SEAFDEC Training Department

SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER

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CELESTIAL NAVIGATION

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PREFACE

To carry out any activities at sea one needs to know how to fix positions, set a course and measure the distance. In the area of fisheries, navigational knowledge is obviously essential. For instance, when a fishing boat is preparing to leave a port for a fishing ground, the planned sea route (Course) must be drawn on the charts, and the course in degrees and distance in nautical miles calculated. The departure and arrival time at the fishing ground must be decided.

After leaving the port, position fixes are taken during coasting. Eventually, terrestrial objects to fix positions by will not be visible, then positions must be fixed by means of observing celestial objects and the use of electronic navigational aids, in order to reach the fishing ground and to navigate safely and economically.

When the ship arrives at the fishing ground, she will move in pursuit of fish schools and position must be checked on the fishing ground chart in order to continue effective fishing activities. On the other hand, when one sets-up a stationary trapnet, a place to set it must be carefully selected and the position and depth of water measured beforehand. This is so that one can design the net, its size and construction, according to the depth of water and place it will be set. Also when one sets-up a conservation or prohibited fishing area, fish shelter or artificial reef, one has to determine the correct and exact position by latitudes and longitudes on a chart and set seamarkers in the water.

To carry out the aforementioned activities at sea, there are many devices and instruments which can be used to fix position e.g. sextant, divider, protractor, triangle ruler, magnetic compass, gyrocompass, chronomenter, radar, echosounder, satellite navigator, loran receiver, decca receiver, omega receiver, doppler-speed log, sonar, direction finder, xy-plotter, course recorder, theodolite distance meter, etc. These devices and instruments will help you fix position but, first you have to know: what latitudes and lognitudes are; how to express ship's course and distance to be travelled; what difference of latitudes and longitudes are; what lines of position given by terrestrial objects are; the celestial bodies; how to observe and measure the distance and altitude of landmarks; how to measure the altitude of heavenly bodies; how to operate electronic instruments; what index error, chronometer error, variation, deviation and compass error are; how to check and select marine charts for navigation; how to make your own charts of fishing grounds and topography of sea-bed.

Without navigational knowledge, no one would understand the positioning of fishing gear in the water or information given by a meteorological agency concerning marine weather. Such knowledge is important to fishing boats in ensuring that their activities at sea are effective and safe. Navigational knowledge is also important in understanding the international laws of the sea such as: "CONVENTION ON THE TERRITORIAL SEA AND CONTIGUOUS ZONE" and "CONVENTION ON THE HIGH SEAS" and thus preventing troubles with other countries.

Trainees learning NAVIGATION at the SEAFDEC Training Department will receive instruction and practical experience, including shipboard training. During the course, it is recommended that you practice by yourself both in the dormitory and on board the training ships. Only practice makes perfect!

Thank you.

(Masato Oishi)
Training Department

CONTENTS

CELESTIAL NAVIGATION

To fix a ship's position by using some knowledge of astronomy is called celestial navigation

Navigators who intend to fix their position on the oceans by celestial navigation must acquire a basic knowledge of astronomy, starting from the basic definition.

1. Basic definitions

1. The celestial sphere

When we look at the sky on a dark night (the moon cannot be seen only stars are twinkling and planets shining), the heavenly bodies look equidistant from us (from the earth), and that they are located on the inner surface of a giant sphere whose center is the earth, and its radius is infinite. This is called the celestial sphere, and this is also an imaginary sphere with infinite radius (Fig. 1, 5)

2. The celestial axis

Is the axis which extends from the minor axis of the earth to the celestial sphere (Fig. 1)

3. The celestial poles

The celestial poles are the points where the minor axis of the earth extends to the celestial sphere and intersects with it (Fig. 1, 5)

4. The celestial equator or the equinoctial

Is the intersection where the plane of the earth's equator is extended to the celestial sphere (Fig. 1, 5)

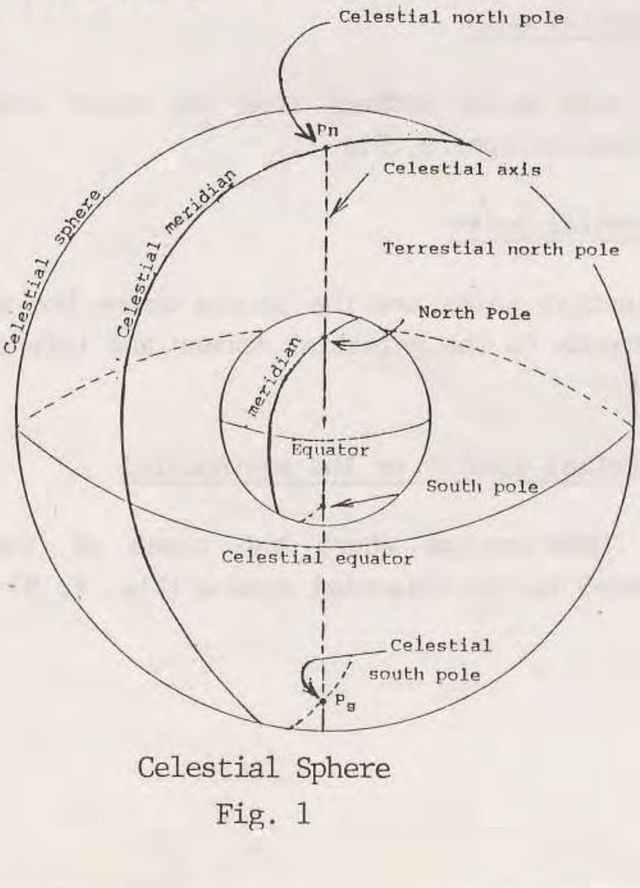
5. The celestial meridians

Are the intersections where the planes of the earth's meridians are extended to the celestial sphere (Fig. 1, 5). These meridians are arcs of great circles through the celestial poles (Fig. 1, 5)

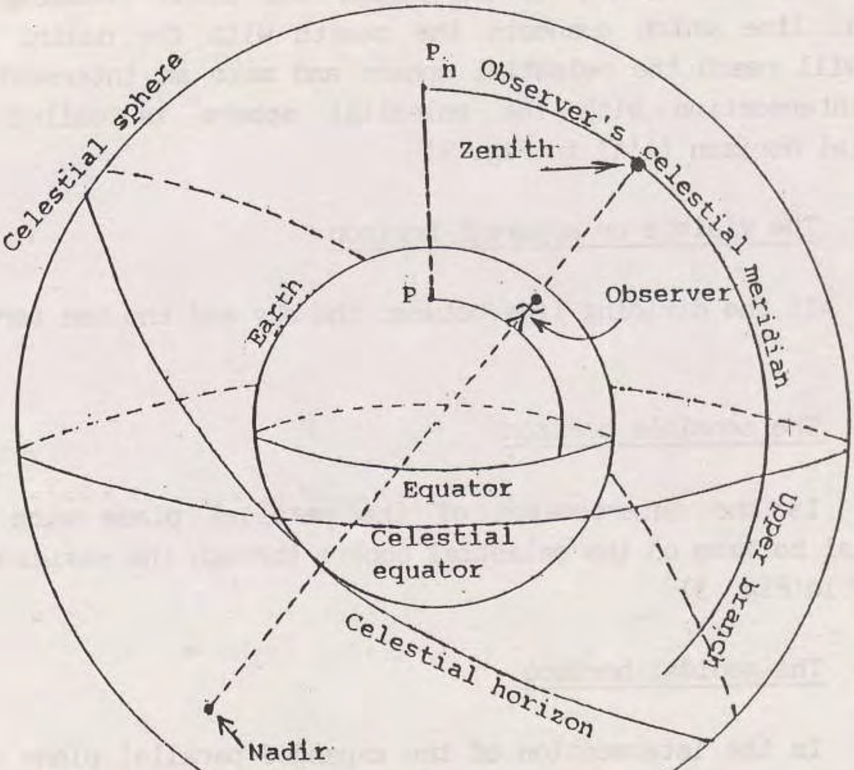
6. The zenith and the nadir

If we extend the straight line connecting the center of the earth with the navigator (observer of a heavenly body), this line will reach the celestial sphere and make a point of intersection on it. This point is called the zenith. Then we extend this straight line to the opposite side of the navigator, this line also reaches the celestial sphere and makes a point of intersection; this point is called the nadir. Therefore, the zenith is your imaginary location on the celestial sphere (Fig. 2, 5).

Note: We suppose that the celestial sphere and the earth have a common center.



Celestial Sphere
Fig. 1



Celestial Sphere & an Observer

Fig. 2

The arc of a celestial meridian connecting with celestial poles and the zenith is called the upper branch, and the lower branch is another arc of a celestial meridian connecting the poles and the nadir (Fig. 2, 5).

Usually a celestial meridian means its upper branch. A celestial meridian takes the name, e.g. 101° east, of its terrestrial counterpart.

7. The celestial horizon

At the center of the celestial sphere which has a common center with the earth, if we expand the plane crossing the straight line which connects the zenith with the nadir, this plane will reach the celestial sphere and make an intersection. This intersection with the celestial sphere is called the celestial horizon (A'A' in Fig. 3)

8. The visible or apparent horizon

Is the dividing line between the sky and the sea (or the earth)

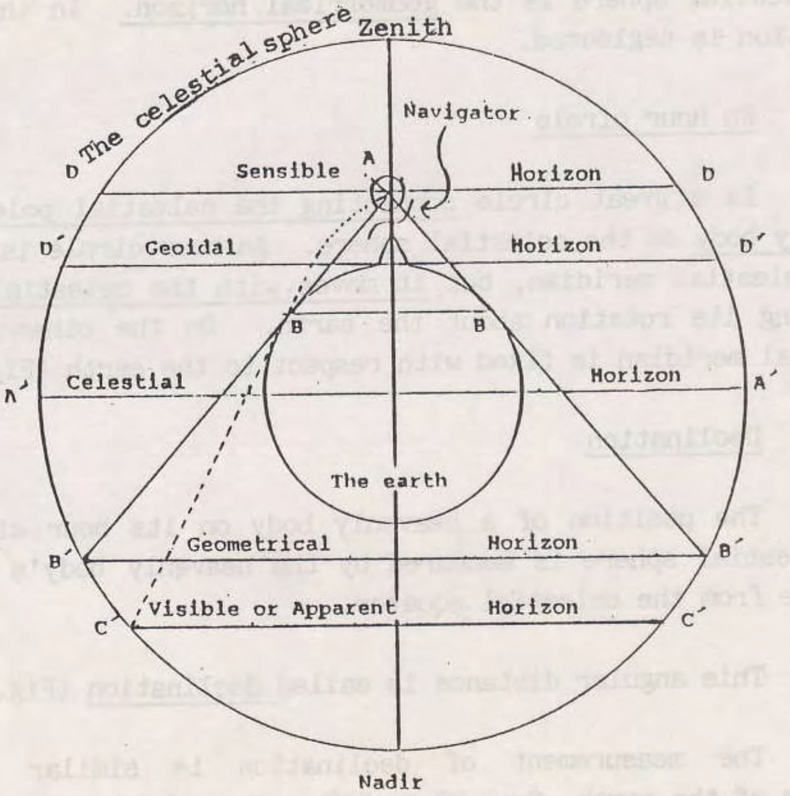
9. The sensible horizon

Is the intersection of the parallel plane with the celestial horizon on the celestial sphere through the navigator's eye (DD in Fig. 3)

10. The geoidal horizon

Is the intersection of the expanded parallel plane with the celestial horizon to the celestial sphere on the surface of the earth at the navigator's stand-point, this horizon is tangent to the surface of the earth at the navigator's stand-point (D'D' in Fig. 3)

(The radius of the earth is negligible in comparison with the radius of the celestial sphere).



Celestial Sphere & Horizon

Fig. 3

11. The geometrical horizon

In Figure 3, the position of navigator's eye is A (the vertex of a cone ABB), and the straight line ABB' is tangent to the surface of the earth at the circle BB. The intersect B' on the celestial sphere is the geometrical horizon. In this case, refraction is neglected.

12. An hour circle

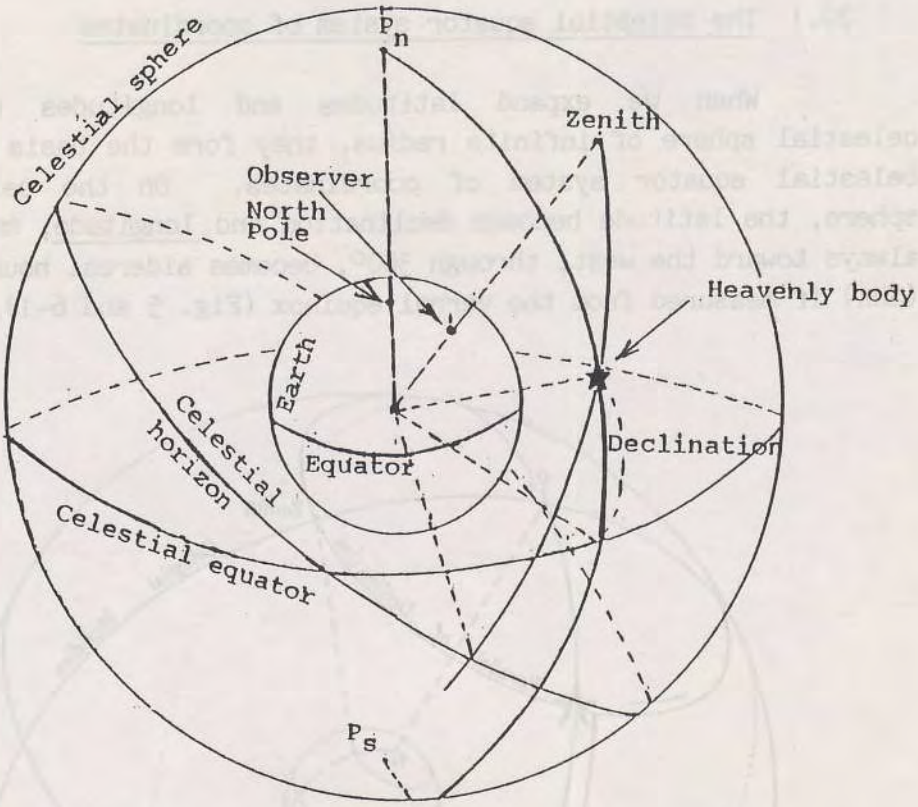
Is a great circle connecting the celestial poles and a heavenly body on the celestial sphere. An hour circle is similar to a celestial meridian, but it moves with the celestial sphere following its rotation about the earth. On the other hand, a celestial meridian is fixed with respect to the earth (Fig. 5).

13. Declination

The position of a heavenly body on its hour circle on the celestial sphere is measured by the heavenly body's angular distance from the celestial equator.

This angular distance is called declination (Fig. 4, 5).

The measurement of declination is similar to the latitude of the earth, from 0^{o} to 90^{o}, and should be named N or S (dec. 8^{o}N, dec. 15^{o}S, Capella 25/12/1979 dec. 45^{o} - 58'6 N, Spica 25/12/1979 dec. 11^{o} - 03'3 S)

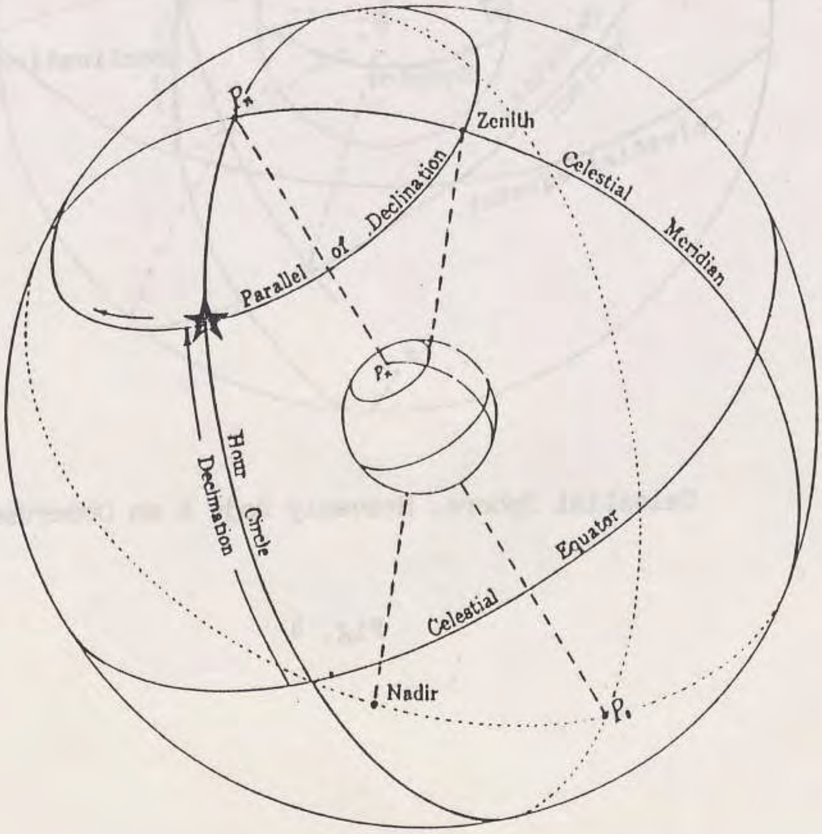


Celestial Sphere, Heavenly Body & an Observer

Fig. 4

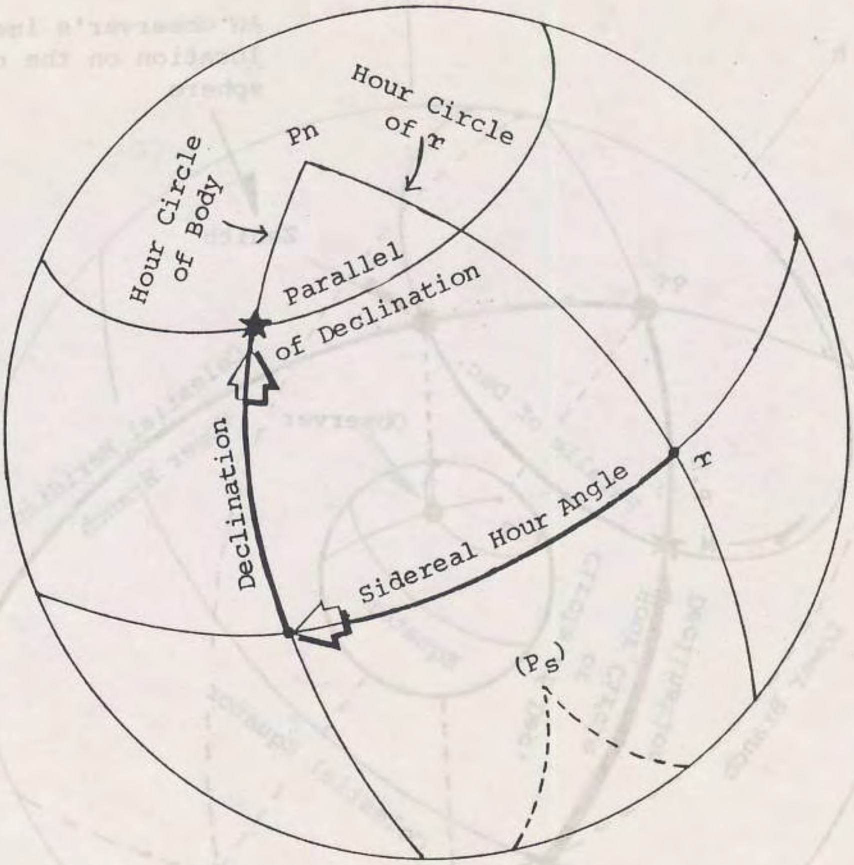
20.1 The celestial equator system of coordinates

When we expand latitudes and longitudes to the celestial sphere of infinite radius, they form the basis of the celestial equator system of coordinates. On the celestial sphere, the latitude becomes declination and longitude, measured always toward the west, through 360°, becomes sidereal hour angle (SHA) if measured from the vernal equinox (Fig. 5 and 6-1).



Celestial Equator System
(Bowditch)

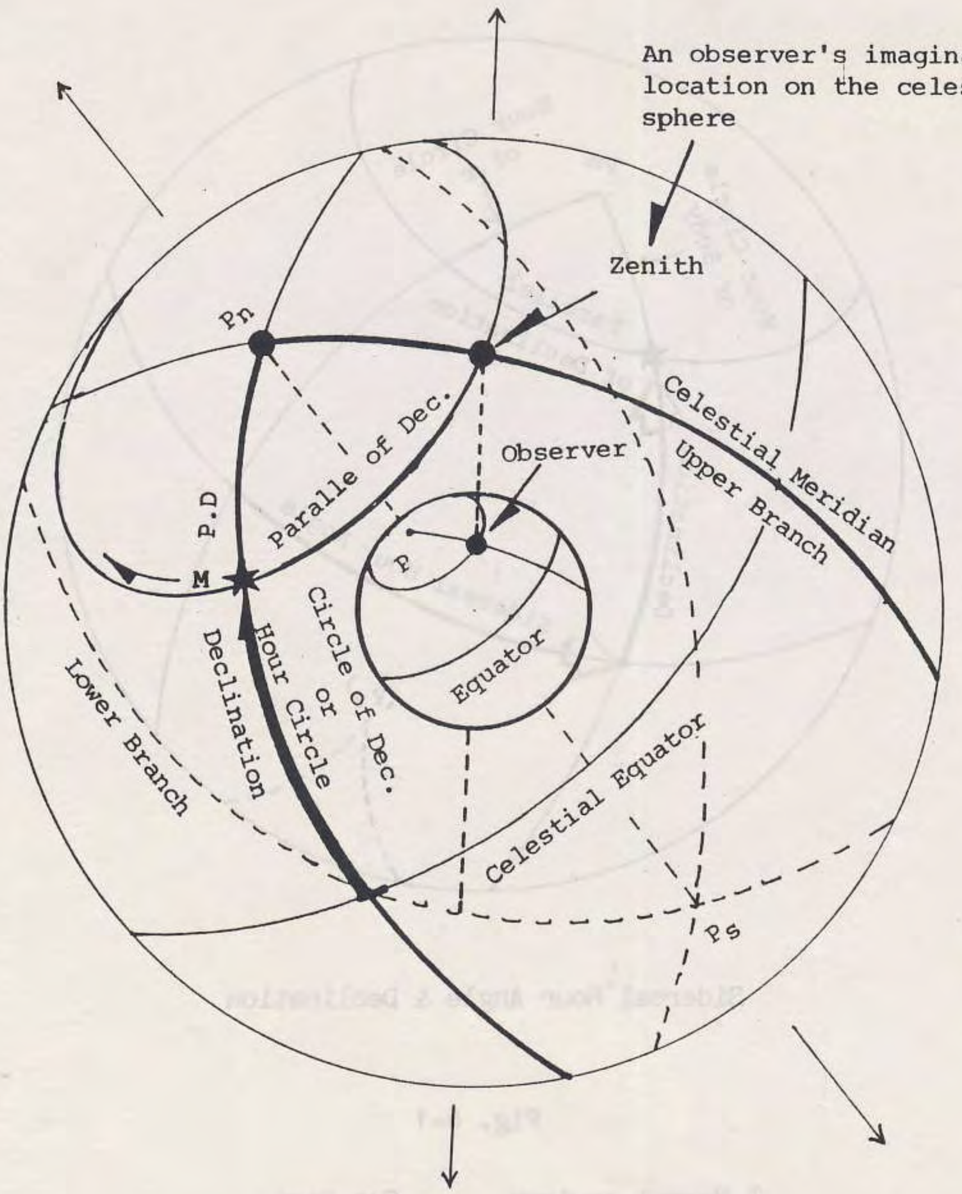
Fig. 5



Sidereal Hour Angle & Declination

Fig. 6-1

♈ Vernal equinox ..... See Page ...



Celestial Sphere

Fig. 6-2

14. The circle of declination

Is a celestial meridian which connects the celestial poles with a celestial body (Fig. 6-2)

15. Polar distance (P.D.)

Is the angular distance from a celestial pole to the heavenly body on the celestial meridian of the heavenly body ($\widehat{P_nM}$ in Figure 6-2)

When the name of observer's latitude is the same as the name of declination,

Polar distance = 90^o - declination

When the name of observer's latitude is different from the name of declination,

Polar distance = 90^o + declination

16. Local hour angle (L.H.A.) and Greenwich hour angle (G.H.A.)

L.H.A. is the angular distance between the observer's celestial meridian and the heavenly body's celestial meridian (the circle of declination) at the celestial pole (Fig. 9)

Local hour angle is customarily measured from the observer's celestial meridian to the heavenly body's meridian westerly through 360^o.

In this case if we use the greenwich meridian as the reference, instead of the local meridian, this hour angle is called Greenwich hour angle (G.H.A.)

17. A parallel of declination

Is a circle which is parallel to the celestial equator, it connects all points of equal declination.

18. Diurnal [də'iə:rnəl] circle

The path of a celestial body during its daily apparent revolution around the earth is called its diurnal circle. This is not exactly a circle because of changes of its declination.

19. The ecliptic [ikliptik]

Is the orbit of the sun's annual motion and considered a great circle of the celestial sphere, inclined at an angle of about 23^o 27' to the celestial equator. This angle is called the obliquity [əblikwəti] of the ecliptic (Fig. 6)

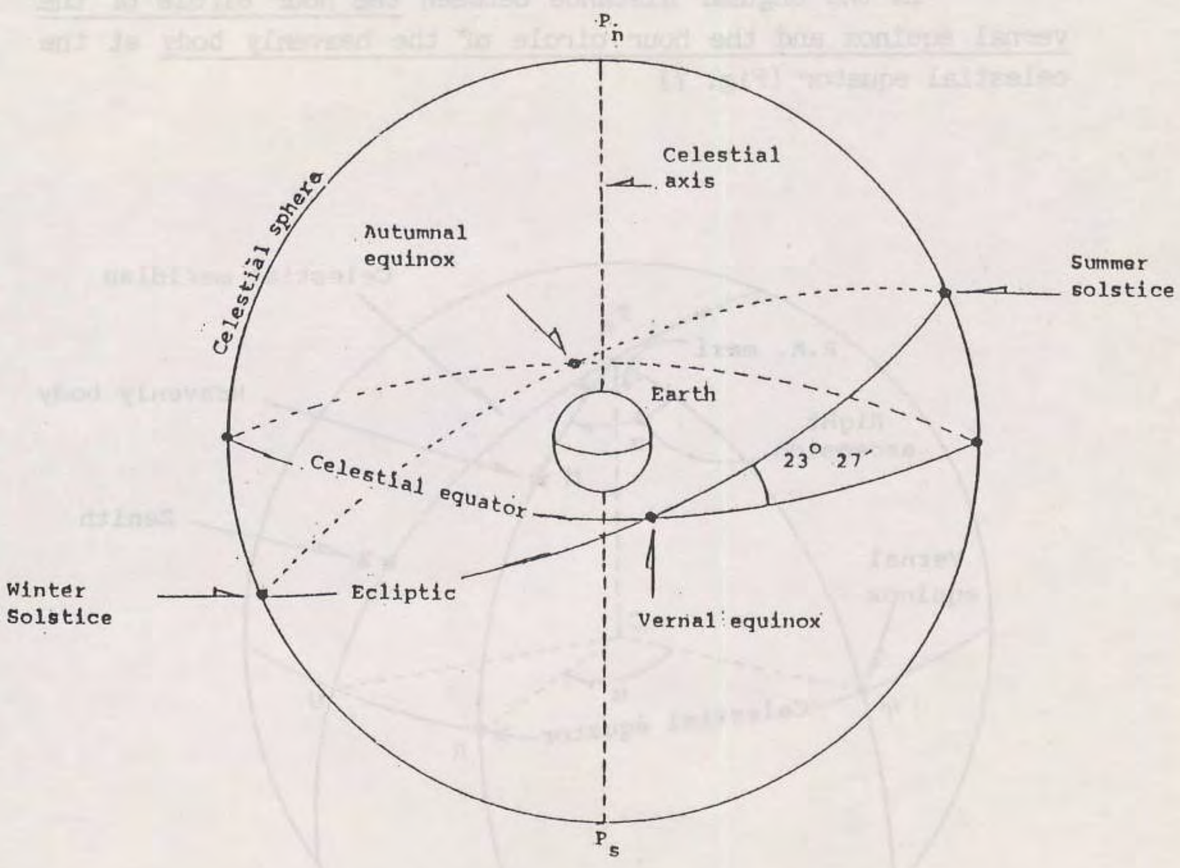
20. The vernal equinox and the autumnal equinox

The ecliptic and the celestial equator intersect and make two equinoxes because both of them are great circles and are non-parallel (Fig. 6)

One equinox that the sun passes through the celestial equator from south to north is called the vernal equinox (symbol γ; [u:psəlan]). The other equinox that the sun passes through the celestial equator from north to south is called the Autumnal equinox (symbol Ω [oum'egə]) (Fig. 6)

21. The summer solstice and the winter solstice

The furthest points on the ecliptic from the celestial equator are called the solstices. The summer solstice is located northward from the celestial equator, and the winter solstice is located southward from the celestial equator (Fig. 6).

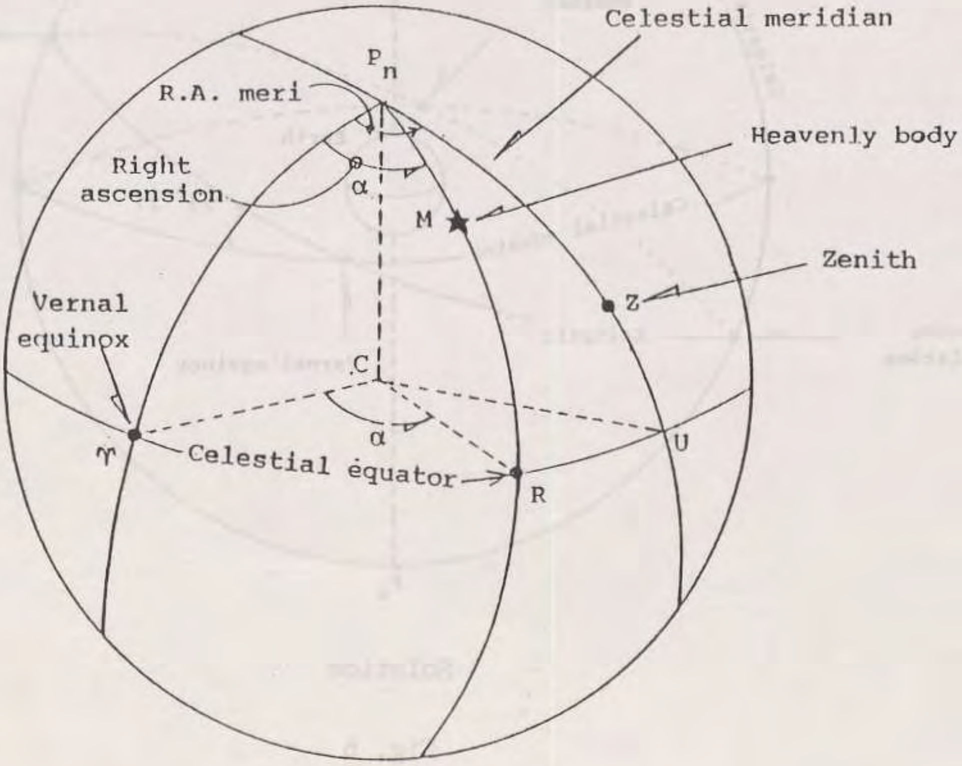


Solstice

Fig. 6

22. <u>The right ascension (R.A.)</u>

Is the angular distance between <u>the hour circle of the vernal equinox and the hour circle of the heavenly body</u> at the celestial equator (Fig. 7)



Right Ascension

Fig. 7

In Figure 7, the right ascension of M (heavenly body) is $\widehat{\Upsilon R}$ at the celestial equator, and $\angle \Upsilon P_n M$ at the P_n

The concept of the right angle is similar to the concept of longitude on the earth and the measurement of the right ascension should be started from the vernal equinox as a reference to east through 0^h to 24^h, so the name E or W is not necessary to the right ascension.

23. The right ascension of meridian (R.A. meri)

Is the angular distance between the hour circle of the vernal equinox and the upper branch of meridian (through the zenith) on the celestial equator, $\widehat{\gamma u}$ or $\angle \gamma P_n Z$ at the celestial pole (Fig. 7)

24. The upper transit (U.Tr.) and lower transit (L.Tr.)

By the diurnal motion, most of the heavenly bodies pass through upper branch of meridian and lower branch of meridian once a day. This passing through the branches is called transit. When a heavenly body passes through the upper branch of meridian, it is called the upper transit, and a heavenly body passing through the lower branch of meridian, it is called the lower transit (Fig. 8)

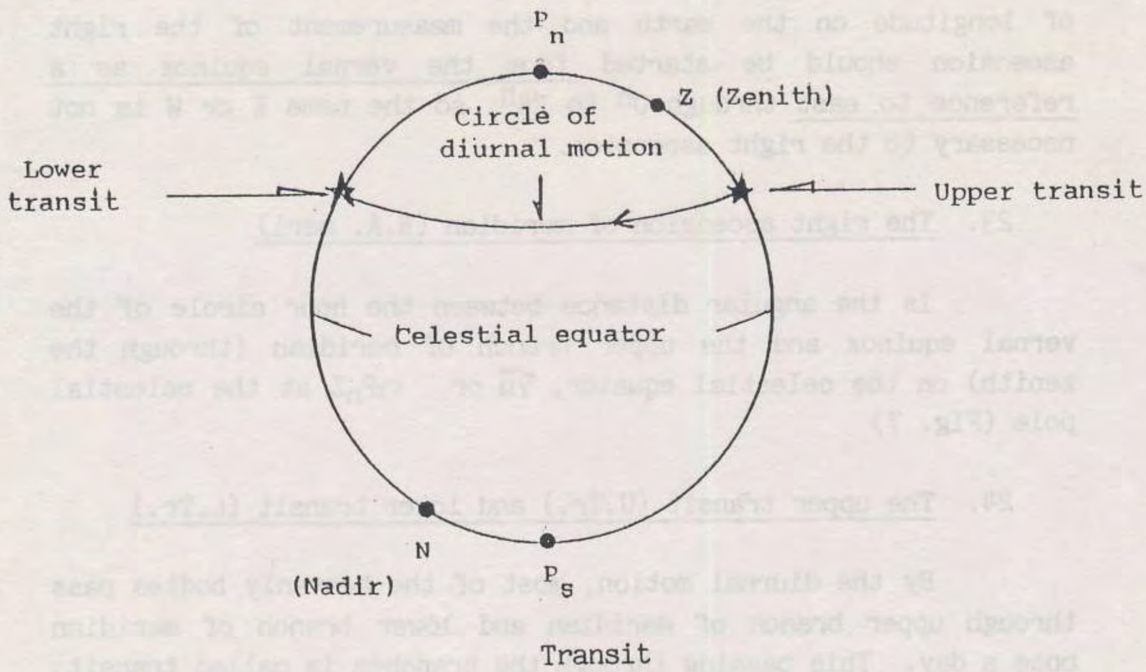


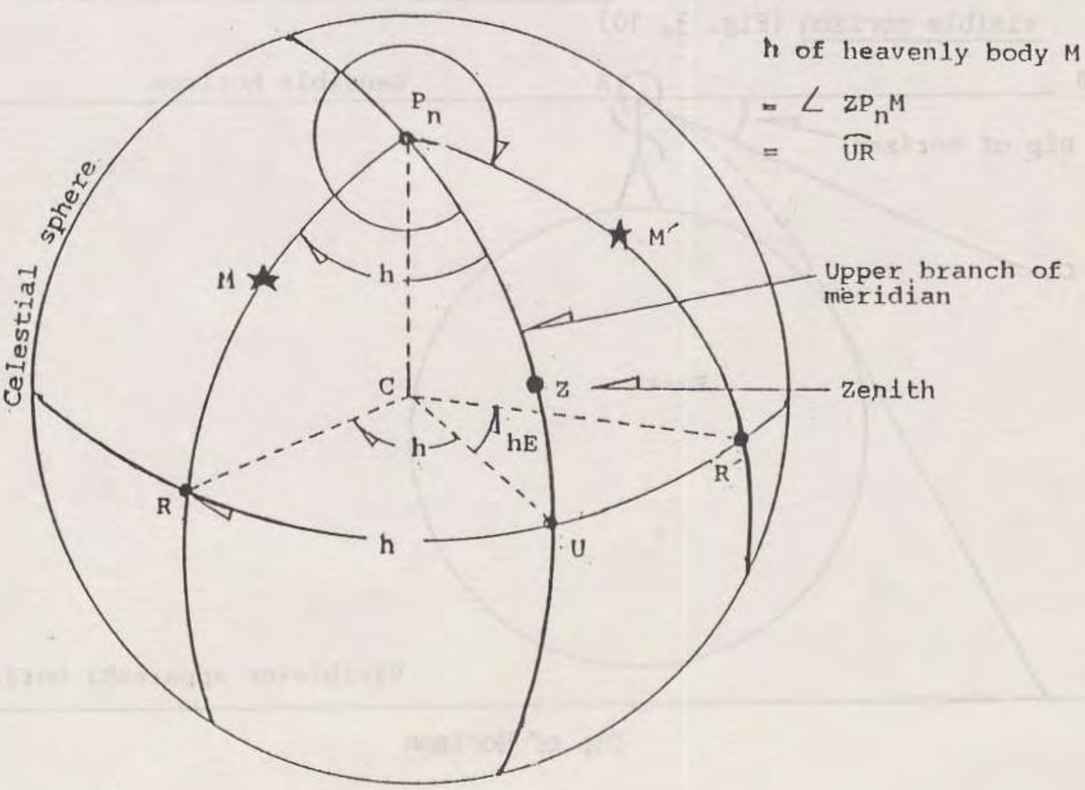
Fig. 8

Navigators call it the <u>meridian passage (meri pass)</u> instead of the upper transit, and call the then altitude of the heavenly body the <u>meridian altitude (meri. alt.)</u>

25. The hour angle (acronym = H.A., abbreviation = h)

Is the angle between the upper branch of the meridian and the hour circle of a heavenly body at the celestial pole, or is the angular distance between the upper branch of the meridian and hour circle of a heavenly body on the celestial equator (Fig. 9)

The hour angle should be measured from the upper branch of the meridian as reference to west side through 0^h to 24^h or through 0° to 360° (Fig. 9)



Hour Angle

Fig. 9

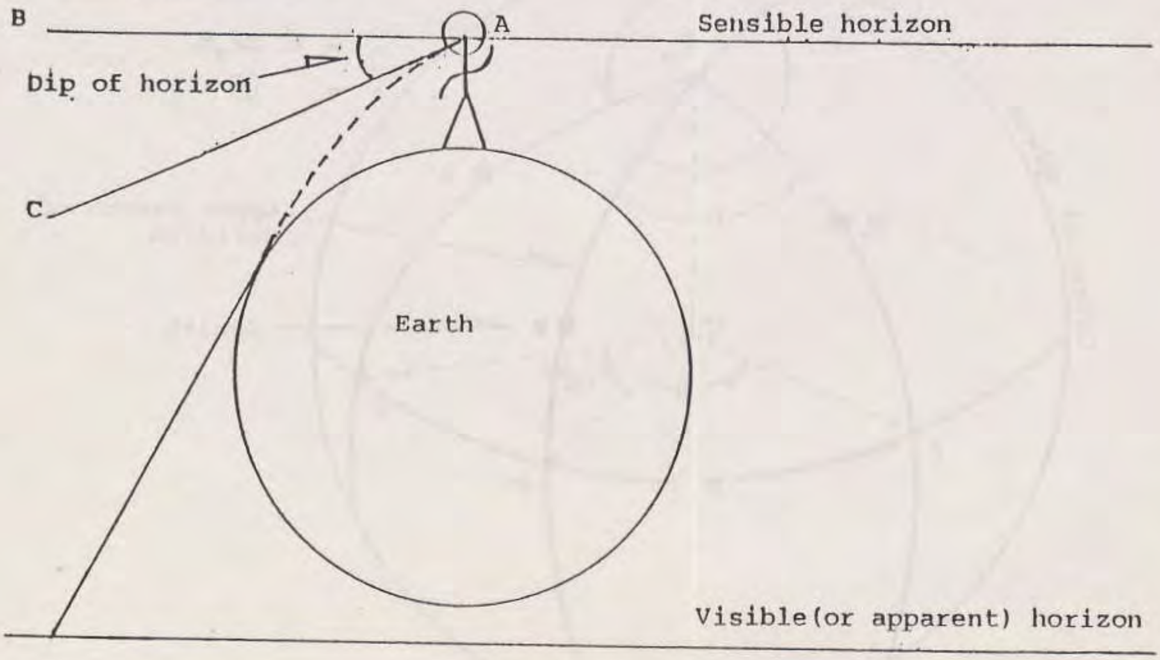
When a heavenly body passes over the lower branch of meridian (M' in Figure 9), the hour angle of M' should be measured from the upper branch of meridian as a reference to east. In case, this hour angle is called = E'ly H.A., easterly hour angle (acronym abbreviation hE)

Then $hE = 24^h - h^h$ or $hE = 360^\circ - h^\circ$

The six o'clock hour circle means $h = 6^h$ or 18^h

26. The dip of horizon (abbreviation = Dip.)

Is the dip angle between the sensible horizon and the visible horizon (Fig. 3, 10)



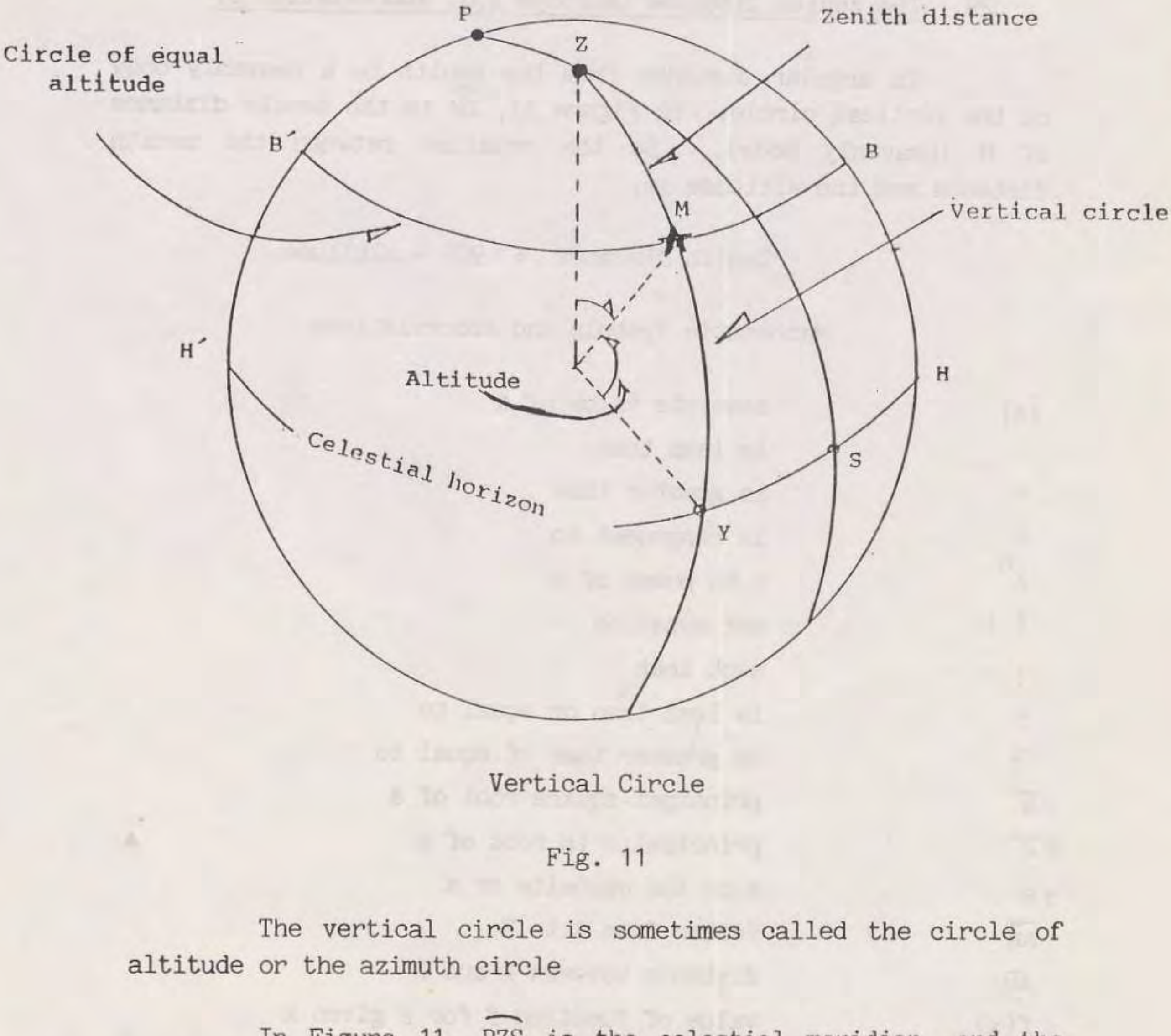
Dip of Horizon

Fig. 10

In Figure 10, dip is $\angle BAC$, between the sensible horizon and a straight line which is tangent to the curving ray of light at the observer's eye (A) from the visible horizon.

27. The vertical circle

Is the great circle passing through the zenith and the nadir (Fig. 11)



Vertical Circle

Fig. 11

The vertical circle is sometimes called the circle of altitude or the azimuth circle

In Figure 11, $\overset{\frown}{PZS}$ is the celestial meridian, and the small circle including a heavenly body which is parallel to the celestial horizon is called the circle of equal altitude, $\overset{\frown}{BMB'}$ in Figure 11.

28. The altitude (of M) (abbreviation alt, or a)

Is the angular distance from horizon to the heavenly body on the vertical circle. In Figure 11, $\overset{\frown}{YM}$ is the altitude of M (heavenly body).

29. The zenith distance (acronym Z.D. abbreviation Z)

Is angular distance from the zenith to a heavenly body on the vertical circle. In Figure 11, $\overset{\frown}{ZM}$ is the zenith distance of M (heavenly body). So the relation between the zenith distance and the altitude is,

$$\text{Zenith distance} = 90^{\circ} - \text{altitude}$$

Mathematic Symbols and Abbreviations

$\lvert a \rvert$	absolute value of a
$<$	is less than
$>$	is greater than
$\cong$	is congruent to
x^n	n th power of x
$\{\ \}$	set notation
$:$	such that
$\leqslant$	is less than or equal to
$\geqslant$	is greater than of equal to
$\sqrt{a}$	principal square root of a
$\sqrt[n]{a}$	principal n th root of a
$\pm a$	a or the opposite or a
$\overrightarrow{AB}$	Vector from A to B
AB	distance between A and B
$f(x)$	value of function f for a given x
$\overline{AB}$	line segment AB
A^{-1}	multiplicative inverse of matrix A

$\log_b x$	logarithm of x, base b,
log x	common logarithm of x
$\sum_{n=1}^{6} An$	summation notation (sigma)
$<$	angle
sin	sine
cos	cosine
tan	tangent
csc	cosecant
sec	secant
cot	cotangent
ABC	triangle ABC
$\sin^2 \theta$	square of sin
$+$	plus (addition)
$-$	minus (subtraction)
$\pm$	plus or minus
$\sim$	difference
$\cdot$	multiplied by
x	times (multiplication)
$\div$	divided by (division)
$\because$	therefore
$\therefore$	because
$=$	equals
$\neq$	not equal to
$\approx$	nearly equal to
$\int$	integral sign
∞	infinity
....	repeating decimal

On positions

◠ (with dot)	dead reckoning position
⊙	fix
⊡	estimated position
◬	symbol used for one set of fixes when simultaneously fixing by two means, e.g. visual and radar sometimes used for radionavigation fix

On celestial bodies

☉	Sun
☾	Moon
☿	Mercury
♀	Venus
⊕	Earth
♂	Mars
♃	Jupiter
♄	Saturn
♅	Uranus
♆	Neptune
♇	Pluto
☆	Star
☆-P	Star-planet altitude Correction (altitude)
$\underline{\odot}$ $\underline{☽}$	Lower limb
☽ ⊖	Center
$\overline{☾}$ $\overline{\odot}$	upper limb

🌑	new moon
🌒	crescent moon
🌓	first quarter
🌔	gibbous moon
🌕	full moon
🌖	gibbous moon
🌗	last quarter
🌘	crescent moon

On signs of zodiac

♈	Aries (vernal equinox)
♉	Taurus
♊	Gemini
♋	Cancer (summer solstice)
♌	Leo
♍	Virgo
♎	Libra (autumnal equinox)
♏	Scorpius
♐	Sagittarius
♑	Capricornus (winter solstice)
♒	Aquaries
♓	Pisces

On years and degrees

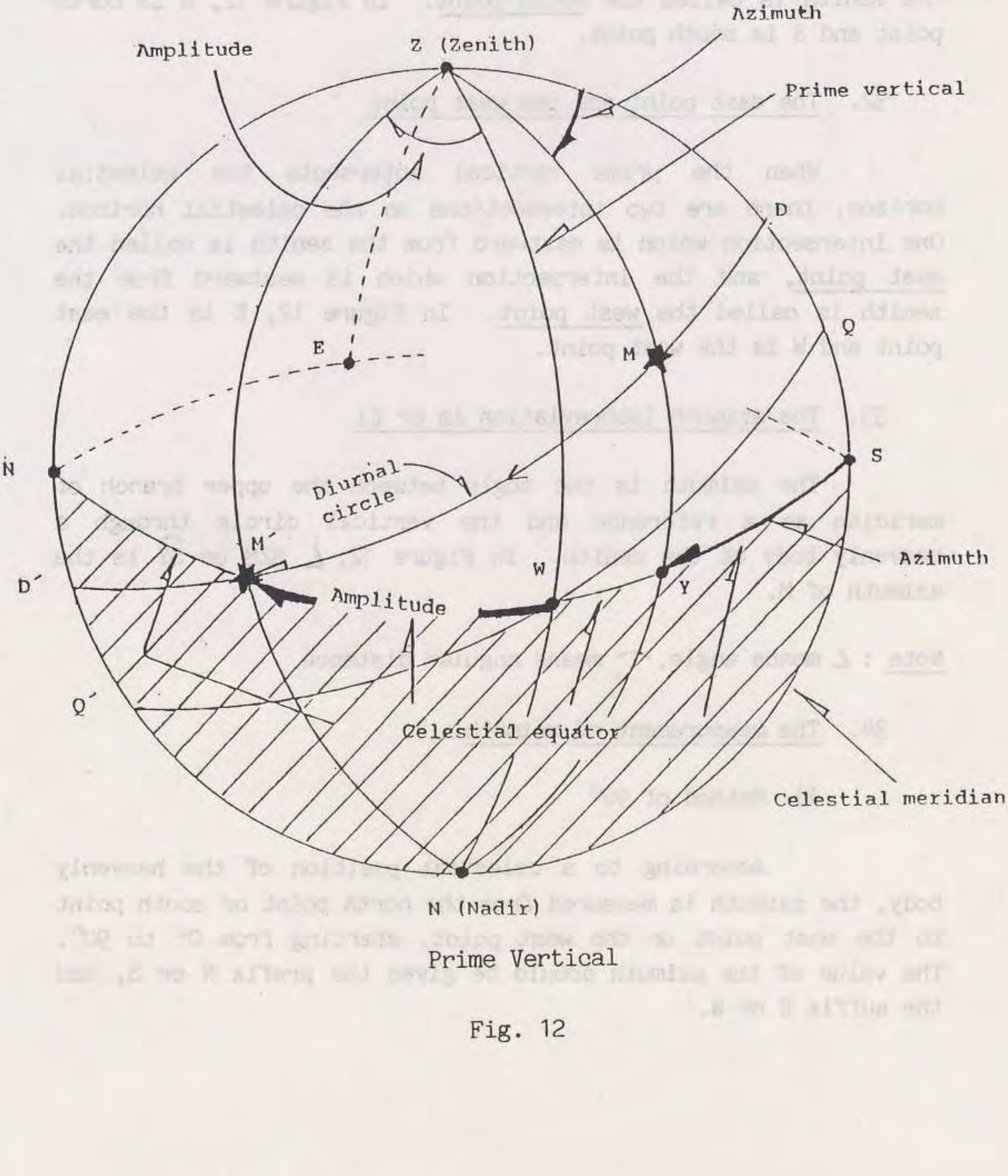
y	Years
m	Months
d	Days
h	Hours
.m	Minutes of time
s	Seconds of time
o	Degrees
'	munutes of arc
"	seconds of arc

Greek Alphabet

Α α a	alpha
Β β B	Beta
Γγ	Gamma
Δδ	Delta
Ε ε	Epsilon
Ζ ζ	Zela
Η η	Eta
Θθ	Theta
Ι ι	Iota
Κ κ	Kappa
Λ λ	Lambda
Μ μ	Mu
Ν ν	Nu
Ξ §	Xi
O O	Omicron
Π	Pi
Ρ ρ	Rho
Σ σ	Sigma
Τ τ	Tau
Υ ν	Upsilon
Φ φ	Phi
Χ x	Chi
Ψ ψ	Psi
Ω ω	Omega

30. The prime vertical

The prime vertical is a vertical circle which is perpendicular to the celestial meridian. This is a great connecting the zenith, the east point and the west point on the celestial horizon (Fig. 12)



Prime Vertical

Fig. 12

31. The north point and the south point

When the celestial meridian intersects the celestial horizon, there are two intersections on the celestial horizon. Then one intersection which is northward from the zenith is called the north point, and the other intersection southward from the zenith is called the south point. In Figure 12, N is north point and S is south point.

32. The east point and the west point

When the prime vertical intersects the celestial horizon, there are two intersections on the celestial horizon. One intersection which is eastward from the zenith is called the east point, and the intersection which is westward from the zenith is called the west point. In Figure 12, E is the east point and W is the west point.

33. The azimuth (abbreviation Az or Z)

The azimuth is the angle between the upper branch of meridian as a reference and the vertical circle through a heavenly body at the zenith. In Figure 12, $\angle$ SZM or $\overset{\frown}{SY}$ is the azimuth of M.

Note : $\angle$ means angle, $\frown$ means angular distance

34. The measurement of azimuth

1) Method of 90°

According to a celestial position of the heavenly body, the azimuth is measured from the north point or south point to the east point or the west point, starting from 0° to 90°. The value of the azimuth should be given the prefix N or S, and the suffix E or W.

2) Method of 180°

According to the observer's position, the azimuth is measured from the north point or the south point to the east point or the west point, starting from 0° to 180°. The value of the azimuth should be given the prefix N or S and the suffix E or W.

3) Method of 360° (clockwise)

The azimuth is measured from the north point as a reference to the eastward, starting from 0° to 360°. The prefix and the suffix are not necessary for the value of the azimuth.

35. Amplitude (abbreviation = Amp.)

Amplitude is the angle between the east point or the west point and the intersection where the diurnal circle intersects the celestial horizon. In Figure 12, $\angle$ WZM' or $\overset{\frown}{WM'}$ is the amplitude of M'

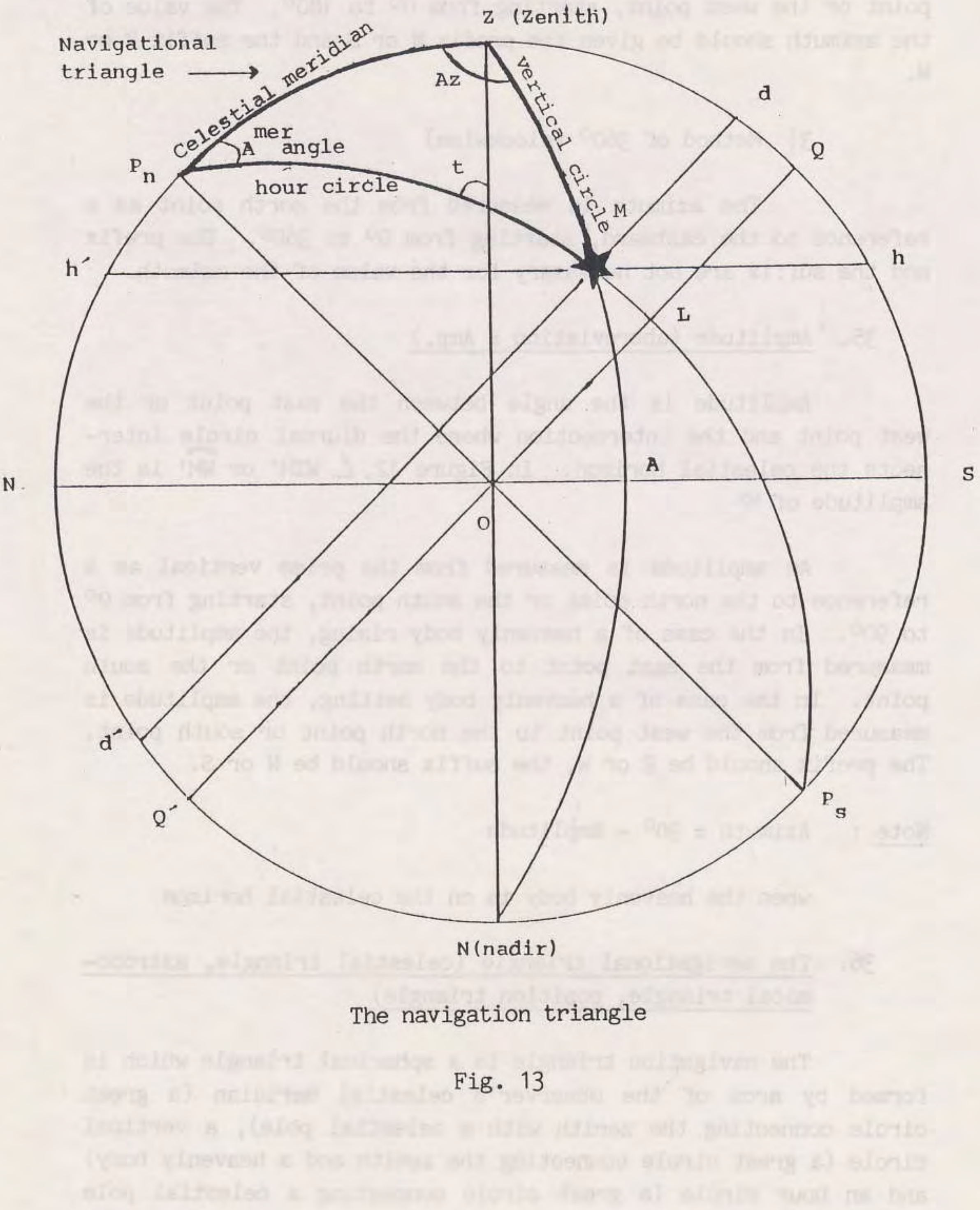
An amplitude is measured from the prime vertical as a reference to the north point or the south point, starting from 0° to 90°. In the case of a heavenly body rising, the amplitude is measured from the east point to the north point or the south point. In the case of a heavenly body setting, the amplitude is measured from the west point to the north point or south point. The prefix should be E or W, the suffix should be N or S.

Note : Azimuth = 90° - Amplitude

when the heavenly body is on the celestial horizon

36. The navigational triangle (celestial triangle, astronomical triangle, position triangle)

The navigation triangle is a spherical triangle which is formed by arcs of the observer's celestial meridian (a great circle connecting the zenith with a celestial pole), a vertical circle (a great circle connecting the zenith and a heavenly body) and an hour circle (a great circle connecting a celestial pole and a heavenly body) (Fig. 13).



The navigation triangle

Fig. 13

In Figure 13

1. The earth is at the center, O.

2. The heavenly body is at M.

3. $\overline{dd'}$ is the parallel of declination of the heavenly body M.

4. $\overline{hh'}$ is the altitude circle of the heavenly body M.

5. $\frown{QZ}$ of the the celestial meridian is the latitude of the observer.

6. $\frown{P_nZ}$, one side of the triangle, is the colatitude.

7. $\frown{AM}$ of the vertical circle is the altitude of the heavenly body.

8. $\frown{ZM}$, one side of the triangle, is the zenith distance or coaltitude.

9. $\frown{LM}$ of the hour circle is the declination of the heavenly body M.

10. $\frown{P_nM}$, one side of the triangle, is the polar distance or codeclination.

11. The angle at P_n (ZP_nM), having the hour circle and the celestial meridian as sides, is the meridian angle.

12. The angle at the $Z(P_nZM)$, having the vertical circle and that arc of the celestial meridian which includes the elevated pole as sides, is the azimuth angle.

13. The angle at $M(ZMP_n)$, having the hour circle and the vertical circle as sides, is the parallactic angle (x), which is not generally used by the navigator.

The navigational triangle is utilized for solution of problems by navigators as follows:

1. Given latitude, declination, and the meridian angle, to find altitude and azimuth angle. This is used in the reduction of a celestial observation, to establish a line of position.

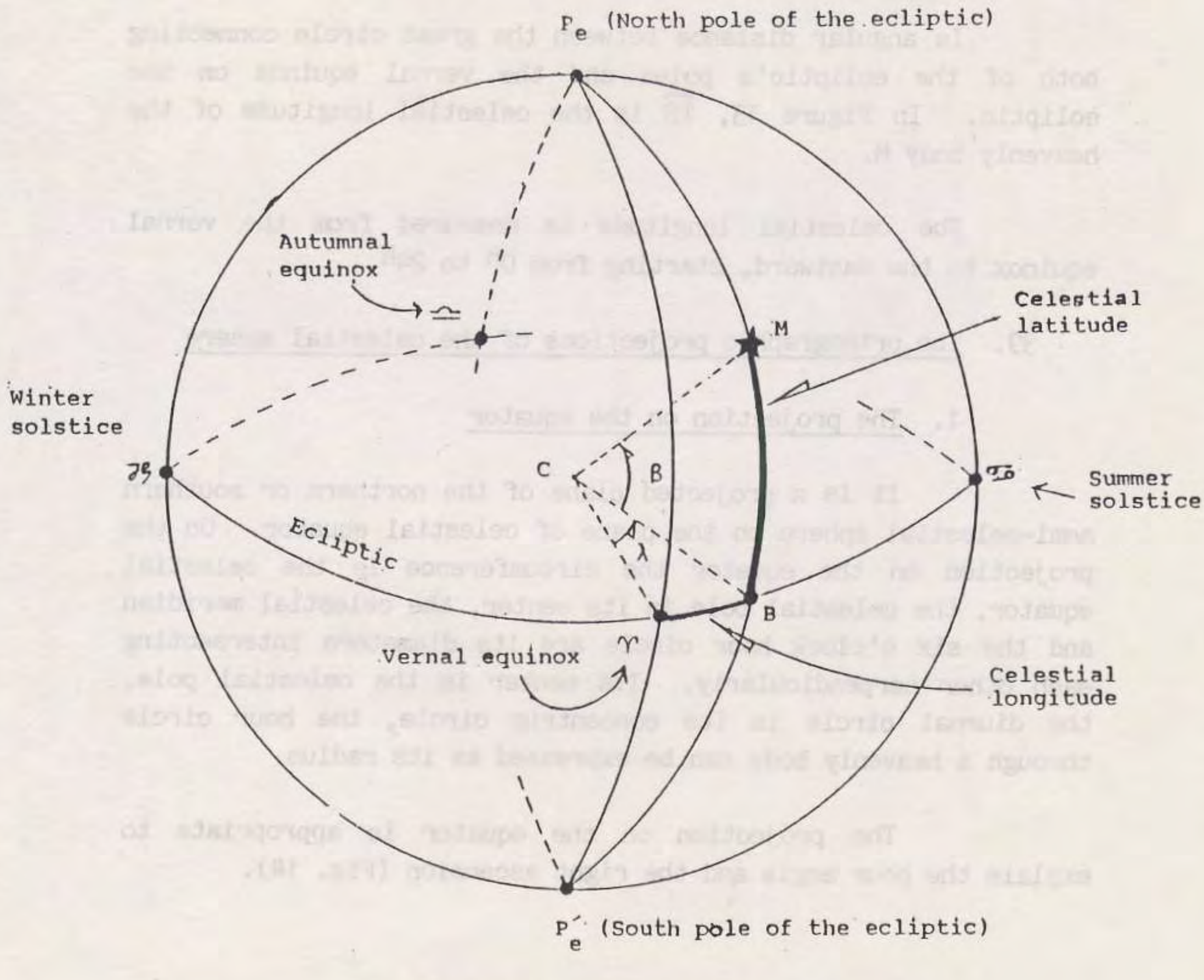
2. Given latitude, altitude, and azimuth angle to find declination and meridian angle. This is used to identify an unknown celestial body.

3. Given meridian angle, declination, and altitude, to find azimuth angle. This is used to find azimuth when the latitude is known.

4. Given the latitude of two places on the earth and the difference of longitude between them; to find the intital great-circle course and the great-circle distance.

37. The celestiaal latitude and the celestial longitude

The celestial latitude (abbreviation = Cel. Lat. symbol β) is angular distance from the ecliptic to the heavenly body on the great circle connection the poles of the ecliptic and the heavenly body (Fig. 13)



Celestial latitude & longitude

Fig. 13a

In Figure 13, $\overset{\frown}{BM}$ is the celestial latitude of the heavenly body M. The celestial latitude is measured from the ecliptic to the northward or southward, starting from 0^o to 90^o and it has the suffix N or S.

38. The celestial longitude (abbreviation = Cel.Long. symbol = λ)

Is angular distance between the great circle connecting both of the ecliptic's poles and the vernal equinox on the ecliptic. In Figure 13, $\widehat{TB}$ is the celestial longitude of the heavenly body M.

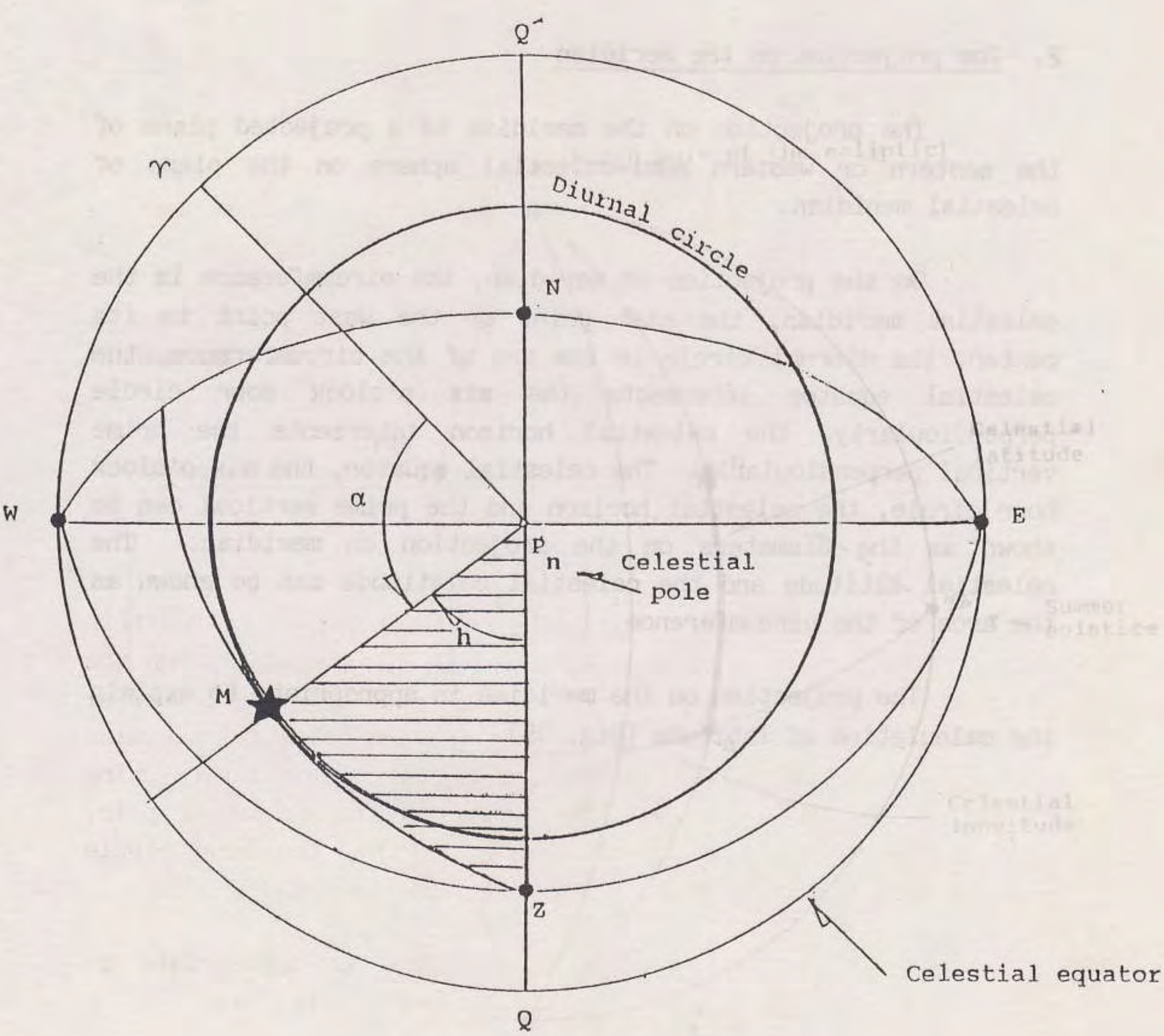
The celestial longitude is measured from the vernal equinox to the eastward, starting from 0^h to 24^h.

39. The orthographic projections of the celestial sphere

1. The projection on the equator

It is a projected plane of the northern or southern semi-celestial sphere on the plane of celestial equator. On the projection on the equator the circumference is the celestial equator, the celestial pole is its center, the celestial meridian and the six o'clock hour circle are its diameters intersecting each other perpendicularly. Its center is the celestial pole, the diurnal circle is its concentric circle, the hour circle through a heavenly body can be expressed as its radius.

The projection on the equator is appropriate to explain the hour angle and the right ascension (Fig. 14).



Projection on the equator

Fig. 14

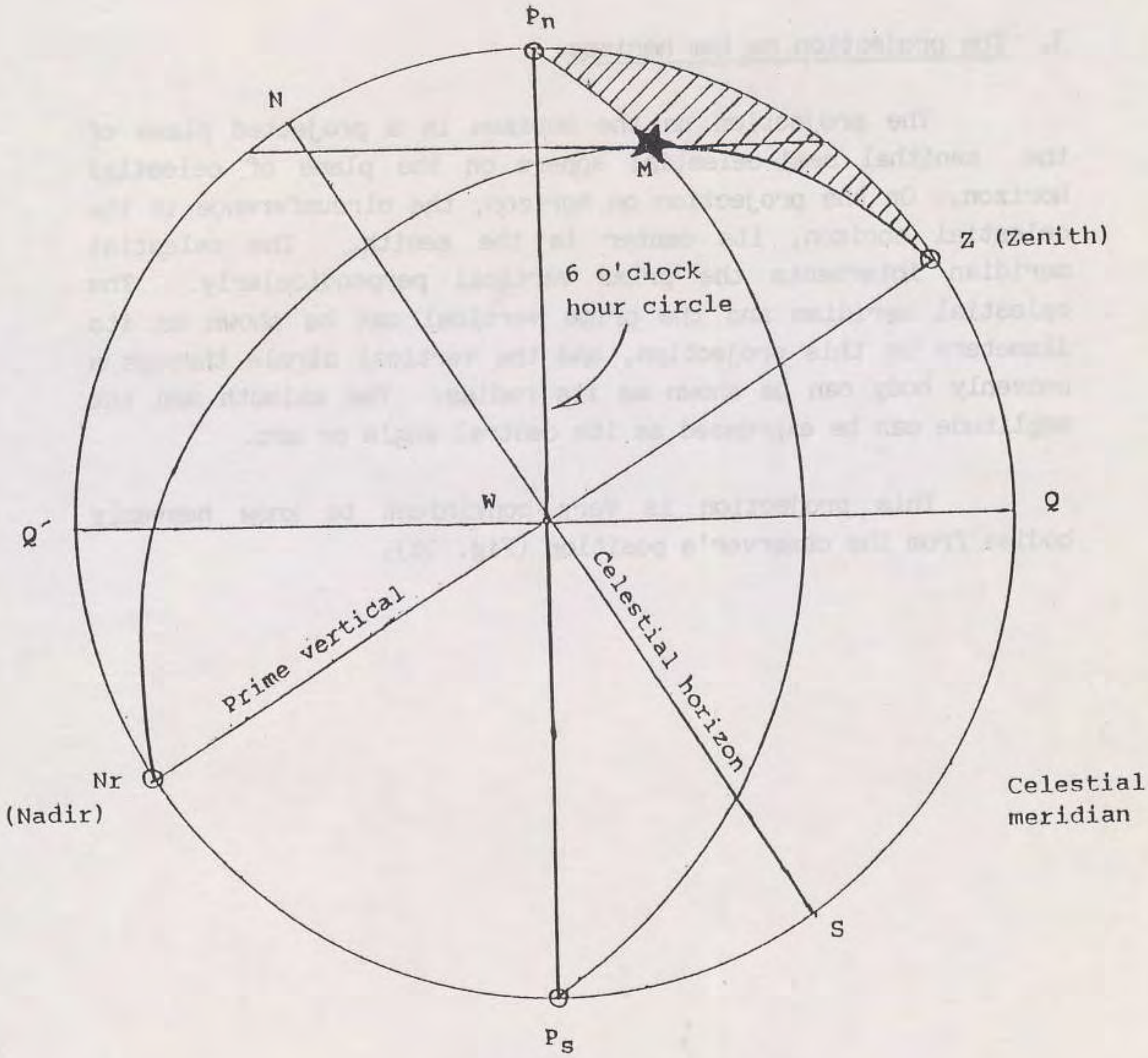
P_n = Celestial pole (north)
Z = Zenith
M = Heavenly body
h = Hour angle
α = Right ascension
$\overline{WE}$ = Six o'clock hour circle
$\overline{Q'Q}$ = Celestial meridian
T = Vernal equinox

2. The projection on the meridian

The projection on the meridian is a projected plane of the eastern or western semi-celestial sphere on the plane of celestial meridian.

On the projection on meridian, the circumference is the celestial meridian, the east point or the west point is its center, the diurnal circle is the arc of the circumference, the celestial equator intersects the six o'clock hour circle perpendicularly, the celestial horizon intersects the prime vertical perpendicularly. The celestial equator, the six o'clock hour circle, the celestial horizon and the prime vertical can be shown as the diameters on the projection on meridian. The celestial latitude and the celestial colatitude can be shown as the arcs of the circumference.

The projection on the meridian is appropriate to explain the calculation of latitude (Fig. 15)



Projection on meridian

Fig. 15

W = West point

$\overparen{P_nQ'P_sQ}$ = Celestial meridian

$\overline{NS}$ = Celestial horizon

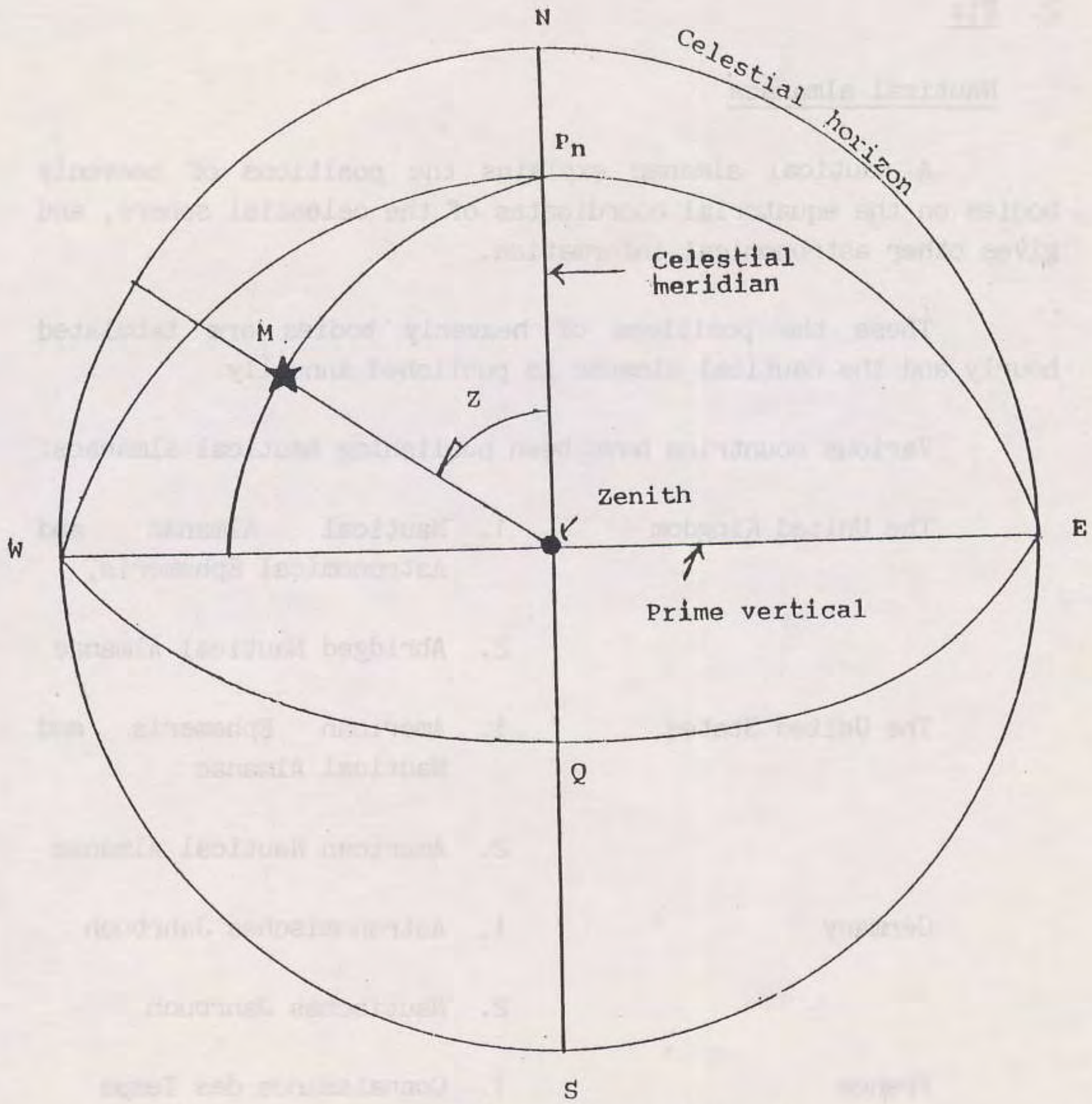
$\overline{Z\ Nr}$ = Prime vertical

M = Heavenly body

3. The projection on the horizon

The projection on the horizon is a projected plane of the zenithal semi-celestial sphere on the plane of celestial horizon. On the projection on horizon, the circumference is the celestial horizon, its center is the zenith. The celestial meridian intersects the prime vertical perpendicularly. The celestial meridian and the prime vertical can be shown as its diameters on this projection, and the vertical circle through a heavenly body can be shown as its radius. The azimuth and the amplitude can be expressed as its central angle or arc.

This projection is very convinient to know heavenly bodies from the observer's position (Fig. 16).



Heavenly Body & an Observer

Fig. 16

Z = Azimuth

$\overline{WE}$ = Prime vertical

$\overline{NS}$ = Celestial meridian

M = Heavenly body

2. Fix

Nautical almanacs

A nautical almanac explains the positions of heavenly bodies on the equatorial coordinates of the celestial sphere, and gives other astronomical information.

These the positions of heavenly bodies are tabulated hourly and the nautical almanac is published annually.

Various countries have been publishing nautical almanacs:

The United Kingdom	1. Nautical Almanac and Astronomical Ephemeris,
	2. Abridged Nautical Almanac
The United States	1. American Ephemeris and Nautical Almanac
	2. American Nautical Almanac
Germany	1. Astronomisches Jahrbuch
	2. Nautisches Jahrbuch
France	1. Connaissance des Temps
	2. Ephemerides Nautiques
Japan	1. Nautical Almanac
	2. Abridged Nautical Almanac

In these almanacs, the astronomical information is tabulated to a practical degree of accuracy, such as 0'.1 of arc and 1^s of time at hourly intervals.

The major part of the nautical almanac consists of the value of greenwich hour angle and declination, GHA of Aries and both GHA and the declination of Venus, Mars, Jupiter, and Saturn, also SHA and the declination of stars. The GHA and declination of the sun and moon, and the horizontal parallax of the moon, are tabulated.

For the sun and the moon, the time of transit is given for each day. For the moon, both upper and lower transits and the age and the phase are given in the table. Altitude corrections of sextant and dip table are also given.

Before calculating greenwich hour angle, declination, etc. by making use of a nautical almanac, please study how to use a programmable calculator CASIO fx-4000 P on page 43.

Altitude corrections

The altitude of a heavenly body is the angular distance from the horizon to the heavenly body on the vertical circle or the altitude is an included angle between the center of the heavenly body and the plane of the celestial horizon at the center of the earth. But as a matter of fact, it is impossible for us to measure this altitude (the true altitude) or the included angle. Usually, navigators measure altitude by marine sextant, and the altitude is the angular distance from the apparent horizon to the heavenly body.

This altitude obtained with the sextant is called Sextant Altitude (Sex. alt.) and corrected altitude by index error is called Observed Altitude (Obs. alt. or Ao). Then the observed altitude is the included angle between the lower limb or the upper limb (in the case of the sun and the moon) or the center (in the case of stars and planets) of the heavenly body and the plane of apparent horizon to the observer's eye.

This observed altitude is under the effects of many factors and quite different from the true altitude.

To obtain the true altitude of a heavenly body, the correction (astronomical refraction, dip of horizon, parallax, apparent semidiameter, index error) should be added to the sextant altitude.

Nautical Almanac

52 Example of 1985 MARCH 5, 6, 7 (TUES., WED., THURS.)

G.M.T. (UT)	ARIES G.H.A.	VENUS −4.3 G.H.A.	VENUS Dec.	MARS +1.5 G.H.A.	MARS Dec.	JUPITER −1.5 G.H.A.	JUPITER Dec.	SATURN +0.6 G.H.A.	SATURN Dec.	STARS Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
5 00	162 41.0	145 41.7	N13 32.2	141 49.3	N 8 43.5	214 25.0	S19 10.6	286 17.5	S17 33.3	Acamar	315 34.8	S40 22.1
01	177 43.5	160 43.5	32.9	156 50.1	44.2	229 27.0	10.4	301 20.0	33.3	Achernar	335 43.0	S57 19.0
02	192 46.0	175 45.4	33.5	171 50.8	44.9	244 28.9	10.3	316 22.4	33.3	Acrux	173 33.2	S63 00.9
03	207 48.4	190 47.2	·· 34.2	186 51.6	·· 45.7	259 30.8	·· 10.2	331 24.9	·· 33.3	Adhara	255 29.3	S28 57.2
04	222 50.9	205 49.1	34.9	201 52.3	46.4	274 32.8	10.1	346 27.3	33.3	Aldebaran	291 14.2	N16 28.8
05	237 53.3	220 51.0	35.5	216 53.1	47.1	289 34.7	10.0	1 29.8	33.3			
06	252 55.8	235 52.8	N13 36.2	231 53.8	N 8 47.8	304 36.6	S19 09.8	16 32.2	S17 33.2	Alioth	166 38.8	N56 02.3
07	267 58.3	250 54.7	36.8	246 54.6	48.5	319 38.5	09.7	31 34.7	33.2	Alkaid	153 15.3	N49 23.0
08	283 00.7	265 56.6	37.5	261 55.3	49.2	334 40.5	09.6	46 37.1	33.2	Al Na'ir	28 11.0	S47 02.2
09	298 03.2	280 58.5	·· 38.2	276 56.1	·· 49.9	349 42.4	·· 09.5	61 39.6	·· 33.2	Alnilam	276 08.2	S 1 12.7
10	313 05.7	296 00.4	38.8	291 56.8	50.6	4 44.3	09.3	76 42.0	33.2	Alphard	218 17.0	S 8 35.7
11	328 08.1	311 02.2	39.5	306 57.6	51.3	19 46.3	09.2	91 44.5	33.2			
12	343 10.6	326 04.1	N13 40.1	321 58.3	N 8 52.0	34 48.2	S19 09.1	106 46.9	S17 33.2	Alphecca	126 29.1	N26 45.6
13	358 13.1	341 06.0	40.8	336 59.1	52.8	49 50.1	09.0	121 49.4	33.2	Alpheratz	358 06.3	N29 00.4
14	13 15.5	356 07.9	41.4	351 59.8	53.5	64 52.0	08.8	136 51.8	33.2	Altair	62 29.5	N 8 49.4
15	28 18.0	11 09.8	·· 42.1	7 00.6	·· 54.2	79 54.0	·· 08.7	151 54.3	·· 33.2	Ankaa	353 37.2	S42 23.4
16	43 20.5	26 11.7	42.7	22 01.3	54.9	94 55.9	08.6	166 56.7	33.2	Antares	112 52.8	S26 24.0
17	58 22.9	41 13.6	43.4	37 02.1	55.6	109 57.8	08.5	181 59.2	33.2			
18	73 25.4	56 15.5	N13 44.0	52 02.8	N 8 56.3	124 59.8	S19 08.4	197 01.7	S17 33.2	Arcturus	146 15.2	N19 15.4
19	88 27.8	71 17.4	44.6	67 03.6	57.0	140 01.7	08.2	212 04.1	33.2	Atria	108 14.1	S68 59.9
20	103 30.3	86 19.4	45.3	82 04.3	57.7	155 03.6	08.1	227 06.6	33.2	Avior	234 26.5	S59 27.8
21	118 32.8	101 21.3	·· 45.9	97 05.1	·· 58.4	170 05.6	·· 08.0	242 09.0	·· 33.2	Bellatrix	278 55.2	N 6 20.2
22	133 35.2	116 23.2	46.6	112 05.8	59.1	185 07.5	07.9	257 11.5	33.2	Betelgeuse	271 24.6	N 7 24.3
23	148 37.7	131 25.1	47.2	127 06.6	8 59.9	200 09.4	07.7	272 13.9	33.1			
6 00	163 40.2	146 27.0	N13 47.8	142 07.3	N 9 00.6	215 11.4	S19 07.6	287 16.4	S17 33.1	Canopus	264 05.6	S52 41.4
01	178 42.6	161 29.0	48.5	157 08.1	01.3	230 13.3	07.5	302 18.8	33.1	Capella	281 06.4	N45 59.3
02	193 45.1	176 30.9	49.1	172 08.8	02.0	245 15.2	07.4	317 21.3	33.1	Deneb	49 46.7	N45 13.3
03	208 47.6	191 32.8	·· 49.7	187 09.6	·· 02.7	260 17.1	·· 07.3	332 23.8	·· 33.1	Denebola	182 55.3	N14 39.2
04	223 50.0	206 34.8	50.3	202 10.3	03.4	275 19.1	07.1	347 26.2	33.1	Diphda	349 17.8	S18 04.3
05	238 52.5	221 36.7	51.0	217 11.1	04.1	290 21.0	07.0	2 28.7	33.1			
06	253 55.0	236 38.7	N13 51.6	232 11.8	N 9 04.8	305 22.9	S19 06.9	17 31.1	S17 33.1	Dubhe	194 17.1	N61 49.9
07	268 57.4	251 40.6	52.2	247 12.6	05.5	320 24.9	06.8	32 33.6	33.1	Elnath	278 39.9	N28 35.9
08	283 59.9	266 42.6	52.8	262 13.3	06.2	335 26.8	06.6	47 36.0	33.1	Eltanin	90 56.3	N51 29.0
09	299 02.3	281 44.5	·· 53.5	277 14.1	·· 06.9	350 28.7	·· 06.5	62 38.5	·· 33.1	Enif	34 08.6	N 9 48.1
10	314 04.8	296 46.5	54.1	292 14.8	07.6	5 30.7	06.4	77 41.0	33.1	Fomalhaut	15 48.0	S29 42.3
11	329 07.3	311 48.5	54.7	307 15.6	08.3	20 32.6	06.3	92 43.4	33.1			
12	344 09.7	326 50.4	N13 55.3	322 16.3	N 9 09.0	35 34.5	S19 06.1	107 45.9	S17 33.1	Gacrux	172 24.8	S57 01.7
13	359 12.2	341 52.4	55.9	337 17.1	09.8	50 36.5	06.0	122 48.3	33.1	Gienah	176 14.3	S17 27.6
14	14 14.7	356 54.4	56.5	352 17.8	10.5	65 38.4	05.9	137 50.8	33.1	Hadar	149 18.5	S60 18.0
15	29 17.1	11 56.4	·· 57.2	7 18.6	·· 11.2	80 40.3	·· 05.8	152 53.2	·· 33.0	Hamal	328 25.5	N23 23.5
16	44 19.6	26 58.3	57.8	22 19.3	11.9	95 42.3	05.7	167 55.7	33.0	Kaus Aust.	84 12.6	S34 23.6
17	59 22.1	42 00.3	58.4	37 20.1	12.6	110 44.2	05.5	182 58.2	33.0			
18	74 24.5	57 02.3	N13 59.0	52 20.8	N 9 13.3	125 46.1	S19 05.4	198 00.6	S17 33.0	Kochab	137 18.1	N74 12.7
19	89 27.0	72 04.3	13 59.6	67 21.6	14.0	140 48.1	05.3	213 03.1	33.0	Markab	14 00.2	N15 09.3
20	104 29.4	87 06.3	14 00.2	82 22.3	14.7	155 50.0	05.2	228 05.5	33.0	Menkar	314 37.8	N 4 01.8
21	119 31.9	102 08.3	·· 00.8	97 23.1	·· 15.4	170 51.9	·· 05.0	243 08.0	·· 33.0	Menkent	148 32.7	S36 17.8
22	134 34.4	117 10.3	01.4	112 23.8	16.1	185 53.9	04.9	258 10.5	33.0	Miaplacidus	221 43.8	S69 39.4
23	149 36.8	132 12.3	02.0	127 24.6	16.8	200 55.8	04.8	273 12.9	33.0			
7 00	164 39.3	147 14.3	N14 02.6	142 25.3	N 9 17.5	215 57.7	S19 04.7	288 15.4	S17 33.0	Mirfak	309 11.7	N49 48.7
01	179 41.8	162 16.3	03.2	157 26.1	18.2	230 59.7	04.5	303 17.8	33.0	Nunki	76 25.2	S26 19.1
02	194 44.2	177 18.3	03.8	172 26.8	18.9	246 01.6	04.4	318 20.3	33.0	Peacock	53 53.4	S56 47.1
03	209 46.7	192 20.3	·· 04.4	187 27.6	·· 19.6	261 03.5	·· 04.3	333 22.8	·· 33.0	Pollux	243 53.8	N28 03.9
04	224 49.2	207 22.4	05.0	202 28.3	20.3	276 05.5	04.2	348 25.2	33.0	Procyon	245 22.1	N 5 15.8
05	239 51.6	222 24.4	05.5	217 29.1	21.0	291 07.4	04.1	3 27.7	32.9			
06	254 54.1	237 26.4	N14 06.1	232 29.8	N 9 21.7	306 09.4	S19 03.9	18 30.1	S17 32.9	Rasalhague	96 26.5	N12 33.9
07	269 56.6	252 28.4	06.7	247 30.6	22.4	321 11.3	03.8	33 32.6	32.9	Regulus	208 06.1	N12 02.4
08	284 59.0	267 30.5	07.3	262 31.3	23.1	336 13.2	03.7	48 35.1	32.9	Rigel	281 32.8	S 8 13.2
09	300 01.5	282 32.5	·· 07.9	277 32.1	·· 23.8	351 15.2	·· 03.6	63 37.5	·· 32.9	Rigil Kent.	140 21.2	S60 46.3
10	315 03.9	297 34.5	08.5	292 32.8	24.5	6 17.1	03.4	78 40.0	32.9	Sabik	102 37.3	S15 42.6
11	330 06.4	312 36.6	09.1	307 33.6	25.2	21 19.0	03.3	93 42.4	32.9			
12	345 08.9	327 38.6	N14 09.6	322 34.3	N 9 25.9	36 21.0	S19 03.2	108 44.9	S17 32.9	Schedar	350 06.0	N56 27.4
13	0 11.3	342 40.7	10.2	337 35.1	26.6	51 22.9	03.1	123 47.4	32.9	Shaula	96 51.3	S37 05.7
14	15 13.8	357 42.7	10.8	352 35.8	27.3	66 24.8	03.0	138 49.8	32.9	Sirius	258 52.6	S16 41.8
15	30 16.3	12 44.8	·· 11.4	7 36.6	·· 28.0	81 26.8	·· 02.8	153 52.3	·· 32.9	Spica	158 53.8	S11 05.1
16	45 18.7	27 46.9	11.9	22 37.3	28.7	96 28.7	02.7	168 54.8	32.9	Suhail	223 08.1	S43 22.4
17	60 21.2	42 48.9	12.5	37 38.1	29.5	111 30.7	02.6	183 57.2	32.9			
18	75 23.7	57 51.0	N14 13.1	52 38.8	N 9 30.2	126 32.6	S19 02.5	198 59.7	S17 32.9	Vega	80 53.8	N38 45.8
19	90 26.1	72 53.1	13.6	67 39.6	30.9	141 34.5	02.3	214 02.1	32.8	Zuben'ubi	137 29.2	S15 58.9
20	105 28.6	87 55.1	14.2	82 40.3	31.6	156 36.5	02.2	229 04.6	32.8			
21	120 31.1	102 57.2	·· 14.8	97 41.1	·· 32.3	171 38.4	·· 02.1	244 07.1	·· 32.8		S.H.A. ° ′	Mer. Pass. h m
22	135 33.5	117 59.3	15.3	112 41.8	33.0	186 40.3	02.0	259 09.5	32.8	Venus	342 46.9	14 12
23	150 36.0	133 01.4	15.9	127 42.6	33.7	201 42.3	01.9	274 12.0	32.8	Mars	338 27.2	14 31
Mer. Pass. 13 03.2 (h m)		v 2.0	d 0.6	v 0.8	d 0.7	v 1.9	d 0.1	v 2.5	d 0.0	Jupiter	51 31.2	9 38
										Saturn	123 36.2	4 50

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Nautical Almanac

Example of 1985 MARCH 5, 6, 7 (TUES., WED., THURS.)

Day	G.M.T. (UT) h	SUN G.H.A. ° ′	SUN Dec. ° ′	MOON G.H.A. ° ′	v ′	MOON Dec. ° ′	d ′	H.P. ′
5 TUESDAY	00	177 05.2	S 6 07.4	23 01.2	06.9	N20 57.6	10.8	57.5
	01	192 05.4	06.4	37 27.1	06.9	20 46.8	10.8	57.5
	02	207 05.5	07.4	51 53.0	07.0	20 36.0	11.0	57.5
	03	222 05.7	.. 06.5	66 19.0	07.0	20 25.0	11.1	57.6
	04	237 05.8	05.5	80 45.0	07.1	20 13.9	11.3	57.6
	05	252 05.9	04.5	95 11.1	07.1	20 02.6	11.4	57.6
	06	267 06.1	S 6 03.6	109 37.2	07.2	N19 51.2	11.5	57.7
	07	282 06.2	02.6	124 03.4	07.2	19 39.7	11.7	57.7
	08	297 06.4	01.6	138 29.6	07.2	19 28.0	11.8	57.7
	09	312 06.5	6 00.7	152 55.8	07.3	19 16.2	11.9	57.8
	10	327 06.7	5 59.7	167 22.1	07.3	19 04.3	12.1	57.8
	11	342 06.8	58.7	181 48.4	07.4	18 52.2	12.2	57.8
	12	357 06.9	S 5 57.8	196 14.8	07.4	N18 40.0	12.4	57.9
	13	12 07.1	56.8	210 41.2	07.5	18 27.6	12.4	57.9
	14	27 07.2	55.8	225 07.7	07.5	18 15.2	12.6	57.9
	15	42 07.4	.. 54.9	239 34.2	07.6	18 02.6	12.7	60.0
	16	57 07.5	53.9	254 00.8	07.6	17 49.9	12.8	60.0
	17	72 07.7	52.9	268 27.4	07.7	17 37.1	13.0	60.0
	18	87 07.8	S 5 52.0	282 54.1	07.7	N17 24.1	13.1	60.1
	19	102 07.9	51.0	297 20.8	07.8	17 11.0	13.2	60.1
	20	117 08.1	50.0	311 47.6	07.8	16 57.8	13.3	60.1
	21	132 08.2	.. 49.1	326 14.4	07.9	16 44.5	13.4	60.1
	22	147 08.4	48.1	340 41.3	07.9	16 31.1	13.5	60.2
	23	162 08.5	47.1	355 08.2	07.9	16 17.6	13.7	60.2
6 WEDNESDAY	00	177 08.7	S 5 46.2	9 35.1	08.1	N16 03.9	13.7	60.2
	01	192 08.8	45.2	24 02.2	08.0	15 50.2	13.9	60.2
	02	207 09.0	44.2	38 29.2	08.1	15 36.3	14.0	60.3
	03	222 09.1	.. 43.3	52 56.3	08.2	15 22.3	14.1	60.3
	04	237 09.3	42.3	67 23.5	08.2	15 08.2	14.2	60.3
	05	252 09.4	41.3	81 50.7	08.2	14 54.0	14.2	60.4
	06	267 09.5	S 5 40.4	96 17.9	08.3	N14 39.8	14.4	60.4
	07	282 09.7	39.4	110 45.2	08.4	14 25.4	14.5	60.4
	08	297 09.8	38.4	125 12.6	08.3	14 10.9	14.6	60.4
	09	312 10.0	.. 37.4	139 39.9	08.5	13 56.3	14.7	60.5
	10	327 10.1	36.5	154 07.4	08.5	13 41.6	14.8	60.5
	11	342 10.3	35.5	168 34.9	08.5	13 26.8	14.8	60.5
	12	357 10.4	S 5 34.5	183 02.4	08.5	N13 12.0	15.0	60.5
	13	12 10.6	33.6	197 29.9	08.7	12 57.0	15.1	60.5
	14	27 10.7	32.6	211 57.6	08.6	12 41.9	15.1	60.6
	15	42 10.9	.. 31.6	226 25.2	08.7	12 26.8	15.2	60.6
	16	57 11.0	30.7	240 52.9	08.8	12 11.6	15.3	60.6
	17	72 11.2	29.7	255 20.7	08.7	11 56.3	15.4	60.6
	18	87 11.3	S 5 28.7	269 48.4	08.9	N11 40.9	15.5	60.6
	19	102 11.5	27.7	284 16.3	08.8	11 25.4	15.5	60.7
	20	117 11.6	26.8	298 44.1	08.9	11 09.9	15.6	60.7
	21	132 11.8	.. 25.8	313 12.0	09.0	10 54.3	15.7	60.7
	22	147 11.9	24.8	327 40.0	09.0	10 38.6	15.8	60.7
	23	162 12.1	23.9	342 08.0	09.0	10 22.8	15.8	60.7
7 THURSDAY	00	177 12.2	S 5 22.9	356 36.0	09.1	N10 07.0	15.9	60.8
	01	192 12.4	21.9	11 04.1	09.1	9 51.1	16.0	60.8
	02	207 12.5	20.9	25 32.2	09.1	9 35.1	16.0	60.8
	03	222 12.7	.. 20.0	40 00.3	09.2	9 19.1	16.1	60.8
	04	237 12.8	19.0	54 28.5	09.2	9 03.0	16.2	60.8
	05	252 13.0	18.0	68 56.7	09.2	8 46.8	16.2	60.8
	06	267 13.1	S 5 17.1	83 24.9	09.3	N 8 30.6	16.3	60.8
	07	282 13.3	16.1	97 53.2	09.3	8 14.3	16.3	60.9
	08	297 13.4	15.1	112 21.5	09.4	7 58.0	16.4	60.9
	09	312 13.6	.. 14.1	126 49.9	09.3	7 41.6	16.5	60.9
	10	327 13.7	13.2	141 18.2	09.4	7 25.1	16.5	60.9
	11	342 13.9	12.2	155 46.6	09.5	7 08.6	16.5	60.9
	12	357 14.0	S 5 11.2	170 15.1	09.4	N 6 52.1	16.6	60.9
	13	12 14.2	10.2	184 43.5	09.5	6 35.5	16.6	60.9
	14	27 14.3	09.3	199 12.0	09.5	6 18.9	16.7	60.9
	15	42 14.5	.. 08.3	213 40.5	09.6	6 02.2	16.7	60.9
	16	57 14.6	07.3	228 09.1	09.5	5 45.5	16.7	61.0
	17	72 14.8	06.4	242 37.6	09.6	5 28.8	16.8	61.0
	18	87 14.9	S 5 05.4	257 06.2	09.7	N 5 12.0	16.8	61.0
	19	102 15.1	04.4	271 34.9	09.6	4 55.2	16.9	61.0
	20	117 15.2	03.4	286 03.5	09.6	4 38.3	16.9	61.0
	21	132 15.4	.. 02.5	300 32.1	09.7	4 21.4	16.9	61.0
	22	147 15.5	01.5	315 00.8	09.7	4 04.5	16.9	61.0
	23	162 15.7	00.5	329 29.5	09.7	3 47.6	17.0	61.0
		S.D. 16.1	d 1.0	S.D.	16.3	16.5		16.6

Lat. °	Twilight Naut. h m	Twilight Civil h m	Sunrise h m	Moonrise 5 h m	Moonrise 6 h m	Moonrise 7 h m	Moonrise 8 h m
N 72	04 45	06 04	07 11	▭	15 07	17 48	20 16
N 70	04 53	06 04	07 04	12 32	15 30	17 55	20 13
68	04 57	06 03	06 57	13 20	15 48	18 02	20 10
66	05 04	06 03	06 54	13 50	16 02	18 07	20 08
64	05 08	06 03	06 50	14 12	16 14	18 11	20 06
62	05 12	06 03	06 47	14 30	16 24	18 15	20 04
60	05 15	06 03	06 44	14 45	16 32	18 18	20 02
N 58	05 17	06 02	06 41	14 57	16 40	18 21	20 01
56	05 19	06 02	06 39	15 08	16 46	18 23	20 00
54	05 21	06 02	06 37	15 18	16 52	18 26	19 59
52	05 22	06 01	06 35	15 26	16 57	18 28	19 58
50	05 24	06 01	06 33	15 33	17 01	18 29	19 57
45	05 26	06 00	06 29	15 49	17 11	18 33	19 55
N 40	05 28	05 59	06 26	16 02	17 20	18 37	19 54
35	05 29	05 58	06 23	16 13	17 27	18 40	19 52
30	05 29	05 57	06 21	16 23	17 33	18 42	19 51
20	05 28	05 54	06 16	16 39	17 44	18 47	19 49
N 10	05 26	05 51	06 12	16 54	17 53	18 51	19 47
0	05 23	05 47	06 08	17 07	18 02	18 54	19 46
S 10	05 18	05 43	06 04	17 20	18 10	18 58	19 44
20	05 11	05 37	06 00	17 35	18 19	19 02	19 43
30	05 02	05 30	05 54	17 51	18 30	19 06	19 41
35	04 56	05 26	05 51	18 00	18 36	19 09	19 40
40	04 48	05 20	05 48	18 11	18 43	19 11	19 39
45	04 38	05 14	05 44	18 23	18 50	19 15	19 38
S 50	04 26	05 06	05 39	18 38	19 00	19 19	19 36
52	04 20	05 02	05 37	18 45	19 04	19 20	19 35
54	04 13	04 58	05 34	18 53	19 09	19 22	19 35
56	04 06	04 53	05 31	19 01	19 14	19 24	19 34
58	03 57	04 48	05 28	19 11	19 20	19 27	19 33
S 60	03 46	04 41	05 25	19 22	19 26	19 29	19 32

Lat. °	Sunset h m	Twilight Civil h m	Twilight Naut. h m	Moonset 5 h m	Moonset 6 h m	Moonset 7 h m	Moonset 8 h m
N 72	17 14	18 22	19 41	▭	08 57	08 10	07 34
N 70	17 20	18 21	19 33	09 34	08 31	07 59	07 33
68	17 25	18 21	19 26	08 45	08 11	07 50	07 32
66	17 30	18 21	19 21	08 13	07 55	07 42	07 30
64	17 34	18 21	19 16	07 50	07 42	07 36	07 29
62	17 37	18 21	19 13	07 31	07 31	07 30	07 29
60	17 40	18 21	19 10	07 15	07 21	07 25	07 28
N 58	17 42	18 22	19 07	07 02	07 13	07 21	07 27
56	17 45	18 22	19 05	06 50	07 05	07 17	07 27
54	17 47	18 22	19 03	06 40	06 59	07 13	07 26
52	17 49	18 22	19 01	06 31	06 53	07 10	07 26
50	17 50	18 23	19 00	06 23	06 47	07 07	07 25
45	17 54	18 23	18 57	06 05	06 35	07 01	07 24
N 40	17 57	18 24	18 56	05 51	06 25	06 55	07 23
35	18 00	18 25	18 55	05 39	06 17	06 51	07 23
30	18 02	18 26	18 54	05 28	06 09	06 47	07 22
20	18 07	18 29	18 54	05 09	05 56	06 39	07 21
N 10	18 11	18 32	18 56	04 53	05 44	06 33	07 20
0	18 15	18 35	18 59	04 38	05 33	06 27	07 19
S 10	18 19	18 40	19 04	04 22	05 22	06 20	07 18
20	18 23	18 45	19 11	04 06	05 10	06 14	07 16
30	18 28	18 52	19 20	03 46	04 56	06 06	07 15
35	18 31	18 56	19 26	03 35	04 48	06 02	07 14
40	18 34	19 01	19 34	03 22	04 39	05 56	07 13
45	18 38	19 08	19 43	03 07	04 28	05 50	07 12
S 50	18 43	19 16	19 55	02 48	04 15	05 43	07 11
52	18 45	19 19	20 01	02 38	04 09	05 40	07 10
54	18 47	19 23	20 08	02 28	04 02	05 36	07 10
56	18 50	19 28	20 15	02 17	03 54	05 32	07 09
58	18 53	19 33	20 24	02 03	03 45	05 27	07 08
S 60	18 56	19 39	20 34	01 47	03 35	05 22	07 07

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
5	11 37	11 33	12 12	23 20	10 52	14	○
6	11 26	11 19	12 11	24 14	11 47	15	
7	11 11	11 04	12 11	00 14	12 40	16	

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Computation of DMS by CASIO fx-4000 p.

Example — Keystrokes — Display

$41^\circ 49'.8$
$11^\circ 48'.3$ +
$53^\circ 38'.1$

4	1	°'"	4	9	°	8	°'"	+
1	1	°'"	4	8	°	3	°'"	EXE
SHIFT	°'"							

Display:
53.635
$53^\circ 38' 6''$
(= $53^\circ 38'.1$)
$6''/60'' = 0.1$

Example

$18^\circ 33'.2$
$0'.5$ −
$18^\circ 32'.7$

1	8	°'"	3	3	°	2	°'"	−
0	0	°'"		0	°	5	°'"	EXE
SHIFT	°'"							

Display:
18.545
$18^\circ 32' 42''$
(= $18^\circ 32'.7$)
$42''/60'' = 0.7$

Example

$297^\circ 12'.0$
$11^\circ 16'.0$
$8'.0$ +
$308^\circ 36'.0$

2	9	7	°'"	1	2	°	0	°'"	+
	1	1	°'"	1	6	°	0	°'"	+
	0	0	°'"		8	°	0	°'"	EXE
SHIFT	°'"								

Display:
308.600
$308^\circ 36' 00''$
(= $308^\circ 36'.0$)
$00''/60'' = 0.0$

Example

$319^\circ 54'.9$
$14^\circ 22'.0$
(−) $0'.3$ +
$334^\circ 16'.6$

3	1	9	°'"	5	4	°	9	°'"	+
	1	4	°'"	2	2	°	0	°'"	+
(−)	0	0	°'"		0	°	3	°'"	EXE
SHIFT	°'"								

Display:
334.227
$334^\circ 16.36''$
(= $334^\circ 16'.6$)
$36''/60'' = 0.6$

Example	Keystrokes										Result
158°51'.5	1	5	8	°'"	5	1	°	5	°'"	+	
215°44'.9	2	1	5	°'"	4	4	°	9	°'"	+	
7°42'.5			7	°'"	4	2	°	5	°'"	+	
(-)360° +	(-)	3	6	0	'"	EXE					22.35
22°18'.9	SHIFT	°'"									22°18'54"

(=22°18'.9)

54"/60" = 0.9

Example	Keystrokes										Result
24°49'.3		2	4	°'"	4	9	°	3	°'"	+	
12°12'.8		1	2	°'"	1	2	°	8	°'"	+	
0'.6		0	0	°'"		0	°	6	°'"	+	
(-)71°12'.6	(-)	7	1	°'"	1	2	°	0	°'"	+	
360° +	3	6	0	°'"	EXE						325.845
325°50'.7	SHIFT	°'"									325°50'42"

(=325°50'.7)

42"/60" = 0.7

How to compute Greenwich Day (GD) and Greenwich Mean Time (GMT)

Example

Required:- Approximate Greenwich Day (GD) and Greenwich Mean Time (GMT)

where :- Ship's time = March 21st $14^h\ 25^m\ 18^s$. Longitude = $139^o46'E$.

Ans. 21/3 $05^h\ 06^m\ 14^s$

Ship's time 21/3	$14^h\ 25^m\ 18^s$	
Long. in time	09 19 04	⊖ (= $139^o46'E$ ÷ 15)
Approx. GD & GMT 21/3	$05^h\ 06^m\ 14^s$	

	Keystrokes (fx-4000 p)									Display
1	4	o'"	2	5	o'"	1	8	o'"	–	
(	1	3	9	o'"	4	6	o'"	÷	1	
5	EXE	⟶								5.104
SHIFT	o'"	⟶								$5^o6'14''$

Ref. 1. 1 hour = 15^o, See NAVIGATION TABLES TD/LN/52 Rev. page 1 "Conversion of Arc to Time".

2. GMT = Local Mean Time (or ship's time) +(W) longitude -(E) (ZD) See NAVIGATION TABLE TD/LN/52 Rev. page 97 & 104.

Example

Required:- Approximate GD & GMT and also GMT.

where :- Ship's time November 16th, 14^h 15^m. Chronometer time (CT) 04^h 50^m 20^s. Chronometer error (CE) ⊖ 0^m 28^s. Longitude $38°48'$W.

Ans. 16/11 16^h 49^m 52^s

Ship's time 16/11	14^h	15^m	00^s	
Long. in time	2	35	12	⊕ (= $38°48'$W ÷ 15)
GD & Approx. GMT 16/11	16	50	12	
CT	04^h	50^m	20^s	
CE		0	28	⊖
Corr.^{d} CT	04	49	52	
+			12	(Because of Approx. GMT. = 16^h 50^m 12^s)
GD & GMT 16/11	16^h	49^m	52^s	

Keystrokes (fx-4000 p)										Display	
1	4	°'"	1	5	°'"	+	(	3	8		
°'"	4	8	°'"	÷	1	5	EXE			16.837	
SHIFT	°'"									16°50'12"	← Approx. GMT
4	°'"	5	0	°'"	2	0	°'"	−	0		
°'"	0	°'"	2	8	°'"	+	1	2	°'"		
EXE										16.831	
SHIFT	°'"									16°49'52"	← GMT

Example

Required:- Approximate GD & GMT and also GMT.

Where :- Ship's time April 27th $05^h\ 22^m$. GT $07^h\ 13^m\ 17^s$
Longitude $155^{o}07'$E. CE ⊖ $12^m\ 58^s$

Ans. 26/4 $19^h\ 00^m\ 19^s$

Ship's time 27/4	05^h	22^m	00^s	
Long. in time (LT)	10	20	28 ⊖	(= $155^{o}07'$E ÷ 15)
	− 04	58	28	
	+ 24			
Approx. GD & GMT 26/4	19	01	32	
CT	07	13	17	
CE		12	58 ⊖	
Corr.[d] CT	07	00	19	
	+ 12	(Because of Approx. GMT = $19^h\ 01^m\ 32^s$)		
GD & GMT 26/4	19^h	00^m	19^s	

Keystrokes (fx-4000 p)										Display	
5	°'"	2	2	°'"	−	(	1	5	5		
°'"	7	°'"	÷	1	5	°'"	)	+	2		
4	°'"	EXE	→							19.026	
SHIFT	°'"	→								19°1'32"	← Approx. GMT
7	°'"	1	3	°'"	1	7	°'"	−	0		
°'"	1	2	°'"	5	8	°'"	+	1	2		
°'"	EXE	→								19.005	
SHIFT	°'"	→								19°0'19"	← GMT

Problems: Required approximate GD, GMT and GMT.

#	Date	Ship's time	D.R.P.	Chro. time	Chro. error	Approx.GD&GMT	GD & GMT
1.	14/9/56	$18^h\ 00^m$	26°15' N 141°27' E	$09^h\ 46^m\ 25^s$	⊖ $01^h\ 01^m\ 12^s$	?	?
2.	6/7/56	$06^h\ 50^m$	34°28' N 135°00' E	$10^h\ 21^m\ 50^s$	⊖ $00^h\ 29^m\ 26^s$	?	?
3.	27/4/56	$04^h\ 20^m$	32°32' N 133°46' E	$07^h\ 24^m\ 18^s$	⊖ $00^h\ 01^m\ 36^s$	?	?
4.	5/8/56	$04^h\ 35^m$	21°13' N 161°35' W	$03^h\ 14^m\ 35^s$	⊕ $00^h\ 12^m\ 43^s$	?	?
5.	16/11/56	$12^h\ 00^m$	04°06' S 41°28' E	$08^h\ 21^m\ 38^s$	⊕ $00^h\ 04^m\ 13^s$	?	?
6.	22/3/56	$12^h\ 00^m$	02°10' N 70°10' E	$06^h\ 58^m\ 53^s$	⊖ $00^h\ 00^m\ 16^s$	?	?
7.	10/6/56	$09^h\ 20^m$	32°32' N 133°46' E	$00^h\ 43^m\ 37^s$	⊖ $00^h\ 16^m\ 17^s$	?	?
8.	12/12/56	$15^h\ 30^m$	04°06' S 41°28' E	$00^h\ 40^m\ 20^s$	⊖ $00^h\ 02^m\ 35^s$	?	?
9.	6/5/79	$05^h\ 00^m$	06°10' N 141°35' E	$07^h\ 54^m\ 57^s$	⊕ $00^h\ 00^m\ 05^s$	?	?
10.	6/5/79	$05^h\ 00^m$	06°10' N 141°35' E	$08^h\ 00^m\ 41^s$	⊕ $00^h\ 00^m\ 05^s$	?	?
11.	10/10/79	$05^h\ 00^m$	18°47' S 103°43' W	$11^h\ 54^m\ 44^s$	⊕ $00^h\ 00^m\ 04^s$	?	?

#	Date	Ship's time	D.R.P.	Chro. time	Chro. error	Approx.GD&GMT	GD & GMT
12.	10/10/79	$05^h\ 00^m$	18°47' S 103°43' W	$11^h\ 58^m\ 20^s$	⊕ $00^h\ 00^m\ 04^s$	?	?
13.	10/9/63	$07^h\ 30^m$	19°56' N 128°24' E	$10^h\ 31^m\ 24^s$	⊕ $00^h\ 23^m\ 10^s$	?	?
14.	10/9/63	$11^h\ 00^m$	19°26.4N 128°20.6E	$02^h\ 04^m\ 02^s$	⊕ $00^h\ 23^m\ 10^s$	?	?
15.	13/6/85	$05^h\ 17^m$	17°11.3N 118°23.4E	$09^h\ 08^m\ 00^s$	Nil	?	?
16.	13/6/85	$05^h\ 17^m$	17°11.3N 118°23.4E	$09^h\ 10^m\ 30^s$	Nil	?	?

Answers:

#	Approx. GD & GMT		GD & GMT		Remarks
1.	14/9	$08^h\ 34^m\ 12^s$	14/9	$08^h\ 45^m\ 13^s$	P. 60 Textbook TD/TRB/37 Rev.
2.	5/7	$21^h\ 50^m\ 00^s$	5/7	$21^h\ 52^m\ 24^s$	P. 88
3.	26/4	$19^h\ 24^m\ 56^s$	26/4	$19^h\ 22^m\ 42^s$	P. 91
4.	5/8	$15^h\ 21^m\ 00^s$	5/8	$15^h\ 27^m\ 18^s$	P. 101
5.	16/11	$09^h\ 14^m\ 08^s$	16/11	$08^h\ 25^m\ 51^s$	P. 108
6.	22/3	$07^h\ 19^m\ 20^s$	22/3	$06^h\ 58^m\ 37^s$	P. 110
7.	10/6	$00^h\ 24^m\ 56^s$	10/6	$00^h\ 27^m\ 20^s$	P. 126
8.	12/12	$12^h\ 44^m\ 08^s$	12/12	$12^h\ 37^m\ 45^s$	P. 162
9.	5/5	$19^h\ 33^m\ 40^s$	5/5	$19^h\ 55^m\ 02^s$	P. 190
10.	5/5	$19^h\ 33^m\ 40^s$	5/5	$20^h\ 00^m\ 46^s$	P. 191
11.	10/10	$11^h\ 54^m\ 52^s$	10/10	$11^h\ 54^m\ 48^s$	P. 197
12.	10/10	$11^h\ 54^m\ 52^s$	10/10	$11^h\ 58^m\ 24^s$	P. 198
13.	9/9	$22^h\ 56^m\ 24^s$	9/9	$22^h\ 54^m\ 34^s$	P. 205
14.	10/9	$02^h\ 26^m\ 37.6^s$	10/9	$02^h\ 27^m\ 12^s$	P. 209
15.	12/6	$21^h\ 23^m\ 26.4^s$	12/6	$21^h\ 08^m\ 00^s$	P. 239
16.	12/6	$21^h\ 23^m\ 26.4^s$	12/6	$21^h\ 10^m\ 30^s$	P. 240

Utilization of Nautical Almanac

Example 1

What were the GHA and the Declination of the sun and the moon on 22 January 1983 at GMT $15^h - 47^m - 13^s$? Use the nautical almanac published by "Her Majesty's Stationery Office". Pages 57& 58.

Solution

ALMANAC

1983 JANUARY 22, 23, 24 (SAT., SUN., MON.) Pages 57, 58.

		SUN		MOON				
		GHA	Dec.	GHA	V	Dec.	d	HP
22d	00h	177°09'2	S 19°51'2	92°30'9	13.1	N 6° 31'0	12'6	57'0
S	01	192 09.0	50.6	107 03.0	13.1	6 43.6	12.6	57.0
A T U		--- ---	--- ---	--- ---	---	---	---	---
R D	15	42 06.6	42.7	310 25.9	12.1	9 38.2	12.3	57.5
A	16	57 06.5	42.1	324 57.0	12.0	9 50.5	12.2	57.5
Y	---	--- ---	---	--- ---	---	---	---	---

INCREMENTS AND CORRECTIONS Page 60

47^m

47^m	SUN PLANETS	ARIES	MOON	v or d Corr^n	v or d Corr^n	v or d Corr^n
00^s	11°45'.0	11°46'.9	11°12'.9	0'.0 0'.0	6'.0 4'.8	12'.0 9'.5
01	11°45'.3	11°47'.2	11°13'.1	0'.1 0'.1	6'.1 4'.8	12'.1 9'.6
---	---	---	---	---	---	---
05	11°46'.3	11°48'.2	11°14'.1	0'.5 0'.4	6'.5 5'.1	12'.5 9'.9
06	11°46'.5	11°48'.4	11°14'.3	[0'.6 0'.5]	6'.6 5'.2	12'.6 10'.0
---	---	---	---	---	---	---
[13]	[11°48'.3]	11°50'.2	11°16'.0	1'.3 1'.0	7'.3 5'.8	13'.3 10'.5
14	11°48'.5	11°50'.4	11°16'.2	1'.4 1'.1	7'.4 5'.9	13'.4 10'.6
---	---	---	---	---	---	---

<u>The sun</u>

GMT. 22 Jan. 83 — <u>GHA</u>

15^h....... — 42° - 06'.6 (from almanac)

47^m-13^s — <u>11° - 48'.3</u> ⊕ (from "increments and corrections") ↖ attention!

15^h-47^m-13^s — 53° - 54'.9

===========

GMT. 22 Jan. 83 — <u>Declination</u>

15^h....... — S 19°- 42'.7 d = 0'.6 (from almanac ... at the foot of column)

47^m — <u>0'.5</u> ⊖ 0.5 correction from the table "INCREMENTS AND CORRECTIONS".

15^h-47^m-13^s... — S 19°- 42'.2

============ attention!

Ans. <u>GHA 53°-54'.9, Declination S. 19°-42'.2</u>

The moon

GMT. 22 Jan. '83	GHA	
15^h..................	$310^\circ - 25'.9$	(from almanac)
$47^m - 13^s$	$11^\circ - 16'.0$ ⊕	(from "increments and corrections")
	$321^\circ - 41'.9$	↑ attention!
	$9'.6$ ⊕	(from almanac, v is $12'.1$) $v = 12.1 \longrightarrow$ correction $= 9'.6$
$15^h - 47^m - 13^s$	$321^\circ - 51'.5$	from "increments and correction".

GMT. 22 Jan. 83	Declination	
15^h..................	N $9^\circ - 38'.2$	$d = 12'.3 \longrightarrow$ Correction $9'.7$
47^m..................	$9'.7$ ⊕	
$15^h - 47^m - 13^s$	N $9^\circ - 47'.9$	

Ans. GHA $321^\circ - 51'5$, Declination n $09^\circ - 47'.9$

Example 2

What were the LHA and the declination of Venus on 22 Jan. 1983 at GMT $12^h - 57^m - 28^s$ at longitude E. $91^\circ - 12'$?

Solution $\quad$ LHA(h) = GHA ± Longitude (E ⊕, W ⊖)

GMT 22 Jan. 83	GAH	v	Dec.	d	
12^h	$337^\circ - 23'.3$	$0'.6$	S $15^\circ - 59'.1$	$1'.0$	(from almanac)
$57^m - 28^s$......	$14^\circ - 22'.0$ +				
	$351^\circ - 45'.3$				
v or d correction..	$- 0'.6$		$- 1'.0$		(incr. and corr.)
GHA	$351^\circ - 44'.7$		Dec. S $15^\circ - 58'.1$		
Longitude ......E	$91^\circ - 12'.0$ ⊕		==========		
	$442^\circ - 56'.7$	increments and corrections			
	360° ⊖				
LHA	$82^\circ - 56'.7$				
	===========				

Ans. LHA $82^\circ - 56'.7$, Declination S $15^\circ - 58'.1$

Example 3

Waht were the LHA and the declination of Jupiter on 22 Jan. 1983 at GMT $11^h- 48^m- 51^s$ at longitude W. $120^o- 45'$?

Solution

GMT 22 Jan, 83	GAH	v	Dec	d
11^h	$42^o- 56'.4$	2.0	S. $20^o- 19'.5$	$0'.1$ (from almanac)
$48^m- 51^s$	$12^o- 12'.8$ (+)			
	$54^o- 69'.2$			
	$55^o- 09'.2$			
v or d - correction	$1'.6$ (+) ←		$0'.1$ (+) ←	(incr. and corr.)
	$55^o- 10'.8$			
GHA	$(415^o- 10'.8)$		Dec. S. $20^o- 19'.6$	
Longitude W	$120^o- 45'.0$ (−)			
L H A	$294^o- 25'.8$			

Ans. LHA $294^o- 25'.8$, Declination S. $20^o- 19'.6$

Example 4

What were the GHA and the declination of Aldebaran on 22 Jan. 1983 at GMT 15^{h}- 55^{m}- 13^{s}?

Solution

GMT 22 Jan. 83 GHA	Declination
291°- 15'.9	N. 16°- 28'.5 from almanac
GHA - Aries (15^{h}) 346°- 23'.6	from almanac
55^{m}- 13^{s} 13°- 50'.5 ⊕	from INCREMENTS and CORRECTIONS
GHA 651°- 30'.0 360° ⊖ 291°- 30'.0 ===========	

Ans. GHA 291°- 30'.0, Declination N 16°- 28'.5

Example 5

What were the GHA and the declination of Vega on 22 Jan. 1983 at GMT $18^h - 02^m - 45^s$?

Solution

GMT 22 Jan. 83	GHA	Declination
	$80^\circ - 55'.1$	N. $38^\circ - 45'.9$ from almanac
GHA Aries 18^h	$31^\circ - 31'.0$	
$02^m - 45^s$	$0^\circ - 41'.4$ ⊕	from INCREMENTS and CORRECTIONS
GHA	$111^\circ - 127'.5$ $120'.0$ ⊖ $113^\circ - 007'.5$ ============	

Ans. GHA $113^\circ - 007'.5$, Declination N $38^\circ - 45'.9$

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 1983 JANUARY 22, 23, 24 (SAT., SUN., MON.)

G.M.T.	ARIES G.H.A.	VENUS −3.3 G.H.A.	VENUS Dec.	MARS +1.4 G.H.A.	MARS Dec.	JUPITER −1.4 G.H.A.	JUPITER Dec.	SATURN +0.8 G.H.A.	SATURN Dec.	STARS Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
22 00	120 46.6	157 30.7	S16 11.0	145 00.2	S11 08.3	237 34.1	S20 18.7	268 08.5	S10 31.9	Acamar	315 35.8	S40 22.7
01	135 49.1	172 30.1	10.0	160 00.8	07.5	252 36.1	18.8	283 10.9	31.9	Achernar	335 44.0	S57 19.8
02	150 51.6	187 29.5	09.0	175 01.4	06.8	267 38.2	18.8	298 13.3	31.9	Acrux	173 35.2	S63 00.0
03	165 54.0	202 28.9 ··	08.0	190 02.0 ··	06.1	282 40.2 ··	18.9	313 15.6 ··	31.9	Adhara	255 30.4	S28 57.0
04	180 56.5	217 28.3	07.1	205 02.6	05.3	297 42.2	19.0	328 18.0	32.0	Aldebaran	291 15.9	N16 28.5
05	195 59.0	232 27.6	06.1	220 03.2	04.6	312 44.3	19.0	343 20.4	32.0			
06	211 01.4	247 27.0	S16 05.1	235 03.8	S11 03.9	327 46.3	S20 19.1	358 22.8	S10 32.0	Alioth	166 40.8	N56 02.9
07	226 03.9	262 26.4	04.1	250 04.4	03.1	342 48.3	19.2	13 25.1	32.0	Alkaid	153 17.1	N49 23.6
S 08	241 06.4	277 25.8	03.1	265 05.1	02.4	357 50.4	19.3	28 27.5	32.0	Al Na'ir	28 13.2	S47 02.9
A 09	256 08.8	292 25.2 ··	02.1	280 05.7 ··	01.7	12 52.4 ··	19.3	43 29.9 ··	32.1	Alnilam	276 09.7	S 1 12.8
T 10	271 11.3	307 24.5	01.1	295 06.3	00.9	27 54.4	19.4	58 32.2	32.1	Alphard	218 18.6	S 8 35.1
U 11	286 13.7	322 23.9	16 00.1	310 06.9	11 00.2	42 56.4	19.5	73 34.6	32.1			
R 12	301 16.2	337 23.3	S15 59.1	325 07.5	S10 59.5	57 58.5	S20 19.5	88 37.0	S10 32.1	Alphecca	126 30.8	N26 46.1
D 13	316 18.7	352 22.7	58.1	340 08.1	58.7	73 00.5	19.6	103 39.4	32.1	Alpheratz	358 07.8	N28 59.8
A 14	331 21.1	7 22.1	57.1	355 08.7	58.0	88 02.5	19.7	118 41.7	32.2	Altair	62 31.2	N 8 49.3
Y 15	346 23.6	22 21.5 ··	56.1	10 09.3 ··	57.3	103 04.6 ··	19.8	133 44.1 ··	32.2	Ankaa	353 38.7	S42 24.2
16	1 26.1	37 20.9	55.1	25 10.0	56.5	118 06.6	19.8	148 46.5	32.2	Antares	112 55.0	S26 23.6
17	16 28.5	52 20.3	54.1	40 10.6	55.8	133 08.6	19.9	163 48.9	32.2			
18	31 31.0	67 19.6	S15 53.1	55 11.2	S10 55.0	148 10.7	S20 20.0	178 51.2	S10 32.2	Arcturus	146 16.9	N17 16.1
19	46 33.5	82 19.0	52.1	70 11.8	54.3	163 12.7	20.0	193 53.6	32.3	Atria	108 18.2	S68 57.6
20	61 35.9	97 18.4	51.1	85 12.4	53.6	178 14.7	20.1	208 56.0	32.3	Avior	234 26.9	S59 27.2
21	76 38.4	112 17.8 ··	50.1	100 13.0 ··	52.8	193 16.8 ··	20.2	223 58.4 ··	32.3	Bellatrix	278 56.7	N 6 20.0
22	91 40.9	127 17.2	49.1	115 13.6	52.1	208 18.8	20.3	239 00.7	32.3	Betelgeuse	271 26.2	N 7 24.2
23	106 43.3	142 16.6	48.1	130 14.2	51.4	223 20.8	20.3	254 03.1	32.3			
23 00	121 45.8	157 16.0	S15 47.1	145 14.9	S10 50.6	238 22.9	S20 20.4	269 05.5	S10 32.4	Canopus	264 06.0	S52 41.3
01	136 48.2	172 15.4	46.1	160 15.5	49.9	253 24.9	20.5	284 07.9	32.4	Capella	281 08.5	N45 59.0
02	151 50.7	187 14.8	45.0	175 16.1	49.1	268 26.9	20.5	299 10.2	32.4	Deneb	49 47.8	N45 13.1
03	166 53.2	202 14.2 ··	44.0	190 16.7 ··	48.4	283 29.0 ··	20.6	314 12.6 ··	32.4	Denebola	182 57.1	N14 40.0
04	181 55.6	217 13.6	43.0	205 17.3	47.7	298 31.0	20.7	329 15.0	32.4	Diphda	349 19.3	S18 05.0
05	196 58.1	232 13.0	42.0	220 17.9	46.9	313 33.0	20.8	344 17.4	32.5			
06	212 00.6	247 12.4	S15 41.0	235 18.5	S10 46.2	328 35.1	S20 20.8	359 19.7	S10 32.5	Dubhe	194 19.4	N61 50.4
07	227 03.0	262 11.8	40.0	250 19.2	45.5	343 37.1	20.9	14 22.1	32.5	Elnath	278 41.7	N28 35.7
08	242 05.5	277 11.1	39.0	265 19.8	44.7	358 39.1	21.0	29 24.5	32.5	Eltanin	90 57.4	N51 29.3
S 09	257 08.0	292 10.5 ··	38.0	280 20.4 ··	44.0	13 41.2 ··	21.0	44 26.9 ··	32.5	Enif	34 10.3	N 9 47.7
U 10	272 10.4	307 09.9	37.0	295 21.0	43.2	28 43.2	21.1	59 29.3	32.6	Fomalhaut	15 49.8	S29 43.0
N 11	287 12.9	322 09.3	35.9	310 21.6	42.5	43 45.2	21.2	74 31.6	32.6			
D 12	302 15.4	337 08.7	S15 34.9	325 22.2	S10 41.8	58 47.3	S20 21.3	89 34.0	S10 32.6	Gacrux	172 26.7	S57 00.8
A 13	317 17.8	352 08.1	33.9	340 22.9	41.0	73 49.3	21.3	104 36.4	32.6	Gienah	176 16.1	S17 26.7
Y 14	332 20.3	7 07.5	32.9	355 23.5	40.3	88 51.3	21.4	119 38.8	32.6	Hadar	149 21.1	S60 17.2
15	347 22.7	22 06.9 ··	31.9	10 24.1 ··	39.5	103 53.4 ··	21.5	134 41.1 ··	32.7	Hamal	328 27.0	N23 22.9
16	2 25.2	37 06.3	30.8	25 24.7	38.8	118 55.4	21.5	149 43.5	32.7	Kaus Aust.	84 15.0	S34 23.6
17	17 27.7	52 05.7	29.8	40 25.3	38.1	133 57.4	21.6	164 45.9	32.7			
18	32 30.1	67 05.1	S15 28.8	55 25.9	S10 37.3	148 59.5	S20 21.7	179 48.3	S10 32.7	Kochab	137 19.2	N74 13.2
19	47 32.6	82 04.5	27.8	70 26.6	36.6	164 01.5	21.8	194 50.7	32.7	Markab	14 01.8	N15 06.7
20	62 35.1	97 04.0	26.8	85 27.2	35.8	179 03.6	21.8	209 53.0	32.8	Menkar	314 39.3	N 4 01.3
21	77 37.5	112 03.4 ··	25.7	100 27.8 ··	35.1	194 05.6 ··	21.9	224 55.4 ··	32.8	Menkent	148 35.1	S36 17.0
22	92 40.0	127 02.8	24.7	115 28.4	34.4	209 07.6	22.0	239 57.8	32.8	Miaplacidus	221 43.8	S69 38.7
23	107 42.5	142 02.2	23.7	130 29.0	33.6	224 09.7	22.0	255 00.2	32.8			
24 00	122 44.9	157 01.6	S15 22.7	145 29.6	S10 32.9	239 11.7	S20 22.1	270 02.5	S10 32.8	Mirfak	307 13.6	N49 40.2
01	137 47.4	172 01.0	21.6	160 30.3	32.1	254 13.7	22.2	285 04.9	32.8	Nunki	76 27.4	S26 19.2
02	152 49.8	187 00.4	20.6	175 30.9	31.4	269 15.8	22.2	300 07.3	32.9	Peacock	53 56.3	S56 47.6
03	167 52.3	201 59.8 ··	19.6	190 31.5 ··	30.6	284 17.8 ··	22.3	315 09.7 ··	32.9	Pollux	243 55.7	N28 04.1
04	182 54.8	216 59.2	18.6	205 32.1	29.9	299 19.9	22.4	330 12.1	32.9	Procyon	245 23.7	N 5 16.1
05	197 57.2	231 58.6	17.5	220 32.7	29.2	314 21.9	22.5	345 14.4	32.9			
06	212 59.7	246 58.0	S15 16.5	235 33.4	S10 28.4	329 23.9	S20 22.5	0 16.8	S10 32.9	Rasalhague	96 28.3	N12 34.2
07	228 02.2	261 57.4	15.5	250 34.0	27.7	344 26.0	22.6	15 19.2	33.0	Regulus	208 07.9	N12 03.0
08	243 04.6	276 56.8	14.4	265 34.6	26.9	359 28.0	22.7	30 21.6	33.0	Rigel	281 34.2	S 8 13.4
M 09	258 07.1	291 56.2 ··	13.4	280 35.2 ··	26.2	14 30.0 ··	22.7	45 24.0 ··	33.0	Rigil Kent.	140 23.8	S60 45.6
O 10	273 09.6	306 55.7	12.4	295 35.8	25.4	29 32.1	22.8	60 26.4	33.0	Sabik	102 39.5	S15 42.3
N 11	288 12.0	321 55.1	11.4	310 36.4	24.7	44 34.1	22.9	75 28.7	33.0			
D 12	303 14.5	336 54.5	S15 10.3	325 37.1	S10 24.0	59 36.2	S20 22.9	90 31.1	S10 33.0	Schedar	350 07.4	N56 24.8
A 13	318 17.0	351 53.9	09.3	340 37.7	23.2	74 38.2	23.0	105 33.5	33.1	Shaula	96 53.8	S37 05.5
Y 14	333 19.4	6 53.3	08.3	355 38.3	22.5	89 40.2	23.1	120 35.9	33.1	Sirius	258 53.9	S16 41.7
15	348 21.9	21 52.7 ··	07.2	10 38.9 ··	21.7	104 42.3 ··	23.1	135 38.3 ··	33.1	Spica	158 55.7	S11 04.3
16	3 24.3	36 52.1	06.2	25 39.6	21.0	119 44.3	23.2	150 40.6	33.1	Suhail	223 09.2	S43 21.7
17	18 26.8	51 51.5	05.1	40 40.2	20.2	134 46.4	23.3	165 43.0	33.1			
18	33 29.3	66 51.0	S15 04.1	55 40.8	S10 19.5	149 48.4	S20 23.4	180 45.4	S10 33.1	Vega	80 55.1	N38 45.9
19	48 31.7	81 50.4	03.1	70 41.4	18.7	164 50.4	23.4	195 47.8	33.2	Zuben'ubi	137 31.3	S15 58.2
20	63 34.2	96 49.8	02.0	85 42.0	18.0	179 52.5	23.5	210 50.2	33.2		S.H.A.	Mer. Pass.
21	78 36.7	111 49.2 ··	15 01.0	100 42.7 ··	17.3	194 54.5 ··	23.6	225 52.6 ··	33.2		° ′	h m
22	93 39.1	126 48.6	14 59.9	115 43.3	16.5	209 56.6	23.6	240 54.9	33.2	Venus	35 30.2	13 31
23	108 41.6	141 48.1	58.9	130 43.9	15.8	224 58.6	23.7	255 57.3	33.2	Mars	23 29.1	14 18
	h m									Jupiter	116 37.1	8 05
Mer. Pass.	15 50.3	v −0.6	d 1.0	v 0.6	d 0.7	v 2.0	d 0.1	v 2.4	d 0.0	Saturn	147 19.7	6 03

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Nautical Almanac

1983 JANUARY 22, 23, 24 (SAT., SUN., MON.)

G.M.T.		SUN G.H.A.	SUN Dec.	MOON G.H.A.	v	MOON Dec.	d	H.P.
	h	° ′	° ′	° ′	′	° ′	′	′
22	00	177 09.2	S19 51.2	92 30.9	13.1	N 6 31.0	12.6	57.0
	01	192 09.0	50.6	107 03.0	13.1	6 43.6	12.6	57.0
	02	207 08.9	50.0	121 35.1	13.0	6 56.2	12.6	57.0
	03	222 08.7	·· 49.5	136 07.1	13.0	7 08.8	12.6	57.1
	04	237 08.5	48.9	150 39.1	12.9	7 21.4	12.5	57.1
	05	252 08.3	48.4	165 11.0	12.8	7 33.9	12.6	57.1
	06	267 08.2	S19 47.8	179 42.8	12.7	N 7 46.5	12.5	57.2
	07	282 08.0	47.2	194 14.5	12.7	7 59.0	12.5	57.2
S	08	297 07.8	46.7	208 46.2	12.6	8 11.5	12.4	57.3
A	09	312 07.7	·· 46.1	223 17.8	12.5	8 23.9	12.5	57.3
T	10	327 07.5	45.5	237 49.3	12.5	8 36.4	12.4	57.3
U	11	342 07.3	45.0	252 20.8	12.4	8 48.8	12.4	57.4
R	12	357 07.1	S19 44.4	266 52.2	12.3	N 9 01.2	12.4	57.4
D	13	12 07.0	43.8	281 23.5	12.2	9 13.6	12.3	57.4
A	14	27 06.8	43.3	295 54.7	12.2	9 25.9	12.3	57.5
Y	15	42 06.6	·· 42.7	310 25.9	12.1	9 38.2	12.3	57.5
	16	57 06.5	42.1	324 57.0	12.0	9 50.5	12.2	57.5
	17	72 06.3	41.5	339 28.0	11.9	10 02.7	12.2	57.6
	18	87 06.1	S19 41.0	353 58.9	11.8	N10 14.9	12.2	57.6
	19	102 06.0	40.4	8 29.7	11.8	10 27.1	12.1	57.7
	20	117 05.8	39.8	23 00.5	11.7	10 39.2	12.1	57.7
	21	132 05.6	·· 39.3	37 31.2	11.6	10 51.3	12.1	57.7
	22	147 05.5	38.7	52 01.8	11.5	11 03.4	12.0	57.8
	23	162 05.3	38.1	66 32.3	11.4	11 15.4	12.0	57.8
23	00	177 05.1	S19 37.5	81 02.7	11.3	N11 27.4	11.9	57.8
	01	192 05.0	37.0	95 33.0	11.2	11 39.3	11.9	57.9
	02	207 04.8	36.4	110 03.2	11.2	11 51.2	11.9	57.9
	03	222 04.6	·· 35.8	124 33.4	11.0	12 03.1	11.8	58.0
	04	237 04.5	35.2	139 03.4	11.0	12 14.9	11.7	58.0
	05	252 04.3	34.6	153 33.4	10.9	12 26.6	11.7	58.0
	06	267 04.1	S19 34.1	168 03.3	10.8	N12 38.3	11.7	58.1
	07	282 04.0	33.5	182 33.1	10.6	12 50.0	11.6	58.1
	08	297 03.8	32.9	197 02.7	10.6	13 01.6	11.5	58.1
S	09	312 03.7	·· 32.3	211 32.3	10.5	13 13.1	11.5	58.2
U	10	327 03.5	31.7	226 01.8	10.4	13 24.6	11.4	58.2
N	11	342 03.3	31.2	240 31.2	10.3	13 36.0	11.4	58.3
D	12	357 03.2	S19 30.6	255 00.5	10.2	N13 47.4	11.3	58.3
A	13	12 03.0	30.0	269 29.7	10.1	13 58.7	11.3	58.3
Y	14	27 02.8	29.4	283 58.8	10.0	14 10.0	11.2	58.4
	15	42 02.7	·· 28.8	298 27.8	9.9	14 21.2	11.1	58.4
	16	57 02.5	28.2	312 56.7	9.8	14 32.3	11.1	58.5
	17	72 02.4	27.7	327 25.5	9.7	14 43.4	11.0	58.5
	18	87 02.2	S19 27.1	341 54.2	9.6	N14 54.4	11.0	58.5
	19	102 02.0	26.5	356 22.8	9.5	15 05.4	10.8	58.6
	20	117 01.9	25.9	10 51.3	9.3	15 16.2	10.8	58.6
	21	132 01.7	·· 25.3	25 19.6	9.3	15 27.0	10.7	58.6
	22	147 01.6	24.7	39 47.9	9.2	15 37.7	10.7	58.7
	23	162 01.4	24.1	54 16.1	9.0	15 48.4	10.6	58.7
24	00	177 01.3	S19 23.5	68 44.1	9.0	N15 59.0	10.5	58.8
	01	192 01.1	23.0	83 12.1	8.8	16 09.5	10.4	58.8
	02	207 00.9	22.4	97 39.9	8.8	16 19.9	10.3	58.8
	03	222 00.8	·· 21.8	112 07.7	8.6	16 30.2	10.3	58.9
	04	237 00.6	21.2	126 35.3	8.5	16 40.5	10.1	58.9
	05	252 00.5	20.6	141 02.8	8.4	16 50.6	10.1	59.0
	06	267 00.3	S19 20.0	155 30.2	8.3	N17 00.7	10.0	59.0
	07	282 00.2	19.4	169 57.5	8.2	17 10.7	9.9	59.0
	08	297 00.0	18.8	184 24.7	8.1	17 20.6	9.9	59.1
M	09	311 59.9	·· 18.2	198 51.8	7.9	17 30.5	9.7	59.1
O	10	326 59.7	17.6	213 18.7	7.9	17 40.2	9.6	59.1
N	11	341 59.5	17.0	227 45.6	7.7	17 49.8	9.6	59.2
D	12	356 59.4	S19 16.4	242 12.3	7.7	N17 59.4	9.4	59.2
A	13	11 59.2	15.8	256 39.0	7.5	18 08.8	9.4	59.3
Y	14	26 59.1	15.2	271 05.5	7.4	18 18.2	9.2	59.3
	15	41 58.9	·· 14.6	285 31.9	7.3	18 27.4	9.2	59.3
	16	56 58.8	14.0	299 58.2	7.2	18 36.6	9.0	59.4
	17	71 58.6	13.4	314 24.4	7.0	18 45.6	8.9	59.4
	18	86 58.5	S19 12.8	328 50.4	7.0	N18 54.5	8.9	59.4
	19	101 58.3	12.2	343 16.4	6.8	19 03.4	8.7	59.5
	20	116 58.2	11.6	357 42.2	6.7	19 12.1	8.6	59.5
	21	131 58.0	·· 11.0	12 07.9	6.7	19 20.7	8.5	59.6
	22	146 57.9	10.4	26 33.6	6.5	19 29.2	8.4	59.6
	23	161 57.7	09.8	40 59.1	6.4	19 37.6	8.2	59.6
		S.D. 16.3	d 0.6	S.D. 15.6		15.9		16.1

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 22	Moonrise 23	Moonrise 24	Moonrise 25
°	h m	h m	h m	h m	h m	h m	h m
N 72	07 41	09 20	▬	10 19	09 50	08 49	▭
N 70	07 29	08 54	10 45	10 32	10 14	09 47	▭
68	07 19	08 34	09 59	10 42	10 33	10 21	09 59
66	07 11	08 18	09 29	10 50	10 48	10 46	10 46
64	07 04	08 05	09 07	10 58	11 00	11 06	11 17
62	06 57	07 54	08 49	11 04	11 11	11 22	11 40
60	06 52	07 44	08 35	11 09	11 20	11 36	11 59
N 58	06 47	07 36	08 22	11 14	11 28	11 47	12 15
56	06 42	07 28	08 11	11 19	11 35	11 57	12 28
54	06 38	07 22	08 02	11 23	11 42	12 06	12 40
52	06 34	07 15	07 53	11 26	11 48	12 14	12 50
50	06 30	07 10	07 46	11 29	11 53	12 22	12 59
45	06 22	06 58	07 30	11 36	12 04	12 37	13 19
N 40	06 14	06 47	07 16	11 42	12 14	12 50	13 34
35	06 07	06 38	07 05	11 47	12 22	13 01	13 48
30	06 00	06 29	06 55	11 52	12 29	13 11	14 00
20	05 48	06 14	06 38	12 00	12 41	13 28	14 20
N 10	05 35	06 00	06 22	12 07	12 52	13 42	14 38
0	05 21	05 46	06 08	12 13	13 03	13 56	14 54
S 10	05 05	05 31	05 54	12 20	13 13	14 10	15 11
20	04 46	05 14	05 38	12 27	13 24	14 25	15 29
30	04 22	04 54	05 20	12 36	13 37	14 42	15 50
35	04 07	04 41	05 10	12 40	13 45	14 52	16 02
40	03 48	04 26	04 57	12 46	13 53	15 04	16 16
45	03 24	04 08	04 43	12 52	14 04	15 18	16 33
S 50	02 51	03 45	04 25	13 00	14 16	15 35	16 53
52	02 34	03 34	04 17	13 03	14 22	15 42	17 03
54	02 12	03 21	04 07	13 07	14 28	15 51	17 14
56	01 42	03 05	03 57	13 12	14 35	16 01	17 27
58	00 49	02 47	03 45	13 17	14 43	16 13	17 42
S 60	////	02 24	03 30	13 22	14 52	16 26	17 59

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 22	Moonset 23	Moonset 24	Moonset 25
°	h m	h m	h m	h m	h m	h m	h m
N 72	▬	15 04	16 44	01 16	03 26	06 16	▭
N 70	13 40	15 30	16 56	01 06	03 04	05 20	▭
68	14 26	15 50	17 05	00 58	02 47	04 46	07 07
66	14 55	16 06	17 14	00 51	02 33	04 22	06 20
64	15 17	16 19	17 21	00 46	02 22	04 04	05 50
62	15 35	16 30	17 27	00 41	02 12	03 48	05 28
60	15 50	16 40	17 32	00 37	02 04	03 36	05 09
N 58	16 02	16 48	17 38	00 33	01 57	03 25	04 54
56	16 13	16 56	17 42	00 30	01 51	03 15	04 42
54	16 22	17 03	17 46	00 27	01 45	03 07	04 30
52	16 31	17 09	17 50	00 24	01 40	03 00	04 21
50	16 38	17 14	17 54	00 21	01 36	02 53	04 12
45	16 54	17 27	18 02	00 16	01 26	02 38	03 53
N 40	17 08	17 37	18 10	00 12	01 18	02 27	03 38
35	17 19	17 46	18 17	00 08	01 11	02 17	03 25
30	17 29	17 54	18 23	00 05	01 05	02 08	03 14
20	17 46	18 09	18 36	24 54	00 54	01 53	02 55
N 10	18 01	18 23	18 49	24 45	00 45	01 40	02 39
0	18 15	18 37	19 03	24 36	00 36	01 28	02 23
S 10	18 30	18 52	19 18	24 28	00 28	01 15	02 08
20	18 45	19 09	19 37	24 19	00 19	01 02	01 51
30	19 03	19 29	20 01	24 09	00 09	00 48	01 33
35	19 14	19 42	20 16	24 03	00 03	00 39	01 22
40	19 26	19 56	20 35	23 56	24 29	00 29	01 09
45	19 40	20 14	20 58	23 48	24 18	00 18	00 55
S 50	19 57	20 37	21 31	23 39	24 04	00 04	00 37
52	20 06	20 48	21 48	23 34	23 58	24 28	00 28
54	20 15	21 01	22 09	23 30	23 51	24 19	00 19
56	20 25	21 16	22 38	23 24	23 43	24 08	00 08
58	20 37	21 34	23 25	23 19	23 34	23 56	24 30
S 60	20 52	21 57	////	23 12	23 24	23 42	24 12

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	Age	Phase
	m s	m s	h m	h m	h m	d	
22	11 23	11 31	12 12	18 25	06 01	08	◐
23	11 39	11 47	12 12	19 15	06 49	09	
24	11 55	12 02	12 12	20 10	07 42	10	

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Sight Reduction Table

INCREMENTS AND CORRECTIONS

2m

2m	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	0 30·0	0 30·1	0 28·6	0·0	0·0	6·0	0·3	12·0	0·5
01	0 30·3	0 30·3	0 28·7	0·1	0·0	6·1	0·3	12·1	0·5
02	0 30·5	0 30·6	0 29·1	0·2	0·0	6·2	0·3	12·2	0·5
03	0 30·8	0 30·8	0 29·3	0·3	0·0	6·3	0·3	12·3	0·5
04	0 31·0	0 31·1	0 29·6	0·4	0·0	6·4	0·3	12·4	0·5
05	0 31·3	0 31·3	0 29·8	0·5	0·0	6·5	0·3	12·5	0·5
06	0 31·5	0 31·6	0 30·1	0·6	0·0	6·6	0·3	12·6	0·5
07	0 31·8	0 31·8	0 30·3	0·7	0·0	6·7	0·3	12·7	0·5
08	0 32·0	0 32·1	0 30·5	0·8	0·0	6·8	0·3	12·8	0·5
09	0 32·3	0 32·3	0 30·8	0·9	0·0	6·9	0·3	12·9	0·5
10	0 32·5	0 32·6	0 31·0	1·0	0·0	7·0	0·3	13·0	0·5
11	0 32·8	0 32·8	0 31·3	1·1	0·0	7·1	0·3	13·1	0·5
12	0 33·0	0 33·1	0 31·5	1·2	0·1	7·2	0·3	13·2	0·6
13	0 33·3	0 33·3	0 31·7	1·3	0·1	7·3	0·3	13·3	0·6
14	0 33·5	0 33·6	0 32·0	1·4	0·1	7·4	0·3	13·4	0·6
15	0 33·8	0 33·8	0 32·2	1·5	0·1	7·5	0·3	13·5	0·6
16	0 34·0	0 34·1	0 32·5	1·6	0·1	7·6	0·3	13·6	0·6
17	0 34·3	0 34·3	0 32·7	1·7	0·1	7·7	0·3	13·7	0·6
18	0 34·5	0 34·6	0 32·9	1·8	0·1	7·8	0·3	13·8	0·6
19	0 34·8	0 34·8	0 33·2	1·9	0·1	7·9	0·3	13·9	0·6
20	0 35·0	0 35·1	0 33·4	2·0	0·1	8·0	0·3	14·0	0·6
21	0 35·3	0 35·3	0 33·6	2·1	0·1	8·1	0·3	14·1	0·6
22	0 35·5	0 35·6	0 33·9	2·2	0·1	8·2	0·3	14·2	0·6
23	0 35·8	0 35·8	0 34·1	2·3	0·1	8·3	0·3	14·3	0·6
24	0 36·0	0 36·1	0 34·4	2·4	0·1	8·4	0·4	14·4	0·6
25	0 36·3	0 36·3	0 34·6	2·5	0·1	8·5	0·4	14·5	0·6
26	0 36·5	0 36·6	0 34·8	2·6	0·1	8·6	0·4	14·6	0·6
27	0 36·8	0 36·9	0 35·1	2·7	0·1	8·7	0·4	14·7	0·6
28	0 37·0	0 37·1	0 35·3	2·8	0·1	8·8	0·4	14·8	0·6
29	0 37·3	0 37·4	0 35·6	2·9	0·1	8·9	0·4	14·9	0·6
30	0 37·5	0 37·6	0 35·8	3·0	0·1	9·0	0·4	15·0	0·6
31	0 37·8	0 37·9	0 36·0	3·1	0·1	9·1	0·4	15·1	0·6
32	0 38·0	0 38·1	0 36·3	3·2	0·1	9·2	0·4	15·2	0·6
33	0 38·3	0 38·4	0 36·5	3·3	0·1	9·3	0·4	15·3	0·6
34	0 38·5	0 38·6	0 36·7	3·4	0·1	9·4	0·4	15·4	0·6
35	0 38·8	0 38·9	0 37·0	3·5	0·1	9·5	0·4	15·5	0·6
36	0 39·0	0 39·1	0 37·2	3·6	0·2	9·6	0·4	15·6	0·7
37	0 39·3	0 39·4	0 37·5	3·7	0·2	9·7	0·4	15·7	0·7
38	0 39·5	0 39·6	0 37·7	3·8	0·2	9·8	0·4	15·8	0·7
39	0 39·8	0 39·9	0 37·9	3·9	0·2	9·9	0·4	15·9	0·7
40	0 40·0	0 40·1	0 38·2	4·0	0·2	10·0	0·4	16·0	0·7
41	0 40·3	0 40·4	0 38·4	4·1	0·2	10·1	0·4	16·1	0·7
42	0 40·5	0 40·6	0 38·7	4·2	0·2	10·2	0·4	16·2	0·7
43	0 40·8	0 40·9	0 38·9	4·3	0·2	10·3	0·4	16·3	0·7
44	0 41·0	0 41·1	0 39·1	4·4	0·2	10·4	0·4	16·4	0·7
45	0 41·3	0 41·4	0 39·4	4·5	0·2	10·5	0·4	16·5	0·7
46	0 41·5	0 41·6	0 39·6	4·6	0·2	10·6	0·4	16·6	0·7
47	0 41·8	0 41·9	0 39·8	4·7	0·2	10·7	0·4	16·7	0·7
48	0 42·0	0 42·1	0 40·1	4·8	0·2	10·8	0·5	16·8	0·7
49	0 42·3	0 42·4	0 40·3	4·9	0·2	10·9	0·5	16·9	0·7
50	0 42·5	0 42·6	0 40·6	5·0	0·2	11·0	0·5	17·0	0·7
51	0 42·8	0 42·9	0 40·8	5·1	0·2	11·1	0·5	17·1	0·7
52	0 43·0	0 43·1	0 41·0	5·2	0·2	11·2	0·5	17·2	0·7
53	0 43·3	0 43·4	0 41·3	5·3	0·2	11·3	0·5	17·3	0·7
54	0 43·5	0 43·6	0 41·5	5·4	0·2	11·4	0·5	17·4	0·7
55	0 43·8	0 43·9	0 41·8	5·5	0·2	11·5	0·5	17·5	0·7
56	0 44·0	0 44·1	0 42·0	5·6	0·2	11·6	0·5	17·6	0·7
57	0 44·3	0 44·4	0 42·2	5·7	0·2	11·7	0·5	17·7	0·7
58	0 44·5	0 44·6	0 42·5	5·8	0·2	11·8	0·5	17·8	0·7
59	0 44·8	0 44·9	0 42·7	5·9	0·2	11·9	0·5	17·9	0·7
60	0 45·0	0 45·1	0 43·0	6·0	0·3	12·0	0·5	18·0	0·8

