THE COMPLETE DECK OFFICERS, RYA, AYF, AND SA SAILING SYLLABUS

MILLENNIUM  2000

CELESTIAL NAVIGATION

for

DECK OFFICERS

and for

YACHTMASTERS OCEAN

A South African Maritime Safety Authority Approved Course

Part 1 - NAVIGATION

By
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Cape Town

Written with the 'D.I.Y.' learner in mind for 'self teaching'.

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INCLUDED: NAUTICAL ALMANAC AND SIGHT REDUCTION TABLES EXTRACTS INCLUDED WITH EXAMPLES' SOLUTIONS IN PART 2.

By the same author:

The Radiotelephone Operators' Restricted (Marine) Certificate Course.

Competent Crew/Yacht Hand Practical Course Notes.

Yacht Skipper (Local Waters) Practical Course Notes.

Competent Crew and Yacht Skipper, Part 1, (Inland Waters), and Part 2, (Local Waters) Shorebased Course.

Coastal Skipper/Yachtmaster Offshore - The Complete Syllabus Shorebased Course.

Astro Nav in Emergencies, for the Non-Navigator. (The GPS Back-Up.)

All courses conform with the RYA, AYF and CASA syllabuses, and are S.A.M.S.A. approved.

Written to be the most comprehensive syllabus coverage course notes for an instructor to issue to his or her students.

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HENTON JAABACK - YACHTMASTER OCEAN INSTRUCTOR - RYA AND CASA SKIPPER OF COMMERCIAL AND PLEASURE CRAFT UP TO 200 TONS SOUTH AFRICAN MARITIME SAFETY AUTHORITY DECK OFFICER CLASS 6 (200 TONS), UK DEPARTMENT OF TRANSPORT APPROVED 200 TONS

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THE RYA, AYF AND CASA SYLLABUS

The syllabuses for the Royal Yachting Association, Australian Yachting Federation, and SA Sailing/the Cruising Association of South Africa 'Yachtmaster Ocean' shorebased courses (there is no official practical Yachtmaster Ocean course) are almost identical. The syllabus, with recommended minimum time (in hours) to be spent on each aspect, and the detail of each, is contained in the RYA *YACHTSMAN'S LOGBOOK*, and is copied by the Australian and South African Associations.

THIS COURSE

These course notes may be used as a **D.I.Y.** 'teach yourself' book, or with the course delivered by your course presenter. They are, nevertheless, complete notes and **no extra reading is necessary**.

WHAT TO GET

Students working on their own will find all the Almanac and Sight Reduction reference tables, etc., they require are contained in this book. They will, however, need a parallel rule or a plotter, dividers, and a sharp pencil (2B is recommended) for plotting. Students attending formal classes should, if possible, bring their own:

1. Parallel rule or plotter (any type - the Breton or Hurst Plotters are recommended), and a set of navigator's dividers.

2. *Sight Reduction Tables for Air Navigation (Selected Stars)*, Publication Number 249, Volume 1. An epoch is a five year period, being two years before and two years after the year as shown on the cover. (It is rumoured these volumes are to become redundant soon, so another method of resolving star sights is preferable.)

3. Scientific calculator capable of processing trigonometric calculations. A programmed astro-navigation calculator is not accepted for examinations although they are ideal for use in daily navigation situations.
Note: For examination purposes, a candidate may use either a scientific calculator (non astro-navigation programmed type) or any Sight Reduction Tables method. (See 6. below).

4. A sextant if possible (two are available for loan), for the calibration lecture, which is normally on the first day of the course, and for the practical on Day 8 or Day 9, depending on the weather.

5. A sharp pointed soft lead pencil (2B is recommended) and eraser, for plotting.

6. In lieu of the 'concise' sight reduction tables in *The Nautical Almanac*, one may optionally choose to use:
   a. *Marine Sight Reduction Tables*, publication number NP 401, Volumes 1, 2, 3, etc. (one volume for each successive band of 16° of latitude - e.g. Vol 1, 0° to 15°; Vol 2, 15° to 30°). These books are expensive, bulky and heavy; they are only very slightly more accurate (less than 1 mile) and are a little more complicated to use).

b. *Sight Reduction Tables for Air Navigation*, publication number 249. They can only be used for celestial observation resolutions where the declination of the body does not exceed 30°00'. They can therefore be used for sights of the sun, moon, and planets and some stars (providing the stars can be independently identified):
   i. Volume 2 (Volume 1 was for stars - see 2. above). It is used when one is in any latitudes from 0° to 40°.
   ii. Volume 3. For latitudes from 39° to 89°.

c. Other Tables. As tables such as *Burton's* and *Norie's* are not commonly found on cruising yachts, their description has been omitted from this book. They nevertheless are tables from which sight resolutions, given the Almanac data, can be completed.

PRE-COURSE QUALIFICATIONS

There are no, repeat NO pre-course certificated qualifications required for people wishing to attend this course. However, one should be at the standard of local Club qualified skipper or Skipper (Local Waters) and/or understand the elements of coastal navigation such as the Mercator and Gnomonic Projection charts, positions by Latitude and Longitude, the relationship of a minute of arc of a Great Circle being 1 nautical mile, etc. It does not matter therefore, if you have not yet done the test for Coastal Skipper. However if you intend to sit the Yachtmaster Ocean examination after this course, please be aware that:

1. In South Africa, you may not be allowed to sit the examination for a short period immediately after a course. At the time of writing, the period is one month. Check at your examining authority's offices.
2. You must either be qualified at Yachtmaster Offshore, or as it is in South Africa at the time of writing, successful examination candidates will be credited with a pass for up to six months during which time they must qualify at Yachtmaster Offshore standard. They will not be issued their Yachtmaster Ocean Certificates of Competence until they are in possession of a Yachtmaster Offshore Certificate of Competence.
3. An examination may not be necessary as some Associations (e.g. South Africa) allow the submission of proof of astro navigation experience in lieu of a test.

CERTIFICATES OF COMPLETION

Attendance at this course, and satisfactory performance during the course, may qualify the candidate for the Association's course completion certificate which should be inserted in and become part of his or her personal Log Book.

QUERIES

Henton's all-hours telephone and facsimile number is 'Cape Town (021) 462-3413', and any queries can be put to him at any reasonable time.

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The author wishes to acknowledge and thank:

The Director of the Royal Greenwich Observatory, Cambridge, for accepting the book and arranging for the correct authorities for the inclusion of copyright material.

The Controller of Her Britannic Majesty's Stationery Office for the kind permission to reproduce sections of *The Nautical Almanac* and other British Admiralty publications - in particular, the *Marine Sight Reduction Tables*. These publications are Crown Copyright.

The Defense Mapping Agency, U.S. Government, for their kind consideration in providing the information from Publication 249 (*Air Sight Reduction Tables*).

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Mr Roger N Hunter, Managing Director of Barnacle Marine, Nautical Publishers and Distributors for the RYA, for his valuable advice.

A Yachtmaster examiner for his personal comment "The best book on the subject I have ever read".

His wife, Daphne, for being such a fantastic First Mate!

THE SEXTANT

A SEXTANT'S COMPOSITION AND USE

1. **Its Use**. Let's deal with the use of a sextant first. A sextant measures angles. Accurately. To one decimal place of a minute of arc (0.1' = 1/10 of 1/60 th of a degree). It does nothing else. Unless you use it as a weapon to throw at pirates!

2. **Its Composition**. Next, its composition. Look at the illustration below. Read the labels naming the parts and identify the equivalent parts on your sextant:

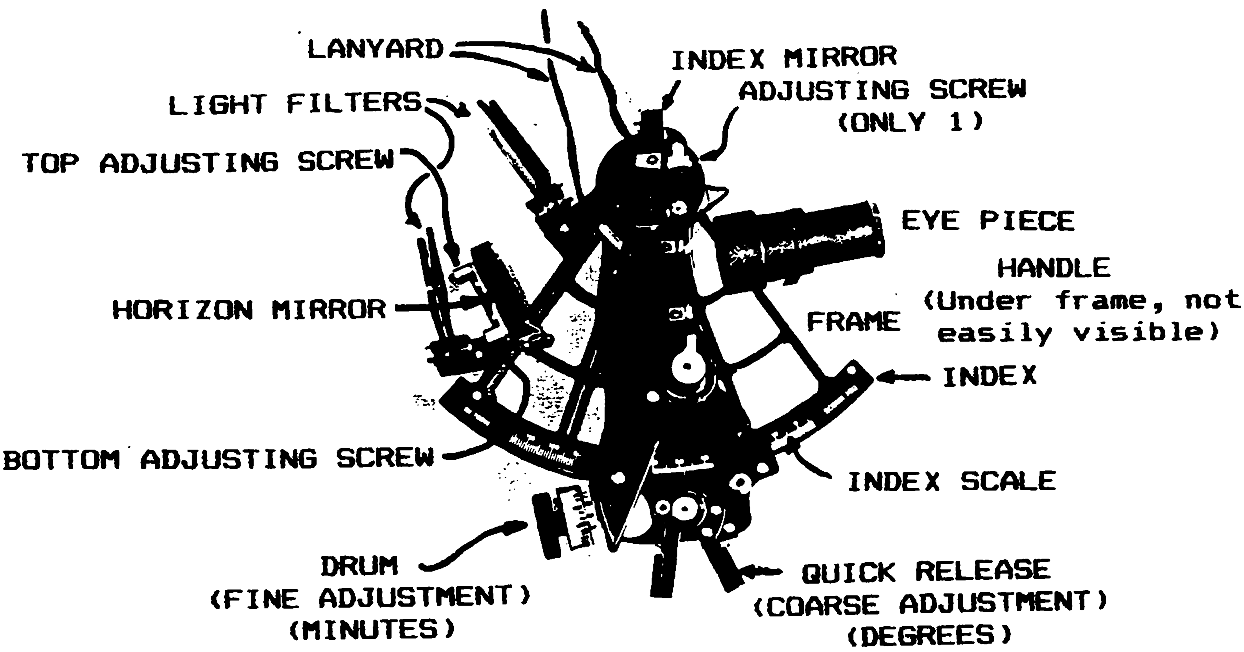


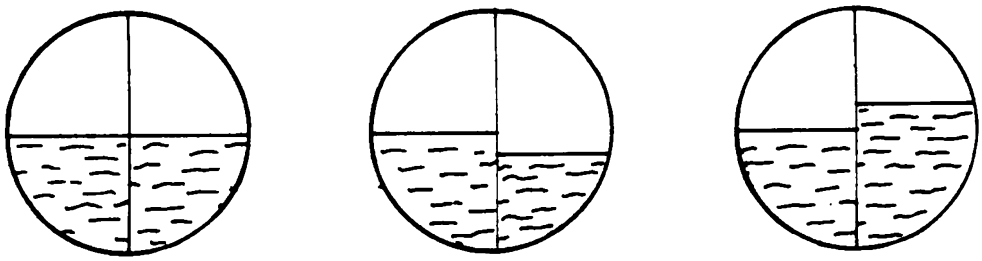
Fig. 1. THE SEXTANT AND ITS PARTS

The **FRAME** holds the **HORIZON MIRROR**, the **EYE PIECE**, the **INDEX SCALE** and **HANDLE**, while providing a pivot for the **INDEX ARM** to be able to move through the arc of the scale. The Horizon Mirror has two adjusting screws behind it. The adjustable Eye-Piece allows the user to focus on distant objects. The Index Arm has a graduation mark next to the Index Scale to enable the user to read off whole numbers of degrees, and a rotatable **DRUM** to show the fractions of a degree as 'minutes' and decimals of a minute. Near the drum is a **QUICK RELEASE** mechanism to enable coarse adjustments of the Index Arm setting. The Index Mirror is mounted on the Index Arm at the pivot end and therefore moves with the Index Arm when it is moved. This mirror has only one adjusting screw behind it.

Check the mirrors' alignments and therefore **Index Error** (I.E.) before using it to measure any angle(s). If necessary, recalibrate it to reduce or, preferably, eliminate it completely. Any Index Error (I.E.) in the sextant at the time of taking a sight will have to be allowed for when determining the correct Sextant Angle (SA).

CALIBRATION ADJUSTMENTS

Begin by setting the **INDEX ARM** to zero degrees, zero minutes. Hold the sextant in your right hand and hold it up to the eye so that the **FRAME IS VERTICAL** and the eyepiece enables you to see a distant object which has a distinct horizontal line. The horizon is best - it is far away. If the object chosen is not far away, you may get a false reading. You will see one of the three images in Figure 2.



A B C

Fig. 2. A. IMAGES IN LINE - MIRRORS PROBABLY SET CORRECTLY,
B. and C. IMAGES NOT IN LINE - MIRRORS NEED ADJUSTING.

The reason we see these images is because the left half of what we look at is viewed directly from the eyepiece but the right half involves the visible picture reaching the eye after reflecting off the mirrors:

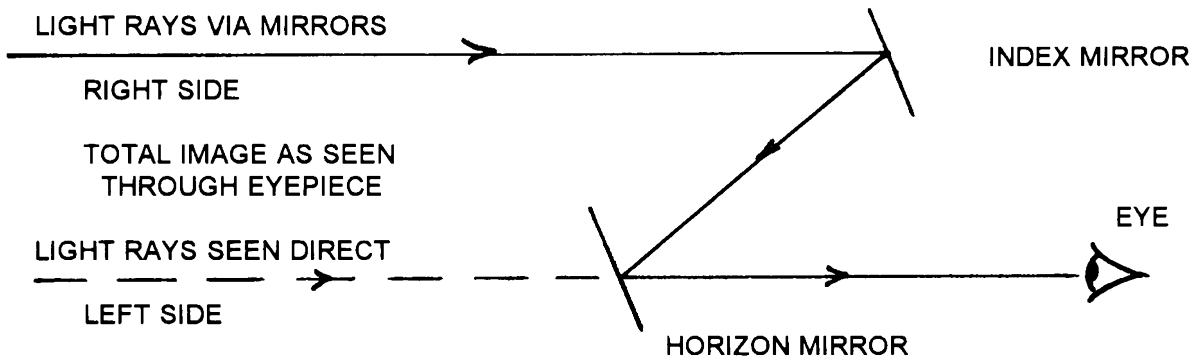


Fig. 3. HOW THE LIGHT RAYS REACH THE EYE

If the two halves, the left and the right, of the distant horizontal line image are in line, incline the sextant 45 degrees (45°) to one side and then to the other - the images must remain in line. If they do, the mirrors are correctly set. If at any of the three positions the images are not in line, the mirrors' settings need checking - one or both will need adjusting.

Setting the INDEX MIRROR

Set the index arm at about 45° to 50°. Now hold the sextant so that the frame is in an approximately horizontal plane with the index mirror between your eye and the index scale. See Figure 4. You need to be able to see over the pivot point, past the index mirror's right edge (as seen when the sextant is horizontal - the same edge which would be its bottom side if the sextant were held in the vertical plane), to the index scale near the zero degrees part of the scale. At the same time look into the right (normally bottom) part of the mirror to see the reflection of the index scale near its maximum reading. The far edges of the index scale arc should be in line. If they are not, turn the adjusting screw (there is only one) behind the index mirror. The two images of the far edges of the index scale will either get closer or further apart as you turn the screw. Turn the screw in the direction that brings them together.

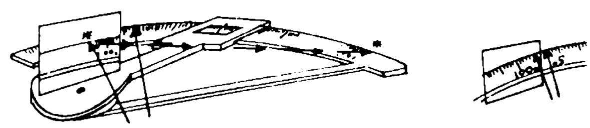
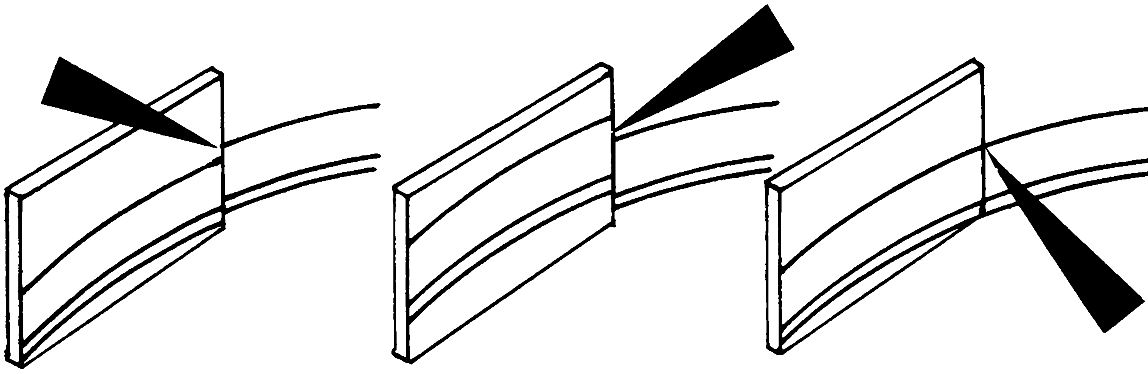


Fig. 4.

When they are in line, the index mirror will be vertical or PERPENDICULAR to the plane of the frame of the sextant - the Index mirror will be correctly aligned. If they are not in line you will experience the ERROR OF PERPENDICULARITY - a tendency to see double images, one higher than the other.



A B C

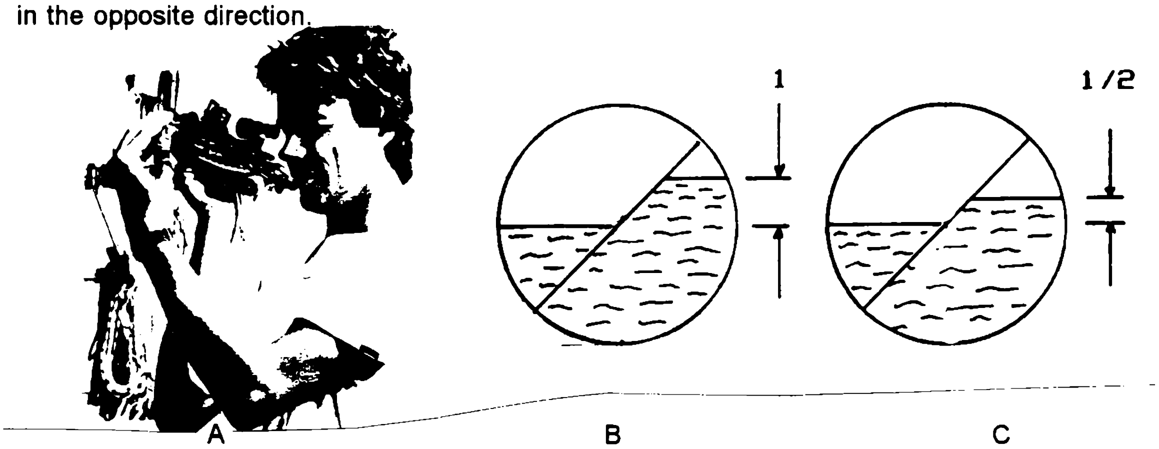
Fig. 5. ALIGNMENT OF THE INDEX MIRROR
A. IMAGE TOO LOW
B. IMAGE TOO HIGH
C. IMAGE AND INDEX SCALE IN LINE

Setting the HORIZON MIRROR

(The index mirror must be correctly adjusted before starting these adjustments).
Set the index arm to zero degrees, and the drum to zero minutes. Hold the sextant in the right hand, bring it to the eye so that it is in the vertical plane, and look at the far distant horizontal line selected earlier (preferably the horizon). Are the two images of the line 'in line'? You will see one of the three images shown in Figure 2. If the two images are in line, tilt the sextant to one side, 45° off the vertical. Are they still in line? Now tilt the sextant 45° to the opposite side of the vertical. Are they in line? If at any of the three positions the images were not in line, the horizon mirror will need adjustment. It will need to be set exactly parallel to the plane of the index mirror which was set **PERPENDICULAR** to the frame of the sextant. 'Double' images, side by side, must be removed. These double images are called **SIDE ERROR**. This mirror must now be reset, and this can be done one of two ways:

Method 1. Look at the double image of a distant point (a star, the moon or sun - use the sun filters) and adjust the two screws, one at a time, until the double image becomes one image overlapping the other.

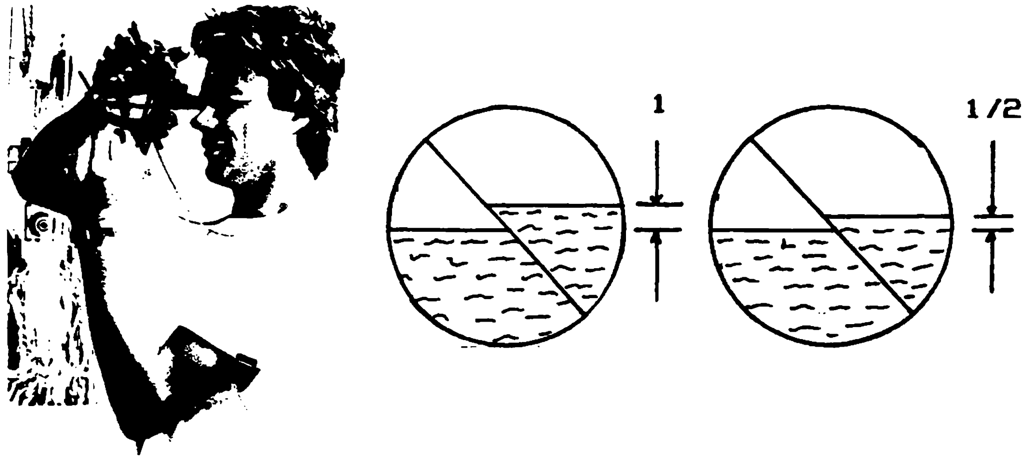
Method 2. Checking that the drum is still on 0.0', hold the sextant so that you can see the distant horizontal line through the eyepiece. With the sextant tilted 45° to the right, note the difference in levels between the left and right halves of the distant horizontal line. Now by turning the higher of the two adjusting screws behind the horizon mirror, reduce the difference in the two levels BY HALF. If you turn the top adjusting screw the wrong way, the difference in levels will increase - turn the adjusting screw in the opposite direction.



A B C

Fig. 6. THE RIGHT TILT ADJUSTMENT
A. THE TOP ADJUSTING SCREW
B. THE DIFFERENCE BEFORE ADJUSTING
C. THE DIFFERENCE AFTER ADJUSTING (REDUCED BY HALF)

Now tilt the sextant 45° to the left of vertical and do the same again, this time using the bottom of the two adjusting screws behind the horizon mirror.



A B C

Fig. 7. THE LEFT TILT ADJUSTMENT
A. THE BOTTOM ADJUSTMENT SCREW
B. THE DIFFERENCE BEFORE ADJUSTMENT
C. THE DIFFERENCE AFTER ADJUSTMENT

REMEMBER: ONLY REDUCE THE DIFFERENCE IN LEVELS BY HALF AT EACH TILT ANGLE. Now repeat the process with the sextant inclined 45° to the right. ONLY REDUCE THE DIFFERENCE IN LEVELS BY HALF AT EACH ANGLE OF TILT. Now repeat again, with the sextant tilted to the left. Continue the left and right tilting adjustments until the difference in levels is eliminated.

With the sextant held in the vertical plane, check the left and right halves of the distant horizontal line. They should be in line. They should be in line whether the sextant is vertical, or tilted 45° to either side. If they are not, re-check the index mirror as it is possible you turned its adjusting screw by mistake while adjusting the horizon mirror. If this is the case, start again. If the index mirror is still correctly aligned, re-check the horizon mirror and re-adjust.

INDEX ERROR

It is possible that you do not have time to complete the horizon mirror adjustments, or while you are still getting used to the procedure, you get close to 'in line' but not exactly 'in line'. There will be a small amount of error remaining at the time you wish to use the sextant to measure an angle (take a sight?). You therefore need to know what this error is. It is called the '**Index Error**' (**I.E.**).

Hold the sextant to the eye so that it is vertical and you can see the distant horizontal line. While KEEPING THE SEXTANT VERTICAL, adjust the drum until the left and right images of the distant horizontal line come in line while KEEPING THE SEXTANT VERTICAL.

Note the reading on the drum. It will either be a few minutes (and decimals?) of an angle greater than zero (zero degrees, zero minutes) ie a positive angle ('ON' the scale), or less than zero, i.e. a negative angle ('OFF' the scale).

Note that the 'scale' we refer to is from zero degrees towards the left, towards the 100°, as one looks at a sextant's index scale.

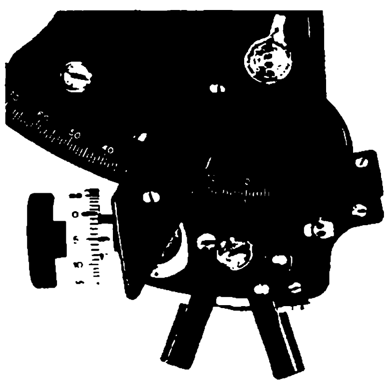


Fig. 8. INDEX ERROR 'ON' THE SCALE.

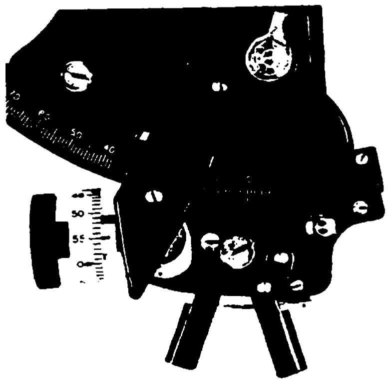


Fig. 9. INDEX ERROR 'OFF' THE SCALE.

If the index error was 3.5' OFF the scale, we must add it to any angle measured. We say 'Index Error "OFF" the scale, add'.

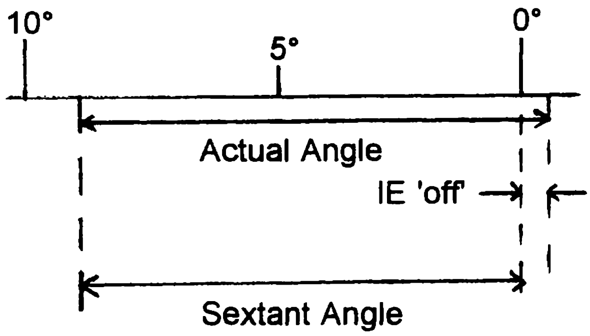


Fig. 10. INDEX ERROR 'OFF' THE SCALE, ADD.

The index error found must now be added or subtracted to any angle measured with the sextant. If the error was 3.5' ON the scale, this would represent the zero position of the sextant at the time. So any angle measured will include this error. The true angle required must therefore have this error subtracted; we say 'Index Error "on" the scale, subtract'.

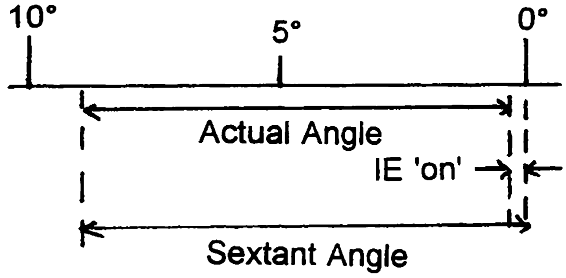


Fig. 11. INDEX ERROR 'ON' THE SCALE, SUBTRACT

Index error should be checked just before a sextant is used - it can be dangerous to assume that it will be the same as the last time the sextant was used. Anything can happen to alter it and plastic sextants will have index errors which change with temperature changes - plastic sextants' errors should be checked before and after use and the average taken as the Index Error for the angle measured.

COLLIMATION ERROR

Collimation error is the error which results when the axis of the telescope or eyepiece is not correctly aligned with the plane of the sextant. A good sextant will not have any collimation error, and the average sextant used in the present day does not have any means of adjusting for it.

OTHER ERRORS

There can be other errors caused by the pivot point on the index arm not being correctly aligned with the index scale, incorrect graduation of the index scale, or imperfect lenses used in the telescope eyepiece. They can not be adjusted and the manufacturer normally supplies a table of values to be used to compensate for these errors. The values one would see in a good sextant's table would be very small and for the yachtsman or woman who is not needing the accuracy of a few metres, they can be ignored.

DIP / HEIGHT OF EYE

The height of the sextant user's eye above sea level effects the resulting angle when measuring the angular height of a celestial body, be it the sun, moon, a star or a planet. The angular height is called the ALTITUDE of the body, and it will be changing constantly because of the rotation of the earth on its axis. The altitude or angle to be measured uses the horizon as the base of the angle. An horizon at sea level is not parallel to an horizon as seen by a person whose eye is several metres above sea level. So at the same moment in time, the angle at sea level is smaller than the angle measured some metres above sea level - due only to the two using different reference horizons. The higher one's eye is above sea level, the larger the sextant angle will be. We need to know the angle between a line to/from the celestial body and the horizon where we are at sea level, so we need to subtract from the sextant reading taken above sea level, an amount which will correct for the difference between the 'at eye level' and the 'at sea level' angles.

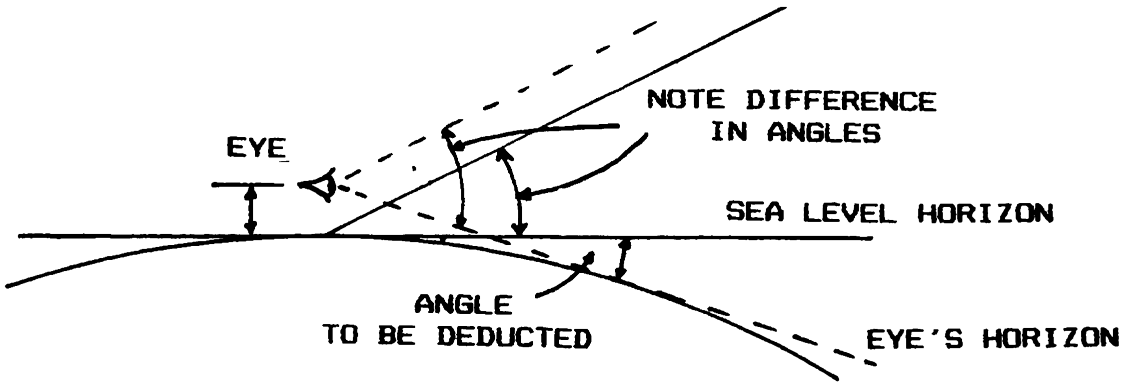


Fig. 12. EFFECT OF HEIGHT OF EYE ON ANGLE MEASURED

Fortunately, the amounts to subtract, depending on the height of eye, are constant all over the world because of its (almost) uniform round shape. The Almanac has a table, conveniently worked out for us so we do not have to get involved in the mathematics. It is called the DIP table and it appears in the Almanac at the front as part of the page titled ALTITUDE CORRECTION TABLES 10°-90° -SUN, STARS, PLANETS. It also appears on a loose-leaf card reproduction of that page for ease of use. This card can be used as a book mark.
The table appears on page 7 as Table 1.

The average height of a sextant user's eye on a cruising yacht is 3 m. So if we look at the DIP table (Table 1, next page), we can use the left half of the DIP figures where we will see:

	m	'	ft (feet)
	....		...
	2.8		9.2
		- 3.0 ←	
→	3.0		9.8
		- 3.1	
	3.2		10.5
	...		....

Under the centre column, opposite and slightly above '3.0' in the left ('m' for metres) column we see '-3.0'. This is the amount to be subtracted from the sextant angle to get the angle applicable at sea level.

We could also have looked under the right-hand half of the DIP table where 3.0 m is directly next to '-3.0'. What would the correction be if the height of eye (of the sextant user) was only six feet? Look just over half way down on the extreme right hand column - the answer is '-2.4'
So the sextant angle or angular height (SEXTANT ALTITUDE) - called SA or Hs in calculations - obtained from the sextant needs to be corrected for Index Error and DIP. If the Index Error was 3.5' OFF the scale when the sextant angle was seen to be 47° 38.2' and height of eye was 3 metres, the corrections to be made are:

SA (or Hs)	47°38.2'	
Index Error(+or-)	+ 3.5' (+, "OFF")	
DIP (always -)	- 3.0'	
Answer	47°38.7'	(Continued on page 8.)

ALTITUDE CORRECTION TABLES 10°-90°—SUN, STARS, PLANETS

SUN — OCT.—MAR.

App. Alt.	Lower Limb	Upper Limb
° ′	′	′
9 34		
	+10·8	−21·5
9 45		
	+10·9	−21·4
9 56		
	+11·0	−21·3
10 08		
	+11·1	−21·2
10 21		
	+11·2	−21·1
10 34		
	+11·3	−21·0
10 47		
	+11·4	−20·9
11 01		
	+11·5	−20·8
11 15		
	+11·6	−20·7
11 30		
	+11·7	−20·6
11 46		
	+11·8	−20·5
12 02		
	+11·9	−20·4
12 19		
	+12·0	−20·3
12 37		
	+12·1	−20·2
12 55		
	+12·2	−20·1
13 14		
	+12·3	−20·0
13 35		
	+12·4	−19·9
13 56		
	+12·5	−19·8
14 18		
	+12·6	−19·7
14 42		
	+12·7	−19·6
15 06		
	+12·8	−19·5
15 32		
	+12·9	−19·4
15 59		
	+13·0	−19·3
16 28		
	+13·1	−19·2
16 59		
	+13·2	−19·1
17 32		
	+13·3	−19·0
18 06		
	+13·4	−18·9
18 42		
	+13·5	−18·8
19 21		
	+13·6	−18·7
20 03		
	+13·7	−18·6
20 48		
	+13·8	−18·5
21 35		
	+13·9	−18·4
22 26		
	+14·0	−18·3
23 22		
	+14·1	−18·2
24 21		
	+14·2	−18·1
25 26		
	+14·3	−18·0
26 36		
	+14·4	−17·9
27 52		
	+14·5	−17·8
29 15		
	+14·6	−17·7
30 46		
	+14·7	−17·6
32 26		
	+14·8	−17·5
34 17		
	+14·9	−17·4
36 20		
	+15·0	−17·3
38 36		
	+15·1	−17·2
41 08		
	+15·2	−17·1
43 59		
	+15·3	−17·0
47 10		
	+15·4	−16·9
50 46		
	+15·5	−16·8
54 49		
	+15·6	−16·7
59 23		
	+15·7	−16·6
64 30		
	+15·8	−16·5
70 12		
	+15·9	−16·4
76 26		
	+16·0	−16·3
83 05		
	+16·1	−16·2
90 00		

SUN — APR.—SEPT.

App. Alt.	Lower Limb	Upper Limb
° ′	′	′
9 39		
	+10·6	−21·2
9 51		
	+10·7	−21·1
10 03		
	+10·8	−21·0
10 15		
	+10·9	−20·9
10 27		
	+11·0	−20·8
10 40		
	+11·1	−20·7
10 54		
	+11·2	−20·6
11 08		
	+11·3	−20·5
11 23		
	+11·4	−20·4
11 38		
	+11·5	−20·3
11 54		
	+11·6	−20·2
12 10		
	+11·7	−20·1
12 28		
	+11·8	−20·0
12 46		
	+11·9	−19·9
13 05		
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13 24		
	+12·1	−19·7
13 45		
	+12·2	−19·6
14 07		
	+12·3	−19·5
14 30		
	+12·4	−19·4
14 54		
	+12·5	−19·3
15 19		
	+12·6	−19·2
15 46		
	+12·7	−19·1
16 14		
	+12·8	−19·0
16 44		
	+12·9	−18·9
17 15		
	+13·0	−18·8
17 48		
	+13·1	−18·7
18 24		
	+13·2	−18·6
19 01		
	+13·3	−18·5
19 42		
	+13·4	−18·4
20 25		
	+13·5	−18·3
21 11		
	+13·6	−18·2
22 00		
	+13·7	−18·1
22 54		
	+13·8	−18·0
23 51		
	+13·9	−17·9
24 53		
	+14·0	−17·8
26 00		
	+14·1	−17·7
27 13		
	+14·2	−17·6
28 33		
	+14·3	−17·5
30 00		
	+14·4	−17·4
31 35		
	+14·5	−17·3
33 20		
	+14·6	−17·2
35 17		
	+14·7	−17·1
37 26		
	+14·8	−17·0
39 50		
	+14·9	−16·9
42 31		
	+15·0	−16·8
45 31		
	+15·1	−16·7
48 55		
	+15·2	−16·6
52 44		
	+15·3	−16·5
57 02		
	+15·4	−16·4
61 51		
	+15·5	−16·3
67 17		
	+15·6	−16·2
73 16		
	+15·7	−16·1
79 43		
	+15·8	−16·0
86 32		
	+15·9	−15·9
90 00		

STARS AND PLANETS

App. Alt.	Corrⁿ
° ′	′
9 56	
	−5·3
10 08	
	−5·2
10 20	
	−5·1
10 33	
	−5·0
10 46	
	−4·9
11 00	
	−4·8
11 14	
	−4·7
11 29	
	−4·6
11 45	
	−4·5
12 01	
	−4·4
12 18	
	−4·3
12 35	
	−4·2
12 54	
	−4·1
13 13	
	−4·0
13 33	
	−3·9
13 54	
	−3·8
14 16	
	−3·7
14 40	
	−3·6
15 04	
	−3·5
15 30	
	−3·4
15 57	
	−3·3
16 26	
	−3·2
16 56	
	−3·1
17 28	
	−3·0
18 02	
	−2·9
18 38	
	−2·8
19 17	
	−2·7
19 58	
	−2·6
20 42	
	−2·5
21 28	
	−2·4
22 19	
	−2·3
23 13	
	−2·2
24 11	
	−2·1
25 14	
	−2·0
26 22	
	−1·9
27 36	
	−1·8
28 56	
	−1·7
30 24	
	−1·6
32 00	
	−1·5
33 45	
	−1·4
35 40	
	−1·3
37 48	
	−1·2
40 08	
	−1·1
42 44	
	−1·0
45 36	
	−0·9
48 47	
	−0·8
52 18	
	−0·7
56 11	
	−0·6
60 28	
	−0·5
65 08	
	−0·4
70 11	
	−0·3
75 34	
	−0·2
81 13	
	−0·1
87 03	
	0·0
90 00	

STARS AND PLANETS — Additional Corrⁿ

App. Alt.	Additional Corrⁿ
19··	
VENUS	
Jan. 1–July 18	
°	′
0	
	+0·1
60	
July 19–Sept. 6	
°	′
0	
	+0·2
41	
	+0·1
76	
Sept. 7–Sept. 28, Dec. 10–Dec. 31	
°	′
0	
	+0·3
34	
	+0·2
60	
	+0·1
80	
Sept. 29–Oct. 14, Nov. 25–Dec. 9	
°	′
0	
	+0·4
29	
	+0·3
51	
	+0·2
68	
	+0·1
83	
Oct. 15–Nov. 24	
°	′
0	
	+0·5
26	
	+0·4
46	
	+0·3
60	
	+0·2
73	
	+0·1
84	
MARS	
Jan. 1–Dec. 14	
°	′
0	
	+0·1
60	
Dec. 15–Dec. 31	
°	′
0	
	+0·2
41	
	+0·1
76	

DIP

Ht. of Eye (m)	Corrⁿ (′)	Ht. of Eye (ft.)
2·4		8·0
	−2·8	
2·6		8·6
	−2·9	
2·8		9·2
	−3·0	
3·0		9·8
	−3·1	
3·2		10·5
	−3·2	
3·4		11·2
	−3·3	
3·6		11·9
	−3·4	
3·8		12·6
	−3·5	
4·0		13·3
	−3·6	
4·3		14·1
	−3·7	
4·5		14·9
	−3·8	
4·7		15·7
	−3·9	
5·0		16·5
	−4·0	
5·2		17·4
	−4·1	
5·5		18·3
	−4·2	
5·8		19·1
	−4·3	
6·1		20·1
	−4·4	
6·3		21·0
	−4·5	
6·6		22·0
	−4·6	
6·9		22·9
	−4·7	
7·2		23·9
	−4·8	
7·5		24·9
	−4·9	
7·9		26·0
	−5·0	
8·2		27·1
	−5·1	
8·5		28·1
	−5·2	
8·8		29·2
	−5·3	
9·2		30·4
	−5·4	
9·5		31·5
	−5·5	
9·9		32·7
	−5·6	
10·3		33·9
	−5·7	
10·6		35·1
	−5·8	
11·0		36·3
	−5·9	
11·4		37·6
	−6·0	
11·8		38·9
	−6·1	
12·2		40·1
	−6·2	
12·6		41·5
	−6·3	
13·0		42·8
	−6·4	
13·4		44·2
	−6·5	
13·8		45·5
	−6·6	
14·2		46·9
	−6·7	
14·7		48·4
	−6·8	
15·1		49·8
	−6·9	
15·5		51·3
	−7·0	
16·0		52·8
	−7·1	
16·5		54·3
	−7·2	
16·9		55·8
	−7·3	
17·4		57·4
	−7·4	
17·9		58·9
	−7·5	
18·4		60·5
	−7·6	
18·8		62·1
	−7·7	
19·3		63·8
	−7·8	
19·8		65·4
	−7·9	
20·4		67·1
	−8·0	
20·9		68·8
	−8·1	
21·4		70·5

Ht. of Eye	Corrⁿ
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.

Table 1. THE DIP TABLE (RIGHT-HAND COLUMNS)

The 'Answer' is what is called the Apparent Altitude or AA - it is still not the angle formed at your position, between the horizon and a line to/from the celestial body. Although it APPEARS to be the required angle, there are still two other factors to be taken into account - so until they have been allowed for, this angle is the APPARENT ANGLE or APPARENT ALTITUDE.

If the sextant angle to a star was seen on the sextant to be 51° 21.9' when the Index Error was 4.6' 'ON' the scale and the height of eye was 5 metres, what would the AA be?

SA (or Hs)	51°21.9'	
IE (for Index Error)	- 4.6'	(-, 'ON')
DIP (-)	- 3.9'	
AA	= 51°13.4'	

NOTE: Index Error can be + or -, depending on whether the error is on or off the scale, but DIP is always negative.

This AA is still not the real or TRUE ANGLE or TRUE ALTITUDE (TA) we require. Of the other two factors to be taken into account, the first is the result of the refraction of light rays passing through the atmosphere giving the impression that the star is where you see it while it is in fact closer to the horizon.

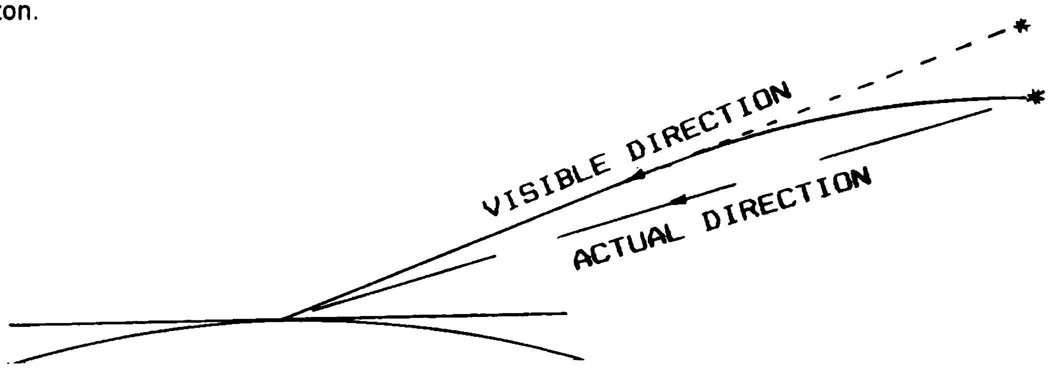


Fig. 13. HOW REFRACTION AFFECTS THE TRUE ALTITUDE (TA)

The other is called 'semi-diameter'. Semi-diameter (SD) is the allowance made for the fact that when taking a sextant sight (angle) of the sun or moon which are large when compared to a star or planet, we sight up the bottom arc of the sun or moon (known as a Lower Limb - LL -sight) or the top arc (an Upper Limb - UL -sight) with the horizon. Viewed through a sextant it looks like this:

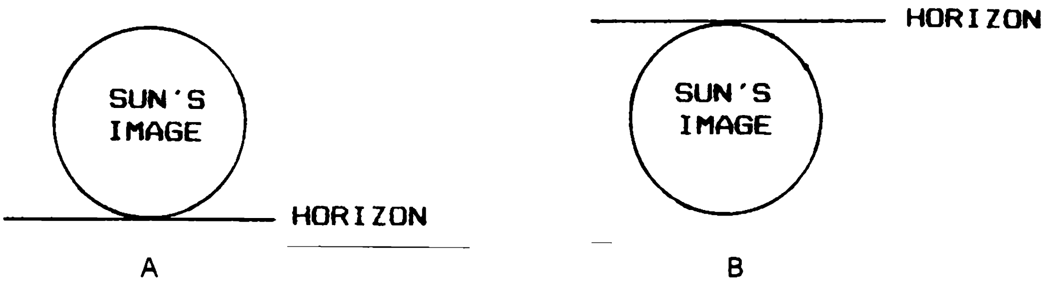


Fig. 14. A. LOWER LIMB SIGHT. B. UPPER LIMB SIGHT.

