimate of LAN.

Solving for latitude requires that the navigator calculate two quantities: the Sun's declination and the Sun's zenith distance. First, calculate the Sun's true declination at LAN. The problem states that LAN is 12-28-30. (Determining the exact time of LAN is covered in Article 2011.) Enter the time of observed LAN and add the correct zone description to determine GMT. Determine the Sun's declination in the same manner as in the sight reduction problem in Article 2006. In this case, the tabulated declination was N 19° 19.1', and the d correction +0.2'. The true declination, therefore, is N 19° 19.3'.

Next, calculate zenith distance. Recall from Navigational Astronomy that zenith distance is simply 90° - observed altitude. Therefore, correct h_s to obtain h_a; then correct h_a to obtain h_o. Then, subtract h_o from 90° to determine the zenith distance. Name the zenith distance North or South depending on the relative position of the observer and the Sun's declination. If the observer is to the north of the Sun's declination, name the zenith distance north. Conversely, if the observer is to the south of the Sun's declination, name the zenith distance south. In this case, the DR latitude is N 39° 55.0' and the Sun's declination is N 19° 19.3'. The observer is to the north of the Sun's declination; therefore, name the zenith distance north. Next, compare the names of the zenith distance and the declination. If their names are the same (i.e., both are north or both are south), add the two values together to obtain the latitude. This was the case in this problem. Both the Sun's declination and zenith distance were north; therefore, the observer's latitude is the sum of the two.

If the name of the body's zenith distance is contrary to the name of the Sun's declination, then subtract the smaller of the two quantities from the larger, carrying for the name of the difference the name of the larger of the two quantities. The result is the observer's latitude. The following examples illustrate this process.

Zenith Distance	N 25°	Zenith Distance	S 50°
<u>True Declination</u>	<u>S 15°</u>	<u>True Declination</u>	<u>N10°</u>
Latitude	N 10°	Latitude	S 40°

2011. Longitude at Meridian Passage

Determining a vessel's longitude at LAN is straightforward. In the western hemisphere, the Sun's GHA at LAN equals the vessel's longitude. In the eastern hemisphere, subtract the Sun's GHA from 360° to determine longitude. The difficult part lies in determining the precise moment of meridian passage.

Determining the time of meridian passage presents a problem because the Sun appears to hang for a finite time at its local maximum altitude. Therefore, noting the time of maximum sextant altitude is not sufficient for determining the precise time of LAN. Two methods are available to obtain LAN with a precision sufficient for determining longitude: (1) the graphical method and (2) the calculation method. The graphical method is discussed first below.

See Figure 2011. For about 30 minutes before the estimated time of LAN, measure and record several sextant altitudes and their corresponding times. Continue taking sights for about 30 minutes after the Sun has descended from the maximum recorded altitude. Increase the sighting frequency near the meridian passage. One sight every 20-30 seconds should yield good results near meridian passage; less frequent sights are required before and after.

Plot the resulting data on a graph of sextant altitude versus time and draw a fair curve through the plotted data. Next, draw a series of horizontal lines across the curve formed by the data points. These lines will intersect the faired curve at two different points. The x coordinates of the points where these lines intersect the faired curve represent the two different times when the Sun's altitude was equal (one time when the Sun was ascending; the other time when the Sun was descending). Draw three such lines, and ensure the lines have sufficient vertical separation. For each line, average the two times where it intersects the faired curve. Finally, average the three resulting times to obtain a final value