3m

3m	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	0 45·0	0 45·1	0 43·0	0·0	0·0	6·0	0·4	12·0	0·7
01	0 45·3	0 45·4	0 43·2	0·1	0·0	6·1	0·4	12·1	0·7
02	0 45·5	0 45·6	0 43·4	0·2	0·0	6·2	0·4	12·2	0·7
03	0 45·8	0 45·9	0 43·7	0·3	0·0	6·3	0·4	12·3	0·7
04	0 46·0	0 46·1	0 43·9	0·4	0·0	6·4	0·4	12·4	0·7
05	0 46·3	0 46·4	0 44·1	0·5	0·0	6·5	0·4	12·5	0·7
06	0 46·5	0 46·6	0 44·4	0·6	0·0	6·6	0·4	12·6	0·7
07	0 46·8	0 46·9	0 44·6	0·7	0·0	6·7	0·4	12·7	0·7
08	0 47·0	0 47·1	0 44·9	0·8	0·0	6·8	0·4	12·8	0·7
09	0 47·3	0 47·4	0 45·1	0·9	0·1	6·9	0·4	12·9	0·8
10	0 47·5	0 47·6	0 45·3	1·0	0·1	7·0	0·4	13·0	0·8
11	0 47·8	0 47·9	0 45·6	1·1	0·1	7·1	0·4	13·1	0·8
12	0 48·0	0 48·1	0 45·8	1·2	0·1	7·2	0·4	13·2	0·8
13	0 48·3	0 48·4	0 46·1	1·3	0·1	7·3	0·4	13·3	0·8
14	0 48·5	0 48·6	0 46·3	1·4	0·1	7·4	0·4	13·4	0·8
15	0 48·8	0 48·9	0 46·5	1·5	0·1	7·5	0·4	13·5	0·8
16	0 49·0	0 49·1	0 46·8	1·6	0·1	7·6	0·4	13·6	0·8
17	0 49·3	0 49·4	0 47·0	1·7	0·1	7·7	0·4	13·7	0·8
18	0 49·5	0 49·6	0 47·2	1·8	0·1	7·8	0·5	13·8	0·8
19	0 49·8	0 49·9	0 47·5	1·9	0·1	7·9	0·5	13·9	0·8
20	0 50·0	0 50·1	0 47·7	2·0	0·1	8·0	0·5	14·0	0·8
21	0 50·3	0 50·4	0 48·0	2·1	0·1	8·1	0·5	14·1	0·8
22	0 50·5	0 50·6	0 48·2	2·2	0·1	8·2	0·5	14·2	0·8
23	0 50·8	0 50·9	0 48·4	2·3	0·1	8·3	0·5	14·3	0·8
24	0 51·0	0 51·1	0 48·7	2·4	0·1	8·4	0·5	14·4	0·8
25	0 51·3	0 51·4	0 48·9	2·5	0·1	8·5	0·5	14·5	0·8
26	0 51·5	0 51·6	0 49·2	2·6	0·2	8·6	0·5	14·6	0·9
27	0 51·8	0 51·9	0 49·4	2·7	0·2	8·7	0·5	14·7	0·9
28	0 52·0	0 52·1	0 49·6	2·8	0·2	8·8	0·5	14·8	0·9
29	0 52·3	0 52·4	0 49·9	2·9	0·2	8·9	0·5	14·9	0·9
30	0 52·5	0 52·6	0 50·1	3·0	0·2	9·0	0·5	15·0	0·9
31	0 52·8	0 52·9	0 50·3	3·1	0·2	9·1	0·5	15·1	0·9
32	0 53·0	0 53·1	0 50·6	3·2	0·2	9·2	0·5	15·2	0·9
33	0 53·3	0 53·4	0 50·8	3·3	0·2	9·3	0·5	15·3	0·9
34	0 53·5	0 53·6	0 51·1	3·4	0·2	9·4	0·5	15·4	0·9
35	0 53·8	0 53·9	0 51·3	3·5	0·2	9·5	0·6	15·5	0·9
36	0 54·0	0 54·1	0 51·5	3·6	0·2	9·6	0·6	15·6	0·9
37	0 54·3	0 54·4	0 51·8	3·7	0·2	9·7	0·6	15·7	0·9
38	0 54·5	0 54·6	0 52·0	3·8	0·2	9·8	0·6	15·8	0·9
39	0 54·8	0 54·9	0 52·3	3·9	0·2	9·9	0·6	15·9	0·9
40	0 55·0	0 55·2	0 52·5	4·0	0·2	10·0	0·6	16·0	0·9
41	0 55·3	0 55·4	0 52·7	4·1	0·2	10·1	0·6	16·1	0·9
42	0 55·5	0 55·7	0 53·0	4·2	0·2	10·2	0·6	16·2	0·9
43	0 55·8	0 55·9	0 53·2	4·3	0·3	10·3	0·6	16·3	1·0
44	0 56·0	0 56·2	0 53·4	4·4	0·3	10·4	0·6	16·4	1·0
45	0 56·3	0 56·4	0 53·7	4·5	0·3	10·5	0·6	16·5	1·0
46	0 56·5	0 56·7	0 53·9	4·6	0·3	10·6	0·6	16·6	1·0
47	0 56·8	0 56·9	0 54·2	4·7	0·3	10·7	0·6	16·7	1·0
48	0 57·0	0 57·2	0 54·4	4·8	0·3	10·8	0·6	16·8	1·0
49	0 57·3	0 57·4	0 54·6	4·9	0·3	10·9	0·6	16·9	1·0
50	0 57·5	0 57·7	0 54·9	5·0	0·3	11·0	0·6	17·0	1·0
51	0 57·8	0 57·9	0 55·1	5·1	0·3	11·1	0·6	17·1	1·0
52	0 58·0	0 58·2	0 55·4	5·2	0·3	11·2	0·7	17·2	1·0
53	0 58·3	0 58·4	0 55·6	5·3	0·3	11·3	0·7	17·3	1·0
54	0 58·5	0 58·7	0 55·8	5·4	0·3	11·4	0·7	17·4	1·0
55	0 58·8	0 58·9	0 56·1	5·5	0·3	11·5	0·7	17·5	1·0
56	0 59·0	0 59·2	0 56·3	5·6	0·3	11·6	0·7	17·6	1·0
57	0 59·3	0 59·4	0 56·6	5·7	0·3	11·7	0·7	17·7	1·0
58	0 59·5	0 59·7	0 56·8	5·8	0·3	11·8	0·7	17·8	1·0
59	0 59·8	0 59·9	0 57·0	5·9	0·3	11·9	0·7	17·9	1·0
60	1 00·0	1 00·2	0 57·3	6·0	0·4	12·0	0·7	18·0	1·1

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Sight Reduction Table

INCREMENTS AND CORRECTIONS

46ᵐ

46ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	11 30·0	11 31·9	10 58·6	0·0	0·0	6·0	4·7	12·0	9·3
01	11 30·3	11 32·1	10 58·8	0·1	0·1	6·1	4·7	12·1	9·4
02	11 30·5	11 32·4	10 59·0	0·2	0·2	6·2	4·8	12·2	9·5
03	11 30·8	11 32·6	10 59·3	0·3	0·2	6·3	4·9	12·3	9·5
04	11 31·0	11 32·9	10 59·5	0·4	0·3	6·4	5·0	12·4	9·6
05	11 31·3	11 33·1	10 59·8	0·5	0·4	6·5	5·0	12·5	9·7
06	11 31·5	11 33·4	11 00·0	0·6	0·5	6·6	5·1	12·6	9·8
07	11 31·8	11 33·6	11 00·2	0·7	0·5	6·7	5·2	12·7	9·8
08	11 32·0	11 33·9	11 00·5	0·8	0·6	6·8	5·3	12·8	9·9
09	11 32·3	11 34·1	11 00·7	0·9	0·7	6·9	5·3	12·9	10·0
10	11 32·5	11 34·4	11 01·0	1·0	0·8	7·0	5·4	13·0	10·1
11	11 32·8	11 34·6	11 01·2	1·1	0·9	7·1	5·5	13·1	10·2
12	11 33·0	11 34·9	11 01·4	1·2	0·9	7·2	5·6	13·2	10·2
13	11 33·3	11 35·1	11 01·7	1·3	1·0	7·3	5·7	13·3	10·3
14	11 33·5	11 35·4	11 01·9	1·4	1·1	7·4	5·7	13·4	10·4
15	11 33·8	11 35·6	11 02·1	1·5	1·2	7·5	5·8	13·5	10·5
16	11 34·0	11 35·9	11 02·4	1·6	1·2	7·6	5·9	13·6	10·5
17	11 34·3	11 36·2	11 02·6	1·7	1·3	7·7	6·0	13·7	10·6
18	11 34·5	11 36·4	11 02·9	1·8	1·4	7·8	6·0	13·8	10·7
19	11 34·8	11 36·7	11 03·1	1·9	1·5	7·9	6·1	13·9	10·8
20	11 35·0	11 36·9	11 03·3	2·0	1·6	8·0	6·2	14·0	10·9
21	11 35·3	11 37·2	11 03·6	2·1	1·6	8·1	6·3	14·1	10·9
22	11 35·5	11 37·4	11 03·8	2·2	1·7	8·2	6·4	14·2	11·0
23	11 35·8	11 37·7	11 04·1	2·3	1·8	8·3	6·4	14·3	11·1
24	11 36·0	11 37·9	11 04·3	2·4	1·9	8·4	6·5	14·4	11·2
25	11 36·3	11 38·2	11 04·5	2·5	1·9	8·5	6·6	14·5	11·2
26	11 36·5	11 38·4	11 04·8	2·6	2·0	8·6	6·7	14·6	11·3
27	11 36·8	11 38·7	11 05·0	2·7	2·1	8·7	6·7	14·7	11·4
28	11 37·0	11 38·9	11 05·2	2·8	2·2	8·8	6·8	14·8	11·5
29	11 37·3	11 39·2	11 05·5	2·9	2·2	8·9	6·9	14·9	11·5
30	11 37·5	11 39·4	11 05·7	3·0	2·3	9·0	7·0	15·0	11·6
31	11 37·8	11 39·7	11 06·0	3·1	2·4	9·1	7·1	15·1	11·7
32	11 38·0	11 39·9	11 06·2	3·2	2·5	9·2	7·1	15·2	11·8
33	11 38·3	11 40·2	11 06·4	3·3	2·6	9·3	7·2	15·3	11·9
34	11 38·5	11 40·4	11 06·7	3·4	2·6	9·4	7·3	15·4	11·9
35	11 38·8	11 40·7	11 06·9	3·5	2·7	9·5	7·4	15·5	12·0
36	11 39·0	11 40·9	11 07·2	3·6	2·8	9·6	7·4	15·6	12·1
37	11 39·3	11 41·2	11 07·4	3·7	2·9	9·7	7·5	15·7	12·2
38	11 39·5	11 41·4	11 07·6	3·8	2·9	9·8	7·6	15·8	12·2
39	11 39·8	11 41·7	11 07·9	3·9	3·0	9·9	7·7	15·9	12·3
40	11 40·0	11 41·9	11 08·1	4·0	3·1	10·0	7·8	16·0	12·4
41	11 40·3	11 42·2	11 08·3	4·1	3·2	10·1	7·8	16·1	12·5
42	11 40·5	11 42·4	11 08·6	4·2	3·3	10·2	7·9	16·2	12·6
43	11 40·8	11 42·7	11 08·8	4·3	3·3	10·3	8·0	16·3	12·6
44	11 41·0	11 42·9	11 09·1	4·4	3·4	10·4	8·1	16·4	12·7
45	11 41·3	11 43·2	11 09·3	4·5	3·5	10·5	8·1	16·5	12·8
46	11 41·5	11 43·4	11 09·5	4·6	3·6	10·6	8·2	16·6	12·9
47	11 41·8	11 43·7	11 09·8	4·7	3·6	10·7	8·3	16·7	12·9
48	11 42·0	11 43·9	11 10·0	4·8	3·7	10·8	8·4	16·8	13·0
49	11 42·3	11 44·2	11 10·3	4·9	3·8	10·9	8·4	16·9	13·1
50	11 42·5	11 44·4	11 10·5	5·0	3·9	11·0	8·5	17·0	13·2
51	11 42·8	11 44·7	11 10·7	5·1	4·0	11·1	8·6	17·1	13·3
52	11 43·0	11 44·9	11 11·0	5·2	4·0	11·2	8·7	17·2	13·3
53	11 43·3	11 45·2	11 11·2	5·3	4·1	11·3	8·8	17·3	13·4
54	11 43·5	11 45·4	11 11·5	5·4	4·2	11·4	8·8	17·4	13·5
55	11 43·8	11 45·7	11 11·7	5·5	4·3	11·5	8·9	17·5	13·6
56	11 44·0	11 45·9	11 11·9	5·6	4·3	11·6	9·0	17·6	13·6
57	11 44·3	11 46·2	11 12·2	5·7	4·4	11·7	9·1	17·7	13·7
58	11 44·5	11 46·4	11 12·4	5·8	4·5	11·8	9·1	17·8	13·8
59	11 44·8	11 46·7	11 12·6	5·9	4·6	11·9	9·2	17·9	13·9
60	11 45·0	11 46·9	11 12·9	6·0	4·7	12·0	9·3	18·0	14·0

47ᵐ

47ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	11 45·0	11 46·9	11 12·9	0·0	0·0	6·0	4·8	12·0	9·5
01	11 45·3	11 47·2	11 13·1	0·1	0·1	6·1	4·8	12·1	9·6
02	11 45·5	11 47·4	11 13·4	0·2	0·2	6·2	4·9	12·2	9·7
03	11 45·8	11 47·7	11 13·6	0·3	0·2	6·3	5·0	12·3	9·7
04	11 46·0	11 47·9	11 13·8	0·4	0·3	6·4	5·1	12·4	9·8
05	11 46·3	11 48·2	11 14·1	0·5	0·4	6·5	5·1	12·5	9·9
06	11 46·5	11 48·4	11 14·3	0·6	0·5	6·6	5·2	12·6	10·0
07	11 46·8	11 48·7	11 14·6	0·7	0·6	6·7	5·3	12·7	10·1
08	11 47·0	11 48·9	11 14·8	0·8	0·6	6·8	5·4	12·8	10·1
09	11 47·3	11 49·2	11 15·0	0·9	0·7	6·9	5·5	12·9	10·2
10	11 47·5	11 49·4	11 15·3	1·0	0·8	7·0	5·5	13·0	10·3
11	11 47·8	11 49·7	11 15·5	1·1	0·9	7·1	5·6	13·1	10·4
12	11 48·0	11 49·9	11 15·7	1·2	1·0	7·2	5·7	13·2	10·5
13	11 48·3	11 50·2	11 16·0	1·3	1·0	7·3	5·8	13·3	10·5
14	11 48·5	11 50·4	11 16·2	1·4	1·1	7·4	5·9	13·4	10·6
15	11 48·8	11 50·7	11 16·5	1·5	1·2	7·5	5·9	13·5	10·7
16	11 49·0	11 50·9	11 16·7	1·6	1·3	7·6	6·0	13·6	10·8
17	11 49·3	11 51·2	11 16·9	1·7	1·3	7·7	6·1	13·7	10·8
18	11 49·5	11 51·4	11 17·2	1·8	1·4	7·8	6·2	13·8	10·9
19	11 49·8	11 51·7	11 17·4	1·9	1·5	7·9	6·3	13·9	11·0
20	11 50·0	11 51·9	11 17·7	2·0	1·6	8·0	6·3	14·0	11·1
21	11 50·3	11 52·2	11 17·9	2·1	1·7	8·1	6·4	14·1	11·2
22	11 50·5	11 52·4	11 18·1	2·2	1·7	8·2	6·5	14·2	11·2
23	11 50·8	11 52·7	11 18·4	2·3	1·8	8·3	6·6	14·3	11·3
24	11 51·0	11 52·9	11 18·6	2·4	1·9	8·4	6·7	14·4	11·4
25	11 51·3	11 53·2	11 18·8	2·5	2·0	8·5	6·7	14·5	11·5
26	11 51·5	11 53·4	11 19·1	2·6	2·1	8·6	6·8	14·6	11·6
27	11 51·8	11 53·7	11 19·3	2·7	2·1	8·7	6·9	14·7	11·6
28	11 52·0	11 53·9	11 19·6	2·8	2·2	8·8	7·0	14·8	11·7
29	11 52·3	11 54·2	11 19·8	2·9	2·3	8·9	7·0	14·9	11·8
30	11 52·5	11 54·5	11 20·0	3·0	2·4	9·0	7·1	15·0	11·9
31	11 52·8	11 54·7	11 20·3	3·1	2·5	9·1	7·2	15·1	12·0
32	11 53·0	11 55·0	11 20·5	3·2	2·5	9·2	7·3	15·2	12·0
33	11 53·3	11 55·2	11 20·8	3·3	2·6	9·3	7·4	15·3	12·1
34	11 53·5	11 55·5	11 21·0	3·4	2·7	9·4	7·4	15·4	12·2
35	11 53·8	11 55·7	11 21·2	3·5	2·8	9·5	7·5	15·5	12·3
36	11 54·0	11 56·0	11 21·5	3·6	2·9	9·6	7·6	15·6	12·4
37	11 54·3	11 56·2	11 21·7	3·7	2·9	9·7	7·7	15·7	12·4
38	11 54·5	11 56·5	11 22·0	3·8	3·0	9·8	7·8	15·8	12·5
39	11 54·8	11 56·7	11 22·2	3·9	3·1	9·9	7·8	15·9	12·6
40	11 55·0	11 57·0	11 22·4	4·0	3·2	10·0	7·9	16·0	12·7
41	11 55·3	11 57·2	11 22·7	4·1	3·2	10·1	8·0	16·1	12·7
42	11 55·5	11 57·5	11 22·9	4·2	3·3	10·2	8·1	16·2	12·8
43	11 55·8	11 57·7	11 23·1	4·3	3·4	10·3	8·2	16·3	12·9
44	11 56·0	11 58·0	11 23·4	4·4	3·5	10·4	8·2	16·4	13·0
45	11 56·3	11 58·2	11 23·6	4·5	3·6	10·5	8·3	16·5	13·1
46	11 56·5	11 58·5	11 23·9	4·6	3·6	10·6	8·4	16·6	13·1
47	11 56·8	11 58·7	11 24·1	4·7	3·7	10·7	8·5	16·7	13·2
48	11 57·0	11 59·0	11 24·3	4·8	3·8	10·8	8·6	16·8	13·3
49	11 57·3	11 59·2	11 24·6	4·9	3·9	10·9	8·6	16·9	13·4
50	11 57·5	11 59·5	11 24·8	5·0	4·0	11·0	8·7	17·0	13·5
51	11 57·8	11 59·7	11 25·1	5·1	4·0	11·1	8·8	17·1	13·5
52	11 58·0	12 00·0	11 25·3	5·2	4·1	11·2	8·9	17·2	13·6
53	11 58·3	12 00·2	11 25·5	5·3	4·2	11·3	8·9	17·3	13·7
54	11 58·5	12 00·5	11 25·8	5·4	4·3	11·4	9·0	17·4	13·8
55	11 58·8	12 00·7	11 26·0	5·5	4·4	11·5	9·1	17·5	13·9
56	11 59·0	12 01·0	11 26·2	5·6	4·4	11·6	9·2	17·6	13·9
57	11 59·3	12 01·2	11 26·5	5·7	4·5	11·7	9·3	17·7	14·0
58	11 59·5	12 01·5	11 26·7	5·8	4·6	11·8	9·3	17·8	14·1
59	11 59·8	12 01·7	11 27·0	5·9	4·7	11·9	9·4	17·9	14·2
60	12 00·0	12 02·0	11 27·2	6·0	4·8	12·0	9·5	18·0	14·3

Sight Reduction Table

48m INCREMENTS AND CORRECTIONS 49m

48 s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corr^n ′	v or d ′	Corr^n ′	v or d ′	Corr^n ′
00	12 00·0	12 02·0	11 27·2	0·0	0·0	6·0	4·9	12·0	9·7
01	12 00·3	12 02·2	11 27·4	0·1	0·1	6·1	4·9	12·1	9·8
02	12 00·5	12 02·5	11 27·7	0·2	0·2	6·2	5·0	12·2	9·9
03	12 00·8	12 02·7	11 27·9	0·3	0·2	6·3	5·1	12·3	9·9
04	12 01·0	12 03·0	11 28·2	0·4	0·3	6·4	5·2	12·4	10·0
05	12 01·3	12 03·2	11 28·4	0·5	0·4	6·5	5·3	12·5	10·1
06	12 01·5	12 03·5	11 28·6	0·6	0·5	6·6	5·3	12·6	10·2
07	12 01·8	12 03·7	11 28·9	0·7	0·6	6·7	5·4	12·7	10·3
08	12 02·0	12 04·0	11 29·1	0·8	0·6	6·8	5·5	12·8	10·3
09	12 02·3	12 04·2	11 29·3	0·9	0·7	6·9	5·6	12·9	10·4
10	12 02·5	12 04·5	11 29·6	1·0	0·8	7·0	5·7	13·0	10·5
11	12 02·8	12 04·7	11 29·8	1·1	0·9	7·1	5·7	13·1	10·6
12	12 03·0	12 05·0	11 30·1	1·2	1·0	7·2	5·8	13·2	10·7
13	12 03·3	12 05·2	11 30·3	1·3	1·1	7·3	5·9	13·3	10·8
14	12 03·5	12 05·5	11 30·5	1·4	1·1	7·4	6·0	13·4	10·8
15	12 03·8	12 05·7	11 30·8	1·5	1·2	7·5	6·1	13·5	10·9
16	12 04·0	12 06·0	11 31·0	1·6	1·3	7·6	6·1	13·6	11·0
17	12 04·3	12 06·2	11 31·3	1·7	1·4	7·7	6·2	13·7	11·1
18	12 04·5	12 06·5	11 31·5	1·8	1·5	7·8	6·3	13·8	11·2
19	12 04·8	12 06·7	11 31·7	1·9	1·5	7·9	6·4	13·9	11·2
20	12 05·0	12 07·0	11 32·0	2·0	1·6	8·0	6·5	14·0	11·3
21	12 05·3	12 07·2	11 32·2	2·1	1·7	8·1	6·5	14·1	11·4
22	12 05·5	12 07·5	11 32·4	2·2	1·8	8·2	6·6	14·2	11·5
23	12 05·8	12 07·7	11 32·7	2·3	1·9	8·3	6·7	14·3	11·6
24	12 06·0	12 08·0	11 32·9	2·4	1·9	8·4	6·8	14·4	11·6
25	12 06·3	12 08·2	11 33·2	2·5	2·0	8·5	6·9	14·5	11·7
26	12 06·5	12 08·5	11 33·4	2·6	2·1	8·6	7·0	14·6	11·8
27	12 06·8	12 08·7	11 33·6	2·7	2·2	8·7	7·0	14·7	11·9
28	12 07·0	12 09·0	11 33·9	2·8	2·3	8·8	7·1	14·8	12·0
29	12 07·3	12 09·2	11 34·1	2·9	2·3	8·9	7·2	14·9	12·0
30	12 07·5	12 09·5	11 34·4	3·0	2·4	9·0	7·3	15·0	12·1
31	12 07·8	12 09·7	11 34·6	3·1	2·5	9·1	7·4	15·1	12·2
32	12 08·0	12 10·0	11 34·8	3·2	2·6	9·2	7·4	15·2	12·3
33	12 08·3	12 10·2	11 35·1	3·3	2·7	9·3	7·5	15·3	12·4
34	12 08·5	12 10·5	11 35·3	3·4	2·7	9·4	7·6	15·4	12·4
35	12 08·8	12 10·7	11 35·6	3·5	2·8	9·5	7·7	15·5	12·5
36	12 09·0	12 11·0	11 35·8	3·6	2·9	9·6	7·8	15·6	12·6
37	12 09·3	12 11·2	11 36·0	3·7	3·0	9·7	7·8	15·7	12·7
38	12 09·5	12 11·5	11 36·3	3·8	3·1	9·8	7·9	15·8	12·8
39	12 09·8	12 11·7	11 36·5	3·9	3·2	9·9	8·0	15·9	12·9
40	12 10·0	12 12·0	11 36·7	4·0	3·2	10·0	8·1	16·0	12·9
41	12 10·3	12 12·2	11 37·0	4·1	3·3	10·1	8·2	16·1	13·0
42	12 10·5	12 12·5	11 37·2	4·2	3·4	10·2	8·2	16·2	13·1
43	12 10·8	12 12·8	11 37·5	4·3	3·5	10·3	8·3	16·3	13·2
44	12 11·0	12 13·0	11 37·7	4·4	3·6	10·4	8·4	16·4	13·3
45	12 11·3	12 13·3	11 37·9	4·5	3·6	10·5	8·5	16·5	13·3
46	12 11·5	12 13·5	11 38·2	4·6	3·7	10·6	8·6	16·6	13·4
47	12 11·8	12 13·8	11 38·4	4·7	3·8	10·7	8·6	16·7	13·5
48	12 12·0	12 14·0	11 38·7	4·8	3·9	10·8	8·7	16·8	13·6
49	12 12·3	12 14·3	11 38·9	4·9	4·0	10·9	8·8	16·9	13·7
50	12 12·5	12 14·5	11 39·1	5·0	4·0	11·0	8·9	17·0	13·7
51	12 12·8	12 14·8	11 39·4	5·1	4·1	11·1	9·0	17·1	13·8
52	12 13·0	12 15·0	11 39·6	5·2	4·2	11·2	9·1	17·2	13·9
53	12 13·3	12 15·3	11 39·8	5·3	4·3	11·3	9·1	17·3	14·0
54	12 13·5	12 15·5	11 40·1	5·4	4·4	11·4	9·2	17·4	14·1
55	12 13·8	12 15·8	11 40·3	5·5	4·4	11·5	9·3	17·5	14·1
56	12 14·0	12 16·0	11 40·6	5·6	4·5	11·6	9·4	17·6	14·2
57	12 14·3	12 16·3	11 40·8	5·7	4·6	11·7	9·5	17·7	14·3
58	12 14·5	12 16·5	11 41·0	5·8	4·7	11·8	9·5	17·8	14·4
59	12 14·8	12 16·8	11 41·3	5·9	4·8	11·9	9·6	17·9	14·5
60	12 15·0	12 17·0	11 41·5	6·0	4·9	12·0	9·7	18·0	14·6

49 s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corr^n ′	v or d ′	Corr^n ′	v or d ′	Corr^n ′
00	12 15·0	12 17·0	11 41·5	0·0	0·0	6·0	5·0	12·0	9·9
01	12 15·3	12 17·3	11 41·8	0·1	0·1	6·1	5·0	12·1	10·0
02	12 15·5	12 17·5	11 42·0	0·2	0·2	6·2	5·1	12·2	10·1
03	12 15·8	12 17·8	11 42·2	0·3	0·2	6·3	5·2	12·3	10·1
04	12 16·0	12 18·0	11 42·5	0·4	0·3	6·4	5·3	12·4	10·2
05	12 16·3	12 18·3	11 42·7	0·5	0·4	6·5	5·4	12·5	10·3
06	12 16·5	12 18·5	11 42·9	0·6	0·5	6·6	5·4	12·6	10·4
07	12 16·8	12 18·8	11 43·2	0·7	0·6	6·7	5·5	12·7	10·5
08	12 17·0	12 19·0	11 43·4	0·8	0·7	6·8	5·6	12·8	10·6
09	12 17·3	12 19·3	11 43·7	0·9	0·7	6·9	5·7	12·9	10·6
10	12 17·5	12 19·5	11 43·9	1·0	0·8	7·0	5·8	13·0	10·7
11	12 17·8	12 19·8	11 44·1	1·1	0·9	7·1	5·9	13·1	10·8
12	12 18·0	12 20·0	11 44·4	1·2	1·0	7·2	5·9	13·2	10·9
13	12 18·3	12 20·3	11 44·6	1·3	1·1	7·3	6·0	13·3	11·0
14	12 18·5	12 20·5	11 44·9	1·4	1·2	7·4	6·1	13·4	11·1
15	12 18·8	12 20·8	11 45·1	1·5	1·2	7·5	6·2	13·5	11·1
16	12 19·0	12 21·0	11 45·3	1·6	1·3	7·6	6·3	13·6	11·2
17	12 19·3	12 21·3	11 45·6	1·7	1·4	7·7	6·4	13·7	11·3
18	12 19·5	12 21·5	11 45·8	1·8	1·5	7·8	6·4	13·8	11·4
19	12 19·8	12 21·8	11 46·1	1·9	1·6	7·9	6·5	13·9	11·5
20	12 20·0	12 22·0	11 46·3	2·0	1·7	8·0	6·6	14·0	11·6
21	12 20·3	12 22·3	11 46·5	2·1	1·7	8·1	6·7	14·1	11·6
22	12 20·5	12 22·5	11 46·8	2·2	1·8	8·2	6·8	14·2	11·7
23	12 20·8	12 22·8	11 47·0	2·3	1·9	8·3	6·8	14·3	11·8
24	12 21·0	12 23·0	11 47·2	2·4	2·0	8·4	6·9	14·4	11·9
25	12 21·3	12 23·3	11 47·5	2·5	2·1	8·5	7·0	14·5	12·0
26	12 21·5	12 23·5	11 47·7	2·6	2·1	8·6	7·1	14·6	12·0
27	12 21·8	12 23·8	11 48·0	2·7	2·2	8·7	7·2	14·7	12·1
28	12 22·0	12 24·0	11 48·2	2·8	2·3	8·8	7·3	14·8	12·2
29	12 22·3	12 24·3	11 48·4	2·9	2·4	8·9	7·3	14·9	12·3
30	12 22·5	12 24·5	11 48·7	3·0	2·5	9·0	7·4	15·0	12·4
31	12 22·8	12 24·8	11 48·9	3·1	2·6	9·1	7·5	15·1	12·5
32	12 23·0	12 25·0	11 49·2	3·2	2·6	9·2	7·6	15·2	12·5
33	12 23·3	12 25·3	11 49·4	3·3	2·7	9·3	7·7	15·3	12·6
34	12 23·5	12 25·5	11 49·6	3·4	2·8	9·4	7·8	15·4	12·7
35	12 23·8	12 25·8	11 49·9	3·5	2·9	9·5	7·8	15·5	12·8
36	12 24·0	12 26·0	11 50·1	3·6	3·0	9·6	7·9	15·6	12·9
37	12 24·3	12 26·3	11 50·3	3·7	3·1	9·7	8·0	15·7	13·0
38	12 24·5	12 26·5	11 50·6	3·8	3·1	9·8	8·1	15·8	13·0
39	12 24·8	12 26·8	11 50·8	3·9	3·2	9·9	8·2	15·9	13·1
40	12 25·0	12 27·0	11 51·1	4·0	3·3	10·0	8·3	16·0	13·2
41	12 25·3	12 27·3	11 51·3	4·1	3·4	10·1	8·3	16·1	13·3
42	12 25·5	12 27·5	11 51·5	4·2	3·5	10·2	8·4	16·2	13·4
43	12 25·8	12 27·8	11 51·8	4·3	3·5	10·3	8·5	16·3	13·4
44	12 26·0	12 28·0	11 52·0	4·4	3·6	10·4	8·6	16·4	13·5
45	12 26·3	12 28·3	11 52·3	4·5	3·7	10·5	8·7	16·5	13·6
46	12 26·5	12 28·5	11 52·5	4·6	3·8	10·6	8·7	16·6	13·7
47	12 26·8	12 28·8	11 52·7	4·7	3·9	10·7	8·8	16·7	13·8
48	12 27·0	12 29·0	11 53·0	4·8	4·0	10·8	8·9	16·8	13·9
49	12 27·3	12 29·3	11 53·2	4·9	4·0	10·9	9·0	16·9	13·9
50	12 27·5	12 29·5	11 53·4	5·0	4·1	11·0	9·1	17·0	14·0
51	12 27·8	12 29·8	11 53·7	5·1	4·2	11·1	9·2	17·1	14·1
52	12 28·0	12 30·0	11 53·9	5·2	4·3	11·2	9·2	17·2	14·2
53	12 28·3	12 30·3	11 54·2	5·3	4·4	11·3	9·3	17·3	14·3
54	12 28·5	12 30·5	11 54·4	5·4	4·5	11·4	9·4	17·4	14·4
55	12 28·8	12 30·8	11 54·6	5·5	4·5	11·5	9·5	17·5	14·4
56	12 29·0	12 31·1	11 54·9	5·6	4·6	11·6	9·6	17·6	14·5
57	12 29·3	12 31·3	11 55·1	5·7	4·7	11·7	9·7	17·7	14·6
58	12 29·5	12 31·6	11 55·4	5·8	4·8	11·8	9·7	17·8	14·7
59	12 29·8	12 31·8	11 55·6	5·9	4·9	11·9	9·8	17·9	14·8
60	12 30·0	12 32·1	11 55·8	6·0	5·0	12·0	9·9	18·0	14·9

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Sight Reduction Table

54ᵐ INCREMENTS AND CORRECTIONS 55ᵐ

54ᵐ s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′
00	13 30·0	13 32·2	12 53·1	0·0	0·0	6·0	5·5	12·0	10·9
01	13 30·3	13 32·5	12 53·3	0·1	0·1	6·1	5·5	12·1	11·0
02	13 30·5	13 32·7	12 53·6	0·2	0·2	6·2	5·6	12·2	11·1
03	13 30·8	13 33·0	12 53·8	0·3	0·3	6·3	5·7	12·3	11·2
04	13 31·0	13 33·2	12 54·1	0·4	0·4	6·4	5·8	12·4	11·3
05	13 31·3	13 33·5	12 54·3	0·5	0·5	6·5	5·9	12·5	11·4
06	13 31·5	13 33·7	12 54·5	0·6	0·5	6·6	6·0	12·6	11·4
07	13 31·8	13 34·0	12 54·8	0·7	0·6	6·7	6·1	12·7	11·5
08	13 32·0	13 34·2	12 55·0	0·8	0·7	6·8	6·2	12·8	11·6
09	13 32·3	13 34·5	12 55·2	0·9	0·8	6·9	6·3	12·9	11·7
10	13 32·5	13 34·7	12 55·5	1·0	0·9	7·0	6·4	13·0	11·8
11	13 32·8	13 35·0	12 55·7	1·1	1·0	7·1	6·4	13·1	11·9
12	13 33·0	13 35·2	12 56·0	1·2	1·1	7·2	6·5	13·2	12·0
13	13 33·3	13 35·5	12 56·2	1·3	1·2	7·3	6·6	13·3	12·1
14	13 33·5	13 35·7	12 56·4	1·4	1·3	7·4	6·7	13·4	12·2
15	13 33·8	13 36·0	12 56·7	1·5	1·4	7·5	6·8	13·5	12·3
16	13 34·0	13 36·2	12 56·9	1·6	1·5	7·6	6·9	13·6	12·4
17	13 34·3	13 36·5	12 57·2	1·7	1·5	7·7	7·0	13·7	12·4
18	13 34·5	13 36·7	12 57·4	1·8	1·6	7·8	7·1	13·8	12·5
19	13 34·8	13 37·0	12 57·6	1·9	1·7	7·9	7·2	13·9	12·6
20	13 35·0	13 37·2	12 57·9	2·0	1·8	8·0	7·3	14·0	12·7
21	13 35·3	13 37·5	12 58·1	2·1	1·9	8·1	7·4	14·1	12·8
22	13 35·5	13 37·7	12 58·3	2·2	2·0	8·2	7·4	14·2	12·9
23	13 35·8	13 38·0	12 58·6	2·3	2·1	8·3	7·5	14·3	13·0
24	13 36·0	13 38·2	12 58·8	2·4	2·2	8·4	7·6	14·4	13·1
25	13 36·3	13 38·5	12 59·1	2·5	2·3	8·5	7·7	14·5	13·2
26	13 36·5	13 38·7	12 59·3	2·6	2·4	8·6	7·8	14·6	13·3
27	13 36·8	13 39·0	12 59·5	2·7	2·5	8·7	7·9	14·7	13·4
28	13 37·0	13 39·2	12 59·8	2·8	2·5	8·8	8·0	14·8	13·4
29	13 37·3	13 39·5	13 00·0	2·9	2·6	8·9	8·1	14·9	13·5
30	13 37·5	13 39·7	13 00·3	3·0	2·7	9·0	8·2	15·0	13·6
31	13 37·8	13 40·0	13 00·5	3·1	2·8	9·1	8·3	15·1	13·7
32	13 38·0	13 40·2	13 00·7	3·2	2·9	9·2	8·4	15·2	13·8
33	13 38·3	13 40·5	13 01·0	3·3	3·0	9·3	8·4	15·3	13·9
34	13 38·5	13 40·7	13 01·2	3·4	3·1	9·4	8·5	15·4	14·0
35	13 38·8	13 41·0	13 01·5	3·5	3·2	9·5	8·6	15·5	14·1
36	13 39·0	13 41·2	13 01·7	3·6	3·3	9·6	8·7	15·6	14·2
37	13 39·3	13 41·5	13 01·9	3·7	3·4	9·7	8·8	15·7	14·3
38	13 39·5	13 41·7	13 02·2	3·8	3·5	9·8	8·9	15·8	14·4
39	13 39·8	13 42·0	13 02·4	3·9	3·5	9·9	9·0	15·9	14·4
40	13 40·0	13 42·2	13 02·6	4·0	3·6	10·0	9·1	16·0	14·5
41	13 40·3	13 42·5	13 02·9	4·1	3·7	10·1	9·2	16·1	14·6
42	13 40·5	13 42·7	13 03·1	4·2	3·8	10·2	9·3	16·2	14·7
43	13 40·8	13 43·0	13 03·4	4·3	3·9	10·3	9·4	16·3	14·8
44	13 41·0	13 43·2	13 03·6	4·4	4·0	10·4	9·4	16·4	14·9
45	13 41·3	13 43·5	13 03·8	4·5	4·1	10·5	9·5	16·5	15·0
46	13 41·5	13 43·7	13 04·1	4·6	4·2	10·6	9·6	16·6	15·1
47	13 41·8	13 44·0	13 04·3	4·7	4·3	10·7	9·7	16·7	15·2
48	13 42·0	13 44·3	13 04·6	4·8	4·4	10·8	9·8	16·8	15·3
49	13 42·3	13 44·5	13 04·8	4·9	4·5	10·9	9·9	16·9	15·4
50	13 42·5	13 44·8	13 05·0	5·0	4·5	11·0	10·0	17·0	15·4
51	13 42·8	13 45·0	13 05·3	5·1	4·6	11·1	10·1	17·1	15·5
52	13 43·0	13 45·3	13 05·5	5·2	4·7	11·2	10·2	17·2	15·6
53	13 43·3	13 45·5	13 05·7	5·3	4·8	11·3	10·3	17·3	15·7
54	13 43·5	13 45·8	13 06·0	5·4	4·9	11·4	10·4	17·4	15·8
55	13 43·8	13 46·0	13 06·2	5·5	5·0	11·5	10·4	17·5	15·9
56	13 44·0	13 46·3	13 06·5	5·6	5·1	11·6	10·5	17·6	16·0
57	13 44·3	13 46·5	13 06·7	5·7	5·2	11·7	10·6	17·7	16·1
58	13 44·5	13 46·8	13 06·9	5·8	5·3	11·8	10·7	17·8	16·2
59	13 44·8	13 47·0	13 07·2	5·9	5·4	11·9	10·8	17·9	16·3
60	13 45·0	13 47·3	13 07·4	6·0	5·5	12·0	10·9	18·0	16·4

55ᵐ s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′
00	13 45·0	13 47·3	13 07·4	0·0	0·0	6·0	5·6	12·0	11·1
01	13 45·3	13 47·5	13 07·7	0·1	0·1	6·1	5·6	12·1	11·2
02	13 45·5	13 47·8	13 07·9	0·2	0·2	6·2	5·7	12·2	11·3
03	13 45·8	13 48·0	13 08·1	0·3	0·3	6·3	5·8	12·3	11·4
04	13 46·0	13 48·3	13 08·4	0·4	0·4	6·4	5·9	12·4	11·5
05	13 46·3	13 48·5	13 08·6	0·5	0·5	6·5	6·0	12·5	11·6
06	13 46·5	13 48·8	13 08·8	0·6	0·6	6·6	6·1	12·6	11·7
07	13 46·8	13 49·0	13 09·1	0·7	0·6	6·7	6·2	12·7	11·7
08	13 47·0	13 49·3	13 09·3	0·8	0·7	6·8	6·3	12·8	11·8
09	13 47·3	13 49·5	13 09·6	0·9	0·8	6·9	6·4	12·9	11·9
10	13 47·5	13 49·8	13 09·8	1·0	0·9	7·0	6·5	13·0	12·0
11	13 47·8	13 50·0	13 10·0	1·1	1·0	7·1	6·6	13·1	12·1
12	13 48·0	13 50·3	13 10·3	1·2	1·1	7·2	6·7	13·2	12·2
13	13 48·3	13 50·5	13 10·5	1·3	1·2	7·3	6·8	13·3	12·3
14	13 48·5	13 50·8	13 10·8	1·4	1·3	7·4	6·8	13·4	12·4
15	13 48·8	13 51·0	13 11·0	1·5	1·4	7·5	6·9	13·5	12·5
16	13 49·0	13 51·3	13 11·2	1·6	1·5	7·6	7·0	13·6	12·6
17	13 49·3	13 51·5	13 11·5	1·7	1·6	7·7	7·1	13·7	12·7
18	13 49·5	13 51·8	13 11·7	1·8	1·7	7·8	7·2	13·8	12·8
19	13 49·8	13 52·0	13 12·0	1·9	1·8	7·9	7·3	13·9	12·9
20	13 50·0	13 52·3	13 12·2	2·0	1·9	8·0	7·4	14·0	13·0
21	13 50·3	13 52·5	13 12·4	2·1	1·9	8·1	7·5	14·1	13·0
22	13 50·5	13 52·8	13 12·7	2·2	2·0	8·2	7·6	14·2	13·1
23	13 50·8	13 53·0	13 12·9	2·3	2·1	8·3	7·7	14·3	13·2
24	13 51·0	13 53·3	13 13·1	2·4	2·2	8·4	7·8	14·4	13·3
25	13 51·3	13 53·5	13 13·4	2·5	2·3	8·5	7·9	14·5	13·4
26	13 51·5	13 53·8	13 13·6	2·6	2·4	8·6	8·0	14·6	13·5
27	13 51·8	13 54·0	13 13·9	2·7	2·5	8·7	8·0	14·7	13·6
28	13 52·0	13 54·3	13 14·1	2·8	2·6	8·8	8·1	14·8	13·7
29	13 52·3	13 54·5	13 14·3	2·9	2·7	8·9	8·2	14·9	13·8
30	13 52·5	13 54·8	13 14·6	3·0	2·8	9·0	8·3	15·0	13·9
31	13 52·8	13 55·0	13 14·8	3·1	2·9	9·1	8·4	15·1	14·0
32	13 53·0	13 55·3	13 15·1	3·2	3·0	9·2	8·5	15·2	14·1
33	13 53·3	13 55·5	13 15·3	3·3	3·1	9·3	8·6	15·3	14·2
34	13 53·5	13 55·8	13 15·5	3·4	3·1	9·4	8·7	15·4	14·2
35	13 53·8	13 56·0	13 15·8	3·5	3·2	9·5	8·8	15·5	14·3
36	13 54·0	13 56·3	13 16·0	3·6	3·3	9·6	8·9	15·6	14·4
37	13 54·3	13 56·5	13 16·2	3·7	3·4	9·7	9·0	15·7	14·5
38	13 54·5	13 56·8	13 16·5	3·8	3·5	9·8	9·1	15·8	14·6
39	13 54·8	13 57·0	13 16·7	3·9	3·6	9·9	9·2	15·9	14·7
40	13 55·0	13 57·3	13 17·0	4·0	3·7	10·0	9·3	16·0	14·8
41	13 55·3	13 57·5	13 17·2	4·1	3·8	10·1	9·3	16·1	14·9
42	13 55·5	13 57·8	13 17·4	4·2	3·9	10·2	9·4	16·2	15·0
43	13 55·8	13 58·0	13 17·7	4·3	4·0	10·3	9·5	16·3	15·1
44	13 56·0	13 58·3	13 17·9	4·4	4·1	10·4	9·6	16·4	15·2
45	13 56·3	13 58·5	13 18·2	4·5	4·2	10·5	9·7	16·5	15·3
46	13 56·5	13 58·8	13 18·4	4·6	4·3	10·6	9·8	16·6	15·4
47	13 56·8	13 59·0	13 18·6	4·7	4·3	10·7	9·9	16·7	15·4
48	13 57·0	13 59·3	13 18·9	4·8	4·4	10·8	10·0	16·8	15·5
49	13 57·3	13 59·5	13 19·1	4·9	4·5	10·9	10·1	16·9	15·6
50	13 57·5	13 59·8	13 19·3	5·0	4·6	11·0	10·2	17·0	15·7
51	13 57·8	14 00·0	13 19·6	5·1	4·7	11·1	10·3	17·1	15·8
52	13 58·0	14 00·3	13 19·8	5·2	4·8	11·2	10·4	17·2	15·9
53	13 58·3	14 00·5	13 20·1	5·3	4·9	11·3	10·5	17·3	16·0
54	13 58·5	14 00·8	13 20·3	5·4	5·0	11·4	10·5	17·4	16·1
55	13 58·8	14 01·0	13 20·5	5·5	5·1	11·5	10·6	17·5	16·2
56	13 59·0	14 01·3	13 20·8	5·6	5·2	11·6	10·7	17·6	16·3
57	13 59·3	14 01·5	13 21·0	5·7	5·3	11·7	10·8	17·7	16·4
58	13 59·5	14 01·8	13 21·3	5·8	5·4	11·8	10·9	17·8	16·5
59	13 59·8	14 02·0	13 21·5	5·9	5·5	11·9	11·0	17·9	16·6
60	14 00·0	14 02·3	13 21·7	6·0	5·6	12·0	11·1	18·0	16·7

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Sight Reduction Table

INCREMENTS AND CORRECTIONS

56ᵐ

56	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 00·0	14 02·3	13 21·7	0·0	0·0	6·0	5·7	12·0	11·3
01	14 00·3	14 02·6	13 22·0	0·1	0·1	6·1	5·7	12·1	11·4
02	14 00·5	14 02·8	13 22·2	0·2	0·2	6·2	5·8	12·2	11·5
03	14 00·8	14 03·1	13 22·4	0·3	0·3	6·3	5·9	12·3	11·6
04	14 01·0	14 03·3	13 22·7	0·4	0·4	6·4	6·0	12·4	11·7
05	14 01·3	14 03·6	13 22·9	0·5	0·5	6·5	6·1	12·5	11·8
06	14 01·5	14 03·8	13 23·2	0·6	0·6	6·6	6·2	12·6	11·9
07	14 01·8	14 04·1	13 23·4	0·7	0·7	6·7	6·3	12·7	12·0
08	14 02·0	14 04·3	13 23·6	0·8	0·8	6·8	6·4	12·8	12·1
09	14 02·3	14 04·6	13 23·9	0·9	0·8	6·9	6·5	12·9	12·1
10	14 02·5	14 04·8	13 24·1	1·0	0·9	7·0	6·6	13·0	12·2
11	14 02·8	14 05·1	13 24·4	1·1	1·0	7·1	6·7	13·1	12·3
12	14 03·0	14 05·3	13 24·6	1·2	1·1	7·2	6·8	13·2	12·4
13	14 03·3	14 05·6	13 24·8	1·3	1·2	7·3	6·9	13·3	12·5
14	14 03·5	14 05·8	13 25·1	1·4	1·3	7·4	7·0	13·4	12·6
15	14 03·8	14 06·1	13 25·3	1·5	1·4	7·5	7·1	13·5	12·7
16	14 04·0	14 06·3	13 25·6	1·6	1·5	7·6	7·2	13·6	12·8
17	14 04·3	14 06·6	13 25·8	1·7	1·6	7·7	7·3	13·7	12·9
18	14 04·5	14 06·8	13 26·0	1·8	1·7	7·8	7·3	13·8	13·0
19	14 04·8	14 07·1	13 26·3	1·9	1·8	7·9	7·4	13·9	13·1
20	14 05·0	14 07·3	13 26·5	2·0	1·9	8·0	7·5	14·0	13·2
21	14 05·3	14 07·6	13 26·7	2·1	2·0	8·1	7·6	14·1	13·3
22	14 05·5	14 07·8	13 27·0	2·2	2·1	8·2	7·7	14·2	13·4
23	14 05·8	14 08·1	13 27·2	2·3	2·2	8·3	7·8	14·3	13·5
24	14 06·0	14 08·3	13 27·5	2·4	2·3	8·4	7·9	14·4	13·6
25	14 06·3	14 08·6	13 27·7	2·5	2·4	8·5	8·0	14·5	13·7
26	14 06·5	14 08·8	13 27·9	2·6	2·4	8·6	8·1	14·6	13·7
27	14 06·8	14 09·1	13 28·2	2·7	2·5	8·7	8·2	14·7	13·8
28	14 07·0	14 09·3	13 28·4	2·8	2·6	8·8	8·3	14·8	13·9
29	14 07·3	14 09·6	13 28·7	2·9	2·7	8·9	8·4	14·9	14·0
30	14 07·5	14 09·8	13 28·9	3·0	2·8	9·0	8·5	15·0	14·1
31	14 07·8	14 10·1	13 29·1	3·1	2·9	9·1	8·6	15·1	14·2
32	14 08·0	14 10·3	13 29·4	3·2	3·0	9·2	8·7	15·2	14·3
33	14 08·3	14 10·6	13 29·6	3·3	3·1	9·3	8·8	15·3	14·4
34	14 08·5	14 10·8	13 29·8	3·4	3·2	9·4	8·9	15·4	14·5
35	14 08·8	14 11·1	13 30·1	3·5	3·3	9·5	8·9	15·5	14·6
36	14 09·0	14 11·3	13 30·3	3·6	3·4	9·6	9·0	15·6	14·7
37	14 09·3	14 11·6	13 30·6	3·7	3·5	9·7	9·1	15·7	14·8
38	14 09·5	14 11·8	13 30·8	3·8	3·6	9·8	9·2	15·8	14·9
39	14 09·8	14 12·1	13 31·0	3·9	3·7	9·9	9·3	15·9	15·0
40	14 10·0	14 12·3	13 31·3	4·0	3·8	10·0	9·4	16·0	15·1
41	14 10·3	14 12·6	13 31·5	4·1	3·9	10·1	9·5	16·1	15·2
42	14 10·5	14 12·8	13 31·8	4·2	4·0	10·2	9·6	16·2	15·3
43	14 10·8	14 13·1	13 32·0	4·3	4·0	10·3	9·7	16·3	15·3
44	14 11·0	14 13·3	13 32·2	4·4	4·1	10·4	9·8	16·4	15·4
45	14 11·3	14 13·6	13 32·5	4·5	4·2	10·5	9·9	16·5	15·5
46	14 11·5	14 13·8	13 32·7	4·6	4·3	10·6	10·0	16·6	15·6
47	14 11·8	14 14·1	13 32·9	4·7	4·4	10·7	10·1	16·7	15·7
48	14 12·0	14 14·3	13 33·2	4·8	4·5	10·8	10·2	16·8	15·8
49	14 12·3	14 14·6	13 33·4	4·9	4·6	10·9	10·3	16·9	15·9
50	14 12·5	14 14·8	13 33·7	5·0	4·7	11·0	10·4	17·0	16·0
51	14 12·8	14 15·1	13 33·9	5·1	4·8	11·1	10·5	17·1	16·1
52	14 13·0	14 15·3	13 34·1	5·2	4·9	11·2	10·5	17·2	16·2
53	14 13·3	14 15·6	13 34·4	5·3	5·0	11·3	10·6	17·3	16·3
54	14 13·5	14 15·8	13 34·6	5·4	5·1	11·4	10·7	17·4	16·4
55	14 13·8	14 16·1	13 34·9	5·5	5·2	11·5	10·8	17·5	16·5
56	14 14·0	14 16·3	13 35·1	5·6	5·3	11·6	10·9	17·6	16·6
57	14 14·3	14 16·6	13 35·3	5·7	5·4	11·7	11·0	17·7	16·7
58	14 14·5	14 16·8	13 35·6	5·8	5·5	11·8	11·1	17·8	16·8
59	14 14·8	14 17·1	13 35·8	5·9	5·6	11·9	11·2	17·9	16·9
60	14 15·0	14 17·3	13 36·1	6·0	5·7	12·0	11·3	18·0	17·0

57ᵐ

57	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 15·0	14 17·3	13 36·1	0·0	0·0	6·0	5·8	12·0	11·5
01	14 15·3	14 17·6	13 36·3	0·1	0·1	6·1	5·8	12·1	11·6
02	14 15·5	14 17·8	13 36·5	0·2	0·2	6·2	5·9	12·2	11·7
03	14 15·8	14 18·1	13 36·8	0·3	0·3	6·3	6·0	12·3	11·8
04	14 16·0	14 18·3	13 37·0	0·4	0·4	6·4	6·1	12·4	11·9
05	14 16·3	14 18·6	13 37·2	0·5	0·5	6·5	6·2	12·5	12·0
06	14 16·5	14 18·8	13 37·5	0·6	0·6	6·6	6·3	12·6	12·1
07	14 16·8	14 19·1	13 37·7	0·7	0·7	6·7	6·4	12·7	12·2
08	14 17·0	14 19·3	13 38·0	0·8	0·8	6·8	6·5	12·8	12·3
09	14 17·3	14 19·6	13 38·2	0·9	0·9	6·9	6·6	12·9	12·4
10	14 17·5	14 19·8	13 38·4	1·0	1·0	7·0	6·7	13·0	12·5
11	14 17·8	14 20·1	13 38·7	1·1	1·1	7·1	6·8	13·1	12·6
12	14 18·0	14 20·3	13 38·9	1·2	1·2	7·2	6·9	13·2	12·7
13	14 18·3	14 20·6	13 39·2	1·3	1·2	7·3	7·0	13·3	12·7
14	14 18·5	14 20·9	13 39·4	1·4	1·3	7·4	7·1	13·4	12·8
15	14 18·8	14 21·1	13 39·6	1·5	1·4	7·5	7·2	13·5	12·9
16	14 19·0	14 21·4	13 39·9	1·6	1·5	7·6	7·3	13·6	13·0
17	14 19·3	14 21·6	13 40·1	1·7	1·6	7·7	7·4	13·7	13·1
18	14 19·5	14 21·9	13 40·3	1·8	1·7	7·8	7·5	13·8	13·2
19	14 19·8	14 22·1	13 40·6	1·9	1·8	7·9	7·6	13·9	13·3
20	14 20·0	14 22·4	13 40·8	2·0	1·9	8·0	7·7	14·0	13·4
21	14 20·3	14 22·6	13 41·1	2·1	2·0	8·1	7·8	14·1	13·5
22	14 20·5	14 22·9	13 41·3	2·2	2·1	8·2	7·9	14·2	13·6
23	14 20·8	14 23·1	13 41·5	2·3	2·2	8·3	8·0	14·3	13·7
24	14 21·0	14 23·4	13 41·8	2·4	2·3	8·4	8·1	14·4	13·8
25	14 21·3	14 23·6	13 42·0	2·5	2·4	8·5	8·1	14·5	13·9
26	14 21·5	14 23·9	13 42·3	2·6	2·5	8·6	8·2	14·6	14·0
27	14 21·8	14 24·1	13 42·5	2·7	2·6	8·7	8·3	14·7	14·1
28	14 22·0	14 24·4	13 42·7	2·8	2·7	8·8	8·4	14·8	14·2
29	14 22·3	14 24·6	13 43·0	2·9	2·8	8·9	8·5	14·9	14·3
30	14 22·5	14 24·9	13 43·2	3·0	2·9	9·0	8·6	15·0	14·4
31	14 22·8	14 25·1	13 43·4	3·1	3·0	9·1	8·7	15·1	14·5
32	14 23·0	14 25·4	13 43·7	3·2	3·1	9·2	8·8	15·2	14·6
33	14 23·3	14 25·6	13 43·9	3·3	3·2	9·3	8·9	15·3	14·7
34	14 23·5	14 25·9	13 44·2	3·4	3·3	9·4	9·0	15·4	14·8
35	14 23·8	14 26·1	13 44·4	3·5	3·4	9·5	9·1	15·5	14·9
36	14 24·0	14 26·4	13 44·6	3·6	3·5	9·6	9·2	15·6	15·0
37	14 24·3	14 26·6	13 44·9	3·7	3·5	9·7	9·3	15·7	15·0
38	14 24·5	14 26·9	13 45·1	3·8	3·6	9·8	9·4	15·8	15·1
39	14 24·8	14 27·1	13 45·4	3·9	3·7	9·9	9·5	15·9	15·2
40	14 25·0	14 27·4	13 45·6	4·0	3·8	10·0	9·6	16·0	15·3
41	14 25·3	14 27·6	13 45·8	4·1	3·9	10·1	9·7	16·1	15·4
42	14 25·5	14 27·9	13 46·1	4·2	4·0	10·2	9·8	16·2	15·5
43	14 25·8	14 28·1	13 46·3	4·3	4·1	10·3	9·9	16·3	15·6
44	14 26·0	14 28·4	13 46·5	4·4	4·2	10·4	10·0	16·4	15·7
45	14 26·3	14 28·6	13 46·8	4·5	4·3	10·5	10·1	16·5	15·8
46	14 26·5	14 28·9	13 47·0	4·6	4·4	10·6	10·2	16·6	15·9
47	14 26·8	14 29·1	13 47·3	4·7	4·5	10·7	10·3	16·7	16·0
48	14 27·0	14 29·4	13 47·5	4·8	4·6	10·8	10·4	16·8	16·1
49	14 27·3	14 29·6	13 47·7	4·9	4·7	10·9	10·4	16·9	16·2
50	14 27·5	14 29·9	13 48·0	5·0	4·8	11·0	10·5	17·0	16·3
51	14 27·8	14 30·1	13 48·2	5·1	4·9	11·1	10·6	17·1	16·4
52	14 28·0	14 30·4	13 48·5	5·2	5·0	11·2	10·7	17·2	16·5
53	14 28·3	14 30·6	13 48·7	5·3	5·1	11·3	10·8	17·3	16·6
54	14 28·5	14 30·9	13 48·9	5·4	5·2	11·4	10·9	17·4	16·7
55	14 28·8	14 31·1	13 49·2	5·5	5·3	11·5	11·0	17·5	16·8
56	14 29·0	14 31·4	13 49·4	5·6	5·4	11·6	11·1	17·6	16·9
57	14 29·3	14 31·6	13 49·7	5·7	5·5	11·7	11·2	17·7	17·0
58	14 29·5	14 31·9	13 49·9	5·8	5·6	11·8	11·3	17·8	17·1
59	14 29·8	14 32·1	13 50·1	5·9	5·7	11·9	11·4	17·9	17·2
60	14 30·0	14 32·4	13 50·4	6·0	5·8	12·0	11·5	18·0	17·3

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Problem 1

What were the GHA and the declination of the sun on 22 Jan. 1978 at GMT $15^h - 47^m - 13^s$?

Problem 2

What were the GHA and the declination of the moon on 22 Jan. 1978 at GMT $15^h - 47^m - 13^s$?

Problem 3

What were the LHA and the declination of Venus on 6 Apr. 1978 at GMT $10^h - 57^m - 28^s$ at longitude E. $113^o - 55'$?

Problem 4

What were the LHA and the declination of Mars on 6 Apr. 1978 at GMT $23^h - 25^m - 12^s$ at longitude W. $71^o - 12'$?

Problem 5

What were the GHA and the declination of Aldebaran on 22 Jan. 1978 at GMT $15^h - 55^m - 13^s$?

Problem 6

What were the GHA and the declination of Vega on 22 Jan. 1978 at GMT $16^h - 02^m - 45^s$?

Nautical Almanac

1978 JANUARY 22, 23, 24 (SUN., MON., TUES.)

G.M.T.	ARIES G.H.A.	VENUS −3.5 G.H.A.	VENUS Dec.	MARS −1.1 G.H.A.	MARS Dec.	JUPITER −2.2 G.H.A.	JUPITER Dec.	SATURN +0.4 G.H.A.	SATURN Dec.	STARS Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
22 00	120 59.4	176 57.7	S20 48.7	356 03.4	N24 05.9	33 45.5	N23 14.1	329 16.6	N13 11.9	Acamar	315 38.5	S40 23.9
01	136 01.9	191 56.9	48.1	11 07.0	06.2	48 48.2	14.1	344 17.2	12.0	Achernar	335 46.8	S57 21.2
02	151 04.4	206 56.1	47.4	26 10.5	06.4	63 50.9	14.1	359 21.8	12.0	Acrux	173 38.7	S62 58.4
03	166 06.8	221 55.3	46.8	41 14.0	06.7	78 53.6	14.1	14 24.4	12.1	Adhara	255 33.1	S28 56.8
04	181 09.3	236 54.4	46.2	56 17.5	06.9	93 56.3	14.1	29 27.1	12.2	Aldebaran	291 19.8	N16 27.8
05	196 11.[illegible]	251 53.6	45.5	71 21.0	07.2	108 59.0	14.2	44 29.7	12.2			
06	211 14.2	266 52.8	S20 44.9	86 24.6	N24 07.4	124 01.8	N23 14.2	59 32.3	N13 12.3	Alioth	166 44.0	N56 04.4
07	226 16.[illegible]	281 52.0	44.2	101 28.1	07.7	139 04.5	14.2	74 34.9	12.4	Alkaid	153 19.9	N49 25.1
08	241 19.[illegible]	296 51.1	43.6	116 31.6	07.9	154 07.2	14.2	89 37.6	12.4	Al Na'ir	28 17.6	S47 04.2
S 09	256 21.6	311 50.3	43.0	131 35.1	08.2	169 09.9	14.2	104 40.2	12.5	Alnilam	276 13.2	S 1 13.1
U 10	271 24.1	326 49.5	42.3	146 38.7	08.4	184 12.6	14.2	119 42.8	12.6	Alphard	218 22.0	S 8 34.0
N 11	286 26.5	341 48.7	41.7	161 42.2	08.7	199 15.3	14.2	134 45.4	12.6			
D 12	301 29.0	356 47.8	S20 41.0	176 45.7	N24 08.9	214 18.0	N23 14.2	149 48.1	N13 12.7	Alphecca	126 33.8	N26 47.2
A 13	316 31.5	11 47.0	40.4	191 49.2	09.1	229 20.7	14.2	164 50.7	12.8	Alpheratz	358 11.3	N28 58.3
Y 14	331 33.9	26 46.2	39.8	206 52.8	09.4	244 23.5	14.2	179 53.3	12.8	Altair	62 34.6	N 8 48.6
15	346 36.4	41 45.4	39.1	221 56.3	09.6	259 26.2	14.2	194 55.9	12.9	Ankaa	353 42.2	S42 25.8
16	1 38.9	56 44.5	38.5	236 59.8	09.9	274 28.9	14.2	209 58.5	13.0	Antares	112 59.2	S26 22.9
17	16 41.3	71 43.7	37.8	252 03.3	10.1	289 31.6	14.2	225 01.2	13.0			
18	31 43.8	86 42.9	S20 37.2	267 06.8	N24 10.4	304 34.3	N23 14.2	240 03.8	N13 13.1	Arcturus	146 20.1	N19 17.6
19	46 46.2	101 42.1	36.5	282 10.4	10.6	319 37.0	14.2	255 06.4	13.2	Atria	108 25.4	S68 59.0
20	61 48.7	116 41.3	35.9	297 13.9	10.9	334 39.7	14.2	270 09.0	13.2	Avior	234 28.2	S59 26.5
21	76 51.2	131 40.4	35.2	312 17.4	11.1	349 42.4	14.2	285 11.7	13.3	Bellatrix	279 00.4	N 6 19.7
22	91 53.6	146 39.6	34.6	327 20.9	11.3	4 45.1	14.2	300 14.3	13.4	Betelgeuse	271 29.9	N 7 24.0
23	106 56.1	161 38.8	33.9	342 24.5	11.6	19 47.8	14.2	315 16.9	13.4			
23 00	121 58.6	176 38.0	S20 33.2	357 28.0	N24 11.8	34 50.5	N23 14.2	330 19.5	N13 13.5	Canopus	264 07.5	S52 41.3
01	137 01.0	191 37.2	32.6	12 31.5	12.1	49 53.2	14.2	345 22.2	13.6	Capella	281 13.5	N45 58.6
02	152 03.5	206 36.4	31.9	27 35.0	12.3	64 55.9	14.2	0 24.8	13.6	Deneb	49 50.1	N45 12.2
03	167 06.0	221 35.5	31.3	42 38.5	12.5	79 58.7	14.2	15 27.4	13.7	Denebola	183 00.7	N14 41.5
04	182 08.4	236 34.7	30.6	57 42.1	12.8	95 01.4	14.2	30 30.0	13.8	Diphda	349 22.8	S18 06.6
05	197 10.9	251 33.9	29.9	72 45.6	13.0	110 04.1	14.2	45 32.7	13.8			
06	212 13.3	266 33.1	S20 29.3	87 49.1	N24 13.3	125 06.8	N23 14.2	60 35.3	N13 13.9	Dubhe	194 23.9	N61 51.9
07	227 15.8	281 32.3	28.6	102 52.6	13.5	140 09.5	14.2	75 37.9	14.0	Elnath	278 46.1	N28 35.3
08	242 18.3	296 31.5	28.0	117 56.2	13.7	155 12.2	14.2	90 40.5	14.0	Eltanin	90 59.0	N51 29.4
M 09	257 20.7	311 30.7	27.3	132 59.7	14.0	170 14.9	14.2	105 43.2	14.1	Enif	34 13.6	N 9 46.5
O 10	272 23.2	326 29.8	26.6	148 03.2	14.2	185 17.6	14.2	120 45.8	14.2	Fomalhaut	15 53.7	S29 44.4
N 11	287 25.7	341 29.0	26.0	163 06.7	14.5	200 20.3	14.2	135 48.4	14.2			
D 12	302 28.1	356 28.2	S20 25.[illegible]	178 10.2	N24 14.7	215 23.0	N23 14.2	150 51.1	N13 14.3	Gacrux	172 30.4	S56 59.2
A 13	317 30.6	11 27.4	24.6	193 13.8	14.9	230 25.7	14.2	165 53.7	14.4	Gienah	176 19.6	S17 25.2
Y 14	332 33.1	26 26.6	24.0	208 17.3	15.2	245 28.4	14.2	180 56.3	14.4	Hadar	149 25.7	S60 15.8
15	347 35.5	41 25.8	23.3	223 20.8	15.4	260 31.1	14.2	195 58.9	14.5	Hamal	328 30.9	N23 21.6
16	2 38.0	56 25.0	22.6	238 24.3	15.7	275 33.8	14.2	211 01.6	14.6	Kaus Aust.	84 19.6	S34 23.6
17	17 40.5	71 24.2	21.9	253 27.8	15.9	290 36.5	14.2	226 04.2	14.6			
18	32 42.9	86 23.4	S20 21.3	268 31.4	N24 16.1	305 39.2	N23 14.2	241 06.8	N13 14.7	Kochab	137 19.4	N74 14.5
19	47 45.4	101 22.6	20.6	283 34.9	16.4	320 41.9	14.2	256 09.4	14.8	Markab	14 05.2	N15 05.3
20	62 47.8	116 21.8	19.9	298 38.4	16.6	335 44.6	14.2	271 12.1	14.8	Menkar	314 42.9	N 4 00.1
21	77 50.3	131 20.9	19.2	313 41.9	16.8	350 47.3	14.2	286 14.7	14.9	Menkent	148 39.1	S36 15.6
22	92 52.8	146 20.1	18.6	328 45.4	17.1	5 50.0	14.2	301 17.3	15.0	Miaplacidus	221 44.3	S69 37.7
23	107 55.2	161 19.3	17.9	343 49.0	17.3	20 52.7	14.[illegible]	316 19.9	15.0			
24 00	122 57.7	176 18.5	S20 17.2	358 52.5	N24 17.5	35 55.4	N23 14.3	331 22.6	N13 15.1	Mirfak	309 18.4	N49 47.1
01	138 00.2	191 17.7	16.5	13 56.0	17.8	50 58.1	14.3	346 25.2	15.2	Nunki	76 31.7	S26 19.4
02	153 02.6	206 16.9	15.8	28 59.5	18.0	66 00.8	14.3	1 27.8	15.2	Peacock	54 01.8	S56 48.3
03	168 05.1	221 16.1	15.1	44 03.0	18.2	81 03.5	14.3	16 30.5	15.3	Pollux	244 00.0	N28 04.6
04	183 07.6	236 15.3	14.5	59 06.6	18.5	96 06.2	14.3	31 33.1	15.4	Procyon	245 27.3	N 5 16.7
05	198 10.0	251 14.5	13.8	74 10.1	18.7	111 08.9	14.3	46 35.7	15.4			
06	213 12.5	266 13.7	S20 13.1	89 13.6	N24 18.9	126 11.6	N23 14.3	61 38.3	N13 15.5	Rasalhague	96 31.5	N12 34.5
07	228 15.0	281 12.9	12.4	104 17.1	19.2	141 14.3	14.3	76 41.0	15.6	Regulus	208 11.6	N12 04.3
08	243 17.4	296 12.1	11.7	119 20.6	19.4	156 17.0	14.3	91 43.6	15.6	Rigel	281 37.5	S 8 13.8
T 09	258 19.9	311 11.3	11.0	134 24.1	19.6	171 19.7	14.3	106 46.2	15.7	Rigil Kent.	140 28.2	S60 44.3
U 10	273 22.3	326 10.5	10.3	149 27.7	19.9	186 22.4	14.3	121 48.8	15.8	Sabik	102 43.4	S15 41.8
E 11	288 24.8	341 09.7	09.6	164 31.2	20.1	201 25.1	14.3	136 51.5	15.8			
S 12	303 27.3	356 08.9	S20 08.9	179 34.7	N24 20.3	216 27.8	N23 14.3	151 54.1	N13 15.9	Schedar	350 11.1	N56 25.3
D 13	318 29.7	11 08.1	08.2	194 38.2	20.5	231 30.5	14.3	166 56.7	16.0	Shaula	96 58.5	S37 05.1
A 14	333 32.2	26 07.3	07.5	209 41.7	20.8	246 33.2	14.3	181 59.4	16.0	Sirius	258 56.9	S16 41.4
Y 15	348 34.7	41 06.5	06.9	224 45.3	21.0	261 35.9	14.3	197 02.0	16.1	Spica	158 59.3	S11 02.8
16	3 37.1	56 05.7	06.2	239 48.8	21.2	276 38.6	14.3	212 04.6	16.2	Suhail	223 11.6	S43 20.7
17	18 39.6	71 04.9	05.5	254 52.3	21.5	291 41.3	14.3	227 07.3	16.2			
18	33 42.1	86 04.1	S20 04.8	269 55.8	N24 21.7	306 44.0	N23 14.3	242 09.9	N13 16.3	Vega	80 57.4	N38 45.8
19	48 44.5	101 03.3	04.1	284 59.3	21.9	321 46.6	14.[illegible]	257 12.5	16.4	Zuben'ubi	137 35.1	S15 57.0
20	63 47.0	116 02.5	03.4	300 02.8	22.1	336 49.3	14.3	272 15.1	16.4		S.H.A.	Mer. Pass.
21	78 49.5	131 01.7	02.7	315 06.3	22.4	351 52.0	14.3	287 17.8	16.5		° ′	h m
22	93 51.9	146 00.9	01.9	330 09.9	22.6	6 54.7	14.3	302 20.4	16.6	Venus	54 39.4	12 14
23	108 54.4	161 00.1	01.2	345 13.4	22.8	21 57.4	14.3	317 23.0	16.6	Mars	235 29.4	0 10
										Jupiter	272 52.0	21 37
Mer. Pass.	h m 15 49.5	v −0.8	d 0.7	v 3.5	d 0.2	v 2.7	d 0.0	v 2.6	d 0.1	Saturn	208 21.0	1 58

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Nautical Almanac

1978 JANUARY 22, 23, 24 (SUN., MON., TUES.)

G.M.T. d h	SUN G.H.A. ° ′	SUN Dec. ° ′	MOON G.H.A. ° ′	MOON v ′	MOON Dec. ° ′	MOON d ′	MOON H.P. ′
22 00	177 08.3	S19 48.1	24 40.3	12.3	N18 16.9	1.4	54.0
01	192 08.1	47.6	39 11.6	12.3	18 15.5	1.6	54.0
02	207 07.9	47.0	53 42.9	12.3	18 13.9	1.6	54.1
03	222 07.8	·· 46.4	68 14.2	12.3	18 12.3	1.7	54.1
04	237 07.6	45.9	82 45.5	12.3	18 10.6	1.8	54.1
05	252 07.4	45.3	97 16.8	12.3	18 08.8	1.9	54.1
06	267 07.2	S19 44.7	111 48.1	12.3	N18 06.9	1.9	54.1
07	282 07.1	44.2	126 19.4	12.4	18 05.0	2.1	54.1
08	297 06.9	43.6	140 50.8	12.3	18 02.9	2.1	54.1
S 09	312 06.7	·· 43.0	155 22.1	12.3	18 00.8	2.2	54.1
U 10	327 06.6	42.5	169 53.4	12.3	17 58.6	2.3	54.1
N 11	342 06.4	41.9	184 24.7	12.3	17 56.3	2.4	54.1
D 12	357 06.2	S19 41.3	198 56.0	12.4	N17 53.9	2.4	54.1
A 13	12 06.1	40.8	213 27.4	12.3	17 51.5	2.6	54.1
Y 14	27 05.9	40.2	227 58.7	12.4	17 48.9	2.6	54.1
15	42 05.7	·· 39.6	242 30.1	12.3	17 46.3	2.7	54.1
16	57 05.6	39.0	257 01.4	12.4	17 43.6	2.8	54.1
17	72 05.4	38.5	271 32.8	12.3	17 40.8	2.8	54.1
18	87 05.2	S19 37.9	286 04.1	12.4	N17 38.0	3.0	54.1
19	102 05.1	37.3	300 35.5	12.4	17 35.0	3.0	54.1
20	117 04.9	36.7	315 06.9	12.4	17 32.0	3.1	54.2
21	132 04.8	·· 36.2	329 38.3	12.4	17 28.9	3.2	54.2
22	147 04.6	35.6	344 09.7	12.4	17 25.7	3.3	54.2
23	162 04.4	35.0	358 41.1	12.4	17 22.4	3.4	54.2
23 00	177 04.3	S19 34.4	13 12.5	12.4	N17 19.0	3.4	54.2
01	192 04.1	33.8	27 43.9	12.4	17 15.6	3.5	54.2
02	207 03.9	33.3	42 15.3	12.5	17 12.1	3.6	54.2
03	222 03.8	·· 32.7	56 46.8	12.4	17 08.5	3.7	54.2
04	237 03.6	32.1	71 18.2	12.5	17 04.8	3.7	54.2
05	252 03.4	31.5	85 49.7	12.4	17 01.1	3.9	54.2
06	267 03.3	S19 30.9	100 21.1	12.5	N16 57.2	3.9	54.2
07	282 03.1	30.4	114 52.6	12.5	16 53.3	4.0	54.2
08	297 03.0	29.8	129 24.1	12.5	16 49.3	4.0	54.3
M 09	312 02.8	·· 29.2	143 55.6	12.5	16 45.3	4.2	54.3
O 10	327 02.6	28.6	158 27.1	12.5	16 41.1	4.2	54.3
N 11	342 02.5	28.0	172 58.6	12.6	16 36.9	4.3	54.3
D 12	357 02.3	S19 27.4	187 30.2	12.5	N16 32.6	4.4	54.3
A 13	12 02.2	26.9	202 01.7	12.6	16 28.2	4.4	54.3
Y 14	27 02.0	26.3	216 33.3	12.5	16 23.8	4.6	54.3
15	42 01.9	·· 25.7	231 04.8	12.6	16 19.2	4.6	54.3
16	57 01.7	25.1	245 36.4	12.6	16 14.6	4.7	54.3
17	72 01.5	24.5	260 08.0	12.6	16 09.9	4.7	54.3
18	87 01.4	S19 23.9	274 39.6	12.6	N16 05.2	4.9	54.4
19	102 01.2	23.3	289 11.2	12.6	16 00.3	4.9	54.4
20	117 01.1	22.7	303 42.8	12.7	15 55.4	5.0	54.4
21	132 00.9	·· 22.1	318 14.5	12.6	15 50.4	5.0	54.4
22	147 00.8	21.5	332 46.1	12.7	15 45.4	5.2	54.4
23	162 00.6	20.9	347 17.8	12.7	15 40.2	5.2	54.4
24 00	177 00.4	S19 20.4	1 49.5	12.6	N15 35.0	5.3	54.4
01	192 00.3	19.8	16 21.1	12.7	15 29.7	5.3	54.4
02	207 00.1	19.2	30 52.8	12.8	15 24.4	5.4	54.4
03	222 00.0	·· 18.6	45 24.6	12.7	15 19.0	5.5	54.5
04	236 59.8	18.0	59 56.3	12.7	15 13.5	5.6	54.5
05	251 59.7	17.4	74 28.0	12.8	15 07.9	5.6	54.5
06	266 59.5	S19 16.8	88 59.8	12.8	N15 02.3	5.7	54.5
07	281 59.4	16.2	103 31.6	12.8	14 56.6	5.8	54.5
T 08	296 59.2	15.6	118 03.4	12.8	14 50.8	5.9	54.5
U 09	311 59.1	·· 15.0	132 35.2	12.8	14 44.9	5.9	54.5
E 10	326 58.9	14.4	147 07.0	12.8	14 39.0	6.0	54.5
S 11	341 58.8	13.8	161 38.8	12.8	14 33.0	6.0	54.5
D 12	356 58.6	S19 13.2	176 10.6	12.9	N14 27.0	6.2	54.6
A 13	11 58.5	12.6	190 42.5	12.9	14 20.8	6.2	54.6
Y 14	26 58.3	12.0	205 14.4	12.8	14 14.6	6.2	54.6
15	41 58.2	·· 11.4	219 46.2	12.9	14 08.4	6.4	54.6
16	56 58.0	10.8	234 18.1	12.9	14 02.0	6.4	54.6
17	71 57.9	10.2	248 50.0	13.0	13 55.6	6.4	54.6
18	86 57.7	S19 09.6	263 22.0	12.9	N13 49.2	6.5	54.6
19	101 57.6	09.0	277 53.9	13.0	13 42.7	6.6	54.6
20	116 57.4	08.4	292 25.9	12.9	13 36.1	6.7	54.7
21	131 57.3	·· 07.8	306 57.8	13.0	13 29.4	6.7	54.7
22	146 57.1	07.1	321 29.8	13.0	13 22.7	6.8	54.7
23	161 57.0	06.5	336 01.8	13.0	13 15.9	6.8	54.7
	S.D. 16.3	d 0.6	S.D. 14.7		14.8		14.9

Lat. °	Twilight Naut. h m	Twilight Civil h m	Sunrise h m	Moonrise 22 h m	Moonrise 23 h m	Moonrise 24 h m	Moonrise 25 h m
N 72	07 40	09 19	▬	11 14	13 14	15 00	16 42
N 70	07 28	08 53	10 43	12 38	14 00	15 29	17 01
68	07 19	08 34	09 58	13 17	14 30	15 51	17 16
66	07 10	08 18	09 28	13 44	14 52	16 08	17 28
64	07 03	08 05	09 06	14 05	15 10	16 22	17 38
62	06 57	07 54	08 49	14 21	15 24	16 33	17 46
60	06 52	07 44	08 34	14 35	15 36	16 43	17 54
N 58	06 46	07 36	08 22	14 47	15 47	16 52	18 00
56	06 42	07 28	08 11	14 57	15 56	16 59	18 06
54	06 38	07 21	08 02	15 06	16 04	17 06	18 11
52	06 34	07 15	07 53	15 14	16 11	17 12	18 15
50	06 30	07 10	07 46	15 22	16 18	17 17	18 19
45	06 22	06 57	07 29	15 37	16 32	17 29	18 28
N 40	06 14	06 47	07 16	15 50	16 43	17 39	18 36
35	06 07	06 38	07 05	16 01	16 53	17 47	18 42
30	06 00	06 29	06 55	16 10	17 01	17 54	18 48
20	05 47	06 14	06 38	16 26	17 16	18 07	18 57
N 10	05 35	06 00	06 23	16 41	17 29	18 18	19 06
0	05 21	05 46	06 08	16 54	17 41	18 28	19 14
S 10	05 05	05 31	05 54	17 07	17 53	18 38	19 22
20	04 46	05 15	05 38	17 22	18 06	18 49	19 30
30	04 22	04 54	05 20	17 38	18 21	19 01	19 40
35	04 07	04 41	05 10	17 47	18 29	19 08	19 45
40	03 48	04 27	04 58	17 58	18 39	19 17	19 52
45	03 24	04 09	04 43	18 11	18 50	19 26	19 59
S 50	02 52	03 46	04 26	18 26	19 04	19 37	20 08
52	02 34	03 34	04 17	18 33	19 10	19 43	20 12
54	02 13	03 21	04 08	18 41	19 17	19 49	20 16
56	01 43	03 06	03 57	18 50	19 25	19 55	20 21
58	00 51	02 48	03 45	19 00	19 34	20 02	20 26
S 60	////	02 24	03 31	19 12	19 44	20 10	20 32

Lat. °	Sunset h m	Twilight Civil h m	Twilight Naut. h m	Moonset 22 h m	Moonset 23 h m	Moonset 24 h m	Moonset 25 h m
N 72	▬	15 05	16 45	10 13	09 52	09 44	09 37
N 70	13 41	15 31	16 56	08 49	09 06	09 13	09 17
68	14 27	15 51	17 06	08 10	08 35	08 51	09 01
66	14 56	16 07	17 14	07 43	08 12	08 33	08 48
64	15 18	16 20	17 21	07 22	07 54	08 19	08 37
62	15 36	16 31	17 27	07 05	07 40	08 07	08 28
60	15 50	16 40	17 33	06 51	07 27	07 56	08 20
N 58	16 03	16 49	17 38	06 39	07 16	07 47	08 13
56	16 13	16 56	17 42	06 29	07 07	07 39	08 07
54	16 23	17 03	17 47	06 20	06 59	07 32	08 01
52	16 31	17 09	17 51	06 11	06 51	07 26	07 56
50	16 39	17 15	17 54	06 04	06 44	07 20	07 52
45	16 55	17 27	18 03	05 48	06 30	07 07	07 42
N 40	17 08	17 37	18 10	05 35	06 18	06 57	07 33
35	17 19	17 46	18 17	05 24	06 08	06 48	07 26
30	17 29	17 55	18 24	05 15	05 59	06 40	07 20
20	17 46	18 10	18 36	04 58	05 43	06 27	07 09
N 10	18 01	18 23	18 49	04 43	05 30	06 15	06 59
0	18 15	18 37	19 03	04 30	05 17	06 04	06 50
S 10	18 30	18 52	19 18	04 16	05 04	05 53	06 41
20	18 45	19 09	19 37	04 01	04 50	05 40	06 31
30	19 03	19 29	20 01	03 44	04 35	05 27	06 20
35	19 13	19 42	20 16	03 34	04 26	05 19	06 13
40	19 25	19 56	20 35	03 23	04 15	05 10	06 06
45	19 40	20 14	20 58	03 10	04 03	04 59	05 57
S 50	19 57	20 37	21 30	02 54	03 48	04 46	05 47
52	20 05	20 48	21 47	02 46	03 41	04 40	05 42
54	20 15	21 01	22 09	02 38	03 33	04 33	05 36
56	20 25	21 16	22 37	02 28	03 24	04 25	05 30
58	20 37	21 34	23 23	02 18	03 14	04 17	05 24
S 60	20 51	21 56	////	02 05	03 03	04 07	05 16

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	MOON Age d	MOON Phase
22	11 27	11 35	12 12	23 05	10 42	13	○
23	11 43	11 50	12 12	23 52	11 29	14	
24	11 58	12 05	12 12	24 39	12 16	15	

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Sight Reduction Table

2ᵐ INCREMENTS AND CORRECTIONS 3ᵐ

2ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	0 30·0	0 30·1	0 28·6	0·0	0·0	6·0	0·3	12·0	0·5
01	0 30·3	0 30·3	0 28·9	0·1	0·0	6·1	0·3	12·1	0·5
02	0 30·5	0 30·6	0 29·1	0·2	0·0	6·2	0·3	12·2	0·5
03	0 30·8	0 30·8	0 29·3	0·3	0·0	6·3	0·3	12·3	0·5
04	0 31·0	0 31·1	0 29·6	0·4	0·0	6·4	0·3	12·4	0·5
05	0 31·3	0 31·3	0 29·8	0·5	0·0	6·5	0·3	12·5	0·5
06	0 31·5	0 31·6	0 30·1	0·6	0·0	6·6	0·3	12·6	0·5
07	0 31·8	0 31·8	0 30·3	0·7	0·0	6·7	0·3	12·7	0·5
08	0 32·0	0 32·1	0 30·5	0·8	0·0	6·8	0·3	12·8	0·5
09	0 32·3	0 32·3	0 30·8	0·9	0·0	6·9	0·3	12·9	0·5
10	0 32·5	0 32·6	0 31·0	1·0	0·0	7·0	0·3	13·0	0·5
11	0 32·8	0 32·8	0 31·3	1·1	0·0	7·1	0·3	13·1	0·5
12	0 33·0	0 33·1	0 31·5	1·2	0·1	7·2	0·3	13·2	0·6
13	0 33·3	0 33·3	0 31·7	1·3	0·1	7·3	0·3	13·3	0·6
14	0 33·5	0 33·6	0 32·0	1·4	0·1	7·4	0·3	13·4	0·6
15	0 33·8	0 33·8	0 32·2	1·5	0·1	7·5	0·3	13·5	0·6
16	0 34·0	0 34·1	0 32·5	1·6	0·1	7·6	0·3	13·6	0·6
17	0 34·3	0 34·3	0 32·7	1·7	0·1	7·7	0·3	13·7	0·6
18	0 34·5	0 34·6	0 32·9	1·8	0·1	7·8	0·3	13·8	0·6
19	0 34·8	0 34·8	0 33·2	1·9	0·1	7·9	0·3	13·9	0·6
20	0 35·0	0 35·1	0 33·4	2·0	0·1	8·0	0·3	14·0	0·6
21	0 35·3	0 35·3	0 33·6	2·1	0·1	8·1	0·3	14·1	0·6
22	0 35·5	0 35·6	0 33·9	2·2	0·1	8·2	0·3	14·2	0·6
23	0 35·8	0 35·8	0 34·1	2·3	0·1	8·3	0·3	14·3	0·6
24	0 36·0	0 36·1	0 34·4	2·4	0·1	8·4	0·4	14·4	0·6
25	0 36·3	0 36·3	0 34·6	2·5	0·1	8·5	0·4	14·5	0·6
26	0 36·5	0 36·6	0 34·8	2·6	0·1	8·6	0·4	14·6	0·6
27	0 36·8	0 36·9	0 35·1	2·7	0·1	8·7	0·4	14·7	0·6
28	0 37·0	0 37·1	0 35·3	2·8	0·1	8·8	0·4	14·8	0·6
29	0 37·3	0 37·4	0 35·6	2·9	0·1	8·9	0·4	14·9	0·6
30	0 37·5	0 37·6	0 35·8	3·0	0·1	9·0	0·4	15·0	0·6
31	0 37·8	0 37·9	0 36·0	3·1	0·1	9·1	0·4	15·1	0·6
32	0 38·0	0 38·1	0 36·3	3·2	0·1	9·2	0·4	15·2	0·6
33	0 38·3	0 38·4	0 36·5	3·3	0·1	9·3	0·4	15·3	0·6
34	0 38·5	0 38·6	0 36·7	3·4	0·1	9·4	0·4	15·4	0·6
35	0 38·8	0 38·9	0 37·0	3·5	0·1	9·5	0·4	15·5	0·6
36	0 39·0	0 39·1	0 37·2	3·6	0·2	9·6	0·4	15·6	0·7
37	0 39·3	0 39·4	0 37·5	3·7	0·2	9·7	0·4	15·7	0·7
38	0 39·5	0 39·6	0 37·7	3·8	0·2	9·8	0·4	15·8	0·7
39	0 39·8	0 39·9	0 37·9	3·9	0·2	9·9	0·4	15·9	0·7
40	0 40·0	0 40·1	0 38·2	4·0	0·2	10·0	0·4	16·0	0·7
41	0 40·3	0 40·4	0 38·4	4·1	0·2	10·1	0·4	16·1	0·7
42	0 40·5	0 40·6	0 38·7	4·2	0·2	10·2	0·4	16·2	0·7
43	0 40·8	0 40·9	0 38·9	4·3	0·2	10·3	0·4	16·3	0·7
44	0 41·0	0 41·1	0 39·1	4·4	0·2	10·4	0·4	16·4	0·7
45	0 41·3	0 41·4	0 39·4	4·5	0·2	10·5	0·4	16·5	0·7
46	0 41·5	0 41·6	0 39·6	4·6	0·2	10·6	0·4	16·6	0·7
47	0 41·8	0 41·9	0 39·8	4·7	0·2	10·7	0·4	16·7	0·7
48	0 42·0	0 42·1	0 40·1	4·8	0·2	10·8	0·5	16·8	0·7
49	0 42·3	0 42·4	0 40·3	4·9	0·2	10·9	0·5	16·9	0·7
50	0 42·5	0 42·6	0 40·6	5·0	0·2	11·0	0·5	17·0	0·7
51	0 42·8	0 42·9	0 40·8	5·1	0·2	11·1	0·5	17·1	0·7
52	0 43·0	0 43·1	0 41·0	5·2	0·2	11·2	0·5	17·2	0·7
53	0 43·3	0 43·4	0 41·3	5·3	0·2	11·3	0·5	17·3	0·7
54	0 43·5	0 43·6	0 41·5	5·4	0·2	11·4	0·5	17·4	0·7
55	0 43·8	0 43·9	0 41·8	5·5	0·2	11·5	0·5	17·5	0·7
56	0 44·0	0 44·1	0 42·0	5·6	0·2	11·6	0·5	17·6	0·7
57	0 44·3	0 44·4	0 42·2	5·7	0·2	11·7	0·5	17·7	0·7
58	0 44·5	0 44·6	0 42·5	5·8	0·2	11·8	0·5	17·8	0·7
59	0 44·8	0 44·9	0 42·7	5·9	0·2	11·9	0·5	17·9	0·7
60	0 45·0	0 45·1	0 43·0	6·0	0·3	12·0	0·5	18·0	0·8

3ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	0 45·0	0 45·1	0 43·0	0·0	0·0	6·0	0·4	12·0	0·7
01	0 45·3	0 45·4	0 43·2	0·1	0·0	6·1	0·4	12·1	0·7
02	0 45·5	0 45·6	0 43·4	0·2	0·0	6·2	0·4	12·2	0·7
03	0 45·8	0 45·9	0 43·7	0·3	0·0	6·3	0·4	12·3	0·7
04	0 46·0	0 46·1	0 43·9	0·4	0·0	6·4	0·4	12·4	0·7
05	0 46·3	0 46·4	0 44·1	0·5	0·0	6·5	0·4	12·5	0·7
06	0 46·5	0 46·6	0 44·4	0·6	0·0	6·6	0·4	12·6	0·7
07	0 46·8	0 46·9	0 44·6	0·7	0·0	6·7	0·4	12·7	0·7
08	0 47·0	0 47·1	0 44·9	0·8	0·0	6·8	0·4	12·8	0·7
09	0 47·3	0 47·4	0 45·1	0·9	0·1	6·9	0·4	12·9	0·8
10	0 47·5	0 47·6	0 45·3	1·0	0·1	7·0	0·4	13·0	0·8
11	0 47·8	0 47·9	0 45·6	1·1	0·1	7·1	0·4	13·1	0·8
12	0 48·0	0 48·1	0 45·8	1·2	0·1	7·2	0·4	13·2	0·8
13	0 48·3	0 48·4	0 46·1	1·3	0·1	7·3	0·4	13·3	0·8
14	0 48·5	0 48·6	0 46·3	1·4	0·1	7·4	0·4	13·4	0·8
15	0 48·8	0 48·9	0 46·5	1·5	0·1	7·5	0·4	13·5	0·8
16	0 49·0	0 49·1	0 46·8	1·6	0·1	7·6	0·4	13·6	0·8
17	0 49·3	0 49·4	0 47·0	1·7	0·1	7·7	0·4	13·7	0·8
18	0 49·5	0 49·6	0 47·2	1·8	0·1	7·8	0·5	13·8	0·8
19	0 49·8	0 49·9	0 47·5	1·9	0·1	7·9	0·5	13·9	0·8
20	0 50·0	0 50·1	0 47·7	2·0	0·1	8·0	0·5	14·0	0·8
21	0 50·3	0 50·4	0 48·0	2·1	0·1	8·1	0·5	14·1	0·8
22	0 50·5	0 50·6	0 48·2	2·2	0·1	8·2	0·5	14·2	0·8
23	0 50·8	0 50·9	0 48·4	2·3	0·1	8·3	0·5	14·3	0·8
24	0 51·0	0 51·1	0 48·7	2·4	0·1	8·4	0·5	14·4	0·8
25	0 51·3	0 51·4	0 48·9	2·5	0·1	8·5	0·5	14·5	0·8
26	0 51·5	0 51·6	0 49·2	2·6	0·2	8·6	0·5	14·6	0·9
27	0 51·8	0 51·9	0 49·4	2·7	0·2	8·7	0·5	14·7	0·9
28	0 52·0	0 52·1	0 49·6	2·8	0·2	8·8	0·5	14·8	0·9
29	0 52·3	0 52·4	0 49·9	2·9	0·2	8·9	0·5	14·9	0·9
30	0 52·5	0 52·6	0 50·1	3·0	0·2	9·0	0·5	15·0	0·9
31	0 52·8	0 52·9	0 50·3	3·1	0·2	9·1	0·5	15·1	0·9
32	0 53·0	0 53·1	0 50·6	3·2	0·2	9·2	0·5	15·2	0·9
33	0 53·3	0 53·4	0 50·8	3·3	0·2	9·3	0·5	15·3	0·9
34	0 53·5	0 53·6	0 51·1	3·4	0·2	9·4	0·5	15·4	0·9
35	0 53·8	0 53·9	0 51·3	3·5	0·2	9·5	0·6	15·5	0·9
36	0 54·0	0 54·1	0 51·5	3·6	0·2	9·6	0·6	15·6	0·9
37	0 54·3	0 54·4	0 51·8	3·7	0·2	9·7	0·6	15·7	0·9
38	0 54·5	0 54·6	0 52·0	3·8	0·2	9·8	0·6	15·8	0·9
39	0 54·8	0 54·9	0 52·3	3·9	0·2	9·9	0·6	15·9	0·9
40	0 55·0	0 55·2	0 52·5	4·0	0·2	10·0	0·6	16·0	0·9
41	0 55·3	0 55·4	0 52·7	4·1	0·2	10·1	0·6	16·1	0·9
42	0 55·5	0 55·7	0 53·0	4·2	0·2	10·2	0·6	16·2	0·9
43	0 55·8	0 55·9	0 53·2	4·3	0·3	10·3	0·6	16·3	1·0
44	0 56·0	0 56·2	0 53·4	4·4	0·3	10·4	0·6	16·4	1·0
45	0 56·3	0 56·4	0 53·7	4·5	0·3	10·5	0·6	16·5	1·0
46	0 56·5	0 56·7	0 53·9	4·6	0·3	10·6	0·6	16·6	1·0
47	0 56·8	0 56·9	0 54·2	4·7	0·3	10·7	0·6	16·7	1·0
48	0 57·0	0 57·2	0 54·4	4·8	0·3	10·8	0·6	16·8	1·0
49	0 57·3	0 57·4	0 54·6	4·9	0·3	10·9	0·6	16·9	1·0
50	0 57·5	0 57·7	0 54·9	5·0	0·3	11·0	0·6	17·0	1·0
51	0 57·8	0 57·9	0 55·1	5·1	0·3	11·1	0·6	17·1	1·0
52	0 58·0	0 58·2	0 55·4	5·2	0·3	11·2	0·7	17·2	1·0
53	0 58·3	0 58·4	0 55·6	5·3	0·3	11·3	0·7	17·3	1·0
54	0 58·5	0 58·7	0 55·8	5·4	0·3	11·4	0·7	17·4	1·0
55	0 58·8	0 58·9	0 56·1	5·5	0·3	11·5	0·7	17·5	1·0
56	0 59·0	0 59·2	0 56·3	5·6	0·3	11·6	0·7	17·6	1·0
57	0 59·3	0 59·4	0 56·6	5·7	0·3	11·7	0·7	17·7	1·0
58	0 59·5	0 59·7	0 56·8	5·8	0·3	11·8	0·7	17·8	1·0
59	0 59·8	0 59·9	0 57·0	5·9	0·3	11·9	0·7	17·9	1·0
60	1 00·0	1 00·2	0 57·3	6·0	0·4	12·0	0·7	18·0	1·1

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Sight Reduction Table

24ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	6 00·0	6 01·0	5 43·6	0·0	0·0	6·0	2·5	12·0	4·9
01	6 00·3	6 01·2	5 43·8	0·1	0·0	6·1	2·5	12·1	4·9
02	6 00·5	6 01·5	5 44·1	0·2	0·1	6·2	2·5	12·2	5·0
03	6 00·8	6 01·7	5 44·3	0·3	0·1	6·3	2·6	12·3	5·0
04	6 01·0	6 02·0	5 44·6	0·4	0·2	6·4	2·6	12·4	5·1
05	6 01·3	6 02·2	5 44·8	0·5	0·2	6·5	2·7	12·5	5·1
06	6 01·5	6 02·5	5 45·0	0·6	0·2	6·6	2·7	12·6	5·1
07	6 01·8	6 02·7	5 45·3	0·7	0·3	6·7	2·7	12·7	5·2
08	6 02·0	6 03·0	5 45·5	0·8	0·3	6·8	2·8	12·8	5·2
09	6 02·3	6 03·2	5 45·7	0·9	0·4	6·9	2·8	12·9	5·3
10	6 02·5	6 03·5	5 46·0	1·0	0·4	7·0	2·9	13·0	5·3
11	6 02·8	6 03·7	5 46·2	1·1	0·4	7·1	2·9	13·1	5·3
12	6 03·0	6 04·0	5 46·5	1·2	0·5	7·2	2·9	13·2	5·4
13	6 03·3	6 04·2	5 46·7	1·3	0·5	7·3	3·0	13·3	5·4
14	6 03·5	6 04·5	5 46·9	1·4	0·6	7·4	3·0	13·4	5·5
15	6 03·8	6 04·7	5 47·2	1·5	0·6	7·5	3·1	13·5	5·5
16	6 04·0	6 05·0	5 47·4	1·6	0·7	7·6	3·1	13·6	5·6
17	6 04·3	6 05·2	5 47·7	1·7	0·7	7·7	3·1	13·7	5·6
18	6 04·5	6 05·5	5 47·9	1·8	0·7	7·8	3·2	13·8	5·6
19	6 04·8	6 05·7	5 48·1	1·9	0·8	7·9	3·2	13·9	5·7
20	6 05·0	6 06·0	5 48·4	2·0	0·8	8·0	3·3	14·0	5·7
21	6 05·3	6 06·3	5 48·6	2·1	0·9	8·1	3·3	14·1	5·8
22	6 05·5	6 06·5	5 48·8	2·2	0·9	8·2	3·3	14·2	5·8
23	6 05·8	6 06·8	5 49·1	2·3	0·9	8·3	3·4	14·3	5·8
24	6 06·0	6 07·0	5 49·3	2·4	1·0	8·4	3·4	14·4	5·9
25	6 06·3	6 07·3	5 49·6	2·5	1·0	8·5	3·5	14·5	5·9
26	6 06·5	6 07·5	5 49·8	2·6	1·1	8·6	3·5	14·6	6·0
27	6 06·8	6 07·8	5 50·0	2·7	1·1	8·7	3·6	14·7	6·0
28	6 07·0	6 08·0	5 50·3	2·8	1·1	8·8	3·6	14·8	6·0
29	6 07·3	6 08·3	5 50·5	2·9	1·2	8·9	3·6	14·9	6·1
30	6 07·5	6 08·5	5 50·8	3·0	1·2	9·0	3·7	15·0	6·1
31	6 07·8	6 08·8	5 51·0	3·1	1·3	9·1	3·7	15·1	6·2
32	6 08·0	6 09·0	5 51·2	3·2	1·3	9·2	3·8	15·2	6·2
33	6 08·3	6 09·3	5 51·5	3·3	1·3	9·3	3·8	15·3	6·2
34	6 08·5	6 09·5	5 51·7	3·4	1·4	9·4	3·8	15·4	6·3
35	6 08·8	6 09·8	5 52·0	3·5	1·4	9·5	3·9	15·5	6·3
36	6 09·0	6 10·0	5 52·2	3·6	1·5	9·6	3·9	15·6	6·4
37	6 09·3	6 10·3	5 52·4	3·7	1·5	9·7	4·0	15·7	6·4
38	6 09·5	6 10·5	5 52·7	3·8	1·6	9·8	4·0	15·8	6·5
39	6 09·8	6 10·8	5 52·9	3·9	1·6	9·9	4·0	15·9	6·5
40	6 10·0	6 11·0	5 53·1	4·0	1·6	10·0	4·1	16·0	6·5
41	6 10·3	6 11·3	5 53·4	4·1	1·7	10·1	4·1	16·1	6·6
42	6 10·5	6 11·5	5 53·6	4·2	1·7	10·2	4·2	16·2	6·6
43	6 10·8	6 11·8	5 53·9	4·3	1·8	10·3	4·2	16·3	6·7
44	6 11·0	6 12·0	5 54·1	4·4	1·8	10·4	4·2	16·4	6·7
45	6 11·3	6 12·3	5 54·3	4·5	1·8	10·5	4·3	16·5	6·7
46	6 11·5	6 12·5	5 54·6	4·6	1·9	10·6	4·3	16·6	6·8
47	6 11·8	6 12·8	5 54·8	4·7	1·9	10·7	4·4	16·7	6·8
48	6 12·0	6 13·0	5 55·1	4·8	2·0	10·8	4·4	16·8	6·9
49	6 12·3	6 13·3	5 55·3	4·9	2·0	10·9	4·5	16·9	6·9
50	6 12·5	6 13·5	5 55·5	5·0	2·0	11·0	4·5	17·0	6·9
51	6 12·8	6 13·8	5 55·8	5·1	2·1	11·1	4·5	17·1	7·0
52	6 13·0	6 14·0	5 56·0	5·2	2·1	11·2	4·6	17·2	7·0
53	6 13·3	6 14·3	5 56·2	5·3	2·2	11·3	4·6	17·3	7·1
54	6 13·5	6 14·5	5 56·5	5·4	2·2	11·4	4·7	17·4	7·1
55	6 13·8	6 14·8	5 56·7	5·5	2·2	11·5	4·7	17·5	7·1
56	6 14·0	6 15·0	5 57·0	5·6	2·3	11·6	4·7	17·6	7·2
57	6 14·3	6 15·3	5 57·2	5·7	2·3	11·7	4·8	17·7	7·2
58	6 14·5	6 15·5	5 57·4	5·8	2·4	11·8	4·8	17·8	7·3
59	6 14·8	6 15·8	5 57·7	5·9	2·4	11·9	4·9	17·9	7·3
60	6 15·0	6 16·0	5 57·9	6·0	2·5	12·0	4·9	18·0	7·4

25ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	6 15·0	6 16·0	5 57·9	0·0	0·0	6·0	2·6	12·0	5·1
01	6 15·3	6 16·3	5 58·2	0·1	0·0	6·1	2·6	12·1	5·1
02	6 15·5	6 16·5	5 58·4	0·2	0·1	6·2	2·6	12·2	5·2
03	6 15·8	6 16·8	5 58·6	0·3	0·1	6·3	2·7	12·3	5·2
04	6 16·0	6 17·0	5 58·9	0·4	0·2	6·4	2·7	12·4	5·3
05	6 16·3	6 17·3	5 59·1	0·5	0·2	6·5	2·8	12·5	5·3
06	6 16·5	6 17·5	5 59·3	0·6	0·3	6·6	2·8	12·6	5·4
07	6 16·8	6 17·8	5 59·6	0·7	0·3	6·7	2·8	12·7	5·4
08	6 17·0	6 18·0	5 59·8	0·8	0·3	6·8	2·9	12·8	5·4
09	6 17·3	6 18·3	6 00·1	0·9	0·4	6·9	2·9	12·9	5·5
10	6 17·5	6 18·5	6 00·3	1·0	0·4	7·0	3·0	13·0	5·5
11	6 17·8	6 18·8	6 00·5	1·1	0·5	7·1	3·0	13·1	5·6
12	6 18·0	6 19·0	6 00·8	1·2	0·5	7·2	3·1	13·2	5·6
13	6 18·3	6 19·3	6 01·0	1·3	0·6	7·3	3·1	13·3	5·7
14	6 18·5	6 19·5	6 01·3	1·4	0·6	7·4	3·1	13·4	5·7
15	6 18·8	6 19·8	6 01·5	1·5	0·6	7·5	3·2	13·5	5·7
16	6 19·0	6 20·0	6 01·7	1·6	0·7	7·6	3·2	13·6	5·8
17	6 19·3	6 20·3	6 02·0	1·7	0·7	7·7	3·3	13·7	5·8
18	6 19·5	6 20·5	6 02·2	1·8	0·8	7·8	3·3	13·8	5·9
19	6 19·8	6 20·8	6 02·5	1·9	0·8	7·9	3·4	13·9	5·9
20	6 20·0	6 21·0	6 02·7	2·0	0·9	8·0	3·4	14·0	6·0
21	6 20·3	6 21·3	6 02·9	2·1	0·9	8·1	3·4	14·1	6·0
22	6 20·5	6 21·5	6 03·2	2·2	0·9	8·2	3·5	14·2	6·0
23	6 20·8	6 21·8	6 03·4	2·3	1·0	8·3	3·5	14·3	6·1
24	6 21·0	6 22·0	6 03·6	2·4	1·0	8·4	3·6	14·4	6·1
25	6 21·3	6 22·3	6 03·9	2·5	1·1	8·5	3·6	14·5	6·2
26	6 21·5	6 22·5	6 04·1	2·6	1·1	8·6	3·7	14·6	6·2
27	6 21·8	6 22·8	6 04·4	2·7	1·1	8·7	3·7	14·7	6·2
28	6 22·0	6 23·0	6 04·6	2·8	1·2	8·8	3·7	14·8	6·3
29	6 22·3	6 23·3	6 04·8	2·9	1·2	8·9	3·8	14·9	6·3
30	6 22·5	6 23·5	6 05·1	3·0	1·3	9·0	3·8	15·0	6·4
31	6 22·8	6 23·8	6 05·3	3·1	1·3	9·1	3·9	15·1	6·4
32	6 23·0	6 24·0	6 05·6	3·2	1·4	9·2	3·9	15·2	6·5
33	6 23·3	6 24·3	6 05·8	3·3	1·4	9·3	4·0	15·3	6·5
34	6 23·5	6 24·5	6 06·0	3·4	1·4	9·4	4·0	15·4	6·5
35	6 23·8	6 24·8	6 06·3	3·5	1·5	9·5	4·0	15·5	6·6
36	6 24·0	6 25·1	6 06·5	3·6	1·5	9·6	4·1	15·6	6·6
37	6 24·3	6 25·3	6 06·7	3·7	1·6	9·7	4·1	15·7	6·7
38	6 24·5	6 25·6	6 07·0	3·8	1·6	9·8	4·2	15·8	6·7
39	6 24·8	6 25·8	6 07·2	3·9	1·7	9·9	4·2	15·9	6·8
40	6 25·0	6 26·1	6 07·5	4·0	1·7	10·0	4·3	16·0	6·8
41	6 25·3	6 26·3	6 07·7	4·1	1·7	10·1	4·3	16·1	6·8
42	6 25·5	6 26·6	6 07·9	4·2	1·8	10·2	4·3	16·2	6·9
43	6 25·8	6 26·8	6 08·2	4·3	1·8	10·3	4·4	16·3	6·9
44	6 26·0	6 27·1	6 08·4	4·4	1·9	10·4	4·4	16·4	7·0
45	6 26·3	6 27·3	6 08·7	4·5	1·9	10·5	4·5	16·5	7·0
46	6 26·5	6 27·6	6 08·9	4·6	2·0	10·6	4·5	16·6	7·1
47	6 26·8	6 27·8	6 09·1	4·7	2·0	10·7	4·5	16·7	7·1
48	6 27·0	6 28·1	6 09·4	4·8	2·0	10·8	4·6	16·8	7·1
49	6 27·3	6 28·3	6 09·6	4·9	2·1	10·9	4·6	16·9	7·2
50	6 27·5	6 28·6	6 09·8	5·0	2·1	11·0	4·7	17·0	7·2
51	6 27·8	6 28·8	6 10·1	5·1	2·2	11·1	4·7	17·1	7·3
52	6 28·0	6 29·1	6 10·3	5·2	2·2	11·2	4·8	17·2	7·3
53	6 28·3	6 29·3	6 10·6	5·3	2·3	11·3	4·8	17·3	7·4
54	6 28·5	6 29·6	6 10·8	5·4	2·3	11·4	4·8	17·4	7·4
55	6 28·8	6 29·8	6 11·0	5·5	2·3	11·5	4·9	17·5	7·4
56	6 29·0	6 30·1	6 11·3	5·6	2·4	11·6	4·9	17·6	7·5
57	6 29·3	6 30·3	6 11·5	5·7	2·4	11·7	5·0	17·7	7·5
58	6 29·5	6 30·6	6 11·8	5·8	2·5	11·8	5·0	17·8	7·6
59	6 29·8	6 30·8	6 12·0	5·9	2·5	11·9	5·1	17·9	7·6
60	6 30·0	6 31·1	6 12·2	6·0	2·6	12·0	5·1	18·0	7·7

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Sight Reduction Table

INCREMENTS AND CORRECTIONS

46ᵐ

46ᵐ s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′
00	11 30·0	11 31·9	10 58·6	0·0	0·0	6·0	4·7	12·0	9·3
01	11 30·3	11 32·1	10 58·8	0·1	0·1	6·1	4·7	12·1	9·4
02	11 30·5	11 32·4	10 59·0	0·2	0·2	6·2	4·8	12·2	9·5
03	11 30·8	11 32·6	10 59·3	0·3	0·2	6·3	4·9	12·3	9·5
04	11 31·0	11 32·9	10 59·5	0·4	0·3	6·4	5·0	12·4	9·6
05	11 31·3	11 33·1	10 59·8	0·5	0·4	6·5	5·0	12·5	9·7
06	11 31·5	11 33·4	11 00·0	0·6	0·5	6·6	5·1	12·6	9·8
07	11 31·8	11 33·6	11 00·2	0·7	0·5	6·7	5·2	12·7	9·8
08	11 32·0	11 33·9	11 00·5	0·8	0·6	6·8	5·3	12·8	9·9
09	11 32·3	11 34·1	11 00·7	0·9	0·7	6·9	5·3	12·9	10·0
10	11 32·5	11 34·4	11 01·0	1·0	0·8	7·0	5·4	13·0	10·1
11	11 32·8	11 34·6	11 01·2	1·1	0·9	7·1	5·5	13·1	10·2
12	11 33·0	11 34·9	11 01·4	1·2	0·9	7·2	5·6	13·2	10·2
13	11 33·3	11 35·1	11 01·7	1·3	1·0	7·3	5·7	13·3	10·3
14	11 33·5	11 35·4	11 01·9	1·4	1·1	7·4	5·7	13·4	10·4
15	11 33·8	11 35·6	11 02·1	1·5	1·2	7·5	5·8	13·5	10·5
16	11 34·0	11 35·9	11 02·4	1·6	1·2	7·6	5·9	13·6	10·5
17	11 34·3	11 36·2	11 02·6	1·7	1·3	7·7	6·0	13·7	10·6
18	11 34·5	11 36·4	11 02·9	1·8	1·4	7·8	6·0	13·8	10·7
19	11 34·8	11 36·7	11 03·1	1·9	1·5	7·9	6·1	13·9	10·8
20	11 35·0	11 36·9	11 03·3	2·0	1·6	8·0	6·2	14·0	10·9
21	11 35·3	11 37·2	11 03·6	2·1	1·6	8·1	6·3	14·1	10·9
22	11 35·5	11 37·4	11 03·8	2·2	1·7	8·2	6·4	14·2	11·0
23	11 35·8	11 37·7	11 04·1	2·3	1·8	8·3	6·4	14·3	11·1
24	11 36·0	11 37·9	11 04·3	2·4	1·9	8·4	6·5	14·4	11·2
25	11 36·3	11 38·2	11 04·5	2·5	1·9	8·5	6·6	14·5	11·2
26	11 36·5	11 38·4	11 04·8	2·6	2·0	8·6	6·7	14·6	11·3
27	11 36·8	11 38·7	11 05·0	2·7	2·1	8·7	6·7	14·7	11·4
28	11 37·0	11 38·9	11 05·2	2·8	2·2	8·8	6·8	14·8	11·5
29	11 37·3	11 39·2	11 05·5	2·9	2·2	8·9	6·9	14·9	11·5
30	11 37·5	11 39·4	11 05·7	3·0	2·3	9·0	7·0	15·0	11·6
31	11 37·8	11 39·7	11 06·0	3·1	2·4	9·1	7·1	15·1	11·7
32	11 38·0	11 39·9	11 06·2	3·2	2·5	9·2	7·1	15·2	11·8
33	11 38·3	11 40·2	11 06·4	3·3	2·6	9·3	7·2	15·3	11·9
34	11 38·5	11 40·4	11 06·7	3·4	2·6	9·4	7·3	15·4	11·9
35	11 38·8	11 40·7	11 06·9	3·5	2·7	9·5	7·4	15·5	12·0
36	11 39·0	11 40·9	11 07·2	3·6	2·8	9·6	7·4	15·6	12·1
37	11 39·3	11 41·2	11 07·4	3·7	2·9	9·7	7·5	15·7	12·2
38	11 39·5	11 41·4	11 07·6	3·8	2·9	9·8	7·6	15·8	12·2
39	11 39·8	11 41·7	11 07·9	3·9	3·0	9·9	7·7	15·9	12·3
40	11 40·0	11 41·9	11 08·1	4·0	3·1	10·0	7·8	16·0	12·4
41	11 40·3	11 42·2	11 08·3	4·1	3·2	10·1	7·8	16·1	12·5
42	11 40·5	11 42·4	11 08·6	4·2	3·3	10·2	7·9	16·2	12·6
43	11 40·8	11 42·7	11 08·8	4·3	3·3	10·3	8·0	16·3	12·6
44	11 41·0	11 42·9	11 09·1	4·4	3·4	10·4	8·1	16·4	12·7
45	11 41·3	11 43·2	11 09·3	4·5	3·5	10·5	8·1	16·5	12·8
46	11 41·5	11 43·4	11 09·5	4·6	3·6	10·6	8·2	16·6	12·9
47	11 41·8	11 43·7	11 09·8	4·7	3·6	10·7	8·3	16·7	12·9
48	11 42·0	11 43·9	11 10·0	4·8	3·7	10·8	8·4	16·8	13·0
49	11 42·3	11 44·2	11 10·3	4·9	3·8	10·9	8·4	16·9	13·1
50	11 42·5	11 44·4	11 10·5	5·0	3·9	11·0	8·5	17·0	13·2
51	11 42·8	11 44·7	11 10·7	5·1	4·0	11·1	8·6	17·1	13·3
52	11 43·0	11 44·9	11 11·0	5·2	4·0	11·2	8·7	17·2	13·3
53	11 43·3	11 45·2	11 11·2	5·3	4·1	11·3	8·8	17·3	13·4
54	11 43·5	11 45·4	11 11·5	5·4	4·2	11·4	8·8	17·4	13·5
55	11 43·8	11 45·7	11 11·7	5·5	4·3	11·5	8·9	17·5	13·6
56	11 44·0	11 45·9	11 11·9	5·6	4·3	11·6	9·0	17·6	13·6
57	11 44·3	11 46·2	11 12·2	5·7	4·4	11·7	9·1	17·7	13·7
58	11 44·5	11 46·4	11 12·4	5·8	4·5	11·8	9·1	17·8	13·8
59	11 44·8	11 46·7	11 12·6	5·9	4·6	11·9	9·2	17·9	13·9
60	11 45·0	11 46·9	11 12·9	6·0	4·7	12·0	9·3	18·0	14·0

47ᵐ

47ᵐ s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′
00	11 45·0	11 46·9	11 12·9	0·0	0·0	6·0	4·8	12·0	9·5
01	11 45·3	11 47·2	11 13·1	0·1	0·1	6·1	4·8	12·1	9·6
02	11 45·5	11 47·4	11 13·4	0·2	0·2	6·2	4·9	12·2	9·7
03	11 45·8	11 47·7	11 13·6	0·3	0·2	6·3	5·0	12·3	9·7
04	11 46·0	11 47·9	11 13·8	0·4	0·3	6·4	5·1	12·4	9·8
05	11 46·3	11 48·2	11 14·1	0·5	0·4	6·5	5·1	12·5	9·9
06	11 46·5	11 48·4	11 14·3	0·6	0·5	6·6	5·2	12·6	10·0
07	11 46·8	11 48·7	11 14·6	0·7	0·6	6·7	5·3	12·7	10·1
08	11 47·0	11 48·9	11 14·8	0·8	0·6	6·8	5·4	12·8	10·1
09	11 47·3	11 49·2	11 15·0	0·9	0·7	6·9	5·5	12·9	10·2
10	11 47·5	11 49·4	11 15·3	1·0	0·8	7·0	5·5	13·0	10·3
11	11 47·8	11 49·7	11 15·5	1·1	0·9	7·1	5·6	13·1	10·4
12	11 48·0	11 49·9	11 15·7	1·2	1·0	7·2	5·7	13·2	10·5
13	11 48·3	11 50·2	11 16·0	1·3	1·0	7·3	5·8	13·3	10·5
14	11 48·5	11 50·4	11 16·2	1·4	1·1	7·4	5·9	13·4	10·6
15	11 48·8	11 50·7	11 16·5	1·5	1·2	7·5	5·9	13·5	10·7
16	11 49·0	11 50·9	11 16·7	1·6	1·3	7·6	6·0	13·6	10·8
17	11 49·3	11 51·2	11 16·9	1·7	1·3	7·7	6·1	13·7	10·8
18	11 49·5	11 51·4	11 17·2	1·8	1·4	7·8	6·2	13·8	10·9
19	11 49·8	11 51·7	11 17·4	1·9	1·5	7·9	6·3	13·9	11·0
20	11 50·0	11 51·9	11 17·7	2·0	1·6	8·0	6·3	14·0	11·1
21	11 50·3	11 52·2	11 17·9	2·1	1·7	8·1	6·4	14·1	11·2
22	11 50·5	11 52·4	11 18·1	2·2	1·7	8·2	6·5	14·2	11·2
23	11 50·8	11 52·7	11 18·4	2·3	1·8	8·3	6·6	14·3	11·3
24	11 51·0	11 52·9	11 18·6	2·4	1·9	8·4	6·7	14·4	11·4
25	11 51·3	11 53·2	11 18·8	2·5	2·0	8·5	6·7	14·5	11·5
26	11 51·5	11 53·4	11 19·1	2·6	2·1	8·6	6·8	14·6	11·6
27	11 51·8	11 53·7	11 19·3	2·7	2·1	8·7	6·9	14·7	11·6
28	11 52·0	11 53·9	11 19·6	2·8	2·2	8·8	7·0	14·8	11·7
29	11 52·3	11 54·2	11 19·8	2·9	2·3	8·9	7·0	14·9	11·8
30	11 52·5	11 54·5	11 20·0	3·0	2·4	9·0	7·1	15·0	11·9
31	11 52·8	11 54·7	11 20·3	3·1	2·5	9·1	7·2	15·1	12·0
32	11 53·0	11 55·0	11 20·5	3·2	2·5	9·2	7·3	15·2	12·0
33	11 53·3	11 55·2	11 20·8	3·3	2·6	9·3	7·4	15·3	12·1
34	11 53·5	11 55·5	11 21·0	3·4	2·7	9·4	7·4	15·4	12·2
35	11 53·8	11 55·7	11 21·2	3·5	2·8	9·5	7·5	15·5	12·3
36	11 54·0	11 56·0	11 21·5	3·6	2·9	9·6	7·6	15·6	12·4
37	11 54·3	11 56·2	11 21·7	3·7	2·9	9·7	7·7	15·7	12·4
38	11 54·5	11 56·5	11 22·0	3·8	3·0	9·8	7·8	15·8	12·5
39	11 54·8	11 56·7	11 22·2	3·9	3·1	9·9	7·8	15·9	12·6
40	11 55·0	11 57·0	11 22·4	4·0	3·2	10·0	7·9	16·0	12·7
41	11 55·3	11 57·2	11 22·7	4·1	3·2	10·1	8·0	16·1	12·7
42	11 55·5	11 57·5	11 22·9	4·2	3·3	10·2	8·1	16·2	12·8
43	11 55·8	11 57·7	11 23·1	4·3	3·4	10·3	8·2	16·3	12·9
44	11 56·0	11 58·0	11 23·4	4·4	3·5	10·4	8·2	16·4	13·0
45	11 56·3	11 58·2	11 23·6	4·5	3·6	10·5	8·3	16·5	13·1
46	11 56·5	11 58·5	11 23·9	4·6	3·6	10·6	8·4	16·6	13·1
47	11 56·8	11 58·7	11 24·1	4·7	3·7	10·7	8·5	16·7	13·2
48	11 57·0	11 59·0	11 24·3	4·8	3·8	10·8	8·6	16·8	13·3
49	11 57·3	11 59·2	11 24·6	4·9	3·9	10·9	8·6	16·9	13·4
50	11 57·5	11 59·5	11 24·8	5·0	4·0	11·0	8·7	17·0	13·5
51	11 57·8	11 59·7	11 25·1	5·1	4·0	11·1	8·8	17·1	13·5
52	11 58·0	12 00·0	11 25·3	5·2	4·1	11·2	8·9	17·2	13·6
53	11 58·3	12 00·2	11 25·5	5·3	4·2	11·3	8·9	17·3	13·7
54	11 58·5	12 00·5	11 25·8	5·4	4·3	11·4	9·0	17·4	13·8
55	11 58·8	12 00·7	11 26·0	5·5	4·4	11·5	9·1	17·5	13·9
56	11 59·0	12 01·0	11 26·2	5·6	4·4	11·6	9·2	17·6	13·9
57	11 59·3	12 01·2	11 26·5	5·7	4·5	11·7	9·3	17·7	14·0
58	11 59·5	12 01·5	11 26·7	5·8	4·6	11·8	9·3	17·8	14·1
59	11 59·8	12 01·7	11 27·0	5·9	4·7	11·9	9·4	17·9	14·2
60	12 00·0	12 02·0	11 27·2	6·0	4·8	12·0	9·5	18·0	14·3

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Sight Reduction Table

54ᵐ INCREMENTS AND CORRECTIONS 55ᵐ

54ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	13 30·0	13 32·2	12 53·1	0·0	0·0	6·0	5·5	12·0	10·9
01	13 30·3	13 32·5	12 53·3	0·1	0·1	6·1	5·5	12·1	11·0
02	13 30·5	13 32·7	12 53·6	0·2	0·2	6·2	5·6	12·2	11·1
03	13 30·8	13 33·0	12 53·8	0·3	0·3	6·3	5·7	12·3	11·2
04	13 31·0	13 33·2	12 54·1	0·4	0·4	6·4	5·8	12·4	11·3
05	13 31·3	13 33·5	12 54·3	0·5	0·5	6·5	5·9	12·5	11·4
06	13 31·5	13 33·7	12 54·5	0·6	0·5	6·6	6·0	12·6	11·4
07	13 31·8	13 34·0	12 54·8	0·7	0·6	6·7	6·1	12·7	11·5
08	13 32·0	13 34·2	12 55·0	0·8	0·7	6·8	6·2	12·8	11·6
09	13 32·3	13 34·5	12 55·2	0·9	0·8	6·9	6·3	12·9	11·7
10	13 32·5	13 34·7	12 55·5	1·0	0·9	7·0	6·4	13·0	11·8
11	13 32·8	13 35·0	12 55·7	1·1	1·0	7·1	6·4	13·1	11·9
12	13 33·0	13 35·2	12 56·0	1·2	1·1	7·2	6·5	13·2	12·0
13	13 33·3	13 35·5	12 56·2	1·3	1·2	7·3	6·6	13·3	12·1
14	13 33·5	13 35·7	12 56·4	1·4	1·3	7·4	6·7	13·4	12·2
15	13 33·8	13 36·0	12 56·7	1·5	1·4	7·5	6·8	13·5	12·3
16	13 34·0	13 36·2	12 56·9	1·6	1·5	7·6	6·9	13·6	12·4
17	13 34·3	13 36·5	12 57·2	1·7	1·5	7·7	7·0	13·7	12·4
18	13 34·5	13 36·7	12 57·4	1·8	1·6	7·8	7·1	13·8	12·5
19	13 34·8	13 37·0	12 57·6	1·9	1·7	7·9	7·2	13·9	12·6
20	13 35·0	13 37·2	12 57·9	2·0	1·8	8·0	7·3	14·0	12·7
21	13 35·3	13 37·5	12 58·1	2·1	1·9	8·1	7·4	14·1	12·8
22	13 35·5	13 37·7	12 58·3	2·2	2·0	8·2	7·4	14·2	12·9
23	13 35·8	13 38·0	12 58·6	2·3	2·1	8·3	7·5	14·3	13·0
24	13 36·0	13 38·2	12 58·8	2·4	2·2	8·4	7·6	14·4	13·1
25	13 36·3	13 38·5	12 59·1	2·5	2·3	8·5	7·7	14·5	13·2
26	13 36·5	13 38·7	12 59·3	2·6	2·4	8·6	7·8	14·6	13·3
27	13 36·8	13 39·0	12 59·5	2·7	2·5	8·7	7·9	14·7	13·4
28	13 37·0	13 39·2	12 59·8	2·8	2·5	8·8	8·0	14·8	13·4
29	13 37·3	13 39·5	13 00·0	2·9	2·6	8·9	8·1	14·9	13·5
30	13 37·5	13 39·7	13 00·3	3·0	2·7	9·0	8·2	15·0	13·6
31	13 37·8	13 40·0	13 00·5	3·1	2·8	9·1	8·3	15·1	13·7
32	13 38·0	13 40·2	13 00·7	3·2	2·9	9·2	8·4	15·2	13·8
33	13 38·3	13 40·5	13 01·0	3·3	3·0	9·3	8·4	15·3	13·9
34	13 38·5	13 40·7	13 01·2	3·4	3·1	9·4	8·5	15·4	14·0
35	13 38·8	13 41·0	13 01·5	3·5	3·2	9·5	8·6	15·5	14·1
36	13 39·0	13 41·2	13 01·7	3·6	3·3	9·6	8·7	15·6	14·2
37	13 39·3	13 41·5	13 01·9	3·7	3·4	9·7	8·8	15·7	14·3
38	13 39·5	13 41·7	13 02·2	3·8	3·5	9·8	8·9	15·8	14·4
39	13 39·8	13 42·0	13 02·4	3·9	3·5	9·9	9·0	15·9	14·4
40	13 40·0	13 42·2	13 02·6	4·0	3·6	10·0	9·1	16·0	14·5
41	13 40·3	13 42·5	13 02·9	4·1	3·7	10·1	9·2	16·1	14·6
42	13 40·5	13 42·7	13 03·1	4·2	3·8	10·2	9·3	16·2	14·7
43	13 40·8	13 43·0	13 03·4	4·3	3·9	10·3	9·4	16·3	14·8
44	13 41·0	13 43·2	13 03·6	4·4	4·0	10·4	9·4	16·4	14·9
45	13 41·3	13 43·5	13 03·8	4·5	4·1	10·5	9·5	16·5	15·0
46	13 41·5	13 43·7	13 04·1	4·6	4·2	10·6	9·6	16·6	15·1
47	13 41·8	13 44·0	13 04·3	4·7	4·3	10·7	9·7	16·7	15·2
48	13 42·0	13 44·3	13 04·6	4·8	4·4	10·8	9·8	16·8	15·3
49	13 42·3	13 44·5	13 04·8	4·9	4·5	10·9	9·9	16·9	15·4
50	13 42·5	13 44·8	13 05·0	5·0	4·5	11·0	10·0	17·0	15·4
51	13 42·8	13 45·0	13 05·3	5·1	4·6	11·1	10·1	17·1	15·5
52	13 43·0	13 45·3	13 05·5	5·2	4·7	11·2	10·2	17·2	15·6
53	13 43·3	13 45·5	13 05·7	5·3	4·8	11·3	10·3	17·3	15·7
54	13 43·5	13 45·8	13 06·0	5·4	4·9	11·4	10·4	17·4	15·8
55	13 43·8	13 46·0	13 06·2	5·5	5·0	11·5	10·4	17·5	15·9
56	13 44·0	13 46·3	13 06·5	5·6	5·1	11·6	10·5	17·6	16·0
57	13 44·3	13 46·5	13 06·7	5·7	5·2	11·7	10·6	17·7	16·1
58	13 44·5	13 46·8	13 06·9	5·8	5·3	11·8	10·7	17·8	16·2
59	13 44·8	13 47·0	13 07·2	5·9	5·4	11·9	10·8	17·9	16·3
60	13 45·0	13 47·3	13 07·4	6·0	5·5	12·0	10·9	18·0	16·4

55ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	13 45·0	13 47·3	13 07·4	0·0	0·0	6·0	5·6	12·0	11·1
01	13 45·3	13 47·5	13 07·7	0·1	0·1	6·1	5·6	12·1	11·2
02	13 45·5	13 47·8	13 07·9	0·2	0·2	6·2	5·7	12·2	11·3
03	13 45·8	13 48·0	13 08·1	0·3	0·3	6·3	5·8	12·3	11·4
04	13 46·0	13 48·3	13 08·4	0·4	0·4	6·4	5·9	12·4	11·5
05	13 46·3	13 48·5	13 08·6	0·5	0·5	6·5	6·0	12·5	11·6
06	13 46·5	13 48·8	13 08·8	0·6	0·6	6·6	6·1	12·6	11·7
07	13 46·8	13 49·0	13 09·1	0·7	0·6	6·7	6·2	12·7	11·7
08	13 47·0	13 49·3	13 09·3	0·8	0·7	6·8	6·3	12·8	11·8
09	13 47·3	13 49·5	13 09·6	0·9	0·8	6·9	6·4	12·9	11·9
10	13 47·5	13 49·8	13 09·8	1·0	0·9	7·0	6·5	13·0	12·0
11	13 47·8	13 50·0	13 10·0	1·1	1·0	7·1	6·6	13·1	12·1
12	13 48·0	13 50·3	13 10·3	1·2	1·1	7·2	6·7	13·2	12·2
13	13 48·3	13 50·5	13 10·5	1·3	1·2	7·3	6·8	13·3	12·3
14	13 48·5	13 50·8	13 10·8	1·4	1·3	7·4	6·8	13·4	12·4
15	13 48·8	13 51·0	13 11·0	1·5	1·4	7·5	6·9	13·5	12·5
16	13 49·0	13 51·3	13 11·2	1·6	1·5	7·6	7·0	13·6	12·6
17	13 49·3	13 51·5	13 11·5	1·7	1·6	7·7	7·1	13·7	12·7
18	13 49·5	13 51·8	13 11·7	1·8	1·7	7·8	7·2	13·8	12·8
19	13 49·8	13 52·0	13 12·0	1·9	1·8	7·9	7·3	13·9	12·9
20	13 50·0	13 52·3	13 12·2	2·0	1·9	8·0	7·4	14·0	13·0
21	13 50·3	13 52·5	13 12·4	2·1	1·9	8·1	7·5	14·1	13·0
22	13 50·5	13 52·8	13 12·7	2·2	2·0	8·2	7·6	14·2	13·1
23	13 50·8	13 53·0	13 12·9	2·3	2·1	8·3	7·7	14·3	13·2
24	13 51·0	13 53·3	13 13·1	2·4	2·2	8·4	7·8	14·4	13·3
25	13 51·3	13 53·5	13 13·4	2·5	2·3	8·5	7·9	14·5	13·4
26	13 51·5	13 53·8	13 13·6	2·6	2·4	8·6	8·0	14·6	13·5
27	13 51·8	13 54·0	13 13·9	2·7	2·5	8·7	8·0	14·7	13·6
28	13 52·0	13 54·3	13 14·1	2·8	2·6	8·8	8·1	14·8	13·7
29	13 52·3	13 54·5	13 14·3	2·9	2·7	8·9	8·2	14·9	13·8
30	13 52·5	13 54·8	13 14·6	3·0	2·8	9·0	8·3	15·0	13·9
31	13 52·8	13 55·0	13 14·8	3·1	2·9	9·1	8·4	15·1	14·0
32	13 53·0	13 55·3	13 15·1	3·2	3·0	9·2	8·5	15·2	14·1
33	13 53·3	13 55·5	13 15·3	3·3	3·1	9·3	8·6	15·3	14·2
34	13 53·5	13 55·8	13 15·5	3·4	3·1	9·4	8·7	15·4	14·2
35	13 53·8	13 56·0	13 15·8	3·5	3·2	9·5	8·8	15·5	14·3
36	13 54·0	13 56·3	13 16·0	3·6	3·3	9·6	8·9	15·6	14·4
37	13 54·3	13 56·5	13 16·2	3·7	3·4	9·7	9·0	15·7	14·5
38	13 54·5	13 56·8	13 16·5	3·8	3·5	9·8	9·1	15·8	14·6
39	13 54·8	13 57·0	13 16·7	3·9	3·6	9·9	9·2	15·9	14·7
40	13 55·0	13 57·3	13 17·0	4·0	3·7	10·0	9·3	16·0	14·8
41	13 55·3	13 57·5	13 17·2	4·1	3·8	10·1	9·3	16·1	14·9
42	13 55·5	13 57·8	13 17·4	4·2	3·9	10·2	9·4	16·2	15·0
43	13 55·8	13 58·0	13 17·7	4·3	4·0	10·3	9·5	16·3	15·1
44	13 56·0	13 58·3	13 17·9	4·4	4·1	10·4	9·6	16·4	15·2
45	13 56·3	13 58·5	13 18·2	4·5	4·2	10·5	9·7	16·5	15·3
46	13 56·5	13 58·8	13 18·4	4·6	4·3	10·6	9·8	16·6	15·4
47	13 56·8	13 59·0	13 18·6	4·7	4·3	10·7	9·9	16·7	15·4
48	13 57·0	13 59·3	13 18·9	4·8	4·4	10·8	10·0	16·8	15·5
49	13 57·3	13 59·5	13 19·1	4·9	4·5	10·9	10·1	16·9	15·6
50	13 57·5	13 59·8	13 19·3	5·0	4·6	11·0	10·2	17·0	15·7
51	13 57·8	14 00·0	13 19·6	5·1	4·7	11·1	10·3	17·1	15·8
52	13 58·0	14 00·3	13 19·8	5·2	4·8	11·2	10·4	17·2	15·9
53	13 58·3	14 00·5	13 20·1	5·3	4·9	11·3	10·5	17·3	16·0
54	13 58·5	14 00·8	13 20·3	5·4	5·0	11·4	10·5	17·4	16·1
55	13 58·8	14 01·0	13 20·5	5·5	5·1	11·5	10·6	17·5	16·2
56	13 59·0	14 01·3	13 20·8	5·6	5·2	11·6	10·7	17·6	16·3
57	13 59·3	14 01·5	13 21·0	5·7	5·3	11·7	10·8	17·7	16·4
58	13 59·5	14 01·8	13 21·3	5·8	5·4	11·8	10·9	17·8	16·5
59	13 59·8	14 02·0	13 21·5	5·9	5·5	11·9	11·0	17·9	16·6
60	14 00·0	14 02·3	13 21·7	6·0	5·6	12·0	11·1	18·0	16·7

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Sight Reduction Table

56ᵐ INCREMENTS AND CORRECTIONS 57ᵐ

56ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 00·0	14 02·3	13 21·7	0·0	0·0	6·0	5·7	12·0	11·3
01	14 00·3	14 02·6	13 22·0	0·1	0·1	6·1	5·7	12·1	11·4
02	14 00·5	14 02·8	13 22·2	0·2	0·2	6·2	5·8	12·2	11·5
03	14 00·8	14 03·1	13 22·4	0·3	0·3	6·3	5·9	12·3	11·6
04	14 01·0	14 03·3	13 22·7	0·4	0·4	6·4	6·0	12·4	11·7
05	14 01·3	14 03·6	13 22·9	0·5	0·5	6·5	6·1	12·5	11·8
06	14 01·5	14 03·8	13 23·2	0·6	0·6	6·6	6·2	12·6	11·9
07	14 01·8	14 04·1	13 23·4	0·7	0·7	6·7	6·3	12·7	12·0
08	14 02·0	14 04·3	13 23·6	0·8	0·8	6·8	6·4	12·8	12·1
09	14 02·3	14 04·6	13 23·9	0·9	0·8	6·9	6·5	12·9	12·1
10	14 02·5	14 04·8	13 24·1	1·0	0·9	7·0	6·6	13·0	12·2
11	14 02·8	14 05·1	13 24·4	1·1	1·0	7·1	6·7	13·1	12·3
12	14 03·0	14 05·3	13 24·6	1·2	1·1	7·2	6·8	13·2	12·4
13	14 03·3	14 05·6	13 24·8	1·3	1·2	7·3	6·9	13·3	12·5
14	14 03·5	14 05·8	13 25·1	1·4	1·3	7·4	7·0	13·4	12·6
15	14 03·8	14 06·1	13 25·3	1·5	1·4	7·5	7·1	13·5	12·7
16	14 04·0	14 06·3	13 25·6	1·6	1·5	7·6	7·2	13·6	12·8
17	14 04·3	14 06·6	13 25·8	1·7	1·6	7·7	7·3	13·7	12·9
18	14 04·5	14 06·8	13 26·0	1·8	1·7	7·8	7·3	13·8	13·0
19	14 04·8	14 07·1	13 26·3	1·9	1·8	7·9	7·4	13·9	13·1
20	14 05·0	14 07·3	13 26·5	2·0	1·9	8·0	7·5	14·0	13·2
21	14 05·3	14 07·6	13 26·7	2·1	2·0	8·1	7·6	14·1	13·3
22	14 05·5	14 07·8	13 27·0	2·2	2·1	8·2	7·7	14·2	13·4
23	14 05·8	14 08·1	13 27·2	2·3	2·2	8·3	7·8	14·3	13·5
24	14 06·0	14 08·3	13 27·5	2·4	2·3	8·4	7·9	14·4	13·6
25	14 06·3	14 08·6	13 27·7	2·5	2·4	8·5	8·0	14·5	13·7
26	14 06·5	14 08·8	13 27·9	2·6	2·4	8·6	8·1	14·6	13·7
27	14 06·8	14 09·1	13 28·2	2·7	2·5	8·7	8·2	14·7	13·8
28	14 07·0	14 09·3	13 28·4	2·8	2·6	8·8	8·3	14·8	13·9
29	14 07·3	14 09·6	13 28·7	2·9	2·7	8·9	8·4	14·9	14·0
30	14 07·5	14 09·8	13 28·9	3·0	2·8	9·0	8·5	15·0	14·1
31	14 07·8	14 10·1	13 29·1	3·1	2·9	9·1	8·6	15·1	14·2
32	14 08·0	14 10·3	13 29·4	3·2	3·0	9·2	8·7	15·2	14·3
33	14 08·3	14 10·6	13 29·6	3·3	3·1	9·3	8·8	15·3	14·4
34	14 08·5	14 10·8	13 29·8	3·4	3·2	9·4	8·9	15·4	14·5
35	14 08·8	14 11·1	13 30·1	3·5	3·3	9·5	8·9	15·5	14·6
36	14 09·0	14 11·3	13 30·3	3·6	3·4	9·6	9·0	15·6	14·7
37	14 09·3	14 11·6	13 30·6	3·7	3·5	9·7	9·1	15·7	14·8
38	14 09·5	14 11·8	13 30·8	3·8	3·6	9·8	9·2	15·8	14·9
39	14 09·8	14 12·1	13 31·0	3·9	3·7	9·9	9·3	15·9	15·0
40	14 10·0	14 12·3	13 31·3	4·0	3·8	10·0	9·4	16·0	15·1
41	14 10·3	14 12·6	13 31·5	4·1	3·9	10·1	9·5	16·1	15·2
42	14 10·5	14 12·8	13 31·8	4·2	4·0	10·2	9·6	16·2	15·3
43	14 10·8	14 13·1	13 32·0	4·3	4·0	10·3	9·7	16·3	15·3
44	14 11·0	14 13·3	13 32·2	4·4	4·1	10·4	9·8	16·4	15·4
45	14 11·3	14 13·6	13 32·5	4·5	4·2	10·5	9·9	16·5	15·5
46	14 11·5	14 13·8	13 32·7	4·6	4·3	10·6	10·0	16·6	15·6
47	14 11·8	14 14·1	13 32·9	4·7	4·4	10·7	10·1	16·7	15·7
48	14 12·0	14 14·3	13 33·2	4·8	4·5	10·8	10·2	16·8	15·8
49	14 12·3	14 14·6	13 33·4	4·9	4·6	10·9	10·3	16·9	15·9
50	14 12·5	14 14·8	13 33·7	5·0	4·7	11·0	10·4	17·0	16·0
51	14 12·8	14 15·1	13 33·9	5·1	4·8	11·1	10·5	17·1	16·1
52	14 13·0	14 15·3	13 34·1	5·2	4·9	11·2	10·5	17·2	16·2
53	14 13·3	14 15·6	13 34·4	5·3	5·0	11·3	10·6	17·3	16·3
54	14 13·5	14 15·8	13 34·6	5·4	5·1	11·4	10·7	17·4	16·4
55	14 13·8	14 16·1	13 34·9	5·5	5·2	11·5	10·8	17·5	16·5
56	14 14·0	14 16·3	13 35·1	5·6	5·3	11·6	10·9	17·6	16·6
57	14 14·3	14 16·6	13 35·3	5·7	5·4	11·7	11·0	17·7	16·7
58	14 14·5	14 16·8	13 35·6	5·8	5·5	11·8	11·1	17·8	16·8
59	14 14·8	14 17·1	13 35·8	5·9	5·6	11·9	11·2	17·9	16·9
60	14 15·0	14 17·3	13 36·1	6·0	5·7	12·0	11·3	18·0	17·0

57ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 15·0	14 17·3	13 36·1	0·0	0·0	6·0	5·8	12·0	11·5
01	14 15·3	14 17·6	13 36·3	0·1	0·1	6·1	5·8	12·1	11·6
02	14 15·5	14 17·8	13 36·5	0·2	0·2	6·2	5·9	12·2	11·7
03	14 15·8	14 18·1	13 36·8	0·3	0·3	6·3	6·0	12·3	11·8
04	14 16·0	14 18·3	13 37·0	0·4	0·4	6·4	6·1	12·4	11·9
05	14 16·3	14 18·6	13 37·2	0·5	0·5	6·5	6·2	12·5	12·0
06	14 16·5	14 18·8	13 37·5	0·6	0·6	6·6	6·3	12·6	12·1
07	14 16·8	14 19·1	13 37·7	0·7	0·7	6·7	6·4	12·7	12·2
08	14 17·0	14 19·3	13 38·0	0·8	0·8	6·8	6·5	12·8	12·3
09	14 17·3	14 19·6	13 38·2	0·9	0·9	6·9	6·6	12·9	12·4
10	14 17·5	14 19·8	13 38·4	1·0	1·0	7·0	6·7	13·0	12·5
11	14 17·8	14 20·1	13 38·7	1·1	1·1	7·1	6·8	13·1	12·6
12	14 18·0	14 20·3	13 38·9	1·2	1·2	7·2	6·9	13·2	12·7
13	14 18·3	14 20·6	13 39·2	1·3	1·2	7·3	7·0	13·3	12·7
14	14 18·5	14 20·9	13 39·4	1·4	1·3	7·4	7·1	13·4	12·8
15	14 18·8	14 21·1	13 39·6	1·5	1·4	7·5	7·2	13·5	12·9
16	14 19·0	14 21·4	13 39·9	1·6	1·5	7·6	7·3	13·6	13·0
17	14 19·3	14 21·6	13 40·1	1·7	1·6	7·7	7·4	13·7	13·1
18	14 19·5	14 21·9	13 40·3	1·8	1·7	7·8	7·5	13·8	13·2
19	14 19·8	14 22·1	13 40·6	1·9	1·8	7·9	7·6	13·9	13·3
20	14 20·0	14 22·4	13 40·8	2·0	1·9	8·0	7·7	14·0	13·4
21	14 20·3	14 22·6	13 41·1	2·1	2·0	8·1	7·8	14·1	13·5
22	14 20·5	14 22·9	13 41·3	2·2	2·1	8·2	7·9	14·2	13·6
23	14 20·8	14 23·1	13 41·5	2·3	2·2	8·3	8·0	14·3	13·7
24	14 21·0	14 23·4	13 41·8	2·4	2·3	8·4	8·1	14·4	13·8
25	14 21·3	14 23·6	13 42·0	2·5	2·4	8·5	8·1	14·5	13·9
26	14 21·5	14 23·9	13 42·3	2·6	2·5	8·6	8·2	14·6	14·0
27	14 21·8	14 24·1	13 42·5	2·7	2·6	8·7	8·3	14·7	14·1
28	14 22·0	14 24·4	13 42·7	2·8	2·7	8·8	8·4	14·8	14·2
29	14 22·3	14 24·6	13 43·0	2·9	2·8	8·9	8·5	14·9	14·3
30	14 22·5	14 24·9	13 43·2	3·0	2·9	9·0	8·6	15·0	14·4
31	14 22·8	14 25·1	13 43·4	3·1	3·0	9·1	8·7	15·1	14·5
32	14 23·0	14 25·4	13 43·7	3·2	3·1	9·2	8·8	15·2	14·6
33	14 23·3	14 25·6	13 43·9	3·3	3·2	9·3	8·9	15·3	14·7
34	14 23·5	14 25·9	13 44·2	3·4	3·3	9·4	9·0	15·4	14·8
35	14 23·8	14 26·1	13 44·4	3·5	3·4	9·5	9·1	15·5	14·9
36	14 24·0	14 26·4	13 44·6	3·6	3·5	9·6	9·2	15·6	15·0
37	14 24·3	14 26·6	13 44·9	3·7	3·5	9·7	9·3	15·7	15·0
38	14 24·5	14 26·9	13 45·1	3·8	3·6	9·8	9·4	15·8	15·1
39	14 24·8	14 27·1	13 45·4	3·9	3·7	9·9	9·5	15·9	15·2
40	14 25·0	14 27·4	13 45·6	4·0	3·8	10·0	9·6	16·0	15·3
41	14 25·3	14 27·6	13 45·8	4·1	3·9	10·1	9·7	16·1	15·4
42	14 25·5	14 27·9	13 46·1	4·2	4·0	10·2	9·8	16·2	15·5
43	14 25·8	14 28·1	13 46·3	4·3	4·1	10·3	9·9	16·3	15·6
44	14 26·0	14 28·4	13 46·5	4·4	4·2	10·4	10·0	16·4	15·7
45	14 26·3	14 28·6	13 46·8	4·5	4·3	10·5	10·1	16·5	15·8
46	14 26·5	14 28·9	13 47·0	4·6	4·4	10·6	10·2	16·6	15·9
47	14 26·8	14 29·1	13 47·3	4·7	4·5	10·7	10·3	16·7	16·0
48	14 27·0	14 29·4	13 47·5	4·8	4·6	10·8	10·4	16·8	16·1
49	14 27·3	14 29·6	13 47·7	4·9	4·7	10·9	10·4	16·9	16·2
50	14 27·5	14 29·9	13 48·0	5·0	4·8	11·0	10·5	17·0	16·3
51	14 27·8	14 30·1	13 48·2	5·1	4·9	11·1	10·6	17·1	16·4
52	14 28·0	14 30·4	13 48·5	5·2	5·0	11·2	10·7	17·2	16·5
53	14 28·3	14 30·6	13 48·7	5·3	5·1	11·3	10·8	17·3	16·6
54	14 28·5	14 30·9	13 48·9	5·4	5·2	11·4	10·9	17·4	16·7
55	14 28·8	14 31·1	13 49·2	5·5	5·3	11·5	11·0	17·5	16·8
56	14 29·0	14 31·4	13 49·4	5·6	5·4	11·6	11·1	17·6	16·9
57	14 29·3	14 31·6	13 49·7	5·7	5·5	11·7	11·2	17·7	17·0
58	14 29·5	14 31·9	13 49·9	5·8	5·6	11·8	11·3	17·8	17·1
59	14 29·8	14 32·1	13 50·1	5·9	5·7	11·9	11·4	17·9	17·2
60	14 30·0	14 32·4	13 50·4	6·0	5·8	12·0	11·5	18·0	17·3

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Nautical Almanac

1978 APRIL 4, 5, 6 (TUES., WED., THURS.)

	G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	v	MOON Dec.	d	H.P.
	h	° ′	° ′	° ′	′	° ′	′	′
	4 00	179 11.9	N 5 28.2	222 51.4	9.5	S 9 05.9	9.5	58.7
	01	194 12.1	29.2	237 19.9	9.5	8 56.4	9.6	58.7
	02	209 12.3	30.1	251 48.4	9.6	8 46.8	9.6	58.7
	03	224 12.5	· · 31.1	266 17.0	9.7	8 37.2	9.7	58.7
	04	239 12.7	32.0	280 45.7	9.6	8 27.5	9.7	58.7
	05	254 12.8	33.0	295 14.3	9.8	8 17.8	9.8	58.6
	06	269 13.0	N 5 33.9	309 43.1	9.7	S 8 08.0	9.8	58.6
	07	284 13.2	34.9	324 11.8	9.8	7 58.2	9.8	58.6
T	08	299 13.4	35.8	338 40.6	9.9	7 48.4	9.9	58.6
U	09	314 13.6	· · 36.8	353 09.5	9.9	7 38.5	9.9	58.6
E	10	329 13.8	37.8	7 38.4	9.9	7 28.6	10.0	58.6
S	11	344 13.9	38.7	22 07.3	10.0	7 18.6	10.0	58.6
D	12	359 14.1	N 5 39.7	36 36.3	10.0	S 7 08.6	10.0	58.5
A	13	14 14.3	40.6	51 05.3	10.0	6 58.6	10.1	58.5
Y	14	29 14.5	41.6	65 34.3	10.1	6 48.5	10.1	58.5
	15	44 14.7	· · 42.5	80 03.4	10.1	6 38.4	10.1	58.5
	16	59 14.8	43.5	94 32.5	10.1	6 28.3	10.2	58.5
	17	74 15.0	44.4	109 01.6	10.2	6 18.1	10.2	58.5
	18	89 15.2	N 5 45.4	123 30.8	10.3	S 6 07.9	10.2	58.4
	19	104 15.4	46.3	138 00.1	10.2	5 57.7	10.3	58.4
	20	119 15.6	47.3	152 29.3	10.3	5 47.4	10.3	58.4
	21	134 15.8	· · 48.2	166 58.6	10.4	5 37.1	10.3	58.4
	22	149 15.9	49.2	181 28.0	10.3	5 26.8	10.3	58.4
	23	164 16.1	50.1	195 57.3	10.4	5 16.5	10.4	58.4
	5 00	179 16.3	N 5 51.1	210 26.7	10.5	S 5 06.1	10.3	58.3
	01	194 16.5	52.0	224 56.2	10.4	4 55.8	10.4	58.3
	02	209 16.7	53.0	239 25.6	10.5	4 45.4	10.5	58.3
	03	224 16.8	· · 53.9	253 55.1	10.6	4 34.9	10.4	58.3
	04	239 17.0	54.9	268 24.7	10.6	4 24.5	10.5	58.3
	05	254 17.2	55.8	282 54.3	10.6	4 14.0	10.5	58.3
	06	269 17.4	N 5 56.8	297 23.9	10.6	S 4 03.5	10.5	58.2
W	07	284 17.6	57.7	311 53.5	10.7	3 53.0	10.5	58.2
E	08	299 17.7	58.7	326 23.2	10.7	3 42.5	10.5	58.2
D	09	314 17.9	5 59.7	340 52.9	10.7	3 32.0	10.5	58.2
N	10	329 18.1	6 00.6	355 22.6	10.8	3 21.5	10.6	58.2
E	11	344 18.3	01.5	9 52.4	10.7	3 10.9	10.5	58.2
S	12	359 18.5	N 6 02.5	24 22.1	10.9	S 3 00.4	10.6	58.1
D	13	14 18.6	03.4	38 52.0	10.8	2 49.8	10.6	58.1
A	14	29 18.8	04.4	53 21.8	10.9	2 39.2	10.6	58.1
Y	15	44 19.0	· · 05.3	67 51.7	10.9	2 28.6	10.6	58.1
	16	59 19.2	06.3	82 21.6	10.9	2 18.0	10.6	58.1
	17	74 19.4	07.2	96 51.5	11.0	2 07.4	10.6	58.0
	18	89 19.5	N 6 08.2	111 21.5	11.0	S 1 56.8	10.6	58.0
	19	104 19.7	09.1	125 51.5	11.0	1 46.2	10.6	58.0
	20	119 19.9	10.1	140 21.5	11.0	1 35.6	10.7	58.0
	21	134 20.1	· · 11.0	154 51.5	11.1	1 24.9	10.6	58.0
	22	149 20.3	12.0	169 21.6	11.0	1 14.3	10.6	57.9
	23	164 20.4	12.9	183 51.6	11.2	1 03.7	10.6	57.9
	6 00	179 20.6	N 6 13.9	198 21.8	11.1	S 0 53.1	10.6	57.9
	01	194 20.8	14.8	212 51.9	11.2	0 42.5	10.6	57.9
	02	209 21.0	15.8	227 22.1	11.1	0 31.9	10.7	57.9
	03	224 21.2	· · 16.7	241 52.2	11.2	0 21.2	10.6	57.8
	04	239 21.3	17.7	256 22.4	11.3	S 0 10.6	10.6	57.8
	05	254 21.5	18.6	270 52.7	11.2	0 00.0	10.5	57.8
	06	269 21.7	N 6 19.6	285 22.9	11.3	N 0 10.5	10.6	57.8
	07	284 21.9	20.5	299 53.2	11.3	0 21.1	10.6	57.8
T	08	299 22.0	21.5	314 23.5	11.3	0 31.7	10.6	57.7
H	09	314 22.2	· · 22.4	328 53.8	11.3	0 42.3	10.5	57.7
U	10	329 22.4	23.3	343 24.1	11.4	0 52.8	10.6	57.7
R	11	344 22.6	24.3	357 54.5	11.3	1 03.4	10.5	57.7
S	12	359 22.8	N 6 25.2	12 24.8	11.4	N 1 13.9	10.5	57.7
D	13	14 22.9	26.2	26 55.2	11.4	1 24.4	10.5	57.6
A	14	29 23.1	27.1	41 25.6	11.4	1 34.9	10.5	57.6
Y	15	44 23.3	· · 28.1	55 56.0	11.5	1 45.4	10.5	57.6
	16	59 23.5	29.0	70 26.5	11.4	1 55.9	10.4	57.6
	17	74 23.6	30.0	84 56.9	11.5	2 06.3	10.4	57.5
	18	89 23.8	N 6 30.9	99 27.4	11.5	N 2 16.7	10.4	57.5
	19	104 24.0	31.8	113 57.9	11.5	2 27.1	10.4	57.5
	20	119 24.2	32.8	128 28.4	11.5	2 37.5	10.4	57.5
	21	134 24.4	· · 33.7	142 58.9	11.6	2 47.9	10.4	57.5
	22	149 24.5	34.7	157 29.5	11.5	2 58.3	10.3	57.4
	23	164 24.7	35.6	172 00.0	11.6	3 08.6	10.3	57.4
		S.D. 16.0	d 0.9	S.D. 15.9		15.8		15.7

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 4	Moonrise 5	Moonrise 6	Moonrise 7
°	h m	h m	h m	h m	h m	h m	h m
N 72	00 32	03 18	04 37	05 08	05 03	04 58	04 54
N 70	01 49	03 38	04 46	04 55	04 57	04 58	04 59
68	02 25	03 53	04 54	04 45	04 52	04 58	05 04
66	02 50	04 05	05 00	04 37	04 48	04 58	05 07
64	03 09	04 15	05 06	04 30	04 44	04 58	05 11
62	03 24	04 24	05 10	04 24	04 41	04 58	05 14
60	03 36	04 31	05 15	04 18	04 39	04 58	05 16
N 58	03 47	04 37	05 18	04 13	04 36	04 57	05 18
56	03 56	04 43	05 21	04 09	04 34	04 57	05 20
54	04 03	04 48	05 24	04 05	04 32	04 57	05 22
52	04 10	04 52	05 27	04 02	04 30	04 57	05 24
50	04 16	04 56	05 29	03 59	04 29	04 57	05 25
45	04 29	05 04	05 34	03 52	04 25	04 57	05 28
N 40	04 38	05 11	05 38	03 46	04 22	04 57	05 31
35	04 46	05 16	05 42	03 41	04 20	04 57	05 34
30	04 53	05 21	05 45	03 37	04 18	04 57	05 36
20	05 03	05 28	05 51	03 29	04 14	04 57	05 39
N 10	05 10	05 34	05 55	03 22	04 10	04 57	05 43
0	05 15	05 39	05 59	03 16	04 07	04 57	05 46
S 10	05 18	05 43	06 04	03 10	04 04	04 57	05 49
20	05 20	05 46	06 08	03 03	04 01	04 57	05 52
30	05 21	05 49	06 13	02 55	03 57	04 57	05 56
35	05 21	05 50	06 15	02 51	03 54	04 57	05 58
40	05 20	05 51	06 19	02 46	03 52	04 57	06 01
45	05 19	05 53	06 22	02 40	03 49	04 57	06 04
S 50	05 16	05 54	06 26	02 33	03 45	04 57	06 08
52	05 15	05 54	06 28	02 30	03 44	04 57	06 09
54	05 14	05 55	06 30	02 26	03 42	04 57	06 11
56	05 12	05 55	06 32	02 22	03 40	04 57	06 13
58	05 10	05 56	06 35	02 18	03 38	04 57	06 15
S 60	05 08	05 56	06 38	02 13	03 35	04 57	06 18

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 4	Moonset 5	Moonset 6	Moonset 7
°	h m	h m	h m	h m	h m	h m	h m
N 72	19 32	20 52	////	14 10	16 00	17 48	19 34
N 70	19 22	20 32	22 25	14 21	16 04	17 45	19 24
68	19 14	20 16	21 46	14 29	16 07	17 42	19 16
66	19 07	20 03	21 20	14 36	16 09	17 40	19 10
64	19 02	19 53	21 00	14 42	16 11	17 38	19 04
62	18 57	19 44	20 45	14 47	16 13	17 37	18 59
60	18 53	19 36	20 32	14 52	16 14	17 36	18 55
N 58	18 49	19 30	20 21	14 55	16 16	17 34	18 52
56	18 46	19 24	20 12	14 59	16 17	17 33	18 48
54	18 43	19 19	20 04	15 02	16 18	17 32	18 46
52	18 40	19 15	19 57	15 05	16 19	17 32	18 43
50	18 37	19 11	19 51	15 07	16 20	17 31	18 41
45	18 32	19 02	19 38	15 13	16 22	17 29	18 35
N 40	18 28	18 55	19 28	15 17	16 23	17 28	18 31
35	18 24	18 50	19 20	15 21	16 24	17 27	18 27
30	18 21	18 45	19 13	15 25	16 26	17 25	18 24
20	18 15	18 37	19 03	15 31	16 28	17 24	18 19
N 10	18 10	18 32	18 56	15 36	16 29	17 22	18 14
0	18 06	18 27	18 51	15 41	16 31	17 20	18 07
S 10	18 02	18 23	18 47	15 45	16 33	17 19	18 04
20	17 57	18 19	18 45	15 50	16 34	17 17	17 59
30	17 52	18 16	18 44	15 56	16 36	17 15	17 54
35	17 50	18 15	18 44	15 57	16 37	17 14	17 51
40	17 46	18 13	18 45	16 03	16 38	17 13	17 47
45	17 43	18 12	18 46	16 07	16 40	17 11	17 43
S 50	17 39	18 11	18 48	16 12	16 41	17 10	17 38
52	17 37	18 10	18 49	16 15	16 42	17 09	17 35
54	17 34	18 10	18 51	16 17	16 43	17 08	17 33
56	17 32	18 09	18 52	16 20	16 44	17 07	17 30
58	17 30	18 09	18 54	16 23	16 45	17 06	17 27
S 60	17 27	18 08	18 56	16 26	16 46	17 05	17 23

Day	SUN Eqn. of Time 00ʰ	SUN Eqn. of Time 12ʰ	SUN Mer. Pass.	MOON Mer. Pass. Upper	MOON Mer. Pass. Lower	MOON Age	MOON Phase
	m s	m s	h m	h m	h m	d	
4	03 13	03 04	12 03	09 28	21 54	26	
5	02 55	02 47	12 03	10 19	22 44	27	●
6	02 38	02 29	12 02	11 09	23 33	28	

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Nautical Almanac

1978 APRIL 4, 5, 6 (TUES., WED., THURS.)

Day	GMT	ARIES G.H.A.	VENUS −3.3 G.H.A.	VENUS Dec	MARS +0.6 G.H.A.	MARS Dec	JUPITER −1.7 G.H.A.	JUPITER Dec	SATURN +0.5 G.H.A.	SATURN Dec	STARS Name	S.H.A.	Dec
TUESDAY	4 00	191 57.4	162 32.5	N11 27.2	71 30.4	N23 14.1	103 07.7	N23 25.4	45 03.3	N14 57.9	Acamar	315 38.9	S40 23.8
	01	206 59.9	177 32.0	28.4	86 32.1	13.9	118 09.8	25.4	60 05.8	58.0	Achernar	335 47.2	S57 21.0
	02	222 02.3	192 31.5	29.5	101 33.7	13.7	133 11.9	25.4	75 08.4	58.0	Acrux	173 38.3	S62 58.8
	03	237 04.8	207 31.1	.. 30.7	116 35.4	.. 13.5	148 14.0	.. 25.4	90 10.9	.. 58.0	Adhara	255 33.4	S28 56.9
	04	252 07.3	222 30.6	31.8	131 37.1	13.2	163 16.1	25.4	105 13.5	58.1	Aldebaran	291 20.1	N16 27.8
	05	267 09.7	237 30.2	33.0	146 38.7	13.0	178 18.3	25.5	120 16.0	58.1			
	06	282 12.2	252 29.7	N11 34.2	161 40.4	N23 12.8	193 20.4	N23 25.5	135 18.6	N14 58.1	Alioth	166 43.5	N56 04.6
	07	297 14.7	267 29.3	35.3	176 42.1	12.6	208 22.5	25.5	150 21.2	58.1	Alkaid	153 19.4	N49 25.2
	08	312 17.1	282 28.8	36.5	191 43.7	12.3	223 24.6	25.5	165 23.7	58.2	Al Na'ir	28 17.4	S47 03.9
	09	327 19.6	297 28.4	.. 37.6	206 45.4	.. 12.1	238 26.8	.. 25.5	180 26.3	.. 58.2	Alnilam	276 13.5	S 1 13.2
	10	342 22.0	312 27.9	38.8	221 47.0	11.9	253 28.9	25.5	195 28.8	58.2	Alphard	218 22.0	S 8 34.1
	11	357 24.5	327 27.5	39.9	236 48.7	11.7	268 31.0	25.5	210 31.4	58.3			
	12	12 27.0	342 27.0	N11 41.1	251 50.4	N23 11.5	283 33.1	N23 25.5	225 33.9	N14 58.3	Alphecca	126 33.3	N26 47.1
	13	27 29.4	357 26.5	42.2	266 52.0	11.2	298 35.2	25.5	240 36.5	58.3	Alpheratz	358 11.4	N28 58.1
	14	42 31.9	12 26.1	43.4	281 53.7	11.0	313 37.4	25.5	255 39.0	58.3	Altair	62 34.2	N 8 48.6
	15	57 34.4	27 25.6	.. 44.5	296 55.3	.. 10.8	328 39.5	.. 25.5	270 41.6	.. 58.4	Ankaa	353 42.4	S42 25.5
	16	72 36.8	42 25.2	45.7	311 57.0	10.6	343 41.6	25.5	285 44.1	58.4	Antares	112 58.7	S26 23.0
	17	87 39.3	57 24.7	46.9	326 58.7	10.3	358 43.7	25.5	300 46.7	58.4			
	18	102 41.8	72 24.2	N11 48.0	342 00.3	N23 10.1	13 45.8	N23 25.5	315 49.2	N14 58.4	Arcturus	146 19.7	N19 17.6
	19	117 44.2	87 23.8	49.2	357 02.0	09.9	28 47.9	25.6	330 51.8	58.5	Atria	108 24.1	S68 59.1
	20	132 46.7	102 23.3	50.3	12 03.6	09.7	43 50.1	25.6	345 54.4	58.5	Avior	234 28.6	S59 76.8
	21	147 49.2	117 22.9	.. 51.5	27 05.3	.. 09.4	58 52.2	.. 25.6	0 56.9	.. 58.5	Bellatrix	279 00.7	N 6 19.6
	22	162 51.6	132 22.4	52.6	42 06.9	09.2	73 54.3	25.6	15 59.5	58.6	Betelgeuse	271 30.2	N 7 24.0
	23	177 54.1	147 21.9	53.8	57 08.6	09.0	88 56.4	25.6	31 02.0	58.6			
WEDNESDAY	5 00	192 56.5	162 21.5	N11 54.9	72 10.2	N23 08.8	103 58.5	N23 25.6	46 04.6	N14 58.6	Canopus	264 08.0	S52 41.5
	01	207 59.0	177 21.0	56.1	87 11.9	08.5	119 00.6	25.6	61 07.1	58.6	Capella	281 14.0	N45 58.6
	02	223 01.5	192 20.6	57.2	102 13.5	08.3	134 02.8	25.6	76 09.7	58.7	Deneb	49 49.7	N45 11.9
	03	238 03.9	207 20.1	.. 58.3	117 15.2	.. 08.1	149 04.9	.. 25.6	91 12.2	.. 58.7	Denebola	183 00.4	N14 41.5
	04	253 06.4	222 19.6	11 59.5	132 16.8	07.9	164 07.0	25.6	106 14.8	58.7	Diphda	349 22.9	S18 06.5
	05	268 08.9	237 19.2	12 00.6	147 18.5	07.6	179 09.1	25.6	121 17.3	58.8			
	06	283 11.3	252 18.7	N12 01.8	162 20.1	N23 07.4	194 11.2	N23 25.6	136 19.9	N14 58.8	Dubhe	194 23.7	N61 52.2
	07	298 13.8	267 18.2	02.9	177 21.8	07.2	209 13.3	25.6	151 22.4	58.8	Elnath	278 46.4	N28 35.3
	08	313 16.3	282 17.8	04.1	192 23.4	07.0	224 15.5	25.6	166 25.0	58.8	Eltanin	90 58.4	N51 29.3
	09	328 18.7	297 17.3	.. 05.2	207 25.1	.. 06.7	239 17.6	.. 25.7	181 27.5	.. 58.9	Enif	34 13.4	N 9 46.4
	10	343 21.2	312 16.8	06.4	222 26.7	06.5	254 19.7	25.7	196 30.1	58.9	Fomalhaut	15 53.6	S29 44.3
	11	358 23.6	327 16.4	07.5	237 28.4	06.3	269 21.8	25.7	211 32.6	58.9			
	12	13 26.1	342 15.9	N12 08.6	252 30.0	N23 06.1	284 23.9	N23 25.7	226 35.2	N14 58.9	Gacrux	172 29.9	S56 59.6
	13	28 28.6	357 15.5	09.8	267 31.6	05.8	299 26.0	25.7	241 37.7	59.0	Gienah	176 19.3	S17 25.4
	14	43 31.0	12 15.0	10.9	282 33.3	05.6	314 28.1	25.7	256 40.3	59.0	Hadar	149 25.0	S60 16.1
	15	58 33.5	27 14.5	.. 12.1	297 34.9	.. 05.4	329 30.3	.. 25.7	271 42.8	.. 59.0	Hamal	328 31.1	N23 21.5
	16	73 36.0	42 14.1	13.2	312 36.6	05.1	344 32.4	25.7	286 45.4	59.0	Kaus Aust.	84 19.0	S34 23.6
	17	88 38.4	57 13.6	14.4	327 38.2	04.9	359 34.5	25.7	301 47.9	59.1			
	18	103 40.9	72 13.1	N12 15.5	342 39.8	N23 04.7	14 36.6	N23 25.7	316 50.5	N14 59.1	Kochab	137 18.0	N74 14.6
	19	118 43.4	87 12.6	16.6	357 41.5	04.5	29 38.7	25.7	331 53.0	59.1	Markab	14 05.1	N15 05.2
	20	133 45.8	102 12.2	17.8	12 43.1	04.2	44 40.8	25.7	346 55.6	59.2	Menkar	314 43.1	N 4 00.1
	21	148 48.3	117 11.7	.. 18.9	27 44.8	.. 04.0	59 42.9	.. 25.7	1 58.1	.. 59.2	Menkent	148 38.6	S36 15.8
	22	163 50.8	132 11.2	20.0	42 46.4	03.8	74 45.0	25.7	17 00.7	59.2	Miaplacidus	221 44.7	S69 38.0
	23	178 53.2	147 10.8	21.2	57 48.0	03.6	89 47.1	25.7	32 03.2	59.2			
THURSDAY	6 00	193 55.7	162 10.3	N12 22.3	72 49.7	N23 03.3	104 49.3	N23 25.8	47 05.8	N14 59.3	Mirfak	309 18.8	N49 47.0
	01	208 58.1	177 09.8	23.5	87 51.3	03.1	119 51.4	25.8	62 08.3	59.3	Nunki	76 31.2	S26 19.3
	02	224 00.6	192 09.4	24.6	102 52.9	02.9	134 53.5	25.8	77 10.9	59.3	Peacock	54 01.3	S56 48.1
	03	239 03.1	207 08.9	.. 25.7	117 54.6	.. 02.6	149 55.6	.. 25.8	92 13.4	.. 59.3	Pollux	244 00.2	N28 04.7
	04	254 05.5	222 08.4	26.9	132 56.2	02.4	164 57.7	25.8	107 15.9	59.4	Procyon	245 27.5	N 5 16.7
	05	269 08.0	237 07.9	28.0	147 57.8	02.2	179 59.8	25.8	122 18.5	59.4			
	06	284 10.5	252 07.5	N12 29.1	162 59.5	N23 01.9	195 01.9	N23 25.8	137 21.0	N14 59.4	Rasalhague	96 31.0	N12 34.4
	07	299 12.9	267 07.0	30.3	178 01.1	01.7	210 04.0	25.8	152 23.6	59.4	Regulus	208 11.6	N12 04.3
	08	314 15.4	282 06.5	31.4	193 02.7	01.5	225 06.1	25.8	167 26.1	59.5	Rigel	281 37.8	S 8 13.9
	09	329 17.9	297 06.1	.. 32.5	208 04.4	.. 01.3	240 08.2	.. 25.8	182 28.7	.. 59.5	Rigil Kent.	140 27.4	S60 44.6
	10	344 20.3	312 05.6	33.7	223 06.0	01.0	255 10.4	25.8	197 31.2	59.5	Sabik	102 42.9	S15 41.9
	11	359 22.8	327 05.1	34.8	238 07.6	00.8	270 12.5	25.8	212 33.8	59.5			
	12	14 25.3	342 04.6	N12 35.9	253 09.2	N23 00.6	285 14.6	N23 25.8	227 36.3	N14 59.6	Schedar	350 11.4	N56 25.0
	13	29 27.7	357 04.2	37.1	268 10.9	00.3	300 16.7	25.8	242 38.9	59.6	Shaula	96 57.9	S37 05.1
	14	44 30.2	12 03.7	38.2	283 12.5	23 00.1	315 18.8	25.8	257 41.4	59.6	Sirius	258 57.2	S16 41.5
	15	59 32.6	27 03.2	.. 39.3	298 14.1	22 59.9	330 20.9	.. 25.9	272 44.0	.. 59.6	Spica	158 59.0	S11 03.0
	16	74 35.1	42 02.7	40.4	313 15.7	59.6	345 23.0	25.9	287 46.5	59.7	Suhail	223 11.7	S43 21.0
	17	89 37.6	57 02.3	41.6	328 17.4	59.4	0 25.1	25.9	302 49.1	59.7			
	18	104 40.0	72 01.8	N12 42.7	343 19.0	N22 59.2	15 27.2	N23 25.9	317 51.6	N14 59.7	Vega	80 56.9	N38 45.6
	19	119 42.5	87 01.3	43.8	358 20.6	58.9	30 29.3	25.9	332 54.1	59.7	Zuben'ubi	137 34.6	S15 57.1
	20	134 45.0	102 00.8	44.9	13 22.2	58.7	45 31.4	25.9	347 56.7	59.8		S.H.A.	Mer. Pass
	21	149 47.4	117 00.3	.. 46.1	28 23.9	.. 58.5	60 33.5	.. 25.9	2 59.2	.. 59.8		° ′	h m
	22	164 49.9	131 59.9	47.2	43 25.5	58.2	75 35.6	25.9	18 01.8	59.8	Venus	329 24.9	13 11
	23	179 52.4	146 59.4	48.3	58 27.1	58.0	90 37.7	25.9	33 04.3	59.8	Mars	239 13.7	19 09
											Jupiter	271 02.0	17 02
	Mer. Pass	11 06.4 (h m)	v −0.5	d 1.1	v 1.6	d 0.2	v 2.1	d 0.0	v 2.5	d 0.0	Saturn	213 08.0	20 52

Extracted from the NAUTICAL ALMANAC, HER MAJESTY'S NAUTICAL ALMANAC OFFICE, LONDON, U.K.