....but the Almanac tables are based on data relevant to the centre of celestial bodies. The corrections for refraction and SD are combined in the Almanac tables, so there is only one number to add to or subtract from the AA to get TA - the TRUE ALTITUDE or True Angular HEIGHT actually applicable at the time of the sight or OBSERVATION of the celestial body, therefore TA is also sometimes called the 'Ho' (of the body).

Look back at the table on page 7, Table 1, left third for the SUN - and we see it is in two 6-months sections, October to March (inclusive) and April to September. So if it was July when we took our sight we would use the right-hand half of the SUN section. If in July the AA was 51°13.4', we look down the right half under the columns headed 'App Alt', 'Lower Limb', and 'Upper Limb' and see....

App Alt	Lower Limb	Upper Limb
...		
48°55'		
	+15.2'	-16.6'
52°44'		
...		

Since our AA (51°13.4') is between 48°55' and 52°44', if our sextant sight was a LL (Lower limb) sight, the TA or Ho would be

AA	51°13.4'
Correction	+ 15.2'
TA or Ho	51°28.6'

The 'correction' is often referred to as the 'main correction'. Remember it makes allowance for refraction and semi-diameter.

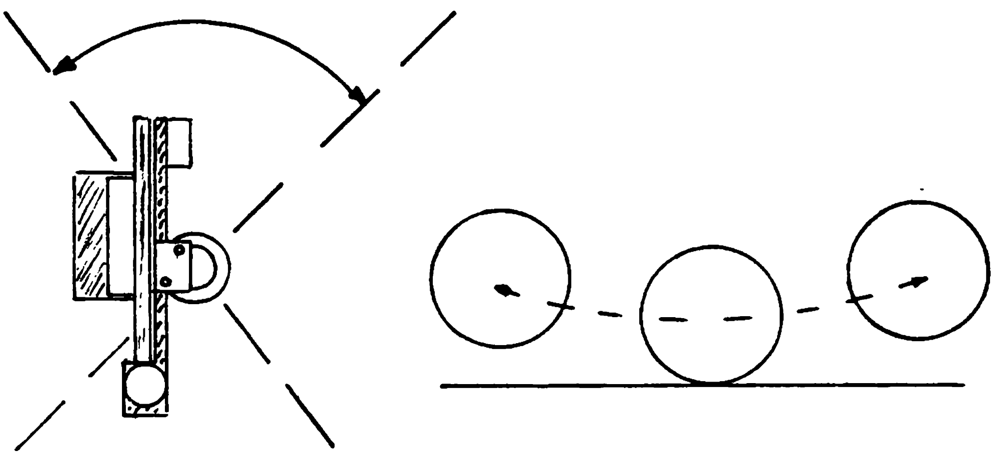
It is the TA or Ho that we need when we take a sight.

The centre section of the table 'Altitude Correction Tables' (page 7) is for use with stars and planets - both are small dots on the horizon so there is no Upper or Lower Limb involved, and there is no 'semi-diameter' - the correction is for refraction only. For planets we use the correction applied to the stars AND, if applicable, the correction for the applicable planet for any/the months/dates shown. The moon, being closer, has its own correction tables.

Every sight taken in astro-navigation starts with the steps we have just covered - converting the sextant angle, SA or Hs, via the AA to get the TA or Ho.

Before we end the subject of the sextant we need to cover 'tips' for its practical use and care at sea. So:

1. A sextant is an expensive, delicate and accurate measuring instrument - treat it with care and respect, keeping it in its box when it is not needed. Store the box in as dry a place as possible and where it cannot get knocked about, or have heavy things dropped or placed on top of it.
2. Keep the sextant in the box until you are in the cockpit. You do not want to stumble or fall with it in your hands while on your way out of the saloon.
3. As soon as you remove it from the box, place the lanyard around your neck (if your sextant does not have a lanyard, fit one immediately - a strong, thin, nylon string cord one metre in length tied as a loop around the handle such that the loop length is just less than half a metre). If you then stumble and have to grab on to the yacht as it lurches, the sextant will not fall and it is very unlikely that it will get damaged.
4. When handling the sextant, do not apply any pressure or force(s) to any part of it. To reduce the risk of applying unintentional force, keep it held in the right hand, using the handle at all times except when necessary to hold it otherwise, for example, when calibrating/adjusting for index error, etc.
5. When using a plastic sextant, take your left hand off the drum after rotating it for fine adjustment, take your left hand off the drum so that no twisting force is applied to the frame giving incorrect readings.
6. Check index error often but only adjust to reduce this error when it is greater than 4.0'.
7. Avoid taking sights of celestial bodies which are less than 10° above the horizon - the refraction is too great.
8. Before taking a sight of the sun, ensure all the sunlight filters are in position to protect your eye. Once you have the sun sighted, if it or the horizon is too dark, remove one filter at a time to get the best image. Some filters are of different colours so you can adjust to get the most suitable for your eye.
9. When taking a sight of a celestial body, ensure the sextant frame is in a vertical plane. If it is not, a false reading will result. To check the frame is vertical, 'rock' the sextant from side to side and you will see the celestial body appear to move in an arc like a hanging pendulum. When it is at the bottom of the swing, the sextant is vertical. See Figure 15 on page 10.



A B

Fig. 15. A. ROCKING THE SEXTANT B. THE PENDULUM IMAGE

10. The exact Universal Time (UT), or Universal Time Co-ordinated (UTC), i.e. the new name for Greenwich Mean Time, GMT, must be used or a time which one can convert to UT/GMT. For sights taken in an easterly or westerly direction, every 4-second error in timing represents an error of one nautical mile in the resulting line of position obtained.

11. In rough weather or with a big swell running, try to take sights from the top of swells as a more accurate view of the horizon is possible - sometimes it can not be seen at all!

12. Take several sights in fairly quick succession noting the exact time of each sight. You will later be able to average the readings, discarding any that do not fit the pattern of the majority. The average obtained will lead to the most accurate final result. (How to average these readings will be discussed in detail when we examine sun sights).

13. When taking a sight, get someone to take the time for you if possible. When you have the sextant angle right, call out 'mark' (or anything to signify the exact moment) - your assistant can then note the time accurately. If you are on your own, at the exact moment the sextant angle is right, start counting at the rate of one per second - it may take practice. As soon as you can, look at your clock or watch and when the second hand gets to a convenient multiple of 5 seconds, note that time and subtract the number of seconds you counted to.

14. Do not take it for granted that the person noting the time for you will always get it right - it is easy and it often happens that the time is wrongly recorded, so check. It is just as easy and frequent for the sextant-user to read the angle from the sextant wrongly! Check your own reading again!

15. Star and planet sights are best taken during twilight. Moon sights, other than those taken during the day when the moon is visible, are also best taken at twilight. If they are taken during the hours of darkness with a full moon, the horizon is difficult to distinguish through the eyepiece and false readings are often obtained.

16. The moon and the planets Venus and Jupiter are sometimes visible during the day (I am told, although I have never seen the planets by day!). Sights taken on the sun and one or more of these bodies within a few minutes of each other enable one to get a position fix within minutes.

17. At evening twilight the eastern horizon disappears first and in the morning the stars and planets over the eastern horizon will disappear first - this affects the choice of sequence of taking sights. At sunset and sunrise, take the eastern star/planet sights first.

18. As soon as you have finished using the sextant, clean it and put it back in its box and the box back in its proper stowage place. To clean a sextant, wipe it over with a soft dry or just off-dry cloth. If the cloth is damp, it should be because of fresh water, not sea water. Remove any sea spray that may have splashed on to the sextant. A wipe with a light oil on a cloth will help to keep it in good condition . Do not do this for plastic sextants.

19. Periodically check that no screws, bolts or nuts are coming loose. If any are, tighten them so that they are just tight - be careful not to over-tighten them.

20. Keep the sextant box clean and dry!

DO NOT LET UNSUPERVISED CHILDREN OR NOVICES PLAY OR FIDDLE WITH A SEXTANT.

THE NOON OR MERIDIAN PASSAGE SIGHT

EXPLANATION OF THE LOGIC

NOON

Noon, where the observer is, is when the sun is directly north or south of the observer. At that moment the sun and the observer are on the same meridian. Also at that moment, as the sun passes over the observer's meridian (the Meridian Passage or MP of the sun), the vertical angle the sun makes at the observer, between the horizon and a line from the observer to the sun, is at its maximum* on that day.

LONGITUDE

We know that the earth rotates 360° on its axis once every 24 hours. If we know the exact time meridian passage occurs over the Greenwich Meridian (0° Longitude), and if we can establish the exact time meridian passage occurs where the observer is, the time difference between the two meridian passages enables us to determine longitude. For example, if the observer's (the local) meridian passage, called the LMP, is 3 hours before Greenwich Meridian Passage, called GMP, the observer's longitude will be 3/24 ths of 360°. This is 45° and since the earth rotates from west to east, and as LMP occurs BEFORE GMP, the observer is east of Greenwich. So the longitude is 45° 00.0' East.

LATITUDE

To understand the latitude calculation, one must know the meanings of a few terms used.

1. **True Altitude (TA or Ho)** - this was covered in Chapter 1. It is the sextant angle after corrections. It is also called the angular height of the sun at the moment of the observation - the height at the time of observation using the sextant, or Ho.
2. **Zenith Distance (ZD)** - this is the difference between TA/Ho and 90°.

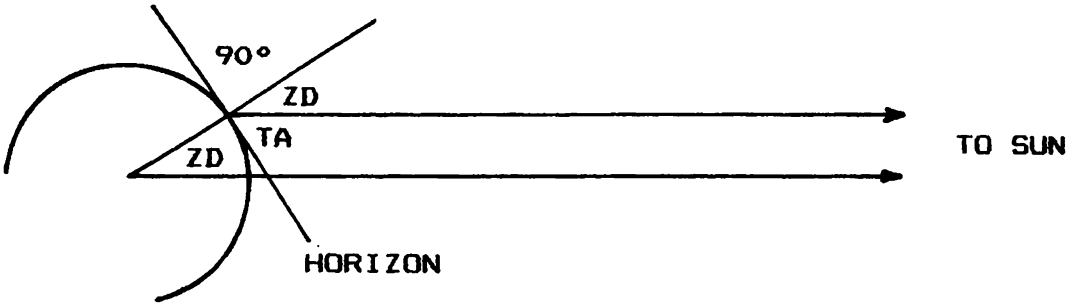


Fig. 16. TRUE ALTITUDE AND ZENITH DISTANCE

3. **Declination of the sun (Dec)** - this is the angle between the plane of the equator and a line from the centre of the earth to the centre of the sun.

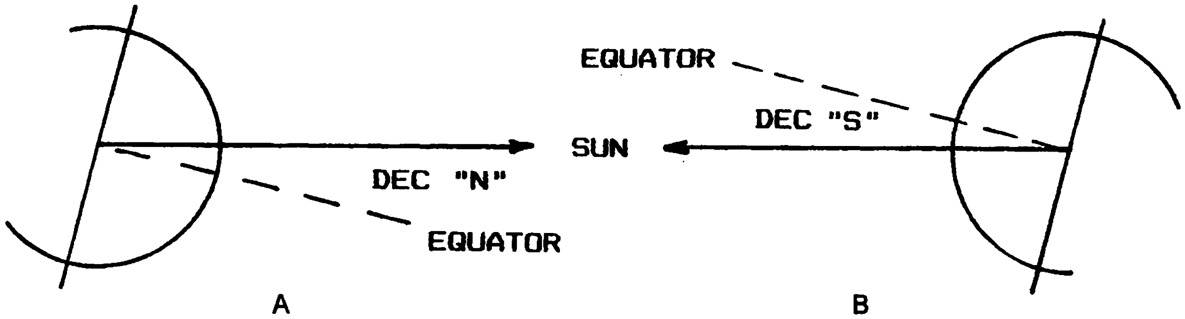


Fig. 17. DECLINATION: A.'NORTH' (SUMMER NORTHERN HEMISPHERE

B. 'SOUTH' (SUMMER IN SOUTHERN HEMISPHERE

At LMP we measure the SA/Hs (sextant angle) and convert it to the equivalent TA/Ho (true altitude). We subtract the TA/Ho from 90° to get the ZD (zenith distance). Knowing the EXACT time of the sight at LMP we look in the Almanac on the page for the day and find the Dec (Declination) for the hour, and the additional part, the INCREMENT, for the minutes, we get from the 'yellow pages' to arrive at the total Dec. Now it is simple geometry as there are six possible permutations:

*Not exactly true, but see the bottom of page 25 and page 26.

i. Dec 'North'; DR latitude 'North' and north of Dec.

Lat = Dec + ZD

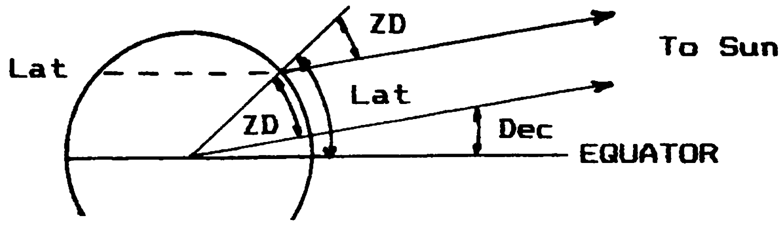


Fig. 18.

ii. Dec 'North', DR latitude 'North' but south of Dec.

Lat = Dec - ZD

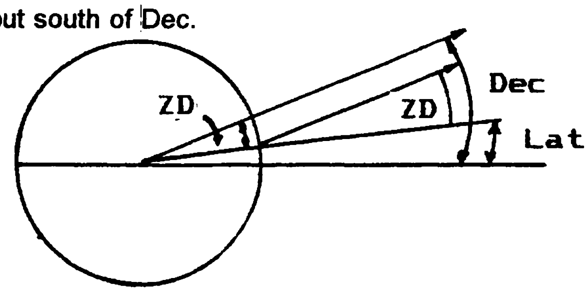


Fig. 19.

iii. Dec 'North', DR latitude 'South'.

Lat = ZD - Dec

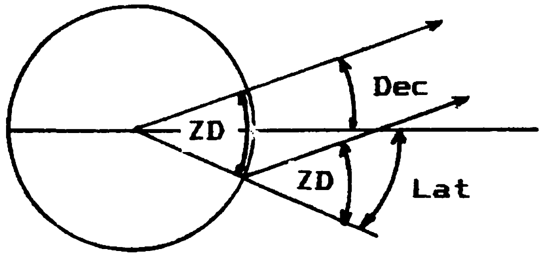


Fig. 20.

iv. Dec 'South', DR latitude 'North'.

Lat = ZD - Dec

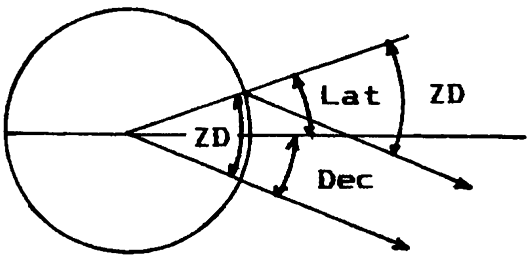


Fig. 21.

v. Dec 'South', DR latitude 'South' but north of Dec.

Lat = Dec - ZD

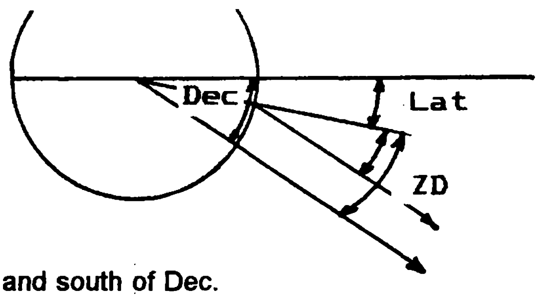


Fig. 22.

vi. Dec 'South', DR latitude 'South' and south of Dec.

Lat = Dec + ZD

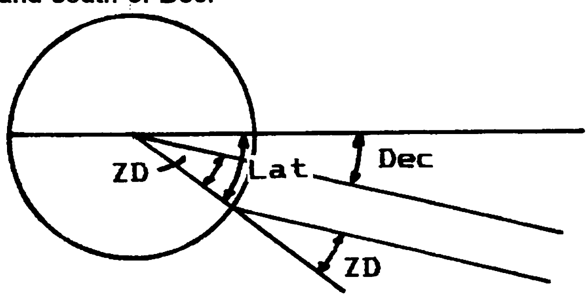


Fig. 23.

As long as we can determine the exact time and sextant angle applicable at LMP, with the aid of an Almanac we can find our latitude and longitude daily as at the time of LMP, or MP.
Now let's examine the detail of how to do it.

WARNING: The Longitude obtained by this method can be unreliable - the reason will be explained later. (See the bottom of page 25 and page 26.)

LONGITUDE

As the sun rises during the morning and sets in the afternoon (it rises up until noon then sets after noon), it follows a smooth arc or curved path through the sky. At or in the vicinity of the top of this arc, the angle as we would measure it with a sextant, changes very slowly as noon approaches, then appears to remain constant for a minute or so around noon, then very slowly it begins to decrease. So the exact second of time applicable to LMP is not discernible. However, during the middle of the morning and afternoon the sun is seen to be rising or setting rapidly - an exact sextant angle can be related to an exact second in time.

We therefore take a sextant sight of the sun during the morning, noting the exact angle and time. Near noon we watch the sun's sextant angle very closely to get the apparent maximum angle although the exact time to the second is not discernable. As the sun angle decreases after noon, we watch, having re-set the sextant to the angle applicable at the time of the first sight taken in the morning. When the sun gets down to that angle we note the exact time. Since the path taken by the sun is the arc of a circle, and the sextant angles in the morning and in the afternoon were the same, the mid-way time between these two sights will be the exact time of LMP.
Let's look at it in diagrammatic form:

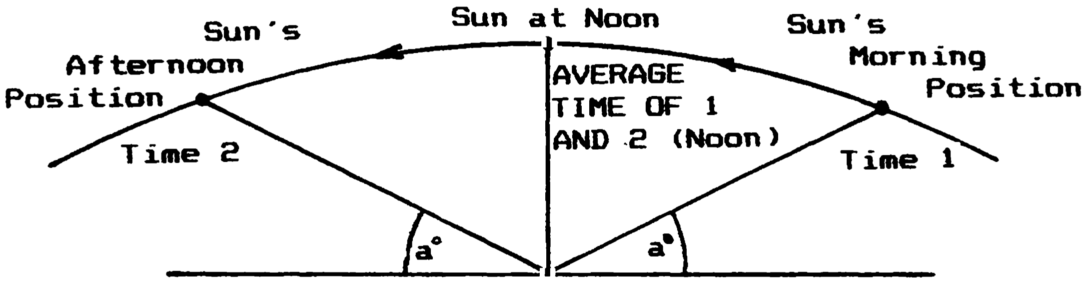


Fig. 24. SIGHTS TAKEN FOR LONGITUDE AT NOON / MP.

We could take two separate readings in the morning at an interval of, say, an hour, and then we would have two sextant angles to use to take times for in the afternoon. The two pairs, each pair being of the same angle but at different times, can be used independently to determine the mid-time - the time of noon, which is also the average of the two times using the same angles. In chronological sequence they would be Sight 1 (angle 1), Sight 2 (angle 2), Sight 3 at MP (angle 3), Sight 4 (angle 2) and Sight 5 (angle 1). Note that sights 1 and 5, and sights 2 and 4 have the same sextant angles. Let's look at it diagrammatically:

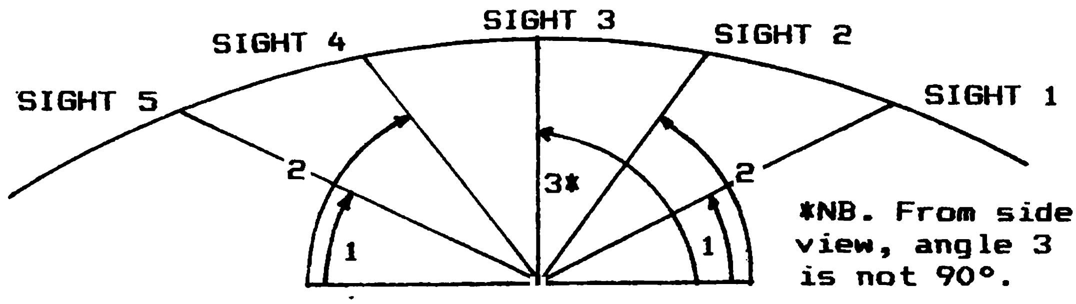


Fig. 25. PAIRED SIGHTS TAKEN FOR LONGITUDE AT NOON

Why, you may ask, do we need to take two sets of sights before and after noon? REMEMBER THE WARNING EARLIER? We take two (or more!) sets of sights each side of noon because we can then take the average time of MP obtained from each matching set of times and same sextant angle readings. Each MP will not be the same. This is because of the difficulty in seeing the horizon, and seeing it clearly, just as the afternoon sun's angle gets to the preset angle of the sextant - it is difficult to assess the correct moment and errors in timing can easily occur. For every 4 seconds of time error in resulting MP, the longitude error increases by one nautical mile. See also the bottom of page 25.

So the clock, watch, chronometer or whatever we use to measure time with, needs to be accurate, or its error needs to be known exactly and this error taken into account when determining the time of a sight. Some navigators like to keep their watches set to local time, then adjust for the difference with UT (UTC/GMT) as all detail in the Almanac is based on Universal Time. I recommend that the navigator's timing device (his watch?) is kept set to UTC (GMT). Most modern wrist watches are quite accurate enough as long as the user knows the error and its rate of change (does it gain or lose time and if so, by how much per day/week). These watches often have the advantage that they can, at the push of a button, show a second time so they can be set for UT and local time.

EXAMPLE 1. Let us now do an example of determining MP. We will assume five sights were taken during the day (28 February 199x), two before noon, one at MP when it was not possible to note the exact time of MP, and two after MP using the same angles in our sextant as were used in the morning sights. Let's also assume that our timepiece, set to UTC, was known to be 9 seconds fast. If our clock is fast, it is ahead of the true time, so we need to deduct the 'fast' error from the time seen on the watch to get the correct time. Our sight detail is as follows:

Sight Number	Sextant Angle	Watch/clock time	Corrected time
1	46° 26.7'	07h31m48s	07h31m39s
2	52° 03.2'	08h46m51s	08h46m42s
3, LMP i.e. max SA	53° 12.8'	Not discernable-LMP	LMP ? (To be found)
4	Same as #2	10h13m25s	10h13m16s
5	Same as #1	11h29m08s	11h28m59s

Since longitude is concerned only with 'time', the sextant angles have no significance until we get on to latitude. We find the mid-way time between sights 1 and 5 as they had a common sextant angle. This is also the average of the two times:

07h31m39s
+ 11h28m59s
= 19h00m38s

Divide by 2 to average = 09h30m19s which is the MP time obtained from sights 1 and 5.

We do the same for sights 2 and 4 and see that the MP time is not exactly the same:

08h46m42s
+ 10h13m16s
= 18h59m58s

Divide by 2 to average = 09h29m59s - the time of MP obtained from sights 2 and 4.

We now take the two times obtained for MP and find the average which is used for the MP in the rest of the calculations. Note that there is 20 seconds between them which equates to 5 nautical miles - which one in fact was closer to the correct time for noon will never be known! If we had used three, four or more pairs of times having common sextant angles, we would have obtained more versions of MP time, so giving a more reliable average. Our average of the above two times for MP is:

09h30m19s
+ 09h29m59s
= 19h00m18s

Divide by 2 for LMP = 09h30m09s

This is the time we set out to find - noon/MP where we are. Its accuracy may be slightly improved if we apply the 'LMP Adjustment' - usually ignored by yachtsmen - see the bottom of page 25 and page 26. The next step is to compare this time with that at which GMP occurs - when the sun passes over the

Greenwich meridian. One tends to think that noon at Greenwich is at 12h00m00s UTC (GMT) every day. This is not in fact the case as it can be over 16 minutes earlier or over 14 minutes later! It changes during the year and the Almanac will tell us on any given day the exact time of GMP, to the second. On the page in the Almanac for the date concerned, at the bottom right-hand corner of the right-hand facing page, we see a section headed 'Equation of Time'. The section for 28 February in our Almanac is as shown in Table 2. (Copies of the relevant Almanac pages can be found in Part 2 of this course.)

Day	SUN Eqn. of Time 00 h	12 h	Mer. Pass.	MOON Mer. Pass. Upper	Lower	Age	Phase
	m s	m s	h m	h m	h m	d	
27	12 51	12 46	12 13	00 56	13 23	17	
28	12 40	12 35	12 13	01 50	14 17	18	◑
1	12 29	12 23	12 12	02 45	15 13	19	

Table 2. THE 'EQUATION OF TIME' AS IT APPEARS IN THE ALMANAC

Each pair of facing pages in the Almanac, with daily values (from 1 January to 31 December), has the data for three days - we see the days on our page(s) are 27 and 28 February and 1 March - as seen at the top of the page in the Almanac, although we are only looking at the Equation of Time section. Under the left half headed 'SUN' we see three columns, the left one being '00h' (midnight) which we do not use, the centre one being '12h' and the right hand one being 'Mer Pass.' Under the '12h' column, opposite the 28 for 28 th February, we see:

m s
12 35

This tells us that GMP differs from 12h00 UTC by 12 minutes and 35 seconds on 28 February. But is it earlier or later? We now look at the 'Mer Pass.' column and see:

h m
12 13

GMP is therefore 13 minutes *to the nearest minute*, **after** 12h00 UTC. The exact amount after 12h00 UTC is 12m35s so GMP on the 28 th February is at 12h12m35s UTC.

From our earlier (fictitious) determination of LMP being at 09h30m09s (assume it was on 28 February), the difference (always subtract the smaller from the larger) between LMP and GMP is:

GMP 12h12m35s
LMP -09h30m09s ('-' to get difference)
Difference = 2h42m26s

Now since the earth rotates 360° in 24 hours, it will rotate:

180° in 12 hours and
90° in 6 hours,
15° in 1 hour,
1° in 4 minutes,
1' in 4 seconds and
0,25' in 1 second.

So 2 hours 42 minutes and 26 seconds elapses as the earth rotates through an arc of:

2 hours = 30°
40 mins = 10°, and
2 minutes and 26 secs = 0°36,50'
Total arc = 40°36,5'

LMP occurred before GMP therefore we must be East of Greenwich.

Our longitude was therefore 40°36,5' East

An easier way to convert the time difference to an angle would be to look up the 'Arc to Time Conversion Table' in the Almanac, the first of the yellow pages near the back of the book (see page 17 which forms part of our Almanac Extracts; the others are in the Almanac section of Part 2).

We see that, from the left, there are six columns each for 60° and each is sub-divided into two columns, the left half for degrees and the right for hours and minutes. Next to 1° we see '0h04m' (4 minutes), next to 2°, '8 minutes', and so on. The right-hand third of the page has five vertical columns, the left being minutes (of angle/arc, not time) from 0' to 59'. The next four columns are for quarters of minutes (of arc), and each is headed by 'm s' for minutes and seconds.

Our LMP left us with a difference, relative to GMP, of 2 hours 42 minutes 26 seconds. To use this table to convert this time to an angle - we look for the time '2h42m' or the nearest lesser number being 2h40m, and next to it we see the angle '40°'. In the right hand section we look for the remainder of the total time, i.e. '2m26s', and see it appears opposite 36' and under 0'.50. So we are able to convert the time, 2h42m26s to the angle 40° 36.5'. Notice that in the left section the degrees and 'h m' increase as we go down the page by 4 minutes each line. If our time had been 2h45m07s, we look for the nearest value of time (2h44m) being just LESS than the actual time (2h45m - of our noon/MP) and we see 41°. We are then left with a balance of 1m07s. So in the right hand section of the page we look for '1m07s' and see it is opposite 16' and under 0'.75. The angle, which would be our Longitude, would then be 41° 16.75'.

If the time of LMP was later than that for GMP, we would be west of Greenwich and the amount would be found by using the 'Conversion of Arc to Time' table (see next page) just as we have done in the example above.

LATITUDE

Look back at Figures 18 to 23 on page 12. You will be reminded that there are six possible permutations depending on whether the Dec (Declination) is north or south, whether the DR latitude is north or south, and if 'DR Lat' and Dec are both north or south, whether DR Lat is less or greater than Dec.

TA/Ho

We will stay with the example we used earlier when five sight readings were taken on 28 February 199x. We determined that LMP was at 09h30m09s UTC (GMT) and at that time the (maximum) sextant angle was 53°12,8'. Let's assume that the height of eye at the time we took the LOWER LIMB sight was 4 metres and the IE (index error) was 2,7' OFF the scale. We must change this SA (Hs) -the sextant angle- to the TA (Ho) -the True Angle or True Altitude. See Chapter 1 if you need a reminder on how we do this. Here it is:

SA (or Hs)	53° 12.8'	
IE (+ for OFF)	+ 2.7'	
DIP (always -)	- 3.5'	(see DIP table)
AA	= 53° 12.0'	
Correction	+ 15.5'	(LL sight)
TA (or Ho)	= 53°27.5'	

ZD

In all of the six permutations, we need to know ZD (zenith distance) and Dec (declination). ZD is 90° minus TA. See Figure 16 on page 11. So our ZD is:

90° 00,0'
- 53° 27,5'
ZD = 36° 32,5'

Declination

Now we need Dec. (Declination). Using the time of 09h30m09s UTC which is our time for LMP on 28 February, we look up the daily pages in the Almanac for that day and see the pages cover three days, the top third of the pages (left and right) being for the 27 th, and the centre section for the 28 February. On the right hand page, left side, we find the detail for the sun.

Continued on page 18.

CONVERSION OF ARC TO TIME

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

Table 3. CONVERSION OF ARC TO TIME (AND VICE VERSA) TABLE

UT (GMT)		SUN		MOON				
	d h	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	v ′	Dec. ° ′	d ′	H.P. ′
	28 00	176 50.0	S 8 08.0	333 29.9	8.3	S 6 01.6	12.9	60.6
	01	191 50.1	07.0	347 57.2	8.4	6 14.5	12.8	60.6
	02	206 50.2	06.1	2 24.6	8.3	6 27.3	12.8	60.6
	03	221 50.3	. . 05.1	16 51.9	8.3	6 40.1	12.7	60.6
	04	236 50.4	04.2	31 19.2	8.2	6 52.8	12.7	60.6
	05	251 50.5	03.3	45 46.4	8.3	7 05.5	12.7	60.6
	06	266 50.6	S 8 02.3	60 13.7	8.2	S 7 18.2	12.6	60.6
	07	281 50.8	01.4	74 40.9	8.2	7 30.8	12.5	60.6
	08	296 50.9	8 00.4	89 08.1	8.1	7 43.3	12.5	60.6
M	09	311 51.0	7 59.5	103 35.2	8.2	7 55.8	12.5	60.6
O	10	326 51.1	58.5	118 02.4	8.1	8 08.3	12.4	60.6
N	11	341 51.2	57.6	132 29.5	8.0	8 20.7	12.3	60.6
D	12	356 51.3	S 7 56.6	146 56.5	8.1	S 8 33.0	12.3	60.6
A		11 ' 5	55.7	161 23.6	8.0	8 45.3	12.2	60.6
Y								

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 27	Moonrise 28	Moonrise 1	Moonrise 2
°	h m	h m	h m	h m	h m	h m	h m
N 72	05 16	06 34	07 43	20 48	23 02	25 31	01 31
S 50	04 14	04 55	05 29	19 13	19 41	20 13	20 50
52	04 07	04 50	05 25	19 11	19 38	20 08	20 43
54	03 59	04 45	05 22	19 09	19 33	20 01	20 35
56	03 49	04 39	05 18	19 07	19 29	19 55	20 26
58	03 38	04 32	05 14	19 05	19 24	19 47	20 16
S 60	03 26	04 24	05 09	19 02	19 18	19 38	20 04
Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 27	Moonset 28	Moonset 1	Moonset 2
°	h m	h m	h m	h m	h m	h m	h m
N 72	16 44	17 54	19 12	06 39	06 24	06 05	05 34
N 70	16 54	17 56	19 07	06 42	06 34	06 26	06 14
68	17 02	17 59	19 03	06 45	06 43	06 42	06 42

Table 4. THE CENTRE (28 FEBRUARY) OF THE RIGHT HAND DAILY PAGE OF THE ALMANAC

We are concerned with the sun, so we look at the right-hand facing page, left columns under 'SUN'. We see it has two columns, one headed 'GHA' and the other 'Dec'. Notice that under the Dec column we have the 'degrees' symbol and that for 'minutes'. Under the former, the actual number of degrees is only printed on every sixth line whereas there is a value for minutes on every line. This is done for the sake of clarity and you must use the whole number of degrees appearing nearest above the line of interest. So the Dec for '09h' (UTC) is:

South 7°59,5'

Look now at what the minutes value is on the next line down (for one hour later). We see it is 58,5' which is less than the 59,5' at 09h. In other words Dec is in the process of DECREASING. As our time for LMP had minutes and seconds as well, we need to find out how much to change the 'on the hour' value of Dec to get the Dec applicable at the time of our sight. This extra amount, called the INCREMENT, will have to be SUBTRACTED because each hour Dec is seen to be DECREASING. To find the Increment value, we look to the bottom of the page, below the 'Dec' column, and we see:

21	131 55.3	. . 25.3	263 32.9	[illegible]	[illegible]
22	146 55.5	24.4	277 58[illegible]	[illegible]	[illegible]
23	161 55.6	23.4	29[illegible]	7.0	14 58.5
	S.D. 16.2	d 0.9	S.D.	16.5	16.5

Table 5. THE 'd' FACTOR FOR INCREMENTS OF DEC

This 'd' factor, 0,9 is used on the 'Increments and Corrections' page (see examples in the yellow pages in your Almanac or the copied pages in Part 2) applicable to the number of minutes of time of our time for LMP. In our example it is 30 minutes. The Almanac page looks like this:

30ᵐ INCREMENTS AND CORRECTIONS **31ᵐ**

30	SUN PLANETS	ARIES	MOON	v or d	Corr	v or d	Corr	v or d	Corr
s	° ′	° ′	° ′	′	′	′	′	′	′
00	7 30·0	7 31·2	7 09·5	0·0	0·0	6·0	3·1	12·0	6·1
01	7 30·3	7 31·5	7 09·7	0·1	0·1	6·1	3·1	12·1	6·2
02	7 30·5	7 31·7	7 10·0	0·2	0·1	6·2	3·2	12·2	6·2
03	7 30·8	7 32·0	7 10·2	0·3	0·2	6·3	3·2	12·3	6·3
04	7 31·0	7 32·2	7 10·5	0·4	0·2	6·4	3·3	12·4	6·3
05	7 31·3	7 32·5	7 10·7	0·5	0·3	6·5	3·3	12·5	6·4
06	7 31·5	7 32·7	7 10·9	0·6	0·3	6·6	3·4	12·6	6·4
07	7 31·8	7 33·0	7 11·2	0·7	0·4	6·7	3·4	12·7	6·5
08	7 32·0	7 33·2	7 11·4	0·8	0·4	6·8	3·5	12·8	6·5
09	7 32·3	7 33·5	7 11·6	0·9	0·5	6·9	3·5	12·9	6·6

31	SUN PLANETS	ARIES	MOON	v or d	Corr	v or d	Corr	v or d	Corr
s	° ′	° ′	° ′	′	′	′	′	′	′
00	7 45·0	7 46·3	7 23·8	0·0	0·0	6·0	3·2	12·0	6·3
01	7 45·3	7 46·5	7 24·1	0·1	0·1	6·1	3·2	12·1	6·4
02	7 45·5	7 46·8	7 24·3	0·2	0·1	6·2	3·3	12·2	6·4
03	7 45·8	7 47·0	7 24·5	0·3	0·2	6·3	3·3	12·3	6·5
04	7 46·0	7 47·3	7 24·8	0·4	0·2	6·4	3·4	12·4	6·5
05	7 46·3	7 47·5	7 25·0	0·5	0·3	6·5	3·4	12·5	6·6
06	7 46·5	7 47·8	7 25·2	0·6	0·3	6·6	3·5	12·6	6·6
07	7 46·8	7 48·0	7 25·5	0·7	0·4	6·7	3·5	12·7	6·7
08	7 47·0	7 48·3	7 25·7	0·8	0·4	6·8	3·6	12·8	6·7
09	7 47·3	7 48·5	7 26·0	0·9	0·5	6·9	3·6	12·9	6·8

Table 6. TOP SECTION OF THE 'INCREMENTS AND CORRECTIONS' PAGE FOR 30 MINUTES

Using the left half of the page which applies to '30m' (30 mins), under the three columns each headed

	v or d Corrn	

look under the 'v or d' side of the column to find the factor, '0,9'. Next to this 0,9 and under 'Corrn' we see the correction, or 'Increment' which is 0,5'. To get the complete Dec we need, we must now take the hour value of Dec and subtract the Increment ('subtract' because Dec is decreasing every hour according to our Almanac, and therefore continuously decreasing).

Dec (hour value)	S 7°59,5'
Increment	- 0,5'
TOTAL DEC AT LMP	S 7°59,0'

Note that no account is taken of the seconds part of the LMP time. This is because Dec is changing very slowly; if we were to calculate the increment for the seconds it would be so small as to form a value several decimal places of a minute (of angle of Dec). In half an hour the increment was only 0,5'

The Latitude

Having found the values for Dec and ZD we can now find 'Lat'. If we were in the Northern Hemisphere (see Figures 18 to 20 on page 12):

Lat = ZD - Dec
= 36°32,5' - 7°59,0'
= 28°33,5'

So our **LATITUDE is 28°33,5' North**

If we were in the Southern Hemisphere (see Figures 21 to 23 on page 12):

Lat = ZD + Dec
= 36°32,5' + 7°59,0'
= 44°31,5' S

(If we chose the wrong permutation we would end up with a number for Lat which is very far from the DR, or is greater than 90°, or is a minus quantity - all would be obviously wrong. The only time you may have difficulty will be near the equator when you are not sure whether you are on the north or south side of it. Don't worry because only one of the possible permutations will give a logical answer!).

WORK SHEETS

Now for the good news! It is time to introduce you to the concept of 'work sheets' which are also, and probably more frequently, called 'idiot sheets'! A work sheet is a printed form on which the step-by-step process of doing a celestial navigation calculation is laid out. An example of the work sheet for the Noon or Meridian Passage sight calculation is shown on page 21. (On page 21.a. is another Work Sheet which can be used if 'LMP Adjustment' - pages 25/26 - is to be used for greater accuracy.) Here are some explanations about the work sheet:

Top Box, General Information:

Line 1. Writing the date avoids errors later, when looking up the Almanac data. It also serves as a reference later. Log, Course and Speed will facilitate DR Navigation from the fix, as well as possibly be relevant to plotting if the results are used with an earlier or later sight.

Line 2. Contains details that will be needed at the calculation stage.

Line 3. Reminds us that clock error must be known accurately for the calculation.

Second Box, 'ESTIMATING TIME OF LMP':

Line 4. Tells us to covert the DR Longitude to a time (Arc to Time table - first of the Yellow Pages in an Almanac).

Line 5. This time is subtracted from 12h00 if DR Longitude is East, and added if west: this is done preparatory to finding out the estimated time of LMP which in turn gives us an idea when to go out on deck to take the first sight (we try for a couple of hours or so before local noon).

Line 6. The Equation of Time (the difference of noon at Greenwich to 12h00m00s UTC) to facilitate a more accurate estimate of LMP. This we find in the bottom right hand corner of the two facing pages in the Almanac for the current date. Look in the section labelled 'SUN', and under the column headed 'Mer Pass.' to get the number of minutes noon at Greenwich will be before or after 12h00. If the time stated is 12h07, the equation of time is plus 7 minutes (ignoring seconds as we are only calculating an estimate for LMP). If the time stated is 11h56, the equation of time is minus 4 minutes. The result is the Estimated LMP's time. We can now decide what time to go on deck for the first sight.

Third Box, 'LMP';

1. Write in the sextant angles recorded; angles 4 and 5 MUST be exactly the same as 2 and 1 respectively; if not, their times cannot be used.
2. In the column next to the Sextant Angle column, headed Clock Time of Sight, insert the exact clock times for each (except the time of the maximum angle - when time was not accurately discernable).

Fourth Box (three columns);

In this box we can add times 1 and 5, and get their average, as well as the average for 2 and 4. We can also average these two averages for a more accurate result, then apply the clock error to get the time of your noon or LMP. See "NB" below for 'LMP Adjustment (Page 21.a.).

Since we have been dealing with 'time', it is logical to stay with time to find Longitude before we work with angles to find Latitude.

Fifth Box, (Work Sheet 1, page 21) 'LONGITUDE':

See Line 6 above. Next to 'Mer Pass.' is the column headed '12h' which gives us the exact number of minutes and seconds for the equation of time. (We already know whether it is plus or minus.) With our newly determined time of LMP and that of GMP, the difference can be ascertained for converting to an angle (Arc to Time table) which will be our Longitude. If our LMP was before GMP, we must be East of the Greenwich meridian - Longitude is East.

Sixth Box, 'LATITUDE':

Now we determine Declination (as described on pages 16 to 19), Ho and ZD (page 19), and we are reminded of the six possible permutations of Lat = +/-ZD, +/-Dec as a guide as to which one to use. We must select according to the circumstances we are in. And the result is Latitude

NB: On page 21.a., Work Sheet 1.a., there is another box which allows for a correction to the time of LMP due to any change in the Dec or change in the observer's Lat between the time of sight 1 and sight 5. Most yachtsmen leave this step out as the actual correction is usually so small.

Now we have both the Latitude and the Longitude as at LMP - we can plot the position on our chart, remembering to note, next to the position on the chart, the date, time, and log at the time the fix was taken.

Look at the unused Work Sheets on pages 21 and 21.a. - see how there are blank spaces where you have to fill the detail required, then add or subtract, to get the results needed. See how the Work Sheets have been used on pages 22 and 22.a., (Solution 1), initailly leaving out the 'LMP Adjustment" and secondly including this step. Note the difference in the two answers for LMP and therefore in Longitudes.

Our subsequent examples will use Work Sheet 1, omitting the small 'LMP Adjustment' step.