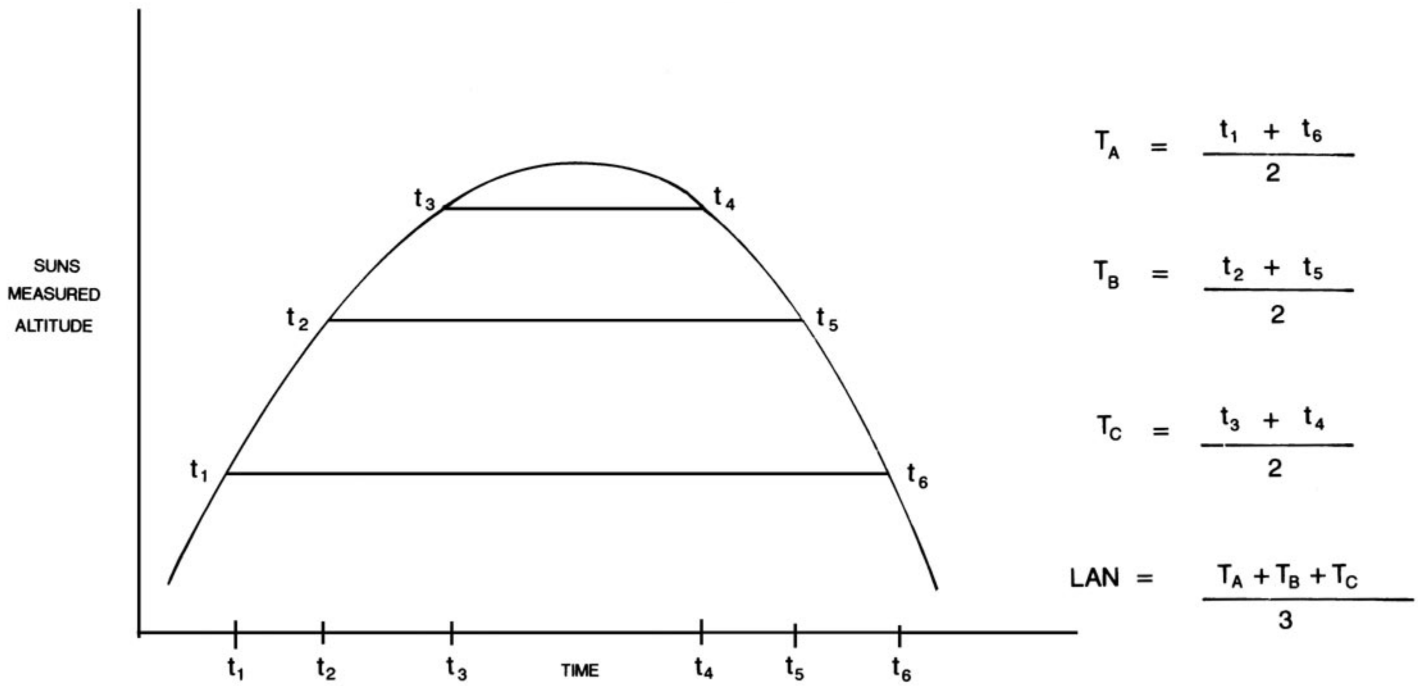

Figure 2011. Time of LAN.

for the time of LAN. From the *Nautical Almanac*, determine the Sun's GHA at that time; this is your longitude in the western hemisphere. In the eastern hemisphere, subtract the Sun's GHA from 360° to determine longitude. For a quicker but less exact time, simply drop a perpendicular from the apex of the curve and read the time along the time scale.

The second method of determining LAN is similar to the first. Estimate the time of LAN as discussed above, Measure and record the Sun's altitude as the Sun approaches its maximum altitude. As the Sun begins to descend, set the sextant to correspond to the altitude recorded just before the Sun's reaching its maximum altitude. Note the time when the Sun is again at that altitude. Average the two times. Repeat this procedure with two other altitudes recorded before LAN, each time presetting the sextant to those altitudes and recording the corresponding times that the Sun, now on its descent, passes through those altitudes. Average these corresponding times. Take a final average among the three averaged times; the result will be the time of meridian passage. Determine the vessel's longitude by determining the Sun's GHA at the exact time of LAN.

LATITUDE BY POLARIS

2012. Latitude by Polaris

Since Polaris is always within about 1° of the North Pole, the altitude of Polaris, with a few minor corrections, equals the latitude of the observer. This relationship makes Polaris an extremely important navigational star in the northern hemisphere.

The corrections are necessary because Polaris orbits in a small circle around the pole. When Polaris is at the exact same altitude as the pole, the correction is zero. At two points in its orbit it is in a direct line with the observer and the pole, either nearer than or beyond the pole. At these points the corrections are maximum. The following example illustrates converting a Polaris sight to latitude.

At 23-18-56 GMT, on April 21, 1994, at DR Lat. 50° 23.8' N, λ=37° 14.0' W, the observed altitude of Polaris (h_o) is 49° 31.6'. Find the vessel's latitude.