Identification of stars (*)

It is very important and necessary for navigators to be able to identify stars in the sky because of fixing position at sea. Navigators have to know the names of stars, so that they can obtain the stars' G.H.A. and declination from the nautical almanac.

Navigational stars can be distinguished from others by their relative positions, brightness and their characteristic colour.

On the other hand, we occasionally observe an unfamiliar star in the sky. In this case, we can also find its proper name by D.R.P., G.M.T., altitude and azimuth.

To memorize the names of navigational stars, it is convenient and effective for you to compare a Star Map with stars shining in the dark sky.

1. Star identification by Star Map or table "Position of navigational stars".

The positions of navigational stars are shown on a Star Map (Fig. 16 & 17) and a table for position of navigational stars, with their declination and right ascension.

The navigator has to choose the Star Map for north latitude or the Star Map for south latitude to identify a star (see Fig. 16, 17 and 18), depending on his own position. To use the Star Map, some calculations are necessary as follows:

1) According to the observer's latitude, he must choose the Star Map for north latitude or south latitude.

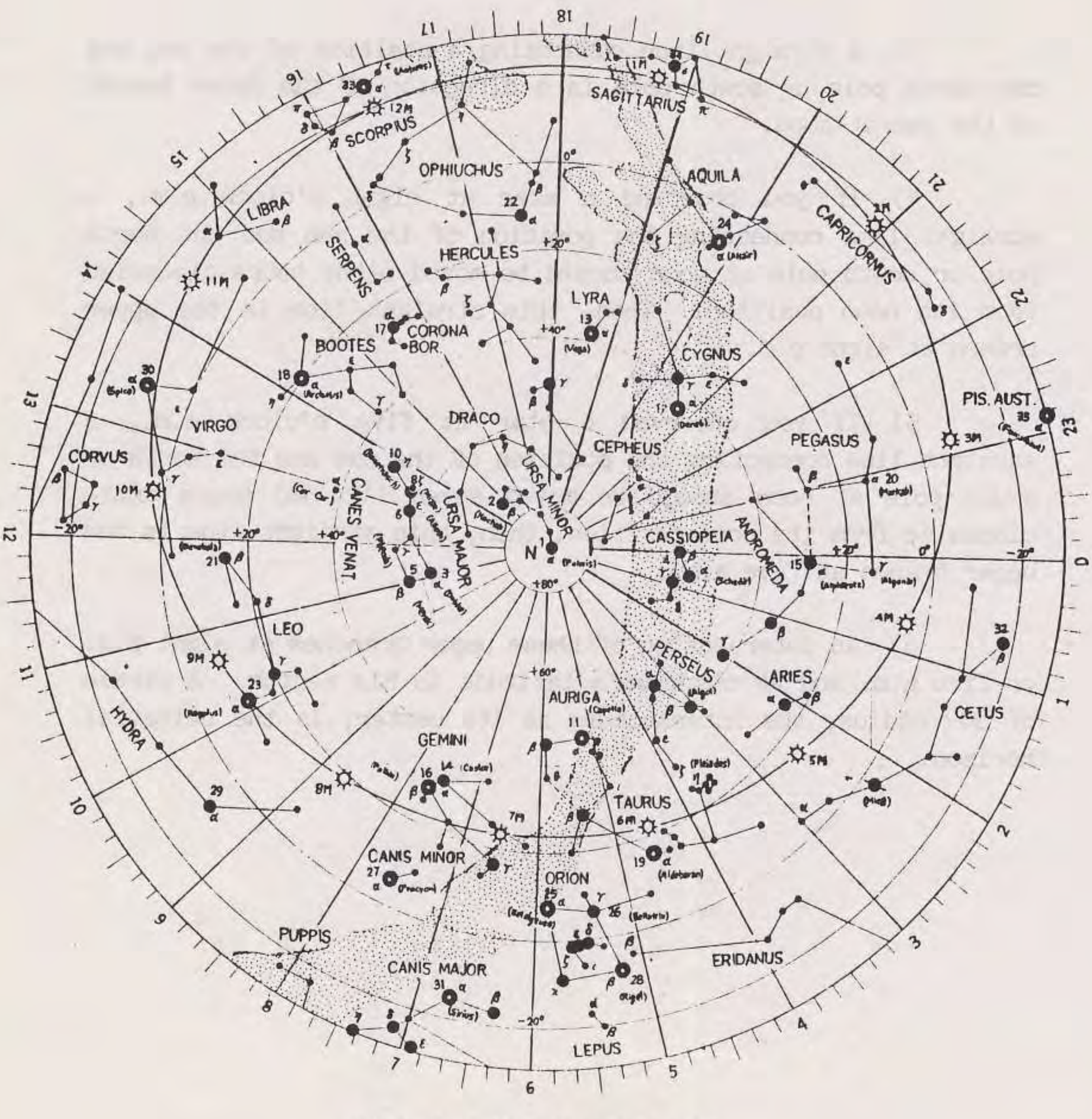
2) A star map has the position of the sun for the first day of each month on a circle of ecliptic (Fig. 16 and 17), so you should check the then position of the sun on the ecliptic.

3) A straight line connecting a position of the sun and the north pole or south pole is a direction of the upper branch of the sun at noon.

4) If you observed a star at eight o'clock p.m., a straight line connecting the position of the sun and the north pole or south pole at noon should be moved eight hours clockwise from its noon position. Then, this straight line is the upper branch at eight p.m..

5) If you observed a star at five o'clock a.m., a straight line connecting the position of the sun and the north or south pole at noon should be moved seven (12h-5h) hours anti-clockwise from its noon position, then, this straight line is the upper branch at five a.m..

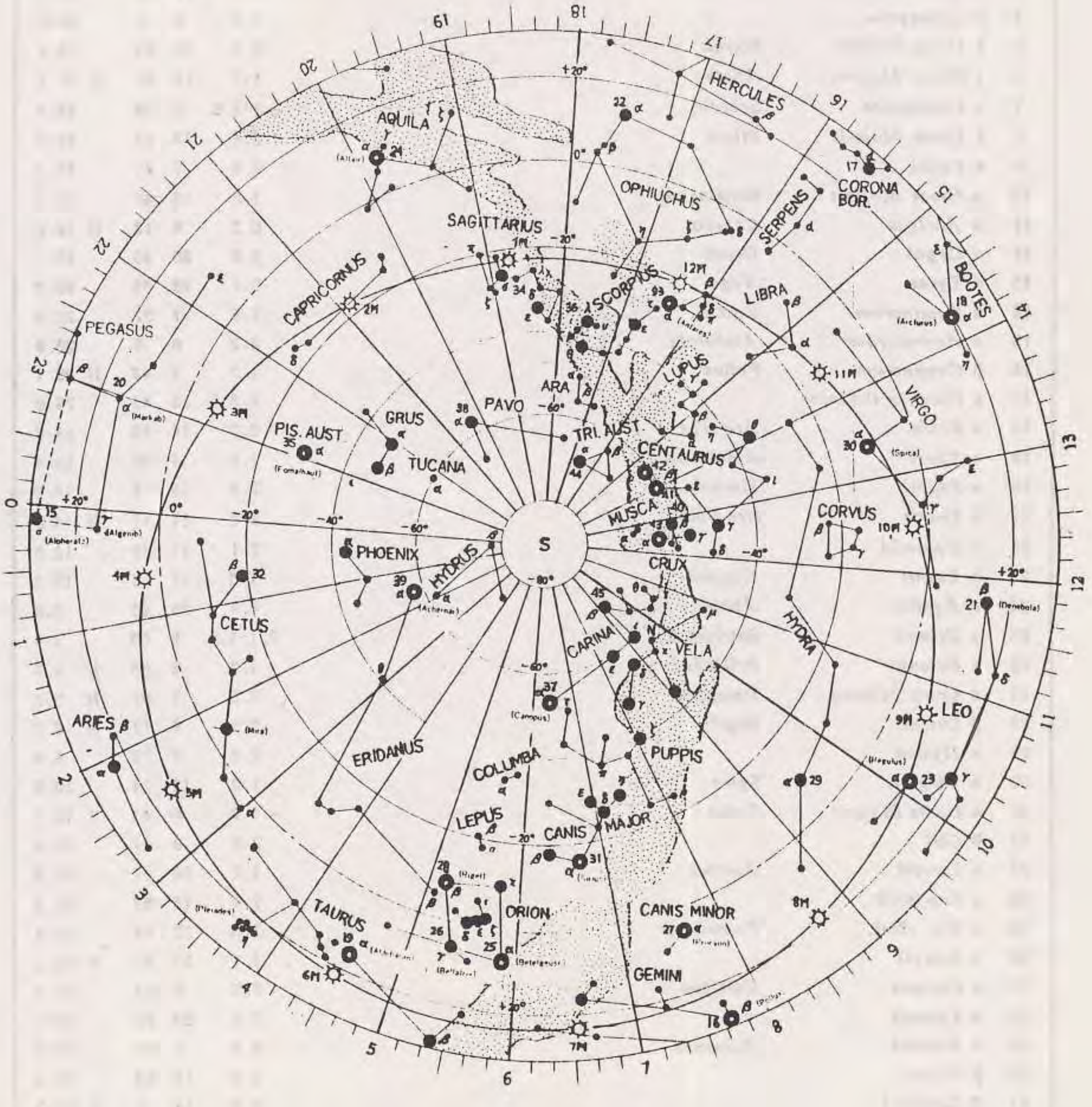
6) An intersection of these upper branches at eight p.m. or five a.m. and an observer's latitude is his zenith. A circle of 90° radius, the intersection as its center, is the celestial horizon.



Star Map (North Latitude)

Fig. 16-a

- First Magnitude or over
- Second Magnitude
- Third Magnitude
- Variable Star
- ( ) Proper Name of Star
- Milky Way



Star Map (South Latitude)

Fig. 17

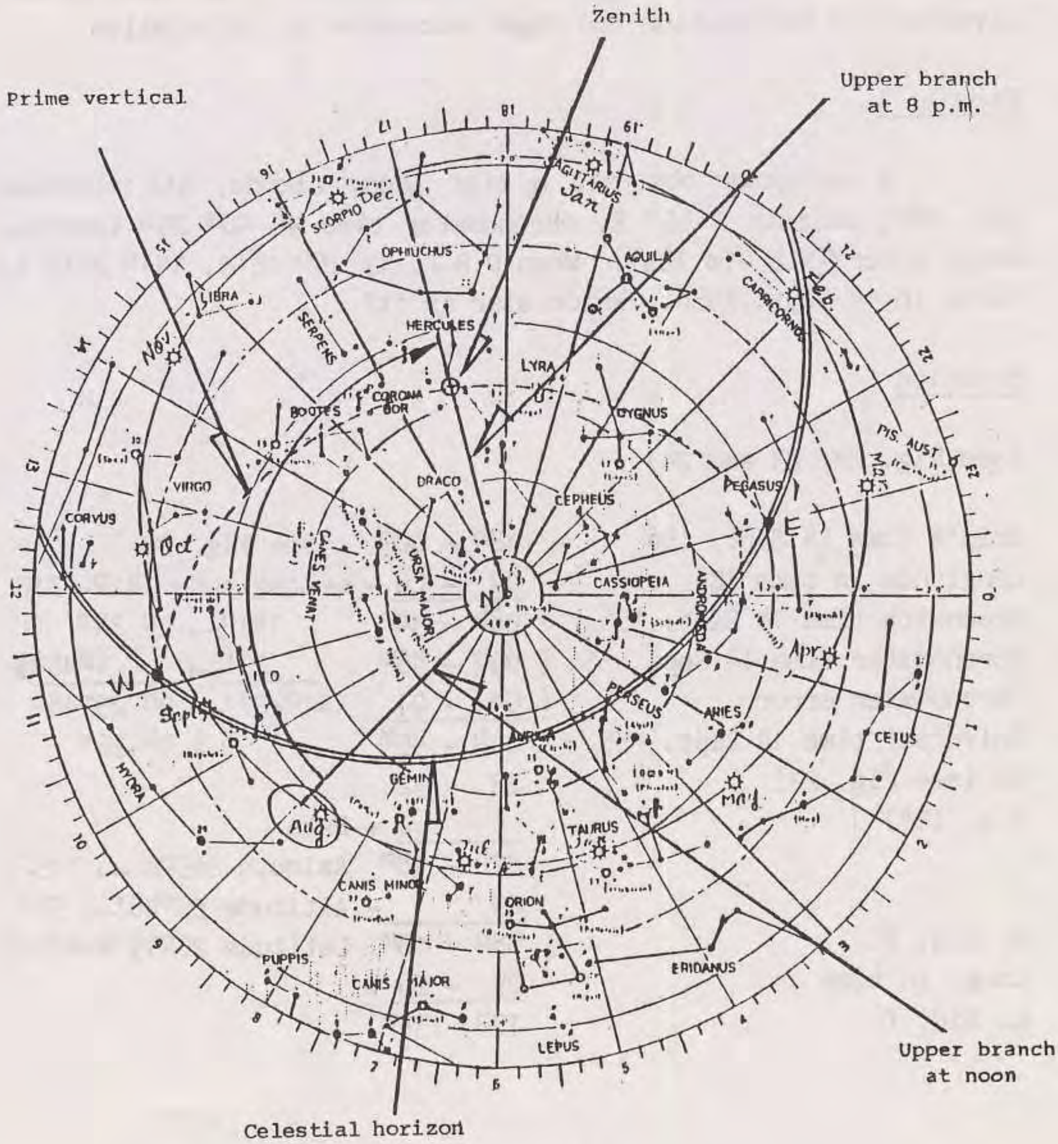
No.	Star	Proper Name	Mag.	R. A. h	R. A. m	d °
1	α Ursae Minoris	Polaris	2.1	1	53	N 89.1
2	β Ursae Minoris	Kochab	2.2	14	51	74.3
3	α Ursae Majoris	Dubhe	2.0	11	1	62.0
4	β Cassiopeiae		2.4	0	7	58.9
5	β Ursae Majoris	Merak	2.4	10	59	56.6
6	ε Ursae Majoris	Alioth	1.7	12	52	N 56.2
7	α Cassiopeiae	Schedir	2.1-2.6	0	38	56.3
8	ζ Ursae Majoris	Mizar	2.4	13	22	55.2
9	α Persei		1.9	3	21	49.7
10	η Ursae Majoris	Benetnasch	1.9	13	46	49.5
11	α Aurigae	Capella	0.2	5	13	N 46.0
12	α Cygni	Deneb	1.3	20	40	45.1
13	α Lyrae	Vega	0.1	18	35	38.7
14	α Geminorum	Castor	1.6	7	32	32.0
15	α Andromedae	Alpheratz	2.2	0	6	28.9
16	β Geminorum	Pollux	1.2	7	43	N 28.1
17	α Coronae Borealis		2.3	15	33	26.9
18	α Bootis	Arcturus	0.2	14	14	19.4
19	α Tauri	Aldebaran	1.1	4	33	16.4
20	α Pegasi	Markab	2.6	23	3	15.0
21	β Leonis	Denebola	2.2	11	47	N 14.8
22	α Ophiuchi		2.1	17	33	12.6
23	α Leonis	Regulus	1.3	10	6	12.2
24	α Aquilae	Altair	0.9	19	49	8.8
25	α Orionis	Betelgeuse	0.1-1.2	5	53	7.4
26	γ Orionis	Bellatrix	1.7	5	23	N 6.3
27	α Canis Minoris	Procyon	0.5	7	37	N 5.3
28	β Orionis	Rigel	0.3	5	12	S 8.3
29	α Hydrae		2.2	9	25	8.5
30	α Virginis	Spica	1.2	13	23	10.9
31	α Canis Majoris	Sirius	- 1.6	6	43	S 16.7
32	β Ceti		2.2	0	41	18.2
33	α Scorpii	Antares	1.2	16	27	26.3
34	σ Sagittarii		2.1	18	53	26.4
35	α Pis. Aust.	Fomalhaut	1.3	22	55	29.9
36	λ Scorpii		1.7	17	31	S 37.1
37	α Carinae	Canopus	- 0.9	6	23	52.7
38	α Pavonis		2.1	20	22	56.9
39	α Eridani	Achernar	0.6	1	36	57.5
40	β Crucis		1.5	12	45	59.4
41	β Centauri		0.9	14	1	S 60.2
42	α Centauri		0.1	14	37	60.7
43	α Crucis		1.1	12	24	62.9
44	α Trianguli Australis		1.9	16	44	68.9
45	β Carinae		1.8	9	13	S 69.5

Fig. 18 Position of navigational stars.

Example 6

Show navigational stars and their position in Lat. $35^{o}N$ at 8 p.m., 4 Aug. 1956, by Star Map.

Solution



Star map & Celestial horizon

Fig. 19

Identification by calculation

When the sky is clear, we can identify navigational stars by sight. But if we find a star among some clouds in the sky, it is very difficult to identify and find the name of the star using the Star Map. In this case, we can identify the star by observing its altitude, azimuth and time, because this information gives us its declination and right ascension by calculation.

Example 7

A navigator observed a star among clouds, its altitude 55^{o}- 48', azimuth S 65^{o} E, chronometer time 9^{h} 46^{m} 25^{s} (chronometer error ⊖ 1h 01m 12s). When D.R.P. is 26^{o} 15'N, 141^{o} 27'E at 18:00 in 14 Sept. 1956. Which star is it?

Solution

(see Fig. 22, 23 and 24)

ship's time 14 Sept. '56		18^{h} - 00^{m}	see Fig. 20
Longitude in time (E)		09 - 26 -	↔ Longitude 141^{o}-27'E
Greenwich time 14 Sept. '56		08^{h} - 34^{m}	141^{o} → 9^{h} 24^{m}
Chronometer time 14 Sept. '56	≑	09^{h} - 46^{m}	27' → $1^{m}48^{s}$ ⊕
Chronometer error	≑	01 - 01	141^{o}-27' → 9^{h} $25^{m}48^{s}$
Universal time 14 Sept. '56		08^{h} - 45^{m}	≑ 9^{h}-26^{m}
Ro (see Fig. 21)		23 - 32	
p.p. (E*)		1 +	Data
		32^{h} - 18^{m}	Azimuth S65^{o}E → 115^{o}E
		24 -	Altitude $55^{o}48'$ → 56^{o}
G. Sid. T.		08^{h} - 18^{m}	Latitude $26^{o}15'$N → 26^{o}N
Long. in time		09 - 26 +	
L. Sid. T.		17^{h} - 34^{m}	

	K	D	H
Z = 115°E	$K_1 = 374$		$H_1 = 3331$
Alt. = 56°	$K_2 = 3171 \oplus$	$D_1 = 2919$	
$\ell = \oplus 26°N$			
$K = \ominus 16° \leftarrow$	$K_3 = 3545$	$D_2 = 17$	$H_2 = 2440$
$\ell + K = \oplus 10$		$D_3 = 2240 \oplus$	$H_3 = 7 \oplus$
		$D_4 = 5176$	$H_4 = 5778$
		↓ d = 9°N	↓ hE = $2^h - 04^m$

L. sid, T = $17 - 34 \oplus$

R.A. = $19^h\ 48^m$

From d = 9°N, R.A. = $19^h\ 48^m$, the star's proper name is Altair on Star map or table of Position of Navigational Stars.

Ans. Altair

h m	°	h m	°	h m	°	h m	°	h m	°	h m	°	m s	'	s	'
0 0	0	4 0	60	8 0	120	12 0	180	16 0	240	20 0	300	0 0	0	0.0	0.0
4	1	4	61	4	121	4	181	4	241	4	301	4	1	0.1	0.0
8	2	8	62	8	122	8	182	8	242	8	302	8	2	0.2	0.1
12	3	12	63	12	123	12	183	12	243	12	303	12	3	0.3	0.1
16	4	16	64	16	124	16	184	16	244	16	304	16	4	0.4	0.1
20	5	20	65	20	125	20	185	20	245	20	305	20	5	0.5	0.1
24	6	24	66	24	126	24	186	24	246	24	306	24	6	0.6	0.2
28	7	28	67	28	127	28	187	28	247	28	307	28	7	0.7	0.2
32	8	32	68	32	128	32	188	32	248	32	308	32	8	0.8	0.2
36	9	36	69	36	129	36	189	36	249	36	309	36	9	0.9	0.2
40	10	40	70	40	130	40	190	40	250	40	310	40	10	1.0	0.3
44	11	44	71	44	131	44	191	44	251	44	311	44	11	1.1	0.3
48	12	48	72	48	132	48	192	48	252	48	312	48	12	1.2	0.3
52	13	52	73	52	133	52	193	52	253	52	313	52	13	1.3	0.3
56	14	56	74	56	134	56	194	56	254	56	314	56	14	1.4	0.4
1 0	15	5 0	75	9 0	135	13 0	195	17 0	255	21 0	315	1 0	15	1.5	0.4
4	16	4	76	4	136	4	196	4	256	4	316	4	16	1.6	0.4
8	17	8	77	8	137	8	197	8	257	8	317	8	17	1.7	0.4
12	18	12	78	12	138	12	198	12	258	12	318	12	18	1.8	0.5
16	19	16	79	16	139	16	199	16	259	16	319	16	19	1.9	0.5
20	20	20	80	20	140	20	200	20	260	20	320	20	20	2.0	0.5
24	21	24	81	24	141	24	201	24	261	24	321	24	21	2.1	0.5
28	22	28	82	28	142	28	202	28	262	28	322	28	22	2.2	0.6
32	23	32	83	32	143	32	203	32	263	32	323	32	23	2.3	0.6
36	24	36	84	36	144	36	204	36	264	36	324	36	24	2.4	0.6
40	25	40	85	40	145	40	205	40	265	40	325	40	25	2.5	0.6
44	26	44	86	44	146	44	206	44	266	44	326	44	26	2.6	0.7
48	27	48	87	48	147	48	207	48	267	48	327	48	27	2.7	0.7
52	28	52	88	52	148	52	208	52	268	52	328	52	28	2.8	0.7
56	29	56	89	56	149	56	209	56	269	56	329	56	29	2.9	0.7
2 0	30	6 0	90	10 0	150	14 0	210	18 0	270	22 0	330	2 0	30	3.0	0.8
4	31	4	91	4	151	4	211	4	271	4	331	4	31	3.1	0.8
8	32	8	92	8	152	8	212	8	272	8	332	8	32	3.2	0.8
12	33	12	93	12	153	12	213	12	273	12	333	12	33	3.3	0.8
16	34	16	94	16	154	16	214	16	274	16	334	16	34	3.4	0.9
20	35	20	95	20	155	20	215	20	275	20	335	20	35	3.5	0.9
24	36	24	96	24	156	24	216	24	276	24	336	24	36	3.6	0.9
28	37	28	97	28	157	28	217	28	277	28	337	28	37	3.7	0.9
32	38	32	98	32	158	32	218	32	278	32	338	32	38	3.8	1.0
36	39	36	99	36	159	36	219	36	279	36	339	36	39	3.9	1.0
40	40	40	100	40	160	40	220	40	280	40	340	40	40		
44	41	44	101	44	161	44	221	44	281	44	341	44	41		
48	42	48	102	48	162	48	222	48	282	48	342	48	42		
52	43	52	103	52	163	52	223	52	283	52	343	52	43		
56	44	56	104	56	164	56	224	56	284	56	344	56	44		
3 0	45	7 0	105	11 0	165	15 0	225	19 0	285	23 0	345	3 0	45		
4	46	4	106	4	166	4	226	4	286	4	346	4	46		
8	47	8	107	8	167	8	227	8	287	8	347	8	47		
12	48	12	108	12	168	12	228	12	288	12	348	12	48		
16	49	16	109	16	169	16	229	16	289	16	349	16	49		
20	50	20	110	20	170	20	230	20	290	20	350	20	50		
24	51	24	111	24	171	24	231	24	291	24	351	24	51		
28	52	28	112	28	172	28	232	28	292	28	352	28	52		
32	53	32	113	32	173	32	233	32	293	32	353	32	53		
36	54	36	114	36	174	36	234	36	294	36	354	36	54		
40	55	40	115	40	175	40	235	40	295	40	355	40	55		
44	56	44	116	44	176	44	236	44	296	44	356	44	56		
48	57	48	117	48	177	48	237	48	297	48	357	48	57		
52	58	52	118	52	178	52	238	52	298	52	358	52	58		
56	59	56	119	56	179	56	239	56	299	56	359	56	59		

Fig. 20 Conversion of Arc to Time.

Nautical Almanac

14 Sept. 1956

Lunar Age 9.2 d

☉ Sun

U (h)	E☉ (h m s)	d (° ′)	P.P. (h m)	P.P. (′)
0	12 4 18	N 3 30.6	0 0	0.0
2	20	28.7	10	2
4	22	26.8	20	3
6	24	24.9	30	5
8	25	22.9	40	6
10	27	21.0	0 50	0.8
12	12 4 29	N 3 19.1	1 0	1.0
14	31	17.2	10	1
16	32	15.3	20	3
18	34	13.3	30	4
20	36	11.4	40	6
22	38	9.5	1 50	7
24	12 4 40	N 3 7.6	2 0	1.9

S.D. 15′ 56″)

$U = 0^h$

No.	Star	E_* (h m s)	d (° ′)
1	*Polaris*	21 36 59	N89 3.6
2	*Kochab*	8 41 2	74 20.2
3	*Dubhe*	12 30 44	61 59.0
4	*β Cassiop.*	23 24 52	58 54.8
5	*Merak*	12 32 34	56 36.8
6	*Alioth*	10 39 40	N56 11.9
7	*Schedir*	22 53 41	56 18.1
8	*Mizar*	10 9 37	55 9.2
9	*α Persei*	20 10 31	49 42.4
10	*Benetnasch*	9 45 58	49 31.9
11	*Capella*	18 18 16	N45 57.2
12	*Deneb*	2 51 47	45 7.8
13	*Vega*	4 56 17	38 44.9
14	*Castor*	15 59 56	31 59.0
15	*Alpheratz*	23 25 35	28 51.3
16	*Pollux*	15 49 6	N28 7.8
17	*α Cor. Bor.*	7 58 55	26 51.8
18	*Arcturus*	9 18 6	19 24.6
19	*Aldebaran*	18 58 19	16 25.5
20	*Markab*	0 29 8	14 58.6
21	*Denebola*	11 44 56	N14 48.9
22	*α Ophiuchi*	5 58 50	12 35.7
23	*Regulus*	13 25 43	12 10.8
24	*Altair*	3 43 5	8 45.4
25	*Betelgeuse*	17 38 56	7 24.1
26	*Bellatrix*	18 8 57	N 6 18.8
27	*Procyon*	15 54 44	N 5 20.3
28	*Rigel*	18 19 18	S 8 14.9
29	*α Hydrae*	14 6 19	8 28.2
30	*Spica*	10 8 52	10 56.1
31	*Sirius*	16 48 32	S16 39.2
32	*β Ceti*	22 50 20	18 13.2
33	*Antares*	7 5 1	26 20.3
34	*σ Sagittarii*	4 39 10	26 21.1
35	*Fomalhaut*	0 36 29	29 50.9
36	*λ Scorpii*	6 1 5	S37 4.5
37	*Canopus*	17 8 47	52 40.0
38	*α Pavonis*	3 9 30	56 52.5
39	*Achernar*	21 55 38	57 27.1
40	*β Crucis*	10 46 37	59 27.3
41	*β Centauri*	9 31 2	S60 10.1
42	*α Centauri*	8 55 8	60 39.7
43	*α Crucis*	11 7 37	62 51.7
44	*α Tri. Aust.*	6 47 41	68 57.3
45	*β Carinae*	14 19 5	S69 32.2

$R_\odot$ 23h 31m 47s

Planet

♀ Venus — Tr. 8h 59m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	15 0 52	N17 14.6	0 0	0	0.0
2	50	13.7	10	0	1
4	48	12.9	20	0	2
6	46	12.0	30	1	2
8	44	11.2	40	1	3
10	42	10.3	0 50	1	4
12	15 0 40	N17 9.4	1 0	1	0.5
14	38	8.5	10	1	5
16	36	7.7	20	1	6
18	34	6.8	30	2	7
20	32	5.9	40	2	8
22	30	5.0	1 50	2	8
24	15 0 28	N17 4.1	2 0	2	0.9

♂ Mars — Tr. 23h 46m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	0 9 22	S10 19.8	0 0	0	0.0
2	9 47	20.1	10	2	0
4	10 12	20.4	20	4	1
6	10 37	20.7	30	6	1
8	11 2	21.0	40	8	1
10	27	21.2	0 50	10	1
12	0 11 52	S10 21.5	1 0	12	0.2
14	12 17	21.8	10	15	2
16	12 43	22.1	20	17	2
18	13 8	22.4	30	19	2
20	33	22.6	40	21	3
22	13 58	22.9	1 50	23	3
24	0 14 23	S10 23.2	2 0	25	0.3

♃ Jupiter — Tr. 11h 30m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	12 28 49	N 7 9.7	0 0	0	0.0
2	29 5	9.2	10	1	0
4	21	8.8	20	3	1
6	36	8.4	30	4	1
8	29 52	8.0	40	5	1
10	30 8	7.6	0 50	7	2
12	12 30 23	N 7 7.2	1 0	8	0.2
14	39	6.8	10	9	2
16	30 55	6.4	20	11	3
18	31 10	6.0	30	12	3
20	26	5.5	40	13	3
22	42	5.1	1 50	15	4
24	12 31 57	N 7 4.7	2 0	16	0.4

♄ Saturn — Tr. 16h 10m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	7 48 1	S17 52.1	0 0	0	0.0
2	19	52.1	10	2	0
4	37	52.2	20	3	0
6	48 56	52.3	30	5	0
8	49 14	52.4	40	6	0
10	32	52.5	0 50	8	0
12	7 49 51	S17 52.6	1 0	9	0.1
14	50 9	52.7	10	11	1
16	27	52.8	20	12	1
18	50 46	52.9	30	14	1
20	51 4	53.0	40	15	1
22	22	53.1	1 50	17	1
24	7 51 40	S17 53.2	2 0	18	0.1

☾ Moon Tr. 20h 1m

U (h)	$E_☾$ (h m s)	d (° ′)
0	4 36 39	S19 30.1
	35 42	27.7
1	34 45	25.3
	33 48	22.9
2	32 51	20.4
	31 54	17.9
3	30 57	15.4
	30 0	12.9
4	29 3	10.4
	28 7	7.8
5	27 10	5.2
	26 13	2.6
(H.P. 54′.2, S.D. 14′ 47″)		
6	4 25 16	S19 0.0
	24 20	18 57.3
7	23 23	54.6
	22 27	51.9
8	21 30	49.2
	20 34	46.5
9	19 37	43.7
	18 41	41.0
10	17 44	38.2
	16 48	35.3
11	15 52	32.5
	14 55	29.6
(H.P. 54′.2, S.D. 14′ 46″)		
12	4 13 59	S18 26.8
	13 3	23.9
13	12 7	21.0
	11 11	18.0
14	10 14	15.1
	9 18	12.1
15	8 22	9.1
	7 26	6.1
16	6 30	3.0
	5 35	18 0.0
17	4 39	17 56.9
	3 43	53.8
(H.P. 54′.2, S.D. 14′ 45″)		
18	4 2 47	S17 50.7
	1 51	47.5
19	0 56	44.4
	4 0 0	41.2
20	3 59 4	38.0
	58 9	34.8
21	57 13	31.6
	56 17	28.3
22	55 22	25.0
	54 26	21.7
23	53 31	18.4
	52 36	15.1
24	3 51 40	S17 11.8
(H.P. 54′.2, S.D. 14′ 45″)		

P.P. (Moon)

m	$E_☾$ (s)	d (′)
1	2	0.1
2	4	2
3	6	3
4	8	3
5	10	4
6	11	5
7	13	6
8	15	7
9	17	8
10	19	0.9
11	21	1.0
12	23	0
13	25	1
14	27	2
15	29	3
16	30	4
17	32	5
18	34	6
19	36	6
20	38	7
21	40	8
22	42	1.9
23	44	2.0
24	46	1
25	48	2
26	49	3
27	51	3
28	53	4
29	55	5
30	57	2.6

m	s	′
1	2	0.1
2	4	2
3	6	3
4	7	4
5	9	5
6	11	6
7	13	7
8	15	8
9	17	0.9
10	19	1.0
11	21	1
12	22	2
13	24	3
14	26	4
15	28	6
16	30	7
17	32	8
18	34	1.9
19	35	2.0
20	37	1
21	39	2
22	41	3
23	43	4
24	45	5
25	47	6
26	49	7
27	50	8
28	52	2.9
29	54	3.0
30	56	3.1

Planets

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	8 31	N17 15	−3.9	0.2	10
♂	23 22	S10 20	−2.6	0.4	12
♃	11 3	N 7 10	−1.2	0.0	14
♄	15 44	S17 52	+0.8	0.0	7
☿	12 38	S 8 29	+1.0	0.2	5

Fig. 21

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

Star Identification

Z (°)	Z (°)	K_1	H_1	Z (°)	Z (°)	K_1	H_1
0	180	0	− ∞	45	135	151	3000
1	179	0	+ 1242	46	134	158	3015
2	178	0	1543	47	133	166	3030
3	177	1	1719	48	132	174	3046
4	176	1	1845	49	131	183	3061
5	175	2	1942	50	130	192	3076
6	174	2	2022	51	129	201	3092
7	173	3	2089	52	128	211	3107
8	172	4	2148	53	127	221	3123
9	171	5	2200	54	126	231	3139
10	170	7	2246	55	125	241	3155
11	169	8	2289	56	124	252	3171
12	168	10	2327	57	123	264	3187
13	167	11	2363	58	122	276	3204
14	166	13	2397	59	121	288	3221
15	165	15	2428	60	120	301	3239
16	164	17	2457	61	119	314	3256
17	163	19	2485	62	118	328	3274
18	162	22	2512	63	117	343	3293
19	161	24	2537	64	116	358	3312
20	160	27	2561	65	115	374	3331
21	159	30	2584	66	114	391	3351
22	158	33	2606	67	113	408	3372
23	157	36	2628	68	112	426	3394
24	156	39	2649	69	111	446	3416
25	155	43	2669	70	110	466	3439
26	154	46	2688	71	109	487	3463
27	153	50	2707	72	108	510	3488
28	152	54	2726	73	107	534	3515
29	151	58	2744	74	106	560	3543
30	150	62	2761	75	105	587	3572
31	149	67	2779	76	104	616	3603
32	148	72	2796	77	103	648	3637
33	147	76	2813	78	102	682	3673
34	146	81	2829	79	101	719	3711
35	145	87	2845	80	100	760	3754
36	144	92	2861	81	99	806	3800
37	143	98	2877	82	98	856	3852
38	142	103	2893	83	97	914	3911
39	141	109	2908	84	96	981	3978
40	140	116	2924	85	95	1060	4058
41	139	122	2939	86	94	1156	4155
42	138	129	2954	87	93	1281	4281
43	137	136	2970	88	92	1457	4457
44	136	143	2985	89	91	1758	4758
45	135	151	3000	90	90	+ ∞	+ ∞

a (°)	K_2	D_1	a (°)	K_2	D_1
0	− ∞	− ∞	45	3000	2849
1	+ 1242	+ 1242	46	3015	2857
2	1543	1543	47	3030	2864
3	1719	1719	48	3046	2871
4	1845	1844	49	3061	2878
5	1942	1940	50	3076	2884
6	2022	2019	51	3092	2891
7	2089	2086	52	3107	2897
8	2148	2144	53	3123	2902
9	2200	2194	54	3139	2908
10	2246	2240	55	3155	2913
11	2289	2281	56	3171	2919
12	2327	2318	57	3187	2924
13	2363	2352	58	3204	2928
14	2397	2384	59	3221	2933
15	2428	2413	60	3239	2938
16	2457	2440	61	3256	2942
17	2485	2466	62	3274	2946
18	2512	2490	63	3293	2950
19	2537	2513	64	3312	2954
20	2561	2534	65	3331	2957
21	2584	2554	66	3351	2961
22	2606	2574	67	3372	2964
23	2628	2592	68	3394	2967
24	2649	2609	69	3416	2970
25	2669	2626	70	3439	2973
26	2688	2642	71	3463	2976
27	2707	2657	72	3488	2978
28	2726	2672	73	3515	2981
29	2744	2686	74	3543	2983
30	2761	2699	75	3572	2985
31	2779	2712	76	3603	2987
32	2796	2724	77	3637	2989
33	2813	2736	78	3673	2990
34	2829	2748	79	3711	2992
35	2845	2759	80	3754	2993
36	2861	2769	81	3800	2995
37	2877	2779	82	3852	2996
38	2893	2789	83	3911	2997
39	2908	2799	84	3978	2998
40	2924	2808	85	4058	2998
41	2939	2817	86	4155	2999
42	2954	2826	87	4281	2999
43	2970	2834	88	4457	3000
44	2985	2842	89	4758	3000
45	3000	2849	90	+ ∞	3000

Measurement of Z (Azimuth)

Start from North as 0° to 180° easterly or westerly

$Z \rightarrow K_1$, $a \rightarrow K_2$, $K \leftarrow K_3$, $l \rightarrow K$

$K_1 + K_2 = K_3$

$D_1 + D_2 + D_3 = D_4 \rightarrow d$

$H_1 + H_2 + H_3 = H_4 \rightarrow \lambda$

Fig. 22

Extracted from NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

K

K_3	K	D_2	H_2	K_3	K	D_2	H_2
+ ∞	0°	0	− ∞	3000	45°	151	2849
4758	1	0	+1242	2985	46	158	2857
4457	2	0	1543	2970	47	166	2864
4281	3	1	1719	2954	48	174	2871
4155	4	1	1844	2939	49	183	2878
4058	5	2	1940	2924	50	192	2884
3978	6	2	2019	2908	51	201	2891
3911	7	3	2086	2893	52	211	2897
3852	8	4	2144	2877	53	221	2902
3800	9	5	2194	2861	54	231	2908
3754	10	7	2240	2845	55	241	2913
3711	11	8	2281	2829	56	252	2919
3673	12	10	2318	2813	57	264	2924
3637	13	11	2352	2796	58	276	2928
3603	14	13	2384	2779	59	288	2933
3572	15	15	2413	2761	60	301	2938
3543	16	17	2440	2744	61	314	2942
3515	17	19	2466	2726	62	328	2946
3488	18	22	2490	2707	63	343	2950
3463	19	24	2513	2688	64	358	2954
3439	20	27	2534	2669	65	374	2957
3416	21	30	2554	2649	66	391	2961
3394	22	33	2574	2628	67	408	2964
3372	23	36	2592	2606	68	426	2967
3351	24	39	2609	2584	69	446	2970
3331	25	43	2626	2561	70	466	2973
3312	26	46	2642	2537	71	487	2976
3293	27	50	2657	2512	72	510	2978
3274	28	54	2672	2485	73	534	2981
3256	29	58	2686	2457	74	560	2983
3239	30	62	2699	2428	75	587	2985
3221	31	67	2712	2397	76	616	2987
3204	32	72	2724	2363	77	648	2989
3187	33	76	2736	2327	78	682	2990
3171	34	81	2748	2289	79	719	2992
3155	35	87	2759	2246	80	760	2993
3139	36	92	2769	2200	81	806	2995
3123	37	98	2779	2148	82	856	2996
3107	38	103	2789	2089	83	914	2997
3092	39	109	2799	2022	84	981	2998
3076	40	116	2808	1942	85	1060	2998
3061	41	122	2817	1845	86	1156	2999
3046	42	129	2826	1719	87	1281	2999
3030	43	136	2834	1543	88	1457	3000
3015	44	143	2842	+1242	89	1758	3000
3000	45	151	2849	− ∞	90	+ ∞	3000

l + K

l+K		D_3	H_3	l+K		D_3	H_3
± 0°	±180°	− ∞	0	±45°	±135°	2849	151
1	179	+1242	0	46	134	2857	158
2	178	1543	0	47	133	2864	166
3	177	1719	1	48	132	2871	174
4	176	1844	1	49	131	2878	183
5	175	1940	2	50	130	2884	192
6	174	2019	2	51	129	2891	201
7	173	2086	3	52	128	2897	211
8	172	2144	4	53	127	2902	221
9	171	2194	5	54	126	2908	231
10	170	2240	7	55	125	2913	241
11	169	2281	8	56	124	2919	252
12	168	2318	10	57	123	2924	264
13	167	2352	11	58	122	2928	276
14	166	2384	13	59	121	2933	288
15	165	2413	15	60	120	2938	301
16	164	2440	17	61	119	2942	314
17	163	2466	19	62	118	2946	328
18	162	2490	22	63	117	2950	343
19	161	2513	24	64	116	2954	358
20	160	2534	27	65	115	2957	374
21	159	2554	30	66	114	2961	391
22	158	2574	33	67	113	2964	408
23	157	2592	36	68	112	2967	426
24	156	2609	39	69	111	2970	446
25	155	2626	43	70	110	2973	466
26	154	2642	46	71	109	2976	487
27	153	2657	50	72	108	2978	510
28	152	2672	54	73	107	2981	534
29	151	2686	58	74	106	2983	560
30	150	2699	62	75	105	2985	587
31	149	2712	67	76	104	2987	616
32	148	2724	72	77	103	2989	648
33	147	2736	76	78	102	2990	682
34	146	2748	81	79	101	2992	719
35	145	2759	87	80	100	2993	760
36	144	2769	92	81	99	2995	806
37	143	2779	98	82	98	2996	856
38	142	2789	103	83	97	2997	914
39	141	2799	109	84	96	2998	981
40	140	2808	116	85	95	2998	1060
41	139	2817	122	86	94	2999	1156
42	138	2826	129	87	93	2999	1281
43	137	2834	136	88	92	3000	1457
44	136	2842	143	89	91	3000	1758
±45	±135	2849	151	±90	±90	3000	+ ∞

Name of (K)

l	Z	K
N	0°～ 90° 90°～180°	+ −
S	0°～ 90° 90°～180°	− +

Name of lat.

always (+)

Fig. 23

Extracted from NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

d, h

D_4	d (°)	D_4	d (°)
− ∞	0	5849	45
+ 4242	1	5857	46
4543	2	5864	47
4719	3	5871	48
4844	4	5878	49
4940	5	5884	50
5019	6	5891	51
5086	7	5897	52
5144	8	5902	53
5194	9	5908	54
5240	10	5913	55
5281	11	5919	56
5318	12	5924	57
5352	13	5928	58
5384	14	5933	59
5413	15	5938	60
5440	16	5942	61
5466	17	5946	62
5490	18	5950	63
5513	19	5954	64
5534	20	5957	65
5554	21	5961	66
5574	22	5964	67
5592	23	5967	68
5609	24	5970	69
5626	25	5973	70
5642	26	5976	71
5657	27	5978	72
5672	28	5981	73
5686	29	5983	74
5699	30	5985	75
5712	31	5987	76
5724	32	5989	77
5736	33	5990	78
5748	34	5992	79
5759	35	5993	80
5769	36	5995	81
5779	37	5996	82
5789	38	5997	83
5799	39	5998	84
5808	40	5998	85
5817	41	5999	86
5826	42	5999	87
5834	43	6000	88
5842	44	6000	89
5849	45	6000	90

H_4	h (h m)	h (°)	h (h m)	h (°)	H_4	h (h m)	h (°)	h (h m)	h (°)
− ∞	0 0	0	12 0	180	6000	3 0	45	9 0	135
+ 4242	0 4	1	11 56	179	6015	3 4	46	8 56	134
4543	0 8	2	11 52	178	6030	3 8	47	8 52	133
4719	0 12	3	11 48	177	6046	3 12	48	8 48	132
4845	0 16	4	11 44	176	6061	3 16	49	8 44	131
4942	0 20	5	11 40	175	6076	3 20	50	8 40	130
5022	0 24	6	11 36	174	6092	3 24	51	8 36	129
5089	0 28	7	11 32	173	6107	3 28	52	8 32	128
5148	0 32	8	11 28	172	6123	3 32	53	8 28	127
5200	0 36	9	11 24	171	6139	3 36	54	8 24	126
5246	0 40	10	11 20	170	6155	3 40	55	8 20	125
5289	0 44	11	11 16	169	6171	3 44	56	8 16	124
5327	0 48	12	11 12	168	6187	3 48	57	8 12	123
5363	0 52	13	11 8	167	6204	3 52	58	8 8	122
5397	0 56	14	11 4	166	6221	3 56	59	8 4	121
5428	1 0	15	11 0	165	6239	4 0	60	8 0	120
5457	1 4	16	10 56	164	6256	4 4	61	7 56	119
5485	1 8	17	10 52	163	6274	4 8	62	7 52	118
5512	1 12	18	10 48	162	6293	4 12	63	7 48	117
5537	1 16	19	10 44	161	6312	4 16	64	7 44	116
5561	1 20	20	10 40	160	6331	4 20	65	7 40	115
5584	1 24	21	10 36	159	6351	4 24	66	7 36	114
5606	1 28	22	10 32	158	6372	4 28	67	7 32	113
5628	1 32	23	10 28	157	6394	4 32	68	7 28	112
5649	1 36	24	10 24	156	6416	4 36	69	7 24	111
5669	1 40	25	10 20	155	6439	4 40	70	7 20	110
5688	1 44	26	10 16	154	6463	4 44	71	7 16	109
5707	1 48	27	10 12	153	6488	4 48	72	7 12	108
5726	1 52	28	10 8	152	6515	4 52	73	7 8	107
5744	1 56	29	10 4	151	6543	4 56	74	7 4	106
5761	2 0	30	10 0	150	6572	5 0	75	7 0	105
5779	2 4	31	9 56	149	6603	5 4	76	6 56	104
5796	2 8	32	9 52	148	6637	5 8	77	6 52	103
5813	2 12	33	9 48	147	6673	5 12	78	6 48	102
5829	2 16	34	9 44	146	6711	5 16	79	6 44	101
5845	2 20	35	9 40	145	6754	5 20	80	6 40	100
5861	2 24	36	9 36	144	6800	5 24	81	6 36	99
5877	2 28	37	9 32	143	6852	5 28	82	6 32	98
5893	2 32	38	9 28	142	6911	5 32	83	6 28	97
5908	2 36	39	9 24	141	6978	5 36	84	6 24	96
5924	2 40	40	9 20	140	7058	5 40	85	6 20	95
5939	2 44	41	9 16	139	7155	5 44	86	6 16	94
5954	2 48	42	9 12	138	7281	5 48	87	6 12	93
5970	2 52	43	9 8	137	7457	5 52	88	6 8	92
5985	2 56	44	9 4	136	7758	5 56	89	6 4	91
6000	3 0	45	9 0	135	+ ∞	6 0	90	6 0	90

Name of Dec. and R.A.

1. N or S of d.	when ℓ + k > 0, same name as ℓ ℓ + k < 0, contrary name to ℓ.
2. E or W of h	° h should be measured form meridian to 12h, easterly or westerly. ° when ℓ and d are the same name and ℓ + k > 90°, h_j > 6h
3. R.A.	Sid. T.=U+R±L in T. + E.L − W.L R.A.= Sid. T.±h + Easterly from meridian − Westerly from meridian

Fig. 24

Extracted from NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Problem

A star's altitude is 50°2 and its azimuth is 057° in D.R.P. lat. 34°28'N, long. 135°0'E. Chronometer time is $10^h\ 21^m\ 50^s$ (C.E. = $029^m\ 26^s$ ⊖) and local time 06:50, 6 July 1956. (see Figs. 25, 26 and 27) What is the star's name? (See page 88 & 89)

6 July 1956

Nautical Almanac

Lunar Age 27.1

⊙ Sun

U (h)	E⊙ (h m s)	d (° ')	P.P. (h m)	P.P. (')
0	11 55 28	N22 43.2	0 0	0.0
2	27	42.7	10	0
4	26	42.2	20	1
6	25	41.7	30	1
8	24	41.2	40	2
10	24	40.7	0 50	2
12	11 55 23	N22 40.2	1 0	0.3
14	22	39.6	10	3
16	21	39.1	20	3
18	20	39.6	30	4
20	20	38.1	40	4
22	19	37.6	1 50	5
24	11 55 18	N22 37.0	2 0	0.5

(S.D. 15' 46")

★ Star, U = 0h

No.	Star	E★ (h m s)	d (° ')
1	Polaris	17 2 29	N89 3.4
2	Kochab	4 4 57	74 20.3
3	Dubhe	7 54 45	61 59.3
4	β Cassiop.	18 48 55	58 54.4
5	Merak	7 58 35	56 37.1
6	Alioth	6 3 40	N56 11.9
7	Schedir	18 17 45	56 17.8
8	Mizar	5 33 36	55 9.9
9	α Persei	15 34 35	49 42.3
10	Benetnasch	5 9 57	49 32.0
11	Capella	19 42 20	N45 57.2
12	Deneb	22 15 48	45 7.5
13	Vega	0 20 17	38 44.7
14	Castor	11 23 58	31 59.1
15	Alpheratz	18 49 38	28 51.0
16	Pollux	11 19 9	N28 7.9
17	α Cor. Bor.	3 22 55	26 51.7
18	Arcturus	4 42 6	19 24.6
19	Aldebaran	14 22 23	16 25.4
20	Markab	19 53 11	14 58.8
21	Denebola	7 8 57	N14 48.9
22	α Ophiuchi	1 22 51	12 35.5
23	Regulus	8 49 44	12 10.8
24	Altair	23 7 6	8 45.3
25	Betelgeuse	13 2 59	7 24.0
26	Bellatrix	13 33 0	N 6 18.7
27	Procyon	11 18 47	N 5 20.2
28	Rigel	13 43 21	S 8 15.0
29	α Hydrae	8 30 21	8 28.8
30	Spica	5 32 53	10 56.2
31	Sirius	12 12 35	S16 39.4
32	β Ceti	18 14 22	18 13.3
33	Antares	2 39 1	26 20.3
34	ε Sagittarii	0 3 11	26 21.0
35	Fomalhaut	20 0 31	29 50.9
36	λ Scorpii	1 25 6	S37 4.4
37	Canopus	12 32 50	52 40.3
38	α Pavonis	22 33 31	56 52.3
39	Achernar	17 19 42	57 27.1
40	β Crucis	6 10 36	59 27.4
41	β Centauri	4 55 1	S60 10.2
42	α Centauri	4 19 7	60 39.8
43	α Crucis	6 31 36	62 51.9
44	α Tri. Aust.	2 11 40	68 57.2
45	β Carinae	9 49 6	S69 32.6

R_* 18h 55m 48s

Planet

♀ Venus — Tr. 10h 35m

U (h)	E_p (h m s)	d (° ')	P.P. (h m)	P.P. E_p (s)	P.P. d (')
0	13 22 13	N18 41.9	0 0	0	0.0
2	22 39	41.8	10	2	1
4	23 5	40.6	20	4	1
6	31	40.0	30	7	2
8	23 57	39.3	40	9	2
10	24 25	38.7	0 50	11	3
12	13 24 49	N18 38.0	1 0	13	0.3
14	25 14	37.4	10	15	4
16	25 40	36.8	20	17	4
18	26 5	36.2	30	20	5
20	31	35.6	40	22	5
22	26 56	35.0	1 50	24	6
24	13 27 22	N18 34.3	2 0	26	0.6

♂ Mars — Tr. 4h 19m

U (h)	E_p (h m s)	d (° ')	P.P. (h m)	P.P. E_p (s)	P.P. d (')
0	19 41 0	S 9 27.7	0 0	0	0.0
2	12	27.2	10	1	0
4	24	26.7	20	2	1
6	36	26.1	30	3	1
8	41 48	25.6	40	4	2
10	42 0	25.0	0 50	5	2
12	19 42 12	S 9 24.5	1 0	6	0.3
14	24	24.0	10	7	3
16	36	23.5	20	8	3
18	42 49	22.9	30	9	4
20	43 1	22.4	40	10	4
22	13	21.9	1 50	11	5
24	19 43 25	S 9 21.4	2 0	12	0.5

♃ Jupiter — Tr. 15h 11m

U (h)	E_p (h m s)	d (° ')	P.P. (h m)	P.P. E_p (s)	P.P. d (')
0	8 47 16	N12 30.4	0 0	0	0.0
2	32	30.1	10	1	0
4	47 49	29.8	20	3	1
6	48 5	29.4	30	4	1
8	21	29.1	40	5	1
10	37	28.8	0 50	7	1
12	8 48 54	N12 28.5	1 0	8	0.2
14	49 10	28.2	10	9	2
16	26	27.8	20	11	2
18	42	27.5	30	12	2
20	49 59	27.2	40	13	3
22	50 15	26.9	1 50	15	3
24	8 50 31	N12 26.5	2 0	16	0.3

♄ Saturn — Tr. 20h 40m

U (h)	E_p (h m s)	d (° ')	P.P. (h m)	P.P. E_p (s)	P.P. d (')
0	3 16 21	S17 20.7	0 0	0	0.0
2	16 42	20.6	10	2	0
4	17 2	20.6	20	4	0
6	23	20.6	30	5	0
8	17 43	20.6	40	7	0
10	18 4	20.5	0 50	9	0
12	3 18 24	S17 20.5	1 0	11	0.0
14	18 45	20.5	10	12	0
16	19 5	20.5	20	14	0
18	25	20.4	30	16	0
20	19 46	20.4	40	18	0
22	20 6	20.4	1 50	19	0
24	3 20 27	S17 20.4	2 0	21	0.0

☾ Moon — Tr. 10h 17m

U (h)	$E_☾$ (h m s)	d (° ')
0	14 9 3	N21 53.5
	7 49	54.1
1	6 34	54.7
	5 20	55.2
2	4 5	55.8
	2 50	56.2
3	1 35	56.7
	14 0 20	57.0
4	13 59 5	57.4
	57 51	57.7
5	56 36	58.0
	55 21	58.2
(H.P. 60'.5, S.D. 16' 29")		
6	13 54 5	N21 58.4
	52 50	58.5
7	51 35	58.6
	50 20	58.7
8	49 5	58.7
	47 49	58.7
9	46 34	58.7
	45 19	58.6
10	44 3	58.4
	42 48	58.3
11	41 32	58.0
	40 17	57.8
(H.P. 60'.7, S.D. 16' 32")		
12	13 39 1	N21 57.5
	37 46	57.1
13	36 30	56.8
	35 15	56.3
14	33 59	55.9
	32 43	55.4
15	31 28	54.0
	30 12	54.3
16	28 56	53.6
	27 40	53.0
17	26 25	52.2
	25 9	51.5
(H.P. 60'.8, S.D. 16' 34")		
18	13 23 53	N21 50.7
	22 37	49.9
19	21 21	49.0
	20 6	48.1
20	18 50	47.1
	17 34	46.1
21	16 18	45.1
	15 2	44.0
22	13 46	42.9
	12 30	41.7
23	11 14	40.5
	9 58	39.3
24	13 8 42	N21 38.0
(H.P. 60'.9, S.D. 15' 36")		

P.P. (Moon)

m	$E_☾$ (s)	d (')
1	3	0.0
2	5	0
3	8	0
4	10	1
5	13	1
6	15	1
7	18	1
8	20	1
9	23	1
10	25	1
11	28	1
12	30	2
13	33	2
14	35	2
15	38	2
16	40	2
17	43	2
18	45	2
19	48	3
20	50	3
21	53	3
22	55	3
23	58	3
24	60	3
25	63	3
26	65	3
27	68	4
28	70	4
29	73	4
30	75	0.4

m	$E_☾$ (s)	d (')
1	3	0.0
2	5	1
3	8	1
4	10	1
5	13	1
6	15	2
7	18	2
8	20	2
9	23	2
10	25	3
11	28	3
12	30	3
13	33	3
14	35	4
15	38	4
16	41	4
17	43	5
18	46	5
19	48	5
20	51	5
21	53	6
22	56	6
23	58	6
24	61	6
25	63	7
26	66	7
27	68	7
28	71	7
29	73	8
30	76	0.8

	R.A. (h m)	d (° ')	Mag.	H.P. (')	S.D. (")
♀	5 34	N18 42	−3.7	0.5	28
♂	23 15	S 9 28	−1.1	0.2	8
♃	10 9	N12 30	−1.4	0.0	15
♄	15 39	S17 21	+0.5	0.0	8
☿	5 54	N22 54	−0.8	0.1	3

Fig. 25

Extracted from NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

5 July 1956
Nautical Almanac

Lunar Age 26.1

☉ Sun

U (h)	$E_\odot$ (h m s)	d (° ′)	P.P. of d (dの比例部分) (h m)	(′)
0	11 55 38	N22 48.9	0 0	0.0
2	37	48.4	10	0
4	37	48.0	20	1
6	36	47.5	30	1
8	35	47.0	40	2
10	34	46.6	0 50	2
12	11 55 33	N22 46.1	1 0	0.3
14	32	45.6	10	3
16	31	45.1	20	3
18	30	44.6	30	4
20	30	44.1	40	4
22	29	43.7	1 50	5
24	11 55 28	N22 43.2	2 0	0.5

S.D. 15′ 46″

Star (U = 0ʰ の値)

No.	Star	E_* (h m s)	d (° ′)
1	*Polaris*	16 58 34	N89 3.4
2	*Kochab*	4 1 1	74 20.2
3	*Dubhe*	7 50 48	61 59.3
4	*β Cassiop.*	18 44 59	58 54.4
5	*Merak*	7 52 38	56 37.1
6	*Alioth*	5 59 43	N56 11.9
7	*Schedir*	18 13 48	56 17.8
8	*Mizar*	5 29 40	55 9.3
9	*α Persei*	15 30 39	49 42.3
10	*Benetnasch*	5 6 0	49 32.0
11	*Capella*	13 38 23	N45 57.2
12	*Deneb*	22 11 52	45 7.5
13	*Vega*	0 16 21	38 44.7
14	*Castor*	11 20 2	31 59.1
15	*Alpheratz*	18 45 42	28 51.0
16	*Pollux*	11 9 12	N28 7.9
17	*α Cor. Bor.*	3 18 59	26 51.7
18	*Arcturus*	4 38 9	19 24.6
19	*Aldebaran*	14 18 26	16 25.4
20	*Markab*	19 49 14	14 58.3
21	*Denebola*	7 5 0	N14 48.9
22	*α Ophiuchi*	1 18 54	12 35.5
23	*Regulus*	8 45 48	12 10.8
24	*Altair*	23 3 9	8 45.3
25	*Betelgeuse*	12 59 3	7 24.0
26	*Bellatrix*	13 29 4	N 6 18.7
27	*Procyon*	11 14 50	N 5 20.2
28	*Rigel*	13 39 25	S 8 15.0
29	*α Hydrae*	9 26 24	8 28.3
30	*Spica*	5 28 56	10 56.2
31	*Sirius*	12 8 38	S16 39.4
32	*β Ceti*	18 10 26	18 13.3
33	*Antares*	2 25 5	26 20.3
34	*σ Sagittarii*	23 59 14	26 21.0
35	*Fomalhaut*	19 56 34	29 50.9
36	*λ Scorpii*	1 21 9	S37 4.4
37	*Canopus*	12 28 54	52 40.3
38	*α Pavonis*	22 29 35	56 52.3
39	*Achernar*	17 15 46	57 27.1
40	*β Crucis*	6 6 40	59 27.4
41	*β Centauri*	4 51 4	S60 10.2
42	*α Centauri*	4 15 11	60 39.8
43	*α Crucis*	6 27 40	62 51.9
44	*α Tri. Aust.*	2 7 43	68 57.2
45	*β Carinae*	9 39 9	S69 32.6

R_0 18ʰ 51ᵐ 51ˢ

Planet

♀ Venus Tr. 10ʰ 41ᵐ

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	13 16 55	N18 50.1	0 0	0	0.0
2	17 22	49.4	10	2	1
4	17 49	48.7	20	5	1
6	18 16	48.0	30	7	2
8	18 42	47.3	40	9	2
10	19 9	46.6	0 50	11	3
12	13 19 35	N18 45.9	1 0	14	0.4
14	20 2	45.2	10	16	4
16	28	44.6	20	18	5
18	20 55	43.9	30	20	5
20	21 21	43.2	40	23	6
22	21 47	42.6	1 50	25	6
24	13 22 13	N18 41.9	2 0	27	0.7

♂ Mars 正中時 Tr. 4ʰ 21ᵐ

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	19 38 37	S 9 34.3	0 0	0	0.0
2	38 49	33.7	10	1	0
4	39 0	33.2	20	2	1
6	12	32.6	30	3	1
8	24	32.1	40	4	2
10	36	31.5	0 50	5	2
12	19 39 48	S 9 31.0	1 0	6	0.3
14	40 0	30.4	10	7	3
16	12	29.9	20	8	3
18	24	29.3	30	9	4
20	36	28.8	40	10	4
22	40 48	28.3	1 50	11	5
24	19 41 0	S 9 27.7	2 0	12	0.5

♃ Jupiter 正中時 Tr. 15ʰ 14ᵐ

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	8 44 1	N12 34.2	0 0	0	0.0
2	17	33.9	10	1	0
4	33	33.6	20	3	1
6	44 50	33.3	30	4	1
8	45 6	33.0	40	5	1
10	22	32.6	0 50	7	1
12	8 45 38	N12 32.3	1 0	8	0.2
14	45 55	32.0	10	9	2
16	46 11	31.7	20	11	2
18	27	31.4	30	12	2
20	46 43	31.0	40	13	3
22	47 0	30.7	1 50	15	3
24	8 47 16	N12 30.4	2 0	16	0.3

♄ Saturn 正中時 Tr. 20ʰ 44ᵐ

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	3 12 15	S17 21.0	0 0	0	0.0
2	35	21.0	10	2	0
4	12 56	20.9	20	4	0
6	13 16	20.9	30	5	0
8	37	20.9	40	7	0
10	13 57	20.9	0 50	9	0
12	3 14 18	S17 20.8	1 0	11	0.0
14	38	20.8	10	12	0
16	14 59	20.8	20	14	0
18	15 19	20.8	30	16	0
20	15 40	20.7	40	18	0
22	16 1	20.7	1 50	19	0
24	3 16 21	S17 20.7	2 0	21	0.0

☾ Moon Tr. 9ʰ 15ᵐ

U (h)	$E_☾$ (h m s)	d (° ′)
0	15 7 23	N20 39.3
	6 12	41.7
1	5 1	44.0
	3 50	46.3
2	2 38	48.6
	1 27	50.8
3	15 0 15	53.0
	14 59 4	55.2
4	57 52	57.4
	56 40	20 59.5
5	55 29	21 1.5
	54 17	3.6
(H.P.59′.7, S.D.16′ 16″)		
6	14 53 5	N21 5.6
	51 53	7.6
7	50 41	9.5
	49 28	11.4
8	48 16	13.3
	47 4	15.1
9	45 51	16.9
	44 38	18.6
10	43 26	20.4
	42 13	22.0
11	41 0	23.7
	39 47	25.3
(H.P.59′.9, S.D.16′ 19″)		
12	14 38 35	N21 26.9
	37 22	28.4
13	36 8	29.9
	34 55	31.4
14	33 42	32.8
	32 29	34.2
15	31 15	35.6
	30 2	36.9
16	28 48	38.2
	27 35	39.4
17	26 21	40.6
	25 7	41.8
(H.P.60′.1, S.D.16′ 23″)		
18	14 23 54	N21 42.9
	22 40	44.0
19	21 26	45.1
	20 12	46.1
20	18 58	47.1
	17 44	48.0
21	16 30	48.9
	15 15	49.8
22	14 1	50.6
	12 47	51.4
23	11 32	52.1
	10 18	52.8
24	14 9 3	N21 53.5
(H.P.60′.3, S.D.16′ 26″)		

Moon P.P. (0ʰ–12ʰ)

m	$E_☾$ (s)	d (′)
1	2	0.1
2	5	1
3	7	2
4	10	3
5	12	3
6	14	4
7	17	5
8	19	5
9	22	6
10	24	7
11	26	7
12	29	8
13	31	9
14	34	0.9
15	36	1.0
16	38	1
17	41	1
18	43	2
19	46	3
20	48	3
21	50	4
22	53	5
23	55	5
24	58	6
25	60	7
26	62	7
27	65	8
28	67	9
29	70	1.9
30	72	2.0

Moon P.P. (12ʰ–24ʰ)

m	$E_☾$ (s)	d (′)
1	2	0.0
2	5	1
3	7	1
4	10	1
5	12	2
6	15	2
7	17	3
8	19	3
9	22	3
10	24	4
11	27	4
12	29	4
13	32	5
14	34	5
15	37	6
16	39	6
17	41	6
18	44	7
19	46	7
20	49	7
21	51	8
22	54	8
23	56	8
24	58	9
25	61	0.9
26	63	1.0
27	63	0
28	69	0
29	71	1
30	73	1.1

Planet

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	5 35	N18 50	−3.7	0.5	27
♂	23 13	S 9 34	−1.1	0.2	8
♃	10 8	N12 34	−1.4	0.0	15
♄	15 40	S17 21	+0.5	0.0	8
☿	5 46	N22 40	−0.7	0.1	3

Fig. 26

Extracted from NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

P.P. for E_{*}

U	m 0	m 10	m 20	m 30
h	m s	m s	m s	m s
0	0 00	0 02	0 03	0 05
1	10	11	13	15
2	20	21	23	25
3	30	31	33	34
4	39	41	43	44
5	49	0 51	0 53	0 54
6	0 59	1 01	1 02	1 04
7	1 09	11	12	14
8	19	20	22	24
9	29	30	32	34
10	39	40	42	43
11	48	1 50	1 52	1 53
12	1 58	2 00	2 02	2 03
13	2 08	10	11	13
14	18	20	21	23
15	28	29	31	33
16	38	39	41	43
17	48	49	2 51	2 52
18	2 57	2 59	3 01	3 02
19	3 07	3 09	11	12
20	17	19	20	22
21	27	29	30	32
22	37	38	40	42
23	3 47	3 48	3 50	3 52

U	m 30	m 40	m 50	m 60
h	m s	m s	m s	m s
0	0 05	0 07	0 08	0 10
1	15	16	18	20
2	25	26	28	30
3	34	36	38	39
4	44	46	48	49
5	0 54	0 56	0 57	0 59
6	1 04	1 06	1 07	1 09
7	14	16	17	19
8	24	25	27	29
9	34	35	37	39
10	43	45	47	48
11	1 53	1 55	1 57	1 58
12	2 03	2 05	2 06	2 08
13	13	15	16	18
14	23	25	26	28
15	33	34	36	38
16	43	44	46	48
17	2 52	2 54	2 56	2 57
18	3 02	3 04	3 06	3 07
19	12	14	15	17
20	22	24	25	27
21	32	34	35	37
22	42	43	45	47
23	3 52	3 53	3 55	3 57

Table of Proportional Parts

Fig. 27

Extracted from NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Latitude observation

1. Solution for meridian altitude

It is possible to give a latitude line for any celestial body when we observe its altitude at transit. The sun and Polaris are most commonly used for a latitude line. The sun transits the observer's meridian at local apparent noon (LAN). The LAN observation for a latitude line is very important, because this observation can show the most dependable celestial line of position of the day. The sun should be observed at local apparent noon as part of routine work on board vessel.

When the celestial body is either due north or south of the observer,

Transit upper branch $h = 0^h$ (h : Hour angle)
Transit lower branch $h = 12^h$

The formulae of spherical triangle are known as below,

$\cos Z = \pm \sin \ell \sin d + \cos \ell \cos d \cos h$ (Z : Zenith distance)

$\sin a = \sin \ell \cos p + \cos \ell \sin p \cos h$

When a celestial body transits upper branch, "h" should be 0^h (0°) then

$$\begin{aligned}
\cos Z &= \pm \sin \ell \sin d + \cos \ell \cos d \underline{\cos 0^\circ} \\
&= \pm \sin \ell \sin d + \cos \ell \cos d \times 1 \\
&= \pm \sin \ell \sin d + \cos \ell \cos d \\
&= \cos \ell \cos d \pm \sin \ell \sin d \\
&= \cos (\ell \mp d) \quad \text{Ref. Additive formulae of trigonometry}
\end{aligned}$$

$\therefore \cos z = \cos (\ell \mp d)$ ※ $\cos (\theta \pm \Psi) = \cos \theta \cos \Psi \pm \sin \theta \sin \Psi$

※ $\sin (\theta \pm \Psi) = \sin \theta \cos \Psi \pm \cos \theta \sin \Psi$

$\tan (\theta \pm \Psi) = \dfrac{\tan \theta \pm \tan \psi}{1 \pm \tan \theta \tan \psi}$

In this case, zenith distance is meridian zenith distance (Zm), So Z = Zm.

$$\underline{Zm = \ell \mp d}$$

When a celestial body transits lower branch, "h" should be 12^h (180^o), so

$$\sin a = \sin \ell \cos p + \cos \ell \sin p \cos 180^o \quad (P : \text{Polar distance})$$

$$= \sin \ell \cos p + \cos \ell \sin p \times (-1)$$

$$= \sin \ell \cos p - \cos \ell \sin p$$ Refer additive formulae of trigonometry.

$$= \sin (\ell - p)$$

$$\sin a = \sin (\ell - p)$$

$$\therefore a = \ell - p$$

In this case, the altitude (a) is meridian alitude (am) so a = am. then

$$\underline{am = \ell - p}$$

If we know the meridian zenith distance (Zm) or meridian altitude (am) and declination of a celestial body, by the formulae both $Zm = \ell \mp d$ and $am = \ell - p$, a latitude line of observer is obtainable as shown in Fig. 28.

Transit	d and Zm		Latitude	Name of latitude
Upper branch	d same name as Zm		$\ell = Zm + d$	Same name as d or Zm
	d contrary name to Zm	d > Zm	$\ell = d - Zm$	Same name as bigger value of d or Zm
		d < Zm	$\ell = Zm - d$	
Lower branch			$\ell = am + P$	Same name as d

Attention

About name of Zm (N or S).

N → Direction of Zm from celestial body is north.

S → Direction of Zm from celestial body is south.

Ref. A) lat & dec same names,
lat > dec
Latitude = Zm + dec.

B) 1. lat & dec same names,
lat < dec

2. lat & dec contrary names,
Latitude = Zm ~ dec.

Fig. 28

※ Compare fixed lat. with D.R. lat..

Example 8

Find the Japan Standard Time of upper branch transit of the sun in longitude 141° 20'E, 10 June 1956.

At this standard time, a navigator observed the southerly meridian altitude (or apparent maximum altitude) of the sun's lower limb ($\underline{\odot}$) as 75° - 12!2.

What was the latitude at the time when he observed the sun?

where : Index error (I.E.) ⊖ 5!5, Height of eye (H.E.) 8 metres
Air temperature was 3°C warmer than the sea water temperature.

Solution

L.A.T. 10 June 1956	$12^h - 00^m - 00^s$	
L. in T. (141°- 20'E)	$9 - 25 - 20$ ⊖	← 141°- 21' (see Fig. 20)
G.A.T. 10 June 1956	$2 - 34 - 40$	
E.T.	$0 - 46$ ⊖	← E.T. = $E_{\odot}$ - 12 (see Fig. 25) = ($12^h - 00^m - 46^s$ - 12 (MT = AT - ET)
U	$2^h - 33^m - 54^s$	→ d = 23°- 00'.2N (see Fig. 29)
L. in T. (135°E, JAPAN)	$9 - 00 - 00$ ⊕	
J.S.T.	$11^h - 33^m - 54^s$	

Ref. : $E_{\odot} = -12^h + E.T. + (24^h)$
E☾ $= R - R.A. + (24^h)$
$E_p = R - R.A.P. + (24^h)$
$E_* = R - R.A.* + (24^h)$
$R = - 12^h + R.A.M.S. + (24^h)$

$$S = 24^h - R.A.*$$
$$h_G = U + E$$
$$h_{G\odot} = U + E_{\odot}$$
$$h_{G☾} = U + E_{☾}$$
$$h_G P = U + E_P$$
$$h_G* = U + E*$$
$$h = h_G \pm L \begin{cases} \text{Long. E} \oplus \\ \text{Long. W} \ominus \end{cases}$$

Altitude correction

Sex. alt. $\underline{\odot}$	$75^\circ - 12'.2$	
I,E	$\ominus$ 5.5	
Obs. alt $\underline{\odot}$	$75^\circ - 06'.7$	
Corr. 1	$\oplus$ 10.5	(see Fig. 30)
	$75^\circ - 17'.2$	
Corr. 2	0.0	(see Fig. 30)
	$75^\circ - 17'.2$	
Corr. temp.	$\oplus$ 0.6	(see Fig. 30)
True Alt. $\underline{\odot}$	$75^\circ - 17'.8$	
	$90 - 00.0 \ominus$	
Zm	$14^\circ - 42'.2$N	
d	$23 - 00.2$N $\oplus$	
ℓ	$37^\circ - 42'.4$N	

Ans. Time of transit = JST $11^h\ 33^m\ 54^s$ (10 June 1956)
Latitude = $37^\circ - 42'.4$N.

Problem

On 4 August 1956, a navigator observed the northerly altitude of the sun's lower limb when it transited the upper branch in longitude $7^\circ 15'$W. as $66^\circ 05'.5$. When index error was $\oplus$ $2'.4$, height of eye 12 metres, air temperature 25°C, sea water temperature 24°C, What was his latitude?

10 June 1956

Nautical Almanac — Lunar Age $1^{d}.1$

☉ Sun

U (h)	$E_☉$ (h m s)	d (° ′)	P.P. (h m)	d (′)
0	12 0 47	N22 59.7	0 0	0.0
2	46	23 0.1	10	0
4	45	0.5	20	1
6	44	0.9	30	1
8	43	1.2	40	1
10	42	1.6	0 50	2
12	12 0 41	N23 2.0	1 0	0.2
14	40	2.4	10	2
16	39	2.7	20	3
18	38	3.1	30	3
20	37	3.5	40	3
22	36	3.8	1 50	4
24	12 0 35	N23 4.2	2 0	0.4

S.D. 15′ 47″)

$U = 0^h$

No.	Star	E_* (h m s)	d (° ′)
1	*Polaris*	15 20 32	N89 3.4
2	*Kochab*	2 22 25	74 20.2
3	*Dubhe*	6 12 13	61 59.4
4	*β Cassiop.*	17 6 26	58 54.4
5	*Merak*	6 14 3	56 37.1
6	*Alioth*	4 21 9	N56 11.9
7	*Schedir*	16 35 15	56 17.7
8	*Mizar*	3 51 5	55 9.3
9	*α Persei*	13 52 6	49 42.3
10	*Benetnasch*	3 27 26	49 31.9
11	*Capella*	11 59 50	N45 57.3
12	*Deneb*	20 33 19	45 7.3
13	*Vega*	22 37 47	38 44.5
14	*Castor*	9 41 28	31 59.1
15	*Alpheratz*	17 7 9	28 50.9
16	*Pollux*	9 30 38	N28 7.9
17	*α Cor. Bor.*	1 40 25	26 51.7
18	*Arcturus*	2 59 35	19 24.5
19	*Aldebaran*	12 39 52	16 25.3
20	*Markab*	18 10 41	14 58.2
21	*Denebola*	5 26 26	N14 48.9
22	*α Ophiuchi*	23 40 20	12 35.4
23	*Regulus*	7 7 14	12 10.8
24	*Altair*	21 24 36	8 45.2
25	*Betelgeuse*	11 20 29	7 24.0
26	*Bellatrix*	11 50 30	N 6 18.6
27	*Procyon*	9 36 16	N 5 20.2
28	*Rigel*	12 0 51	S 8 15.1
29	*α Hydrae*	7 47 50	8 28.3
30	*Spica*	3 50 22	10 56.2
31	*Sirius*	10 30 4	S16 39.4
32	*β Ceti*	16 31 53	18 13.4
33	*Antares*	0 46 31	26 20.3
34	*σ Sagittarii*	22 20 41	26 21.0
35	*Fomalhaut*	18 18 1	29 50.9
36	*λ Scorpii*	23 42 35	S37 4.4
37	*Canopus*	10 50 20	52 40.4
38	*α Pavonis*	20 51 2	56 52.3
39	*Achernar*	15 37 13	57 27.2
40	*β Crucis*	4 28 5	59 27.4
41	*β Centauri*	3 12 30	S60 10.1
42	*α Centauri*	2 36 36	60 39.7
43	*α Crucis*	4 49 5	62 51.9
44	*α Tri. Aust.*	0 29 9	68 57.1
45	*β Carinae*	8 0 35	S69 32.7

R_0 17h 13m 17s

Planet

♀ Venus — Tr. 13h 16m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	10 41 12	N23 55.2	0 0	0	0.0
2	41 40	54.3	10	2	1
4	42 8	53.3	20	5	2
6	42 36	52.4	30	7	2
8	43 5	51.4	40	9	3
10	43 33	50.5	0 50	12	4
12	10 44 1	N23 49.5	1 0	14	0.5
14	29	48.5	10	16	6
16	44 58	47.6	20	19	7
18	45 26	46.6	30	21	7
20	45 55	45.6	40	23	8
22	46 23	44.7	1 50	26	0.9
24	10 46 52	N23 43.7	2 0	28	1.0

♂ Mars — Tr. 5h 13m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	18 46 33	S12 59.7	0 0	0	0.0
2	43	59.0	10	1	1
4	46 52	58.2	20	2	1
6	47 1	57.4	30	2	2
8	10	56.6	40	3	3
10	20	55.9	0 50	4	3
12	18 47 29	S12 55.1	1 0	5	0.4
14	38	54.3	10	5	5
16	47	53.5	20	6	5
18	47 57	52.8	30	7	6
20	48 6	52.0	40	8	7
22	15	51.2	1 50	8	7
24	18 48 24	S12 50.4	2 0	9	0.8

♃ Jupiter — Tr. 16h 37m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	7 20 50	N13 58.8	0 0	0	0.0
2	21 7	58.5	10	1	0
4	24	58.3	20	3	1
6	41	58.0	30	4	1
8	21 58	57.8	40	6	1
10	22 15	57.6	0 50	7	1
12	7 22 32	N13 57.3	1 0	9	0.2
14	22 49	57.1	10	10	2
16	23 6	56.8	20	11	2
18	23	56.6	30	13	2
20	40	56.3	40	14	3
22	23 57	56.1	1 50	16	3
24	7 24 14	N13 55.8	2 0	17	0.3

♄ Saturn — Tr. 22h 28m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	1 28 3	S17 35.0	0 0	0	0.0
2	24	34.9	10	2	0
4	28 45	34.9	20	4	0
6	29 6	34.8	30	5	0
8	27	34.8	40	7	0
10	29 48	34.7	0 50	9	0
12	1 30 9	S17 34.6	1 0	11	0.1
14	30	34.6	10	12	1
16	30 51	34.5	20	14	1
18	31 12	34.4	30	16	1
20	33	34.4	40	18	1
22	31 54	34.3	1 50	19	1
24	1 32 16	S17 34.3	2 0	21	0.1

☾ Moon — Tr. 13h 40m

U (h)	$E_☾$ (h m s)	d (° ′)
0	10 53 43	N21 0.8
	52 28	20 58.6
1	51 13	56.3
	49 58	54.0
2	48 43	51.7
	47 28	49.4
3	46 13	47.0
	44 58	44.5
4	43 43	42.0
	42 28	39.5
5	41 14	37.0
	39 59	34.4
(H.P. 61′.0, S.D. 16′ 37″)		
6	10 38 44	N20 31.8
	37 30	29.1
7	36 15	26.4
	35 1	23.6
8	33 46	20.9
	32 32	18.0
9	31 17	15.2
	30 3	12.3
10	28 49	9.4
	27 34	6.4
11	26 20	3.4
	25 6	20 0.4
(H.P. 61′.0, S.D. 16′ 36″)		
12	10 23 52	N19 57.3
	22 38	54.2
13	21 24	51.1
	20 10	47.9
14	18 57	44.7
	17 43	41.4
15	16 23	38.1
	15 16	34.8
16	14 2	31.4
	12 49	28.1
17	11 35	24.6
	10 22	21.2
(H.P. 60′.9, S.D. 16′ 36″)		
18	10 9 9	N19 17.7
	7 55	14.1
19	6 42	10.6
	5 29	7.0
20	4 16	19 3.4
	3 3	18 59.7
21	1 50	56.0
	10 0 38	52.3
22	9 59 25	48.5
	58 12	44.7
23	57 0	40.9
	55 47	37.0
24	9 54 35	N18 33.1
(H.P. 60′.9, S.D. 16′ 35″)		

P.P. (Moon)

m (0h–12h)	$E_☾$ (s)	d (′)	m (12h–24h)	$E_☾$ (s)	d (′)
1	3	0.1	1	2	0.1
2	5	2	2	5	2
3	8	3	3	7	3
4	10	3	4	10	5
5	13	4	5	12	6
6	15	5	6	15	7
7	18	6	7	17	8
8	20	7	8	19	0.9
9	23	8	9	22	1.0
10	25	0.9	10	24	2
11	28	1.0	11	27	3
12	30	0	12	29	4
13	33	1	13	32	5
14	35	2	14	34	6
15	38	3	15	37	8
16	40	4	16	39	1.9
17	43	5	17	41	2.0
18	45	6	18	44	1
19	48	6	19	46	2
20	50	7	20	49	3
21	53	8	21	51	4
22	55	1.9	22	54	6
23	58	2.0	23	56	7
24	60	1	24	58	8
25	63	2	25	61	2.9
26	65	3	26	63	3.0
27	68	3	27	66	1
28	70	4	28	68	3
29	73	5	29	71	4
30	75	2.6	30	73	3.5

Planet

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	6 32	N23 55	−3.6	0.5	27
♂	22 27	S13 0	−0.5	0.2	6
♃	9 52	N13 59	−1.5	0.0	16
♄	15 45	S17 35	+0.3	0.0	8
☿	3 57	N16 13	+1.6	0.2	5

Fig. 29

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

4 August 1956

Nautical Almanac

Lunar Age 26.8

☉ Sun

U	$E_☉$	d	P.P.	
h	h m s	° ′	h m	′
0	11 53 59	N17 18.9	0 0	0.0
2	53 59	17.5	10	1
4	54 0	16.2	20	2
6	0	14.9	30	3
8	0	13.5	40	4
10	1	12.2	0 50	5
12	11 54 1	N17 10.9	1 0	0.7
14	2	9.5	10	8
16	2	8.2	20	0.9
18	3	6.9	30	1.0
20	3	5.5	40	1
22	4	4.2	1 50	2
24	11 54 4	N17 2.8	2 0	1.3

(S.D. 15′ 48″)

Stars ($U = 0^h$)

No.	Star	E_* (h m s)	d (° ′)
1	Polaris	18 56 9	N89 3.4
2	Kochab	5 59 20	74 20.3
3	Dubhe	9 49 6	61 59.2
4	β Cassiop.	20 43 14	58 54.6
5	Merak	9 50 55	56 37.0
6	Alioth	7 58 1	N56 11.9
7	Schedir	20 12 4	56 17.9
8	Mizar	7 27 57	55 9.3
9	α Persei	17 28 54	49 42.3
10	Benetnasch	7 4 18	49 32.0
11	Capella	15 36 39	N45 57.2
12	Deneb	0 10 8	45 7.6
13	Vega	2 14 38	38 44.8
14	Castor	13 18 18	31 59.1
15	Alpheratz	20 43 58	28 51.1
16	Pollux	13 7 29	N28 7.9
17	α Cor. Bor.	5 17 16	26 51.8
18	Arcturus	6 36 26	19 24.6
19	Aldebaran	16 16 42	16 25.4
20	Markab	21 47 30	14 58.4
21	Denebola	9 3 17	N14 48.9
22	α Ophiuchi	3 17 11	12 35.6
23	Regulus	10 44 4	12 10.8
24	Altair	1 1 26	8 45.4
25	Betelgeuse	14 57 19	7 24.0
26	Bellatrix	15 27 20	N 6 18.7
27	Procyon	13 13 6	N 5 20.2
28	Rigel	15 37 41	S 8 14.9
29	α Hydrae	11 24 41	8 28.2
30	Spica	7 27 13	10 56.2
31	Sirius	14 6 54	S16 39.3
32	β Ceti	20 8 42	18 13.2
33	Antares	4 23 22	26 20.3
34	σ Sagittarii	1 57 31	26 21.0
35	Fomalhaut	21 54 50	29 50.9
36	λ Scorpii	3 19 26	S37 4.5
37	Canopus	14 27 10	52 40.2
38	α Pavonis	0 27 51	56 52.4
39	Achernar	19 14 1	57 27.0
40	β Crucis	8 4 57	59 27.4
41	β Centauri	6 49 22	S60 10.2
42	α Centauri	6 13 28	60 39.8
43	α Crucis	8 25 57	62 51.8
44	α Tri. Aust.	4 6 1	68 57.3
45	β Carinae	11 37 27	S69 32.4

$R_☉$ 20h 50m 8s

Planet

♀ Venus — Tr. 9h 8m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	14 51 12	N18 29.0	0 0	0	0.0
2	19	29.2	10	1	0
4	25	29.5	20	1	1
6	32	29.8	30	2	1
8	39	30.1	40	2	1
10	45	30.4	0 50	3	1
12	14 51 52	N18 30.7	1 0	4	0.2
14	51 58	30.9	10	4	2
16	52 5	31.2	20	5	2
18	11	31.5	30	5	2
20	18	31.8	40	6	3
22	24	32.1	1 50	6	3
24	14 52 30	N18 32.3	2 0	7	0.3

♂ Mars — Tr. 2h 54m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	21 5 32	S 7 49.6	0 0	0	0.0
2	5 50	49.6	10	2	0
4	6 7	49.7	20	3	0
6	25	49.7	30	5	0
8	6 43	49.7	40	6	0
10	7 1	49.7	0 50	8	0
12	21 7 18	S 7 49.7	1 0	9	0.0
14	36	49.8	10	11	0
16	7 54	49.8	20	12	0
18	8 12	49.8	30	14	0
20	.30	49.9	40	15	0
22	8 48	49.9	1 50	17	0
24	21 9 6	S 7 49.9	2 0	18	0.0

♃ Jupiter — Tr. 13h 38m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	10 20 7	N10 27.5	0 0	0	0.0
2	23	27.1	10	1	0
4	38	26.7	20	3	1
6	20 54	26.3	30	4	1
8	21 10	26.0	40	5	1
10	26	25.6	0 50	7	2
12	10 21 42	N10 25.2	1 0	8	0.2
14	21 57	24.8	10	9	2
16	22 13	24.4	20	11	3
18	29	24.0	30	12	3
20	22 45	23.7	40	13	3
22	23 1	23.3	1 50	15	4
24	10 23 16	N10 22.9	2 0	16	0.4

♄ Saturn — Tr. 18h 44m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	5 12 42	S17 20.9	0 0	0	0.0
2	13 2	21.0	10	2	0
4	22	21.0	20	3	0
6	13 41	21.0	30	5	0
8	14 1	21.0	40	7	0
10	20	21.1	0 50	8	0
12	5 14 40	S17 21.1	1 0	10	0.0
14	15 0	21.1	10	12	0
16	19	21.2	20	13	0
18	39	21.2	30	15	0
20	15 58	21.2	40	17	0
22	16 18	21.3	1 50	18	0
24	5 16 37	S17 21.3	2 0	20	0.0

☾ Moon — Tr. 10h 2m

U	$E_☾$	d
h	h m s	° ′
0	14 22 31	N20 42.9
	21 17	40.6
1	20 3	38.2
	18 49	35.8
2	17 35	33.4
	16 20	30.9
3	15 6	28.4
	13 52	25.8
4	12 38	23.2
	11 24	20.6
5	10 10	17.9
	8 56	15.2
(H.P. 60′.8, S.D. 16′ 34″)		
6	14 7 42	N20 12.5
	6 28	9.7
7	5 14	6.9
	4 0	4.0
8	2 46	20 1.1
	1 32	19 58.2
9	14 0 18	55.2
	13 59 4	52.2
10	57 50	49.1
	56 36	46.1
11	55 22	42.9
	54 8	39.8
(H.P. 60′.9, S.D. 16′ 36″)		
12	13 52 55	N19 36.6
	51 41	33.4
13	50 27	30.1
	49 13	26.8
14	48 0	23.5
	46 46	20.1
15	45 32	16.7
	44 19	13.2
16	43 5	9.7
	41 52	6.2
17	40 38	19 2.7
	39 25	18 59.1
(H.P. 61′.0, S.D. 16′ 38″)		
18	13 38 11	N18 55.5
	36 58	51.8
19	35 45	48.1
	34 31	44.4
20	33 18	40.6
	32 5	36.8
21	30 52	33.0
	29 39	29.1
22	28 25	25.2
	27 12	21.3
23	25 59	17.3
	24 46	13.3
24	13 23 33	N18 9.3
(H.P. 61′.1, S.D. 16′ 39″)		

Moon P.P.

m	$E_☾$ (s)	d (′)	m	$E_☾$ (s)	d (′)
1	2	0.1	1	2	0.1
2	5	2	2	5	2
3	7	3	3	7	4
4	10	4	4	10	5
5	12	5	5	12	6
6	15	5	6	15	7
7	17	6	7	17	0.8
8	20	7	8	19	1.0
9	22	8	9	22	1
10	25	0.9	10	24	2
11	27	1.0	11	27	3
12	30	1	12	29	4
13	32	2	13	32	6
14	35	3	14	34	7
15	37	4	15	37	8
16	39	4	16	39	1.9
17	42	5	17	41	2.0
18	44	6	18	44	2
19	47	7	19	46	3
20	49	8	20	49	4
21	52	1.9	21	51	5
22	54	2.0	22	54	6
23	57	1	23	56	8
24	59	2	24	58	2.9
25	62	3	25	61	3.0
26	64	3	26	63	1
27	67	4	27	66	2
28	69	5	28	68	4
29	72	6	29	71	5
30	74	2.7	30	73	3.6

Planet

	R.A.	d	Mag.	H.P.	S.D.
	h m	° ′		′	″
♀	5 59	N18 29	−4.2	0.3	17
♂	23 45	S 7 50	−1.9	0.3	10
♃	10 30	N10 27	−1.3	0.0	15
♄	15 37	S17 21	+0.7	0.0	8
☿	9 58	N13 52	−0.5	0.1	3

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

Altitude Correction of Sun $6^{\circ} \sim 90^{\circ}$

Alt. Obs.	0	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Alt. Obs.
	Height of Eye (m) (+)																
° ′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	° ′
6 0	7.5	4.3	3.8	3.4	3.0	2.7	2.3	2.0	1.7	1.4	1.2	0.9	0.7	0.4	0.2	0.0	6 0
20	7.8	4.7	4.2	3.8	3.4	3.1	2.7	2.4	2.1	1.8	1.6	1.3	1.1	0.8	0.6	0.4	20
40	8.2	5.1	4.6	4.2	3.8	3.4	3.1	2.8	2.5	2.2	1.9	1.7	1.4	1.2	1.0	0.8	40
7 0	8.5	5.4	4.9	4.5	4.1	3.8	3.4	3.1	2.8	2.5	2.3	2.0	1.8	1.5	1.3	1.1	7 0
20	8.8	5.7	5.2	4.8	4.4	4.1	3.7	3.4	3.1	2.9	2.6	2.3	2.1	1.8	1.6	1.4	20
40	9.1	6.0	5.5	5.1	4.7	4.3	4.0	3.7	3.4	3.1	2.9	2.6	2.4	2.1	1.9	1.7	40
8 0	9.4	6.3	5.8	5.4	5.0	4.6	4.3	4.0	3.7	3.4	3.1	2.9	2.6	2.4	2.2	2.0	8 0
20	9.6	6.5	6.0	5.6	5.2	4.9	4.5	4.2	3.9	3.7	3.4	3.1	2.9	2.6	2.4	2.2	20
40	9.8	6.7	6.2	5.8	5.4	5.1	4.8	4.4	4.1	3.9	3.6	3.4	3.1	2.9	2.7	2.4	40
9 0	10.0	6.9	6.5	6.0	5.6	5.3	5.0	4.7	4.4	4.1	3.8	3.6	3.3	3.1	2.9	2.6	9 0
20	10.2	7.1	6.7	6.2	5.8	5.5	5.2	4.9	4.6	4.3	4.0	3.8	3.5	3.3	3.1	2.8	20
40	10.4	7.3	6.8	6.4	6.0	5.7	5.4	5.0	4.7	4.5	4.2	4.0	3.7	3.5	3.3	3.0	40
10 0	10.6	7.5	7.0	6.6	6.2	5.9	5.5	5.2	4.9	4.7	4.4	4.1	3.9	3.7	3.4	3.2	10 0
30	10.8	7.7	7.3	6.8	6.5	6.1	5.8	5.5	5.2	4.9	4.6	4.4	4.1	3.9	3.7	3.5	30
11 0	11.1	8.0	7.5	7.1	6.7	6.3	6.0	5.7	5.4	5.1	4.9	4.6	4.4	4.1	3.9	3.7	11 0
30	11.3	8.2	7.7	7.3	6.9	6.5	6.2	5.9	5.6	5.3	5.1	4.8	4.6	4.3	4.1	3.9	30
12 0	11.5	8.4	7.9	7.5	7.1	6.7	6.4	6.1	5.8	5.5	5.3	5.0	4.8	4.5	4.3	4.1	12 0
30	11.6	8.5	8.1	7.6	7.3	6.9	6.6	6.3	6.0	5.7	5.4	5.2	4.9	4.7	4.5	4.3	30
13 0	11.8	8.7	8.2	7.8	7.4	7.1	6.7	6.4	6.1	5.9	5.6	5.4	5.1	4.9	4.7	4.4	13 0
30	11.9	8.8	8.4	8.0	7.6	7.2	6.9	6.6	6.3	6.0	5.8	5.5	5.3	5.0	4.8	4.6	30
14 0	12.1	9.0	8.5	8.1	7.7	7.4	7.0	6.7	6.4	6.2	5.9	5.7	5.4	5.2	4.9	4.7	14 0
30	12.2	9.1	8.7	8.2	7.9	7.5	7.2	6.9	6.6	6.3	6.0	5.8	5.5	5.3	5.1	4.9	30
15 0	12.3	9.3	8.8	8.4	8.0	7.6	7.3	7.0	6.7	6.4	6.2	5.9	5.7	5.4	5.2	5.0	15 0
16 0	12.6	9.5	9.0	8.6	8.2	7.8	7.5	7.2	6.9	6.7	6.4	6.1	5.9	5.7	5.4	5.2	16 0
17 0	12.8	9.7	9.2	8.8	8.4	8.1	7.7	7.4	7.1	6.9	6.6	6.4	6.1	5.9	5.6	5.4	17 0
18 0	12.9	9.9	9.4	9.0	8.6	8.2	7.9	7.6	7.3	7.0	6.8	6.5	6.3	6.1	5.8	5.6	18 0
19 0	13.1	10.0	9.6	9.1	8.7	8.4	8.1	7.8	7.5	7.2	6.9	6.7	6.4	6.2	6.0	5.8	19 0
20 0	13.3	10.2	9.7	9.3	8.9	8.6	8.2	7.9	7.6	7.4	7.1	6.9	6.6	6.4	6.2	5.9	20 0
22 0	13.5	10.4	10.0	9.5	9.1	8.8	8.5	8.2	7.9	7.6	7.3	7.1	6.8	6.6	6.4	6.2	22 0
24 0	13.7	10.6	10.2	9.8	9.4	9.0	8.7	8.4	8.1	7.8	7.6	7.3	7.1	6.8	6.6	6.4	24 0
26 0	13.9	10.8	10.4	9.9	9.6	9.2	8.9	8.6	8.3	8.0	7.8	7.5	7.3	7.0	6.8	6.6	26 0
28 0	14.1	11.0	10.5	10.1	9.7	9.4	9.0	8.7	8.4	8.2	7.9	7.7	7.4	7.2	7.0	6.7	28 0
30 0	14.2	11.1	10.7	10.2	9.9	9.5	9.2	8.9	8.6	8.3	8.1	7.8	7.6	7.3	7.1	6.9	30 0
32 0	14.3	11.2	10.8	10.4	10.0	9.6	9.3	9.0	8.7	8.4	8.2	7.9	7.7	7.4	7.2	7.0	32 0
34 0	14.4	11.4	10.9	10.5	10.1	9.7	9.4	9.1	8.8	6.5	8.3	8.0	7.8	7.6	7.3	7.1	34 0
36 0	14.5	11.5	11.0	10.6	10.2	9.8	9.5	9.2	8.9	8.6	8.4	8.1	7.9	7.7	7.4	7.2	36 0
38 0	14.6	11.5	11.1	10.7	10.3	9.9	9.6	9.3	9.0	8.7	8.5	8.2	8.0	7.7	7.5	7.3	38 0
40 0	14.7	11.6	11.2	10.7	10.4	10.0	9.7	9.4	9.1	8.8	8.6	8.3	8.1	7.8	7.6	7.4	40 0
45 0	14.9	11.8	11.3	10.9	10.5	10.2	9.9	9.6	9.3	9.0	8.7	8.5	8.2	8.0	7.8	7.6	45 0
50 0	15.0	12.0	11.5	11.1	10.7	10.3	10.0	9.7	9.4	9.1	8.9	8.6	8.4	8.2	7.9	7.7	50 0
55 0	15.2	12.1	11.6	11.2	10.8	10.5	10.1	9.8	9.5	9.3	9.0	8.8	8.5	8.3	8.1	7.8	55 0
60 0	15.3	12.2	11.7	11.3	10.9	10.6	10.2	9.9	9.6	9.4	9.1	8.9	8.6	8.4	8.2	7.9	60 0
65 0	15.4	12.3	11.8	11.4	11.0	10.7	10.3	10.0	9.7	9.5	9.2	9.0	8.7	8.5	8.3	8.0	65 0
70 0	15.4	12.4	11.9	11.5	11.1	10.7	10.4	10.1	9.8	9.6	9.3	9.0	8.8	8.6	8.3	8.1	70 0
75 0	15.5	12.4	12.0	11.6	11.2	10.8	10.5	10.2	9.9	9.6	9.4	9.1	8.9	8.6	8.4	8.2	75 0
80 0	15.6	12.5	12.1	11.6	11.3	10.9	10.6	10.3	10.0	9.7	9.5	9.2	9.0	8.7	8.5	8.3	80 0
85 0	15.7	12.6	12.1	11.7	11.3	11.0	10.7	10.3	10.1	9.8	9.5	9.3	9.0	8.8	8.6	8.4	85 0
90 0	15.8	12.7	12.2	11.8	11.4	11.0	10.7	10.4	10.1	9.9	9.6	9.3	9.1	8.9	8.6	8.4	90 0
Dip	0.0	3.1	3.6	4.0	4.4	4.7	5.0	5.3	5.6	5.9	6.2	6.4	6.6	6.9	7.1	7.3	
H.P. dist.	0.0	3.6	4.1	4.6	5.1	5.5	5.9	6.2	6.6	6.9	7.2	7.5	7.8	8.0	8.3	8.5	

Corr. for S. D.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Lower ☉	+ 0′.5	+ 0′.5	+ 0′.4	+ 0′.2	+ 0′.1	0′.0	0′.0	+ 0′.1	+ 0′.2	+ 0′.3	+ 0′.5	+ 0′.5
Upper ☉	−32′.0	−32′.0	−31′.9	−31′.7	−31′.6	−31′.5	−31′.5	−31′.6	−31′.7	−31′.8	−32′.0	−32′.0

Diff. of temp. between Air and sea water	(°C)	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°
	Corr.	0′.0	0′.2	0′.4	0′.6	0′.8	1′.0	1′.2	1′.4	1′.6	1′.8	2′.0	2′.2	2′.4	2′.6	2′.8

when Air temp. > Sea water temp. ⊕
Air temp. < Sea water tem. ⊖

※ Air temp. → at height of eye.

Fig. 30

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY JAPAN.

Method of inverse operation for meridian altitude

Differentiation of the formula $Zm = \ell \tilde{+} d$ is

$$\Delta Zm = \Delta\ell \tilde{+} \Delta d$$

and declination (d) is constant for very short time,

then $|\Delta Zm| = |\Delta\ell|$ because of $\Delta d = 0$.

The formula $|\Delta Zm| = |\Delta\ell|$ shows that if two navigators who are on the same meridian and different latitudes observe meridian zenith distance (Zm) at the same time, the difference $|\Delta Zm|$ between two navigators is equal to the difference of latitude $|\Delta\ell|$.

So before observing meridian altitude, if you set up D.R. latitude (ℓD) and declination (d) of the celestial body when it transits the upper branch, you can have the following formula,

$(Am)_c = 90^o - (\ell D \tilde{+} d)$

$(Am)_c$ = Calculated (assumed) meridian altitude

ℓD = latitude by dead reckoning

By above mentioned formula, you compute Calculated meridian altitude {Cal. meri. alt. $\Longrightarrow (Am)_c$} beforehand. Next procedure is that you observe Meridian True Altitude {Meri. True Alt. $\Longrightarrow$ (Am) t} by sextant, so you can know

$$\Delta Am = (Am)_c - (Am)t$$

According to $|\Delta Am = |\Delta\ell|$, you can calculate the latitude as shown below,

$$\underline{\ell = \ell D \pm |\Delta\ell|}$$

Note

Name of $\Delta\ell$, When $(Am)t > (Am)_c$ same name as observed direction.

$(Am)t < (Am)_c$ contrary name to observed direction.

Actual procedure of calculation on board ship is that inverse name of altitude corrections and index error of sextant should add to $(Am)_c$ and subtract it from meridian sextant altitude {Meri. Sex. Alt. $\Longrightarrow$ (Am)s}, then you can have $|\Delta Am|$.

Note

In case of upper branch transit
name of $|\Delta \ell|$; when (Am)s > (Am)c', same name as observed direction.
(Am)s < (Am)c', contrary name to observed direction.

※ (Am)c' = (Am)c + (inverse altitude correction)

when you observe lower branch transit, the formula

$$Am = \ell - P$$

can give latitude, and

$$Am = \ell - P$$
$$\downarrow$$
$$Am = \Delta\ell - P$$

when polar distance (P) is constant,

$$|\Delta Am| = |\Delta \ell|$$

By $|\Delta Am| = |\Delta \ell|$, you also calculate latitude.

Note

In the case of lower branch transit
name of $|\Delta \ell|$; when (Am)s > (Am)c', same name as declination.
(Am)s < (Am)c', contrary to declination.

Example 9

Calculate the time of the sun's upper branch transit by using ship's chronometer (Universal time $3^h\ 30^m$) on 22 October 1956 in D.R.P. 08°20'N, 56°40'W. and at local apparent noon, a navigator observed apparent maximum altitude of the sun's lower limb as 70°16'.6. What is latitude? Calculate by the method of inverse operation for meridian altitude.

where: Index error ⊖ 0'.5, Height of eye 14 metres,
Air temperature 28°C, Sea water temperature 25°C.

Solution (see Fig. 31)

L.A.T.	22 Oct. 1956	$12^h - 00^m - 00^s$	
L. in T.		$3 - 46 - 40$	⊕
G.A.T.	22 Oct. 1956	$15^h - 46^m - 40^s$	
E.T.		⊕ 15 - 32	⊖
U.	22 Oct. 1956	$15^h - 31^m - 08^s$ → d = 11°- 11'.8 S	
L. in T.		3 - 30 - 00	⊖
Ship's T.	22 Oct. 1956	$12^h - 01^m - 08^s$	
ℓD		8° - 20'.0 N	
d		11 - 11.8 S	⊕
(Zm)c		19 - 31.8	
		90 - 00.0	⊖
(Am)c		70° - 28'.2	
Corr. 1		8.8	⊖
		70° - 19'.4	
Corr. 2		0.3	⊖
		70° - 19'.1	
Corr. t		0.6	⊖
		70° - 18'.5	
I.E.		0.5	⊕
(Am)c'		70° - 19'.0	
(Am)s		70° - 16.6	⊖
ΔAm = Δℓ		2.4 N.	
ℓD		8° - 20.0	⊕
ℓ		8° - 22'.4 N	

Ans. Transit time $12^h - 01^m - 08^s$
lat. = 8° - 22'.4 N

22 October 1956 Age $17^d.8$

☉ Sun

U	$E_☉$	d	P.P.	
h	h m s	° ′	h m	′
0	12 15 26	S 10 58.0	0 0	0.0
2	26	10 59.8	10	2
4	27	11 1.5	20	3
6	28	3.3	30	5
8	29	5.1	40	6
10	29	6.8	0 50	8
12	12 15 30	S 11 8.6	1 0	0.9
14	31	10.4	10	1.1
16	32	12.1	20	2
18	32	13.9	30	4
20	33	15.7	40	5
22	34	17.4	1 50	7
24	12 15 35	S 11 19.2	2 0	1.8

S.D. 16′ 6″

Star ($U = 0^h$)

No. Star	E_*	d
	h m s	° ′
1 *Polaris*	0 6 26	N 89 3.8
2 *Kochab*	11 10 53	74 20.0
3 *Dubhe*	15 0 32	61 58.8
4 *β Cassiop.*	1 54 41	58 55.0
5 *Merak*	15 2 22	56 36.6
6 *Alioth*	13 9 29	N 56 11.6
7 *Schedir*	1 23 30	56 18.3
8 *Mizar*	12 39 26	55 9.0
9 *α Persei*	22 40 19	49 42.6
10 *Benetnasch*	12 15 47	49 31.7
11 *Capella*	20 48 4	N 45 57.2
12 *Deneb*	5 21 37	45 7.9
13 *Vega*	7 26 7	38 44.9
14 *Castor*	18 29 44	31 58.9
15 *Alpheratz*	1 55 24	28 51.4
16 *Pollux*	18 18 54	N 28 7.8
17 *α Cor. Bor.*	10 28 45	26 51.7
18 *Arcturus*	11 47 55	19 24.5
19 *Aldebaran*	21 28 7	16 25.5
20 *Markab*	2 58 57	14 58.6
21 *Denebola*	14 14 45	N 14 48.8
22 *α Ophiuchi*	8 28 40	12 35.6
23 *Regulus*	15 55 31	12 10.7
24 *Altair*	6 12 54	8 45.5
25 *Betelgeuse*	20 8 44	7 24.1
26 *Bellatrix*	20 38 45	N 6 18.8
27 *Procyon*	18 24 32	N 5 20.2
28 *Rigel*	20 49 6	S 8 14.9
29 *α Hydrae*	16 36 7	8 28.2
30 *Spica*	12 39 41	10 56.1
31 *Sirius*	19 18 20	S 16 39.2
32 *β Ceti*	1 20 8	18 13.2
33 *Antares*	9 34 50	26 20.2
34 *σ Sagittarii*	7 9 0	26 21.1
35 *Fomalhaut*	3 6 18	29 51.0
36 *λ Scorpii*	8 30 55	S 37 4.5
37 *Canopus*	19 33 35	52 40.1
38 *α Pavonis*	5 39 20	56 52.6
39 *Achernar*	0 25 27	57 27.2
40 *β Crucis*	13 16 26	59 27.1
41 *β Centauri*	12 0 51	S 60 9.9
42 *α Centauri*	11 24 58	60 39.6
43 *α Crucis*	13 37 26	62 51.5
44 *α Tri. Aust.*	9 17 32	68 57.2
45 *β Carinae*	16 46 52	S 69 32.1

R_0 2h 1m 36s

Planet

♀ Venus (Tr. 9h 17m)

U	E_P	d	P.P.		
h	h m s	° ′	h m	s	′
0	14 42 44	N 5 36.3	0 0	0	0.0
2	42	34.2	10	0	2
4	40	32.1	20	0	4
6	37	30.1	30	1	5
8	35	28.0	40	1	7
10	32	25.9	0 50	1	0.9
12	14 42 30	N 5 23.8	1 0	1	1.1
14	27	21.7	10	1	2
16	25	19.6	20	1	4
18	23	17.5	30	2	6
20	20	15.5	40	2	8
22	18	13.4	1 50	2	1.9
24	14 42 15	N 5 11.3	2 0	2	2.1

♂ Mars (Tr. 21h 1m)

U	E_P	d	P.P.		
h	h m s	° ′	h m	s	′
0	2 55 52	S 9 0.1	0 0	0	0.0
2	56 9	8 59.5	10	1	1
4	27	58.8	20	3	1
6	56 44	58.2	30	4	2
8	57 2	57.6	40	6	2
10	19	56.9	0 50	7	3
12	2 57 37	S 8 56.3	1 0	9	0.3
14	57 54	55.7	10	10	4
16	58 12	55.0	20	11	4
18	29	54.4	30	13	5
20	58 46	53.7	40	14	5
22	59 4	53.1	1 50	16	6
24	2 59 21	S 8 52.5	2 0	17	0.6

♃ Jupiter (Tr. 9h 29m)

U	E_P	d	P.P.		
h	h m s	° ′	h m	s	′
0	14 29 23	N 4 8.3	0 0	0	0.0
2	39	7.9	10	1	0
4	29 55	7.6	20	3	1
6	30 11	7.2	30	4	1
8	28	6.8	40	5	1
10	30 44	6.4	0 50	7	2
12	14 31 0	N 4 6.1	1 0	8	0.2
14	16	5.7	10	9	2
16	32	5.3	20	11	3
18	31 48	5.0	30	12	3
20	32 4	4.6	40	13	3
22	21	4.2	1 50	15	4
24	14 32 37	N 4 3.8	2 0	16	0.4

♄ Saturn (Tr. 13h 54m)

U	E_P	d	P.P.		
h	h m s	° ′	h m	s	′
0	10 4 0	S 18 41.7	0 0	0	0.0
2	17	41.8	10	2	0
4	35	42.0	20	3	0
6	4 52	42.1	30	5	0
8	5 10	42.2	40	6	0
10	27	42.3	0 50	8	0
12	10 5 45	S 18 42.4	1 0	9	0.1
14	6 2	42.6	10	11	1
16	20	42.7	20	12	1
18	37	42.8	30	14	1
20	6 55	42.9	40	15	1
22	7 12	43.0	1 50	17	1
24	10 7 30	S 18 43.1	2 0	18	0.1

☾ Moon (Tr. 1h 40m)

U	$E_☾$	d
h	h m s	° ′
0	22 23 28	N 19 40.2
	22 21	42.6
1	21 14	45.0
	20 7	47.3
2	18 59	49.6
	17 52	51.9
3	16 44	54.2
	15 37	56.4
4	14 29	19 58.6
	13 21	20 0.8
5	12 13	3.0
	11 6	5.1
(H.P. 58′.2, S.D. 15′ 52″)		
6	22 9 58	N 20 7.2
	8 50	9.2
7	7 42	11.2
	6 34	13.2
8	5 26	15.2
	4 18	17.1
9	3 10	19.0
	2 2	20.9
10	22 0 53	22.7
	21 59 45	24.5
11	58 37	26.3
	57 28	28.0
(H.P. 58′.3, S.D. 15′ 54″)		
12	21 56 20	N 20 29.7
	55 11	31.4
13	54 3	33.0
	52 54	34.7
14	51 46	36.2
	50 37	37.8
15	49 29	39.3
	48 20	40.8
16	47 11	42.3
	46 2	43.7
17	44 53	45.1
	43 45	46.4
(H.P. 58′.4, S.D. 15′ 55″)		
18	21 42 36	N 20 47.7
	41 27	49.0
19	40 18	50.3
	39 9	51.5
20	38 0	52.7
	36 51	53.9
21	35 41	55.0
	34 32	56.1
22	33 23	57.1
	32 14	58.2
23	31 5	20 59.2
	29 55	21 0.1
24	21 28 46	N 21 1.0
(H.P. 58′.5, S.D. 15′ 57″)		

P.P.

m	$E_☾$ (s)	d (′)
1	2	0.1
2	5	1
3	7	2
4	9	3
5	11	4
6	14	4
7	16	5
8	18	6
9	20	7
10	23	8
11	25	8
12	27	0.9
13	29	1.0
14	32	1
15	34	1
16	36	2
17	39	3
18	41	3
19	43	4
20	45	5
21	48	5
22	50	6
23	52	7
24	54	8
25	57	8
26	59	1.9
27	61	2.0
28	63	0
29	66	1
30	68	2.1

m	$E_☾$ (s)	d (′)
1	2	0.0
2	5	1
3	7	1
4	9	2
5	12	2
6	14	3
7	16	3
8	18	3
9	21	4
10	23	4
11	25	5
12	28	5
13	30	6
14	32	6
15	35	7
16	37	7
17	39	7
18	41	8
19	44	8
20	46	9
21	49	0.9
22	51	1.0
23	53	0
24	55	0
25	58	1
26	60	1
27	62	2
28	64	2
29	67	3
30	69	1.3

Planet

	R.A.	d	Mag.	H.P.	S.D.
	h m	° ′		′	″
♀	11 19	N 5 36	−3.6	0.1	8
♂	23 6	S 9 0	−1.6	0.3	9
♃	11 32	N 4 8	−1.3	0.0	15
♄	15 58	S 18 42	+0.8	0.0	7
☿	12 56	S 3 54	−0.9	0.1	3

Fig. 31

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

Solution (Page 85)

Refer to Figs. 22, 23 and 24

Ship's T. 6 July 1956	$06^h\ 50^m\ 00^s$	
L. in T. (135° 00'E)	09	
G.D. 6 July 1956	$21^h\ 50^m\ 00^s$	←
Chro. T.	$22^h\ 21^m\ 50^s$	(← 10h 21m 50s p.m.)
C.E.	29 26 ⊖	
U. 5 July 1956	$21^h\ 52^m\ 24^s$	
Ro (for 5 July 1956) →	18 51 51	← from the nautical almanac
P.P. E*	3 35 ⊕	← from Figure 27. (page 87)
	40 47 50	
	24 ⊖	
G. Sid. T.	$16^h\ 47^m\ 50^s$	
L. in T.	09 ⊕	
	25 47 50	
	24 ⊖	
L. Sid. T.	$01^h\ 47^m\ 50^s$	

Data

Z - 57°E A = 50°2 ℓ = 34°28'N

		K		D		H		
Z	57°E	K_1	264			H_1	3187	
A	50°2	K_2	3076 ⊕	D_1	2884			
ℓ	⊕ 34°28'N	K_3	3340					
K	⊕ 25°			D_2	43	H_2	2626	
ℓ+K	⊕ 59°28'N			D_3	2933 ⊕	H_3	288 ⊕	
				D_4	5860	H_4	6101	→ hE = 3h28m00s
								L.Sid.T = 1 47 50 ⊕
				d	46°N			→ R.A. = 5h15m50s

By the table positions of navigational stars (page 76) or the star map for the Northern hemisphere the name of the star should be Capella.

Ans. Capella

Solution (Page 92)

L.A.T.	4 Aug. 1956	$12^h\ 00^m\ 00^s$	
L. in T. (7°15'W)		0 29 00 ⊕	(see page 80)
G.A.T.	4 Aug. 1956	$12^h\ 29^m\ 00^s$	
E.T.		5 59 ⊖ →	{ E.T.= $E_{\odot}$ + 12^h - (24h) see page , Ref. and nautical almanac }
		d = 17° - 10′.6N	(From nautical almanac)

Note

How to calculate d.
In the nautical almanac for 4 Aug. 1956
d for Universal time 12h is N 17° - 10.9,
P.P. of d for 34m 59s = is 0.3 ⊖
17° - 10′.6 N
===========

Sex. Alt. ☉	66° - 05′.5	
I.E	2.4 ⊕	
Abs. Alt. ☉	66° - 07′.9	
Corr. 1	9.2 ⊕	(see page 94)
	66° - 17′.1	
Corr. 2	0.1 ⊕	(see page 94)
	66° - 17′.2	
Corr. t.	0.2 ⊕	(see page 94)
True Alt. ⊖	66° - 17′.4	
	90° ⊖	
	23° - 42′.6 S	(Direction of zenith from the sun is south, see page 90)
d	17° - 10′.6 N ⊖	(when d < Zm, ℓ = Zm ⊖ d, see page 90)
ℓ	6° - 32′.0 S	(when d is contrary name to Zm, the name of latitude should be the same as the name of the larger value. See page 90.
Ans. Lat = 06° - 32′.0 S		

Determination of latitude by Polaris

The latitude of a location is equal to the altitude of the elevated pole as shown in figure 32.

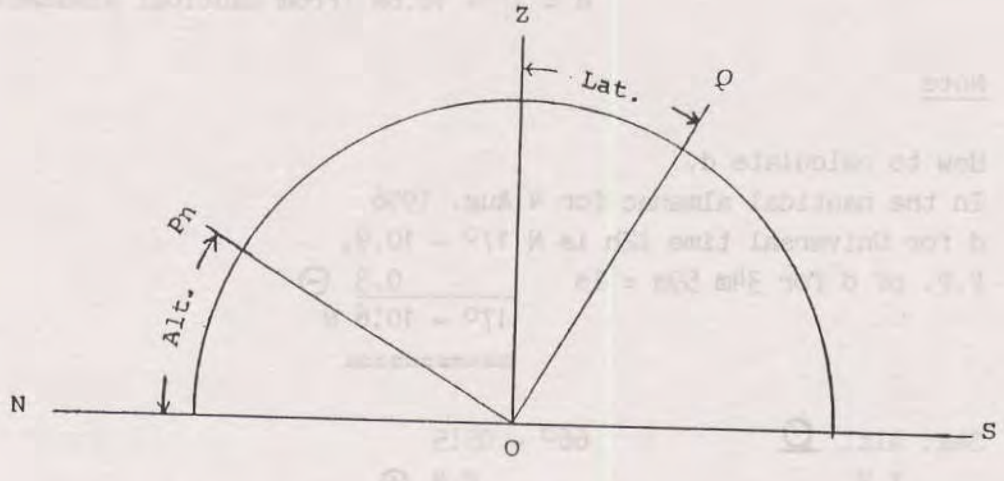


Fig. 32

Both the latitude of the observer (= QOZ) and the altitude of the pole (= NOPn) equals 90° minus PnOZ. If a star is located exactly at each celestial pole, the corrected altitude of the star should be equal to the observer's latitude.

Actually a star is not located at the north or south celestial poles, but Polaris is less than one degree from the north celestial pole. Polaris alternately transits the upper and lower branches of each celestial meridian in completing its diurnal circle. Twice during every 24 hours, as it moves in its diurnal circle, Polaris is at the same altitude as the celestial pole, and at that moment no correction would be required to its observed altitude to obtain latitude.

At all other times, a correction must be applied. The value for any instant may be obtained from <u>Tables for Finding Latitude by Observing Polaris</u> in the nautical almanac.

The corrections are tabulated in three tables, the first table is for "h" correction, the second table is for "altitude h" correction and the third table is for "Date h" correction.

So,

Latitude = (Obs. true Alt.) + (table 1 correction) + (table 2 correction) + (table 3 correction)

h = U + E* ± Longitude in Time

where; East longitude → ⊕
West longitude → ⊖

Example

At $04^h\ 20^m$ on 27 April 1956, a navigator observed the altitude of Polaris as 32° 19.'8 in D.R.P. 32° 32.'0 N, 133° 46'E. What was his latitude?

Where : Chronometer time when he observed Polaris was $7^h\ 24^m\ 18^s$, chronometer error - $1^m\ 36^s$, index error + 2.7, height of eye 15 metres, air temperature 13°C, sea water temperature 22°C

Solution

Ship's time	27 April 1956	$04^h\ 20^m\ 00^s$ ⟷	$28^h\ 20^m\ 00^s$
L in T. (133° 46'E)		8 55 04 ⊖	(see fig. 20)
G.D.	26 April 1956		
	(Greenwich Day)	$19^h\ 24^m\ 56^s$	
Chro. T.	26 April 1956	$19^h\ 24^m\ 18^s$	
C.E.		1 36 ⊖	
U.	26 April 1956	$19^h\ 22^m\ 42^s$	

E* (U = 0h)	12 23 42	(see Fig. 35)
P.P. (E*)*	3 11 ⊕	(see Fig. 27)
	31 49 35	
	24 ⊖	
h_G	$07^h 49^m 35^s$	
L. in T. (133°46'E)	08 55 04	
h	$16^h 44^m 39^s$	
Sex. Alt.*	32°- 19'.8	
I.E.	2.7 ⊕	
Obs. Alt.	32°- 22'.5	
Corr. 1	8.4 ⊖	(see Fig. 32)
	32°- 14'.1	
Corr. 2	1.8 ⊖	(see Fig. 32. 13°C-22°C = -9°C)
True Alt. *	32°- 12'.3	
Corr. I.	17.3 ⊕	(see Fig. 38 Table 1)
	32°- 29'.6	
Corr. II.	0.2 ⊕	(see Fig. 39 Table 2)
	32°- 29'.8	
Corr. III.	1.0 ⊕	(see Fig. 39 Table 3)
ℓ	32°- 30.8 N	

Ans. Lat. = 32° - 30'.8 N

P* Altitude correction of star & planet

First Correction

Obs. alt.	0	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Obs. Alt.
	Height of eye (m) — Subtract from Obs.alt. (−)																
° ′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	° ′
3 0	14.5	17.7	18.2	18.6	19.0	19.4	19.7	20.1	20.4	20.7	20.9	21.2	21.5	21.7	21.9	22.2	3 0
20	13.5	16.7	17.2	17.6	18.0	18.4	18.7	19.0	19.3	19.6	19.9	20.2	20.4	20.7	20.9	21.1	20
40	12.6	15.8	16.3	16.7	17.1	17.5	17.8	18.1	18.4	18.7	19.0	19.3	19.5	19.8	20.0	20.2	40
4 0	11.8	15.0	15.5	15.9	16.3	16.7	17.0	17.3	17.6	17.9	18.2	18.4	18.7	18.9	19.2	19.4	4 0
20	11.1	14.3	14.8	15.2	15.6	16.0	16.3	16.6	16.9	17.2	17.5	17.7	18.0	18.2	18.4	18.7	20
40	10.5	13.6	14.1	14.6	14.9	15.3	15.6	16.0	16.3	16.5	16.8	17.1	17.3	17.6	17.8	18.0	40
5 0	9.9	13.1	13.6	14.0	14.4	14.7	15.1	15.4	15.7	16.0	16.2	16.5	16.8	17.0	17.2	17.4	5 0
20	9.4	12.5	13.0	13.5	13.8	14.2	14.5	14.9	15.1	15.4	15.7	15.9	16.2	16.4	16.7	16.9	20
40	8.9	12.1	12.6	13.0	13.4	13.8	14.1	14.4	14.7	15.0	15.2	15.5	15.7	16.0	16.2	16.4	40
6 0	8.5	11.6	12.1	12.6	12.9	13.3	13.6	13.9	14.2	14.5	14.8	15.0	15.3	15.5	15.8	16.0	6 0
20	8.1	11.3	11.7	12.2	12.5	12.9	13.2	13.5	13.8	14.1	14.4	14.6	14.9	15.1	15.3	15.6	20
40	7.8	10.9	11.4	11.8	12.2	12.5	12.9	13.2	13.5	13.7	14.0	14.3	14.5	14.8	15.0	15.2	40
7 0	7.4	10.6	11.0	11.5	11.8	12.2	12.5	12.8	13.1	13.4	13.7	13.9	14.2	14.4	14.6	14.9	7 0
20	7.1	10.3	10.7	11.2	11.5	11.9	12.2	12.5	12.8	13.1	13.4	13.6	13.9	14.1	14.3	14.5	20
40	6.8	10.0	10.4	10.9	11.3	11.6	11.9	12.2	12.5	12.8	13.1	13.3	13.6	13.8	14.0	14.3	40
8 0	6.6	9.7	10.2	10.6	11.0	11.3	11.7	12.0	12.3	12.5	12.8	13.1	13.3	13.5	13.8	14.0	8 0
20	6.3	9.5	9.9	10.4	10.7	11.1	11.4	11.7	12.0	12.3	12.6	12.8	13.1	13.3	13.5	13.7	20
40	6.1	9.2	9.7	10.1	10.5	10.9	11.2	11.5	11.8	12.1	12.3	12.6	12.8	13.1	13.3	13.5	40
9 0	5.9	9.0	9.5	9.9	10.3	10.6	11.0	11.3	11.6	11.8	12.1	12.4	12.6	12.8	13.1	13.3	9 0
20	5.7	8.8	9.3	9.7	10.1	10.5	10.8	11.1	11.4	11.7	11.9	12.2	12.4	12.7	12.9	13.1	20
40	5.5	8.6	9.1	9.5	9.9	10.3	10.6	10.9	11.2	11.5	11.7	12.0	12.2	12.5	12.7	12.9	40
10 0	5.3	8.4	8.9	9.3	9.7	10.1	10.4	10.7	11.0	11.3	11.6	11.8	12.0	12.3	12.5	12.7	10 0
30	5.1	8.1	8.6	9.0	9.4	9.8	10.1	10.4	10.7	11.0	11.2	11.5	11.7	11.9	12.2	12.4	30
11 0	4.8	7.9	8.4	8.8	9.2	9.5	9.9	10.2	10.5	10.7	11.0	11.2	11.5	11.7	11.9	12.2	11 0
30	4.6	7.7	8.2	8.6	9.0	9.3	9.7	10.0	10.3	10.5	10.8	11.0	11.3	11.5	11.7	12.0	30
12 0	4.4	7.5	8.0	8.4	8.8	9.1	9.5	9.8	10.1	10.3	10.6	10.8	11.1	11.3	11.5	11.8	12 0
30	4.3	7.4	7.8	8.2	8.6	9.0	9.3	9.6	9.9	10.2	10.4	10.7	10.9	11.2	11.4	11.6	30
13 0	4.1	7.2	7.7	8.1	8.5	8.8	9.1	9.4	9.7	10.0	10.3	10.5	10.8	11.0	11.2	11.4	13 0
30	4.0	7.0	7.5	7.9	8.3	8.7	9.0	9.3	9.6	9.8	10.1	10.4	10.6	10.8	11.1	11.3	30
14 0	3.8	6.9	7.4	7.8	8.2	8.5	8.8	9.1	9.4	9.7	10.0	10.2	10.5	10.7	10.9	11.1	14 0
30	3.7	6.8	7.2	7.7	8.0	8.4	8.7	9.0	9.3	9.6	9.8	10.1	10.3	10.6	10.8	11.0	30
15 0	3.6	6.6	7.1	7.5	7.9	8.3	8.6	8.9	9.2	9.4	9.7	10.0	10.2	10.4	10.7	10.9	16 0
16 0	3.3	6.4	6.9	7.3	7.7	8.0	8.4	8.7	9.0	9.2	9.5	9.7	10.0	10.2	10.4	10.7	16 0
17 0	3.1	6.2	6.7	7.1	7.5	7.8	8.2	8.5	8.8	9.0	9.3	9.5	9.8	10.0	10.2	10.5	17 0
18 0	3.0	6.0	6.5	6.9	7.3	7.7	8.0	8.3	8.6	8.8	9.1	9.4	9.6	9.8	10.1	10.3	18 0
19 0	2.8	5.9	6.3	6.8	7.1	7.5	7.8	8.1	8.4	8.7	8.9	9.2	9.4	9.7	9.9	10.1	19 0
20 0	2.6	5.7	6.2	6.6	7.0	7.3	7.7	8.0	8.3	8.5	8.8	9.0	9.3	9.5	9.7	10.0	20 0
22 0	2.4	5.5	5.9	6.4	6.7	7.1	7.4	7.7	8.0	8.3	8.5	8.8	9.0	9.3	9.5	9.7	22 0
24 0	2.2	5.2	5.7	6.1	6.5	6.9	7.2	7.5	7.8	8.1	8.3	8.6	8.8	9.0	9.3	9.5	24 0
26 0	2.0	5.1	5.5	5.9	6.3	6.7	7.0	7.3	7.6	7.9	8.1	8.4	8.6	8.9	9.1	9.3	26 0
28 0	1.8	4.9	5.4	5.8	6.2	6.5	6.8	7.1	7.4	7.7	8.0	8.2	8.5	8.7	8.9	9.1	28 0
30 0	1.7	4.8	5.2	5.6	6.0	6.4	6.7	7.0	7.3	7.6	7.8	8.1	8.3	8.6	8.8	9.0	30 0
32 0	1.5	4.6	5.1	5.5	5.9	6.2	6.6	6.9	7.2	7.4	7.7	7.9	8.2	8.4	8.6	8.9	32 0
34 0	1.4	4.5	5.0	5.4	5.8	6.1	6.5	6.8	7.1	7.3	7.6	7.8	8.1	8.3	8.5	8.8	34 0
36 0	1.3	4.4	4.9	5.3	5.7	6.0	6.4	6.7	7.0	7.2	7.5	7.7	8.0	8.2	8.4	8.7	36 0
38 0	1.2	4.3	4.8	5.2	5.6	5.9	6.3	6.6	6.9	7.1	7.4	7.6	7.9	8.1	8.3	8.6	38 0
40 0	1.2	4.2	4.7	5.1	5.5	5.9	6.2	6.5	6.8	7.0	7.3	7.6	7.8	8.0	8.3	8.5	40 0
45 0	1.0	4.1	4.5	4.9	5.3	5.7	6.0	6.3	6.6	6.9	7.1	7.4	7.6	7.9	8.1	8.3	45 0
50 0	0.8	3.9	4.4	4.8	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.2	7.5	7.7	7.9	8.1	50 0
55 0	0.7	3.8	4.2	4.7	5.0	5.4	5.7	6.0	6.3	6.6	6.8	7.1	7.3	7.6	7.8	8.0	55 0
60 0	0.6	3.6	4.1	4.5	4.9	5.3	5.6	5.9	6.2	6.5	6.7	7.0	7.2	7.4	7.7	7.9	60 0
65 0	0.5	3.5	4.0	4.4	4.8	5.2	5.5	5.8	6.1	6.3	6.6	6.9	7.1	7.3	7.6	7.8	65 0
70 0	0.4	3.4	3.9	4.3	4.7	5.1	5.4	5.7	6.0	6.2	6.5	6.8	7.0	7.2	7.5	7.7	70 0
75 0	0.3	3.3	3.8	4.2	4.6	5.0	5.3	5.6	5.9	6.2	6.4	6.7	6.9	7.1	7.4	7.6	75 0
80 0	0.2	3.3	3.7	4.1	4.5	4.9	5.2	5.5	5.8	6.1	6.3	6.6	6.8	7.1	7.3	7.5	80 0
85 0	0.1	3.2	3.6	4.1	4.4	4.8	5.1	5.4	5.7	6.0	6.2	6.5	6.7	7.0	7.2	7.4	85 0
90 0	0.0	3.1	3.6	4.0	4.4	4.7	5.0	5.3	5.6	5.9	6.2	6.4	6.7	6.9	7.1	7.3	90 0

Planet only — 2nd Corr. — add to Obs.alt.

Obs. Alt.	Subtract from 0′.1	0′.2	0′.3	0′.4	0′.5	0′.6	Obs. alt.
°	′	′	′	′	′	′	°
10	0.1	0.2	0.3	0.4	0.5	0.6	10
30	0.1	0.2	0.3	0.3	0.4	0.5	30
50	0.1	0.1	0.2	0.2	0.3	0.4	50
70	0.0	0.1	0.1	0.1	0.2	0.2	70
90	0.0	0.0	0.0	0.0	0.0	0.0	90

Diff.of temp.(°C)	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°
Correction	0′.0	0′.2	0′.4	0′.6	0′.8	1′.0	1′.2	1′.4	1′.6	1′.8	2′.0	2′.2	2′.4	2′.6	2′.8

Note: When: air temp.>sea water temp. ⊕ / air temp.<sea water temp. ⊖ — temp.at height of eye

Fig. 33

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

P＊ Altitude correction of star & planet

First Correction — Height of eye (m) — Subtract from Obs.alt. (−)

Obs. Alt. (° ′)	17	18	19	20	21	22	23	24	25	26	27	28	29	30	32	34	36	Obs. Alt.
3 0	22.2	22.4	22.6	22.8	23.0	23.2	23.4	23.6	23.8	24.0	24.2	24.4	24.5	24.7	25.1	25.4	25.7	3 0
20	21.1	21.4	21.6	21.8	22.0	22.2	22.4	22.6	22.8	23.0	23.1	23.3	23.5	23.7	24.0	24.3	24.6	20
40	20.2	20.4	20.7	20.9	21.1	21.3	21.5	21.6	21.8	22.0	22.2	22.4	22.5	22.7	23.1	23.4	23.7	40
4 0	19.4	19.6	19.8	20.0	20.2	20.4	20.6	20.8	21.0	21.2	21.4	21.6	21.7	21.9	22.2	22.5	22.9	4 0
20	18.7	18.9	19.1	19.3	19.5	10.7	19.9	20.1	20.3	20.5	20.6	20.8	21.0	21.2	21.5	21.8	22.1	20
40	18.0	18.2	18.4	18.6	18.9	19.0	19.2	19.4	19.6	19.8	20.0	20.2	20.3	20.5	20.8	21.1	21.5	40
5 0	17.4	17.7	17.9	18.1	18.3	18.5	18.7	18.9	19.0	19.2	19.4	19.6	19.7	19.9	20.2	20.6	20.9	5 0
20	16.9	17.1	17.3	17.5	17.7	17.9	18.1	18.3	18.5	18.7	18.8	19.0	19.2	19.4	19.7	20.0	20.3	20
40	16.4	16.6	16.9	17.1	17.3	17.5	17.7	17.8	18.0	18.2	18.4	18.5	18.7	18.9	19.2	19.5	19.8	40
6 0	16.0	16.2	16.4	16.6	16.8	17.0	17.2	17.4	17.6	17.8	17.9	18.1	18.3	18.4	18.8	19.1	19.4	6 0
20	15.6	15.8	16.0	16.2	16.4	16.6	16.8	17.0	17.2	17.3	17.5	17.7	17.9	18.0	18.4	18.7	19.0	20
40	15.2	15.4	15.6	15.8	16.0	16.2	16.4	16.6	16.8	17.0	17.2	17.3	17.5	17.7	18.0	18.3	18.6	40
7 0	14.9	15.1	15.3	15.5	15.7	15.9	16.1	16.3	16.5	16.6	16.8	17.0	17.1	17.3	17.6	18.0	18.3	7 0
20	14.5	14.8	15.0	15.2	15.4	15.6	15.8	16.0	16.1	16.3	16.5	16.7	16.8	17.0	17.3	17.6	17.9	20
40	14.3	14.5	14.7	14.9	15.1	15.3	15.5	15.7	15.9	16.0	16.2	16.4	16.5	16.7	17.0	17.4	17.7	40
8 0	14.0	14.2	14.4	14.6	11.8	15.0	15.2	15.4	15.6	15.8	15.9	16.1	16.3	16.4	16.8	17.1	17.4	8 0
20	13.7	14.0	14.2	14.4	14.6	14.8	15.0	15.1	15.3	15.5	15.7	15.8	16.0	16.2	16.5	16.8	17.1	20
40	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3	15.5	15.6	15.8	16.0	16.3	16.6	16.9	40
9 0	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.2	15.4	15.6	15.7	16.1	16.4	16.7	9 0
20	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.0	15.2	15.4	15.5	15.9	16.2	16.5	20
40	12.9	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.8	15.0	15.1	15.3	15.7	16.0	16.3	40
10 0	12.7	12.9	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.6	14.8	15.0	15.1	15.5	15.8	16.1	10 0
30	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8	13.9	14.1	14.3	14.5	14.6	14.8	15.1	15.4	15.7	30
11 0	12.2	12.4	12.6	12.8	13.0	13.2	13.4	13.5	13.7	13.9	14.1	14.2	14.4	14.6	14.9	15.2	15.5	11 0
30	12.0	12.2	12.4	12.6	12.8	13.0	13.2	13.3	13.5	13.7	13.9	14.0	14.2	14.4	14.7	15.0	15.3	30
12 0	11.8	12.0	12.2	12.4	12.6	12.8	13.0	13.1	13.3	13.5	13.7	13.8	14.0	14.2	14.5	14.8	15.1	12 0
30	11.6	11.8	12.0	12.2	12.4	12.6	12.8	13.0	13.2	13.3	13.5	13.7	13.8	14.0	14.3	14.6	14.9	30
13 0	11.4	11.6	11.8	12.0	12.2	12.4	12.6	12.8	13.0	13.2	13.3	13.5	13.7	13.8	14.2	14.5	14.8	13 0
30	11.3	11.5	11.7	11.9	12.1	12.3	12.5	12.7	12.8	13.0	13.2	13.4	13.5	13.7	14.0	14.3	14.6	30
14 0	11.1	11.3	11.6	11.8	12.0	12.1	12.3	12.5	12.7	12.9	13.0	13.2	13.4	13.5	13.9	14.2	14.5	14 0
30	11.0	11.2	11.4	11.6	11.8	12.0	12.2	12.4	12.6	12.7	12.9	13.1	13.2	13.4	13.7	14.0	14.3	30
15 0	10.9	11.1	11.3	11.5	11.7	11.9	12.1	12.3	12.4	12.6	12.8	13.0	13.1	13.3	13.6	13.9	14.2	15 0
16 0	10.7	10.9	11.1	11.3	11.5	11.7	11.9	12.0	12.2	12.4	12.6	12.7	12.9	13.1	13.4	13.7	14.0	16 0
17 0	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.8	12.0	12.2	12.4	12.5	12.7	12.9	13.2	13.5	13.8	17 0
18 0	10.3	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.8	12.0	12.2	12.4	12.5	12.7	13.0	13.3	13.6	18 0
19 0	10.1	10.3	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.8	12.0	12.2	12.3	12.5	12.8	13.1	13.4	19 0
20 0	10.0	10.2	10.4	10.6	10.8	11.0	11.2	11.3	11.5	11.7	11.9	12.0	12.2	12.4	12.7	13.0	13.3	20 0
22 0	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.3	11.4	11.6	11.8	11.9	12.1	12.4	12.7	13.0	22 0
24 0	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.0	11.2	11.4	11.6	11.7	11.9	12.2	12.5	12.8	24 0
26 0	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.0	11.2	11.4	11.5	11.7	12.0	12.3	12.6	26 0
28 0	9.1	9.3	9.6	9.8	10.0	10.1	10.3	10.5	10.7	10.9	11.0	11.2	11.4	11.5	11.9	12.2	12.5	28 0
30 0	9.0	9.2	9.4	9.6	9.8	10.0	10.2	10.4	10.6	10.7	10.9	11.1	11.2	11.4	11.7	12.0	12.3	30 0
32 0	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.2	10.4	10.6	10.8	10.9	11.1	11.3	11.6	11.9	12.2	32 0
34 0	8.8	9.0	9.2	9.4	9.6	9.8	10.0	10.1	10.3	10.5	10.7	10.8	11.0	11.2	11.5	11.8	12.1	34 0
36 0	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.0	10.2	10.4	10.6	10.7	10.9	11.1	11.4	11.7	12.0	36 0
38 0	8.6	8.8	9.0	9.2	9.4	9.6	9.8	9.9	10.1	10.3	10.5	10.6	10.8	11.0	11.3	11.6	11.9	38 0
40 0	8.5	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.0	10.2	10.4	10.6	10.7	10.9	11.2	11.5	11.8	40 0
45 0	8.3	8.5	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.0	10.2	10.4	10.5	10.7	11.0	11.3	11.6	45 0
50 0	8.1	8.3	8.6	8.8	9.0	9.1	9.3	9.5	9.7	9.9	10.0	10.2	10.4	10.5	10.9	11.2	11.5	50 0
55 0	8.0	8.2	8.4	8.6	8.8	9.0	9.2	9.4	9.6	9.7	9.9	10.1	10.2	10.4	10.7	11.0	11.3	55 0
60 0	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.3	9.4	9.6	9.8	10.0	10.1	10.3	10.6	10.9	11.2	60 0
65 0	7.8	8.0	8.2	8.4	8.6	8.8	9.0	9.2	9.3	9.5	9.7	9.9	10.0	10.2	10.5	10.8	11.1	65 0
70 0	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.2	9.4	9.6	9.8	9.9	10.1	10.4	10.7	11.0	70 0
75 0	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.0	9.1	9.3	9.5	9.7	9.8	10.0	10.3	10.6	10.9	75 0
80 0	7.5	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.2	9.4	9.6	9.7	9.9	10.2	10.5	10.8	80 0
85 0	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8	9.0	9.1	9.3	9.5	9.6	9.8	10.1	10.4	10.7	85 0
90 0	7.3	7.5	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.2	9.4	9.6	9.7	10.1	10.4	10.7	90 0

Planet only — 2nd Corr. — add to Obs.alt.