In this example, Example 1 (pages 14 to 19), we will say that the additional relevant information about the sight was as follows:
DR Lat, 28°25' N, Long 40°30' E; Log 1234,5 Miles; Course 045°M (Variation 21°W); Speed 6,5 Knots.

Make sure you can find, in the Almanac section in Part 2, where all the extracted figures come from. If you have any difficulty, see Example 2 and its Solution 2, (page 24) with notes that follow the solution on page 25.

Then turn back to page 23 for example questions for you to try - the answers are in the 'Solutions' section in Part 2. Compare your workings with the solution supplied.

MERIDIAN PASSAGE OR LOCAL NOON SIGHT WORK SHEET

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: .... Log: .... Course: ....°T/M/C. Speed: ....Knots
D.R. Lat: ......°.......,...' N/S, Long: ....°.......,...' E/W, IE: .....' ON(-)/OFF(+), Ht of eye: ......ft/m
CLOCK ERROR RELATIVE TO UTC/GMT: ...... h ...... m ...... s. FAST/SLOW? (- Fast,+ slow)

ESTIMATING TIME OF LMP Convert DR Long to 'time': = ... h .... m (nearest).
If East, 12h00 - 'time': = ... h ..... m*. If West, 12h00 + 'time': = ... h ..... m*. *Apparent LMP.
Apparent LMP ± Eqn of time (± ...... m [nearest]) = Estimated time of LMP = ...h.......m

LMP	Sight	SA/Hs	Clock Time	
	# 1	° , '	......h......m......s	
	# 2	° , '	......h......m......s	
Max. angle at noon	# 3	° , '	LMP - to be found	Approx?......h.......m,
	# 4	Same as # 2	......h......m......s	and Log:............M
	# 5	Same as # 1	......h......m......s	

Time # 1 ......h......m......s	Time # 2 ......h......m......s	Time (A) ....h.......m.......s
Time # 5 +......h......m......s	Time # 4 +......h......m......s	Time (B) +.......h.......m.......s
Total =......h......m......s	Total =......h......m......s	Total =.......h.......m.......s
Average (A) =......h......m......s	Average (B) =......h......m......s	Average =.......h.......m.......s
		Clock error±.......h.......m.......s
		LMP =.......h.......m.......s

LONGITUDE

Mid-day, 'Noon', at Greenwich assumed to be at..........................	12 h 00 m 00 s	UTC
Eqn of Time, Almanac's date page, bottom right, + if after 12h.......	± ....m......s	
GMP, Greenwich Meridian Passage, Greenwich Noon....................	=.....h.......m......s	(I)
LMP, Local Meridian Passage, Local Noon (from above box)..........	......h.......m......s	(II)
Difference between GMP (I) and LMP (II) (Smaller from larger)......	=.....h.......m......s	

Convert Difference to an angle (Arc to Time); = Longitude ° , ' E/W (E if LMP earlier)

LATITUDE

1. **Declination**:
   Dec Hour (LMP) value... N/S ....° ....,....'
   d Factor = ...(incr +, decr -) Corrn ....,....'
   DECLINATION = N/S ....° ....'

2. **True Altitude (Ho)**:
   S.A. (Hs) ....° ....,....'
   I.E. (- ON, + OFF).........+/- ....,....'
   DIP (-; from eye ht)........- ....,....'
   AA ....= ....°.......,....'
   Main corrn (Almanac card) +/- ....,....'
   T.A. (Ho) ....° ....'

3. **Zenith Distance**:
   Max poss altitude ..90..°.00,.0.'
   True Altitude (Ho) -........°..........'
   ZENITH DISTANCE = ...° ....'

4. **Latitude**:
   Dec ....° ....,....' ZD
   +/- ZD ....° ....' - Dec
   LAT = ° , ' N/S

If 'Dec' "N",
DR Lat "N" of 'Dec' .... Lat = Dec + ZD
DR Lat "N" but "S" of Dec....Lat = Dec - ZD
and DR Lat "S"...Lat = ZD - Dec

If 'Dec' "S",
DR Lat "S" of Dec .... Lat = Dec + ZD
DR Lat "S" but "N" of Dec..Lat = Dec - ZD
DR Lat "N" ....Lat = ZD - Dec

Work Sheet 1. THE MERIDIAN PASSAGE OR NOON SIGHT WORK SHEET.

NOTES

MERIDIAN PASSAGE OR LOCAL NOON SIGHT WORK SHEET

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: .... Log: .... Course: ....°T/M/C. Speed: ....Knots
D.R. Lat: ....°..........' N/S, Long: ....°.........' E/W, IE: .....' ON(-)/OFF(+), Ht of eye: ......ft/m
CLOCK ERROR RELATIVE TO UTC/GMT: ...... h ...... m ...... s. FAST/SLOW? (- Fast,+ slow)

ESTIMATING TIME OF LMP Convert DR Long to 'time': = ... h .... m (nearest).
If East, 12h00 - 'time': = ... h ..... m*. If West, 12h00 + 'time': = ... h ..... m*. *Apparent LMP.
Apparent LMP ± Eqn of time (± ...... m [nearest]) = Estimated time of LMP = ...h.......m

LMP	**Sight**	**SA/Hs**	**Clock Time**	
Details of sights:	**# 1**	° , '	......h......m......s	
	# 2	° , '	......h......m......s	
Max. angle at noon	**# 3**	° , '	LMP - to be found	Approx?......h.......m,
	# 4	Same as # 2	......h......m......s	and Log:............M
	# 5	Same as # 1	......h......m......s	

Time # 1	......h......m......s	Time # 2	......h......m......s	Time (A)	.......h.......m.......s
Time # 5	+......h......m......s	Time # 4	+......h......m......s	Time (B)	+.......h.......m.......s
Total	=......h......m......s	Total	=......h......m......s	Total	=.......h.......m.......s
Average (A)	=......h......m......s	Average (B)	=......h......m......s	Average	=.......h.......m.......s
				Clock error	±.......h.......m.......s
				LMP(Av)	=.......h.......m.......s

LMP Adjustment* (Allows for North / South Movement of a Vessel and changing Declination.)
*Ignore for vessels heading East - West/West - East during Solstices (18-24 June and 18-24 December), .

Time adjustment (Seconds) = 15,28 x 'Y' x (Tan Lat +/- Tan Dec) = ...s

Where Y = Vessel's Latitude change in 1 hour +/-* Rate of change of Dec ('d').
[*+/- : If changing in the same direction = "-"]
+/- = If Lat and Dec in opposite Hemispheres, Add; if same Subtract smaller from larger.
If Lat is changing towards the sun, or if stationary, if Dec is changing towards Lat, **True LMP** is earlier than **LMP(av)** above. If changing away, later.
LMP with N/S movement adjustment = **LMP(True)** = LMP (Av) +/- Time Adjustment.
LMP (True) = ...h .... m .... s +/- ....s = **........ h .... m .... s**

LONGITUDE

Mid-day, 'Noon', at Greenwich assumed to be at..........................	12 h 00 m 00 s	UTC
Eqn of Time, Almanac's date page, bottom right, + if after 12h.......	± ....m......s	
GMP, Greenwich Meridian Passage, Greenwich Noon....................	=.....h.......m......s	(I)
LMP, Local Meridian Passage, Local Noon (from above box)..........	......h.......m......s	(II)
Difference between GMP (I) and LMP (II) (Smaller from larger)......	=.....h.......m......s	

Convert Diff'ence to an angle (Arc to Time); = **Longitude ° , ' E/W** (E if LMP earlier)

LATITUDE (At the time of True LMP)

1. **Declination**:
   Dec Hour (LMP) value... N/S ....° ......,....'
   d Factor = ...(incr +, decr -) Corrn ....'
   DECLINATION = N/S ....° ....'
2. **True Altitude (Ho)**:
   S.A. (Hs) ....° ......,....'
   I.E. (- ON, + OFF).........+/- ......,....'
   DIP (-; from eye ht)........- ....'
   AA ....= ....°......,....'
   Main corrn (Almanac card) +/- ....'
   T.A. (Ho) ....° ....'
3. **Zenith Distance**:
   Max poss altitude ..90..°.00,.0.'
   True Altitude (Ho) - ....°..........'
   ZENITH DISTANCE = ...° ....'
4. **Latitude***:
   Dec ....° ......,....' ZD
   +/- ZD ......° ....' - Dec
   LAT = ° , ' N/S

***If 'Dec' "N",**
DR Lat "N" of 'Dec' .... Lat = Dec + ZD
DR Lat "N" but "S" of Dec....Lat = Dec - ZD
and DR Lat "S"...Lat = ZD - Dec

If 'Dec' "S",
DR Lat "S" of Dec .... Lat = Dec + ZD
DR Lat "S" but "N" of Dec..Lat = Dec - ZD
DR Lat "N" ....Lat = ZD - Dec

Work Sheet 1.a. THE NOON/LMP SIGHT WITH CORRECTION FOR N/S LAT/DEC CHANGES.

NOTES

'LMP ADJUSTMENT' CALCULATION

In the Work Sheet on the facing page, the 'LMP Adjustment' just shows an answer of 53 seconds which has to be added to the LMP previously obtained.
Lets see how we get these values:

Time adjustment = 15,28 x Y x (Tan Lat +/- Tan Dec)

Y : a. 6,5 knots at 045°M (024°T) = 6,0 n.m. northwards/change in Lat. (This was done by plotting the course on a chart and measuring the vertical Lat change.)

b. Dec's rate of change (d = 0,9) was 0,9 n.m. in 1 hour

c. Dec was 'S' and decreasing, i.e. getting more North, and Lat was getting more North (they were changing in the same directon). So we subtract one from the other: Y = 6,0 - 0,9 = 5,1

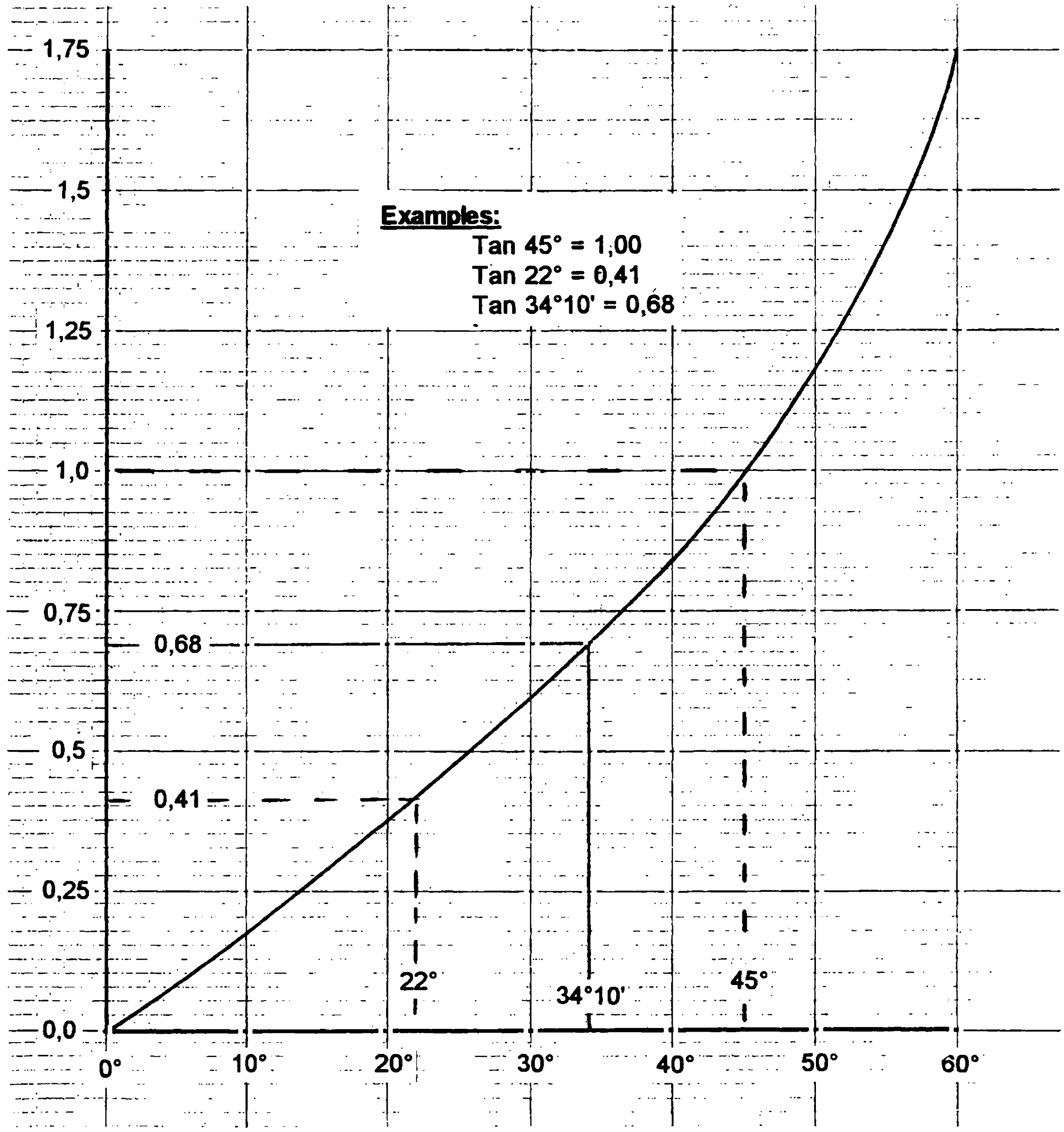
Tan Lat (from a scientific calculator, tables, or the graph below)
28°25' = 28,4166°
Tan 28,4166 = 0,5411

Tan Dec Dec = 7°59' = 7,9833°
Tan Dec = 0,1402

+/- = + (Lat and Dec are in opposite hemispheres; Lat is North, Dec is South)
So 'Time Adjustment = 15,28 x 5,1 x (0,5411 + 0,1402)
= 53 seconds (to the nearest whole number)

Lat is changing by becoming more north; lat is moving away from the sun,
so **LMP is later by 53 seconds**.

'Tan' Graph - for Latitudes up to 60°N/S and any Declination of the Sun



Using the example starting on page 14, our used Work Sheet would look like this:

MERIDIAN PASSAGE OR LOCAL NOON SIGHT WORK SHEET

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 28 Feb Log: 1 234,5 M Course: 045°M °T/M/C. Speed: 6,5 Knots
D.R. Lat: 28°...25.' N/S, Long: 40°...30..' E/W, IE: 2,7' ON(-)/OFF(+), Ht of eye: 4 ft/m
CLOCK ERROR RELATIVE TO UTC/GMT: ...... h ...... m -9. s. FAST/SLOW? (- Fast,+ slow)

ESTIMATING TIME OF LMP Convert DR Long to 'time': = 2 h 42 m (nearest).
If East, 12h00 - 'time': = 9 h 18 m*. If West, 12h00 + 'time': = ... h ..... m*. *Apparent LMP.
Apparent LMP ± Eqn of time (± +13 m [nearest]) = Estimated time of LMP = 9 h 31 m

LMP	Sight	SA/Hs	Clock Time	
	# 1	46° 26 ,7'	07 h 31 m 48 s	
	# 2	52° 03 ,2'	08 h 46 m 51 s	
Max. angle at noon	# 3	53° 12 ,8'	LMP - to be found	Approx? 09 h 30 m, and Log 1234,5 M
	# 4	Same as # 2	10 h 13 m 25 s	
	# 5	Same as # 1	11 h 29 m 08 s	

Time # 1	07 h 31 m 48 s	Time # 2	08 h 46 m 51 s	Time (A)	9 h 30 m 28 s
Time # 5	+ 11 h 29 m 08 s	Time # 4	+ 10 h 13 m 25 s	Time (B)	+ 9 h 30 m 08 s
Total	= 19 h 00 m 56 s	Total	= 19 h 00 m 16 s	Total	= 19 h 00 m 36 s
Average (A)	= 9 h 30 m 28 s	Average (B)	= 9 h 30 m 08 s	Average	= 9 h 30 m 18 s
				Clock error±	...... h ...... m -9 s
				LMP	= 9 h 30 m 09 s

LONGITUDE

Mid-day, 'Noon', at Greenwich assumed to be at...........................	12 h 00 m 00 s	UTC
Eqn of Time, Almanac's date page, bottom right, + if after 12h.......	± + 12 m 35 s	
GMP, Greenwich Meridian Passage, Greenwich Noon.....................	= 12 h 12 m 35 s	(I)
LMP, Local Meridian Passage, Local Noon (from above box)..........	9 h 30 m 09 s	(II)
Difference between GMP (I) and LMP (II) (Smaller from larger)......	= 2 h 42 m 26 s	

Convert Difference to an angle (Arc to Time); = Longitude 40°36,5' E/W (E if LMP earlier)

LATITUDE

1. **Declination**:
   Dec Hour (LMP) value... N/S 7°59,5'
   d Factor = 0,9 (incr +, decr -) Corrn -0,5'
   DECLINATION = N/S 7°59,0'

2. **True Altitude (Ho)**:
   S.A. (Hs) .... 53° 12,8'
   I.E. (- ON, + OFF).........+/- +2,7'
   DIP (-; from eye ht)........- -3,5'
   AA ....= 53° 12,0'
   Main corrn (Almanac card) +/- +15,5'
   T.A. (Ho) .... 53° 27,5'

3. **Zenith Distance**:
   Max poss altitude 90°00,0'
   True Altitude (Ho) - 53°27,5'
   ZENITH DISTANCE = 36°32,5'

4. **Latitude**:
   Dec / ZD 36°32,5' ZD
   +/- ZD / Dec 7°59,0' - Dec
   LAT = 28°33,5' N/S

If 'Dec' "N",
DR Lat "N" of 'Dec' .... Lat = Dec + ZD
DR Lat "N" but "S" of Dec....Lat = Dec - ZD
and DR Lat "S"...Lat = ZD - Dec

If 'Dec' "S",
DR Lat "S" of Dec .... Lat = Dec + ZD
DR Lat "S" but "N" of Dec..Lat = Dec - ZD
DR Lat "N" ....Lat = ZD - Dec

Solution 1. SOLUTION TO EXAMPLE 1, STARTING ON PAGE 14 (TO 19).

MERIDIAN PASSAGE OR LOCAL NOON SIGHT WORK SHEET

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 28 Feb Log: 1234.5 Course: 045° M °T/M/C. Speed: 6.5 Knots
D.R. Lat: 28° 25' N/S, Long: 40° 30' E/W, IE: 2.7 ON(-)/OFF(+), Ht of eye: 4 ft/m
CLOCK ERROR RELATIVE TO UTC/GMT: ...... h ...... m -9 s. FAST/SLOW? (- Fast,+ slow)

ESTIMATING TIME OF LMP Convert DR Long to 'time': = 2 h 42 m (nearest).
If East, 12h00 - 'time': = 9 h 18 m*. If West, 12h00 + 'time': = ... h ..... m*. *Apparent LMP.
Apparent LMP ± Eqn of time (± +13 m [nearest]) = Estimated time of LMP = 9 h 31 m

LMP	**Sight**	**SA/Hs**	**Clock Time**	
Details of sights:	**# 1**	46° 26.7'	07 h 31 m 48 s	
	# 2	52° 03.2'	08 h 46 m 51 s	
Max. angle at noon	**# 3**	53° 12.8'	LMP - to be found	Approx? 09 h 30 m,
	# 4	Same as # 2	10 h 13 m 25 s	and Log: 1234.5 M
	# 5	Same as # 1	11 h 29 m 08 s	

Time # 1	07 h 31 m 48 s	Time # 2	08 h 46 m 51 s	Time (A)	9 h 30 m 28 s
Time # 5	+ 11 h 29 m 08 s	Time # 4	+ 10 h 13 m 25 s	Time (B)	+ 9 h 30 m 08 s
Total	= 19 h 00 m 56 s	Total	= 19 h 00 m 16 s	Total	= 19 h 00 m 36 s
Average (A)	= 9 h 30 m 28 s	Average (B)	= 9 h 30 m 08 s	Average	= 9 h 30 m 18 s
				Clock error±	.... h .... m -9 s
				LMP(Av)	= 9 h 30 m 09 s

LMP Adjustment* (Allows for North / South Movement of a Vessel and changing Declination.)
*Ignore for vessels heading East - West/West - East during Solstices (18-24 June and 18-24 December),

Time adjustment (Seconds) = 15,28 x 'Y' x (Tan Lat +/- Tan Dec) = 53 s

Where Y = Vessel's Latitude change in 1 hour +/-* Rate of change of Dec ('d').
[*+/- : If changing in the same direction = "-"]

+/- = If Lat and Dec in opposite Hemispheres, Add; if same Subtract smaller from larger.
If Lat is changing towards the sun, or if stationary, if Dec is changing towards Lat, **True LMP** is earlier than **LMP(av)** above. If changing away, later.
LMP with N/S movement adjustment = **LMP(True)** = LMP (Av) +/- Time Adjustment.
LMP (True) = 9 h 30 m 09 s + 53 s = 9 h 31 m 02 s

LONGITUDE

Mid-day, 'Noon', at Greenwich assumed to be at........................	12 h 00 m 00 s	UTC
Eqn of Time, Almanac's date page, bottom right, + if after 12h.......	± + 12 m 35 s	
GMP, Greenwich Meridian Passage, Greenwich Noon....................	= 12 h 12 m 35 s	(I)
LMP, Local Meridian Passage, Local Noon (from above box)..........	9 h 31 m 02 s	(II)
Difference between GMP (I) and LMP (II) (Smaller from larger)......	= 2 h 41 m 33 s	

Convert Diff'ence to an angle (Arc to Time); = **Longitude** 40° 23.25' **E/W** (E if LMP earlier)

LATITUDE (At the time of True LMP)

1. **Declination**:
   Dec Hour (LMP) value... N/S 7° 59.5'
   d Factor = ...(incr +, decr -) Corrn - 0.5'
   DECLINATION = N/S 7° 59.0'
2. **True Altitude (Ho)**:
   S.A. (Hs) .... 53° 12.8'
   I.E. (- ON, + OFF).........+ + 2.7'
   DIP (-; from eye ht)........- - 3.5'
   AA ....= 53° 12.0'
   Main corrn (Almanac card) +/- + 15.5'
   T.A. (Ho) .... 53° 27.5'
3. **Zenith Distance**:
   Max poss altitude 90° 00.0'
   True Altitude (Ho) - 53° 27.5'
   ZENITH DISTANCE = 36° 32.5'
4. **Latitude***:
   Dec ZD 36° 32.5' ZD
   +/- ZD - 7° 59.0' - Dec
   LAT = 28° 33.5' N/S

***If 'Dec' "N",**
DR Lat "N" of 'Dec' .... Lat = Dec + ZD
DR Lat "N" but "S" of Dec....Lat = Dec - ZD
and DR Lat "S"...Lat = ZD - Dec

If 'Dec' "S",
DR Lat "S" of Dec .... Lat = Dec + ZD
DR Lat "S" but "N" of Dec..Lat = Dec - ZD
DR Lat "N" ....Lat = ZD - Dec

Solution 1.a. SOLUTION TO EXAMPLE 1, USING 'LMP ADJUSTMENT'.

NOTES

Now it is time to see some examples of Noon Sight/Meridian Passage calculations. Use the Almanac extracts at the back of this book. All of these examples use Lower Limb sights of the sun.

EXAMPLE 2

On 20 June at approximately 10h00 local time your DR is 15°40' N, and 80°25' E. Your MP sight detail is: IE 4,1' 'off'; clock 48 secs slow; height of eye 2,5 metres; LL sight; Sight 1 SA 79°52,0' at 04h51m04s; Sight 2 SA 81°06,5' at 05h40m26s; Sight 3 SA 82°05,0'; Sight 4 at 07h37m52s; Sight 5 at 08h26m39s. Log at MP 12 893 M, course 270°T, speed 5,5 knots. Times are clock times, clock set to UTC.

The worked solution appears on page 24 as Solution 2 - make sure you can find, in the Almanac (extracts, in part 2), all values extracted on to the work sheet. Help in this regard appears on page 25.

NOW YOU TRY THESE

(Answers, 'Solutions', are in Part 2; as 'SOLUTION 3' to 'SOLUTION 7'.)

EXAMPLE 3

Date 28 February, Log 31 106 m, Course 080°T, speed 4,5 knots, DR 38°45'N, 26°30' W, I.E. 2,6' 'on', Height of eye 3,3 metres. Clock 1m07s fast relative to UTC. Sight 1 SA 40°43,7' at 11h15m38s; Sight 2 SA 42°21,6' at 12h44m27s; Sight 3 SA 43°13,0' at approximately 14h00 at MP; Sight 4 at 15h14m06; Sight 5 at 16h43m25s.

EXAMPLE 4

DR 10°45' S, 11°30' W; I.E. 3,6' 'on'; eye height 5 m; clock 43 s fast; course 320°T, speed 5,5 knots; Date 5 December, Log at noon 6 371,5 M. Sight 1, SA 70°01,8' at 10h00m48s; Sight 2, SA 73°49,9' at 11h05m17s; Sight 3 SA 78°06,3' at noonat approx 12h35; Sight 4 at 14h04m58s; Sight 5 at 15h10m09s.

EXAMPLE 5

IE 1,8' 'off'; clock 6 s slow; eye height 4 m; DR 38° 12' N, 8° 50' E; Date 31 August; Log 7634 M; course 330°T; Speed 5 knots. Sight 1, SA 57°13,8' at 08h34m58s; Sight 2 SA 59°09,1' at 09h55m43s; Sight 3 SA 60°14,8' at LMP (at approx 11h26); Sight 4 at 12h52m23s; Sight 5 at 14h18m37s.

EXAMPLE 6

On 20 June at DR 15°50' N, 165°40' E, IE 2,9' 'on', clock 22 s fast, eye height 2,5 m, course 200°T speed 7 knots, and log 8 643 M at midday, sights taken were as follows:

1. SA 77°53,0' at 22h01m37s (19 June). 2. SA 80°41,1' at 23h27m58s (19 June).
3. SA 82°19,4' at noon (+/- 01h00 UT 20 June). 4. At 02h30m16s 5. At 03h55m21s.

EXAMPLE 7

DR 10°10' S, 128°40' W. Date 28 February 199x. I.E. 1,3' 'off'; eye height 3 m; clock 2m16s slow; log 372,0 M, course 265°T speed 6 knots. Sight 1 SA 81°26,5' at 18h04m01s. Sight 2 SA 85°08,4' at 19h15m48s. Sight 3 SA 87°27,2' at approximately 20h45 at LMP. Sight 4 at 22h14m03s. Sight 5 at 23h23m50s.

Solution 2.

MERIDIAN PASSAGE OR LOCAL NOON SIGHT WORK SHEET

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 20 June Log: 12 893 Course: 270°T °T/M/C. Speed: 5.5 Knots
D.R. Lat: 15°40' N/S, Long: 80°25.0' E/W, IE: 4.1' ON(-)/OFF(+), Ht of eye: 2.5ft/m
CLOCK ERROR RELATIVE TO UTC/GMT: ...... h ...... m 48 s. FAST/SLOW? (- Fast,+ slow)

ESTIMATING TIME OF LMP Convert DR Long to 'time': = 5 h 22 m (nearest).
If East, 12h00 - 'time': = 6 h 38 m*. If West, 12h00 + 'time': = ... h ..... m*. *Apparent LMP.
Apparent LMP ± Eqn of time (±+1 m [nearest]) = Estimated time of LMP = 6h39m

LMP	Sight	SA/Hs	Clock Time	
	# 1	79°52,0'	04h51m04s	
	# 2	81°06,5'	05h40m26s	
Max. angle at noon	# 3	82°05,0'	LMP - to be found	Approx? 6 h 40 m,
	# 4	Same as # 2	07h37m52s	and Log: 12893 M
	# 5	Same as # 1	08h26m39s	

Time # 1	04h51m04s	Time # 2	05h40m26s	Time (A)	06h38m51s
Time # 5	+08h26m39s	Time # 4	+07h37m52s	Time (B)	+06h39m09s
Total	=13h17m43s	Total	=13h18m18s	Total	=13h18m00s
Average (A)	=6h38m51s	Average (B)	=6h39m09s	Average	=6h39m00s
				Clock error±	......h + m48s
				LMP	=6h39m48s

LONGITUDE

Mid-day, 'Noon', at Greenwich assumed to be at..........................	12 h 00 m 00 s	UTC
Eqn of Time, Almanac's date page, bottom right, + if after 12h.......	± 1m29s	
GMP, Greenwich Meridian Passage, Greenwich Noon..................	=12h01m29s	(I)
LMP, Local Meridian Passage, Local Noon (from above box)..........	6h39m48s	(II)
Difference between GMP (I) and LMP (II) (Smaller from larger)......	=5h21m41s	

Convert Difference to an angle (Arc to Time); = **Longitude** 80°25,25' E/W (E if LMP earlier)

LATITUDE

1. Declination:
Dec Hour (LMP) value... N/S 23°25.9'
d Factor = 0.0 (incr +, decr -) Corrn 0.0'
DECLINATION = N/S 23°25.9'

2. True Altitude (Ho):
S.A. (Hs) .... 82°05.0'
I.E. (- ON, + OFF).........+/- + 4.1'
DIP (-; from eye ht)........- − 2.8'
AA ....= 82°06.3'
Main corm (Almanac card) +/- +15.8'
T.A. (Ho) .... 82°22.1'

3. Zenith Distance:
Max poss altitude 90°00.0'
True Altitude (Ho) - 82°22.1'
ZENITH DISTANCE = 7°37.9'

4. Latitude:
Dec 23°25.9' ZD
+/- ZD 7°37.9' - Dec
LAT = 15°48.0' N/S

If 'Dec' "N",
DR Lat "N" of 'Dec' .... Lat = Dec + ZD
DR Lat "N" but "S" of Dec....Lat = Dec - ZD
and DR Lat "S"...Lat = ZD - Dec

If 'Dec' "S",
DR Lat "S" of Dec .... Lat = Dec + ZD
DR Lat "S" but "N" of Dec..Lat = Dec - ZD
DR Lat "N" ....Lat = ZD - Dec

Solution 2. SOLUTION TO EXAMPLE 2, PAGE 23.

How did you get on? Let's go through it.

Lines 1 to 3. These lines just required you to write down a series of facts which were given to you - no problems.

Line 4. 80° 25 ' East longitude converted becomes 80° = 5h20m
25' = 1m40s
5h21m40s (5h22 to the nearest).

Line 5. The time, 5h22 is equivalent to 'DR Long'. Since we are 'East' we must subtract this time from 12h00. The result is 06h38 which we enter here as 'Apparent LMP'.

Line 6. In the Almanac (page in the Almanac Extracts section), in the bottom right-hand corner, 'Equation of Time', 'SUN', 'Mer Pass.' column opposite 20 for 20 June, we see 12h01m. This is 12h00 PLUS 1 minute - the "+1" minute is the value we need. It is the amount GMP differs from 12h00, "+" for after 12h00, "-" for before 12h00. So our 'Estimated Time of LMP' becomes 06h38 + 1 = 06h39 (UTC). It tells us approximately what time LMP will occur in terms of UTC, and therefore we have an idea at what time to take the first sight (usually about 2 hours before the expected LMP).

'LMP'. This section requires you to enter the Sextant Angles and Clock Time of each sight - and average the times taken for like sextant angles. Averages are averaged for a better result. Note that no account is taken initially of clock error - this is done once only; less chance for more errors. The actual LMP, time of local noon, emerges, BUT ...

WARNING: 1. Most errors in navigation are caused by wrong addition, subtraction, multiplication or division.
2. See the top, and bottom of page 13 with the top of page 14 - Longitudes obtained using this method may be unreliable.

'LONGITUDE'. Here we are converting the reference time of 12h00 UTC to the time of GMP by adding the exact 'Equation of Time' value (1m29s). The difference of this time and the time of LMP is noted and converted to an angle which is the magnitude of 'Longitude'. It becomes 'Longitude' when we qualify it with 'East' or 'West'. Since LMP occurred before GMP (at 06h39m48s UTC), our longitude is 'East'.

'DECLINATION'. LMP was at 06h39m48s. On the daily page for June 20 th opposite 06h and under the 'Dec' column we see N 23°25,9'. At the bottom of that column we see the factor '0,0'. The increment for the '39m' (we ignore the '48s'-Dec changes slowly) we get from the yellow pages, page xxi, the page for '39 m'. Under the 'v or d' column opposite 0,0 we see the correction of 0,0'. If the factor and therefore the correction had been a number other than 0,0 it would be added to the 06h value if Dec was increasing, and subtracted if it was decreasing. In our case we can ignore it - it is zero.

'TRUE ALTITUDE'. This was covered in Chapter 1 and should be straight forward now. Check back if you need to.

'ZD'. 90° - TA! Simple arithmetic.

'LAT' Choose the one out of the six permutations that applies: Lat = Dec - ZD
The rest is plain sailing!

WARNING: SEXTANT MAXIMUM ANGLE AND MERIDIAN PASSAGE ANGLE (ALTITUDE)

At or near the dates of Solstice (December and June), the rate of change of Dec is zero or very small. At equinox it is at its maximum. At equinox, a sight taken two hours before noon will not have the same Dec as a sight taken two hours after noon. And if the vessel is sailing at speed either north or south, the sextant angles will be larger or smaller than if taken on a stationary vessel where there will be no movement towards or away from the sun. East - West movement, strangely, does not affect the time.

The effect of changing Dec other than close to Solstice, and the vessel's movement north or south, have an effect on the SA at noon ; the maximum angle from the sextant can be a few minutes before or after meridian passage. The angle at MP may also be very slightly less than the maximum seen on the sextant (about less than half of 1' which we can therefore ignore - Latitude will be accurate enough).
UNLESS STATIONARY, THEREFORE, LONGITUDES MAY BE VERY INACCURATE. So ...

The exact time correction can be determined using the formula:

Time (seconds) = 15.28 (a constant) x 'Y' x (Tan Lat +/- Tan Dec)

Where: 'Y' is the amount of change in one hour, of the north/south latitude in minutes of arc (determined from your vessel's course and speed), combined (added) with the rate of change of Dec ('d'). e.g:

If:
Dec at the time of LMP as per the worksheet, was S 15°48,6',
'd' (the rate of change of Dec) was 0,9
Latitude was determined to be 21°20' North, and
Course 225°True at 7 knots (i.e. 5 minutes change in Lat per hour)

Then: Y = 5 + 0,9 = 5,9

+/- is determined by whether Lat and Dec are both North or South, or if one is north while the other is south. If one is north while the other south, the combined angle effect is found by adding the Tan of each angle - if the two are in the same hemisphere, we subtract the smaller Tan from the largerTan.

Lets say:
Lat as at approximately noon/LMP (i.e. at the time of the maximum Sextant Angle) was found by the worksheet calculation method, to be 21°20' North, and Dec S 15°48,6'.

Time (seconds) = 15.28 x 5,9 x (Tan 21°20' + Tan 15°48,6')
= 90,152 x (0.3905 + 0,2832)
= 61 seconds (to the nearest whole number)
= 1 minute 01 seconds.

If Lat was changing towards the sun, Meridian Passage would have been 1min 01secs earlier than the LMP calculation on the worksheet.
As Lat was changing away from the sun, Meridian Passage was 1 minute 01 secs later than the worksheet LMP.
i.e. Vessel's movement towards the sun, SUBTRACT this time from the LMP per the worksheet.
Vessel's movement away from the sun, ADD this time to the LMP per the worksheet.

NB: If the vessel is (or almost) stationary, and the date near Solstice, 'Y' will be Zero, or almost Zero.
Any number x Zero = Zero, i.e. no time change effect.
If stationary but the date is near equinox, 'Y' may be as much as 1': in the above example it would make a time difference of about 10 seconds, or 2,5 miles.

NOTES

THE LOGIC OF NON-MERIDIAN PASSAGE SIGHTS

LUNACY?

Non-meridian passage sights start by finding the DR position, then we arbitrarily change it to another position which we call the ASSUMED POSITION, or CHOSEN POSITION, then we set out to prove we are not there! No wonder land lubbers regard us as crazy. It is not as stupid as it sounds because by proving we are not at the Assumed or Chosen Position (AP/CP), we prove that we are on a line of position a known distance and direction from it.

THE LOGIC

When we start sailing from a known point in one direction at a constant speed, we can at any moment thereafter very easily calculate how far we have moved and this is easily plotted on our chart as our 'DR' - our Deduced or Dead Reckoned position. No matter where this may be, we only have to move the DR a maximum of about 40 nautical miles and we can be at the intersection of a whole degree of latitude and a meridian marking a whole degree of longitude - at an AP/CP.

For the intersection of every degree of latitude and of longitude there are 'values' calculated in advance for us to use. They tell us what our True Altitude (TA or the angular height observed, Ho), and the direction (called AZIMUTH or Zn) from that place to the sun (or other celestial body), should be if we were at that place at any particular time.

So, for any second in time on any day during any year we can, if we have the right information available, calculate what the angular height (of a celestial body) will be at any of the intersections of degrees of latitude and longitude. The information we need is contained in the Almanac and Sight Reduction Tables - (see extracts in Part 2) - and the angular height (of the body) obtained from the calculations using the tables is called the Tabulated Altitude - it is the angular HEIGHT obtained from CALCULATION and has the symbol 'Hc'. Note the similarity to 'Ho' which is the angular HEIGHT measured from OBSERVATION using the sextant and corrected for IE (index error), DIP (height of eye), and SD (semi-diameter)/ Refraction.

If we happen to be at the intersection of one of these squares formed by the crossing of lines being the degrees of latitude and of longitude, and if we take an accurate sextant sight and use the tables correctly, we will find that the Ho obtained using the sextant will be the same as the Hc obtained from calculation using the tables.

If we were not exactly at the intersection there would be a difference in the values of Ho and Hc. The difference is called the 'Intercept'. As both Ho and Hc are angles, the intercept is also an angle. Unless our DR was very inaccurate, the Assumed or Chosen Position (the AP or CP) will be less than one degree (60 nautical miles) away from the actual position we are setting out to find - the intercept will be a number of minutes of a degree.

The actual position may be closer TOWARDS the celestial body than the AP or CP, or further AWAY from it. Look at the diagrams below:

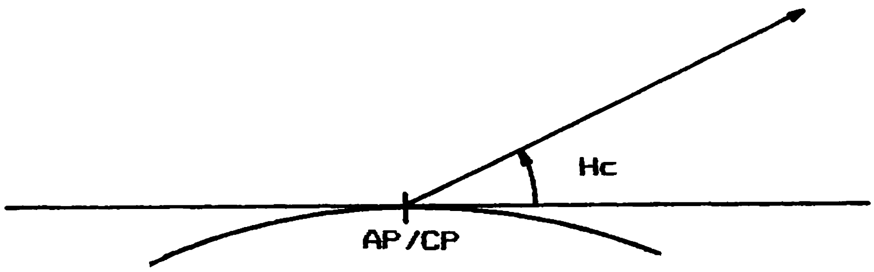


Fig. 26. 'Hc' AT THE AP / CP

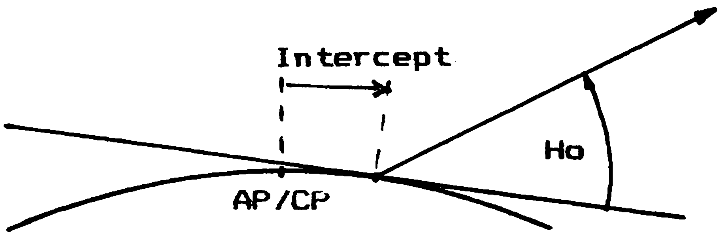


Fig. 27. 'Ho' IS LARGER THAN 'Hc', INTERCEPT IS 'TOWARDS'

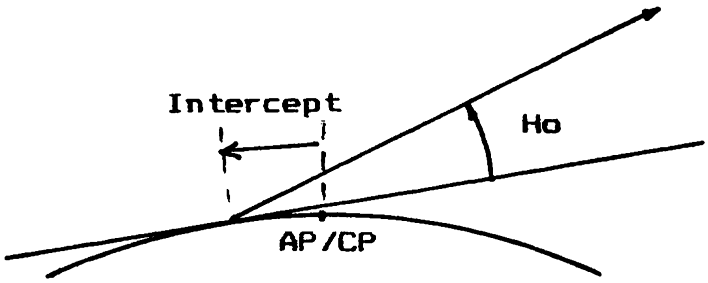


Fig. 28. 'Ho' IS SMALLER THAN 'Hc', INTERCEPT IS 'AWAY'

By definition, one nautical mile is the length of an arc of a great circle on the surface of the earth subtended by an angle of 1 minute at its centre, the centre of the earth. An intercept of 1' is also a distance of one nautical mile on the earth's surface. To be able to understand and accept this, look at these diagrams:

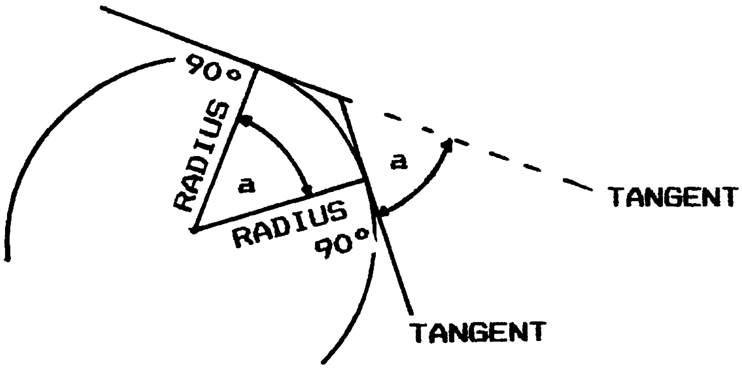


Fig. 29. ANGLE BETWEEN TANGENTS (HORIZONS) = ANGLE AT EARTH'S CENTRE.

No matter what the angle at the centre of the earth, the angle formed by the tangents will be the same.

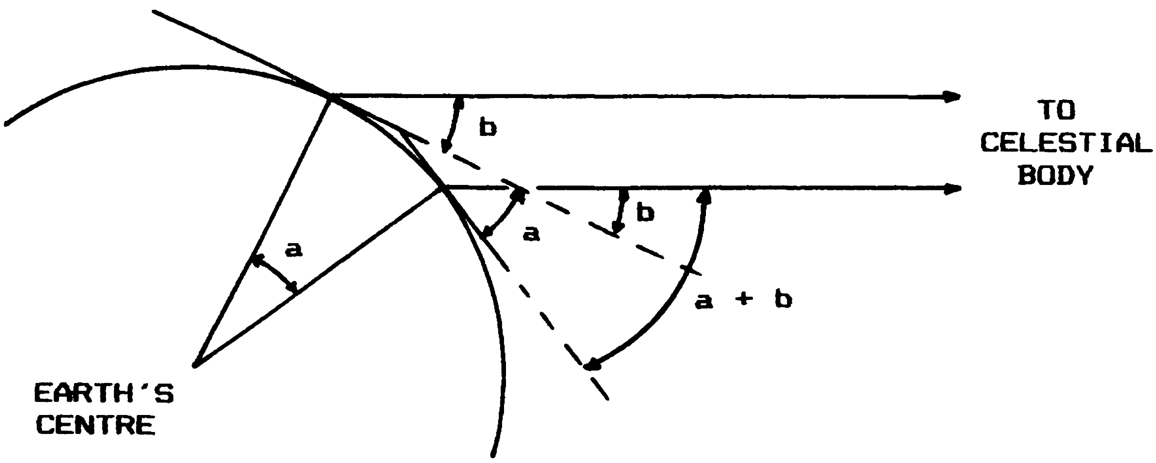


Fig. 30. ANGLE AT EARTH'S CENTRE = DIFFERENCE BETWEEN ANGLES TO SUN (STARS, ETC.)