To solve this problem, use the equation:

$$\text{Latitude} = h_o - 1° + A_0 + A_1 + A_2$$

where h_o is the sextant altitude (h_s) corrected as in any other star sight; 1° is a constant; and A_0, A_1, and A_2 are correction factors from the Polaris tables found in the *Nautical Almanac*. These three correction factors are always positive. One needs the following information to enter the tables: LHA of Aries, DR latitude, and the month of the year. Therefore:

Enter the Polaris table with the calculated LHA of Aries

POLARIS (POLE STAR) TABLES, 1994

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

LHA ARIES	120°–129°	130°–139°	140°–149°	150°–159°	160°–169°	170°–179°	180°–189°	190°–199°	200°–209°	210°–219°	220°–229°	230°–239°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 53·9	1 01·8	1 09·7	1 17·2	1 24·1	1 30·3	1 35·5	1 39·6	1 42·5	1 44·1	1 44·3	1 43·2
1	54·7	02·6	10·4	17·9	24·8	30·9	36·0	40·0	42·7	44·2	44·3	43·0
2	55·5	03·4	11·2	18·6	25·4	31·4	36·4	40·3	42·9	44·3	44·2	42·8
3	56·3	04·2	12·0	19·3	26·1	32·0	36·9	40·6	43·1	44·3	44·1	42·6
4	57·1	05·0	12·7	20·0	26·7	32·5	37·3	40·9	43·3	44·4	44·0	42·4
5	0 57·8	1 05·8	1 13·5	1 20·7	1 27·3	1 33·0	1 37·7	1 41·2	1 43·5	1 44·4	1 43·9	1 42·1
6	58·6	06·6	14·2	21·4	27·9	33·5	38·1	41·5	43·6	44·4	43·8	41·9
7	0 59·4	07·3	15·0	22·1	28·5	34·1	38·5	41·8	43·8	44·4	43·7	41·6
8	1 00·2	08·1	15·7	22·8	29·1	34·6	38·9	42·0	43·9	44·4	43·5	41·3
9	01·0	08·9	16·4	23·5	29·7	35·0	39·3	42·3	44·0	44·4	43·4	41·0
10	1 01·8	1 09·7	1 17·2	1 24·1	1 30·3	1 35·5	1 39·6	1 42·5	1 44·1	1 44·3	1 43·2	1 40·7
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·6	0·6	0·6	0·6	0·6
10	·3	·3	·3	·4	·4	·5	·5	·6	·6	·6	·6	·6
20	·3	·4	·4	·4	·4	·5	·5	·6	·6	·6	·6	·6
30	·4	·4	·4	·5	·5	·5	·5	·6	·6	·6	·6	·6
40	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·6	0·6
45	·5	·5	·5	·6	·6	·6	·6	·6	·6	·6	·6	·6
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·7	·7	·7	·7	·6	·6	·6	·6	·6	·6	·6	·6
60	·8	·8	·7	·7	·7	·7	·6	·6	·6	·6	·6	·6
62	0·8	0·8	0·8	0·8	0·7	0·7	0·7	0·6	0·6	0·6	0·6	0·6
64	·9	·9	·8	·8	·8	·7	·7	·6	·6	·6	·6	·6
66	0·9	0·9	·9	·8	·8	·7	·7	·6	·6	·6	·6	·6
68	1·0	1·0	0·9	0·9	0·8	0·8	0·7	0·7	0·6	0·6	0·6	0·6
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·6	0·6	0·6	0·5	0·5	0·5	0·4	0·4	0·4	0·4	0·4	0·4
Feb.	·8	·8	·7	·7	·6	·6	·5	·5	·4	·4	·4	·3
Mar.	0·9	0·9	0·9	·8	·8	·7	·6	·6	·5	·5	·4	·4
Apr.	1·0	1·0	1·0	0·9	0·9	0·8	0·8	0·7	0·7	0·6	0·5	0·5
May	0·9	1·0	1·0	1·0	1·0	0·9	·9	·9	·8	·8	·7	·6
June	·8	0·9	0·9	0·9	0·9	1·0	·9	·9	·9	·9	·8	·8
July	0·7	0·7	0·8	0·8	0·8	0·9	0·9	0·9	0·9	0·9	0·9	0·9
Aug.	·5	·5	·6	·6	·7	·7	·8	·8	·8	·9	·9	·9
Sept.	·3	·4	·4	·5	·5	·6	·6	·7	·7	·7	·8	·8
Oct.	0·3	0·3	0·3	0·3	0·3	0·4	0·4	0·5	0·5	0·6	0·6	0·7
Nov.	·2	·2	·2	·2	·2	·2	·2	·3	·3	·4	·5	·5
Dec.	0·3	0·2	0·2	0·2	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·4
Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	359·2	359·2	359·3	359·3	359·4	359·5	359·6	359·7	359·8	0·0	0·1	0·2
20	359·2	359·2	359·2	359·3	359·4	359·5	359·6	359·7	359·8	0·0	0·1	0·3
40	359·0	359·0	359·1	359·1	359·2	359·3	359·5	359·6	359·8	0·0	0·1	0·3
50	358·8	358·8	358·9	359·0	359·1	359·2	359·4	359·6	359·8	0·0	0·2	0·4
55	358·7	358·7	358·7	358·8	359·0	359·1	359·3	359·5	359·7	0·0	0·2	0·4
60	358·5	358·5	358·6	358·7	358·8	359·0	359·2	359·5	359·7	0·0	0·2	0·5
65	358·2	358·2	358·3	358·4	358·6	358·8	359·1	359·4	359·6	359·9	0·3	0·6