Obs. alt. (°)	H.P. of Planet 0′.1	0′.2	0′.3	0′.4	0′.5	0′.6	Obs. alt. (°)
10	0.1	0.2	0.3	0.4	0.5	0.6	10
30	0.1	0.2	0.3	0.3	0.4	0.5	30
50	0.1	0.1	0.2	0.2	0.3	0.4	50
70	0.0	0.1	0.1	0.1	0.2	0.2	70
90	0.0	0.0	0.0	0.0	0.0	0.0	90

Diff.of temp.(°C)	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°
Correction	0′.0	0′.2	0′.4	0′.6	0′.8	1′.0	1′.2	1′.4	1′.6	1′.8	2′.0	2′.2	2′.4	2′.6	2′.8

Note — When: air temp.>sea water temp.⊕ / air temp.<sea water temp.⊖ — temp.at height of eye

Fig. 34

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

26 April 1956
Nautical Almanac

Lunar Age 14.9 d

⊙ Sun

U (h)	$E_\odot$ (h m s)	d (° ′)	P.P. of d (h m)	P.P. of d (′)
0	12 2 10	N13 26.2	0 0	0.0
2	11	27.8	10	1
4	11	29.4	20	3
6	12	31.0	30	4
8	13	32.6	40	5
10	14	34.2	0 50	7
12	12 2 15	N13 35.8	1 0	0.8
14	16	37.4	10	0.9
16	16	39.0	20	1.1
18	17	40.6	30	2
20	18	42.2	40	3
22	19	43.8	1 50	5
24	12 2 20	N13 45.4	2 0	1.6

S.D. 15′ 55″

✳ Star ($U = 0^h$)

No.	Star	E_* (h m s)	d (° ′)
1	Polaris	12 23 42	N89 3.6
2	Kochab	23 25 0	74 19.9
3	Dubhe	3 14 47	61 59.3
4	β Cassiop.	14 9 3	58 54.4
5	Merak	3 16 37	56 37.1
6	Alioth	1 23 43	N56 11.8
7	Schedir	13 37 52	56 17.8
8	Mizar	0 53 39	55 9.1
9	α Persei	10 54 41	49 42.5
10	Benetnasch	0 30 1	49 31.0
11	Capella	9 2 25	N45 57.4
12	Deneb	17 35 55	45 7.2
13	Vega	19 40 23	38 44.3
14	Castor	6 44 3	31 59.2
15	Alpheratz	14 9 45	28 50.9
16	Pollux	6 33 13	N28 8.0
17	α Cor. Bor.	22 43 0	26 51.5
18	Arcturus	0 2 10	19 24.4
19	Aldebaran	9 42 20	16 25.3
20	Markab	15 13 17	14 58.1
21	Denebola	2 29 0	N14 48.0
22	α Ophiuchi	20 42 55	12 35.3
23	Regulus	4 9 43	12 10.7
24	Altair	18 27 12	8 45.0
25	Betelgeuse	8 23 4	7 23.9
26	Bellatrix	8 53 5	N 6 10.6
27	Procyon	6 39 51	N 5 20.1
28	Rigel	9 3 26	S 8 15.2
29	α Hydrae	4 50 25	8 28.4
30	Spica	0 52 57	10 56.2
31	Sirius	7 32 39	S16 39.5
32	β Ceti	13 34 29	18 13.5
33	Antares	21 49 6	26 20.2
34	ε Sagittarii	19 23 17	26 21.1
35	Fomalhaut	15 20 38	29 51.1
36	λ Scorpii	20 45 12	S37 4.3
37	Canopus	7 52 54	52 40.6
38	α Pavonis	17 53 39	56 52.3
39	Achernar	12 39 49	57 27.4
40	β Crucis	1 30 39	59 27.3
41	β Centauri	0 15 5	S60 9.9
42	α Centauri	23 39 11	60 39.5
43	α Crucis	1 51 39	62 51.7
44	α Tri. Aust.	21 31 46	69 56.9
45	β Carinae	5 3 7	S69 32.7

R_0 14h 15m 52s

Planet

♀ Venus Tr. 15h 2m

U (h)	E (h m s)	d (° ′)	P.P. (h m)	P.P. E (s)	P.P. d (′)
0	8 57 40	N27 1.0	0 0	0	0.0
2	41	2.2	10	0	0
4	42	2.6	20	0	1
6	42	3.1	30	0	1
8	43	3.5	40	0	1
10	44	3.9	0 50	0	2
12	8 57 45	N27 4.3	1 0	1	0.2
14	45	4.7	10	1	2
16	46	5.1	20	1	3
18	47	5.5	30	1	3
20	48	5.9	40	1	3
22	49	6.3	1 50	1	4
24	8 57 50	N27 6.7	2 0	1	0.4

♂ Mars Tr. 6h 23m

U (h)	E (h m s)	d (° ′)	P.P. (h m)	P.P. E (s)	P.P. d (′)
0	17 36 48	S19 53.5	0 0	0	0.0
2	36 54	52.9	10	1	1
4	37 1	52.2	20	1	1
6	8	51.5	30	2	2
8	14	50.9	40	2	2
10	21	50.2	0 50	3	3
12	17 37 27	S19 49.5	1 0	4	0.4
14	34	48.9	10	4	4
16	41	48.2	20	5	5
18	47	47.5	30	5	5
20	37 54	46.9	40	6	6
22	38 1	46.2	1 50	6	6
24	17 38 7	S19 45.5	2 0	7	0.7

♃ Jupiter Tr. 19h 18m

U (h)	E (h m s)	d (° ′)	P.P. (h m)	P.P. E (s)	P.P. d (′)
0	4 38 30	N15 21.2	0 0	0	0.0
2	38 50	21.1	10	2	0
4	39 9	21.1	20	3	0
6	28	21.0	30	5	0
8	39 47	21.0	40	6	0
10	40 6	20.9	0 50	8	0
12	4 40 26	N15 20.9	1 0	10	0.1
14	40 45	20.8	10	11	1
16	41 4	20.7	20	13	1
18	23	20.7	30	14	1
20	41 42	20.6	40	16	1
22	42 2	20.6	1 50	17	1
24	4 42 21	N15 20.5	2 0	19	0.1

♄ Saturn Tr. 1h 42m

U (h)	E (h m s)	d (° ′)	P.P. (h m)	P.P. E (s)	P.P. d (′)
0	22 17 25	S18 13.9	0 0	0	0.0
2	17 46	13.8	10	2	0
4	18 7	13.8	20	4	0
6	28	13.7	30	5	0
8	18 49	13.6	40	7	0
10	19 10	13.6	0 50	9	0
12	22 19 31	S18 13.5	1 0	11	0.1
14	19 52	13.4	10	12	1
16	20 13	13.4	20	14	1
18	34	13.3	30	16	1
20	20 55	13.2	40	18	1
22	21 16	13.2	1 50	19	1
24	22 21 37	S18 13.1	2 0	21	0.1

☾ Moon Tr. 0h 40m

U (h)	$E_{\text{☾}}$ (h m s)	d (° ′)
0	23 21 8	S18 40.9
	20 8	44.1
1	19 7	47.4
	18 6	50.6
2	17 5	53.8
	16 5	18 56.9
3	15 4	19 0.1
	14 3	3.2
4	13 2	6.3
	12 1	9.3
5	11 1	12.4
	10 0	15.4

(H.P. 55′.9, S.D. 15′ 13″)

U (h)	$E_{\text{☾}}$ (h m s)	d (° ′)
6	23 8 59	S19 18.3
	7 58	21.3
7	6 57	24.2
	5 56	27.1
8	4 55	30.0
	3 54	32.8
9	2 54	35.7
	1 53	38.5
10	23 0 52	41.2
	22 59 51	44.0
11	58 50	46.7
	57 49	49.4

(H.P. 55′.7, S.D. 15′ 11″)

U (h)	$E_{\text{☾}}$ (h m s)	d (° ′)
12	22 56 48	S19 52.1
	55 47	54.7
13	54 46	57.3
	53 45	19 59.9
14	52 44	20 2.5
	51 43	5.0
15	50 42	7.5
	49 40	10.0
16	48 39	12.5
	47 38	14.9
17	46 37	17.3
	45 36	19.7

(H.P. 55′.6, S.D. 15′ 9″)

U (h)	$E_{\text{☾}}$ (h m s)	d (° ′)
18	22 44 35	S20 22.0
	43 34	24.3
19	42 33	26.6
	41 32	28.9
20	40 31	31.1
	39 29	33.3
21	38 28	35.5
	37 27	37.7
22	36 26	39.8
	35 25	41.9
23	34 21	44.0
	33 23	46.0
24	22 32 21	S20 48.1

(H.P. 55′.5, S.D. 15′ 7″)

P.P. (U 0h–12h)

m	$E_{\text{☾}}$ (s)	d (′)
1	2	0.1
2	4	2
3	6	3
4	8	4
5	10	5
6	12	6
7	14	7
8	16	8
9	18	0.9
10	20	1.0
11	22	1
12	24	2
13	26	3
14	28	4
15	31	5
16	33	6
17	35	7
18	37	8
19	39	1.9
20	41	2.0
21	43	1
22	45	2
23	47	3
24	49	4
25	51	5
26	53	6
27	55	7
28	57	8
29	59	2.9
30	61	3.0

P.P. (U 12h–24h)

m	$E_{\text{☾}}$ (s)	d (′)
1	2	0.1
2	4	2
3	6	2
4	8	3
5	10	4
6	12	5
7	14	6
8	16	6
9	18	7
10	20	8
11	22	0.9
12	24	1.0
13	26	0
14	28	1
15	31	2
16	33	3
17	35	4
18	37	4
19	39	5
20	41	6
21	43	7
22	45	8
23	47	8
24	49	1.9
25	51	2.0
26	53	1
27	55	2
28	57	2
29	59	3
30	61	2.4

Planet

Planet	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	5 18	N27 2	−4.1	0.2	14
♂	20 39	S19 54	+0.4	0.1	4
♃	9 37	N15 21	−1.8	0.0	18
♄	15 58	S18 14	+0.3	0.0	8
☿	3 27	N21 11	−0.3	0.1	3

Fig. 35

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

TABLES FOR FINDING LATITUDE BY OBSERVING POLARIS (1956)

Table (1)

h	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h
m	′	′	′	′	′	′	′	′	′	′	′	′
0	−57.4	−55.4	−49.8	−40.9	−29.2	−15.6	− 1.0	+13.6	+27.2	+38.9	+47.8	+53.4
1	57.4	55.4	49.7	40.7	29.0	15.4	0.8	13.8	27.4	39.0	47.9	53.5
2	57.4	55.3	49.6	40.5	28.8	15.1	0.5	14.1	27.6	39.2	48.1	53.6
3	57.4	55.2	49.4	40.3	28.5	14.9	− 0.3	14.3	27.8	39.4	48.2	53.6
4	57.3	55.2	49.3	40.2	28.3	14.6	0.0	14.5	28.0	39.5	48.3	53.7
5	−57.3	−55.1	−49.2	−40.0	−28.1	−14.4	+ 0.2	+14.8	+28.2	+39.7	+48.4	+53.8
6	57.3	55.0	49.1	39.8	27.9	14.2	0.5	15.0	28.5	39.9	48.5	53.8
7	57.3	55.0	48.9	39.6	27.7	13.9	0.7	15.3	28.7	40.1	48.6	53.9
8	57.3	54.9	48.8	39.4	27.5	13.7	1.0	15.5	28.9	40.2	48.8	53.9
9	57.3	54.8	48.7	39.3	27.2	13.4	1.2	15.7	29.1	40.4	48.9	54.0
10	−57.3	−54.8	−48.5	−39.1	−27.0	−13.2	+ 1.5	+16.0	+29.3	+40.6	+49.0	+54.0
11	57.3	54.7	48.4	38.9	26.8	13.0	1.7	16.2	29.5	40.7	49.1	54.1
12	57.3	54.6	48.3	38.7	26.6	12.7	1.9	16.4	29.7	40.9	49.2	54.1
13	57.3	54.5	48.1	38.5	26.4	12.5	2.2	16.7	29.9	41.0	49.3	54.2
14	57.3	54.5	48.0	38.3	26.2	12.2	2.4	16.9	30.1	41.2	49.5	54.2
15	−57.2	−54.4	−47.9	−38.2	−25.9	−12.0	+ 2.7	+17.2	+30.3	+41.4	+49.6	+54.3
16	57.2	54.3	47.7	38.0	25.7	11.8	2.9	17.4	30.5	41.5	49.7	54.3
17	57.2	54.2	47.6	37.8	25.5	11.5	3.2	17.6	30.7	41.7	49.8	54.4
18	57.2	54.1	47.4	37.6	25.3	11.3	3.4	17.8	30.9	41.9	49.9	54.4
19	57.2	54.0	47.3	37.4	25.0	11.0	3.7	18.0	31.1	42.0	50.0	54.5
20	−57.1	−54.0	−47.2	−37.2	−24.8	−10.8	+ 3.9	+18.3	+31.3	+42.2	+50.1	+54.5
21	57.1	53.9	47.0	37.0	24.6	10.6	4.1	18.5	31.5	42.3	50.2	54.5
22	57.1	53.8	46.9	36.9	24.4	10.3	4.4	18.7	31.7	42.5	50.3	54.6
23	57.1	53.7	46.7	36.7	24.1	10.1	4.6	19.0	31.9	42.6	50.4	54.6
24	57.0	53.6	46.6	36.5	23.9	9.8	4.9	19.2	32.1	42.8	50.5	54.7
25	−57.0	−53.5	−46.4	−36.3	−23.7	− 9.6	+ 5.1	+19.4	+32.3	+42.9	+50.6	+54.7
26	57.0	53.4	46.3	36.1	23.5	9.3	5.4	19.7	32.5	43.1	50.7	54.7
27	56.9	53.4	46.2	35.9	23.2	9.1	5.6	19.9	32.7	43.3	50.8	54.8
28	56.9	53.3	46.0	35.7	23.0	8.8	5.9	20.1	32.9	43.4	50.9	54.8
29	56.9	53.2	45.9	35.5	22.8	8.6	6.1	20.3	33.1	43.6	51.0	54.8
30	−56.9	−53.1	−45.7	−35.3	−22.6	− 8.4	+ 6.4	+20.6	+33.3	+43.7	+51.1	+54.9
31	56.8	53.0	45.6	35.1	22.3	8.1	6.6	20.8	33.5	43.9	51.2	54.9
32	56.8	52.9	45.4	34.9	22.1	7.9	6.8	21.0	33.7	44.0	51.3	54.9
33	56.8	52.8	45.3	34.7	21.9	7.6	7.1	21.2	33.9	44.2	51.4	54.9
34	56.7	52.7	45.1	34.5	21.7	7.4	7.3	21.5	34.1	44.3	51.4	55.0
35	−56.7	−52.6	−44.9	−34.3	−21.4	− 7.1	+ 7.6	+21.7	+34.3	+44.4	+51.5	+55.0
36	56.7	52.5	44.8	34.1	21.2	6.9	7.8	21.9	34.5	44.6	51.6	55.0
37	56.6	52.4	44.6	33.9	21.0	6.6	8.1	22.1	34.7	44.7	51.7	55.1
38	56.6	52.3	44.5	33.7	20.7	6.4	8.3	22.4	34.9	44.9	51.8	55.1
39	56.5	52.2	44.3	33.5	20.5	6.1	8.6	22.6	35.0	45.0	51.9	55.1
40	−56.5	−52.1	−44.2	−33.3	−20.3	− 5.9	+ 8.8	+22.8	+35.2	+45.2	+52.0	+55.1
41	56.5	52.0	44.0	33.1	20.0	5.7	9.0	23.0	35.4	45.3	52.0	55.2
42	56.4	51.9	43.9	32.9	19.8	5.4	9.3	23.3	35.6	45.4	52.1	55.2
43	56.4	51.8	43.7	32.7	19.6	5.2	9.5	23.5	35.8	45.6	52.2	55.2
44	56.3	51.7	43.5	32.5	19.4	4.9	9.8	23.7	36.0	45.7	52.3	55.2
45	−56.3	−51.6	−43.4	−32.3	−19.1	− 4.7	+10.0	+23.9	+36.2	+45.9	+52.4	+55.2
46	56.2	51.5	43.2	32.1	18.9	4.4	10.2	24.2	36.3	46.0	52.5	55.3
47	56.2	51.3	43.0	31.9	18.7	4.2	10.5	24.4	36.5	46.1	52.5	55.3
48	56.1	51.2	42.9	31.7	18.4	3.9	10.7	24.6	36.7	46.3	52.6	55.3
49	56.1	51.1	42.7	31.5	18.2	3.7	11.0	24.8	36.9	46.4	52.7	55.3
50	−56.0	−51.0	−42.6	−31.3	−18.0	− 3.5	+11.2	+25.0	+37.1	+46.5	+52.8	+55.3
51	56.0	50.9	42.4	31.1	17.7	3.2	11.4	25.2	37.3	46.7	52.8	55.3
52	55.9	50.8	42.2	30.9	17.5	3.0	11.7	25.5	37.4	46.8	52.9	55.3
53	55.9	50.6	42.1	30.7	17.3	2.7	11.9	25.7	37.6	46.9	53.0	55.3
54	55.8	50.5	41.9	30.5	17.0	2.5	12.2	25.9	37.8	47.1	53.0	55.3
55	−55.8	−50.4	−41.7	−30.2	−16.8	− 2.2	+12.4	+26.1	+38.0	+47.2	+53.1	+55.3
56	55.7	50.3	41.5	30.0	16.5	2.0	12.6	26.3	38.2	47.3	53.2	55.3
57	55.6	50.2	41.4	29.8	16.3	1.7	12.9	26.5	38.3	47.4	53.2	55.4
58	55.6	50.1	41.2	29.6	16.1	1.5	13.1	26.8	38.5	47.6	53.3	55.4
59	55.5	49.9	41.0	29.4	15.8	1.3	13.4	27.0	38.7	47.7	53.4	55.4
60	−55.4	−49.8	−40.9	−29.2	−15.6	− 1.0	+13.6	+27.2	+38.9	+47.8	+53.4	+55.4

Fig. 36

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

TABLES FOR FINDING LATITUDE BY OBSERVING POLARIS (1956)

Table (2)

Add always

Alt.	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h
°	′	′	′	′	′	′	′	′	′	′	′	′	′
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
20	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0
25	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.0
30	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.2	0.2	0.1	0.1	0.0	0.0
35	0.0	0.0	0.1	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.1	0.0	0.0
40	0.0	0.0	0.1	0.2	0.3	0.4	0.4	0.4	0.3	0.2	0.1	0.0	0.0
45	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.4	0.3	0.2	0.1	0.0	0.0
50	0.0	0.0	0.1	0.3	0.4	0.5	0.5	0.5	0.4	0.3	0.1	0.0	0.0
55	0.0	0.0	0.2	0.3	0.5	0.6	0.7	0.6	0.5	0.3	0.2	0.0	0.0
60	0.0	0.1	0.2	0.4	0.6	0.7	0.8	0.7	0.6	0.4	0.2	0.1	0.0
65	0.0	0.1	0.2	0.5	0.7	0.9	1.0	0.9	0.7	0.5	0.2	0.1	0.0
70	0.0	0.1	0.3	0.6	1.0	1.2	1.3	1.2	1.0	0.6	0.3	0.1	0.0

h (hour angle)

Table (3)

Add always

Date M.D.	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h
	′	′	′	′	′	′	′	′	′	′	′	′	′
1 1	1.3	1.2	1.2	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.8	0.7
21	1.3	1.3	1.2	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.7
2 10	1.3	1.3	1.2	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.7
3 1	1.2	1.2	1.2	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.8	0.8
21	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9
4 10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
30	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1
5 20	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2
6 9	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.2
29	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.3
7 19	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.3
8 8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.2
28	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2
9 17	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1
10 7	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9
27	1.2	1.2	1.2	1.1	1.1	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8
11 16	1.3	1.3	1.3	1.2	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7	0.7
12 6	1.4	1.4	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.6	0.6
26	1.5	1.5	1.4	1.4	1.2	1.1	1.0	0.9	0.8	0.6	0.6	0.5	0.5
46	1.5	1.5	1.5	1.4	1.3	1.1	1.0	0.9	0.7	0.6	0.5	0.5	0.5

h (hour angle)

Lat. = (Obs. true Alt.)+(Tab.1)+(Tab.2)+(Tab.3)

$$h = U + E\ast \pm L \text{ in T.} \left(L \longrightarrow \begin{matrix} \text{E. Long.} \longrightarrow + \\ \text{W. Long.} \longrightarrow - \end{matrix} \right)$$

Fig. 37

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

TABLES FOR FINDING LATITUDE BY OBSERVING POLARIS (1956)

Table (1)

h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
m	′	′	′	′	′	′	′	′	′	′	′	′
0	+55.4	+53.4	+47.8	+38.9	+27.2	+13.6	− 1.0	−15.6	−29.2	−40.9	−49.8	−55.4
1	55.4	53.4	47.7	38.7	27.0	13.4	1.3	15.8	29.4	41.0	49.9	55.5
2	55.4	53.3	47.6	38.5	26.8	13.1	1.5	16.1	29.6	41.2	50.1	55.6
3	55.4	53.2	47.4	38.3	26.5	12.9	1.7	16.3	29.8	41.4	50.2	55.6
4	55.3	53.2	47.3	38.2	26.3	12.6	2.0	16.5	30.0	41.5	50.3	55.7
5	+55.3	+53.1	+47.2	+38.0	+26.1	+12.4	− 2.2	−16.8	−30.2	−41.7	−50.4	−55.8
6	55.3	53.0	47.1	37.8	25.9	12.2	2.5	17.0	30.5	41.9	50.5	55.8
7	55.3	53.0	46.9	37.6	25.7	11.9	2.7	17.3	30.7	42.1	50.6	55.9
8	55.3	52.9	46.8	37.4	25.5	11.7	3.0	17.5	30.9	42.2	50.8	55.9
9	55.3	52.8	46.7	37.3	25.2	11.4	3.2	17.7	31.1	42.4	50.9	56.0
10	+55.3	+52.8	+46.5	+37.1	+25.0	+11.2	− 3.5	−18.0	−31.3	−42.6	−51.0	−56.0
11	55.3	52.7	46.4	36.9	24.8	11.0	3.7	18.2	31.5	42.7	51.1	56.1
12	55.3	52.6	46.3	36.7	24.6	10.7	3.9	18.4	31.7	42.9	51.2	56.1
13	55.3	52.5	46.1	36.5	24.4	10.5	4.2	18.7	31.9	43.0	51.3	56.2
14	55.3	52.5	46.0	36.3	24.2	10.2	4.4	18.9	32.1	43.2	51.5	56.2
15	+55.2	+52.4	+45.9	+36.2	+23.9	+10.0	− 4.7	−19.1	−32.3	−43.4	−51.6	−56.3
16	55.2	52.3	45.7	36.0	23.7	9.8	4.9	19.4	32.5	43.5	51.7	56.3
17	55.2	52.2	45.6	35.8	23.5	9.5	5.2	19.6	32.7	43.7	51.8	56.4
18	55.2	52.1	45.4	35.6	23.3	9.3	5.4	19.8	32.9	43.9	51.9	56.4
19	55.2	52.0	45.3	35.4	23.0	9.0	5.7	20.0	33.1	44.0	52.0	56.5
20	+55.1	+52.0	+45.2	+35.2	+22.8	+ 8.8	− 5.9	−20.3	−33.3	−44.2	−52.1	−56.5
21	55.1	51.9	45.0	35.0	22.6	8.6	6.1	20.5	33.5	44.3	52.2	56.5
22	55.1	51.8	44.9	34.9	22.4	8.3	6.4	20.7	33.7	44.5	52.3	56.6
23	55.1	51.7	44.7	34.7	22.1	8.1	6.6	21.0	33.9	44.6	52.4	56.6
24	55.0	51.6	44.6	34.5	21.9	7.8	6.9	21.2	34.1	44.8	52.5	56.7
25	+55.0	+51.5	+44.4	+34.3	+21.7	+ 7.6	− 7.1	−21.4	−34.3	−44.9	−52.6	−56.7
26	55.0	51.4	44.3	34.1	21.5	7.3	7.4	21.7	34.5	45.1	52.7	56.7
27	54.9	51.4	44.2	33.9	21.2	7.1	7.6	21.9	34.7	45.3	52.8	56.8
28	54.9	51.3	44.0	33.7	21.0	6.8	7.9	22.1	34.9	45.4	52.9	56.8
29	54.9	51.2	43.9	33.5	20.8	6.6	8.1	22.3	35.1	45.6	53.0	56.8
30	+54.9	+51.1	+43.7	+33.3	+20.6	+ 6.4	− 8.4	−22.6	−35.3	−45.7	−53.1	−56.9
31	54.8	51.0	43.6	33.1	20.3	6.1	8.6	22.8	35.5	45.9	53.2	56.9
32	54.8	50.9	43.4	32.9	20.1	5.9	8.8	23.0	35.7	46.0	53.3	56.9
33	54.8	50.8	43.3	32.7	19.9	5.6	9.1	23.2	35.9	46.2	53.4	56.9
34	54.7	50.7	43.1	32.5	19.7	5.4	9.3	23.5	36.1	46.3	53.4	57.0
35	+54.7	+50.6	+42.9	+32.3	+19.4	+ 5.1	− 9.6	−23.7	−36.3	−46.4	−53.5	−57.0
36	54.7	50.5	42.8	32.1	19.2	4.9	9.8	23.9	36.5	46.6	53.6	57.0
37	54.6	50.4	42.6	31.9	19.0	4.6	10.1	24.1	36.7	46.7	53.7	57.1
38	54.6	50.3	42.5	31.7	18.7	4.4	10.3	24.4	36.9	46.9	53.8	57.1
39	54.5	50.2	42.3	31.5	18.5	4.1	10.6	24.6	37.0	47.0	53.9	57.1
40	+54.5	+50.1	+42.2	+31.3	+18.3	+ 3.9	−10.8	−24.8	−37.2	−47.2	−54.0	−57.1
41	54.5	50.0	42.0	31.1	18.0	3.7	11.0	25.0	37.4	47.3	54.0	57.2
42	54.4	49.9	41.9	30.9	17.8	3.4	11.3	25.3	37.6	47.4	54.1	57.2
43	54.4	49.8	41.7	30.7	17.6	3.2	11.5	25.5	37.8	47.6	54.2	57.2
44	54.3	49.7	41.5	30.5	17.4	2.9	11.8	25.7	38.0	47.7	54.3	57.2
45	+54.3	+49.6	+41.4	+30.3	+17.2	+ 2.7	−12.0	−25.9	−38.2	−47.9	−54.4	−57.2
46	54.2	49.5	41.2	30.1	16.9	2.4	12.2	26.2	38.3	48.0	54.5	57.3
47	54.2	49.3	41.0	29.9	16.7	2.2	12.5	26.4	38.5	48.1	54.5	57.3
48	54.1	49.2	40.9	29.7	16.4	1.9	12.7	26.6	38.7	48.3	54.6	57.3
49	54.1	49.1	40.7	29.5	16.2	1.7	13.0	26.8	38.9	48.4	54.7	57.3
50	+54.0	+49.0	+40.6	+29.3	+16.0	+ 1.5	−13.2	−27.0	−39.1	−48.5	−54.8	−57.3
51	54.0	48.9	40.4	29.1	15.7	1.2	13.4	27.2	39.3	48.7	54.8	57.3
52	53.9	48.8	40.2	28.9	15.5	1.0	13.7	27.5	39.4	48.8	54.9	57.3
53	53.9	48.6	40.1	28.7	15.3	0.7	13.9	27.7	39.6	48.9	55.0	57.3
54	53.8	48.5	39.9	28.5	15.0	0.5	14.2	27.9	39.8	49.1	55.0	57.3
55	+53.8	+48.4	+39.7	+28.2	+14.8	+ 0.2	−14.4	−28.1	−40.0	−49.2	−55.1	−57.3
56	53.7	48.3	39.5	28.0	14.5	0.0	14.6	28.3	40.2	49.3	55.2	57.3
57	53.6	48.2	39.4	27.8	14.3	− 0.3	14.9	28.5	40.3	49.4	55.2	57.4
58	53.6	48.1	39.2	27.6	14.1	0.5	15.1	28.8	40.5	49.6	55.3	57.4
59	53.5	47.9	39.0	27.4	13.8	0.8	15.4	29.0	40.7	49.7	55.4	57.4
60	+53.4	+47.8	+38.9	+27.2	+13.6	− 1.0	−15.6	−29.2	−40.9	−49.8	−55.4	−57.4

Fig. 38

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

TABLES FOR FINDING LATITUDE BY OBSERVING POLARIS (1956)

Table (2)

Add always

Alt. \ h (hour angle)	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
°	′	′	′	′	′	′	′	′	′	′	′	′	′
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0
25	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.0
30	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.2	0.2	0.1	0.1	0.0	0.0
35	0.0	0.0	0.1	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.1	0.0	0.0
40	0.0	0.0	0.1	0.2	0.3	0.4	0.4	0.4	0.3	0.2	0.1	0.0	0.0
45	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.4	0.3	0.2	0.1	0.0	0.0
50	0.0	0.0	0.1	0.3	0.4	0.5	0.5	0.5	0.4	0.3	0.1	0.0	0.0
55	0.0	0.0	0.2	0.3	0.5	0.6	0.7	0.6	0.5	0.3	0.2	0.0	0.0
60	0.0	0.1	0.2	0.4	0.6	0.7	0.8	0.7	0.6	0.4	0.2	0.1	0.0
65	0.0	0.1	0.2	0.5	0.7	0.9	1.0	0.9	0.7	0.5	0.2	0.1	0.0
70	0.0	0.1	0.3	0.6	1.0	1.2	1.3	1.2	1.0	0.6	0.3	0.1	0.0

Table (3)

Add always

Date M.D. \ h (hour angle)	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
M. D.	′	′	′	′	′	′	′	′	′	′	′	′	′
1 1	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.3
21	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.3	1.3
2 10	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.3	1.3
3 1	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.2
21	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1
4 10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
30	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9
5 20	1.2	1.2	1.1	1.1	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8
6 9	1.2	1.2	1.2	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.8	0.8
29	1.3	1.2	1.2	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.8	0.7
7 19	1.3	1.2	1.2	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.8	0.7
8 8	1.2	1.2	1.2	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.8	0.8
28	1.2	1.1	1.1	1.1	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.8
9 17	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9
10 7	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1
27	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2
11 16	0.7	0.7	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.2	1.3	1.3	1.3
12 6	0.6	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.4	1.4
26	0.5	0.5	0.6	0.6	0.8	0.9	1.0	1.1	1.2	1.4	1.4	1.5	1.6
46	0.5	0.5	0.5	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.5	1.5	1.5

Lat.= (Obs. true Alt.)+(Tab. 1)+(Tab.2)+(Tab.3)

$h = U + E_{*} + L$ in T. $\left(L \longrightarrow \begin{matrix} \text{E. Long.} \longrightarrow + \\ \text{W. Long.} \longrightarrow - \end{matrix} \right)$

Fig. 39

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

1956

AZIMUTH OF POLARIS

	h												
l	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h
		W	W	W	W	W	W	W	W	W	W	W	
0°	0.0°	0.2°	0.5°	0.7°	0.8°	0.9°	0.9°	0.9°	0.8°	0.7°	0.5°	0.2°	0.0°
5	0.0	0.2	0.5	0.7	0.8	0.9	0.9	0.9	0.8	0.7	0.5	0.2	0.0
10	0.0	0.2	0.5	0.7	0.8	0.9	1.0	0.9	0.8	0.7	0.5	0.2	0.0
15	0.0	0.3	0.5	0.7	0.8	0.9	1.0	0.9	0.8	0.7	0.5	0.3	0.0
20	0.0	0.3	0.5	0.7	0.9	1.0	1.0	1.0	0.9	0.7	0.5	0.3	0.0
25	0.0	0.3	0.5	0.7	0.9	1.0	1.0	1.0	0.9	0.7	0.5	0.3	0.0
30	0.0	0.3	0.5	0.8	0.9	1.0	1.1	1.0	0.9	0.8	0.5	0.3	0.0
35	0.0	0.3	0.6	0.8	1.0	1.1	1.1	1.1	1.0	0.8	0.6	0.3	0.0
40	0.0	0.3	0.6	0.9	1.1	1.2	1.2	1.2	1.1	0.9	0.6	0.3	0.0
45	0.0	0.3	0.7	0.9	1.2	1.3	1.3	1.3	1.2	0.9	0.7	0.3	0.0
50	0.0	0.4	0.7	1.0	1.3	1.4	1.5	1.4	1.3	1.0	0.7	0.4	0.0
55	0.0	0.4	0.8	1.2	1.4	1.6	1.6	1.6	1.4	1.2	0.8	0.4	0.0
60	0.0	0.5	0.9	1.3	1.6	1.8	1.9	1.8	1.6	1.3	0.9	0.5	0.0
65	0.0	0.6	1.1	1.6	1.9	2.1	2.2	2.1	1.9	1.6	1.1	0.6	0.0
70	0.0	0.7	1.4	1.9	2.4	2.7	2.7	2.7	2.4	1.9	1.4	0.7	0.0

	h												
l	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
		E	E	E	E	E	E	E	E	E	E	E	
0°	0.0°	0.2°	0.5°	0.7°	0.8°	0.9°	0.9°	0.9°	0.8°	0.7°	0.5°	0.2°	0.0°
5	0.0	0.2	0.5	0.7	0.8	0.9	0.9	0.9	0.8	0.7	0.5	0.2	0.0
10	0.0	0.2	0.5	0.7	0.8	0.9	1.0	0.9	0.8	0.7	0.5	0.2	0.0
15	0.0	0.3	0.5	0.7	0.8	0.9	1.0	0.9	0.8	0.7	0.5	0.3	0.0
20	0.0	0.3	0.5	0.7	0.9	1.0	1.0	1.0	0.9	0.7	0.5	0.3	0.0
25	0.0	0.3	0.5	0.7	0.9	1.0	1.0	1.0	0.9	0.7	0.5	0.3	0.0
30	0.0	0.3	0.5	0.8	0.9	1.0	1.1	1.0	0.9	0.8	0.5	0.3	0.0
35	0.0	0.3	0.6	0.8	1.0	1.1	1.1	1.1	1.0	0.8	0.6	0.3	0.0
40	0.0	0.3	0.6	0.9	1.1	1.2	1.2	1.2	1.1	0.9	0.6	0.3	0.0
45	0.0	0.3	0.7	0.9	1.2	1.3	1.3	1.3	1.2	0.9	0.7	0.3	0.0
50	0.0	0.4	0.7	1.0	1.3	1.4	1.5	1.4	1.3	1.0	0.7	0.4	0.0
55	0.0	0.4	0.8	1.2	1.4	1.6	1.6	1.6	1.4	1.2	0.8	0.4	0.0
60	0.0	0.5	0.9	1.3	1.6	1.8	1.9	1.8	1.6	1.3	0.9	0.5	0.0
65	0.0	0.6	1.1	1.6	1.9	2.1	2.2	2.1	1.9	1.6	1.1	0.6	0.0
70	0.0	0.7	1.4	1.9	2.4	2.7	2.7	2.7	2.4	1.9	1.4	0.7	0.0

$h = u + E \pm L$ in T E. long → + W. long → -

$0^h < h < 12^h$ suffix → W

$12^h < h < 24^h$ suffix → E

Prefix is always N

Fig. 39-a

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

Problem

At $04^h\ 35^m$ on 5 August 1956, a navigator observed the altitude of Polaris as $22^\circ 17'.0$ in D.R.P. $21^\circ 13$ N, $161^\circ 35$ W. What was his latitude?

Where : Chronometer time when he observed Polaris was $3^h\ 14^m\ 35^s$, chronometer error ⊕ $12^m\ 43^s$, index error ⊖ 0.2, height of eye 16 metres, air temperature $23^\circ C$, sea water temperature $25^\circ C$,

Solution

Ship's Time 5 Aug. 1956	$04^h\ 35^m\ 00^s$		
L. in T. (161°– 35'W)	10 46 00	⊕	
G.D. 5 Aug. 1956	$15^h\ 21^m\ 00^s$		
Chro. T.	$15^h\ 14^m\ 35^s$		($3^h\ 14^m\ 35^s$ p.m.)
C.E.	12 43	⊕	
U 5 Aug. 1956	$15^h\ 27^m\ 18^s$		(See Fig. 40)
E* (u = 0h)	19 00 04		(From nautical almanac)
P.P. (E*)	2 32	⊕	(From Fig. 27)
	34 29 54		
	24	⊖	
hG	$10^h\ 29^m\ 54^s$		
L. in T.	10 46 20	⊖	
h.	$23^h\ 43^m\ 34^s$		
Sex Alt.*	22° - $17'.0$		
I.E.	0.2	⊖	
Obs. Alt.	22° - $16'.8$		
Corr. 1	9.5	⊖	
	22° - $07'.3$		
Corr. 2	0.1	⊕	
	22° - $07'.4$		
Corr. t	0.4	⊖	
True Alt.*	22° - $07'.0$		
	==========		

True Alt.*	22° - 07!0
Corr. I	57.2 ⊖
	21° - 09!8
Corr. II	0.0
	21° - 09!8
Corr. III	0.8 ⊕
ℓ	21° - 10!6 N

Ans. Lat. = 21° - 10!6 N

1956 | 5 August 1956 Nautical Almanac | Lunar Age 27.8

☉ Sun

U	E☉	d	P.P. of d	
h	h m s	° ′	h m	′
0	11 54 4	N17 2.8	0 0	0.0
2	5	1.5	10	1
4	5	17 0.1	20	2
6	6	16 50.8	30	4
8	6	57.4	40	5
10	7	56.1	0 50	6
12	11 54 7	N16 54.7	1 0	0.7
14	8	53.3	10	8
16	8	52.0	20	0.9
18	9	50.6	30	1.1
20	9	49.2	40	2
22	10	47.9	1 50	3
24	11 54 10	N16 46.5	2 0	1.4

S.D. 15′ 48″

✱ Star (U = 0h)

No.	Star	E★	d
		h m s	° ′
1	Polaris	19 0 4	N89 3.4
2	Kochab	6 3 17	74 20.3
3	Dubhe	9 53 2	61 59.2
4	β Cassiop.	20 47 11	58 54.6
5	Merak	9 54 52	56 37.0
6	Alioth	8 1 58	N56 11.9
7	Schedir	20 16 0	56 17.9
8	Mizar	7 31 54	55 9.3
9	α Persei	17 32 51	49 42.3
10	Benetnasch	7 8 15	49 32.0
11	Capella	15 40 35	N45 57.2
12	Deneb	0 14 5	45 7.7
13	Vega	2 18 34	38 44.8
14	Castor	13 22 15	31 59.1
15	Alpheratz	20 47 54	28 51.1
16	Pollux	13 11 25	N28 7.9
17	α Cor. Bor.	5 21 13	26 51.8
18	Arcturus	6 40 23	19 24.6
19	Aldebaran	16 20 38	16 25.4
20	Markab	21 51 27	14 58.4
21	Denebola	9 7 14	N14 48.9
22	α Ophiuchi	3 21 8	12 35.6
23	Regulus	10 48 1	12 10.8
24	Altair	1 5 22	8 45.4
25	Betelgeuse	15 1 15	7 24.0
26	Bellatrix	15 31 16	N 6 18.7
27	Procyon	13 17 3	N 5 20.2
28	Rigel	15 41 37	S 8 14.9
29	α Hydrae	11 28 38	8 28.2
30	Spica	7 31 10	10 56.2
31	Sirius	14 10 51	S16 39.3
32	β Ceti	20 12 38	18 13.2
33	Antares	4 27 18	26 20.3
34	σ Sagittarii	2 1 28	26 21.0
35	Fomalhaut	21 58 47	29 50.9
36	λ Scorpii	3 23 23	S37 4.5
37	Canopus	11 31 7	52 40.2
38	α Pavonis	0 31 47	56 52.4
39	Achernar	19 17 58	57 27.0
40	β Crucis	8 8 54	59 27.4
41	β Centauri	6 53 19	S60 10.2
42	α Centauri	6 17 25	60 39.8
43	α Crucis	8 29 54	62 51.8
44	α Tri. Aust.	4 9 57	68 57.3
45	β Carinae	11 41 23	S69 32.4

R_0 20h 54m 4s

Planet

♀ Venus Tr. 9h 7m

U	E_p	d	P.P.	E_p	d
h	h m s	° ′	h m	s	′
0	14 52 30	N18 32.3	0 0	0	0.0
2	37	32.6	10	1	0
4	43	32.9	20	1	1
6	49	33.2	30	2	1
8	52 55	33.5	40	2	1
10	53 2	33.7	0 50	3	1
12	14 53 8	N18 34.0	1 0	3	0.2
14	14	34.3	10	4	2
16	20	34.6	20	4	2
18	26	34.8	30	5	2
20	32	35.1	40	5	3
22	38	35.4	1 50	6	3
24	14 53 44	N18 35.7	2 0	6	0.3

♂ Mars Tr. 2h 50m

U	E_p	d	P.P.	E_p	d
h	h m s	° ′	h m	s	′
0	21 9 6	S 7 49.9	0 0	0	0.0
2	24	50.0	10	2	0
4	9 42	50.0	20	3	0
6	10 0	50.1	30	5	0
8	18	50.1	40	6	0
10	36	50.2	0 50	8	0
12	21 10 54	S 7 50.2	1 0	9	0.1
14	11 12	50.3	10	11	1
16	30	50.3	20	12	1
18	11 48	50.4	30	14	1
20	12 6	50.4	40	15	1
22	24	50.5	1 50	17	1
24	21 12 43	S 7 50.6	2 0	18	0.1

♃ Jupiter Tr. 13h 35m

U	E_p	d	P.P.	E_p	d
h	h m s	° ′	h m	s	′
0	10 23 16	N10 22.9	0 0	0	0.0
2	32	22.5	10	1	0
4	23 48	22.1	20	3	1
6	24 4	21.7	30	4	1
8	20	21.4	40	5	1
10	35	21.0	0 50	7	2
12	10 24 51	N10 20.6	1 0	8	0.2
14	25 7	20.2	10	9	2
16	23	19.8	20	11	3
18	38	19.4	30	12	3
20	25 51	19.1	40	13	3
22	26 10	18.7	1 50	15	4
24	10 26 26	N10 18.3	2 0	16	0.4

♄ Saturn Tr. 18h 40m

U	E_p	d	P.P.	E_p	d
h	h m s	° ′	h m	s	′
0	5 16 37	S17 21.3	0 0	0	0.0
2	16 57	21.3	10	2	0
4	17 16	21.3	20	3	0
6	36	21.4	30	5	0
8	17 56	21.4	40	7	0
10	18 15	21.4	0 50	8	0
12	5 18 35	S17 21.5	1 0	10	0.0
14	18 54	21.5	10	12	0
16	19 14	21.5	20	13	0
18	33	21.6	30	15	0
20	19 53	21.6	40	17	0
22	20 12	21.6	1 50	18	0
24	5 20 32	S17 21.7	2 0	20	0.0

☾ Moon Tr. 11h 3m

U	$E_☾$	d
h	h m s	° ′
0	13 23 33	N18 9.3
	22 21	5.2
1	21 0	18 1.1
	19 55	17 57.0
2	18 42	52.8
	17 29	48.6
3	16 17	44.4
	15 4	40.1
4	13 52	35.8
	12 39	31.5
5	11 27	27.1
	10 14	22.7
(H.P. 61′.2, S.D. 16′ 40″)		
6	13 9 2	N17 18.3
	7 49	13.8
7	6 37	9.4
	5 25	4.8
8	4 13	17 0.3
	3 1	16 55.7
9	1 49	51.1
	13 0 37	46.5
10	12 59 25	41.8
	58 13	37.1
11	57 1	32.3
	55 49	27.6
(H.P. 61′.2, S.D. 16′ 41″)		
12	12 54 37	N16 22.8
	53 26	18.0
13	52 14	13.1
	51 2	8.2
14	49 51	16 3.3
	48 39	15 58.4
15	47 28	53.4
	46 17	48.5
16	45 5	43.4
	43 54	38.4
17	42 43	33.3
	41 32	28.2
(H.P. 61′.3, S.D. 16′ 42″)		
18	12 40 21	N15 23.1
	39 10	17.9
19	37 59	12.7
	36 48	7.5
20	35 37	15 2.3
	34 26	14 57.0
21	33 16	51.7
	32 5	46.4
22	30 54	41.1
	29 44	35.7
23	28 33	30.3
	27 23	24.9
24	12 26 13	N14 19.5
(H.P. 61′.3, S.D. 16′ 42″)		

P.P. (Moon, U 0h–12h)

m	$E_☾$ (s)	d (′)
1	2	0.1
2	5	3
3	7	4
4	10	6
5	12	7
6	14	0.9
7	17	1.0
8	19	2
9	22	3
10	24	5
11	26	6
12	29	8
13	31	1.9
14	34	2.1
15	36	2
16	38	3
17	41	5
18	43	6
19	46	8
20	48	2.9
21	50	3.1
22	53	2
23	55	4
24	58	5
25	60	7
26	62	3.8
27	65	4.0
28	67	1
29	70	3
30	72	4.4

P.P. (Moon, U 12h–24h)

m	$E_☾$ (s)	d (′)
1	2	0.2
2	5	.3
3	7	5
4	9	7
5	12	0.9
6	14	1.0
7	17	2
8	19	4
9	21	5
10	24	7
11	26	1.9
12	28	2.0
13	31	2
14	33	4
15	36	6
16	38	7
17	40	2.9
18	43	3.1
19	45	2
20	47	4
21	50	6
22	52	7
23	54	3.9
24	57	4.1
25	59	3
26	62	4
27	64	6
28	66	8
29	69	4.9
30	71	5.1

Planet

	R.A.	d	Mag.	H.P.	S.D.
	h m	° ′		′	″
♀	6 2	N18 32	−4.2	0.3	17
♂	23 45	S 7 50	−1.9	0.3	10
♃	10 31	N10 23	−1.3	0.0	15
♄	15 37	S17 21	+0.7	0.0	8
☿	10 5	N13 11	−0.4	0.1	3

Fig. 40

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

Longitude by equal altitude of a celestial body

If a ship is proceeding with a constant course and at a constant speed, the value of variation of celestial body's altitude should be zero (nil) at the time of observation of its apparent maximum altitude. The variation of celestial body's altitude should be the same value and contrary name when the navigator observes this celestial body in accurate time interval before its transit and after its transit to the time of apparent maximum altitude.

In this particular case, a celestial body's altitude before transit and after transit must be equal, so if the navigator observes the altitude of the celestial body some minutes before its transit and records the time observed (= T_1), and its equal altitude after transit by the same sextant and at the same height of eye, and records the time observed ($=T_2$), the mean time (T) of T_1, and T_2 is given as shown below,

$$T = \frac{1}{2}(T_1 + T_2)$$

By using the arithmetic mean time (T), it is possible for navigators to obtain longitude. In other words, very accurate time (T) of a celestial body's transit in apparent maximum altitude can show navigator's longitude using some calculations.

Hour angle "h" at the time of transit can be given as follows,

$$h = -\ 15^s.28\ (\tan \ell \mp \tan d)(\Delta\ell \mp \Delta d)\left(1 - \frac{\Delta E}{3,600} \mp \frac{\Delta L}{900}\right)$$

ℓ = latitude, d = declination, $\Delta\ell$ = value of variant of ℓ for one hour, Δd = value of variant of d for ten or some minutes (obtainable from the nautical almanac), $\Delta E \Rightarrow$ value of variant of E for one hour {E = R-R.A. + (24h), R = R.A.M.S. - 12h + (24h)}

Note

Name of the above mentioned, values when each value is increasing, name should be positive + when each value is decreasing, name should be negative-.

In the formula

$$h = 15^s.28\ (\tan \ell \mp \tan d)\ (\Delta\ell \mp d)\ \left(1 - \frac{\Delta E}{3600} \mp \frac{\Delta\angle}{900}\right)$$

when ℓ has same name as d, $\rightarrow \ominus$ } $\rightarrow$ $(\tan \ell \mp \tan d)$
ℓ has contrary name to d, $\rightarrow \oplus$ } $\rightarrow$ $(\Delta\ell \pm \Delta)$

Longitude is east $\rightarrow \ominus$ }
Longitude is west $\rightarrow \oplus$ } $\rightarrow$ $\left(1 - \frac{\Delta E}{3600} + \frac{\Delta\angle}{900}\right)$

Units of $\Delta\ell$, Δd and $\Delta\angle$ should be 1' (minute)

Units of ΔE should be 1^s (second) and except for observations of the moon value of ΔE can be regarded as zero (nil)

The values of 15.28 tan L and 15.28 tan d are shown in the table (Fig. 41). After calculation according to the formula, if there is negative name of local hour angle (h), subtract it from 24h to convert it into the west local hour angle.

When the value of "h" is given, navigators can calculate the Local Mean Time (L.M.T.) using the following equation

$$L.M.T. = h - E\ (E = E^{\odot},\ E_* \text{ etc.})$$

In comparison with Local Mean Time (L.M.T.) and Universal Time (U.T.), it is possible to obtain the correct Longitude in Time (L. in T.) at the time of celestial body's apparent maximum altitude.

Calculation procedure:

1. when L.M.T. is faster than U.T.
   L.M.T. - U.T. = L. in T. (Longitude → east)

2. when L.M.T. is slower than U.T.
   U.T. - L.M.T. = L. in T. (Longitude → west)

To carry out this method to obtain longitude, it is most important for navigators to measure time accurately when they observe equal altitude of a celestial body.

Example

On 16 November 1956, a navigator observed the sun's equal altitude before the time of trannsit after the time of transit in D.R.P. $04^{o} - 06'$ S, $41^{o} - 28.'0$ E. What was the longitude at arithmetical mean time? (see Fig. 41 and 42)

Where : Ship's true course was 015^{o}, speed 16 knots,
Chronometer error ⊕ 4m 13s
Chronometer time of 1st observation was $08^{h}\ 21^{m}\ 38^{s}$
Chronometer time of 2nd observation was $09^{h}\ 26^{m}\ 08^{s}$

Table for value of 15.28 tan ℓ or 15.28 tan d

ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d	ℓ or d
0° 0′	0.00	10° 0′	2.69	20° 0′	5.56	30° 0′	8.82	40° 0′	12.82	50° 0′	18.21	60° 0′	26.47
10	0.04	10	2.74	10	5.61	10	8.88	10	12.90	10	18.32	10	26.64
20	0.09	20	2.79	20	5.66	20	8.94	20	12.97	20	18.43	20	26.83
30	0.13	30	2.83	30	5.71	30	9.00	30	13.05	30	18.54	30	27.01
40	0.18	40	2.88	40	5.76	40	9.06	40	13.13	40	18.65	40	27.19
50	0.22	50	2.92	50	5.81	50	9.12	50	13.20	50	18.76	50	27.38
1 0	0.27	11 0	2.97	21 0	5.87	31 0	9.18	41 0	13.28	51 0	18.87	61 0	27.57
10	0.31	10	3.02	10	5.92	10	9.24	10	13.36	10	18.98	10	27.76
20	0.36	20	3.06	20	5.97	20	9.30	20	13.44	20	19.10	20	27.95
30	0.40	30	3.11	30	6.02	30	9.36	30	13.52	30	19.21	30	28.14
40	0.44	40	3.16	40	6.07	40	9.42	40	13.60	40	19.32	40	28.31
50	0.48	50	3.20	50	6.12	50	9.49	50	13.68	50	19.44	50	28.51
2 0	0.53	12 0	3.25	22 0	6.17	32 0	9.55	42 0	13.76	52 0	19.56	62 0	28.71
10	0.58	10	3.29	10	6.23	10	9.61	10	13.84	10	19.68	10	28.91
20	0.62	20	3.34	20	6.28	20	9.67	20	13.92	20	19.79	20	29.15
30	0.67	30	3.39	30	6.33	30	9.73	30	14.00	30	19.91	30	29.35
40	0.71	40	3.43	40	6.38	40	9.80	40	14.08	40	20.03	40	29.56
50	0.76	50	3.48	50	6.43	50	9.86	50	14.17	50	20.15	50	29.77
3 0	0.80	13 0	3.53	23 0	6.49	33 0	9.92	43 0	14.25	53 0	20.28	63 0	29.99
10	0.85	10	3.57	10	6.54	10	9.99	10	14.33	10	20.40	10	30.21
20	0.89	20	3.62	20	6.59	20	10.05	20	14.42	20	20.52	20	30.42
30	0.93	30	3.67	30	6.64	30	10.11	30	14.50	30	20.65	30	30.65
40	0.98	40	3.72	40	6.70	40	10.18	40	14.58	40	20.78	40	30.87
50	1.02	50	3.76	50	6.75	50	10.24	50	14.67	50	20.90	50	31.10
4 0	1.07	14 0	3.81	24 0	6.80	34 0	10.31	44 0	14.76	54 0	21.03	64 0	31.33
10	1.11	10	3.86	10	6.86	10	10.37	10	14.84	10	21.16	10	31.56
20	1.16	20	3.90	20	6.91	20	10.44	20	14.93	20	21.29	20	31.80
30	1.20	30	3.95	30	6.96	30	10.50	30	15.02	30	21.42	30	32.04
40	1.25	40	4.00	40	7.02	40	10.57	40	15.10	40	21.55	40	32.28
50	1.29	50	4.05	50	7.07	50	10.63	50	15.19	50	21.69	50	32.52
5 0	1.34	15 0	4.09	25 0	7.13	35 0	10.70	45 0	15.28	55 0	21.82	65 0	32.77
10	1.38	10	4.14	10	7.18	10	10.77	10	15.37	10	21.96	10	33.02
20	1.43	20	4.19	20	7.23	20	10.83	20	15.46	20	22.09	20	33.27
30	1.47	30	4.24	30	7.29	30	10.90	30	15.55	30	22.23	30	33.53
40	1.52	40	4.29	40	7.34	40	10.97	40	15.64	40	22.37	40	33.79
50	1.56	50	4.33	50	7.40	50	11.03	50	15.73	50	22.51	50	34.05
6 0	1.61	16 0	4.38	26 0	7.45	36 0	11.10	46 0	15.82	56 0	22.65	66 0	34.32
10	1.65	10	4.43	10	7.51	10	11.17	10	15.92	10	22.80	10	34.59
20	1.70	20	4.48	20	7.56	20	11.24	20	16.01	20	22.94	20	34.86
30	1.74	30	4.53	30	7.62	30	11.31	30	16.10	30	23.09	30	35.14
40	1.79	40	4.57	40	7.67	40	11.38	40	16.20	40	23.23	40	35.42
50	1.83	50	4.62	50	7.73	50	11.44	50	16.29	50	23.38	50	35.71
7 0	1.88	17 0	4.67	27 0	7.79	37 0	11.51	47 0	16.39	57 0	23.53	67 0	36.00
10	1.92	10	4.72	10	7.84	10	11.58	10	16.48	10	23.68	10	36.29
20	1.97	20	4.77	20	7.90	20	11.65	20	16.58	20	23.83	20	36.59
30	2.01	30	4.82	30	7.95	30	11.72	30	16.68	30	23.98	30	36.89
40	2.06	40	4.87	40	8.01	40	11.80	40	16.77	40	24.14	40	37.19
50	2.10	50	4.92	50	8.07	50	11.87	50	16.87	50	24.30	50	37.50
8 0	2.15	18 0	4.96	28 0	8.12	38 0	11.94	48 0	16.97	58 0	24.45	68 0	37.82
10	2.19	10	5.01	10	8.18	10	12.01	10	17.07	10	24.61	10	38.14
20	2.24	20	5.06	20	8.24	20	12.08	20	17.17	20	24.77	20	38.46
30	2.28	30	5.11	30	8.30	30	12.15	30	17.27	30	24.93	30	38.79
40	2.33	40	5.16	40	8.35	40	12.23	40	17.37	40	25.10	40	39.12
50	2.37	50	5.21	50	8.41	50	12.30	50	17.47	50	25.26	50	39.46
9 0	2.42	19 0	5.26	29 0	8.47	39 0	12.37	49 0	17.58	59 0	25.43	69 0	39.81
10	2.47	10	5.31	10	8.53	10	12.45	10	17.68	10	25.60	10	40.15
20	2.51	20	5.36	20	8.59	20	12.52	20	17.79	20	25.77	20	40.51
30	2.56	30	5.41	30	8.65	30	12.60	30	17.89	30	25.94	30	40.87
40	2.60	40	5.46	40	8.70	40	12.67	40	18.00	40	26.11	40	41.23
50	2.65	50	5.51	50	8.76	50	12.75	50	18.10	50	26.29	50	41.60
10 0	2.69	20 0	5.56	30 0	8.82	40 0	12.82	50 0	18.21	60 0	26.47	70 0	41.98

Fig. 41

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

16 November 1956
Nautical Almanac

Lunar Age 13.3

☉ Sun

U	E_n	d	P.P. of d	
h	h m s	° ′	h m	′
0	12 15 14	S 18 40.8	0 0	0.0
2	13	42.1	10	1
4	12	43.3	20	2
6	11	44.6	30	3
8	10	45.9	40	4
10	10	47.1	0 50	5
12	12 15 9	S 18 48.3	1 0	0.6
14	8	49.6	10	7
16	7	50.8	20	8
18	6	52.0	30	0.9
20	5	53.3	40	1.0
22	4	54.5	1 50	1
24	12 15 3	S 18 55.7	2 0	1.2

(視半径 S.D. 16′ 12″)

Star ($U = 0^h$)

No.	Star	E (h m s)	d (° ′)
1	Polaris	1 45 1	N 89 4.0
2	Kochab	12 49 27	71 19.9
3	Dubhe	16 39 5	61 50.7
4	β Cassiop.	3 33 15	58 55.1
5	Merak	16 40 55	56 36.5
6	Alioth	14 48 3	N 56 11.4
7	Schedir	3 2 4	56 18.4
8	Mizar	14 18 0	55 8.8
9	α Persei	0 18 52	49 42.6
10	Benetnasch	13 54 20	49 31.6
11	Capella	22 26 37	N 45 57.3
12	Deneb	7 0 12	45 7.9
13	Vega	9 4 42	38 44.8
14	Castor	20 8 17	31 58.9
15	Alpheratz	3 33 58	28 51.4
16	Pollux	19 57 27	N 28 7.7
17	α Cor. Bor.	12 7 19	26 51.6
18	Arcturus	13 26 29	19 24.4
19	Aldebaran	23 6 41	16 25.5
20	Markab	4 37 32	14 58.6
21	Denebola	15 53 18	N 14 48.7
22	α Ophiuchi	10 7 14	12 35.6
23	Regulus	17 34 4	12 10.6
24	Altair	7 51 29	8 45.4
25	Betelgeuse	21 47 17	7 24.0
26	Bellatrix	22 17 19	N 6 18.7
27	Procyon	20 3 5	N 5 20.2
29	Rigel	22 27 40	S 8 15.0
29	α Hydrae	18 14 41	8 20.2
30	Spica	14 17 15	10 56.2
31	Sirius	20 56 53	S 16 39.3
32	β Ceti	2 58 42	18 13.3
33	Antares	11 13 24	26 20.2
34	σ Sagittarii	8 47 34	26 21.1
35	Fomalhaut	4 44 52	29 51.1
36	λ Scorpii	10 9 29	S 37 4.4
37	Canopus	21 17 8	52 40.2
38	α Pavonis	7 17 54	56 52.6
39	Achernar	2 4 1	57 27.4
40	β Crucis	14 54 59	59 27.0
41	β Centauri	13 39 25	S 60 9.8
42	α Centauri	13 3 32	60 39.5
43	α Crucis	15 15 59	62 51.5
44	α Tri. Aust.	10 56 6	68 57.1
45	β Carinae	18 27 24	S 69 32.1

R_0 = 3h 40m 9s

Planet

♀ Venus — Tr. 9h 31m

U	E_p	d	P.P. E_p		P.P. d
h	h m s	° ′	h m	s	′
0	14 29 44	S 5 29.3	0 0	0	0.0
2	41	31.6	10	0	2
4	38	33.9	20	1	4
6	35	36.1	30	1	6
8	32	38.3	40	1	0.8
10	29	40.6	0 50	1	1.0
12	14 29 26	S 5 42.8	1 0	2	1.2
14	23	45.1	10	2	3
16	20	47.3	20	2	5
18	17	49.6	30	2	7
20	14	51.9	40	3	1.9
22	11	54.1	1 50	3	2.1
24	14 29 8	S 5 56.4	2 0	3	2.3

♂ Mars — Tr. 19h 47m

U	E_p	d	P.P. E_p		P.P. d
h	h m s	° ′	h m	s	′
0	4 11 21	S 4 51.3	0 0	0	0.0
2	34	50.3	10	1	1
4	11 48	49.3	20	2	2
6	12 1	48.3	30	3	2
8	14	47.3	40	4	3
10	27	46.3	0 50	5	4
12	4 12 40	S 4 45.3	1 0	7	0.5
14	12 53	44.3	10	8	6
16	13 5	43.3	20	9	7
18	18	42.3	30	10	7
20	31	41.3	40	11	8
22	44	40.3	1 50	12	0.9
24	4 13 57	S 4 39.3	2 0	13	1.0

♃ Jupiter — Tr. 8h 7m

U	E_p	d	P.P. E_p		P.P. d
h	h m s	° ′	h m	s	′
0	15 51 30	N 2 26.5	0 0	0	0.0
2	51 47	26.2	10	1	0
4	52 4	25.9	20	3	1
6	21	25.6	30	4	1
8	38	25.2	40	6	1
10	52 54	24.9	0 50	7	1
12	15 53 11	N 2 24.5	1 0	9	0.2
14	28	24.3	10	10	2
16	53 45	24.0	20	11	2
18	54 2	23.8	30	13	2
20	18	23.5	40	14	3
22	35	23.2	1 50	16	3
24	15 54 52	N 2 22.9	2 0	17	0.3

♄ Mars — Tr. 12h 27m

U	E_p	d	P.P. E_p		P.P. d
h	h m s	° ′	h m	s	′
0	11 30 54	S 19 17.0	0 0	0	0.0
2	31 12	17.1	10	1	0
4	29	17.2	20	3	0
6	31 46	17.3	30	4	0
8	32 3	17.5	40	6	0
10	21	17.6	0 50	7	0
12	11 32 38	S 19 17.7	1 0	9	0.1
14	32 55	17.8	10	10	1
16	33 12	17.9	20	11	1
18	30	18.0	30	13	1
20	33 47	18.2	40	14	1
22	34 4	18.3	1 50	16	1
24	11 34 22	S 19 18.4	2 0	17	0.1

☾ Moon — Tr. 22h 34m

U	$E_{☾}$	d
h	h m s	° ′
0	2 12 19	N 12 24.5
	11 19	29.4
1	10 19	34.3
	9 19	39.2
2	8 19	44.0
	7 19	48.9
3	6 19	53.7
	5 18	12 58.6
4	4 18	13 3.4
	3 18	8.2
5	2 17	13.0
	1 17	17.8
(H.P. 57′.2, S.D. 15′ 36″)		
6	2 0 16	N 13 22.5
	1 59 15	27.3
7	58 14	32.0
	57 13	36.7
8	56 12	41.4
	55 11	46.1
9	54 10	50.8
	53 9	13 55.4
10	52 7	14 0.1
	51 6	4.7
11	50 5	9.3
	49 3	13.9
(H.P. 57′.4, S.D. 15′ 39″)		
12	1 48 1	N 14 18.5
	47 0	23.0
13	45 58	27.6
	44 56	32.1
14	43 54	36.6
	42 52	41.1
15	41 50	45.5
	40 47	50.0
16	39 45	54.4
	38 43	14 58.9
17	37 40	15 3.3
	36 38	7.6
(H.P. 57′.6, S.D. 15′ 42″)		
18	1 35 35	N 15 12.0
	34 32	16.3
19	33 29	20.7
	32 27	25.0
20	31 23	29.2
	30 20	33.5
21	29 17	37.8
	28 14	42.0
22	27 11	46.2
	26 7	50.4
23	25 4	54.6
	24 0	15 58.7
24	1 22 56	N 16 2.8
(H.P. 57′.8, S.D. 15′ 46″)		

P.P. (Moon, U 0h–11h)

$E_{☾}$ (m)	(s)	d (′)
1	2	0.2
2	4	3
3	6	5
4	8	6
5	10	8
6	12	0.9
7	14	1.1
8	16	3
9	18	4
10	20	6
11	22	7
12	24	1.9
13	26	2.0
14	28	2
15	31	4
16	33	5
17	35	7
18	37	2.8
19	39	3.0
20	41	1
21	43	3
22	45	4
23	47	6
24	49	8
25	51	3.9
26	53	4.1
27	55	2
28	57	4
29	59	5
30	61	4.7

P.P. (Moon, U 12h–24h)

$E_{☾}$ (m)	(s)	d (′)
1	2	0.1
2	4	3
3	6	4
4	8	6
5	11	7
6	13	0.9
7	15	1.0
8	17	2
9	19	3
10	21	5
11	23	6
12	25	8
13	27	1.9
14	29	2.1
15	32	2
16	34	3
17	36	5
18	38	6
19	40	8
20	42	2.9
21	44	3.1
22	46	2
23	48	4
24	50	5
25	53	7
26	55	3.8
27	57	4.0
28	59	1
29	61	3
30	63	4.4

Planet

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	13 10	S 5 29	−3.5	0.1	7
♂	23 29	S 4 51	−0.8	0.2	7
♃	11 49	N 2 26	−1.4	0.0	16
♄	16 9	S 19 17	+0.7	0.0	7
♅	15 32	S 19 33	−0.8	0.1	2

Fig. 42

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

Solution

Ship's time 16 Nov. 1956	$12^h\ 00^m\ 00^s$	
L. in T. (41^o - 28′E)	2 45 52 ⊖	
G.D.	$09^h\ 14^m\ 08^s$	
T_2	$09^h\ 26^m\ 08^s$	
T_1	08 21 38 ⊖	
	01 04 30	
2)	01 04 30	
Diff.	$0^h\ 32^m\ 15^s$	
T_1	$08^h\ 21^m\ 38^s$	
C.E.	04 13 ⊕	
U. 16 Nov. 1956	$08^h\ 25^m\ 51^s$	
Diff.	0 32 15 ⊕	
U. 16 Nov. 1956	$08^h\ 58^m\ 06^s$	→ d = 18^o - 46.4 S

E ⊙ for 08h 58m 10s = $12^h\ 15^m\ 10^s$ (from the nautical almanac)

Δd = ⊕ 0.6 (d of P.P. for one hour)

By the nautical almanac,

U = 8h → d	= 18^o- 45′.8s
P.P. for $58^m\ 06^s$	0.6
d for $08^h\ 58^m\ 06^s$=	18^o- 46′.4s

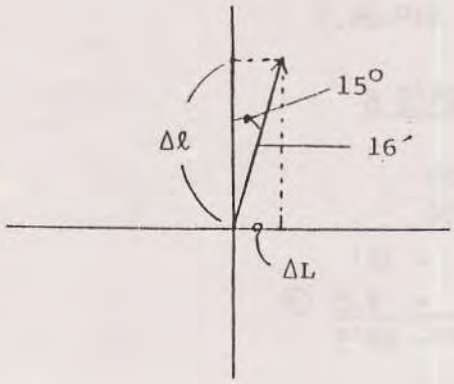
True course 015^o = N 15^oE } → Δℓ = ⊖ 15′.5 (for one hour)

speed = 16 knots ΔL = ⊕ 4′.1 (for one hour)

ℓ = 04^o- 06′.s Δℓ = 16′ x cos 15^o ≒ 15′.5

ΔL = 16′ x sin 15^o ≒ 4′.1

Feb.



ℓ had the same name as d, celestial body was the sun, longitude was east

$$h = -15^s.28\,(\tan \ell - \tan d)(\Delta\ell - \Delta d)\left(1 - \frac{\Delta L}{900}\right)$$

$$= -15^s.28\,\{\tan(04^\circ 06') - \tan(18^\circ 46'.4)\}(\ominus 15.5 - 0.6)\left\{1 - \frac{4.1}{900}\right\}$$

$$= -\left[15^s.28\,\{\tan(04^\circ 06)\}\right] - \left[15^a.28 \tan(18^\circ 46'.4)\right](\ominus 15.5 - 0.6)\left[1 - \frac{4.1}{900}\right]$$

$15^s.28\,\{\tan(04^\circ 06)\}$ → -1.09

$15^a.28 \tan(18^\circ 46'.4)$ → 5.19

By the table

So,

$$= -(1.09 - 5.19)(-15.5 - 0.6)\left(1 - \frac{4.1}{900}\right)$$

$$= -(-4.1)(-16.1)(0.995)$$

$$= -(66.01)(0.995)$$

$$= -65^s.67955$$

$$\doteqdot \ominus 1^m\ 06^s$$

then,	$24^h\ 00^m\ 00^s$	
	01 06	$\ominus$
h	$23^h\ 58^m\ 54^s$	
$E_\odot$	12 15 10	$\ominus$
L.M.L. 16 Nov. 1956	$11^h\ 43^m\ 44^s$	
U. 16 Nov. 1956	8 58 06	$\ominus$
L. in T.	2 45 38	
	↓	
Longitude	41°-24.5	

<u>Ans. long = $41^\circ - 24'.5$ E</u>

2^h	30°
-44^m	11°
-01^m	$-15'$
$-38^s\ \oplus$	$-9.5\ \oplus$
2^h- 45^m- 38^s ⟶	41°- 24'5

Example

On 22 March 1956, a navigator observed the sun's equal altitude before the time of transit and after the time of transit in D.R.P. 02° - 10'N, 70° - 10'E

What was the longitude at noon of ship's time?

Where: Ship's true course was 325°, speed 18 Knots,
chronometer error ⊖ 0^m 16^s
Chronometer time of 1st observation was 06^h 58^m 53^s
Chronometer time of 2nd observation was 07^h 54^m 57^s
Time zone was (U + 4^h 36^m)

Solution (See Figs. 41 and 43)

Ship's T.	22 Mar, 1956	12^h 00^m 00^s	T_1	07^h 54^m 57^s
L in T		4 41 00 ⊖	T_2	06 58 53 ⊖
G.D.	22 Mar, 1956	07 19 00		00 56 04
			2)	00 56 04
			Diff.	00^h 28^m 02^s
T_1		06^h 58^m 53^s		
C.E.		0 16 ⊖		
U_1	22 Mar, 1956	06 58 37		
Diff.		0 28 02	⊕ d = 0° - 39'.6 N	
U	22 Mar, 1956	07 26 39 →	Δd = ⊕ 1.0 (d of P.P. for one hour)	
$E_⊙$		11 53 01	(From nautical almanac)	

True Course 325° = N 35°W
Speed = 18.0 knots ⟶ Δℓ ⊕ 14'.7
ℓ = 2° - 10'N ΔL ⊖ 10'.3

ℓ had the same name as d
celestial body was the sun
longitude was east

$$h = -15^s.28\,(\tan \ell - \tan d)\,(\Delta\ell - \Delta d)\left(1 - \frac{\Delta L}{900}\right)$$

$$= -(0.58 - 0.18)(14.7 - 1.0)\left(1 + \frac{10.3}{900}\right)$$

$$= -\left(0.40 \times 13.7 \times \frac{910.3}{900}\right)$$

$$= -6^s$$

	24^h	00^m	00^s		
			06	⊖	
h	23	59	54		
E ☉	11	53	01	⊖	
L.M.T.	12	06	53		(22 Mar. 1956)
U	7	26	39	⊖	(22 Mar. 1956)
L. in T.	4	40	14		
Long.	70° 03'.5 E ← This longitude was for arithmetic mean time				

So the arithmetic mean time should be converted into ship's time as follows:

U 22 Mar. 1956	07^h	26^m	39^s	
L. in T.	04	36	00	⊕
Ship's T. 22 Mar. 1956	12	02	39	

Next, calculate D. long for $02^m\ 39^s$ shown as below:

$$10'.3\ W \times \frac{2.65}{60} = 0'.5\ W$$

then

70° - 03'.5 E
0.5 E ⊕ ← Be careful of the sign

Ans. 70° - 04.0 E

22 March 1956
Nautical Almanac

Lunar Age $9^d.4$

☉ Sun

U (h)	E☉ (h m s)	d (° ′)	P.P. of d (h m)	P.P. of d (′)
0	11 52 56	N 0 32.2	0 0	0.0
2	57	34.2	10	2
4	52 59	36.2	20	3
6	53 0	38.2	30	5
8	2	40.1	40	7
10	3	42.1	0 50	0.8
12	11 53 5	N 0 44.1	1 0	1.0
14	6	46.0	10	2
16	8	48.0	20	3
18	9	50.0	30	5
20	11	52.0	40	7
22	12	53.9	1 50	1.8
24	11 53 14	N 0 55.9	2 0	2.0

S.D. 16′ 5″

✳ Star ($U = 0^h$)

No.	Star	E* (h m s)	d (° ′)
1	Polaris	10 5 39	N89 3.8
2	Kochab	21 7 1	74 19.8
3	Dubhe	0 56 47	61 59.2
4	β Cassiop.	11 51 4	58 54.5
5	Merak	0 58 37	56 36.9
6	Alioth	23 5 44	N56 11.6
7	Schedir	11 19 53	56 17.9
8	Mizar	22 35 40	55 9.0
9	α Persei	8 36 42	49 42.6
10	Benetnasch	22 12 2	49 31.6
11	Capella	6 44 25	N45 57.5
12	Deneb	15 17 57	45 7.2
13	Vega	17 22 25	38 44.3
14	Castor	4 26 3	31 59.2
15	Alpheratz	11 51 46	28 50.9
16	Pollux	4 15 13	N28 8.0
17	α Cor. Bor.	20 25 1	26 51.4
18	Arcturus	21 44 11	19 24.3
19	Aldebaran	7 24 20	16 25.3
20	Markab	12 55 19	14 58.1
21	Denebola	0 11 1	N14 48.8
22	α Ophiuchi	18 24 58	12 35.3
23	Regulus	1 51 48	12 10.7
24	Altair	16 9 14	8 45.0
25	Betelgeuse	6 5 4	7 23.9
26	Bellatrix	6 35 5	N 6 18.6
27	Procyon	4 20 51	N 5 20.1
28	Rigel	6 45 26	S 8 15.2
29	α Hydrae	2 32 25	8 28.4
30	Spica	22 34 58	10 58.2
31	Sirius	5 14 39	S16 39.6
32	β Ceti	11 16 30	18 13.6
33	Antares	19 31 8	26 20.2
34	σ Sagittarii	17 5 19	26 21.1
35	Fomalhaut	13 2 39	29 51.2
36	λ Scorpii	18 27 13	S37 4.3
37	Canopus	5 34 54	52 40.6
38	α Pavonis	15 35 41	56 52.4
39	Achernar	10 21 49	57 27.6
40	β Crucis	23 12 40	59 27.1
41	β Centauri	21 57 6	S60 9.8
42	α Centauri	21 21 13	60 39.[illegible]
43	α Crucis	23 33 40	62 51.5
44	α Tri. Aust.	19 13 49	68 56.8
45	β Carinae	2 45 6	S69 32.5

R_0 11h 57m 53s

Planet

♀ Venus — Tr. 14h 53m

U (h)	E (h m s)	d (° ′)	P.P. (h m)	P.P. E (s)	P.P. d (′)
0	9 6 56	N18 29.3	0 0	0	0.0
2	54	31.2	10	0	2
4	52	33.2	20	0	3
6	50	35.1	30	1	5
8	48	37.1	40	1	6
10	46	39.0	0 50	1	0.8
12	9 6 44	N18 40.9	1 0	1	1.0
14	42	42.8	10	1	1
16	40	44.8	20	1	3
18	38	46.7	30	2	4
20	36	48.6	40	2	6
22	34	50.5	1 50	2	7
24	9 6 32	N18 52.4	2 0	2	1.9

♂ Mars — Tr. 7h 5m

U (h)	E (h m s)	d (° ′)	P.P. (h m)	P.P. E (s)	P.P. d (′)
0	16 54 41	S23 11.2	0 0	0	0.0
2	47	11.0	10	1	0
4	52	10.7	20	1	1
6	54 58	10.5	30	2	1
8	55 3	10.2	40	2	1
10	9	10.0	0 50	3	1
12	16 55 15	S23 9.7	1 0	3	0.2
14	20	9.5	10	4	2
16	26	9.2	20	4	2
18	31	8.9	30	5	2
20	37	8.7	40	5	3
22	42	8.4	1 50	6	3
24	16 55 48	S23 8.2	2 0	6	0.3

♃ Jupiter — Tr. 21h 40m

U (h)	E (h m s)	d (° ′)	P.P. (h m)	P.P. E (s)	P.P. d (′)
0	2 16 36	N15 5.7	0 0	0	0.0
2	16 53	5.8	10	2	0
4	17 19	5.9	20	4	0
6	17 40	6.1	30	5	0
8	18 2	6.2	40	7	0
10	23	6.3	0 50	9	0
12	2 18 44	N15 6.4	1 0	11	0.1
14	19 5	6.5	10	12	1
16	27	6.7	20	14	1
18	19 40	6.8	30	16	1
20	20 9	6.9	40	18	1
22	30	7.0	1 50	19	1
24	2 20 52	N15 7.2	2 0	21	0.1

♄ Saturn — Tr. 4h 6m

U (h)	E (h m s)	d (° ′)	P.P. (h m)	P.P. E (s)	P.P. d (′)
0	19 53 25	S18 35.2	0 0	0	0.0
2	53 45	35.2	10	2	0
4	54 5	35.1	20	3	0
6	25	35.1	30	5	0
8	54 45	35.1	40	7	0
10	55 5	35.1	0 50	8	0
12	19 55 25	S18 35.0	1 0	10	0.0
14	55 45	35.0	10	12	0
16	56 5	35.0	20	13	0
18	25	34.9	30	15	0
20	56 45	34.9	40	17	0
22	57 5	34.9	1 50	10	0
24	19 57 25	S18 34.8	2 0	20	0.0

☾ Moon — Tr. 20h 59m

U (h)	E☾ (h m s)	d (° ′)
0	3 46 35	N16 1.2
	45 29	15 56.3
1	44 22	51.5
	43 16	46.6
2	42 10	41.7
	41 3	36.7
3	39 57	31.8
	38 51	26.8
4	37 45	21.8
	36 38	16.8
5	35 32	11.7
	34 26	6.6
(H.P. 59′.5, S.D. 16′ 12″)		
6	3 33 21	N15 1.5
	32 15	14 56.4
7	31 9	51.3
	30 3	46.1
8	28 57	40.9
	27 52	35.7
9	26 46	30.4
	25 41	25.2
10	24 35	19.9
	23 30	14.6
11	22 24	9.3
	21 19	14 3.9
(H.P. 59′.5, S.D. 16′ 12″)		
12	3 20 14	N13 58.6
	19 8	53.2
13	18 3	47.0
	16 58	42.4
14	15 53	36.9
	14 48	31.4
15	13 43	26.0
	12 38	20.4
16	11 33	14.9
	10 29	9.4
17	9 24	13 3.8
	8 19	12 58.2
(H.P. 59′.4, S.D. 16′ 12″)		
18	3 7 15	N12 52.6
	6 10	47.0
19	5 6	41.4
	4 1	35.7
20	2 57	30.0
	1 52	24.3
21	3 0 48	18.6
	2 59 44	12.9
22	58 40	7.1
	57 36	12 1.4
23	56 31	11 55.6
	55 27	49.8
24	2 54 23	N11 43.9
(H.P. 59′.4, S.D. 16′ 11″)		

P.P.

m	E☾ (s)	d (′)
1	2	0.2
2	4	3
3	6	5
4	9	7
5	11	0.9
6	13	1.0
7	15	2
8	17	4
9	19	5
10	22	7
11	24	1.9
12	26	2.0
13	28	2
14	30	4
15	33	6
16	35	7
17	37	2.9
18	39	3.1
19	41	2
20	43	4
21	45	6
22	48	7
23	50	3.9
24	52	4.1
25	54	3
26	56	4
27	58	6
28	61	8
29	63	4.9
30	65	5.1

m	E☾ (s)	d (′)
1	2	0.2
2	4	4
3	6	6
4	9	7
5	11	0.9
6	13	1.1
7	15	3
8	17	5
9	19	7
10	21	1.9
11	23	2.1
12	26	2
13	28	4
14	30	6
15	32	2.8
16	34	3.0
17	36	2
18	38	4
19	41	5
20	43	7
21	45	3.9
22	47	4.1
23	49	3
24	51	5
25	53	7
26	55	4.9
27	58	5.0
28	60	2
29	62	4
30	64	5.6

Planet

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	2 51	N18 29	−3.8	0.2	10
♂	19 3	S23 11	+0.9	0.1	3
♃	9 41	N15 6	−2.0	0.0	20
♄	16 4	S18 35	+0.5	0.0	8
♅	23 17	S 7 4	−0.5	0.1	3

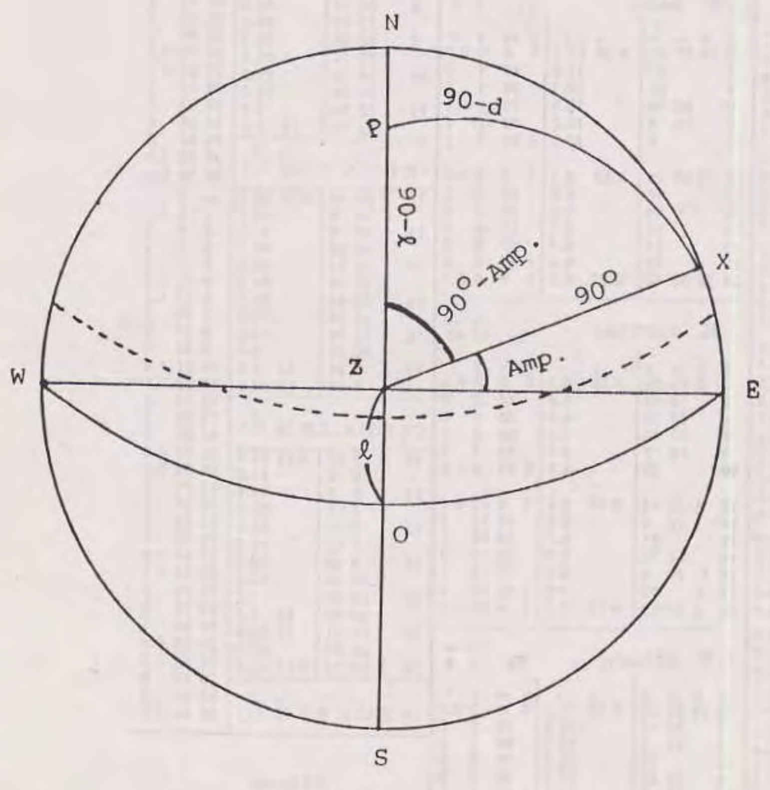
Fig. 43

Extrated from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

True Bearing by Amplitude

When the navigator observes direction of a celestial body by ship's compass and knows its true direction by calculation, it is possible to obtain the compass error or its deviation.

If the navigator observes the direction of a celestial body when its true altitude is zero or its center is just on the celestial horizon by his compass, and calculates its true direction, he can obtain compass error or deviation of the compass.



P = Celestial pole
Z = Zenith
X = Celestial body on the celestial horizon

Fig. 44

In Figure 44, ZX = 90°, so PZX is quadrantal triangle
then, $\sin(90^\circ - PX) = \cos(90^\circ - PZ)\cos \angle PZX$

$$PX = 90^\circ - d,\ PZ = 90^\circ - \ell^\circ$$

$$\sin\{90^\circ - (90^\circ - d^\circ)\} = \cos\{90^\circ - (90^\circ - \ell^\circ)\}\cos \angle PZX$$

$$\sin\{90^\circ - 90^\circ + d^\circ\} = \cos\{90^\circ - 90^\circ + \ell^\circ\}\cos \angle PZX$$

$$\sin d = \cos\ell^\circ \,.\, \cos \angle PZX$$

$$\angle PZX = 90^\circ \pm \text{Amp.}$$

$$\sin d = \cos \ell.\ \cos(90^\circ \pm \text{Amp.})$$

$$= \cos \ell.\ \sin \text{Amp.}$$

$$\sin \text{Amp.} = \frac{\sin d}{\cos \ell} \quad \sec \ell.\ \sin d$$

$$\therefore \underline{\sin \text{Amp.} = \sec \ell.\ \sin d} \quad \text{or Amp.} = \sin^{-1}(\sec\ell \sin d)$$

Ref.

Formula of trigonometric function

$$\cos(\theta \pm \Psi) = \cos\theta \cos\Psi \pm \sin\theta \sin\Psi$$

so, $\cos(90^\circ \pm \text{Amp.}) = \underline{\cos 90.}\ \cos \text{Amp.} \mp \underline{\sin 90}.\ \sin \text{Amp.}$

$$\cos 90 \to 0, \quad \sin 90 \to 1$$

$$= \underline{0.\ \cos \text{Amp}}. \mp \underline{1.\ \sin \text{Amp}}.$$

$$\to 0 \quad \mp \quad \sin \text{Amp.}$$

$$= \mp \sin \text{Amp.}$$

If the navigator knows the amplitude of a celestial body, true bearing can be given as follows,

$$\underline{\text{True bearing} = 90^\circ - \text{true Amp.}}$$

Note 1

Prefix of amplitude should be E or W, and suffix of amplitude should be N or S.

At sunrise, prefix of amplitude → E
At sunset, prefix of amplitude → W
Suffix is the same as declination's name

Note 2

When d is zero, that is, the celestial body is located on the celestial equator,

$$\begin{aligned} \sin \text{Amp.} &= \sec \ell \times \sin d \\ &= \sec \ell \times \sin d\ 0^{\circ} \\ &= \sec \ell \times 0 \\ &= 0 \\ \text{Amp.} &= 0 \end{aligned}$$

In this case, the celestial body rises in due east (90°) sets in due west (270°)

When ℓ is zero, the navigator is located on the equator.

$$\begin{aligned} \sin \text{Amp.} &= \sec 0^{\circ} \times \sin d \\ & \quad 1 \times \sin d \\ &= \sin d \\ \text{Amp.} &= d \end{aligned}$$

In this case, the value of Amplitude is equal to the value of d.

True bearing by Amplitude of the sun

The sun is the celestial body observed most frequently when obtaining an Amplitude

When the navigator observes the lower limb of the sun, its altitude correction is shown as:

True Alt.$\ominus$ = Obs. Alt. - Dip-Ref. + S.D. + Par
Ref. = Refraction. S.D. = Visible semi-diameter
Par. = Parallax

In the case of observing Amplitude, True. Alt ⊖ (true altitude of the sun) should be zero. so.

$$0 = \text{Obs. Alt.} - \text{Dip.} - \text{Ref.} + \text{S.D.} + \text{Par.}$$
$$\therefore \text{Obs. Alt.} = \text{Dip.} + \text{Ref.} - \text{S.D.} - \text{Par.}$$

When sunset or sunrise,

Ref. = 29', S.D. = 13' and Par. = 8" 95 ≑ 0
then Obs. Alt. = Dip. + 29' - 13' - 0' = Dip + 16'

If the observer's height of eye is 15 feet (= 4.6 metres), Dip is about 4', so, Obs. Alt. 4' + 16' = 20'

"Obs. Alt. = 20'" means that when the lower limb of the sun is 20 above the horizon, true altitude of the sun should be zero (sunrise or sunset)

The only time when the navigator should observe the amplitude of the sun is when the sun's lower limb is about 20' (nearly half of semidiameter) above visible horizon.

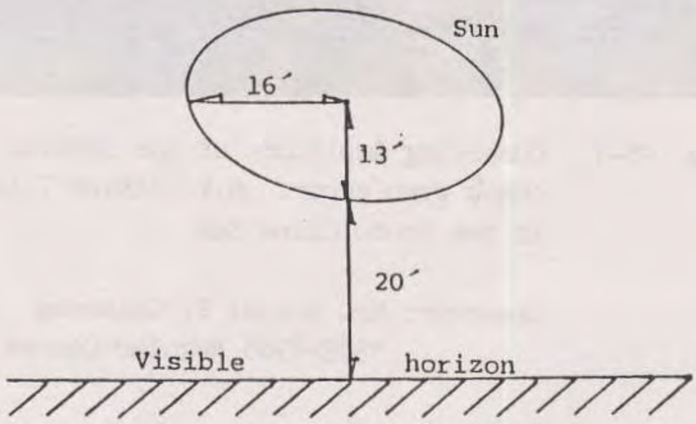


Fig. 45 Amplitude of the sun

Needless to say, when you observe the direction of the sun, you have to observe the center of the sun.

Fig. 45-1 Observing Amplitude of the setting sun to check gyro error. M.V. PAKNAM 7 Aug. 1985, in the South China Sea

Observer: Mr. Roscal P. Galunsag
1983-1985 Regular Course Trainee

Example 10

On 5 August 1956, a navigator observed true amplitude of the rising sun in D.R.P. 32°- 20'N, 129°- 48'E by magnetic compass as N 88°.5 E. What was the deviation of compass? Where: variation 5°.2 W

Solution

(From nautical almanac Fig. 47)
↓

d (5 Aug. 1956, U = 0h)	17° 02'.8 N	} → $6^h\ 45^n$ (from Fig. 50)
ℓ	32° 20' N	
	$12^h\ 00^m\ 00^s$	
h_o	06 45 00 ⊖	
L.A.T. 5 Aug. 1956	05 15 00	
L in T.	08 39 00 ⊖	
G.A.T. 4 Aug. 1956	20 36 00	

↓

d (4 Aug. 1956 U = $20^h\ 36^m\ 00^s$) 17°- 05'.9 N } 20°.4 (from Fig. 51)
32°- 20'.0 N

Ref.

sin Amp. = sin d Sec ℓ = sin (17° 05'.9) x sec (32°- 20'.0)
= 0.29404 x 1.18350 = 0.347996 ....
Amp. = 20°- 22'
= 20°.4 ←

True Amp. = E 20°.4 N ← Be careful about both prefix and suffix

	90°.0 -	
True B'g	= N 69°.6 E	
Comp. B'g	= N 88°.5 E	
Comp. error	= 18°.9 W	
Var.	= 5°.2 W	
Dev.	= 13°.7 W	Ans. Deviation = 13°.7 W

4 August 1956
Nautical Almanac

Lunar Age 26.8 d

☉ Sun

U	$E_☉$	d	P.P. of d	
h	h m s	° ′	h m	′
0	11 53 59	N17 18.9	0 0	0.0
2	53 59	17.5	10	1
4	54 0	16.2	20	2
6	0	14.9	30	3
8	0	13.5	40	4
10	1	12.2	0 50	5
12	11 54 1	N17 10.9	1 0	0.7
14	2	9.5	10	8
16	2	8.2	20	0.9
18	3	6.9	30	1.0
20	3	5.5	40	1
22	4	4.2	1 50	2
24	11 54 4	N17 2.8	2 0	1.3

S.D. 15′ 48″

✱ Star ($U = 0^h$)

No.	Star	$E_✱$ (h m s)	d (° ′)
1	*Polaris*	18 56 9	N89 3.4
2	*Kochab*	5 59 20	74 20.3
3	*Dubhe*	9 49 6	61 59.2
4	*β Cassiop.*	20 43 14	58 54.6
5	*Merak*	9 50 55	56 37.0
6	*Alioth*	7 58 1	N56 11.9
7	*Schedir*	20 12 4	56 17.9
8	*Mizar*	7 27 57	55 9.3
9	*α Persei*	17 28 54	49 42.3
10	*Benetnasch*	7 4 18	49 32.0
11	*Capella*	15 36 39	N45 57.2
12	*Deneb*	0 10 8	45 7.6
13	*Vega*	2 14 38	38 44.8
14	*Castor*	13 18 18	31 59.1
15	*Alpheratz*	20 43 58	28 51.1
16	*Pollux*	13 7 29	N28 7.9
17	*α Cor. Bor.*	5 17 16	26 51.8
18	*Arcturus*	6 36 26	19 24.6
19	*Aldebaran*	16 16 42	16 25.4
20	*Markab*	21 47 30	14 58.4
21	*Denebola*	9 3 17	N14 48.9
22	*α Ophiuchi*	3 17 11	12 35.6
23	*Regulus*	10 44 4	12 10.8
24	*Altair*	1 1 26	8 45.4
25	*Betelgeuse*	14 57 19	7 24.0
26	*Bellatrix*	15 27 20	N 6 18.7
27	*Procyon*	13 13 6	N 5 20.2
28	*Rigel*	15 37 41	S 8 14.9
29	*α Hydrae*	11 24 41	8 28.2
30	*Spica*	7 27 13	10 56.2
31	*Sirius*	14 6 54	S16 39.3
32	*β Ceti*	20 8 42	18 19.2
33	*Antares*	4 23 22	26 20.3
34	*σ Sagittarii*	1 57 31	26 21.0
35	*Fomalhaut*	21 54 50	29 50.9
36	*λ Scorpii*	3 19 26	S37 4.5
37	*Canopus*	14 27 10	52 40.2
38	*α Pavonis*	0 27 51	56 52.4
39	*Achernar*	19 14 1	57 27.0
40	*β Crucis*	8 4 57	59 27.4
41	*β Centauri*	6 49 22	S60 10.2
42	*α Centauri*	6 13 28	60 39.8
43	*α Crucis*	8 25 57	62 51.8
44	*α Tri. Aust.*	4 6 1	68 57.3
45	*β Carinae*	11 37 27	S69 32.4

$R_☉$ 20h 50m 8s

Planet

♀ Venus Tr. 9h 8m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	14 51 12	N18 29.0	0 0	0	0.0
2	19	29.2	10	1	0
4	25	29.5	20	1	1
6	32	29.8	30	2	1
8	39	30.1	40	2	1
10	45	30.4	0 50	3	1
12	14 51 52	N18 30.7	1 0	4	0.2
14	51 58	30.9	10	4	2
16	52 5	31.2	20	5	2
18	11	31.5	30	5	2
20	18	31.8	40	6	3
22	24	32.1	1 50	6	3
24	14 52 30	N18 32.3	2 0	7	0.3

♂ Mars Tr. 2h 54m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	21 5 32	S 7 49.6	0 0	0	0.0
2	5 50	49.6	10	2	0
4	6 7	49.7	20	3	0
6	25	49.7	30	5	0
8	6 43	49.7	40	6	0
10	7 1	49.7	0 50	8	0
12	21 7 18	S 7 49.7	1 0	9	0.0
14	36	49.8	10	11	0
16	7 54	49.8	20	12	0
18	8 12	49.8	30	14	0
20	30	49.9	40	15	0
22	8 48	49.9	1 50	17	0
24	21 9 6	S 7 49.9	2 0	18	0.0

♃ Jupiter Tr. 13h 38m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	10 20 7	N10 27.5	0 0	0	0.0
2	23	27.1	10	1	0
4	38	26.7	20	3	1
6	20 54	26.3	30	4	1
8	21 10	26.0	40	5	1
10	26	25.6	0 50	7	2
12	10 21 42	N10 25.2	1 0	8	0.2
14	21 57	24.8	10	9	2
16	22 13	24.4	20	11	3
18	29	24.0	30	12	3
20	22 45	23.7	40	13	3
22	23 1	23.3	1 50	15	4
24	10 23 16	N10 22.9	2 0	16	0.4

♄ Saturn Tr. 10h 44m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	5 12 42	S17 20.9	0 0	0	0.0
2	19 2	21.0	10	2	0
4	22	21.0	20	3	0
6	18 41	21.0	30	5	0
8	14 1	21.0	40	7	0
10	20	21.1	0 50	8	0
12	5 14 40	S17 21.1	1 0	10	0.0
14	15 0	21.1	10	12	0
16	19	21.2	20	13	0
18	39	21.2	30	15	0
20	15 58	21.2	40	17	0
22	16 18	21.3	1 50	18	0
24	5 16 37	S17 21.3	2 0	20	0.0

☾ Moon Tr. 10h 2m

U	$E_☾$	d
h	h m s	° ′
0	14 22 31	N20 42.9
	21 17	40.6
1	20 3	38.2
	18 49	35.8
2	17 35	33.4
	16 20	30.9
3	15 6	28.4
	13 52	25.8
4	12 38	23.2
	11 24	20.6
5	10 10	17.9
	8 56	15.2
(H.P.60.′8, S.D.16′ 34″)		
6	14 7 42	N20 12.5
	6 28	9.7
7	5 14	6.9
	4 0	4.0
8	2 46	20 1.1
	1 32	19 58.2
9	14 0 18	55.2
	13 59 4	52.2
10	57 50	49.1
	56 36	46.1
11	55 22	42.9
	54 8	39.8
(H.P.60.′9, S.D.16′ 36″)		
12	13 52 55	N19 36.6
	51 41	33.4
13	50 27	30.1
	49 13	26.8
14	48 0	23.5
	46 46	20.1
15	45 32	16.7
	44 19	13.2
16	43 5	9.7
	41 52	6.2
17	40 38	19 2.7
	39 25	18 59.1
(H.P.61.′0, S.D.16′ 38″)		
18	13 38 11	N18 55.5
	36 58	51.8
19	35 45	48.1
	34 31	44.4
20	33 18	40.6
	32 5	36.8
21	30 52	33.0
	29 39	29.1
22	28 25	25.2
	27 12	21.3
23	25 59	17.3
	24 46	13.3
24	13 23 33	N18 9.3
(H.P.61.′1, S.D.16′ 39″)		

P.P. (Moon)

$E_☾$ (m)	(s)	d (′)
1	2	0.1
2	5	2
3	7	3
4	10	4
5	12	5
6	15	5
7	17	6
8	20	7
9	22	8
10	25	0.9
11	27	1.0
12	30	1
13	32	2
14	35	3
15	37	4
16	39	4
17	42	5
18	44	6
19	47	7
20	49	8
21	52	1.9
22	54	2.0
23	57	1
24	59	2
25	62	3
26	64	3
27	67	4
28	69	5
29	72	6
30	74	2.7

$E_☾$ (m)	(s)	d (′)
1	2	0.1
2	5	2
3	7	4
4	10	5
5	12	6
6	15	7
7	17	0.8
8	19	1.0
9	22	1
10	24	2
11	27	3
12	29	4
13	32	6
14	34	7
15	37	8
16	39	1.9
17	41	2.0
18	44	2
19	46	3
20	49	4
21	51	5
22	54	6
23	56	8
24	58	2.9
25	61	3.0
26	63	1
27	66	2
28	68	4
29	71	5
30	73	3.6

Planet

	R.A.	d	Mag.	H.P.	S.D.
	h m	° ′		′	″
♀	5 59	N18 23	−4.2	0.3	17
♂	23 45	S 7 50	−1.9	0.3	10
♃	10 30	N10 27	−1.3	0.0	15
♄	15 37	S17 21	+0.7	0.0	8
☿	9 58	N13 52	−0.5	0.1	3

Fig. 46

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

5 August 1956
Nautical Almanac

Lunar d
Age 27.8

☉ Sun

U (h)	E☉ (h m s)	d (° ')	P.P. of d (h m)	(')
0	11 54 4	N17 2.8	0 0	0.0
2	5	1.5	10	1
4	5	17 0.1	20	2
6	5	16 58.8	30	4
8	6	57.4	40	5
10	7	56.1	0 50	6
12	11 54 7	N16 54.7	1 0	0.7
14	8	53.3	10	8
16	8	52.0	20	0.9
18	9	50.6	30	1.1
20	9	49.2	40	2
22	10	47.9	1 50	3
24	11 54 10	N16 46.5	2 0	1.4

S.D. 15' 48"

✱ Star (U = 0h)

No.	Star	E✱ (h m s)	d (° ')
1	Polaris	19 0 4	N89 3.4
2	Kochab	6 3 17	74 20.3
3	Dubhe	9 53 2	61 59.2
4	β Cassiop.	20 47 11	58 54.6
5	Merak	9 54 52	56 37.0
6	Alioth	8 1 58	N56 11.9
7	Schedir	20 16 0	56 17.9
8	Mizar	7 31 54	55 9.3
9	α Persei	17 32 51	49 42.3
10	Benetnasch	7 8 15	49 32.0
11	Capella	15 40 35	N45 57.2
12	Deneb	0 14 5	45 7.7
13	Vega	2 18 34	38 44.0
14	Castor	13 22 15	31 59.1
15	Alpheratz	20 47 54	28 51.1
16	Pollux	13 11 25	N28 7.9
17	α Cor. Bor.	5 21 13	26 51.8
18	Arcturus	6 40 23	19 24.6
19	Aldebaran	16 20 30	16 25.4
20	Markab	21 51 27	14 58.4
21	Denebola	9 7 14	N14 48.9
22	α Ophiuchi	3 21 8	12 35.6
23	Regulus	10 48 1	12 10.0
24	Altair	1 5 22	8 45.4
25	Betelgeuse	15 1 15	7 24.0
26	Bellatrix	15 31 16	N 6 18.7
27	Procyon	13 17 3	N 5 20.2
28	Rigel	15 41 37	S 8 14.9
29	α Hydrae	11 28 38	8 28.2
30	Spica	7 31 10	10 56.2
31	Sirius	14 10 51	S16 39.3
32	β Ceti	20 12 38	18 13.2
33	Antares	4 27 18	26 20.3
34	σ Sagittarii	2 1 28	26 21.0
35	Fomalhaut	21 58 47	29 50.9
36	λ Scorpii	3 23 23	S37 4.5
37	Canopus	14 31 7	52 40.2
38	α Pavonis	0 31 47	56 52.4
39	Achernar	19 17 58	57 27.0
40	β Crucis	8 8 54	59 27.4
41	β Centauri	6 53 10	S60 10.2
42	α Centauri	6 17 25	60 39.8
43	α Crucis	8 29 54	62 51.8
44	α Tri. Aust.	4 9 57	68 57.3
45	θ Carinae	11 41 23	S69 32.4

Rθ 20h 54m 4s

Planet

♀ Venus (Tr. 9h 7m)

U (h)	Ep (h m s)	d (° ')	P.P. (h m)	Ep (s)	d (')
0	11 52 30	N18 32.3	0 0	0	0.0
2	37	32.6	10	1	0
4	43	32.9	20	1	1
6	49	33.2	30	2	1
8	52 55	33.5	40	2	1
10	53 2	33.7	0 50	3	1
12	11 53 8	N18 34.0	1 0	3	0.2
14	14	34.3	10	4	2
16	20	34.6	20	4	2
18	26	34.9	30	5	2
20	32	35.1	40	5	3
22	39	35.4	1 50	6	3
24	11 53 41	N18 35.7	2 0	6	0.3

♂ Mars (Tr. 2h 50m)

U (h)	Ep (h m s)	d (° ')	P.P. (h m)	Ep (s)	d (')
0	21 9 6	S 7 49.9	0 0	0	0.0
2	21	50.0	10	2	0
4	9 42	50.0	20	3	0
6	10 0	50.1	30	5	0
8	18	50.1	40	6	0
10	36	50.2	0 50	8	0
12	21 10 54	S 7 50.2	1 0	9	0.1
14	11 12	50.3	10	11	1
16	30	50.3	20	12	1
18	11 48	50.4	30	14	1
20	12 6	50.4	40	15	1
22	24	50.5	1 50	17	1
24	21 12 43	S 7 50.6	2 0	18	0.1

♃ Jupiter (Tr. 13h 35m)

U (h)	Ep (h m s)	d (° ')	P.P. (h m)	Ep (s)	d (')
0	10 23 16	N10 22.9	0 0	0	0.0
2	32	22.5	10	1	0
4	23 48	22.1	20	3	1
6	24 4	21.7	30	4	1
8	20	21.4	40	5	1
10	35	21.0	0 50	7	2
12	10 24 51	N10 20.6	1 0	8	0.2
14	25 7	20.2	10	9	2
16	23	19.8	20	11	3
18	39	19.4	30	12	3
20	25 51	19.1	40	13	3
22	26 10	18.7	1 50	15	4
24	10 26 26	N10 18.3	2 0	16	0.4

♄ Saturn (Tr. 18h 40m)

U (h)	Ep (h m s)	d (° ')	P.P. (h m)	Ep (s)	d (')
0	5 16 37	S17 21.3	0 0	0	0.0
2	16 57	21.3	10	2	0
4	17 16	21.3	20	3	0
6	36	21.4	30	5	0
8	17 56	21.4	40	7	0
10	18 15	21.4	0 50	8	0
12	5 18 35	S17 21.5	1 0	10	0.0
14	18 54	21.5	10	12	0
16	19 14	21.5	20	13	0
18	[illegible]	21.6	30	15	0
20	19 53	21.6	40	17	0
22	20 12	21.6	1 50	18	0
24	5 20 32	S17 21.7	2 0	20	0.0

☾ Moon (Tr. 11h 3m)

U (h)	E☾ (h m s)	d (° ')
0	13 23 33	N18 9.3
	22 21	5.2
1	21 0	18 1.1
	19 55	17 57.0
2	18 42	52.8
	17 29	48.6
3	16 17	44.4
	15 4	40.1
4	13 52	35.8
	12 39	31.5
5	11 27	27.1
	10 14	22.7
(H.P. 61'.2, S.D. 16' 40")		
6	13 9 2	N17 18.3
	7 49	13.6
7	6 37	9.4
	5 25	4.8
8	4 13	17 0.3
	3 1	16 55.7
9	1 49	51.1
	13 0 37	46.5
10	12 59 25	41.8
	58 13	37.1
11	57 1	32.3
	55 49	27.6
(H.P. 61'.2, S.D. 16' 41")		
12	12 54 37	N16 22.8
	53 26	18.0
13	52 14	13.1
	51 2	8.2
14	49 51	16 3.3
	48 39	15 58.4
15	47 28	53.4
	46 17	48.5
16	45 5	43.4
	43 54	38.4
17	42 43	33.3
	41 32	28.2
(H.P. 61'.3, S.D. 16' 42")		
18	12 40 21	N15 23.1
	39 10	17.9
19	37 59	12.7
	36 48	7.5
20	35 37	15 2.3
	34 26	14 57.0
21	33 16	51.7
	32 5	46.4
22	30 54	41.1
	29 44	35.7
23	28 33	30.3
	27 23	24.9
24	12 26 13	N14 19.5
(H.P. 61'.3, S.D. 16' 42")		

P.P. (Moon)

m	E☾ (s)	d (')	m	E☾ (s)	d (')
1	2	0.1	1	2	0.2
2	5	3	2	5	3
3	7	4	3	7	5
4	10	6	4	9	7
5	12	7	5	12	0.9
6	14	0.9	6	14	1.0
7	17	1.0	7	17	2
8	19	2	8	19	4
9	22	3	9	21	5
10	24	5	10	24	7
11	26	6	11	26	1.9
12	29	8	12	28	2.0
13	31	1.9	13	31	2
14	34	2.1	14	33	4
15	36	2	15	36	6
16	38	3	16	38	7
17	41	5	17	40	2.9
18	43	6	18	43	3.1
19	46	8	19	45	2
20	48	2.9	20	47	4
21	50	3.1	21	50	6
22	53	2	22	52	7
23	55	4	23	54	3.9
24	58	5	24	57	4.1
25	60	7	25	59	3
26	62	3.8	26	62	4
27	65	4.0	27	64	6
28	67	1	28	66	8
29	70	3	29	69	4.9
30	72	4.4	30	71	5.1

Planet

	R.A. (h m)	d (° ')	Mag.	H.P. (')	S.D. (")
♀	6 2	N10 32	−4.2	0.3	17
♂	23 45	S 7 50	−1.9	0.3	10
♃	10 31	N10 23	−1.3	0.0	15
♄	15 37	S17 21	+0.7	0.0	8
☿	10 5	N13 11	−0.4	0.1	3

Fig. 47

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

RISING AND SETTING HOUR ANGLE (True Alt.=0°) (1956)

lat.	*d*															
l	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0
2	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2
4	0	1	1	1	1	2	2	2	3	3	3	3	4	4	4	5
6	0	1	1	2	2	3	3	3	4	4	5	5	6	6	6	7
8	1	1	2	2	3	3	4	5	5	6	6	7	7	8	9	9
10	6 1	6 1	6 2	6 3	6 4	6 4	6 5	6 6	6 6	6 7	6 8	6 9	6 9	6 10	6 11	6 12
12	1	2	3	3	4	5	6	7	8	9	9	10	11	12	13	14
14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16	1	2	3	5	6	7	8	9	10	12	13	14	15	16	18	19
18	1	3	4	5	7	8	9	10	12	13	14	16	17	19	20	21
20	6 1	6 3	6 4	6 6	6 7	6 9	6 10	6 12	6 13	6 15	6 16	6 18	6 19	6 21	6 22	6 24
21	2	3	5	6	8	9	11	12	14	16	17	19	20	22	24	25
22	2	3	5	6	8	10	11	13	15	16	18	20	21	23	25	27
23	2	3	5	7	9	10	12	14	15	17	19	21	22	24	26	28
24	2	4	5	7	9	11	13	14	16	18	20	22	24	25	27	29
25	6 2	6 4	6 6	6 7	6 9	6 11	6 13	6 15	6 17	6 19	6 21	6 23	6 25	6 27	6 29	6 31
26	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
27	2	4	6	8	10	12	14	16	19	21	23	25	27	29	31	34
28	2	4	6	9	11	13	15	17	19	22	24	26	28	30	33	35
29	2	4	7	9	11	13	16	18	20	22	25	27	29	32	34	37
30	6 2	6 5	6 7	6 9	6 12	6 14	6 16	6 19	6 21	6 23	2 26	6 28	6 31	6 33	6 36	6 38
31	2	5	7	10	12	14	17	19	22	24	27	29	32	34	37	40
32	3	5	8	10	13	15	18	20	23	25	28	31	33	36	39	41
33	3	5	8	10	13	16	18	21	24	26	29	32	34	37	40	43
34	3	5	8	11	14	16	19	22	25	27	30	33	36	39	42	45
35	6 3	6 6	6 8	6 11	6 14	6 17	6 20	6 23	6 25	6 28	6 31	6 34	6 37	6 40	6 43	6 46
36	3	6	9	12	15	18	20	23	26	29	32	36	39	42	45	48
37	3	6	9	12	15	18	21	24	27	31	34	37	40	43	47	50
38	3	6	9	13	16	19	22	25	28	32	35	38	42	45	48	52
39	3	6	10	13	16	20	23	26	29	33	36	40	43	47	50	54
40	6 3	6 7	6 10	6 13	6 17	6 20	6 24	6 27	6 31	6 34	6 38	6 41	6 45	6 48	6 52	6 56
41	3	7	10	14	17	21	25	28	32	35	39	43	46	50	54	6 58
42	4	7	11	14	18	22	25	29	33	37	40	44	48	52	56	7 0
43	4	7	11	15	19	22	26	30	34	38	42	46	50	54	6 58	2
44	4	8	12	15	19	23	27	31	35	39	43	47	52	56	7 0	4
45	6 4	6 8	6 12	6 16	6 20	6 24	6 28	6 32	6 36	6 41	6 45	6 49	6 53	6 58	7 2	7 7
46	4	8	12	17	21	25	29	33	38	42	46	51	55	7 0	4	9
47	4	9	13	17	22	26	30	35	39	44	48	53	57	2	7	12
48	4	9	13	18	22	27	31	36	41	45	50	55	6 59	4	9	14
49	5	9	14	18	23	28	32	37	42	47	52	57	7 2	7	12	17
50	6 5	6 10	6 14	6 19	6 24	6 29	6 34	6 39	6 44	6 49	6 54	6 59	7 4	7 9	7 14	7 20
51	5	10	15	20	25	30	35	40	45	50	56	7 1	6	12	17	23
52	5	10	15	21	26	31	36	41	47	52	6 58	3	9	14	20	26
53	5	11	16	21	27	32	38	43	49	54	7 0	6	11	17	23	29
54	6	11	17	22	28	33	39	45	50	56	2	8	14	20	27	33
55	6 6	6 11	6 17	6 23	6 29	6 35	6 40	6 46	6 52	6 58	7 4	7 11	7 17	7 23	7 30	7 37
56	6	12	18	24	30	36	42	48	54	7 1	7	13	20	27	34	41
57	6	12	19	25	31	37	44	50	56	3	10	16	23	30	37	45
58	6	13	19	26	32	39	45	52	6 59	6	12	20	27	34	42	49
59	7	13	20	27	33	40	47	54	7 1	8	15	23	30	38	46	54
60	6 7	6 14	6 21	6 28	6 35	6 42	6 49	6 56	7 4	7 11	7 19	7 26	7 34	7 42	7 51	7 59
61	7	14	22	29	36	44	51	6 59	6	14	22	30	38	47	7 56	8 5
62	8	15	23	30	38	46	53	7 1	9	17	26	34	43	52	8 1	11
63	8	16	24	32	40	48	56	4	12	21	30	39	48	7 57	7	17
64	8	16	25	33	41	50	6 58	7	16	25	34	43	53	8 3	13	24
65	6 9	6 17	6 26	6 34	6 43	6 52	7 1	7 10	7 19	7 29	7 39	7 48	7 59	8 9	8 20	8 32

when name of latitude is the same as declination, use tabulated value, when it is contrary, use as follows: 12h - tabulated value

Fig. 48

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

RISING AND SETTING AZIMUTH (True Alt.=0°) (1956)

lat.	Declination															
l	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°
0°	1.0°	2.0°	3.0°	4.0°	5.0°	6.0°	7.0°	8.0°	9.0°	10.0°	11.0°	12.0°	13.0°	14.0°	15.0°	16.0°
2	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
4	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
6	1.0	2.0	3.0	4.0	5.0	6.0	7.1	8.1	9.1	10.1	11.1	12.1	13.1	14.1	15.1	16.1
8	1.0	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.1	10.1	11.1	12.1	13.1	14.1	15.2	16.2
10	1.0	2.0	3.1	4.1	5.1	6.1	7.1	8.1	9.2	10.2	11.2	12.2	13.2	14.2	15.3	16.3
12	1.0	2.1	3.1	4.1	5.1	6.1	7.2	8.2	9.2	10.2	11.3	12.3	13.3	14.3	15.4	16.4
14	1.0	2.1	3.1	4.1	5.2	6.2	7.2	8.3	9.3	10.3	11.3	12.4	13.4	14.4	15.5	16.5
16	1.1	2.1	3.1	4.2	5.2	6.2	7.3	8.3	9.4	10.4	11.5	12.5	13.5	14.6	15.6	16.7
18	1.1	2.1	3.2	4.2	5.3	6.3	7.4	8.4	9.5	10.5	11.6	12.6	13.7	14.7	15.8	16.9
20	1.1	2.1	3.2	4.3	5.3	6.4	7.5	8.5	9.6	10.6	11.7	12.8	13.9	14.9	16.0	17.1
21	1.1	2.2	3.2	4.3	5.4	6.4	7.5	8.6	9.7	10.7	11.8	12.9	14.0	15.0	16.1	17.2
22	1.1	2.2	3.2	4.3	5.4	6.5	7.6	8.6	9.7	10.8	11.9	13.0	14.1	15.1	16.2	17.3
23	1.1	2.2	3.3	4.4	5.4	6.5	7.6	8.7	9.8	10.9	12.0	13.1	14.2	15.3	16.3	17.4
24	1.1	2.2	3.3	4.4	5.5	6.6	7.7	8.8	9.9	11.0	12.1	13.2	14.3	15.4	16.5	17.6
25	1.1	2.2	3.3	4.4	5.5	6.6	7.7	8.8	9.9	11.1	12.2	13.3	14.4	15.5	16.6	17.7
26	1.1	2.2	3.4	4.5	5.6	6.7	7.8	8.9	10.0	11.2	12.3	13.4	14.5	15.6	16.8	17.9
27	1.1	2.3	3.4	4.5	5.6	6.7	7.9	9.0	10.1	11.3	12.4	13.5	14.6	15.8	16.9	18.0
28	1.1	2.3	3.4	4.5	5.7	6.8	7.9	9.1	10.2	11.4	12.5	13.6	14.8	15.9	17.1	18.2
29	1.2	2.3	3.4	4.6	5.7	6.9	8.0	9.2	10.3	11.5	12.6	13.8	14.9	16.1	17.2	18.4
30	1.2	2.3	3.5	4.6	5.8	6.9	8.1	9.3	10.4	11.6	12.7	13.9	15.1	16.2	17.4	18.6
31	1.2	2.3	3.5	4.7	5.8	7.0	8.2	9.4	10.5	11.7	12.9	14.0	15.2	16.4	17.6	18.8
32	1.2	2.4	3.6	4.7	5.9	7.1	8.3	9.5	10.6	11.8	13.0	14.2	15.4	16.6	17.8	19.0
33	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4	15.6	16.8	18.0	19.2
34	1.2	2.4	3.6	4.8	6.0	7.3	8.5	9.7	10.9	12.1	13.3	14.5	15.8	17.0	18.2	19.4
35	1.2	2.5	3.7	4.9	6.1	7.3	8.6	9.8	11.0	12.2	13.5	14.7	16.0	17.2	18.4	19.7
36	1.2	2.5	3.7	5.0	6.2	7.4	8.7	9.9	11.2	12.4	13.7	14.9	16.2	17.4	18.7	19.9
37	1.3	2.5	3.8	5.0	6.3	7.5	8.8	10.0	11.3	12.6	13.8	15.1	16.4	17.6	18.9	20.2
38	1.3	2.5	3.8	5.1	6.4	7.6	8.9	10.2	11.4	12.7	14.0	15.3	16.6	17.9	19.2	20.5
39	1.3	2.6	3.9	5.2	6.4	7.7	9.0	10.3	11.6	12.9	14.2	15.5	16.8	18.1	19.5	20.8
40	1.3	2.6	3.9	5.2	6.5	7.9	9.2	10.5	11.8	13.1	14.4	15.8	17.1	18.4	19.8	21.1
41	1.3	2.7	4.0	5.3	6.6	8.0	9.3	10.6	12.0	13.3	14.7	16.0	17.4	18.7	20.1	21.4
42	1.4	2.7	4.0	5.4	6.7	8.1	9.4	10.8	12.2	13.5	14.9	16.3	17.6	19.0	20.4	21.8
43	1.4	2.7	4.1	5.5	6.9	8.2	9.6	11.0	12.4	13.7	15.1	16.5	17.9	19.3	20.7	22.1
44	1.4	2.8	4.2	5.6	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.1	22.5
45	1.4	2.8	4.3	5.7	7.1	8.5	9.9	11.4	12.8	14.2	15.7	17.1	18.6	20.0	21.5	23.0
46	1.4	2.9	4.3	5.8	7.2	8.7	10.1	11.6	13.0	14.5	16.0	17.4	18.9	20.4	21.9	23.4
47	1.5	2.9	4.4	5.9	7.4	8.8	10.3	11.8	13.3	14.8	16.3	17.8	19.3	20.8	22.3	23.8
48	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.1	16.6	18.1	19.7	21.2	22.8	24.3
49	1.5	3.1	4.6	6.1	7.6	9.2	10.7	12.3	13.8	15.4	16.9	18.5	20.1	21.6	23.2	24.9
50	1.6	3.1	4.7	6.2	7.8	9.4	10.9	12.5	14.1	15.7	17.3	18.9	20.5	22.1	23.8	25.4
51	1.6	3.2	4.8	6.4	8.0	9.6	11.2	12.8	14.4	16.0	17.7	19.3	21.0	22.6	24.3	26.0
52	1.6	3.3	4.9	6.5	8.1	9.8	11.4	13.1	14.7	16.4	18.1	19.7	21.4	23.2	24.9	26.6
53	1.7	3.3	5.0	6.7	8.3	10.0	11.7	13.4	15.1	16.8	18.5	20.2	22.0	23.7	25.5	27.3
54	1.7	3.4	5.1	6.8	8.5	10.3	12.0	13.7	15.4	17.2	19.0	20.7	22.5	24.3	26.1	28.0
55	1.8	3.5	5.2	7.0	8.7	10.5	12.3	14.1	15.8	17.6	19.4	21.2	23.1	25.0	26.8	28.7
56	1.8	3.6	5.4	7.2	9.0	10.8	12.6	14.4	16.3	18.1	20.0	21.8	23.7	25.6	27.6	29.5
57	1.8	3.7	5.5	7.4	9.2	11.1	12.9	14.8	16.7	18.6	20.5	22.4	24.4	26.4	28.4	30.4
58	1.9	3.8	5.7	7.6	9.5	11.4	13.3	15.2	17.2	19.1	21.1	23.1	25.1	27.2	29.2	31.3
59	2.0	3.9	5.8	7.8	9.8	11.7	13.7	15.7	17.7	19.7	21.7	23.8	25.9	28.0	30.2	32.4
60	2.0	4.0	6.0	8.0	10.0	12.1	14.1	16.2	18.2	20.3	22.4	24.6	26.7	28.9	31.2	33.5
61	2.1	4.1	6.2	8.3	10.4	12.5	14.6	16.7	18.8	21.0	23.2	25.4	27.7	29.9	32.3	34.7
62	2.1	4.3	6.4	8.6	10.7	12.9	15.1	17.3	19.5	21.7	24.0	26.3	28.6	31.0	33.5	36.0
63	2.2	4.4	6.6	8.8	11.1	13.3	15.6	17.9	20.2	22.5	24.9	27.3	29.7	32.2	34.8	37.4
64	2.3	4.6	6.9	9.2	11.5	13.8	16.1	18.5	20.9	23.3	25.8	28.3	30.9	33.5	36.2	39.0
65	2.4	4.7	7.1	9.5	11.8	14.3	16.8	19.2	21.7	24.3	26.8	29.5	32.2	34.9	37.8	40.7

Azimuth should be measured from E or W (Prefix)
Suffix is the same as for declination

Fig. 49

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

RISING AND SETTING HOUR ANGLE (True Alt.=0°) (1956)

lat.	Declination d														
l	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0
2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	5
4	5	5	5	6	6	6	6	7	7	7	8	8	9	9	9
6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14
8	9	10	10	11	12	12	13	14	14	15	16	16	17	18	19
10	6 12	6 12	6 13	6 14	6 15	6 16	6 16	6 17	6 18	6 19	6 20	6 21	6 22	6 22	6 23
12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
14	16	17	19	20	21	22	23	24	25	27	28	29	30	32	33
16	19	20	21	23	24	25	27	28	29	31	32	34	35	37	38
18	21	23	24	26	27	29	30	32	33	35	36	38	40	42	43
20	6 24	6 26	6 27	6 29	6 30	6 32	6 34	6 36	6 37	6 39	6 41	6 43	6 45	6 47	6 49
21	25	27	29	30	32	34	36	38	39	41	43	45	47	49	51
22	27	28	30	32	34	36	38	40	41	43	45	48	50	52	54
23	28	30	32	34	36	38	40	42	44	46	48	50	52	54	6 57
24	29	31	33	35	37	39	41	44	46	48	50	52	55	6 57	7 0
25	6 31	6 33	6 35	6 37	6 39	6 41	6 43	6 46	6 48	6 50	6 53	6 55	6 57	7 0	7 2
26	32	34	36	39	41	43	45	48	50	53	55	6 58	7 0	3	5
27	34	36	38	40	43	45	48	50	52	55	6 58	7 0	3	6	8
28	35	37	40	42	45	47	50	52	55	6 57	7 0	3	6	9	12
29	37	39	42	44	47	49	52	54	6 57	7 0	3	6	9	12	15
30	6 38	6 41	6 43	6 46	6 49	6 51	6 54	6 57	7 0	7 2	7 5	7 8	7 12	7 15	7 18
31	40	42	45	48	51	53	56	6 59	2	5	8	11	15	18	21
32	41	44	47	50	53	56	6 58	7 2	5	8	11	14	18	21	25
33	43	46	49	52	55	6 58	7 1	4	7	11	14	17	21	24	28
34	45	48	51	54	57	7 0	3	7	10	13	17	20	24	28	32
35	6 46	6 49	6 53	6 56	6 59	7 2	7 6	7 9	7 13	7 16	7 20	7 24	7 27	7 31	7 35
36	48	51	55	6 58	7 1	5	8	12	15	19	23	27	31	35	39
37	50	53	57	7 0	4	7	11	15	18	22	26	30	34	39	43
38	52	55	6 59	2	6	10	14	17	21	25	30	34	38	43	47
39	54	57	7 1	5	9	12	16	20	25	29	33	37	42	47	51
40	6 56	6 59	7 3	7 7	7 11	7 15	7 19	7 23	7 28	7 32	7 37	7 41	7 46	7 51	7 56
41	6 58	7 2	6	10	14	18	22	27	31	36	40	45	50	7 55	8 0
42	7 0	4	8	12	17	21	25	30	35	39	44	49	54	8 0	5
43	2	6	11	15	19	24	29	33	38	43	48	53	7 59	4	10
44	4	9	13	18	22	27	32	37	42	47	52	7 58	8 4	9	16
45	7 7	7 11	7 16	7 21	7 25	7 30	7 35	7 40	7 46	7 51	7 57	8 3	8 8	8 15	8 21
46	9	14	19	24	29	34	39	44	50	7 55	8 1	7	14	20	27
47	12	17	22	27	32	37	43	48	54	8 0	6	12	19	26	33
48	14	19	25	30	35	41	47	53	7 59	5	11	18	25	32	40
49	17	22	28	33	39	45	51	7 57	8 3	10	17	24	31	38	46
50	7 20	7 25	7 31	7 37	7 43	7 49	7 55	8 2	8 8	8 15	8 22	8 30	8 37	8 45	8 54
51	23	29	35	41	47	53	8 0	6	13	21	28	36	44	8 53	9 2
52	26	32	38	45	51	7 58	5	12	19	27	35	43	8 52	9 1	11
53	29	36	42	49	7 56	8 2	10	17	25	33	41	50	9 0	9	20
54	33	40	46	53	8 0	8	15	23	31	40	49	8 58	8	19	30
55	7 37	7 44	7 51	7 58	8 5	8 13	8 21	8 29	8 38	8 47	8 57	9 7	9 18	9 29	9 42
56	41	48	7 55	8 3	11	19	27	36	45	8 55	9 5	16	28	41	9 55
57	45	52	8 0	8	16	25	34	43	8 53	9 4	15	27	40	9 54	10 11
58	49	7 57	5	14	22	32	41	8 51	9 2	13	25	38	9 53	10 10	30
59	54	8 2	11	20	29	39	49	9 0	11	24	37	9 52	10 9	29	10 56
60	7 59	8 8	8 17	8 26	8 36	8 47	8 58	9 9	9 22	9 35	9 51	10 8	10 28	10 55	12 0
61	8 5	14	24	34	44	8 55	9 7	20	34	9 49	10 7	27	10 54	12 0	
62	11	20	31	41	8 53	9 5	18	32	9 47	10 5	26	10 54	12 0		
63	17	27	38	8 50	9 2	16	30	9 46	10 4	25	10 53	12 0			
64	24	35	47	9 0	13	28	9 44	10 2	24	10 52	12 0				
65	8 32	8 44	8 57	9 10	9 25	9 42	10 0	10 22	10 51	12 0					

when the name of latitude is the same as declination, use tabulated value; when contrary, use 12h - tabulated value

Fig. 50

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

RISING AND SETTING AZIMUTH (True Alt.=0°) (1956)

lat. *l*	Declination *d* 16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
0°	16.0°	17.0°	18.0°	19.0°	20.0°	21.0°	22.0°	23.0°	24.0°	25.0°	26.0°	27.0°	28.0°	29.0°	30.0°
2	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0
4	16.0	17.1	18.1	19.1	20.1	21.1	22.1	23.1	24.1	25.1	26.1	27.1	28.1	29.1	30.1
6	16.1	17.1	18.1	19.1	20.1	21.1	22.1	23.1	24.1	25.1	26.2	27.2	28.2	29.2	30.2
8	16.2	17.2	18.2	19.2	20.2	21.2	22.2	23.2	24.3	25.3	26.3	27.3	28.3	29.3	30.3
10	16.3	17.3	18.3	19.3	20.3	21.4	22.4	23.4	24.4	25.4	26.4	27.5	28.5	29.5	30.5
12	16.4	17.4	18.4	19.4	20.5	21.5	22.5	23.6	24.6	25.6	26.6	27.7	28.7	29.7	30.7
14	16.5	17.5	18.6	19.6	20.6	21.7	22.7	23.8	24.8	25.8	26.9	27.9	28.9	30.0	31.0
16	16.7	17.7	18.8	19.8	20.9	21.9	22.9	24.0	25.0	26.1	27.1	28.2	29.2	30.3	31.4
18	16.9	17.9	19.0	20.0	21.1	22.1	23.2	24.3	25.3	26.4	27.5	28.5	29.6	30.7	31.7
20	17.1	18.1	19.2	20.3	21.4	22.4	23.5	24.6	25.6	26.7	27.8	28.9	30.0	31.1	32.2
21	17.2	18.3	19.3	20.4	21.5	22.6	23.7	24.8	25.8	26.9	28.0	29.1	30.2	31.3	32.4
22	17.3	18.4	19.5	20.6	21.7	22.7	23.8	24.9	26.0	27.1	28.2	29.3	30.4	31.5	32.6
23	17.4	18.5	19.6	20.7	21.8	22.9	24.0	25.1	26.2	27.3	28.4	29.6	30.7	31.8	32.9
24	17.6	18.7	19.8	20.9	22.0	23.1	24.2	25.3	26.4	27.6	28.7	29.8	30.9	32.1	33.2
25	17.7	18.8	19.9	21.1	22.2	23.3	24.4	25.5	26.7	27.8	28.9	30.1	31.2	32.3	33.5
26	17.9	19.0	20.1	21.2	22.4	23.5	24.6	25.8	26.9	28.0	29.2	30.3	31.5	32.6	33.8
27	18.0	19.2	20.3	21.4	22.6	23.7	24.9	26.0	27.2	28.3	29.5	30.6	31.8	33.0	34.1
28	18.2	19.3	20.5	21.6	22.8	24.0	25.1	26.3	27.4	28.6	29.8	30.9	32.1	33.3	34.5
29	18.4	19.5	20.7	21.9	23.0	24.2	25.4	26.5	27.7	28.9	30.1	31.3	32.5	33.7	34.9
30	18.6	19.7	20.9	22.1	23.3	24.5	25.6	26.8	28.0	29.2	30.4	31.6	32.8	34.1	35.3
31	18.8	20.0	21.1	22.3	23.5	24.7	25.9	27.1	28.3	29.5	30.8	32.0	33.2	34.5	35.7
32	19.0	20.2	21.4	22.6	23.8	25.0	26.2	27.4	28.7	29.9	31.1	32.4	33.6	34.9	36.1
33	19.2	20.4	21.6	22.9	24.1	25.3	26.5	27.8	29.0	30.3	31.5	32.8	34.0	35.3	36.6
34	19.4	20.6	21.9	23.1	24.4	25.6	26.9	28.1	29.4	30.7	31.9	33.2	34.5	35.8	37.1
35	19.7	20.9	22.2	23.4	24.7	26.0	27.2	28.5	29.8	31.1	32.4	33.7	35.0	36.3	37.6
36	19.9	21.2	22.5	23.7	25.0	26.3	27.6	28.9	30.2	31.5	32.8	34.1	35.5	36.8	38.2
37	20.2	21.5	22.8	24.1	25.4	26.7	28.0	29.3	30.6	31.9	33.3	34.6	36.0	37.4	38.8
38	20.5	21.8	23.1	24.4	25.7	27.1	28.4	29.7	31.1	32.4	33.8	35.2	36.6	38.0	39.4
39	20.8	22.1	23.4	24.8	26.1	27.5	28.8	30.2	31.6	32.9	34.3	35.8	37.2	38.6	40.1
40	21.1	22.4	23.8	25.2	26.5	27.9	29.3	30.7	32.1	33.5	34.9	36.4	37.8	39.3	40.8
41	21.4	22.8	24.2	25.6	27.0	28.4	29.8	31.2	32.6	34.1	35.5	37.0	38.5	40.0	41.5
42	21.8	23.2	24.6	26.0	27.4	28.8	30.3	31.7	33.2	34.7	36.2	37.7	39.2	40.7	42.3
43	22.1	23.6	25.0	26.4	27.9	29.3	30.8	32.3	33.8	35.3	36.8	38.4	39.9	41.5	43.1
44	22.5	24.0	25.4	26.9	28.4	29.9	31.4	32.9	34.4	36.0	37.5	39.2	40.7	42.4	44.0
45	23.0	24.4	25.9	27.4	28.9	30.5	32.0	33.6	35.1	36.7	38.3	39.9	41.6	43.3	45.0
46	23.4	24.9	26.4	28.0	29.5	31.1	32.6	34.2	35.8	37.5	39.1	40.8	42.5	44.3	46.0
47	23.8	25.4	27.0	28.5	30.1	31.7	33.3	35.0	36.6	38.3	40.0	41.7	43.5	45.3	47.2
48	24.3	25.9	27.5	29.1	30.7	32.4	34.1	35.7	37.4	39.2	40.9	42.7	44.5	46.4	48.4
49	24.9	26.5	28.1	29.8	31.4	33.1	34.8	36.6	38.3	40.1	41.9	43.8	45.7	47.7	49.7
50	25.4	27.1	28.7	30.4	32.2	33.9	35.6	37.4	39.3	41.1	43.0	44.9	46.9	49.0	51.1
51	26.0	27.7	29.4	31.2	32.9	34.7	36.5	38.4	40.3	42.2	44.2	46.2	48.2	50.4	52.6
52	26.6	28.4	30.1	31.9	33.8	35.6	37.5	39.4	41.4	43.4	45.4	47.5	49.7	52.0	54.3
53	27.3	29.1	30.9	32.8	34.6	36.6	38.5	40.5	42.5	44.6	46.7	49.0	51.3	53.7	56.2
54	28.0	29.8	31.7	33.6	35.6	37.6	39.6	41.7	43.8	46.0	48.2	50.6	53.0	55.6	58.3
55	28.7	30.7	32.6	34.6	36.7	33.7	40.8	42.9	45.2	47.5	49.8	52.3	54.9	57.7	60.7
56	29.5	31.5	33.6	35.6	37.7	39.9	42.1	44.3	46.7	49.1	51.6	54.3	57.1	60.1	63.4
57	30.4	32.5	34.6	36.7	38.9	41.2	43.5	45.9	48.3	50.9	53.6	56.5	59.6	62.9	66.7
58	31.3	33.5	35.7	37.9	40.2	42.6	45.0	47.5	50.1	52.9	55.8	59.9	62.4	66.2	70.7
59	32.4	34.6	36.9	39.2	41.6	44.1	46.7	49.4	52.2	55.1	58.3	61.8	65.7	70.3	76.2
60	33.5	35.3	38.2	40.6	43.2	45.8	48.5	51.4	54.4	57.7	61.2	65.2	69.9	75.8	90.0
61	34.7	37.1	39.6	42.2	44.9	47.7	50.6	53.7	57.0	60.6	64.7	69.4	75.5	90.0	
62	36.0	38.5	41.2	43.9	46.8	49.8	52.9	56.3	60.0	64.2	69.0	75.2	90.0		
63	37.4	40.1	42.9	45.8	48.9	52.1	55.6	59.4	63.6	68.6	74.9	90.0			
64	39.0	41.8	44.8	48.0	51.3	54.8	58.7	63.0	68.1	74.6	90.0				
65	40.7	43.6	47.0	50.4	54.0	58.0	62.4	67.6	74.2	90.0					

Azimuth should be measured from E or W (Prefix)
Suffix is the same as declination name

Fig. 51

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

Problem

On 14 February 1956, a navigator observed true amplitude of the sun setting in D.R.P. 27° - 06'N, 109° - 17'W by magnetic compass as N $87^{\circ}.5$ W. What was the compass deviation?

Where: Variation was $11^{\circ}.0$ E. (Ans. $27^{\circ}.7$W)
(Ref. True Amp. = W $14^{\circ}.2$ S, True b'g = s $75^{\circ}.8$ W)

Direction of Celestial Body by Time-Azimuth

Time-Azimuth method is used for calculating true direction of a celestial body by considering the local hour angle (h), declination (d) and observer's latitude (ℓ).

The time of celestial observation in this method for obtaining direction of a celestial body is not limited, unlike such as the method of True Bearing by Amplitude.

Basically, navigators can utilize this method at any time, but it is desirable and advisable that they observe a celestial body when its altitude is not too high.

For the purpose of obtaining true direction by using h, d, and ℓ, Tables of SDh are given. These tables are derived from the following formulae (see Fig. 52-61).

$$Z = X + Y$$

$$\log \tan x = \log \cos \frac{S}{2} + \log \operatorname{cosec} \frac{D}{2} + \log \tan \frac{h}{2}$$

$$\log \tan y = \log \sin \frac{S}{2} + \log \sec \frac{D}{2} + \log \tan \frac{h}{2}$$

$\log \tan x$	=	$\log \cos \frac{S}{2}$	+	$\log \operatorname{cosec} \frac{D}{2}$	+	$\log \tan \frac{h}{2}$
$\log \tan y$	=	$\log \sin \frac{S}{2}$	+	$\log \sec \frac{D}{2}$	+	$\log \tan \frac{h}{2}$
↓ Table xy		↓ Table S		↓ Table D		↓ Table h

To obtain true direction (bearing) by making use of these tables, it is necessary to calculate local hour angle (h) and declination by nautical almanac and navigator's dead reckoning position for latitude (ℓ)

Example

At $09^h\ 20^m$ a.m. on 10 June 1956, a navigator observed the compass bearing of the sun as S 86°.5 E in D.R.P. 32° - 32′N. 133° - 46′E. What was the deviation of this compass?

Where: Chronometer time was $0^h\ 43^m\ 37^s$, variation 5°.4 W, and chronometer error ⊖ $16^m\ 17^s$ (see Figs. 62 and 52-61)

Solution

1. To obtain d

Ship's T.	10 June 1956	$09^h\ 20^m\ 00^s$	
L. in T. (133°- 46′E)		08 55 04 ⊖	
G.D.	10 June 1956	00 24 56	(From almanac see Fig. 10) ↓
Chro. T.		00 43 37	
C.E.		16 17 ⊖	
U	10 June 1956	00 27 20 →	d = 22°- 59′.8 N

2. To obtain h

Ref. 1	U. 10 June 1956	$00^h\ 27^m\ 20^s$	(From almanac see Fig. 10)
	$E_{\odot}$	12 00 47 ⊕ ↙	
	h_G	12 28 07	
	h_G	187°- 01′.8	
Ref. 2	L (133° 46′E)	133 - 46.0 ⊕	
	h	320°- 47.8	
	d	22°- 59.8 N	
	ℓ	32°- 32.0 N	

Ref. 1

$h_G = U + E$ $h_G\odot = U + E_\odot$, $h_G ☾ = U + E ☾$ $h_GP = U + E_P$

$h_G* = U + E*$

Ref. 2

$H = h_G \pm L$ (when east longitude ⊕ and when west longitude ⊖)

$h = 320^\circ - 47.8$, $d = 22^\circ\ 59.8$ N, $= 32^\circ\ 32.0$ N

About S. Name of ℓ is same as name of d,

$S = \ell + d = (32^\circ\ 32) + (22^\circ\ 59'.8) = 55^\circ - 31'.8$

About D. Name of ℓ is same as name of d,

$D = \ell \sim d = (32^\circ - 32') \sim (22^\circ - 59'.8) = 09^\circ - 32'.2$

About h is given as $320^\circ\ 47'.8$

So,	S. = $55^\circ - 31'.8$	X_1 3147		Y_1 2868
	D = $09^\circ - 32'.2$	X_2 1080		Y_2 1
	h = $320^\circ - 47'.8$	X_3 2751	⊕	Y_3 2751 ⊕
		X_4 6978		Y_4 5620
		↓		↓
		$X = 75^\circ.2$		Y $9^\circ.4$

$x = 75^\circ.2$

$Y = \underline{9^\circ.4}$ ⊕ ← when $\ell > d$, $Z = X + Y$

$Z = \underline{S}\ 84^\circ.6\ \underline{E}$ when $h = 12^h \sim 24^h$, suffix should be E

$h = 320^\circ - 47'.8 \rightarrow 21h - 23m - 11s$

When $\ell > d$, measure from pole of contrary name of ℓ. ($\ell = 32^\circ$-32'N)

True bearing	=	S 84°6 E
Comp. bearing	=	S 86.5 E ⊖
Comp. error	=	1.9 E
Var.	=	5.4 W ⊕
Dev.	=	7°3 E

Ans. Deviation = 7°3 E

Azimuth Table-S

ℓ&d { same name → ℓ+d = S ; contrary name → ℓ~d = S }

S	X_1	Y_1	S	X_1	Y_1	S	X_1	Y_1	S	X_1	Y_1
° ′			° ′			° ′			° ′		
0 0	3200	− ∞	6 0	3199	1919	18 0	3195	2394	30 0	3185	2613
5	3200	+ 62	10	3199	1931	10	3195	2398	10	3185	2615
10	3200	363	20	3199	1942	20	3194	2402	20	3185	2618
15	3200	539	30	3199	1954	30	3194	2406	30	3184	2620
20	3200	664	40	3199	1965	40	3194	2410	40	3184	2622
25	3200	761	50	3199	1975	50	3194	2414	50	3184	2625
30	3200	840	7 0	3199	1986	19 0	3194	2418	31 0	3184	2627
35	3200	907	10	3199	1996	10	3194	2421	10	3184	2629
40	3200	965	20	3199	2006	20	3194	2425	20	3184	2631
45	3200	1016	30	3199	2016	30	3194	2429	30	3183	2634
50	3200	1062	40	3199	2025	40	3194	2432	40	3183	2636
55	3200	1103	50	3199	2034	50	3193	2436	50	3183	2638
1 0	3200	1141	8 0	3199	2044	20 0	3193	2440	32 0	3183	2640
5	3200	1176	10	3199	2053	10	3193	2443	10	3183	2643
10	3200	1208	20	3199	2061	20	3193	2447	20	3182	2645
15	3200	1238	30	3199	2070	30	3193	2450	30	3182	2647
20	3200	1266	40	3199	2078	40	3193	2454	40	3182	2649
25	3200	1292	50	3199	2087	50	3193	2457	50	3182	2651
30	3200	1317	9 0	3199	2095	21 0	3193	2461	33 0	3182	2653
35	3200	1340	10	3199	2103	10	3193	2464	10	3182	2655
40	3200	1363	20	3199	2110	20	3192	2467	20	3181	2658
45	3200	1384	30	3199	2118	30	3192	2471	30	3181	2660
50	3200	1404	40	3198	2126	40	3192	2474	40	3181	2662
55	3200	1423	50	3198	2133	50	3192	2477	50	3181	2664
2 0	3200	1442	10 0	3199	2140	22 0	3192	2481	34 0	3181	2666
5	3200	1460	10	3198	2147	10	3192	2484	10	3180	2668
10	3200	1477	20	3198	2154	20	3192	2487	20	3180	2670
15	3200	1493	30	3198	2161	30	3192	2490	30	3180	2672
20	3200	1509	40	3198	2168	40	3191	2493	40	3180	2674
25	3200	1524	50	3198	2175	50	3191	2497	50	3180	2676
30	3200	1539	11 0	3198	2182	23 0	3191	2500	35 0	3179	2678
35	3200	1553	10	3198	2188	10	3191	2503	10	3179	2680
40	3200	1567	20	3198	2194	20	3191	2506	20	3179	2682
45	3200	1580	30	3198	2201	30	3191	2509	30	3179	2684
50	3200	1593	40	3198	2207	40	3191	2512	40	3179	2686
55	3200	1606	50	3198	2213	50	3191	2515	50	3178	2688
3 0	3200	1618	12 0	3198	2219	24 0	3190	2518	36 0	3178	2690
5	3200	1630	10	3198	2225	10	3190	2521	10	3178	2692
10	3200	1641	20	3197	2231	20	3190	2524	20	3178	2694
15	3200	1653	30	3197	2237	30	3190	2527	30	3178	2696
20	3200	1664	40	3197	2243	40	3190	2530	40	3177	2698
25	3200	1674	50	3197	2248	50	3190	2532	50	3177	2700
30	3200	1685	13 0	3197	2254	25 0	3190	2535	37 0	3177	2701
35	3200	1695	10	3197	2259	10	3189	2538	10	3177	2703
40	3200	1705	20	3197	2265	20	3189	2541	20	3177	2705
45	3200	1715	30	3197	2270	30	3189	2544	30	3176	2707
50	3200	1724	40	3197	2275	40	3189	2547	40	3176	2709
55	3200	1734	50	3197	2281	50	3189	2549	50	3176	2711
4 0	3200	1743	14 0	3197	2286	26 0	3189	2552	38 0	3176	2713
5	3200	1752	10	3197	2291	10	3189	2555	10	3175	2714
10	3200	1761	20	3197	2296	20	3188	2558	20	3175	2716
15	3200	1769	30	3197	2301	30	3188	2560	30	3175	2718
20	3200	1778	40	3196	2306	40	3188	2563	40	3175	2720
25	3200	1786	50	3196	2311	50	3188	2566	50	3175	2722
30	3200	1794	15 0	3196	2316	27 0	3188	2568	39 0	3174	2723
35	3200	1802	10	3196	2320	10	3188	2571	10	3174	2725
40	3200	1810	20	3196	2325	20	3188	2573	20	3174	2727
45	3200	1817	30	3196	2330	30	3187	2576	30	3174	2729
50	3200	1825	40	3196	2334	40	3187	2579	40	3173	2731
55	3200	1832	50	3196	2339	50	3187	2581	50	3173	2732
5 0	3200	1840	16 0	3196	2344	28 0	3187	2584	40 0	3173	2734
5	3200	1847	10	3196	2348	10	3187	2586	10	3173	2736
10	3200	1854	20	3196	2352	20	3187	2589	20	3173	2738
15	3200	1861	30	3195	2357	30	3186	2591	30	3172	2739
20	3200	1868	40	3195	2361	40	3186	2594	40	3172	2741
25	3200	1874	50	3195	2365	50	3186	2596	50	3172	2743
30	3199	1881	17 0	3195	2370	29 0	3186	2599	41 0	3172	2744
35	3199	1888	10	3195	2374	10	3186	2601	10	3171	2746
40	3199	1894	20	3195	2378	20	3186	2603	20	3171	2748
45	3199	1900	30	3195	2382	30	3185	2606	30	3171	2749
50	3199	1907	40	3195	2386	40	3185	2608	40	3171	2751
55	3199	1913	50	3195	2390	50	3185	2611	50	3170	2753
6 0	3199	1919	18 0	3195	2394	30 0	3185	2613	42 0	3170	2754

$X_1 + X_2 + X_3 = X_4 \rightarrow x$ $Y_1 + Y_2 + Y_3 = Y_4 \rightarrow y$ $x \pm y = Z$

Fig. 52

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Azimuth Table-S

ℓ&d { same name → ℓ+d = S
contrary name → ℓ~d = S

S	X_1	Y_1	S	X_1	Y_1	S	X_1	Y_1	S	X_1	Y_1
42° 0′	3170	2754	54° 0′	3150	2857	66° 0′	3124	2936	78° 0′	3091	2999
10	3170	2756	10	3150	2858	10	3123	2937	10	3090	3000
20	3170	2758	20	3149	2860	20	3123	2938	20	3089	3000
30	3169	2759	30	3149	2861	30	3122	2939	30	3089	3001
40	3169	2761	40	3149	2862	40	3122	2940	40	3088	3002
50	3169	2762	50	3148	2863	50	3122	2941	50	3088	3003
43 0	3169	2764	55 0	3149	2864	67 0	3121	2942	79 0	3087	3004
10	3168	2766	10	3148	2866	10	3121	2943	10	3087	3004
20	3168	2767	20	3147	2867	20	3120	2944	20	3086	3005
30	3168	2769	30	3147	2868	30	3120	2945	30	3086	3006
40	3168	2770	40	3147	2869	40	3119	2946	40	3085	3007
50	3167	2772	50	3146	2870	50	3119	2947	50	3085	3007
44 0	3167	2774	56 0	3146	2872	68 0	3119	2948	80 0	3084	3008
10	3167	2775	10	3146	2873	10	3118	2948	10	3084	3009
20	3167	2777	20	3145	2874	20	3118	2949	20	3083	3010
30	3166	2778	30	3145	2875	30	3117	2950	30	3083	3010
40	3166	2780	40	3145	2876	40	3117	2951	40	3082	3011
50	3166	2781	50	3144	2877	50	3116	2952	50	3082	3012
45 0	3166	2783	57 0	3144	2879	69 0	3116	2953	81 0	3081	3013
10	3165	2784	10	3144	2880	10	3116	2954	10	3081	3013
20	3165	2786	20	3143	2881	20	3115	2955	20	3080	3014
30	3165	2787	30	3143	2882	30	3115	2956	30	3079	3015
40	3165	2789	40	3143	2883	40	3114	2957	40	3079	3015
50	3164	2790	50	3142	2884	50	3114	2958	50	3078	3016
46 0	3164	2792	58 0	3142	2886	70 0	3113	2959	82 0	3078	3017
10	3164	2793	10	3141	2887	10	3113	2959	10	3077	3018
20	3163	2795	20	3141	2888	20	3112	2960	20	3077	3018
30	3163	2796	30	3141	2889	30	3112	2961	30	3076	3019
40	3163	2798	40	3140	2890	40	3112	2962	40	3076	3020
50	3163	2799	50	3140	2891	50	3111	2963	50	3075	3021
47 0	3162	2801	59 0	3140	2892	71 0	3111	2964	83 0	3074	3021
10	3162	2802	10	3139	2893	10	3110	2965	10	3074	3022
20	3162	2804	20	3139	2895	20	3110	2966	20	3073	3023
30	3162	2805	30	3139	2896	30	3109	2967	30	3073	3023
40	3161	2806	40	3138	2897	40	3109	2967	40	3072	3024
50	3161	2808	50	3138	2898	50	3108	2968	50	3072	3025
48 0	3161	2809	60 0	3138	2899	72 0	3108	2969	84 0	3071	3026
10	3160	2811	10	3137	2900	10	3107	2970	10	3071	3026
20	3160	2812	20	3137	2901	20	3107	2971	20	3070	3027
30	3160	2814	30	3136	2902	30	3107	2972	30	3069	3028
40	3160	2815	40	3136	2903	40	3106	2973	40	3069	3028
50	3159	2816	50	3136	2904	50	3106	2974	50	3068	3029
49 0	3159	2818	61 0	3135	2905	73 0	3105	2974	85 0	3068	3030
10	3159	2819	10	3135	2907	10	3105	2975	10	3067	3030
20	3158	2820	20	3135	2908	20	3104	2976	20	3066	3031
30	3158	2822	30	3134	2909	30	3104	2977	30	3066	3032
40	3158	2823	40	3134	2910	40	3103	2978	40	3065	3032
50	3158	2825	50	3133	2911	50	3103	2979	50	3065	3033
50 0	3157	2826	62 0	3133	2912	74 0	3102	2979	86 0	3064	3034
10	3157	2827	10	3133	2913	10	3102	2980	10	3064	3034
20	3157	2829	20	3132	2914	20	3101	2981	20	3063	3035
30	3156	2830	30	3132	2915	30	3101	2982	30	3062	3036
40	3156	2831	40	3132	2916	40	3100	2983	40	3062	3036
50	3156	2833	50	3131	2917	50	3100	2984	50	3061	3037
51 0	3155	2834	63 0	3131	2918	75 0	3099	2984	87 0	3061	3038
10	3155	2835	10	3130	2919	10	3099	2985	10	3060	3038
20	3155	2837	20	3130	2920	20	3098	2986	20	3059	3039
30	3155	2838	30	3130	2921	30	3098	2987	30	3059	3040
40	3154	2839	40	3129	2922	40	3098	2988	40	3058	3040
50	3154	2841	50	3129	2923	50	3097	2989	50	3058	3041
52 0	3154	2842	64 0	3128	2924	76 0	3097	2989	88 0	3057	3042
10	3153	2843	10	3128	2925	10	3096	2990	10	3056	3042
20	3153	2844	20	3128	2926	20	3096	2991	20	3056	3043
30	3153	2846	30	3127	2927	30	3095	2992	30	3055	3044
40	3152	2847	40	3127	2928	40	3095	2993	40	3054	3044
50	3152	2848	50	3126	2929	50	3094	2993	50	3054	3045
53 0	3152	2850	65 0	3126	2930	77 0	3094	2994	89 0	3053	3046
10	3151	2851	10	3126	2931	10	3093	2995	10	3053	3046
20	3151	2852	20	3125	2932	20	3093	2996	20	3052	3047
30	3151	2853	30	3125	2933	30	3092	2997	30	3051	3048
40	3151	2855	40	3124	2934	40	3092	2997	40	3051	3048
50	3150	2856	50	3124	2935	50	3091	2998	50	3050	3049
54 0	3150	2857	66 0	3124	2936	78 0	3091	2999	90 0	3049	3049

$X_1+X_2+X_3=X_4 \rightarrow x$ $Y_1+Y_2+Y_3=Y_4 \rightarrow y$ $x \pm y = Z$

Fig. 53

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Azimuth Table-D

ℓ&d { same name → ℓ−d = D
contrary name → ℓ+d = D

D	X_1	Y_1		D	X_1	Y_1		D	X_1	Y_1		D	X_1	Y_1	
° '				° '				° '				° '			
0 0	+∞	0	180 0	6 0	1281	1	174 0	18 0	806	5	162 0	30 0	587	15	150 0
5	3138	0	55	10	1269	1	50	10	802	5	50	10	585	15	50
10	2837	0	50	20	1258	1	40	20	798	6	40	20	582	15	40
15	2661	0	45	30	1246	1	30	30	794	6	30	30	580	16	30
20	2536	0	40	40	1235	1	20	40	790	6	20	40	578	16	20
25	2439	0	35	50	1225	1	10	50	786	6	10	50	575	16	10
30	2360	0	30	7 0	1214	1	173 0	19 0	782	6	161 0	31 0	573	16	149 0
35	2293	0	25	10	1204	1	50	10	779	6	50	10	571	16	50
40	2235	0	20	20	1194	1	40	20	775	6	40	20	569	16	40
45	2184	0	15	30	1184	1	30	30	771	6	30	30	566	17	30
50	2138	0	10	40	1175	1	20	40	768	6	20	40	564	17	20
55	2097	0	5	50	1166	1	10	50	764	7	10	50	562	17	10
1 0	2059	0	179 0	8 0	1156	1	172 0	20 0	760	7	160 0	32 0	560	17	148 0
5	2024	0	55	10	1147	1	50	10	757	7	50	10	557	17	50
10	1992	0	50	20	1139	1	40	20	753	7	40	20	555	18	40
15	1962	0	45	30	1130	1	30	30	750	7	30	30	553	18	30
20	1934	0	40	40	1122	1	20	40	746	7	20	40	551	18	20
25	1908	0	35	50	1113	1	10	50	743	7	10	50	549	18	10
30	1883	0	30	9 0	1105	1	171 0	21 0	739	7	159 0	33 0	547	18	147 0
35	1860	0	25	10	1097	1	50	10	736	7	50	10	545	18	50
40	1837	0	20	20	1090	1	40	20	733	8	40	20	542	19	40
45	1816	0	15	30	1082	1	30	30	729	8	30	30	540	19	30
50	1796	0	10	40	1074	2	20	40	726	8	20	40	538	19	20
55	1777	0	5	50	1067	2	10	50	723	8	10	50	536	19	10
2 0	1758	0	178 0	10 0	1060	2	170 0	22 0	719	8	158 0	34 0	534	19	146 0
5	1740	0	55	10	1053	2	50	10	716	8	50	10	532	20	50
10	1723	0	50	20	1046	2	40	20	713	8	40	20	530	20	40
15	1707	0	45	30	1039	2	30	30	710	8	30	30	528	20	30
20	1691	0	40	40	1032	2	20	40	707	9	20	40	526	20	20
25	1676	0	35	50	1025	2	10	50	703	9	10	50	524	20	10
30	1661	0	30	11 0	1018	2	169 0	23 0	700	9	157 0	35 0	522	21	145 0
35	1647	0	25	10	1012	2	50	10	697	9	50	10	520	21	50
40	1633	0	20	20	1006	2	40	20	694	9	40	20	518	21	40
45	1620	0	15	30	999	2	30	30	691	9	30	30	516	21	30
50	1607	0	10	40	993	2	20	40	688	9	20	40	514	21	20
55	1594	0	5	50	987	2	10	50	685	9	10	50	512	22	10
3 0	1582	0	177 0	12 0	981	2	168 0	24 0	682	10	156 0	36 0	510	22	144 0
5	1570	0	55	10	975	2	50	10	679	10	50	10	508	22	50
10	1559	0	50	20	969	3	40	20	676	10	40	20	506	22	40
15	1547	0	45	30	963	3	30	30	673	10	30	30	504	22	30
20	1536	0	40	40	957	3	20	40	670	10	20	40	502	23	20
25	1526	0	35	50	952	3	10	50	668	10	10	50	500	23	10
30	1515	0	30	13 0	946	3	167 0	25 0	665	10	155 0	37 0	499	23	143 0
35	1505	0	25	10	941	3	50	10	662	11	50	10	497	23	50
40	1495	0	20	20	935	3	40	20	659	11	40	20	495	23	40
45	1485	0	15	30	930	3	30	30	656	11	30	30	493	24	30
50	1476	0	10	40	925	3	20	40	653	11	20	40	491	24	20
55	1466	0	5	50	919	3	10	50	651	11	10	50	489	24	10
4 0	1457	0	176 0	14 0	914	3	166 0	26 0	648	11	154 0	38 0	487	24	142 0
5	1448	0	55	10	909	3	50	10	645	11	50	10	486	25	50
10	1439	0	50	20	904	3	40	20	642	12	40	20	484	25	40
15	1431	0	45	30	899	3	30	30	640	12	30	30	482	25	30
20	1422	0	40	40	894	4	20	40	637	12	20	40	480	25	20
25	1414	0	35	50	889	4	10	50	634	12	10	50	478	25	10
30	1406	0	30	15 0	884	4	165 0	27 0	632	12	153 0	39 0	477	26	141 0
35	1398	0	25	10	880	4	50	10	629	12	50	10	475	26	50
40	1390	0	20	20	875	4	40	20	627	12	40	20	473	26	40
45	1383	0	15	30	870	4	30	30	624	13	30	30	471	26	30
50	1375	0	10	40	866	4	20	40	621	13	20	40	469	27	20
55	1368	0	5	50	861	4	10	50	619	13	10	50	468	27	10
5 0	1360	0	175 0	16 0	856	4	164 0	28 0	616	13	152 0	40 0	466	27	140 0
5	1353	0	55	10	852	4	50	10	614	13	50	10	464	27	50
10	1346	0	50	20	848	4	40	20	611	13	40	20	462	27	40
15	1339	0	45	30	843	5	30	30	609	14	30	30	461	28	30
20	1332	0	40	40	839	5	20	40	606	14	20	40	459	28	20
25	1326	0	35	50	835	5	10	50	604	14	10	50	457	28	10
30	1319	1	30	17 0	830	5	163 0	29 0	601	14	151 0	41 0	456	28	139 0
35	1312	1	25	10	826	5	50	10	599	14	50	10	454	29	50
40	1306	1	20	20	822	5	40	20	597	14	40	20	452	29	40
45	1300	1	15	30	818	5	30	30	594	15	30	30	451	29	30
50	1293	1	10	40	814	5	20	40	592	15	20	40	449	29	20
55	1287	1	5	50	810	5	10	50	589	15	10	50	447	30	10
6 0	1281	1	174 0	18 0	806	5	162 0	30 0	587	15	150 0	42 0	446	30	138 0
			° '				° '				° '				° '
	Y_1	X_1	D		Y_1	X_1	D		Y_1	X_1	D		Y_1	X_1	D