The difference in the angles formed between the tangents, which in our case are the respective horizons, and the lines to the celestial body, equals the angle at the centre of the earth. If the two angles were Ho and Hc, this difference is called the intercept. If the difference or intercept is 5' then the angle at the centre of the earth must be 5'. The arc formed on the earth's surface from an angle of 5' at the earth's centre must be 5 nautical miles long. So our intercept is 5 miles from the AP/CP.

This intercept distance being TOWARDS or AWAY from the AP/CP, is towards or away in the direction AP/CP to celestial body. It is called the AZIMUTH ('Zn') and is simply taken from the Sight Reduction Tables. It is stated as a number of degrees in the 0° to 360° notation where 0° and 360° are both True North. So an INTERCEPT of 5 miles TOWARDS and AZIMUTH of 090°True means the LINE OF POSITION is 5 miles from the AP/CP in the direction 090° True. The Line of Position (LOP) is at right angles to the Azimuth line.

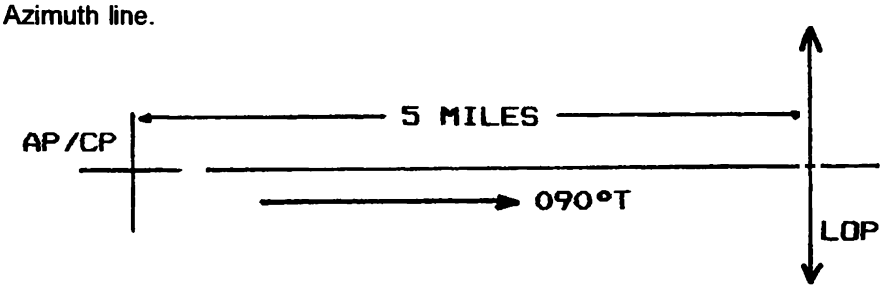


Fig. 31. INTERCEPT 'TOWARDS', 5 MILES, AZIMUTH 090° TRUE

An intercept of 5 miles AWAY and AZIMUTH 090° True means that the LOP is 5 miles from the AP/CP in the direction AWAY from the AZIMUTH. To go AWAY from the direction 090°True we must go in the direction 270°True i.e. 180° in the opposite direction.

At this point 5 miles along the Azimuth line, either 'towards' or 'away' from the AP/CP, we rule the LOP (Line of Position) at right angles to the Azimuth line. The 'LOP' is for practical purposes a straight line as we only use a short section of it in the vicinity of our position. In reality, it is an arc or circle of position, depending on how much of it we wish to use, as our sextant angle at a moment in time could also be the same sextant angle measured at the same time by other navigators in other places along that circle of position.

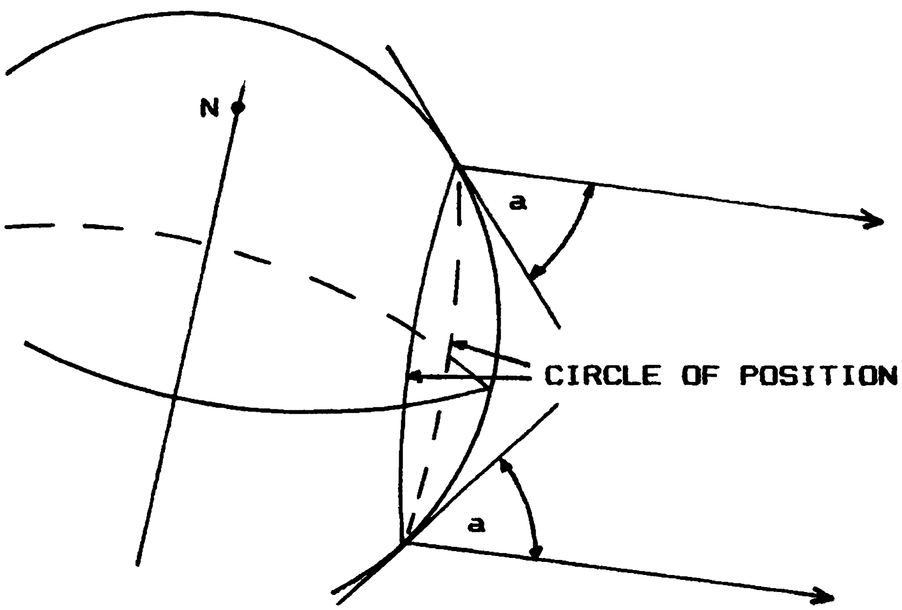


Fig. 32. SAME SEXTANT ANGLES ON A CIRCLE OF POSITION

As time moves on, so the earth continues to rotate on its axis and move along its orbital path around the sun. So the LOP we get from a sight of the sun in the morning will form an angle, and intersect, an LOP resulting from a sight taken in the afternoon. If we stayed at the same place during the day, the point at which the two LOPs intersected would be our 'fix' position. Three LOPs on the same day would be better as we would get a 'cocked hat' triangle, the centre of which would be our position - this is more reliable and accurate than the intersection of two LOPs. The latitude from a noon or Meridian Passage (MP) sight could be used for one of the LOPs, but do not use MP longitude because of the possible (probable?) error.

THE ALMANAC FOR SUN'S GHA AND DEC

The Almanac which is published annually, we have already seen, gives us DECLINATION. Declination angle affects the TABULATED ALTITUDE (Hc) and the TRUE ALTITUDE (Ho). If we were to measure Ho from exactly the same place, and at the same time of day on two occasions some months apart, we would get two different answers. This is due to 'Dec' changing as the days tick by. So we need 'Dec' when looking up Hc and Zn (AZIMUTH) in the Sight Reduction Tables. We have already seen how to establish the value of Dec (see pages 16, 18, and 19).

The next value we need in order to use the Sight Reduction Tables is the latitude of the AP (or CP). Here we simply take the DR latitude and round it off to the nearest whole number of degrees. We also need to know if the latitude, be it north or south, is in the SAME or different (CONTRARY) hemisphere as the Dec. Is Dec north or south, are they both north or both south (SAME) or is one north and the other south (CONTRARY)?

Finally before we can go to the tables we need to know the LHA - the 'LOCAL HOUR ANGLE'.

HOUR ANGLES

When we looked at Noon/MP sights we saw that the earth rotates once every 24 hours through 360° and it therefore moves through an angle of 180° in 12 hours, 90° in 6 hours and so on. If we are able to look down on the earth from above the North Pole and see the reference meridian, the Greenwich Meridian, we would see:

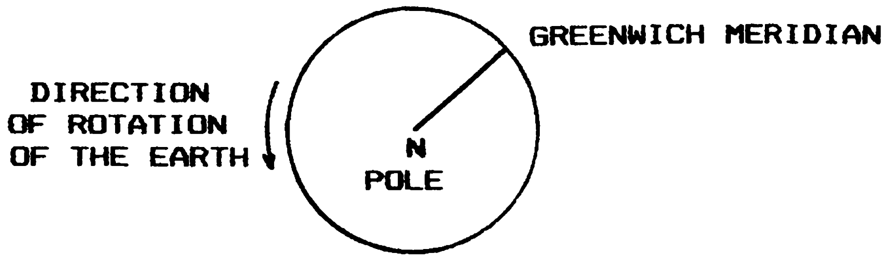


Fig. 33. THE EARTH, NORTH POLE AND GREENWICH MERIDIAN

The angle at the centre of the earth between the Greenwich Meridian and an imaginary line from the centre of the earth to the centre of the sun is called the GREENWICH HOUR ANGLE.

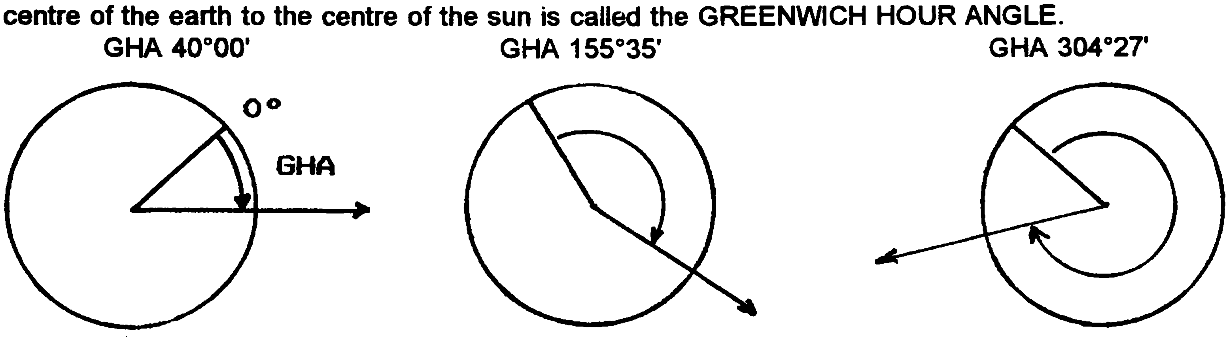


Fig. 34. THE GREENWICH HOUR ANGLE

The Greenwich Hour Angle, or 'GHA', is constantly increasing as the earth rotates. As with all hour angles, it is always measured from the meridian of interest (in this case Greenwich) in a westerly direction, from 0° to 360°. The angle is increasing at the rate of 1' every 4 seconds - so if we are to know the magnitude of this angle accurately for navigation purposes, we must have an accurate means of telling the time.

Let's assume we need to know GHA at 10h38m14s on 28 February 199x. We go to the Almanac daily page for that date, right-hand facing page, left side and we see the heading 'SUN' and below it to the left of where we found 'Dec' - Declination (pages 18 and 19), we see 'GHA'. At 10h (00m00s) GHA is 326°51,1'. See Table 7. Having got the value for 10h we need to find the extra 'bit' for the minutes and seconds - the increment of GHA. We turn to the yellow pages 'Increments and Corrections' and find the half page for 38 minutes. It has seven columns, the left being headed 's' (seconds) and the rows below the 's' are numbered from '00' to '60'. Our time was 38 minutes 14 seconds so having got the right page we look down the 's' column and along the '14' row to the adjacent column under the heading 'SUN PLANETS'. As this column applies to the sun, we extract the GHA incremental value 9°33,5'. See Table 8.

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UT (GMT)	SUN G.H.A.	SUN Dec.	MOON G.H.A.	MOON v	MOON Dec.	MOON d	MOON H.P.
d h	° ′	° ′	° ′	′	° ′	′	′
27 00	176 47.[illegible]	S 8 30.5	346 [illegible]	[illegible]	S 0 44.8	13.4	60.5
01	191 47.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]3.4	60.5
[illegible]	[illegible]	[illegible]	[illegible] 35.0	8.5	[illegible]	[illegible]	[illegible]
23	161 49.8	[illegible]	[illegible] 02.5	8.4	5 48.7	12.9	[illegible]
28 00	176 50.0	S 8 08.0	[illegible]33 29.9	8.3	S 6 01.6	12.9	60.6
01	191 50.1	07.0	347 57.2	8.4	6 14.5	12.8	60.6
02	206 50.2	06.1	2 24.6	8.3	6 27.3	12.8	60.6
03	221 50.3	. . 05.1	16 51.9	8.3	6 40.1	12.7	60.6
04	236 50.4	04.2	31 19.2	8.2	6 52.8	12.7	60.6
05	251 50.5	03.3	45 46.4	8.3	7 05.5	12.7	60.6
06	266 50.6	S 8 02.3	60 13.7	8.2	S 7 18.2	12.6	60.6
07	281 50.8	01.4	74 40.9	8.2	7 30.8	12.5	60.6
08	296 50.9	8 00.4	89 08.1	8.1	7 43.3	12.5	60.6
M 09	311 51.0	7 59.5	103 35.2	8.2	7 55.8	12.5	60.6
O 10	326 51.1	58.5	118 02.4	8.1	8 08.3	12.4	60.6
N 11	341 [illegible]	57.6	132 29.5	8.0	8 20.7	12.3	60.6
D 12	356 51.3	[illegible]	146 56.5	8.1	S 8 33.0	12.3	60.6
A 13	11 51.5	[illegible]	[illegible] 23.6	8.0	8 45.3	12.2	60.6
Y 14	26 51.6	[illegible]	[illegible]	8.0	8 57.5	12.2	60.5
15	41 51.7	. . [illegible]	[illegible] 17.6	7.9	9 09.7	12.0	60.5
16	56 51.8	52.9	[illegible] 44.5	7.9	9 21.7	12.1	60.5
17	71 51.9	[illegible]	[illegible]	[illegible]	9 33.8	12.0	60.5

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Moonrise 27	Moonrise 28	Moonrise 1	Moonrise 2
°	h m	h m	h m	h m	h m	h m	h m
N 72	05 16	06 34	07 43	20 48	23 02	25 31	01 31
N 70	05 21	[illegible]	[illegible]	[illegible]	22 43	24 52	00 52
68	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24 25	[illegible]
[illegible]	[illegible]	[illegible] 13	05 41	19 [illegible]	[illegible]	[illegible]	[illegible] 19
[illegible]	04 29	05 05	05 35	19 17	19 49	[illegible]	21 06
S 50	04 14	04 55	05 29	19 13	19 41	20 13	20 50
52	04 07	04 50	05 25	19 11	19 38	20 08	20 43
54	03 59	04 45	05 22	19 09	19 33	20 01	20 35
56	03 49	04 39	05 18	19 07	19 29	19 55	20 26
58	03 38	04 32	05 14	19 05	19 24	19 47	20 16
S 60	03 26	04 24	05 09	19 02	19 18	19 38	20 04

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 27	Moonset 28	Moonset 1	Moonset 2
°	h m	h m	h m	h m	h m	h m	h m
N 72	16 44	17 54	19 12	06 39	06 24	06 05	05 34
N 70	16 54	17 56	19 07	06 42	06 34	06 26	06 14
68	17 02	17 59	19 03	06 45	06 43	06 42	06 42
66	17 09	18 01	19 00	06 47	06 51	06 56	07 04
64	17 15	18 03	18 58	06 49	06 57	07 07	07 21
62	17 20	18 05	[illegible]	06 50	07 02	07 17	07 35
60	17 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	07 25	[illegible]

Table 7. ALMANAC FOR GHA 'SUN' AT 10H ON 28 FEBRUARY 199x

38ᵐ INCREMENTS AND CORRECTIONS **39ᵐ**

38ᵐ s	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	9 30·0	9 31·6	9 04·0	0·0	0·0	6·0	3·9	12·0	7·7
01	9 30·3	9 31·8	9 04·3	0·1	0·1	6·1	3·9	12·1	7·8
02	9 30·5	9 32·1	9 04·5	0·2	0·1	6·2	4·0	12·2	7·8
03	9 30·8	9 32·3	9 04·7	0·3	0·2	6·3	4·0	12·3	7·9
04	9 31·0	9 32·6	9 05·0	0·4	0·3	6·4	4·1	12·4	8·0
05	9 31·3	9 32·8	9 05·2	0·5	0·3	6·5	4·2	12·5	8·0
06	9 31·5	9 33·1	9 05·5	0·6	0·4	6·6	4·2	12·6	8·1
07	9 31·8	9 33·3	9 05·7	0·7	0·4	6·7	4·3	12·7	8·1
08	9 32·0	9 33·6	9 05·9	[illegible]	0·5	6·8	4·4	12·8	8·2
09	9 32·3	9 33·8	9 06·2	[illegible]	0·6	6·9	4·4	12·9	8·3
10	9 32·5	9 34·1	[illegible]	[illegible]	0·6	7·0	4·5	13·0	8·3
11	9 32·8	9 34·3	[illegible]	[illegible]	0·7	7·1	4·6	13·1	8·4
12	9 33·0	[illegible]	[illegible]	1·2	0·8	7·2	4·6	13·2	8·5
13	9 33·3	[illegible]	9 07·1	1·3	0·8	7·3	4·7	13·3	8·5
14	9 33·5	9 35·1	9 07·4	1·4	0·9	7·4	4·7	13·4	8·6
15	9 33·8	[illegible]	[illegible]	[illegible]	[illegible]	7·5	4·8	13·5	8·7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13·6	8·7

39ᵐ s	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	9 45·0	9 46·6	9 18·4	0·0	0·0	6·0	4·0	12·0	7·9
01	9 45·3	9 46·9	9 18·6	0·1	0·1	6·1	4·0	12·1	8·0
02	9 45·5	9 47·1	9 18·8	0·2	0·1	6·2	4·1	12·2	8·0
03	9 45·8	9 47·4	9 19·1	0·3	0·2	6·3	4·1	12·3	8·1
04	9 46·0	9 47·6	9 19·3	0·4	0·3	6·4	4·2	12·4	8·2
05	9 46·3	9 47·9	9 19·5	0·5	0·3	6·5	4·3	12·5	8·2
06	9 46·5	9 48·1	9 19·8	0·6	0·4	6·6	4·3	12·6	8·3
07	9 46·8	9 48·4	9 20·0	0·7	0·5	6·7	4·4	12·7	8·4
08	9 47·0	9 48·6	9 20·3	0·8	0·5	6·8	4·5	12·8	8·4
09	9 47·3	9 48·9	9 20·5	0·9	0·6	6·9	4·5	12·9	8·5
10	9 47·5	9 49·1	9 20·7	1·0	0·7	7·0	4·6	13·0	8·6
11	9 47·8	9 49·4	9 21·0	1·1	0·7	7·1	4·7	13·1	8·6
12	9 48·0	9 49·6	9 21·2	1·2	0·8	7·2	4·7	13·2	8·7
13	9 48·3	9 49·9	9 21·5	1·3	0·9	7·3	4·8	13·3	8·8
14	9 48·5	9 50·1	9 21·7	1·4	0·9	7·4	4·9	13·4	8·8
15	[illegible]	[illegible]	[illegible]	1·5	1·0	7·5	4·9	13·5	[illegible]

Table 8. INCREMENT PAGE SHOWING 38 MINUTES 14 SECONDS

So we have:

GHA (hour value - as at 10h)	326°51,1'
Increment (for 38m14s) add	+ 9°33,5'
GHA at 10h38m14s UTC	=336°24,6'

Note that the increment is always added, because **as the earth turns, the GHA is getting bigger** until it gets to 360° then it starts up from 0° (360°) towards 360° again - a never-ending, constant process.

Having found the value for GHA, we see the Sight Reduction Tables need 'LHA' - LOCAL HOUR ANGLE. To convert GHA to LHA we add or subtract our DR longitude. If our DR longitude is east of Greenwich we add it to GHA to get LHA; if it is west of Greenwich we subtract it from GHA to get LHA. Remember that hour angles are always measured from the meridian of interest westward to the line from the centre of the earth to the centre of the celestial body.

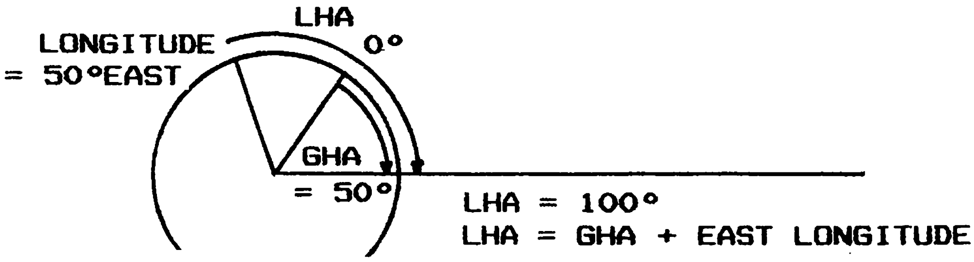

Fig. 35. LHA WHEN LONGITUDE IS 'EAST'

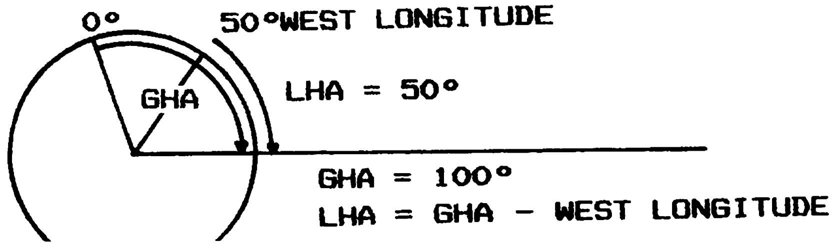

Fig. 36. LHA WHEN LONGITUDE IS 'WEST'

There is one minor complication. LHA as used in the Sight Reduction Tables must be a whole number of degrees. To achieve this, when we add or subtract our longitude to/from GHA, we add or subtract as required the number of degrees of our longitude but we change the number of the minutes of our longitude so that when added or subtracted to/from the minutes of GHA, the answer will be a whole number of degrees. This means we have changed the minutes of our DR longitude and we have a new longitude - the AP or CP longitude, 'ASSUMED' or 'CHOSEN LONGITUDE'.

As an example, assume our DR longitude is 37°49,2' East. If the GHA is the same as our earlier example, LHA will be:

GHA	336°24,6'	
Chosen Longitude	37°35,4'	East (so "+")
LHA	374°00,0'	(LHA must be between 0°and 360°)
	-360°00,0'	+ or - 360°(if necessary)
LHA	14°00,0'	

Note that the DR longitude (its minutes) was changed and it became the 'Chosen Longitude'.
Now what if the DR longitude was 'West'? When west, we subtract (see Figure 36.). The minutes of the DR longitude are changed to be the same as the minutes of GHA so that when subtracted, the result will be a whole number of degrees for LHA:

GHA	336°24,6'	
Chosen Longitude	- 37°24,6'	West (so '-')
LHA	299°00,0'	
+/-360° (if nec)	N/A	* See the top of the next page.
LHA	299°00,0'	

* It could and does happen that at times GHA is small and chosen longitude (west) is large so the initial LHA is negative. If this happens, we just add 360°. If LHA exceeds 360°, we subtract 360°.

SIGHT REDUCTION TABLES

There are three main types of Sight Reduction Tables. See examples, pages 120/121 and in Part 2.
1. Sight Reduction Tables for Air Navigation. These are easy to use and were until recently required to be used in Yachtmaster Ocean examinations for the RYA and CASA certificates of competence. This has now changed and the candidate may use any tables or method as long as it does NOT involve the use of 'programmed' celestial navigation calculators. Ordinary scientific calculators are acceptable.
2. Sight Reduction Tables for Marine Navigation. These tables are very similar to the Air Tables, but although they allow a slightly greater degree of accuracy, they are more difficult to use, and more expensive volumes of the set of tables need to be purchased. The increase in accuracy over the Air tables is so small that the extra cost and complexity no longer justify their use. If, however, you already have and wish to use these tables both for this course and subsequent navigation, their use is explained in Appendix A, page 119.
3. Concise Sight Reduction Tables - in the Almanac. Since 1989 the Almanac has included a section of Reduction Tables which, the Almanac states, may be used when more comprehensive tables are not available. For the yachtsman or -woman the accuracy provided is quite good enough as, in the worst case, the error through inaccuracy is less than 2 miles. No one in this day and age on a yacht needs that degree of accuracy from celestial navigation. If you are possibly that close to danger and need a more accurate than 2 miles fix, you should either switch on the radar (if not already 'on') or stop/go back until conditions improve! The biggest advantage to using these tables is that there is only one book to get, use, stow and keep dry- and pay for!

There are other tables the navigator can use in stead of Sight Reduction Tables, such as Burton's and Norie's Tables. However, their use today is rare, so they will not be used on this course.

USE OF SIGHT REDUCTION TABLES FOR AIR NAVIGATION

We will now look at the first type mentioned - Air Tables.

To use any Sight Reduction Tables one needs to know:

a. The Chosen Latitude.
b. The Declination.
c. Whether the above two are SAME (same hemisphere) or CONTRARY (different hemispheres).
d. The LHA.

There are six pages in the tables for every degree of latitude. The first three pages cover declinations from 0° to 14° and the next three cover declinations from 15° to 29° . Each set of three pages has one and a half pages under the heading SAME and the other one and a half under the heading CONTRARY. Volume 2 covers latitudes from 0° to 40° and Volume 3 covers latitudes from 39° to 89°. (Volume 1 is for use with star sights and will be dealt with later.)

Note there is a disadvantage to the use of these tables in that resolution of sights taken from celestial bodies whose declinations are greater than 30° is not possible. This affects some star sights, so stars with declinations greater than 30° and which are not one of the seven selected stars at a moment in time as used in the star tables (Volume 1), cannot be resolved with these tables. This will become clear when we do the star sight resolutions later.

Let's assume the following:

Chosen Latitude	15°00,0' North (the DR latitude 'rounded off' to the nearest degree.)
Declination	17°38,1' South (obtained from the Almanac for the applicable date/time.)
LHA	299°00,0' (GHA + East/- West Longitude.)

As Lat and Dec are in opposite hemispheres, CONTRARY applies.

So we go to Volume 2 of the Air Sight Reduction Tables (Volume 2 is for latitudes from 0° to 40° and Declinations up to 30°), and open it to the six pages which have LAT 15° printed in bold letters at the top. We see that the first three pages are for Declinations 0° to 14° so we look at the next three pages.

N. Lat. {LHA greater than 180°……Zn=Z; LHA less than 180°……Zn=360−Z}

DECLINATION (15°-29°) CONTRARY NAME TO LATITUDE — LAT 15°

LHA	15° Hc d Z	16° Hc d Z	17° Hc d Z	18° Hc d Z	19° Hc d Z	20° Hc d Z	21° Hc d Z	22° Hc d Z	23° Hc d Z	24° Hc d Z	25° Hc d Z	26° Hc d Z	27° Hc d Z	28° Hc d Z	29° Hc d Z	LHA
	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	° ′ ′ °	
69	15 31 22 111	15 09 21 112	14 48 22 113	[illegible] 114	14 04 22 115	13 42 23 116	13 19 22 116	12 57 23 117	12 34 23 118	[illegible]	[illegible] 24 120	11 24 24 121	11 00 23 122	10 37 24 123	10 13 24 124	291
68	16 25 22 111	16 03 22 112	15 41 22 113	[illegible] 114	14 57 23 115	14 34 23 116	14 11 23 117	13 48 23 118	13 25 24 119	13 01 [illegible]	[illegible] 24 121	12 14 25 122	11 49 24 122	11 25 24 123	11 01 25 124	292
67	17 19 22 111	16 57 23 112	16 34 22 113	16 12 [illegible]	[illegible] 23 115	15 26 23 116	15 03 24 117	14 39 23 118	14 16 24 119	13 52 [illegible]	[illegible] 121	13 03 25 122	12 38 25 123	12 13 25 124	11 48 25 125	293
66	18 13 23 112	17 50 22 113	17 28 23 114	17 05 [illegible]	[illegible] 24 116	16 18 24 117	15 54 24 118	15 30 24 119	15 06 24 119	14 42 25 [illegible]	[illegible] 121	13 52 25 122	13 27 25 123	13 02 26 124	12 36 26 125	294
65	19 06 -22 112	18 44 -23 113	18 21 -24 114	17 57 -23 [illegible]	[illegible] 116	17 10 -24 117	16 46 -25 118	16 21 -25 119	15 56 -24 120	15 32 -26 [illegible]	[illegible] 122	14 41 -26 123	14 15 -26 124	13 49 -26 125	13 23 -26 125	295
64	20 00 23 113	19 37 24 114	19 13 23 115	18 50 24 [illegible]	[illegible] 25 116	18 01 24 117	17 37 25 118	17 12 25 119	16 47 26 120	16 21 25 121	[illegible] 26 122	15 30 27 123	15 03 26 124	14 37 27 125	14 10 26 126	296
63	20 54 24 113	20 30 24 114	20 06 24 115	19 42 24 116	[illegible] 25 117	18 53 25 118	18 28 26 119	18 02 25 120	17 37 26 121	17 11 26 122	[illegible] 27 123	16 18 27 123	15 51 26 124	15 25 28 125	14 57 27 126	297
62	21 47 24 113	21 23 24 114	20 59 25 115	20 34 25 116	20 09 25 117	19 44 26 118	19 18 25 119	18 53 27 120	18 26 26 121	18 00 27 122	17 33 27 123	17 06 27 124	16 39 27 125	16 12 28 126	15 44 28 127	298
61	22 40 24 114	22 16 25 115	21 51 25 116	21 26 25 117	21 01 26 118	20 35 26 119	20 09 26 120	19 43 27 121	19 16 27 122	18 49 27 122	18 22 28 123	17 54 27 124	17 27 28 125	16 59 29 126	16 30 28 127	299
60	23 33 -25 114	23 08 -25 [illegible]	22 43 -25 116	[illegible] 117	21 52 -26 118	21 26 -27 119	20 59 -27 120	20 32 -27 121	20 05 -27 122	19 38 -28 123	19 10 -28 124	18 42 -28 125	18 14 -29 126	17 45 -29 127	17 16 [illegible]	300
59	24 26 25 115	24 01 [illegible] 116	23 35 26 [illegible]	23 09 26 [illegible]	[illegible] 119	22 16 27 120	21 49 27 121	21 22 28 121	20 54 28 122	20 26 28 123	19 58 28 124	19 30 29 125	19 01 29 126	18 32 [illegible]	[illegible] 128	301
58	25 18 25 115	[illegible] 116	24 27 27 [illegible]	[illegible] 26 118	[illegible] 119	23 07 28 120	22 39 28 121	22 11 28 122	21 43 28 123	21 15 29 124	20 46 29 125	20 17 30 126	19 47 29 127	[illegible]	[illegible] 30 128	302
57	26 11 26 116	[illegible] 27 117	25 18 27 118	[illegible] 27 119	24 24 [illegible] 120	23 57 28 120	23 29 29 121	23 00 28 122	22 32 29 123	22 03 30 124	21 33 29 125	21 04 30 126	20 34 30 127	[illegible]	[illegible] 31 129	303
56	27 03 27 [illegible]	[illegible] 26 117	26 10 28 118	[illegible] 119	25 15 28 120	24 47 29 121	24 18 29 122	23 49 29 123	23 20 30 124	22 50 29 125	22 21 31 126	21 50 30 127	21 20 31 128	[illegible]	20 18 31 129	304
55	27 55 -27 [illegible]	[illegible] -27 117	27 01 -28 118	[illegible] 119	26 05 -29 120	25 36 -29 121	25 07 -29 122	24 38 -30 123	24 08 -30 124	23 38 -30 125	23 08 -31 126	22 37 -31 127	22 06 -32 128	[illegible] 129	21 03 -32 130	305
54	28 47 [illegible]	[illegible] 27 118	27 52 29 119	27 23 [illegible]	26 55 30 121	26 25 29 122	25 56 30 123	25 26 30 124	24 56 31 125	24 25 31 126	23 54 31 127	23 23 32 128	22 51 32 129	[illegible] 32 130	21 47 33 130	306
53	[illegible]	29 10 28 119	28 42 29 120	28 13 [illegible]	27 44 30 121	27 14 30 122	26 44 30 123	26 14 31 124	25 43 31 125	25 12 31 126	24 41 32 127	24 09 33 128	23 36 32 129	23 04 33 130	22 31 33 131	307
52	[illegible]	30 01 29 119	29 32 29 120	29 03 30 [illegible]	28 33 30 122	28 03 30 123	27 33 31 124	27 02 32 125	26 30 31 126	25 59 32 127	25 27 33 128	24 54 33 129	24 21 33 130	23 48 33 131	23 15 34 131	308
51	[illegible] 119	30 52 30 120	30 22 [illegible] 121	29 53 31 122	29 22 30 123	28 52 31 124	28 21 32 125	27 49 32 125	27 17 32 126	26 45 33 127	26 12 33 128	25 39 33 129	25 06 34 130	24 32 34 131	23 58 34 132	309
50	32 12 [illegible] 119	31 42 -30 120	[illegible] 121	30 42 -31 122	30 11 -31 123	29 40 -32 124	29 08 -32 125	28 36 -32 126	28 04 -33 127	27 31 -33 128	26 58 -34 129	26 24 -34 130	25 50 -34 131	25 16 -35 132	24 41 -35 133	310
49	33 02 30 120	32 32 30 121	[illegible] 122	31 31 31 123	31 00 32 124	30 28 32 125	29 56 33 126	29 23 33 127	28 50 34 128	28 16 34 129	27 42 34 129	27 08 34 130	26 34 35 131	25 59 36 132	25 23 35 133	311
48	33 52 30 120	33 22 31 121	[illegible] 122	32 20 32 123	31 48 33 124	31 15 33 125	30 42 33 126	30 09 33 127	29 36 34 128	29 02 35 129	28 27 35 130	27 52 35 131	27 17 36 132	26 41 35 133	26 06 37 134	312
47	34 42 31 121	34 11 31 122	[illegible] 123	33 08 33 124	32 35 33 125	32 02 33 126	31 29 34 127	30 55 34 128	30 21 35 129	29 46 35 130	29 11 35 131	28 36 36 132	28 00 36 132	27 24 37 133	26 47 37 134	313
46	35 32 32 121	35 00 32 122	[illegible] 123	33 56 33 125	33 23 34 126	32 49 34 127	32 15 34 127	31 41 35 128	31 06 35 129	30 31 36 130	29 55 36 131	29 19 36 132	28 43 37 133	28 06 37 134	27 29 38 135	314
45	36 21 -32 122	35 49 -32 123	[illegible] 124	34 43 -33 125	34 10 -34 126	33 36 -35 127	33 01 -35 128	32 26 -35 129	31 51 -36 130	31 15 -37 131	30 38 -36 132	30 02 -37 133	29 25 -38 134	28 47 -37 135	28 10 -39 136	315
44	37 10 32 123	36 38 34 124	[illegible] 125	35 31 35 126	34 56 34 127	34 22 35 128	33 47 36 129	33 11 36 130	32 35 37 131	31 58 37 132	31 21 37 133	30 44 38 133	30 06 38 134	29 28 38 135	28 50 39 136	316
43	37 59 33 123	37 26 34 124	[illegible] 125	36 17 34 126	35 43 36 127	35 07 35 128	34 32 37 129	33 55 36 130	33 19 38 131	32 41 37 132	32 04 38 133	31 26 38 134	30 48 39 135	30 09 39 136	29 30 39 137	317
42	38 47 34 124	38 13 34 125	37 39 35 126	37 04 36 127	36 28 35 128	35 53 37 129	35 16 37 130	34 39 37 131	34 02 38 132	33 24 38 133	32 46 39 134	32 07 39 135	31 28 39 136	30 49 40 137	30 09 40 137	318
41	39 35 35 125	39 00 35 126	38 25 35 127	37 50 36 128	37 14 37 129	36 37 37 130	36 00 37 131	35 23 38 132	34 45 39 133	34 06 39 134	33 27 39 135	32 48 39 135	32 09 40 136	31 29 41 137	30 48 40 138	319
40	40 22 -35 125	39 47 -35 127	39 12 -37 128	38 35 -36 129	37 59 -37 130	37 22 -38 131	36 44 -38 132	36 06 -39 133	35 27 -39 133	34 48 -39 134	34 09 -40 135	33 29 -41 136	32 48 -40 137	32 08 -41 138	31 27 -42 139	320
39	41 09 35 126	40 34 37 127	39 57 36 128	39 21 38 129	38 43 38 130	38 05 38 131	37 27 39 132	36 48 39 133	36 09 40 134	35 29 40 135	34 49 40 136	34 09 41 137	33 28 42 138	32 46 41 139	32 05 42 140	321
38	41 56 36 127	41 20 37 128	40 43 38 129	40 05 38 130	39 27 38 131	38 49 39 132	38 10 40 133	37 30 40 134	36 50 40 135	36 10 41 136	35 29 41 137	34 48 42 138	34 06 42 139	33 24 42 139	32 42 43 140	322
37	42 42 37 128	42 05 38 129	41 27 38 130	40 49 38 131	40 11 40 132	39 31 39 133	38 52 40 134	38 12 41 135	37 31 41 136	36 50 42 137	36 08 41 138	35 27 43 138	34 44 42 139	34 02 43 140	33 19 43 141	323
36	43 28 38 129	42 50 38 130	42 12 39 131	41 33 40 132	40 53 39 133	40 14 41 134	39 33 41 135	38 52 41 136	38 11 42 137	37 29 42 137	36 47 42 138	36 05 43 139	35 22 43 140	34 39 44 141	33 55 44 142	324
35	44 13 -39 129	43 34 -39 130	42 55 -39 132	42 16 -40 133	41 36 -41 134	40 55 -41 135	40 14 -41 136	39 33 -42 136	38 51 -43 137	38 08 -42 138	37 26 -44 139	36 42 -43 140	35 59 -44 141	35 15 -44 142	34 31 -45 143	325
34	44 57 39 130	44 18 40 131	43 38 40 132	42 58 40 133	42 18 42 134	41 36 41 135	40 55 43 136	40 12 42 137	39 30 43 138	38 47 44 139	38 03 44 140	37 19 44 141	36 35 44 142	35 51 45 143	35 06 46 143	326
33	45 41 40 131	45 01 40 132	44 21 41 133	43 40 41 134	42 59 42 135	42 17 43 136	41 34 43 137	40 51 43 138	40 08 44 139	39 24 44 140	38 40 44 141	37 56 45 142	37 11 45 143	36 26 46 143	35 40 46 144	327
32	46 24 40 132	45 44 41 133	45 03 42 134	44 21 42 135	43 39 43 136	42 56 43 137	42 13 43 138	41 30 44 139	40 46 45 140	40 01 45 141	39 16 45 142	38 31 45 143	37 46 46 143	37 00 46 144	36 14 47 145	328
31	47 07 41 133	46 26 42 134	45 44 42 135	45 02 43 136	44 19 43 137	43 36 44 138	42 52 45 139	42 07 44 140	41 23 45 141	40 38 46 142	39 52 46 143	39 06 46 143	38 20 47 144	37 33 46 145	36 47 48 146	329
30	47 49 -42 134	47 07 -42 135	46 25 -43 136	45 42 -44 137	44 58 -44 138	44 14 -45 139	43 29 -45 140	42 44 -45 141	41 59 -46 142	41 13 -46 143	40 27 -47 144	39 40 -46 144	38 54 -48 145	38 06 -47 146	37 19 -48 147	330
29	48 31 43 135	47 48 44 136	47 04 43 137	46 21 45 138	45 36 44 139	44 52 46 140	44 06 45 141	43 21 47 142	42 34 46 143	41 48 47 144	41 01 47 144	40 14 48 145	39 26 48 146	38 38 48 147	37 50 48 148	331
28	49 11 43 136	48 28 44 137	47 44 45 138	46 59 45 139	46 14 46 140	45 28 46 141	44 42 46 142	43 56 47 143	43 09 47 144	42 22 48 145	41 34 47 145	40 47 49 146	39 58 48 147	39 10 49 148	38 21 49 148	332
27	49 51 44 137	49 07 45 138	48 22 45 139	47 37 46 140	46 51 47 141	46 04 46 142	45 18 47 143	44 31 48 144	43 43 48 145	42 55 48 146	42 07 49 146	41 18 48 147	40 30 50 148	39 40 49 149	38 51 50 149	333
26	50 30 45 138	49 45 46 139	48 59 46 140	48 13 46 141	47 27 47 142	46 40 48 143	45 52 48 144	45 04 48 145	44 16 48 146	43 28 49 147	42 39 50 147	41 49 49 148	41 00 50 149	40 10 50 150	39 20 50 150	334
25	51 08 -46 139	50 22 -46 140	49 36 -47 141	48 49 -47 142	48 02 -48 143	47 14 -48 144	46 26 -49 145	45 37 -49 146	44 48 -49 147	43 59 -49 148	43 10 -50 148	42 20 -50 149	41 30 -51 150	40 39 -51 151	39 48 -51 151	335
24	51 45 46 141	50 59 47 142	50 12 48 143	49 24 48 144	48 36 49 144	47 47 48 145	46 59 50 146	46 09 49 147	45 20 50 148	44 30 50 149	43 40 51 149	42 49 51 150	41 58 51 151	41 07 51 152	40 16 52 152	336
23	52 22 48 142	51 34 48 143	50 46 48 144	49 58 49 145	49 09 49 146	48 20 50 147	47 30 50 147	46 40 50 148	45 50 50 149	45 00 51 150	44 09 52 150	43 17 51 151	42 26 52 152	41 34 52 153	40 42 52 153	337
22	52 57 48 143	52 09 49 144	51 20 49 145	50 31 50 146	49 41 50 147	48 51 50 148	48 01 51 149	47 10 50 149	46 20 51 150	45 28 51 151	44 37 52 152	43 45 52 152	42 53 52 153	42 01 53 154	41 08 53 154	338
21	53 31 49 144	52 42 49 145	51 53 50 146	51 03 50 147	50 13 51 148	49 22 51 149	48 31 51 150	47 40 52 150	46 48 52 151	45 56 52 152	45 04 53 153	44 11 52 153	43 19 53 154	42 26 53 155	41 33 53 155	339
20	54 04 -49 146	53 15 -51 147	52 24 -50 148	51 34 -51 149	50 43 -52 149	49 51 -51 150	49 00 -52 151	48 08 -53 152	47 15 -52 152	46 23 -53 153	45 30 -53 154	44 37 -53 154	43 44 -54 155	42 50 -53 156	41 57 -54 156	340
19	54 36 50 147	53 46 51 148	52 55 52 149	52 03 51 150	51 12 52 151	50 20 53 151	49 27 52 152	48 35 53 153	47 42 53 154	46 49 54 154	45 55 53 155	45 02 54 156	44 08 54 156	43 14 55 157	42 19 54 157	341
18	55 07 51 149	54 16 52 149	53 24 52 150	52 32 52 151	51 40 53 152	50 47 53 153	49 54 53 153	49 01 54 154	48 07 54 155	47 13 54 155	46 19 54 156	45 25 54 157	44 31 55 157	43 36 55 158	42 41 [illegible] 158	342
17	55 37 52 150	54 45 53 151	53 52 53 152	52 59 53 153	52 06 53 153	51 13 54 154	50 19 54 155	49 25 54 155	48 31 54 156	47 37 55 156	46 42 55 157	45 47 55 158	44 52 55 158	43 57 55 159	[illegible] 160	343
16	56 05 53 152	55 12 53 152	54 19 53 153	53 26 54 154	52 32 54 155	51 38 55 155	50 43 55 156	49 49 55 157	48 54 55 157	47 59 55 158	47 04 55 159	46 09 56 159	45 13 55 160	44 18 56 160	[illegible] 161	344
15	56 32 -53 153	55 39 -54 154	54 45 -55 155	53 50 -54 155	52 56 -55 156	52 01 -55 157	51 06 -55 157	50 11 -55 158	49 16 -56 159	48 20 -55 159	47 25 -56 160	46 29 -56 160	45 33 -56 161	44 37 -57 161	[illegible] 162	345
14	56 58 55 155	56 03 54 155	55 09 55 156	54 14 55 157	53 19 56 158	52 23 55 158	51 28 56 159	50 32 56 159	49 36 56 160	48 40 56 160	47 44 56 161	46 48 57 162	45 51 56 162	44 55 57 162	[illegible]	346
13	57 22 55 156	56 27 55 157	55 32 56 158	54 36 56 158	53 40 56 159	52 44 56 160	51 48 56 160	50 52 56 161	49 56 57 161	48 59 57 162	48 02 56 162	47 06 57 163	46 09 57 163	45 12 57 164	[illegible]	347
12	57 44 55 158	56 49 56 159	55 53 56 159	54 57 57 160	54 00 56 161	53 04 57 161	52 07 56 162	51 11 57 162	50 14 57 163	49 17 58 163	48 19 57 164	47 22 57 164	46 25 58 164	45 27 57 165	44 30 [illegible]	348
11	58 05 56 160	57 09 56 160	56 13 57 161	55 16 57 161	54 19 57 162	53 22 57 163	52 25 57 163	51 28 58 164	50 30 57 164	49 33 58 164	48 35 57 165	47 38 58 165	46 40 58 166	45 42 58 166	44 44 [illegible]	349
10	58 25 -57 161	57 28 -57 162	56 31 -57 163	55 34 -58 163	54 36 -57 164	53 39 -58 164	52 41 -58 165	51 43 -57 165	50 46 -58 165	49 48 -58 166	48 50 -58 166	47 52 -58 167	46 54 -59 167	45 55 -58 167	44 57 -58 [illegible]	350
9	58 43 58 163	57 45 58 164	56 47 57 164	55 50 58 165	54 52 58 165	53 54 58 166	52 56 58 166	51 58 58 166	51 00 59 167	50 01 58 167	49 03 58 168	48 05 59 168	47 06 58 168	46 08 59 169	45 09 59 [illegible]	351
8	58 59 58 165	58 01 58 165	57 03 59 166	56 04 58 166	55 06 58 167	54 08 59 167	53 09 58 168	52 11 59 168	51 12 58 168	50 14 59 169	49 15 59 169	48 16 59 169	47 17 59 170	46 18 58 170	45 20 59 [illegible]	352
7	59 13 59 167	58 14 58 167	57 16 59 168	56 17 58 168	55 19 59 168	54 20 59 169	53 21 59 169	52 22 59 169	51 23 59 170	50 24 59 170	49 25 59 170	48 26 59 171	47 27 59 171	46 28 59 171	45 29 59 [illegible]	353
6	59 25 59 169	58 26 59 169	57 27 58 169	56 29 60 170	55 29 59 170	54 30 59 170	53 31 59 171	52 32 59 171	51 33 59 171	50 34 59 171	49 35 60 172	48 35 59 172	47 36 59 172	46 37 60 172	45 37 59 173	354
5	59 36 -59 170	58 37 -60 171	57 37 -59 171	56 38 -59 171	55 39 -60 172	54 39 -59 172	53 40 -59 172	52 41 -60 172	51 41 -59 173	50 42 -60 173	49 42 -59 173	48 43 -60 173	47 43 -59 173	46 44 -60 174	45 44 -59 174	355
4	59 44 59 172	58 45 59 173	57 46 60 173	56 46 60 173	55 46 59 173	54 47 60 174	53 47 59 174	52 48 60 174	51 48 60 174	50 48 59 174	49 49 60 174	48 49 60 175	47 49 59 175	46 50 60 175	45 50 60 175	356
3	59 51 59 174	58 52 60 174	57 52 60 175	56 52 60 175	55 52 59 175	54 53 60 175	53 53 60 175	52 53 60 175	51 53 60 176	50 53 59 176	49 54 60 176	48 54 60 176	47 54 60 176	46 54 60 176	45 54 60 176	357
2	59 56 60 176	58 56 60 176	57 56 59 176	56 57 60 177	55 57 60 177	54 57 60 177	53 57 60 177	52 57 60 177	51 57 60 177	50 57 60 177	49 57 60 177	48 57 60 177	47 57 60 177	46 57 59 177	45 58 60 178	358
1	59 59 60 178	58 59 60 178	57 59 60 178	56 59 60 178	55 59 60 178	54 59 60 178	53 59 60 178	52 59 60 179	51 59 60 179	50 59 60 179	49 59 60 179	48 59 60 179	47 59 60 179	46 59 60 179	45 59 60 179	359
0	60 00 -60 180	59 00 -60 180	58 00 -60 180	57 00 -60 180	56 00 -60 180	55 00 -60 180	54 00 -60 180	53 00 -60 180	52 00 -60 180	51 00 -60 180	50 00 -60 180	49 00 -60 180	48 00 -60 180	47 00 -60 180	46 00 -60 180	360

S. Lat. {LHA greater than 180°……Zn=180−Z; LHA less than 180°……Zn=180+Z}

DECLINATION (15°-29°) CONTRARY NAME TO LATITUDE — LAT 15°

Table 9. A PAGE FROM 'AIR' SIGHT REDUCTION TABLES

We find that the first of these three pages with LAT 15° is headed SAME, the next has SAME at the top and CONTRARY at the bottom, and the third page has the heading CONTRARY. We need to look at the second and third pages, down the side columns (either left or right will have our LHA) to find our LHA of 299°. We find it on the third page in the right-hand column, nine rows down. Opposite the 299° and in the column for '17°' of Dec, we see three numbers. The first is under the column headed 'Hc', the second 'd' and the third 'Z'. Note that the 'd' numbers are either '+' or '-'.