Figure 2012. Excerpt from the Polaris Tables.

(162° 03.5'). See Figure 2012. The first correction, A_0, is a function solely of the LHA of Aries. Enter the table column indicating the proper range of LHA of Aries; in this case, enter the 160°-169° column. The numbers on the left hand side of the A_0 correction table represent the whole degrees of LHA ♈ ; interpolate to determine the proper A_0 correction. In this case, LHA ♈ was 162° 03.5'. The A_0 correction for LHA = 162° is 1° 25.4' and the A_0 correction for LHA = 163° is 1° 26.1'. The A_0 correction for 162° 03.5' is 1° 25.4'.

LHA ♈	162° 03.5'
A_0 (162° 03.5')	+1° 25.4'
A_1 (L = 50°N)	+0.6'
A_2 (April)	+0.9'
Sum	1° 26.9'
Constant	-1° 00.0'
Observed Altitude	49° 31.6'
Total Correction	+26.9'
Latitude	N 49° 58.5'

Tabulated GHA ♈ (2300 hrs.)	194° 32.7'
Increment (18-56)	4° 44.8'
GHA ♈	199° 17.5'
DR Longitude (-W +E)	37° 14.0'

To calculate the A_1 correction, enter the A_1 correction table with the DR latitude, being careful to stay in the 160°-169° LHA column. There is no need to interpolate here; simply choose the latitude that is closest to the vessel's DR latitude. In this case, L is 50°N. The A_1 correction corresponding to an LHA range of 160°-169° and a latitude of 50°N is + 0.6'.

Finally, to calculate the A_2 correction factor, stay in the 160°-169° LHA ♈ column and enter the A_2 correction table. Follow the column down to the month of the year; in this case, it is April. The correction for April is + 0.9'.

Sum the corrections, remembering that all three are always positive. Subtract 1° from the sum to determine the total correction; then apply the resulting value to the observed altitude of Polaris. This is the vessel's latitude.

THE DAY'S WORK IN CELESTIAL NAVIGATION

2013. Celestial Navigation Daily Routine

The navigator need not follow the entire celestial routine if celestial navigation is not the primary navigation method. It is appropriate to use only the steps of the celestial day's work that are necessary to provide a meaningful check on the primary fix source and maintain competency in celestial techniques.

The list of procedures below provides a complete daily celestial routine to follow. This sequence works equally well for all sight reduction methods, whether tabular, mathematical, computer program, or celestial navigation calculator. See Figure 2013 for an example of a typical day's celestial plot.

1. Before dawn, compute the time of morning twilight and plot the dead reckoning position for that time.
2. At morning twilight, take and reduce celestial observations for a fix. At sunrise take an amplitude of the Sun for a compass check.
3. Mid-morning, wind the chronometer and determine chronometer error with a radio time tick.
4. Mid-morning, reduce a Sun sight for a morning Sun line.
5. Calculate an azimuth of the Sun for a compass check, if no amplitude was taken at sunrise.
6. At LAN, obtain a Sun line and advance the morning Sun line for the noon fix. Compute a longitude determined at LAN for an additional LOP.
7. Mid afternoon, again take and reduce a Sun sight. This is primarily for use with an advanced noon Sun line, or with a Moon or Venus line if the skies are overcast during evening twilight.
8. Calculate an azimuth of the Sun for a compass check at about the same time as the afternoon Sun observation. The navigator may replace this azimuth with an amplitude observation at sunset.
9. During evening twilight, reduce celestial observations for a fix.
10. Be alert at all times for the moon or brighter planets which may be visible during daylight hours for additional LOP's, and Polaris at twilight for a latitude line.