$X_1+X_2+X_3 = X_4 \to x$ $Y_1+Y_2+Y_3 = Y_4 \to y$ $x \pm y = Z$

Fig. 54

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Azimuth Table-D

ℓ&d { same name → ℓ~d = D
contrary name → ℓ+d = D

D	X_1	Y_1		D	X_1	Y_1		D	X_1	Y_1		D	X_1	Y_1	
° '				° '				° '				° '			
42 0	446	30	138 0	54 0	343	50	126 0	66 0	264	76	114 0	78 0	201	109	102 0
10	444	30	50	10	342	50	50	10	263	77	50	10	200	110	50
20	442	30	40	20	340	51	40	20	262	77	40	20	200	111	40
30	441	31	30	30	339	51	30	30	261	78	30	30	199	111	30
40	439	31	20	40	338	51	20	40	260	78	20	40	198	112	20
50	438	31	10	50	337	52	10	50	259	78	10	50	197	112	10
43 0	436	31	137 0	55 0	336	52	125 0	67 0	258	79	113 0	79 0	196	113	101 0
10	434	32	50	10	334	52	50	10	257	79	50	10	196	113	50
20	433	32	40	20	333	53	40	20	256	80	40	20	195	114	40
30	431	32	30	30	332	53	30	30	255	80	30	30	194	114	30
40	430	32	20	40	331	53	20	40	254	81	20	40	193	115	20
50	428	33	10	50	330	54	10	50	253	81	10	50	193	115	10
44 0	426	33	136 0	56 0	328	54	124 0	68 0	252	81	112 0	80 0	192	116	100 0
10	425	33	50	10	327	54	50	10	252	82	50	10	191	116	50
20	423	33	40	20	326	55	40	20	251	82	40	20	190	117	40
30	422	34	30	30	325	55	30	30	250	83	30	30	190	117	30
40	420	34	20	40	324	55	20	40	249	83	20	40	189	118	20
50	419	34	10	50	323	56	10	50	248	84	10	50	188	118	10
45 0	417	34	135 0	57 0	321	56	123 0	69 0	247	84	111 0	81 0	187	119	99 0
10	416	35	50	10	320	56	50	10	246	84	50	10	187	119	50
20	414	35	40	20	319	57	40	20	245	85	40	20	186	120	40
30	413	35	30	30	318	57	30	30	244	85	30	30	185	121	30
40	411	35	20	40	317	57	20	40	243	86	20	40	185	121	20
50	410	36	10	50	316	58	10	50	242	86	10	50	184	122	10
46 0	408	36	134 0	58 0	314	58	122 0	70 0	241	87	110 0	82 0	183	122	98 0
10	407	36	50	10	313	59	50	10	241	87	50	10	182	123	50
20	405	37	40	20	312	59	40	20	240	88	40	20	182	123	40
30	404	37	30	30	311	59	30	30	239	88	30	30	181	124	30
40	402	37	20	40	310	60	20	40	238	88	20	40	180	124	20
50	401	37	10	50	309	60	10	50	237	89	10	50	179	125	10
47 0	399	38	133 0	59 0	308	60	121 0	71 0	236	89	109 0	83 0	179	126	97 0
10	398	38	50	10	307	61	50	10	235	90	50	10	178	126	50
20	396	38	40	20	305	61	40	20	234	90	40	20	177	127	40
30	395	39	30	30	304	61	30	30	233	91	30	30	177	127	30
40	394	39	20	40	303	62	20	40	233	91	20	40	176	128	20
50	392	39	10	50	302	62	10	50	232	92	10	50	175	128	10
48 0	391	39	132 0	60 0	301	62	120 0	72 0	231	92	108 0	84 0	174	129	96 0
10	389	40	50	10	300	63	50	10	230	93	50	10	174	129	50
20	388	40	40	20	299	63	40	20	229	93	40	20	173	130	40
30	386	40	30	30	298	64	30	30	228	93	30	30	172	131	30
40	385	40	20	40	297	64	20	40	227	91	20	40	172	131	20
50	384	41	10	50	296	64	10	50	226	94	10	50	171	132	10
49 0	382	41	131 0	61 0	295	65	119 0	73 0	226	95	107 0	85 0	170	132	95 0
10	381	41	50	10	293	65	50	10	225	95	50	10	170	133	50
20	380	42	40	20	292	65	40	20	224	96	40	20	169	134	40
30	378	42	30	30	291	66	30	30	223	96	30	30	168	134	30
40	377	42	20	40	290	66	20	40	222	97	20	40	168	135	20
50	375	42	10	50	289	67	10	50	221	97	10	50	167	135	10
50 0	374	43	130 0	62 0	288	67	118 0	74 0	221	98	106 0	86 0	166	136	94 0
10	373	43	50	10	287	67	50	10	220	98	50	10	166	136	50
20	371	43	40	20	286	68	40	20	219	99	40	20	165	137	40
30	370	44	30	30	285	68	30	30	218	99	30	30	164	138	30
40	369	44	20	40	284	68	20	40	217	100	20	40	164	138	20
50	367	44	10	50	283	69	10	50	216	100	10	50	163	139	10
51 0	366	45	129 0	63 0	282	69	117 0	75 0	216	101	105 0	87 0	162	139	93 0
10	365	45	50	10	281	70	50	10	215	101	50	10	162	140	50
20	363	45	40	20	280	70	40	20	214	102	40	20	161	141	40
30	362	45	30	30	279	70	30	30	213	102	30	30	160	141	30
40	361	46	20	40	278	71	20	40	212	102	20	40	160	142	20
50	359	46	10	50	277	71	10	50	211	103	10	50	159	142	10
52 0	358	46	128 0	64 0	276	72	116 0	76 0	211	103	104 0	88 0	158	143	92 0
10	357	47	50	10	275	72	50	10	210	104	50	10	158	144	50
20	356	47	40	20	274	72	40	20	209	104	40	20	157	144	40
30	354	47	30	30	273	73	30	30	208	105	30	30	156	145	30
40	353	48	20	40	272	73	20	40	207	105	20	40	156	146	20
50	352	48	10	50	271	74	10	50	207	106	10	50	155	146	10
53 0	350	48	127 0	65 0	270	74	115 0	77 0	206	106	103 0	89 0	154	147	91 0
10	349	49	50	10	269	74	50	10	205	107	50	10	154	147	50
20	348	49	40	20	268	75	40	20	204	107	40	20	153	148	40
30	347	49	30	30	267	75	30	30	203	108	30	30	152	149	30
40	345	49	20	40	266	76	20	40	203	108	20	40	152	149	20
50	344	50	10	50	265	76	10	50	202	109	10	50	151	150	10
54 0	343	50	126 0	66 0	264	76	114 0	78 0	201	109	102 0	90 0	151	151	90 0
			° '				° '				° '				° '
	Y_1	X_1	D		Y_1	X_1	D		Y_1	X_1	D		Y_1	X_1	D

$X_1 + X_2 + X_3 = X_4 \rightarrow x$ $Y_1 + Y_2 + Y_3 = Y_4 \rightarrow y$ $x \pm y = Z$

Fig. 55

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Azimuth Table-h

h (° ′)	X_1 Y_1		h (° ′)	X_2 Y_2		h (° ′)	X_3 Y_3		h (° ′)	X_1 Y_1	
0 0	− ∞	360 0	6 0	1919	354 0	18 0	2400	342 0	30 0	2628	330 0
5	+ 62	55	10	1931	50	10	2404	50	10	2631	50
10	363	50	20	1943	40	20	2408	40	20	2633	40
15	539	45	30	1954	30	30	2412	30	30	2636	30
20	664	40	40	1965	20	40	2416	20	40	2638	20
25	761	35	50	1976	10	50	2420	10	50	2641	10
30	840	30	7 0	1986	353 0	19 0	2424	341 0	31 0	2643	329 0
35	907	25	10	1997	50	10	2427	50	10	2645	50
40	965	20	20	2007	40	20	2431	40	20	2648	40
45	1016	15	30	2017	30	30	2435	30	30	2650	30
50	1062	10	40	2026	20	40	2439	20	40	2653	20
55	1103	5	50	2035	10	50	2443	10	50	2655	10
1 0	1141	359 0	8 0	2045	352 0	20 0	2446	340 0	32 0	2657	328 0
5	1176	55	10	2054	50	10	2450	50	10	2660	50
10	1208	50	20	2062	40	20	2454	40	20	2662	40
15	1238	45	30	2071	30	30	2457	30	30	2665	30
20	1266	40	40	2080	20	40	2461	20	40	2667	20
25	1292	35	50	2088	10	50	2464	10	50	2669	10
30	1317	30	9 0	2096	351 0	21 0	2468	339 0	33 0	2672	327 0
35	1340	25	10	2104	50	10	2471	50	10	2674	50
40	1363	20	20	2112	40	20	2475	40	20	2676	40
45	1384	15	30	2120	30	30	2478	30	30	2679	30
50	1404	10	40	2127	20	40	2482	20	40	2681	20
55	1423	5	50	2135	10	50	2485	10	50	2683	10
2 0	1442	358 0	10 0	2142	350 0	22 0	2489	338 0	34 0	2685	326 0
5	1460	55	10	2149	50	10	2492	50	10	2688	50
10	1477	50	20	2156	40	20	2495	40	20	2690	40
15	1493	45	30	2163	30	30	2499	30	30	2692	30
20	1509	40	40	2170	20	40	2502	20	40	2694	20
25	1524	35	50	2177	10	50	2505	10	50	2697	10
30	1539	30	11 0	2184	349 0	23 0	2508	337 0	35 0	2699	325 0
35	1553	25	10	2190	50	10	2512	50	10	2701	50
40	1567	20	20	2197	40	20	2515	40	20	2703	40
45	1580	15	30	2203	30	30	2518	30	30	2705	30
50	1593	10	40	2209	20	40	2521	20	40	2707	20
55	1606	5	50	2216	10	50	2524	10	50	2710	10
3 0	1618	357 0	12 0	2222	348 0	24 0	2527	336 0	36 0	2712	324 0
5	1630	55	10	2228	50	10	2531	50	10	2714	50
10	1642	50	20	2234	40	20	2534	40	20	2716	40
15	1653	45	30	2239	30	30	2537	30	30	2718	30
20	1664	40	40	2245	20	40	2540	20	40	2720	20
25	1675	35	50	2251	10	50	2543	10	50	2722	10
30	1685	30	13 0	2257	347 0	25 0	2546	335 0	37 0	2725	323 0
35	1695	25	10	2262	50	10	2549	50	10	2727	50
40	1705	20	20	2268	40	20	2552	40	20	2729	40
45	1715	15	30	2273	30	30	2555	30	30	2731	30
50	1725	10	40	2279	20	40	2558	20	40	2733	20
55	1734	5	50	2284	10	50	2560	10	50	2735	10
4 0	1743	356 0	14 0	2289	346 0	26 0	2563	334 0	38 0	2737	322 0
5	1752	55	10	2294	50	10	2566	50	10	2739	50
10	1761	50	20	2299	40	20	2569	40	20	2741	40
15	1769	45	30	2305	30	30	2572	30	30	2743	30
20	1778	40	40	2310	20	40	2575	20	40	2745	20
25	1788	35	50	2315	10	50	2578	10	50	2747	10
30	1794	30	15 0	2319	345 0	27 0	2580	333 0	39 0	2749	321 0
35	1802	25	10	2324	50	10	2583	50	10	2751	50
40	1810	20	20	2329	40	20	2586	40	20	2753	40
45	1818	15	30	2334	30	30	2589	30	30	2755	30
50	1825	10	40	2339	20	40	2591	20	40	2757	20
55	1833	5	50	2343	10	50	2594	10	50	2759	10
5 0	1840	355 0	16 0	2348	344 0	28 0	2597	332 0	40 0	2761	320 0
5	1847	55	10	2352	50	10	2599	50	10	2763	50
10	1854	50	20	2357	40	20	2602	40	20	2765	40
15	1861	45	30	2361	30	30	2605	30	30	2767	30
20	1868	40	40	2366	20	40	2607	20	40	2769	20
25	1875	35	50	2370	10	50	2610	10	50	2771	10
30	1882	30	17 0	2374	343 0	29 0	2613	331 0	41 0	2773	319 0
35	1888	25	10	2379	50	10	2615	50	10	2775	50
40	1895	20	20	2383	40	20	2618	40	20	2777	40
45	1901	15	30	2387	30	30	2620	30	30	2778	30
50	1907	10	40	2391	20	40	2623	20	40	2780	20
55	1913	5	50	2396	10	50	2626	10	50	2782	10
6 0	1919	354 0	18 0	2400	342 0	30 0	2628	330 0	42 0	2784	318 0
	X_1 Y_1	h (° ′)		X_2 Y_2	h (° ′)		X_3 Y_3	h (° ′)		X_1 Y_1	h (° ′)

$X_1 + X_2 + X_3 - X_4 \rightarrow x$ $\quad Y_1 + Y_2 + Y_3' - Y_4 \rightarrow y$ $\quad x \pm y = Z$

Fig. 56

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Azimuth Table-h

h	$X_3\ Y_3$		h	$X_3\ Y_3$		h	$X_3\ Y_3$		h	$X_3\ Y_3$	
° ′			° ′			° ′			° ′		
42 0	2784	318 0	54 0	2907	306 0	66 0	3013	294 0	78 0	3108	282 0
10	2786	50	10	2909	50	10	3014	50	10	3110	50
20	2788	40	20	2910	40	20	3015	40	20	3111	40
30	2790	30	30	2912	30	30	3017	30	30	3112	30
40	2792	20	40	2913	20	40	3018	20	40	3114	20
50	2794	10	50	2915	10	50	3019	10	50	3115	10
43 0	2795	317 0	55 0	2916	305 0	67 0	3021	293 0	79 0	3116	281 0
10	2797	50	10	2918	50	10	3022	50	10	3117	50
20	2799	40	20	2920	40	20	3024	40	20	3119	40
30	2801	30	30	2921	30	30	3025	30	30	3120	30
40	2803	20	40	2923	20	40	3026	20	40	3121	20
50	2805	10	50	2924	10	50	3028	10	50	3123	10
44 0	2806	316 0	56 0	2926	304 0	68 0	3029	292 0	80 0	3124	280 0
10	2808	50	10	2927	50	10	3030	50	10	3125	50
20	2810	40	20	2929	40	20	3032	40	20	3126	40
30	2812	30	30	2930	30	30	3033	30	30	3128	30
40	2814	20	40	2932	20	40	3034	20	40	3129	20
50	2815	10	50	2933	10	50	3036	10	50	3130	10
45 0	2817	315 0	57 0	2935	303 0	69 0	3037	291 0	81 0	3131	279 0
10	2819	50	10	2936	50	10	3038	50	10	3133	50
20	2821	40	20	2938	40	20	3040	40	20	3134	40
30	2823	30	30	2939	30	30	3041	30	30	3135	30
40	2824	20	40	2941	20	40	3043	20	40	3137	20
50	2826	10	50	2942	10	50	3044	10	50	3138	10
46 0	2828	314 0	58 0	2944	302 0	70 0	3045	290 0	82 0	3139	278 0
10	2830	50	10	2945	50	10	3047	50	10	3140	50
20	2831	40	20	2947	40	20	3048	40	20	3142	40
30	2833	30	30	2948	30	30	3049	30	30	3143	30
40	2835	20	40	2950	20	40	3051	20	40	3144	20
50	2837	10	50	2951	10	50	3052	10	50	3146	10
47 0	2838	313 0	59 0	2953	301 0	71 0	3053	289 0	83 0	3147	277 0
10	2840	50	10	2954	50	10	3055	50	10	3148	50
20	2842	40	20	2956	40	20	3056	40	20	3149	40
30	2843	30	30	2957	30	30	3057	30	30	3151	30
40	2845	20	40	2959	20	40	3059	20	40	3152	20
50	2847	10	50	2960	10	50	3060	10	50	3153	10
48 0	2849	312 0	60 0	2961	300 0	72 0	3061	288 0	84 0	3154	276 0
10	2850	50	10	2963	50	10	3063	50	10	3156	50
20	2852	40	20	2964	40	20	3064	40	20	3157	40
30	2854	30	30	2966	30	30	3065	30	30	3158	30
40	2855	20	40	2967	20	40	3067	20	40	3160	20
50	2857	10	50	2969	10	50	3068	10	50	3161	10
49 0	2859	311 0	61 0	2970	299 0	73 0	3069	287 0	85 0	3162	275 0
10	2860	50	10	2972	50	10	3071	50	10	3163	50
20	2862	40	20	2973	40	20	3072	40	20	3165	40
30	2864	30	30	2974	30	30	3073	30	30	3166	30
40	2865	20	40	2976	20	40	3074	20	40	3167	20
50	2867	10	50	2977	10	50	3076	10	50	3168	10
50 0	2869	310 0	62 0	2979	298 0	74 0	3077	286 0	86 0	3170	274 0
10	2870	50	10	2980	50	10	3078	50	10	3171	50
20	2872	40	20	2982	40	20	3080	40	20	3172	40
30	2874	30	30	2983	30	30	3081	30	30	3173	30
40	2875	20	40	2984	20	40	3082	20	40	3175	20
50	2877	10	50	2986	10	50	3084	10	50	3176	10
51 0	2878	309 0	63 0	2987	297 0	75 0	3085	285 0	87 0	3177	273 0
10	2880	50	10	2989	50	10	3086	50	10	3179	50
20	2882	40	20	2990	40	20	3088	40	20	3180	40
30	2883	30	30	2992	30	30	3089	30	30	3181	30
40	2885	20	40	2993	20	40	3090	20	40	3182	20
50	2887	10	50	2994	10	50	3092	10	50	3184	10
52 0	2888	308 0	64 0	2996	296 0	76 0	3093	284 0	88 0	3185	272 0
10	2890	50	10	2997	50	10	3094	50	10	3186	50
20	2891	40	20	2999	40	20	3095	40	20	3187	40
30	2893	30	30	3000	30	30	3097	30	30	3189	30
40	2895	20	40	3001	20	40	3098	20	40	3190	20
50	2896	10	50	3003	10	50	3099	10	50	3191	10
53 0	2898	307 0	65 0	3004	295 0	77 0	3101	283 0	89 0	3192	271 0
10	2899	50	10	3006	50	10	3102	50	10	3194	50
20	2901	40	20	3007	40	20	3103	40	20	3195	40
30	2902	30	30	3008	30	30	3104	30	30	3196	30
40	2904	20	40	3010	20	40	3106	20	40	3197	20
50	2906	10	50	3011	10	50	3107	10	50	3199	10
54 0	2907	306 0	66 0	3013	294 0	78 0	3108	282 0	90 0	3200	270 0
		° ′			° ′			° ′			° ′
	$X_3\ Y_3$	h		$X_3\ Y_3$	h		$X_3\ Y_3$	h		$X_3\ Y_3$	h

$X_1 + X_2 + X_3 = X_4 \rightarrow x$ $Y_1 + Y_2 + Y_3 = Y_4 \rightarrow y$ $x \pm y = Z$

Fig. 57

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Azimuth Table-h

h	X_2 Y_2		h	X_2 Y_1		h	X_1 Y_1		h	X_1 Y_2	
° ′			° ′			° ′			° ′		
90 0	3200	270 0	102 0	3292	258 0	114 0	3387	246 0	126 0	3493	234 0
10	3201	50	10	3293	50	10	3389	50	10	3494	50
20	3203	40	20	3294	40	20	3390	40	20	3496	40
30	3204	30	30	3296	30	30	3392	30	30	3498	30
40	3205	20	40	3297	20	40	3393	20	40	3499	20
50	3206	10	50	3298	10	50	3394	10	50	3501	10
91 0	3208	269 0	103 0	3299	257 0	115 0	3396	245 0	127 0	3502	233 0
10	3209	50	10	3301	50	10	3397	50	10	3504	50
20	3210	40	20	3302	40	20	3399	40	20	3505	40
30	3211	30	30	3303	30	30	3400	30	30	3507	30
40	3213	20	40	3305	20	40	3401	20	40	3509	20
50	3214	10	50	3306	10	50	3403	10	50	3510	10
92 0	3215	268 0	104 0	3307	256 0	116 0	3404	244 0	128 0	3512	232 0
10	3216	50	10	3308	50	10	3406	50	10	3513	50
20	3218	40	20	3310	40	20	3407	40	20	3515	40
30	3219	30	30	3311	30	30	3408	30	30	3517	30
40	3220	20	40	3312	20	40	3410	20	40	3518	20
50	3221	10	50	3314	10	50	3411	10	50	3520	10
93 0	3223	267 0	105 0	3315	255 0	117 0	3413	243 0	129 0	3522	231 0
10	3224	50	10	3316	50	10	3414	50	10	3523	50
20	3225	40	20	3318	40	20	3416	40	20	3525	40
30	3227	30	30	3319	30	30	3417	30	30	3526	30
40	3228	20	40	3320	20	40	3418	20	40	3528	20
50	3229	10	50	3322	10	50	3420	10	50	3530	10
94 0	3230	266 0	106 0	3323	254 0	118 0	3421	242 0	130 0	3531	230 0
10	3232	50	10	3324	50	10	3423	50	10	3533	50
20	3233	40	20	3326	40	20	3424	40	20	3535	40
30	3234	30	30	3327	30	30	3426	30	30	3536	30
40	3235	20	40	3328	20	40	3427	20	40	3538	20
50	3237	10	50	3329	10	50	3428	10	50	3540	10
95 0	3238	265 0	107 0	3331	253 0	119 0	3430	241 0	131 0	3541	229 0
10	3239	50	10	3332	50	10	3431	50	10	3543	50
20	3240	40	20	3333	40	20	3433	40	20	3545	40
30	3242	30	30	3335	30	30	3434	30	30	3546	30
40	3243	20	40	3336	20	40	3436	20	40	3548	20
50	3244	10	50	3337	10	50	3437	10	50	3550	10
96 0	3246	264 0	108 0	3339	252 0	120 0	3439	240 0	132 0	3551	228 0
10	3247	50	10	3340	50	10	3440	50	10	3553	50
20	3248	40	20	3341	40	20	3441	40	20	3555	40
30	3249	30	30	3343	30	30	3443	30	30	3557	30
40	3251	20	40	3344	20	40	3444	20	40	3558	20
50	3252	10	50	3345	10	50	3446	10	50	3560	10
97 0	3253	263 0	109 0	3347	251 0	121 0	3447	239 0	133 0	3562	227 0
10	3254	50	10	3348	50	10	3449	50	10	3563	50
20	3256	40	20	3349	40	20	3450	40	20	3565	40
30	3257	30	30	3351	30	30	3452	30	30	3567	30
40	3258	20	40	3352	20	40	3453	20	40	3569	20
50	3260	10	50	3353	10	50	3455	10	50	3570	10
98 0	3261	262 0	110 0	3355	250 0	122 0	3456	238 0	134 0	3572	226 0
10	3262	50	10	3356	50	10	3458	50	10	3574	50
20	3263	40	20	3357	40	20	3459	40	20	3576	40
30	3265	30	30	3359	30	30	3461	30	30	3577	30
40	3266	20	40	3360	20	40	3462	20	40	3579	20
50	3267	10	50	3362	10	50	3464	10	50	3581	10
99 0	3269	261 0	111 0	3363	249 0	123 0	3465	237 0	135 0	3583	225 0
10	3270	50	10	3364	50	10	3467	50	10	3585	50
20	3271	40	20	3366	40	20	3468	40	20	3586	40
30	3272	30	30	3367	30	30	3470	30	30	3588	30
40	3274	20	40	3368	20	40	3471	20	40	3590	20
50	3275	10	50	3370	10	50	3473	10	50	3592	10
100 0	3276	260 0	112 0	3371	248 0	124 0	3474	236 0	136 0	3594	224 0
10	3277	50	10	3372	50	10	3476	50	10	3595	50
20	3279	40	20	3374	40	20	3477	40	20	3597	40
30	3280	30	30	3375	30	30	3479	30	30	3599	30
40	3281	20	40	3376	20	40	3480	20	40	3601	20
50	3283	10	50	3378	10	50	3482	10	50	3603	10
101 0	3284	259 0	113 0	3379	247 0	125 0	3484	235 0	137 0	3605	223 0
10	3285	50	10	3381	50	10	3485	50	10	3606	50
20	3286	40	20	3382	40	20	3487	40	20	3608	40
30	3288	30	30	3383	30	30	3488	30	30	3610	30
40	3289	20	40	3385	20	40	3490	20	40	3612	20
50	3290	10	50	3386	10	50	3491	10	50	3614	10
102 0	3292	258 0	114 0	3387	246 0	126 0	3493	234 0	138 0	3616	222 0
		° ′			° ′			° ′			° ′
	X_1 Y_2	h		X_1 Y_2	h		X_2 Y_1	h		X_1 Y_1	h

$X_1 + X_2 + X_3 = X_4 \rightarrow x$ $Y_1 + Y_2 + Y_3 = Y_4 \rightarrow y$ $x \pm y = Z$

Fig. 58

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Azimuth Table-h

h	X_3 Y_3		h	X_3 Y_3		h	X_3 Y_3		h	X_3 Y_3	
° ′			° ′			° ′			° ′		
138 0	3616	222 0	150 0	3772	210 0	162 0	4000	198 0	174 0	4481	186 0
10	3618	50	10	3774	50	10	4004	50	5	4486	55
20	3620	40	20	3777	40	20	4009	40	10	4493	50
30	3622	30	30	3780	30	30	4013	30	15	4499	45
40	3623	20	40	3782	20	40	4017	20	20	4505	40
50	3625	10	50	3785	10	50	4021	10	25	4512	35
139 0	3627	221 0	151 0	3787	209 0	163 0	4026	197 0	30	4518	30
10	3629	50	10	3790	50	10	4030	50	35	4525	25
20	3631	40	20	3793	40	20	4034	40	40	4532	20
30	3633	30	30	3795	30	30	4039	30	45	4539	15
40	3635	20	40	3798	20	40	4043	20	50	4546	10
50	3637	10	50	3801	10	50	4048	10	55	4553	5
140 0	3639	220 0	152 0	3803	208 0	164 0	4052	196 0	175 0	4560	185 0
10	3641	50	10	3806	50	10	4057	50	5	4567	55
20	3643	40	20	3809	40	20	4061	40	10	4575	50
30	3645	30	30	3811	30	30	4066	30	15	4583	45
40	3647	20	40	3814	20	40	4071	20	20	4590	40
50	3649	10	50	3817	10	50	4076	10	25	4598	35
141 0	3651	219 0	153 0	3820	207 0	165 0	4081	195 0	30	4606	30
10	3653	50	10	3822	50	10	4085	50	35	4614	25
20	3655	40	20	3825	40	20	4090	40	40	4622	20
30	3657	30	30	3828	30	30	4095	30	45	4631	15
40	3659	20	40	3831	20	40	4101	20	50	4639	10
50	3661	10	50	3834	10	50	4106	10	55	4648	5
142 0	3663	218 0	154 0	3837	206 0	166 0	4111	194 0	176 0	4657	184 0
10	3665	50	10	3840	50	10	4116	50	5	4666	55
20	3667	40	20	3842	40	20	4121	40	10	4675	50
30	3669	30	30	3845	30	30	4127	30	15	4685	45
40	3671	20	40	3848	20	40	4132	20	20	4695	40
50	3673	10	50	3851	10	50	4138	10	25	4705	35
143 0	3675	217 0	155 0	3854	205 0	167 0	4143	193 0	30	4715	30
10	3678	50	10	3857	50	10	4149	50	35	4725	25
20	3680	40	20	3860	40	20	4155	40	40	4736	20
30	3682	30	30	3863	30	30	4161	30	45	4747	15
40	3684	20	40	3866	20	40	4166	20	50	4758	10
50	3686	10	50	3869	10	50	4172	10	55	4770	5
144 0	3688	216 0	156 0	3873	204 0	168 0	4178	192 0	177 0	4782	183 0
10	3690	50	10	3876	50	10	4184	50	5	4794	55
20	3693	40	20	3879	40	20	4191	40	10	4807	50
30	3695	30	30	3882	30	30	4197	30	15	4820	45
40	3697	20	40	3885	20	40	4203	20	20	4833	40
50	3699	10	50	3888	10	50	4210	10	25	4847	35
145 0	3701	215 0	157 0	3892	203 0	169 0	4216	191 0	30	4861	30
10	3703	50	10	3895	50	10	4223	50	35	4876	25
20	3706	40	20	3898	40	20	4230	40	40	4891	20
30	3708	30	30	3901	30	30	4237	30	45	4907	15
40	3710	20	40	3905	20	40	4244	20	50	4923	10
50	3712	10	50	3908	10	50	4251	10	55	4940	5
146 0	3715	214 0	158 0	3911	202 0	170 0	4258	190 0	178 0	4958	182 0
10	3717	50	10	3915	50	10	4265	50	5	497.	55
20	3719	40	20	3918	40	20	4273	40	10	4996	50
30	3721	30	30	3922	30	30	4280	30	15	5016	45
40	3724	20	40	3925	20	40	4288	20	20	5037	40
50	3726	10	50	3929	10	50	4296	10	25	5060	35
147 0	3728	213 0	159 0	3932	201 0	171 0	4304	189 0	30	5083	30
10	3731	50	10	3936	50	10	4312	50	35	5108	25
20	3733	40	20	3939	40	20	4320	40	40	5134	20
30	3735	30	30	3943	30	30	4329	30	45	5162	15
40	3738	20	40	3946	20	40	4338	20	50	5192	10
50	3740	10	50	3950	10	50	4346	10	55	5224	5
148 0	3743	212 0	160 0	3954	200 0	172 0	4355	188 0	179 0	5259	181 0
10	3745	50	10	3957	50	10	4365	50	5	5297	55
20	3747	40	20	3961	40	20	4374	40	10	5338	50
30	3750	30	30	3965	30	30	4383	30	15	5384	45
40	3752	20	40	3969	20	40	4393	20	20	5435	40
50	3755	10	50	3973	10	50	4403	10	25	5493	35
149 0	3757	211 0	161 0	3976	199 0	173 0	4414	187 0	30	5560	30
10	3759	50	10	3980	50	10	4424	50	35	5640	25
20	3762	40	20	3984	40	20	4435	40	40	5736	20
30	3764	30	30	3988	30	30	4446	30	45	5862	15
40	3767	20	40	3992	20	40	4457	20	50	6037	10
50	3769	10	50	3996	10	50	4469	10	55	6347	5
150 0	3772	210 0	162 0	4000	198 0	174 0	4481	186 0	180 0	∞	180 0
		° ′			° ′			° ′			° ′
	X_3 Y_3	h		X_3 Y_3	h		X_3 Y_3	h		X_3 Y_3	h

$X_1 + X_2 + X_3 = X_4 \to x$ $\quad Y_1 + Y_2 + Y_3 = Y_4 \to y$ $\quad x \pm y = Z$

Fig. 59

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Azimuth Table-x.y

x / y	X4 / Y4	x / y	X4 / Y4	x / y	X4 / Y4	x / y	X4 / Y4	x / y	X4 / Y4	x / y	X4 / Y4	x / y	X4 / Y4	x / y	X4 / Y4
0.0°	-∞	3.0°	5119	9.0°	5600	15.0°	5828	21.0°	5984	27.0°	6107	33.0°	6213	39.0°	6308
	+3341	1	5134	1	5605	1	5831	1	5986	1	6109	1	6214	1	6310
1	3642	2	5147	2	5609	2	5834	2	5989	2	6111	2	6216	2	6311
	3818	3	5161	3	5614	3	5837	3	5991	3	6113	3	6217	3	6313
2	3943	4	5174	4	5619	4	5840	4	5993	4	6115	4	6219	4	6315
	4040	5	5186	5	5624	5	5843	5	5995	5	6116	5	6221	5	6316
3	4119	6	5199	6	5628	6	5846	6	5998	6	6118	6	6222	6	6318
	4186	7	5211	7	5633	7	5849	7	6000	7	6120	7	6224	7	6319
4	4244	8	5222	8	5637	8	5852	8	6002	8	6122	8	6226	8	6321
	4296	9	5234	9	5642	9	5855	9	6004	9	6124	9	6227	9	6322
5	4341	4.0	5245	10.0	5646	16.0	5857	22.0	6006	28.0	6126	34.0	6229	40.0	6324
	4382	1	5255	1	5651	1	5860	1	6009	1	6128	1	6231	1	6325
6	4420	2	5266	2	5655	2	5863	2	6011	2	6129	2	6232	2	6327
	4455	3	5276	3	5659	3	5866	3	6013	3	6131	3	6234	3	6328
7	4487	4	5286	4	5664	4	5869	4	6015	4	6133	4	6236	4	6330
	4517	5	5296	5	5668	5	5872	5	6017	5	6135	5	6237	5	6331
8	4545	6	5306	6	5672	6	5874	6	6019	6	6137	6	6239	6	6333
	4571	7	5315	7	5676	7	5877	7	6021	7	6138	7	6240	7	6335
9	4596	8	5324	8	5680	8	5880	8	6024	8	6140	8	6242	8	6336
	4620	9	5333	9	5685	9	5883	9	6026	9	6142	9	6244	9	6338
1.0	4642	5.0	5342	11.0	5689	17.0	5885	23.0	6028	29.0	6144	35.0	6245	41.0	6339
	4663	1	5351	1	5693	1	5888	1	6030	1	6146	1	6247	1	6341
1	4683	2	5359	2	5697	2	5891	2	6032	2	6147	2	6248	2	6342
	4703	3	5367	3	5701	3	5893	3	6034	3	6149	3	6250	3	6344
2	4721	4	5376	4	5705	4	5896	4	6036	4	6151	4	6252	4	6345
	4739	5	5384	5	5708	5	5899	5	6038	5	6153	5	6253	5	6347
3	4756	6	5391	6	5712	6	5901	6	6040	6	6154	6	6255	6	6348
	4772	7	5399	7	5716	7	5904	7	6042	7	6156	7	6256	7	6350
4	4788	8	5407	8	5720	8	5907	8	6044	8	6158	8	6258	8	6351
	4803	9	5414	9	5724	9	5909	9	6047	9	6160	9	6260	9	6353
5	4818	6.0	5422	12.0	5727	18.0	5912	24.0	6049	30.0	6161	36.0	6261	42.0	6354
	4832	1	5429	1	5731	1	5914	1	6051	1	6163	1	6263	1	6356
6	4846	2	5436	2	5735	2	5917	2	6053	2	6165	2	6264	2	6357
	4859	3	5443	3	5739	3	5919	3	6055	3	6167	3	6266	3	6359
7	4872	4	5450	4	5742	4	5922	4	6057	4	6168	4	6268	4	6361
	4885	5	5457	5	5746	5	5925	5	6059	5	6170	5	6269	5	6362
8	4897	6	5463	6	5749	6	5927	6	6061	6	6172	6	6271	6	6364
	4909	7	5470	7	5753	7	5930	7	6063	7	6174	7	6272	7	6365
9	4921	8	5476	8	5756	8	5932	8	6065	8	6175	8	6274	8	6367
	4932	9	5483	9	5760	9	5935	9	6067	9	6177	9	6276	9	6368
2.0	4943	7.0	5489	13.0	5763	19.0	5937	25.0	6069	31.0	6179	37.0	6277	43.0	6370
	4954	1	5495	1	5767	1	5939	1	6071	1	6180	1	6279	1	6371
1	4964	2	5502	2	5770	2	5942	2	6073	2	6182	2	6280	2	6373
	4975	3	5508	3	5774	3	5944	3	6075	3	6184	3	6282	3	6374
2	4985	4	5514	4	5777	4	5947	4	6077	4	6186	4	6283	4	6376
	4994	5	5519	5	5780	5	5949	5	6078	5	6187	5	6285	5	6377
3	5004	6	5525	6	5784	6	5952	6	6080	6	6189	6	6287	6	6379
	5013	7	5531	7	5787	7	5954	7	6082	7	6191	7	6288	7	6380
4	5022	8	5537	8	5790	8	5956	8	6084	8	6192	8	6290	8	6382
	5031	9	5542	9	5794	9	5959	9	6086	9	6194	9	6291	9	6383
5	5040	8.0	5548	14.0	5797	20.0	5961	26.0	6088	32.0	6196	38.0	6293	44.0	6385
	5049	1	5553	1	5800	1	5963	1	6090	1	6197	1	6294	1	6386
6	5057	2	5559	2	5803	2	5966	2	6092	2	6199	2	6296	2	6388
	5065	3	5564	3	5806	3	5968	3	6094	3	6201	3	6297	3	6389
7	5074	4	5569	4	5810	4	5970	4	6096	4	6203	4	6299	4	6391
	5082	5	5574	5	5813	5	5973	5	6098	5	6204	5	6301	5	6392
8	5089	6	5580	6	5816	6	5975	6	6100	6	6206	6	6302	6	6394
	5097	7	5585	7	5819	7	5977	7	6102	7	6208	7	6304	7	6395
9	5105	8	5590	8	5822	8	5980	8	6103	8	6209	8	6305	8	6397
	5112	9	5595	9	5825	9	5982	9	6105	9	6211	9	6307	9	6398
3.0	5119	9.0	5600	15.0	5828	21.0	5984	27.0	6107	33.0	6213	39.0	6308	45.0	6400

Azimuth Z should be measured from south or north to 180°

when h = oh~12h→W, 12h~24h→E

Result when ℓ>d, Z = x+y, measure from pole of contrary name to ℓ

ℓ<d, Z = x-y, ℓ & d contrary name, measure from pole of contrary name to ℓ

ℓ & d same name, measure from pole of same name as ℓ

Fig. 60

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Azimuth Table-x.y

x	X	x	X	x	X	x	X	x	X	x	X	x	X	x	X
y	Y	y	Y	y	Y	y	Y	y	Y	y	Y	y	Y	y	Y
45.0	6400	51.0	6492	57.0	6587	63.0	6693	69.0	6816	75.0	6972	81.0	7200	87.0	7681
1	6402	1	6493	1	6589	1	6695	1	6818	1	6975	1	7205		7688
2	6403	2	6495	2	6591	2	6697	2	6820	2	6979	2	7210	1	7695
3	6405	3	6496	3	6592	3	6698	3	6823	3	6981	3	7215		7703
4	6406	4	6498	4	6594	4	6700	4	6825	4	6984	4	7220	2	7711
5	6408	5	6499	5	6596	5	6702	5	6827	5	6987	5	7225		7718
6	6409	6	6501	6	6597	6	6704	6	6830	6	6990	6	7231	3	7726
7	6411	7	6503	7	6599	7	6706	7	6832	7	6994	7	7236		7735
8	6412	8	6504	8	6601	8	6708	8	6834	8	6997	8	7241	4	7743
9	6414	9	6506	9	6603	9	6710	9	6837	9	7000	9	7247		7751
46.0	6415	52.0	6507	58.0	6604	64.0	6712	70.0	6839	76.0	7003	82.0	7252	5	7760
1	6417	1	6509	1	6606	1	6714	1	6841	1	7006	1	7258		7769
2	6418	2	6510	2	6608	2	6716	2	6844	2	7010	2	7263	6	7778
3	6420	3	6512	3	6609	3	6718	3	6846	3	7013	3	7269		7787
4	6421	4	6513	4	6611	4	6720	4	6849	4	7016	4	7275	7	7796
5	6423	5	6515	5	6613	5	6722	5	6851	5	7020	5	7281		7806
6	6424	6	6517	6	6614	6	6723	6	6853	6	7023	6	7286	8	7815
7	6426	7	6518	7	6616	7	6725	7	6856	7	7026	7	7292		7825
8	6427	8	6520	8	6618	8	6727	8	6859	8	7030	8	7298	9	7836
9	6429	9	6521	9	6620	9	6729	9	6861	9	7033	9	7305		7846
47.0	6430	53.0	6523	59.0	6621	65.0	6731	71.0	6863	77.0	7037	83.0	7311	88.0	7857
1	6432	1	6524	1	6623	1	6733	1	6865	1	7040	1	7317		7868
2	6433	2	6526	2	6625	2	6735	2	6868	2	7044	2	7324	1	7879
3	6435	3	6528	3	6626	3	6737	3	6870	3	7047	3	7330		7891
4	6436	4	6529	4	6628	4	6739	4	6873	4	7051	4	7337	2	7903
5	6438	5	6531	5	6630	5	6741	5	6875	5	7054	5	7343		7915
6	6439	6	6532	6	6632	6	6743	6	6878	6	7058	6	7350	3	7929
7	6441	7	6534	7	6633	7	6745	7	6881	7	7061	7	7357		7941
8	6443	8	6536	8	6635	8	6747	8	6883	8	7065	8	7364	4	7954
9	6444	9	6537	9	6637	9	6749	9	6886	9	7069	9	7371		7968
48.0	6446	54.0	6539	60.0	6639	66.0	6751	72.0	6889	78.0	7073	84.0	7378	5	7982
1	6447	1	6540	1	6640	1	6753	1	6891	1	7076	1	7386		7997
2	6449	2	6542	2	6642	2	6756	2	6893	2	7080	2	7393	6	8012
3	6450	3	6544	3	6644	3	6758	3	6896	3	7084	3	7401		8028
4	6452	4	6545	4	6646	4	6760	4	6899	4	7088	4	7409	7	8044
5	6453	5	6547	5	6647	5	6762	5	6901	5	7092	5	7416		8061
6	6455	6	6548	6	6649	6	6764	6	6904	6	7095	6	7424	8	8079
7	6456	7	6550	7	6651	7	6766	7	6907	7	7099	7	7433		8097
8	6458	8	6552	8	6653	8	6768	8	6909	8	7103	8	7441	9	8117
9	6459	9	6553	9	6654	9	6770	9	6912	9	7107	9	7449		8137
49.0	6461	55.0	6555	61.0	6656	67.0	6772	73.0	6915	79.0	7111	85.0	7458	89.0	8158
1	6462	1	6556	1	6658	1	6774	1	6917	1	7115	1	7467		8180
2	6464	2	6558	2	6660	2	6776	2	6920	2	7120	2	7476	1	8204
3	6465	3	6560	3	6662	3	6779	3	6923	3	7124	3	7485		8229
4	6467	4	6561	4	6663	4	6781	4	6926	4	7128	4	7494	2	8255
5	6469	5	6563	5	6665	5	6783	5	6929	5	7132	5	7504		8283
6	6470	6	6564	6	6667	6	6785	6	6931	6	7136	6	7514	3	8313
7	6472	7	6566	7	6669	7	6787	7	6934	7	7141	7	7524		8345
8	6473	8	6568	8	6671	8	6789	8	6937	8	7145	8	7534	4	8390
9	6475	9	6569	9	6672	9	6791	9	6940	9	7149	9	7545		8418
50.0	6476	56.0	6571	62.0	6674	68.0	6794	74.0	6943	80.0	7154	86.0	7555	5	8459
1	6478	1	6573	1	6676	1	6796	1	6945	1	7158	1	7566		8505
2	6479	2	6574	2	6678	2	6798	2	6948	2	7163	2	7578	6	8556
3	6481	3	6576	3	6680	3	6800	3	6951	3	7167	3	7589		8614
4	6482	4	6578	4	6682	4	6802	4	6954	4	7172	4	7601	7	8681
5	6484	5	6579	5	6684	5	6805	5	6957	5	7176	5	7614		8760
6	6485	6	6581	6	6685	6	6807	6	6960	6	7181	6	7626	8	8857
7	6487	7	6583	7	6687	7	6809	7	6963	7	7186	7	7639		8982
8	6489	8	6584	8	6689	8	6811	8	6966	8	7191	8	7653	9	9158
9	6490	9	6586	9	6691	9	6814	9	6969	9	7195	9	7668		9459
51.0	6492	57.0	6587	63.0	6693	69.0	6816	75.0	6972	81.0	7200	87.0	7681	90.0	+∞

Azimuth Z should be measured from south or north to 180°

when h = oh~12h→W, 12h~24h→E

Result when ℓ>d, Z = x+y, measure from pole of contrary name to ℓ

ℓ>d, Z = x-y, ℓ & d contrary name, measure from pole of contrary name toℓ

ℓ & d same name, measure from pole of same name as ℓ

Fig. 61

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

10 June 1956
Nautical Almanac

Lunar Age 1ᵈ.1

☉ Sun

U (h)	E_s (h m s)	d (° ′)	P.P. of d (h m)	P.P. of d (′)
0	12 0 47	N22 59.7	0 0	0.0
2	46	23 0.1	10	0
4	45	0.5	20	1
6	44	0.9	30	1
8	43	1.2	40	1
10	42	1.6	0 50	2
12	12 0 41	N23 2.0	1 0	0.2
14	40	2.4	10	2
16	39	2.7	20	3
18	38	3.1	30	3
20	37	3.5	40	3
22	36	3.8	1 50	4
24	12 0 35	N23 4.2	2 0	0.4

(S.D. 15′ 47″)

✱ Star ($U = 0^h$)

No.	Star	E_* (h m s)	d (° ′)
1	Polaris	15 20 32	N89 3.4
2	Kochab	2 22 25	74 20.2
3	Dubhe	6 12 13	61 59.4
4	β Cassiop.	17 6 26	58 54.4
5	Merak	6 14 3	56 37.1
6	Alioth	4 21 9	N56 11.9
7	Schedir	16 35 15	56 17.7
8	Mizar	3 51 5	55 9.3
9	α Persei	13 52 6	49 42.3
10	Benetnasch	3 27 26	49 31.9
11	Capella	11 59 50	N45 57.3
12	Deneb	20 33 19	45 7.3
13	Vega	22 37 47	38 44.5
14	Castor	9 41 28	31 59.1
15	Alpheratz	17 7 9	28 50.9
16	Pollux	9 30 38	N28 7.9
17	α Cor. Bor.	1 40 25	26 51.7
18	Arcturus	2 59 35	19 24.5
19	Aldebaran	12 39 52	16 25.3
20	Markab	18 10 41	14 58.2
21	Denebola	5 26 26	N14 40.9
22	α Ophiuchi	23 40 20	12 35.4
23	Regulus	7 7 14	12 10.8
24	Altair	21 24 36	8 45.2
25	Betelgeuse	11 20 29	7 24.0
26	Bellatrix	11 50 30	N 6 18.6
27	Procyon	9 36 15	N 5 20.2
28	Rigel	12 0 51	S 8 15.1
29	α Hydrae	7 47 50	8 28.8
30	Spica	3 50 22	10 56.2
31	Sirius	10 30 4	S16 39.4
32	β Ceti	16 31 53	18 13.4
33	Antares	0 46 31	26 20.3
34	σ Sagittarii	22 20 41	26 21.0
35	Fomalhaut	18 18 1	29 50.9
36	λ Scorpii	23 42 35	S37 4.4
37	Canopus	10 50 20	52 40.4
38	α Pavonis	20 51 2	56 52.3
39	Achernar	15 37 13	57 27.2
40	β Crucis	4 28 5	59 27.4
41	β Centauri	3 12 30	S60 10.1
42	α Centauri	2 36 36	60 39.7
43	α Crucis	4 49 5	62 51.9
44	α Tri. Aust.	0 29 9	68 57.1
45	β Carinae	8 0 35	S69 32.7

R_0 17ʰ 13ᵐ 17ˢ

Planet

♀ Venus (Tr. 13ʰ 16ᵐ)

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	P.P. E_P (s)	P.P. d (′)
0	10 41 12	N23 55.2	0 0	0	0.0
2	41 40	54.3	10	2	1
4	42 8	53.3	20	5	2
6	42 36	52.4	30	7	2
8	43 5	51.4	40	9	3
10	43 33	50.5	0 50	12	4
12	10 44 1	N23 49.5	1 0	14	0.5
14	29	48.5	10	16	6
16	44 58	47.6	20	19	7
18	45 26	46.6	30	21	7
20	45 55	45.6	40	23	8
22	46 23	44.7	1 50	26	0.9
24	10 46 52	N23 43.7	2 0	28	1.0

♂ Mars (Tr. 5ʰ 13ᵐ)

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	P.P. E_P (s)	P.P. d (′)
0	18 46 33	S12 59.7	0 0	0	0.0
2	43	59.0	10	1	1
4	46 52	58.2	20	2	1
6	47 1	57.4	30	2	2
8	10	56.6	40	3	3
10	20	55.9	0 50	4	3
12	18 47 29	S12 55.1	1 0	5	0.4
14	38	54.3	10	5	5
16	47	53.5	20	6	5
18	47 57	52.8	30	7	6
20	48 6	52.0	40	8	7
22	15	51.2	1 50	8	7
24	18 48 24	S12 50.4	2 0	9	0.8

♃ Jupiter (Tr. 16ʰ 37ᵐ)

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	P.P. E_P (s)	P.P. d (′)
0	7 20 50	N13 58.8	0 0	0	0.0
2	21 7	58.5	10	1	0
4	24	58.3	20	3	1
6	41	58.0	30	4	1
8	21 58	57.8	40	6	1
10	22 15	57.6	0 50	7	1
12	7 22 32	N13 57.3	1 0	9	0.2
14	22 49	57.1	10	10	2
16	23 6	56.8	20	11	2
18	23	56.6	30	13	2
20	40	56.3	40	14	3
22	23 57	56.1	1 50	16	3
24	7 24 14	N13 55.8	2 0	17	0.3

♄ Saturn (Tr. 22ʰ 28ᵐ)

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	P.P. E_P (s)	P.P. d (′)
0	1 28 3	S17 35.0	0 0	0	0.0
2	24	34.9	10	2	0
4	28 45	34.9	20	4	0
6	29 6	34.8	30	5	0
8	27	34.8	40	7	0
10	29 48	34.7	0 50	9	0
12	1 30 9	S17 34.6	1 0	11	0.1
14	30	34.6	10	12	1
16	30 51	34.5	20	14	1
18	31 12	34.4	30	16	1
20	33	34.4	40	18	1
22	31 54	34.3	1 50	19	1
24	1 32 16	S17 34.3	2 0	21	0.1

☾ Moon (Tr. 13ᵐ 40)

U (h)	$E_☾$ (h m s)	d (° ′)
0	10 53 43	N21 0.8
	52 28	20 58.6
1	51 13	56.3
	49 58	54.0
2	48 43	51.7
	47 28	49.4
3	46 13	47.0
	44 58	44.5
4	43 43	42.0
	42 28	39.5
5	41 14	37.0
	39 59	34.4
(H.P.61′.0, S.D.16′ 37″)		
6	10 38 44	N20 31.8
	37 30	29.1
7	36 15	26.4
	35 1	23.6
8	33 46	20.9
	32 32	18.0
9	31 17	15.2
	30 3	12.3
10	28 49	9.4
	27 34	6.4
11	26 20	3.4
	25 6	20 0.4
(H.P.61′.0, S.D.16′ 36″)		
12	10 23 52	N19 57.3
	22 38	54.2
13	21 24	51.1
	20 10	47.9
14	18 57	44.7
	17 43	41.4
15	16 29	38.1
	15 16	34.8
16	14 2	31.4
	12 49	28.1
17	11 35	24.6
	10 22	21.2
(H.P.60′.9, S.D.16′ 36″)		
18	10 9 9	N19 17.7
	7 55	14.1
19	6 42	10.6
	5 29	7.0
20	4 16	19 3.4
	3 3	18 59.7
21	1 50	56.0
	10 0 38	52.3
22	9 59 25	48.5
	58 12	44.7
23	57 0	40.9
	55 47	37.0
24	9 54 35	N18 33.1
(H.P.60′.9, S.D.16′ 35″)		

Moon P.P.

m	$E_☾$ (s)	d (′)	m	$E_☾$ (s)	d (′)
1	3	0.1	1	2	0.1
2	5	2	2	5	2
3	8	3	3	7	3
4	10	3	4	10	5
5	13	4	5	12	6
6	15	5	6	15	7
7	18	6	7	17	8
8	20	7	8	19	0.9
9	23	8	9	22	1.0
10	25	0.9	10	24	2
11	28	1.0	11	27	3
12	30	0	12	29	4
13	33	1	13	32	5
14	35	2	14	34	6
15	38	3	15	37	8
16	40	4	16	39	1.9
17	43	5	17	41	2.0
18	45	5	18	44	1
19	48	6	19	46	2
20	50	7	20	49	3
21	53	8	21	51	4
22	55	1.9	22	54	6
23	58	2.0	23	56	7
24	60	1	24	58	8
25	63	2	25	61	2.9
26	65	3	26	63	3.0
27	68	3	27	66	1
28	70	4	28	68	3
29	73	5	29	71	4
30	75	2.6	30	73	3.5

Planet

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	6 32	N23 55	−3.6	0.5	27
♂	22 27	S13 0	−0.5	0.2	6
♃	9 52	N13 59	−1.5	0.0	16
♄	15 45	S17 35	+0.3	0.0	8
☿	3 57	N16 13	+1.6	0.2	5

Fig. 62

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

14 February 1956 Lunar Age 2.1

Nautical Almanac

☉ Sun

U (h)	$E_☉$ (h m s)	d (° ′)	P.P. of d (h m)	(′)
0	11 45 41	S13 26.0	0 0	0.0
2	41	24.3	10	1
4	41	22.6	20	3
6	42	20.9	30	4
8	42	19.3	40	6
10	42	17.6	0 50	7
12	11 45 42	S13 15.9	1 0	0.9
14	42	14.2	10	1.0
16	42	12.5	20	1
18	42	10.8	30	3
20	43	9.1	40	4
22	43	7.4	1 50	6
24	11 45 43	S13 5.7	2 0	1.7

S.D. 16′ 14″)

✱ Star ($U = 0^h$)

No.	Star	$E_✱$ (h m s)	d (° ′)
1	*Polaris*	7 39 13	N89 3.9
2	*Kochab*	18 41 12	74 19.7
3	*Dubhe*	22 30 55	61 59.0
4	*β Cassiop.*	9 25 12	58 54.7
5	*Merak*	22 32 45	56 36.8
6	*Alioth*	20 39 52	N56 11.5
7	*Schedir*	8 54 0	56 18.1
8	*Mizar*	20 9 49	55 8.9
9	*α Persei*	6 10 48	49 42.6
10	*Benetnasch*	19 46 10	49 31.5
11	*Capella*	4 18 31	N45 57.5
12	*Deneb*	12 52 5	45 7.3
13	*Vega*	14 56 34	38 44.3
14	*Castor*	2 0 10	31 59.1
15	*Alpheratz*	9 25 54	28 51.0
16	*Pollux*	1 49 20	N28 7.9
17	*α Cor. Bor.*	17 59 10	26 51.4
18	*Arcturus*	19 18 20	19 24.3
19	*Aldebaran*	4 58 35	16 25.3
20	*Markab*	10 29 26	14 58.2
21	*Denebola*	21 45 9	N14 48.8
22	*α Ophiuchi*	15 59 6	12 35.3
23	*Regulus*	23 25 56	12 10.7
24	*Altair*	13 43 22	8 45.0
25	*Betelgeuse*	3 39 11	7 23.9
26	*Bellatrix*	4 9 12	N 6 18.6
27	*Procyon*	1 54 58	N 5 20.1
28	*Rigel*	4 19 33	S 8 15.2
29	*α Hydrae*	0 6 32	8 28.3
30	*Spica*	20 9 6	10 56.1
31	*Sirius*	2 48 46	S16 39.5
32	*β Ceti*	8 50 37	18 13.7
33	*Antares*	17 5 17	26 20.2
34	*σ Sagittarii*	14 39 28	26 21.1
35	*Fomalhaut*	10 36 47	29 51.3
36	*λ Scorpii*	16 1 22	S37 4.3
37	*Canopus*	3 9 0	52 40.6
38	*α Pavonis*	13 9 50	56 52.5
39	*Achernar*	7 55 56	57 27.8
40	*β Crucis*	20 46 49	59 26.9
41	*β Centauri*	19 31 15	S60 9.6
42	*α Centauri*	18 55 22	60 39.2
43	*α Crucis*	21 7 48	62 51.3
44	*α Tri. Aust.*	16 47 59	68 56.8
45	*β Carinae*	0 19 13	S69 32.3

R₀ 9h 32m 0s

Planet

♀ Venus Tr. 14h 41m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	9 19 27	N 0 48.1	0 0	0	0.0
2	25	50.7	10	0	2
4	24	53.3	20	0	4
6	22	56.0	30	1	7
8	20	0 58.6	40	1	0.9
10	18	1 1.2	0 50	1	1.1
12	9 19 17	N 1 3.8	1 0	1	1.3
14	15	6.5	10	1	5
16	13	9.1	20	1	1.7
18	11	11.7	30	2	2.0
20	10	14.3	40	2	2
22	8	17.0	1 50	2	4
24	9 19 6	N 1 19.6	2 0	2	2.6

♂ Mars Tr. 7h 45m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	16 14 20	S22 58.8	0 0	0	0.0
2	26	59.1	10	1	0
4	31	59.4	20	1	1
6	37	22 59.7	30	2	1
8	42	23 0.1	40	2	1
10	48	0.4	0 50	3	1
12	16 14 53	S23 0.7	1 0	3	0.2
14	14 59	1.0	10	4	2
16	15 4	1.3	20	4	2
18	10	1.6	30	5	2
20	15	1.9	40	5	3
22	21	2.2	1 50	6	3
24	16 15 26	S23 2.5	2 0	6	0.3

♃ Jupiter Tr. 0h 26m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	23 34 11	N13 39.7	0 0	0	0.0
2	34	39.9	10	2	0
4	34 56	40.2	20	4	0
6	35 18	40.4	30	5	1
8	35 40	40.6	40	7	1
10	36 3	40.9	0 50	9	1
12	23 36 25	N13 41.1	1 0	11	0.1
14	36 47	41.3	10	13	1
16	37 9	41.6	20	15	1
18	32	41.8	30	17	2
20	37 54	42.0	40	18	2
22	38 16	42.3	1 50	20	2
24	23 38 38	N13 42.5	2 0	22	0.2

♄ Saturn Tr. 6h 29m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	17 29 51	S18 35.0	0 0	0	0.0
2	30 10	35.0	10	2	0
4	29	35.0	20	3	0
6	30 47	35.1	30	5	0
8	31 6	35.1	40	6	0
10	25	35.1	0 50	8	0
12	17 31 44	S18 35.2	1 0	10	0.0
14	32 3	35.2	10	11	0
16	21	35.2	20	13	0
18	40	35.2	30	14	0
20	32 59	35.3	40	16	0
22	33 18	35.3	1 50	17	0
24	17 33 37	S18 35.3	2 0	19	0.0

☾ Moon Tr. 14h 3m

U (h)	$E_☾$ (h m s)	d (° ′)
0	10 22 33	N 0 1.8
	21 39	7.8
1	20 46	13.9
	19 52	20.0
2	18 59	26.1
	18 5	32.2
3	17 12	38.2
	16 18	44.3
4	15 25	50.4
	14 31	0 56.5
5	13 37	1 2.6
	12 44	8.7
(H.P.55′.9, S.D.15′ 13″)		
6	10 11 50	N 1 14.8
	10 56	20.9
7	10 3	26.9
	9 9	33.0
8	8 15	39.1
	7 21	45.2
9	6 27	51.3
	5 33	1 57.4
10	4 40	2 3.5
	3 46	9.6
11	2 52	15.7
	1 58	21.7
(H.P.56′.0, S.D.15′ 15″)		
12	10 1 4	N 2 27.8
	10 0 10	33.9
13	9 59 16	40.0
	58 22	46.1
14	57 27	52.2
	56 33	2 58.2
15	55 39	3 4.3
	54 45	10.4
16	53 51	16.5
	52 56	22.6
17	52 2	28.6
	51 8	34.7
(H.P.56′.1, S.D.15′ 17″)		
18	9 50 13	N 3 40.8
	49 19	46.8
19	48 25	52.9
	47 30	3 59.0
20	46 36	4 5.0
	45 41	11.1
21	44 47	17.1
	43 52	23.2
22	42 57	29.2
	42 3	35.3
23	41 8	41.3
	40 13	47.4
24	9 39 18	N 4 53.4
(H.P.56′.2, S.D.15′ 19″)		

P.P. (Moon)

m	$E_☾$ (s)	d (′)	m	$E_☾$ (s)	d (′)
1	2	0.2	1	2	0.2
2	4	4	2	4	4
3	5	6	3	5	6
4	7	0.8	4	7	0.8
5	9	1.0	5	9	1.0
6	11	2	6	11	2
7	13	4	7	13	4
8	14	6	8	15	6
9	16	1.8	9	16	1.8
10	18	2.0	10	18	2.0
11	20	2	11	20	2
12	22	4	12	22	4
13	23	6	13	24	6
14	25	2.8	14	26	2.8
15	27	3.1	15	28	3.1
16	29	3	16	29	3
17	31	5	17	31	5
18	32	7	18	33	7
19	34	3.9	19	35	3.9
20	36	4.1	20	37	4.1
21	38	3	21	38	3
22	40	5	22	40	5
23	41	7	23	42	7
24	43	4.9	24	44	4.9
25	45	5.1	25	46	5.1
26	47	3	26	48	3
27	49	5	27	49	5
28	50	7	28	51	7
29	52	5.9	29	53	5.9
30	54	6.1	30	55	6.1

Planet

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	0 13	N 0 48	−3.6	0.1	7
♂	17 18	S22 59	+1.4	0.1	3
♃	9 58	N13 40	−2.1	0.0	21
♄	16 2	S18 35	+0.7	0.0	7
☿	20 4	S18 52	+0.5	0.2	4

Fig. 63

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

Problem

At 07^h 40^m p.m. on 14 February 1956, a navigator observed the compass bearing of Jupiter as N 72°.2 E in D.R.P. 32°16'S, 41° 52 E. What was the deviation of this compass?

Where; Chronometer time was 04h 26m 08s, variation 18°.8 W, and chronometer error ⊕ 26^m - 32^s
(Ans. Deviation = 14°.5 E, Ref. x = 60°.8, y = 7°.1

Navigation by lines of position

The line of position is one on a point of which the ship can be presumed to be located.

A line of position is a segment of a great circle, but invisible plotting on nautical charts, the segment is so short that it may be plotted as a straight line or rhumb line on a mercator chart.

Geographical position of a celestial body

The position on the earth where a navigator observes a celestial body exactly in the zenith is called its geographical position.

In figure 64, p = north pole, p' = south pole, $\overline{qq}'$ = plane of the equator, C = center of the earth, X = celestial body, x = geographical position of the celestial body x (✱) Because strictly speaking the earth is not a perfect sphere, a straight line through X and x does not pass the earth's center C. This straight line intersects the plane of equator $\overline{qq}'$ at C'.

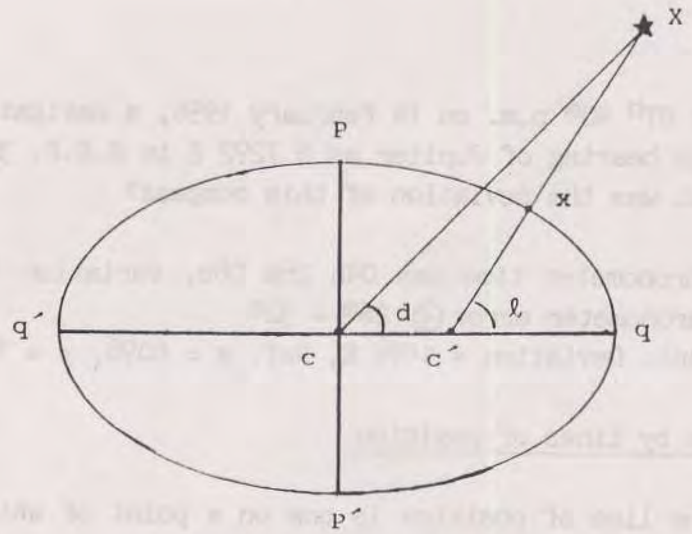


Fig. 64 Geographical Position

So, $\angle XC_q'$ is the latitude of the celestial body's geographical position (x) and the included angle between $\overline{XC}$ and C_q ($\angle XC_q$) is the declination of X.

From Figure 64, $xC_q' = \angle XCq + \angle CXC'$

$\angle CXC'$ is negligible (e.g. in the case of the Moon, $\angle CXC' = 0.2'$ only), then $\angle XC_q = \angle XC_q$

$\angle XC_q' \rightarrow$ Latitude of geographical position + ℓx,

$\angle XC_q \rightarrow$ Declination dx

$\therefore \ell x = dx$

Thus the intersection obtained by the earth's surface and the straight line connecting the center of the earth (c) with the center of celestial body (X) is the geographical position (x) of the celestial body (X) and the equation $\angle XC_q' = \angle XC_q$ is used with the assumption that the earth as a perfect sphere.

In Figure 65, g = position of Greenwich, $\widehat{pgqp'}$ = prime meridian, $\widehat{PGQP'}$ = hour circle corresponding to $\widehat{pgqp'}$.

$\overset{\frown}{QQ'}$ is the Greenwich Hour Angle (G.H.A.) of celestial body X, and $\overset{\frown}{qq'}$ on the earth's surface is the longitude of celestial body X at its geographical position (in this case the longitude is westerly).

The western longitude of geographical position (LWx) is equivalent to the Greenwich Hour Angle of celestial body X (= hgx)

$$LWx = \angle hgx$$

Therefore if a navigator knows a celestial body's declination (available by nautical almanac) and its Greenwich Hour Angle (available by nautical almanac and astronomical navigation table h = U + E), he can decide its geographical position on the earth's surface.

<u>Ref.</u> LWx = West longitude of Geographical Position
hgx = Greenwich Hour Angle

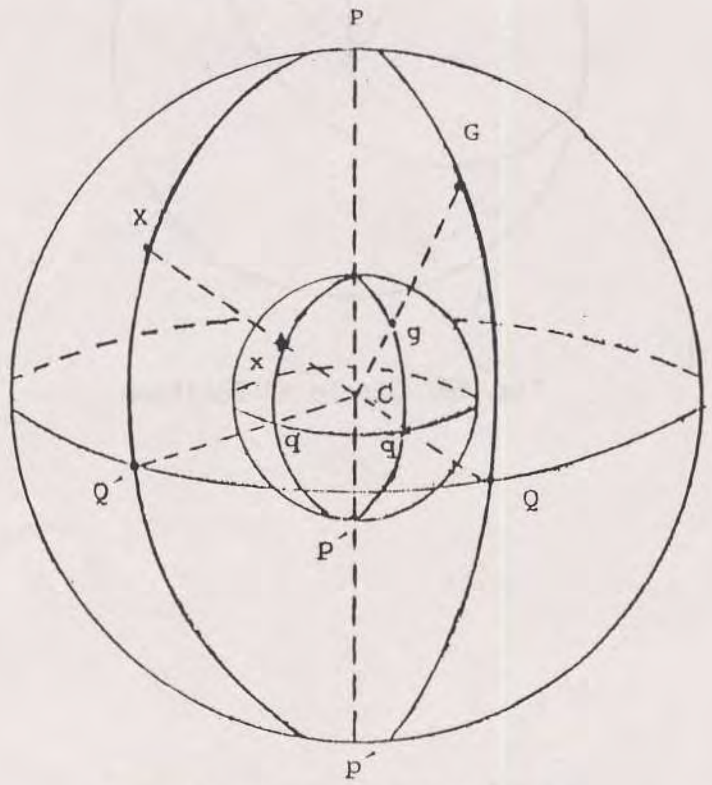


Fig. 65 Geographical Position

Circle of position

In Figure 66,

C = center of the earth, p = north pole, x = geographical position of celestial body X (✶), O = observer's position
p' = south pole, X = celestial body, Z = zenith

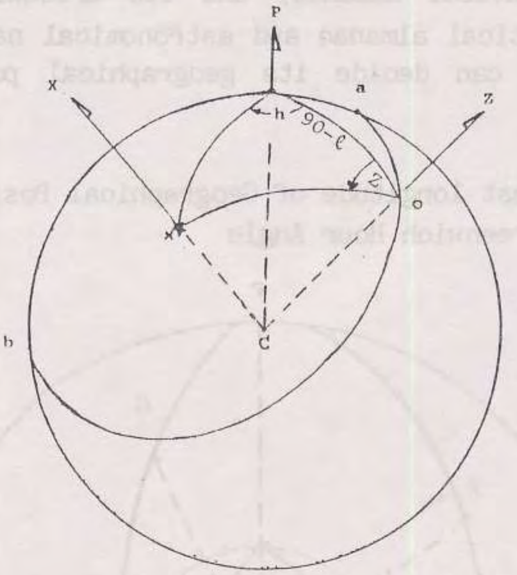


Fig. 66 Circle of Position

LIGHT RAYS FROM A CELESTIAL BODY

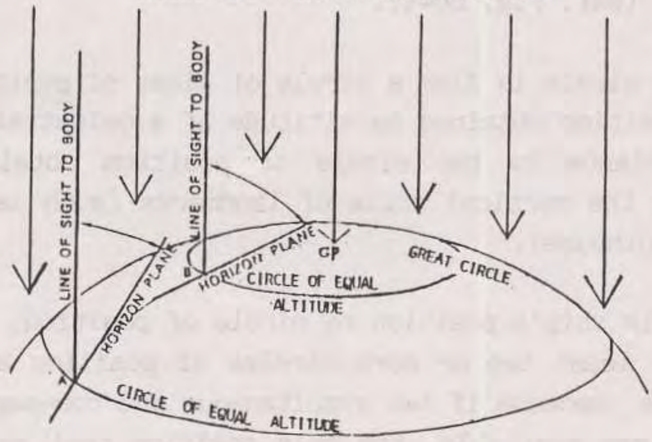


Fig. 66-1 Parallel light rays

Spherical triangle (pxo) on the earth's surface is similar or symmetric to a spherical triangle on the celestial sphere.

So,
- px = polar distance (p)
- xo = zenith distance (z) → (90^{o}- Alt.)
- po = co-latitude (90^{o} - ℓ)
- ∠ opx = local hour angle (h)
- ∠ pox = Azimuth (z)

If a navigator observes the altitude of celestial body X, he can obtain the zenith distance z (= 90^{o}- Alt.), and he can have a circle of position given by the celestial body X, with point x as its center and zenith distance z as its radius.

This circle of position of the celestial sphere corresponds to a circle of position on the earth.

In Figure 66, the circle of $\overset{\frown}{aob}$ is the circle of position. If a navigator on any point of this circle of position observes the altitude of the celestial body, the altitude should be (90^{o} - Z) (Ref. Fig. 66-1).

This circle is also a circle of lines of position and the circle of position obtained by altitude of a celestial body has a close resemblance to the circle of position obtained by the method using the vertical angle of landmarks (such as a mountain tap or a lighthouse).

To fix ship's position by circle of position, a navigator must have at least two or more circles of position available at the same time, because if two simultaneous and non-parallel lines of position are available, the only position that satisfies the requirements of being on both lines at the same time is the intersection of the two lines.

We have two intersections (0 and 0' in Figure 67) given by two circles of position obtained by observing two celestial bodies (X and X' in Figure 24). But actually the distance between the two positions 0 and 0' is hundreds or thousands of nautical miles and a navigator knows that his dead reckoning position is near true position. Therefore it is not difficult to distinguish true intersection, as his location, from the false one,

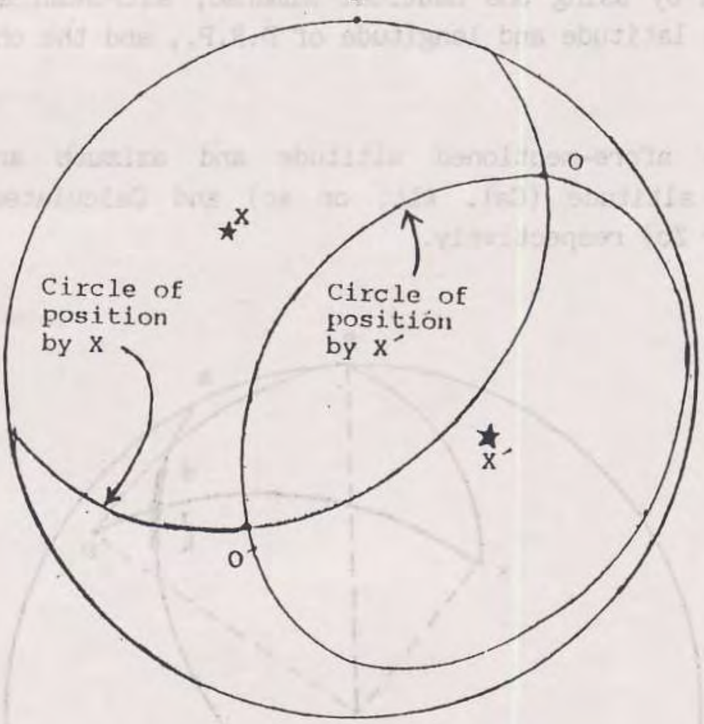


Fig. 67 Two intersections by two circles of position

How to draw lines of position on Mercator chart

In Figure 68,

p = pole, x = geographical position of celestial body X,
D = observer's D.R.P. $\widehat{ab}$ = circle of position, $\widehat{HJK}$ = minute particle on circle of position ($\widehat{ab}$) in the vicinity of D.R.P. (D).

If the navigator's location is in D.R.D. (D) at a particular time, he can calculate a celestial body's altitude and its azimuth by using the nautical almanac, astronomical navigation tables latitude and longitude of D.R.P., and the chronometer time.

The afore-mentioned altitude and azimuth are called Calculated altitude (Cal. Alt. or ac) and Calculated Azimuth (Cal. az or Zc) respectively.

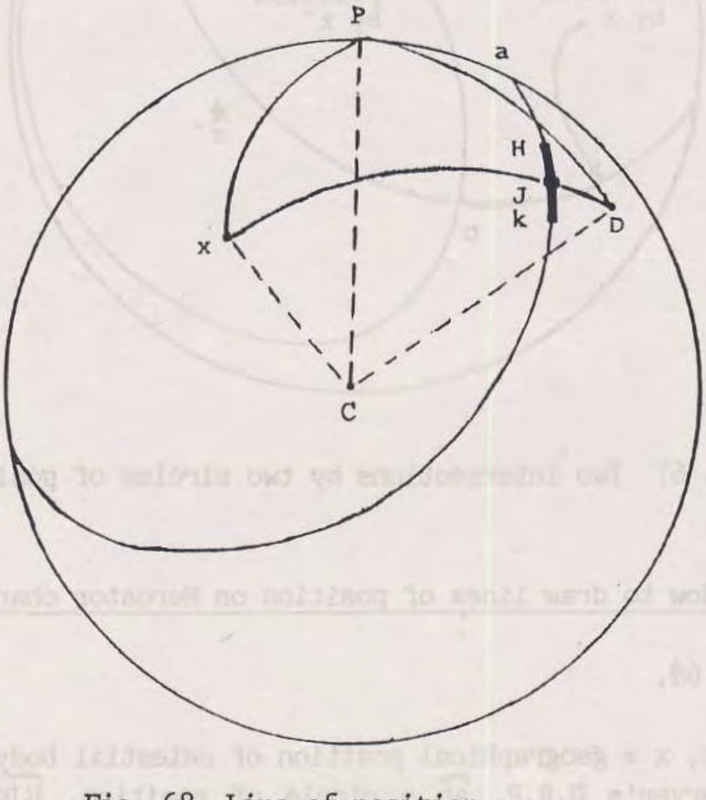


Fig. 68 Line of position

The altitude ($90^\circ - \widehat{xJ}$, in Figure 68) observed by a navigator with altitude corrections is called true altitude (True Alt. or at)

According to Figure 25,

$$\widehat{DJ} = \widehat{xD} \sim \widehat{xJ} = ac \sim at$$

$\widehat{DJ}$ is called intercept (Inter, or I) and point J is called Extremity of Intercept. In figure 25, D.R.P. (D) exists outside the circle of position $\widehat{aJb}$, but in other cases, D can be inside the circle of position $\widehat{aJb}$.

To distinguish whether D is outside or inside the circle of position $\widehat{aJb}$, it is very useful to designate intercept puls ⊕ or minus ⊖ , For this reason we must give the definition of Intercept (I) as follows;

$$I = at - ac$$

In Figure 68,

1. Extremity of Intercept (J) is located on the great circle passing through D.R.P. (D) and geographical position (x), that is, azimuth line from D.R.P. (D) to geographical position (x).

   So when I (= at - ac) is plus ⊕, Extremity of Intercept exists towards the celestial body from D.R.P. (D), and

   when I (= at - ac) is minus ⊖ , Extremity of Intercept is on the opposite side of the celestial body from D.R.P. (D).

2. Angular distance $\widehat{DJ}$, that is, distance from D.R.P. (D) to extremity is equal to the value of Intercept. Value of Intercept should be expressed in nautical minutes (')

3. $\overset{\frown}{DJ}$ and $\overset{\frown}{HJK}$, that is, azimuth line from D.R.P. (D) to geographical position (x) and circle of position (minute particle of circle of position to be exact) intersect at a right angle (90°) at Extremity of Intercept, because geographical position (x) is the center of the circle of position, $\widehat{xJ}$ as its radius.

Therefore navigators can draw lines of position on mercator charts using the following procedure.

1. Draw the azimuth line through D.R.P. (D) by Calculated Azimuth (obtainable from nautical almanac and astronomical calculation tables);

2. To set up Extremity of Intercept,

   a. When Intercept (I) is positive ⊕, draw a straight line from D.R.P. (D) towards the celestial body (same direction as Calculated Azimuth Zc), and mark the distance from D.R.P. (D) according to the value of Intercept

   b. When Intercept (I) is negative ⊖, Draw a straight line from D.R.P. (D) to the opposite side from the celestial body (contrary direction to Calculated Azimuth Zc), and mark the distance from D.R.P. (D) according to value of Intercept (I) on this straight line to set up the Extremity of Intercept.

3. To draw line of position. The straight line passing through Extremity of Intercept (J) which intersects the azimuth line is the line of position (see Fig. 26).

   To fix position, the navigator observes two or more celestial bodies, to obtain lines of position and an intersection at his location. When he measures the altitude of a celestial body by sextant, it is very important to select navigational stars.

   It is desirable that the directions of the celestial bodies of which he intends to observe the altitudes intersect at right angles, or at a 30°, 40°, 60° and it is most undesirable that directions of celestial bodies by parallel or nearly parallel.

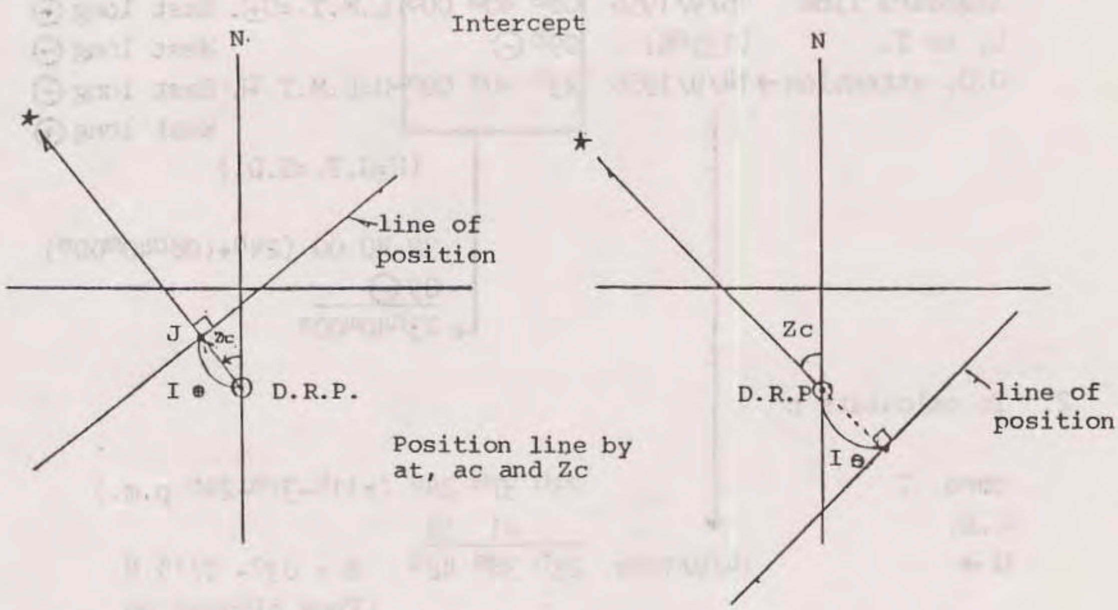


Fig. 69

Example 12

At the standard time $08^h\ 40^m\ 00^s$ (standard time for 135^oE) on 15 September 1956, a navigator observed the altitude of the sun's lower limb ($\underline{\odot}$) as $39^o\ 07'8$ in D.R.P. $34^o\ 45'N$, $141^o\ 28'E$.

Draw a line of position on the chart.

Where : Chronometer time was $11^h\ 37^m\ 24^s$, chronometer error ⊕ $01^m\ 18^s$, index error ⊕ 2.3, height of eye 15 metres, air temperature 22^oC, sea water temperature 18^oC.

Solution

1. To calculate G.D.

			Ref.
Standard Time	15/9/1956	$08^h\ 40^m\ 00^s$	L.M.T.=U±L East long ⊕
L. in T.	(135^oE)	09^h ⊖	West long ⊖
G.D. attention →	14/9/1956	$23^h\ 40^m\ 00^s$	←U=L.M.T.∓L East long ⊖
			West long ⊕

(U=G.T.=G.D.)

32 40 00 (24^h+($08^h 40^m 00^s$))
09 ⊖
↳ $23^h 40^m 00^s$

2. To calculate h

chro. T		$23^h\ 37^m\ 24^s$	(=11^h-37^m-24^s p.m.)
C.E.		01 18	
U →	14/9/1956	$23^h\ 38^m\ 42^s$	d = 03^o- 07'9 N (From almanac on 14/9/1956)
E. (23 38 42 on 14/9/1956)		12 04 40 ⊕	(From almanac)
		$35^h\ 43^m\ 22^s$	
h_G		24 ⊖	
h_G		11 43 21	

h_G	175° - 50!5
L (141°-28!0 E)	141° - 28!0 +
h	317° - 18!5

3. To calculate ac and Z_c by astronomical navigation Table (Altitude-Azimuth Table) corresponding h, d and ℓ.

h	317° - 18!5	A_1 87780	(see Fig. 29)	Z_1 16874		
d	03° - 07!9	A_2 65	(see Fig. 30)	Z_1 65 ⊕	(A_2= Z_2)	
	34° - 45!0	A_3 8531 ⊕	(see Fig. 31)	16939		
		A_4 96376	⟶	A_5 10871		

ℓ~d (34°45!0)-(03°07!9) = 31°- 37!1 → A_6 7422 ⊕

a_c 39°- 21!4 ← A_7 18293 → Z_3 11170 ⊖

Z_4 5769

(see Fig. 34) Z 61°07'

S 61°1 E

4. To calculate true altitude (a_t)

Sex. Alt. ⊙	39° - 07!8		
I.E.	02!3	⊕	
Obs. Alt. ⊙	39° - 10!1		
Corr. 1	07!8	⊕	(see Fig. 36)
	39° - 17!9		
Coor. 2	0!2	⊕	(see Fig. 36)
	39° - 18!1		
Corr. 3	0!8	⊕	(air temp.-sea water temp. = 22°C - 18°C = 4°C)
a_t	39° - 18!9		

5. To calculate I

a_t ~~⊕~~	39° - 18!9
a_c	39° - 21!4 ⊖
I	⊖ 2.5

Ans. Fig. 70

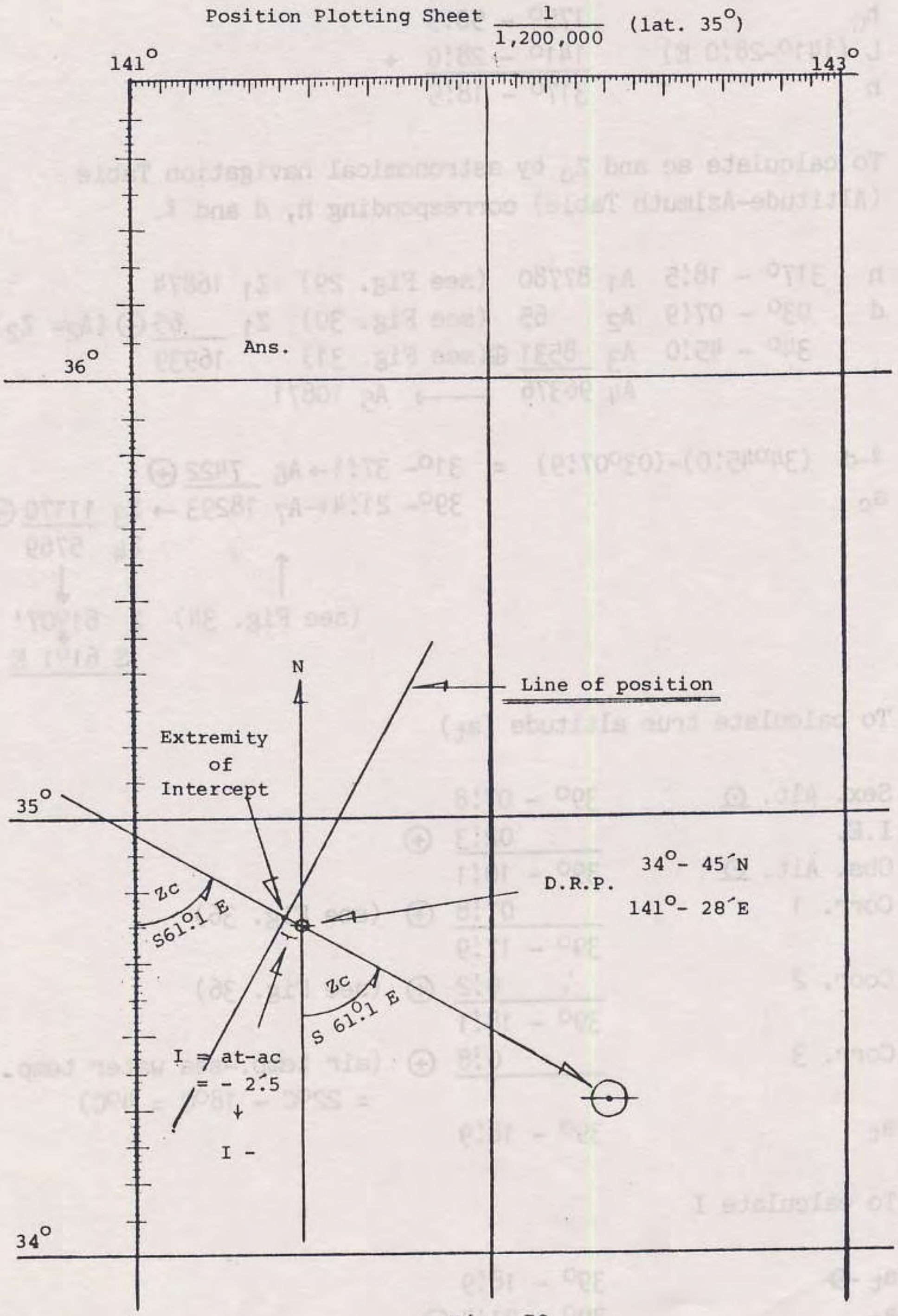

Position Plotting Sheet 1/1,200,000 (lat. 35°)
141°
143°
36°
Ans.
35°
34°
N
Line of position
Extremity of Intercept
34°- 45´N
141°- 28´E
D.R.P.
Zc
S61°.1 E
Zc
S 61°.1 E
I = at-ac
= - 2.5
I -

Fig. 70

Fig. 70-1 Meridian Observation

The sun should be observed at local apparent noon as routine work aboard ship.

1983-1985 Regular Course Trainees observing the sun on board M.V. PAKNAM near the Bashi Channel, 7 August 1985.

14 September 1956
Nautical Almanac

Lunar Age 9ᵈ.2

☉ Sun

U (h)	E☉ (h m s)	d (° ′)	P.P. of d (h m)	P.P. of d (′)
0	12 4 18	N 3 30.6	0 0	0.0
2	20	28.7	10	2
4	22	26.8	20	3
6	24	24.9	30	5
8	25	22.9	40	6
10	27	21.0	0 50	0.8
12	12 4 29	N 3 19.1	1 0	1.0
14	31	17.2	10	1
16	32	15.3	20	3
18	34	13.3	30	4
20	36	11.4	40	6
22	38	9.5	1 50	7
24	12 4 40	N 3 7.6	2 0	1.9

(S.D. 15′ 56″)

✱ Star ($U = 0^h$)

No.	Star	E✱ (h m s)	d (° ′)
1	*Polaris*	21 36 59	N 89 3.6
2	*Kochab*	8 41 2	74 20.2
3	*Dubhe*	12 30 44	61 59.0
4	*β Cassiop.*	23 24 52	58 54.8
5	*Merak*	12 32 34	56 36.8
6	*Alioth*	10 39 40	N 56 11.8
7	*Schedir*	22 53 41	56 18.1
8	*Mizar*	10 9 37	55 9.2
9	*α Persei*	20 10 31	49 42.4
10	*Benetnasch*	9 45 58	49 31.9
11	*Capella*	18 18 16	N 45 57.2
12	*Deneb*	2 51 47	45 7.8
13	*Vega*	4 56 17	38 44.9
14	*Castor*	15 59 56	31 59.0
15	*Alpheratz*	23 25 35	28 51.3
16	*Pollux*	15 49 6	N 28 7.8
17	*α Cor. Bor.*	7 58 55	26 51.8
18	*Arcturus*	9 18 6	19 24.6
19	*Aldebaran*	18 58 19	16 25.5
20	*Markab*	0 29 8	14 58.6
21	*Denebola*	11 44 56	N 14 48.9
22	*α Ophiuchi*	5 58 50	12 35.7
23	*Regulus*	13 25 43	12 10.8
24	*Altair*	3 43 5	8 45.4
25	*Betelgeuse*	17 39 56	7 24.1
26	*Bellatrix*	18 8 57	N 6 18.8
27	*Procyon*	15 54 44	N 5 20.3
28	*Rigel*	18 19 18	S 8 14.9
29	*α Hydrae*	14 6 19	8 28.2
30	*Spica*	10 8 52	10 56.1
31	*Sirius*	16 48 32	S 16 39.2
32	*β Ceti*	22 50 20	18 13.2
33	*Antares*	7 5 1	26 20.3
34	*σ Sagittarii*	4 39 10	26 21.1
35	*Fomalhaut*	0 36 29	29 50.9
36	*λ Scorpii*	6 1 5	S 37 4.5
37	*Canopus*	17 8 47	52 40.0
38	*α Pavonis*	3 9 30	56 52.5
39	*Achernar*	21 55 38	57 27.1
40	*β Crucis*	10 46 37	59 27.3
41	*β Centauri*	9 31 2	S 60 10.1
42	*α Centauri*	8 55 8	60 39.7
43	*α Crucis*	11 7 37	62 51.7
44	*α Tri. Aust.*	6 47 41	68 57.3
45	*ζ Carinae*	14 19 5	S 69 32.2

R_0 23ʰ 31ᵐ 47ˢ

Planet

♀ Venus Tr. 8ʰ 59ᵐ

U (h)	Eₚ (h m s)	d (° ′)	P.P. (h m)	P.P. Eₚ (s)	P.P. d (′)
0	15 0 52	N 17 14.6	0 0	0	0.0
2	50	13.7	10	0	1
4	48	12.9	20	0	2
6	46	12.0	30	1	2
8	44	11.2	40	1	3
10	42	10.3	0 50	1	4
12	15 0 40	N 17 9.4	1 0	1	0.5
14	38	8.5	10	1	5
16	36	7.7	20	1	6
18	34	6.8	30	2	7
20	32	5.9	40	2	8
22	30	5.0	1 50	2	8
24	15 0 28	N 17 4.1	2 0	2	0.9

♂ Mars Tr. 23ʰ 46ᵐ

U (h)	Eₚ (h m s)	d (° ′)	P.P. (h m)	P.P. Eₚ (s)	P.P. d (′)
0	0 9 22	S 10 19.8	0 0	0	0.0
2	9 47	20.1	10	2	0
4	10 12	20.4	20	4	1
6	10 37	20.7	30	6	1
8	11 2	21.0	40	8	1
10	27	21.2	0 50	10	1
12	0 11 52	S 10 21.5	1 0	12	0.2
14	12 17	21.8	10	15	2
16	12 43	22.1	20	17	2
18	13 8	22.4	30	19	2
20	33	22.6	40	21	3
22	13 58	22.9	1 50	23	3
24	0 14 23	S 10 23.2	2 0	25	0.3

♃ Jupiter Tr. 11ʰ 30ᵐ

U (h)	Eₚ (h m s)	d (° ′)	P.P. (h m)	P.P. Eₚ (s)	P.P. d (′)
0	12 28 49	N 7 9.7	0 0	0	0.0
2	29 5	9.2	10	1	0
4	21	8.8	20	3	1
6	36	8.4	30	4	1
8	29 52	8.0	40	5	1
10	30 8	7.6	0 50	7	2
12	12 30 23	N 7 7.2	1 0	8	0.2
14	39	6.8	10	9	2
16	30 55	6.4	20	11	3
18	31 10	6.0	30	12	3
20	26	5.5	40	13	3
22	42	5.1	1 50	15	4
24	12 31 57	N 7 4.7	2 0	16	0.4

♄ Saturn Tr. 16ʰ 10ᵐ

U (h)	Eₚ (h m s)	d (° ′)	P.P. (h m)	P.P. Eₚ (s)	P.P. d (′)
0	7 48 1	S 17 52.1	0 0	0	0.0
2	19	52.1	10	2	0
4	37	52.2	20	3	0
6	48 56	52.3	30	5	0
8	49 14	52.4	40	6	0
10	32	52.5	0 50	8	0
12	7 49 51	S 17 52.6	1 0	9	0.1
14	50 9	52.7	10	11	1
16	27	52.8	20	12	1
18	50 46	52.9	30	14	1
20	51 4	53.0	40	15	1
22	22	53.1	1 50	17	1
24	7 51 40	S 17 53.2	2 0	18	0.1

☾ Moon Tr. 20ʰ 1ᵐ

U (h)	E☾ (h m s)	d (° ′)
0	4 36 39	S 19 30.1
	35 42	27.7
1	34 45	25.3
	33 48	[illegible]
2	32 51	20.4
	31 54	17.9
3	30 57	15.4
	30 0	12.9
4	29 3	10.4
	28 7	7.8
5	27 10	5.2
	26 13	2.6
(H.P. 54′.2, S.D. 14′ 47″)		
6	4 25 16	S 19 0.0
	24 20	18 57.3
7	23 23	54.6
	22 27	51.3
8	21 30	49.2
	20 34	46.5
9	19 37	43.7
	18 41	41.0
10	17 44	38.2
	16 48	35.3
11	15 52	32.5
	14 55	29.6
(H.P. 54′.2, S.D. 14′ 46″)		
12	4 13 59	S 18 26.8
	13 3	23.9
13	12 7	21.0
	11 11	18.0
14	10 14	15.1
	9 18	12.1
15	8 22	9.1
	7 26	6.1
16	6 30	3.0
	5 35	18 0.0
17	4 39	17 56.9
	3 43	53.8
(H.P. 54′.2, S.D. 14′ 45″)		
18	4 2 47	S 17 50.7
	1 51	47.5
19	0 56	44.4
	4 0 0	41.2
20	3 59 4	38.0
	58 9	34.8
21	57 13	31.6
	56 17	28.3
22	55 22	25.0
	54 26	21.7
23	53 31	18.4
	52 36	15.1
24	3 51 40	S 17 11.8
(H.P. 54′.2, S.D. 14′ 45″)		

P.P. (Moon)

E☾ (m)	E☾ (s)	d (′)
1	2	0.1
2	4	2
3	6	3
4	8	3
5	10	4
6	11	5
7	13	6
8	15	7
9	17	8
10	19	0.9
11	21	1.0
12	23	0
13	25	1
14	27	2
15	29	3
16	30	4
17	32	5
18	34	6
19	36	6
20	38	7
21	40	8
22	42	1.9
23	44	2.0
24	46	1
25	48	2
26	49	3
27	51	3
28	53	4
29	55	5
30	57	2.6

E☾ (m)	E☾ (s)	d (′)
1	2	0.1
2	4	2
3	6	3
4	7	4
5	9	5
6	11	6
7	13	7
8	15	8
9	17	0.9
10	19	1.0
11	21	1
12	22	2
13	24	3
14	26	4
15	28	6
16	30	7
17	32	8
18	34	1.9
19	35	2.0
20	37	1
21	39	2
22	41	3
23	43	4
24	45	5
25	47	6
26	49	7
27	50	8
28	52	2.9
29	54	3.0
30	56	3.1

Planet

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	8 31	N 17 15	−3.9	0.2	10
♂	23 22	S 10 20	−2.6	0.4	12
♃	11 3	N 7 10	−1.2	0.0	14
♄	15 44	S 17 52	+0.8	0.0	7
☿	12 38	S 8 29	+1.0	0.2	5

Fig. 71

Table for Altitude (Ac) and Azimuth (Zc)

Table of Altitude and Azimuth

$A_1 + A_2 + A_3 = A_4 \quad A_5 \quad A_6 = A_7$
(h) (d) (l) (l±d)(a)

ℓ & d contrary name → ℓ+d
ℓ & d same name → ℓ~d

° / ′	A_1 h / A_4	P.P.	A_5 / A_6 l±d	P.P.	Z_1 h / Z_4 Z	P.P.	A_1 h / A_4	P.P.	A_5 / A_6 l±d	P.P.	Z_1 h / Z_4 Z	P.P.	
0	↑ 89134	0	↓ 12843	0	↑ 17449	0	↑ 87185	0	↓ 13432	0	↑ 16622	0	60
1	89101	3	12852	1	17435	1	87153	3	13442	1	16609	1	59
2	89068	7	12862	2	17421	3	87121	6	13452	2	16595	3	58
3	89035	10	12872	3	17407	4	87089	10	13462	3	16581	4	57
4	89003	13	12882	4	17393	6	87057	13	13472	4	16568	6	56
5	88970	17	12891	5	17379	7	87025	16	13482	5	16554	7	55
6	88937	20	12901	5	17365	8	86993	19	13492	6	16541	8	54
7	88904	23	12911	6	17351	10	86961	22	13502	7	16527	10	53
8	88871	26	12921	7	17337	11	86929	26	13512	8	16514	11	52
9	88839	30	12930	8	17323	13	86897	29	13522	9	16500	13	51
10	88806	0	12940	0	17309	0	86865	0	13532	0	16487	0	50
11	88773	3	12950	1	17295	1	86833	3	13542	1	16473	1	49
12	88740	7	12960	2	17281	3	86801	6	13552	2	16460	3	48
13	88708	10	12970	3	17267	4	86769	10	13562	3	16446	4	47
14	88675	13	12979	4	17253	6	86737	13	13571	4	16433	6	46
15	88642	17	12989	5	17239	7	86705	16	13581	5	16419	7	45
16	88609	20	12999	6	17225	8	86674	19	13591	6	16406	8	44
17	88577	23	13009	7	17212	10	86642	22	13601	7	16392	10	43
18	88544	26	13018	8	17198	11	86610	26	13611	8	16379	11	42
19	88511	30	13028	9	17184	13	86578	29	13621	9	16366	13	41
20	88479	0	13038	0	17170	0	86546	0	13631	0	16352	0	40
21	88446	3	13048	1	17156	1	86514	3	13641	1	16339	1	39
22	88414	6	13058	2	17142	3	86483	6	13651	2	16326	3	38
23	88381	10	13067	3	17128	4	86451	10	13661	3	16312	4	37
24	88348	13	13077	4	17115	6	86419	13	13671	4	16299	6	36
25	88316	16	13087	5	17101	7	86387	16	13681	5	16285	7	35
26	88283	19	13097	6	17087	8	86356	19	13691	6	16272	8	34
27	88251	22	13107	7	17073	10	86324	22	13701	7	16259	10	33
28	88218	26	13116	8	17059	11	86292	26	13711	8	16245	11	32
29	88146	29	13126	9	17045	13	86261	29	13721	9	16232	13	31
30	88153	0	13136	0	17032	0	86229	0	13731	0	16219	0	30
31	88121	3	13146	1	17018	1	86197	3	13741	1	16205	1	29
32	88088	6	13156	2	17004	3	86166	6	13761	2	16192	3	28
33	88056	10	13166	3	16990	4	86134	9	13761	3	16179	4	27
34	88023	13	13176	4	16977	6	86102	12	13771	4	16166	6	26
35	87991	16	13185	5	16963	7	86071	16	13781	5	16152	7	25
36	87959	19	13195	6	16949	8	86039	19	13791	6	16139	8	24
37	87926	22	13205	7	16935	10	86008	22	13801	7	16126	10	23
38	87894	26	13215	8	16922	11	85976	25	13811	8	16113	11	22
39	87861	29	13225	9	16908	13	85944	28	13822	9	16099	13	21
40	87829	0	13235	0	16894	0	85913	0	13832	0	16086	0	20
41	87797	3	13244	1	16880	1	85881	3	13842	1	16073	1	19
42	87764	6	13254	2	16867	3	85850	6	13852	2	16060	3	18
43	87732	10	13264	3	16853	4	85818	10	13862	3	16046	4	17
44	87700	13	13274	4	16839	5	85787	13	13872	4	16033	5	16
45	87668	16	13284	5	16826	7	85755	16	13882	5	16020	7	15
46	87635	19	13294	6	16812	8	85724	19	13892	6	16007	8	14
47	87603	22	13304	7	16798	9	85693	22	13902	7	15994	9	13
48	87571	26	13314	8	16785	10	85661	26	13912	8	15980	10	12
49	87539	29	13323	9	16771	12	85630	29	13922	9	15967	12	11
50	87506	0	13333	0	16758	0	85598	0	13932	0	15954	0	10
51	87474	3	13343	1	16744	1	85567	3	13942	1	15941	1	9
52	87442	7	13353	2	16730	3	85535	6	13952	2	15928	3	8
53	87410	10	13363	3	16717	4	85504	10	13962	3	15915	4	7
54	87378	13	13373	4	16703	5	85473	13	13972	4	15902	6	6
55	87345	17	13383	5	16690	7	85441	16	13983	6	15888	7	5
56	87313	20	13393	6	16676	8	85410	19	13993	7	15875	8	4
57	87281	23	13403	7	16662	9	85379	22	14003	8	15862	10	3
58	87249	26	13412	8	16649	10	85347	26	14013	9	15849	11	2
59	87217	30	13422	9	16635	12	85316	29	14023	10	15836	13	1
60	↑ 87185		↓ 13432		↑ 16622		↑ 85285		↓ 14033		↑ 15823		0
	A_1 h	P.P.	A_7 a	P.P.	A_2 d / A_3 l / Z_3 a	P.P.	A_1 h	P.P.	A_7 a	P.P.	A_2 d / A_3 l / Z_3 a	P.P.	′ / °
	317°		47°				316°		46°				

$Z_1 + Z_2 (= A_2) - Z_3 = Z_4$
(h) (d) (a) (Z)

Fig. 72

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth

$$\underset{(h)}{A_1} + \underset{(d)}{A_2} + \underset{(l)}{A_3} = A_4 \rightarrow A_5 + \underset{(l \pm d)}{A_6} = \underset{(a)}{A_7}$$

ℓ & d contrary name → ℓ+d
ℓ & d same name → ℓ-d

° / ′	86° A_1 h / A_4	P.P.	A_5 / A_6 $l \pm d$	P.P.	Z_1 h / Z_4 Z	P.P.	87° A_1 h / A_4	P.P.	A_5 / A_6 $l \pm d$	P.P.	Z_1 h / Z_4 Z	P.P.	
0	↑ 33243	0	↓ 46512	0	↑ 106	0	↑ 32438	0	↓ 47383	0	↑ 60	0	60
1	33230	1	46527	2	105	0	32424	1	47398	2	59	0	59
2	33216	3	46541	3	104	0	32411	3	47412	3	58	0	58
3	33203	4	46556	5	103	0	32398	4	47427	5	58	0	57
4	33189	5	46570	6	102	0	32384	5	47441	6	57	0	56
5	33176	7	46585	8	102	0	32371	7	47456	8	56	1	55
6	33162	8	46599	9	101	0	32358	8	47470	9	56	1	54
7	33149	9	46614	11	100	0	32344	9	47485	11	55	1	53
8	33135	10	46628	12	99	0	32331	10	47499	12	54	1	52
9	33122	12	46643	14	98	0	32318	12	47514	14	54	1	51
10	33108	0	46657	0	97	0	32305	0	47528	0	53	0	50
11	33095	1	46672	2	96	0	32291	1	47543	1	52	0	49
12	33081	3	46686	3	96	0	32278	3	47558	3	52	0	48
13	33068	4	46701	5	95	0	32265	4	47572	4	51	0	47
14	33054	5	46715	6	94	0	32252	6	47587	6	51	0	46
15	33041	7	46730	8	93	1	32238	7	47601	7	50	1	45
16	33027	8	46744	9	92	1	32225	8	47616	8	49	1	44
17	33014	9	46759	11	91	1	32212	10	47630	10	49	1	43
18	33000	10	46773	12	91	1	32199	11	47645	11	48	1	42
19	32987	12	46788	14	90	1	32185	13	47659	13	48	1	41
20	32973	0	46802	0	89	0	32172	0	47674	0	47	0	40
21	32960	1	46817	2	88	0	32159	1	47688	1	46	0	39
22	32946	3	46831	3	87	0	32146	3	47703	3	46	0	38
23	32933	4	46846	5	87	0	32132	4	47717	4	45	0	37
24	32919	5	46860	6	86	0	32119	5	47732	6	45	0	36
25	32906	7	46875	8	85	1	32106	7	47746	7	44	1	35
26	32892	8	46890	9	84	1	32093	8	47761	8	44	1	34
27	32879	9	46904	11	83	1	32080	9	47776	10	43	1	33
28	32866	10	46919	12	83	1	32066	10	47790	11	42	1	32
29	32852	12	46933	14	82	1	32053	12	47805	13	42	1	31
30	32839	0	46948	0	81	0	32040	0	47819	0	41	0	30
31	32825	1	46962	1	80	0	32027	1	47834	1	41	0	29
32	32812	3	46977	3	80	0	32014	3	47848	3	40	0	28
33	32798	4	46991	4	79	0	32000	4	47863	5	40	0	27
34	32785	5	47006	6	78	0	31987	5	47877	6	39	0	26
35	32772	7	47020	7	77	1	31974	7	47892	8	39	0	25
36	32758	8	47035	8	77	1	31961	8	47906	9	38	0	24
37	32745	9	47049	10	76	1	31948	9	47921	11	38	0	23
38	32731	10	47064	11	75	1	31934	10	47935	12	37	0	22
39	32718	12	47078	13	74	1	31921	12	47950	14	37	0	21
40	32705	0	47093	0	74	0	31908	0	47964	0	36	0	20
41	32691	1	47107	1	73	0	31895	1	47979	2	36	0	19
42	32678	3	47122	3	72	0	31882	3	47993	3	35	0	18
43	32664	4	47136	4	71	0	31869	4	48008	5	34	0	17
44	32651	5	47151	6	71	0	31856	6	48022	6	34	0	16
45	32638	7	47165	7	70	1	31842	7	48037	8	33	1	15
46	32624	8	47180	8	69	1	31829	8	48052	9	33	1	14
47	32611	9	47194	10	68	1	31816	10	48066	11	33	1	13
48	32598	10	47209	11	68	1	31803	11	48081	12	32	1	12
49	32584	12	47223	13	67	1	31790	13	48095	14	32	1	11
50	32571	0	47238	0	66	0	31777	0	48110	0	31	0	10
51	32557	1	47252	2	66	0	31764	1	48124	1	31	0	9
52	32544	3	47267	3	65	0	31751	3	48139	3	30	0	8
53	32531	4	47282	5	64	0	31737	4	48153	4	30	0	7
54	32517	5	47296	6	64	0	31724	5	48168	6	29	0	6
55	32504	7	47311	8	63	1	31711	7	48182	7	29	0	5
56	32491	8	47325	9	62	1	31698	8	48197	8	23	0	4
57	32478	9	47340	11	62	1	31685	9	48211	10	28	0	3
58	32464	10	47354	12	61	1	31672	10	48226	11	27	0	2
59	32451	12	47369	14	60	1	31659	12	48241	13	27	0	1
60	↑ 32438		↓ 47383		↑ 60		↑ 31646		↓ 48255		↑ 26		0
	A_1 h	P.P.	A_7 a	P.P.	A_2 d / A_3 l / Z_2 a	P.P.	A_1 h	P.P.	A_7 a	P.P.	A_2 d / A_3 l / Z_2 a	P.P.	′
	273°		3°				272°		2°				°

$$\underset{(h)}{Z_1} + \underset{(d)}{Z_2} (= A_2) - \underset{(a)}{Z_3} = \underset{(Z)}{Z_4}$$

Fig. 73

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth

$A_1 + A_2 + A_3 = A_4 \to A_5 + A_6 = A_7$
(h) (d) (l) (l±d) (a)

ℓ & d contrary name → ℓ+d
ℓ & d same name → ℓ-d

° / ′	54° A_1 A_4 h	P.P.	A_5 A_6 $l \pm d$	P.P.	Z_1 Z_4 h Z	P.P.	55° A_1 A_4 h	P.P.	A_5 A_6 $l \pm d$	P.P.	Z_1 Z_4 h Z	P.P.	
0	↑ 68591	0	↓ 20611	0	↑ 9204	0	↑ 67119	0	↓ 21321	0	↑ 8664	0	60
1	68566	3	20623	1	9195	1	67095	2	21333	1	8655	1	59
2	68541	5	20634	2	9186	2	67070	5	21345	2	8646	2	58
3	68516	8	20646	4	9177	3	67046	7	21357	4	8637	3	57
4	68492	10	20658	5	9168	4	67022	10	21369	5	8628	4	56
5	68467	13	20670	6	9158	5	66998	12	21381	6	8619	5	55
6	68442	15	20681	7	9149	6	66973	14	21393	7	8611	5	54
7	68417	18	20693	8	9140	7	66949	17	21405	8	8602	6	53
8	68393	20	20705	10	9131	8	66925	19	21417	10	8593	7	52
9	68368	23	20717	11	9122	9	66901	22	21429	11	8584	8	51
10	68343	0	20729	0	9113	0	66877	0	21440	0	8575	0	50
11	68318	2	20740	1	9104	1	66852	2	21452	1	8567	1	49
12	68294	5	20752	2	9094	2	66828	5	21464	2	8558	2	48
13	68269	7	20764	4	9085	3	66804	7	21476	4	8549	3	47
14	68244	10	20776	5	9076	4	66780	10	21488	5	8540	4	46
15	68220	12	20788	6	9067	5	66756	12	21500	6	8531	5	45
16	68195	14	20799	7	9058	5	66732	14	21512	7	8523	5	44
17	68170	17	20811	8	9049	6	66708	17	21524	8	8514	6	43
18	68146	19	20823	10	9040	7	66683	19	21536	10	8505	7	42
19	68121	22	20835	11	9031	8	66659	22	21548	11	8496	8	41
20	68097	0	20847	0	9022	0	66635	0	21560	0	8488	0	40
21	68072	2	20858	1	9013	1	66611	2	21572	1	8479	1	39
22	68047	5	20870	2	9004	2	66587	5	21584	2	8470	2	38
23	68023	7	20882	4	8995	3	66563	7	21596	4	8462	3	37
24	67998	10	20894	5	8986	4	66539	10	21608	5	8453	4	36
25	67974	12	20906	6	8977	5	66515	12	21620	6	8444	5	35
26	67949	14	20918	7	8967	5	66491	14	21632	7	8435	5	34
27	67924	17	20929	8	8958	6	66467	17	21644	8	8427	6	33
28	67900	19	20941	10	8949	7	66443	19	21656	10	8418	7	32
29	67875	22	20953	11	8940	8	66419	22	21668	11	8409	8	31
30	67851	0	20965	0	8931	0	66395	0	21680	0	8401	0	30
31	67826	3	20977	1	8922	1	66371	2	21692	1	8392	1	29
32	67802	5	20989	2	8913	2	66347	5	21704	2	8383	2	28
33	67777	8	21000	4	8904	3	66323	7	21716	4	8375	3	27
34	67753	10	21012	5	8895	4	66299	10	21728	5	8366	4	26
35	67728	13	21024	6	8886	5	66275	12	21740	6	8357	5	25
36	67704	15	21036	7	8877	5	66251	14	21752	7	8349	5	24
37	67679	18	21048	8	8868	6	66227	17	21764	8	8340	6	23
38	67655	20	21060	10	8859	7	66203	19	21776	10	8331	7	22
39	67630	23	21072	11	8851	8	66179	22	21788	11	8323	8	21
40	67606	0	21083	0	8842	0	66155	0	21800	0	8314	0	20
41	67582	2	21095	1	8833	1	66131	2	21812	1	8305	1	19
42	67557	5	21107	2	8824	2	66107	5	21824	2	8297	2	18
43	67533	7	21119	4	8815	3	66083	7	21836	4	8288	3	17
44	67508	10	21131	5	8806	4	66059	10	21848	5	8290	4	16
45	67484	12	21143	6	8797	5	66035	12	21860	6	8271	5	15
46	67459	14	21155	7	8788	5	66012	14	21872	7	8262	5	14
47	67435	17	21167	8	8779	6	65988	17	21884	8	8254	6	13
48	67411	19	21178	10	8770	7	65964	19	21896	10	8245	7	12
49	67386	22	21190	11	8761	8	65940	22	21908	11	8237	8	11
50	67362	0	21202	0	8752	0	65916	0	21920	0	8228	0	10
51	67338	3	21214	1	8743	1	65892	2	21932	1	8219	1	9
52	67313	5	21226	2	8734	2	65868	5	21944	2	8211	2	8
53	67289	8	21238	4	8726	3	65845	7	21956	4	8202	3	7
54	67265	10	21250	5	8717	4	65821	10	21968	5	8194	4	6
55	67240	13	21262	6	8708	5	65797	12	21980	6	8185	5	5
56	67216	15	21274	7	8699	5	65773	14	21992	7	8177	5	4
57	67192	18	21285	8	8690	6	65749	17	22004	8	8168	6	3
58	67167	20	21297	10	8681	7	65726	19	22016	10	8160	7	2
59	67143	23	21309	11	8672	8	65702	22	22028	11	8151	8	1
60	↑ 67119		↓ 21321		↑ 8664		↑ 65678		↓ 22040		↑ 8143		0
	A_1 h	P.P.	A_7 a	P.P.	A_2 A_3 Z_3 / d l a	P.P.	A_1 h	P.P.	A_7 a	P.P.	A_2 A_3 Z_3 / d l a	P.P.	′ / °
	305°		35°				304°		34°				

$Z_1 + Z_2 (= A_2) - Z_3 \to Z_4$
(h) (d) (a) (Z)

Fig. 74

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth

$\underset{(h)}{A_1} + \underset{(d)}{A_2} + \underset{(l)}{A_3} = A_4 \rightarrow A_5 + \underset{(l \pm d)}{A_6} = \underset{(a)}{A_7}$

ℓ & d contrary name → ℓ+d
ℓ & d same name → ℓ-d

° / ′	38° A_1 A_4 (h)	P.P.	38° A_4 A_8 ($l \pm d$)	P.P.	38° Z_1 Z_4 (h, Z)	P.P.	39° A_1 A_4 (h)	P.P.	39° A_5 A_8 ($l \pm d$)	P.P.	39° Z_1 Z_4 (h, Z)	P.P.	
0	↑ 97472	0	↓ 10599	0	↑ 21066	0	↑ 95301	0	↓ 11143	0	↑ 20113	0	60
1	97435	4	10608	1	21050	2	95265	4	11152	1	20097	2	59
2	97398	7	10617	2	21033	3	95230	7	11161	2	20082	3	58
3	97362	11	10626	3	21017	5	95194	11	11170	3	20066	5	57
4	97325	15	10635	4	21001	6	95158	14	11179	4	20050	6	56
5	97288	19	10644	5	20985	8	95123	18	11189	5	20035	8	55
6	97252	22	10653	5	20969	10	95087	21	11198	6	20019	9	54
7	97215	26	10662	6	20953	11	95052	25	11207	7	20004	11	53
8	97179	30	10671	7	20937	13	95016	28	11216	8	19988	12	52
9	97142	33	10680	8	20921	14	94981	32	11225	9	19973	14	51
10	97106	0	10689	0	20905	0	94945	0	11234	0	19957	0	50
11	97069	4	10698	1	20889	2	94910	4	11244	1	19942	2	49
12	97033	7	10707	2	20872	3	94874	7	11253	2	19926	3	48
13	96996	11	10716	3	20856	5	94839	11	11262	3	19911	5	47
14	96960	15	10725	4	20840	6	94803	14	11271	4	19895	6	46
15	96923	19	10734	5	20824	8	94768	18	11280	5	19880	8	45
16	96887	22	10743	5	20808	10	94732	21	11290	5	19864	9	44
17	96850	26	10752	6	20792	11	94697	25	11299	6	19849	11	43
18	96814	30	10761	7	20776	13	94661	28	11308	7	19834	12	42
19	96778	33	10770	8	20760	14	94626	32	11317	8	19818	14	41
20	96741	0	10779	0	20744	0	94591	0	11326	0	19803	0	40
21	96705	4	10788	1	20728	2	94555	4	11336	1	19787	2	39
22	96669	7	10797	2	20712	3	94520	7	11345	2	19772	3	38
23	96632	11	10806	3	20696	5	94485	11	11354	3	19756	5	37
24	96596	14	10815	4	20681	6	94449	14	11363	4	19741	6	36
25	96560	18	10824	5	20665	8	94414	18	11373	5	19726	8	35
26	96524	22	10833	5	20649	10	94379	21	11382	6	19710	9	34
27	96487	25	10842	6	20633	11	94344	25	11391	7	19695	11	33
28	96451	29	10851	7	20617	13	94308	28	11400	8	19680	12	32
29	96415	32	10861	8	20601	14	94273	32	11410	9	19664	14	31
30	96379	0	10870	0	20585	0	94238	0	11419	0	19649	0	30
31	96343	4	10879	1	20569	2	94203	4	11428	1	19634	2	29
32	96306	7	10888	2	20553	3	94168	7	11437	2	19618	3	28
33	96270	11	10897	3	20537	5	94133	11	11447	3	19603	5	27
34	96234	14	10906	4	20522	6	94097	14	11456	4	19588	6	26
35	96198	18	10915	5	20506	8	94062	18	11465	5	19572	8	25
36	96162	22	10924	5	20490	10	94027	21	11474	5	19557	10	24
37	96126	25	10933	6	20474	11	93992	25	11484	6	19542	11	23
38	96090	29	10942	7	20458	13	93957	28	11493	7	19527	13	22
39	96054	32	10951	8	20442	14	93922	32	11502	8	19511	14	21
40	96018	0	10960	0	20427	0	93887	0	11511	0	19496	0	20
41	95982	4	10969	1	20411	2	93852	4	11521	1	19481	2	19
42	95946	7	10978	2	20395	3	93817	7	11530	2	19466	3	18
43	95910	11	10988	3	20379	5	93782	11	11539	3	19450	5	17
44	95874	14	10997	4	20364	6	93747	14	11549	4	19435	6	16
45	95838	18	11006	5	20348	8	93712	18	11558	5	19420	8	15
46	95802	22	11015	5	20332	10	93677	21	11567	5	19405	9	14
47	95766	25	11024	6	20316	11	93642	25	11577	6	19390	11	13
48	95730	29	11033	7	20301	13	93607	28	11586	7	19375	12	12
49	95694	32	11042	8	20285	14	93572	32	11595	8	19359	14	11
50	95659	0	11051	0	20269	0	93538	0	11604	0	19344	0	10
51	95623	4	11060	1	20254	2	93503	4	11614	1	19329	2	9
52	95587	7	11070	2	20238	3	93468	7	11623	2	19314	3	8
53	95551	11	11079	3	20222	5	93433	11	11632	3	19299	5	7
54	95515	14	11088	4	20207	6	93398	14	11642	4	19284	5	6
55	95480	18	11097	5	20191	8	93363	18	11651	5	19269	8	5
56	95444	21	11106	5	20175	10	93329	21	11660	5	19254	9	4
57	95408	25	11115	6	20160	11	93294	25	11670	6	19238	11	3
58	95372	28	11124	7	20144	13	93259	28	11679	7	19223	12	2
59	95337	32	11134	8	20128	14	93224	32	11688	8	19208	14	1
60	↑ 95301		↓ 11143		↑ 20113		↑ 93190		↓ 11698		↑ 19193		0
	A_1 (h)	P.P.	A_7 (a)	P.P.	A_1 A_3 Z_3 (d, l, a)	P.P.	A_1 (h)	P.P.	A_7 (a)	P.P.	A_1 A_3 Z_3 (d, l, a)	P.P.	′ / °
	321°		51°				320°		50°				

$\underset{(h)}{Z_1} + \underset{(d)}{Z_2}(= A_7) - \underset{(a)}{Z_3} = \underset{(Z)}{Z_4}$

Fig. 75

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth

$A_1 + A_2 + A_3 = A_4 \rightarrow A_5 + A_6 = A_7$
(h) (d) (l) (l±d) (a)

ℓ & d contrary name → ℓ+d
ℓ & d same name → ℓ~d

° / ′	30°						31°						
	A_1 A_4 h	P.P.	A_3 A_4 l±d	P.P.	Z_1 Z_4 h Z	P.P.	A_1 A_4 h	P.P.	A_3 A_4 l±d	P.P.	Z_1 Z_4 h Z	P.P.	
0	↑ 117401	0	↓ 6699	0	↑ 30103	0	↑ 114620	0	↓ 7142	0	↑ 28818	0	60
1	117354	5	6706	1	30081	2	114575	5	7149	1	28795	2	59
2	117306	9	6713	1	30059	4	114529	9	7157	1	28774	4	58
3	117259	14	6721	2	30037	7	114484	14	7164	2	28753	6	57
4	117212	19	6728	3	30016	9	114438	18	7172	3	28732	8	56
5	117165	24	6735	4	29994	11	114393	23	7179	4	28711	11	55
6	117118	28	6742	4	29972	13	114347	27	7187	4	28690	13	54
7	117071	33	6750	5	29950	15	114302	32	7194	5	28669	15	53
8	117024	38	6757	6	29928	18	114257	36	7202	6	28648	17	52
9	116977	42	6764	6	29907	20	114211	41	7209	6	28627	19	51
10	116931	0	6772	0	29885	0	114166	0	7217	0	28607	0	50
11	116884	5	6779	1	29863	2	114121	5	7224	1	28586	2	49
12	116837	9	6786	1	29841	4	114075	9	7232	1	28565	4	48
13	116790	14	6794	2	29820	7	114030	14	7239	2	28544	6	47
14	116743	18	6801	3	29798	9	113985	18	7247	3	28523	8	46
15	116697	23	6808	4	29776	11	113940	23	7254	4	28502	11	45
16	116650	28	6816	4	29755	13	113895	27	7262	4	28481	13	44
17	116603	32	6823	5	29733	15	113849	32	7270	5	28461	15	43
18	116556	37	6830	6	29712	18	113804	36	7277	6	28440	17	42
19	116510	41	6838	6	29690	20	113759	41	7285	6	28419	19	41
20	116463	0	6845	0	29668	0	113714	0	7292	0	28398	0	40
21	116417	5	6852	1	29647	2	113669	5	7300	1	28378	2	39
22	116370	9	6860	2	29625	4	113624	9	7307	2	28357	4	38
23	116324	14	6867	2	29604	6	113579	14	7315	2	28336	6	37
24	116277	18	6874	3	29582	8	113534	18	7322	3	28315	8	36
25	116231	23	6882	4	29561	11	113489	23	7330	4	28295	10	35
26	116184	28	6889	5	29539	13	113444	27	7338	5	28274	12	34
27	116138	32	6896	6	29518	15	113400	32	7345	6	28253	14	33
28	116091	37	6904	6	29496	17	113355	36	7353	6	28233	16	32
29	116045	41	6911	7	29475	19	113310	41	7360	7	28212	18	31
30	115998	0	6919	0	29453	0	113265	0	7368	0	28191	0	30
31	115952	5	6926	1	29432	2	113220	5	7376	1	28171	2	29
32	115906	9	6933	2	29410	4	113175	9	7383	2	28150	4	28
33	115860	14	6941	2	29389	6	113131	14	7391	2	28130	6	27
34	115813	18	6948	3	29367	8	113086	18	7398	3	28109	8	26
35	115767	23	6956	4	29346	11	113041	23	7406	4	28089	10	25
36	115721	28	6963	5	29325	13	112997	27	7414	5	28068	12	24
37	115675	32	6970	6	29303	15	112952	32	7421	6	28048	14	23
38	115629	37	6978	6	29282	17	112907	36	7429	6	28027	16	22
39	115583	41	6985	7	29261	19	112863	41	7437	7	28006	18	21
40	115536	0	6993	0	29239	0	112818	0	7444	0	27986	0	20
41	115490	5	7000	1	29218	2	112774	4	7452	1	27966	2	19
42	115444	9	7007	2	29197	4	112729	9	7459	1	27945	4	18
43	115398	14	7015	2	29176	6	112685	13	7467	2	27925	6	17
44	115352	18	7022	3	29154	8	112640	18	7475	3	27904	8	16
45	115306	23	7030	4	29133	11	112596	22	7482	4	27884	10	15
46	115260	28	7037	5	29112	13	112552	26	7490	4	27863	12	14
47	115215	32	7045	6	29091	15	112507	31	7498	5	27843	14	13
48	115169	37	7052	6	29069	17	112463	35	7505	6	27823	16	12
49	115123	41	7059	7	29048	19	112418	40	7513	6	27802	18	11
50	115077	0	7067	0	29027	0	112374	0	7521	0	27782	0	10
51	115031	5	7074	1	29006	2	112330	4	7528	1	27762	2	9
52	114985	9	7082	1	28985	4	112286	9	7536	2	27741	4	8
53	114940	14	7089	2	28964	6	112241	13	7544	2	27721	6	7
54	114894	18	7097	3	28942	8	112197	18	7551	3	27701	8	6
55	114848	23	7104	4	28921	11	112153	22	7559	4	27680	11	5
56	114803	28	7112	4	28900	13	112109	26	7567	5	27660	13	4
57	114757	32	7119	5	28879	15	112065	31	7574	6	27640	15	3
58	114711	37	7127	6	28858	17	112020	35	7582	6	27619	17	2
59	114666	41	7134	6	28837	19	111976	40	7590	7	27599	19	1
60	↑ 114620		↓ 7142		↑ 28816		↑ 111932		↓ 7598		↑ 27579		0
	A_1 h	P.P.	A_7 a	P.P.	A_2 A_3 Z_3 d l a	P.P.	A_1 h	P.P.	A_7 a	P.P.	A_2 A_3 Z_3 d l a	P.P.	′ / °
	329°		59′				328°		58′				

$Z_1 + Z_2 (= A_2) - Z_3 = Z_4$
(h) (d) (a) (Z)

Fig. 76

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth

$A_1 + A_2 + A_3 = A_4 \quad A_5 + A_6 = A_7$
$(h) \ (d) \ (l) \qquad (l+d)(a)$

ℓ & d contrary name → ℓ+d
ℓ & d same name → ℓ~d

′ \ °	50° A_1 h / A_4	P.P.	A_3 / A_6 $l \pm d$	P.P.	Z_1 h / Z_4 Z	P.P.	51° A_1 h / A_4	P.P.	A_5 / A_6 $l \pm d$	P.P.	Z_1 h / Z_4 Z	P.P.	
0	↑ 74810	0	↓ 17861	0	↑ 11575	0	↑ 73203	0	↓ 18534	0	↑ 10950	0	60
1	74783	3	17872	1	11564	1	73177	1	18545	1	10940	1	59
2	74756	5	17883	2	11553	2	73150	5	18557	2	10929	2	58
3	74729	8	17894	3	11543	3	73124	8	18568	4	10919	3	57
4	74702	11	17905	4	11532	4	73097	10	18579	5	10909	4	56
5	74675	14	17916	6	11522	5	73071	13	18591	6	10899	5	55
6	74648	16	17928	7	11511	6	73044	16	18602	7	10888	6	54
7	74621	19	17939	8	11501	7	73018	18	18613	8	10878	7	53
8	74594	22	17950	9	11490	8	72992	21	18624	10	10868	8	52
9	74567	24	17961	10	11479	9	72965	23	18636	11	10858	9	51
10	74540	0	17972	0	11469	0	72939	0	18647	0	10848	0	50
11	74513	3	17983	1	11458	1	72912	3	18658	1	10838	1	49
12	74486	5	17995	2	11448	2	72886	5	18670	2	10827	2	48
13	74459	8	18006	3	11437	3	72860	8	18681	4	10817	3	47
14	74432	11	18017	4	11427	4	72833	10	18692	5	10807	4	46
15	74405	14	18028	6	11416	6	72807	13	18704	6	10797	5	45
16	74378	16	18039	7	11406	7	72781	16	18715	7	10787	6	44
17	74351	19	18050	8	11395	8	72754	18	18727	8	10777	7	43
18	74324	22	18062	9	11385	9	72728	21	18738	10	10767	8	42
19	74297	24	18073	10	11374	10	72702	23	18749	11	10756	9	41
20	74271	0	18084	0	11364	0	72675	0	18761	0	10746	0	40
21	74244	3	18095	1	11353	1	72649	3	18772	1	10736	1	39
22	74217	5	18106	2	11343	2	72623	5	18783	2	10726	2	38
23	74190	8	18118	3	11332	3	72597	8	18795	3	10716	3	37
24	74163	11	18129	4	11322	4	72570	10	18806	4	10706	4	36
25	74136	14	18140	6	11312	5	72544	13	18817	6	10696	5	35
26	74109	16	18151	7	11301	6	72518	16	18829	7	10686	6	34
27	74083	19	18162	8	11291	7	72492	18	18840	8	10676	7	33
28	74056	22	18174	9	11280	8	72465	21	18852	9	10666	8	32
29	74029	24	18185	10	11270	9	72439	23	18863	10	10656	9	31
30	74002	0	18196	0	11259	0	72413	0	18874	0	10646	0	30
31	73975	3	18207	1	11249	1	72387	3	18886	1	10636	1	29
32	73949	5	18219	2	11239	2	72361	5	18897	2	10625	2	28
33	73922	8	18230	3	11228	3	72334	8	18908	3	10615	3	27
34	73895	11	18241	4	11218	4	72308	10	18920	4	10605	4	26
35	73868	14	18252	6	11207	6	72282	13	18931	6	10595	5	25
36	73842	16	18263	7	11197	7	72256	16	18943	7	10585	6	24
37	73815	19	18275	8	11187	8	72230	18	18954	8	10575	7	23
38	73788	22	18286	9	11176	9	72204	21	18965	9	10565	8	22
39	73762	24	18297	10	11166	10	72178	23	18977	10	10555	9	21
40	73735	0	18308	0	11156	0	72152	0	18988	0	10545	0	20
41	73708	3	18320	1	11145	1	72125	3	19000	1	10535	1	19
42	73681	5	18331	2	11135	2	72099	5	19011	2	10525	2	18
43	73655	8	18342	4	11125	3	72073	8	19022	3	10515	3	17
44	73628	10	18353	5	11114	4	72047	10	19034	4	10505	4	16
45	73602	13	18365	6	11104	5	72021	13	19045	6	10496	5	15
46	73575	16	18376	7	11094	6	71995	16	19057	7	10486	5	14
47	73548	18	18387	8	11083	7	71969	18	19068	8	10476	6	13
48	73522	21	18399	10	11073	8	71943	21	19080	9	10466	7	12
49	73495	23	18410	11	11063	9	71917	23	19091	10	10456	8	11
50	73468	0	18421	0	11052	0	71891	0	19102	0	10446	0	10
51	73442	3	18432	1	11042	1	71865	3	19114	1	10436	1	9
52	73415	5	18444	2	11032	2	71839	5	19125	2	10426	2	8
53	73389	8	18455	4	11022	3	71813	8	19137	4	10416	3	7
54	73362	10	18466	5	11011	4	71787	10	19148	5	10406	4	6
55	73336	13	18478	6	11001	5	71761	13	19160	6	10396	5	5
56	73309	16	18489	7	10991	6	71735	16	19171	7	10386	6	4
57	73283	18	18500	8	10980	7	71709	18	19183	8	10376	7	3
58	73256	21	18511	10	10970	8	71683	21	19194	10	10367	8	2
59	73230	23	18523	11	10960	9	71658	23	19205	11	10357	9	1
60	↑ 73203		↓ 18534		↑ 10950		↑ 71632		↓ 19217		↑ 10347		0
	A_1 h	P.P.	A_7 a	P.P.	A_2 d / A_5 l / Z_3 a	P.P.	A_1 h	P.P.	A_7 a	P.P.	A_2 d / A_5 l / Z_3 a	P.P.	′
	309°		39°				308°		38°				°

$Z_1 + Z_2 (= A_2) - Z_3 = Z_4$
$(h) \ (d) \qquad (a) \ (Z)$

Fig. 77

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth

$A_1 + A_2 + A_3 = A_4 \quad A_5 + A_6 = A_7$
$(h) \; (d) \; (l) \qquad (l+d) \; (a)$

l & d contrary name → $l+d$
l & d same name → $l \sim d$

′ \ °	60° A_1 h / A_4	P.P.	60° A_3 / A_4 $l \pm d$	P.P.	60° Z_1 h / Z_4 Z	P.P.	61° A_1 h / A_4	P.P.	61° A_3 / A_4 $l \pm d$	P.P.	61° Z_1 h / Z_4 Z	P.P.	
0	↑ 60206	0	↓ 25000	0	↑ 6247	0	↑ 58906	0	↓ 25760	0	↑ 5818	0	60
1	60184	2	25013	1	6240	1	58885	2	25772	1	5811	1	59
2	60162	4	25025	3	6232	1	58861	4	25785	3	5804	1	58
3	60140	7	25038	4	6225	2	58842	6	25798	4	5797	2	57
4	60119	9	25050	5	6218	3	58820	8	25810	5	5790	3	56
5	60097	11	25063	7	6211	4	58799	11	25823	7	5783	4	55
6	60075	13	25076	8	6203	4	58778	13	25836	8	5776	4	54
7	60053	15	25088	9	6196	5	58756	15	25849	9	5769	5	53
8	60031	18	25101	10	6189	6	58735	17	25861	10	5762	6	52
9	60009	20	25113	12	6181	6	58713	19	25874	12	5755	6	51
10	59988	0	25126	0	6174	0	58692	0	25887	0	5748	0	50
11	59966	2	25139	1	6167	1	58671	2	25900	1	5741	1	49
12	59944	4	25151	2	6160	1	58649	4	25912	3	5734	1	48
13	59922	6	25164	4	6153	2	58628	7	25925	4	5727	2	47
14	59900	8	25177	5	6145	3	58607	9	25938	5	5721	3	46
15	59879	11	25189	6	6138	4	58585	11	25951	7	5714	4	45
16	59857	13	25202	7	6131	4	58564	13	25963	8	5707	4	44
17	59835	15	25214	8	6124	5	58543	15	25976	9	5700	5	43
18	59813	17	25227	10	6116	6	58521	18	25989	10	5693	6	42
19	59792	19	25240	11	6109	6	58500	20	26002	12	5686	6	41
20	59770	0	25252	0	6102	0	58479	0	26014	0	5679	0	40
21	59748	2	25265	1	6095	1	58457	2	26027	1	5672	1	39
22	59726	4	25278	3	6088	1	58436	4	26040	3	5665	1	38
23	59705	7	25290	4	6080	2	58415	7	26053	4	5658	2	37
24	59683	9	25303	5	6073	3	58394	9	26065	5	5651	2	36
25	59661	11	25316	7	6066	4	58372	11	26078	7	5645	3	35
26	59640	13	25328	8	6059	4	58351	13	26091	8	5638	4	34
27	59618	15	25341	9	6052	5	58330	15	26104	9	5631	4	33
28	59596	18	25354	10	6045	6	58308	18	26117	10	5624	5	32
29	59575	20	25366	12	6037	6	58287	20	26129	12	5617	5	31
30	59553	0	25379	0	6030	0	58266	0	26142	0	5610	0	30
31	59531	2	25391	1	6023	1	58245	2	26155	1	5603	1	29
32	59510	4	25404	3	6016	1	58224	4	26168	3	5596	1	28
33	59488	6	25417	4	6009	2	58202	6	26180	4	5590	2	27
34	59466	8	25429	5	6002	3	58181	8	26193	5	5583	3	26
35	59445	11	25442	7	5995	4	58160	11	26206	7	5576	4	25
36	59423	13	25455	8	5988	4	58139	13	26219	8	5569	4	24
37	59401	15	25467	9	5960	5	58118	15	26232	9	5562	5	23
38	59380	17	25480	10	5973	6	58096	17	26244	10	5555	6	22
39	59358	19	25493	12	5966	6	58075	19	26257	12	5549	6	21
40	59337	0	25506	0	5959	0	58054	0	26270	0	5542	0	20
41	59315	2	25518	1	5952	1	58033	2	26283	1	5535	1	19
42	59293	4	25531	3	5945	1	58012	4	26296	3	5528	1	18
43	59272	6	25544	4	5938	2	57991	6	26308	4	5521	2	17
44	59250	8	25556	5	5931	3	57969	8	26321	5	5515	3	16
45	59229	11	25569	7	5924	4	57948	11	26334	7	5508	4	15
46	59207	13	25582	8	5917	4	57927	13	26347	8	5501	4	14
47	59186	15	25594	9	5910	5	57906	15	26360	9	5494	5	13
48	59164	17	25607	10	5902	6	57885	17	26372	10	5487	6	12
49	59143	19	25620	12	5895	6	57864	19	26385	12	5481	6	11
50	59121	0	25632	0	5888	0	57843	0	26398	0	5474	0	10
51	59100	2	25645	1	5881	1	57822	2	26411	1	5467	1	9
52	59078	4	25658	3	5874	1	57801	4	26424	3	5460	1	8
53	59057	6	25671	4	5867	2	57779	6	26437	4	5454	2	7
54	59035	8	25683	5	5860	3	57758	8	26449	5	5447	3	6
55	59014	11	25696	7	5853	4	57737	11	26462	7	5440	4	5
56	58992	13	25709	8	5846	4	57716	13	26475	8	5433	4	4
57	58971	15	25721	9	5839	5	57695	15	26488	9	5427	5	3
58	58949	17	25734	10	5832	6	57674	17	26501	10	5420	6	2
59	58928	19	25747	12	5825	6	57653	19	26514	12	5413	6	1
60	↑ 58906		↓ 25760		↑ 5818		↑ 57632		↓ 26526		↑ 5407		0
	299° A_1 h	P.P.	29° A_7 a	P.P.	29° A_2 d / A_3 l / Z_3 a	P.P.	298° A_1 h	P.P.	28° A_7 a	P.P.	28° A_2 d / A_3 l / Z_3 a	P.P.	° \ ′

$Z_1 + Z_2 (= A_2) - Z_3 = Z_4$
$(h) \; (d) \qquad (a) \; (Z)$

Fig. 78

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Altitude Correction of Sun $6^{\circ}-90^{\circ}$

First Correction

Obs. alt.	Height of Eye (m) 0	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Obs. alt.
° ′	(+) ′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	° ′
6 0	7.5	4.3	3.8	3.4	3.0	2.7	2.3	2.0	1.7	1.4	1.2	0.9	0.7	0.4	0.2	0.0	6 0
20	7.8	4.7	4.2	3.8	3.4	3.1	2.7	2.4	2.1	1.8	1.6	1.3	1.1	0.8	0.6	0.4	20
40	8.2	5.1	4.6	4.2	3.8	3.4	3.1	2.8	2.5	2.2	1.9	1.7	1.4	1.2	1.0	0.8	40
7 0	8.5	5.4	4.9	4.5	4.1	3.8	3.4	3.1	2.8	2.5	2.2	2.0	1.8	1.5	1.3	1.1	7 0
20	8.8	5.7	5.2	4.8	4.4	4.1	3.7	3.4	3.1	2.9	2.6	2.3	2.1	1.8	1.6	1.4	20
40	9.1	6.0	5.5	5.1	4.7	4.3	4.0	3.7	3.4	3.1	2.9	2.6	2.4	2.1	1.9	1.7	40
8 0	9.4	6.3	5.8	5.4	5.0	4.6	4.3	4.0	3.7	3.4	3.1	2.9	2.6	2.4	2.2	2.0	8 0
20	9.6	6.5	6.0	5.6	5.2	4.9	4.5	4.2	3.9	3.7	3.4	3.1	2.9	2.6	2.4	2.2	20
40	9.8	6.7	6.2	5.8	5.4	5.1	4.8	4.4	4.1	3.9	3.6	3.4	3.1	2.9	2.7	2.4	40
9 0	10.0	6.9	6.5	6.0	5.6	5.3	5.0	4.7	4.4	4.1	3.8	3.6	3.3	3.1	2.9	2.6	9 0
20	10.2	7.1	6.7	6.2	5.8	5.5	5.2	4.9	4.6	4.3	4.0	3.8	3.5	3.3	3.1	2.8	20
40	10.4	7.3	6.8	6.4	6.0	5.7	5.4	5.0	4.7	4.5	4.2	4.0	3.7	3.5	3.3	3.0	40
10 0	10.6	7.5	7.0	6.6	6.2	5.9	5.5	5.2	4.9	4.7	4.4	4.1	3.9	3.7	3.4	3.2	10 0
30	10.8	7.7	7.3	6.8	6.5	6.1	5.8	5.5	5.2	4.9	4.6	4.4	4.1	3.9	3.7	3.5	30
11 0	11.1	8.0	7.5	7.1	6.7	6.3	6.0	5.7	5.4	5.1	4.9	4.6	4.4	4.1	3.9	3.7	11 0
30	11.3	8.2	7.7	7.3	6.9	6.5	6.2	5.9	5.6	5.3	5.1	4.8	4.6	4.3	4.1	3.9	30
12 0	11.5	8.4	7.9	7.5	7.1	6.7	6.4	6.1	5.8	5.5	5.3	5.0	4.8	4.5	4.3	4.1	12 0
30	11.6	8.5	8.1	7.6	7.3	6.9	6.6	6.3	6.0	5.7	5.4	5.2	4.9	4.7	4.5	4.3	30
13 0	11.8	8.7	8.2	7.8	7.4	7.1	6.7	6.4	6.1	5.9	5.6	5.4	5.1	4.9	4.7	4.4	13 0
30	11.9	8.8	8.4	8.0	7.6	7.2	6.9	6.6	6.3	6.0	5.8	5.5	5.3	5.0	4.8	4.6	30
14 0	12.1	9.0	8.5	8.1	7.7	7.4	7.0	6.7	6.4	6.2	5.9	5.7	5.4	5.2	4.9	4.7	14 0
30	12.2	9.1	8.7	8.2	7.9	7.5	7.2	6.9	6.6	6.3	6.0	5.8	5.5	5.3	5.1	4.9	30
15 0	12.3	9.3	8.8	8.4	8.0	7.6	7.3	7.0	6.7	6.4	6.2	5.9	5.7	5.4	5.2	5.0	15 0
16 0	12.6	9.5	9.0	8.6	8.2	7.8	7.5	7.2	6.9	6.7	6.4	6.1	5.9	5.7	5.4	5.2	16 0
17 0	12.8	9.7	9.2	8.8	8.4	8.1	7.7	7.4	7.1	6.9	6.6	6.4	6.1	5.9	5.6	5.4	17 0
18 0	12.9	9.9	9.4	9.0	8.6	8.2	7.9	7.6	7.3	7.0	6.8	6.5	6.3	6.1	5.8	5.6	18 0
19 0	13.1	10.0	9.6	9.1	8.7	8.4	8.1	7.8	7.5	7.2	6.9	6.7	6.4	6.2	6.0	5.8	19 0
20 0	13.3	10.2	9.7	9.3	8.9	8.6	8.2	7.9	7.6	7.4	7.1	6.9	6.6	6.4	6.2	5.9	20 0
22 0	13.5	10.4	10.0	9.5	9.1	8.8	8.5	8.2	7.9	7.6	7.3	7.1	6.8	6.6	6.4	6.2	22 0
24 0	13.7	10.6	10.2	9.8	9.4	9.0	8.7	8.4	8.1	7.8	7.6	7.3	7.1	6.8	6.6	6.4	24 0
26 0	13.9	10.8	10.4	9.9	9.6	9.2	8.9	8.6	8.3	8.0	7.8	7.5	7.3	7.0	6.8	6.6	26 0
28 0	14.1	11.0	10.5	10.1	9.7	9.4	9.0	8.7	8.4	8.2	7.9	7.7	7.4	7.2	7.0	6.7	28 0
30 0	14.2	11.1	10.7	10.2	9.9	9.5	9.2	8.9	8.6	8.3	8.1	7.8	7.6	7.3	7.1	6.9	30 0
32 0	14.3	11.2	10.8	10.4	10.0	9.6	9.3	9.0	8.7	8.4	8.2	7.9	7.7	7.4	7.2	7.0	32 0
34 0	14.4	11.4	10.9	10.5	10.1	9.7	9.4	9.1	8.8	8.5	8.3	8.0	7.8	7.6	7.3	7.1	34 0
36 0	14.5	11.5	11.0	10.6	10.2	9.8	9.5	9.2	8.9	8.6	8.4	8.1	7.9	7.7	7.4	7.2	36 0
38 0	14.6	11.5	11.1	10.7	10.3	9.9	9.6	9.3	9.0	8.7	8.5	8.2	8.0	7.7	7.5	7.3	38 0
40 0	14.7	11.6	11.2	10.7	10.4	10.0	9.7	9.4	9.1	8.8	8.6	8.3	8.1	7.8	7.6	7.4	40 0
45 0	14.9	11.8	11.3	10.9	10.5	10.2	9.9	9.6	9.3	9.0	8.7	8.5	8.2	8.0	7.8	7.6	45 0
50 0	15.0	12.0	11.5	11.1	10.7	10.3	10.0	9.7	9.4	9.1	8.9	8.6	8.4	8.2	7.9	7.7	50 0
55 0	15.2	12.1	11.6	11.2	10.8	10.5	10.1	9.8	9.5	9.3	9.0	8.8	8.5	8.3	8.1	7.8	55 0
60 0	15.3	12.2	11.7	11.3	10.9	10.6	10.2	9.9	9.6	9.4	9.1	8.9	8.6	8.4	8.2	7.9	60 0
65 0	15.4	12.3	11.8	11.4	11.0	10.7	10.3	10.0	9.7	9.5	9.2	9.0	8.7	8.5	8.3	8.0	65 0
70 0	15.4	12.4	11.9	11.5	11.1	10.7	10.4	10.1	9.8	9.6	9.3	9.0	8.8	8.6	8.3	8.1	70 0
75 0	15.5	12.4	12.0	11.6	11.2	10.8	10.5	10.2	9.9	9.6	9.4	9.1	8.9	8.6	8.4	8.2	75 0
80 0	15.6	12.5	12.1	11.6	11.3	10.9	10.6	10.3	10.0	9.7	9.5	9.2	9.0	8.7	8.5	8.3	80 0
85 0	15.7	12.6	12.1	11.7	11.3	11.0	10.7	10.3	10.1	9.8	9.5	9.3	9.0	8.8	8.6	8.4	85 0
90 0	15.8	12.7	12.2	11.8	11.4	11.0	10.7	10.4	10.1	9.9	9.6	9.3	9.1	8.9	8.6	8.4	90 0
	0.0	3.1	3.6	4.0	4.4	4.7	5.0	5.3	5.6	5.9	6.2	6.4	6.6	6.9	7.1	7.3	
	0.0	3.6	4.1	4.6	5.1	5.5	5.9	6.2	6.6	6.9	7.2	7.5	7.8	8.0	8.3	8.5	

Corr. for S.D.	Jan.	Feb	Mar.	Apr.	May	Jun.	Jul.	Aug	Sep.	Oct	Nov.	Dec.
Lower ☉	+ 0′.5	+ 0′.5	+ 0′.4	+ 0′.2	+ 0′.1	0′.0	0′.0	+ 0′.1	+ 0′.2	+ 0′.3	+ 0′.5	+ 0′.5
Upper ☉	−32′.0	−32′.0	−31′.9	−31′.7	−31′.6	−31′.5	−31′.5	−31′.6	−31′.7	−31′.8	−32′.0	−32′.0

Diff. of temp. between air and sea water	C°	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°
	Corr.	0′.0	0′.2	0′.4	0′.6	0′.8	1′.0	1′.2	1′.4	1′.6	1′.8	2′.0	2′.2	2′.4	2′.6	2′.8
		when air temp>Sea water temp.(+) ×Air temp. at height of eye air temp<Sea water temp.(−)														

Fig. 79

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Example 13

At $03^h\ 30^m$ p.m. on 12 December 1956, a navigator observed the altitude of the sun's upper limb ($\overline{\odot}$) as 36°27'.2 in D.R.P. 04°06'S, 41°28'E.

What were I and Zc?

Where: Chronometer Time was $0^h\ 40^m\ 20^s$, chronometer error ⊖ $2^m\ 35^s$, index error ⊖ 1.7, height of eye 18 meters, air temperature 29°C, and sea water temperature 26°C (see Figs. 80-87).

Solution

1) To calculate G.D.

Ship's Time 12/12/56	$15^h\ 30^m\ 00^s$	($\leftarrow 03^h\ 30^m\ 00^s$ p.m.)	U=L.M.T.± L
L. in T. (41°-28'E)	2 45 52 ⊖	(41°=$2^h\ 44^m$ 28'= $1^m\ 52^s$) ↓	East long ⊖ / West long ⊕
G.D. 12/12/56	$12^h\ 44^m\ 08^s$		G.D.=Ship's Time+Long in Time

2) To calculate d and h

Chro. T.		$12^h\ 40^m\ 20^s$	($\leftarrow 0^h\ 40^m\ 20^s$)
C.E.		2 35 ⊖	
U.	12/12/56	12 37 45	$\rightarrow$ d = 23°- 06.1S (by almanac)
			$h_G = U + E_{\odot}$
E ⊙ (by almanac)		12 06 08 ⊕	
h_G		24 43 53	
↓		24 ⊖	
h_G		00 43 53	($\rightarrow 40^m$ = 10°, 3^m = 45', 52^s = 13', 1^s = 0'.3)
h_G		10°-58'.3	
L (41°28'E)		41°-28'.0 ⊕	$h = h_G \pm L$ (East long. ⊕ / West long. ⊖)
h		52°-26'.3	
		===========	

3) To calculate ac and zc

h 52°- 26!3	A_1 70953 ⟶		Z_1 10089
	A_2 3631 ⟶		Z_2 3631 ⊕
d 23°- 06!1 S	A_3 111 ⊕		13720
l 04°- 06!0 S	A_4 74695 ⟶	A_5 17908	
		A_6 2725 ⊕	
		⟵ A_7 20633 ⟶	Z_3 9187 ⊖
l~d 19°- 00!1			Z_4 4533 ↓
ac 35°- 58!1			
			Zc 64°- 16!5 ↓
			S 64°. 3 W

4) To calculate at and I

Sex. Alt. ☉	36°- 27!2
I.E.	1.7 ⊖
Obs. Alt.	36°- 25!5
Corr. 1	7!0 ⊕
	36°- 32!5
Corr. 2	32!0 ⊖
	36°- 00!5
Corr. 3	0!6 ⊕
True Alt. ☉	36°- 01!1 (at)
ac	35°- 58!1 ⊖
I	⊕ 3!0

Ans. I = ⊕ 3!0 Zc = S 64°.3 W

12 December 1956

U	E			☉ d		p.p. of d		
h	h	m	s	'		h	m	'
0	12	6	23	S23	3.8	0	0	0.0
2			21		4.2		10	0
4			19		4.5		20	1
6			16		4.9		30	1
8			14		5.3		40	1
10			12		5.7	0	50	2
(12	12	6	9	S23	6.0	1	0	0.2
14			7		8.4		10	2
16			5		6.7		20	3
18			2		7.1		30	3
20		6	0		7.4		40	3
22		5	58		7.8	1	50	4
24	12	5	55	S23	8.1	2	0	0.4

Fig. 80

Table of Altitude and Azimuth

$A_1 + A_2 + A_3 = A_4 + A_5 + A_6 = A_7$
(h) (d) (l) (l±d) (a)

ℓ & d contrary name → ℓ + d
ℓ & d same name → ℓ ~ d

′ \ °	57° A1 A4 (h)	P.P.	A5 A6 (l±d)	P.P.	Z1 Z4 (h Z)	P.P.	53° A1 A4 (h)	P.P.	A5 A6 (l±d)	P.P.	Z1 Z4 (h Z)	P.P.	
0	↑ 71632	0	↓ 19217	0	↑ 10347	0	↑ 70094	0	↓ 19909		↑ 9765	0	60
1	71606	3	19228	1	10337	1	70069	1	19921	1	9756	1	59
2	71580	5	19240	2	10327	2	70044	5	19932	2	9746	2	58
3	71554	8	19251	3	10317	3	70019	8	19944	3	9737	3	57
4	71528	10	19263	4	10307	4	69993	10	19956	4	9727	4	56
5	71502	13	19274	6	10298	5	69968	13	19967	6	9718	5	55
6	71476	16	19286	7	10288	5	69943	15	19979	7	9708	5	54
7	71451	18	19297	8	10278	6	69917	18	19991	8	9699	6	53
8	71425	21	19309	9	10268	7	69892	20	20002	9	9689	7	52
9	71399	23	19320	10	10258	8	69867	23	20014	10	9680	8	51
10	71373	0	19332	0	10248	0	69842	0	20026	0	9670	0	50
11	71347	3	19343	1	10239	1	69816	3	20037	1	9661	1	49
12	71321	5	19355	2	10229	2	69791	5	20049	2	9651	2	48
13	71296	8	19366	3	10219	3	69766	8	20060	4	9642	3	47
14	71270	10	19378	4	10209	4	69741	10	20072	5	9632	4	46
15	71244	13	19389	6	10199	5	69715	13	20084	6	9623	5	45
16	71218	16	19401	7	10190	6	69690	16	20095	7	9614	5	44
17	71193	18	19412	8	10180	7	69665	18	20107	8	9604	6	43
18	71167	21	19424	9	10170	8	69640	21	20119	10	9595	7	42
19	71141	23	19435	10	10160	9	69615	23	20130	11	9585	8	41
20	71115	0	19447	0	10151	0	69590	0	20142	0	9576	0	40
21	71090	3	19458	1	10141	1	69564	3	20154	1	9566	1	39
22	71064	5	19470	2	10131	2	69539	5	20165	2	9557	2	38
23	71038	(8)	18481	3	10121	(3)	69514	8	20177	3	9548	3	37
24	71013	10	19493	4	10112	4	69489	10	20189	4	9538	4	36
25	70987	13	19504	6	10102	5	69464	13	20200	6	9529	5	35
26	70961	16	19516	7	10092	6	69439	15	20212	7	9520	5	34
27	70936	18	19527	8	10082	7	69414	18	20224	8	9510	6	33
28	70910	21	19539	9	10073	8	69389	20	20235	9	9501	7	32
29	70884	23	19550	10	10063	9	69364	23	20247	10	9491	8	31
30	70859	0	19562	0	10053	0	69338	0	20259	0	9482	0	30
31	70833	3	19573	1	10044	1	69313	3	20271	1	9473	1	29
32	70808	5	19585	2	10034	2	69288	5	20282	2	9463	2	28
33	70782	8	19597	4	10024	3	69263	8	20294	3	9454	3	27
34	70756	10	19608	5	10015	4	69239	10	20306	4	9445	4	26
35	70731	13	19620	6	10005	5	69213	13	20317	6	9435	5	25
36	70705	15	19631	7	9995	6	69188	15	20329	7	9426	6	24
37	70680	18	19643	8	9986	7	69163	18	20341	8	9417	7	23
38	70654	20	19654	10	9976	8	69138	20	20352	9	9408	8	22
39	70629	23	19666	11	9966	9	69113	23	20364	10	9398	9	21
40	70603	0	19677	0	9957	0	69088	0	20376	0	9389	0	20
41	70578	3	19689	1	9947	1	69063	2	20388	1	9380	1	19
42	70552	5	19701	2	9937	2	69038	5	20399	2	9370	2	18
43	70527	8	19712	3	9928	3	69013	7	20411	4	9361	3	17
44	70501	10	19724	4	9918	4	68988	10	20423	5	9352	4	16
45	70476	13	19735	6	9909	5	68964	12	20435	6	9343	5	15
46	70450	15	19747	7	9899	5	68939	14	20446	7	9333	5	14
47	70423	18	19758	8	9889	6	68914	17	20458	8	9324	6	13
48	70399	20	19770	9	9880	7	68889	19	20470	10	9315	7	12
49	70374	23	19782	10	9870	8	68864	22	20481	11	9306	8	11
50	70348	0	19793	0	9861	0	68839	0	20493	0	9296	0	10
51	70323	3	19805	1	9851	1	68814	3	20505	1	9287	1	9
52	70297	5	19816	2	9841	2	68789	5	20517	2	9278	2	8
53	70272	8	19828	3	9832	3	68764	8	20528	4	9269	3	7
54	70247	10	19840	4	9822	4	68740	10	20540	5	9259	4	6
55	70221	13	19851	6	9813	5	68715	13	20552	6	9250	5	5
56	70196	16	19863	7	9803	5	68690	15	20564	7	9241	5	4
57	70171	18	19874	8	9794	6	68665	18	20575	8	9232	6	3
58	70145	21	19886	9	9784	7	68640	20	20587	10	9223	7	2
59	70120	23	19898	10	9775	8	68615	23	20599	11	9213	8	1
60	↑ 70094		↓ 19909		↑ 9765		↑ 68591		↓ 20611		↑ 9204		0
	A1 h	P.P.	A7 a	P.P.	A2 A3 Z1 (d l a)	P.P.	A1 h	P.P.	A7 a	P.P.	A2 A3 Z1 (d l a)	P.P.	° \ ′
	307°		37°				306°		36°				

$Z_1 + Z_2 (= A_2) - Z_7 = Z_4$
(h) (d) (a) (Z)

Fig. 81

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth

$A_1 + A_2 + A_3 = A_4 \rightarrow A_5 + A_6 = A_7$
(h) (d) (l) (l±d) (a)

ℓ & d contrary name →ℓ+d
ℓ & d same name →ℓ~d

° / ′	66						67°						
	A_1 | A_4 (h)	P.P.	A_5 | A_6 (l±d)	P.P.	Z_1 | Z_4 (h Z)	P.P.	A_1 | A_4 (h)	P.P.	A_5 | A_6 (l±d)	P.P.	Z_1 | Z_4 (h Z)	P.P.	
0	↑ 52778	0	↓ 29663	0	↑ 3927	0	↑ 51622	0	↓ 30463	0	↑ 3597	0	60
1	52759	2	29676	1	3921	1	51603	2	30477	1	3592	1	59
2	52739	4	29690	1	3916	1	51584	4	30490	3	3587	1	58
3	52720	6	29703	4	3910	2	51565	6	30504	4	3581	2	57
4	52700	8	29716	6	3905	2	51546	8	30517	5	3576	2	56
5	52681	10	29730	7	3899	3	51527	10	30530	7	3571	3	55
6	52662	11	29743	8	3893	4	51508	11	30544	8	3565	3	54
7	52642	13	29756	10	3888	4	51489	13	30557	9	3560	4	53
8	52623	15	29770	11	3882	5	51470	15	30571	10	3555	4	52
9	52603	17	29783	13	3877	5	51451	17	30584	12	3549	5	51
10	52584	0	29796	0	3871	0	51432	0	30597	0	3544	0	50
11	52565	2	29809	1	3865	1	51413	2	30611	1	3539	1	49
12	52545	4	29823	3	3860	1	51393	4	30624	3	3533	1	48
13	52526	6	29836	4	3854	2	51374	6	30638	4	3528	2	47
14	52507	8	29849	6	3849	2	51355	8	30651	5	3523	2	46
15	52487	10	29863	7	3843	3	51336	10	30664	7	3517	3	45
16	52468	12	29876	8	3838	4	51317	11	30678	8	3512	4	44
17	52448	14	29889	10	3832	4	51298	13	30691	9	3507	4	43
18	52429	16	29903	11	3826	5	51280	15	30705	10	3502	5	42
19	52410	18	29916	13	3821	5	51261	17	30718	12	3496	5	41
20	52390	0	29929	0	3815	0	51242	0	30732	0	3491	0	40
21	52371	2	29943	1	3810	1	51223	2	30745	1	3486	1	39
22	52352	4	29956	3	3804	1	51204	4	30758	3	3480	1	38
23	52332	6	29969	4	3799	2	51185	6	30772	4	3475	2	37
24	52313	8	29983	5	3793	2	51166	8	30785	6	3470	2	36
25	52294	10	29996	7	3788	3	51147	10	30799	7	3465	3	35
26	52275	11	30009	8	3782	3	51128	11	30812	8	3459	3	34
27	52255	13	30023	9	3777	4	51109	13	30826	10	3454	4	33
28	52236	15	30036	10	3771	4	51090	15	30839	11	3449	4	32
29	52217	17	30049	12	3766	5	51071	17	30852	13	3444	5	31
30	52197	0	30063	0	3760	0	51052	0	30866	0	3438	0	30
31	52178	2	30076	1	3755	1	51033	2	30879	1	3433	1	29
32	52159	4	30089	3	3749	1	51014	4	30893	3	3428	1	28
33	52140	6	30103	4	3744	2	50996	6	30906	4	3423	2	27
34	52120	8	30116	5	3738	2	50977	8	30920	5	3418	2	26
35	52101	10	30129	7	3733	3	50958	10	30933	7	3412	3	25
36	52082	11	30143	8	3727	3	50939	11	30946	8	3407	4	24
37	52063	13	30156	9	3722	4	50920	13	30960	9	3402	4	23
38	52043	15	30169	10	3716	4	50901	15	30973	10	3397	5	22
39	52024	17	30183	12	3711	5	50882	17	30987	12	3392	5	21
40	52005	0	30196	0	3706	0	50863	0	31000	0	3386	0	20
41	51986	2	30209	1	3700	1	50845	2	31014	1	3381	1	19
42	51967	4	30223	3	3695	1	50826	4	31027	3	3376	1	18
43	51947	6	30236	4	3689	2	50807	6	31041	4	3371	2	17
44	51928	8	30249	6	3684	2	50788	8	31054	6	3366	2	16
45	51909	10	30263	7	3678	3	50769	10	31068	7	3360	3	15
46	51890	11	30276	8	3673	4	50750	11	31081	8	3355	4	14
47	51871	13	30290	10	3667	4	50732	13	31095	10	3350	4	13
48	51852	15	30303	11	3662	5	50713	15	31108	11	3345	5	12
49	51832	17	30316	13	3657	5	50694	17	31121	13	3340	5	11
50	51813	0	30330	0	3651	0	50675	0	31135	0	3335	0	10
51	51794	2	30343	1	3646	(1)	50656	2	31148	1	3330	1	9
52	51775	4	30356	3	3640	1	50638	4	31162	3	3324	1	8
53	51756	6	30370	4	3635	2	50619	6	31175	4	3319	2	7
54	51737	8	30383	6	3630	2	50600	8	31189	5	3314	2	6
55	51718	10	30397	7	3624	3	50581	10	31202	7	3309	3	5
56	51698	11	30410	8	3619	4	50563	11	31216	8	3304	3	4
57	51679	13	30423	10	3613	4	50544	13	31229	9	3299	4	3
58	51660	15	30437	11	3608	5	50525	15	31243	10	3294	4	2
59	51641	17	30450	13	3603	5	50506	17	31256	12	3289	5	1
60	↑ 51622		↓ 30463		↑ 3597		↑ 50488		↓ 31270		↑ 3283		0
	A_1 (h)	P.P.	A_7 (a)	P.P.	A_2 | A_3, Z_3 (d l a)	P.P.	A_1 (h)	P.P.	A_7 (a)	P.P.	A_2 | A_3, Z_3 (d l a)	P.P.	′ / °
	293°		23°				297°		27°				

$Z_1 + Z_2 (= A_3) - Z_3 = Z_4$
(h) (d) (a) (Z)

Fig. 82

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth.