The Hc quoted (21°51') is the Hc that would apply IF the Dec were a whole number of degrees (17°00,0'). Our Dec is 17°38,1', so we have to take the 38,1' into account.
The number which appears under the 'd' column (25), is 'negative'- as seen by the '-' symbol which is repeated only on every 5 th line for the sake of clarity.
We take these two numbers, 38,1' and 25, to 'TABLE 5' of the Sight Reduction Tables (see Table 10 - next page). The 38,1' must be 'rounded off' to the nearest whole number as this table does not deal in fractions (decimals) of minutes.

(NB: Remember we said Air Tables were not as accurate as Marine Tables - the latter do not round off, but use every fraction/decimal).

Looking along the top we find '38' and we then look down the side column to opposite '25' and we see '16'. This is the 'd' value which is now to be subtracted (the 'd' factor was negative) from our Hc of 21°51' to get the Hc required: Hc = 21°35'.

The third value we found was 116° and it appeared under the column headed 'Z'. 'Z' is the symbol for AZIMUTH ANGLE which is not the same as AZIMUTH (Zn) which is the direction from the AP/CP to the celestial body. Z enables us to calculate Zn. (The explanation of the relationship between Z and Zn can be found on pages 58/59 in the section on the Spherical Triangle). Look back to the table on page 34. At the top and bottom left corners you will see:

At the top N.Lat, LHA greater than 180°............ Zn = Z
LHA less than 180°....... Zn = 360°- Z
At the bottom S.Lat. LHA greater than 180°....Zn = 180°- Z
LHA less than 180°........Zn = 180°+ Z

Since our latitude is 'North', we use the top section and as our LHA was greater than 180° (it was 299°), we use

Zn = Z
So Zn is .... Zn = 116° True

Our Air Tables have given us Hc and Zn relative to our chosen position. The difference between the Hc and Ho from the corrected sextant angle is the intercept. Knowing the Chosen Lat, Chosen Long, Azimuth and Intercept, and whether it is AWAY or TOWARDS, we can go to our plotting sheet and plot the resulting LOP. (Plotting will be discussed in detail later. At this stage see Figure 31 on page 29.)

On page 37 we have a work sheet designed for resolving sun sights using Air Tables. Have a quick look at it now. See how explanatory notes appear down the right-hand side. Once you have mastered it, you can use 'Work Sheet 2' which has three columns (see page 38) for three sights taken on the same day, but as you will appreciate, there is no room for all the detailed explanatory notes.

Example 8. A worked example (Solution 8.a.) appears on page 39 using the following facts recorded by the navigator: Date 5/12/199x; clock 7s fast; IE 3,4' on; height of eye 10 ft; Sun LL; course 360°T; speed 6 knots.
Sight 1: SA 39°40,4', DR Lat 15°15' N, Long 26°40' W, at 11h22m16s.

(The solution to the above is on page 39. To be of use to the navigator, two more sights are taken during the day so that the three LOPs will allow a 'cocked hat' triangle to be plotted and a fix position to be established. The other two sights' details are below - you try and get the answers, and only when you have or are 'stuck', look at the answers in the Solutions section in Part 2 - see Solution 8.b.). Sight 2: SA 52°02,0', DR Lat 15°28' N, Long 26°40' W, at 13h38m20s. Sight 3: SA 39°19,9', DR Lat 15°41' N, Long 26°40' W, at 15h52m43s.

(The 'Plotting' of the position from these sights is shown on page 74 as 'Solution 8 (Plotting.)'

TABLE 5.—Correction to Tabulated Altitude for Minutes of Declination

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

Table 10. 'TABLE 5' OF AIR SIGHT REDUCTION TABLES

EXPLAINED WORK SHEET FOR SUN SIGHTS: AIR SIGHT REDUCTION TABLES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: Index Error of sextant, IE +/- , '; Ht of Eye ft/m, Lower or Upper limb of the sun 'LL/UL' ; Course °T/M/C, Speed Knots (for later plotting), DR Lat ° , ' N/S, Long ° , ' E/W, Clock error relative to UTC/GMT+/- h m s.
Chosen Latitude (C Lat) **° 00,0' N/S**. (DR Lat 'rounded off' to nearest degree.)

TIME

Clock's time of sight: h m s As per clock used, including error.
Clock's error(to UTC) ___h___m___s '+' Slow, '-' Fast
UTC of sight ___h___m___s For use in Almanac.

LHA

GHA (hour value) ° , ' Almanac, date page (right) 'SUN' opp Hour, UT of sight.
Increment ('+') _____°___,' Almanac's Yellow Pages, minutes page, seconds row.
Total GHA _____°___,' Sum of above two lines.
-360° if nec ° , ' If above line exceeds 360°
GHA Required ° , '
Chosen Longitude _____°___,' E/W '+'E,'-'W; change 'mins' value so LHA is whole No of°.
Total LHA ° 00,0' May be '-', 0° to 360°, or >360°
+/-360° if nec _____° 00,0' To get LHA to be between 0° and 360°
LHA Required _____° 00,0' For use in Sight Reduction Tables.

DECLINATION Almanac, date page, under 'SUN', next to GHA:
Dec (as per hour of our sight) 'hour value': N/S ° , ' Is it increasing or decreasing hourly?*
'd' factor....... Bottom of 'Dec' Column
d corrn (+/- *)Yellow Pages, 'mins' (sight time) _______,' Under 'v or d' Corrns. *'+' if Increasing.
Declination N/S___°___,' For use in Sight Reduction Tables.

SAME or CONTRARY ? Dec and Lat both N or S, or one N, other S.

Hc

Tables Hc value ° ' Select 'Tables' page for above Lat/Dec/SAME or CONTRARY/LHA as obtained above.
'd'(+/-...............) For use with mins of Dec in Table 5 to get next line...
D Correction (+/-) ______' From Table 5-see above lines
Hc Required ___°___' Sum/difference of above.

Zn

Tables value for Z: °. Found with Hc and d in Sight Reduction Tables.
Convert to Zn = °T. See the tables, outside the page margin, top and bottom left side,
e.g. Top: "(If DR) N Lat, LHA > 180°, Zn = Z; LHA < 180°, Zn = 360° - Z."
Bottom: "(If DR) S Lat, LHA > 180°, Zn=180°- Z; LHA < 180°, Zn = 180° + Z."

Ho

Sextant Angle ° , ' As read from the sextant's Index and Drum.
Index Error(+/-) , ' From earlier calibrating.
DIP(Ht of eye) (-) ________,' Almanac's loose leaf card or its first page.
Apparent Altitude ° , ' For use with same card.
Main correction(+/-) ________,' From card, choose correct 6 months column.
True Altitude (TA/**Ho**) ___°___,' To compare with Hc, above, to get Intercept.

Intercept

Ho ° , ' From above.
Hc______°___,' From above, before 'Zn'.
Intcpt , ' Difference of above two. TOWARDS/AWAY? 'Towards' if Ho>Hc.

Table 11. EXPLAINED WORK SHEET FOR AIR SIGHT REDUCTION TABLES (SUN)

WORK SHEET FOR A DAY'S (THREE) SUN SIGHTS: AIR SIGHT REDUCTION TABLES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: IE: +/- , '(-On,+Off) Eye ht: ft/m; Clock error: h m s (Fast/Slow?)
Course: °T/M/C; Speed: Knots; Upper or Lower Limb:

DR Latitude	° 'N/S	° 'N/S	° 'N/S
DR Longitude	° 'E/W	° 'E/W	° 'E/W
Chosen Latitude (Nearest whole degree)	° 00 ,0'N/S	° 00 ,0'N/S	° 00 ,0'N/S
TIME Clock time of sight	h m s	h m s	h m s
Clock error relative to UTC (-Fast,+Slow) +/-	h m s	h m s	h m s
Corrected UTC time of sight =	h m s	h m s	h m s
LHA GHA as at day, hour of sight; Almanac	° , '	° , '	° , '
+ Increment for mins/secs; Yellow pages +	° , '	° , '	° , '
Total GHA as at exact time of sight =	° , '	° , '	° , '
- 360° if nec; GHA to be between 0°/360° -	° , '	° , '	° , '
GHA Required =	° , '	° , '	° , '
Chosen Longitude (+ E, - W) +/-	° , 'E/W	° , 'E/W	° , 'E/W
Apparent LHA =	° 00 , 0'	° 00 , 0'	° 00 , 0'
+/- 360° if nec;LHA to be between 0°/360° +/-	° 00 , 0'	° 00 , 0'	° 00 , 0'
LHA =	° 00 , 0'	° 00 , 0'	°00 , 0'
DEC as at day, hour of sight; next to GHA.	N/S ° , '	N/S ° , '	N/S ° , '
(d = ?) factor; bottom of the column: Exclude	(d =)	(d =)	(d =)
Corrn;Yellow p's, mins (+ if Dec increasing) +/-	, '	, '	, '
TOTAL **DECLINATION** =	N/S ° , '	N/S ° , '	N/S ° , '
Lat and Dec, **SAME** or not i.e. **CONTRARY?**			
Hc : Sight Redt. Tables (Page from C Lat) Hc:	° '	° '	° '
(d+/-?)To be used with Dec's mins, Table 5.	(+/-)	(+/-)	(+/-)
d Correction. From Table 5. +/-	'	'	'
TOTAL **Hc** (Transfer to Intercept, below) =	° '	° '	° '
Z→Zn Top/bottom left corner of tables page.	Z °, Zn °	Z °, Zn °	Z °, Zn °
Ho : Sextant Angle (Hs)(Upper/Lower Limb?)	° , '	° , '	° , '
IE (+/-) +/-	, '	, '	, '
DIP (Eye Ht corrn; Almanac card/1 st page) -	, '	, '	, '
Apparent Altitude (AA) =	° , '	° , '	° , '
Main Corrn; Al'nac card: check month, top. +/-	, '	, '	, '
Ho Ho =	° , '	° , '	° , '
Intercept : Ho - Hc or Hc - Ho: Hc =	° , 0'	° , 0'	° ,0'
Intcpt (Difference);**TOWARDS** or **AWAY?** ~	T/A , '	T/A , '	T/A , '

Work Sheet 2. WORK SHEET FOR SUN SIGHTS; AIR SIGHT REDUCTION TABLES

Solution 8.a.

WORK SHEET FOR A DAY'S (THREE) SUN SIGHTS: AIR SIGHT REDUCTION TABLES

Date: 5 Dec '9x IE: +/- 3 ,4 '(-On,+Off) Eye ht: 10 ft/m; Clock error: h m 7 s (Fast/Slow?)
Course: 360 °T/M/C, Speed: 6 Knots; Upper or Lower Limb: Lower

DR Latitude	15°15 'N/S	° 'N/S	° 'N/S
DR Longitude	26°40 'E/W	° 'E/W	° 'E/W
Chosen Latitude (Nearest whole degree)	15 ° 00 ,0'N/S	° 00 ,0'N/S	° 00 ,0'N/S
TIME Clock time of sight	11 h 22 m 16 s	h m s	h m s
Clock error relative to UTC (-Fast,+Slow) +/-	h m -7 s	h m s	h m s
Corrected UTC time of sight =	11 h 22 m 09 s	h m s	h m s
LHA GHA as at day, hour of sight; Almanac	347°21 ,6'	° , '	° , '
+ Increment for mins/secs; Yellow pages +	5°32,3'	° , '	° , '
Total GHA as at exact time of sight =	352°53,9'	° , '	° , '
- 360° if nec; GHA to be between 0°/360° -	— ° , '	° , '	° , '
GHA Required =	352°53,9'	° , '	° , '
Chosen Longitude (+ E, - W) +/-	-26° 53,9'E/W	° , 'E/W	° , 'E/W
Apparent LHA =	326° 00 , 0'	° 00 , 0'	° 00 , 0'
+/- 360° if nec;LHA to be between 0°/360° +/-	— ° 00 , 0'	° 00 , 0'	° 00 , 0'
LHA =	326° 00 , 0'	° 00 , 0'	°00 , 0'
DEC as at day, hour of sight; next to GHA.	N/S 22°22,0'	N/S ° , '	N/S ° , '
(d = ?) factor; bottom of the column: Exclude	(d = 0,3)	(d =)	(d =)
Corrn;Yellow p's, mins (+ if Dec increasing) +/-	+ 0,1'	, '	, '
TOTAL **DECLINATION** =	N/S 22°22,1'	N/S ° , '	N/S ° , '
Lat and Dec, **SAME** or not i.e. **CONTRARY**?	CONTRARY		
Hc : Sight Redt. Tables (Page from C Lat) Hc:	40° 12 '	° '	° '
(d+/-?)To be used with Dec's mins, Table 5.	(+/- 42)	(+/-)	(+/-)
d Correction. From Table 5. +/-	— 15 '	'	'
TOTAL **Hc** (Transfer to Intercept, below) =	39° 57 '	° '	° '
Z→Zn Top/bottom left corner of tables page.	Z 137°, Zn 137°	Z °, Zn °	Z °, Zn °
Ho : Sextant Angle (Hs)(Upper/Lower Limb?)	39°40,4'	° , '	° , '
IE (+/-) +/-	— 3,4'	, '	, '
DIP (Eye Ht corrn; Almanac card/1st page) -	— 3,1'	, '	, '
Apparent Altitude (AA) =	39°33,9'	° , '	° , '
Main Corrn; Al'nac card: check month, top. +/-	+ 15,1'	, '	, '
Ho Ho =	39° 49 ,0'	° , '	° , '
Intercept : Ho - Hc or Hc - Ho: Hc =	39° 57 , 0'	° , 0'	° ,0'
Intcpt (Difference);**TOWARDS** or **AWAY**? ~	T/A 8,0'	T/A , '	T/A , '

Solution 8 from Example 8, page 35.

USE OF THE ALMANAC'S CONCISE SIGHT REDUCTION TABLES

The calculations to get Ho, Dec, LHA (and therefore chosen longitude) and the changing of DR Lat to chosen latitude are the same no matter which sight reduction tables are being used.

Notice that the Almanac's tables (pages 286-317 in the Almanac; example for Latitudes 30° to 35° is shown on pages 42 and 43 as Table 12) cover 6° of latitude per two facing pages, and that the left vertical column is for LHA's from 0° to 180° AND values of 'F°' up to 180°, and the right-hand column is for LHA's from 180° to 360°. The six vertical columns for each degree of latitude are used twice; once using the Chosen Latitude (e.g. 34°N or S) to select which page (Almanac's page 296, our page 42) and column to use in order to get values for 'A', 'B', and 'Z1', and secondly using the nearest whole number of 'A' (A° just obtained) in place of the latitude (e.g. in place of 34°) on the applicable page, for values of 'H', 'P' and 'Z2'. 'A' and 'F' (the sum or difference of 'B' and Dec) are just factors used to find values for Hc). (See where these figures are entered on the worksheet, and the notes of explanation.)

Put another way, each main column of the tables is subdivided into three columns, and each has two headings: the first is 'A/H' (A and H), the next 'B/P' and the third 'Z1/Z2'. So each of these 'double headed' columns can be used for either value, i.e. the first for 'A' or for 'H', the second for 'B' or for 'P' and the third for 'Z1' or for 'Z2'. The reason is that we look up the tables once using LHA and Lat to get 'A' (and 'B' and 'Z1'), then we go to the pages with the number just obtained for 'A' (A°) instead of Lat at the top of the column, and opposite 'F°' (the sum or difference of B and Dec) to find 'H' (and 'P' and 'Z2'). This 'H' value is a major component of what will become Hc.

To get Hc we need the corrections to H which we get from the 'Auxiliary Tables' (Almanac pages 316 and 317, shown on pages 44 and 45) using the minutes part of the value for F' (obtained from the first values extracted from these tables) and P°, for the first correction , and then the minutes part of A' with Z2 to get the second correction.

The need to make values positive or negative when necessary appears complex at first glance. This process is not difficult to follow but it is very important to get it right. See the worksheet notes where applicable. As with all worksheets, each line should have a prompt or explanation what to do.

A work sheet for use when using the Almanac's concise Sight Reduction Tables is shown on page 41. Note that this 'Work Sheet 3' is not just for the sun; there are a few additional spaces for data relating to the moon, planets, and stars. When doing sun sight resolutions using this work sheet, we simply ignore these other spaces.

EXAMPLE 9. On page 46 is the worked example (Solution 9.) of a sun sight calculation based on the following information recorded by a navigator:
Date is 28 February 199x, and DR at the time of the sight is Lat 38°17' North, Long 26°10' West, when the Log reading is 4633. Index error is 3' 'on' the scale; height of eye 3,5 metres;, clock error relative to UTC is 16 seconds fast. The sight is of the sun's lower limb while sailing 280° True at 7 knots (this information is recorded to facilitate plotting a fix with later sights, and for subsequent DR navigation). The sextant angle (SA/Hs) is 37°22,6'. Clock time of sight is 12h07m26s.

Follow it through step by step to make sure you see where each number is obtained, whether from the above information or from the Almanac (applicable extracts are in the 'Almanac' section in Part 2).

(This same example has been done using the Sine/Cosine method - see pages 56 and 57.)

Then try the Example Questions on page 47.

WORK SHEET FOR USE WITH ALMANAC'S SIGHT REDUCTION TABLES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: DR ° , 'N/S, ° , 'E/W; IE , ' 'on'/'off', Eye ht: ft/m,Body UL/LL
Course °T/M/C, Speed knots. Clock error to UTC h m s (-fast,+slow?),
Sight clock time h m s, Sight Time Corrected to UTC(GMT) h m s.

Ho		↓→ Apparent Altitude (AA)	° , '
Sextant Angle (Hs)	° , '	Main Correction (Al'nac card) or(+/-) Moon Correction, back of Al'nac (+)	° , '
Index Error +/-	° , '	Planet Correction (Almanac card)(+)	° , '
DIP (Height of eye) (-)	° , '	Moon HP Corrn (Back of Al'nac) (+)	° , '
Apparent Altitude (AA)	° , →	↑ Moon UL Corrn (-30.0' only if UL) (-)	° , '
Yachtmaster Ocean Services		**True Altitude (Ho)**	° , '

DECLINATION 'Dec' as at day, hour of sight; Almanac.	N/S ° , '	Increasing/Decreasing* hourly?
(d= ? at bottom of Dec column in Al'nac)	(d)	Not part of sum. See next line.
d Corrn, Yellow p's, Mins (time of sight)	+/- , '	*+ if Dec increasing, - if decreasing
TOTAL DECLINATION	N/S ° , '	
Chosen Latitude	°00,0' N/S	DR Lat rounded off, nearest degree
SAME or CONTRARY ?		Dec and Lat, SAME hemisphere?

LHA		
GHA (hr)Cel'stial Body, Al'nac	° , '	Date page, choose body's name column.
Increment, for mins/secs. +	° , '	Yellow p's; NB: Use correct column heading.
v:(factor) +/-Planets; +Moon. Corrn= +/-	° , '	Bottom of Planet column; or Moon, next to GHA; treat as d for Dec Corrn, Yellow p's.
Total GHA =	° , '	Sum of above lines.
- 360° if above line >360° -	° 00 ,0'	GHA must be between 0° and 360°.
Total GHA if different. =	° , '	GHA: angle, 0° westward, to meridian of GP.
SHA of Star +	° , '	Almanac, left day page, right hand column.
GHA of Celestial Body =	° , '	Omit this and above line if not for a star.
Chosen Longitude (+E, -W) +/-	° , '	DR degrees; mins to make LHA whole number.
LHA of Celestial Body =	° 00,0'	Angle, your meridian west to meridian of GP.
+/- 360° if necessary +/-	° 00,0'	LHA to be between 0° and 360°.
LHA Required =	° 00,0'	Now we can start with the Sight Redn. Tables.

USE OF SIGHT REDUCTION TABLE (SRT) *By Henton Jaaback*

1. Select SRT page with above 'Chosen Lat' Under Lat , opposite LHA (as above):
[A°= ° (nearest whole degree), A'= ']
B = ° ', Z1= , ° (B/Z1 '-' if 90°<LHA<270°)
Dec =+/- ° 'N/S ('+' SAME, '-' CONTRARY)
F =+/- ° '
(F°=+/- °[nearest degree], F'= ')

2. SRT page with A° value as column heading. Under A° opposite F°; H = ° , '
P° = °(nearest whole degree), Z2 = , °

3. Go to Auxiliary Table (pages 316/317). Under F' column opposite P° in left column, what is: Corrn 1 ? +/- , ' ('-' if F°<90° and F'>29', or if F°>90° and F'<30'. Otherwise '+')

4. Under A' column, opposite Z2 (right hand column), what is Corrn 2 ? +/-* , ' ('-' if A'<30')

Hc = ° , ' Z1 = , ° + or - as for B.
Corrn 1 = , ' Z2 = , ° (If F°'-', use 180°-Z2).
Corrn 2 = , ' (Z2 is '-' if F°>90°).
Hc = ° , ' Z = , ° Ignore '-' if applic.
Ho = ° , '
Intcpt = , '
TOWARDS if Ho>Hc, **AWAY** if Hc >Ho Zn = °T

IF DR in N LAT:
If LHA>180° Zn=Z
If LHA<180° Zn=360°-Z
IF DR in S LAT:
If LHA>180° Zn=180°-Z
If LHA<180° Zn=180°+Z

Work Sheet 3. ALMANAC'S SIGHT REDUCTION TABLES WORK SHEET (ALL ASTRO BODIES)

SIGHT REDUCTION TABLE

B: (–) for 90° < LHA < 270°
Dec: (–) for Lat. contrary name

Z_1 : same sign as B
Z_2 : (–) for F > 90°

Lat. / A		30°			31°			32°			33°			34°			35°			Lat. / A	
LHA / F		A / H	B / P	Z_1 / Z_2	A / H	B / P	Z_1 / Z_2	A / H	B / P	Z_1 / Z_2	A / H	B / P	Z_1 / Z_2	A / H	B / P	Z_1 / Z_2	A / H	B / P	Z_1 / Z_2	LHA	
°	°	° ′	° ′	°	° ′	° ′	°	° ′	° ′	°	° ′	° ′	°	° ′	° ′	°	° ′	° ′	°	°	°
0	180	0 00	60 00	90.0	0 00	59 00	90.0	0 00	58 00	90.0	0 00	57 00	90.0	0 00	56 00	90.0	0 00	55 00	90.0	180	360
1	179	0 52	60 00	89.5	0 51	59 00	89.5	0 51	58 00	89.5	0 50	57 00	89.5	0 50	56 00	89.4	0 49	55 00	89.4	181	359
2	178	1 44	59 59	89.0	1 43	58 59	89.0	1 42	57 59	88.9	1 41	56 59	88.9	1 39	55 59	88.9	1 38	54 59	88.9	182	358
3	177	2 36	59 58	88.5	2 34	58 58	88.5	2 33	57 58	88.4	2 31	56 58	88.4	2 29	55 58	88.3	2 27	54 58	88.3	183	357
4	176	3 28	59 56	88.0	3 26	58 56	87.9	3 23	57 56	87.9	3 21	56 56	87.8	3 19	55 56	87.8	3 17	54 56	87.7	184	356
5	175	4 20	59 54	87.5	4 17	58 54	87.4	4 14	57 54	87.3	4 12	56 54	87.3	4 09	55 54	87.2	4 06	54 54	87.1	185	355
6	174	5 12	59 52	87.0	5 08	58 52	86.9	5 05	57 52	86.8	5 02	56 51	86.7	4 58	55 51	86.6	4 55	54 51	86.6	186	354
7	173	6 04	59 49	86.5	6 00	58 49	86.4	5 56	57 48	86.3	5 52	56 48	86.2	5 48	55 48	86.1	5 44	54 48	86.0	187	353
8	172	6 55	59 45	86.0	6 51	58 45	85.9	6 47	57 45	85.7	6 42	56 45	85.6	6 38	55 44	85.5	6 33	54 44	85.4	188	352
9	171	7 47	59 42	85.5	7 42	58 41	85.3	7 37	57 41	85.2	7 32	56 40	85.1	7 27	55 40	84.9	7 22	54 40	84.8	189	351
10	170	8 39	59 37	85.0	8 34	58 37	84.8	8 28	57 36	84.7	8 22	56 36	84.5	8 17	55 36	84.4	8 11	54 35	84.2	190	350
11	169	9 31	59 32	84.4	9 25	58 32	84.3	9 19	57 31	84.1	9 13	56 31	84.0	9 06	55 30	83.8	9 00	54 30	83.6	191	349
12	168	10 22	59 27	83.9	10 16	58 26	83.8	10 09	57 26	83.6	10 03	56 25	83.4	9 56	55 25	83.2	9 48	54 24	83.0	192	348
13	167	11 14	59 21	83.4	11 07	58 20	83.2	11 00	57 20	83.0	10 52	56 19	82.8	10 45	55 18	82.6	10 37	54 18	82.5	193	347
14	166	12 06	59 15	82.9	11 58	58 14	82.7	11 50	57 13	82.5	11 42	56 12	82.3	11 34	55 12	82.1	11 26	54 11	81.9	194	346
15	165	12 57	59 08	82.4	12 49	58 07	82.1	12 41	57 06	81.9	12 32	56 05	81.7	12 23	55 04	81.5	12 14	54 04	81.3	195	345
16	164	13 49	59 01	81.8	13 40	57 59	81.6	13 31	56 58	81.4	13 22	55 57	81.1	13 13	54 57	80.9	13 03	53 56	80.7	196	344
17	163	14 40	58 53	81.3	14 31	57 51	81.1	14 21	56 50	80.8	14 12	55 49	80.5	14 02	54 48	80.3	13 51	53 47	80.1	197	343
18	162	15 31	58 44	80.8	15 22	57 43	80.5	15 12	56 42	80.2	15 01	55 40	80.0	14 51	54 39	79.7	14 40	53 38	79.4	198	342
19	161	16 23	58 35	80.2	16 12	57 34	79.9	16 02	56 32	79.7	15 51	55 31	79.4	15 40	54 30	79.1	15 28	53 29	78.8	199	341
20	160	17 14	58 26	79.7	17 03	57 24	79.4	16 52	56 23	79.1	16 40	55 21	78.8	16 28	54 20	78.5	16 16	53 19	78.2	200	340
21	159	18 05	58 16	79.1	17 53	57 14	78.8	17 42	56 12	78.5	17 29	55 11	78.2	17 17	54 09	77.9	17 04	53 08	77.6	201	339
22	158	18 56	58 05	78.6	18 44	57 03	78.2	18 31	56 01	77.9	18 19	55 00	77.6	18 06	53 58	77.3	17 52	52 56	77.0	202	338
23	157	19 47	57 54	78.0	19 34	56 52	77.7	19 21	55 50	77.3	19 08	54 48	77.0	18 54	53 46	76.6	18 40	52 44	76.3	203	337
24	156	20 37	57 42	77.4	20 24	56 40	77.1	20 11	55 38	76.7	19 57	54 36	76.4	19 42	53 34	76.0	19 28	52 32	75.7	204	336
25	155	21 28	57 30	76.9	21 14	56 27	76.5	21 00	55 25	76.1	20 46	54 23	75.7	20 31	53 21	75.4	20 15	52 19	75.0	205	335
26	154	22 19	57 17	76.3	22 04	56 14	75.9	21 49	55 12	75.5	21 34	54 09	75.1	21 19	53 07	74.7	21 03	52 05	74.4	206	334
27	153	23 09	57 03	75.7	22 54	56 00	75.3	22 39	54 57	74.9	22 23	53 55	74.5	22 07	52 52	74.1	21 50	51 50	73.7	207	333
28	152	23 59	56 49	75.1	23 44	55 46	74.7	23 28	54 43	74.3	23 11	53 40	73.8	22 54	52 37	73.4	22 37	51 35	73.0	208	332
29	151	24 50	56 34	74.5	24 33	55 31	74.1	24 17	54 27	73.6	23 59	53 24	73.2	23 42	52 22	72.8	23 24	51 19	72.4	209	331
30	150	25 40	56 19	73.9	25 23	55 15	73.4	25 05	54 11	73.0	24 48	53 08	72.5	24 29	52 05	72.1	24 11	51 03	71.7	210	330
31	149	26 29	56 02	73.3	26 12	54 58	72.8	25 54	53 54	72.3	25 35	52 51	71.9	25 17	51 48	71.4	24 57	50 45	71.0	211	329
32	148	27 19	55 45	72.6	27 01	54 41	72.2	26 42	53 37	71.7	26 23	52 33	71.2	26 04	51 30	70.7	25 44	50 27	70.3	212	328
33	147	28 09	55 27	72.0	27 50	54 23	71.5	27 31	53 19	71.0	27 11	52 15	70.5	26 50	51 12	70.0	26 30	50 08	69.6	213	327
34	146	28 58	55 09	71.4	28 38	54 04	70.8	28 19	53 00	70.3	27 58	51 56	69.8	27 37	50 52	69.3	27 16	49 49	68.8	214	326
35	145	29 47	54 49	70.7	29 27	53 44	70.2	29 06	52 40	69.6	28 45	51 36	69.1	28 24	50 32	68.6	28 01	49 29	68.1	215	325
36	144	30 36	54 29	70.0	30 15	53 24	69.5	29 54	52 19	68.9	29 32	51 15	68.4	29 10	50 11	67.9	28 47	49 07	67.4	216	324
37	143	31 25	54 08	69.4	31 03	53 03	68.8	30 41	51 58	68.2	30 19	50 53	67.7	29 56	49 49	67.2	29 32	48 45	66.6	217	323
38	142	32 13	53 46	68.7	31 51	52 40	68.1	31 28	51 35	67.5	31 05	50 30	66.9	30 41	49 26	66.4	30 17	48 23	65.9	218	322
39	141	33 02	53 23	68.0	32 39	52 17	67.4	32 15	51 12	66.8	31 51	50 07	66.2	31 27	49 03	65.6	31 02	47 59	65.1	219	321
40	140	33 50	53 00	67.2	33 26	51 53	66.6	33 02	50 48	66.0	32 37	49 43	65.4	32 12	48 38	64.9	31 46	47 34	64.3	220	320
41	139	34 37	52 35	66.5	34 13	51 29	65.9	33 48	50 23	65.3	33 23	49 17	64.7	32 57	48 13	64.1	32 30	47 09	63.5	221	319
42	138	35 25	52 09	65.8	35 00	51 03	65.1	34 34	49 56	64.5	34 08	48 51	63.9	33 42	47 46	63.3	33 14	46 42	62.7	222	318
43	137	36 12	51 43	65.0	35 46	50 36	64.3	35 20	49 29	63.7	34 53	48 24	63.1	34 26	47 19	62.5	33 58	46 15	61.9	223	317
44	136	36 59	51 15	64.2	36 33	50 08	63.6	36 06	49 01	62.9	35 38	47 55	62.3	35 10	46 51	61.6	34 41	45 46	61.0	224	316
45	135	37 46	50 46	63.4	37 19	49 39	62.7	36 51	48 32	62.1	36 22	47 26	61.4	35 53	46 21	60.8	35 24	45 17	60.2	225	315

Table 12. a. TOP PAGE OF SIGHT REDUCTION DATA FOR 30° TO 35°

Lat. / A		30°			31°			32°			33°			34°			35°			Lat. / A	
LHA / F		A / H	B / P	Z1 / Z2	A / H	B / P	Z1 / Z2	A / H	B / P	Z1 / Z2	A / H	B / P	Z1 / Z2	A / H	B / P	Z1 / Z2	A / H	B / P	Z1 / Z2	LHA	
°	°	° ′	° ′	°	° ′	° ′	°	° ′	° ′	°	° ′	° ′	°	° ′	° ′	°	° ′	° ′	°	°	°
45	135	37 46	50 46	63.4	37 19	49 39	62.7	36 51	48 32	62.1	36 22	47 26	61.4	35 53	46 21	60.8	35 24	45 17	60.2	225	315
46	134	38 32	50 16	62.6	38 04	49 08	61.9	37 36	48 02	61.2	37 06	46 56	60.6	36 37	45 51	59.9	36 06	44 46	59.3	226	314
47	133	39 18	49 45	61.8	38 49	48 37	61.1	38 20	47 30	60.4	37 50	46 24	59.7	37 19	45 19	59.1	36 48	44 15	58.4	227	313
48	132	40 04	49 13	61.0	39 34	48 05	60.2	39 04	46 58	59.5	38 33	45 51	58.8	38 02	44 46	58.2	37 30	43 42	57.5	228	312
49	131	40 49	48 39	60.1	40 19	47 31	59.4	39 48	46 24	58.6	39 16	45 18	57.9	38 44	44 12	57.2	38 11	43 08	56.6	229	311
50	130	41 34	48 04	59.2	41 03	46 56	58.5	40 31	45 49	57.7	39 59	44 42	57.0	39 26	43 37	56.3	38 52	42 33	55.6	230	310
51	129	42 18	47 28	58.3	41 46	46 20	57.5	41 14	45 12	56.8	40 41	44 06	56.1	40 07	43 01	55.4	39 32	41 57	54.7	231	309
52	128	43 02	46 50	57.4	42 29	45 42	56.6	41 56	44 34	55.9	41 22	43 28	55.1	40 47	42 23	54.4	40 12	41 19	53.7	232	308
53	127	43 46	46 11	56.4	43 12	45 03	55.6	42 38	43 55	54.9	42 03	42 49	54.1	41 28	41 44	53.4	40 52	40 41	52.7	233	307
54	126	44 29	45 31	55.5	43 54	44 22	54.7	43 19	43 15	53.9	42 44	42 09	53.1	42 07	41 04	52.4	41 30	40 01	51.7	234	306
55	125	45 11	44 49	54.5	44 36	43 40	53.7	44 00	42 33	52.9	43 24	41 27	52.1	42 46	40 23	51.4	42 09	39 19	50.7	235	305
56	124	45 53	44 05	53.5	45 17	42 57	52.6	44 40	41 50	51.8	44 03	40 44	51.1	43 25	39 40	50.3	42 46	38 37	49.6	236	304
57	123	46 35	43 20	52.4	45 58	42 11	51.6	45 20	41 05	50.8	44 42	39 59	50.0	44 03	38 55	49.3	43 24	37 53	48.5	237	303
58	122	47 16	42 33	51.3	46 38	41 25	50.5	45 59	40 18	49.7	45 20	39 13	48.9	44 40	38 09	48.2	44 00	37 07	47.5	238	302
59	121	47 56	41 44	50.2	47 17	40 36	49.4	46 38	39 30	48.6	45 58	38 25	47.8	45 17	37 22	47.1	44 36	36 20	46.3	239	301
60	120	48 35	40 54	49.1	47 56	39 46	48.3	47 16	38 40	47.5	46 35	37 36	46.7	45 53	36 33	45.9	45 11	35 32	45.2	240	300
61	119	49 14	40 01	47.9	48 34	38 54	47.1	47 53	37 48	46.3	47 11	36 45	45.5	46 29	35 42	44.7	45 46	34 42	44.0	241	299
62	118	49 53	39 07	46.8	49 11	38 00	45.9	48 29	36 55	45.1	47 46	35 52	44.3	47 03	34 50	43.6	46 19	33 50	42.8	242	298
63	117	50 30	38 11	45.5	49 48	37 04	44.7	49 05	36 00	43.9	48 21	34 57	43.1	47 37	33 57	42.3	46 53	32 57	41.6	243	297
64	116	51 07	37 13	44.3	50 23	36 07	43.4	49 40	35 03	42.6	48 55	34 01	41.8	48 10	33 01	41.1	47 25	32 03	40.4	244	296
65	115	51 43	36 12	43.0	50 58	35 07	42.2	50 14	34 04	41.3	49 28	33 03	40.6	48 43	32 04	39.8	47 56	31 07	39.1	245	295
66	114	52 18	35 10	41.7	51 33	34 06	40.8	50 47	33 04	40.0	50 01	32 04	39.3	49 14	31 05	38.5	48 27	30 09	37.8	246	294
67	113	52 52	34 05	40.3	52 06	33 02	39.5	51 19	32 01	38.7	50 32	31 02	37.9	49 44	30 05	37.2	48 56	29 10	36.5	247	293
68	112	53 25	32 59	38.9	52 38	31 56	38.1	51 50	30 57	37.3	51 02	29 59	36.6	50 14	29 03	35.8	49 25	28 09	35.2	248	292
69	111	53 57	31 50	37.5	53 09	30 49	36.7	52 21	29 50	35.9	51 32	28 53	35.2	50 43	27 59	34.5	49 53	27 06	33.8	249	291
70	110	54 28	30 39	36.1	53 39	29 39	35.2	52 50	28 42	34.5	52 00	27 46	33.8	51 10	26 53	33.1	50 20	26 02	32.4	250	290
71	109	54 58	29 25	34.6	54 08	28 27	33.8	53 18	27 31	33.0	52 28	26 38	32.3	51 37	25 46	31.6	50 46	24 56	31.0	251	289
72	108	55 27	28 09	33.0	54 37	27 13	32.2	53 46	26 19	31.5	52 54	25 27	30.8	52 03	24 37	30.2	51 10	23 49	29.5	252	288
73	107	55 55	26 51	31.4	55 03	25 57	30.7	54 12	25 04	30.0	53 19	24 14	29.3	52 27	23 26	28.7	51 34	22 40	28.1	253	287
74	106	56 21	25 31	29.8	55 29	24 39	29.1	54 36	23 48	28.4	53 43	23 00	27.8	52 50	22 14	27.1	51 57	21 29	26.6	254	286
75	105	56 46	24 09	28.2	55 53	23 18	27.5	55 00	22 30	26.8	54 06	21 44	26.2	53 12	21 00	25.6	52 18	20 17	25.0	255	285
76	104	57 10	22 44	26.5	56 16	21 56	25.8	55 22	21 10	25.2	54 28	20 26	24.6	53 33	19 44	24.0	52 38	19 04	23.5	256	284
77	103	57 33	21 17	24.8	56 38	20 31	24.1	55 43	19 48	23.5	54 48	19 06	23.0	53 53	18 27	22.4	52 57	17 49	21.9	257	283
78	102	57 54	19 48	23.0	56 59	19 05	22.4	56 03	18 24	21.9	55 07	17 45	21.3	54 11	17 08	20.8	53 15	16 32	20.3	258	282
79	101	58 13	18 17	21.2	57 17	17 37	20.7	56 21	16 59	20.1	55 25	16 22	19.6	54 28	15 48	19.2	53 31	15 15	18.7	259	281
80	100	58 32	16 44	19.4	57 35	16 07	18.9	56 38	15 32	18.4	55 41	14 58	17.9	54 44	14 26	17.5	53 47	13 56	17.1	260	280
81	99	58 48	15 10	17.6	57 51	14 36	17.1	56 53	14 03	16.6	55 56	13 33	16.2	54 58	13 03	15.8	54 00	12 36	15.4	261	279
82	98	59 03	13 33	15.7	58 05	13 02	15.3	57 07	12 33	14.9	56 09	12 06	14.5	55 11	11 40	14.1	54 13	11 14	13.8	262	278
83	97	59 16	11 55	13.8	58 18	11 28	13.4	57 19	11 02	13.0	56 21	10 38	12.7	55 22	10 14	12.4	54 24	9 52	12.1	263	277
84	96	59 28	10 16	11.9	58 29	9 52	11.5	57 30	9 30	11.2	56 31	9 09	10.9	55 32	8 49	10.6	54 33	8 29	10.4	264	276
85	95	59 37	8 35	9.9	58 38	8 15	9.6	57 39	7 56	9.4	56 40	7 39	9.1	55 41	7 22	8.9	54 41	7 06	8.7	265	275
86	94	59 46	6 53	8.0	58 46	6 37	7.7	57 47	6 22	7.5	56 47	6 08	7.3	55 48	5 54	7.1	54 48	5 41	7.0	266	274
87	93	59 52	5 11	6.0	58 52	4 59	5.8	57 52	4 47	5.6	56 53	4 36	5.5	55 53	4 26	5.4	54 53	4 16	5.2	267	273
88	92	59 56	3 28	4.0	58 57	3 19	3.9	57 57	3 12	3.8	56 57	3 05	3.7	55 57	2 58	3.6	54 57	2 51	3.5	268	272
89	91	59 59	1 44	2.0	58 59	1 40	1.9	57 59	1 36	1.9	56 59	1 32	1.8	55 59	1 29	1.8	54 59	1 26	1.7	269	271
90	90	60 00	0 00	0.0	59 00	0 00	0.0	58 00	0 00	0.0	57 00	0 00	0.0	56 00	0 00	0.0	55 00	0 00	0.0	270	270

N. Lat.: for LHA > 180°... $Z_n = Z$
for LHA < 180°... $Z_n = 360° - Z$

S. Lat.: for LHA > 180°... $Z_n = 180° - Z$
for LHA < 180°... $Z_n = 180° + Z$

Table 12. b. BOTTOM PAGE OF SIGHT REDUCTION DATA FOR 30° TO 35°

AUXILIARY TABLE

F < 90° and F′ > 29′ : (–) corr.
F > 90° and F′ < 30′ : (–) corr.