Chapter 7, Chapter 17, and Chapter 20 contain detailed explanations of the procedures required to carry out the various functions of this routine.

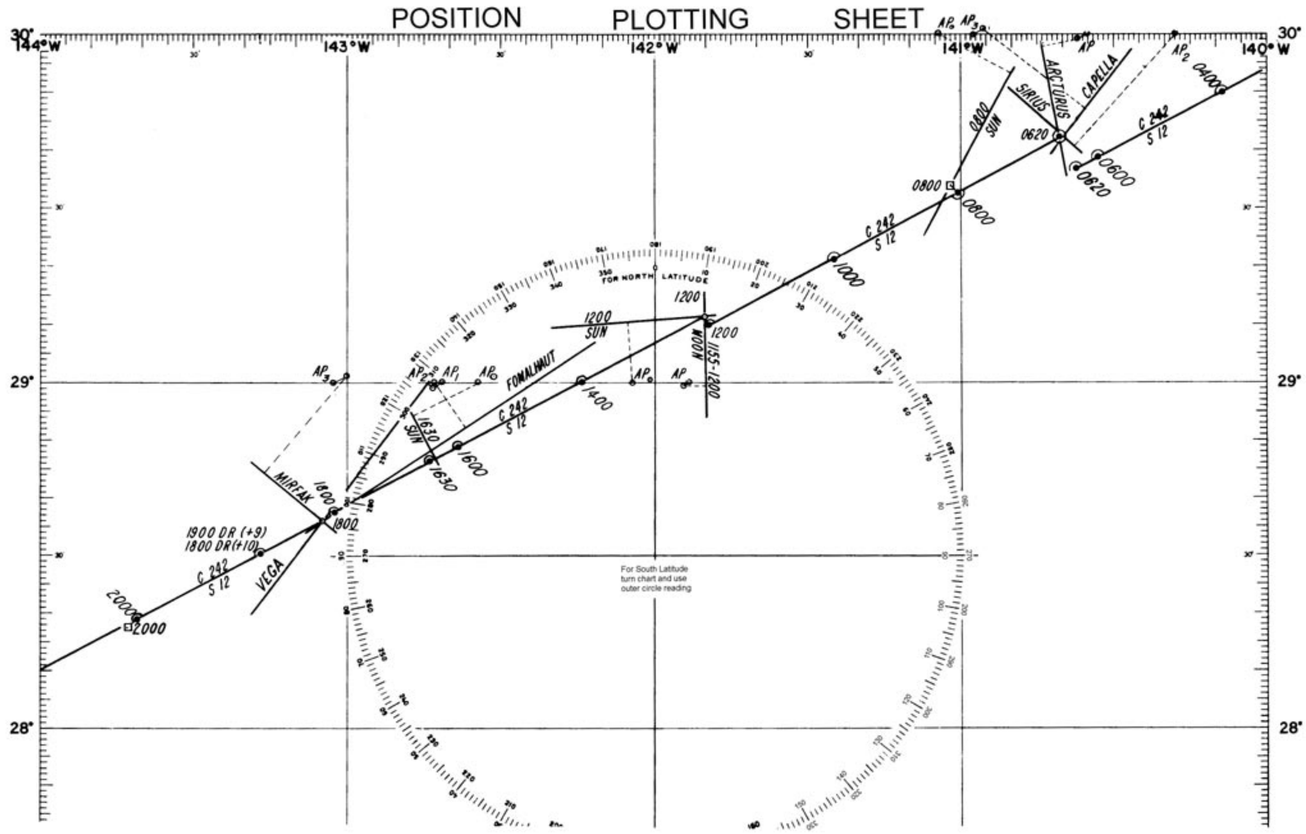

Figure 2013. Typical celestial plot at sea.