$\underset{(h)}{A_1} + \underset{(d)}{A_2} + \underset{(l)}{A_3} = A_4 \rightarrow \underset{(l \pm d)}{A_5} + A_6 = \underset{(a)}{A_7}$

ℓ & d contrary name → ℓ+d

ℓ & d same name → ℓ~d

° / ′	84°						85°						
	A_1 h / A_4	P.P.	A_5 / A_6 $l \pm d$	P.P.	Z_1 h / Z_4 Z	P.P.	A_1 h / A_4	P.P.	A_5 / A_6 $l \pm d$	P.P.	Z_1 h / Z_4 Z	P.P.	
0	↑ 34898	0	↓ 44774	0	↑ 239	0	↑ 34063	0	↓ 45642	0	↑ 166	0	60
1	34884	1	44788	2	237	0	34050	1	45657	2	164	0	59
2	34870	3	44803	3	236	0	34036	3	45671	3	163	0	58
3	34856	4	44817	5	235	0	34022	4	45686	5	162	0	57
4	34842	6	44831	6	233	0	34008	6	45700	6	161	0	56
5	34828	7	44846	8	232	1	33994	7	45715	8	160	1	55
6	34814	8	44860	9	231	1	33981	8	45729	9	159	1	54
7	34800	10	44875	11	229	1	33967	10	45744	11	158	1	53
8	34786	11	44889	12	228	1	33953	11	45758	12	157	1	52
9	34772	13	44904	14	227	1	33939	13	45773	14	156	1	51
10	34758	0	44918	0	225	0	33926	0	45787	0	155	0	50
11	34744	1	44933	2	224	0	33912	1	45802	2	154	0	49
12	34730	3	44947	3	223	0	33898	3	45816	3	153	0	48
13	34716	4	44962	5	222	0	33884	4	45831	5	152	0	47
14	34702	6	44976	6	220	0	33871	6	45845	6	150	0	46
15	34688	7	44991	8	219	1	33857	7	45860	8	149	1	45
16	34674	8	45005	9	218	1	33843	8	45874	9	148	1	44
17	34660	10	45020	11	217	1	33830	10	45889	11	147	1	43
18	34646	11	45034	12	215	1	33816	11	45903	12	146	1	42
19	34632	13	45048	14	214	1	33802	13	45918	14	145	1	41
20	34618	0	45063	0	213	0	33788	0	45932	0	144	0	40
21	34604	1	45077	1	212	0	33775	1	45947	2	143	0	39
22	34590	3	45092	3	210	0	33761	3	45961	3	142	0	38
23	34576	4	45106	4	209	0	33747	4	45976	5	141	0	37
24	34562	6	45121	6	208	0	33734	6	45990	6	140	0	36
25	34548	7	45135	7	207	1	33720	7	46005	8	139	1	35
26	34534	8	45150	8	205	1	33706	8	46019	9	138	1	34
27	34520	10	45164	10	204	1	33693	10	46034	11	137	1	33
28	34507	11	45179	11	203	1	33679	11	46048	12	136	1	32
29	34493	13	45193	13	202	1	33665	13	46063	14	135	1	31
30	34479	0	45208	0	200	0	33652	0	46077	0	134	0	30
31	34465	1	45222	1	199	0	33638	1	46092	2	133	0	29
32	34451	3	45237	3	198	0	33624	3	46106	3	132	0	28
33	34437	4	45251	4	197	1	33611	4	46121	5	131	0	27
34	34423	6	45266	6	196	1	33597	6	46135	6	130	0	26
35	34409	7	45280	7	194	1	33583	7	46150	8	129	1	25
36	34395	8	45295	8	193	1	33570	8	46164	9	128	1	24
37	34381	10	45309	10	192	1	33556	10	46179	11	127	1	23
38	34368	11	45324	11	191	2	33542	11	46193	12	126	1	22
39	34354	13	45338	13	190	2	33529	13	46208	14	125	1	21
40	34340	0	45353	0	188	0	33515	0	46222	0	124	0	20
41	34326	1	45367	2	187	0	33501	1	46237	2	123	0	19
42	34312	3	45381	3	186	0	33488	3	46251	3	122	0	18
43	34298	4	45396	5	185	0	33474	4	46266	5	121	0	17
44	34284	5	45410	6	184	0	33461	6	46280	6	121	0	16
45	34271	7	45425	8	183	1	33447	7	46295	8	120	1	15
46	34257	8	45439	9	181	1	33433	8	46309	9	119	1	14
47	34243	9	45454	11	180	1	33420	10	46324	11	118	1	13
48	34229	10	45468	12	179	1	33406	11	46338	12	117	1	12
49	34215	12	45483	14	178	1	33393	13	46353	14	116	1	11
50	34201	0	45497	0	177	0	33379	0	46367	0	115	0	10
51	34188	1	45512	2	176	0	33365	1	46382	2	114	0	9
52	34174	3	45526	3	175	0	33352	3	46396	3	113	0	8
53	34160	4	45541	5	173	0	33338	4	46411	5	112	0	7
54	34146	6	45555	6	172	0	33325	6	46425	6	111	0	6
55	34132	7	45570	8	171	1	33311	7	46440	8	110	1	5
56	34119	8	45584	9	170	1	33298	8	46454	9	109	1	4
57	34105	10	45599	11	169	1	33284	10	46469	11	109	1	3
58	34091	11	45613	12	168	1	33270	11	46483	12	108	1	2
59	34077	13	45628	14	167	1	33257	13	46498	14	107	1	1
60	↑ 34063		↓ 45642		↑ 166		↑ 33243		↓ 46512		↑ 106		0
	A_1 h	P.P.	A_7 a	P.P.	A_2 d / A_3 l / Z_3 a	P.P.	A_1 h	P.P.	A_7 a	P.P.	A_2 d / A_3 l / Z_7 a	P.P.	′ / °
	275°		6°				274°		5°				

$\underset{(h)}{Z_1} + \underset{(d)}{Z_2} (= A_1) - \underset{(a)}{Z_3} = \underset{(Z)}{Z_4}$

Fig. 83

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth

$A + A_2 + A_3 = A_4 \quad A_5 + A_6 = A_7$

(h) (d) (l) (l+d) (a)

ℓ & d contrary name → ℓ+d
ℓ & d same name → ℓ∼d

°	18°						19°						
′	A_1 A_4 h	P.P.	A_5 A_6 l±d	P.P.	Z_1 Z_2 h Z	P.P.	A_1 A_4 h	P.P.	A_5 A_6 l±d	P.P.	Z_1 Z_2 h Z	P.P.	
0	↑ 161133	0	↓ 2447	0	↑ 51002	0	↑ 156478	0	↓ 2724	0	↑ 48736	0	60
1	161054	8	2452	1	50963	4	156403	8	2729	1	48699	4	59
2	160974	16	2456	1	50924	8	156327	15	2733	1	48662	7	58
3	160895	24	2461	2	50885	12	156252	23	2738	2	48626	11	57
4	160815	32	2465	2	50847	16	156177	30	2743	2	48589	14	56
5	160736	40	2470	3	50808	20	156101	38	2748	3	48553	18	55
6	160656	47	2474	3	50769	23	156026	46	2753	3	48516	22	54
7	160577	55	2479	4	50731	27	155951	53	2757	4	48480	25	53
8	160498	63	2483	4	50692	31	155876	61	2762	4	48443	29	52
9	160419	71	2488	5	50653	35	155801	68	2767	5	48407	32	51
10	160340	0	2492	0	50615	0	155727	0	2772	0	48371	0	50
11	160261	8	2497	1	50576	4	155652	8	2776	1	48334	4	49
12	160182	16	2501	1	50538	8	155577	15	2781	1	48298	7	48
13	160103	24	2506	2	50500	11	155502	23	2786	2	48262	11	47
14	160024	32	2510	2	50461	15	155428	30	2791	2	48226	15	46
15	159945	40	2515	3	50423	19	155353	38	2796	3	48189	19	45
16	159867	47	2520	3	50385	23	155279	45	2800	3	48153	22	44
17	159788	55	2524	4	50346	27	155204	53	2805	4	48117	26	43
18	159710	63	2529	4	50308	30	155130	60	2810	4	48081	30	42
19	159631	71	2533	5	50270	34	155056	68	2815	5	48045	33	41
20	159553	0	2538	0	50232	0	154982	0	2820	0	48009	0	40
21	159475	8	2542	1	50194	4	154907	7	2824	1	47973	4	39
22	159397	15	2547	1	50156	8	154833	15	2829	1	47937	7	38
23	159319	23	2552	2	50118	11	154759	22	2834	2	47901	11	37
24	159240	31	2556	2	50080	15	154685	29	2839	2	47865	14	36
25	159163	39	2561	3	50042	19	154612	37	2844	3	47829	18	35
26	159085	46	2565	3	50004	23	154538	44	2849	3	47793	22	34
27	159007	54	2570	4	49966	27	154464	51	2853	4	47758	25	33
28	158929	62	2575	4	49928	30	154390	58	2858	4	47722	29	32
29	158851	69	2579	5	49890	34	154317	66	2863	5	47686	32	31
30	158774	0	2584	0	49852	0	154243	0	2868	0	47650	0	30
31	158696	8	2588	1	49815	4	154170	7	2873	1	47615	4	29
32	158619	15	2593	1	49777	8	154096	15	2878	1	47579	7	28
33	158541	23	2598	2	49739	11	154023	22	2883	2	47544	11	27
34	158464	31	2602	2	49702	15	153950	30	2887	2	47508	14	26
35	158387	39	2607	3	49664	19	153876	37	2892	3	47473	18	25
36	158310	46	2612	3	49626	23	153803	44	2897	3	47437	21	24
37	158233	54	2616	4	49589	27	153730	52	2902	4	47402	25	23
38	158155	62	2621	4	49551	30	153657	59	2907	4	47366	28	22
39	158079	69	2626	5	49514	34	153584	67	2912	5	47331	32	21
40	158002	0	2630	0	49477	0	153511	0	2917	0	47295	0	20
41	157925	8	2635	0	49439	4	153438	7	2922	1	47260	4	19
42	157848	15	2639	1	49402	7	153366	14	2926	1	47225	7	18
43	157771	23	2644	1	49365	11	153293	22	2931	2	47189	11	17
44	157695	31	2649	2	49327	15	153220	29	2936	2	47154	14	16
45	157618	39	2653	2	49290	19	153148	36	2941	3	47119	18	15
46	157542	46	2658	2	49253	22	153075	43	2946	3	47084	21	14
47	157465	54	2663	3	49216	26	153002	50	2951	4	47049	25	13
48	157389	62	2668	3	49179	30	152930	58	2956	4	47014	28	12
49	157313	69	2672	4	49142	33	152858	65	2961	5	46979	32	11
50	157236	0	2677	0	49104	0	152785	0	2966	0	46944	0	10
51	157160	8	2682	0	49067	4	152713	7	2971	1	46908	4	9
52	157084	15	2686	1	49030	7	152641	14	2976	1	46874	7	8
53	157008	23	2691	1	48993	11	152569	22	2981	2	46839	11	7
54	156932	30	2696	2	48957	15	152497	29	2986	2	46804	14	6
55	156856	38	2700	2	48920	19	152425	36	2991	3	46769	18	5
56	156781	46	2705	2	48883	22	152353	43	2996	3	46734	21	4
57	156705	53	2710	3	48846	26	152281	50	3000	4	46699	25	3
58	156629	61	2715	3	48809	30	152209	58	3005	4	46664	28	2
59	156554	68	2719	4	48773	33	152138	65	3010	5	46630	32	1
60	↑ 156478		↓ 2724		↑ 48736		↑ 152066		↓ 3015		↑ 46695		0
	A_1 h	P.P.	A_7 a	P.P.	A_2 A_3 Z_3 d l a	P.P.	A_1 h	P.P.	A_7 a	P.P.	A_2 A_3 Z_3 d l a	P.P.	′
	341°		71°				340°		70°				°

$Z_1 + Z_2\ (=A_2) - Z_3 = Z_4$

(h) (d) (a) (z)

Fig. 84

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

Table of Altitude and Azimuth

$A_1 + A_2 + A_3 = A_4$ $A_5 + A_6 = A_7$
(h) (d) (l) (l±d) (a)

ℓ & d contrary name → ℓ+d
ℓ & d same name → ℓ~d

° / ′	64°						65°						
	A_1 A_4 h	P.P.	A_5 A_4 l±d	P.P.	Z_1 Z_4 h Z	P.P.	A_1 A_4 h	P.P.	A_5 A_4 l±d	P.P.	Z_1 Z_4 h Z	P.P.	
0	↑ 55158	0	↓ 28081	0	↑ 4634	0	↑ 53957	0	↓ 28869	0	↑ 4272	0	60
1	55138	2	28095	1	4628	1	53937	2	28882	1	4267	1	59
2	55118	4	28108	3	4622	1	53917	4	28895	3	4261	1	58
3	55097	6	28121	4	4616	2	53897	6	28909	4	4255	2	57
4	55077	8	28134	5	4609	2	53877	8	28922	5	4249	2	56
5	55057	10	28147	7	4603	3	53858	10	28935	7	4243	3	55
6	55037	12	28160	8	4597	4	53838	11	28948	8	4237	4	54
7	55017	14	28173	9	4591	4	53818	13	28961	9	4231	4	53
8	54997	16	28186	10	4585	5	53798	15	28975	10	4225	5	52
9	54976	18	28199	12	4579	5	53778	17	28988	12	4220	5	51
10	54956	0	28212	0	4573	0	53759	0	29001	0	4214	0	50
11	54936	2	28225	1	4566	1	53739	2	29014	1	4208	1	49
12	54916	4	28238	3	4560	1	53719	4	29027	1	4202	1	48
13	54896	6	28252	4	4554	2	53699	6	29041	4	4196	2	47
14	54876	8	28265	5	4548	2	53680	8	29054	5	4190	2	46
15	54856	10	28278	7	4542	3	53660	10	29067	7	4185	3	45
16	54835	12	28291	8	4536	4	53640	12	29080	8	4179	3	44
17	54815	14	28304	9	4530	4	53620	14	29093	9	4173	4	43
18	54795	16	28317	10	4524	5	53601	16	29107	10	4167	4	42
19	54775	18	28330	12	4518	5	53581	18	29120	12	4161	5	41
20	54755	0	28343	0	4512	0	53561	0	29133	0	4156	0	40
21	54735	2	28356	1	4506	1	53542	2	29146	1	4150	1	39
22	54715	4	28369	3	4500	1	53522	4	29168	3	4144	1	38
23	54695	6	28383	4	4493	2	53502	6	29173	4	4138	2	37
24	54675	8	28396	5	4487	2	53483	8	29186	5	4132	2	36
25	54655	10	28409	7	4481	3	53463	10	29199	7	4127	3	35
26	54635	12	28422	8	4475	4	53443	12	29212	8	4121	3	34
27	54615	14	28435	9	4469	4	53424	14	29226	9	4115	4	33
28	54595	16	28448	10	4463	5	53404	16	29239	10	4109	4	32
29	54574	18	28461	12	4457	5	53384	18	29252	12	4103	5	31
30	54554	0	28474	0	4451	0	53365	0	29265	0	4098	0	30
31	54534	2	28488	1	4445	1	53345	2	29279	1	4092	1	29
32	54514	4	28501	3	4439	1	53325	4	29292	3	4086	1	28
33	54494	6	28514	4	4433	2	53306	6	29305	4	4080	2	27
34	54474	8	28527	5	4427	2	53286	8	29318	6	4075	2	26
35	54454	10	28540	7	4421	3	53267	10	29332	7	4069	3	25
36	54434	12	28553	8	4415	4	53247	11	29345	8	4063	4	24
37	54414	14	28566	9	4409	4	53227	13	29358	10	4058	4	23
38	54394	16	28580	10	4403	5	53208	15	29371	11	4052	5	22
39	54375	18	28593	12	4397	5	53188	17	29385	13	4046	5	21
40	54355	0	28606	0	4391	0	53169	0	29398	0	4040	0	20
41	54335	2	28619	1	4385	1	53149	2	29411	1	4035	1	19
42	54315	4	28632	3	4379	1	53129	4	29424	3	4029	1	18
43	54295	6	28645	4	4373	2	53110	6	29438	4	4023	2	17
44	54275	8	28658	6	4367	2	53090	8	29451	5	4018	2	16
45	54255	10	28672	7	4361	3	53071	10	29464	7	4012	3	15
46	54235	12	28685	8	4355	4	53051	11	29477	8	4006	4	14
47	54215	14	28698	10	4349	4	53032	13	29491	9	4000	4	13
48	54195	16	28711	11	4343	5	53012	15	29504	10	3995	5	12
49	54175	18	28724	13	4337	5	52993	17	29517	12	3989	5	11
50	54155	0	28737	0	(4332)	0	52973	0	29530	0	3983	0	10
51	54135	2	28751	1	4326	1	52954	2	29544	1	3978	1	9
52	54116	4	28764	3	4320	1	52934	4	29557	3	3972	1	8
53	54096	6	28777	4	4314	2	52915	6	29570	4	3966	2	7
54	54076	8	28790	5	4308	2	52895	8	29583	6	3961	2	6
55	54056	10	28803	7	4302	3	52876	10	29597	7	3955	3	5
56	54036	12	28816	8	4296	4	52856	11	29610	8	3950	4	4
57	54016	14	28830	9	4290	4	52837	13	29623	10	3944	4	3
58	53996	16	28843	10	4284	5	52817	15	29637	11	3939	5	2
59	53977	18	28856	12	4278	5	52798	17	29650	13	3933	5	1
60	↑ 53957		↓ 28869		↑ 4272		↑ 52778		↓ 29663		↑ 3927		0
	A_1 h	P.P.	A_7 a	P.P.	A_2 d, A_3 l, Z_3 a	P.P.	A_1 h	P.P.	A_7 a	P.P.	A_2 d, A_3 l, Z_3 a	P.P.	′ / °
	295°		25°				294°		24°				

$Z_1 + Z_2 (= A_1) - Z_3 = Z_4$
(h) (d) (a) (Z)

Fig. 85

Extracted from ASTRONOMICAL NAVIGATION TABLES, MARITIME SAFETY AGENCY, JAPAN.

How to fix the ship's position on position plotting sheet

To fix the ship's position by lines of position, we have to use specialized sheets as follows:

1. Plotting Sheet for Astronomical Position (Fig. 88)

2. Position plotting sheet (Fig. 89)

3. Nautical chart

4. Diagram of concentric circles in quadrates (Fig. 90)

Lines of position are drawn in a very small and limited area on the chart which corresponds to the earth, so we can apply the theory of the mid-latitude sailing ($\text{D-long} = \frac{\text{Dep}}{\cos \ell}$) to fix position on the chart.

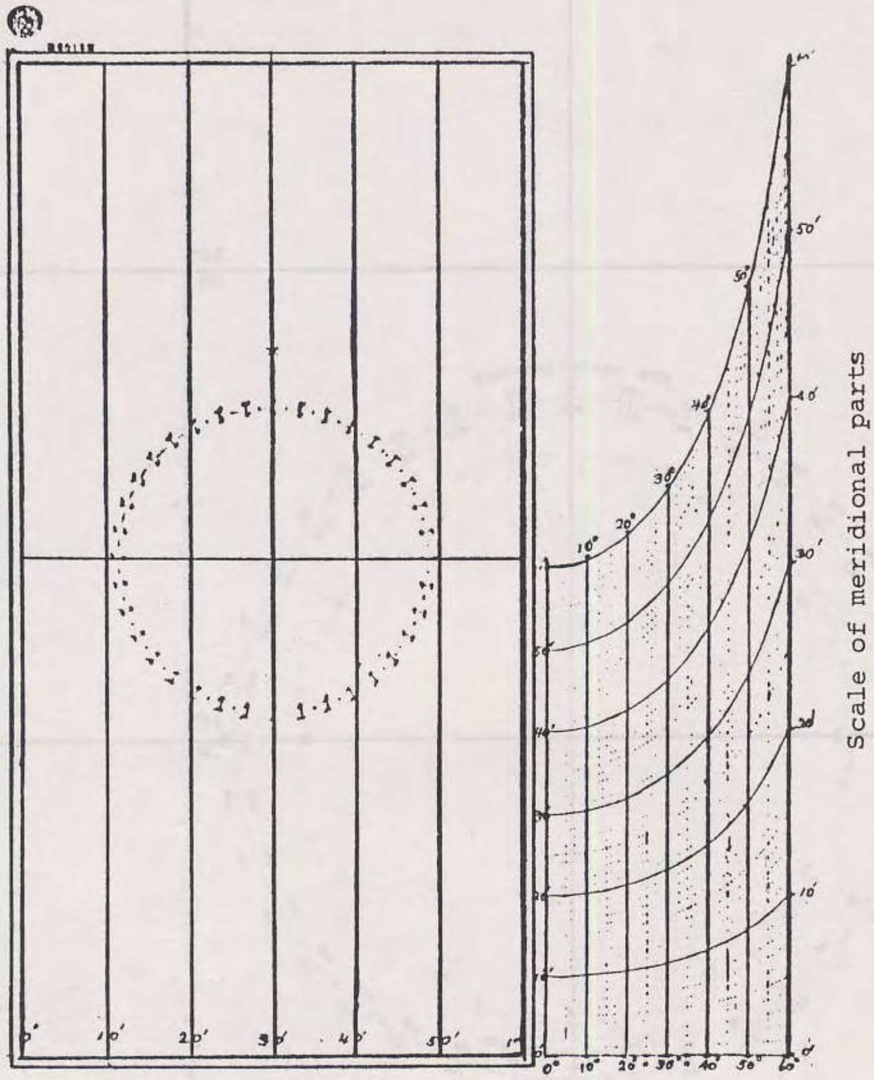
On method for the applications of the mid-latitude sailing is to use a diagram of concentric circles in quadrates (Fig. 90).

This diagram consists of latitudinal line ($\overline{EW}$), longitudinal line ($\overline{NS}$), concentric circles and quadrates. In Figure 90, Point D is Dead Reckoning Position, the line $\overline{NDS}$ is its longitude, $\overline{EDW}$ is its latitude and each interval of circles and straight line is one nautical mile.

Example 14 (use Fig. 90)

A navigator observed the stars A and B at the same time and obtained Zc = N 80°W, I = + 5'.0 by the star A and Zc = S 30°W, I = + 7'.0 by the star B, in D.R.P. 30°00'.0 N, 150°50'.0 E.

Draw lines of position, fix ship's position, current set and current drift.



Scale of longitude Latitude

Plotting Sheet for Astronomical Position

Fig. 88

Position Plotting Sheet

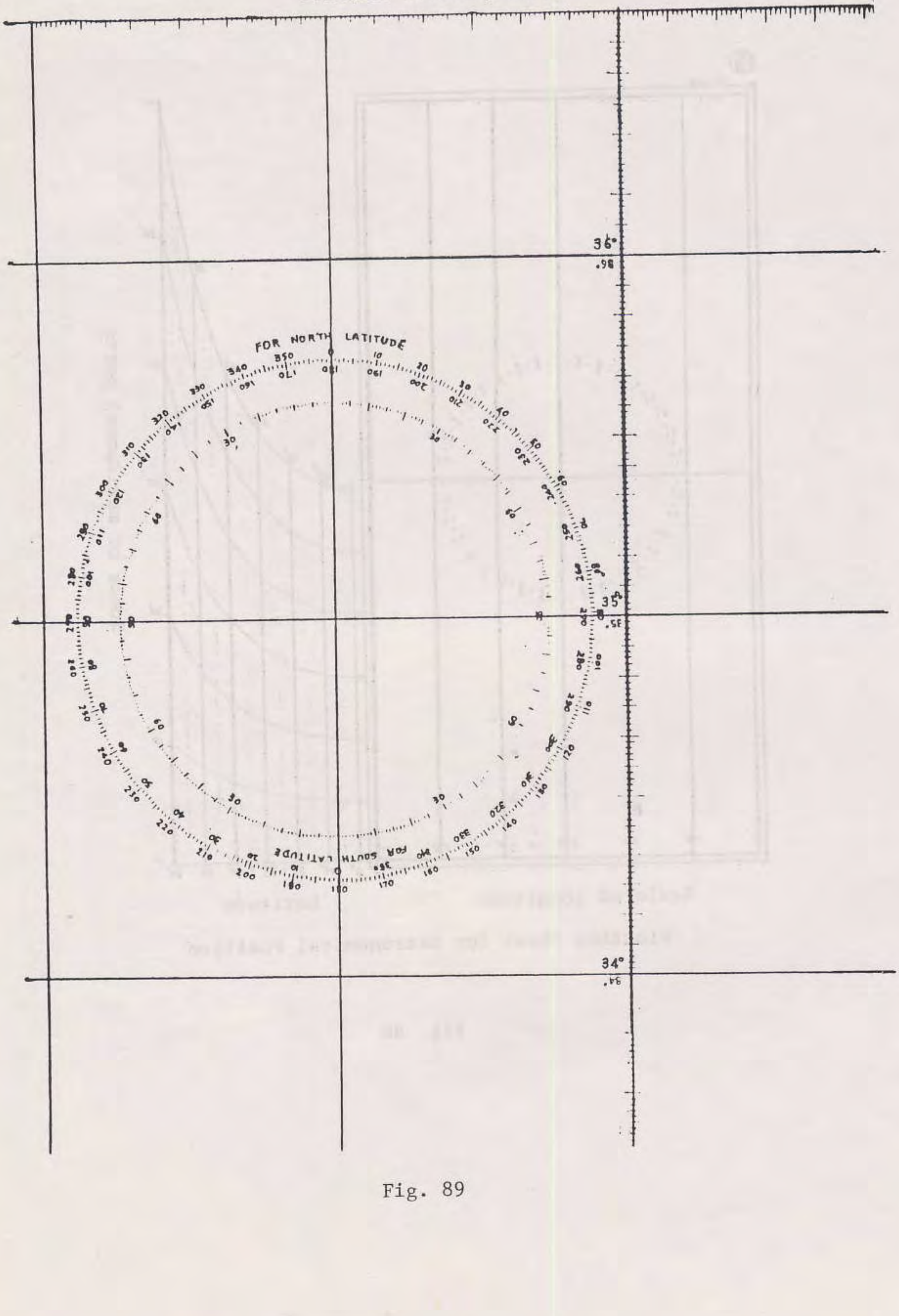


Fig. 89

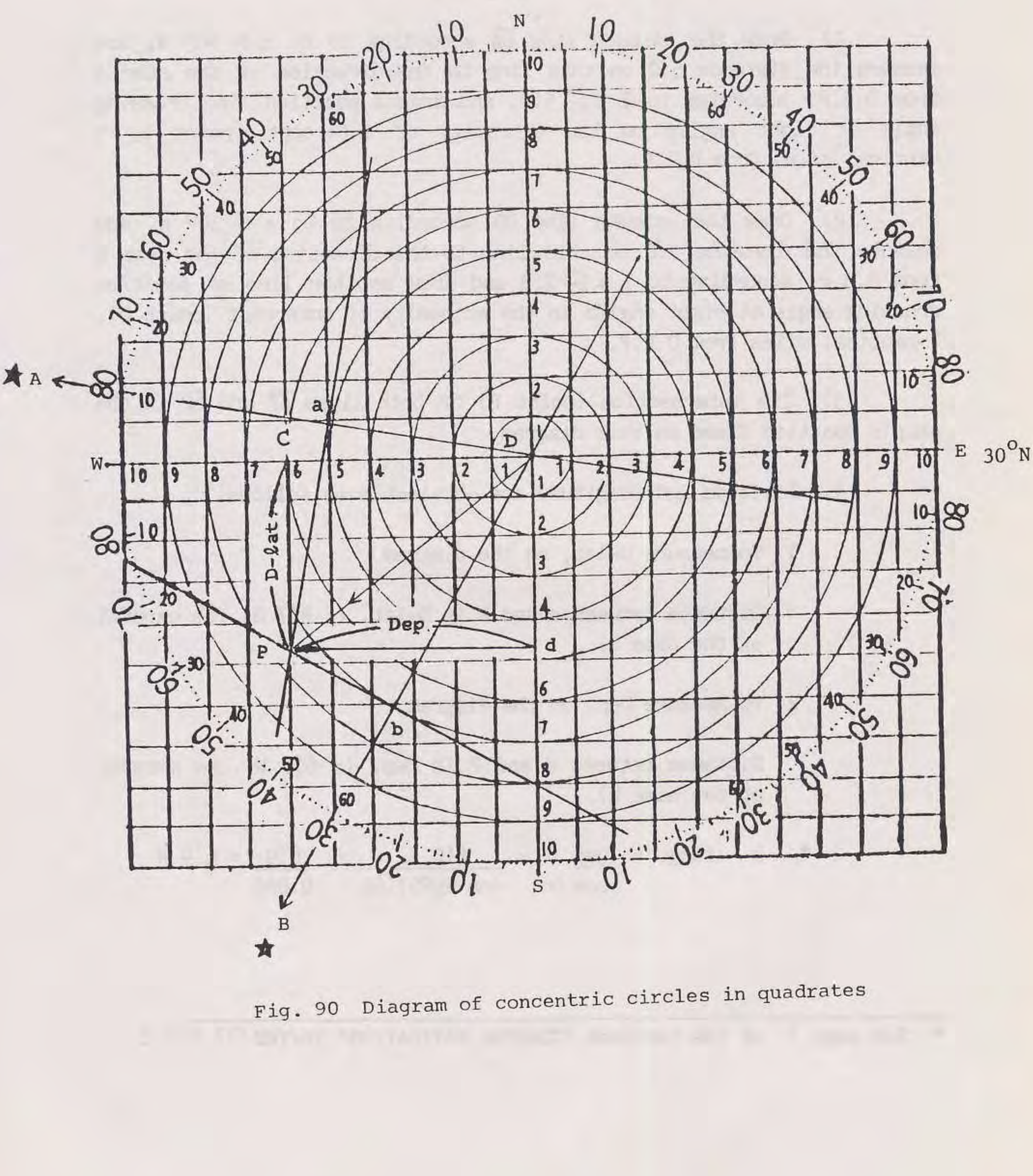


Fig. 90 Diagram of concentric circles in quadrates

<u>Solution A</u> by diagram of concentric circles in quadrates (Fig. 90)

1) Draw the azimuth line $\overrightarrow{DA}$ according to Zc = N 80° W, and measure the distance 5'.0 on this line to the direction of the star A from D.R.P. according to I = ⊕ 5'.0, and draw a position line crossing angle at right angles on the extremity of intercept (point a) 5 nautical miles from D.R.P.

2) Draw the azimuth line $\overrightarrow{DB}$ according to Zc = S 30° W, and measure the distance 7'.0 on this line to the direction of the star B from D.R.P. according to I = ⊕ 7.0 and draw another line of position crossing angle at right angles in the extremity of intercept (point b), 7 nautical miles from D.R.P.

3) The intersection (point P) of both lines $\overline{aP}$ and $\overline{bP}$ is the ship's position fixed on this diagram.

4) Latitude and longitude are obtainable as follows,

1 To measure D-lat, on the diagram

Distance between c and P is D-lat. (= 4'.7 S...be careful of the name S).

2 To measure Dep. on the diagram

Distance between d and P is Dep. (= 6'.0 W...be careful of the name W).

* $\text{D - long.} = \dfrac{\text{Dep}}{\cos \ell m} = \dfrac{6'.0}{\cos 29°57'.65} = \dfrac{6'.0}{0.866} = 6'.9\ \text{W}$

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* See page 3 of the textbook "COASTAL NAVIGATION" TD/TRB/37 Rev.2

So. D.R.P. Lat.	30 - 00!0 N	D.R.P. long.	150° - 50!0 E
D - Lat.	4!7 S ⊖	D - long.	6!9 W ⊖
	29°- 55!3 N		150° - 43!1 E

Then fixed position ⊕ { 29°- 55!3 N, 150°- 43!1 E }

5) Current set is $\overrightarrow{DP}$ (= S 52°W) and current drift is the distance between point D and P (= 7!6).

Ans. Fixed position 29° - 55!3 N, 150° - 43!1 E
Current set S 52° W
Current drift 7!6 nautical miles

Solution B by a triangle ruler (Figs. 91-96)

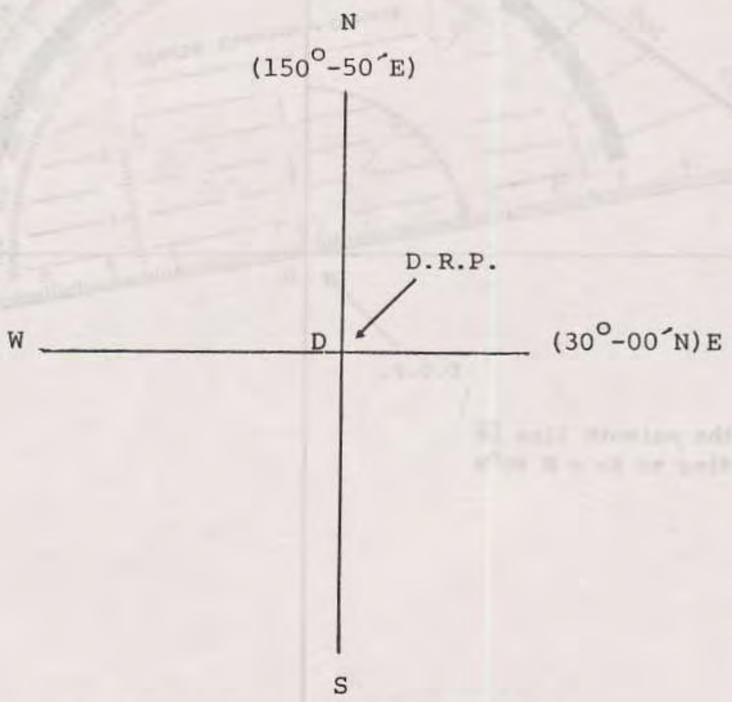


Fig. 91 Latitude and Longitude

1) Draw the latitude and longitude lines in your note book as shown in Figure 91. Intersection of these two lines in D.R.P.

2) About the star A (see Figs. 92, 93).

Draw the azimuth line $\overline{DA}$ by a triangle ruler according to Zc = N 80°W (see Fig. 92), and measure the distance 5'.0 on this line to the direction of star A from D.R.P. according to I = ⊕ 5'.0, and draw a line of position crossing angle at right angles on the extremity of intercept (point a), 5 nautical miles from D.R.P. (see Fig. 93).

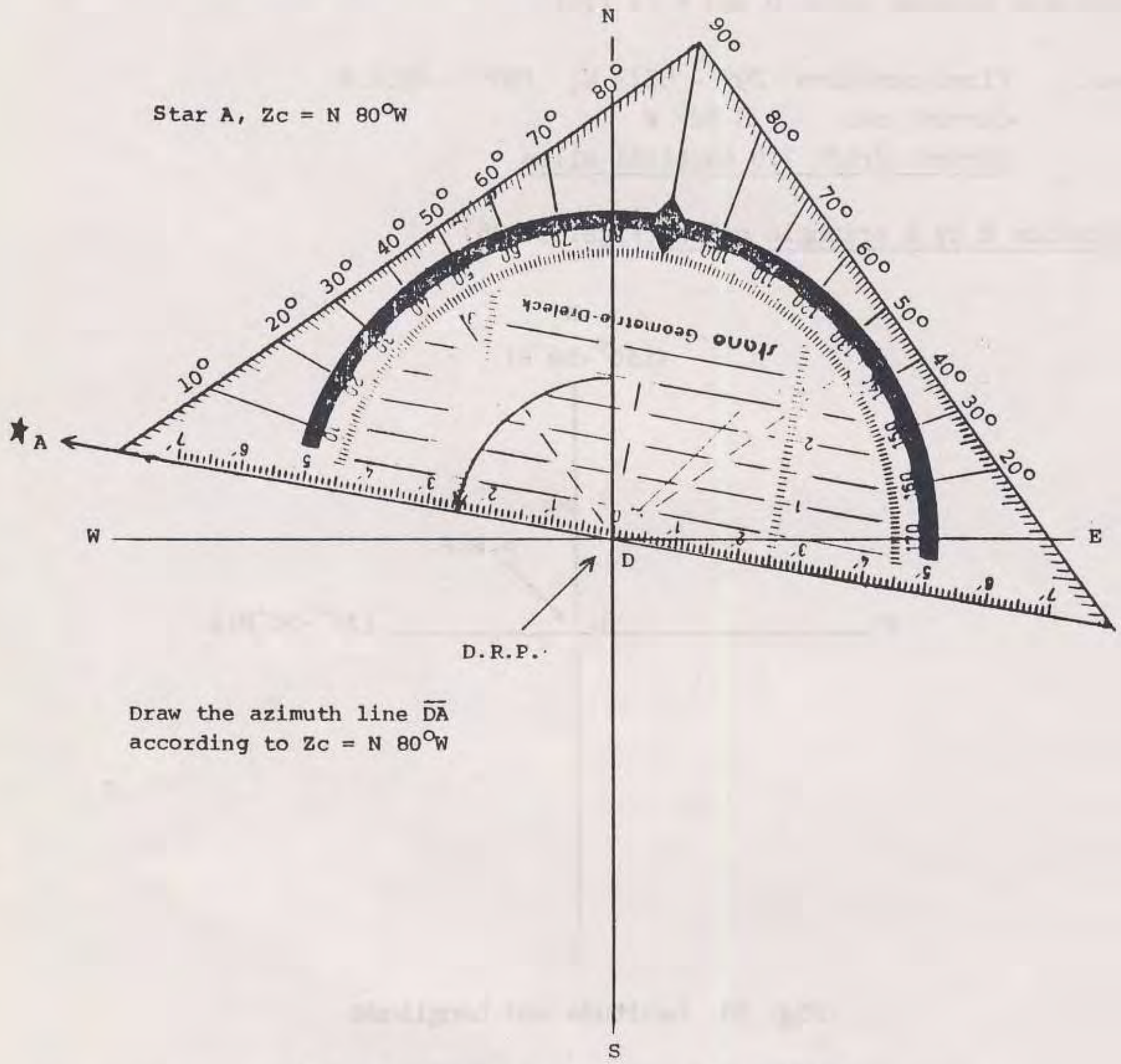
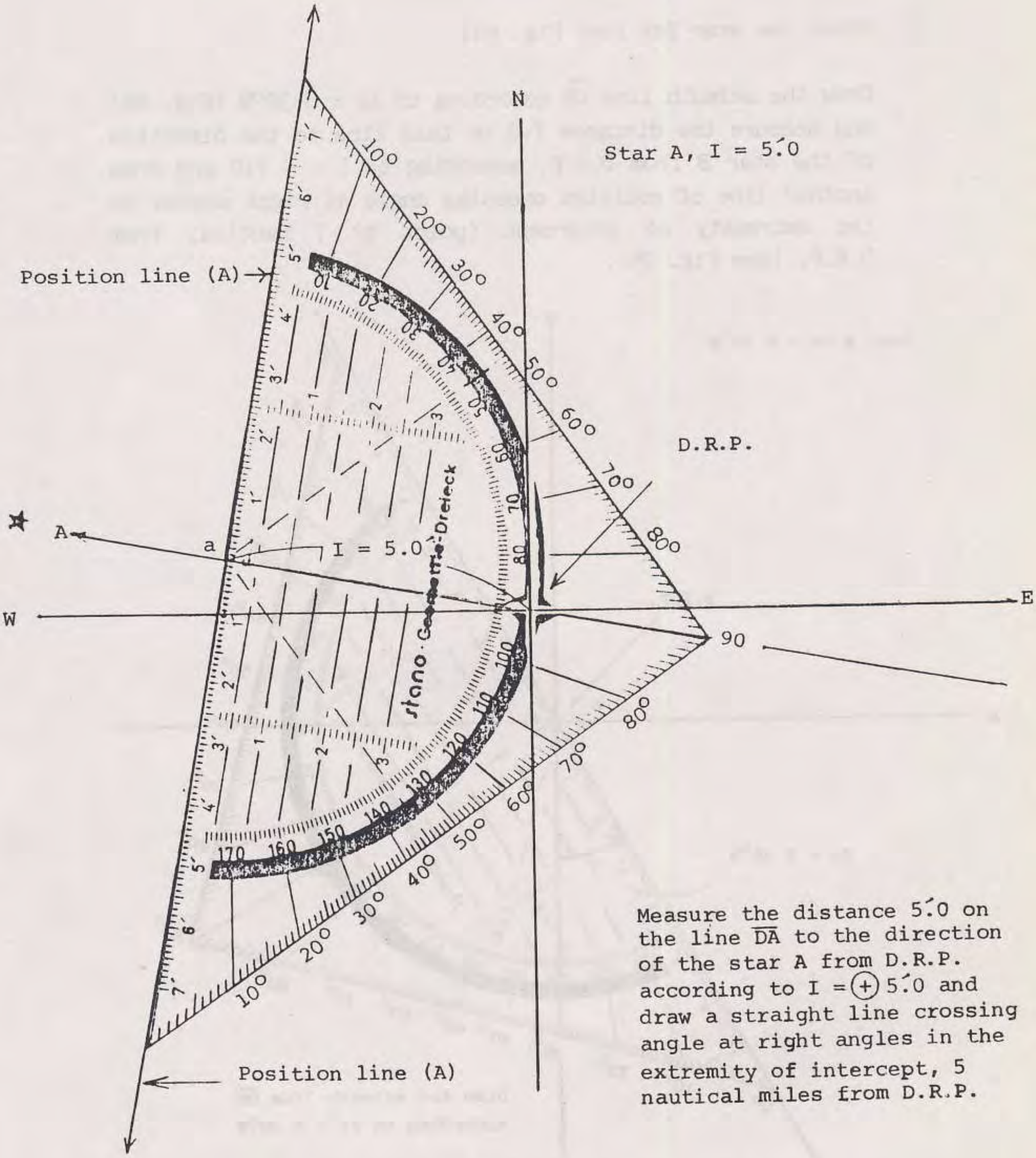


Fig. 92 How to draw line of position



Measure the distance 5'.0 on the line $\overline{DA}$ to the direction of the star A from D.R.P. according to I = (+) 5'.0 and draw a straight line crossing angle at right angles in the extremity of intercept, 5 nautical miles from D.R.P.

Fig. 93 How to draw line of position

3) About the star Bar (see Fig. 94)

Draw the azimuth line $\overline{DB}$ according to Zc = S 30°W (Fig. 94) and measure the distance 7.0 on this line to the direction of the star B from D.R.P. according to I = + 7!0 and draw another line of position crossing angle at right angles on the extremity of intercept (point b) 7 nautical from D.R.P. (see Fig. 95).

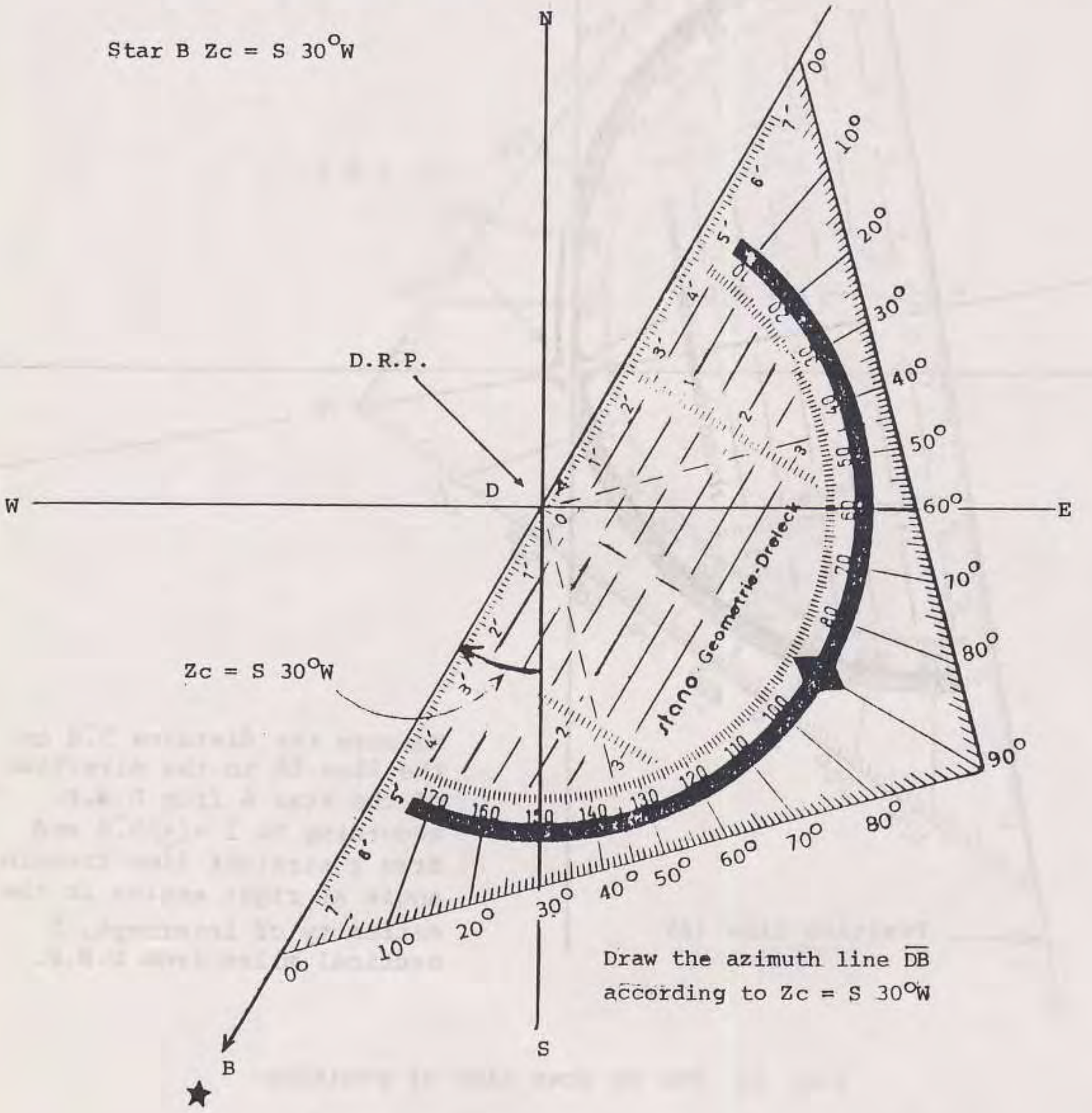
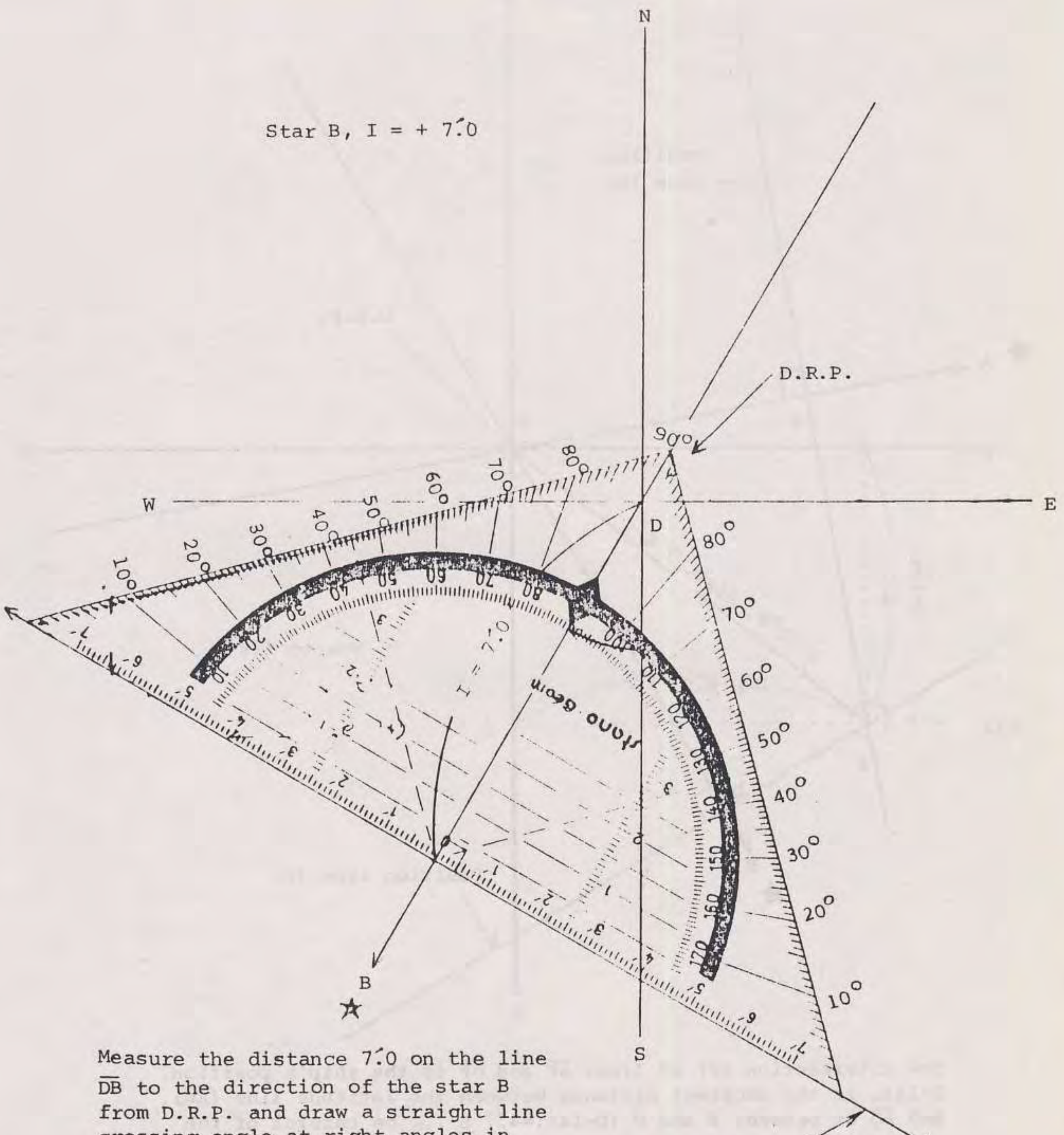
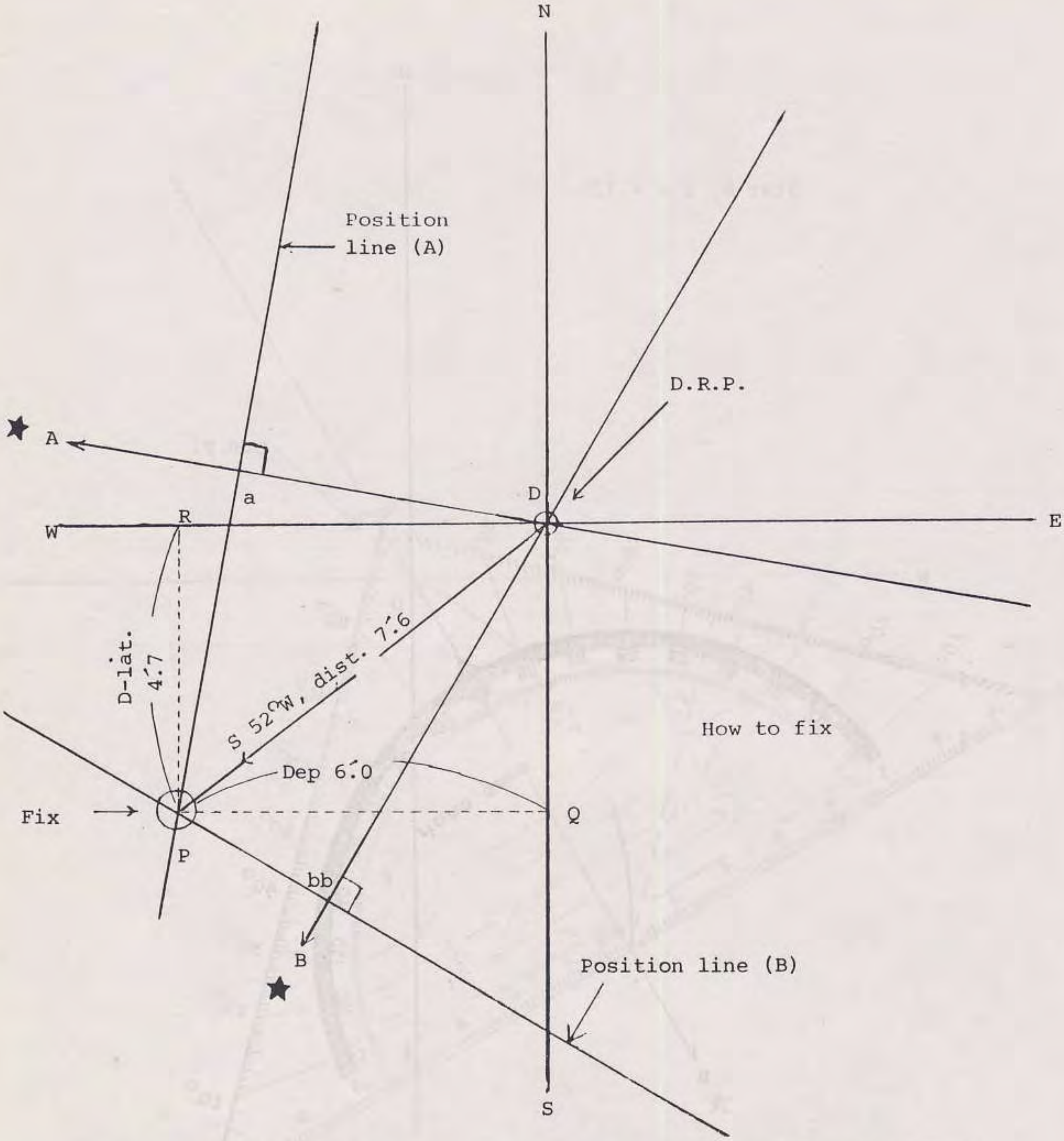


Fig. 94 How to draw line of Position



Measure the distance 7.'0 on the line $\overline{DB}$ to the direction of the star B from D.R.P. and draw a straight line crossing angle at right angles in the extremity of intercept, 7 nautical miles from D.R.P.

Fig. 95 How to draw line of position



The intersection (P) of lines $\overline{aP}$ and $\overline{bP}$ is the ship's position. D-lat. is the shortest distance between the latitude line (EW). and $\overline{PQ}$ or between R and P (D-lat.=4.'7 S ... be careful of the name S)

Another shortest distance between $\overline{NS}$ and $\overline{RP}$ or between P and Q is Dep. (= 6.'0 W ... be careful of the name W)

Fig. 96

4) Ship's position to be fixed (see Fig. 96)

The intersection (p) of line aP and bP is the ship's position.

5) Latitude and longitude (see Fig. 96)

To obtain both latitude and longitude of fix, it is necessary to measure D - Lat. It should be the shortest distance between the latitude line ($\overline{EW}$) and point P (or line $\overline{PQ}$). It is 4ʹ.7 nautical miles southerly (D - Lat. = 4ʹ.7 s = $\overline{RP}$)

The value of departure (Dep.) should be the shortest distance between the longitude line ($\overline{NS}$) and point P (or line $\overline{PR}$). It is 6.0 nautical miles westerly (Dep. = 6ʹ.0 W = $\overline{QP}$).

By the mid-latitude sailing,

$$D - long = \frac{Dep.}{\cos \ell m} = \frac{6'.0}{\cos 29^{\circ}57'.65} = \frac{6'.0}{0.866} = 6'.9\ W$$

So, D.R.P. Lat.	30°- 00ʹ.0 N	D.R.P. long.	150°- 50ʹ.0 E
D - Lat.	4ʹ.7 S ⊖	D - long.	6ʹ.9 W ⊖
	29°- 55ʹ.3 N		150°- 43ʹ.1 E

6) Current set and current drift (see Fig. 96)

Current set is $\overline{DP}$ (= S 52°W, measured by a triangle ruler).

Current drift is the distance between point d and point P (= 7ʹ.6) measured by a triangle ruler).

7) Ans. Fixed position 29°- 55!3 N, 150°- 43!1 E
Current set S 52° W
Current drift 7!6 nautical miles

Note

It is convenient and advisable to use Solution B

Solution C ... by the position plotting sheet

Latitude scales are printed on this sheet (see Figs. 89 & 97), so you must mark longitudes depending on your D.R.P. (see Fig. 97).

1) Check your D.R.P. on the sheet and mark it with a small circle. next, draw azimuth line ($\overrightarrow{OA}$) of the star A through D.R.P. (point D) according to Zc = N 80°W, then measure the distance 5.0 on this line to the direction of star A from D.R.P. according to I = ⊕ 5!0 and draw a line of position crossing angle at right angles on the extremity of intercept (point a) 5 nautical miles from D.R.P.

2) Draw the azimuth line ($\overrightarrow{DB}$) of the star B through D.R.P. (point D) according to Zc = S 30°W, then measure the distance 7!0 on this line to the direction of the star B from D.R.P. according to I = ⊕ 5.0 and draw another line of position crossing angle at right angles on the extremity of intercept (point b), 7 nautical miles from D.R.P.

3) The intersection (point P) of both lines of position is the ship's fixed position. So the latitude and longitude of the fix can be directly obtained by divider measurement on the sheet.

4) Current set is the line $\overrightarrow{DP}$ (= S 52°W) and current drift is the distance between point D and P (≒ 7!6).

5) Ans. Fixed position 29°- 55!3 N, 150°- 43!1 E
Current set S 52°W
Current drift 7'.6 nautical miles

<u>Note</u> This sheet is based on Mercator sailing

<u>Solution D</u> .. by plotting sheet for astronomical position

Longitude scales are printed on this sheet and latitude scales are also printed for every 10 nautical miles from latitude 0° to 60° (see Figs. 88, 98-100).

In this problem, the latitude is 30° 00' north, so you must choose the scale of 30° latitude (see Figs. 98, 99 & 100), shown by a small circle as 30°, to measure distance and fixed latitude (or D - Lat.) on this sheet.

Scale of longitude is also shown on the sheet (see Figs. 98 & 101).

1) D.R.P. should be marked on the center of the sheet (see Fig. 101).

2) Draw the azimuth line $\overrightarrow{DA}$ according to Zc = N 80°W, and measure the distance 5.0 (see Figs. 99 & 101) on this line in the direction of the star A from D.R.P. according to I = ⊕ 5!0, and draw a position line crossing angle at right angles on the extremity of intercept (point a), 5 nautical miles from D.R.P.

3) Draw the azimuth line $\overrightarrow{DB}$ according to Zc = S 30°W, and measure the distance 7!0 (see Figs. 100 & 101) on this line in the direction of the star B from D.R.P. according to I = ⊕ 7!0 and draw another line of position crossing angle at right angles on the extremity of intercept (point b), 7 anutical miles from D.R.P.

4) The intersection (point P) of lines of position $\overrightarrow{aP}$ and $\overrightarrow{bP}$, is the ship's position fixed.

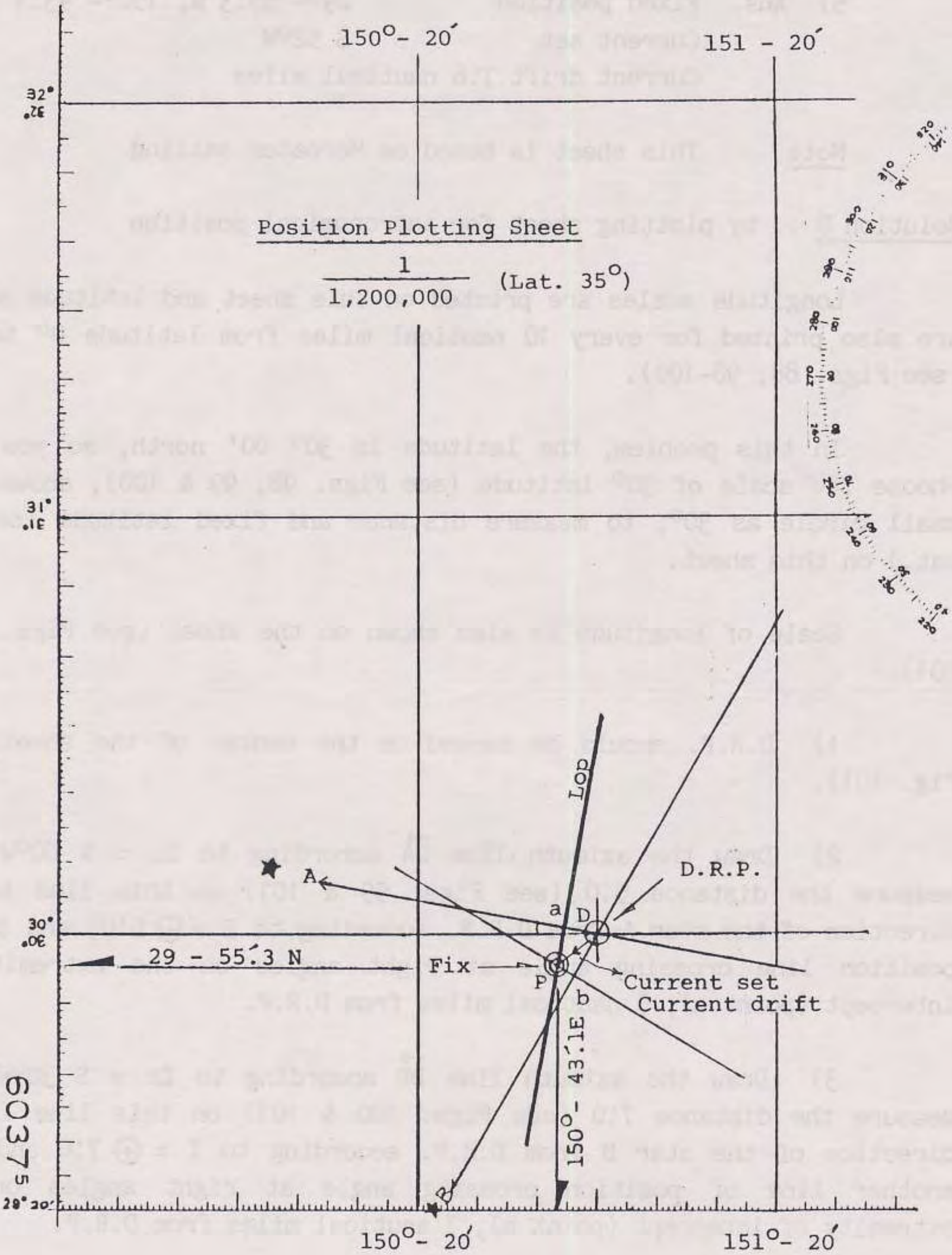


Fig. 97 How to fix

5) Latitude and longitude are obtained as follows;

1) To measure D - lat. on the sheet by dividers.

The shortest distance between latitude line ($\overline{EW}$ = 30°-00'N) and point P is D - Lat. (= 4!7 S ... Attention to the name S).

2) To measure D - Long. on the sheet by dividers.

The shortest distance between longitude line ($\overline{NS}$ = 150°- 50'E) and point P is D - Long. (= 6!9 W ... Don't forget suffix W).

6)

D.R.P. Lat.	30°- 00!0 N	D.R.P. Long.	150°- 50!0 E
D - Lat.	4!7 S ⊖	D - Long.	6!9 W ⊖
	29°- 55!3 N		150°- 43!1 E

7) Current set is the line $\overrightarrow{DP}$ (= S 52°W) and current drift is the distance between D and P (= 7!6).

8) Ans. Fixed position 29°- 55!3 N, 150°- 43!1 E
Current set S 52°W
Current drift 7!6 nautical miles

Note Plotting sheet for astronomical position is also based on Mercator sailing.

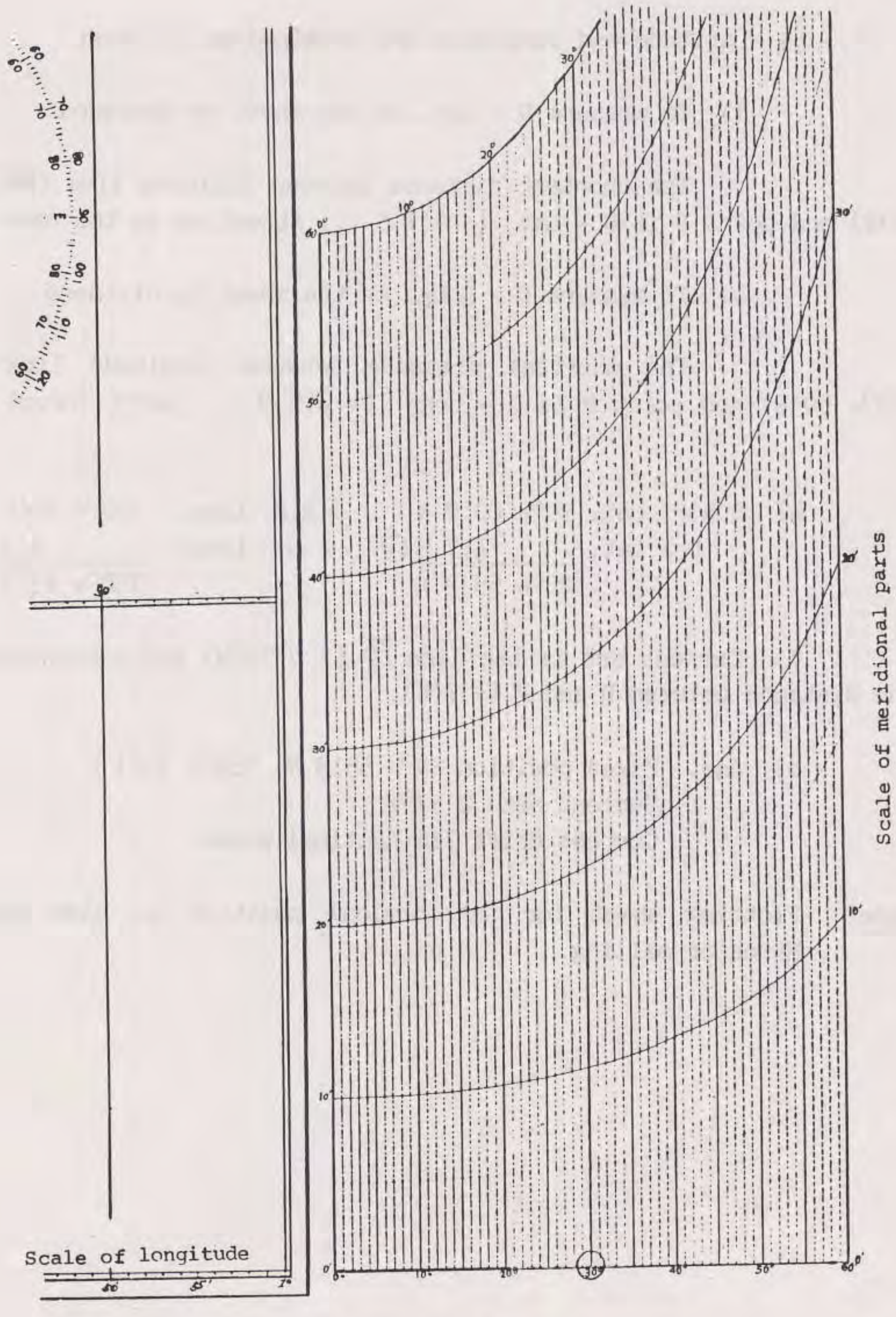


Fig. 98 Latitude

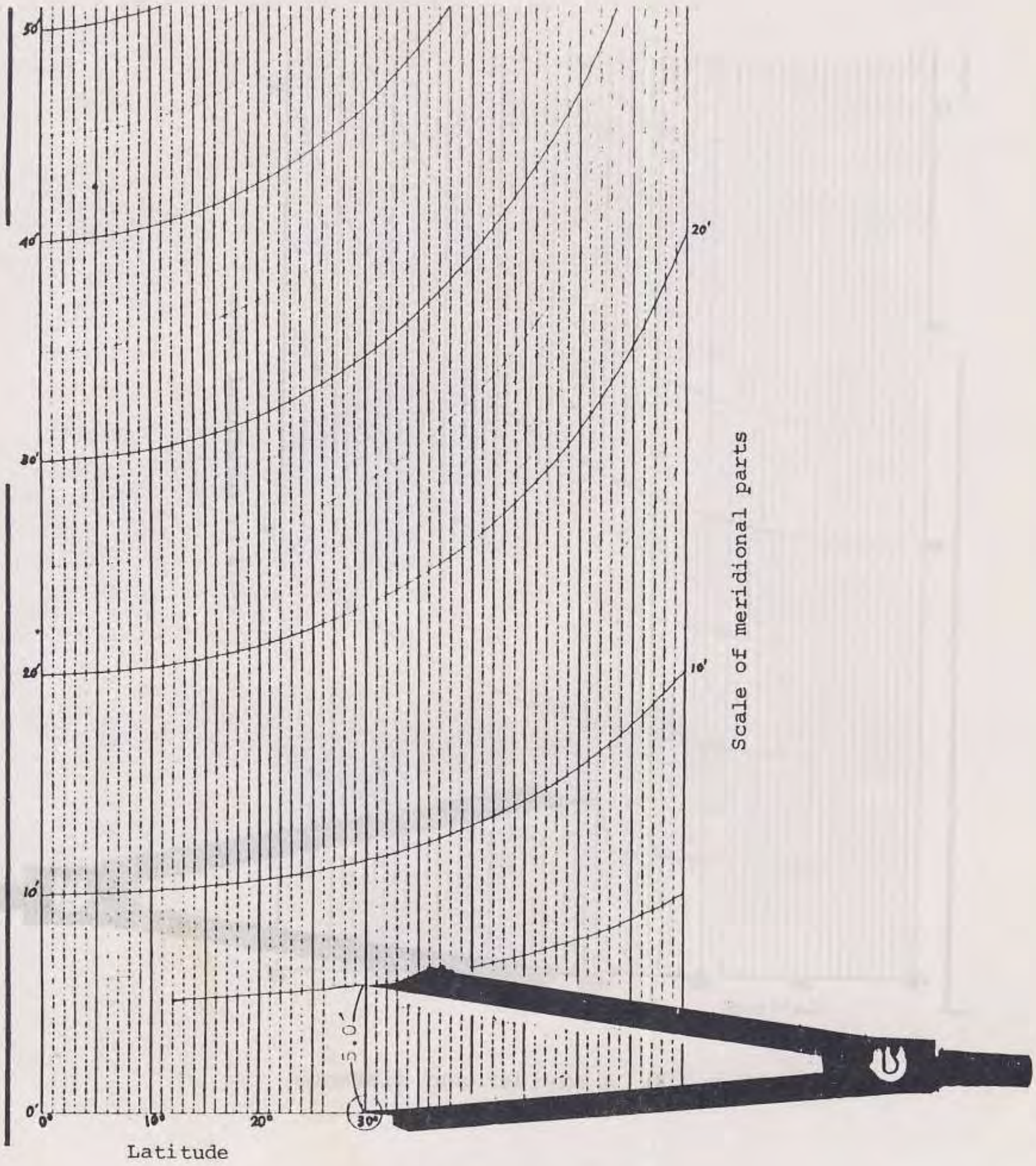


Fig. 99 A divider and distance

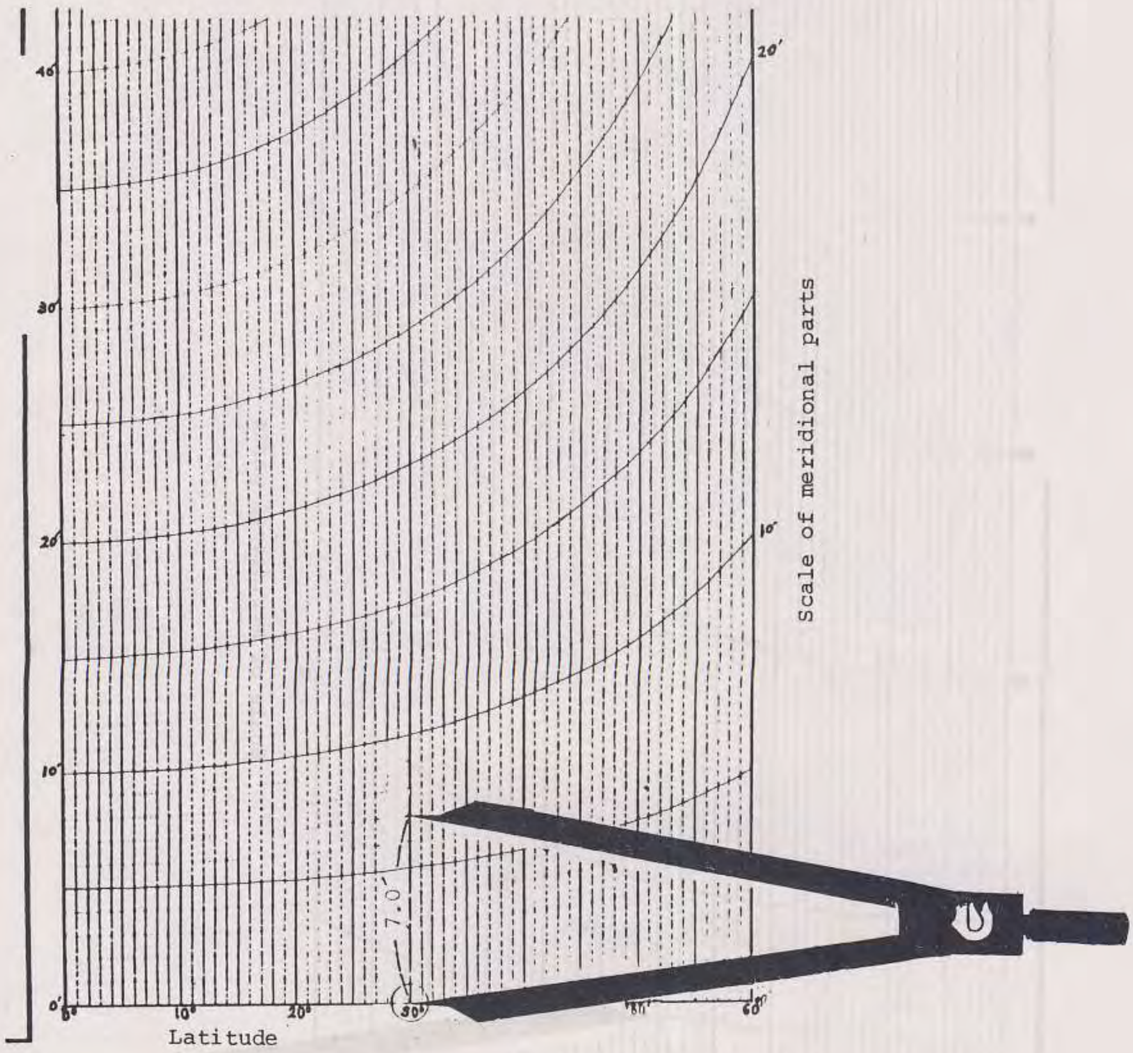


Fig. 100 A divider and distance

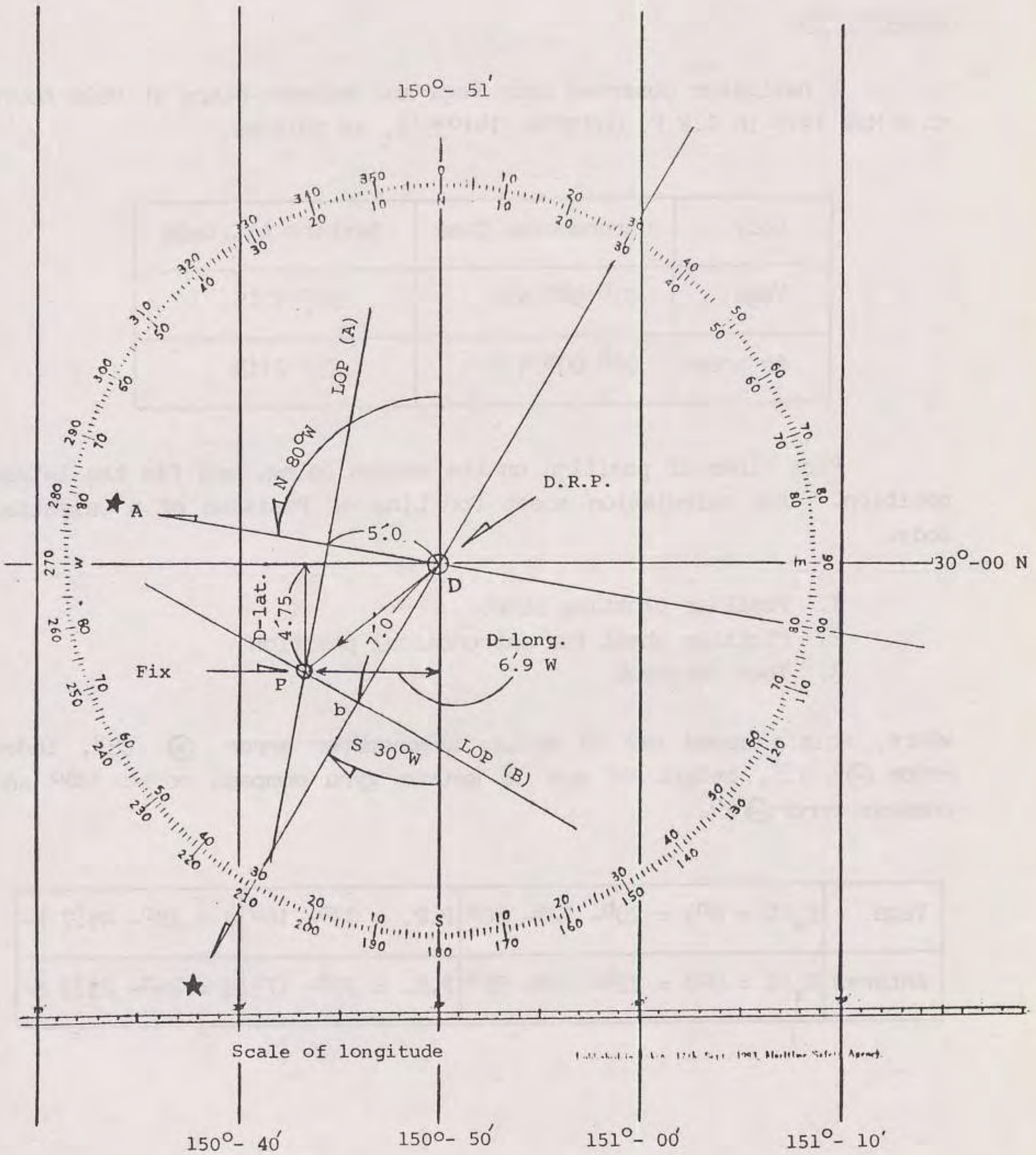


Fig. 101 How to fix

Example 15

A navigator observed both Vega and Antares stars at 0500 hours on 6 May 1979 in D.R.P. 06°10'N, 141°35'E, as follows,

Body	Chronometer Time	Sextant Altitude
Vega	$07^h\ 54^m\ 57^s$	50° 47'.5
Antares	$08^h\ 00^m\ 41^s$	25° 21'.3

Plot lines of position on the sheets below, and fix the latest position. Use calculation sheet for Line of Position of a Celestial Body.

1. Position plotting sheet
2. Plotting sheet for astronomical position
3. Your notebook

where, ship's speed was 20 knots, chronometer error ⊕ 05^s, index error ⊖ 1'.5, height of eye 18 metres gyro compass corse 128° and compass error ⊕ 2°.

Vega	$E_*(U = 0^h) = 20^h\text{-}\ 12^m\text{-}\ 50^s$	P.P. = $03^m\text{-}\ 16^s$	d = 38°- 45'.7 N
Antares	$E_*(U = 0^h) = 22^h\text{-}\ 20^m\text{-}\ 56^s$	P.P. = $30^m\text{-}\ 17^s$	d = 26°- 23'.1 S

Line of Position of a Celestial Body

Body's name	

Date	Month	Year	Z.T.	+ / −	h

D.R.P.	° ′	N / S	° ′	E / W	True Co.	°	sp'd	kt.

	Ship's Time	Date	Month	h m s	
※1	L. in T.				±
	Approx. U. (Date /)				
	Chro. T.			h m s	
	Chro. E.				±
	Corrected chro.T.				
	Morning or Afternoon			(12)	+
	U. (Date /)				
	E☉✱☾P (d = ° ′ N/S)				
	P.P				+
				(24)	− ⊙
	$h_{☾}$ in hours				
	$h_{☾}$ in degrees	⊕360°		° ′	⊙
※2	Long.				±
		⊖360°			⊙
					−
	h				

Sex. Alt.	° ′	
I.E.		±
Obs. Alt		
Corr. 1		±
Corr. 2		±
Corr. 3		±
a_t		
a_c		−
I		±

		° ′								
	h			→	A_1		→	Z_1		
	d		N/S	→	A_2		=	Z_2		+
	ℓ		N/S	→	A_3	+				
					A_4					
					↓					
					A_5					
※3	ℓ±d				A_6	+				
					A_7		→	Z_3		−
					↓			Z_4		
					a_c ° ′			↓ Z_c	N/S ° ′ E/W	※4

Ref.

1. Approx. U = Ship's Time ± L.in T. (E − long → ⊖, W − long. → ⊕)
2. $h = h_{☾} \pm L$ (E − long → ⊕, W − long → ⊖)
3. When ℓ and d same name → ℓ~d, contrary → ℓ + d
4. When h > 180° suffix of Z_c → E, h < 180° suffix of Z_c → W

Fig. 102 Calculation Sheet

Line of Position of a Celestial Body

Body's name	Vega.

Date	Month	Year	Z.T.	+/−	h
6	May	1979		−	—

D.R.P.	06° 10'	(N)/S	141° 35'	(E)/W	True Co.	130°	sp'd	20 kt.

	Date	Month	h	m	s	
Ship's Time	6	5	05	00	00	
※1 L. in T.			09	26	20	±(−)
Approx. U. (Date 5/5)			19	33	40	
Chro. T.			07	54	57	
Chro. E.					05	(+)/−
Corrected chro.T.			07	55	02	
Morning or Afternoon			(12)			(+)
U. (Date 5/5)			19	55	02	
E☉✱☾P (d = 38°45!7 (N)/S)			20	12	50	
P.P				03	16	+
			40	11	08	
·			(24)			− ⊙
h_G in hours			16	11	08	
h_G in degrees	⊕360°		242°		47.0	⊙
※2 Long.			141		35.0	(+)
	⊖360°		384		22.0	⊙
						−
h			24		22.0	

Sex. Alt.	50° 47!5	
I.E.	01.5	±(−)
Obs. Alt	50 46.0	
Corr. 1	08.3	±(−)
	50 37.7	
Corr. 2	—	±
	—	
Corr. 3	—	±
a_t	50 37.7	
a_c	50 39.7	−
I	02.0	±(+)

h	24° 22!0		→	A_1	135127	→	Z_1	38450
d	38 45.7	(N)/S	→	A_2	10804	=	Z_2	10804 +
ℓ	06 10.0	(N)/S	→	A_3	252 +			49254
				A_4	146183			
				↓				
				A_5	3453			
※3 ℓ±d				A_6	7876 +			
				A_7	11329	→	Z_3	19798 −
				↓			Z_4	29456
				a_c	50° 39!7		↓ Z_c	(N)/S 30° 29!9 E/(W) ※4

Ref.

1. Approx. U = Ship's Time + L.in T. (E − long → ⊖, W − long. → ⊕)
2. h = h_G + L (E − long → ⊕, W − long → ⊖)
3. When ℓ and d same name → ℓ~d, contrary → ℓ + d
4. When h > 180° suffix of Z_c → E, h < 180° suffix of Z_c → W

Fig. 103 Calculation Sheet

Line of Position of a Celestial Body

Body's name	Antares

Date	Month	Year	Z.T.	+ / −	h
6	May	1979			—

D.R.P.	06° 10'	(N) / S	141° 35'	(E) / W	True Co.	130°	sp'd	20 kt.

※1	Ship's Time (Date 6, Month 5)	h m s 05 00 00		
	L. in T.	09 26 20	± (−)	
	Approx. U. (Date /)	19 33 40		
	Chro. T.	h m s 08 00 41		
	Chro. E.	05	(+) −	
	Corrected chro.T.	08 00 46		
	Morning or Afternoon	(12)	(+)	
	U. (Date 5/5)	20 00 46		
	E☉ * ☾ P (d = 26°23.1' N/(S))	22 20 56		
	P.P	03 17	+	
		42 24 59		
		(24)	−	⊙
	h_G in hours	18 24 59		
※2	h_G in degrees (+)360°	276° 14.8		⊙
	Long.	141 35.0	(+) −	
	(−)360°	417 49.8		⊙
			−	
	h	57 49.8		

Sex. Alt.	25° 21!3	
I.E.	01.5	+ (−)
Obs. Alt	25 19.8	
Corr. 1	09.6	+ (−)
	25 10.2	
Corr. 2	—	+ −
	—	
Corr. 3	—	+ −
a_t	25 10.2	
a_c	25 14.6	−
I	04.4	+ (−)

	h 57° 49!8		→	A_1 63119		→	Z_1	7239	
	d 26 23.1	N (S)	→	A_2 4778		=	Z_2	4778	+
	ℓ 06 10.0	(N) S	→	A_3 252	+			12017	
				A_4 68149					
				↓					
				A_5 20822					
※3	ℓ±d			A_6 7855	+				
				A_7 28677		→	Z_3		−
				↓			Z_4		
				a_c 25° 14!6			↓ Z_c	N (S) 56° 57!9 E (W)	※4

Ref.

1. Approx. U = Ship's Time + L.in T. (E - long →(−), W - long. →(+))
2. $h = h_G + L$ (E - long →(+), W - long →(−))
3. When ℓ and d same name → ℓ~d, contrary → ℓ + d
4. When h > 180° suffix of Z_c → E, h < 180° suffix of Z_c → W

Fig. 104 Calculation Sheet

2) Running fix calculation

- o Gyro Compass Course 128°
  Compass error 2° +
  True Course 130°

$$\begin{array}{lr} \text{Gyro Compass Course} & 128^\circ \\ \text{Compass error} & 2^\circ + \\ \hline \text{True Course} & 130^\circ \end{array}$$

- o Time lag between first and second observation

$$\begin{array}{lr} \text{First observation chro. T.} & = 07^h - 54^m - 57^s \\ \text{Second observation chro. T.} & = 08 - 00 - 41\ - \\ \hline & 05 - 44 = 5^m.7 \end{array}$$

- o Distance run $= \dfrac{20^m \times 5'.7}{60^m} = 1'.9$

20 miles → 60 minutes
1.9 miles ← 5'.7 minutes

3. Plotting sheet

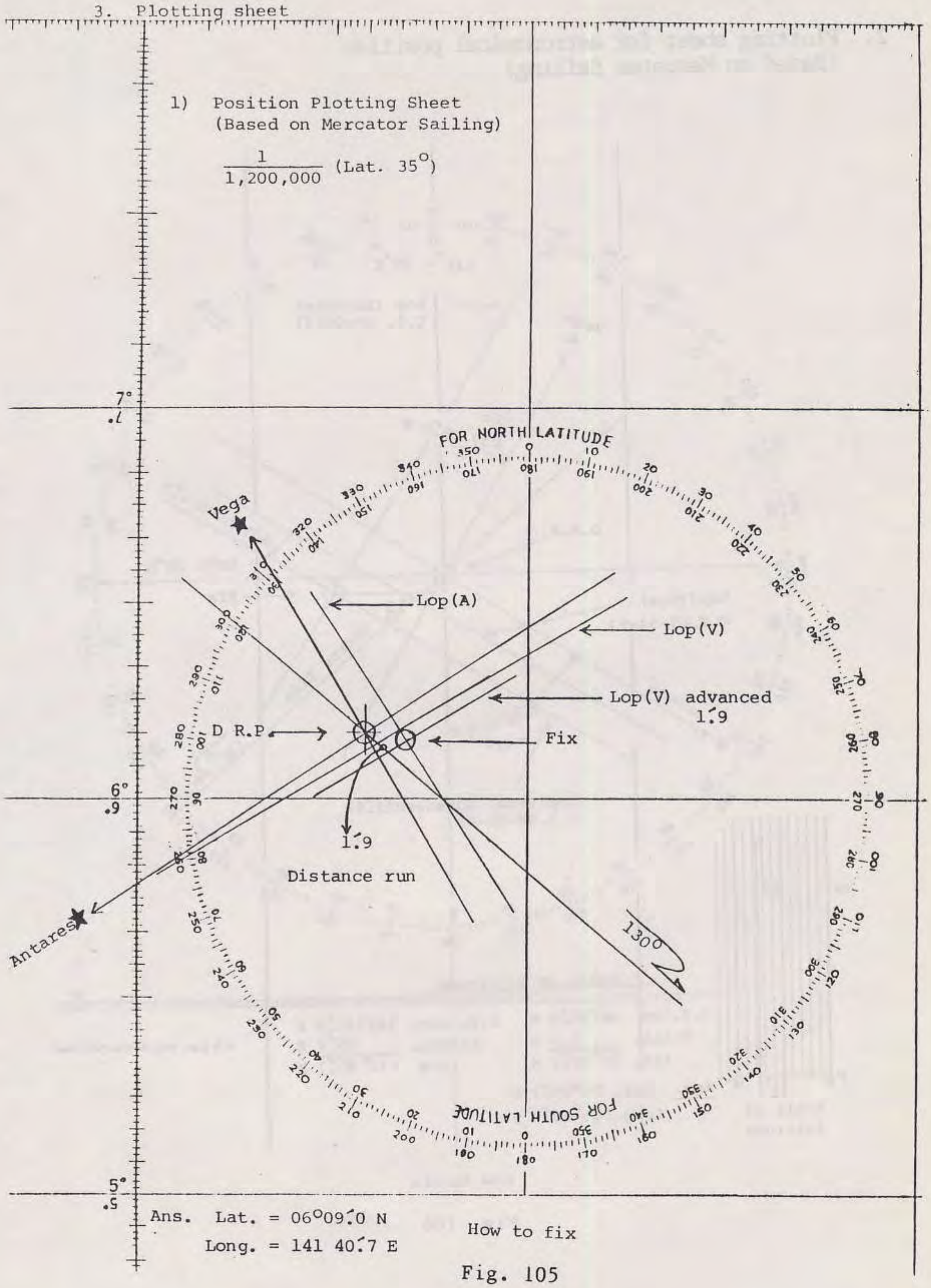
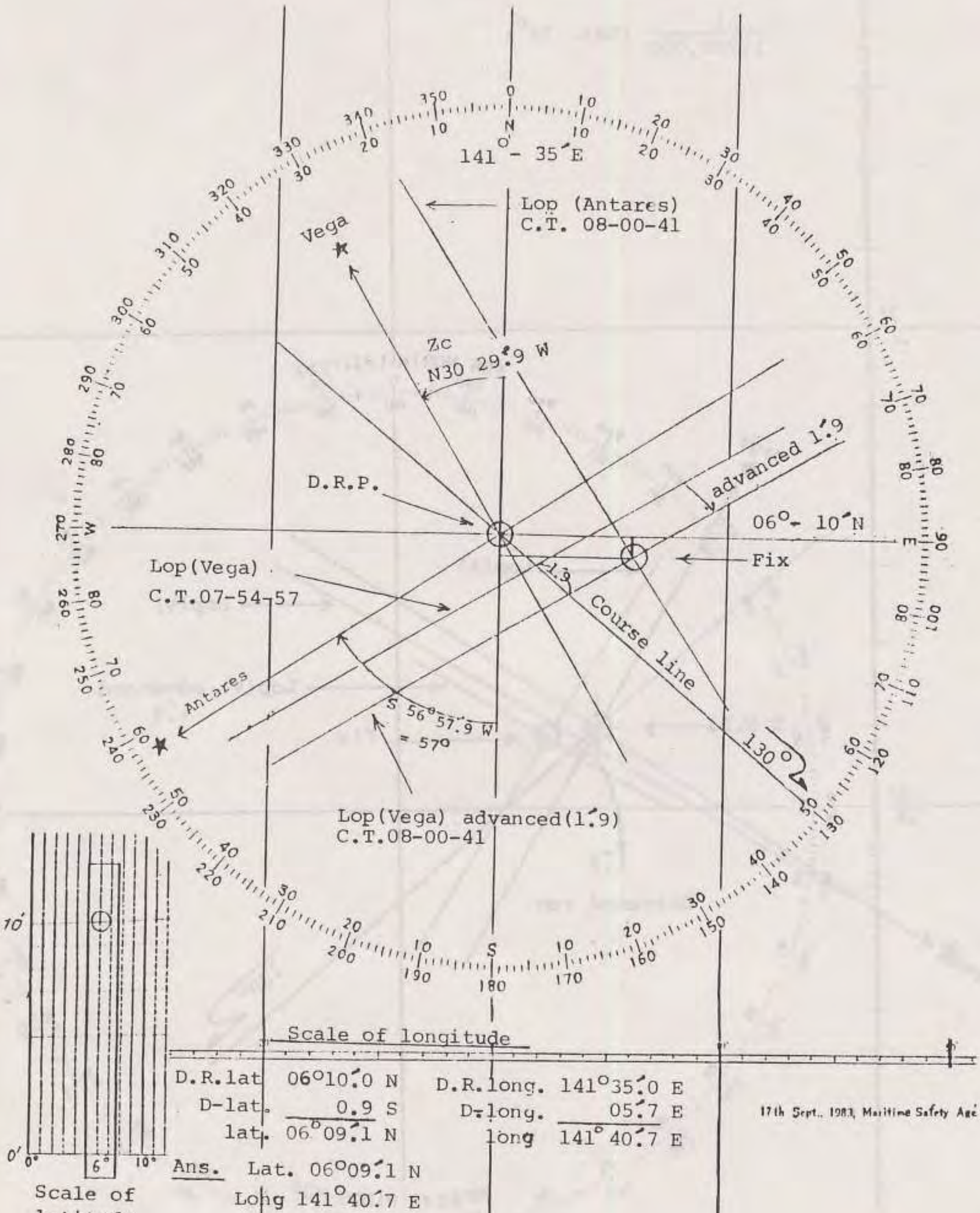


Fig. 105

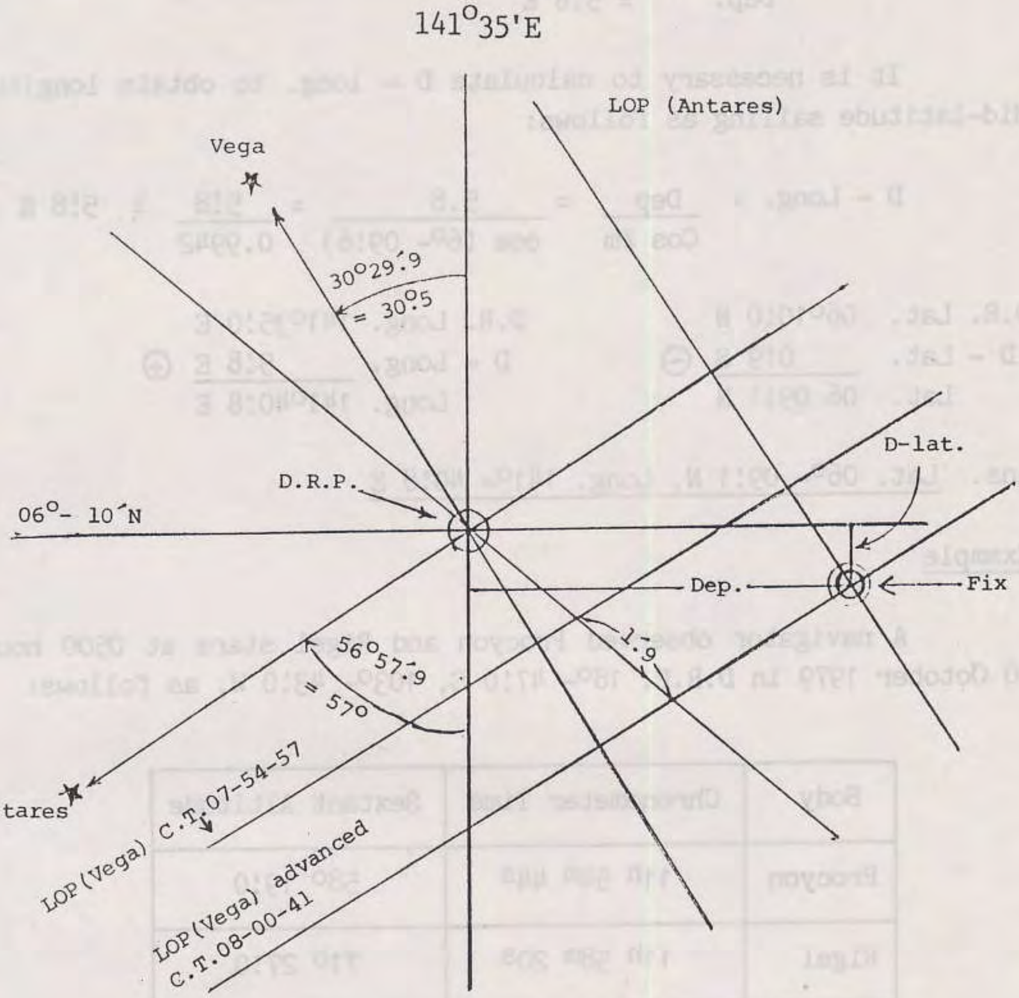
2. Plotting sheet for astronomical position (Based on Mercator Sailing)



How to fix

Fig. 106

3. On note book (Based on Mid-latitude sailing)



By triangle ruler (This sheet is not based on Mercator Sailing)
→ D-long. = $\frac{\text{Dep.}}{\text{Cos.}\ell m}$

How to fix

Fig. 107

D - Lat. = 0'.9 S
Dep. = 5'.8 E

It is necessary to calculate D - long. to obtain longitude by Mid-latitude sailing as follows:

$$\text{D - Long.} = \frac{\text{Dep}}{\text{Cos } \ell m} = \frac{5.8}{\cos (6^{\circ}\text{- } 09'.6)} = \frac{5'.8}{0.9942} \doteqdot 5'.8 \text{ E}$$

D.R. Lat.	06°10'.0 N		D.R. Long.	141°35'.0 E
D - Lat.	0'.9 S ⊖		D - Long.	5'.8 E ⊕
Lat.	06 09'.1 N		Long.	141°40'.8 E

Ans. Lat. 06°- 09'.1 N, Long. 141°- 40'.8 E

Example

A navigator observed Procyon and Rigel stars at 0500 hours on 10 October 1979 in D.R.P. 18°- 47'.0 S, 103°- 43'.0 W, as follows:

Body	Chronometer Time	Sextant Altitude
Procyon	$11^h\ 54^m\ 44^s$	58° 19'.0
Rigel	$11^h\ 58^m\ 20^s$	71° 27'.0

Plot lines of position, fix the latest position in your note book and show the current set and current drift.

where; Ship's speed was 22 knots, true course 297°, chronometer error ⊕ 4^s, index error ⊖ 1.5, height of eye 21 metres.

Procyon	$E_*(U = 0^h) = 17^h\ 33^m\ 47^s$	P.P. = $1^m\ 57^s.5$	d = 5°16'.6 N
Rigel	$E_*(U = 0^h) = 19^h\ 58^m\ 27^s$	P.P. = $1^m\ 58^s$	d = 8°13'.4 S

Solution 1) Calculation for lines of position

Line of Position of a Celestial Body

Body's name	Procyon	Date	Month	Year	Z.T.	+ / -	h
		10	Oct.	1979			

D.R.P.	18° 47'	N (S)	130° 43'	E (W)	True Co.	297°	sp'd	22 kt.

		Date	Month	h	m	s	
	Ship's Time	10	10	05	00	00	
※1	L. in T.			06	54	52	(+)
	Approx. U. (Date 10/10)			11	54	52	
	Chro. T.			11	54	44	
	Chro. E.					4	(+) / −
	Corrected chro.T.			11	54	48	
	Morning or Afternoon			(12)			+
	U. (Date 10/10)			11	54	48	
	E⊙＊☾P (d = 5° 16!6 N/S)			17	33	47	
	P.P				1	57.5	+
				29	30	32.5	
				(24)			− ⊙
	h_G in hours			05	30	32.5	
	h_G in degrees	⊕360°		82°		38.1	⊙
※2	Long.			103		43.0	+ / (−)
		⊖360°					⊙
							−
	h			338		55.1	

	Sex. Alt.	58°	19!0	
	I.E.		1.5	+ / (−)
	Obs. Alt	58	17.5	
	Corr. 1		8.7	+ / (−)
		58	08.8	
	Corr. 2			+ / −
	Corr. 3			+ / −
	a_t	58	08.8	
	a_c	58	12.9	−
	I		04.1	+ / (−)

	h	338° 55!1		→	A_1	147540	→	Z_1	44406	
	d	5 16.6	(N) S	→	A_2	185	=	Z_2	185	+
	ℓ	18 47.0	N (S)	→	A_3	2377	+		44591	
					A_4	150102				
					↓					
					A_5	3155				
※3	ℓ±d	24°03!6			A_6	4344	+			
					A_7	7499	→	Z_3	27841	−
					↓			Z_4	16750	
					a_C	58° 12!9		↓ Z_C	(N) S 42° 50!6 W (E)	※4

Ref.

1. Approx. U = Ship's Time + L.in T. (E - long →(−) , W - long. →(+))
2. $h = h_G + L$ (E - long →(+) , W - long →(−))
3. When ℓ and d same name → ℓ~d, contrary → ℓ + d
4. When h > 180° suffix of Z_c → E, h < 180° suffix of Z_c → W

Fig. 108 Calculation Sheet

Line of Position of a Celestial Body

Body's name	Rigel	Day	Month	Year	Z.T.	+/−	h
		10	Oct.	1979		−	/

D.R.P.	18° 47'	N / (S)	130° 43'	E / (W)	True Co.	297°	sp'd	22.0 kt.

	Ship's Time	Date 10	Month 10	h	m	s		
※1	L. in T.						±	
	Approx. U. (Date 10/10)							
				h	m	s		
	Chro. T.			11	58	20		
	Chro. E.					4	(+) −	
	Corrected chro.T.			11	58	24		
	Morning or Afternoon			(12)			+	
	U. (Date 10/10)			11	58	24		
	E⊙✱☾P (d = 8°13'.4 (N))			19	58	27		
	P.P				1	58	+	
				31	58	49		
				(24)			−	⊙
	h_G in hours			07	58	49		
	h_G in degrees		⊕360°	119°		42'.3		⊙
※2	Long.			103		43.0	+ (−)	
			⊖360°	15		59.3		⊙
							−	
	h			15		59.3		

Sex. Alt.	71	27.0	
I.E.		1.5	+ (−)
Obs. Alt	71	25.5	
Corr. 1		8.5	+ (−)
	71	17.0	
Corr. 2		—	±
		—	
Corr. 3		—	±
a_t	71	17.0	
a_c	71	13.6	−
I		3.4	(+) −

	h	15° 59'.3		→	A_1	171352		→	Z_1	55997	
	d	8 13.4	N (S)	→	A_2	449		=	Z_2	449	+
	ℓ	18 47.0	N (S)	→	A_3	2377	+			56446	
					A_4	174178					
					↓						
					A_5	1813					
※3	ℓ±d				A_6	846.8	+				
					A_7	2659.8		→	Z_3	49238	−
					↓				Z_4	7208	
					a_c	71° 13'.6			↓ Z_c	(N) S 57° 53'.6 E (W)	※4

Ref.

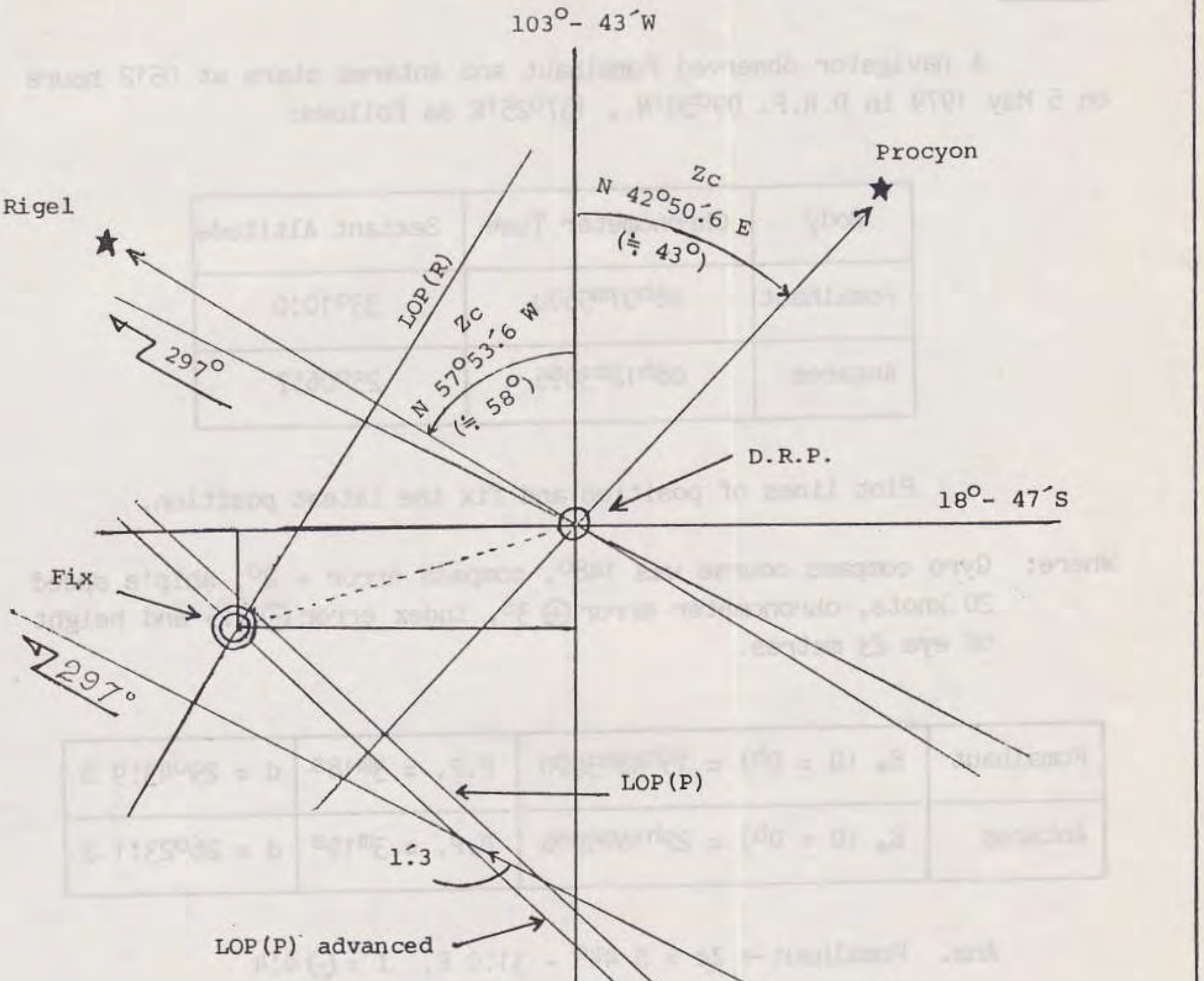
1. Approx. U = Ship's Time + L.in T. (E - long →(−), W - long. →(+))
2. $h = h_G + L$ (E - long →(+), W - long →(−))
3. When ℓ and d same name → ℓ~d, contrary → ℓ + d
4. When h > 180° suffix of Z_c → E, h < 180° suffix of Z_c → W

Fig. 109 Calculation Sheet

2) Running fix calculation

Distance run = $\frac{22' \times 3^m\!.6}{60^m}$ = 1'.32

3) Plotting sheet (note book)



D-lat. = 1'.4 S

Dep. = 4'.9 W → D-long. = $\frac{\text{Dep}}{\cos \ell}$ = $\frac{4'.9}{\cos(18°47')}$ = $\frac{4'.9}{0.94674}$ = 5'.2 W

D.R.lat.	18°-47'.0 S	D.R.long.	103°-43'.0 W
D-lat.	1'.4 S +	D-long.	5'.2 W +
Lat.	18° 48'.4 S	Long.	103° 48'.2 W

Ans. Lat 18°-48'.4 S, Long. 103°-48'.2 W

Current set = S 73°.5 W, Current drift = 5'.1

How to fix

Fig. 110

Problem

A navigator observed Fomalhaut and Antares stars at 0512 hours on 5 May 1979 in D.R.P. 09°50'N., 137°25'E as follows:

Body	Chronometer Time	Sextant Altitude
Fomalhaut	$08^h07^m56^s.0$	33°10'.0
Antares	$08^h12^m30^s.5$	25°06'.7

Plot lines of position and fix the latest position,

Where: Gyro compass course was 148°, compass error + 2°, ship's speed 20 knots, chronometer error ⊕ 3^s, index error ⊖ 2'.5 and height of eye 23 metres.

Fomalhaut	E_* (U = 0^h) = $15^h48^m39^s.0$	P.P. = 3^m18^s	d = 29°43'.9 S
Antares	E_* (U = 0^h) = $22^h16^m59^s.0$	P.P. = 3^m19^s	d = 26°23'.1 S

Ans. Fomalhaut → Zc = S 44° - 31'.0 E, I = ⊖ 4'.4
Antares Zc = S 54° - 40'.0 W, I = ⊖ 5'.5
Fix Lat. = 09° - 56'.5 N,
Long. = 137° - 27'.2 E

A navigator observed Rigel and Aldebaran stars at 0530 hours on 14 July 1979 in D.R.P. 12°- 25'.0 S., 163°- 09'.0 E as follows:

Body	Chronometer Time	Sextant Altitude
Rigel	$6^h54^m51^s.0$	30°44'.8
Aldebaran	$6^h59^m25^s.5$	33°19'.8

Plot lines of position and fix the latest position.

Where; Gyro compass course was 345°, compass error nil, ship's speed 18 knots, chronometer error ⊕ 3^s, index error ⊕ 1'.0 and height of eye 20 metres.

Rigel	E_* (U = 0^h) = $14^h07^m36^s.0$	P.P. = $3^m06^s.5$	d = 8°13'.5 S
Aldebaran	E_* (U = 0^h) = $14^h46^m24^s.0$	P.P. = $3^m07^s.5$	d = 16°28'.0 N

Ans. Rigel → Zc = S 87°42'E, I = + 6'.4
Aldebaran → Zc = N 60°40'E, I = + 5'.7
Fix Lat. = 12°24'.0 S
Long. = 163°15'.2 E

A navigator observed Procyon and Aldebaran stars at 1935 hours on 25 February 1979 in D.R.P. 39°54'.0 S., 79°55'.0 E as follows;

Body	Chronometer Time	Sextant Altitude
Procyon	$02^h21^m45^s$	39°34'.0
Aldebaran	$02^h25^m15^s$	29°55'.0

Plot lines of position and fix the latest position

Where; Gyro compass course was 159°, compass error nil, ship's speed 21 knots, chronometer error ⊖ $2^s.0$, index error ⊕ 2'.0 and height of eye 20 metres.

Procyon	E_* (U = 0^h) = $02^h38^m49^s$	P.P. = $2^m21^s.0$	d = 5°16'.5 N
Aldebaran	E_* (U = 0^h) = $05^h42^m20^s$	P.P. = $2^m22^s.0$	d = 16°27'.9 N

Ans. Procyon → Zc = N 32°12:0 E, I = ⊖ 6:8
Aldebaran → Zc = N 24°56:0 W, I = ⊖ 6:4
Fix Lat. = 39°46:1 N,
Long. = 79°52:8 E,

A navigator observed Bega and Antares stars at 18.50 hours on 10 August in E.R.R. 05°04:0 N., 75°13:0 E as follows:

Body	Chronometer Time	Sextant Altitude
Vega	$01^h46^m59^s$	41°44:0
Antares	$01^h50^m11^s$	58°08:0

Plot lines of position and fix the latest position.

Where: True course was 230°, ship's speed 18 knots, chronometer error ⊕ 3^s, index error ⊖ 1.5 and height of eye 18 metres.

Vega	E* (U = 0^h) = 02^h-35^m-15^s	P.P. = 2^m-$15^s.5$	d = 38°-46:2 N
Antares	E* (U = 0^h) = 04 -43- 21	P.P. = 2 - 16	d = 26°-23:2 S

Ans. Vega → Zc = N 40°-31:0 E, I = ⊕ 7:3
Antares → Zc = S 09°-53:0 E, I = ⊖ 4:2
Fix Lat. = 05°-09:0 N,
Long. = 75°-17:0 E

A navigator observed Denebola and Procyon at 19.20 hours on 24 April 1979 in D.R.P. $34°42'.0$ N., $134°27'.0$ W as follows:

Body	Chronometer Time	Sextant Altitude
Denebola	$04^h20^m07^s$	$53°38'.0$
Procyon	$04^h23^m39^s$	$50°04'.5$

Plot lines of position and fix the latest position

Where; True course was $305°$, ship's speed 20 knots, chronometer error ⊖ 3^s, index error ⊕ 1.5 and height of eye 20 metres.

Denebola	$E_* (U = 0^h) = 02^h21^m39^s$	P.P. = 0^m43^s	d = $14°41'.2$ N
Procyon	$E_* (U = 0^h) = 06^h31^m27^s$	P.P. = 0^m43^s	d = $05°16'.5$ N

Ans. Denebola Zc = S 65°.2 E, I = ⊖ 5'.2
Procyon Zc = S 49°6 W, I = ⊕ 3'.2
Fix Lat. = $34° - 43'.9$ N
Long. = $134° - 34'.1$ E

A navigation observed Procyon and Rigel stars of 0530 hours on 10 October 1979 in D.R.P. 18°47'.0 S, 103°43'.0 W as follows:

Body	Chronometer Time	Sextant Altitude
Procyon	$11^h54^m14^s$	58°19'.0
Rigel	$11^h58^m20^s$	71°27'.0

Plot lines of position and fix the latest position

Where: True course was 297°, ship's speed 22 knots, Chronometer error ⊕ 4s.0, index error ⊖ 1'.5 and height of eye 21 metres.

Procyon	E_* (U = 0^h) = $17^h33^m47^s$	P.P. = $1^m57^s.5$	d = 05°16'.6 N
Rigel	E_* (U = 0^h) = $19^h58^m27^s$	P.P. = 1^m58^s	d = 08°13'.4 S

Ans. Procyon → Zc = N 42°50'.5 E, I = ⊖ 4'.0
Rigel → Zc = N 57°54'.6 W, I = ⊕ 3'.1
Lat. = 18°48'.5 S
Long. = 103°48'.0 W

Example 17

On 10 September 1963, a navigator observed the altitude of the sun's lower limb as 23°02'.0 at ship's time 0730 hours, chronometer time $10^h31^m24^s$ in D.R.P. 19°56' N, 128°24' E and he sailed 30 nautical miles to S 18°W from this D.R.P., and observed the altitude of the sun's lower limb again as 69°58 at ship's time 1100, chronometer time $02^h04^m02^s$.

Plot the position at ship's time 1100 on the PLOTTING SHEET for ASTRONOMICAL POSITION.

Where: Chronometer error was + 23^m10^s, local variation 4°W, deviation 4°W, index error + 1.0, height of eye 16 metres.

1) E⊙ = $12^h02^m39^s$ (at U = $22^h54^m34^s$, Sept. 9th)
d for U = 22^h = 05°20:0 N
P.P. of d for 54^m34^s = 0.9 ⊖

2) E⊙ = $12^h02^m41^s$ (at U = $02^h27^m12^s$, Sept, 10th)
d for U = 02^h = 05°16:2 N
P.P. of d for 27^m12^s = 0:4 ⊖

Solution

1 To obtain true course

Comp. Co.	S 180°W
Deviation	4°W ⊖
Mag. Co	S 14°W
Variation	4°W ⊖
True Co.	S 10°W

2 To calculate at, ac and Zc of 1st observation (see Fig. 111)

Line of Position of a Celestial Body

Body's name	Sun ☉	Day	Month	Year	Z.T.	+ / −	h
		10	Sept.	1963		−	—

1st. D.R.P.	19° 56′	Ⓝ S	128° 24′	Ⓔ W	~~True~~ Comp. Co.	S 18° W	sp'd	30/3.5 kt.

	Date	Month	h	m	s	
Ship's Time	10	9	07	30	00	
*1 L. in T.			08	33	36	± (−)
Approx. U. (Date 9/9)			22	56	24	
Chro. T.			10	31	24	
Chro. E.				23	10	⊕ −
Corrected chro.T.			10	54	34	
Morning or Afternoon			(12)			⊕
U. (Date 9/9)			22	54	34	
E☉✱☾P (d = ° ′ N/S)			12	02	39	
P.P				—		+
			34	57	13	
			(24)			⊖ ☉
h_G in hours			10	57	13	
h_G in degrees	⊕360°		164°		18!3	☉
*2 Long.			128		24.0	⊕
	⊖360°			—		☉
				—		−
h			292		42.3	

	°	′	
Sex. Alt.	23	02.0	
I.E.		01.0	⊕ −
Obs. Alt	23	03.0	
Corr. 1		6.5	⊕ −
	23	09.5	
Corr. 2		0.2	⊕ −
	23	09.7	
Corr. 3		—	+ −
a_t	23	09.7	
a_c	23	08.2	−
I		01.5	⊕ −

h	292°	42′.3	→	A_1	51286		→	Z_1	3504
d	05	19.1 Ⓝ S	→	A_2	187		=	Z_2	187
ℓ	19	56.0 Ⓝ S	→	A_3	2683	+			3691
				A_4	54156				
				↓					
				A_5	28736				
*3 ℓ ± d	14°	36!9		A_6	1618	+			
				A_7	30354		→	Z_3	3641 −
				↓				Z_4	50
				a_c	23° 08′.2			↓ Z_c	N/Ⓢ 87° 15′ Ⓔ/W *4

Ref.

1. Approx. U = Ship's Time + L.in T. (E - long →⊖, W - long. →⊕)
2. $h = h_G + L$ (E - long →⊕, W - long →⊖)
3. When ℓ and d same name → ℓ~d, contrary → ℓ + d
4. When h > 180° suffix of Z_c → E, h < 180° suffix of Z_c → W

Fig. 111

3 To obtain 2nd D.R.P. for second observation

2nd D.R.P. is the point which is 30 nautical miles away and direction is S 10°W from the extremity of intercetp of the first observation (see Fig. 112).

By plotting course line S 10°W and distance 30 nautical miles from the extremity of intercept of the first observation, 2nd D.R.P. is $19^{\circ}26'.4$ N, $128^{\circ}20'.1$ E on the plotting sheet (see Fig. 112).

4 To calculate at ac and Zc of 2nd observation (see Fig. 114).

5 Plotting LOP and fix (see Fig. 112).

Plotting Sheet for Astronomical Position

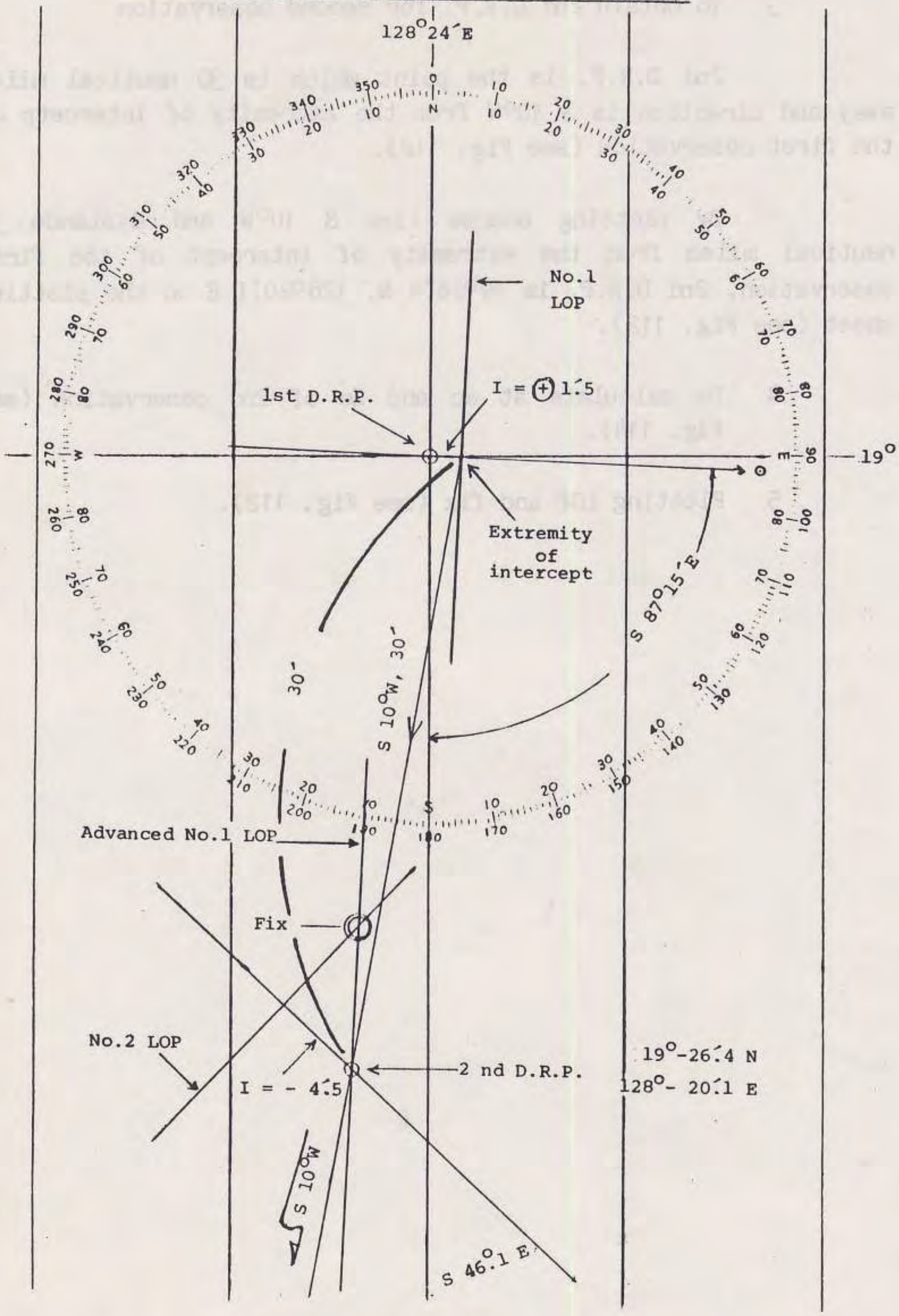


Fig. 112 How to fix

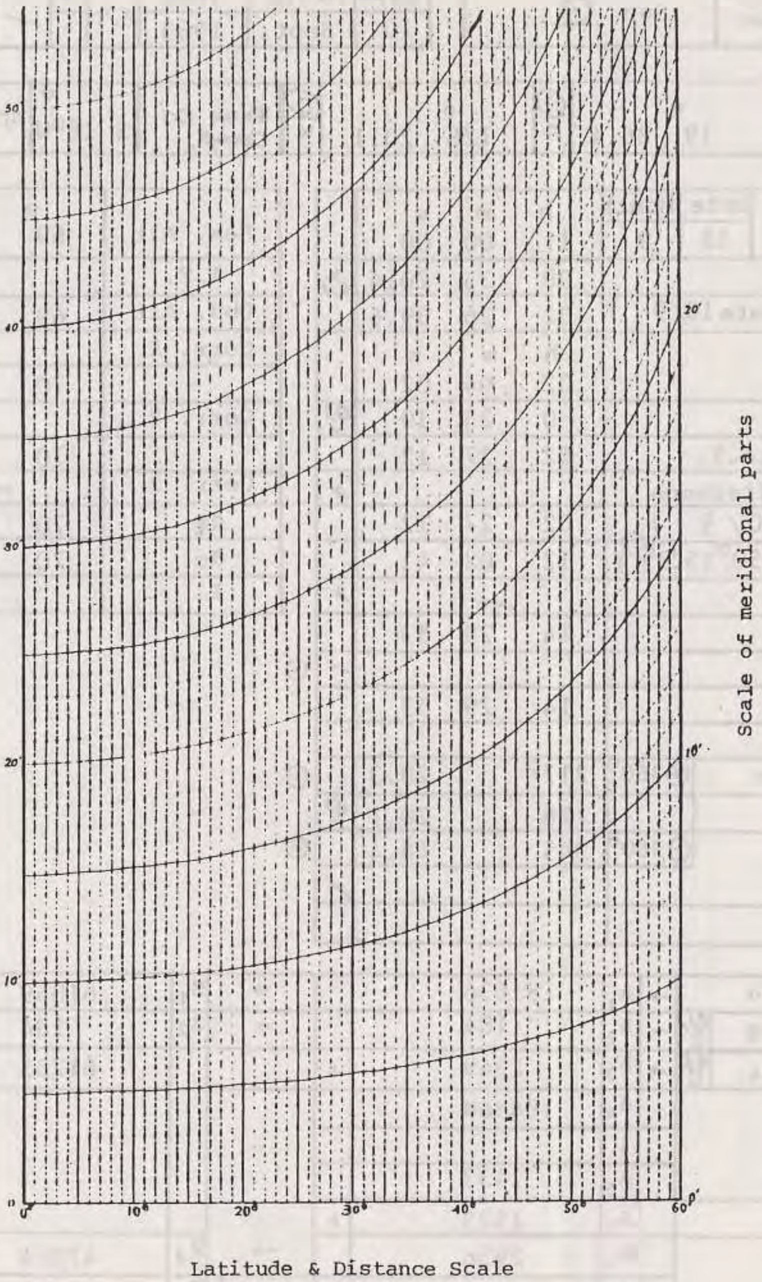

50'
40'
30'
20'
10'
0
0°
10°
20°
30°
40°
50°
60°
20'
10'
0'
Scale of meridional parts
Latitude & Distance Scale

Fig. 113

Line of Position of a Celestial Body

Body's name	Sun ⊙	Date	Month	Year	Z.T.	+ / −	h
		10	Sept.	1963		−	—

D.R.P.	19° 26.4'	(N) S	128° 20.1'	(E) W	~~True~~ Co. Comp.	S 18° W	sp'd	30/35 kt.

	Ship's Time	Date 10	Month 9	h 11	m 00	s 00		
*1	L. in T.			08	33	20.4	+/− (−)	
	Approx. U. (Date 10/9)			02	26	39.6		
	Chro. T.			h 02	m 04	s 02		
	Chro. E.			0	23	10	(+)/−	
	Corrected chro.T.			02	27	12		
	Morning or Afternoon						+	
	U. (Date 10 / 9)			02	27	12		
	E⊙✱☾P (d = 50°15'.8 (N) S)			12	02	41		
	P.P			—			+	
				14	29	53		
							—	⊙
	h_G in hours			14	29	53		
*2	h_G in degrees		⊕360°	217°		28.3		⊙
	Long.			128		20.1	(+)/−	
			⊖360°	345		48.4		⊙
							/	
	h							

Sex. Alt.	69°	58.0'	
I.E.		1.0	(+)/−
Obs. Alt	69	59.0	
Corr. 1		8.3	(+)/−
	70	07.3	
Corr. 2		0.2	(+)/−
	70	07.5	
Corr. 3		—	+/−
a_t	70	07.5	
a_c	70	12.0	−
I		04.5	+/(−)

h	345°	48'.4		→	A_1	181636		→	Z_1	61049	
d	05	15.8	(N) S	→	A_2	184		=	Z_2	184	+
ℓ	19	26.4	(N) S	→	A_3	2549	+			61233	
					A_4	184369					
					↓						
					A_5	1433					
*3	ℓ±d				A_6	1523	+				
					A_7	2956		→	Z_3	47014	−
					↓				Z_4	14219	
					a_c	70° 12.0'			↓ Z_c	N (S) 46° 07.2' (E) W	*4

Ref.

1. Approx. U = Ship's Time + L.in T. (E - long → ⊖ , W - long. → ⊕)
2. $h = h_G + L$ (E - long → ⊕ , W - long → ⊖)
3. When ℓ and d same name → ℓ~d, contrary → ℓ + d
4. When h > 180° suffix of Z_c → E, h < 180° suffix of Z_c → W

Fig. 114 Calculation Sheet

6 According to plotting sheet,

D - Lat.	= 22!8 S	D - Long.	= 3!5 W
Lat.	19°56!0 N	Long.	128°24!0 E
D - Lat.	22!8 S	D - Long.	03!5 W ⊖
	19°33!2 N		128°20!5 E

Ans. 19°33!2 N, 128°20!5 E

- REVIEW -

Amplitude

Example :

On 5 August 1956, a navigator observed the sun's bearing by amplitude with magnetic compass in D.R.P. 32°20'N, 129°48'E.

What was the deviation of this compass? (Variation was 5°2 W here)

Solution 1

1 To obtain h

↓

d (5/81956) U = 0^h

d = 17°02!8 N (by nautical almanac (5/8) → h = 06^h45^m

1 = 32°20!0 N

by the table of "Rising and setting Hour angle" (true Alt. = 0°)

2 To obtain G.A.T.

	$12^h00^m00^s$
h	06 45 00 ⊖
L.A.T.	5 15 00
L. in T.	08 39 12 ⊖
G.A.T. (4/8)	$20^h35^m48^s$

↓

d = 17°05.'1 N (by nautical almanac 4/8 → Rising azimuth (true Lat. = 0°) = E 20°3 N

l = 32°20.'0 N

True amplitude = E 20°3 N
= N 69°7 E → (90°-20°3 = 69°7)

Compass bearing = N 88°5 E ⊖

(by the table of "Rising and Setting Azimuth" (true Alt. = 0°)

Compass error	=	18°8 W
Variation	=	5°2 W -
Deviation	=	13°6 W

Ans. Deviation was 13°6 W

5 August 1956
Nautical Almanac

Moon Age 27.8 d

☉ Sun

U	$E_\odot$	d	P.P. of d	
h	h m s	° ′	h m	′
0	11 54 4	N17 2.8	0 0	0.0
2	5	1.5	10	1
4	5	17 0.1	20	2
6	6	16 58.8	30	4
8	6	57.4	40	5
10	7	56.1	0 50	6
12	11 54 7	N16 54.7	1 0	0.7
14	8	53.8	10	8
16	8	52.0	20	0.9
18	9	50.6	30	1.1
20	9	49.2	40	2
22	10	47.9	1 50	3
24	11 54 10	N16 46.5	2 0	1.4

S.D. 15′ 49″

✳ Star ($U = 0^h$)

No.	Star	E_* (h m s)	d (° ′)
1	Polaris	19 0 4	N89 3.4
2	Kochab	6 3 17	74 20.3
3	Dubhe	9 53 2	61 59.2
4	β Cassiop.	20 47 11	58 54.6
5	Menk	9 54 52	56 37.0
6	Alioth	8 1 58	N56 11.9
7	Schedir	20 16 0	56 17.9
8	Mizar	7 31 54	55 3.3
9	α Persei	17 32 54	49 42.3
10	Benetnasch	7 8 15	49 32.0
11	Capella	15 40 35	N45 57.2
12	Deneb	0 14 5	45 7.7
13	Vega	2 18 34	38 44.8
14	Castor	13 22 15	31 59.1
15	Alpheratz	20 47 54	28 51.1
16	Pollux	13 11 25	N28 7.9
17	α Cor. Bor.	5 21 13	26 51.8
18	Arcturus	6 40 23	19 24.6
19	Aldebaran	16 20 38	16 25.4
20	Markab	21 51 27	14 58.4
21	Denebola	9 7 14	N14 48.9
22	α Ophiuchi	3 21 8	12 35.6
23	Regulus	10 48 1	12 10.8
24	Altair	1 5 22	8 45.4
25	Betelgeuse	15 1 15	7 24.0
26	Bellatrix	15 31 16	N 6 18.7
27	Procyon	13 17 3	N 5 20.2
28	Rigel	15 41 37	S 8 14.9
29	α Hydrae	11 28 38	8 28.2
30	Spica	7 31 10	10 56.2
31	Sirius	14 10 51	S16 39.3
32	β Ceti	20 12 38	18 13.2
33	Antares	4 27 18	26 20.3
34	σ Sagittarii	2 1 28	26 21.0
35	Fomalhaut	21 58 47	29 50.9
36	λ Scorpii	3 23 23	S37 4.5
37	Canopus	14 31 7	52 40.2
38	α Pavonis	0 31 47	56 52.4
39	Achernar	19 17 58	57 27.0
40	β Crucis	8 8 54	59 27.4
41	β Centauri	6 53 19	S60 10.2
42	α Centauri	6 17 25	60 39.8
43	α Crucis	8 29 54	62 51.8
44	α Tri. Aust.	4 9 57	68 57.3
45	β Carinae	11 41 23	S69 32.4

R_0 20h 54m 4s

Planet

♀ Venus — Tr. 9h 7m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	14 52 30	N18 32.3	0 0	0	0.0
2	37	32.6	10	1	0
4	43	32.9	20	1	1
6	49	33.2	30	2	1
8	52 55	33.5	40	2	1
10	53 2	33.7	0 50	3	1
12	14 53 8	N18 34.0	1 0	3	0.2
14	14	34.3	10	4	2
16	20	34.6	20	4	2
18	26	34.8	30	5	2
20	32	35.1	40	5	3
22	38	35.4	1 50	6	3
24	14 53 44	N18 35.7	2 0	6	0.3

♂ Mars — Tr. 2h 50m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	21 9 6	S 7 49.9	0 0	0	0.0
2	24	50.0	10	2	0
4	9 42	50.0	20	3	0
6	10 0	50.1	30	5	0
8	18	50.1	40	6	0
10	36	50.2	0 50	8	0
12	21 10 54	S 7 50.2	1 0	9	0.1
14	11 12	50.3	10	11	1
16	30	50.3	20	12	1
18	11 48	50.4	30	14	1
20	12 6	50.4	40	15	1
22	24	50.5	1 50	17	1
24	21 12 43	S 7 50.6	2 0	18	0.1

♃ Jupiter — Tr. 13h 35m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	10 23 16	N10 22.9	0 0	0	0.0
2	32	22.5	10	1	0
4	23 48	22.1	20	3	1
6	24 4	21.7	30	4	1
8	20	21.4	40	5	1
10	35	21.0	0 50	7	2
12	10 24 51	N10 20.6	1 0	8	0.2
14	25 7	20.2	10	9	2
16	23	19.8	20	11	3
18	38	19.4	30	12	3
20	25 54	19.1	40	13	3
22	26 10	18.7	1 50	15	4
24	10 26 26	N10 18.3	2 0	16	0.4

♄ Saturn — Tr. 18h 40m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	5 16 37	S17 21.5	0 0	0	0.0
2	16 57	21.3	10	2	0
4	17 16	21.3	20	3	0
6	36	21.4	30	5	0
8	17 56	21.4	40	7	0
10	18 15	21.4	0 50	8	0
12	5 18 35	S17 21.5	1 0	10	0.0
14	18 54	21.5	10	12	0
16	19 14	21.5	20	13	0
18	33	21.6	30	15	0
20	19 53	21.6	40	17	0
22	20 12	21.6	1 50	18	0
24	5 20 32	S17 21.7	2 0	20	0.0

☾ Moon — Tr. 11h 3m

U	$E_☾$	d
h	h m s	° ′
0	13 23 33	N18 9.3
	22 21	5.2
1	21 8	18 1.1
	19 55	17 57.0
2	18 42	52.8
	17 29	48.6
3	16 17	44.4
	15 4	40.1
4	13 52	35.8
	12 39	31.5
5	11 27	27.1
	10 14	22.7
(H.P. 61′.2, S.D. 16′ 40″)		
6	13 9 2	N17 18.3
	7 49	13.8
7	6 37	9.4
	5 25	4.8
8	4 13	17 0.3
	3 1	16 55.7
9	1 49	51.1
	13 0 37	46.5
10	12 59 25	41.8
	58 13	37.1
11	57 1	32.3
	55 49	27.6
(H.P. 61′.2, S.D. 16′ 41″)		
12	12 54 37	N16 22.8
	53 26	18.0
13	52 14	13.1
	51 2	8.2
14	49 51	16 3.3
	48 39	15 58.4
15	47 28	53.4
	46 17	48.5
16	45 5	43.4
	43 54	38.4
17	42 43	33.3
	41 32	28.2
(H.P. 61′.3, S.D. 16′ 42″)		
18	12 40 21	N15 23.1
	39 10	17.9
19	37 59	12.7
	36 48	7.5
20	35 37	15 2.3
	34 26	14 57.0
21	33 16	51.7
	32 5	46.4
22	30 54	41.1
	29 44	35.7
23	28 33	30.3
	27 23	24.9
24	12 26 13	N14 19.5
(H.P. 61′.3, S.D. 16′ 42″)		

P.P (Moon)

m	$E_☾$ (s)	d (′)
1	2	0.1
2	5	3
3	7	4
4	10	6
5	12	7
6	14	0.9
7	17	1.0
8	19	2
9	22	3
10	24	5
11	26	6
12	29	8
13	31	1.9
14	34	2.1
15	36	2
16	38	3
17	41	5
18	43	6
19	46	8
20	48	2.9
21	50	3.1
22	53	2
23	55	4
24	58	5
25	60	7
26	62	3.8
27	65	4.0
28	67	1
29	70	3
30	72	4.4

m	$E_☾$ (s)	d (′)
1	2	0.2
2	5	3
3	7	5
4	9	7
5	12	0.9
6	14	1.0
7	17	2
8	19	4
9	21	5
10	24	7
11	26	1.9
12	28	2.0
13	31	2
14	33	4
15	36	6
16	38	7
17	40	2.9
18	43	3.1
19	45	2
20	47	4
21	50	6
22	52	7
23	54	3.9
24	57	4.1
25	59	3
26	62	4
27	64	6
28	66	8
29	69	4.9
30	71	5.1

Planet

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	6 2	N18 32	−4.2	0.3	17
♂	23 45	S 7 50	−1.9	0.3	10
♃	10 31	N10 23	−1.3	0.0	15
♄	15 37	S17 21	+0.7	0.0	8
☿	10 5	N13 11	−0.4	0.1	3

Fig. 115

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

4 August 1956
Nautical Almanac

Moon Age 26.8 d

☉ Sun

U	$E_☉$	d	P.P. of d
h	h m s	° ′	h m ′
0	11 53 59	N17 18.9	0 0 0.0
2	53 59	17.5	10 1
4	54 0	16.2	20 2
6	0	14.9	30 3
8	0	13.5	40 4
10	1	12.2	0 50 5
12	11 54 1	N17 10.9	1 0 0.7
14	2	9.5	10 8
16	2	8.2	20 0.9
18	3	6.9	30 1.0
20	3	5.5	40 1
22	4	4.2	1 50 2
24	11 54 4	N17 2.8	2 0 1.3

S.D. 15′ 48″

✱ Star ($U = 0^h$)

No.	Star	E_*	d
		h m s	° ′
1	Polaris	18 56 9	N89 3.4
2	Kochab	5 59 20	74 20.3
3	Dubhe	9 49 6	61 59.2
4	β Cassiop.	20 43 14	58 54.6
5	Merak	9 50 55	56 37.0
6	Alioth	7 58 1	N56 11.9
7	Schedir	20 12 4	56 17.9
8	Mizar	7 27 57	55 9.3
9	α Persei	17 28 54	49 42.3
10	Benetnasch	7 4 18	49 32.0
11	Capella	15 36 39	N45 57.2
12	Deneb	0 10 8	45 7.6
13	Vega	2 14 38	38 44.8
14	Castor	13 18 18	31 59.1
15	Alpheratz	20 43 58	28 51.1
16	Pollux	13 7 29	N28 7.9
17	α Cor. Bor.	5 17 16	26 51.8
18	Arcturus	6 36 26	19 24.6
19	Aldebaran	16 16 42	16 25.4
20	Markab	21 47 30	14 58.4
21	Denebola	9 3 17	N14 48.9
22	α Ophiuchi	3 17 11	12 35.6
23	Regulus	10 44 4	12 10.8
24	Altair	1 1 26	8 45.4
25	Betelgeuse	14 57 19	7 24.0
26	Bellatrix	15 27 20	N 6 18.7
27	Procyon	13 13 6	N 5 20.2
28	Rigel	15 37 41	S 8 14.9
29	α Hydrae	11 24 41	8 28.2
30	Spica	7 27 13	10 56.2
31	Sirius	14 6 54	S16 39.3
32	β Ceti	20 8 42	18 13.2
33	Antares	4 23 22	26 20.3
34	σ Sagittarii	1 57 31	26 21.0
35	Fomalhaut	21 54 50	29 50.9
36	λ Scorpii	3 19 26	S37 4.5
37	Canopus	14 27 10	52 40.2
38	α Pavonis	0 27 51	56 52.4
39	Achernar	19 14 1	57 27.0
40	β Crucis	8 4 57	59 27.4
41	β Centauri	6 43 22	S60 10.2
42	α Centauri	6 13 28	60 39.8
43	α Crucis	8 25 57	62 51.8
44	α Tri. Aust.	4 6 1	68 57.3
45	β Carinae	11 37 27	S69 32.4

R_0 20h 50m 8s

Planet

♀ Venus (Tr. 9h 8m)

U	E_P	d	P.P. E_P d
h	h m s	° ′	h m s ′
0	14 51 12	N18 29.0	0 0 0 0.0
2	19	29.2	10 1 0
4	25	29.5	20 1 1
6	32	29.8	30 2 1
8	39	30.1	40 2 1
10	45	30.4	0 50 3 1
12	14 51 52	N18 30.7	1 0 4 0.2
14	51 58	30.9	10 4 2
16	52 5	31.2	20 5 2
18	11	31.5	30 5 2
20	18	31.8	40 6 3
22	24	32.1	1 50 6 3
24	14 52 30	N18 32.3	2 0 7 0.3

♂ Mars (Tr. 2h 54m)

U	E_P	d	P.P. E_P d
h	h m s	° ′	h m s ′
0	21 5 32	S 7 49.6	0 0 0 0.0
2	5 50	49.6	10 2 0
4	6 7	49.7	20 3 0
6	25	49.7	30 5 0
8	6 43	49.7	40 6 0
10	7 1	49.7	0 50 8 0
12	21 7 18	S 7 49.7	1 0 9 0.0
14	36	49.8	10 11 0
16	7 54	49.8	20 12 0
18	8 12	49.8	30 14 0
20	30	49.9	40 15 0
22	8 48	49.9	1 50 17 0
24	21 9 6	S 7 49.9	2 0 18 0.0

♃ Jupiter (Tr. 13h 38m)

U	E_P	d	P.P. E_P d
h	h m s	° ′	h m s ′
0	10 20 7	N10 27.5	0 0 0 0.0
2	23	27.1	10 1 0
4	38	26.7	20 3 1
6	20 54	26.3	30 4 1
8	21 10	26.0	40 5 1
10	26	25.6	0 50 7 2
12	10 21 42	N10 25.2	1 0 8 0.2
14	21 57	24.8	10 9 2
16	22 13	24.4	20 11 3
18	29	24.0	30 12 3
20	22 45	23.7	40 13 3
22	23 1	23.3	1 50 15 4
24	10 23 16	N10 22.9	2 0 16 0.4

♄ Saturn (Tr. 18h 44m)

U	E_P	d	P.P. E_P d
h	h m s	° ′	h m s ′
0	5 12 42	S17 20.9	0 0 0 0.0
2	13 2	21.0	10 2 0
4	22	21.0	20 3 0
6	13 41	21.0	30 5 0
8	14 1	21.0	40 7 0
10	20	21.1	0 50 8 0
12	5 14 40	S17 21.1	1 0 10 0.0
14	15 0	21.1	10 12 0
16	19	21.2	20 13 0
18	39	21.2	30 15 0
20	15 58	21.2	40 17 0
22	16 18	21.3	1 50 18 0
24	5 16 37	S17 21.3	2 0 20 0.0

☾ Moon (Tr. 10h 2m)

U	$E_☾$	d
h	h m s	° ′
0	14 22 31	N20 42.9
	21 17	40.6
1	20 3	38.2
	18 49	35.8
2	17 35	33.4
	16 20	30.9
3	15 6	28.4
	13 52	25.8
4	12 38	23.2
	11 24	20.6
5	10 10	17.9
	8 56	15.2
(H.P. 60′.8, S.D. 16′ 34″)		
6	14 7 42	N20 12.5
	6 28	9.7
7	5 14	6.9
	4 0	4.0
8	2 46	20 1.1
	1 32	19 58.2
9	14 0 18	55.2
	13 59 4	52.2
10	57 50	49.1
	56 36	46.1
11	55 22	42.9
	54 8	39.8
(H.P. 60′.9, S.D. 16′ 36″)		
12	13 52 55	N19 36.6
	51 41	33.4
13	50 27	30.1
	49 13	26.8
14	48 0	23.5
	46 46	20.1
15	45 32	16.7
	44 19	13.2
16	43 5	9.7
	41 52	6.2
17	40 38	19 2.7
	39 25	18 59.1
(H.P. 61′.0, S.D. 16′ 38″)		
18	13 38 11	N18 55.5
	36 58	51.8
19	35 45	48.1
	34 31	44.4
20	33 18	40.6
	32 5	36.8
21	30 52	33.0
	29 39	29.1
22	28 25	25.2
	27 12	21.3
23	25 59	17.3
	24 46	13.3
24	13 23 33	N18 9.3
(H.P. 61′.1, S.D. 16′ 39″)		

P.P. ($E_☾$, d)

m	s	′
1	2	0.1
2	5	2
3	7	3
4	10	4
5	12	5
6	15	5
7	17	6
8	20	7
9	22	8
10	25	0.9
11	27	1.0
12	30	1
13	32	2
14	35	3
15	37	4
16	39	4
17	42	5
18	44	6
19	47	7
20	49	8
21	52	1.9
22	54	2.0
23	57	1
24	59	2
25	62	3
26	64	3
27	67	4
28	69	5
29	72	6
30	74	2.7

m	s	′
1	2	0.1
2	5	2
3	7	4
4	10	5
5	12	6
6	15	7
7	17	0.8
8	19	1.0
9	22	1
10	24	2
11	27	3
12	29	4
13	32	6
14	34	7
15	37	8
16	39	1.9
17	41	2.0
18	44	2
19	46	3
20	49	4
21	51	5
22	54	6
23	56	8
24	58	2.9
25	61	3.0
26	63	1
27	66	2
28	68	4
29	71	5
30	73	3.6

Planet

	R.A.	d	Mag.	H.P.	S.D.
	h m	° ′		′	″
♀	5 59	N18 29	−4.2	0.3	17
♂	23 45	S 7 50	−1.9	0.3	10
♃	10 30	N10 27	−1.3	0.0	15
♄	15 37	S17 21	+0.7	0.0	8
♅	9 58	N13 52	−0.5	0.1	3

Fig. 116

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN

RISING AND SETTING AZIMUTH (True Alt.=0°)

lat. *l*	Declination d 16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
0°	16.0°	17.0°	18.0°	19.0°	20.0°	21.0°	22.0°	23.0°	24.0°	25.0°	26.0°	27.0°	28.0°	29.0°	30.0°
2	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0
4	16.0	17.1	18.1	19.1	20.1	21.1	22.1	23.1	24.1	25.1	26.1	27.1	28.1	29.1	30.1
6	16.1	17.1	18.1	19.1	20.1	21.1	22.1	23.1	24.1	25.1	26.2	27.2	28.2	29.2	30.2
8	16.2	17.2	18.2	19.2	20.2	21.2	22.2	23.2	24.3	25.3	26.3	27.3	28.3	29.3	30.3
10	16.3	17.3	18.3	19.3	20.3	21.4	22.4	23.4	24.4	25.4	26.4	27.5	28.5	29.5	30.5
12	16.4	17.4	18.4	19.4	20.5	21.5	22.5	23.6	24.6	25.6	26.6	27.7	28.7	29.7	30.7
14	16.5	17.5	18.6	19.6	20.6	21.7	22.7	23.8	24.8	25.8	26.9	27.9	28.9	30.0	31.0
16	16.7	17.7	18.8	19.8	20.9	21.9	22.9	24.0	25.0	26.1	27.1	28.2	29.2	30.3	31.4
18	16.9	17.9	19.0	20.0	21.1	22.1	23.2	24.3	25.3	26.4	27.5	28.5	29.6	30.7	31.7
20	17.1	18.1	19.2	20.3	21.4	22.4	23.5	24.6	25.6	26.7	27.8	28.9	30.0	31.1	32.2
21	17.2	18.3	19.3	20.4	21.5	22.6	23.7	24.8	25.8	26.9	28.0	29.1	30.2	31.3	32.4
22	17.3	18.4	19.5	20.6	21.7	22.7	23.8	24.9	26.0	27.1	28.2	29.3	30.4	31.5	32.6
23	17.4	18.5	19.6	20.7	21.8	22.9	24.0	25.1	26.2	27.3	28.4	29.6	30.7	31.8	32.9
24	17.6	18.7	19.8	20.9	22.0	23.1	24.2	25.3	26.4	27.6	28.7	29.8	30.9	32.1	33.2
25	17.7	18.8	19.9	21.1	22.2	23.3	24.4	25.5	26.7	27.8	28.9	30.1	31.2	32.3	33.5
26	17.9	19.0	20.1	21.2	22.4	23.5	24.6	25.8	26.9	28.0	29.2	30.3	31.5	32.6	33.8
27	18.0	19.2	20.3	21.4	22.6	23.7	24.9	26.0	27.2	28.3	29.5	30.6	31.8	33.0	34.1
28	18.2	19.3	20.5	21.6	22.8	24.0	25.1	26.3	27.4	28.6	29.8	30.9	32.1	33.3	34.5
29	18.4	19.5	20.7	21.9	23.0	24.2	25.4	26.5	27.7	28.9	30.1	31.3	32.5	33.7	34.9
30	18.6	19.7	20.9	22.1	23.3	24.5	25.6	26.8	28.0	29.2	30.4	31.6	32.8	34.1	35.3
31	18.8	20.0	21.1	22.3	23.5	24.7	25.9	27.1	28.3	29.5	30.8	32.0	33.2	34.5	35.7
32	19.0	20.2	21.4	22.6	23.8	25.0	26.2	27.4	28.7	29.9	31.1	32.4	33.6	34.9	36.1
33	19.2	20.4	21.6	22.9	24.1	25.3	26.5	27.8	29.0	30.3	31.5	32.8	34.0	35.3	36.6
34	19.4	20.6	21.9	23.1	24.4	25.6	26.9	28.1	29.4	30.7	31.9	33.2	34.5	35.8	37.1
35	19.7	20.9	22.2	23.4	24.7	26.0	27.2	28.5	29.8	31.1	32.4	33.7	35.0	36.3	37.6
36	19.9	21.2	22.5	23.7	25.0	26.3	27.6	28.9	30.2	31.5	32.8	34.1	35.5	36.8	38.2
37	20.2	21.5	22.8	24.1	25.4	26.7	28.0	29.3	30.6	31.9	33.3	34.6	36.0	37.4	38.8
38	20.5	21.8	23.1	24.4	25.7	27.1	28.4	29.7	31.1	32.4	33.8	35.2	36.6	38.0	39.4
39	20.8	22.1	23.4	24.8	26.1	27.5	28.8	30.2	31.6	32.9	34.3	35.8	37.2	38.6	40.1
40	21.1	22.4	23.8	25.2	26.5	27.9	29.3	30.7	32.1	33.5	34.9	36.4	37.8	39.3	40.8
41	21.4	22.8	24.2	25.6	27.0	28.4	29.8	31.2	32.6	34.1	35.5	37.0	38.5	40.0	41.5
42	21.8	23.2	24.6	26.0	27.4	28.8	30.3	31.7	33.2	34.7	36.2	37.7	39.2	40.7	42.3
43	22.1	23.6	25.0	26.4	27.9	29.3	30.8	32.3	33.8	35.3	36.8	38.4	39.9	41.5	43.1
44	22.5	24.0	25.4	26.9	28.4	29.9	31.4	32.9	34.4	36.0	37.5	39.2	40.7	42.4	44.0
45	23.0	24.4	25.9	27.4	28.9	30.5	32.0	33.6	35.1	36.7	38.3	39.9	41.6	43.3	45.0
46	23.4	24.9	26.4	28.0	29.5	31.1	32.6	34.2	35.8	37.5	39.1	40.8	42.5	44.3	46.0
47	23.8	25.4	27.0	28.5	30.1	31.7	33.3	35.0	36.6	38.3	40.0	41.7	43.5	45.3	47.2
48	24.3	25.9	27.5	29.1	30.7	32.4	34.1	35.7	37.4	39.2	40.9	42.7	44.5	46.4	48.4
49	24.9	26.5	28.1	29.8	31.4	33.1	34.8	36.6	38.3	40.1	41.9	43.8	45.7	47.7	49.7
50	25.4	27.1	28.7	30.4	32.2	33.9	35.6	37.4	39.3	41.1	43.0	44.9	46.9	49.0	51.1
51	26.0	27.7	29.4	31.2	32.9	34.7	36.5	38.4	40.3	42.2	44.2	46.2	48.2	50.4	52.6
52	26.6	28.4	30.1	31.9	33.8	35.6	37.5	39.4	41.4	43.4	45.4	47.5	49.7	52.0	54.3
53	27.3	29.1	30.9	32.8	34.6	36.6	38.5	40.5	42.5	44.6	46.7	49.0	51.3	53.7	56.2
54	28.0	29.3	31.7	33.6	35.6	37.6	39.6	41.7	43.8	46.0	48.2	50.6	53.0	55.6	58.3
55	28.7	30.7	32.6	34.6	36.7	33.7	40.8	42.9	45.2	47.5	49.8	52.3	54.9	57.7	60.7
56	29.5	31.5	33.5	35.6	37.7	39.9	42.1	44.3	46.7	49.1	51.6	54.3	57.1	60.1	63.4
57	30.4	32.5	34.6	36.7	38.9	41.2	43.5	45.9	48.3	50.9	53.6	56.5	59.6	62.9	66.7
58	31.3	33.5	35.7	37.9	40.2	42.6	45.0	47.5	50.1	52.9	55.8	58.9	62.4	66.2	70.7
59	32.4	34.6	36.9	39.2	41.6	44.1	46.7	49.4	52.2	55.1	58.3	61.8	65.7	70.3	76.2
60	33.5	35.8	38.2	40.6	43.2	45.8	48.5	51.4	54.4	57.7	61.2	65.2	69.9	75.8	90.0
61	34.7	37.1	39.6	42.2	44.9	47.7	50.6	53.7	57.0	60.6	64.7	69.4	75.5	90.0	
62	36.0	38.5	41.2	43.9	46.3	49.8	52.9	56.3	60.0	64.2	69.0	75.2	90.0		
63	37.4	40.1	42.9	45.8	48.9	52.1	55.6	59.4	63.6	68.6	74.9	90.0			
64	39.0	41.8	44.8	48.0	51.3	54.8	58.7	63.0	68.1	74.6	90.0				
65	40.7	43.8	47.0	50.4	54.0	58.0	62.4	67.6	74.2	90.0					

Prefix of Azimuth should be measured from East or west.
Suffix of Azimuth is the same as the name of declination.