A′ < 30′ : (–) corr.

F′ / A′	1′	2′	3′	4′	5′	6′	7′	8′	9′	10′	11′	12′	13′	14′	15′	16′	17′	18′	19′	20′	21′	22′	23′	24′	25′	26′	27′	28′	29′	30′	F′ / A′
	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	
P°	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	Z_2°
1	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	0	1	1	89
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	88
3	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	87
4	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	86
5	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	85
6	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	84
7	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	83
8	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	4	82
9	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	5	5	81
10	0	0	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	80
11	0	0	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	79
12	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	6	78
13	0	0	1	1	1	1	2	2	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5	5	6	6	6	6	7	7	77
14	0	0	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	76
15	0	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	8	8	75
16	0	1	1	1	1	2	2	2	2	3	3	3	4	4	4	4	5	5	5	6	6	6	6	7	7	7	7	8	8	8	74
17	0	1	1	1	1	2	2	2	3	3	3	4	4	4	4	5	5	5	6	6	6	6	7	7	7	8	8	8	8	9	73
18	0	1	1	1	2	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	6	7	7	7	8	8	8	9	9	9	72
19	0	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	7	8	8	8	9	9	9	10	71
20	0	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	10	70
21	0	1	1	1	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	10	11	69
22	0	1	1	1	2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	7	8	8	9	9	9	10	10	10	11	11	68
23	0	1	1	2	2	2	3	3	4	4	4	5	5	5	6	6	7	7	7	8	8	9	9	9	10	10	11	11	11	12	67
24	0	1	1	2	2	2	3	3	4	4	4	5	5	6	6	7	7	7	8	8	9	9	9	10	10	11	11	11	12	12	66
25	0	1	1	2	2	3	3	3	4	4	5	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	11	12	12	13	65
26	0	1	1	2	2	3	3	4	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	11	11	11	12	12	13	13	64
27	0	1	1	2	2	3	3	4	4	5	5	5	6	6	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	14	63
28	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	12	12	13	13	14	14	62
29	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	61
30	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	60
31	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	59
32	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	10	10	11	11	12	12	13	13	14	14	15	15	16	58
33	1	1	2	2	3	3	4	4	5	5	6	7	7	8	8	9	9	10	10	11	11	12	13	13	14	14	15	15	16	16	57
34	1	1	2	2	3	3	4	4	5	6	6	7	7	8	8	9	10	10	11	11	12	12	13	13	14	15	15	16	16	17	56
35	1	1	2	2	3	3	4	5	5	6	6	7	7	8	9	9	10	10	11	11	12	13	13	14	14	15	15	16	17	17	55
36	1	1	2	2	3	4	4	5	5	6	6	7	8	8	9	9	10	11	11	12	12	13	14	14	15	15	16	16	17	18	54
37	1	1	2	2	3	4	4	5	5	6	7	7	8	8	9	10	10	11	11	12	13	13	14	14	15	16	16	17	17	18	53
38	1	1	2	2	3	4	4	5	6	6	7	7	8	9	9	10	10	11	12	12	13	14	14	15	15	16	17	17	18	18	52
39	1	1	2	3	3	4	4	5	6	6	7	8	8	9	9	10	11	11	12	13	13	14	14	15	16	16	17	18	18	19	51
40	1	1	2	3	3	4	4	5	6	6	7	8	8	9	10	10	11	12	12	13	13	14	15	15	16	17	17	18	19	19	50

Table 13. a. TOP PAGE OF AUXILIARY TABLES

F′/A′	1′ 59	2′ 58	3′ 57	4′ 56	5′ 55	6′ 54	7′ 53	8′ 52	9′ 51	10′ 50	11′ 49	12′ 48	13′ 47	14′ 46	15′ 45	16′ 44	17′ 43	18′ 42	19′ 41	20′ 40	21′ 39	22′ 38	23′ 37	24′ 36	25′ 35	26′ 34	27′ 33	28′ 32	29′ 31	30′ 30	F′/A′
P °	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	Z_2 °
41	1	1	2	3	3	4	5	5	6	7	7	8	9	9	10	10	11	12	12	13	14	14	15	16	16	17	18	18	19	20	49
42	1	1	2	3	3	4	5	5	6	7	7	8	9	9	10	11	11	12	13	13	14	15	15	16	17	17	18	19	19	20	48
43	1	1	2	3	3	4	5	5	6	7	8	8	9	10	10	11	12	12	13	14	14	15	16	16	17	18	18	19	20	20	47
44	1	1	2	3	3	4	5	6	6	7	8	8	9	10	10	11	12	13	13	14	15	15	16	17	17	18	19	19	20	21	46
45	1	1	2	3	4	4	5	6	6	7	8	8	9	10	11	11	12	13	13	14	15	16	16	17	18	18	19	20	21	21	45
46	1	1	2	3	4	4	5	6	6	7	8	9	9	10	11	12	12	13	14	14	15	16	17	17	18	19	19	20	21	22	44
47	1	1	2	3	4	4	5	6	7	7	8	9	10	10	11	12	12	13	14	15	15	16	17	18	18	19	20	20	21	22	43
48	1	1	2	3	4	4	5	6	7	7	8	9	10	10	11	12	13	13	14	15	16	16	17	18	19	19	20	21	22	22	42
49	1	2	2	3	4	5	5	6	7	8	8	9	10	11	11	12	13	14	14	15	16	17	17	18	19	20	20	21	22	23	41
50	1	2	2	3	4	5	5	6	7	8	8	9	10	11	11	12	13	14	15	15	16	17	18	18	19	20	21	21	22	23	40
51	1	2	2	3	4	5	5	6	7	8	9	9	10	11	12	12	13	14	15	16	16	17	18	19	19	20	21	22	23	23	39
52	1	2	2	3	4	5	6	6	7	8	9	9	10	11	12	13	13	14	15	16	17	17	18	19	20	20	21	22	23	24	38
53	1	2	2	3	4	5	6	6	7	8	9	10	10	11	12	13	14	14	15	16	17	18	18	19	20	21	22	22	23	24	37
54	1	2	2	3	4	5	6	6	7	8	9	10	11	11	12	13	14	15	15	16	17	18	19	19	20	21	22	23	23	24	36
55	1	2	2	3	4	5	6	7	7	8	9	10	11	11	12	13	14	15	16	16	17	18	19	20	20	21	22	23	24	25	35
56	1	2	2	3	4	5	6	7	7	8	9	10	11	12	12	13	14	15	16	17	17	18	19	20	21	22	22	23	24	25	34
57	1	2	3	3	4	5	6	7	8	8	9	10	11	12	13	13	14	15	16	17	18	18	19	20	21	22	23	23	24	25	33
58	1	2	3	3	4	5	6	7	8	8	9	10	11	12	13	14	14	15	16	17	18	19	20	20	21	22	23	24	25	25	32
59	1	2	3	3	4	5	6	7	8	9	9	10	11	12	13	14	15	15	16	17	18	19	20	21	21	22	23	24	25	26	31
60	1	2	3	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	16	17	18	19	20	21	22	23	23	24	25	26	30
61	1	2	3	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	17	17	18	19	20	21	22	23	24	24	25	26	29
62	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14	15	16	17	18	19	19	20	21	22	23	24	25	26	26	28
63	1	2	3	4	4	5	6	7	8	9	10	11	12	12	13	14	15	16	17	18	19	20	20	21	22	23	24	25	26	27	27
64	1	2	3	4	4	5	6	7	8	9	10	11	12	13	13	14	15	16	17	18	19	20	21	22	22	23	24	25	26	27	26
65	1	2	3	4	5	5	6	7	8	9	10	11	12	13	14	15	15	16	17	18	19	20	21	22	23	24	24	25	26	27	25
66	1	2	3	4	5	5	6	7	8	9	10	11	12	13	14	15	16	16	17	18	19	20	21	22	23	24	25	26	26	27	24
67	1	2	3	4	5	6	6	7	8	9	10	11	12	13	14	15	16	17	17	18	19	20	21	22	23	24	25	26	27	28	23
68	1	2	3	4	5	6	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	21	22	23	24	25	26	27	28	22
69	1	2	3	4	5	6	7	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	21	22	23	24	25	26	27	28	21
70	1	2	3	4	5	6	7	8	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	23	24	25	26	27	28	20
71	1	2	3	4	5	6	7	8	9	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	26	27	28	19
72	1	2	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	18
73	1	2	3	4	5	6	7	8	9	10	11	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	17
74	1	2	3	4	5	6	7	8	9	10	11	12	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	16
75	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	15
76	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	16	17	18	19	20	21	22	23	24	25	26	27	28	29	14
77	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	20	21	22	23	24	25	26	27	28	29	13
78	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	22	23	24	25	26	27	28	29	12
79	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	27	28	29	11
80	1	2	,	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	10

For P > 80°, use 80°. For Z_2 < 10°, use 10°.

Table 13. b. BOTTOM PAGE OF AUXILIARY TABLES

Solution 9.

WORK SHEET FOR USE WITH ALMANAC'S SIGHT REDUCTION TABLES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 28/2 DR 38° 17 'N/~~S~~, 26° 10 '~~E~~/W; IE 3,0' 'on'/'~~off~~', Eye ht: 14 ~~ft~~/m, Body Sun ~~UL~~/LL
Course 280 °T/~~M/C~~, Speed 7 knots. Clock error to UTC h m 16 s (-fast, ~~+slow~~?),
Sight clock time 12 h 07 m 26 s, Sight Time Corrected to UTC(GMT) 12 h 07 m 10 s.

Ho		↓ → Apparent Altitude (AA)	37°16,4'
Sextant Angle (Hs)	37°22,6'	Main Correction (Al'nac card) or(+/-) Moon Correction, back of Al'nac (+)	+° 15,0'
Index Error +/-	- 3,0'	Planet Correction (Almanac card)(+)	° , '
DIP (Height of eye) (-)	- 3,2'	Moon HP Corrn (Back of Al'nac) (+)	° , '
Apparent Altitude (AA)	37°16,4 →	↑ Moon UL Corrn (-30.0' only if UL) (-)	° , '
Yachtmaster Ocean Services		**True Altitude (Ho)**	37°31,4'

DECLINATION 'Dec' as at day, hour of sight; Almanac.	~~N~~/S 7°56,6'	Increasing/Decreasing* hourly? ✓ (Decreasing)
(d= ? at bottom of Dec column in Al'nac)	(d 0,9)	Not part of sum. See next line.
d Corrn, Yellow p's, Mins (time of sight)	+/- — 0,1'	*+ if Dec increasing, - if decreasing ✓
TOTAL DECLINATION	~~N~~/S 7°56,0'	Rounded off - nearest whole minute
Chosen Latitude	38 °00,0' N/~~S~~	DR Lat rounded off, nearest degree
SAME or CONTRARY ?	CONTRARY	Dec and Lat, SAME hemisphere?

LHA		
GHA (hr)Cel'stial Body, Al'nac	356°51,3'	Date page, choose body's name column.
Increment, for mins/secs. +	1°47,5'	Yellow p's; NB: Use correct column heading.
v:(factor) +/-Planets; +Moon. Corrn= +/-	° , '	Bottom of Planet column; or Moon, next to GHA; treat as d for Dec Corrn, Yellow p's.
Total GHA =	358°38,8'	Sum of above lines.
- 360° if above line >360° -	° 00,0'	GHA must be between 0° and 360°.
Total GHA if different. =	° , '	GHA: angle, 0° westward, to meridian of GP.
SHA of Star +	° , '	Almanac, left day page, right hand column.
GHA of Celestial Body =	358°38,8'	Omit this and above line if not for a star.
Chosen Longitude (~~+E~~, -W) +/-	-26°38,8'	DR degrees; mins to make LHA whole number.
LHA of Celestial Body =	332° 00,0'	Angle, your meridian west to meridian of GP.
+/- 360° if necessary +/-	° 00,0'	LHA to be between 0° and 360°.
LHA Required =	332° 00,0'	Now we can start with the Sight Redn. Tables.

USE OF SIGHT REDUCTION TABLE (SRT) *By Henton Jaaback*

1. Select SRT page with above 'Chosen Lat' Under Lat , opposite LHA (as above):
[A°=22° (nearest whole degree), A'=43']
B = +48°30', Z1=71,9° (B/Z1 '-' if 90°<LHA<270°)
Dec = ~~+~~/- 7°56' ~~N~~/S (~~+ SAME~~, '-' CONTRARY)
F = +/- 40°34'
(F°=+/-41° [nearest degree], F'=34')

2. SRT page with A° value as column heading. Under A° opposite F°; H = 37 °28,0'
P° = 62 °(nearest whole degree), Z2 = 72,0°

3. Go to Auxiliary Table (pages 316/317). Under F' column opposite P° in left column, what is: Corrn 1 ? ~~+~~/- 23,0' ('-' if F°<90° and F'>29', or if F°>90° and F'<30'. Otherwise '+')

4. Under A' column, opposite Z2 (right hand column), what is Corrn 2 ? +/~~-~~ 5,0' ('-' if A'<30')

Hc = 37°28,0'
Corrn 1 = - 23,0'
Corrn 2 = + 5,0'
Hc = 37°10,0'
Ho = 37°31,4'
Intcpt = 21,4' TOWARDS
TOWARDS if Ho>Hc, ~~AWAY~~ if Hc >Ho

Z1 = +71,9° + or - as for B.
Z2 = +72,0° (If F°'-', use 180°-Z2).
(Z2 is '-' if F°>90°).
Z = 143,9° Ignore '-' if applic.

IF DR in N LAT:
If LHA>180° Zn=Z
If LHA<180° Zn=360°-Z
IF DR in S LAT:
If LHA>180° Zn=180°-Z
If LHA<180° Zn=180°+Z

Zn = 144°T (To nearest degree.)

Solution 9 from Example 9, page 40.

More Example Questions - try them on your own. Only when you have finished and got an answer, or are really and truly 'stuck', should you turn to the 'Solutions' section in Part 2. The answers to Examples 10 to 14 appear as Solutions 10 to 14 respectively; Solutions 10 to 12 make use of the Air Sight Reduction Tables method, and Solutions 13 and 14 use the Almanac Sight Reduction Table method.

EXAMPLE 10

Look back at the information ending on page 40. Assume the vessel maintained her course and speed, and a second sight of the sun was taken at 14h52m43s. Index error, height of eye, sun's lower limb, and clock error remain the same. The new DR is 38°20' N, 26°30' W, and Log 4653. The sextant angle for this sight was 41°51,5'. Find the Chosen Lat/Chosen Long, the Zn, Intercept, and whether it was Towards or Away.

EXAMPLE 11

As for Example 10 above, a third sight was taken at 18h22m58s from DR 38°23' N, 26°55' W, Log 4677. The sextant angle was 13°10,0'. What are the plotting details arising from this sight?

EXAMPLE 12

On 31 August 199x with height of eye 4 metres, index error 2,7' 'on' the scale, clock 1 minute 52 seconds slow (to UTC), using the Sun's lower limb, course 360° T and speed 6,2 knots, three sights were taken during the day:

1. DR Lat 30°40' S, Long 80°12' E; Sextant angle 45°10,2'; time of sight as per clock 05h05m26s. Log 17 281 M.
2. DR Lat 30°31' S, Long 80°12' E; Sextant angle 50°38,2'; time of sight as per clock 06h36m47s. Log 17 290 M.
3. DR Lat 30°20' S, Long 80°12' E; Sextant angle 43°53,0'; time of sight as per clock 08h20m11s. Log 17 301 M.

Resolve the sights detail for the relevant plotting information.

EXAMPLE 13

On 5 December 199x, using the Sun's UL, (NB: UL) and clock error 2 hours and 7 seconds fast in relation to UTC, I.E. 3,8' 'off', height of eye 3 metres, course 300° T, speed 5 knots,the detail from three sights during the day was as follows:

1. Sight 1; SA 43°12,3'; DR Lat 10°20 'S, Long 165°17' E; Clock time of sight 23h38m18s (4 Dec UT). Log 8106 M.
2. Sight 2; SA 78°10,5'; DR Lat 10°13' S, Long 165°12' E; Clock time 02h52m35s. Log 8 120 M.
3. Sight 3; SA 65°06,7'; DR Lat 10°08' S, Long 165° 07' E; Clock time 04h22m31s. Log 8 130 m.

Resolve the above info for plotting the fix as at the latest (most recent) time.

EXAMPLE 14

The date, 20 June 199x. The detail for three sun sights taken during the day are set out below. Details common to all three are: Course 315°T; IE 2,0' off, eye height 3,0 m, clock 23 seconds fast relative to UTC, and the lower limb of the sun was used. The individual sights detail was:

1. DR 30°45' S, 8°30' E; Log 8537 M; SA 26°00,7' at clock time 09h07m37s.
2. DR 30°32' S, 8°27' E; Log 8551 M; SA 35°46,3' at clock time 11h22m56s.
3. DR 30°18' S, 8°23' E; Log 8565 M; SA 25°53,7' at clock time 13h52m48s.

Resolve the three sights for the relevant plotting information.

NOTES

THE SPHERICAL (OR 'PZX') TRIANGLE

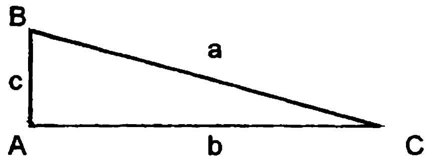
INTRODUCTION

This method of resolving a celestial navigation sight's detail serves as a quick and easy way to find Z and Hc without the need for the use of Sight Reduction Tables. It is an acceptable method for the Yachtmaster Ocean examination and can be used as a quick way of checking other methods used. Ideally suited for use with a scientific calculator, it can also be used when only scientific logarithmic and trigonometric tables are available.

THE TRIANGLE

Let's refresh from the beginning. A triangle has three sides! The three corners formed at the junction of the sides form angles which add up to 180°. So if one of the three angles is known, the sum of the other two must be the difference between 180° and the known angle. If two angles are known, by adding them and subtracting the answer from 180°, we get the third angle.

By convention, the three corners or angles are called A, B and C, and the sides opposite those angles are called a, b and c.



A = 90°
A + B + C = 180°
If B = 60°, then C = 30°

Fig. 37. THE TRIANGLE ABC

If one were asked to draw the above triangle, and no dimensions of sides' lengths were specified, the permutations would be endless. All the possibilities are similar- they will all be enlargements of the smallest triangle drawn. Geometrically this means that the ratios of corresponding sides are the same. Specific names are given to specific ratios and the specific ratios are with respect to either of the acute angles (e.g. 30° or 60° in the above triangle). To identify corresponding sides we use the terms 'hypotenuse' (hyp), 'adjacent' (adj), and 'opp' for 'opposite'.

The 'hyp' is always the side opposite the right angle (A).
For B, 'c' is adjacent and 'b' is opposite.
For C, 'b' is adjacent and 'c' is opposite.

Two examples of ratios are 'sine' (sin) and 'cosine' (cos) and they are defined as follows:

$$\sin = \frac{\text{opp}}{\text{hyp}} \qquad \cos = \frac{\text{adj}}{\text{hyp}}$$

Referring to the above triangle:

$$\sin 60°(B) = \frac{\text{length of b}}{\text{length of a}} \qquad \cos 60°(B) = \frac{\text{length of c}}{\text{length of a}}$$

$$\sin 30°(C) = \frac{\text{length of c}}{\text{length of a}} \qquad \cos 30°(C) = \frac{\text{length of b}}{\text{length of a}}$$

Our spherical triangle's sides are arcs (curves) of 'Great Circles'. However when viewed in the same plane as the great circle, the arcs (sides) are STRAIGHT LINES!

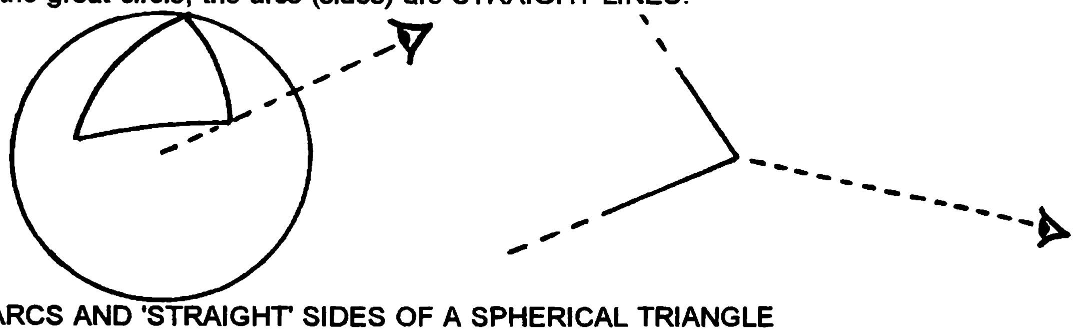
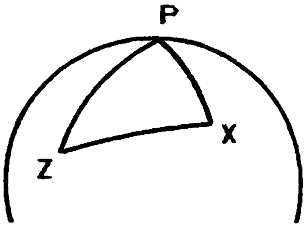


Fig. 38. ARCS AND 'STRAIGHT' SIDES OF A SPHERICAL TRIANGLE

If we were able to look at the corner of a spherical triangle from a point further away from that corner relative to the centre of the sphere, we would see that we were on the same planes as the two great circles whose arcs form the corner of the triangle. As we are on the same planes, the sides are straight lines! So the angle formed at their intersection is the same as it would be in a triangle on a flat surface. So the sum of the angles of a spherical triangle also add up to 180°, and the Sine and Cosine ratios remain valid.

THE NAVIGATION TRIANGLE

We are only really interested in a spherical triangle if the earth is the sphere and the triangle can help us navigate around it. We therefore refer to the NAVIGATION TRIANGLE which has three corners:
1. 'P' the pole, whether the North or the South pole.
2. 'Z' the position of the observer.
3. 'X' the geographic position of the celestial body. This is the position on the earth's surface which is in line with the centre of the earth and the centre of the celestial body.



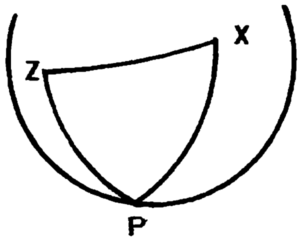
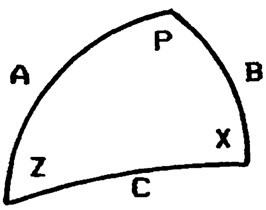


Fig. 39. THE CORNERS OF A NAVIGATION TRIANGLE

...and the three sides:
A. 'Co latitude' the difference between the observer's latitude and 90°. It is also known as 'Latitude Distance'.
B. 'Co declination' the difference between the declination of the celestial body and 90°.
C. 'Co altitude' the difference between the altitude (corrected sextant angle) of the celestial body and 90°. It is the same as Zenith Distance which we saw used with Meridian Passage (Noon) sight calculations in Chapter 2.



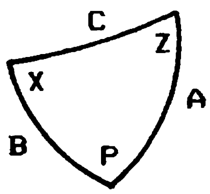


Fig. 40. THE SIDES OF A NAVIGATION TRIANGLE

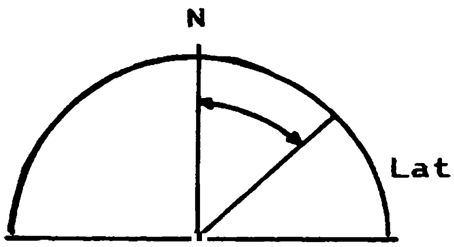


Fig. 41. CO LATITUDE

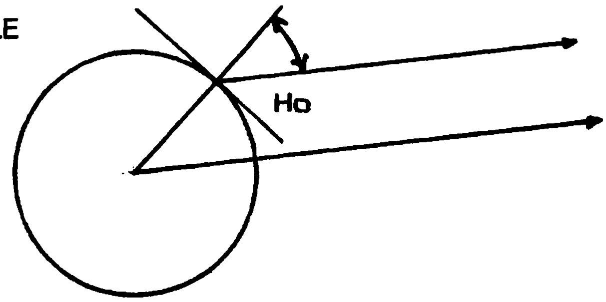


Fig. 42. CO ALTITUDE

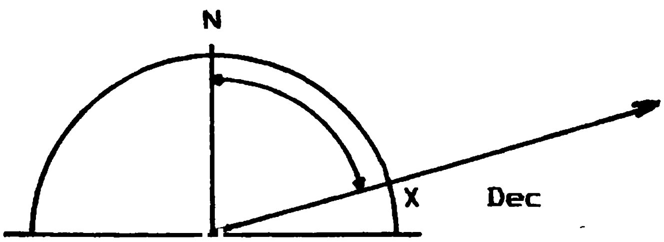


Fig. 43. CO DECLINATION

Notice that the angle formed at the pole between the observer's meridian (of which Co Latitude is a part) and the meridian on which Co Declination is located, is measured westward from the observer's meridian, and is called the LHA (Local Hour Angle) with which we are now familiar.

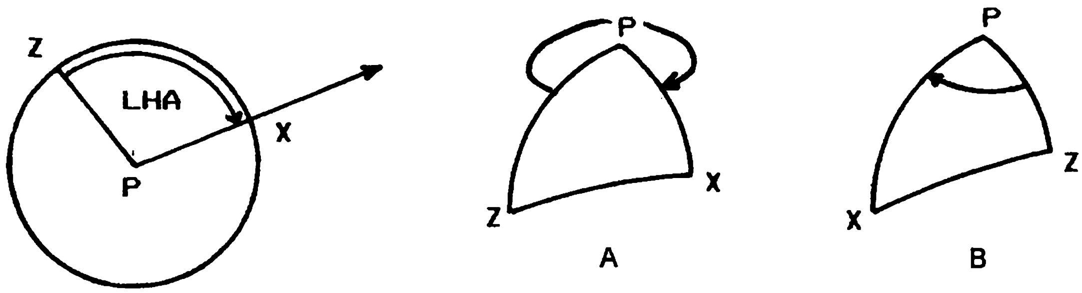


Fig. 44. THE LHA; A. GP EAST OF OBSERVER. B. GP WEST OF OBSERVER.

The angle formed at the observer, Z, between the Co Latitude (on the observer's meridian) and the Co Altitude (the great circle arc/line from the observer to the celestial body's GP) is called the Azimuth Angle; this angle is also called Z. Since it is one of the three angles of a triangle whose angles total 180°, the Azimuth Angle, Z, is always less than 180°.

The angle formed at 'X', the GP of the celestial body, plays no part in the solution of the navigation triangle so we can ignore it from now on.

In deciding which pole to use, we use the pole in the hemisphere in which the GP of the celestial body is located - regardless of which hemisphere the observer is located in. If the observer and the GP are both in the northern or both in the southern hemisphere, they are called 'SAME'. If they are in different hemispheres they are called 'CONTRARY'. Look at the permutations in the following diagrams:

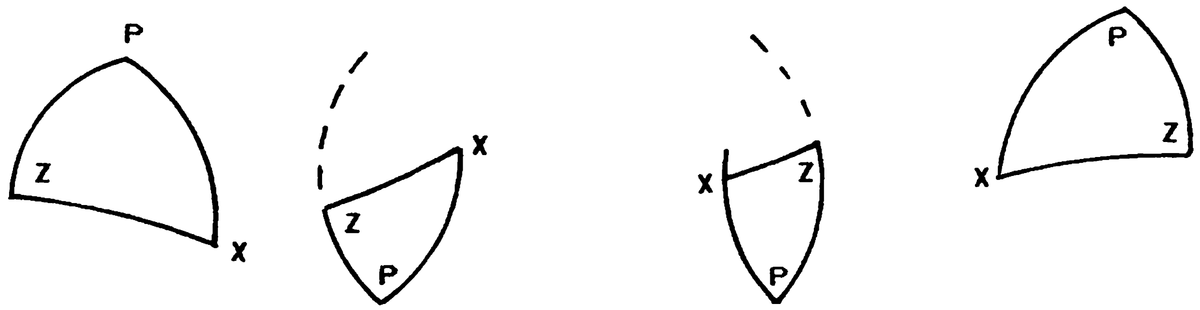


Fig. 45. AZIMUTH ANGLES - THE VARIATIONS

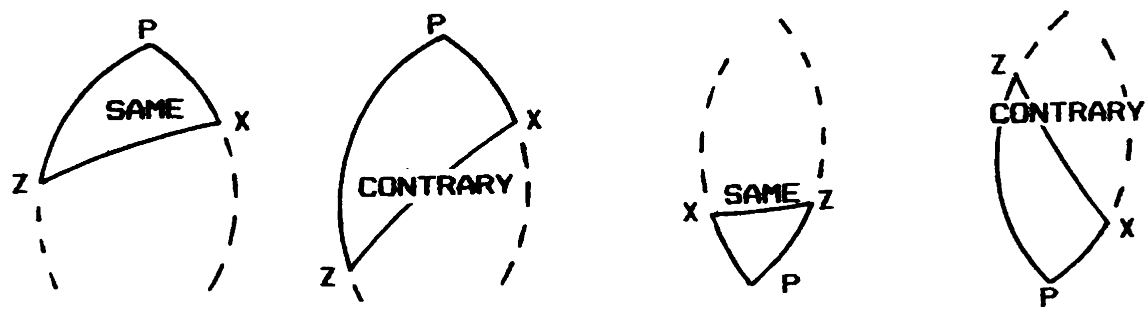


Fig. 46. 'SAME' AND 'CONTRARY' SITUATIONS

The LHA is always measured at a pole, from the observer's meridian westward, to the meridian on which the celestial body's GP is located.

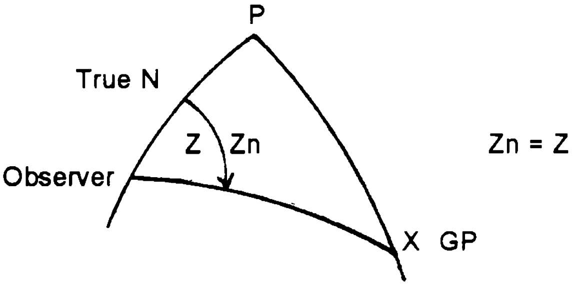


Fig. 47. GP AND POLE 'NORTH'; GP EAST OF OBSERVER; Zn = Z

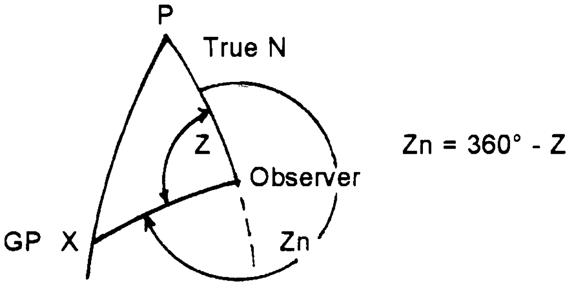


Fig. 48. GP AND POLE 'NORTH'; GP WEST OF OBSERVER; Zn = 360° - Z

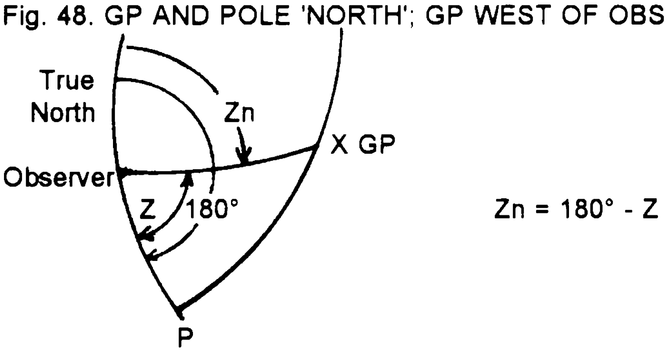


Fig. 49. GP AND POLE 'SOUTH', GP EAST OF OBSERVER; Zn = 180° - Z

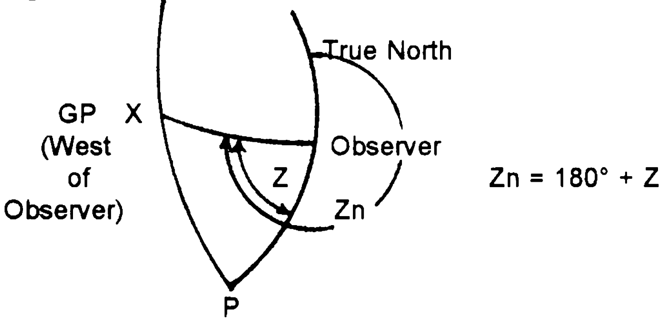


Fig. 50. GP AND POLE 'SOUTH'; GP WEST OF OBSERVER; Zn = 180° + Z

These relationships between Z and Zn are important as they apply in every method we use (except the Meridian Passage sight) to resolve sight details into plotting information. If we are using Sight Reduction Tables, the tables remind us on each page of what the Z/Zn relationship is. If we are using the 'Sine/Cosine' method to solve for elements of the Navigation Triangle, we can use a work sheet which will remind us of the relationship - how to get Zn from Z. If we have no work sheet we must be able to remember and re-draw the above four diagrams so that we can see for ourselves how to get Zn.

Before we can start to think of the trigonometry of calculating Z and Hc, we need to to recall how we get LHA. We need to know its exact value, just as we have to find the exact value for 'Dec' (Declination - see the bottom of page 16 and pages 18 and 19). Rather like finding LHA for Sight Reduction Tables methods, we begin by finding the GHA at the exact second that our sight took place. (See pages 30 to 32.) We then apply our DR longitude to get the LHA. Let's assume our GHA is found to be 234°56' and we apply a DR longitude of 43°21' (East -solid line, West -dotted line):

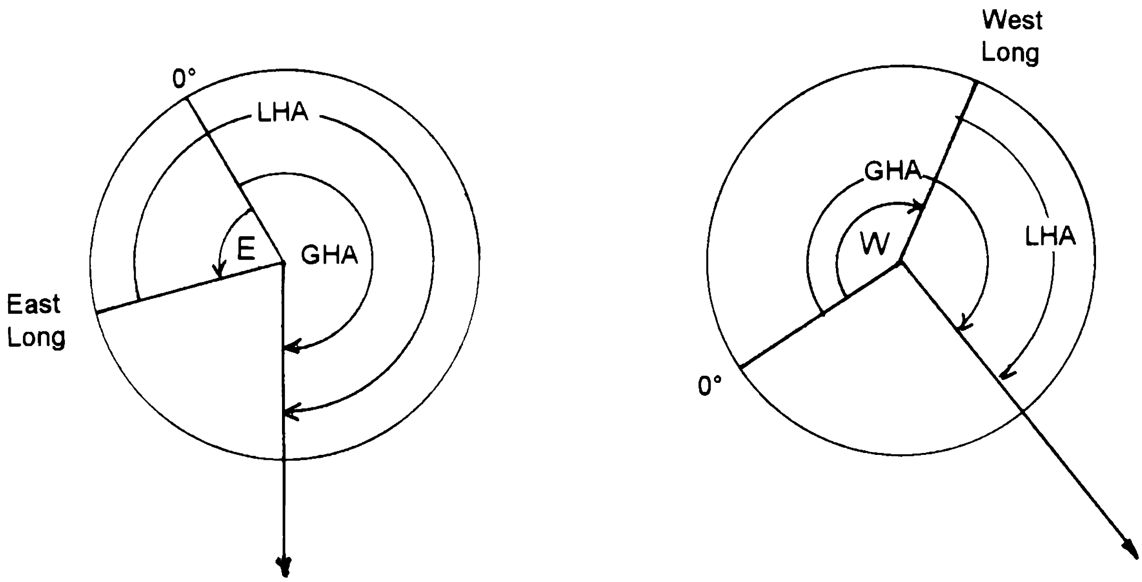


Fig. 51. LHA FROM GHA AND LONGITUDE

The resulting LHA can be any value from 000° to 360°. If, after adding East Longitude, or subtracting West Longitude, the LHA is more than 360° or a negative number (angle), we must subtract or add 360° respectively.

THE 'SINE/COSINE' METHOD

Having found the value of LHA and the Dec, we are able to use a formula to calculate the value of Hc. This obviates the need for Sight Reduction Tables and the need for Chosen Latitude/Chosen Longitude. It is:

$$\mathbf{Hc = Sine^{-1}\ \{[sine(Lat) \times sine(Dec)] + [cosine(Lat) \times cosine(Dec) \times cosine(LHA)]\}}$$

Where:

{ } is a number less than 1.
( ) is an angle.
Lat is the DR's Latitude. Lat is positive if North; it is negative if South.
Dec is the declination of the celestial body. It is positive if North and negative if South.

Once we have calculated our Hc, we use its value to calculate 'Zn' :

If LHA > 180°, $\mathbf{Zn = cos^{-1}\ X}$; if LHA < 180°, $\mathbf{Zn = 360° - cos^{-1}\ X}$

and $$X = \frac{\{[(sin(Dec) \times cos(Lat)] - [cos(Dec) \times cos(LHA) \times sin(Lat)]\}}{cos(Hc)}$$

Where:

X is a number less than or equal to 1. If X > +1, make X = +1; if X < -1, make X = -1.
( ) is an angle.
Lat is the DR latitude.
Dec is the declination of the celestial body. It is positive if North and negative if South.
Hc is the altitude of the celestial body as per calculation based on the DR position, NOT an AP/CP (Assumed or Chosen Position).

As with any other sight, we must convert the sextant angle to a True Altitude (Ho) and this can now be compared to the Hc obtained by the above calculation to get the intercept (and 'Towards or Away'). We can also calculate our 'Zn', and as this method does not use an AP/CP but is based on the DR position, we can plot the Azimuth and then the LOP from the DR.

Note that when using this method to check any other method, the magnitude of the intercept will be different and one may be 'Towards' while the other is 'Away' because one method uses the DR and the others an AP/CP. For the method to be meaningful as a check, use the AP/CP from other methods as the DR when using the Sine/Cosine method. The intercept answers should then be the same (or VERY nearly so).

Let's now see a work sheet for use with this method, and then actually do an example calculation. The example is the same one we did on page 46 (Solution 9) using the information given at the bottom of page 40 (Example 9). We will make one change for comparison purposes, and use the AP/CP from this data as the DR in the method we are about to use. Then the resulting Intercept information should be the same.

Page 55 shows a work sheet (Work Sheet 4) for use with the Sine/Cosine method.

Page 56 shows the example referred to above (Example 9) applied to a work sheet. Page 57 shows the Hc and Zn calculations. Compare the two methods' answers. The Azimuth, Zn, and Intercept will be the same, because we made the DR the same as the 'Assumed' or 'Chosen Position', the AP/CP. In other cases Zn may differ by up to 1°, but the intercepts will nearly always be different. This is because the intercept is calculated/ruled/measured from different places - the Sight Reduction Tables use the AP/CP, whereas the Sine/Cosine method uses the DR. When we plot the resulting lines of position, they will, however, be in the same place.)

Here are some more examples to try. See the Solutions section in Part 2 to check your answers.

Determine the values of Hc and Zn:

<u>EXAMPLE 15</u>
31 August 199x, DR 15°26,5' N, 130°14,8' W. Clock time of sight 18h38m53s; clock 41 seconds fast.

<u>EXAMPLE 16</u>
5 December 199x, DR 10°14,2' S, 80°35' E. Clock time of sight 05h22m16s; clock 28 seconds slow.

<u>EXAMPLE 17</u>
20 June 199x, DR 30°18,5' S, 8°42' E. Clock time of sight 09h07m48s; clock 9 seconds fast.

<u>EXAMPLE 18</u>
28 February 199x, DR 38°51' N, 26°28' W. Clock time of sight 11h52m37s; clock 15 seconds fast.

<u>EXAMPLE 19</u>
5 December 199x, DR 30°47' S, 165°20' E. Clock time of sight 00h38m01s; clock 44 seconds slow.

WORK SHEET FOR SINE/COSINE METHOD OF SIGHT RESOLUTION

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: DR ° 'N/S, ° 'E/W, IE , ' 'on'/'off' Ht of eye: ft/m, Course °T/M/C, Speed knots, Celestial Body (LL/UL). Clock error* to UTC: h m s (*-fast,+slow).Clock time of sight h m s.Time of sight corrected to UTC/GMT h m s

TA/Ho		→ App Alt (AA)	° , '
SA (Hs) as read from sextant, incl any error.	° , '	↑ Main Corrn (Almanac card; For Moon, see back of book)+/-	° , '
IE from sextant -'ON', +'OFF' +/-	, '	Planet Corrn (Al'nac card) +	° , '
DIP (Eye, Almanac card, right side)-	, '	HP Moon Corrn Back of Almanac +	° , '
App Alt (AA) =	° , '→	↑ UL Moon -30'	, '
		TA/Ho =	° , '

DECLINATION	
Dec as at hour of sight, Almanac date page, right, under SUN. Increasing? Y/N	N/S ° , '
d factor, bottom of Dec column; For use with Yellow pages, mins (time) of sight	(d =)
d Corrn; Yellow pages 'mins', under 'd or v', opposite is Corrn. (+ if Dec incr'sing)	+/- , '
TOTAL DECLINATION as at time of sight =	**N/S** ° , '

GHA		
GHA of body; Aries if a star:as at day, hr.	° , '	Al'nac, date page, under applic body.
Incremenet for minutes and seconds +	° , '	Yellow pages, mins, opp secs.
v factor : .... Date page; to find corrn 'Corrn' as for d factor of Dec +/-	, '	+ Moon (v, one of its 5 columns), +/- Planets (bottom of column)
GHA of celestial body sighted, or Aries =	° , '	Sum of above lines.
SHA of star (".........................") if applic +	° , '	Almanac, date page left side.
GHA of celestial body sighted =	° , '	Sum of above two lines.
- 360° if GHA above is greater than 360° -	° , '	An angle cannot be more than360°!
GHA Required =	° , '	
DR Longitude (+ if East, - if West) +/-	° , '	To get the angle from our DR's
LHA of celestial body sighted =	° , '	meridian to the meridian of the GP.
+/- 360° if necessary +/-	° , '	LHA to be between 0° and 360°
LHA Required =	° , '	For use in the formula below.

Hc:

Hc = Sin^{-1}{sin Lat x sin Dec** + cos Lat** x cos Dec** x cos LHA} =** , ° =____°__,__'

Where 'Lat' is Latitude, 'Dec' is Declination. **They are positive if North, negative if South.

Zn: If LHA > 180°, **Zn = cos^{-1} X**; If LHA < 180°, **Zn = 360° - cos^{-1} X**. (Zn taken to nearest degree.)

Where **X = {(sin Dec** x cos Lat**) - (cos Dec** x cos LHA x sin Lat**)} ÷ cos Hc.**

But X must be between -1 and +1; if X > +1, make X = +1: If X < -1, make X = -1. So **Zn = ____° T**

Intercept: Ho ° , ' Hc Subtract smaller from larger.
-Hc____°____,__' -Ho
Intercept =________,__' TOWARDS or AWAY (If Ho is greater than Hc, "TOWARDS".)

Work Sheet 4. WORK SHEET FOR SINE/COSINE METHOD.

Solution 9 (Sine). Compare with the solution on page 46 using the Air Sight Reduction Pages method.

WORK SHEET FOR SINE/COSINE METHOD OF SIGHT RESOLUTION

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 28/2 DR 38° 'N/S, 26 °38,8' E/W, IE 3,0' 'on'/'off' Ht of eye: 3,5 ft/m, Course 280 °T/M/C, Speed 7 knots, Celestial Body Sun (LL/UL). Clock error* to UTC: h — m 16 s (*-fast,+slow). Clock time of sight 12 h 07 m 26 s. Time of sight corrected to UTC/GMT 12 h 07 m 10 s

TA/Ho		→ App Alt (AA)	37° 16,4'
SA (Hs) as read from sextant, incl any error.	37 °22,6'	↑ Main Corrn (Almanac card; For Moon, see back of book) +/-	+°15,0'
IE from sextant -'ON', +'OFF' +/-	− 3,0'	Planet Corrn (Al'nac card) +	° , '
DIP (Eye, Almanac card, right side) -	− 3,2'	HP Moon Corrn Back of Almanac +	° , '
App Alt (AA) =	37° 16,4' →	↑ UL Moon -30'	, '
		TA/Ho =	37°31,4'

DECLINATION	
Dec as at hour of sight, Almanac date page, right, under SUN. Increasing? Y/N	N/S 7° 56,6'
d factor, bottom of Dec column; For use with Yellow pages, mins (time) of sight	(d = 0,9)
d Corrn; Yellow pages 'mins', under 'd or v', opposite is Corrn. (+ if Dec incr'sing)	+/- − 0,1'
TOTAL DECLINATION as at time of sight =	N/S 7° 56,5'

GHA		
GHA of body; Aries if a star:as at day, hr.	356 ° 51 ,3 '	Al'nac, date page, under applic body.
Incremenet for minutes and seconds +	1 ° 47 , 5 '	Yellow pages, mins, opp secs.
v factor : .... Date page; to find corrn 'Corrn' as for d factor of Dec +/-	, '	+ Moon (v, one of its 5 columns), +/- Planets (bottom of column)
GHA of celestial body sighted, or Aries =	358 ° 38 ,8 '	Sum of above lines.
SHA of star ("........................") if applic +	° , '	Almanac, date page left side.
GHA of celestial body sighted =	° , '	Sum of above two lines.
- 360° if GHA above is greater than 360° -	° , '	An angle cannot be more than360°!
GHA Required =	358 ° 38 ,8 '	
DR Longitude (+ if East, - if West) +/-	26 ° 38 ,8 '	To get the angle from our DR's
LHA of celestial body sighted =	332 ° 00 ,0 '	meridian to the meridian of the GP.
+/- 360° if necessary +/-	° , '	LHA to be between 0° and 360°
LHA Required =	332 ° 00 ,0 '	For use in the formula below.

Hc:
Hc = $\sin^{-1}$\{sin Lat x sin Dec** + cos Lat** x cos Dec** x cos LHA\}** = 37,159 ° = 37°09,6'
Where 'Lat' is Latitude, 'Dec' is Declination. **They are positive if North, negative if South.

Zn: If LHA > 180°, **Zn = $\cos^{-1}$ X**; If LHA < 180°, **Zn = 360° - $\cos^{-1}$ X**. (Zn taken to nearest degree.)

Where **X = \{(sin Dec** x cos Lat**) - (cos Dec** x cos LHA x sin Lat**)\} ÷ cos Hc.**
But X must be between -1 and +1; if X > +1, make X = +1: If X < -1, make X = -1. So **Zn = 144° T**

Intercept: Ho 37 °31 ,4 ' Hc Subtract smaller from larger.
-Hc 37 °09 ,6 ' -Ho
Intercept = 21 ,8 ' TOWARDS or AWAY (If Ho is greater than Hc, "TOWARDS".)

Solution 9 (Sine) from Example 9, page 40. Compare with Solution 9, page 46.

Let's examine the step-by-step calculations of both Hc and Z.

(Lat and Dec are both North and are therefore positive.)

Hc	= Sin^{-1} {[Sin (Lat)	x	sin (Dec)]	+	[Cosine (Lat)	x	cosine (Dec)	x	cosine (LHA)]}
	= Sin^{-1} {[Sin 38°	x	sin-7°56,5']	+	[cos 38°	x	cos 7°56,5'	x	cos 332°]}
	= Sin^{-1} {[Sin 38°	x	sin-7,94166°]	+	[cos 38°	x	cos 7,94166°	x	cos 332°]}
	= Sin^{-1} {0.61566	x	-0.13816	+	0.78801	x	0.99041	x	0.88295)

= Sin^{-1} {-0.08506 + 0.68910)

= Sin^{-1} {0.60404}

= 37,1597°

= 37°09,6'

X = {sin Dec x cos Lat} - {cos Dec x cos LHA x sin Lat} / Cos(Hc)

= (sin-7°56,5' x cos 38°00') - (cos 7°56,5' x cos 332°00' x sin 38°00') / cos 37°09,6'

= (sin-7,94166° x cos 38,0°) - (cos 7,94166° x cos 332,0° x sin 38,0°) / cos 37,1597°

= (- 0,13816 x 0,78801) - (0,99040 x 0,61566 x 0,88295) / 0,79695

= (- 0,10887) - (0,53838) / 0,79695

= - 0,64725 / 0,79695

= - 0,80902

But Zn = cos^{-1} X (The LHA is greater than 180°.)

So our Zn = cos^{-1} x - 0,80902

= 144,30739°

= 144°T to the nearest whole degree.

NOTES

PLOTTING LINES OF POSITION: POSITION FIXING

Introduction

Except in the case of the Meridian Passage sight, all the sight details we have looked at so far, and those for the moon, stars and planets, result in an AP/CP (an Assumed or Chosen Position - latitude and longitude), an Intercept, and whether the intercept is 'Towards' or 'Away' an Azimuth (direction).

If this information is to be of any significance, we need to be able to use it to establish a Line of Position (LOP) - a line on which we were located at the time the sight was taken. If we can get two LOPs from two separate sightings which cross, we can establish where on those lines we were at the time of either sight, regardless of the time interval and any movement between the taking of the two sights (so long as the amount of movement is known). As there will be a small degree of inaccuracy due to the sextant user's skill and the 'rounding off' in the tables, it is better whenever possible to take three sights in different directions resulting in three LOPs. This is achieved by sighting the moon and two stars or three stars and/or planets in quick succession, or by taking three sights of the sun (and/or moon when visible by day) at different times during the day. Each sight results in a LOP and the three will, due to the inaccuracies, result in a triangle being formed when each is plotted. The smaller the triangle, the more accurate the fix.

The triangle obtained from three LOPs is sometimes called the Triangle of Uncertainty, but is more popularly known as a 'Cocked Hat'. The position 'fix' is taken as the geometric centre of the triangle.

PLOTTING

Charts used for transocean voyages are usually of a scale which is too small (the degrees of latitude and longitude are too close together) for plotting purposes. Plotting sheets are therefore used which have a more suitable scale and the added advantages of keeping all the irrelevant plotting lines (Azimuths, lines of position, course line, advanced/ transferred lines of position) off the chart in use, and allowing one to keep/file the plotting with the work sheet.

The world we know is round but our charts and plotting sheets are flat, rectangular pieces of paper representing areas on the earth's curved surface. To overcome distortion inaccuracies we use the Mercator Projection method of chart production which uses a fixed scale for longitude and a varying scale for latitude -

↑
←——→ ↓ Latitude
Longitude

Fig. 52. LATITUDE AND LONGITUDE

The further one is away from the equator the greater the vertical scale length. Because the scale is expanded the further one moves from the equator, distances can only be accurately measured on the expanded scale, which we can see is the side vertical (latitude) scale.

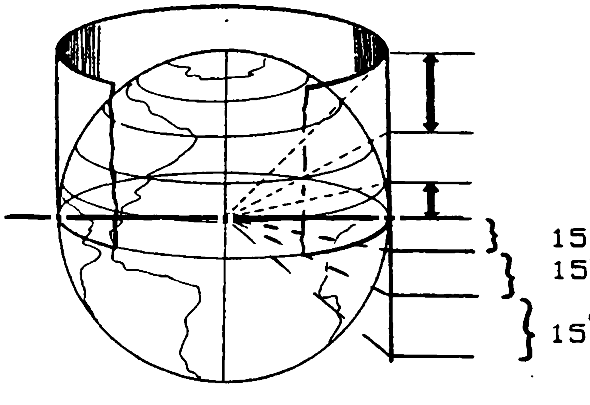


Fig. 53. MERCATOR PROJECTION

Some plotting sheet makers change the variable scale to the horizontal axis keeping a fixed constant scale on the vertical axis. As long as the ratio of the lengths of the vertical and horizontal sides are in proportion for the latitude concerned, it does not matter which of the sides' scales was expanded - as long as we know the scale in use. This scale will always be a factor of latitude.

Look back at Figures 26 to 31 on pages 27 to 29 and re-read the notes relevant to those illustrations.

Now look at an unused plotting sheet of the type that we will use. One appears on the next page as Plotting Sheet 1. Note that a graduated scale has been printed on the centre vertical line and that it represents the 60' of a degree of latitude between each of the horizontal lines. The horizontal lines do not have any scale printed on them so as not to confuse the navigator when translating the 'fix' into the required Latitude and Longitude - the Longitude scale is then taken from the scale graph.

The scale graph for measuring the longitude, depending on latitude, is found at the bottom right-hand corner of the plotting sheet. To use this scale graph we rule a horizontal line through the graph at a level corresponding to our chosen latitude - see the latitudes marked from 0° to 70° at the right of the graph. The length of the line ruled, from the left curved line (50') intersection, to the right-hand vertical line (10') represents 60' or 60 miles. If our CP Lat was 34°S, we would rule our scale line at the 34° level (as near as we can judge). The CP's longitude and the fix longitude's minutes are then measured on this line using dividers (e.g. 25').

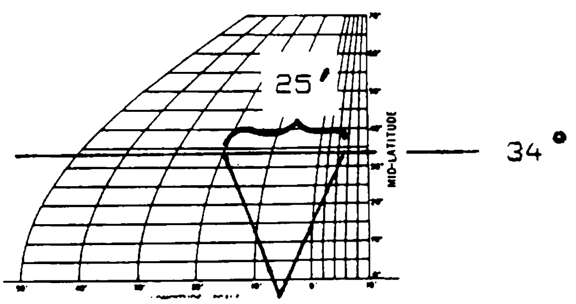


Fig. 54. PLOTTING SHEET SCALE FROM THE SCALE GRAPH

The best way to see how we go about the plotting process is to follow the step-by-step procedure. So, let's plot the LOP resulting from a sight calculation example, Example 8's Solution 8 on page 39. The relevant information was:

Date 5 December 199x, Chosen Latitude 15°N, Chosen Longitude 26°53,9' W, Intercept 8,0' AWAY, Azimuth 137°T.

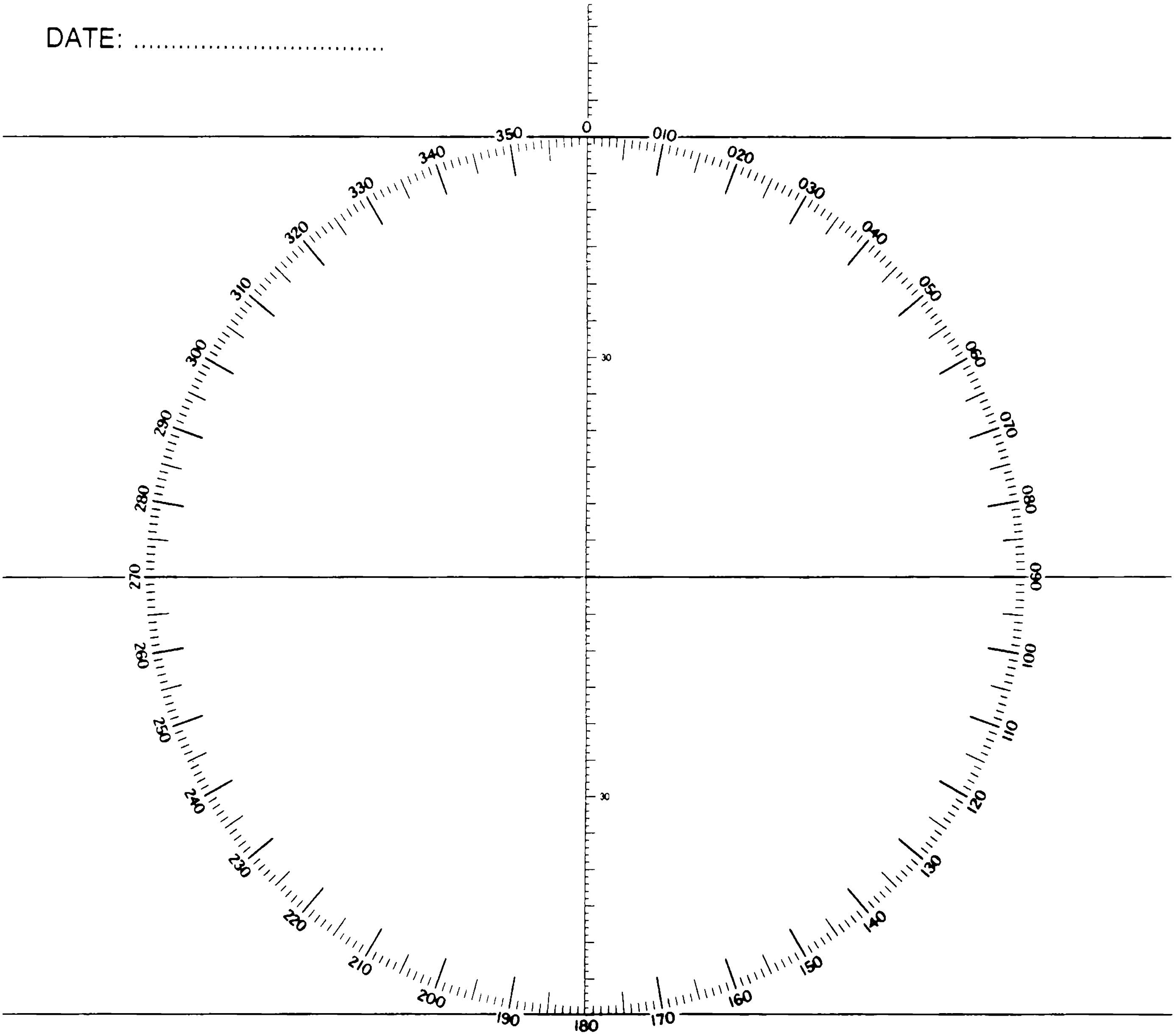
We go to the plotting sheet and begin by labelling the Chosen Latitude at either or both ends of the centre horizontal line. Next we label the vertical line a whole number of degrees nearest to our Chosen Longitude - see Plotting Sheet 2. on page 62.

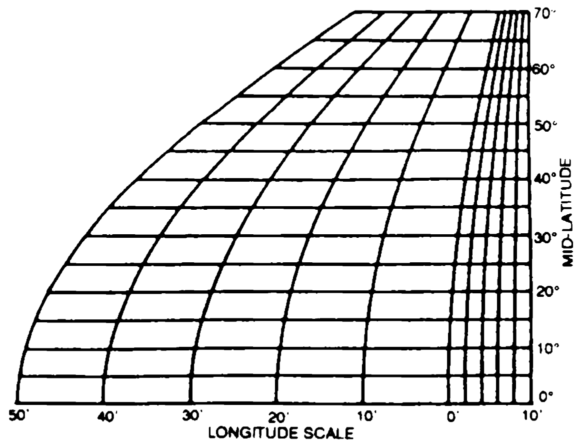
Now rule a horizontal line through the scale graph, bottom right, at 15° Latitude. We take our dividers and measure 53,9' (the minutes of our Chosen Longitude) on the horizontal line in the graph, then mark off that distance along the centre horizontal line (our CP Lat line), from the centre of the circle to the left if longitude 'West', or to the right if longitude 'East'. This mark represents our Chosen Position (the CP). See Plotting Sheet 3, page 63.

Now take a parallel rule or plotter and set it so one edge passes through the chosen position while at an angle/direction of our Azimith, Zn, i.e. 137° to the right/clockwise from the vertical - the direction 137° can be established using the graduated ring. We now rule a line along this edge in the direction from the chosen position AWAY from 137° - in the direction 317° (137° + 180°). Rule it slightly longer than the intercept (8,0 miles) line when drawn to scale. See Plotting Sheet 4, page 64.

A PLOTTING SHEET

DATE: ....





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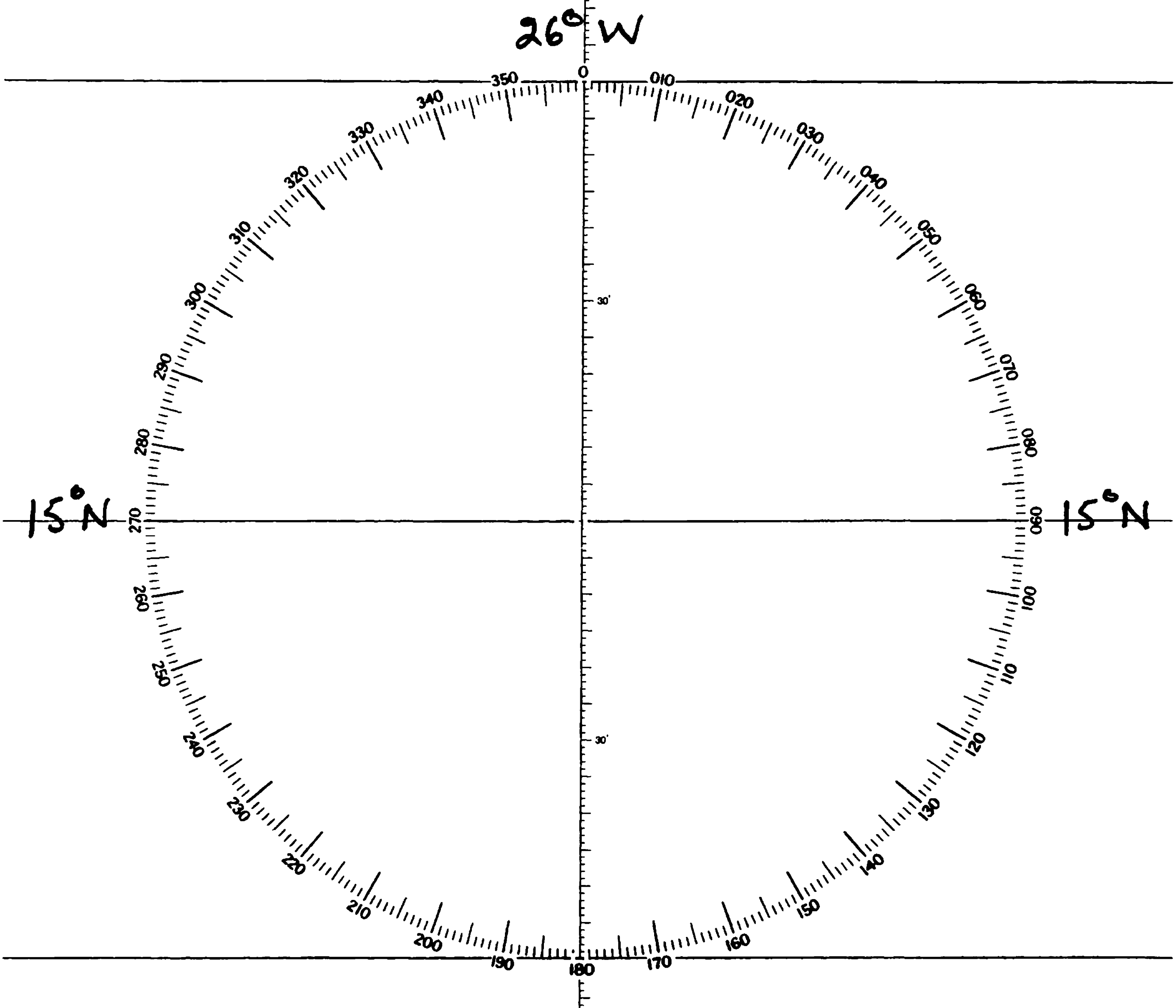
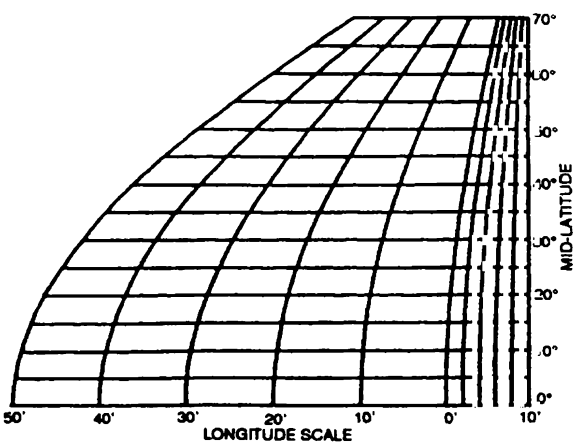
Plotting Sheet 1.

LATITUDE AND LONGITUDES LABELS ADDED

DATE: 5 December 199X





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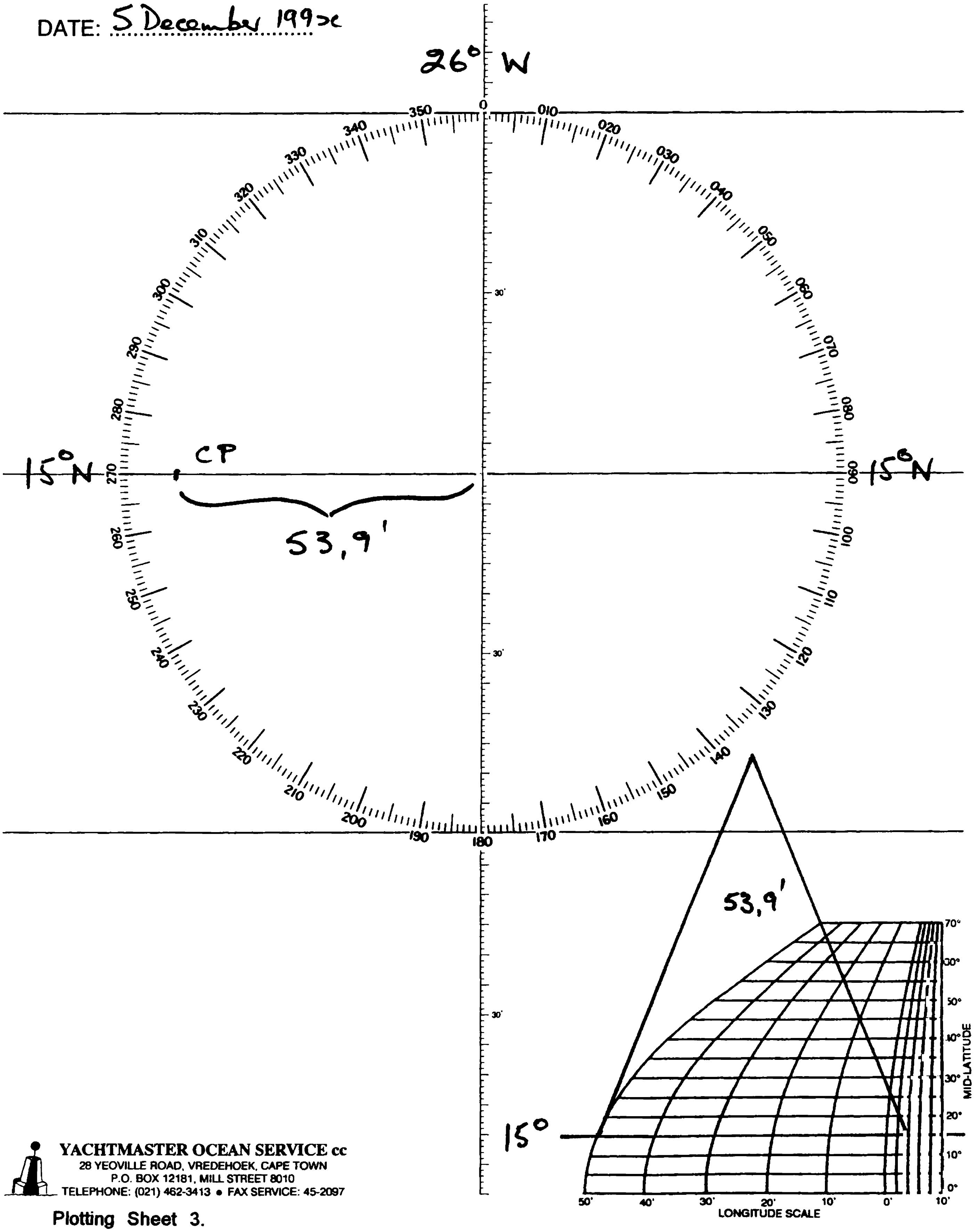
Plotting Sheet 2.

MARKING THE CHOSEN POSITION

DATE: 5 December 199x



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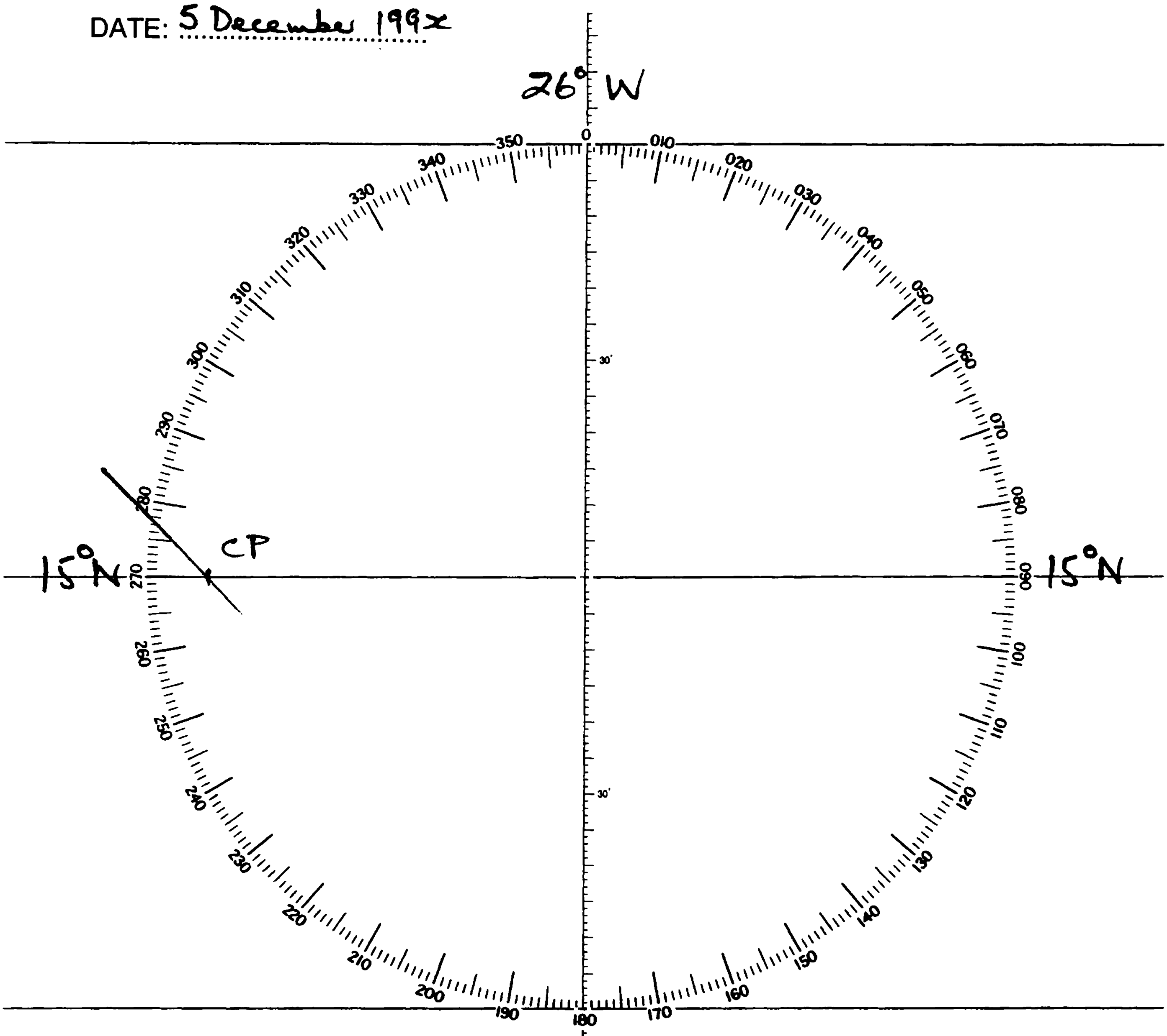
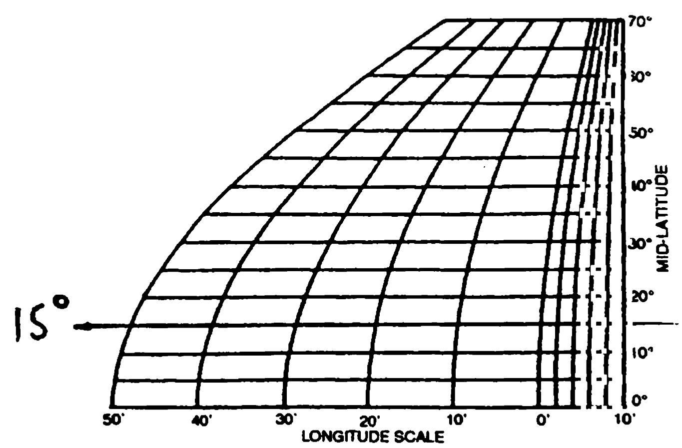
Plotting Sheet 3.

MARKING THE AZIMUTH LINE FOR THE INTERCEPT

DATE: 5 December 199x





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Plotting Sheet 4.

Next we measure the intercept length on the vertical scale with the dividers and mark off its length from the chosen position in the AWAY direction of 317°. See Plotting Sheet 5, page 66. Finally, we construct a line at right angles to the Azimuth line at this AWAY mark. This last line is our LOP. To show it is the LOP we mark it with the navigator's chartwork symbols for 'LOP' by drawing an arrowhead at each end of the LOP. See Plotting Sheet 6, page 67.

Look through the step-by-step sequence of plotting actions from Plotting Sheet 2 to Plotting Sheet 6, then return to this page and continue reading, below.

One LOP is of little use mid-ocean but two intersecting LOPs give us a 'fix'. Just as with LOPs from a hand compass in coastal navigation, the two LOPs may contain a degree of error and a third LOP is desirable. This third LOP will invariably result in a 'cocked hat' triangle due to the slight errors in the individual LOPs. These errors are then minimised by taking the fix position to be the centre of the cocked hat.

In Plotting Sheet 7 on page 68 we show the LOP obtained in the previous example (page 67) when the Azimuth was 137° (the direction to the celestial body). We also show a second plotted LOP, and a fix taken from the intersection of the two LOPs. Read the latitude from the vertical scale. The longitude's 'minutes' is obtained from the scale graph - the horizontal line representing your CP lat throught the scale graph. The dividers are set to the longitude distance from the centre vertical line and the longitude minutes are read off on the graph's horizontal line. In our example the Lat is 15°36,2' N (",2" is an estimation from interpolation), and Long is 26°25,0' W.

A third LOP (e.g. latitude from a Meridian Passage sight when the Azimuth was 360° - the LOP lies east to west) results in a triangle; we take the fix to be the centre of that triangle. Our example, Plotting Sheet 8 on page 69, shows Lat 15°34' N, Long 26°25' W.

The above examples make no allowance for movement of the vessel which is very likely to have been sailing a course and therefore moving at some speed. Since the sights were not taken at the same time they were not taken at the same place. To correct for the movement of the vessel, we must move the earlier LOPS in the direction and by the same amount that the vessel moved in the time between the sights. This is known as 'Transferring' or 'Advancing' LOPs. In Plotting Sheets 9 to 12 on pages 70 to 73 we show LOP 'A' from a sight at 10H00 being 'advanced' to the time of LOP 'B' at 14H30 while the vessel had been sailing a course of 350°T at an average speed of 6 knots. In 4 hours 30 minutes at 6 knots the vessel would have sailed 6 X 4,5 = 27 miles (on course 350°T). The advanced LOP is reconstructed parallel to the original line as at 10H00, at a distance and in the direction the vessel moved between the taking of the two sights. Assume DR 18°S, 6°W.

If three sights are taken during the day, two (normally the first two) are advanced or transferred to equate in time to the third and a 'cocked hat' results as at the time of the third sight. Our 'fix' position is then the centre of that triangle and is as at the time of the third sight.

The sights calculated on page 39 (Solution 8 to Example 8 on page 35), and Solution 8.b. in the Solutions section in Part 2, are used as an example for plotting. Our plotting is on page 74 as Solution 8 (Plotting). Now try your own plotting (Make and use photocopies of page 61). The answers are in the Solutions section in Part 2, as Solutions 20 to 22.

EXAMPLE 20. C Lat 19°N, Course 270°T, Speed 7 knots. Find the fix at 16h01.

Sight 1. C Long 63°25'W, Zn 045°, Intercept 51' Towards. Time of sight 09h57 LMT.
Sight 2. C Long 63 40'W, Zn 350°, Intercept 16' Away. Time of sight 13h03 LMT.
Sight 3. C Long 63 14'W, Zn 305°, Intercept 15' Away. Time of sight 16h01 LMT.

EXAMPLE 21.

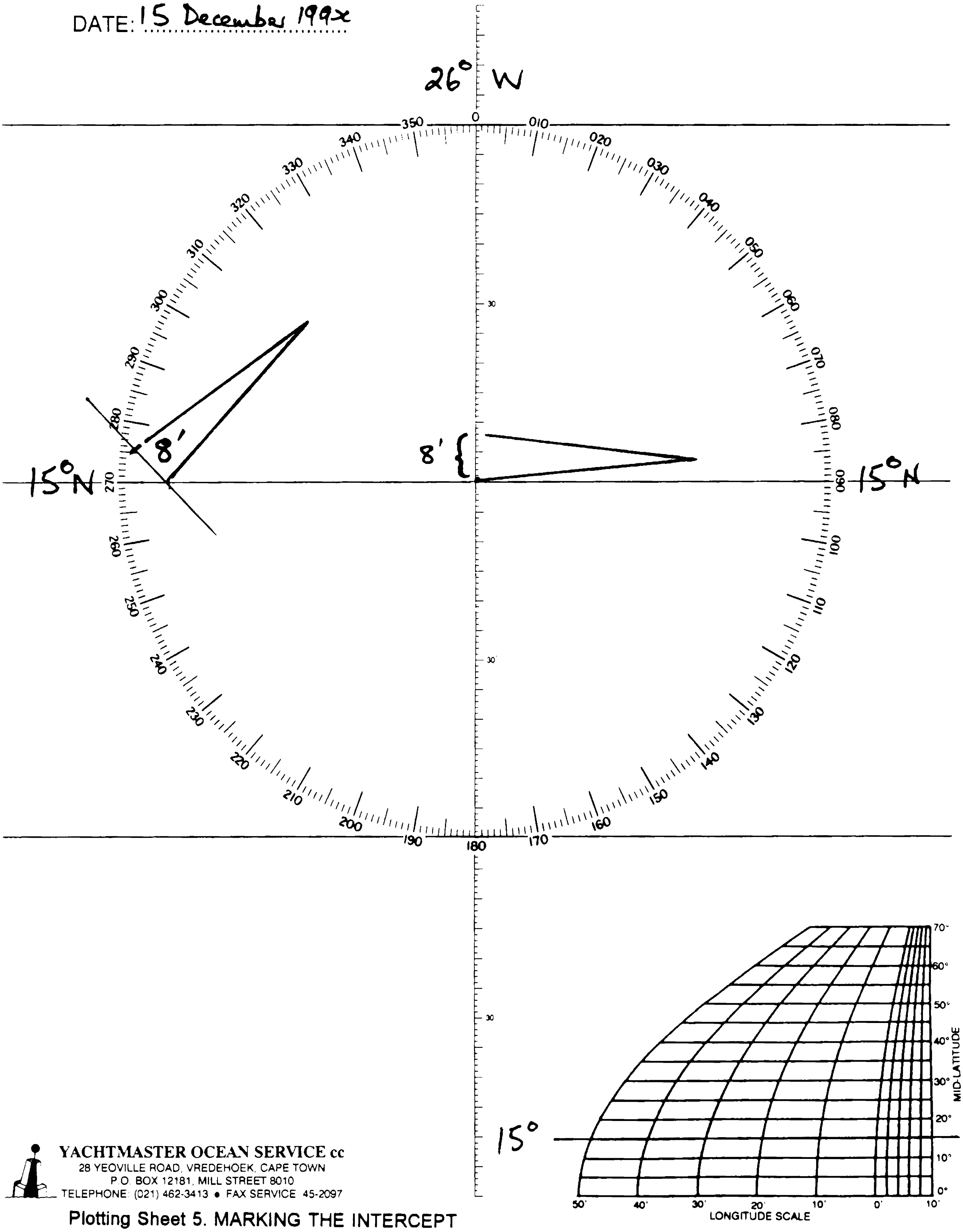
Using the plotting data obtained from Solution 12 in the Solutions section, Part 2, plot the fix of the vessel at the time of the third sight.

EXAMPLE 22.

Using the plotting data obtained from Solution 13 in the Solutions section, Part 2, plot the vessel's position as the time of the third sight.

MARKING THE INTERCEPT

DATE: 15 December 199x



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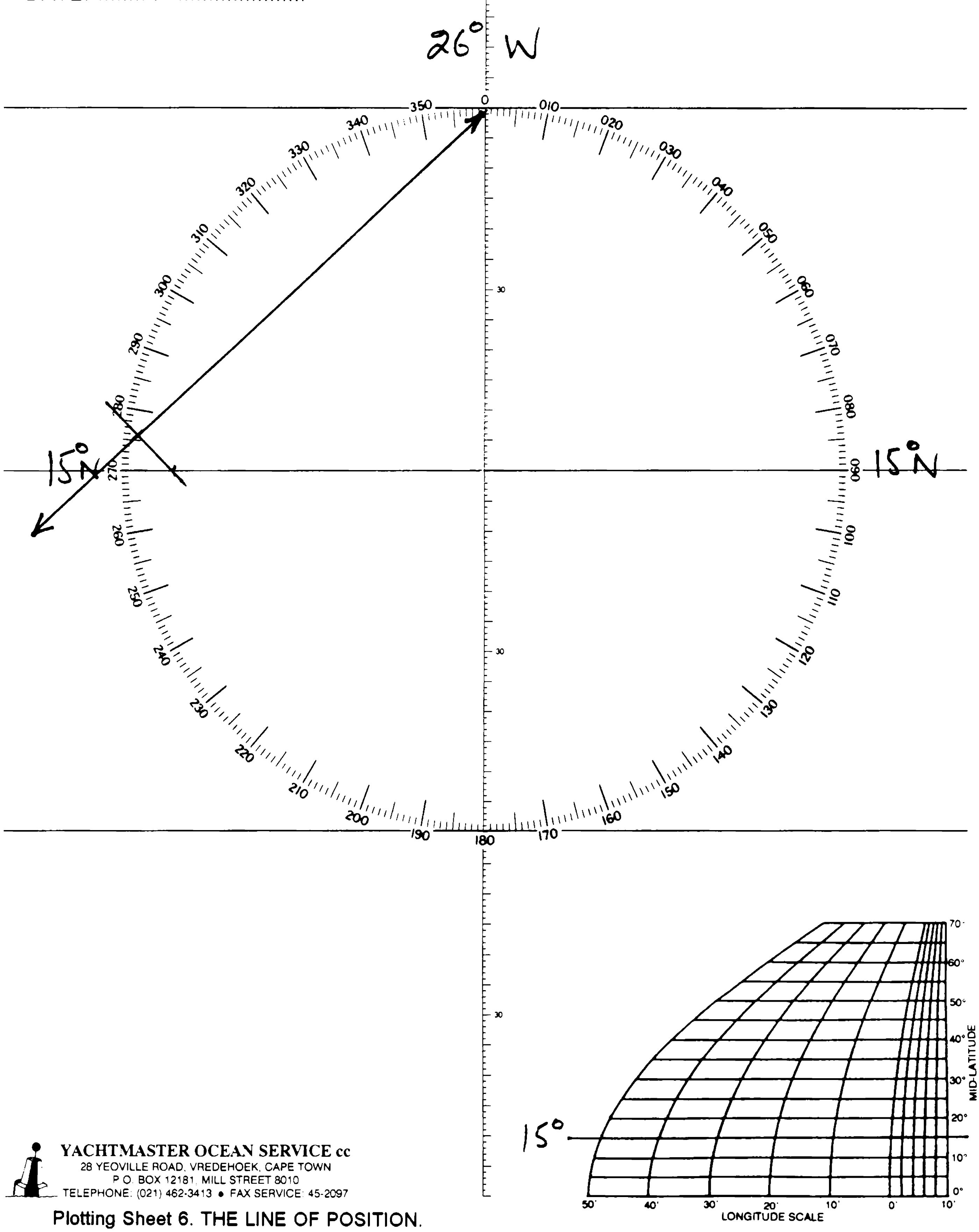
Plotting Sheet 5. MARKING THE INTERCEPT

THE LINE OF POSITION

DATE: 5 December 199x



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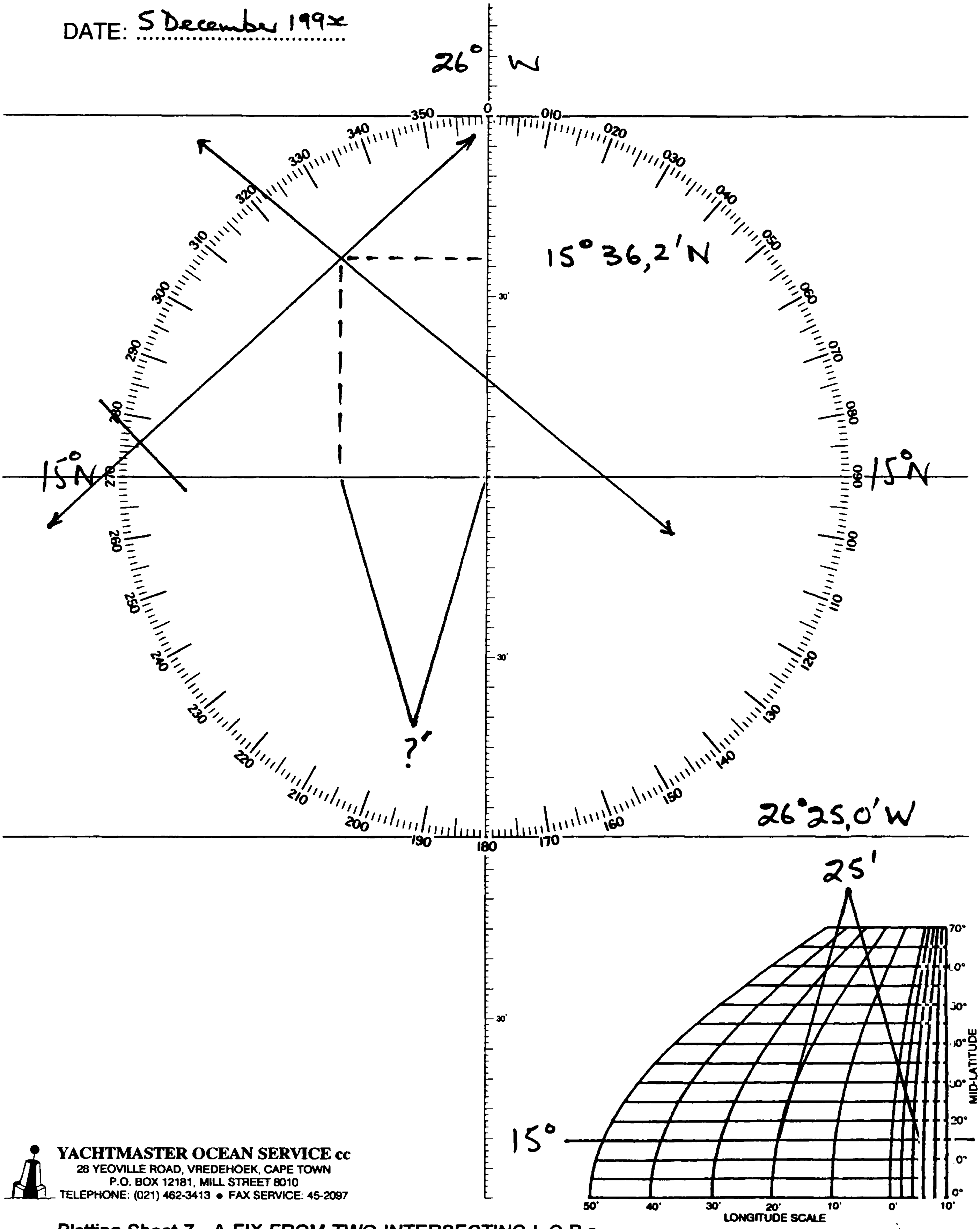
Plotting Sheet 6. THE LINE OF POSITION.