Fig. 117

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

RISING AND SETTING HOUR ANGLE (True Alt.=0°)

lat.	Declination d														
l	16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0
2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	5
4	5	5	5	6	6	6	6	7	7	7	8	8	9	9	9
6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14
8	9	10	10	11	12	12	13	14	14	15	16	16	17	18	19
10	6 12	6 12	6 13	6 14	6 15	6 16	6 16	6 17	6 18	6 19	6 20	6 21	6 22	6 22	6 23
12	14	15	16	17	18	19	20	21	22	23	24	25	25	27	28
14	16	17	19	20	21	22	23	24	25	27	28	29	30	32	33
16	19	20	21	23	24	25	27	28	29	31	32	34	35	37	38
18	21	23	24	26	27	29	30	32	33	35	36	38	40	42	43
20	6 24	6 26	6 27	6 29	6 30	6 32	6 34	6 36	6 37	6 39	6 41	6 43	6 45	6 47	6 49
21	25	27	29	30	32	34	35	38	39	41	43	45	47	49	51
22	27	28	30	32	34	36	38	40	41	43	45	48	50	52	54
23	28	30	32	34	36	38	40	42	43	46	48	50	52	54	6 57
24	29	31	33	35	37	39	41	44	46	48	50	52	55	6 57	7 0
25	6 31	6 33	6 35	6 37	6 39	6 41	6 43	6 46	6 48	6 50	6 53	6 55	6 57	7 0	7 2
26	32	34	36	39	41	43	45	48	50	53	55	6 58	7 0	3	5
27	34	36	38	40	43	45	48	50	52	55	6 58	7 0	3	6	8
28	35	37	40	42	45	47	50	52	55	6 57	7 0	3	6	9	12
29	37	39	42	44	47	49	52	54	6 57	7 0	3	6	9	12	15
30	6 38	6 41	6 43	6 46	6 49	6 51	6 54	6 57	7 0	7 2	7 5	7 8	7 12	7 15	7 18
31	40	42	45	48	51	53	56	6 59	2	5	8	11	15	18	21
[32]	41	[44]	47	50	53	56	6 58	7 2	5	8	11	14	18	21	25
[33]	43	[46]	49	52	55	6 58	7 1	4	7	11	14	17	21	24	28
34	45	48	51	54	57	7 0	3	7	10	13	17	20	24	28	32
35	6 46	6 49	6 53	6 56	6 59	7 2	7 6	7 9	7 13	7 16	7 20	7 24	7 27	7 31	7 35
36	48	51	55	6 58	7 1	5	8	12	15	19	23	27	31	35	39
37	50	53	57	7 0	4	7	11	15	18	22	26	30	34	39	43
38	52	55	6 59	2	6	10	14	17	21	25	30	34	38	43	47
39	54	57	7 1	5	9	12	16	20	25	29	33	37	42	47	51
40	6 55	6 59	7 3	7 7	7 11	7 15	7 19	7 23	7 28	7 32	7 37	7 41	7 45	7 51	7 56
41	6 58	7 2	6	10	14	18	22	27	31	36	40	45	50	7 55	8 0
42	7 0	4	8	12	17	21	25	30	35	39	44	49	54	8 0	5
43	2	6	11	15	19	24	29	33	38	43	48	53	7 59	4	10
44	4	9	13	18	22	27	32	37	42	47	52	7 58	8 4	9	16
45	7 7	7 11	7 16	7 21	7 25	7 30	7 35	7 40	7 46	7 51	7 57	8 3	8 8	8 15	8 21
46	9	14	19	24	29	34	39	44	50	7 55	8 1	7	14	20	27
47	12	17	22	27	32	37	43	48	54	8 0	6	12	19	26	33
48	14	19	25	30	35	41	47	53	7 59	5	11	18	25	32	40
49	17	22	28	33	39	45	51	7 57	8 3	10	17	24	31	38	46
50	7 20	7 25	7 31	7 37	7 43	7 49	7 55	8 2	8 8	8 15	8 22	8 30	8 37	8 45	8 54
51	23	29	35	41	47	53	8 0	6	13	21	28	36	44	8 53	9 2
52	26	32	38	45	51	7 58	5	12	19	27	35	43	8 52	9 1	11
53	29	36	42	49	7 56	8 2	10	17	25	33	41	50	9 0	9	20
54	33	40	46	53	8 0	8	15	23	31	40	49	8 58	8	19	30
55	7 37	7 44	7 51	7 58	8 5	8 13	8 21	8 29	8 38	8 47	8 57	9 7	9 18	9 29	9 42
56	41	48	7 55	8 3	11	19	27	36	45	8 55	9 5	16	28	41	9 55
57	45	52	8 0	8	16	25	34	43	8 53	9 4	15	27	40	9 54	10 11
58	49	7 57	5	14	22	32	41	8 51	9 2	13	25	38	9 53	10 10	30
59	54	8 2	11	20	29	39	49	9 0	11	24	37	9 52	10 9	29	10 56
60	7 59	8 8	8 17	8 26	8 36	8 47	8 58	9 9	9 22	9 35	9 51	10 8	10 29	10 55	12 0
61	8 5	14	24	31	44	8 55	9 7	20	34	9 49	10 7	27	10 54	12 0	
62	11	20	31	41	8 53	9 5	18	32	9 47	10 5	26	10 54	12 0		
63	17	27	38	8 50	9 2	16	30	9 46	10 4	25	10 53	12 0			
64	24	35	47	9 0	13	28	9 44	10 2	24	10 52	12 0				
65	8 32	8 44	8 57	9 10	9 25	9 42	10 0	10 22	10 51	12 0					

when name of declination is the same as that of latitude, use the tabulated value. If contrary, use the value (12^h- tabulated value)

Fig. 118

Extracted from the NAUTICAL ALMANACE, MARITIME SAFETY AGENCY, JAPAN.

Solution 2

1 To obtain h

d (5/8/1956) U = 0^h

↓

d = 17°-20.'8 N (by nautical almanac 5/8) → h = 06^h45^m

l = 32°-20.'0 N

> by the table of "Rising and Setting Hour Angle (true Alt. = 0°

2 To obtain G.A.T. to seek correct d.

	$12^h00^m00^s$
h	06 45 00 ⊖
L.A.T. (5/8)	05 15 00
L. in T.	08 39 12 ⊖
G.A.T. (4/8)	20 35 48

↓

d = $17^{\circ}05'.1$ N

l = $32^{\circ}20'.0$ N

→ By formula sin Amplitude = $\frac{\sin d}{\cos \ell}$

$\frac{\sin (17^{\circ}05')}{\cos (32^{\circ}20')} = \frac{0.29376}{0.84495} = 0.3474$

Amplitude = E $20^{\circ}20'$N (By natural trigonometric functions table)

↑ Because of rising sun

↑ The same name as declination (d)

Ref.

Solution by electronic calculator CASIO fx-950 or fx-180P

Sin Amplitude = $\frac{\sin (17^{\circ}05')}{\cos (32^{\circ}20')}$

Example 18

On 14 February 1956, a navigator observed the sun's bearing by amplitude with magnetic compass when the sun was setting in D.R.P. 22°06′ N, 109°17′W. The magnetic compass bearing of the sun was N 87°.5 W, and local variation was 11°. E.

What was the deviation of this compass?

Solution

1 To obtain h

14/2/56 $U = 0^h \rightarrow d = 13°26'.0$ S (By nautical almanac 14/2/1956 Fig. 119)

$d = 13°26'.0$ S $h = (12^h - 6^h22^m) = 5^h38^m$
$l = 22°06'.0$ N

↑ Be careful!

By the table of "Rising and Setting Hour Angle true Alt. = 0°

2 To obtain G.A.T. to seek correct d

	$12^h00^m00^s$
h	05 38 00 (+)
L.A.T. (14/2)	17 38 00
L in T	07 17 08 (+)
	24 55 08
	24 (−)
G.A.T. (15/2)	00 55 08
$d = (U = 0^h)$	13°05.7 S
P.P. (55^m08^s)	0.8 (−)
$d = (U = 00^h55^m08^s)$	13°04.9 S

→ By nautical almanac 15/2/1956 (Fig. 120)

$d = 13^{\circ}04'.9$ S

$l = 22^{\circ}06'.0$ N

$$\sin \text{amplitude} = \frac{\sin d}{\cos \ell}$$

$$= \frac{\sin (13^{\circ}04'.9)}{\cos (22^{\circ}06'.0)}$$

By electronic calculator CASIO fx-950 or fx-180P

Keys	Display
[1] [3] [°'"] [0] [4] [.] [9] [°'"] →	13 . 0 8 1 6 6 6 6 7
[INV] [°'"] →	13° 4' 54"
[Sin] →	0 . 2 2 6 3 3 9 6 4 5
[÷] [2] [2] [°'"] [0] [6] [°'"] →	22 . 1
[INV] [°'"] →	22° 6' 0"
[cos] →	0 . 9 2 6 5 2 8 6 3
[=] →	0 . 2 4 4 2 8 7 8 0 5
[INV] [Sin] →	14 . 1 3 9 7 4 9 1 6

Ans. 14°.1

Keys	Display
[INV] [°'"] (dashed) →	14° 8' 23"1

Amplitude	=	W 14°.1 S
		↓
Amplitude	=	S 75°.9 W (= 90°-14°.1) Be careful!
Compass bearing	=	N 87°.5 W ⊖
Compass error		16°.6 W
Variation		11°.0 E ⊕
Deviation		27°.6 W

Ans. Deviation was 27°.6 W

14 February 1956

Nautical Almanac

Moon Age 2.1 d

⊙ Sun

U	$E_\odot$	d	P.P. of d	
h	h m s	° ′	h m	′
0	11 45 41	S13 26.0	0 0	0.0
2	41	24.3	10	1
4	41	22.6	20	3
6	42	20.9	30	4
8	42	19.3	40	6
10	42	17.6	0 50	7
12	11 45 42	S13 15.9	1 0	0.9
14	42	14.2	10	1.0
16	42	12.5	20	1
18	42	10.8	30	3
20	43	9.1	40	4
22	43	7.4	1 50	6
24	11 45 43	S13 5.7	2 0	1.7

(S.D. 16′ 14″)

✱ Star ($U = 0^h$)

No.	Star	E_*	d
		h m s	° ′
1	Polaris	7 39 13	N89 3.9
2	Kochab	18 41 12	74 19.7
3	Dubhe	22 39 55	61 59.0
4	β Cassiop.	9 25 12	58 54.7
5	Merak	22 32 45	56 36.8
6	Alioth	20 39 52	N56 11.5
7	Schedir	8 54 0	56 18.1
8	Mizar	20 9 49	55 8.9
9	α Persei	6 10 48	49 42.6
10	Benetnasch	19 46 10	49 31.5
11	Capella	4 18 31	N45 57.5
12	Deneb	12 52 5	45 7.3
13	Vega	14 56 34	38 44.3
14	Castor	2 0 10	31 59.1
15	Alpheratz	9 25 54	28 51.0
16	Pollux	1 49 20	N28 7.9
17	α Cor. Bor.	17 59 10	26 51.4
18	Arcturus	19 18 20	19 24.3
19	Aldebaran	4 58 35	16 25.3
20	Markab	10 29 26	14 58.2
21	Denebola	21 45 9	N14 48.8
22	α Ophiuchi	15 59 6	12 35.3
23	Regulus	23 25 56	12 10.7
24	Altair	13 43 22	8 45.0
25	Betelgeuse	3 39 11	7 23.9
26	Bellatrix	4 9 12	N 6 18.6
27	Procyon	1 54 58	N 5 20.1
28	Rigel	4 19 33	S 8 15.2
29	α Hydrae	0 6 32	8 28.3
30	Spica	20 9 6	10 56.1
31	Sirius	2 48 46	S16 39.5
32	β Ceti	8 50 37	18 13.7
33	Antares	17 5 17	26 20.2
34	σ Sagittarii	14 39 28	26 21.1
35	Fomalhaut	10 36 47	29 51.3
36	λ Scorpii	16 1 22	S37 4.3
37	Canopus	3 9 0	52 40.6
38	α Pavonis	13 9 50	56 52.5
39	Achernar	7 55 56	57 27.8
40	β Crucis	20 46 49	59 26.9
41	β Centauri	19 31 15	S60 9.6
42	α Centauri	18 55 22	60 39.2
43	α Crucis	21 7 48	62 51.3
44	α Tri. Aust.	16 47 59	68 56.8
45	β Carinae	0 19 13	S69 32.3

R_0 9h 32m 0s

Planet

♀ Venus Tr. 14h 41m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	9 19 27	N 0 48.1	0 0	0	0.0
2	25	50.7	10	0	2
4	24	53.3	20	0	4
6	22	56.0	30	1	7
8	20	0 58.6	40	1	0.9
10	18	1 1.2	0 50	1	1.1
12	9 19 17	N 1 3.8	1 0	1	1.3
14	15	6.5	10	1	5
16	13	9.1	20	1	1.7
18	11	11.7	30	2	2.0
20	10	14.3	40	2	2
22	8	17.0	1 50	2	4
24	9 19 6	N 1 19.6	2 0	2	2.6

♂ Mars Tr. 7h 45m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	16 14 20	S22 58.8	0 0	0	0.0
2	26	59.1	10	1	0
4	31	59.4	20	1	1
6	37	22 59.7	30	2	1
8	42	23 0.1	40	2	1
10	48	0.4	0 50	3	1
12	16 14 53	S23 0.7	1 0	3	0.2
14	14 59	1.0	10	4	2
16	15 4	1.3	20	4	2
18	10	1.6	30	5	2
20	15	1.9	40	5	3
22	21	2.2	1 50	6	3
24	16 15 26	S23 2.5	2 0	6	0.3

♃ Jupiter Tr. 0h 26m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	23 34 11	N13 39.7	0 0	0	0.0
2	34	39.9	10	2	0
4	34 56	40.2	20	4	0
6	35 18	40.4	30	5	1
8	35 40	40.6	40	7	1
10	36 3	40.9	0 50	9	1
12	23 36 25	N13 41.1	1 0	11	0.1
14	36 47	41.3	10	13	1
16	37 9	41.6	20	15	1
18	32	41.8	30	17	2
20	37 54	42.0	40	18	2
22	38 16	42.3	1 50	20	2
24	23 38 38	N13 42.5	2 0	22	0.2

♄ Saturn Tr. 6h 20m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	17 29 51	S18 35.0	0 0	0	0.0
2	30 10	35.0	10	2	0
4	29	35.0	20	3	0
6	30 47	35.1	30	5	0
8	31 6	35.1	40	6	0
10	25	35.1	0 50	8	0
12	17 31 44	S18 35.2	1 0	10	0.0
14	32 3	35.2	10	11	0
16	21	35.2	20	13	0
18	40	35.2	30	14	0
20	32 59	35.3	40	16	0
22	33 18	35.3	1 50	17	0
24	17 33 37	S18 35.3	2 0	19	0.0

☾ Moon Tr. 14h 9m

U	$E_☾$	d
h	h m s	° ′
0	10 22 33	N 0 1.8
	21 39	7.8
1	20 45	13.9
	19 51	19.9
2	18 57	26.1
	18 3	32.2
3	17 12	38.2
	16 13	44.3
4	15 25	50.4
	14 31	0 56.5
5	13 37	1 2.6
	12 44	8.7
(H.P. 55′.9, S.D. 15′ 13″)		
6	10 11 50	N 1 14.8
	10 56	20.9
7	10 3	26.9
	9 9	33.0
8	8 15	39.1
	7 21	45.2
9	6 27	51.3
	5 33	1 57.4
10	4 40	2 3.5
	3 46	9.6
11	2 52	15.7
	1 58	21.7
(H.P. 56′.0, S.D. 15′ 15″)		
12	10 1 4	N 2 27.8
	10 0 10	33.9
13	9 59 16	40.0
	58 22	46.1
14	57 27	52.2
	56 33	2 58.2
15	55 39	3 4.3
	54 45	10.4
16	53 51	16.5
	52 56	22.6
17	52 2	28.6
	51 8	34.7
(H.P. 56′.1, S.D. 15′ 17″)		
18	9 50 13	N 3 40.8
	49 19	46.8
19	48 25	52.9
	47 30	3 59.0
20	46 36	4 5.0
	45 41	11.1
21	44 47	17.1
	43 52	23.2
22	42 57	29.2
	42 3	35.3
23	41 8	41.3
	40 13	47.4
24	9 39 18	N 4 53.4
(H.P. 56′.2, S.D. 15′ 19″)		

P.P. (Moon, 0h–12h)

$E_☾$ (m)	(s)	d (′)
1	2	0.2
2	4	4
3	5	6
4	7	0.8
5	9	1.0
6	11	2
7	13	4
8	14	6
9	16	1.8
10	18	2.0
11	20	2
12	22	4
13	23	6
14	25	2.8
15	27	3.1
16	29	3
17	31	5
18	32	7
19	34	3.9
20	36	4.1
21	38	3
22	40	5
23	41	7
24	43	4.9
25	45	5.1
26	47	3
27	49	5
28	50	7
29	52	5.9
30	54	6.1

P.P. (Moon, 12h–24h)

$E_☾$ (m)	(s)	d (′)
1	2	0.2
2	4	4
3	5	6
4	7	0.8
5	9	1.0
6	11	2
7	13	4
8	15	6
9	16	1.8
10	18	2.0
11	20	2
12	22	4
13	24	6
14	26	2.8
15	28	3.1
16	29	3
17	31	5
18	33	7
19	35	3.9
20	37	4.1
21	38	3
22	40	5
23	42	7
24	44	4.9
25	46	5.1
26	48	3
27	49	5
28	51	7
29	53	5.9
30	55	6.1

Planet

	R.A.	d	Mag.	H.P.	S.D.
	h m	° ′		′	″
♀	0 13	N 0 48	−3.6	0.1	7
♂	17 18	S22 59	+1.4	0.1	3
♃	9 58	N13 40	−2.1	0.0	21
♄	16 2	S18 35	+0.7	0.0	7
☿	20 4	S18 52	+0.5	0.2	4

Fig. 119

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

15 February 1956

Nautical Almanac

Moon Age 3.1 d

☉ Sun

U (h)	$E_☉$ (h m s)	d (° ′)	P.P. (h m)	P.P. (′)
0	11 45 43	S13 5.7	0 0	0.0
2	43	4.0	10	1
4	41	2.3	20	3
6	43	13 0.6	30	4
8	44	12 58.9	40	6
10	44	57.2	0 50	7
12	11 45 44	S12 55.5	1 0	0.9
14	44	53.8	10	1.0
16	44	52.1	20	1
18	45	50.4	30	3
20	45	48.7	40	4
22	45	47.0	1 50	6
24	11 45 45	S12 45.3	2 0	1.7

S.D. 16′ 14″

✳ Star ($U = 0^h$)

No.	Star	E_* (h m s)	d (° ′)
1	Polaris	7 43 10	N89 3.9
2	Kochab	18 45 8	74 19.7
3	Dubhe	22 34 51	61 59.0
4	β Cassiop.	9 29 8	58 54.7
5	Merak	22 36 41	56 36.8
6	Alioth	20 43 49	N56 11.5
7	Schedir	8 57 57	56 18.1
8	Mizar	20 13 45	55 8.9
9	α Persei	6 14 45	49 42.6
10	Benetnasch	19 50 7	49 31.5
11	Capella	4 22 28	N45 57.5
12	Deneb	12 56 2	45 7.3
13	Vega	15 0 30	38 44.3
14	Castor	2 4 6	31 59.1
15	Alpheratz	9 29 50	28 51.0
16	Pollux	1 53 17	N28 7.9
17	α Cor. Bor.	18 3 7	26 51.4
18	Arcturus	19 22 16	19 24.3
19	Aldebaran	5 2 31	16 25.3
20	Markab	10 33 23	14 58.2
21	Denebola	21 49 6	N14 40.8
22	α Ophiuchi	16 3 3	12 35.3
23	Regulus	23 29 52	12 10.7
24	Altair	13 47 19	8 45.0
25	Betelgeuse	3 43 7	7 23.9
26	Bellatrix	4 13 9	N 6 18.6
27	Procyon	1 50 55	N 5 20.1
28	Rigel	4 23 30	S 8 15.2
29	α Hydrae	0 10 29	8 28.3
30	Spica	20 13 3	10 56.1
31	Sirius	2 52 42	S16 39.5
32	β Ceti	8 54 34	18 13.7
33	Antares	17 9 13	26 20.2
34	σ Sagittarii	14 43 24	26 21.1
35	Fomalhaut	10 40 44	29 51.3
36	λ Scorpii	16 5 19	S37 4.3
37	Canopus	3 12 57	52 40.6
38	α Pavonis	13 13 47	56 52.5
39	Achernar	7 59 53	57 27.8
40	β Crucis	20 50 45	59 26.9
41	β Centauri	19 35 12	S60 9.6
42	α Centauri	18 59 19	60 33.2
43	α Crucis	21 11 45	62 51.3
44	α Tri. Aust.	16 51 56	68 56.8
45	β Carinae	0 23 9	S69 32.3

$R_☉$ 9h 35m 57s

Planet

♀ Venus — Tr. 14h 41m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	9 19 6	N 1 19.6	0 0	0	0.0
2	4	22.2	10	0	2
4	3	24.8	20	0	4
6	19 1	27.5	30	1	7
8	18 59	30.1	40	1	0.9
10	58	32.7	0 50	1	1.1
12	9 18 56	N 1 35.4	1 0	1	1.3
14	54	38.0	10	1	5
16	52	40.6	20	1	1.7
18	51	43.2	30	2	2.0
20	49	45.9	40	2	2
22	47	48.5	1 50	2	4
24	9 18 46	N 1 51.1	2 0	2	2.6

♂ Mars — Tr. 7h 44m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	16 15 26	S23 2.5	0 0	0	0.0
2	32	2.7	10	1	0
4	37	3.0	20	1	1
6	43	3.3	30	2	1
8	48	3.6	40	2	1
10	54	3.9	0 50	3	1
12	16 15 59	S23 4.2	1 0	3	0.2
14	16 5	4.5	10	4	2
16	10	4.8	20	4	2
18	16	5.1	30	5	2
20	21	5.3	40	5	3
22	27	5.6	1 50	6	3
24	16 16 32	S23 5.9	2 0	6	0.3

♃ Jupiter — Tr. 0h 21m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	23 38 38	N13 42.5	0 0	0	0.0
2	39 1	42.7	10	2	0
4	23	43.0	20	4	0
6	39 45	43.2	30	5	1
8	40 7	43.4	40	7	1
10	30	43.7	0 50	9	1
12	23 40 52	N13 43.9	1 0	11	0.1
14	41 14	44.1	10	13	1
16	36	44.4	20	15	1
18	41 59	44.6	30	17	2
20	42 21	44.8	40	18	2
22	42 43	45.1	1 50	20	2
24	23 43 5	N13 45.3	2 0	22	0.2

♄ Saturn — Tr. 6h 25m

U (h)	E_P (h m s)	d (° ′)	P.P. (h m)	E_P (s)	d (′)
0	17 33 37	S18 35.3	0 0	0	0.0
2	33 55	35.4	10	2	0
4	34 14	35.4	20	3	0
6	33	35.4	30	5	0
8	34 52	35.5	40	6	0
10	35 11	35.5	0 50	8	0
12	17 35 29	S18 35.5	1 0	10	0.0
14	35 48	35.5	10	11	0
16	36 7	35.6	20	13	0
18	26	35.6	30	14	0
20	36 45	35.6	40	16	0
22	37 4	35.6	1 50	17	0
24	17 37 22	S18 35.7	2 0	19	0.0

☾ Moon — Tr. 14h 48m

U (h)	$E_☾$ (h m s)	d (° ′)
0	9 39 18	N 4 53.4
	38 24	4 59.4
1	37 29	5 5.5
	36 34	11.5
2	35 39	17.5
	34 44	23.5
3	33 49	29.5
	32 54	35.5
4	31 59	41.5
	31 4	47.5
5	30 9	53.5
	29 13	5 59.5
(H.P. 56′.4, S.D. 15′ 21″)		
6	9 28 18	N 6 5.5
	27 23	11.5
7	26 27	17.4
	25 32	23.4
8	24 37	29.4
	23 41	35.3
9	22 46	41.3
	21 50	47.2
10	20 54	53.2
	19 59	6 59.1
11	19 3	7 5.0
	18 7	10.9
(H.P. 56′.5, S.D. 15′ 23″)		
12	9 17 12	N 7 16.9
	16 16	22.8
13	15 20	28.7
	14 24	34.6
14	13 28	40.4
	12 32	46.3
15	11 36	52.2
	10 40	7 58.1
16	9 43	8 3.9
	8 47	9.8
17	7 51	15.6
	6 55	21.5
(H.P. 56′.6, S.D. 15′ 25″)		
18	9 5 58	N 8 27.3
	5 2	33.1
19	4 5	38.9
	3 9	44.7
20	2 12	50.5
	1 15	8 56.3
21	9 0 19	9 2.1
	8 59 22	7.8
22	58 25	13.6
	57 28	19.4
23	56 31	25.1
	55 34	30.8
24	8 54 37	N 9 36.5
(H.P. 56′.7, S.D. 15′ 28″)		

Moon P.P. ($E_☾$, d)

m	s	′
1	2	0.2
2	4	4
3	5	6
4	7	0.8
5	9	1.0
6	11	2
7	13	4
8	15	6
9	16	1.8
10	18	2.0
11	20	2
12	22	4
13	24	6
14	26	2.8
15	28	3.0
16	29	2
17	31	4
18	33	6
19	35	3.8
20	37	4.0
21	39	2
22	40	4
23	42	6
24	44	4.8
25	46	5.0
26	48	2
27	49	4
28	51	6
29	53	5.8
30	55	6.0

m	s	′
1	2	0.2
2	4	4
3	6	6
4	7	0.8
5	9	1.0
6	11	2
7	13	4
8	15	5
9	17	7
10	19	1.9
11	21	2.1
12	22	3
13	24	5
14	26	7
15	28	2.9
16	30	3.1
17	32	3
18	34	5
19	35	7
20	37	3.9
21	39	4.1
22	41	3
23	43	4
24	45	6
25	47	4.8
26	43	5.0
27	50	2
28	52	4
29	54	6
30	56	5.8

Planet

	R.A. (h m)	d (° ′)	Mag.	H.P. (′)	S.D. (″)
♀	0 17	N 1 20	−3.6	0.1	7
♂	17 21	S23 2	+1.3	0.1	3
♃	9 57	N13 43	−2.1	0.0	21
♄	16 2	S18 35	+0.7	0.0	7
♅	20 7	S18 56	+0.4	0.2	4

Fig. 120

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

RISING AND SETTING HOUR ANGLE (True Alt.=0°)

	d															
l	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0
2	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2
4	0	1	1	1	1	2	2	2	3	3	3	3	4	4	4	5
6	0	1	1	2	2	3	3	3	4	4	5	5	6	6	6	7
8	1	1	2	2	3	3	4	5	5	6	6	7	7	8	9	9
10	6 1	6 1	6 2	6 3	6 4	6 4	6 5	6 6	6 6	6 7	6 8	6 9	6 9	6 10	6 11	6 12
12	1	2	3	3	4	5	6	7	8	9	9	10	11	12	13	14
14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16	1	2	3	5	6	7	8	9	10	12	13	14	15	16	18	19
18	1	3	4	5	7	8	9	10	12	13	14	16	17	19	20	21
20	6 1	6 3	6 4	6 6	6 7	6 9	6 10	6 12	6 13	6 15	6 16	6 18	6 19	6 21	6 22	6 24
21	2	3	5	6	8	9	11	12	14	16	17	19	20	22	24	25
[22]	2	3	5	6	8	10	11	13	15	16	18	20	[21	23]	25	27
23	2	3	5	7	9	10	12	14	15	17	19	21	22	24	26	28
24	2	4	5	7	9	11	13	14	16	18	20	22	24	25	27	29
25	6 2	6 4	6 6	6 7	6 9	6 11	6 13	6 15	6 17	6 19	6 21	6 23	6 25	6 27	6 29	6 31
26	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
27	2	4	6	8	10	12	14	16	19	21	23	25	27	29	31	34
28	2	4	6	9	11	13	15	17	19	22	24	26	28	30	33	35
29	2	4	7	9	11	13	16	18	20	22	25	27	29	32	34	37
30	6 2	6 5	6 7	6 9	6 12	6 14	6 16	6 19	6 21	6 23	2 26	6 28	6 31	6 33	6 36	6 38
31	2	5	7	10	12	14	17	19	22	24	27	29	32	34	37	40
32	3	5	8	10	13	15	18	20	23	25	28	31	33	36	39	41
33	3	5	8	10	13	16	18	21	24	26	29	32	34	37	40	43
34	3	5	8	11	14	16	19	22	25	27	30	33	36	39	42	45
35	6 3	6 6	6 8	6 11	6 14	6 17	6 20	6 23	6 25	6 28	6 31	6 34	6 37	6 40	6 43	6 46
36	3	6	9	12	15	18	20	23	26	29	32	36	39	42	45	48
37	3	6	9	12	15	18	21	24	27	31	34	37	40	43	47	50
38	3	6	9	13	16	19	22	25	28	32	35	38	42	45	48	52
39	3	6	10	13	16	20	23	26	29	33	36	40	43	47	50	54
40	6 3	6 7	6 10	6 13	6 17	6 20	6 24	6 27	6 31	6 34	6 38	6 41	6 45	6 48	6 52	6 56
41	3	7	10	14	17	21	25	28	32	35	39	43	46	50	54	6 58
42	4	7	11	14	18	22	25	29	33	37	40	44	48	52	56	7 0
43	4	7	11	15	19	22	26	30	34	38	42	46	50	54	6 58	2
44	4	8	12	15	19	23	27	31	35	39	43	47	52	56	7 0	4
45	6 4	6 8	6 12	6 16	6 20	6 24	6 28	6 32	6 36	6 41	6 45	6 49	6 53	6 58	7 2	7 7
46	4	8	12	17	21	25	29	33	38	42	46	51	55	7 0	4	9
47	4	9	13	17	22	26	30	35	39	44	48	53	57	2	7	12
48	4	9	13	18	22	27	31	36	41	45	50	55	6 59	4	9	14
49	5	9	14	18	23	28	32	37	42	47	52	57	7 2	7	12	17
50	6 5	6 10	6 14	6 19	6 24	6 29	6 34	6 39	6 44	6 49	6 54	6 59	7 4	7 9	7 14	7 20
51	5	10	15	20	25	30	35	40	45	50	56	7 1	6	12	17	23
52	5	10	15	21	26	31	36	41	47	52	6 58	3	9	14	20	26
53	5	11	16	21	27	32	38	43	49	54	7 0	6	11	17	23	29
54	6	11	17	22	28	33	39	45	50	56	2	8	14	20	27	33
55	6 6	6 11	6 17	6 23	6 29	6 35	6 40	6 46	6 52	6 58	7 4	7 11	7 17	7 23	7 30	7 37
56	6	12	18	24	30	36	42	48	54	7 1	7	13	20	27	34	41
57	6	12	19	25	31	37	44	50	56	3	10	16	23	30	37	45
58	6	13	19	26	32	39	45	52	6 59	6	12	20	27	34	42	49
59	7	13	20	27	33	40	47	54	7 1	8	15	23	30	38	46	54
60	6 7	6 14	6 21	6 28	6 35	6 42	6 49	6 56	7 4	7 11	7 19	7 26	7 34	7 42	7 51	7 59
61	7	14	22	29	36	44	51	6 59	6	14	22	30	38	47	7 56	8 5
62	8	15	23	30	38	46	53	7 1	9	17	26	34	43	52	8 1	11
63	8	16	24	32	40	48	56	4	12	21	30	39	48	7 57	7	17
64	8	16	25	33	41	50	6 58	7	16	25	34	43	53	8 3	13	24
65	6 9	6 17	6 26	6 34	6 43	6 52	7 1	7 10	7 19	7 29	7 39	7 48	7 59	8 9.	8 20	8 32

When name of declination is the same as that of latitude, use the tabulated value. If contrary, use the value → (12^h - tabulated value)

Fig. 121

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

Example

On 28 December 1973, a navigator observed the bearing of the sun by amplitude as S 56°15'E with magnetic compass when the sun was rising in D.R.P. 42°56'N, 140°12'E and local variation was 4°20'W.

What was the deviation?

Note: In this case ship's time was not given. So you must calculate Local Mean Time of Sunrise first by the table attached in the nautical almanac.

Solution

1 To obtain L.M.T. of Sunrise

By the table L.M.T. of Sunrise, Sunset and Duration of Twilight for Northern Latitudes,

L.M.T. Sunrise 28/12		$07^h30^m00^s$
L. in T.		09 20 48 ⊖
G.M.T.	27/12	22 09 12
		↓
d for 22		23°18'.3 S
P.P. for 09^m12^s		0.0
d for $22^h09^m\ 12^s$		23°18'.3 S

d = 23°18'.3 S

ℓ = 42°56'.0 N (By D.R.P.)

$$\sin \text{Amplitude} = \frac{\sin d}{\cos \ell} = \frac{\sin(23°18'.3)}{\cos(42°56'.0)}$$

2. Calculation by electronic calculator CASIO fx-950 or fx-180P

Key operation		Display
[2] [3] [°'"] [1] [8] [.] [3] [°'"] [INV] [°'"]	→	23° 18' 18"
[sin]	→	0 . 3 9 5 6 2 5 6 5
[÷] [4] [2] [°'"] [5] [6] [°'"] [INV] [°'"]	→	42° 56' 0"
[cos]	→	0 . 7 3 2 1 4 6 7 4 7
[=]	→	0. 5 4 0 3 6 3 8 7 1
[INV] [Sin]	→	32 .7 0 8 4 1 2 5 5
[INV] [°'"]	→	32° 42' 30" 29

= E 32°43' S

True b'g Amp.	=	E 32°43' S
		90° ⊖
True b'g by Amp.		S 57°17' E
Comp. b'g		S 56°15' E ⊖
Comp. error		1°02' W
Variation		4°20' W ⊖
Deviation		3°18' E

Ans. Deviation = 3°18' E

SUNRISE SUNSET AND DURATION OF TWILIGHT FOR NORTHERN LATITUDES L.M.T.

Date		Sunrise												
		42°N	44°N	46°N	48°N	50°N	52°N	54°N	56°N	58°N	60°N	62°N	65°N	70°N
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
1	1	7 28	7 34	7 42	7 49	7 58	8 08	8 18	8 31	8 45	9 02	9 22	10 05	.. ..
1	11	7 27	7 33	7 40	7 47	7 55	8 01	8 14	8 25	8 38	8 53	9 11	9 47	.. ..
1	21	7 22	7 28	7 34	7 40	7 47	7 55	8 03	8 13	8 24	8 37	8 52	9 21	10 55
1	31	7 11	7 18	7 23	7 29	7 36	7 41	7 49	7 57	8 06	8 16	8 28	8 50	9 50
2	10	7 02	7 06	7 10	7 15	7 19	7 24	7 30	7 36	7 43	7 51	8 00	8 17	8 58
2	20	6 49	6 52	6 55	6 58	7 01	7 05	7 09	7 14	7 19	7 24	7 31	7 42	8 09
3	2	6 31	6 35	6 37	6 39	6 41	6 41	6 46	6 19	6 52	6 56	7 00	7 06	7 22
3	12	6 17	6 18	6 19	6 49	6 20	6 21	6 22	6 23	6 25	6 26	6 27	6 30	6 36
3	22	6 00	6 00	5 59	5 59	5 59	5 58	5 58	5 57	5 56	5 56	5 55	5 53	5 50
4	1	5 43	5 42	5 40	5 39	5 37	5 35	5 33	5 31	5 28	5 25	5 22	5 17	5 08
4	11	5 26	5 24	5 21	5 18	5 16	5 12	5 09	5 05	5 00	4 55	4 50	4 39	4 15
4	21	5 10	5 07	5 03	4 59	4 55	4 50	4 45	4 40	4 33	4 26	4 18	4 02	3 25
5	1	4 56	4 52	4 47	4 42	4 36	4 30	4 21	4 16	4 08	3 58	3 47	3 26	2 31
5	11	4 44	4 38	4 33	4 26	4 20	4 12	4 04	3 55	3 41	3 32	3 17	2 49	1 22
5	21	4 34	4 28	4 21	4 14	4 06	3 57	3 48	3 36	3 24	3 09	2 50	2 14	.. ..
5	31	4 27	4 20	4 13	4 05	3 56	3 46	3 35	3 23	3 08	2 50	2 28	1 40	.. ..
6	10	4 21	4 16	4 09	4 00	3 51	3 40	3 28	3 14	2 58	2 38	2 13	1 12	.. ..
6	20	4 24	4 16	4 08	3 59	3 50	3 39	3 26	3 12	2 55	2 34	2 08	0 57	.. ..
6	30	4 27	4 20	4 12	4 03	3 51	3 43	3 31	3 17	3 00	2 40	2 14	1 09	.. ..
7	10	4 33	4 26	4 19	4 10	4 01	3 51	3 40	3 27	3 12	2 53	2 30	1 38	.. ..
7	20	4 41	4 35	4 28	4 21	4 12	4 03	3 53	3 41	3 28	3 12	2 53	2 13	.. ..
7	30	4 51	4 45	4 39	4 33	4 26	4 18	4 09	3 59	3 48	3 35	3 19	2 49	1 00
8	9	5 01	4 56	4 51	4 46	[illegible]	4 33	4 26	4 18	4 09	3 58	3 46	3 23	2 20
8	19	5 11	5 08	5 04	4 59	4 55	4 50	4 44	4 38	4 31	4 23	4 13	3 56	3 14
8	29	5 22	5 19	5 16	5 13	5 10	5 06	5 02	4 57	4 52	4 47	4 40	4 28	4 00
9	8	5 32	5 30	5 29	5 27	5 25	5 22	5 20	5 17	5 14	5 10	5 06	4 59	4 42
9	18	5 42	5 42	5 41	5 40	5 39	5 38	5 37	5 36	5 35	5 34	5 32	5 29	5 22
9	28	5 53	5 53	5 54	5 54	5 55	5 55	5 55	5 56	5 57	5 57	5 58	5 59	6 02
10	8	6 04	6 05	6 07	6 08	6 10	6 12	6 14	6 16	6 18	6 21	6 24	6 30	6 42
10	18	6 15	6 18	6 20	6 23	6 26	6 29	6 33	6 36	6 41	6 46	6 51	7 01	7 24
10	28	6 27	6 30	6 34	6 38	6 42	6 47	6 52	6 58	7 04	7 11	7 19	7 34	8 09
11	7	6 39	6 44	6 48	6 53	6 59	7 05	7 11	7 19	7 27	7 36	7 47	8 08	9 00
11	17	6 52	6 57	7 02	7 09	7 15	7 22	7 31	7 40	7 50	8 02	8 16	8 42	10 00
11	27	7 03	7 09	7 16	7 23	7 30	7 39	7 48	7 59	8 11	8 25	8 42	9 16	.. ..
12	7	7 14	7 20	7 27	7 35	7 43	7 53	8 03	8 15	8 29	8 45	9 05	9 46	.. ..
12	17	7 22	7 29	7 36	7 44	7 53	8 03	8 14	8 26	8 41	8 58	9 20	10 05	.. ..
12	27	7 27	7 33	7 41	7 49	7 58	8 07	8 18	8 31	8 46	9 03	9 24	10 10	.. ..
12	37	7 28	7 34	7 41	7 49	7 57	8 07	8 17	8 29	8 42	8 58	9 18	9 58	.. ..

Date		Duration of Twilight												
		42°N	44°N	46°N	48°N	50°N	52°N	54°N	56°N	58°N	60°N	62°N	65°N	70°N
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
1	1	1 40	1 44	1 48	1 53	1 58	2 05	2 12	2 20	2 31	2 43	2 59	3 35	...
1	11	1 39	1 43	1 47	1 51	1 56	2 02	2 09	2 17	2 27	2 39	2 53	3 23	...
1	21	1 37	1 41	1 45	1 49	1 51	2 00	2 06	2 13	2 22	2 32	2 45	3 10	4 36
1	31	1 36	1 39	1 43	1 47	1 51	1 57	2 03	2 09	2 17	2 27	2 38	2 58	3 57
2	10	1 34	1 37	1 41	1 45	1 49	1 54	2 00	2 06	2 13	2 22	2 32	2 50	3 37
2	20	1 33	1 36	1 39	1 43	1 47	1 52	1 58	2 04	2 11	2 19	2 28	2 46	3 27
3	2	1 32	1 35	1 39	1 43	1 47	1 52	1 57	2 03	2 10	2 18	2 28	2 45	3 27
3	12	1 33	1 36	1 39	1 43	1 48	1 53	1 58	2 05	2 12	2 21	2 31	2 50	3 39
3	22	1 34	1 37	1 41	1 45	1 50	1 55	2 01	2 09	2 17	2 27	2 39	3 02	4 20
4	1	1 36	1 39	1 44	1 48	1 54	2 00	2 07	2 15	2 26	2 38	2 54	3 31	...
4	11	1 39	1 43	1 48	1 53	1 59	2 07	2 16	2 27	2 41	3 00	3 29	...	...
4	21	1 43	1 48	1 53	2 00	2 08	2 17	2 29	2 45	3 10	4 08	...	...	...
5	1	1 48	1 54	2 00	2 09	2 19	2 32	2 51	3 25	...	...	...	...	...
5	11	1 54	2 01	2 09	2 20	2 35	2 57	3 51	...	...	...	...	...	...
5	21	2 00	2 09	2 20	2 34	2 57	...	...	...	...	...	...	...	...
5	31	2 06	2 16	2 30	2 51	3 45	...	...	...	...	...	...	...	...
6	10	2 11	2 22	2 39	3 08	...	...	...	...	...	...	...	...	...
6	20	2 12	2 25	2 43	3 18	...	...	...	...	...	...	...	...	...
6	30	2 11	2 23	2 40	3 11	...	...	...	...	...	...	...	...	...
7	10	2 07	2 18	2 32	2 55	...	...	...	...	...	...	...	...	...

Fig. 122

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

27 December 1973
Nautical Almanac

Moon Age $2^{d}.4$

⊙ Sun

U	$E_⊙$	d	P.P.	d
h	h m s	° ′	h m	′
0	11 59 10	S23 20.7	0 00	0.0
2	11 59 07	S23 20.5	10	0.0
4	11 59 05	S23 20.3	20	0.0
6	11 59 02	S23 20.1	30	0.1
8	11 59 00	S23 19.9	40	0.1
10	11 58 57	S23 19.7	0 50	0.1
12	11 58 55	S23 19.4	1 00	0.1
14	11 58 53	S23 19.2	10	0.1
16	11 58 50	S23 19.0	20	0.1
18	11 58 48	S23 18.8	30	0.2
20	11 58 45	S23 18.6	40	0.2
22	11 58 43	S23 18.3	1 50	0.2
24	11 58 40	S23 18.1	2 00	0.2

S.D. 16′ 17″

✱ Star $U = 0^h$

No.	Star	E_*	d
		h m s	° ′
1	Polaris	4 13 43	N89 09.1
2	Kochab	15 30 38	N74 15.4
3	Dubhe	19 19 10	N61 53.1
4	β Cassiop.	6 13 33	N59 00.8
5	Merak	19 21 02	N56 30.9
6	Alioth	17 28 27	N56 05.6
7	Schedir	5 42 18	N56 24.1
8	Mizar	16 58 28	N55 03.3
9	α Persei	2 59 50	N49 46.4
10	Benetnasch	16 34 50	N49 20.2
11	Capella	1 08 31	N45 58.5
12	Deneb	9 40 19	N45 11.4
13	Vega	11 45 18	N38 45.6
14	Castor	22 48 21	N31 56.7
15	Alpheratz	6 14 17	N28 57.1
16	Pollux	22 37 34	N28 05.3
17	α Cor. Bor	14 47 46	N26 47.9
18	Arcturus	16 06 52	N19 18.8
19	Aldebaran	1 46 53	N16 27.6
20	Markab	7 17 52	N15 04.1
21	Denebola	18 33 36	N14 42.8
22	α Ophiuchi	12 47 38	N12 34.6
23	Regulus	20 14 20	N12 05.5
24	Altair	10 31 50	N 8 48.0
25	Betelgeuse	0 27 33	N 7 24.2
26	Bellatrix	0 57 34	N 6 19.6
27	Procyon	22 43 22	N 5 17.5
28	Rigel	1 08 01	S 8 13.9
29	α Hydrae	20 55 00	S 8 32.8
30	Spica	16 57 31	S11 01.6
31	Sirius	23 37 18	S16 40.8
32	β Ceti	5 39 03	S18 07.8
33	Antares	13 53 32	S26 22.5
34	σ Sagittarii	11 27 42	S26 19.8
35	Fomalhaut	7 25 07	S29 45.7
36	λ Scorpii	12 49 31	S37 05.2
37	Canopus	23 57 56	S52 40.9
38	α Pavonis	9 57 45	S56 49.3
39	Achernar	4 44 34	S57 22.3
40	β Crucis	17 35 08	S59 32.6
41	β Centauri	16 19 22	S60 14.7
42	α Centauri	15 43 31	S60 43.4
43	α Crucis	17 56 11	S62 57.1
44	α Tri. Aust	13 35 28	S68 58.8
45	β Carinae	21 08 22	S69 36.5

R_0 6h 21m 21s

Planet

♀ Venus Tr. 14h 28m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	9 30 27	S17 26.1	0 00	0	0.0
2	9 30 42	S17 24.8	10	1	0.1
4	9 30 57	S17 23.5	20	3	0.2
6	9 31 13	S17 22.1	30	4	0.3
8	9 31 28	S17 20.8	40	5	0.4
10	9 31 44	S17 19.5	0 50	7	0.5
12	9 31 59	S17 18.2	1 00	8	0.7
14	9 32 15	S17 16.9	10	9	0.8
16	9 32 31	S17 15.6	20	10	0.9
18	9 32 47	S17 14.3	30	12	1.0
20	9 33 02	S17 13.0	40	13	1.1
22	9 33 18	S17 11.7	1 50	14	1.2
24	9 33 34	S17 10.4	2 00	16	1.3

♂ Mars Tr. 19h 30m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	4 28 00	N12 44.5	0 00	0	0.0
2	4 28 14	N12 45.2	10	1	0.1
4	4 28 27	N12 45.9	20	2	0.1
6	4 28 41	N12 46.5	30	3	0.2
8	4 28 55	N12 47.2	40	5	0.2
10	4 29 08	N12 47.9	0 50	6	0.3
12	4 29 22	N12 48.5	1 00	7	0.3
14	4 29 35	N12 49.2	10	8	0.4
16	4 29 49	N12 49.9	20	9	0.4
18	4 30 02	N12 50.5	30	10	0.5
20	4 30 16	N12 51.2	40	11	0.6
22	4 30 29	N12 51.9	1 50	12	0.6
24	4 30 43	N12 52.5	2 00	14	0.7

♃ Jupiter Tr. 14h 41m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	9 17 16	S17 31.4	0 00	0	0.0
2	9 17 31	S17 31.1	10	1	0.0
4	9 17 46	S17 30.8	20	3	0.1
6	9 18 02	S17 30.5	30	4	0.1
8	9 18 17	S17 30.2	40	5	0.1
10	9 18 33	S17 29.9	0 50	6	0.1
12	9 18 48	S17 29.6	1 00	8	0.2
14	9 19 04	S17 29.2	10	9	0.2
16	9 19 19	S17 28.9	20	10	0.2
18	9 19 35	S17 28.6	30	12	0.2
20	9 19 50	S17 28.3	40	13	0.3
22	9 20 05	S17 28.0	1 50	14	0.3
24	9 20 21	S17 27.7	2 00	15	0.3

♄ Saturn Tr. 23h 39m

U	E_P	d	P.P.	E_P	d
h	h m s	° ′	h m	s	′
0	0 17 14	N22 23.4	0 00	0	0.0
2	0 17 36	N22 23.4	10	2	0.0
4	0 17 57	N22 23.4	20	4	0.0
6	0 18 19	N22 23.4	30	5	0.0
8	0 18 40	N22 23.4	40	7	0.0
10	0 19 02	N22 23.4	0 50	9	0.0
12	0 19 23	N22 23.4	1 00	11	0.0
14	0 19 44	N22 23.5	10	13	0.0
16	0 20 06	N22 23.5	20	14	0.0
18	0 20 27	N22 23.5	30	16	0.0
20	0 20 49	N22 23.5	40	18	0.0
22	0 21 10	N22 23.5	1 50	20	0.0
24	0 21 32	N22 23.5	2 00	21	0.0

☾ Moon Tr. 14h 13m

U	$E_☾$	d
h	h m s	° ′
0	10 12 31	S17 16.1
	10 11 37	S17 11.9
1	10 10 43	S17 07.6
	10 09 48	S17 03.3
2	10 08 54	S16 58.9
	10 08 00	S16 54.6
3	10 07 06	S16 50.2
	10 06 12	S16 45.9
4	10 05 17	S16 41.5
	10 04 23	S16 37.0
5	10 03 29	S16 32.6
	10 02 35	S16 28.2
H.P. 54′.0 , S.D. 14′ 43″		
6	10 01 41	S16 23.7
	10 00 48	S16 19.2
7	9 59 54	S16 14.7
	9 59 00	S16 10.2
8	9 58 06	S16 05.7
	9 57 12	S16 01.1
9	9 56 19	S15 56.5
	9 55 25	S15 52.0
10	9 54 32	S15 47.4
	9 53 38	S15 42.7
11	9 52 45	S15 38.1
	9 51 51	S15 33.4
H.P. 54′.0 , S.D. 14′ 44″		
12	9 50 58	S15 28.8
	9 50 04	S15 24.1
13	9 49 11	S15 19.4
	9 48 18	S15 14.7
14	9 47 24	S15 09.9
	9 46 31	S15 05.2
15	9 45 38	S15 00.4
	9 44 45	S14 55.7
16	9 43 52	S14 50.9
	9 42 58	S14 46.0
17	9 42 05	S14 41.2
	9 41 12	S14 36.4
H.P. 54′.1 , S.D. 14′ 44″		
18	9 40 19	S14 31.5
	9 39 26	S14 26.6
19	9 38 34	S14 21.8
	9 37 41	S14 16.9
20	9 36 48	S14 11.9
	9 35 55	S14 07.0
21	9 35 02	S14 02.1
	9 34 10	S13 57.1
22	9 33 17	S13 52.1
	9 32 24	S13 47.1
23	9 31 32	S13 42.1
	9 30 39	S13 37.1
24	9 29 46	S13 32.1
H.P. 54′.1 , S.D. 14′ 45″		

P.P. (Moon, 0h–12h)

m	$E_☾$	d
m	s	′
1	2	0.1
2	4	0.3
3	5	0.4
4	7	0.6
5	9	0.7
6	11	0.9
7	13	1.0
8	14	1.2
9	16	1.3
10	18	1.5
11	20	1.6
12	22	1.8
13	23	1.9
14	25	2.1
15	27	2.2
16	29	2.4
17	31	2.5
18	32	2.7
19	34	2.8
20	36	3.0
21	38	3.1
22	40	3.3
23	41	3.4
24	43	3.6
25	45	3.7
26	47	3.9
27	49	4.0
28	50	4.2
29	52	4.3
30	54	4.5

P.P. (Moon, 12h–24h)

m	$E_☾$	d
m	s	′
1	2	0.2
2	4	0.3
3	5	0.5
4	7	0.6
5	9	0.8
6	11	1.0
7	12	1.1
8	14	1.3
9	16	1.5
10	18	1.6
11	19	1.8
12	21	1.9
13	23	2.1
14	25	2.3
15	26	2.4
16	28	2.6
17	30	2.8
18	32	2.9
19	34	3.1
20	35	3.2
21	37	3.4
22	39	3.6
23	41	3.7
24	42	3.9
25	44	4.1
26	46	4.2
27	48	4.4
28	49	4.5
29	51	4.7
30	53	4.9

Planet

	R.A.	d	Mag.	H.P.	S.D.
	h m				
♀ 金	20 51	S17 26	-4.4	0.4	23
♂ 火	1 53	N12 45	-0.4	0.2	8
♃ 木	21 04	S17 31	-1.6	0.0	16
♄ 土	6 04	N22 23	-0.3	0.0	9
☿ 水	17 49	S24 19	-0.8	0.1	2

Fig. 123

Extracted from the NAUTICAL ALMANAC, MARITIME SAFETY AGENCY, JAPAN.

When we are observing compass bearing of the sun's amplitude at sea, we have to check the time simultaneously. By this checked time, we can calculate the declination (d) of the sun at universal time came using the local time.

Latitude (ℓ) is given by our D.R.P. after obtainning the value of ℓ and d, we can calculate the rising or setting azimuth by the formula:

$$\sin \text{amplitude} = \frac{\sin d}{\cos \ell}$$

to check our compass error

Solution of problem on page

Ship's Time 6/7/56		$06^h50^m00^s$	
L. in T.		09 00 00	⊖
U.	5/7/56	21 50 00	
Chro. time		$10^h21^m50^s$	
Chro. E		29 00	⊖
Corrected chro. time		09 52 50	
		12	⊕
U.	5/7/56	21 52 50	
R.		18 51 51	(By nautical almanac 5/7/56)
P.P. (E_*)		3 36	⊕ (see page p.p. for E_*)
G. sin. T.		40 48 17	
		24	⊖
G. sin. T.		16 48 17	
L. in T.		9 00 00	⊕
L. sin T.		25 48 17	
		24	⊖
L. sin T.		01 48 17	

		K	D	H		
Z	57°E	264		3187		
a	50°	3076 +	2884			
ℓ	+ 34°N	3340				
K	+ 25		43	2626		
ℓ+K	+ 59		2933 +	288 ⊕		
			5860	6101 →	h_E	3^h28^m
			↓		L. sin T.	1 49 ⊕
			d = 46°N		R.A.	5^h17^m

d = 46°N, R.A. = 5^h17^m,

By the table "Position of navigation stars" on page , this star's proper name must be Capella.

Ans. Capella

Solution of problem on page

L.A.T. (4/8)	$12^h00^m00^s$
L. in T.	00 29 00 ⊕
G.A.T. (4/8)	12 29 00
E.T.	⊖ 00 05 59 ⊖ (Note, E.T. = E - 12^h)
U. (4/8)	12 34 59 → d = $17^{\circ}10'.6$ N

↓

12^h	d ≐ $17^{\circ}10.9$ N
P.P. of d (34^m59^s)	= 0.3 ⊖
d for $12^h34^m59^s$	= $17^{\circ}10'.6$ N

Sex Alt.	66°05!5	
I.E.	02!4	⊕
Obs. Alt.	66°07!9	
Corr. 1	9!2	⊕
	66°17!1	
Corr. 2	0!1	⊕
	66°17!2	
Corr. 3	0!2	⊕
True Alt.	66°17!4	
	90°00!0	
Zu	23°42!6 S	
d	17°10!6 N	⊖
ℓ	6°32!0 S	

Ans. Latitude 6°32!0 S

3. Time

THE CONCEPT OF TIME

Time is the most important factor in navigation. Any navigation such as celestial, coastal, radio or by dead reckoning is based on the measurement and use of time.

For time measurement, the diurnal motion of celestial bodies such as the sun, the moon, the stars and the celestial point of reference should be observed. There are three major time measurements.

They are:

1. Solar time
2. Sidereal time
3. Lunar time

The units of time are: year, month, week, day, hour, minute and second.

(1) Solar time

1) Apparent Solar Time (Apparent Time, A.T.)

The time when the sun transits the lower branch of a certain location is called apparent Midnight, and when it transits the upper branch it is called Apparent Noon (A.N.).

The sun as mentioned above is the actual sun and is called Apparent Sun (A.S.). The interval from one Apparent Midnight to the next Apparent Midnight is called Apparent Solar Day.

$$A.T. = 12h + h - (24)$$

Apparent Time at Greenwich is called Greenwich Apparent Time (G.A.T.) and Apparent Time at a given location is called Local Apparent Time (L.A.T.).

In terms of navigation, Local Apparent Time is sometimes called Ship's Apparent Time (S.A.T.).

2) Mean Solar Time or Mean Time (M.T.)

Apparent Solar Time (Apparent Time, or A.T.) is not regular because the apparent rotation of the sun around the earth is not at a constant velocity since the apparent path of the sun is along the ecliptic. The included angle between the plane of the celestial equator and the ecliptic is about $23^{\circ}27'$.

To solve this irregularity and other difficulties, Mean Solar Time is based on an imaginary sun that has an hour circle moving along the celestial equator at a constant rate. Mean Solar Time is nearly equal to the average Apparent Solar Time.

Chronometers on board a ship indicate Mean Solar Time and are used for the coordinates of celestial bodies in nautical almanacs.

The time when Mean Sun transits the lower branch of the meridian at a certain location is called Mean Midnight, and the time when Mean Sun transits the upper branch of the meridian at a certain location is called Mean Noon. The interval or length of time from the Mean Midnight to the next Mean Midnight is called Mean Solar Day and,

$$\text{M.T.} = 12h + \text{H.A.M.S.} - (24h)$$

(H.A.M.S. = Hour Angle of Mean Sun)

Mean Time (M.T.) is also sometimes called Civil Time and the day introduced by Mean Time is called Civil Day. Greenwich Mean Time (G.M.T.) or Universal Time (U.T.) is Mean Time at Greenwich in the United Kingdom. Local Mean Time (L.M.T.) is Mean Time at a given location and is sometimes called ship's Mean Time (S.M.T.).

3) Equation of Time (E.T.)

The difference between Apparent Time and Mean Time is called equation of Time, as follows:

$$E.T. = A.T. - M.T.$$

This has the same value as the difference between the Right Ascension of Mean Sun (R.A.M.S.) and the Right Ascension of Apparent Sun (R.A.A.S.);

(2) Sidereal Time (Sid. T.)

The hour angle of the Vernal Equinox is called Sidereal Time. When the Vernal Equinox transits the upper branch of an observer's meridian it is zero hour of Sidereal Time at the observer's location, and the time when the Vernal Equinox's hour angle is one hour it is called one hour of Sidereal Time. Sidereal Time shows the position of the stars and their daily movement westward, which is almost one degree every night.

Sidereal time is not exactly constant in rate because of the earth's rotation. Time based on the average rate is called Mean Sidereal Time. Greenwich Sidereal Time (G.S.T.) uses the meridian of Greenwich as its terrestial reference and Local Sidereal Time (L.S.T.) or Ship's Sidereal Time uses the observer's meridian as its reference. Some timepieces are adjusted to keep Sidereal Time. If they are set to G.S.T., they permit the navigator to read the G.H.A., which is G.S.T. expressed in units of arc, directly from the timepiece at the instant of making a star observation, obviating from the almanac.

Sidereal Time = Hour angle of Vernal Equinox = Right Ascension of meridian

$$Sid.\ T. = h = R.A.\ meri$$

(3) Lunar Time

1) The hour angle of the moon is called Lunar Time. When the moon transits the upper branch of the meridian of a place (hour angle - zero), Lunar Time is zero. When the hour angle of the moon becomes one hour, Lunar Time is one hour. The interval between the moon's transit of the upper branch of the meridian and the next transit of the upper branch is called Lunar Day. The average value of a Lunar Day is approximately 24 hours 50 minutes and 28 seconds because the moon's diurnal motion is irregular.

2) Age of the moon

The moon's age is calculated on the basis of the mean solar day starting from the new moon (zero day to 29th day of the age). The new moon rises and sets with the sun and the full moon rises at almost the same time as the sun sets, and it sets when the sun rises. The phases of the moon are expressed as follows:

1. New moon → 2. Crescent → 3. First quarter → 4. Gibbous
5. Full moon → 6. Gibbous → 7. Last quarter → 8. Crescent (new moon). So if the age of the moon is given, it is possible to imagine its phase, but its 15th age does not always indicate a full moon. (see Fig. 124 & 125).

Ref. Lunar Time and phase are very important in regard to tide and fisheries.

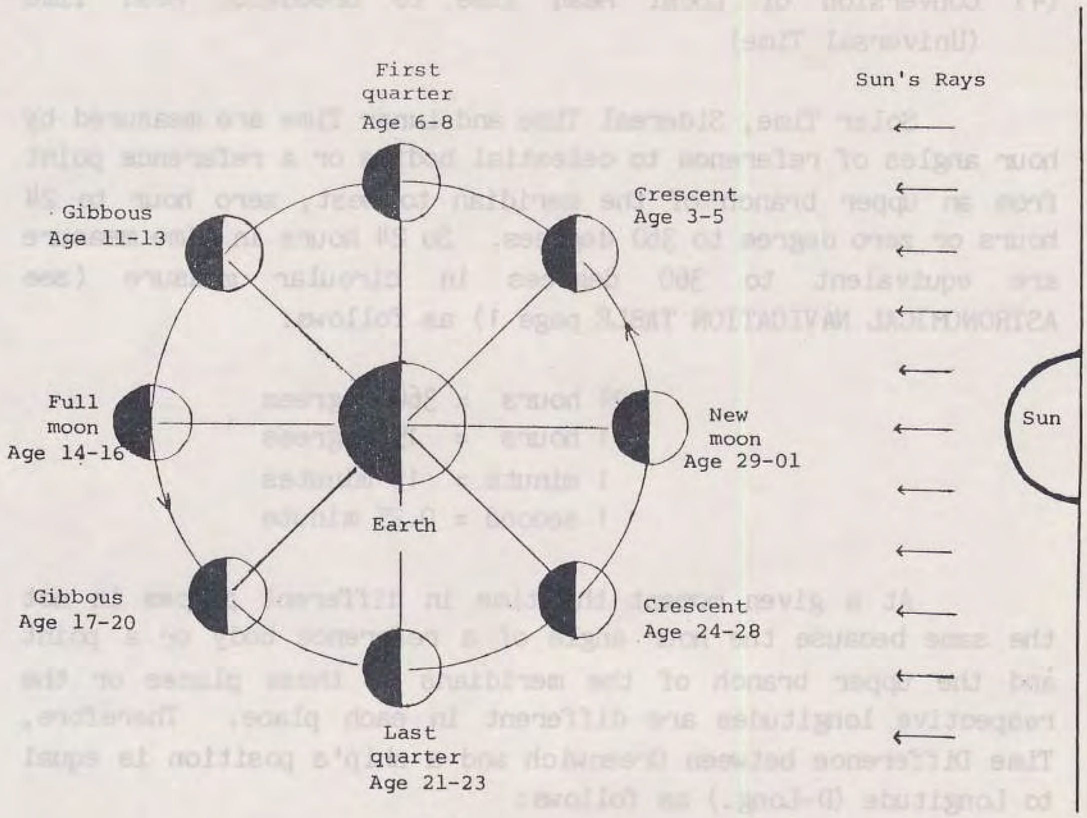


Fig. 124

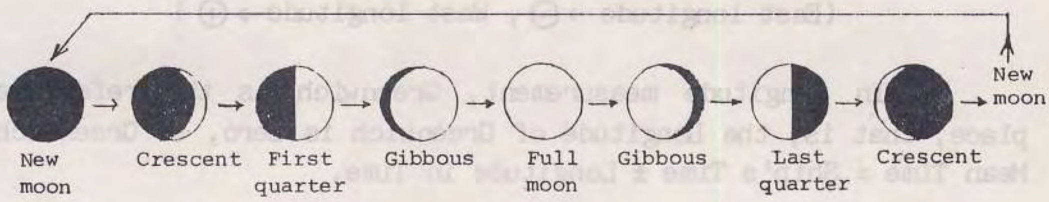


Fig. 125 The eight phases of the mon

(4) Conversion of Local Mean Time to Greenwich Mean Time (Universal Time)

Solar Time, Sidereal Time and Lunar Time are measured by hour angles of reference to celestial bodies or a reference point from an upper branch of the meridian to west, zero hour to 24 hours or zero degree to 360 degrees. So 24 hours in time measure are equivalent to 360 degrees in circular measure (see ASTRONOMICAL NAVIGATION TABLE page 1) as follows:

24 hours = 360 degrees
1 hours = 15 degrees
1 minute = 15 minutes
1 second = 0.25 minute

At a given moment the time in different places is not the same because the hour angle of a reference body or a point and the upper branch of the meridians at these places or the respective longitudes are different in each place. Therefore, Time Difference between Greenwich and a ship's position is equal to Longitude (D-Long.) as follows:

Greenwich Meantime = Ship's Time ± D-Long. in Time
(East longitude → ⊖, West longitude → ⊕)

In longitude measurement, Greenwich is the reference place, that is, the Longitude of Greenwich is zero, so Greenwich Mean Time = Ship's Time ± Longitude in Time.

G.M.T. = Ship's Time ± L. in Time
(East longitude → ⊖, West longitude → ⊕)

For conversion of Ship's Apparent Time (S.A.T.) to Greenwich Apparent Time (G.A.T.), the same formula can be applied as follows:

$$G.A.T. = S.A.T. \pm L. \text{ in Time}$$

(5) Time Zone

At sea, central longitudes are selected for ship's time. These longitudes are exactly multiplied by 15 degrees each, then there are 24 standard longitudes, each of one hour and the boundaries of longitude of each zone are 7 and 1/2 degrees on each side as shown in Figure 126. When a ship is in a Time Zone, it is convenient and recommendable to use the time in that zone on board. But in case of contact or communication among ships, it is advisable to use Greenwich Mean Time as a common time and, in the case of communication with offices of ship owners or agencies, the standard time of the place where they are located is generally used.

Questions

What zone time should be kept on ship in the following longitudes:

1) 55 degrees west?
2) 90 degrees east?
3) 120 degrees east?
4) 175 degrees west?
5) 173 degrees east?
6) 170 degrees west?

Answers

1) +3,
2) -6,
3) -8,
4) +12,
5) -12,
6) +11 (see Fig. 126)

The positive sign + or negative sign - of Zone means that Ship's Mean Time plus or minus Zone equals Greenwich Mean Time.

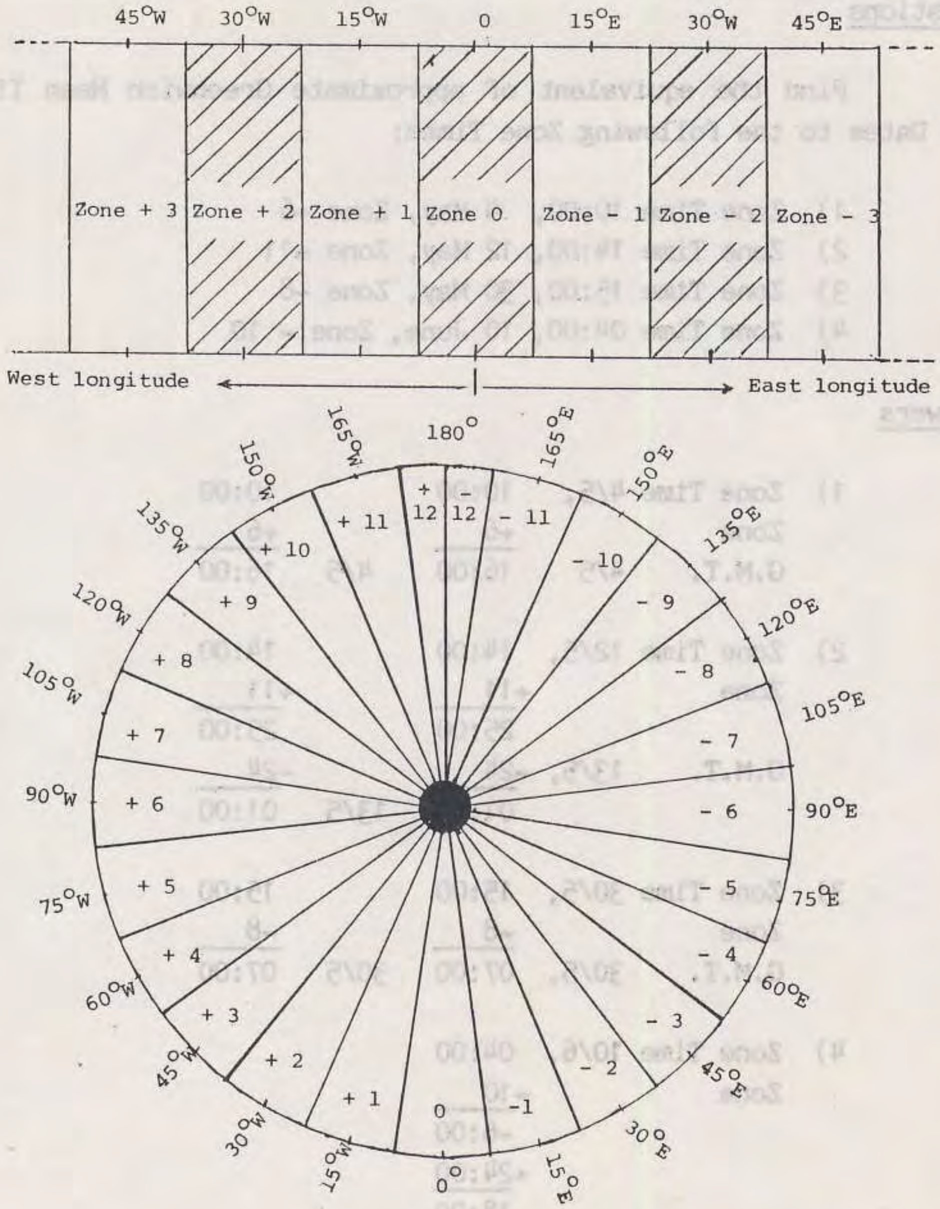


Fig. 126 Time Zones corresponding to longitudes

Questions

Find the equivalent of approximate Greenwich Mean Time and Dates to the following Zone Times:

1) Zone Time 10:00, 4 May, Zone +6
2) Zone Time 14:00, 12 May, Zone +11
3) Zone Time 15:00, 30 May, Zone -8
4) Zone Time 04:00, 10 June, Zone - 10

Answers

1)	Zone Time 4/5,	10:00		10:00
	Zone	+6		+6
	G.M.T. 4/5	16:00	4/5	16:00
2)	Zone Time 12/5,	14:00		14:00
	Zone	+11		+11
		25:00		25:00
	G.M.T. 13/5,	-24		-24
		01:00	13/5	01:00
3)	Zone Time 30/5,	15:00		15:00
	Zone	-8		-8
	G.M.T. 30/5,	07:00	30/5	07:00
4)	Zone Time 10/6,	04:00		
	Zone	-10		
		-6:00		
		+24:00		
		18:00		

G.M.T. 9/6, 18:00

6) Chronometer Time and chronometer error

For calculations in celestial navigation, it is essential to know the correct Greenwich Mean Time because in the nautical almanac, the elementary position of celestial bodies are described by G.M.T. A ship's chronometer must therefore be set by G.M.T. chronometer error is the difference between the ship's chronometer time and G.M.T. as shown below

G.M.T. - Chronometer Time = Chronometer error

Question

	Ship's Time 6/8/85,	18h	20m	00s
	Long. in Time (E-, W+)	3	37	44 +
	Approx. G.M.T.	21	57	44
	Chronometer Time	09h	54m	18s
	Chronometer error		02	14
		12+		
	G.M.T. 6/8/85	21	56	32
Answer	6/8/85	21h	56m	32s

Chronometer error is measured by means of the radio time signal. It should be recorded as F_1 - (fast) or S_1 + (slow) accordingly. Navigation should check the chronometer error everyday and record the daily rate in the Chronometer Error and Rate Book. Sample entries in such a book are shown is Fig. 127.

Date				Error Relative to Radio Signal				
1985 August	Ship's Time	Chro. Time	Radio Signal Time	±	Minutes	Seconds	±	Successive Daily Rate
1	12-00-00	09-00-03.0	09-00-00	-	0	3.0	+	
2	12-00-00	09-00-04.5	09-00-00	-	0	4.5	+	1.5^s
3	12-00-00	09-00-06.0	09-00-00	-	0	6.0	+	1.5
4	12-00-00	08-00-07.5	08-00-00	-	0	7.5	+	1.5
5	12-00-00	08-00-09.0	08-00-00	-	0	9.0	+	1.5
6	12-00-00	08-00-10.5	08-00-00	-	0	10.5	+	1.5
7	12-00-00	07-00-12.5	07-00-00	-	0	12.5	+	2.0
8	12-00-00	07-00-14.5	07-00-00	-	0	14.5	+	2.0
9	12-00-00	07-00-16.5	07-00-00	-	0	16.5	+	2.0

(Fig. 127)

Exericse

Fix by stars, Altair and Vega.

1. British method (Sight Reduction Table)

2. Japanese method (Astronomical Navigation Table)

3. By formulae

A navigator observed the altitude of stars, Altair and Vega, when ship's time was 05h 17m, 13 June 1985, in D.R.P. 17-11.3 N, 118-23.4 E, on the way to Japan from Bangkok:

Altair: Sex. Alt. 51°- 17.5, Chronometer time 09h 08m 00s.

Vega : Sex. Alt. 35°- 30.6 Chronometer time 09h 10m 30s.

Ref. Chronometer error and Index error were nil. Ship's speed was 10 knots. Set course was on 042°. Height of eye was 22 feet.

Question : Fix position by:

1. British method (Sight Reduction Table)

2. Japanese method (Astronomical Navigation Table)

3. By formulae.

Lop of Star by Sight Reduction Table (Pub. No. 229) (U.K., U.S.A.)

Date	13/6/'85	Z.T.	8 h	+ / (−)	Ship's Time 05 h 17 m	C.E.	m s 0 (+ / −)
Co.	042°	Speed	10.0 Kt.	HE	22 (f) m	IE	0′ (+ / −)

D.R.P.	17° − 11.3′	(N) S
	118° − 23.4′	(E) W
◎ Assumed Latitude	17°	(N) S
Body	Altair	
Zone Time / Ship's Time, Date 13/6	h m s 05-17-00	
Long. in time or Z.T.	h m s 07-53-34	(E(−)) W(+)
Approx. U (GMT) Date 12/6	h m s 21-23-26	
If required	24	−
Approx. U (GMT) Date 12/6	h m s 21-23-26	
Chronometer Time	h m s 09-08-00	
Chronometer error	m s 0	+ −
Corrected Chro. Time	h m s 09-08-00	
If approx. U (GMT) is in afternoon	12	+
U (GMT) Date 12/Jun.	h m s 21-08-00	

Sex. Alt.	51° − 17.5′	
I.E.	0.0′	+ −
Obs. Alt.	51° − 17.5′	
Dip (H.E.)	4.6′	− p. 263
App. Alt.	51° − 12.9′	
App. Alt. Corr.	0.8′	− p. 263
True Alt. (Ht)	51° − 12.1′	
Corr. Table Alt. (Hc)	51° − 11.5′	−
Intercept	0.6′ (+) (−)	to away

Almanac		
Almanac Table ARIES GHA (21 h)	216° − 07.5′	P. 249
Incre. (08 m 00 s)	2° − 00.3′	P. 251
Star SHA	62° − 28.8′	P. 249
GHA (h m s)	280° 36.6′	
◎ Assumed Longitude	118° 23.4′	(E+) W−
	399° 0.0′	
If required	360° (−)	
L H A	39°	

Sight Reduction Table		
Table L H A	39°	
Dec.	8° 49.6′	(N) S
Table Dec.	8°	(N) S
Dec. diff/Dec. incre	49.6′	
Table alt.	50° − 57.3′	P. 255
Ist. Alt. diff.	14.2′	(+) −
Corr. Table Alt. (Hc)	51° − 11.5′	

✓ Lat. Same name as Dec. / Lat. Contrary name to Dec.

Sight Reduction Table: d (+) P.255 −17.1 | 10 → 8.3 | 7.1 → 5.9 | + 14.2 p. 264

Dec 08° − 49.6′ (N) S p. 251

Table Dec	Table Z
8°	98.4°
9°	96.9° (−)
	1.5 → I.T. → diff. 1.2 p. 264

Sight Reduction Table (In north latitude ✓)

Table Z	98.4° (−) diff. 1.2 = 97.2°
Zn (Azimuth)	360° − Z = 262.8° (LHA<180°)

Sight Reduction Table (In South latitude)

Table Z =	± diff. ° = °
Zn (Azimuth)	180° − Z = ° (LHA>180°)
	180° + Z = ° (LHA<180°)

Lop of Star by Sight Reduction Table (Pub. No. 229) (U.K., U.S.A.)

Date	13/6/'85	Z.T.	8h	+ − (− circled)	Ship's Time	05h 17m	C.E.	0m 0s	+ −
Co.	042°	Speed	10.0 Kt.	HE	22 m	IE	0'	+ −	

D.R.P.	17°-11.3'	N (circled) S
	118°-23.4'	E (circled) W
Assumed Latitude	17°	N (circled) S
Body Vega.		
Zone Time / Ship's Time Date 13/6	h m s 05-17-00	
Long. in time or Z.T.	h m s 07-53-34	E(-) W(+)
Approx. U (GMT) Date 12/6	h m s 21-23-26	
If required	24	-
Approx. U (GMT) Date 12/6	h m s 21-23-26	
Chronometer Time	h m s 09-10-30	
Chronometer error	m s 0	+ -
Corrected Chro. Time	h m s 09-10-30	
If approx. U (GMT) is in afternoon	12	+
U (GMT) Date 12/Jun.	h m s 21-10-30	
Almanac Table ARIES GHA (21h)	° ' 216-07.5	
Incre. (10m 30s)	2-37.9	
Star SHA	80-53.1	+
GHA (21h 10m 30s)	299 38.5	
Assumed Longitude	118 21.5	E(+) (circled) W-
	418 0.0	
If required	360° (-)	
LHA	58°	
Table LHA	58°	
Dec.	38° 46.0	N (circled) S
Table Dec.	38°	N S
Dec. diff/Dec. incre	46.0	
Table alt.	35-24.2	
Ist. Alt. diff.	04.9	+ − (circled)
Corr. Table Alt. (Hc)	35-19.3	

Sex. Alt.	35-30.6	
I.E.	0.0	+ −
Obs. Alt.	35-30.6	
Dip (H.E.)	4.6	—
App. Alt.	35-26.0	
App. Alt. Corr.	1.4	—
True Alt. (Ht)	35-24.6	
Corr. Table Alt. (Hc)	35-19.3	—
Intercept	5.3 (+) (−)	to awy

Sight Reduction Table

Table Z	± 055.1 ± diff 0.9 = 54.2	
Zn (Azimuth)	360°-Z = 305.8	LHA<180°

In north latitude

Dec	38°-46.0 N (circled) S

Table Dec	Table Z	
38°	55.1	p.255.
39°	53.9 (-)	
	1.2	→ I.T. → diff 0.9

Sight Reduction Table

Table Z	± ± diff. ° = °	
Zn (Azimuth)	180°-Z = °	LHA>180°
	180°+Z = °	LHA<180°

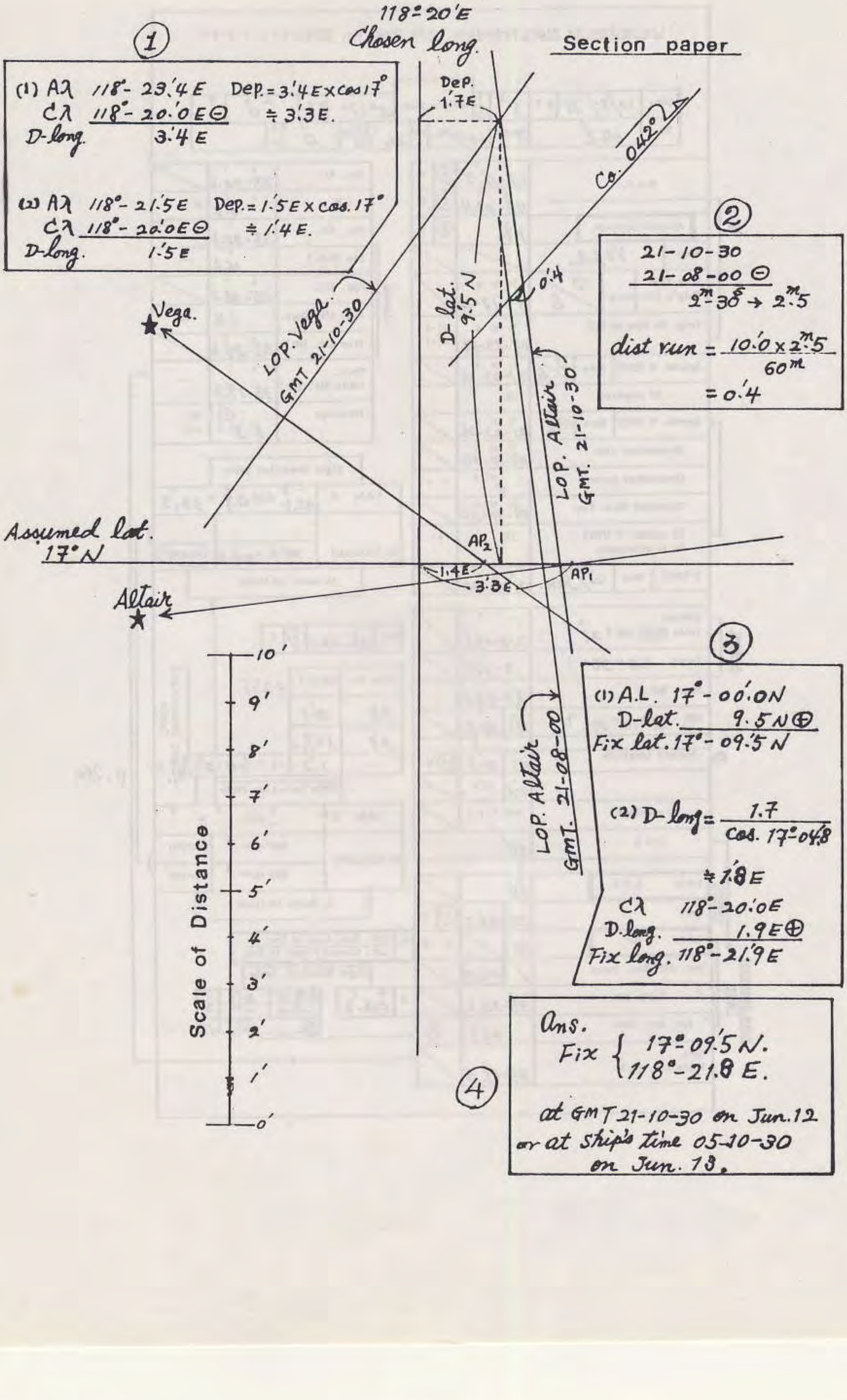
In South latitude

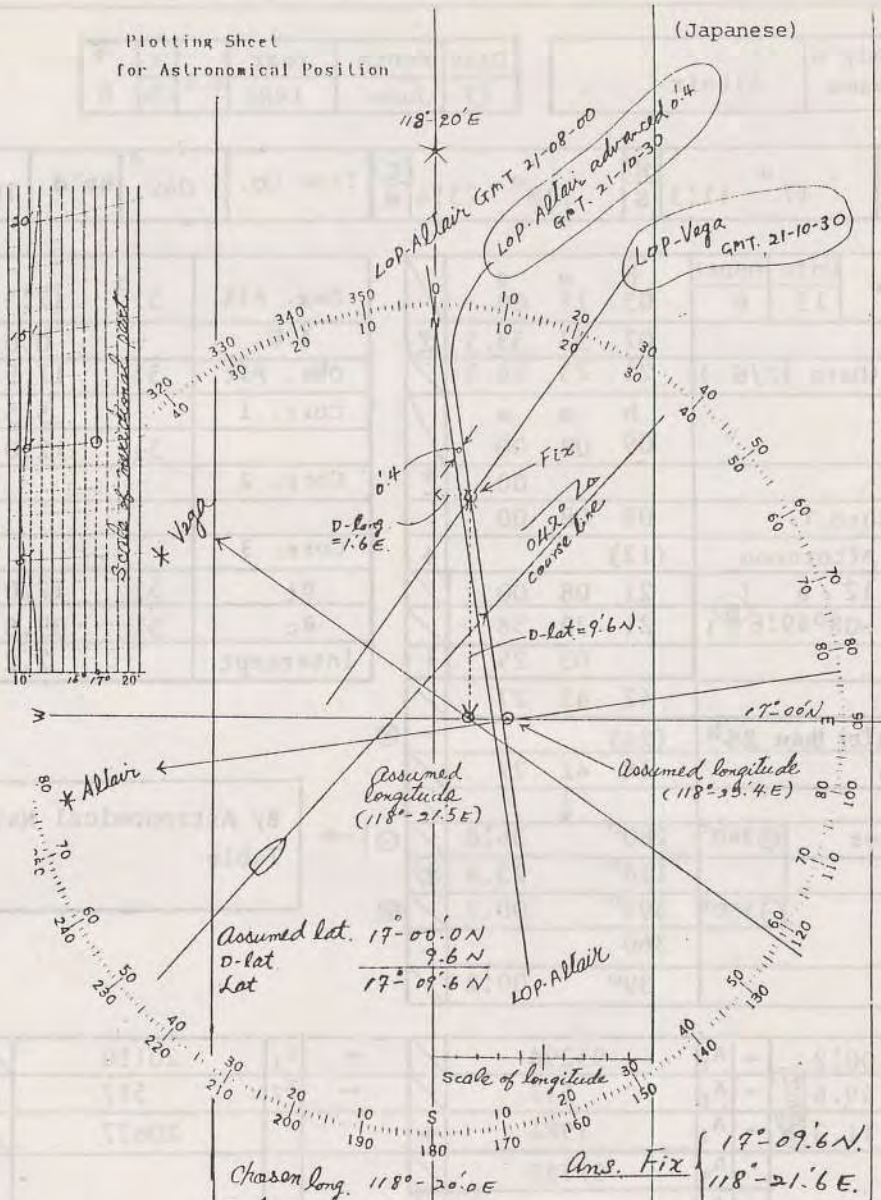
√ Lat. Same name as Dec.
Lat. Contrary name to Dec.

Sight Reduction Table

d	+ − (circled) 6.3	6.3 →	4.9	
		→		+
		3	4.9	−

p.264


118°20'E
Chosen long.
Section paper
①
(1) Aλ 118°-23'.4E Dep.=3'.4E×cos17°
Cλ 118°-20'.0E ⊖ ≒ 3'.3E.
D-long. 3'.4E
(2) Aλ 118°-21'.5E Dep.=1'.5E×cos.17°
Cλ 118°-20'.0E ⊖ ≒ 1'.4E.
D-long. 1'.5E
Dep. 1'.7E
Co. 042°
②
21-10-30
21-08-00 ⊖
2m-30s → 2m.5
dist run = 10'.0×2m.5 / 60m
= 0'.4
0'.4
D-lat. 9'.5N
Vega.
LOP. Vega. GMT 21-10-30
LOP. Altair GMT. 21-10-30
Assumed lat. 17°N
AP2
AP1
1.4E
3'.3E
Altair
LOP. Altair GMT. 21-08-00
Scale of Distance
10'
9'
8'
7'
6'
5'
4'
3'
2'
1'
0'
③
(1) A.L. 17°-00'.0N
D-lat. 9.5N ⊕
Fix lat. 17°-09'.5N
(2) D-long = 1.7 / cos. 17°-04'.8
≒ 1'.8E
Cλ 118°-20'.0E
D.long. 1.9E ⊕
Fix long. 118°-21'.9E
④
Ans.
Fix { 17°09'.5N. 118°-21.8 E.
at GMT 21-10-30 on Jun.12
or at ship's time 05-10-30 on Jun. 13.


Plotting Sheet
for Astronomical Position
(Japanese)
118°-20'E
LOP-Altair GMT 21-08-00
LOP-Altair advanced 0'.4
GMT. 21-10-30
LOP-Vega
GMT. 21-10-30
Scale of meridional part
* Vega
* Altair
Fix
0'.4
D-long =1.6E
042° 20
Course line
D-lat=9'.6N
17°-00'N
Assumed longitude
(118°-21.5E)
Assumed longitude
(118°-39.4E)
Assumed lat. 17°-00'.0N
D-lat 9.6 N
Lat 17°-09'.6 N
LOP-Altair
scale of longitude
Chosen long. 118°-20'.0E
D-long. 1.6E
118°-21'.6E
Ans. Fix 17°-09'.6N. 118°-21'.6E.

Line of Position of a Celestial Body (Japanese)

Body's name	Altair

Date	Month	Year	Z.T.	+ / ⊖	h
13	June	1985		⊖	8

D.R.P.	17° 11!3	(N) / S	118° 23!4	(E) / W	True Co.	042°	sp'd	10.0 kt.

	Date	Month	h	m	s	
Ship's Time	13	6	05	17	00	
※1→ L. in T.			07	53	33.5	±
Approx. U. (Date 12/6)			21	23	26.5	
Chro. T.			09	08	00	
Chro. E.					00	±
Corrected chro.T.			09	08	00	
Morning or Afternoon			(12)			+
Almanac: U. (Date 12 / 6)			21	08	00	
Almanac: E⊙✱☾P (d =08°49!6 (N)/S)			21	30	58	
Almanac: P.P				03	29	+
Almanac: h_G			42	42	27	
If h_G is greater than 24^h			(24)			− ⊙
h_G in hours			18	42	27	
h_G in degrees	⊕360°		280°		36!8	⊙
※2→ Long.			118°		23.4	⊕
	⊖360°		399°		00.2	⊙
			360			−
h			39°		00!2	

By Astronomical Navigation Table

Sex. Alt.	51°	17!5	
I.E.		0.0	±
Obs. Alt	51	17.5	
Corr. 1		5.5	⊕
	51	12.0	
Corr. 2		—	±
Corr. 3		—	±
a_t	51	12.0	
a_c	51	09.8	−
Intercept		2.2	⊕

h	39°	00!2	→	A_1	95294		→	Z_1	20110
d	08	49.6 (N)/S	→	A_2	517		=	Z_2	517 +
ℓ	17	11.3 (N)/S	→	A_3	1984	+			20627
				A_4	97795				
				↓					
				A_5	10521				
※3→ ℓ±d	08	21.7		A_6	531.5	+			
				A_7	11052.5		→	Z_3	20266 −
				↓				Z_4	361
				a_c	51° 09!8			↓ Z_c	N/(S) 82° 37!5 E/(W) ←※4

Ref.

1. Approx. U = Ship's Time ± L.in T.(E - long → ⊖, W - long. → ⊕)
2. h = h_G ± L (E - long → ⊕, W - Long → ⊖)
3. When ℓ and d same name → ℓ−d, contrary → ℓ + d.
4. When h > 180° suffix of Z_c → E, h < 180° suffix of Z_c → W.

Line of Position of a Celestial Body (Japanese)

Body's name	Vega.

Date	Month	Year	Z.T.	+ / ⊖	h
13	Jun.	1985		⊖	8

D.R.P.	17° 11!3	(N) / S	118° 23!4	(E) / W	True Co.	042°	sp'd	10.0 kt.

			h	m	s	
Ship's Time	Date 13	Month 6	05	17	00	
※1 → L. in T.			07	53	33.5	±
Approx. U. (Date 12/6)			21	23	26.5	
Chro. T.			09	10	30	
Chro. E.					00	±
Corrected chro.T.			09	10	30	
Morning or Afternoon			(12)			+
U. (Date /)			21	10	30	
E⊙✱☾P (d = 38°46!0 (N)/S)			22	44	35	
P.P				3	29	+
h_G			43	58	34	
If h_G is greater than 24^h			(24)			− ◎
h_G in hours			19	58	34	
h_G in degrees	⊕360°		299°		38!5	◎
※2 → Long.			118		23.4	± (+)
	⊖360°		418		01.9	◎
			360			−
h			58°		01.9	

Almanac

Sex. Alt.	35°	30!6	
I.E.		0.0	±
Obs. Alt	35	30.6	
Corr. 1		6.0	± (−)
	35	24.6	
Corr. 2		—	±
Corr. 3		—	±
At	35	24.6	
Ac	35	24.5	−
Intercept		0.1	(+)

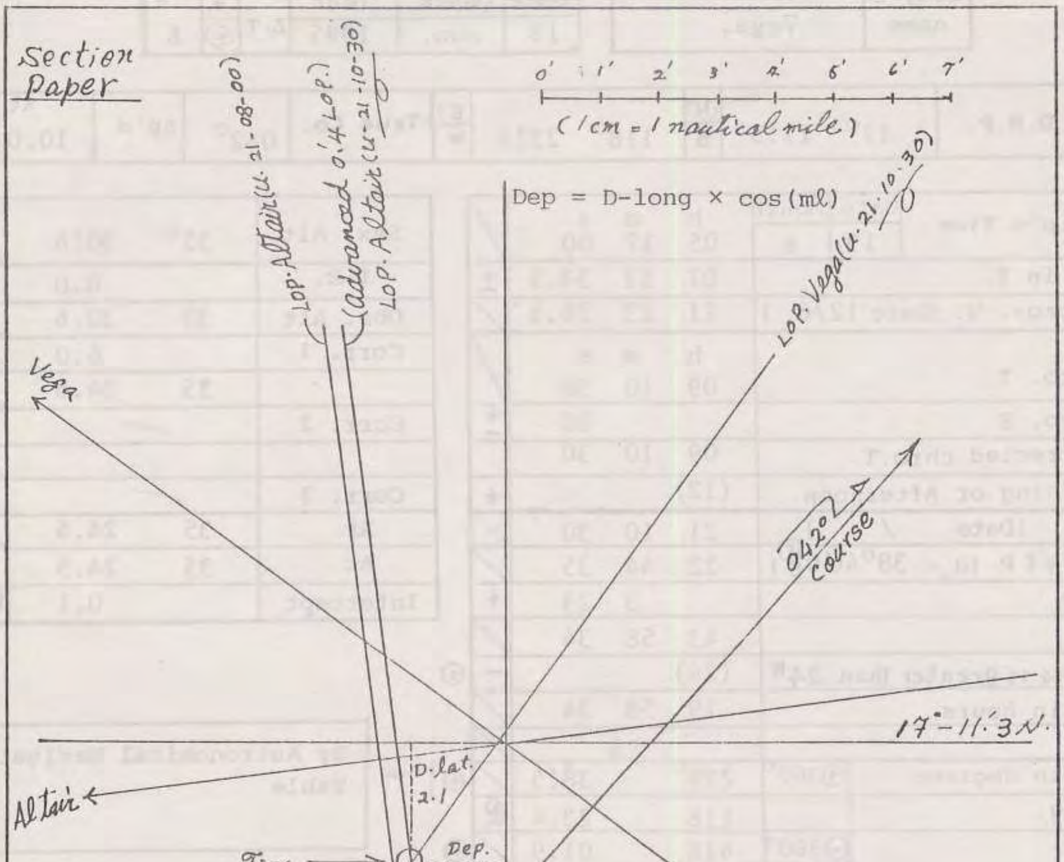
By Astronomical Navigation Table

h	58° 01!9		→ A_1	62842		→	Z_1	7143	
d	38 46.0	(N)/S	→ A_2	10807		=	Z_2	10807	+
ℓ	17 11.3	(N)/S	→ A_3	1984	+			17950	
			A_4	75633					
			↓						
			A_5	17526					
※3 → ℓ±d	21 34.7		A_6	3504	+				
			A_7	21030		→	Z_3	8881	−
			↓				Z_4	9069	
			ac	35° 24!5			↓ Zc	(N) S 54° 14!8 E (W)	← ※4

Ref.

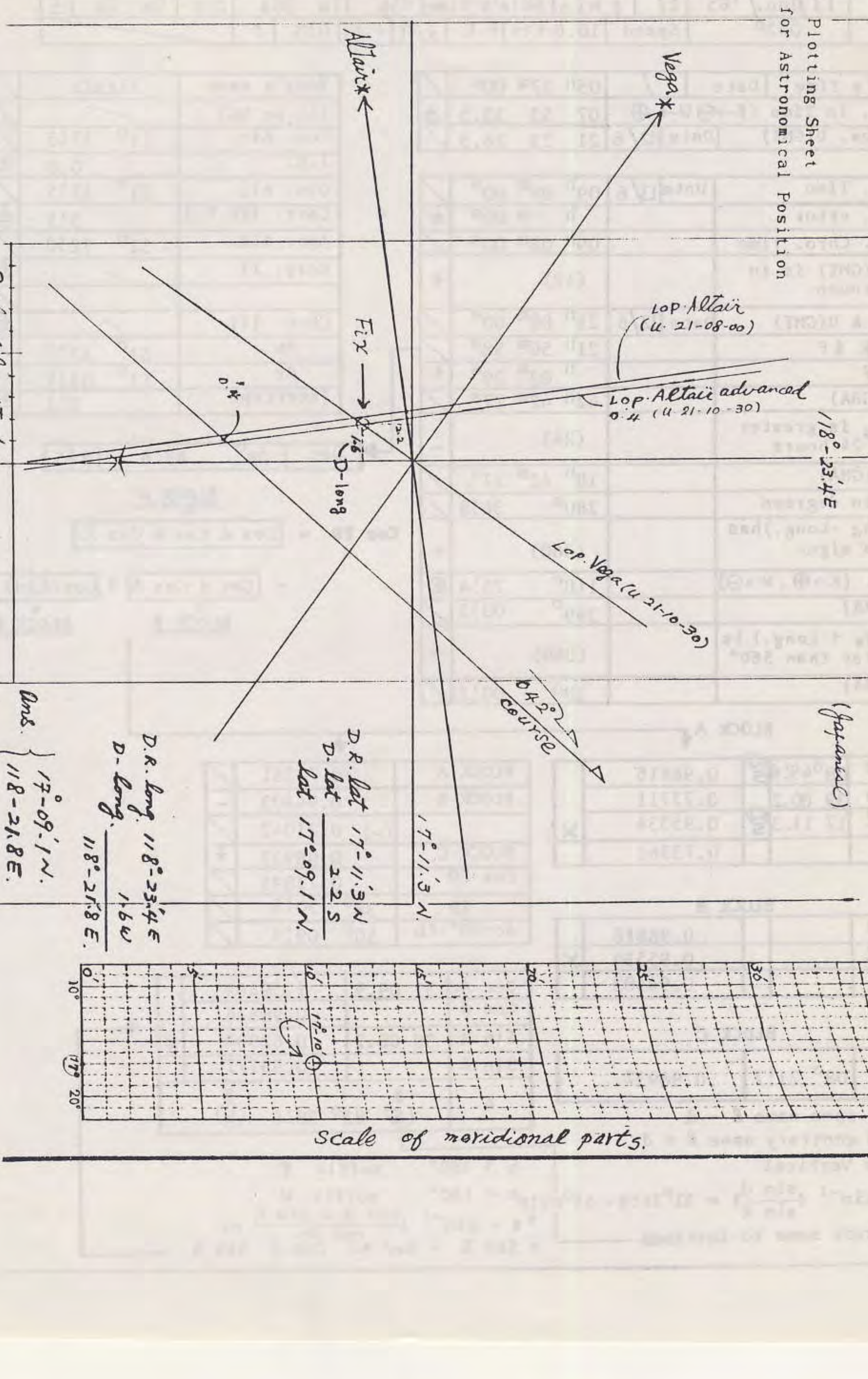
1. Approx. U = Ship's Time ± L.in T. (E - long → ⊖, W - long. → ⊕)
2. h = h_G ± L (E - long → ⊕, W - long → ⊖)
3. When ℓ and d same name → ℓ~d, contrary → ℓ + d.
4. When h > 180° suffix of Z_c → E, h < 180° suffix of Z_c → W.

(Japanese)



コクヨ コヒ-15D (52×36)

Plotting Sheet for Astronomical Position



LOP of Celestial Body → By formulae(⊙ ☾ ✱ P.)

		D.R.P.	17° 11!3	(N) S	118° 23!4	(E) W						
Date	13 Jun./ '85	ZT	8 h ⊖	Ship's Time	05h 17m 00s		C.E	0m 0s	±			
Co.	042°	Speed	10.0 Kts	H.E	22ft	I.E.	0!0	±				

Ship's Time	Date /	$05^h\ 17^m\ 00^s$	/
Long. in Time (E→⊖ W→⊕)		07 53 33.5	⊕
Approx. U(GMT)	Date 12/6	21 23 26.5	/
Chro. Time	Date 13/6	$09^h\ 08^m\ 00^s$	/
Chro. error		h m 00^s	±
Corr. Chro. Time		$09^h\ 08^m\ 00^s$	/
If U(GMT) is in afternoon		(12)	+
Date & U(GMT)	Date 12/6	$21^h\ 08^m\ 00^s$	/
E⊙ ✱ ☾ P		$21^h\ 50^m\ 58^s$	/
P.P		h $03^m\ 29^s$	+
h_G (GHA)		$42^h\ 42^m\ 27^s$	/
If h_G is greater than 24 hours		(24)	−
h_G (GHA)		$18^h\ 42^m\ 27^s$	/
h_G in degrees		280° 36!8	/
If (h_G −Long.) has "minus" sign.		(360)	+
Long. (E→⊕, W→⊖)		118° 25!4	⊕
h (LHA)		399° 00!2	/
If (h_G + Long.) is greater than 360°		(360)	−
h (LHA)		39° 00!2	/

Body's name	Altair	/
(LL or UL)	—	/
Sex. Alt.	51° 17!5	/
I.E.	0.0	±
Obs. Alt.	51° 17!5	/
Corr. I(H.E.)	5!5	⊖
App. Alt.	51° 12!0	/
Corr. II	—	±
		/
Corr. III	—	±
At	51° 12!0	/
Ac	51° 09!9	−
Intercept	2!1	⊕

Dec. 08° 49!6 | N S

BLOCK A

Cos ZD = Cos d Cos h Cos ℓ − Cos d Cos ℓ + Cos(ℓ±d)

BLOCK B   BLOCK C

BLOCK A

Cos d	08°49!6 (N/S)	0.98816		
Cos h	39 00.2	0.77711		
Cos ℓ	17 11.3 (N/S)	0.95534	×	
		0.73361		

BLOCK A	0.73361	/
BLOCK B	0.94403	−
	(−) 0.21042	/
BLOCK C	0.98937	∓
Cos ZD	0.77895	/
ZD	38° 50!1	/
Ac=90°−ZD	50° 09!9	/

BLOCK B

Cos d		0.98816	
Cos ℓ		0.95534	×
		0.94403	

Sec Ac	51 09.9	1.59469	
Cos d		0.98816	
Sin h	39 00.2	0.62937	×
Sin Z		0.99177	
Z	(N/S) 82° 38!6 (E/W)		

BLOCK C

Cos (ℓ±d)	08° 21!7	0.98937

ℓ & d same name ℓ − d

ℓ & d contrary name ℓ + d

Prime Vertical

$a = \sin^{-1}\left(\frac{\sin d}{\sin \ell}\right) = 31°16!9 < 51°09!9$

Contrary name to latitude

h > 180° suffix E

h < 180° suffix W

$°Z = \sin^{-1}\left(\frac{\cos d \times \sin h}{\cos Ac}\right)$ or

∘ Sin Z = Sec Ac Cos d Sin h

LOP of Celestial Body ⟶ By formulae (⊙ ☾ ✳ P.)

		D.R.P.	17° 11!3 (N) S	118° 23!4 (E) W			
Date	13/Jun./'85	ZT h ±	Ship's Time	05h 17m 00s	C.E	m s	±
Co.	042°	Speed	10.0 Kts	H.E 22 ft.	I.E. 0!0	±	

Ship's Time	Date	13/6	05h 17m 00s	╱
Long. in Time (E→⊖ W→ ⊕)			07 53 33.5	⊕
Approx. U(GMT)	Date	12/6	21 23 26.5	╱

Body's name	Vega.	╱
(LL or UL)	—	╱
Sex. Alt.	35° 30!6	╱
I.E.	—	±
Obs. Alt.	35° 30!6	╱
Corr. I(H.E.)	6.0	⊖
App. Alt.	35° 24.6	╱
Corr. II	—	±
		╱
Corr. III	—	±
At	35° 24.6	╱
Ac	35 24.6	−
Intercept	0.0	±

Chro. Time	Date 13/6	09h 10m 30s	╱
Chro. error		h 0m 0s	±
Corr. Chro. Time		09h 10m 30s	╱
If U(GMT) is in afternoon		(12)	+
Date & U(GMT)	Date 12/6	21h 10m 30s	╱
E⊙. ✳. ☾.P.		22h 44m 35s	╱
P.P		h 3m 29s	+
h_G (GHA)		43h 58m 34s	╱
If h_G is greater than 24 hours		(24)	−
h_G (GHA)		19h 58m 34s	╱
h_G in degrees		299° 38!5	╱
If (h_G -Long.)has "minus" sign		(360)	+
Long. (E→⊕, W→⊖)		118° 23!4	⊕
h (LHA)		418° 01!9	╱
If (h_G + Long.) is greater than 360°		(360)	−
h (LHA)		58° 01!9	╱

Dec. 38° 46!0 (N) S

$$\cos ZD = \underbrace{\cos d \cos h \cos \ell}_{\text{BLOCK A}} - \underbrace{\cos d \cos \ell}_{\text{BLOCK B}} + \underbrace{\cos(\ell \pm d)}_{\text{BLOCK C}}$$

BLOCK A

Cos d	38°46!0	(N)S	0.77970	
Cos h	58 01.9		0.52945	
Cos ℓ	17 11.3	(N)S	0.95534	×
			0.39438	

BLOCK B

Cos d	0.77970	
Cos ℓ	0.95534	×
	0.74488	

BLOCK C

Cos (ℓ±d)	21° 34!7	0.92992

ℓ & d same name ℓ − d

ℓ & d contrary name ℓ + d

BLOCK A	0.39438	╱
BLOCK B	0.74488	−
	(−) 0.35050	╱
BLOCK C	0.92992	+
Cos ZD	0.57942	╱
ZD	54° 35!4	╱
Ac=90°−ZD	35° 24!6	╱

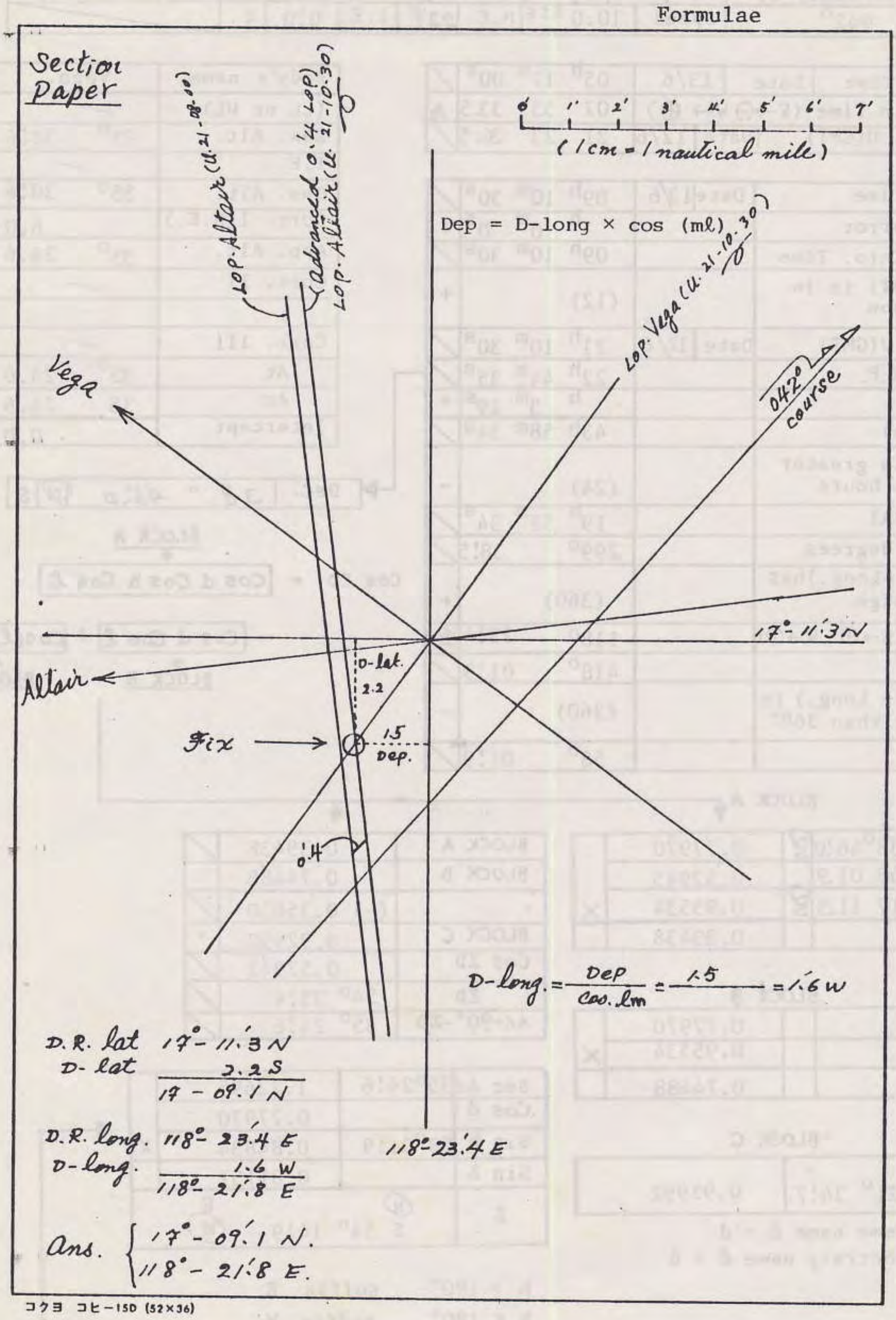
Sec Ac	35°24!6	1.22695	
Cos d		0.77970	
Sin h	58°01!9	0.84834	x
Sin Z		0.81157	
Z	(N) S 54° 14!9 E (W)		

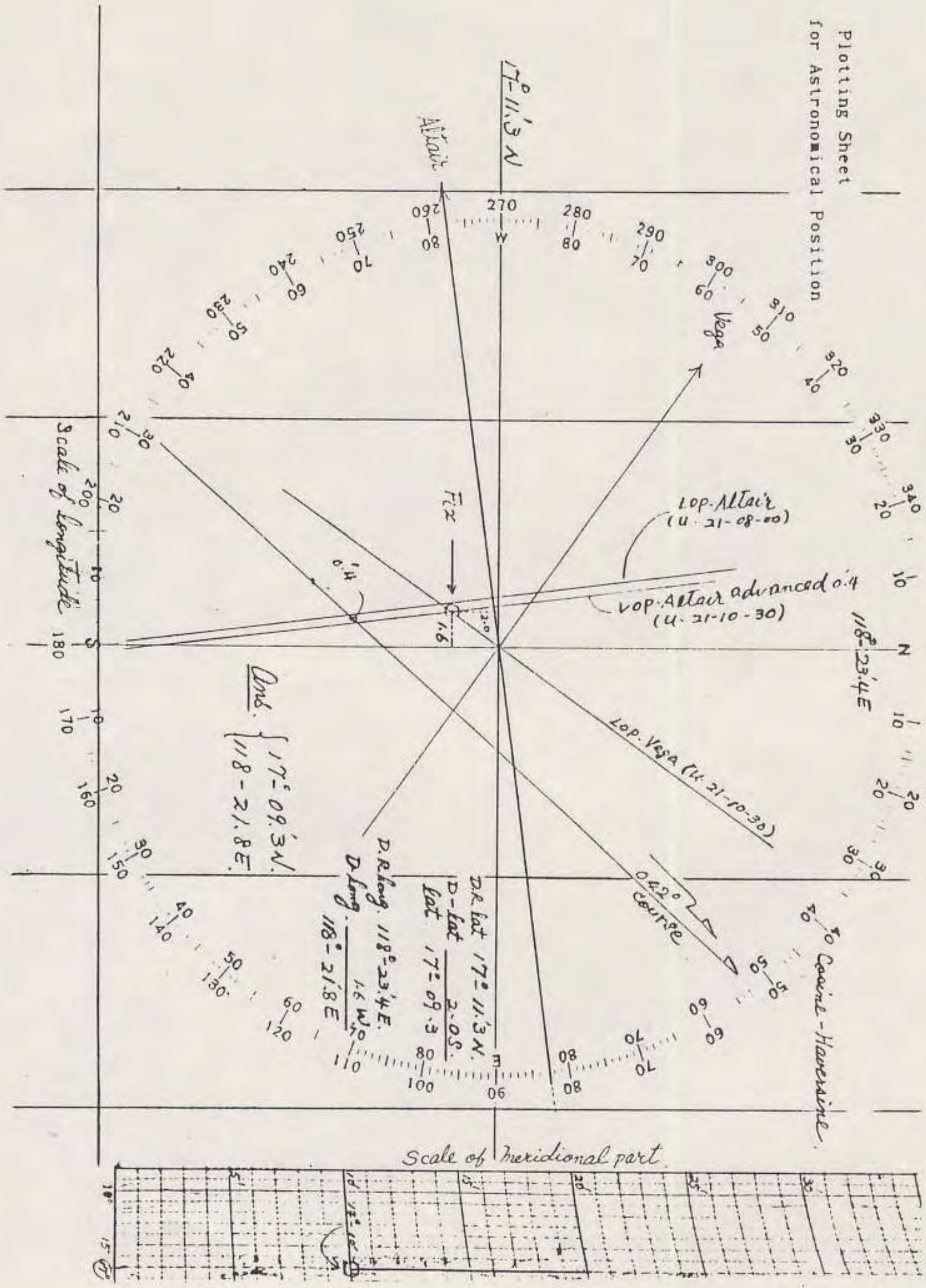
h > 180° suffix E

h < 180° suffix W

∘ Sin Z = Sec Ac Cos d Sin h

Formulae


Section Paper
0' 1' 2' 3' 4' 5' 6' 7'
(1cm = 1 nautical mile)
Dep = D-long × cos (ml)
LOP. Altair (U. 21-10.00)
(advanced 0.'4 LOP)
LOP. Altair (U. 21-10.30)
LOP. Vega (U. 21-10.30)
042° course
Vega
Altair
17°- 11.'3 N
D-lat. 2.2
Fix
1.5 Dep.
0.4
D-long. = Dep / cos. lm = 1.5 / = 1.'6 W
D.R. lat 17°- 11.'3 N
D-lat 2.2 S
17 - 09.1 N
D.R. long. 118°- 23.'4 E
D-long. 1.6 W
118°- 21.'8 E
118°- 23.'4 E
Ans. 17°- 09.'1 N.
118°- 21.'8 E.
コクヨ コヒ-15D (52×36)


Plotting Sheet
for Astronomical Position
17°-11.3'N
Altair
Vega
Fix
Lop-Altair
(U. 21-08-00)
Lop-Altair advanced 0'.4
(U. 21-10-30)
118°-23.4'E
Lop-Vega (U. 21-10-30)
042°
Course
Cosine-Haversine
Scale of Longitude
Ans. 17°-09.3'N.
118-21.8'E.
DR lat 17° 11.3'N.
D-lat 2.0S.
lat 17° 09.3
D.R.long. 118°-23.4'E.
1.6W.
D.long.
118°-21.8'E
Scale of Meridional part

NAUTICAL ALMANAC (1985)

&

INCREMENTS AND CORRECTIONS

EXTRACTED FROM THE NAUTICAL ALMANACE,
HER MAJESTY'S NAUTICAL ALMANAC OFFICE,
LONDON, U.K.

1985 JUNE 12, 13, 14 (WED., THURS., FRI.)

G.M.T. (UT)		ARIES	VENUS −3.9		MARS +1.9		JUPITER −2.2		SATURN +0.4		STARS		
d	h	G.H.A. ° ′	G.H.A. ° ′	Dec ° ′	G.H.A. ° ′	Dec ° ′	G.H.A. ° ′	Dec ° ′	G.H.A. ° ′	Dec ° ′	Name	S.H.A. ° ′	Dec. ° ′
12	00	260 15.8	226 25.8	N10 47.4	168 23.7	N24 17.7	300 42.8	S16 25.5	29 08.2	S16 15.7	Acamar	315 34.8	S40 21.6
	01	275 18.2	241 25.9	48.1	183 24.3	17.7	315 45.3	25.5	44 10.8	15.7	Achernar	335 42.7	S57 18.4
	02	290 20.7	256 26.1	48.8	198 25.0	17.7	330 47.8	25.6	59 13.4	15.6	Acrux	173 33.5	S63 01.3
	03	305 23.2	271 26.2	· · 49.5	213 25.6	· · 17.7	345 50.3	· · 25.6	74 16.1	· · 15.6	Adhara	255 29.7	S28 57.1
	04	320 25.6	286 26.4	50.2	228 26.2	17.7	0 52.9	25.6	89 18.7	15.6	Aldebaran	291 14.3	N16 28.9
	05	335 28.1	301 26.5	50.9	243 26.9	17.7	15 55.4	25.6	104 21.3	15.5			
	06	350 30.6	316 26.7	N10 51.6	258 27.5	N24 17.6	30 57.9	S16 25.7	119 23.9	S16 15.5	Alioth	166 39.0	N56 02.6
W	07	5 33.0	331 26.8	52.3	273 28.1	17.6	46 00.4	25.7	134 26.5	15.5	Alkaid	153 15.3	N49 23.4
E	08	20 35.5	346 27.0	53.0	288 28.8	17.6	61 02.9	25.7	149 29.2	15.4	Al Na'ir	28 10.2	S47 01.8
D	09	35 38.0	1 27.1	· · 53.7	303 29.4	· · 17.6	76 05.5	· · 25.7	164 31.8	· · 15.4	Alnilam	276 08.4	S 1 12.6
N	10	50 40.4	16 27.3	54.5	318 30.1	17.6	91 08.0	25.8	179 34.4	15.4	Alphard	218 17.3	S 8 35.6
E	11	65 42.9	31 27.4	55.2	333 30.7	17.6	106 10.5	25.8	194 37.0	15.3			
S	12	80 45.4	46 27.6	N10 55.9	348 31.3	N24 17.6	121 13.0	S16 25.8	209 39.6	S16 15.3	Alphecca	126 28.7	N26 45.8
D	13	95 47.8	61 27.7	56.6	3 32.0	17.6	136 15.5	25.9	224 42.2	15.3	Alpheratz	358 05.8	N29 00.4
A	14	110 50.3	76 27.8	57.3	18 32.6	17.6	151 18.1	25.9	239 44.9	15.3	Altair	62 28.8	N 8 49.6
Y	15	125 52.7	91 28.0	· · 58.0	33 33.3	· · 17.5	166 20.6	· · 25.9	254 47.5	· · 15.2	Ankaa	353 36.7	S42 23.0
	16	140 55.2	106 28.1	58.7	48 33.9	17.5	181 23.1	25.9	269 50.1	15.2	Antares	112 52.2	S26 24.1
	17	155 57.7	121 28.3	10 59.4	63 34.5	17.5	196 25.6	26.0	284 52.7	15.2			
	18	171 00.1	136 28.4	N11 00.1	78 35.2	N24 17.5	211 28.1	S16 26.0	299 55.3	S16 15.1	Arcturus	146 15.0	N19 15.5
	19	186 02.6	151 28.5	00.8	93 35.8	17.5	226 30.7	26.0	314 58.0	15.1	Atria	108 12.8	S69 00.3
	20	201 05.1	166 28.7	01.5	108 36.5	17.5	241 33.2	26.1	330 00.6	15.1	Avior	234 27.4	S59 27.8
	21	216 07.5	181 28.8	· · 02.2	123 37.1	· · 17.5	256 35.7	· · 26.1	345 03.2	· · 15.0	Bellatrix	278 55.3	N 6 20.3
	22	231 10.0	196 28.9	02.9	138 37.7	17.5	271 38.2	26.1	0 05.8	15.0	Betelgeuse	271 24.8	N 7 24.4
	23	246 12.5	211 29.1	03.6	153 38.4	17.4	286 40.8	26.1	15 08.4	15.0			
13	00	261 14.7	226 29.2	N11 04.3	168 39.0	N24 17.4	301 43.3	S16 26.2	30 11.1	S16 14.9	Canopus	264 06.2	S52 41.2
	01	276 17.4	241 29.3	05.0	183 39.6	17.4	316 45.8	26.2	45 13.7	14.9	Capella	281 06.6	N45 59.1
	02	291 19.8	256 29.5	05.7	198 40.3	17.4	331 48.3	26.2	60 16.3	14.9	Deneb	49 45.9	N45 13.4
	03	306 22.3	271 29.6	· · 06.4	213 40.9	· · 17.4	346 50.9	· · 26.3	75 18.9	· · 14.8	Denebola	182 55.4	N14 39.4
	04	321 24.8	286 29.7	07.1	228 41.6	17.4	1 53.4	26.3	90 21.5	14.8	Diphda	349 17.4	S18 04.0
	05	336 27.2	301 29.9	07.8	243 42.2	17.3	16 55.9	26.3	105 24.1	14.8			
	06	351 29.7	316 30.0	N11 08.5	258 42.8	N24 17.3	31 58.4	S16 26.3	120 26.8	S16 14.8	Dubhe	194 17.6	N61 50.2
	07	6 32.2	331 30.1	09.2	273 43.5	17.3	47 01.0	26.4	135 29.4	14.7	Elnath	278 40.1	N28 35.8
T	08	21 34.6	346 30.3	09.9	288 44.1	17.3	62 03.5	26.4	150 32.0	14.7	Eltanin	90 55.6	N51 29.3
H	09	36 37.1	1 30.4	· · 10.7	303 44.8	· · 17.3	77 06.0	· · 26.4	165 34.6	· · 14.7	Enif	34 08.0	N 9 48.3
U	10	51 39.6	16 30.5	11.4	318 45.4	17.3	92 08.6	26.5	180 37.2	14.6	Fomalhaut	15 47.4	S29 41.9
R	11	66 42.0	31 30.6	12.1	333 46.0	17.2	107 11.1	26.5	195 39.8	14.6			
S	12	81 44.5	46 30.8	N11 12.8	348 46.7	N24 17.2	122 13.6	S16 26.5	210 42.5	S16 14.6	Gacrux	172 24.9	S57 02.1
D	13	96 47.0	61 30.9	13.5	3 47.3	17.2	137 16.1	26.6	225 45.1	14.5	Gienah	176 14.3	S17 27.7
A	14	111 49.4	76 31.0	14.2	18 48.0	17.2	152 18.7	26.6	240 47.7	14.5	Hadar	149 18.2	S60 18.4
Y	15	126 51.9	91 31.1	· · 14.9	33 48.6	· · 17.2	167 21.2	· · 26.6	255 50.3	· · 14.5	Hamal	328 25.2	N23 23.5
	16	141 54.3	106 31.2	15.6	48 49.3	17.1	182 23.7	26.6	270 52.9	14.4	Kaus Aust.	84 11.8	S34 23.6
	17	156 56.8	121 31.4	16.3	63 49.9	17.1	197 26.3	26.7	285 55.5	14.4			
	18	171 59.3	136 31.5	N11 17.0	78 50.5	N24 17.1	212 28.8	S16 26.7	300 58.2	S16 14.4	Kochab	137 17.7	N74 13.1
	19	187 01.7	151 31.6	17.7	93 51.2	17.1	227 31.3	26.7	316 00.8	14.4	Markab	13 59.7	N15 07.4
	20	202 04.2	166 31.7	18.4	108 51.8	17.0	242 33.9	26.8	331 03.4	14.3	Menkar	314 37.7	N 4 02.0
	21	217 06.7	181 31.8	· · 19.1	123 52.5	· · 17.0	257 36.4	· · 26.8	346 06.0	· · 14.3	Menkent	148 32.7	S36 18.1
	22	232 09.1	196 32.0	19.8	138 53.1	17.0	272 38.9	26.8	1 08.6	14.3	Miaplacidus	221 45.1	S69 39.6
	23	247 11.6	211 32.1	20.5	153 53.7	17.0	287 41.4	26.9	16 11.2	14.2			
14	00	262 14.1	226 32.2	N11 21.3	168 54.4	N24 17.0	302 44.0	S16 26.9	31 13.8	S16 14.2	Mirfak	309 11.6	N49 48.5
	01	277 16.5	241 32.3	22.0	183 55.0	16.9	317 46.5	26.9	46 16.5	14.2	Nunki	76 24.4	S26 19.0
	02	292 19.0	256 32.4	22.7	198 55.7	16.9	332 49.0	27.0	61 19.1	14.1	Peacock	53 52.2	S56 46.9
	03	307 21.5	271 32.5	· · 23.4	213 56.3	· · 16.9	347 51.6	· · 27.0	76 21.7	· · 14.1	Pollux	243 54.1	N28 03.9
	04	322 23.9	286 32.6	24.1	228 56.9	16.9	2 54.1	27.0	91 24.3	14.1	Procyon	245 22.4	N 5 15.9
	05	337 26.4	301 32.8	24.8	243 57.6	16.8	17 56.6	27.0	106 26.9	14.1			
	06	352 28.8	316 32.9	N11 25.5	258 58.2	N24 16.8	32 59.2	S16 27.1	121 29.5	S16 14.0	Rasalhague	96 26.0	N12 34.1
	07	7 31.3	331 33.0	26.2	273 58.9	16.8	48 01.7	27.1	136 32.2	14.0	Regulus	208 06.4	N12 02.5
	08	22 33.8	346 33.1	26.9	288 59.5	16.7	63 04.3	27.1	151 34.8	14.0	Rigel	281 33.0	S 8 13.0
F	09	37 36.2	1 33.2	· · 27.6	304 00.2	· · 16.7	78 06.8	· · 27.2	166 37.4	· · 13.9	Rigil Kent.	140 20.8	S60 46.7
R	10	52 38.7	16 33.3	28.3	319 00.8	16.7	93 09.3	27.2	181 40.0	13.9	Sabik	102 36.8	S15 42.6
I	11	67 41.2	31 33.4	29.0	334 01.4	16.7	108 11.9	27.2	196 42.6	13.9			
D	12	82 43.6	46 33.5	N11 29.8	349 02.1	N24 16.6	123 14.4	S16 27.3	211 45.2	S16 13.8	Schedar	350 05.4	N56 27.1
A	13	97 46.1	61 33.6	30.5	4 02.7	16.6	138 16.9	27.3	226 47.8	13.8	Shaula	96 50.6	S37 05.8
Y	14	112 48.6	76 33.7	31.2	19 03.4	16.6	153 19.5	27.3	241 50.4	13.8	Sirius	258 52.9	S16 41.7
	15	127 51.0	91 33.8	· · 31.9	34 04.0	· · 16.6	168 22.0	· · 27.4	256 53.1	· · 13.8	Spica	158 53.7	S11 05.2
	16	142 53.5	106 33.9	32.6	49 04.6	16.5	183 24.5	27.4	271 55.7	13.7	Suhail	223 08.6	S43 22.5
	17	157 55.9	121 34.0	33.3	64 05.3	16.5	198 27.1	27.4	286 58.3	13.7			
	18	172 58.4	136 34.1	N11 34.0	79 05.9	N24 16.5	213 29.6	S16 27.5	302 00.9	S16 13.7	Vega	80 53.1	N38 46.0
	19	188 00.9	151 34.2	34.7	94 06.6	16.4	228 32.2	27.5	317 03.5	13.6	Zuben'ubi	137 28.9	S15 59.0
	20	203 03.3	166 34.3	35.4	109 07.2	16.4	243 34.7	27.5	332 06.1	13.6		S.H.A. ° ′	Mer. Pass. h m
	21	218 05.8	181 34.4	· · 36.1	124 07.9	· · 16.4	258 37.2	· · 27.6	347 08.7	· · 13.6			
	22	233 08.3	196 34.5	36.8	139 08.5	16.3	273 39.8	27.6	2 11.4	13.6	Venus	325 14.3	8 54
	23	248 10.7	211 34.6	37.6	154 09.1	16.3	288 42.3	27.6	17 14.0	13.5	Mars	267 24.1	12 45
Mer. Pass.		h m 6 33.9	v 0.1	d 0.7	v 0.6	d 0.0	v 2.5	d 0.0	v 2.6	d 0.0	Jupiter	40 28.4	3 52
											Saturn	128 56.1	21 55

10ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	2 30·0	2 30·4	2 23·2	0·0	0·0	6·0	1·1	12·0	2·1
01	2 30·3	2 30·7	2 23·4	0·1	0·0	6·1	1·1	12·1	2·1
02	2 30·5	2 30·9	2 23·6	0·2	0·0	6·2	1·1	12·2	2·1
03	2 30·8	2 31·2	2 23·9	0·3	0·1	6·3	1·1	12·3	2·2
04	2 31·0	2 31·4	2 24·1	0·4	0·1	6·4	1·1	12·4	2·2
05	2 31·3	2 31·7	2 24·4	0·5	0·1	6·5	1·1	12·5	2·2
06	2 31·5	2 31·9	2 24·6	0·6	0·1	6·6	1·2	12·6	2·2
07	2 31·8	2 32·2	2 24·8	0·7	0·1	6·7	1·2	12·7	2·2
08	2 32·0	2 32·4	2 25·1	0·8	0·1	6·8	1·2	12·8	2·2
09	2 32·3	2 32·7	2 25·3	0·9	0·2	6·9	1·2	12·9	2·3
10	2 32·5	2 32·9	2 25·6	1·0	0·2	7·0	1·2	13·0	2·3
11	2 32·8	2 33·2	2 25·8	1·1	0·2	7·1	1·2	13·1	2·3
12	2 33·0	2 33·4	2 26·0	1·2	0·2	7·2	1·3	13·2	2·3
13	2 33·3	2 33·7	2 26·3	1·3	0·2	7·3	1·3	13·3	2·3
14	2 33·5	2 33·9	2 26·5	1·4	0·2	7·4	1·3	13·4	2·3
15	2 33·8	2 34·2	2 26·7	1·5	0·3	7·5	1·3	13·5	2·4
16	2 34·0	2 34·4	2 27·0	1·6	0·3	7·6	1·3	13·6	2·4
17	2 34·3	2 34·7	2 27·2	1·7	0·3	7·7	1·3	13·7	2·4
18	2 34·5	2 34·9	2 27·5	1·8	0·3	7·8	1·4	13·8	2·4
19	2 34·8	2 35·2	2 27·7	1·9	0·3	7·9	1·4	13·9	2·4
20	2 35·0	2 35·4	2 27·9	2·0	0·4	8·0	1·4	14·0	2·5
21	2 35·3	2 35·7	2 28·2	2·1	0·4	8·1	1·4	14·1	2·5
22	2 35·5	2 35·9	2 28·4	2·2	0·4	8·2	1·4	14·2	2·5
23	2 35·8	2 36·2	2 28·7	2·3	0·4	8·3	1·5	14·3	2·5
24	2 36·0	2 36·4	2 28·9	2·4	0·4	8·4	1·5	14·4	2·5
25	2 36·3	2 36·7	2 29·1	2·5	0·4	8·5	1·5	14·5	2·5
26	2 36·5	2 36·9	2 29·4	2·6	0·5	8·6	1·5	14·6	2·6
27	2 36·8	2 37·2	2 29·6	2·7	0·5	8·7	1·5	14·7	2·6
28	2 37·0	2 37·4	2 29·8	2·8	0·5	8·8	1·5	14·8	2·6
29	2 37·3	2 37·7	2 30·1	2·9	0·5	8·9	1·6	14·9	2·6
30	2 37·5	2 37·9	2 30·3	3·0	0·5	9·0	1·6	15·0	2·6
31	2 37·8	2 38·2	2 30·6	3·1	0·5	9·1	1·6	15·1	2·6
32	2 38·0	2 38·4	2 30·8	3·2	0·6	9·2	1·6	15·2	2·7
33	2 38·3	2 38·7	2 31·0	3·3	0·6	9·3	1·6	15·3	2·7
34	2 38·5	2 38·9	2 31·3	3·4	0·6	9·4	1·6	15·4	2·7
35	2 38·8	2 39·2	2 31·5	3·5	0·6	9·5	1·7	15·5	2·7
36	2 39·0	2 39·4	2 31·8	3·6	0·6	9·6	1·7	15·6	2·7
37	2 39·3	2 39·7	2 32·0	3·7	0·6	9·7	1·7	15·7	2·7
38	2 39·5	2 39·9	2 32·2	3·8	0·7	9·8	1·7	15·8	2·8
39	2 39·8	2 40·2	2 32·5	3·9	0·7	9·9	1·7	15·9	2·8
40	2 40·0	2 40·4	2 32·7	4·0	0·7	10·0	1·8	16·0	2·8
41	2 40·3	2 40·7	2 32·9	4·1	0·7	10·1	1·8	16·1	2·8
42	2 40·5	2 40·9	2 33·2	4·2	0·7	10·2	1·8	16·2	2·8
43	2 40·8	2 41·2	2 33·4	4·3	0·8	10·3	1·8	16·3	2·9
44	2 41·0	2 41·4	2 33·7	4·4	0·8	10·4	1·8	16·4	2·9
45	2 41·3	2 41·7	2 33·9	4·5	0·8	10·5	1·8	16·5	2·9
46	2 41·5	2 41·9	2 34·1	4·6	0·8	10·6	1·9	16·6	2·9
47	2 41·8	2 42·2	2 34·4	4·7	0·8	10·7	1·9	16·7	2·9
48	2 42·0	2 42·4	2 34·6	4·8	0·8	10·8	1·9	16·8	2·9
49	2 42·3	2 42·7	2 34·9	4·9	0·9	10·9	1·9	16·9	3·0
50	2 42·5	2 42·9	2 35·1	5·0	0·9	11·0	1·9	17·0	3·0
51	2 42·8	2 43·2	2 35·3	5·1	0·9	11·1	1·9	17·1	3·0
52	2 43·0	2 43·4	2 35·6	5·2	0·9	11·2	2·0	17·2	3·0
53	2 43·3	2 43·7	2 35·8	5·3	0·9	11·3	2·0	17·3	3·0
54	2 43·5	2 43·9	2 36·1	5·4	0·9	11·4	2·0	17·4	3·0
55	2 43·8	2 44·2	2 36·3	5·5	1·0	11·5	2·0	17·5	3·1
56	2 44·0	2 44·4	2 36·5	5·6	1·0	11·6	2·0	17·6	3·1
57	2 44·3	2 44·7	2 36·8	5·7	1·0	11·7	2·0	17·7	3·1
58	2 44·5	2 45·0	2 37·0	5·8	1·0	11·8	2·1	17·8	3·1
59	2 44·8	2 45·2	2 37·2	5·9	1·0	11·9	2·1	17·9	3·1
60	2 45·0	2 45·5	2 37·5	6·0	1·1	12·0	2·1	18·0	3·2

11ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	2 45·0	2 45·5	2 37·5	0·0	0·0	6·0	1·2	12·0	2·3
01	2 45·3	2 45·7	2 37·7	0·1	0·0	6·1	1·2	12·1	2·3
02	2 45·5	2 46·0	2 38·0	0·2	0·0	6·2	1·2	12·2	2·3
03	2 45·8	2 46·2	2 38·2	0·3	0·1	6·3	1·2	12·3	2·4
04	2 46·0	2 46·5	2 38·4	0·4	0·1	6·4	1·2	12·4	2·4
05	2 46·3	2 46·7	2 38·7	0·5	0·1	6·5	1·2	12·5	2·4
06	2 46·5	2 47·0	2 38·9	0·6	0·1	6·6	1·3	12·6	2·4
07	2 46·8	2 47·2	2 39·2	0·7	0·1	6·7	1·3	12·7	2·4
08	2 47·0	2 47·5	2 39·4	0·8	0·2	6·8	1·3	12·8	2·5
09	2 47·3	2 47·7	2 39·6	0·9	0·2	6·9	1·3	12·9	2·5
10	2 47·5	2 48·0	2 39·9	1·0	0·2	7·0	1·3	13·0	2·5
11	2 47·8	2 48·2	2 40·1	1·1	0·2	7·1	1·4	13·1	2·5
12	2 48·0	2 48·5	2 40·3	1·2	0·2	7·2	1·4	13·2	2·5
13	2 48·3	2 48·7	2 40·6	1·3	0·2	7·3	1·4	13·3	2·5
14	2 48·5	2 49·0	2 40·8	1·4	0·3	7·4	1·4	13·4	2·6
15	2 48·8	2 49·2	2 41·1	1·5	0·3	7·5	1·4	13·5	2·6
16	2 49·0	2 49·5	2 41·3	1·6	0·3	7·6	1·5	13·6	2·6
17	2 49·3	2 49·7	2 41·5	1·7	0·3	7·7	1·5	13·7	2·6
18	2 49·5	2 50·0	2 41·8	1·8	0·3	7·8	1·5	13·8	2·5
19	2 49·8	2 50·2	2 42·0	1·9	0·4	7·9	1·5	13·9	2·7
20	2 50·0	2 50·5	2 42·3	2·0	0·4	8·0	1·5	14·0	2·7
21	2 50·3	2 50·7	2 42·5	2·1	0·4	8·1	1·6	14·1	2·7
22	2 50·5	2 51·0	2 42·7	2·2	0·4	8·2	1·6	14·2	2·7
23	2 50·8	2 51·2	2 43·0	2·3	0·4	8·3	1·6	14·3	2·7
24	2 51·0	2 51·5	2 43·2	2·4	0·5	8·4	1·6	14·4	2·8
25	2 51·3	2 51·7	2 43·4	2·5	0·5	8·5	1·6	14·5	2·8
26	2 51·5	2 52·0	2 43·7	2·6	0·5	8·6	1·6	14·6	2·8
27	2 51·8	2 52·2	2 43·9	2·7	0·5	8·7	1·7	14·7	2·8
28	2 52·0	2 52·5	2 44·2	2·8	0·5	8·8	1·7	14·8	2·8
29	2 52·3	2 52·7	2 44·4	2·9	0·6	8·9	1·7	14·9	2·9
30	2 52·5	2 53·0	2 44·6	3·0	0·6	9·0	1·7	15·0	2·9
31	2 52·8	2 53·2	2 44·9	3·1	0·6	9·1	1·7	15·1	2·9
32	2 53·0	2 53·5	2 45·1	3·2	0·6	9·2	1·8	15·2	2·9
33	2 53·3	2 53·7	2 45·4	3·3	0·6	9·3	1·8	15·3	2·9
34	2 53·5	2 54·0	2 45·6	3·4	0·7	9·4	1·8	15·4	3·0
35	2 53·8	2 54·2	2 45·8	3·5	0·7	9·5	1·8	15·5	3·0
36	2 54·0	2 54·5	2 46·1	3·6	0·7	9·6	1·8	15·6	3·0
37	2 54·3	2 54·7	2 46·3	3·7	0·7	9·7	1·9	15·7	3·0
38	2 54·5	2 55·0	2 46·6	3·8	0·7	9·8	1·9	15·8	3·0
39	2 54·8	2 55·2	2 46·8	3·9	0·7	9·9	1·9	15·9	3·0
40	2 55·0	2 55·5	2 47·0	4·0	0·8	10·0	1·9	16·0	3·1
41	2 55·3	2 55·7	2 47·3	4·1	0·8	10·1	1·9	16·1	3·1
42	2 55·5	2 56·0	2 47·5	4·2	0·8	10·2	2·0	16·2	3·1
43	2 55·8	2 56·2	2 47·7	4·3	0·8	10·3	2·0	16·3	3·1
44	2 56·0	2 56·5	2 48·0	4·4	0·8	10·4	2·0	16·4	3·1
45	2 56·3	2 56·7	2 48·2	4·5	0·9	10·5	2·0	16·5	3·2
46	2 56·5	2 57·0	2 48·5	4·6	0·9	10·6	2·0	16·6	3·2
47	2 56·8	2 57·2	2 48·7	4·7	0·9	10·7	2·1	16·7	3·2
48	2 57·0	2 57·5	2 48·9	4·8	0·9	10·8	2·1	16·8	3·2
49	2 57·3	2 57·7	2 49·2	4·9	0·9	10·9	2·1	16·9	3·2
50	2 57·5	2 58·0	2 49·4	5·0	1·0	11·0	2·1	17·0	3·3
51	2 57·8	2 58·2	2 49·7	5·1	1·0	11·1	2·1	17·1	3·3
52	2 58·0	2 58·5	2 49·9	5·2	1·0	11·2	2·1	17·2	3·3
53	2 58·3	2 58·7	2 50·1	5·3	1·0	11·3	2·2	17·3	3·3
54	2 58·5	2 59·0	2 50·4	5·4	1·0	11·4	2·2	17·4	3·3
55	2 58·8	2 59·2	2 50·6	5·5	1·1	11·5	2·2	17·5	3·4
56	2 59·0	2 59·5	2 50·8	5·6	1·1	11·6	2·2	17·6	3·4
57	2 59·3	2 59·7	2 51·1	5·7	1·1	11·7	2·2	17·7	3·4
58	2 59·5	3 00·0	2 51·3	5·8	1·1	11·8	2·3	17·8	3·4
59	2 59·8	3 00·2	2 51·6	5·9	1·1	11·9	2·3	17·9	3·4
60	3 00·0	3 00·5	2 51·8	6·0	1·2	12·0	2·3	18·0	3·5

INCREMENTS AND CORRECTIONS

8m

8m s	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° ′	° ′	° ′	′	′	′	′	′	′
00	2 00·0	2 00·3	1 54·5	0·0	0·0	6·0	0·9	12·0	1·7
01	2 00·3	2 00·6	1 54·8	0·1	0·0	6·1	0·9	12·1	1·7
02	2 00·5	2 00·8	1 55·0	0·2	0·0	6·2	0·9	12·2	1·7
03	2 00·8	2 01·1	1 55·2	0·3	0·0	6·3	0·9	12·3	1·7
04	2 01·0	2 01·3	1 55·5	0·4	0·1	6·4	0·9	12·4	1·8
05	2 01·3	2 01·6	1 55·7	0·5	0·1	6·5	0·9	12·5	1·8
06	2 01·5	2 01·8	1 56·0	0·6	0·1	6·6	0·9	12·6	1·8
07	2 01·8	2 02·1	1 56·2	0·7	0·1	6·7	0·9	12·7	1·8
08	2 02·0	2 02·3	1 56·4	0·8	0·1	6·8	1·0	12·8	1·8
09	2 02·3	2 02·6	1 56·7	0·9	0·1	6·9	1·0	12·9	1·8
10	2 02·5	2 02·8	1 56·9	1·0	0·1	7·0	1·0	13·0	1·8
11	2 02·8	2 03·1	1 57·2	1·1	0·2	7·1	1·0	13·1	1·9
12	2 03·0	2 03·3	1 57·4	1·2	0·2	7·2	1·0	13·2	1·9
13	2 03·3	2 03·6	1 57·6	1·3	0·2	7·3	1·0	13·3	1·9
14	2 03·5	2 03·8	1 57·9	1·4	0·2	7·4	1·0	13·4	1·9
15	2 03·8	2 04·1	1 58·1	1·5	0·2	7·5	1·1	13·5	1·9
16	2 04·0	2 04·3	1 58·4	1·6	0·2	7·6	1·1	13·6	1·9
17	2 04·3	2 04·6	1 58·6	1·7	0·2	7·7	1·1	13·7	1·9
18	2 04·5	2 04·8	1 58·8	1·8	0·3	7·8	1·1	13·8	2·0
19	2 04·8	2 05·1	1 59·1	1·9	0·3	7·9	1·1	13·9	2·0
20	2 05·0	2 05·3	1 59·3	2·0	0·3	8·0	1·1	14·0	2·0
21	2 05·3	2 05·6	1 59·5	2·1	0·3	8·1	1·1	14·1	2·0
22	2 05·5	2 05·8	1 59·8	2·2	0·3	8·2	1·2	14·2	2·0
23	2 05·8	2 06·1	2 00·0	2·3	0·3	8·3	1·2	14·3	2·0
24	2 06·0	2 06·3	2 00·3	2·4	0·3	8·4	1·2	14·4	2·0
25	2 06·3	2 06·6	2 00·5	2·5	0·4	8·5	1·2	14·5	2·1
26	2 06·5	2 06·8	2 00·7	2·6	0·4	8·6	1·2	14·6	2·1
27	2 06·8	2 07·1	2 01·0	2·7	0·4	8·7	1·2	14·7	2·1
28	2 07·0	2 07·3	2 01·2	2·8	0·4	8·8	1·2	14·8	2·1
29	2 07·3	2 07·6	2 01·5	2·9	0·4	8·9	1·3	14·9	2·1
30	2 07·5	2 07·8	2 01·7	3·0	0·4	9·0	1·3	15·0	2·1
31	2 07·8	2 08·1	2 01·9	3·1	0·4	9·1	1·3	15·1	2·1
32	2 08·0	2 08·4	2 02·2	3·2	0·5	9·2	1·3	15·2	2·2
33	2 08·3	2 08·6	2 02·4	3·3	0·5	9·3	1·3	15·3	2·2
34	2 08·5	2 08·9	2 02·6	3·4	0·5	9·4	1·3	15·4	2·2
35	2 08·8	2 09·1	2 02·9	3·5	0·5	9·5	1·3	15·5	2·2
36	2 09·0	2 09·4	2 03·1	3·6	0·5	9·6	1·4	15·6	2·2
37	2 09·3	2 09·6	2 03·4	3·7	0·5	9·7	1·4	15·7	2·2
38	2 09·5	2 09·9	2 03·6	3·8	0·5	9·8	1·4	15·8	2·2
39	2 09·8	2 10·1	2 03·8	3·9	0·6	9·9	1·4	15·9	2·3
40	2 10·0	2 10·4	2 04·1	4·0	0·6	10·0	1·4	16·0	2·3
41	2 10·3	2 10·6	2 04·3	4·1	0·6	10·1	1·4	16·1	2·3
42	2 10·5	2 10·9	2 04·6	4·2	0·6	10·2	1·4	16·2	2·3
43	2 10·8	2 11·1	2 04·8	4·3	0·6	10·3	1·5	16·3	2·3
44	2 11·0	2 11·4	2 05·0	4·4	0·6	10·4	1·5	16·4	2·3
45	2 11·3	2 11·6	2 05·3	4·5	0·6	10·5	1·5	16·5	2·3
46	2 11·5	2 11·9	2 05·5	4·6	0·7	10·6	1·5	16·6	2·4
47	2 11·8	2 12·1	2 05·7	4·7	0·7	10·7	1·5	16·7	2·4
48	2 12·0	2 12·4	2 06·0	4·8	0·7	10·8	1·5	16·8	2·4
49	2 12·3	2 12·6	2 06·2	4·9	0·7	10·9	1·5	16·9	2·4
50	2 12·5	2 12·9	2 06·5	5·0	0·7	11·0	1·6	17·0	2·4
51	2 12·8	2 13·1	2 06·7	5·1	0·7	11·1	1·6	17·1	2·4
52	2 13·0	2 13·4	2 06·9	5·2	0·7	11·2	1·6	17·2	2·4
53	2 13·3	2 13·6	2 07·2	5·3	0·8	11·3	1·6	17·3	2·5
54	2 13·5	2 13·9	2 07·4	5·4	0·8	11·4	1·6	17·4	2·5
55	2 13·8	2 14·1	2 07·7	5·5	0·8	11·5	1·6	17·5	2·5
56	2 14·0	2 14·4	2 07·9	5·6	0·8	11·6	1·6	17·6	2·5
57	2 14·3	2 14·6	2 08·1	5·7	0·8	11·7	1·7	17·7	2·5
58	2 14·5	2 14·9	2 08·4	5·8	0·8	11·8	1·7	17·8	2·5
59	2 14·8	2 15·1	2 08·6	5·9	0·8	11·9	1·7	17·9	2·5
60	2 15·0	2 15·4	2 08·9	6·0	0·9	12·0	1·7	18·0	2·6

9m

9m s	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° ′	° ′	° ′	′	′	′	′	′	′
00	2 15·0	2 15·4	2 08·9	0·0	0·0	6·0	1·0	12·0	1·9
01	2 15·3	2 15·6	2 09·1	0·1	0·0	6·1	1·0	12·1	1·9
02	2 15·5	2 15·9	2 09·3	0·2	0·0	6·2	1·0	12·2	1·9
03	2 15·8	2 16·1	2 09·6	0·3	0·0	6·3	1·0	12·3	1·9
04	2 16·0	2 16·4	2 09·8	0·4	0·1	6·4	1·0	12·4	2·0
05	2 16·3	2 16·6	2 10·0	0·5	0·1	6·5	1·0	12·5	2·0
06	2 16·5	2 16·9	2 10·3	0·6	0·1	6·6	1·0	12·6	2·0
07	2 16·8	2 17·1	2 10·5	0·7	0·1	6·7	1·1	12·7	2·0
08	2 17·0	2 17·4	2 10·8	0·8	0·1	6·8	1·1	12·8	2·0
09	2 17·3	2 17·6	2 11·0	0·9	0·1	6·9	1·1	12·9	2·0
10	2 17·5	2 17·9	2 11·2	1·0	0·2	7·0	1·1	13·0	2·1
11	2 17·8	2 18·1	2 11·5	1·1	0·2	7·1	1·1	13·1	2·1
12	2 18·0	2 18·4	2 11·7	1·2	0·2	7·2	1·1	13·2	2·1
13	2 18·3	2 18·6	2 12·0	1·3	0·2	7·3	1·2	13·3	2·1
14	2 18·5	2 18·9	2 12·2	1·4	0·2	7·4	1·2	13·4	2·1
15	2 18·8	2 19·1	2 12·4	1·5	0·2	7·5	1·2	13·5	2·1
16	2 19·0	2 19·4	2 12·7	1·6	0·3	7·6	1·2	13·6	2·2
17	2 19·3	2 19·6	2 12·9	1·7	0·3	7·7	1·2	13·7	2·2
18	2 19·5	2 19·9	2 13·1	1·8	0·3	7·8	1·2	13·8	2·2
19	2 19·8	2 20·1	2 13·4	1·9	0·3	7·9	1·3	13·9	2·2
20	2 20·0	2 20·4	2 13·6	2·0	0·3	8·0	1·3	14·0	2·2
21	2 20·3	2 20·6	2 13·9	2·1	0·3	8·1	1·3	14·1	2·2
22	2 20·5	2 20·9	2 14·1	2·2	0·3	8·2	1·3	14·2	2·2
23	2 20·8	2 21·1	2 14·3	2·3	0·4	8·3	1·3	14·3	2·3
24	2 21·0	2 21·4	2 14·6	2·4	0·4	8·4	1·3	14·4	2·3
25	2 21·3	2 21·6	2 14·8	2·5	0·4	8·5	1·3	14·5	2·3
26	2 21·5	2 21·9	2 15·1	2·6	0·4	8·6	1·4	14·6	2·3
27	2 21·8	2 22·1	2 15·3	2·7	0·4	8·7	1·4	14·7	2·3
28	2 22·0	2 22·4	2 15·5	2·8	0·4	8·8	1·4	14·8	2·3
29	2 22·3	2 22·6	2 15·8	2·9	0·5	8·9	1·4	14·9	2·4
30	2 22·5	2 22·9	2 16·0	3·0	0·5	9·0	1·4	15·0	2·4
31	2 22·8	2 23·1	2 16·2	3·1	0·5	9·1	1·4	15·1	2·4
32	2 23·0	2 23·4	2 16·5	3·2	0·5	9·2	1·5	15·2	2·4
33	2 23·3	2 23·6	2 16·7	3·3	0·5	9·3	1·5	15·3	2·4
34	2 23·5	2 23·9	2 17·0	3·4	0·5	9·4	1·5	15·4	2·4
35	2 23·8	2 24·1	2 17·2	3·5	0·6	9·5	1·5	15·5	2·5
36	2 24·0	2 24·4	2 17·4	3·6	0·6	9·6	1·5	15·6	2·5
37	2 24·3	2 24·6	2 17·7	3·7	0·6	9·7	1·5	15·7	2·5
38	2 24·5	2 24·9	2 17·9	3·8	0·6	9·8	1·6	15·8	2·5
39	2 24·8	2 25·1	2 18·2	3·9	0·6	9·9	1·6	15·9	2·5
40	2 25·0	2 25·4	2 18·4	4·0	0·6	10·0	1·6	16·0	2·5
41	2 25·3	2 25·6	2 18·6	4·1	0·6	10·1	1·6	16·1	2·5
42	2 25·5	2 25·9	2 18·9	4·2	0·7	10·2	1·6	16·2	2·6
43	2 25·8	2 26·1	2 19·1	4·3	0·7	10·3	1·6	16·3	2·6
44	2 26·0	2 26·4	2 19·3	4·4	0·7	10·4	1·6	16·4	2·6
45	2 26·3	2 26·7	2 19·6	4·5	0·7	10·5	1·7	16·5	2·6
46	2 26·5	2 26·9	2 19·8	4·6	0·7	10·6	1·7	16·6	2·6
47	2 26·8	2 27·2	2 20·1	4·7	0·7	10·7	1·7	16·7	2·6
48	2 27·0	2 27·4	2 20·3	4·8	0·8	10·8	1·7	16·8	2·7
49	2 27·3	2 27·7	2 20·5	4·9	0·8	10·9	1·7	16·9	2·7
50	2 27·5	2 27·9	2 20·8	5·0	0·8	11·0	1·7	17·0	2·7
51	2 27·8	2 28·2	2 21·0	5·1	0·8	11·1	1·8	17·1	2·7
52	2 28·0	2 28·4	2 21·3	5·2	0·8	11·2	1·8	17·2	2·7
53	2 28·3	2 28·7	2 21·5	5·3	0·8	11·3	1·8	17·3	2·7
54	2 28·5	2 28·9	2 21·7	5·4	0·9	11·4	1·8	17·4	2·8
55	2 28·8	2 29·2	2 22·0	5·5	0·9	11·5	1·8	17·5	2·8
56	2 29·0	2 29·4	2 22·2	5·6	0·9	11·6	1·8	17·6	2·8
57	2 29·3	2 29·7	2 22·5	5·7	0·9	11·7	1·9	17·7	2·8
58	2 29·5	2 29·9	2 22·7	5·8	0·9	11·8	1·9	17·8	2·8
59	2 29·8	2 30·2	2 22·9	5·9	0·9	11·9	1·9	17·9	2·8
60	2 30·0	2 30·4	2 23·2	6·0	1·0	12·0	1·9	18·0	2·9

SIGHT REDUCTION TABLE (1985)

&

ALTITUDE CORRECTION TABLES

Pub. No. 229, Vol. 2.

HER MAJESTY'S NAUTICAL ALMANAC OFFICE

LONDON, U.K.

A2 ALTITUDE CORRECTION TABLES 10°-90°—SUN, STARS, PLANETS

Each correction applies between the App. Alt. (or Ht. of Eye) on its row and the one on the next row.

SUN OCT.—MAR. App. Alt.	Lower Limb	Upper Limb	SUN APR.—SEPT. App. Alt.	Lower Limb	Upper Limb	STARS AND PLANETS App. Alt.	Corr^n	DIP Ht. of Eye (m)	Corr^n	Ht. of Eye (ft.)
9 34	+10·8	−21·5	9 39	+10·6	−21·2	9 56	−5·3	2·4	−2·8	8·0
9 45	+10·9	−21·4	9 51	+10·7	−21·1	10 08	−5·2	2·6	−2·9	8·6
9 56	+11·0	−21·3	10 03	+10·8	−21·0	10 20	−5·1	2·8	−3·0	9·2
10 08	+11·1	−21·2	10 15	+10·9	−20·9	10 33	−5·0	3·0	−3·1	9·8
10 21	+11·2	−21·1	10 27	+11·0	−20·8	10 46	−4·9	3·2	−3·2	10·5
10 34	+11·3	−21·0	10 40	+11·1	−20·7	11 00	−4·8	3·4	−3·3	11·2
10 47	+11·4	−20·9	10 54	+11·2	−20·6	11 14	−4·7	3·6	−3·4	11·9
11 01	+11·5	−20·8	11 08	+11·3	−20·5	11 29	−4·6	3·8	−3·5	12·6
11 15	+11·6	−20·7	11 23	+11·4	−20·4	11 45	−4·5	4·0	−3·6	13·3
11 30	+11·7	−20·6	11 38	+11·5	−20·3	12 01	−4·4	4·3	−3·7	14·1
11 46	+11·8	−20·5	11 54	+11·6	−20·2	12 18	−4·3	4·5	−3·8	14·9
12 02	+11·9	−20·4	12 10	+11·7	−20·1	12 35	−4·2	4·7	−3·9	15·7
12 19	+12·0	−20·3	12 28	+11·8	−20·0	12 54	−4·1	5·0	−4·0	16·5
12 37	+12·1	−20·2	12 46	+11·9	−19·9	13 13	−4·0	5·2	−4·1	17·4
12 55	+12·2	−20·1	13 05	+12·0	−19·8	13 33	−3·9	5·5	−4·2	18·3
13 14	+12·3	−20·0	13 24	+12·1	−19·7	13 54	−3·8	5·8	−4·3	19·1
13 35	+12·4	−19·9	13 45	+12·2	−19·6	14 16	−3·7	6·1	−4·4	20·1
13 56	+12·5	−19·8	14 07	+12·3	−19·5	14 40	−3·6	6·3	−4·5	21·0
14 18	+12·6	−19·7	14 30	+12·4	−19·4	15 04	−3·5	6·6	−4·6	22·0
14 42	+12·7	−19·6	14 54	+12·5	−19·3	15 30	−3·4	6·9	−4·7	22·9
15 06	+12·8	−19·5	15 19	+12·6	−19·2	15 57	−3·3	7·2	−4·8	23·9
15 32	+12·9	−19·4	15 46	+12·7	−19·1	16 26	−3·2	7·5	−4·9	24·9
15 59	+13·0	−19·3	16 14	+12·8	−19·0	16 56	−3·1	7·9	−5·0	26·0
16 28	+13·1	−19·2	16 44	+12·9	−18·9	17 28	−3·0	8·2	−5·1	27·1
16 59	+13·2	−19·1	17 15	+13·0	−18·8	18 02	−2·9	8·5	−5·2	28·1
17 32	+13·3	−19·0	17 48	+13·1	−18·7	18 38	−2·8	8·8	−5·3	29·2
18 06	+13·4	−18·9	18 24	+13·2	−18·6	19 17	−2·7	9·2	−5·4	30·4
18 42	+13·5	−18·8	19 01	+13·3	−18·5	19 58	−2·6	9·5	−5·5	31·5
19 21	+13·6	−18·7	19 42	+13·4	−18·4	20 42	−2·5	9·9	−5·6	32·7
20 03	+13·7	−18·6	20 25	+13·5	−18·3	21 28	−2·4	10·3	−5·7	33·9
20 48	+13·8	−18·5	21 11	+13·6	−18·2	22 19	−2·3	10·6	−5·8	35·1
21 35	+13·9	−18·4	22 00	+13·7	−18·1	23 13	−2·2	11·0	−5·9	36·3
22 26	+14·0	−18·3	22 54	+13·8	−18·0	24 11	−2·1	11·4	−6·0	37·6
23 22	+14·1	−18·2	23 51	+13·9	−17·9	25 14	−2·0	11·8	−6·1	38·9
24 21	+14·2	−18·1	24 53	+14·0	−17·8	26 22	−1·9	12·2	−6·2	40·1
25 26	+14·3	−18·0	26 00	+14·1	−17·7	27 36	−1·8	12·6	−6·3	41·5
26 36	+14·4	−17·9	27 13	+14·2	−17·6	28 56	−1·7	13·0	−6·4	42·8
27 52	+14·5	−17·8	28 33	+14·3	−17·5	30 24	−1·6	13·4	−6·5	44·2
29 15	+14·6	−17·7	30 00	+14·4	−17·4	32 00	−1·5	13·8	−6·6	45·5
30 46	+14·7	−17·6	31 35	+14·5	−17·3	33 45	−1·4	14·2	−6·7	46·9
32 26	+14·8	−17·5	33 20	+14·6	−17·2	35 40	−1·3	14·7	−6·8	48·4
34 17	+14·9	−17·4	35 17	+14·7	−17·1	37 48	−1·2	15·1	−6·9	49·8
36 20	+15·0	−17·3	37 26	+14·8	−17·0	40 08	−1·1	15·5	−7·0	51·3
38 36	+15·1	−17·2	39 50	+14·9	−16·9	42 44	−1·0	16·0	−7·1	52·8
41 08	+15·2	−17·1	42 31	+15·0	−16·8	45 36	−0·9	16·5	−7·2	54·3
43 59	+15·3	−17·0	45 31	+15·1	−16·7	48 47	−0·8	16·9	−7·3	55·8
47 10	+15·4	−16·9	48 55	+15·2	−16·6	52 18	−0·7	17·4	−7·4	57·4
50 46	+15·5	−16·8	52 44	+15·3	−16·5	56 11	−0·6	17·9	−7·5	58·9
54 49	+15·6	−16·7	57 02	+15·4	−16·4	60 28	−0·5	18·4	−7·6	60·5
59 23	+15·7	−16·6	61 51	+15·5	−16·3	65 08	−0·4	18·8	−7·7	62·1
64 30	+15·8	−16·5	67 17	+15·6	−16·2	70 11	−0·3	19·3	−7·8	63·8
70 12	+15·9	−16·4	73 16	+15·7	−16·1	75 34	−0·2	19·8	−7·9	65·4
76 26	+16·0	−16·3	79 43	+15·8	−16·0	81 13	−0·1	20·4	−8·0	67·1
83 05	+16·1	−16·2	86 32	+15·9	−15·9	87 03	0·0	20·9	−8·1	68·8
90 00			90 00			90 00		21·4		70·5

STARS AND PLANETS — Additional Corr^n (App. Alt.)

1985

VENUS

Period	App. Alt.	Additional Corr^n
Jan. 1-Feb. 4	0°	+0·2′
	41	+0·1
	76	
Feb. 5-Feb. 28	0°	+0·3′
	34	+0·2
	60	+0·1
	80	
Mar. 1-Mar. 16	0°	+0·4′
	29	+0·3
	51	+0·2
	68	+0·1
	83	
Mar. 17-Apr. 21	0°	+0·5′
	26	+0·4
	46	+0·3
	60	+0·2
	73	+0·1
	84	
Apr. 22-May 7	0°	+0·4′
	29	+0·3
	51	+0·2
	68	+0·1
	83	
May 8-May 29	0°	+0·3′
	34	+0·2
	60	+0·1
	80	
May 30-July 18	0°	+0·2′
	41	+0·1
	76	
July 19-Dec. 31	0°	+0·1′
	60	

MARS

Period	App. Alt.	Additional Corr^n
Jan. 1-Dec. 31	0°	+0·1′
	60	

DIP — Ht. of Eye / Corr^n

Ht. of Eye	Corr^n
m	′
1·0	−1·8
1·5	−2·2
2·0	−2·5
2·5	−2·8
3·0	−3·0
See table ←	
m	′
20	−7·9
22	−8·3
24	−8·6
26	−9·0
28	−9·3
30	−9·6
32	−10·0
34	−10·3
36	−10·6
38	−10·8
40	−11·1
42	−11·4
44	−11·7
46	−11·9
48	−12·2
ft.	′
2	−1·4
4	−1·9
6	−2·4
8	−2·7
10	−3·1
See table ←	
ft.	′
70	−8·1
75	−8·4
80	−8·7
85	−8·9
90	−9·2
95	−9·5
100	−9·7
105	−9·9
110	−10·2
115	−10·4
120	−10·6
125	−10·8
130	−11·1
135	−11·3
140	−11·5
145	−11·7
150	−11·9
155	−12·1

App. Alt. = Apparent altitude = Sextant altitude corrected for index error and dip.

SIGHT REDUCTION TABLE

58°, 302° L.H.A. LATITUDE SAME NAME AS DECLINATION

N. Lat. {L.H.A. greater than 180° ...... Zn=Z; L.H.A. less than 180° ...... Zn=360°−Z}

Dec.	15° Hc	d	Z	16° Hc	d	Z	17° Hc	d	Z	18° Hc	d	Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
0	30 47.3	+17.8	99.7	30 37.4	+18.9	99.8	30 26.9	+20.1	100.4	30 15.8	+21.2	100.9
1	31 05.1	17.2	98.1	30 56.3	18.4	98.7	30 47.0	19.5	99.3	30 37.0	20.7	99.8
2	31 22.3	16.6	97.0	31 14.7	17.8	97.6	31 06.5	19.0	98.2	30 57.7	20.1	98.8
3	31 38.9	16.0	95.8	31 32.5	17.2	96.4	31 25.5	18.3	97.0	31 17.8	19.5	97.7
4	31 54.9	15.5	94.7	31 49.7	16.6	95.3	31 43.8	17.8	95.9	31 37.3	19.0	96.5
5	32 10.4	+14.8	93.6	32 06.3	+16.0	94.2	32 01.6	+17.2	94.8	31 56.3	+18.3	95.4
6	32 25.2	14.1	92.4	32 22.3	15.4	93.0	32 18.8	16.6	93.7	32 14.6	17.8	94.3
7	32 39.3	13.6	91.3	32 37.7	14.7	91.9	32 35.4	15.9	92.5	32 32.4	17.1	93.2
8	32 52.9	12.9	90.1	32 52.4	14.2	90.7	32 51.3	15.4	91.4	32 49.5	16.6	92.0
9	33 05.8	12.2	88.9	33 06.6	13.4	89.6	33 06.7	14.6	90.2	33 06.1	15.9	90.9
10	33 18.0	+11.6	87.8	33 20.0	+12.8	88.4	33 21.3	+14.1	89.1	33 22.0	+15.2	89.7
11	33 29.6	10.9	86.6	33 32.8	12.2	87.2	33 35.4	13.4	87.9	33 37.2	14.6	88.6
12	33 40.5	10.3	85.4	33 45.0	11.5	86.1	33 48.8	12.7	86.7	33 51.8	14.0	87.4
13	33 50.8	9.5	84.2	33 56.5	10.8	84.9	34 01.5	12.0	85.6	34 05.8	13.2	86.2
14	34 00.3	8.9	83.0	34 07.3	10.1	83.7	34 13.5	11.3	84.4	34 19.0	12.6	85.1
15	34 09.2	+8.2	81.8	34 17.4	+9.4	82.5	34 24.8	+10.7	83.2	34 31.6	+11.9	83.9
16	34 17.4	7.4	80.6	34 26.8	8.7	81.3	34 35.5	9.9	82.0	34 43.5	11.2	82.7
17	34 24.8	6.8	79.4	34 35.5	8.0	80.1	34 45.4	9.3	80.8	34 54.7	10.5	81.5
18	34 31.6	6.1	78.2	34 43.5	7.3	78.9	34 54.7	8.5	79.6	35 05.2	9.7	80.3
19	34 37.7	5.3	77.0	34 50.8	6.5	77.7	35 03.2	7.8	78.4	35 14.9	9.1	79.1
20	34 43.0	+4.6	75.8	34 57.3	+5.9	76.5	35 11.0	+7.1	77.2	35 24.0	+8.3	77.9
21	34 47.6	3.9	74.6	35 03.2	5.1	75.3	35 18.1	6.4	76.0	35 32.3	7.6	76.6
22	34 51.5	3.1	73.4	35 08.3	4.4	74.1	35 24.5	5.6	74.7	35 39.9	6.8	75.4
23	34 54.6	2.5	72.2	35 12.7	3.6	72.8	35 30.1	4.8	73.5	35 46.7	6.1	74.2
24	34 57.1	1.7	70.9	35 16.3	3.0	71.6	35 34.9	4.2	72.3	35 52.8	5.4	73.0
25	34 58.8	+1.0	69.7	35 19.3	+2.1	70.4	35 39.1	+3.3	71.1	35 58.2	+4.6	71.7
26	34 59.8	+0.2	68.5	35 21.4	1.4	69.2	35 42.4	2.7	69.8	36 02.8	3.8	70.5
27	35 00.0	-0.5	67.3	35 22.8	+0.7	67.9	35 45.1	1.8	68.6	36 06.6	3.1	69.3
28	34 59.5	1.2	66.1	35 23.5	0.0	66.7	35 46.9	1.2	67.4	36 09.7	2.3	68.0
29	34 58.3	2.0	64.8	35 23.5	-0.8	65.5	35 48.1	+0.3	66.1	36 12.0	1.6	66.8
30	34 56.3	-2.7	63.6	35 22.7	-1.6	64.3	35 48.4	-0.4	64.9	36 13.6	+0.7	65.6
31	34 53.6	3.4	62.4	35 21.1	2.3	63.0	35 48.0	1.1	63.7	36 14.3	0.0	64.3
32	34 50.2	4.2	61.2	35 18.8	3.0	61.8	35 46.9	1.9	62.4	36 14.3	-0.7	63.1
33	34 46.0	4.8	60.0	35 15.8	3.8	60.6	35 45.0	2.7	61.2	36 13.6	1.5	61.8
34	34 41.2	5.6	58.8	35 12.0	4.5	59.4	35 42.3	3.4	60.0	36 12.1	2.3	60.6
35	34 35.6	-6.3	57.6	35 07.5	-5.2	58.1	35 38.9	-4.1	58.7	36 09.8	-3.1	59.4
36	34 29.3	7.0	56.3	35 02.3	6.0	56.9	35 34.8	4.9	57.5	36 06.7	3.8	58.1
37	34 22.3	7.7	55.1	34 56.3	6.7	55.7	35 29.9	5.7	56.3	36 02.9	4.6	56.9
38	34 14.6	8.5	53.9	34 49.6	7.4	54.5	35 24.2	6.3	55.1	35 58.3	5.3	55.7
39	34 06.1	9.1	52.7	34 42.2	8.1	53.3	35 17.9	7.1	53.9	35 53.0	6.1	54.4
40	33 57.0	-9.8	51.6	34 34.1	-8.8	52.1	35 10.8	-7.9	52.6	35 46.9	-6.8	53.2
41	33 47.2	10.5	50.4	34 25.3	9.5	50.9	35 02.9	8.5	51.4	35 40.1	7.6	52.0
42	33 36.7	11.1	49.2	34 15.8	10.3	49.7	34 54.4	9.3	50.2	35 32.5	8.3	50.8
43	33 25.6	11.8	48.0	34 05.5	10.9	48.5	34 45.1	10.0	49.0	35 24.2	9.0	49.5
44	33 13.8	12.5	46.8	33 54.6	11.5	47.3	34 35.1	10.7	47.8	35 15.2	9.7	48.3
45	33 01.3	-13.1	45.7	33 43.1	-12.3	46.1	34 24.4	-11.3	46.6	35 05.5	-10.5	47.1
46	32 48.2	13.8	44.5	33 30.8	12.9	45.0	34 13.1	12.1	45.4	34 55.0	11.2	45.9
47	32 34.4	14.4	43.3	33 17.9	13.6	43.8	34 01.0	12.7	44.2	34 43.8	11.8	44.7
48	32 20.0	15.0	42.2	33 04.3	14.2	42.6	33 48.3	13.4	43.1	34 32.0	12.6	43.5
49	32 05.0	15.7	41.0	32 50.1	14.9	41.5	33 34.9	14.1	41.9	34 19.4	13.3	42.4
50	31 49.3	-16.2	39.9	32 35.2	-15.5	40.3	33 20.8	-14.7	40.7	34 06.1	-13.9	41.2
51	31 33.1	16.8	38.8	32 19.7	16.1	39.2	33 06.1	15.3	39.6	33 52.2	14.5	40.0
52	31 16.3	17.5	37.7	32 03.6	16.7	38.0	32 50.8	16.0	38.4	33 37.7	15.3	38.8
53	30 58.8	18.0	36.5	31 46.9	17.3	36.9	32 34.8	16.6	37.3	33 22.4	15.9	37.7
54	30 40.8	18.5	35.4	31 29.6	17.9	35.8	32 18.2	17.2	36.1	33 06.5	16.5	36.5
55	30 22.3	-19.1	34.3	31 11.7	-18.4	34.7	32 01.0	-17.8	35.0	32 50.0	-17.1	35.4
56	30 03.2	19.7	33.2	30 53.3	19.0	33.5	31 43.2	18.4	33.9	32 32.9	17.7	34.2
57	29 43.5	20.3	32.1	30 34.3	19.6	32.4	31 24.8	19.0	32.8	32 15.2	18.4	33.1
58	29 23.2	20.7	31.0	30 14.7	20.2	31.3	31 05.8	19.5	31.7	31 56.8	18.9	32.0
59	29 02.6	21.2	30.0	29 54.5	20.6	30.3	30 46.3	20.1	30.6	31 37.9	19.5	30.9
60	28 41.4	-21.7	28.9	29 33.9	-21.2	29.2	30 26.2	-20.6	29.5	31 18.4	-20.1	29.8
61	28 19.7	22.2	27.8	29 12.7	21.7	28.1	30 05.6	21.2	28.4	30 58.3	20.7	28.7
62	27 57.5	22.7	26.8	28 51.0	22.2	27.0	29 44.4	21.7	27.3	30 37.6	21.1	27.6
63	27 34.8	23.1	25.7	28 28.8	22.7	26.0	29 22.7	22.2	26.2	30 16.5	21.8	26.5
64	27 11.7	23.6	24.7	28 06.1	23.1	24.9	29 00.5	22.7	25.2	29 54.7	22.2	25.4
65	26 48.1	-24.1	23.7	27 43.0	23.7	23.9	28 37.8	-23.2	24.1	29 32.5	22.7	24.3
66	26 24.0	24.5	22.6	27 19.3	24.0	22.8	28 14.6	23.7	23.1	29 09.8	23.3	23.3
67	25 59.5	24.9	21.6	26 55.3	24.6	21.8	27 50.9	24.1	22.0	28 46.5	23.7	22.2
68	25 34.6	25.3	20.6	26 30.7	24.9	20.8	27 26.8	24.6	21.0	28 22.8	24.2	21.2
69	25 09.3	25.7	19.6	26 05.8	25.4	19.8	27 02.2	25.0	20.0	27 58.6	24.7	20.1
70	24 43.6	-26.2	18.6	25 40.4	-25.8	18.8	26 37.2	-25.5	18.9	27 33.9	-25.1	19.1
71	24 17.4	26.5	17.6	25 14.6	26.2	17.8	26 11.7	25.9	17.9	27 08.8	25.6	18.1
72	23 50.9	26.8	16.7	24 48.4	26.6	16.8	25 45.8	26.3	16.9	26 43.2	26.0	17.1
73	23 24.1	27.3	15.7	24 21.8	27.0	15.8	25 19.5	26.7	15.9	26 17.2	26.4	16.1
74	22 56.8	27.6	14.7	23 54.8	27.3	14.8	24 52.8	27.0	14.9	25 50.8	26.8	15.1
75	22 29.2	-27.9	13.7	23 27.5	-27.7	13.8	24 25.8	-27.5	13.9	25 24.0	-27.2	14.1
76	22 01.3	28.2	12.8	22 59.8	28.0	12.9	23 58.3	27.8	13.0	24 56.8	27.6	13.1
77	21 33.1	28.6	11.8	22 31.8	28.4	11.9	23 30.5	28.2	12.0	24 29.2	28.0	12.1
78	21 04.5	28.9	10.9	22 03.4	28.7	11.0	23 02.3	28.5	11.0	24 01.2	28.4	11.1
79	20 35.6	29.2	10.0	21 34.7	29.0	10.0	22 33.8	28.9	10.1	23 32.8	28.7	10.2
80	20 06.4	-29.5	9.0	21 05.7	-29.4	9.1	22 04.9	-29.2	9.1	23 04.1	-29.0	9.2
81	19 36.9	29.7	8.1	20 36.3	29.6	8.1	21 35.7	29.5	8.2	22 35.1	29.4	8.3
82	19 07.2	30.1	7.2	20 06.7	29.9	7.2	21 06.2	29.8	7.3	22 05.7	29.7	7.3
83	18 37.1	30.3	6.3	19 36.8	30.2	6.3	20 36.4	30.1	6.3	21 36.0	30.0	6.4
84	18 06.8	30.5	5.4	19 06.6	30.5	5.4	20 06.3	30.4	5.4	21 06.0	30.3	5.5
85	17 36.3	-30.8	4.4	18 36.1	-30.7	4.5	19 35.9	-30.7	4.5	20 35.7	-30.6	4.5
86	17 05.5	31.1	3.5	18 05.4	31.0	3.6	19 05.2	30.9	3.6	20 05.1	30.9	3.6
87	16 34.4	31.2	2.7	17 34.4	31.3	2.7	18 34.3	31.2	2.7	19 34.2	31.1	2.7
88	16 03.2	31.5	1.8	17 03.1	31.4	1.8	18 03.1	31.4	1.8	19 03.1	31.4	1.8
89	15 31.7	31.7	0.9	16 31.7	31.7	0.9	17 31.7	31.7	0.9	18 31.7	31.7	0.9
90	15 00.0	-31.9	0.0	16 00.0	-31.9	0.0	17 00.0	-31.9	0.0	18 00.0	-31.9	0.0

Dec.	19° Hc	d	Z	20° Hc	d	Z	21° Hc	d	Z	22° Hc	d	Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
0	30 04.2	+22.3	101.5	29 51.9	+23.4	102.1	29 39.1	+24.5	102.6	29 25.7	+25.6	103.2
1	30 26.5	21.8	100.4	30 15.3	22.9	101.0	30 03.6	24.0	101.6	29 51.3	25.0	102.1
2	30 48.3	21.2	99.3	30 38.2	22.4	99.9	30 27.6	23.4	100.5	30 16.3	24.6	101.1
3	31 09.5	20.7	98.3	31 00.6	21.6	98.8	30 51.0	22.9	99.4	30 40.9	24.0	100.0
4	31 30.2	20.1	97.2	31 22.4	21.3	97.8	31 14.0	22.4	98.4	31 04.9	23.5	99.0
5	31 50.3	+19.5	96.0	31 43.6	+20.7	96.7	31 36.4	+21.8	97.3	31 28.4	+22.9	97.9
6	32 09.8	18.9	94.9	32 04.3	20.1	95.6	31 58.2	21.2	96.2	31 51.3	22.4	96.8
7	32 28.7	18.4	93.8	32 24.4	19.5	94.4	32 19.4	20.7	95.1	32 13.8	21.9	95.7
8	32 47.1	17.7	92.7	32 43.9	18.8	93.3	32 40.1	20.1	94.0	32 35.7	21.2	94.6
9	33 04.8	17.1	91.5	33 02.9	18.2	92.2	33 00.2	19.5	92.8	32 56.9	20.7	93.5
10	33 21.9	+16.5	90.4	33 21.1	+17.7	91.1	33 19.7	+18.9	91.7	33 17.6	+20.0	92.4
11	33 38.4	15.8	89.2	33 38.8	17.0	89.9	33 38.6	18.2	90.6	33 37.6	19.4	91.2
12	33 54.2	15.1	88.1	33 55.8	16.4	88.8	33 56.8	17.6	89.4	33 57.0	18.8	90.1
13	34 09.3	14.5	86.9	34 12.2	15.7	87.6	34 14.4	16.9	88.3	34 15.8	18.2	89.0
14	34 23.8	13.9	85.7	34 27.9	15.1	86.4	34 31.3	16.3	87.1	34 34.0	17.5	87.8
15	34 37.7	+13.1	84.6	34 43.0	+14.3	85.2	34 47.6	+15.6	85.9	34 51.5	+16.8	86.6
16	34 50.8	12.4	83.4	34 57.3	13.7	84.1	35 03.2	14.9	84.8	35 08.3	16.2	85.5
17	35 03.2	11.7	82.2	35 11.0	13.0	82.9	35 18.1	14.2	83.6	35 24.5	15.4	84.3
18	35 14.9	11.1	81.0	35 24.0	12.3	81.7	35 32.3	13.5	82.4	35 39.9	14.7	83.1
19	35 26.0	10.3	79.8	35 36.3	11.5	80.5	35 45.8	12.8	81.2	35 54.6	14.1	81.9
20	35 36.3	+9.5	78.6	35 47.8	+10.8	79.3	35 58.6	+12.1	80.0	36 08.7	+13.3	80.7
21	35 45.8	8.8	77.3	35 58.6	10.1	78.1	36 10.7	11.3	78.8	36 22.0	12.5	79.5
22	35 54.6	8.1	76.1	36 08.7	9.3	76.8	36 22.0	10.6	77.5	36 34.5	11.9	78.3
23	36 02.7	7.4	74.9	36 18.0	8.6	75.6	36 32.6	9.8	76.3	36 46.4	11.0	77.0
24	36 10.1	6.5	73.7	36 26.6	7.8	74.4	36 42.4	9.0	75.1	36 57.4	10.4	75.8
25	36 16.6	+5.9	72.4	36 34.4	+7.0	73.1	36 51.4	+8.3	73.9	37 07.8	+9.5	74.6
26	36 22.5	5.0	71.2	36 41.4	6.3	71.9	36 59.7	7.5	72.6	37 17.3	8.7	73.3
27	36 27.5	4.3	70.0	36 47.7	5.5	70.7	37 07.2	6.8	71.4	37 26.0	8.0	72.1
28	36 31.8	3.5	68.7	36 53.2	4.8	69.4	37 14.0	5.9	70.1	37 34.0	7.2	70.9
29	36 35.3	2.8	67.5	36 58.0	3.9	68.2	37 19.9	5.2	68.9	37 41.2	6.4	69.6
30	36 38.1	+1.9	66.2	37 01.9	+3.2	66.9	37 25.1	+4.3	67.6	37 47.6	+5.6	68.3
31	36 40.0	1.2	65.0	37 05.1	2.3	65.7	37 29.4	3.6	66.4	37 53.2	4.7	67.1
32	36 41.2	+0.4	63.7	37 07.4	1.6	64.4	37 33.0	2.8	65.1	37 57.9	4.0	65.8
33	36 41.6	-0.4	62.5	37 09.0	+0.8	63.2	37 35.8	1.9	63.9	38 01.9	3.1	64.5
34	36 41.2	1.1	61.3	37 09.8	0.0	61.9	37 37.7	1.2	62.6	38 05.0	2.3	63.3
35	36 40.1	-2.0	60.0	37 09.8	-0.8	60.7	37 38.9	+0.3	61.3	38 07.3	+1.5	62.0
36	36 38.1	2.7	58.8	37 09.0	1.6	59.4	37 39.2	-0.5	60.1	38 08.8	+0.7	60.7
37	36 35.4	3.5	57.5	37 07.4	2.4	58.1	37 38.7	1.2	58.8	38 09.5	-0.1	59.5
38	36 31.9	4.2	56.3	37 05.0	3.2	56.9	37 37.5	2.1	57.5	38 09.4	1.0	58.2
39	36 27.7	5.1	55.0	37 01.8	4.0	55.6	37 35.4	2.9	56.3	38 08.4	1.8	56.9
40	36 22.6	-5.8	53.8	36 57.8	-4.7	54.4	37 32.5	-3.7	55.0	38 06.6	-2.6	55.7
41	36 16.8	6.5	52.6	36 53.1	5.6	53.1	37 28.8	4.5	53.8	38 04.0	3.4	54.4
42	36 10.3	7.3	51.3	36 47.5	6.3	51.9	37 24.3	5.3	52.5	38 00.6	4.3	53.1
43	36 03.0	8.1	50.1	36 41.2	7.1	50.7	37 19.0	6.1	51.2	37 56.3	5.0	51.9
44	35 54.9	8.8	48.9	36 34.1	7.8	49.4	37 12.9	6.8	50.0	37 51.3	5.9	50.6
45	35 46.1	-9.6	47.7	36 26.3	-8.6	48.2	37 06.1	-7.7	48.8	37 45.4	-6.7	49.3
46	35 36.5	10.2	46.4	36 17.7	9.4	47.0	36 58.4	8.4	47.5	37 38.7	7.4	48.1
47	35 26.3	11.0	45.2	36 08.3	10.1	45.7	36 50.0	9.2	46.3	37 31.3	8.3	46.8
48	35 15.3	11.7	44.0	35 58.2	10.9	44.5	36 40.8	9.9	45.0	37 23.0	9.0	45.6
49	35 03.6	12.4	42.8	35 47.4	11.6	43.3	36 30.9	10.7	43.8	37 14.0	9.8	44.3
50	34 51.2	-13.2	41.6	35 35.8	-12.2	42.1	36 20.2	-11.4	42.6	37 04.2	-10.6	43.1
51	34 38.0	13.7	40.4	35 23.6	13.0	40.9	36 08.8	12.2	41.4	36 53.6	11.3	41.9
52	34 24.3	14.5	39.3	35 10.6	13.7	39.7	35 56.6	12.9	40.2	36 42.3	12.1	40.6
53	34 09.8	15.2	38.1	34 56.9	14.4	38.5	35 43.7	13.6	39.0	36 30.2	12.8	39.4
54	33 54.6	15.8	36.9	34 42.5	15.1	37.3	35 30.1	14.4	37.8	36 17.4	13.6	38.2
55	33 38.8	-16.4	35.8	34 27.4	-15.7	36.2	35 15.7	-15.0	36.6	36 03.8	14.3	37.0
56	33 22.4	17.1	34.6	34 11.7	16.4	35.0	35 00.7	15.7	35.4	35 49.5	15.0	35.8
57	33 05.3	17.7	33.5	33 55.3	17.1	33.8	34 45.0	16.4	34.2	35 34.5	15.7	34.6
58	32 47.6	18.3	32.3	33 38.2	17.7	32.7	34 28.6	17.0	33.0	35 18.8	16.4	33.4
59	32 29.3	18.9	31.2	33 20.5	18.3	31.5	34 11.6	17.7	31.9	35 02.4	17.0	32.2
60	32 10.4	-19.5	30.1	33 02.2	-18.9	30.4	33 53.9	-18.4	30.7	34 45.4	17.8	31.1
61	31 50.9	20.1	28.9	32 43.3	19.6	29.3	33 35.5	18.9	29.6	34 27.6	18.3	29.9
62	31 30.8	20.7	27.8	32 23.7	20.1	28.1	33 16.6	19.6	28.4	34 09.3	19.1	28.8
63	31 10.1	21.2	26.7	32 03.6	20.7	27.0	32 57.0	20.2	27.3	33 50.2	19.6	27.6
64	30 48.9	21.8	25.6	31 42.9	21.3	25.9	32 36.8	20.8	26.2	33 30.6	20.3	26.5
65	30 27.1	-22.3	24.6	31 21.6	-21.8	24.8	32 16.0	-21.3	25.1	33 10.3	20.9	25.4
66	30 04.8	22.8	23.5	30 59.8	22.4	23.7	31 54.7	21.9	24.0	32 49.5	21.5	24.2
67	29 42.0	23.3	22.4	30 37.4	22.9	22.6	31 32.8	22.5	22.9	32 28.0	22.1	23.1
68	29 18.7	23.8	21.4	30 14.5	23.4	21.6	31 10.3	23.0	21.8	32 05.9	22.6	22.0
69	28 54.9	24.3	20.3	29 51.1	23.9	20.5	30 47.3	23.6	20.7	31 43.3	23.1	20.9
70	28 30.6	-24.8	19.3	29 27.2	-24.5	19.5	30 23.7	-24.1	19.6	31 20.2	23.7	19.9
71	28 05.8	25.3	18.2	29 02.7	24.9	18.4	29 59.6	24.5	18.6	30 56.5	24.3	18.8
72	27 40.5	25.7	17.2	28 37.8	25.4	17.4	29 35.1	25.1	17.5	30 32.2	24.7	17.7
73	27 14.8	26.1	16.2	28 12.4	25.8	16.3	29 10.0	25.5	16.5	30 07.5	25.2	16.7
74	26 48.7	26.5	15.2	27 46.6	26.3	15.3	28 44.5	26.1	15.5	29 42.3	25.8	15.6
75	26 22.2	-27.0	14.2	27 20.3	-26.7	14.3	28 18.4	-26.4	14.4	29 16.5	26.3	14.6
76	25 55.2	27.4	13.2	26 53.6	27.2	13.3	27 52.0	26.9	13.4	28 50.3	26.7	13.5
77	25 27.8	27.8	12.2	26 26.4	27.5	12.3	27 25.1	27.4	12.4	28 23.6	27.1	12.5
78	25 00.0	28.1	11.2	25 58.9	28.0	11.3	26 57.7	27.8	11.4	27 56.5	27.6	11.5
79	24 31.9	28.5	10.2	25 30.9	28.3	10.3	26 29.9	28.1	10.4	27 28.9	28.0	10.5
80	24 03.4	-28.9	9.3	25 02.6	28.8	9.4	26 01.8	-28.6	9.4	27 00.9	28.4	9.5
81	23 34.5	29.2	8.3	24 33.8	29.1	8.4	25 33.2	29.0	8.5	26 32.5	28.8	8.5
82	23 05.2	29.5	7.4	24 04.7	29.4	7.4	25 04.2	29.3	7.5	26 03.7	29.2	7.5
83	22 35.7	29.9	6.4	23 35.3	29.8	6.5	24 34.9	29.7	6.5	25 34.5	29.6	6.6
84	22 05.8	30.3	5.5	23 05.5	30.2	5.5	24 05.2	30.1	5.6	25 04.9	29.9	5.6
85	21 35.5	-30.5	4.6	22 35.3	-30.4	4.6	23 35.1	-30.3	4.6	24 35.0	-30.4	4.7
86	21 05.0	30.8	3.6	22 04.9	30.8	3.7	23 04.8	30.8	3.7	24 04.6	30.6	3.7
87	20 34.2	31.1	2.7	21 34.1	31.1	2.7	22 34.0	31.0	2.8	23 34.0	31.0	2.8
88	20 03.1	31.4	1.8	21 03.0	31.3	1.8	22 03.0	31.4	1.8	23 03.0	31.4	1.8
89	19 31.7	31.7	0.9	20 31.7	31.7	0.9	21 31.6	31.6	0.9	22 31.6	31.6	0.9
90	19 00.0	-31.9	0.0	20 00.0	-31.9	0.0	21 00.0	-31.9	0.0	22 00.0	-31.9	0.0

SIGHT REDUCTION TABLE

39°, 321° L.H.A. LATITUDE SAME NAME AS DECLINATION

N. Lat. {L.H.A. greater than 180° ...... Zn = Z; L.H.A. less than 180° ...... Zn = 360° − Z}

Dec.	15° Hc	d	Z	16° Hc	d	Z	17° Hc	d	Z	18° Hc	d	Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
0	48 38.9	+23.0	107.7	48 20.1	+24.4	108.8	48 00.2	+25.8	109.9	47 39.3	+27.1	110.9
1	49 01.9	21.9	106.3	48 44.5	23.3	107.4	48 26.0	24.7	108.5	48 06.4	26.1	109.6
2	49 23.8	20.9	104.9	49 07.8	22.4	106.0	48 50.7	23.8	107.1	48 32.5	25.2	108.2
3	49 44.7	19.8	103.5	49 30.2	21.3	104.6	49 14.5	22.7	105.7	48 57.7	24.2	106.8
4	50 04.5	18.7	102.0	49 51.5	20.2	103.1	49 37.2	21.7	104.3	49 21.9	23.1	105.4
5	50 23.2	+17.5	100.5	50 11.7	+19.0	101.7	49 58.9	+20.6	102.8	49 45.0	+22.1	104.0
6	50 40.7	16.4	99.0	50 30.7	18.0	100.2	50 19.5	19.5	101.4	50 07.1	20.9	102.6
7	50 57.1	15.1	97.5	50 48.7	16.7	98.7	50 39.0	18.3	99.9	50 28.0	19.9	101.1
8	51 12.2	14.0	95.9	51 05.4	15.5	97.2	50 57.3	17.1	98.4	50 47.9	18.7	99.6
9	51 26.2	12.6	94.4	51 20.9	14.3	95.6	51 14.4	15.9	96.9	51 06.6	17.5	98.1
10	51 38.8	+11.4	92.8	51 35.2	+13.1	94.1	51 30.3	+14.7	95.3	51 24.1	+16.3	96.6
11	51 50.2	10.1	91.2	51 48.3	11.8	92.5	51 45.0	13.5	93.8	51 40.4	15.1	95.0
12	52 00.3	8.9	89.6	52 00.1	10.5	90.9	51 58.5	12.1	92.2	51 55.5	13.8	93.5
13	52 09.2	7.4	88.0	52 10.6	9.1	89.3	52 10.6	10.9	90.6	52 09.3	12.6	91.9
14	52 16.6	6.2	86.4	52 19.7	7.9	87.7	52 21.5	9.5	89.0	52 21.9	11.3	90.3
15	52 22.8	+4.8	84.8	52 27.6	+6.5	86.1	52 31.0	+8.2	87.4	52 33.1	+9.9	88.7
16	52 27.6	3.4	83.1	52 34.1	5.1	84.4	52 39.2	6.9	85.7	52 43.0	8.6	87.0
17	52 31.0	2.1	81.5	52 39.2	3.8	82.8	52 46.1	5.5	84.1	52 51.6	7.2	85.4
18	52 33.1	+0.7	79.8	52 43.0	2.4	81.1	52 51.6	4.1	82.4	52 58.8	5.8	83.8
19	52 33.8	−0.6	78.2	52 45.4	+1.1	79.5	52 55.7	2.8	80.8	53 04.6	4.5	82.1
20	52 33.2	−2.0	76.6	52 46.5	−0.4	77.8	52 58.5	+1.3	79.1	53 09.1	+3.1	80.4
21	52 31.2	3.4	74.9	52 46.1	1.7	76.2	52 59.8	0.0	77.5	53 12.2	1.6	78.8
22	52 27.8	4.8	73.3	52 44.4	3.1	74.5	52 59.8	−1.4	75.8	53 13.8	+0.3	77.1
23	52 23.0	6.0	71.6	52 41.3	4.4	72.9	52 58.4	2.9	74.1	53 14.1	−1.1	75.4
24	52 17.0	7.5	70.0	52 36.9	5.9	71.2	52 55.5	4.1	72.5	53 13.0	2.6	73.8
25	52 09.5	−8.7	68.4	52 31.0	−7.1	69.6	52 51.4	−5.6	70.8	53 10.4	−3.9	72.1
26	52 00.8	10.1	66.8	52 23.9	8.5	68.0	52 45.8	6.9	69.2	53 06.5	5.3	70.4
27	51 50.7	11.3	65.2	52 15.4	9.9	66.4	52 38.9	8.3	67.5	53 01.2	6.7	68.8
28	51 39.4	12.6	63.6	52 05.5	11.1	64.7	52 30.6	9.6	65.9	52 54.5	8.1	67.1
29	51 26.8	13.9	62.0	51 54.4	12.4	63.1	52 21.0	11.0	64.3	52 46.4	9.4	65.5
30	51 12.9	−15.1	60.5	51 42.0	−13.7	61.6	52 10.0	−12.2	67.7	52 37.0	−10.7	63.9
31	50 57.8	16.3	58.9	51 28.3	14.9	60.0	51 57.8	13.5	61.1	52 26.3	12.1	62.2
32	50 41.5	17.4	57.4	51 13.4	16.1	58.4	51 44.3	14.7	59.5	52 14.2	13.3	60.6
33	50 24.1	18.7	55.9	50 57.3	17.4	56.9	51 29.6	16.0	58.0	52 00.9	14.6	59.0
34	50 05.4	19.7	54.4	50 39.9	18.5	55.4	51 13.6	17.2	56.4	51 46.3	15.9	57.5
35	49 45.7	−20.9	52.9	50 21.4	−19.6	53.9	50 56.4	−18.4	54.9	51 30.4	−17.0	55.9
36	49 24.8	21.9	51.5	50 01.8	20.7	52.4	50 38.0	19.5	53.4	51 13.4	18.3	54.4
37	49 02.9	22.9	50.1	49 41.1	21.8	51.0	50 18.5	20.6	51.9	50 55.1	19.4	52.9
38	48 40.0	24.0	48.7	49 19.3	22.9	49.5	49 57.9	21.8	50.4	50 35.7	20.6	51.4
39	48 16.0	24.9	47.3	48 56.4	23.9	48.1	49 36.1	22.8	49.0	50 15.1	21.6	49.9
40	47 51.1	−25.9	45.9	48 32.5	−24.8	46.7	49 13.3	−23.8	47.6	49 53.5	−22.8	48.4
41	47 25.2	26.8	44.6	48 07.7	25.9	45.4	48 49.5	24.8	46.2	49 30.7	23.7	47.0
42	46 58.4	27.7	43.3	47 41.8	26.7	44.0	48 24.7	25.8	44.8	49 07.0	24.8	45.6
43	46 30.7	28.5	42.0	47 15.1	27.7	42.7	47 58.9	26.7	43.4	48 42.2	25.8	44.2
44	46 02.2	29.4	40.7	46 47.4	28.5	41.4	47 32.2	27.7	42.1	48 16.4	26.7	42.9
45	45 32.8	−30.2	39.4	46 18.9	−29.4	40.1	47 04.5	−28.5	40.8	47 49.7	−27.6	41.5
46	45 02.6	31.0	38.2	45 49.5	30.2	38.9	46 36.0	29.4	39.5	47 22.1	28.6	40.2
47	44 31.6	31.7	37.0	45 19.3	31.0	37.6	46 06.6	30.1	38.2	46 53.5	29.3	38.9
48	43 59.9	32.5	35.8	44 48.3	31.7	36.4	45 36.5	31.0	37.0	46 24.2	30.2	37.6
49	43 27.4	33.1	34.7	44 16.6	32.4	35.2	45 05.5	31.8	35.8	45 54.0	31.1	36.4
50	42 54.3	−33.8	33.5	43 44.2	−33.2	34.0	44 33.7	−32.5	34.6	45 22.9	−31.7	35.2
51	42 20.5	34.5	32.4	43 11.0	33.8	32.9	44 01.2	33.1	33.4	44 51.2	32.6	34.0
52	41 46.0	35.0	31.3	42 37.2	34.5	31.8	43 28.1	33.9	32.3	44 18.6	33.2	32.8
53	41 11.0	35.7	30.2	42 02.7	35.1	30.7	42 54.2	34.5	31.1	43 45.4	33.9	31.6
54	40 35.3	36.2	29.2	41 27.6	35.7	29.6	42 19.7	35.2	30.0	43 11.5	34.6	30.5
55	39 59.1	−36.8	28.1	40 51.9	−36.3	28.5	41 44.5	−35.8	28.9	42 36.9	−35.2	29.4
56	39 22.3	37.4	27.1	40 15.6	36.9	27.5	41 08.7	36.3	27.9	42 01.7	35.9	28.3
57	38 44.9	37.8	26.1	39 38.7	37.4	26.4	40 32.4	36.9	26.8	41 25.8	36.4	27.2
58	38 07.1	38.4	25.1	39 01.3	37.9	25.4	39 55.5	37.5	25.8	40 49.4	37.0	26.1
59	37 28.7	38.8	24.1	38 23.4	38.3	24.4	39 18.0	38.0	24.8	40 12.4	37.5	25.1
60	36 49.9	−39.2	23.1	37 45.1	−38.9	23.5	38 40.0	−38.4	23.8	39 34.9	−38.1	24.1
61	36 10.7	39.7	22.2	37 06.2	39.3	22.5	38 01.6	39.0	22.8	38 56.8	38.5	23.1
62	35 31.0	40.1	21.3	36 26.9	39.8	21.5	37 22.6	39.4	21.8	38 18.3	39.1	22.1
63	34 50.9	40.5	20.4	35 47.1	40.2	20.6	36 43.2	39.8	20.9	37 39.2	39.5	21.2
64	34 10.4	40.9	19.5	35 06.9	40.6	19.7	36 03.4	40.3	20.0	36 59.7	39.9	20.2
65	33 29.5	−41.3	18.6	34 26.3	−40.9	18.8	35 23.1	−40.7	19.0	36 19.8	−40.4	19.3
66	32 48.2	41.6	17.7	33 45.4	41.4	17.9	34 42.4	41.1	18.1	35 39.4	40.8	18.4
67	32 06.6	41.9	16.9	33 04.0	41.7	17.1	34 01.3	41.4	17.3	34 58.6	41.2	17.5
68	31 24.7	42.3	16.0	32 22.3	42.0	16.2	33 19.9	41.8	16.4	34 17.4	41.5	16.6
69	30 42.4	42.6	15.2	31 40.3	42.4	15.4	32 38.1	42.1	15.5	33 35.9	41.9	15.7
70	29 59.8	−42.9	14.4	30 57.9	−42.7	14.5	31 56.0	−42.5	14.7	32 54.0	−42.3	14.9
71	29 16.9	43.1	13.6	30 15.2	42.9	13.7	31 13.5	42.8	13.9	32 11.7	42.5	14.0
72	28 33.8	43.5	12.8	29 32.3	43.3	12.9	30 30.7	43.1	13.0	31 29.2	42.9	13.2
73	27 50.3	43.7	12.0	28 49.0	43.5	12.1	29 47.6	43.3	12.2	30 46.3	43.2	12.4
74	27 06.6	43.9	11.2	28 05.5	43.8	11.3	29 04.3	43.7	11.4	30 03.1	43.5	11.6
75	26 22.7	−44.2	10.5	27 21.7	−44.1	10.6	28 20.6	−43.9	10.7	29 19.6	−43.8	10.8
76	25 38.5	44.5	9.7	26 37.6	44.3	9.8	27 36.7	44.1	9.9	28 35.8	44.0	10.0
77	24 54.0	44.6	9.0	25 53.3	44.5	9.1	26 52.6	44.5	9.1	27 51.8	44.3	9.2
78	24 09.4	44.8	8.2	25 08.8	44.8	8.3	26 08.1	44.6	8.4	27 07.5	44.5	8.5
79	23 24.6	45.1	7.5	24 24.0	44.9	7.6	25 23.5	44.8	7.6	26 23.0	44.8	7.7
80	22 39.5	−45.2	6.8	23 39.1	−45.2	6.9	24 38.7	−45.1	6.9	25 38.2	−45.0	7.0
81	21 54.3	45.4	6.1	22 53.9	45.3	6.1	23 53.6	45.3	6.2	24 53.2	45.2	6.2
82	21 08.9	45.6	5.4	22 08.6	45.5	5.4	23 08.3	45.4	5.5	24 08.0	45.3	5.5
83	20 23.3	45.8	4.7	21 23.1	45.7	4.7	22 22.9	45.7	4.8	23 22.7	45.6	4.8
84	19 37.5	45.9	4.0	20 37.4	45.9	4.0	21 37.2	45.8	4.1	22 37.1	45.8	4.1
85	18 51.6	−46.0	3.3	19 51.5	−46.0	3.3	20 51.4	−46.0	3.4	21 51.3	−45.9	3.4
86	18 05.6	46.2	2.6	19 05.5	46.2	2.7	20 05.4	46.1	2.7	21 05.4	46.2	2.7
87	17 19.4	46.4	2.0	18 19.3	46.3	2.0	19 19.3	46.3	2.0	20 19.2	46.2	2.0
88	16 33.0	46.4	1.3	17 33.0	46.4	1.3	18 33.0	46.4	1.3	19 33.0	46.4	1.3
89	15 46.6	46.6	0.7	16 46.6	46.6	0.7	17 46.6	46.6	0.7	18 46.6	46.6	0.7
90	15 00.0	−46.7	0.0	16 00.0	−46.7	0.0	17 00.0	−46.7	0.0	18 00.0	−46.7	0.0
	15°			16°			17°			18°		

19° Hc	d	Z	20° Hc	d	Z	21° Hc	d	Z	22° Hc	d	Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
47 17.4	+28.4	111.9	46 54.6	+29.6	112.9	46 30.8	+30.8	113.9	46 06.0	+32.1	114.8	0
47 45.8	27.5	110.6	47 24.2	28.7	111.6	47 01.6	30.0	112.6	46 38.1	31.2	113.6	1
48 13.3	26.5	109.3	47 52.9	27.9	110.3	47 31.6	29.1	111.3	47 09.3	30.4	112.4	2
48 39.8	25.5	107.9	48 20.8	26.9	109.0	48 00.7	28.3	110.0	47 39.7	29.5	111.1	3
49 05.3	24.6	106.5	48 47.7	25.9	107.6	48 29.0	27.3	108.7	48 09.2	28.6	109.8	4
49 29.9	+23.5	105.1	49 13.6	+25.0	106.3	48 56.3	+26.3	107.4	48 37.8	+27.7	108.5	5
49 53.4	22.5	103.7	49 38.6	23.9	104.9	49 22.6	25.4	106.0	49 05.5	26.8	107.1	6
50 15.9	21.4	102.3	50 02.5	22.9	103.4	49 48.0	24.3	104.6	49 32.3	25.8	105.7	7
[illegible] 37.3	20.2	100.8	50 25.4	21.8	102.0	50 12.3	23.3	103.2	49 50.1	24.7	104.3	8
50 57.5	19.1	99.3	50 47.2	20.6	100.5	50 35.6	22.7	101.7	50 22.8	21.2	102.9	9
51 16.6	+17.9	97.8	51 07.8	+19.5	99.0	50 57.8	+21.0	100.3	50 46.5	+22.5	101.5	10
51 34.5	16.7	96.3	51 27.3	18.3	97.5	51 18.8	19.9	98.8	51 09.0	21.5	100.0	11
51 51.2	15.5	94.7	51 45.6	17.1	96.0	51 38.7	18.7	97.3	51 30.5	20.3	98.5	12
52 06.7	14.2	93.2	52 02.7	15.9	94.4	51 57.4	17.5	95.7	51 50.8	19.1	97.0	13
52 20.9	12.9	91.6	52 18.6	14.6	92.9	52 14.9	16.3	94.2	52 09.9	17.9	95.4	14
52 33.8	+11.6	90.0	52 33.2	+13.3	91.3	52 31.2	+14.9	92.6	52 27.8	+16.6	93.9	15
52 45.4	10.3	88.4	52 46.5	12.0	89.7	52 46.1	13.7	91.0	52 44.4	15.4	92.3	16
52 55.7	8.9	86.7	52 58.5	10.6	88.0	52 59.8	12.4	89.4	52 59.8	14.0	90.7	17
53 04.6	7.6	85.1	53 09.1	9.3	86.4	53 12.2	11.0	87.7	53 13.8	12.8	89.1	18
53 12.2	6.2	83.4	53 18.4	7.9	84.8	53 23.2	9.6	86.1	53 26.6	11.3	87.4	19
53 18.4	+4.8	81.8	53 26.3	+6.5	83.1	53 32.8	+8.3	84.4	53 37.9	+10.0	85.8	20
53 23.2	3.4	80.1	53 32.8	5.1	81.4	53 41.1	6.8	82.8	53 47.9	8.6	84.1	21
53 26.6	1.9	78.4	53 37.9	3.7	79.7	53 47.9	5.4	81.1	53 56.5	7.2	82.4	22
53 28.5	+0.6	76.7	53 41.6	2.3	78.1	53 53.3	4.1	79.4	54 03.7	5.7	80.8	23
53 29.1	−0.9	75.1	53 43.9	+0.8	76.4	53 57.4	2.5	77.7	54 09.4	4.4	79.1	24
53 28.2	−2.2	73.4	53 44.7	−0.5	74.7	53 59.9	+1.2	76.0	54 13.8	+2.8	77.4	25
53 26.0	3.7	71.7	53 44.2	2.0	73.0	54 01.1	−0.3	74.3	54 16.6	+1.4	75.6	26
53 22.3	5.1	70.0	53 42.2	3.5	71.3	54 00.8	1.8	72.6	54 18.0	0.0	73.9	27
53 17.2	6.4	68.4	53 38.7	4.8	69.6	53 59.0	3.2	70.9	54 18.0	−1.5	72.2	28
53 10.8	7.9	66.7	53 33.9	6.3	67.9	53 55.8	4.6	69.2	54 16.5	3.0	70.5	29
53 02.9	−9.2	65.0	53 27.6	7.6	66.3	53 51.2	−6.0	67.5	54 13.5	−4.4	68.8	30
52 53.7	10.6	63.4	53 20.0	9.0	64.6	53 45.2	7.5	65.8	54 09.1	5.8	67.1	31
52 43.1	11.8	61.8	53 11.0	10.4	62.9	53 37.7	8.8	64.2	54 03.3	7.3	65.4	32
52 31.3	13.2	60.2	53 00.6	11.7	61.3	53 28.9	10.3	62.5	53 56.0	8.7	63.7	33
52 18.1	14.5	58.6	52 48.9	13.1	59.7	53 18.6	11.5	60.8	53 47.3	10.0	62.0	34
52 03.6	−15.7	57.0	52 35.8	−14.3	58.1	53 07.1	−13.0	59.2	53 37.3	−11.5	60.4	35
51 47.9	17.0	55.4	52 21.5	13.6	56.5	52 54.1	14.3	57.6	53 25.8	12.8	58.7	36
51 30.9	18.1	53.9	52 05.9	16.9	54.9	52 39.9	15.5	56.0	53 13.0	14.1	57.1	37
51 12.8	19.4	52.3	51 49.0	18.1	53.3	52 24.4	16.8	54.4	52 58.9	15.5	55.5	38
50 53.4	20.5	50.8	51 30.9	19.3	51.8	52 07.6	18.0	52.8	52 43.4	16.7	53.9	39
50 32.9	−21.6	49.3	51 11.6	−20.4	50.3	51 49.6	−19.2	51.3	52 26.7	−17.9	52.3	40
50 11.3	22.7	47.9	50 51.2	21.6	48.8	51 30.4	20.4	49.7	52 08.8	19.3	50.7	41
49 48.6	23.7	46.4	50 29.6	22.6	47.3	51 10.0	21.6	48.2	51 49.6	20.4	49.2	42
49 24.9	24.8	45.0	50 07.0	23.7	45.9	50 48.4	22.6	46.7	51 29.2	21.5	47.7	43
49 00.1	25.7	43.6	49 43.3	24.8	44.4	50 25.8	23.7	45.3	51 07.7	22.7	46.2	44
48 34.4	−26.7	42.3	49 18.5	−25.8	43.0	50 02.1	−24.8	43.9	50 45.0	−23.7	44.7	45
48 07.7	27.7	40.9	48 52.7	26.7	41.7	49 37.3	25.8	42.4	50 21.3	24.8	43.2	46
47 40.0	28.5	39.6	48 26.0	27.7	40.3	49 11.5	26.7	41.1	49 56.5	25.8	41.8	47
47 11.5	29.4	38.3	47 58.3	28.5	39.0	48 44.8	27.8	39.7	49 30.7	26.8	40.4	48
46 42.1	30.3	37.0	47 29.8	29.5	37.7	48 17.0	28.6	38.3	49 03.9	27.8	39.1	49
46 11.8	−31.0	35.8	47 00.3	−30.3	36.4	47 48.4	29.5	37.0	48 36.1	−28.7	37.7	50
45 40.8	31.9	34.5	46 30.0	31.1	35.1	47 18.9	30.4	35.7	48 07.4	29.6	36.4	51
45 08.9	32.5	33.3	45 58.9	31.9	33.9	46 48.5	31.1	34.5	47 37.8	30.4	35.1	52
44 36.4	33.3	32.1	45 27.0	32.6	32.7	46 17.4	32.0	33.2	47 07.4	31.3	33.8	53
44 03.1	34.0	31.0	44 54.4	33.4	31.5	45 45.4	32.8	32.0	46 36.1	32.1	32.6	54
43 29.1	−34.7	29.8	44 21.0	−34.1	30.3	45 12.6	−33.4	30.8	46 04.0	−32.8	31.3	55
42 54.4	35.3	28.7	43 46.9	34.7	29.2	44 39.2	34.2	29.6	45 31.2	33.6	30.1	56
42 19.1	35.9	27.6	43 12.2	35.4	28.0	44 05.0	34.9	28.5	44 57.6	34.3	29.0	57
41 43.2	36.5	26.5	42 36.8	36.1	26.9	43 30.1	35.5	27.4	44 23.3	35.0	27.8	58
41 06.7	37.1	25.5	42 00.7	36.6	25.9	42 54.6	36.1	26.3	43 48.3	35.6	26.7	59
40 29.6	−37.7	24.4	41 24.1	−37.2	24.8	42 18.5	−36.7	25.2	43 12.7	−36.3	25.6	60
39 51.9	38.1	23.4	40 46.9	37.7	23.8	41 41.8	37.4	24.1	42 36.4	36.8	24.5	61
39 13.8	38.7	22.4	40 09.2	38.3	22.7	41 04.4	37.8	23.1	41 59.6	37.5	23.4	62
38 35.1	39.1	21.4	39 30.9	38.8	21.7	40 26.6	38.4	22.0	41 22.1	38.0	22.4	63
37 56.0	39.6	20.5	38 52.1	39.2	20.8	39 48.2	38.9	21.0	40 44.1	38.5	21.4	64
37 16.4	−40.1	19.5	38 12.9	−39.8	19.8	39 09.3	−39.4	20.1	40 05.6	−39.1	20.3	65
36 36.3	40.5	18.6	37 33.1	40.2	18.8	38 29.9	39.9	19.1	39 26.5	39.3	19.4	66
35 55.8	40.9	17.7	36 52.9	40.6	17.9	37 50.0	40.3	18.1	38 47.0	40.0	18.4	67
35 14.9	41.3	16.8	36 12.3	41.0	17.0	37 09.7	40.8	17.2	38 07.0	40.5	17.4	68
34 33.6	41.6	15.9	35 31.3	41.4	16.1	36 28.9	41.1	16.3	37 26.5	40.9	16.5	69
33 52.0	−42.1	15.0	34 49.9	−41.8	15.2	35 47.8	41.6	15.4	36 45.6	41.3	15.6	70
33 09.9	42.3	14.2	34 08.1	42.2	14.3	35 06.2	41.9	14.5	36 04.3	41.8	14.7	71
32 27.6	42.7	13.3	33 25.9	42.5	13.5	34 24.3	42.3	13.6	35 22.5	42.1	13.8	72
31 44.9	43.1	12.5	32 43.4	42.8	12.6	33 42.0	42.7	12.8	34 40.4	42.4	12.9	73
31 01.8	43.3	11.7	32 00.6	43.2	11.8	32 59.3	43.0	11.9	33 58.0	42.8	12.1	74
30 18.5	−43.6	10.9	31 17.4	−43.4	11.0	32 16.3	−43.3	11.1	33 15.2	−43.2	11.2	75
29 34.9	43.9	10.1	30 34.0	43.8	10.2	31 33.0	43.6	10.3	32 32.0	43.4	10.4	76
28 51.0	44.2	9.3	29 50.2	44.0	9.4	30 49.4	43.9	9.5	31 48.6	43.8	9.6	77
28 06.8	44.4	8.5	29 06.2	44.3	8.6	30 05.5	44.2	8.7	31 04.8	44.1	8.8	78
27 22.4	44.6	7.8	28 21.9	44.6	7.8	29 21.3	44.4	7.9	30 20.7	44.3	8.0	79
26 37.8	−44.9	7.0	27 37.3	−44.8	7.1	28 36.9	−44.8	7.2	29 36.4	−44.6	7.2	80
25 52.9	45.1	6.3	26 52.5	45.0	6.3	27 52.1	44.9	6.4	28 51.8	44.9	6.5	81
25 07.8	45.4	5.6	26 07.5	45.3	5.6	27 07.2	45.2	5.6	28 06.9	45.1	5.7	82
24 22.4	45.5	4.8	25 22.2	45.4	4.9	26 22.0	45.4	4.9	27 21.8	45.4	5.0	83
23 36.9	45.7	4.1	24 36.8	45.7	4.1	25 36.6	45.6	4.2	26 36.4	45.5	4.2	84
22 51.2	−45.9	3.4	23 51.1	−45.9	3.4	24 51.0	−45.8	3.5	25 50.9	−45.8	3.5	85
22 05.3	46.1	2.7	23 05.2	46.0	2.7	24 05.2	46.1	2.8	25 05.1	46.0	2.8	86
21 19.2	46.3	2.0	22 19.2	46.3	2.0	23 19.1	46.2	2.1	24 19.1	46.2	2.1	87
20 33.0	46.4	1.3	21 32.9	46.3	1.4	22 32.9	46.4	1.4	23 32.9	46.4	1.4	88
19 46.6	46.6	0.7	20 46.6	46.6	0.7	21 46.5	46.5	0.7	22 46.5	46.5	0.7	89
19 00.0	−46.7	0.0	20 00.0	−46.7	0.0	21 00.0	−46.7	0.0	22 00.0	−46.7	0.0	90
19°			20°			21°			22°			

INTERPOLATION TABLE

Dec Inc	Tens 10'	20'	30'	40'	50'	Decimals	Units 0' 1' 2' 3' 4' 5' 6' 7' 8' 9'	Double Second Diff and Corr
44.0	7.3	14.6	22.0	29.3	36.6	.0	0007 1522 3037 4452 5967	
44.1	7.3	14.7	22.0	29.4	36.7	.1	0108 1623 3038 4553 6067	
44.2	7.3	14.7	22.1	29.4	36.8	.2	0109 1624 3139 4653 6168	1.1
44.3	7.4	14.8	22.1	29.5	36.9	.3	0210 1724 3239 4754 6269	3.2 01
44.4	7.4	14.8	22.2	29.6	37.0	.4	0310 1825 3340 4755 6270	5.3 02
44.5	7.4	14.8	22.3	29.7	37.1	.5	0411 1926 3341 4856 6370	7.5 03
44.6	7.4	14.9	22.3	29.7	37.2	.6	0412 1927 3442 4956 6471	9.6 04
44.7	7.5	14.9	22.4	29.8	37.3	.7	0513 2027 3542 5057 6572	11.7 05
44.8	7.5	15.0	22.4	29.9	37.4	.8	0613 2128 3643 5058 6573	13.9 06
44.9	7.5	15.0	22.5	30.0	37.5	.9	0714 2229 3644 5159 6673	16.0 07 18.1 08
45.0	7.5	15.0	22.5	30.0	37.5	.0	0008 1523 3038 4553 6168	20.3 09
45.1	7.5	15.0	22.5	30.0	37.6	.1	0108 1624 3139 4654 6169	22.4 10
45.2	7.5	15.0	22.6	30.1	37.6	.2	0209 1724 3239 4755 6270	24.5 11
45.3	7.5	15.1	22.6	30.2	37.7	.3	0210 1725 3340 4855 6371	26.7 12
45.4	7.6	15.1	22.7	30.3	37.8	.4	0311 1826 3341 4956 6471	28.8 13 30.9 14
45.5	7.6	15.2	22.8	30.3	37.9	.5	0411 1927 3442 4957 6472	15
45.6	7.6	15.2	22.8	30.4	38.0	.6	0512 2027 3542 5058 6573	33.1 16
45.7	7.6	15.3	22.9	30.5	38.1	.7	0513 2028 3643 5158 6674	35.2
45.8	7.7	15.3	22.9	30.6	38.2	.8	0614 2129 3644 5259 6774	
45.9	7.7	15.3	23.0	30.6	38.3	.9	0714 2230 3745 5260 6775	
46.0	7.6	15.3	23.0	30.6	38.3	.0	0008 1523 3139 4654 6270	1.2
46.1	7.7	15.3	23.0	30.7	38.4	.1	0109 1624 3240 4755 6371	3.5 01
46.2	7.7	15.4	23.1	30.8	38.5	.2	0209 1725 3340 4856 6471	5.8 02
46.3	7.7	15.4	23.1	30.9	38.6	.3	0210 1826 3341 4957 6472	8.1 03
46.4	7.7	15.5	23.2	30.9	38.7	.4	0311 1926 3442 5057 6573	10.5 04
46.5	7.8	15.5	23.3	31.0	38.8	.5	0412 1927 3543 5058 6674	12.8 05 06
46.6	7.8	15.5	23.3	31.1	38.8	.6	0512 2028 3643 5159 6774	15.1
46.7	7.8	15.6	23.4	31.2	38.9	.7	0513 2129 3644 5260 6775	17.4 07
46.8	7.8	15.6	23.4	31.2	39.0	.8	0614 2229 3745 5360 6876	19.8 08
46.9	7.9	15.7	23.5	31.3	39.1	.9	0715 2230 3846 5361 6977	22.1 09 24.4 10
47.0	7.8	15.6	23.5	31.3	39.1	.0	0008 1624 3240 4755 6371	26.7 11
47.1	7.8	15.7	23.5	31.4	39.2	.1	0109 1725 3240 4856 6472	29.1 12
47.2	7.8	15.7	23.6	31.4	39.3	.2	0209 1725 3341 4957 6573	31.4 13
47.3	7.9	15.8	23.6	31.5	39.4	.3	0210 1826 3442 5058 6674	33.7 14
47.4	7.9	15.8	23.7	31.6	39.5	.4	0311 1927 3543 5159 6674	36.0 15
47.5	7.9	15.8	23.8	31.7	39.6	.5	0412 2028 3644 5159 6775	
47.6	7.9	15.9	23.8	31.7	39.7	.6	0513 2128 3644 5260 6876	1.3
47.7	8.0	15.9	23.9	31.8	39.8	.7	0613 2129 3745 5361 6977	3.8 01
47.8	8.0	16.0	23.9	31.9	39.9	.8	0614 2230 3846 5462 7078	6.3 02
47.9	8.0	16.0	24.0	32.0	40.0	.9	0715 2331 3947 5563 7078	8.9 03 11.4 04
48.0	8.0	16.0	24.0	32.0	40.0	.0	0008 1624 3240 4857 6573	14.0 05
48.1	8.0	16.0	24.0	32.0	40.1	.1	0109 1725 3341 4957 6574	16.5 06
48.2	8.0	16.0	24.1	32.1	40.1	.2	0210 1826 3442 5058 6674	19.0 07
48.3	8.0	16.1	24.1	32.2	40.2	.3	0211 1927 3543 5159 6775	21.6 08
48.4	8.1	16.1	24.2	32.3	40.3	.4	0311 1927 3644 5260 6876	24.1 09
48.5	8.1	16.2	24.3	32.3	40.4	.5	0412 2028 3644 5361 6977	26.7 10
48.6	8.1	16.2	24.3	32.4	40.5	.6	0513 2129 3745 5361 7078	29.2 11
48.7	8.1	16.3	24.4	32.5	40.6	.7	0614 2230 3846 5462 7078	31.7 12
48.8	8.2	16.3	24.4	32.6	40.7	.8	0615 2331 3947 5563 7179	34.3 13
48.9	8.2	16.3	24.5	32.6	40.8	.9	0715 2332 4048 5664 7280	
49.0	8.1	16.3	24.5	32.6	40.8	.0	0008 1625 3341 4958 6674	
49.1	8.2	16.3	24.5	32.7	40.9	.1	0109 1726 3442 5059 6775	1.4
49.2	8.2	16.4	24.6	32.8	41.0	.2	0210 1826 3543 5159 6876	4.2 01
49.3	8.2	16.4	24.6	32.9	41.1	.3	0211 1927 3544 5260 6877	7.1 02
49.4	8.2	16.5	24.7	32.9	41.2	.4	0312 2028 3645 5361 6978	9.9 03
49.5	8.3	16.5	24.8	33.0	41.3	.5	0412 2129 3745 5462 7078	12.7 04
49.6	8.3	16.5	24.8	33.1	41.3	.6	0513 2130 3846 5463 7179	15.5 05
49.7	8.3	16.6	24.9	33.2	41.4	.7	0614 2231 3947 5564 7280	18.4 06
49.8	8.3	16.6	24.9	33.2	41.5	.8	0715 2331 4048 5664 7381	21.2 07
49.9	8.4	16.7	25.0	33.3	41.6	.9	0716 2432 4049 5765 7382	24.0 08 26.8 09
50.0	8.3	16.6	25.0	33.3	41.6	.0	0008 1725 3442 5059 6776	29.7 10
50.1	8.3	16.7	25.0	33.4	41.7	.1	0109 1826 3543 5160 6877	32.5 11
50.2	8.3	16.7	25.1	33.4	41.8	.2	0210 1927 3544 5261 6977	35.3 12
50.3	8.4	16.8	25.1	33.5	41.9	.3	0311 1928 3645 5361 7078	
50.4	8.4	16.8	25.2	33.6	42.0	.4	0312 2029 3745 5462 7179	
50.5	8.4	16.8	25.3	33.7	42.1	.5	0413 2129 3846 5563 7280	
50.6	8.4	16.9	25.3	33.7	42.2	.6	0513 2230 3947 5664 7281	
50.7	8.5	16.9	25.4	33.8	42.3	.7	0614 2331 4048 5665 7382	
50.8	8.5	17.0	25.4	33.9	42.4	.8	0715 2432 4049 5766 7482	1.6
50.9	8.5	17.0	25.5	34.0	42.5	.9	0816 2433 4150 5866 7583	4.8 01 8.0 02
51.0	8.5	17.0	25.5	34.0	42.5	.0	0009 1726 3443 5160 6977	11.2 03
51.1	8.5	17.0	25.5	34.0	42.6	.1	0109 1827 3544 5261 7078	14.5 04
51.2	8.5	17.0	25.6	34.1	42.6	.2	0210 1927 3645 5362 7079	17.7 05
51.3	8.5	17.1	25.6	34.2	42.7	.3	0311 2028 3745 5463 7180	20.9 06
51.4	8.6	17.1	25.7	34.3	42.8	.4	0312 2129 3846 5564 7281	24.1 07 27.3 08
51.5	8.6	17.2	25.8	34.3	42.9	.5	0413 2130 3947 5664 7382	30.5 09
51.6	8.6	17.2	25.8	34.4	43.0	.6	0514 2231 3948 5765 7482	33.7 10
51.7	8.6	17.3	25.9	34.5	43.1	.7	0615 2332 4049 5866 7583	36.9 11
51.8	8.7	17.3	25.9	34.6	43.2	.8	0715 2433 4150 5867 7684	
51.9	8.7	17.3	26.0	34.6	43.3	.9	0816 2533 4251 5968 7685	
	10'	20'	30'	40'	50'		0' 1' 2' 3' 4' 5' 6' 7' 8' 9'	

Dec Inc	Tens 10'	20'	30'	40'	50'	Decimals	Units 0' 1' 2' 3' 4' 5' 6' 7' 8' 9'	Double Second Diff and Corr
52.0	8.6	17.3	26.0	34.6	43.3	.0	0009 1726 3544 5261 7079	1.8
52.1	8.7	17.3	26.0	34.7	43.4	.1	0110 1827 3645 5362 7180	5.5 01
52.2	8.7	17.4	26.1	34.8	43.5	.2	0210 1928 3745 5463 7280	9.1 02
52.3	8.7	17.4	26.1	34.9	43.6	.3	0311 2029 3846 5564 7381	12.8 03
52.4	8.7	17.5	26.2	34.9	43.7	.4	0312 2130 3847 5665 7382	16.5 04
52.5	8.8	17.5	26.3	35.0	43.8	.5	0413 2231 3948 5766 7483	20.1 05
52.6	8.8	17.5	26.3	35.1	43.8	.6	0514 2331 4049 5866 7584	23.8 06
52.7	8.8	17.6	26.4	35.2	43.9	.7	0615 2432 4150 5967 7685	27.4 07
52.8	8.8	17.6	26.4	35.2	44.0	.8	0716 2433 4251 5968 7786	31.1 08
52.9	8.9	17.7	26.5	35.3	44.1	.9	0817 2534 4352 6069 7887	34.7 09
53.0	8.8	17.6	26.5	35.3	44.1	.0	0009 1827 3645 5362 7180	
53.1	8.8	17.7	26.5	35.4	44.2	.1	0110 1928 3745 5463 7281	2.1
53.2	8.8	17.7	26.6	35.4	44.3	.2	0211 2029 3746 5564 7382	6.2 01
53.3	8.9	17.8	26.6	35.5	44.4	.3	0312 2129 3847 5665 7483	10.4 02
53.4	8.9	17.8	26.7	35.6	44.5	.4	0412 2130 3948 5766 7584	14.5 03 18.6 04
53.5	8.9	17.8	26.8	35.7	44.6	.5	0413 2231 4049 5867 7685	22.8 05
53.6	8.9	17.9	26.8	35.7	44.7	.6	0514 2332 4150 5968 7786	26.9 06
53.7	9.0	17.9	26.9	35.8	44.8	.7	0615 2433 4251 6069 7886	31.1 07
53.8	9.0	18.0	26.9	35.9	44.9	.8	0716 2534 4352 6170 7887	35.2 08
53.9	9.0	18.0	27.0	36.0	45.0	.9	0817 2635 4453 6270 7988	
54.0	9.0	18.0	27.0	36.0	45.0	.0	0009 1827 3645 5464 7382	
54.1	9.0	18.0	27.0	36.0	45.1	.1	0110 1928 3746 5564 7483	2.4
54.2	9.0	18.0	27.1	36.1	45.1	.2	0211 2029 3847 5665 7484	7.2 01
54.3	9.0	18.1	27.1	36.2	45.2	.3	0312 2130 3948 5766 7584	12.0 02
54.4	9.1	18.1	27.2	36.3	45.3	.4	0413 2231 4049 5867 7685	16.8 03 21.6 04
54.5	9.1	18.2	27.3	36.3	45.4	.5	0514 2332 4150 5968 7786	26.4 05
54.6	9.1	18.2	27.3	36.4	45.5	.6	0515 2433 4251 6069 7887	31.2 06
54.7	9.1	18.3	27.4	36.5	45.6	.7	0615 2534 4352 6170 7988	36.0 07
54.8	9.2	18.3	27.4	36.6	45.7	.8	0716 2535 4453 6271 8089	
54.9	9.2	18.3	27.5	36.6	45.8	.9	0817 2635 4554 6372 8190	
55.0	9.1	18.3	27.5	36.6	45.8	.0	0009 1828 3746 5565 7483	
55.1	9.2	18.3	27.5	36.7	45.9	.1	0110 1929 3847 5666 7584	
55.2	9.2	18.4	27.6	36.8	46.0	.2	0211 2030 3948 5767 7685	2.9
55.3	9.2	18.4	27.6	36.9	46.1	.3	0312 2131 4049 5868 7786	8.6 01
55.4	9.2	18.5	27.7	36.9	46.2	.4	0413 2231 4150 5968 7887	14.4 02 20.2 03
55.5	9.3	18.5	27.8	37.0	46.3	.5	0514 2332 4251 6069 7988	25.9 04
55.6	9.3	18.5	27.8	37.1	46.3	.6	0615 2433 4352 6170 8089	31.7 05
55.7	9.3	18.6	27.9	37.2	46.4	.7	0616 2534 4353 6271 8090	37.5 06
55.8	9.3	18.6	27.9	37.2	46.5	.8	0717 2635 4454 6372 8191	
55.9	9.4	18.7	28.0	37.3	46.6	.9	0818 2736 4555 6473 8292	
56.0	9.3	18.6	28.0	37.3	46.6	.0	0009 1928 3847 5666 7585	
56.1	9.3	18.7	28.0	37.4	46.7	.1	0110 2029 3948 5767 7686	
56.2	9.3	18.7	28.1	37.4	46.8	.2	0211 2130 4049 5868 7787	3.6
56.3	9.4	18.8	28.1	37.5	46.9	.3	0312 2231 4050 5969 7888	10.9 01
56.4	9.4	18.8	28.2	37.6	47.0	.4	0413 2332 4151 6070 7989	18.2 02
56.5	9.4	18.8	28.3	37.7	47.1	.5	0514 2433 4252 6171 8089	25.5 03
56.6	9.4	18.9	28.3	37.7	47.2	.6	0615 2434 4353 6272 8190	32.8 04
56.7	9.5	18.9	28.4	37.8	47.3	.7	0716 2535 4454 6373 8291	40.1 05
56.8	9.5	19.0	28.4	37.9	47.4	.8	0817 2636 4555 6473 8392	
56.9	9.5	19.0	28.5	38.0	47.5	.9	0818 2737 4656 6574 8493	
57.0	9.5	19.0	28.5	38.0	47.5	.0	0010 1929 3848 5767 7786	
57.1	9.5	19.0	28.5	38.0	47.6	.1	0111 2030 3949 5868 7887	
57.2	9.5	19.0	28.6	38.1	47.6	.2	0211 2131 4050 5969 7988	
57.3	9.5	19.1	28.6	38.2	47.7	.3	0312 2232 4151 6070 8089	5.0
57.4	9.6	19.1	28.7	38.3	47.8	.4	0413 2333 4252 6171 8090	15.0 01
57.5	9.6	19.2	28.8	38.3	47.9	.5	0514 2434 4353 6272 8191	25.0 02
57.6	9.6	19.2	28.8	38.4	48.0	.6	0615 2534 4454 6373 8292	35.1 03
57.7	9.6	19.3	28.9	38.5	48.1	.7	0716 2635 4555 6474 8393	
57.8	9.7	19.3	28.9	38.6	48.2	.8	0817 2736 4656 6575 8494	
57.9	9.7	19.3	29.0	38.6	48.3	.9	0918 2837 4757 6676 8595	
58.0	9.6	19.3	29.0	38.6	48.3	.0	0010 1929 3949 5868 7888	
58.1	9.7	19.3	29.0	38.7	48.4	.1	0111 2030 4050 5969 7989	
58.2	9.7	19.4	29.1	38.8	48.5	.2	0212 2131 4151 6070 8090	
58.3	9.7	19.4	29.1	38.9	48.6	.3	0313 2232 4252 6171 8191	
58.4	9.7	19.5	29.2	38.9	48.7	.4	0414 2333 4353 6272 8292	8.2
58.5	9.8	19.5	29.3	39.0	48.8	.5	0515 2434 4454 6373 8393	24.6 01 41.0 02
58.6	9.8	19.5	29.3	39.1	48.8	.6	0616 2535 4555 6474 8494	
58.7	9.8	19.6	29.4	39.2	48.9	.7	0717 2636 4656 6575 8595	
58.8	9.8	19.6	29.4	39.2	49.0	.8	0818 2737 4757 6676 8696	
58.9	9.9	19.7	29.5	39.3	49.1	.9	0919 2838 4858 6777 8797	
59.0	9.8	19.6	29.5	39.3	49.1	.0	0010 2030 4050 5969 7989	
59.1	9.8	19.7	29.5	39.4	49.2	.1	0111 2131 4151 6070 8090	16.2
59.2	9.8	19.7	29.6	39.4	49.3	.2	0212 2232 4252 6171 8191	48.6 01
59.3	9.9	19.8	29.6	39.5	49.4	.3	0313 2333 4353 6272 8292	
59.4	9.9	19.8	29.7	39.6	49.5	.4	0414 2434 4454 6373 8393	
59.5	9.9	19.8	29.8	39.7	49.6	.5	0515 2535 4555 6474 8494	
59.6	9.9	19.9	29.8	39.7	49.7	.6	0616 2636 4656 6575 8595	0.0
59.7	10.0	19.9	29.9	39.8	49.8	.7	0717 2737 4757 6676 8696	48.2 00
59.8	10.0	20.0	29.9	39.9	49.9	.8	0818 2838 4858 6777 8797	
59.9	10.0	20.0	30.0	40.0	50.0	.9	0919 2939 4959 6878 8898	
	10'	20'	30'	40'	50'		0' 1' 2' 3' 4' 5' 6' 7' 8' 9'	

The Double-Second-Difference correction (Corr.) is always to be added to the tabulated altitude

4. How to Program the Formulae of Celestial Navigation

By CASIO fx-180P, fx-3600P, fx-4000P, fx-7000G and fx-8000G.

Electronic calculator "Casio fx-180P" can be programmed. It has a program memory of 38 steps and two programmed procedures of computation can be stored in the memory. To store a program in the calculator, execute ordinary calculation in the LRN mode ([MODE] [0]).

Then the program has been memorized. Input data and press [ENT] Key and the calculator executes the program according to the data. So an expeditious solution will be available repeatedly.

As mentioned, "Casio fx-180P" has a memory of only 38 steps, so the basic formula : $Ac = 90^\circ - \cos^{-1}\{(\cos Lat. \times \cos Dec. \times \cos LHA) - \cos L \times \cos D + \cos (L+D)\}$ should be simplified and restated as follows:

$$Ac = 90^\circ - \cos^{-1}\{(\cos Lat. \times \cos Dec. \times \cos LHA) - \underline{\cos Lat. \times \cos Dec.} + \underline{(\cos Lat. \times \cos Dec. - \sin Lat. \times \sin Dec.)}\}$$

$$\because \cos(\alpha + \beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta$$

$$= 90^\circ - \cos^{-1}\{(\cos Lat. \times \cos Dec. \times \cos LHA) + \sin Lat. \sin Dec.\}$$

$$= \underline{\sin^{-1}\{(\cos Lat. \times \cos Dec \times \cos LHA) + \sin Lat \times \sin Dec\}}$$

$$\because 90^\circ - \cos^{-1}(\theta) = \sin^{-1}(\theta)$$

Concerning the formula of azimuth of a celestial body:

$Z = \sin^{-1}(\sin LHA \times \cos Dec. \div \cos Ac)$ can be programmed as it is. Therefore,

$$\text{Program 1 } (P_1) = \sin^{-1}\{(\cos Lat. \times \cos Dec. \times \cos LHA) + \sin Lat. \times \sin Dec.\}$$

$$\text{Program 2 } (P_2) = \sin^{-1}(\sin LHA \times \cos Dec. \div \cos \underset{\updownarrow\,(P_1)}{Ac})$$

Program Lat.(L) = 21°N, Dec.(D) = 19°N, and LHA = 315°

MODE 0 P_1 MODE 4 ENT 2 1 °'" Kin 1 ENT 1 9 °'" Kin 2 ENT
3 1 5 °'" Kin 3

Kout 1 sin x Kout 2 sin)] + Kout 1 cos x Kout 2 cos x
Kout 3 cos)] INV $\sin^{-1}$ = Kin 4 INV HLT

Ref: Ac (= Hc) = $\sin^{-1}$ (cos L x cos D x cos LHA) + (sin L x sin D)

INV P_2 Kout 3 sin x Kout 2 cos ÷ Kout 4 cos)] inv $\sin^{-1}$

Ref: Z = $\sin^{-1}$ (sin LHA x cos D ÷ cos Ac)

Run --- Computation by the program.

Attention!

when latitude (L) and declination (D) are of contrary name declination should be treated as a negative value.

Example 1 — From "Sight Reduction Table" Page 93, Vol.2. Pub. No.229

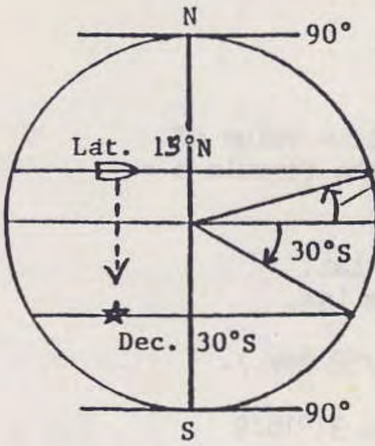
Required:- Ac and Z, when lat. = 15°N, dec. = 30°S and LHA = 315°

Solution

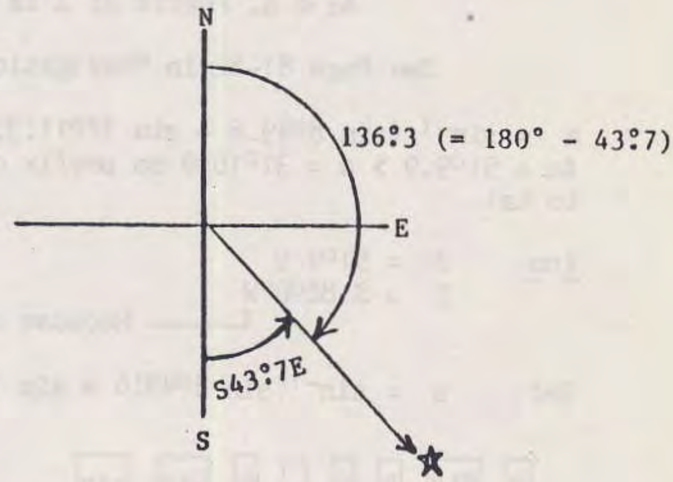
MODE . P_1 1 5 °'" ENT 3 0 °'" +/- ENT 3 1 5 °'" ENT

→ 27.522495 INV °'" → 27°31° 20.98 (=27°31'.3 → 20.98/60 ≑ 0.3497 = 0.3)

INV P_2 ⟶ -43.6711912 (≑ 43°7) INV °'" → -43°40°16.2 (= -43°40'.3 — 16.2/60 = 0.27 ≑ 0.3)



Prefix of Z = South.
Suffix of Z = East (Because of LHA > 270°)
∴ Z = S 43.7°E (S 43°40'.3 E)
or 136°.3



Ans. Ac = 27°31'.3
Z = S 43°.7 E or 136°.3

Example 2 - From page ....

Required:- Ac and Z, when Lat. = 17°11'.3 N, Dec. = 08°- 49'.6 N, and LHA = 39°00'.2.

Solution

[P1] [1] [7] [°' "] [1] [1] [.] [3] [°' "] [ENT] [8] [°' "] [4] [9] [.] [6] [°' "] [ENT]

[3] [9] [°' "] [0] [.] [2] [°' "] [ENT] → 51.16505034 [INV] [°' "] → 51°9'54.18

(= 51°9'.9 → 54.18/60 = 0.903 ≑ 0.9) [RUN] → 82.63971254 (≑ 82°.6) [INV] [°' "] →

82°38°22.97 (= 82°38'.4 → 22.97/60 = 0.38 ≑ 0.4)

Attention!

In a case when

Lat. and Dec. are the same names and the value of Lat. > value of Dec., the prefix of Z (≑ 82°6) should be checked by the formula a = $\sin^{-1}$ (sin D ÷ sin L) of Altitude in Prime Vertical.

when Ac > a, Prefix of Z is contray name to Lat.
Ac < a, Prefix of Z is the same name as Lat.

See Page 81-82 in "Navigation Table" (TD/LN/52 Rev.).

a = $\sin^{-1}$ (sin 8°49.6 ÷ sin 17°11'.3) = 31.28203863 = 31°16'.9
Ac = 51°9.9 > a = 31°16'.9 so prefix of Z should be contrary name to Lat.

<u>Ans.</u> Ac = 51°9'.9
Z = S 82°6 W
↑—— Because of LHA < 180°

Ref: a = $\sin^{-1}$(sin 8°49'.6 ÷ sin 17°11'.3)

[8] [°'"] [4] [9] [.] [6] [°'"] [sin] [÷] [1] [7] [°'"] [1] [1] [.] [3] [°'"]

[sin] [=] → 0.519251226 [INV] [sin] → 31.28203863

[INV] [°'"] → 31°16°55.34 (= 31°<u>16'.9</u> → 55.34/60 = 0.922 ≑ <u>0.9</u>)

<u>Example 3</u> - From page 247.

<u>Required:</u> - Ac and Z, when Lat. - 17°11'.3 N, Dec. = 38°46'.0 N, and LHA = 58°01'.9.

[P1] [1] [7] [°'"] [1] [1] [.] [3] [°'"] [ENT] [3] [8] [°'"] [4] [6] [°'"]

[ENT] [5] [8] [°'"] [.] [9] [°'"] [ENT] → 35.40925418 [INV] [°'"]

→ 35°24° 33.32 (= 35°<u>24'.6</u> → 33.32/60 ≑ 0.5553 = 0<u>.6</u>)

[RUN] → 54.24913429 [INV] [o ' "] 54°14° 56.88 (= 54°14.'9 →

56.88/60 = 0.948 ≒ 0.9

In this case the computation of a = $\sin^{-1}$ (sin D + sin L) to check the prefix of Z (= 54°14.'9) is unnecessary. Because the value of Dec. (38°46.'0) is greater than that of Lat. (= 17°11.'3) although Lat. and Dec. are the same name.

Ans. Ac = 35°24.'6
Z = N 54°2 W or N 54°14.'9 W

Example 4

when Lat. = 52°28.'2 N, Dec. = 11°09.'0 S and LHA = 323°30.'7

Required:- Ac and Z (please be careful when L and D are of contrary name)

Ans. Ac = 19.0967568 = 19°5°48.'32 = 19°5.'8
Z = -38.127409 = -38°7°38.'67 = S 38°7.'6 E

Example 5

when Lat. = 52°28.'2 N, Dec. = 20°16.'3 N, and LHA = 39°44.'0

Required:- Ac and Z

Ans. Ac = 45.57938214 = 45°34°45.78 = 45°34.8
Z = 58.94817626 = 58°56°53.43 = S 58°56.'9 W

Ref. : Lat. and Dec. are the same name and Lat. > Dec.

Then a = $\sin^{-1}$(sin D + sin L) = $\sin^{-1}$(sin 20°16.'3 + sin 52°28.'2)
= 25.90585778 = 25°54°21.09 = 25°54.'4

Ac (= 45°34.'8) > a (=25°54.'4)

So the prefix of Z (=58°56.'9) should be contrary to Lat. (→ S)

Example 6

when Lat. = 15°08.'0 S, Dec. = 56°50.'0 S and LHA = 293°27.'5

Required:- Ac and Z

Ans. Ac = 25.38906874 = 25°23°20.65 = 25°23'.3
Z = -33.7460874 = -33°44°45.9 = S 33°44'.8 E

In this case the computation of a = $\sin^{-1}(\sin D \div \sin L)$ to check the prefix of Z is unnecessary. Because the value of Dec. is greater than that of Lat. although Lat. and Dec. are the same name.

Example 7

when Lat. = 15°08'.0 S, Dec. = 38°44'.9 N and LHA = 321°06'.3

Required:- Ac and Z

Ans. Ac = 24.99537237 = 24°59°43.43 = 24°59'.7
Z = -32.7041063 = -32°42°14.7 = N 32°42'.2 E

Example 8

when Lat. = 28°17'.0 N, Dec. = 15°52'.1 S and LHA = 60°24'.3

Required:- Ac and Z

Ans. Ac = 16.7845703 = 16°47°04'.45 = 16°47'.1
Z = 60.88216353 = 60°52°55.75 = S 60°52'.9 W

Example 9

when Lat. = 28°22'.8 N, Dec. = 16°40'.5 S and LHA 307°16'.5

Required:- Ac and Z

Ans. Ac = 21.96595906 = 21°57°57.45 = 21°57'.9
Z = -55.2797932 = -55°16°47.2 = S 55°16'.8 E

Casio fx-3600 P

Program

MODE 0 P1 MODE 4

ENT 2 1 °'" Kin 1 ENT 1 9 °'" Kin 2 ENT 3 1 5 °'"

Kin 3

Kout 1 cos x Kout 2 cos x Kout 3 cos)] +

Kout 1 sin x Kout 2 sin)] INV sin = Kin 4 INV HLT

Ref.(1): Ac(= Hc) = $\sin^{-1}$\{(cos Lat. x cos Dec. x cos LHA) + (sin Lat. x sin Dec.)\}

Kout 3 sin x Kout 2 cos ÷ Kout 4 cos)] INV $\sin^{-1}$

INV RTN

Ref.(2): Z = $\sin^{-1}$(sin LHA x cos Dec. ÷ cos Ac)

Ref.(3): To erase program P_1 or P_2 ⟶ MODE 0 (or INV P_2)

INV PCL

To erase both P_1 and P_2 ⟶ MODE 0 INV PCL

Run --- The calculator executes the program with the data.

Example 1

[MODE] [.] [P_1] [2] [1] [°'"] [ENT] [1] [9] [°'"] [ENT] [3] [1] [5] [°'"] [ENT] →

47.8037721 [INV] [°'"] → 47°48°13.58 (= 47°48.'2, 13.58/60 ≑ 0.226 ≑ 0.2)

[ENT] → -84.5026918 = -84.°5 → See "Sight Reduction Table" page 92, Vol.2, Pub. No.229

Example 2

when Lat. = 15°N, Dec. = 30°S, and LHA = 315°

Required:- Ac and Z

Attention!: when latitude and declination are of contrary name, declination should be treated as a negative value.

Solution

[MODE] [.] [P_1] [1] [5] [°'"] [ENT] [3] [0] [°'"] [+/-] [ENT] [3] [1] [5] [°'"]

[ENT] → 27.522495 [INV] [°'"] → 27°31°20.98 (= 27°31.'3 → 20.98/60 ≑ 0.3497 ≑ 0.3 [ENT] → -43.6711912 ≑ -43.°7 or 136.°3 (= 180°-43.°7)

See "Sight Reduction Tables" page 93, Vol.2, Pub. No.229

Example 3

when Lat. = 14°N, Dec. = 26°S, and LHA = 327°

Required:- Ac and Z

(MODE [.]) [P1] [1] [4] [°'"] [ENT] [2] [6] [°'"] [+/-] [ENT] [3] [2] [7] [°'"]

[ENT] → 38.70785818 [INV] [°'"] → 38°42°28.29 (=38°42!5 → 28.29/60

≑ 0.47 ≑ 0.5) [ENT] → -38.8519671 ≑ 38°.9 or 141°.1 (= 180°-38°9)

See "Sight Reduction Tables" page 251, Vol.1, Pub. No.229

Example 4

when Lat. = 15°08.0 S

α Pavonis Dec. = 56°50!0 S, LHA = 293°27!5

Vega Dec. = 38°44!9 N, LHA = 321°06!3

Jupiter Dec. = 12°08!6 S, LHA = 27°45!0

Required:- Ac and Z of aforementioned celestial bodies.

Solution

1) α Pavonis

(MODE [.]) [P1] [1] [5] [°'"] [8] [°'"] [ENT] [5] [6] [°'"] [5] [0] [°'"] [2] [9] [3]

[°'"] [2] [7] [.] [5] [°'"] [ENT] → 25.38906874 [INV] [°'"] → 25°23°20.65

(= 25°23!3 → 20.65/60 = 0.3) [ENT] → -33.7460874 [INV] [°'"]

→ 33°44°45.9 (= 33°44!8 → 45.9/60 = 0.765 ≑ 0.8)

Ans. Ac = 25°23!3, Z = S 33°44!8 E.

2) Vega → Be careful when Lat. and Dec. are of contrary name.

[1] [5] [°'"] [8] [°'"] [ENT] [3] [8] [°'"] [4] [4] [.] [9] [°'"] [+/-] [ENT]

[3] [2] [1] [°'"] [6] [.] [3] [°'"] [ENT] → 24.99537237 [INV] [°'"] → 24°59°

43.34 (= 24°59!7 → 43.34/60 ≑ 0.722 ≑ 0.7) [ENT] → -32.7041063

[INV] [°'"] → -32°42°14.7 (= -32°42.'2 → 14.7/60 ≑ 0.245 ≑ 0.2)

Ans. Ac = 24°59.'7, Z = N 32°42.'2 E.

3) Jupiter

[1] [5] [°'"] [8] [°'"] [ENT] [1] [2] [°'"] [8] [.] [6] [°'"] [ENT] [2] [7] [°'"]

[4] [5] [°'"] [ENT] → 62.8856946 [INV] [°'"] → 62°53°8.5 (= 62 53.'1
→ 8.5/60 = 0.1416 --- ≑ 0.1)

[ENT] → 87.13158594 [INV] [°'"] → 87°7'53.71 (= 87°7.'9 → 53.71/60

= 0.8951 --- ≑ 0.9)

Ans. Ac = 62°53.'1, Z = N 87°7.'9 W

See "Astronomical Navigation Tables" page XXIII - XXIV, Pub. No.601 Maritime Safety Agency, Japan.

※ The most important Example is No.4.

Computation by programmable calculators: CASIO fx-4000 P. fx-7000 G and fx-8000 G.

1) Formulae

$Ac(Hc) = \sin^{-1}\{(\cos Lat \times \cos Dec \times \cos LHA) + \sin Lat \times \sin Dec\}$

$Z = \sin^{-1}(\sin LHA \times \cos Dec \div \cos Ac)$

$a = \sin^{-1}(\sin Dec \div \sin L)$

When Dec & Lat are of the same names and, Lat > Dec,

Ac(Hc) > a ... Prefix of Z is contrary name to Latitude,

Ac(Hc) < a ... Prefix of Z is the same name as Latitude.

Note: Ac(Hc) = Calculated Altitude (Degree & minute), Z = Azimuth (Degree) and, a = Altitude in Prime vertical (Degree and minute)

2) Program

```
Lbℓ 0   : " LAT = " : ? → L
        : " DEC = " : ? → D
        : " LHA = " : ? → H
        : sin-1 ((cos L x cos D x cos H) + sin L x sin D)◢
          ? → A
        : sin-1 (sin H x cos D ÷ cos A)
          L > 0 ⇒ D > 0 ⇒ L > D ⇒ sin-1 (sin D ÷ sin L)◢
          Goto 0
```

3) Keystrokes of Program

Switch on [MODE] [2] [EXE]

[SHIFT] [Lbl] [0] [:] [ALPHA] ["] [ALPHA] [L] [ALPHA] [A] [ALPHA] [T] [SHIFT] [=]

[ALPHA] ["] [:] [SHIFT] [?] [→] [ALPHA] [L]

[:] [ALPHA] ["] [ALPHA] [D] [ALPHA] [E] [ALPHA] [C] [SHIFT] [=]

[ALPHA] ["] [:] [SHIFT] [?] [→] [ALPHA] [D]

[:] [ALPHA] ["] [ALPHA] [L] [ALPHA] [H] [ALPHA] [A] [SHIFT] [=]

[ALPHA] ["] [:] [SHIFT] [?] [→] [ALPHA] [H]

[:] [SHIFT] [sin⁻¹] [(] [(] [cos] [ALPHA] [L] [x] [cos] [ALPHA] [D] [x]

[cos] [ALPHA] [H] [)] [+] [sin] [ALPHA] [L] [x] [sin] [ALPHA] [D] [)]

[SHIFT] [◢] [SHIFT] [?] [→] [ALPHA] [A]

[:] [SHIFT] [sin⁻¹] [(] [sin] [ALPHA] [H] [x] [cos] [ALPHA] [D] [÷] [cos]

[ALPHA] [A] [)] [SHIFT] [◢]

[ALPHA] [L] [SHIFT] [>] [0] [SHIFT] [⇒] [ALPHA] [D] [SHIFT]

[>] [0] [SHIFT] [⇒] [ALPHA] [L] [SHIFT] [>] [ALPHA] [D]

[SHIFT] [⇒] [SHIFT] [sin⁻¹] [(] [sin] [ALPHA] [D] [÷] [sin]

[ALPHA] [L] [)] [SHIFT] [◢] [SHIFT] [Goto] [0]

Example 1

when Lat. = 38°N, Dec. = 19°S, and LHA = 340°

Required:- Ac(=Hc) and Z

Solution

[MODE] [1] [Prog] [0] [EXE] [3] [8] [° ' "] [EXE] [(-)] [1] [9] [° ' "] [EXE] [3] [4] [0] [° ' "]

[EXE] → 29.98050372 [SHIFT] [° ' "] → 29°58'49.81"(= 29°58!8

→ 49"81/60 = 0.830--- ≑ 0!8) [EXE] [ANS] [EXE] → -21.92182127 ≑ -21°9

or 158°1 (= 180° - 21°9)

Ans Ac(=Hc) = 29°58!8, = S 21°9 E or 158°1

See "Sight Reduction Tables" page 225, Vol. 3, Pub. No. 229

Example 2

when Lat. = 45°S, Dec. = 40°N, LHA = 320°

Required:- Ac(= Hc) and Z

Solution

[MODE] [1] [Prog] [0] [EXE] [4] [5] [° ' "] [EXE] [(-)] [4] [0] [° ' "] [EXE] [3] [2] [0] [° ' "]

[EXE] — -2.267911364 [SHIFT] [° ' "] — -2°16'4.48" (= -2°16.1

— 4.48"/60 = 0.074 --- ≑ 0.1) [EXE] [ANS] [EXE] — -29.52411728 ≑ 29°5

Ans. Ac(= Hc) = 2°16!1, Z = N 29°.5 E or 29°5

See "Sight Reduction Tables" page 265, Vol.3, Pub. No. 229

Example 3

when Lat. = 52°28.'2 N.
Sun : Dec. = 11°09.'0 S, LHA = 323°30.'7
Moon : Dec. = 20°16.'3 N, LHA = 39°44.'0

Required:- Ac and Z

Solution

1) Sun

[MODE] [1] [Prog] [0] [EXE] [5] [2] [°'"] [2] [8] [.] [2] [°'"] [EXE] [(-)] [1] [1] [°'"] [9]

[°'"] [EXE] [2] [0] [°'"] [1] [6] [.] [3] [°'"] [EXE] → 19.09675689

[SHIFT] [°'"] → 19°5'48.32" (= 19°5.'8 → 48.32"/60 = 0.805 --- ≑ 0.8)

[EXE] [ANS] [EXE] → -38.12740902 [SHIFT] [°'"] → 38°7'38.67"

(= -38°7.'6 → 38.67"/60 = 0.6445 ≑ 0.6)

2) Moon

[EXE] [5] [2] [°'"] [2] [8] [.] [2] [°'"] [EXE] [2] [0] [°'"] [1] [6] [.] [3] [°'"]

[EXE] [3] [9] [°'"] [4] [4] [°'"] [EXE] → 45.57938213

[SHIFT] [°'"] → 45°34'45.78" (= 45°34.'8 → 45.78/60 = 0.763 ≑ 0.8)

[EXE] [ANS] [EXE] → 58.94817624 [SHIFT] [°'"] → 58°56'53.43" (= 58°)

56.'9 → 53.43/60 = 0.8905 ≑ 0.9) [EXE] → 25.90585779

[SHIFT] [°'"] → 25°54'21.09" (≑ 25°54.3), Ac(Hc) > a

Ans. 1) Sun : Ac = 19°05.'8 = S 38°7.'6 E
2) Moon: Ac = 45°34.'8 = S 58°56.'9 W.

Be careful of prefix South!

See "Astronomical Navigation Tables" page XXI, Pub. No.601, Maritime Safety Agency, Japan.

Example 4

Required: Ac(= Hc) and Z

when

1) Lat. = 15°N, Dec. = 30°S and LHA = 315°. (L & D, contrary names)

2) Lat. = 15°N, Dec. = 9°S and LHA = 315°. (L & D, contrary names)

3) Lat. = 21°N, Dec. = 19°N and LHA = 315°. (L & D, same names)

Solution

1) [MODE] [1] [Prog] [0] [EXE]

[1] [5] [°'"] [EXE] [(-)] [3] [0] [°'"] [EXE] [3] [1] [5] [°'"]

[EXE] → 27.52249499 [SHIFT] [°'"] → 27°31'20.98" (= 27°31'.3)

→ 20.98/60 = 0.34 --- ≑ 0.3)

[EXE] [Ans] [EXE] → -43.67119127 ≑ -43°.7

2) [EXE] [1] [5] [°'"] [EXE] [(-)] [9] [°'"] [EXE] [3] [1] [5] [°'"]

[EXE] → 39.35441086 [SHIFT] [°'"] → 39°21°15.88"

(= 39°21'.3 → 15.88/60 = 0.26 --- ≑ 0.3)

[EXE] [Ans] [EXE] → -64.58404476 ≑ -64°.6

3) [EXE] [2] [1] [°'"] [EXE] [1] [9] [°'"] [EXE] [3] [1] [5] [°'"]

[EXE] → 47.80377208 [SHIFT] [°'"] → 47°48'13.58"

(= 47°48'.2 → 13.58/60 = 0.22 --- ≑ 0.2)

[EXE] [Ans] [EXE] → -84.5026916 ≑ -84°.5 [EXE] → 65.2953868

[SHIFT] [°'"] → 65°17'43.39" (≑ 65°17'.7)--- Ac(Hc) < a.

Ans. See "Sight Reduction Tables" page 92, 93 Vol. 2, Pub. No. 229

1) Ac(Hc) = 27°31.'3, Z = S 43.°7 E or 136.°3 (= 180° - 43.°7)

Note: Ship's latitude ⟶ North, Declination ⟶ South
So prefix of Z is South.

360° > LHA (315°) > 180° so suffix of Z is East.

2) Ac(Hc) = 39°21.'3, Z = S 64.°6 E or 115.°4

3) Ac(Hc) = 47°48.'2, Z = N 84.°5 E or 84.°5

Note: When Latitude and Declination are of the same names and, the value of Latitude is greater than that of Declination, there is some probability that the celestial body is located in the Prime Vertical. So to name prefix of Z (Azimuth) should be carefully considered by following procedures.

$a = \sin^{-1} (\sin D \div \sin L)$ a = Altitude in Prime Vertical

when, Ac(Hc) > a, Prefix of Z is contrary name to Latitude.
Ac(Hc) < a, Prefix of Z is the same name as Latitude.

See "Navigation Tables"

In the case of calculation 3),

$a = \sin^{-1} (\sin 19°N \div \sin 21°N) = 65°17.'7$ is greater than the value of Ac(Hc) = 47°48.'2, so prefix of Z is the same name as Latitude 21°N

Example 5

when Lat. = 21°N, Dec. = 13°N and LHA = 300°

Required:- Ac(Hc) and Z

Solution

[MODE] [1] [Prog] [0] [EXE]

[2] [1] [°'"] [EXE] [1] [3] [°'"] [EXE] [3] [0] [0] [°'"]

[EXE] → 32.37386856 [SHIFT] [°'"] → 32°22'25.93" (= 32°22.'4)

[EXE] [Ans] [EXE] → -87.59651094 ÷ -87.6   Z = N 87°.6 E

Lat. and Dec. → same names and value of Lat. > value of Dec., so check the Altitude in Prime Vertical by making use of the formula

$$a = \sin^{-1} (\sin D \div \sin L)$$

[EXE] → 38.8813531 [SHIFT] [°'"] → 38°52'52.87" ≑ 38°52'.9

Ac(Hc) = 32°22'.4 < a = 38°52'.9

so prefix of Z is the same name as Latitude (N)

See "Sight Reduction Tables" page 122, Vol. 2, Pub. No.229

Example 6

when Lat. = 22°N, Dec. = 8°N and LHA = 14°

Required:- Ac(Hc) and Z

Solution

[MODE] [1] [Prog] [0] [EXE]

[2] [2] [°'"] [EXE] [8] [°'"] [EXE] [1] [4] [°'"] [EXE]

→ 70.56549201 [SHIFT] [°'"] → 70°33'55.77" ≑ 70°33'.9

[EXE] [Ans] [EXE] → 46.05511009 = 46°.1

Lat. and Dec. are of the same name and value of Lat. > value of Dec. so Altitude in Prime Vertical should be computed to decide the prefix of Z.

[EXE] → 21.80926819

[SHIFT] [°'"] → 21°48'33.37" = 21°48'.6

AC(Hc) = 70°33'.9 > a = 21°48'.6

So prefix of Z is contrary name to Lat.

Z = S 46.1 W or <u>226°1</u>
↑ Because of LHA < 180°

In the case of "Sight Reduction Tables" page 30, Vol.2, Pub. No. 229

Z = 133°9, Zn = 360° - Z = 360° - 133°9 = <u>226°1</u>

Because of N. Lat. { LHA greater than 180° --- Zn = Z ; LHA less than 180° --- Zn = 360° - Z }

<u>Example 7</u>

<u>Required</u>:- Ac(Hc) and Z

when 1. Sun : Lat. = 52°28'.2 N, Dec. = 11°09'.0 S, LHA = 323°30'.7
2. Moon: Lat. = 52°28'.2 N, Dec. = 20°16'.3 N, LHA = 39°44'.0

<u>Solution</u>

In this case, each Ac(Hc) and Z can be computed continuously by the calculator.

[MODE] [1] [Prog] [0] [EXE] [5] [2] [° ' "] [2] [8] [.] [2] [° ' "] [EXE] [(-)] [1] [1] [° ' "] [9] [° ' "] [EXE] [3] [2] [3] [° ' "] [3] [0] [.] [7] [° ' "] [EXE]

→ 19.09675691 [SHIFT] [° ' "] → 19°05'48.32" = <u>19°05'.8</u> [EXE] [Ans] [EXE]

→ -38.12740902 = <u>-38°1</u>

[EXE] [5] [2] [° ' "] [2] [8] [.] [2] [° ' "] [EXE] [2] [0] [° ' "] [1] [6] [.] [3] [° ' "] [EXE] [3] [9] [° ' "] [4] [4] [° ' "] [EXE] → 45.57938213 [SHIFT] [° ' "]

→ 45°34'45.78" = <u>45°34'.8</u> [EXE] [Ans] [EXE] → 58.94817624 ≑ <u>58°9</u>

[EXE] → 25.90585779 [SHIFT] [° ' "] → 25°54'21.09" --- Ac(Hc) > a.

<u>Ans</u>. Sun Ac(Hc) = 19°05'.8, Z = S 38°1 E.
Moon Ac(Hc) - 45°34'.8, Z = <u>S</u> 58°9 W.

Example 8

Required:- Ac(Hc) and Z

when 1. α Pavonis : Lat. = 15°08'.0 S, Dec. = 56°50'.0 S, LHA = 293°27'.5
2. Vega : Lat. = 15°08'.0 S, Dec. = 38°44'.9 N, LHA = 321°06'.3
3. Jupiter : Lat. = 15°08'.0 S, Dec. = 12°08'.6 S, LHA = 27°45'.0

Solution

By continuous keystrokes

[MODE] [1] [Prog] [0] [EXE]

(α Pavonis)

[1] [5] [°'"] [8] [°'"] [EXE] [5] [6] [°'"] [5] [0] [°'"] [EXE] [2] [9] [3] [°'"]

[2] [7] [.] [5] [°'"] [EXE] → 25.38906872 [SHIFT] [°'"]

→ 25°23'20.65" ≑ 25°23'.3 [EXE] [Ans] [EXE] → -33.74608747 ≑ -33°.7

(Vega)

[EXE] [1] [5] [°'"] [8] [°'"] [EXE] [(-)] [3] [8] [°'"] [4] [4] [.] [9] [°'"] [EXE]

[3] [2] [1] [°'"] [6] [.] [3] [°'"] [EXE] → 24.99537237 [SHIFT]

[°'"] → 24°59'43.34" = <u>24°59'.7</u> [EXE] [Ans] [EXE] → -32.70410639 ≑ <u>-32°.7</u>

(Jupiter)

[EXE] [1] [5] [°'"] [8] [°'"] [EXE] [1] [2] [°'"] [8] [.] [6] [°'"] [EXE] [2] [7] [°'"]

[4] [5] [°'"] [EXE] → 62.88569458

[SHIFT] [°'"] → 62°53'08.5" ≑ 62°53'.1

[EXE] [Ans] [EXE] → 87.13158511 = 87°.1

EXE → 53.68421517 SHIFT °'" → 53°41'3.17"--- Ac(Hc) > a.

Ans. 1. α Pavonis Ac(Hc) = 25°23'.3, Z = S 33°.7 E.
2. Vega Ac(Hc) = 24°59'.7, Z = N 32°.7 E.
3. Jupiter Ac(Hc) = 62°53'.1, Z = N 87°.1 W.

Example 8

Required:- Ac(Hc) and Z

when 1. Sun : Lat. = 29°57'.5 N, Dec. = 10°59'.3 S, LHA = 66°33'.2
2. Moon : Lat. = 29°57'.5 N, Dec. = 24°16'.1 N, LHA = 347°59'.2

Ans. 1. Sun : Ac(Hc) = 14°04'.6, Z = S 68°.2 W
2. Moon : Ac(Hc) = 77°53'.9, Z = S 64°.8 E ---
Ac(Hc) 77°53'.9 > a 55°23'.5

Example 9

Required:- Ac(Hc) and Z

1. Antares : Lat. = 13°42'.0 N, Dec. = 26°20'.0 S,
LHA = 16°46'.8

2. Arcturus: Lat. = 13°42'.0 N, Dec. = 19°25'.4 N,
LHA = 50°37'.0

Ans. 1. Antares : Ac(Hc) = 46°46'.1, Z = S 22°.2 W
2. Arcturus: Ac(Hc) = 41°18'.6, Z = N 76°.0 W

The important review of Prefix and Suffix of Z

1) Prefix

1. Dec. and Lat. are of contrary names, Prefix of Z is contrary name to Lat.

2. Dec. and Lat. are of the same names and, Lat. < Dec., Prefix of Z is the same name as Lat.

3. Dec. and Lat. are of the same names and, Lat. $>$ Dec.,

   <u>when</u> Ac(Hc) $>$ Altitude in Prime Vertical

   $\{a = \sin^{-1} (\sin D \div \sin L)\}$

   Prefix of Z is contrary name to Lat.

   Ac(Hc) $<$ Altitude in Prime Vertical

   $\{a = \sin^{-1} (\sin D \div \sin L)\}$

   Prefix of Z is the same name as Lat.

4. when $180^{\circ} < \text{LHA} < 360^{\circ}$, Suffix is E.

   $0^{\circ} < \text{LHA} < 180^{\circ}$, Suffix is W.

1) Formula

Advancing distance = D ÷ T x A

Note: D = Distance travelled (nautical mile), T = Time elapsed (minute) and, A = Advancing time (minute)

2) Program

Lbℓ 1 : " DST = " : ? → D

: " ETM = " : ? → T

: " ATM = " : ? → A

: D ÷ T x A ◢ Goto 1

3) Keystrokes of Program

Switch on [MODE] [2] [↦] [EXE]

[SHIFT] [Lbℓ] [1] [:] [SHIFT] [ALPHA] ["] [D] [S] [T] [ALPHA] [SHIFT] [=] [ALPHA]

["] [:] [SHIFT] [?] [→] [ALPHA] [D] [:] [SHIFT] [ALPHA]

["] [E] [T] [M] [ALPHA] [SHIFT] [=] [ALPHA] ["] [:] [SHIFT]

[?] [→] [ALPHA] [T] [:] [SHIFT] [ALPHA] ["] [A] [T] [M]

[ALPHA] [SHIFT] [=] [ALPHA] ["] [:] [SHIFT] [?] [→]

[ALPHA] [A] [:] [ALPHA] [D] [÷] [ALPHA] [T] [SHIFT] [◢]

[SHIFT] [Goto] [1]

1) Formula

$$\text{Amplitude} = \sin^{-1}\left(\frac{\sin D - \sin L \times \sin C}{\cos L \times \cos C}\right)$$

Note: D = Declination, L = Latitude and, C = Constant (0° or 0.7°)
when the centre of the sun is on the celestial horizon, C = 0°
when the centre of the sun is on the visible horizon, C = 0.7°

2) Program

Lbℓ 2 : " DEC = " : ? → D
: " LAT = " : ? → L
: " [0°] or [0.7°] = " : ? → C

$$: \sin^{-1}\left(\frac{\sin D - \sin L \times \sin C}{\cos L \times \cos C}\right) ◢ \text{ Goto } 2$$

3) Keystrokes of Program

Switch on [MODE] [2] [⇒] [⇒] [EXE]

[SHIFT] [Lbℓ] [2] [:] [SHIFT] [ALPHA] ["] [D] [E] [C] [ALPHA]

[SHIFT] [=] [ALPHA] ["] [:] [SHIFT] [?] [→] [ALPHA] [D] [:]

[SHIFT] [ALPHA] ["] [L] [A] [T] [ALPHA] [SHIFT] [=] [ALPHA]

["] [:] [SHIFT] [?] [→] [ALPHA] [L] [:] [ALPHA] ["] [ALPHA]

[ʹ] [0] [° ′ ″] [ALPHA] [,] [SHIFT] [ALPHA] [O] [R] [ʹ] [ALPHA]

[0] [.] [7] [° ′ ″] [ALPHA] [,] [SHIFT] [=] [ALPHA] ["] [:]

[SHIFT] [?] [→] [ALPHA] [C] [:] [SHIFT] [sin⁻¹] [(] [(] [sin]

[ALPHA] [D] [−] [sin] [ALPHA] [L] [x] [sin] [ALPHA] [C] [)]

[÷] [cos] [ALPHA] [L] [x] [cos] [ALPHA] [C] [)] [SHIFT] [◢]

[SHIFT] [Goto] [2]

Assumptions to observe true amplitude are;

1. Sun's lower limb is about two-thirds of a diameter above the visible horizon, its center is on the celestial horizon.

2. Moon's upper limb is on the visible horizon, its center is on the celestial horizon.

3. When planets or stars are on the celestial horizon, they are about one sun diameter, or some 32.'0 above the visible horizon.

·X· To check compass error, true amplitude of the sun is most desirable

Example 1

when GMT is 20h 03m 13s (Local apparent time 05h 08m, 20 June '79), 19 June 1979 in D.R.P. 27°30'N, 136°30'E, and the sun, when its lower limb is ⅔ of its diameter above the horizon, bears 068° by gyro.

Required:- The gyro error

Solution

From Nautical Almanac Dec. of the sun = N 23°25.'4 and by D.R.P., Lat. = 27°30'N

[MODE] [1] [Prog] [2] [EXE] [2] [3] [°'"] [2] [5] [.] [4] [°'"] [EXE] [2] [7] [°'"]

[3] [0] [°'"] [EXE] [0] [EXE] → 26.62560823

Amplitude E 26°.6 N = N 63°.4 E or 63°.4

True Azimuth = N 63°.4 E	(Prefix & Suffix See "Celestial Navigation" text - TD/TRB/37, page 114-115)
Gyro Azimuth = N 68°.0 E θ	
Gyro error = 4°.6 W	Ans. 4°.6 W

(From "Celestial Navigation", Prof. K. HASEGAWA 1983, Tokyo)

Example 2

Required:- Ture Amplitude

when 1) Dec. = 18° Lat. = 25°

2) Dec. = 19°.5 Lat. = 30°

3) Dec. = 21°.0 Lat. = 38°

4) Dec. = 23°.5 Lat. = 42°

Solution

[MODE] [1] [Prog] [2] [EXE]

1) [1] [8] [° ' "] [EXE] [2] [5] [° ' "] [EXE] [0] [EXE] → 19.93552733 ≑ 19°.9

2) [EXE] [1] [9] [.] [5] [° ' "] [EXE] [3] [0] [° ' "] [EXE] [0] [EXE] → 22.67149089 ≑ 22°.7

3) [EXE] [2] [1] [° ' "] [EXE] [3] [8] [° ' "] [EXE] [0] [EXE]

4) [EXE] [2] [3] [.] [5] [° ' "] [EXE] [4] [2] [° ' "] [EXE] [0] [EXE] → 32.45043401 ≑ 32°.5

See Figure 2805 a. Table 27, Amplitudes, from Bowditch. Vol. II.

Altitude and Azimuth

The altitude (H_c) and Azimuth (A_z) of a celestial body can be computed by the following formula:

(1) $\sin H = \sin \phi \sin S + \cos \phi \cos S \cos LHA$

(2) $x = \tan A = \sin LHA \div (\cos LHA \sin \phi - \tan S. \cos \phi)$

Since computers and calculators normally give the arc tangent in the range -90° to $+90^\circ$, the correct Azimuth of body measured eastward from north over the range 0° to 360° can be selected according to the following rules:

If $0^\circ \leq LHA \leq 180^\circ$

$A = 180^\circ + \tan^{-1} x$, if x is positive

$A = 360^\circ + \tan^{-1} x$, if x is negative

If $180^\circ \leq LHA \leq 360^\circ$

$A = \tan^{-1} x$, if x is positive

$A = 180^\circ + \tan^{-1} x$, if x is negative

Standard navigational notation

H_c = H computed altitude of the body above (if $\sin H > 0$) or below (if $\sin H < 0$) the horizon;

Z_n = True Azimuth of the body measured eastward from north over the range 0° to 360°

0 = Latitude of observer (+ north, - south)

S = Declination of the body (+ north, - south)

LHA = Local hour angle of the body

The equation (1) and (2) are basic formulae used in preparing sight reduction tables; they do not include the effect of refraction.

Example 3 On 25 April 1978, the 1056 DR position of a ship is Lat. 32°41.'6 N, Long. 62°14.'5 W. At watch time $10^h - 56^m - 27^s$ the navigator observed the lower limb of the Sun with a marine sextant having an IC (+) 1.6, height of eye 42 ft., the observed sextant altitude is 64° 10.'2, watch error is 10^s faster than Zone time.

Required: a. True azimuth (Z_n) b. Intercept (a) c. Assume position (AP.) Solution.

	Sun ⊙			d(+) 0.8		⊙
W	10 -56 -27 April 25		14^h	13°08.'2 N	h_s	64°10.'2
WE (F)	10 ⊖		corr.	+ 0.8	I_c	+ 1.6
ZT	10 -56 -17		dec.	13°09.'0 N	D	- 6.3
ZD (+)	4	See page			⊙	+ 15.5
GMT	14 -56 -17 April 25				H_o	64°21.'0
14^h	30° 29.'6	By the table or				
56^m17^s	14° 04.'3	calculation			By Computer	
GHA ⊙	44° 33.'9					
a	62° 33.'9 W		Ap aL 33°N		Z_n	136.°2 (136.18277...)
LHA ⊙	342°		aλ 62°33.'9 W		a	6.'7 T. (-6.6688..)

Explanation of Solution

1. Converting the time of observation to Greenwich mean time (GMT).

2. At GMT find LHA, and dec, by using nautical Almanac.

3. Correct the observed sextant altitude to get H_o (True altitude).

4. Assume position should be within 30.0 of the DR position.

5. Compute the result by using Prg. ∅.

PROGRAM SHEET

Program for: Compute azimuth and intercept — No. Prg Ø

Description Input Lat = Assume latitude of Observer (+N, -S)

Dec.= Corrected declination of body (+N,-S)

LHA = local hour angle of body

HO = Corrected sextant altitude of body

Output ZN = true azimuth of the body in degrees

INCEPT+A-T = Intercept (a) in minutes

when result is positive (+A) = away
result is negative (-T) = toward

Example

1. a	lat 33° N	Dec	13°12.7 N	LHA	20	HO	63°02.5
2.	" 33° S	"	7°36.3 N	"	301	"	20°32.5
3.	" 17° N	"	22°54.7 S	"	334	"	42°51.2
4.	" 21° S	"	18°40.9 S	"	323	"	54°57.4

Answer 1. ZN 227°36 a 2. 84 (A)
3. ZN 146.68 a -10.48 (T)
4. ZN 092.80 a 14.28 (A)

Preparation and operation
- Store the program written on the next page.
- Execute the program as shown below in the RUN mode (MODE 1).

Step	Key operation	Display	Step	Key operation	Display
1	Prg Ø EXE	INCEPT	11		
2	EXE	LAT+N-S?	12		
3	(-) 3300.0 EXE	DEG+N-S?	13		
4	736.3 EXE	LHA?	14		
5	30100 EXE	HO?	15		
6	2032.5 EXE	ZN	16		
7	EXE	65.39751078	17		
8	EXE	INCEPT+A-T	18		
9	EXE	19.037628	19		
10	EXE EXE	INCEPT	20		

(repeat again)

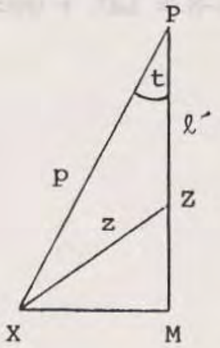
No. Prg Ø

Line	MODE 2 Program	Notes	Number of steps
1	" I N C E P T " ▲ Prg 7 : Prg 8 :		
2	Prg 9 : SIN^{-1} (SIN L x SIN D + COS L x COS		
3	D x COS H) → R : Prg 6 : (R - S		
4	) x 6 Ø → I : " I N C E P T +		
5	A - T " ◢ I ◢		
6			
7			

Ex-Meridian (Reduction formula)

The meridian zenith distance of the body is the least zenith distance and is smaller than the zenith distance obtained from an observation taken a few minutes before or after the body has crossed the meridian by a small quantity called "Reduction".

Derivation of reduction formula:



P = Pole
Z = Zenith
X = The body a few minutes before or after crossing the meridian
M = The body on the meridian
Z = ZX, observed zenith distance
ZM = Mer. zenith distance
p = Co-declination of the body = 90-Dec. (d)
ℓ' = Co-latitude of observer = 90-Lat. (ℓ)
t = Meridian angle

From spherical triangle P x z

$$\cos t = (\cos z - \cos p \cos \ell')/\sin p \sin \ell'$$
$$= (\cos z - \sin d \sin \ell)/\cos d \cos \ell \quad \text{....Eq 1}$$

When body is on meridian $t = 0^\circ$, $\cos t = 1$ if R = reduction,

$ZM = z-R$ sub. in 1

$$1 = (\cos (z-R) - \sin d \sin \ell)/\cos d \cos \ell \quad \text{....Eq 2}$$

2-1 then $1-\cos t = \{\cos (z-R) - \cos z)\}/\cos d \cos \ell$ ....Eq 3

$\because \cos A = 1-2 \sin^2 \frac{A}{2}$ and $\cos B-\cos A = 2 \sin \frac{1}{2}(A+B)$

$\sin \frac{1}{2}(A-B)$: then Eq 3 becomes

$$2\sin^2\frac{t}{2} = 2\sin\tfrac{1}{2}\{(z+z+R)\sin\tfrac{1}{2}(z+z+R)\}/\cos d\cos \ell$$

$$\sin^2\frac{t}{2} = \{\sin(z+\frac{B}{2}).\ \sin\frac{R}{2}\}/\cos d\cos\ell \qquad \text{....Eq 4}$$

Since R is very small so $z-\frac{R}{2} = z-R$

$$\therefore \sin\frac{R}{2} = \cos d\cos\ell\ \sin^2\frac{t}{2}/\sin(z-R) \qquad \text{....Eq 5}$$

When the body is nearly crossing the meridian, t is small, the chord and the subtended arc of the circle are nearly equal then:

$$\sin\theta'' = \theta''\sin 1'',\ \sin^2\frac{t}{2} = \frac{\sin^2 t}{4},\ z-R = \text{Lat} + \text{dec.}$$

So Eq5 may be written

$$\frac{R''}{2}\sin 1'' = \frac{\cos d\cos\ell}{\sin(\ell\pm d)} \times \frac{\sin^2 t}{4}$$

$$R'' = \frac{\cos d\cos\ell}{\sin(\ell\pm d)} \times \frac{2\sin^2 t}{4\sin 1''}$$

Converting t^o to t in minutes of time $\sin^2 t = t^2\sin^2 15'$

$$\therefore R'' = \frac{\cos d\cos\ell}{\sin(\ell\pm d)} \times \frac{\sin^2 15'}{2\sin 1''} \times t^2$$

$\frac{\sin^2 15'}{2\sin 1''}$ is constant = 1.9635 then

$$R'' = \underbrace{1.9635 \times \cos d \times \cos L \times \text{cosec}(\ell\pm d)}_{A} \times t^2$$

Let C = Reduction in minutes

$$\therefore C' = \frac{A \times t^2}{60}$$

These are the formula used in the computation of Ex-meridian tables:

A for table I of Nories or table 29 of Bowditch

C' for table II of Nories or table 30 of Bowditch

by using an electronic calculator or computer, in order to get correct reduction for both upper and lower transit, the formula and condition may be written as follows:

$$R = \frac{.008726 \times \cos D \cos L \times t^2 \times I}{\sin \text{ abs } (L - D \times I)} \qquad \ldots .Eq6$$

where R	=	reduction in degrees	I is for setting condition
L	=	Lat (+N, -s)	I = -1 for lower transit
D	=	dec (+N, -s)	I = 1 for upper transit
t	=	meridian angle in degrees	

if we know the reduction then we can find the latitude of observer by the following procedure:

1. True Meridian altitude = Corrected Sextant altitude ± Reduction

$$\text{T. Mer. Alt.} = H_o \pm R$$

2. True Meridianal zenith distance = 90 - True meridian altitude

$$\text{T. MZD} = 90 - \text{T. Mer. Alt.}$$

3. By the same procedure as latitude by meridian transit, the latitude of observer at the time of Ex-meridian observation can be obtained.

Example : At DR. Lat. 48°12' N, Long. 24°32' W, the true altitude of Antares was 21°28' Hour angle 357°00' Dec. 26°18'.0 S, Determine the Lat. and position line.

By table	Table I	Table II	T. Alt.	21°28'.0
	Lat. 42°12' N	LHA 357°00'	Reduction	3.4
	Dec. 26°18' S	A = 1".4		
	A = 1".4	Red. for 1"= 2.4	T. Mer. Alt.	21°31'.4
		" for 4 = 0.96	T. MZD.	18°28'.6
		Reduction = 3.36	Dec.	26°18'.0 S
			Lat.	42°10'.6 N

True Azimuth 177° (from AZ table)

Position line passes 087° and 267° through Lat. 42°10'.6 N Long. 2432 W.

By program
Lat. 42°12' N
Dec. 26°18' S
LHA 357°00'
Ho 21°28.0

using Prg. 1→T. MZD 68047727667
= 68°28'63
Dec. = 26°18'.5
Lat. = 42°10'.63 N

using Prg. 2→ZN 177°1106136
= 177°1106136
= 177°

direction of position line = ZN±90
= 177°±90° = 267° or 087°

PROGRAM SHEET

Program for: Compute true meridianal zenith distance by EX-MERIDIAN (Reduction formula) — No. Prg. 1

Description

Input Lat = DR. Latitude of observer (+N, -S)

Dec = Corrected declination of body (+N,-S)

LHA = Local hour angle of body

HO = Corrected sextant altitude of body

Output T.MZD = True meridianal zenith distance (degrees)

Example

1. DR.Lat 48°13′N Dec 21°39′S LHA 356°00′HO 19°52′.0
2. " 42°10′N " 62°01′N " 176°30′HO 14°20′.0
3. " 50°02′S " 57°29′S " 184°20′HO 17°20′

Anwer 2. T.MZD 75°70501092, 3. T.MZD 72°.72599481

Preparation and operation

• Execute the program as shown below in the RUN mode (MODE 1).

Step	Key operation	Display	Step	Key operation	Display
1	Prg 1 EXE	X-MER	11		
2	EXE	LAT+N-S?	12		
3	4813.0 EXE	DEC+N-S?	13		
4	(-)2139 EXE	LHA?	14		
5	35600 EXE	HO?	15		
6	1952 EXE	T. MZD	16		
7	EXE	70.04124028	17		
8	EXE	X-MER	18		
9	EXE	(repeat again)	19		
10	EXE		20		

No. Prg. 1

Line	MODE 2						Program									Notes	Number of steps
1	"	X	–	M	E	R	"	◢	Prg	7	:	Prg	8	:	Prg		
2	9	:	Abs	(	H	-	I	8	0	)	→	T	:	(-)	1		
3	→	I	:	T	∠	9	O	⇒	Goto	2	:	1	8	0	-		
4	T	→	T	:	1	→	I	:	Lbl	2	:	.	0	0	8		
5	7	2	6	x	COS	D	x	COS	L	÷	SIN	Abs	(	L	-		
6	D	ẋ	I	)	x	T	x^2	x	I	+	S	→	M	:	"		
7	T	•	M	Z	D	"	◢	9	0	–	M	→	N	▲			
8																	
9																	

Compass error by time azimuth

The azimuth of the body can be obatained by the equation (2) as explained in the problem of altitude and azimuth. The accuracy of computed azimuth depends on the accuracy of the time of observation and the accuracy of the ship's position or the observer's position.

Example: On 24 April 1970, DR Lat. 33°25.2 S Long. 139°22.8 W at ZT 16-26-32. Observed bearing of the sun GB 297.5 CB 290.5 variation at that area is 5°E. Require GE and deviation of magnetic compass.

Solution

	Sun 0			d(+) 0.8	
ZT	16 26 32	24 April	01h	12°59'.7 N	Computed Zn 296°6
ZD	+ 9		corr(+)	.4	GR 297°5
GMT	01 26 32	25 April	dec.	13° 0'.1 N	GE 0.9 W
01h	195°29'.1			========	======
26m32s(+)	6°38'.0				Computed Zn 296°6
GHAO	202°07'.1				Var 5°0 E
DR λ	139°22'.8				MB 291.6
LHA	62°44'.3				CB 290.5
	==========		DR Lat 33 25'.2 S		Dev. 1.1 E
				=========	======

Explanation of Solution

1. Coverting observed zone time (ZT) to GMT.

2. From date and GMT, find true LHA and declination, using nautical almanac.

3. Using DR Lat., and declination as input of Prg. 2 to obtain Zn.

4. Compass the computed Zn with Gyro bearing to obtain Gyro error.

5. Apply variation to Zn to obtain true magnetic bearing (MB).

6. Compare MB with compass bearing to get deviation (Dev.).

PROGRAM SHEET

Program for	No.
Compute true azimuth from Lat, dec, LHA	Prg. 2

Description

Input Lat = Latitude of observer

Dec = Declination of the body

LHA = Local hour angle of the body

Output ZN. = True azimuth of the body

Example 1. Lat 33°24.'0 N Dec 20°13.'8 N LHA 316°41.'2

2. Lat 33°24.'0 S Dec 20°13.'8 N LHA 316°41.'2

Answer 2. ZN = 44°08733264

Preparation and operation

• Execute the program as shown below in the RUN mode (MODE 1).

Step	Key operation		Display	Step	Key operation	Display
1	Prg 2	EXE	T-AZ	11		
2		EXE	LAT+N-S?	12		
3	3324	EXE	Dec+N-S?	13		
4	2013.8	EXE	LHA?	14		
5	31641.2	EXE	ZN	15		
6		EXE	97.71043681	16		
7		EXE	T-AZ	17		
8		EXE	(repeat again)	18		
9		EXE		19		
10		EXE		20		

112

No. Prg. 2

Line	MODE 2 Program	Notes	Number of steps
1	" T - A Z " ◢ Prg 7 : Prg 8 : Prg 6		
2			

Compass error by Amplitude

True azimuth of a celestial body can be obtained by amplitude observation, and being used to compare with the compass in order to get compass error.

Formula $\sin A = \dfrac{\sin d - \sin L . \sin h}{\cos L . \cos h}$

Notation
- A = Amplitude
- d = Declination of a celestial (+N, -S, $d < 24^{\circ}$)
- L = Latitude of observer (+N, -S)
- h = True altitude of center of the body from celestial horizon

Condition:

1. If the body is observed when its center is on the celestial horizon, that means $h = 0^{\circ}$ under the following assumption:

   The Sun's lower limb is about 2/3 of its diameter above visible horizon.

   The Moon's upper limb in on the visible horizon.

   The Star or planet is slightly more than one Sun's diameter or about 32'0 above the visible horizon.

2. If the body is observed when it is on the visible horizon, that means $h \neq o$ and corrections must be applied in order to get the correct observed amplitude when the center of the body is on the celestial horizon.

For the Sun, when observation is made at height of eye 41 ft, standard condition temp. $50^{o}F$, Atmos. pressure 29.83 inches of mercury the value of h may be computed as follows:

Dip	- 6'.2	Dip.	- 6'.2	Dip.	- 6'.2
Refraction	- 35'.3	R	- 33'.2	R	- 33'.2 (A-P)
Irradiation of Hor.	- 0'.6	SD	+ 15'.8	SD	- 15'.8 (daily page)
Parallax	+ 0'.1	P	+ 0'.7	P	+ 0'.1
h	(-)42'.0	h	- 23'.5	h	- 55'.1

(This h is used for determining the corrections in table 28 of Bowditch, Vol. II.)

(For explanation)

By using computer or programmable calculator, the true azimuth (Zn) of the observed body can be computed according to the following rules:

For rising sun when h = 0 Zn = $90 - Sun^{-1}$ A

h = 0 Lat.= dec. same name, h is positive

Lat.= dec. contrary name, h is negative

Zn = $90 + Sin^{-1}$ A

For setting sun when h = 0 Zn = $270 + Sin^{-1}$ A

h = 0 Lat.= dec. same name, h is negative

Lat.= dec. contrary name, h is positive

Zn = $270 + sin^{-1}$ A

Example of amplitude

1. The DR Lat. of a ship is 51°24'.6 N. The navigator observes the setting Sun when the center is on the visible horizon, at that time declination of the Sun is 19°40'.4 N.

Required: 1. Observed amplitude

2. Zn on visible horizon (data from Dutton 12th edition P. 508)

by Table 27, 28 — by computer

T 27	Amp. W	32.6 N		
T 28	Corr.	(+) 1.1		
	Obs. Amp. W	33.7 N	Obs. Amp.	33.716
	Zn	303.7	Zn	303.716

2. DR Lat. 41°03'.8 N Observe rising sun when center is on visible horizon GB 059°.5, declination of Sun is 22°31'.9 N.

Required: Gyro error (Dutton 13th ed.)

by Table — by computer

T 27	True Amp. E	30.5 N	Obs. Amp.	29.84 = 29.8
T 28	Corr.	- .7	Zn	60.15 = 60.2
	Obs. Amp. E	29.8 N	GB	59.5
	Zn	60.2	GE	.7 E
	GB	59.5		
	GE	.7 E		

Program for	Compute true azimuth by amplitute of the Sun	No.	Prg 3

PROGRAM SHEET

Description Input

"LAT+N-S" Input Latitude of observer (+N, -S)

"Dec+N-S" " Declination of the Sun (+N, -S)

"R1-S2" Input 1 for rising observation
" 2 for setting observation

"V1-C2" Input 1 Sun's center on visible horizon
2 Sun's center on celestial horizon

Output True azimuth of the Sun at time of observation

Example

1. DR Lat 51°24.'6 N Dec 19°40.'4 N Set θ on visible horizon
2. DR Lat 16°03.'6 S Dec 20°09.'1 N Rise θ on visible horizon

Answer 2. ZN 69.20611918

Preparation and operation

• Execute the program as shown below in the RUN mode ([MODE] [1]).

Step	Key operation	Display	Step	Key operation	Display
1	Prg 3 [EXE]	AMP.S	11	☐	
2	[EXE]	LAT+N-S?	12	☐	
3	5124.6 [EXE]	DEC+N-S?	13	☐	
4	1940.4 [EXE]	R1-S2?	14	☐	
5	2 [EXE]	V1-C2?	15	☐	
6	1 [EXE]	ZN.	16	☐	
7	[EXE]	303.716742	17	☐	
8	[EXE]	AMP.S	18	☐	
9	[EXE]	(repeat again)	19	☐	
10	[EXE]		20	☐	

Line	[MODE] [2] Program 3															Notes	Number of steps
1	"	A	M	P	.	S	"	▲	Prg	7	;	"	R	1	-		
2	S	2	"	;	?	→	I	:	"	V	1	-	C	2	"		
3	:	?	→	J	:	L	÷	Abs	L	→	E	:	D	÷	Abs		
4	D	→	F	;	Ø	→	H	;	J	=	2	⇒	Goto	5	:		
5	I	=	2	⇒	Goto	2	:	E	=	F	⇒	Goto	3	:	Goto		
6	4	:	Lbl	2	:	E	=	F	⇒	Goto	4	:	Lbl	3	:		
7	.	7	→	H	:	Goto	5	:	Lbl	4	:	-	.	7	→		
8	H	:	Lbl	5	;	SIN^{-1}	(	(	SIN	D	-	SIN	L	X	SIN		
9	H	)	÷	COS	L	÷	COS	H	)	→	P	:	I	=	1		
10	⇒	Goto	7	:	2	7	ø	+	P	→	Z	:	Goto	8	:		
11	Lbl	7	:	9	ø	-	P	→	Z	;	Lbl	8	;	"	Z		
12	N	.	"	▲	Z	◢											
13																	

PROGRAM SHEET

Program for	Sub. Routine	No.

Description

Prg 5 converting Deg Min (1530.0) to Deg. 15°5

Prg 6 Compute true azimuth (ZN) from Lat, dec and LHA

Prg 7 Input Latitude (L) and declination (D)

Prg 8 Input Local hour angle

Prg 9 Input Corrected observed altitude (HO)

No.

	Line	MODE 2 Program	Notes	Number of steps
Prg 5	1	Int (A ÷ 1 ø ø) → B : B + (A		
	2	− B X 1 ø ø) ÷ 6 ø → C		
	3			
Prg 6	4	SIN H ÷ (COS H X SIN L − tan D X COS L		
	5	) → X : tan^{-1} X → Y : H > 1 8 Ø ⇒		
	6	Goto 2 : X ≥ Ø ⇒ Goto 3 : 3 6 Ø + Y		
	7	→ Z : Goto 4 : Lbl 2 : X < Ø ⇒ Goto 3		
	8	: Y → Z : Goto 4 : Lbl 3 : 1 8 Ø +		
	9	Y → Z : Lbl 4 : " Z N . " ◢ Z ◢		
	10			
Prg 7	11	Md : " L A T + N − S " : ? → A		
	12	: Prg 5 : C → L : " D E C + N −		
	13	S " : ? → A : Prg 5 : C → D		
	14			
Prg 8	15	" L H A " : ? → A : Prg 5 : C →		
	16	H		
	17			
Prg 9	18	" H O " : ? → A : Prg 5 : C → S		
	19			

BY NC-88, TAMAYA CO., LTD

Formulae of Celestial Navigation, Piloting, Dead Reckoning and the Nautical Almanac are programmed and stored.

STAR FINDER:

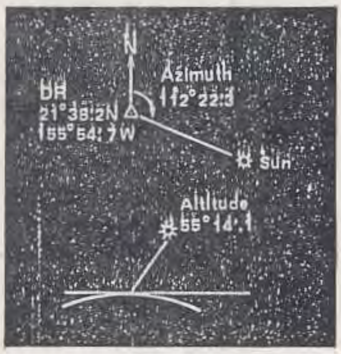
NAUTICAL ALMANAC [ALM] / ALTITUDE AND AZIMUTH [AcZ]

NC-88 Nautical Almanac [ALM] is good with accuracy better than 0:2 through the year 2100. Followed by [AcZ] it computes the altitude and azimuth of any navigational body from any point on the earth. Almanac includes the **Sun, Moon, Venus, Mars, Jupiter, Saturn and 63 navigational stars.**

SUN

Find the GHA and DEC of the Sun at GMT $20^h18^m36^s$ on April 4, 1982. Then compute, its Altitude and Azimuth from the DR position 21°38:2N, 155°54:7W.

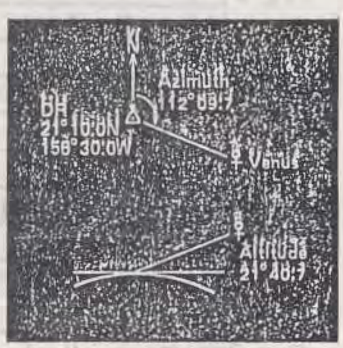
Input Key		Display		Description
[ALM]		[ALM]		*Almanac*
[⊙]	20.1836	HMS	20.1836	*GMT*
[⊙]	1982.0404	YMD	1982.0404	*Date*
[⊙]	0	CB	0	*Celestial Body Number*
[⊙]		CB	Sun	*Body Name*
[⊙]		CB	Sun (Blinks)	
		SD	0.160	*Semidiameter*
[⊙]		DEC	5.483N	*Declination*
[⊙]		GHA	123.543	*Greenwich Hour Angle*
[⊙]		EOT	−0.0259	*Equation of Time*
[AcZ]		[ALTc-AZ]		*Altitude-Azimuth*
[⊙]	21.382 [N]	LAT	21.382N	*DR Lat.*
[⊙]	155.547 [W]	LON	155.547W	*DR Long.*
[⊙]		-PROCESS-		
		ALTc	55.141	*Altitude*
[⊙]		AZ	112.223	*Azimuth*



VENUS

Find the GHA and DEC of Venus at GMT $15^h30^m00^s$ on April 4, 1982. Then compute its Altitude and Azimuth from the DR position 21°10:0N, 156°30:0W.

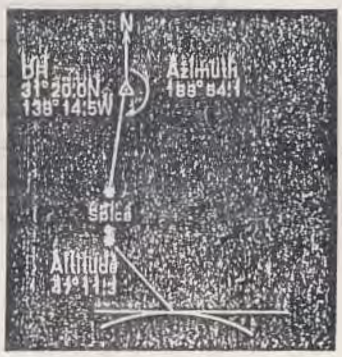
Input Key		Display		Description
[ALM]		[ALM]		*Almanac*
[⊙]	15.3000	HMS	15.3000	*GMT*
[⊙]	1982.0404	YMD	1982.0404	*Date*
[⊙]	70	CB	70	*Celestial Body Number*
[⊙]		CB	Venus	*Body Name*
[⊙]		CB	Venus (Blinks)	
		HP	0.002	*Horizontal Parallax*
[⊙]		DEC	11.095S	*Declination*
[⊙]		GHA	95.116	*Greenwich Hour Angle*
[AcZ]		[ALTc-AZ]		*Altitude-Azimuth*
[⊙]	21.100 [N]	LAT	21.100N	*DR Lat.*
[⊙]	156.300 [W]	LON	156.300W	*DR Long.*
[⊙]		-PROCESS-		
		ALTc	21.407	*Altitude*
[⊙]		AZ	112.097	*Azimuth*



SPICA

Find the GHA and DEC of Spica at GMT $8^h30^m00^s$ on April 30, 1982. Then compute its Altitude and Azimuth from the DR position 31°20:0N, 138°14:5W.

Input Key		Display		Description
[ALM]		[ALM]		*Almanac*
[⊙]	8.3000	HMS	8.3000	*GMT*
[⊙]	1982.0430	YMD	1982.0430	*Date*
[⊙]	60	CB	60	*Celestal Body Number*
[⊙]		CB	Spica	*Body Name*
[⊙]		CB	Spica (Blinks)	
		DEC	11.042S	*Declination*
[⊙]		GHAa	345.275	*GHA Aries*
[⊙]		SHA	158.561	*SHA*
[⊙]		GHA	144.236	*Greenwich Hour Angle*
[AcZ]		[ALTc-AZ]		*Altitude-Azimuth*
[⊙]	31.200 [N]	LAT	31.200N	*DR Lat.*
[⊙]	138.145 [W]	LON	138.145W	*DR Long.*
[⊙]		-PROCESS-		
		ALTc	47.113	*Altitude*
[⊙]		AZ	188.541	*Azimuth*



Applications: Other than the strict Astro-Navigation practice, the true Azimuth of the celestial body may be used effectively in compass adjustment. The computed Sun's altitude is useful in knowing the twilight time in advance.

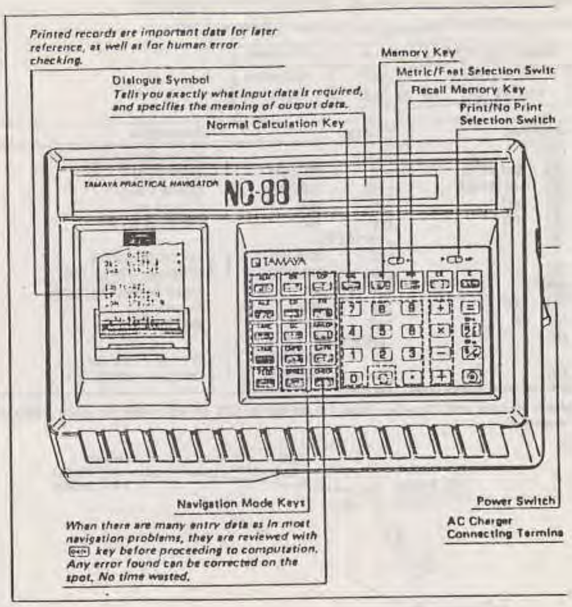
LINE OF POSITION [LOP] AND POSITION FIX [FIX]

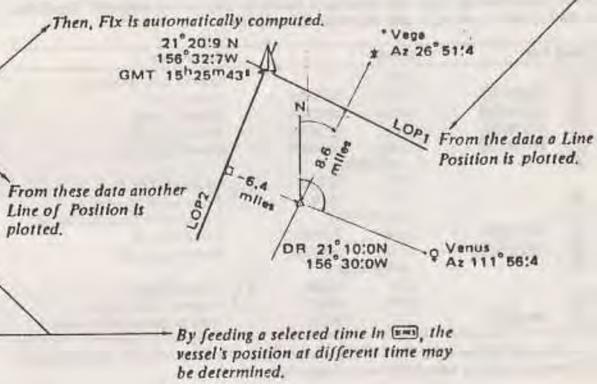
FIX BY TWO SIGHTS

The DR position of a vessel is 21°10:0N, 156°30:0W around 15 o'clock GMT on April 4, 1982. It is steering the true course 67° at speed 8 knots when the following sights are taken. The height of eye is 3 meters. Compute the fix at the time of the sights and at 15 o'clock.

Date	GMT	Body	Sextant Altitude (after index correction)
Apirl 4, 1982	$15^h25^m43^s$	Vega (62)	70°00:3
April 4, 1982	$15^h28^m11^s$	Venus (70)	21°16:3

Input key		Display		Description
[LOP]		[LOP1]		Line of Position No.1
[⊙]	15.2543	HMS1	15.2543	Sight Time (Hour Minutes, Second – GMT)
[⊙]	1982.0404	YMD	1982.0404	Sight Date (Year, Month, Day)
[⊙]	62	CB	62	Celestial Body Number
[⊙]		CB	Vega	Body Name
[⊙]	70.003	AL1	70.003	Sextant Altitude (After Index Correction)
[⊙]	3	HGT	3 m.	Height of Eye
[⊙]		TMP	10 c.	Temperature
[⊙]		PRS	1013.25 mb	Pressure
[⊙]	21.100[N]	LAT	21.100N	DR Lat
[⊙]	156.300[W]	LON	156.300W	DR Long
[⊙]		CHECK?		
[⊙]		-PROCESS (Blinks)-		
		AZ	26.514	Azimuth 26°51'.4
[⊙]		IN1	8.6	Intercept 8'.6 (miles)
[LOP]		[LOP2]		Line of Position No.2
[⊙]	15.2811	HMS2	15.2811	Sight Time
[⊙]		YMD	1982.0404	Sight Date
[⊙]	70	CB	70	Celestial Body Number
[⊙]		CB	Venus	Body Name
[⊙]	21.163	AL2	21.163	Sextant Altitude (After Index Correction)
[⊙]	67	CC	67	True Course
[⊙]	8	SPD	8	Speed (Knots)
[⊙]		CHECK?		
[⊙]		-PROCESS-		
		AZ	111.564	Azimuth 111°56'.4
[⊙]		IN1	-6.4	Intercept -6'.4 (miles)
[FIX]		[FIX]		Position Fix
[⊙]		-PROCESS-		
		LAT	21.209 N	Fix Lat. 21°20'.9 N
[⊙]		LONf	156.327W	Fix Long. 156°32'.7W
[⊙]		HMSf	15.2543	Fix Time 15h 25m 43s
		YMDf	1982.0404	Fix Date
[SERIES]		[FIX SERIES]		Fix Series
[⊙]	15.2811	HMSf	15.2811	Selected Time 15h 28m 11s
[⊙]		YMDf	1982.0404	
[⊙]		-PROCESS-		
		LAT	21.210 N	Fix Lat.21°21'.0 N
[⊙]		LONf	156.324W	Fix Long. 156°32'.4W
[SERIES]		[FIX SERIES]		Fix Series
[⊙]	15	HMSf	15	Selected Time 15h 00m 00s
[⊙]		YMDf	1982.0404	
[⊙]		-PROCESS-		
		LAT	21.195N	Fix Lat. 21°19'.5N
[⊙]		LONf	156.361W	Fix Long. 156°36'.1W

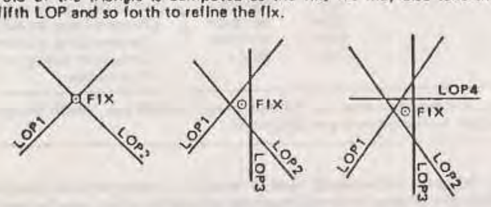




FIX BY MULTIPLE SIGHTS

Fix by multiple sights is also possible by repeating [LOP] with more celestial bodies. Any celestial body in the NC-88 may be used.

In the theory of Astro-Navigation, a ship's position can be determined only after at least two Lines of Position (LOP) are obtained. The intersection of the two LOP's called "Fix" is the ship's position. If three LOP's are given, the centroid of the triangle is computed as the fix. We may also take the fourth and fifth LOP and so forth to refine the fix.

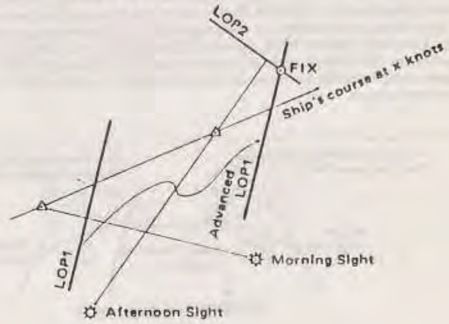


EXTRA FIX [E-FIX] and ADD LOP FIX [ADD LOP]

When pre-computed Azimuths and Intercepts are externally available for two Lines of Position the fix is directly computed by [E-FIX]. The third and more number of LOP's are added by [ADD LOP] to determine the centroid.

RUNNING FIX BY SUN SIGHTS

If it is desired to fix the Ship's position by the Sun sights only, RUNNING is made similarly in [LOP] by feeding ship's course and speed between the sights (e.g. morning and afternoon sights).



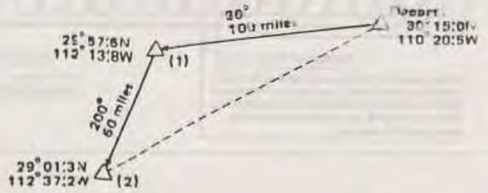
DEAD RECKONING [DR] BY MERCATOR SAILING

Find the DR position after the first and the second run.

Departure Point	Course	Distance
30°15'.0N 110°20'.5W	1) 260° 2) 200°	100 miles 60 miles

Input Key		Display		Description
[DR]		[DR]		Dead Reckoning
[•]	30.150[N]	LAT	30.150N	Depart Lat
[•]	110.205[W]	LON	110.205W	Depart Long
[•]	260	CO	260	Course (1)
[•]	100	DST	100	Distance (1)
[•]		-PROCESS-		
		LAT	29.576N	DR Lat 29°57'.6N
[•]		LON	112.138W	DR Long. 112°13'.8W
[SRS]		[DR SERIES]		Dead Reckoning Series
[•]	200	CO	200	Course (2)
[•]	60	DST	60	Distance (2)
[•]		-PROCESS-		
		LAT	29.013N	DR Lat. 29°01'.3N
[•]		LON	112.372W	DR Long. 112°37'.2W

More courses and distances may be added in DR series mode by using [SRS] key repeatedly.

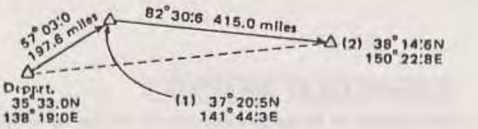


COURSE AND DISTANCE [CD] BY MERCATOR SAILING

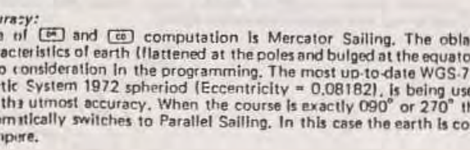
Find the distance from the departure point to the arrival point(1) from the point(1) to the point(2), and the total distance run.

Input Key		Display		Description
[CD]		[CD]		Course and Distance
[•]	35.330[N]	LATd	33.330N	Depart Lat
[•]	138.190[E]	LONd	138.190E	Depart Long
[•]	37.205[N]	LATs	37.205N	Arrival Lat (1)
[•]	141.443[E]	LONa	141.443E	Arrival Long (1)
[•]		-PROCESS-		
		CO	57.030	Course 57°03'.0
[•]		DST	197.6	Distance 197.6 miles
[SRS]		[CD SERIES]		Course and Distance Series
[•]	38.146[N]	LATa	38.146N	Arrival Lat (2)
[•]	150.228[E]	LONa	150.228E	Arrival Long (2)
[•]		-PROCESS-		
		CO	82.306	Course 82°30'.6
[•]		DST	415.0	Distance 415.0 miles
[+]	197.6[=]		612.6	Total Distance 612.6 miles

Courses and distances to more continuing points of arrival may be determined in CD series mode by using [SRS] key repeatedly.



Note on Accuracy:
The principle of [DR] and [CD] computation is Mercator Sailing. The oblate spheriod characteristics of earth (flattened at the poles and bulged at the equator) are taken into consideration in the programming. The most up-to-date WGS-72, World Geodetic System 1972 spheriod (Eccentricity = 0.08182), is being used to guarantee the utmost accuracy. When the course is exactly 090° or 270° the program automatically switches to Parallel Sailing. In this case the earth is considered as a sphere.



COMPOSITE SAILING

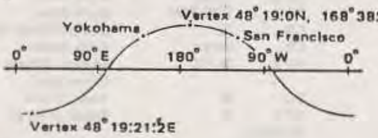
GREAT CIRCLE SAILING [GC]

	Depart, Point (San Francisco)	Arrival Point (Yokohama)
Lat. Long.	37°50'.8 N 122°25'.5 W	34°52'.0 N 139°42'.0 E

Find the great circle distance, initial great circle course, vertex latitude and longitude, and latitude at 145°W and 150°W.

Input Key		Display		Description
[GC]		[GC]		Great Circle Sailing
[•]	37.508[N]	LATd	37.508N	Depart Lat
[•]	122.255[W]	LONd	122.255W	Depart Long
[•]	34.520[N]	LATa	34.520N	Arrival Lat
[•]	139.420[E]	LONa	139.420E	Arrival Long
		-PROCESS-		
		CO	302.379	Initial Great Circle Course 302°37'.9
[•]		DST	4488.8	Great Circle Distance 4488.8 miles
[•]		LATv	48.190N	Vertex Lat 48°19'.0N
[•]		LONv	168.388W	Vertex Long 168°38'.8W
[SRS]		[LATi SERIES]		Intermediate Latitude Series
[•]	145[W]	LONi	145W	Intermediate Long
[•]		-PROCESS-		
		LATi	[illegible]	[illegible]
[DEL]		LONi	145.000W	(change to 150°W)
	150[W]	LONi	150W	Intermediate Long
[•]		-PROCESS-		
		LATi	46.467N	Intermediate Lat. 46°46'.7N

More Intermediate Longitudes may be entered by [DEL] key for Latitude determination.



Point to point planning:
Since a great circle, except the equator and any meridian line, is continuoi changing direction as one proceeds along it, no attempt is customarily mad follow it exactly. Rather, a number of points are selected along the great cir and rhumb lines are followed from point to point, taking advantage of the that for short distances a great circle and a rhumb line almost coincide. Tl points usually are selected every 5° of longitude for convenience (the num of points to use is a matter of personal preference), and the corresponding tudes are computed by NC-88.

COMPOSITE SAILING [CMPST]

Find the composite track with the maximum limiting latitude of 45°N.

Input Key		Display		Description
[GC]		[GC]		Great Circle Sailing
[•]	37.508[N]	LATd	37.508N	Depart Lat
[•]	122.255[W]	LONd	122.255W	Depart Long
[•]	34.520[N]	LATa	34.520N	Arrival Lat
[•]	139.420[E]	LONa	139.420E	Arrival Long
[•]		-PROCESS-		
		CO	302.379	Initial Great Circle Course 302°37'.9
[•]		DST	4488.8	Great Circle Distance 4488.8 miles
[•]		LATv	48.190N	Vertex Lat 48°19'.0N
[•]		LONv	168.388W	Vertex Long 168°38'.8W
[CMPST]		[COMPOSITE]		Composite Sailing
[•]	45[N]	LAT ↑	45N	Limiting Latitude
[•]		-PROCESS-		
		CO	296.259	Initial GC Course to V1 296
[•]		LONI	161.264W	Tangent Long V1 161°26'.4
[•]		LONI	174.280W	Tangent Long V2 174°28'.(
[•]		DST	4504.4	Composite Sailing Distanc 4504.4 miles

More Limiting Latitudes may be determined by [DEL] key, which brings the gram back to the beginning of [CMPST] mode.

When the great circle would carry a vessel to a higher latitude than desir modification of great circle sailing called composite sailing, may be used to advantage. The composite track consists of a great circle from the point o parture and tangent to the limiting parallel, a course line along the parallel a great circle tangent to the limiting parallel and through the destination.

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