A TWO L.O.P. FIX POSITION

DATE: 5 December 199x



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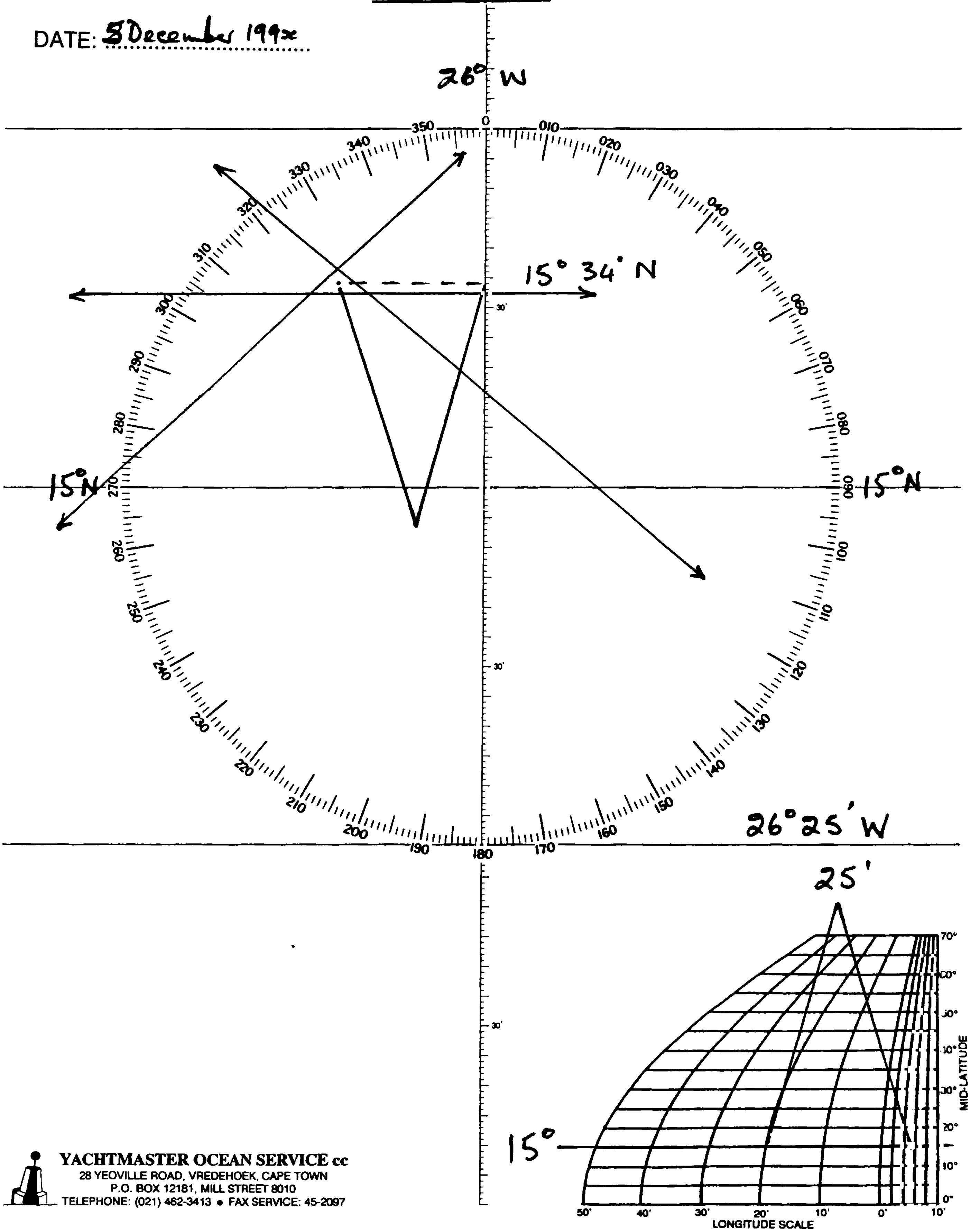
Plotting Sheet 7. A FIX FROM TWO INTERSECTING L.O.P.s

A THREE L.O.P. FIX

DATE: 5 December 199x



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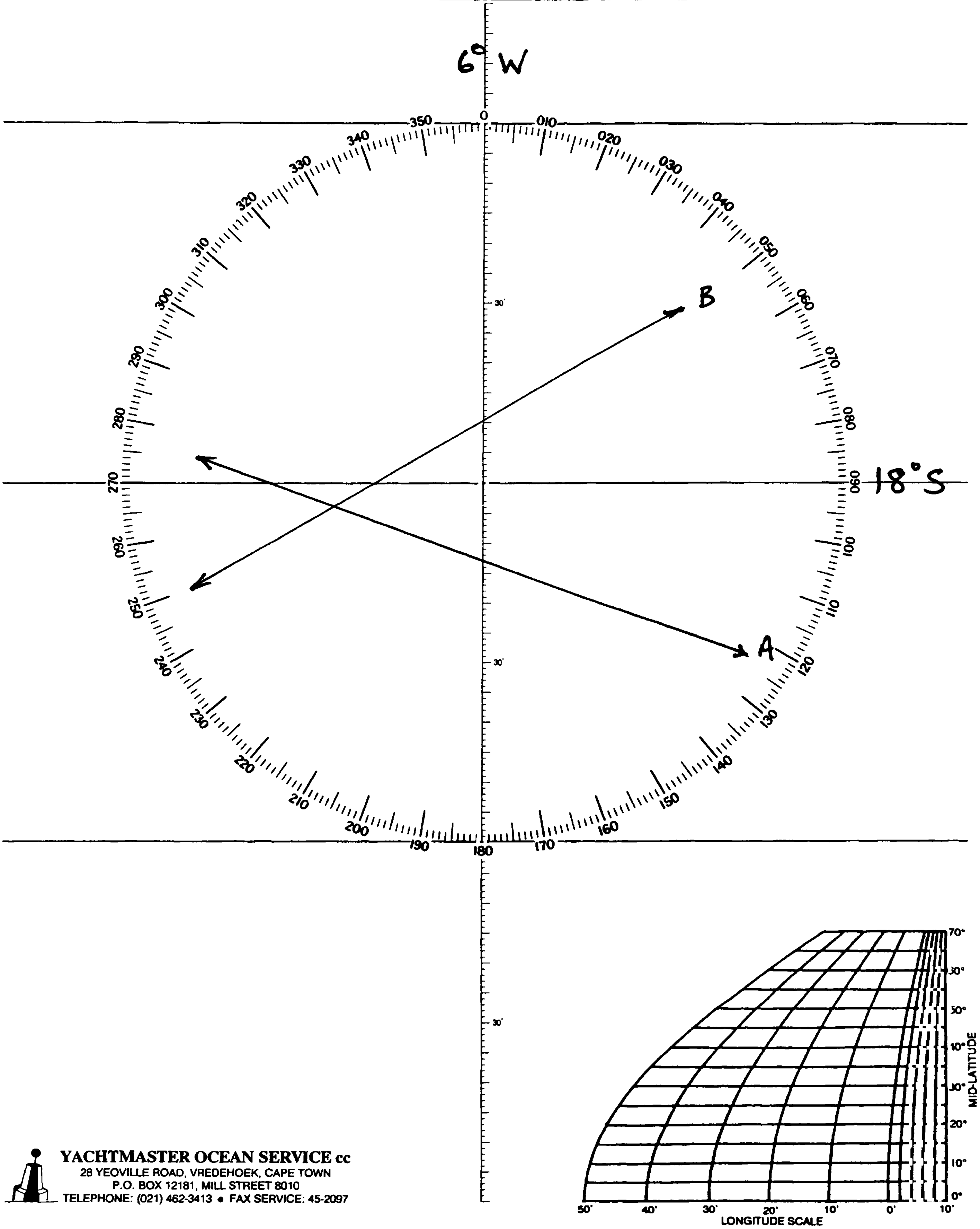
Plotting Sheet 8. A FIX FROM THE COCKED HAT FORMED FROM THREE L.O.P.s

LOP 'A' AT 10H00 AND LOP 'B' AT 14H30



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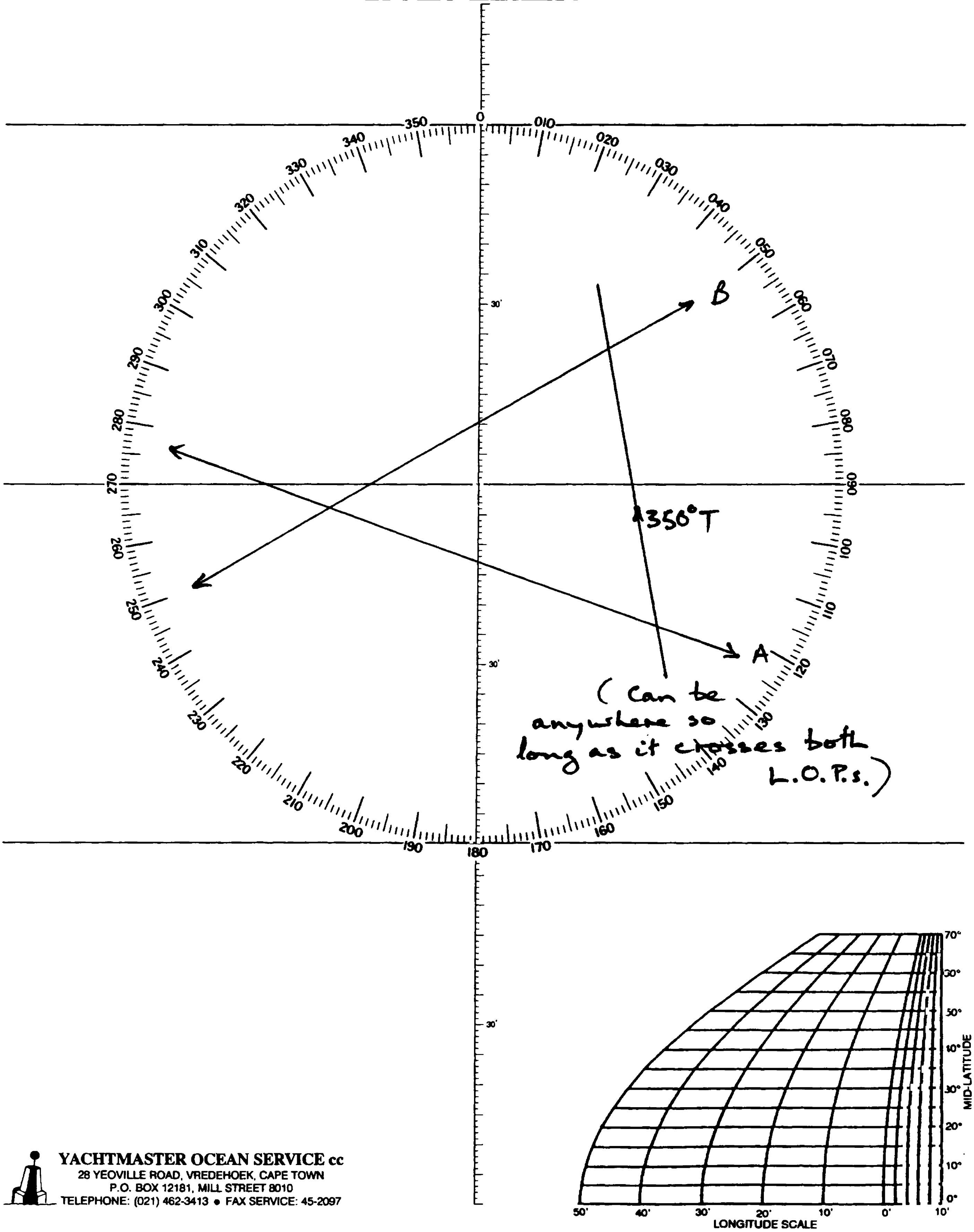
Plotting Sheet 9. STEP 1: PLOT LOP's 'A' AND 'B'

COURSE LINE OVER LOP



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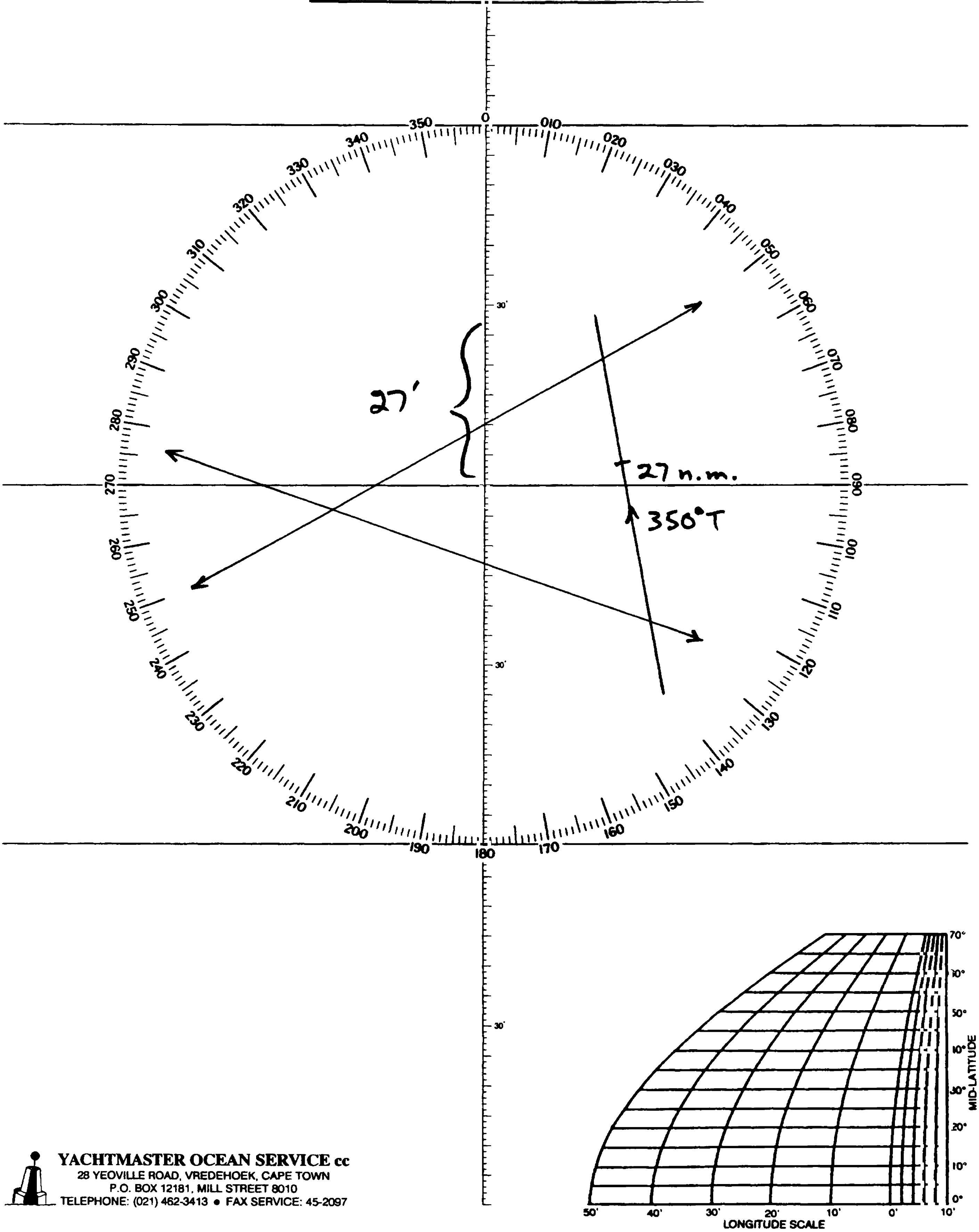
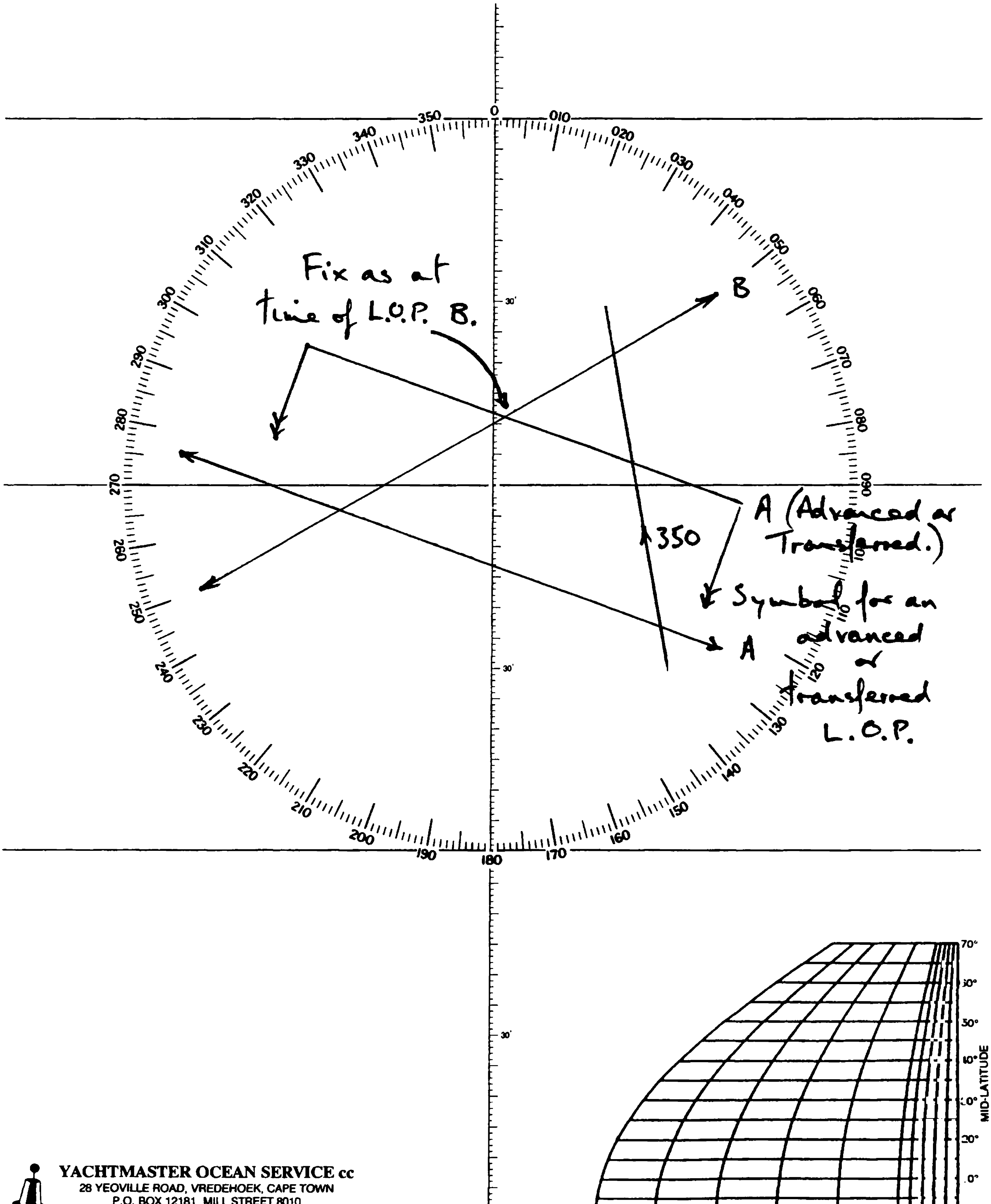
Plotting Sheet 10. PLOT THE COURSE LINE- TO CROSS 'A' AND 'B'

DISTANCE TRAVELLED BETWEEN SIGHTS



Plotting Sheet 11. STEP 3: MARK DISTANCE TRAVELLED BETWEEN TAKING SIGHTS

TO 'ADVANCE' (or 'TRANSFER') LOP 'A'



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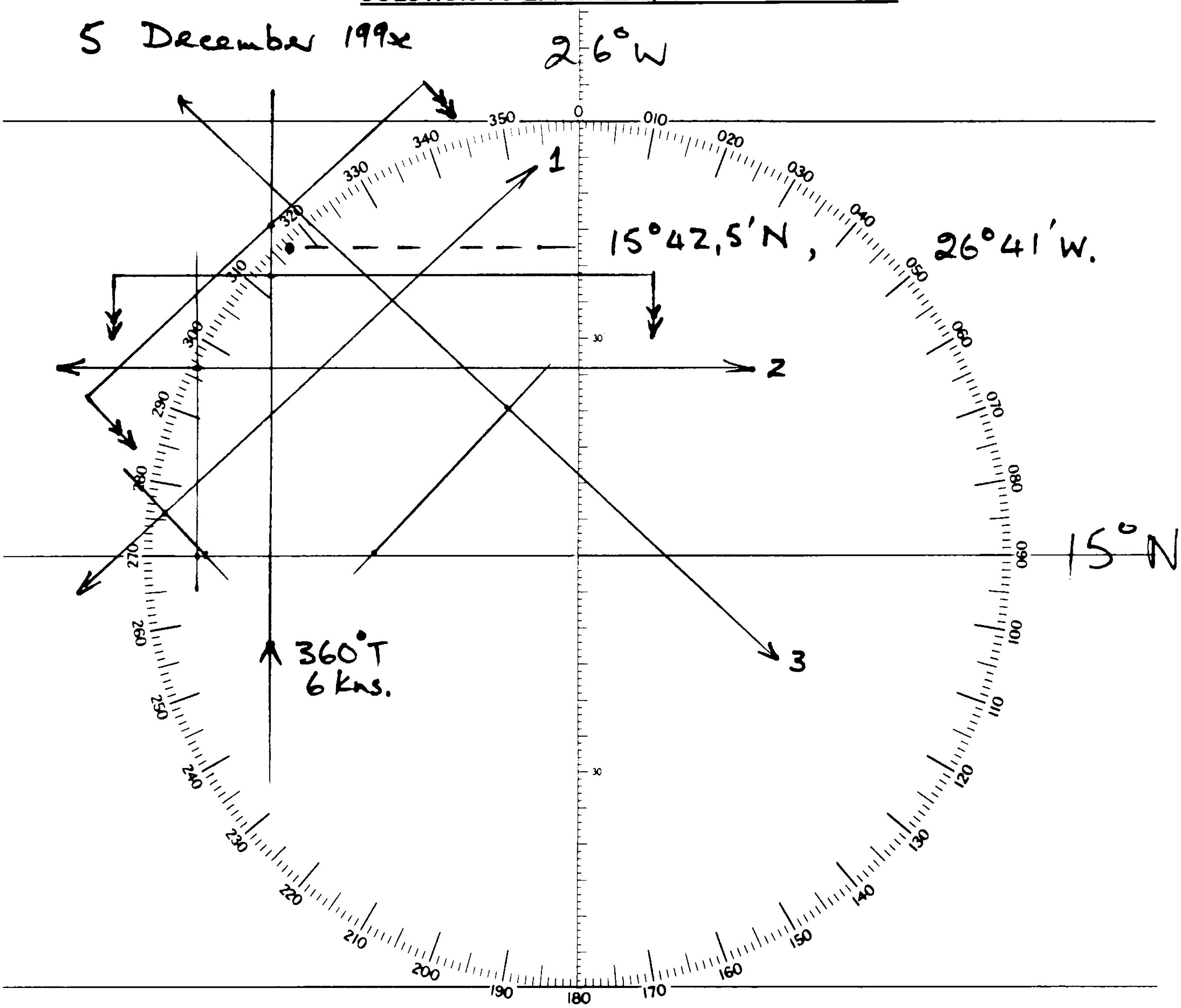
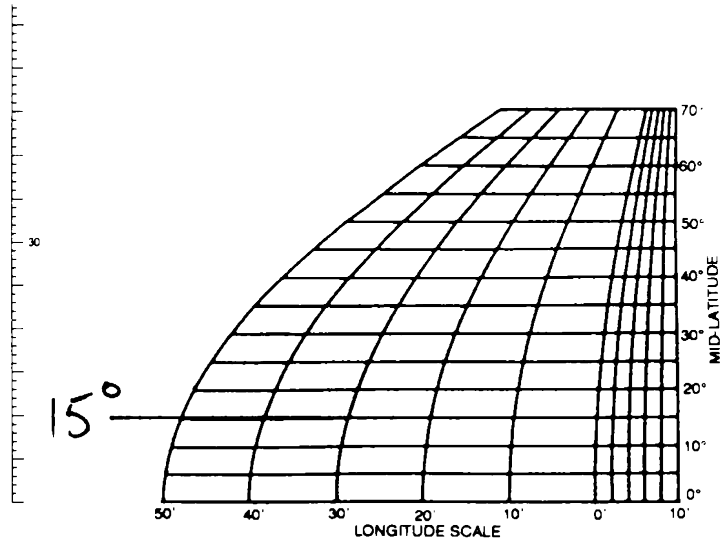
Plotting Sheet 12. THE ADVANCED LOP 'A' INTERSECTS LOP 'B' AT THE FIX

SOLUTION TO EXAMPLE 8; 'SUN-RUN-SUN' PLOT





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Solution 8 (Plotting). PLOT SIGHTS, EXAMPLE 8, PAGE 35 SOLUTION, PAGE 39 /SOLUTION 8.b.

NOTES

THE MOON, PLANETS AND STARS

Introduction

So far we have dealt only with sun sights and in every method used (except the Meridian Passage sight), we obtained a Chosen Position (Chosen Latitude/Chosen Longitude), Azimuth, Intercept and a statement that the intercept was either 'Away' or 'Towards'. This information enabled us to start the plotting process. The good news is that it is no different with the moon, planets or stars sights. There are only minor variations. We do not have to master any new involved concepts, nor do we have to learn to identify one star from another or need to be able to identify the visible planets.

The Moon

As the earth orbits around the sun, so the moon orbits around the earth. The earth takes a year to orbit the sun but the moon takes approximately 28 1/2 days to orbit the earth. The moon's orbit rate is 'approximate' because it does not move at a constant speed. To get LHA so that we can look up the tables for Hc, etc., we need to get the GHA from the Almanac. The Almanac records the GHA based on the slowest speed of the moon, and it gives us a 'v correction' - a correction to be added to the GHA which makes allowance for the increase in hour angle due to the varying speed of the moon's orbit. Look at your copy of the Almanac, right-hand daily page for 20 June 199x. To the right of the GHA column we see a column headed 'v' and notice that the values listed under this heading are 'minutes'. So if we need to know the GHA of the moon at 06h38m07s UTC (GMT), we proceed just as we would for the sun but we add one extra line before the total, namely the 'v' correction:

JUNE 18, 19, 20 (SAT., SUN., MON.)

UT (GMT) d h	SUN G.H.A. ° ′	SUN Dec. ° ′	MOON G.H.A. ° ′	MOON v ′	MOON Dec. ° ′	MOON d ′	MOON H.P. ′
23	164 39.6	[illegible]	[illegible]	6.4	15 59.3	8.4	[illegible]
20 00	179 39.4	N23 25.7	[illegible] 03.7	6.2	S16 07.7	8.4	60.2
01	194 39.3	25.8	[illegible] 28.9	6.2	16 16.1	8.2	60.2
02	209 39.2	25.8	[illegible] 54.1	6.2	16 24.3	8.1	[illegible]
03	224 39.0	.. 25.8	[illegible] 19.3	6.1	16 32.4	[illegible]	[illegible]
04	239 38.9	25.9	[illegible] 44.4	6.0	16 [illegible]	[illegible]	[illegible]
05	254 38.8	25.9	[illegible] 09.4	5.9	[illegible]	7.8	60.3
06	269 38.6	N23 25.9	136 34.3	5.9	S16 56.1	7.7	60.3
07	284 38.5	25.9	150 59.2	5.8	17 03.8	7.5	60.3
08	299 38.3	25.9	165 24.0	5.7	17 11.3	7.5	60.3
M 09	314 38.2	.. 26.0	179 48.7	5.7	17 18.8	7.3	60.3

Table 14. DAILY PAGE, 20 JUNE.

38ᵐ INCREMENTS AND CORRECTIONS

38 s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corr ′	v or d ′	Corr ′	v or d ′	Corr ′
00	9 30·0	9 31·6	9 04·0	0·0	0·0	6·0	3·9	12·0	7·7
01	9 30·3	9 31·8	9 04·3	0·1	0·1	6·1	3·9	12·1	7·8
02	9 30·5	9 32·1	9 04·5	0·2	0·1	6·2	4·0	12·2	[illegible]
03	9 30·8	9 32·3	9 04·7	0·3	0·2	6·3	4·0	[illegible]	[illegible]
04	[illegible]	9 32·6	9 05·0	0·4	0·3	6·4	[illegible]	[illegible]	11·2
05	[illegible]	[illegible]	9 05·2	0·5	0·3	[illegible]	[illegible]	[illegible]	11·2
06	9 31·5	[illegible]	9 05·5	0·6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
07	9 31·8	9 33·3	9 05·7	[illegible]	[illegible]	11·7	[illegible]	[illegible]	11·4
08	9 32·0	9 33·6	[illegible]	[illegible]	3·7	[illegible]	7·6	17·8	11·4
09	9 32·3	9 33·8	[illegible]	5·9	3·8	11·9	7·6	17·9	11·5
10	9 32·5	[illegible]	[illegible] 18·4	6·0	[illegible]	[illegible]	[illegible]	18·0	11·6

Table 15. INCREMENT, 38 MINUTES 07 SECONDS.

So: GHA Hour value 06h = 136°34,3'
Increment 38m07s (+) = 9°05,7' (Yellow pages)
'v' factor 5,9' (Just like 'd' in Dec)
'v' correction (+) = 3,8' (Yellow pages, ALWAYS a plus))
GHA required = 145°43,8' (-360° if necessary)

The second and only other difference in moon sight calculations as compared with sun calculations is

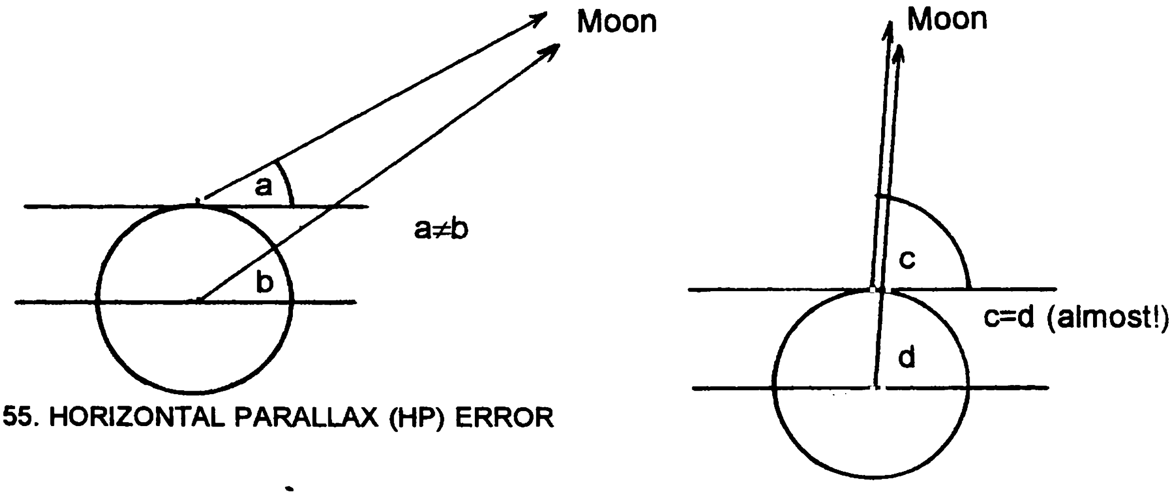


Fig. 55. HORIZONTAL PARALLAX (HP) ERROR

due to the moon being relatively close to the earth. This gives rise to what is termed the "Horizontal Parallax" (HP) error - a line from the observer to the centre of the moon is seldom parallel to a line from the centre of the earth to the centre of the moon:

This will affect the angle measured with the sextant as, after the corrections we apply for the sun, the True Altitude or Height Observed (TA or Ho) will not necessarily be the same as the corresponding angle at the centre of the earth. We use extra corrections to rectify the situation. In addition to the 'Main correction' we add a correction to allow for Upper or Lower Limb 'HP' - and if 'Upper Limb' was used, because the earlier corrections are calculated relative to the centre of the moon and Lower Limb sights, we must subtract 30' to get the angle we need.

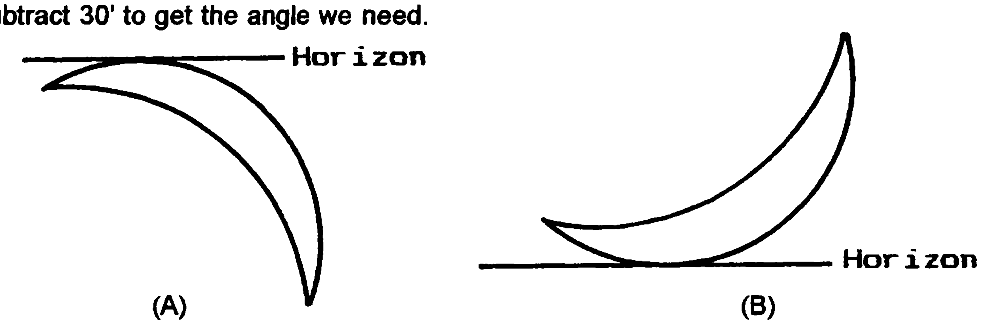


Fig. 56. UPPER (A) AND LOWER (B) LIMB ILLUSTRATIONS

Look at the back of your Almanac, the last two facing pages (or in this book, the last sample page of the Almanac section). The left page is for Apparent Altitudes (sextant angles corrected for index error and DIP - height of eye - only) from 0° to 35°, and the right-hand page is for AA's 35° to 90°. If our AA was 28° 11,2' and we had taken a Lower Limb (LL) sight when the daily pages/hour value for HP was 60,3':

AA	= 28°11,2'	
Main Correction	= +59,7'	ALWAYS a plus
HP Correction (under 'L')	= + 8,0' *	ALWAYS a plus
UL Correction (-30')	= N/A	
TA/Ho	= 29°18,9'	

* Note that if the daily pages of the Almanac gave HP as, say, 54,5', the correction tables for the moon at the back of the Almanac or Almanac section in this book, HP section (bottom half) have horizontal rows for HP values of 54,3' followed by 54,6' i.e. no row for 54,5'. We would therefore have to interpolate:

54,3'	1,1'	
54,4'	1,2'	By
54,5'	1,3'	interpolation
54,6'	1,4'	

So an HP of 54,5' becomes a correction of 1,3' (if necessary, round off to the nearest single decimal).

In all other respects the resolution of a moon sight is the same as that for the sun.

EXAMPLE 23. Let's do an example using the Almanac's concise Sight Reduction Tables (Almanac's tables) method (page 79). We therefore use the work sheet which was shown on page 41 as 'Work Sheet 3'. Or you could use the Air Sight Reduction Tables work sheet (Work Sheet 2, Sun only) with modifications (for use with all/any celestial body), as shown on the next page as Work Sheet 5.

Our sight information is as follows:

Date	: 31 August 199x.	DR	: Lat 10°25 ' S, Long 8°10' E.
IE	: 3,2' "off".	Dip	: 4m height of eye.
Time	: 08h22m37s per clock.	Clock	: Set to UTC but 5 seconds fast.
Sextant	: 51°56,6'	Sight	: Moon, Upper Limb.
Course	: 090°T at 4 knots.	Log	: 12 345 M

(Note that as this sight was taken during the morning when the sun was also visible, a sun sight taken immediately before or after the moon sight will result in a two-LOP fix).
The solution is on page 79 as Solution 23. Check the working against your Almanac Extracts, Part 2.

AIR SIGHT REDUCTION TABLES WORK SHEET; ALL CELESTIAL BODIES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: IE:+/- , '(-On, +Off); Eye Ht: ft/m; Clock error: h m s(Fast/Slow?)
Course: °T/M/C; Speed: kns; Celestial Body/ies-UL/LL:

DR Lat	° 'N/S	° 'N/S	° 'N/S
DR Long	° 'E/W	° 'E/W	° 'E/W
Chosen Lat	° 00 'N/S	° 00 'N/S	° 00 'N/S
<u>TIME</u> Clock time of sight	h m s	h m s	h m s
Clock error relative to UTC (-fast, + slow)±	h m s	h m s	h m s
Corrected UTC time of sight =	h m s	h m s	h m s
<u>LHA</u> GHA as at day, hr of sight: Al'nac	° , '	° , '	° , '
Increments for mins/secs; Yellow pages +	° , '	° , '	° , '
v (?) ±Plnts; +Moon. Corrn.(Yellow p's) ±	( ) , '	( ) , '	( ) , '
Total GHA as at exact time of sight =	° , '	° , '	° , '
-360° if nec; GHA to be between 0°/ 360° -	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
GHA Required =	° , '	° , '	° , '
SHA of star +	° , '	° , '	° , '
GHA of celestial body sighted =	° , '	° , '	° , '
Chosen Longitude (+E, -W) ±	° , '	° , '	° , '
LHA Required =	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
+/- 360° if necessary ±	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
LHA of celestial body sighted =	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
Declination day/hr of sight; next to GHA =	N/S ° , '	N/S ° , '	N/S ° , '
(d = ?)factor; bottom of/or in moon colmn	(d = ,)	(d = ,)	(d = ,)
d Corrn;Yellow p's(mins)(+if Dec incr'ng) ±	, '	, '	, '
TOTAL DECLINATION at time of sight =	N/S ° , '	N/S ° , '	N/S ° , '
Lat/Dec **SAME** or **CONTRARY** (N/S) ?			
<u>Hc</u>: Hc, Sight Red Tables, 'C Lat' page:	° '	° '	° '
(d± ?) Use with Dec's mins, Table 5.	(d =+/-)	(d =+/-)	(d =+/-)
d Correction, from Table 5 ±	'	'	'
TOTAL Hc (Transfer to Intercept, ↓) =	° '	° '	° '
<u>Z → Zn</u> Top/bottom left corner SRT page.	Z = °	Z = °	Z = °
	Zn = °	Zn = °	Zn = °
<u>Ho</u>; Sextant Angle (SA/Hs)Up./Low. Limb=	° , '	° , '	° , '
IE (-On, +Off) ±	, '	, '	, '
DIP (Eye ht; Al'nac card/Page A2) -	, '	, '	, '
Apparant Altitude (AA) =	° , '	° , '	° , '
Main corrn (Al'nac card), OR ±	, '	, '	, '
Moon corrn (Back of Al'nac) +	° , '	° , '	° , '
Planet corrn (Al'nac card) +	° , '	° , '	° , '
Moon HP corrn (Back of Al'nac) +	° , '	° , '	° , '
Moon only, if UL, corrn (-30,0' if UL) -	, '	° , '	° , '
TRUE ALTITUDE / Ho Ho =	° , '	° , '	° , '
<u>**Intercept**</u>; Ho - Hc or Hc - Ho Hc =	° , 0'	° , 0'	° , 0'
Intcpt (Difference); ~	, '	, '	, '
TOWARDS or AWAY? If Ho>Hc, Towards			

Work Sheet 5.

Solution 23 to Example 23, page 77.

WORK SHEET FOR USE WITH ALMANAC'S SIGHT REDUCTION TABLES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 31/8 DR 10 °25 'N/S, 8 ° 10 'E/W; IE 3,2 'on'/'off', Eye ht: 4 ft/m, Body Moon UL/LL
Course 090 °T/M/C, Speed 4 knots. Clock error to UTC h m - 5 s (-fast, +slow?),
Sight clock time 08 h 22 m 37 s, Sight Time Corrected to UTC(GMT) 08 h 22 m 32 s.

Ho		↓ → Apparent Altitude (AA)	51°56,3'
Sextant Angle (Hs)	51 °56,6 '	Main Correction (Al'nac card) or(+/-) Moon Correction, back of Al'nac (+)	° 45,4'
Index Error +/-	+ 3,2 '	Planet Correction (Almanac card)(+)	° , '
DIP (Height of eye) (-)	- ° 3,5 '	Moon HP Corrn (Back of Al'nac) (+)	° 28 '
Apparent Altitude (AA)	51 °56,3 →	↑ Moon UL Corrn (-30.0' only if UL) (-)	- ° 30,0 '
Yachtmaster Ocean Services		**True Altitude (Ho)**	52 °14,5 '

DECLINATION 'Dec' as at day, hour of sight; Almanac.	N/S 19°58,8'	Increasing/Decreasing* hourly?
(d= ? at bottom of Dec column in Al'nac)	(d 2,2)	Not part of sum. See next line.
d Corrn, Yellow p's, Mins (time of sight)	+/- - 0 ,8'	*+ if Dec increasing, - if decreasing
TOTAL DECLINATION	N/S 19°58,0'	
Chosen Latitude	10 °00,0' N/S	DR Lat rounded off, nearest degree
SAME or CONTRARY ?	Contrary	Dec and Lat, SAME hemisphere?

LHA		
GHA (hr)Cel'stial Body, Al'nac	8 °43,7'	Date page, choose body's name column.
Increment, for mins/secs. +	5 °22,6'	Yellow p's; NB: Use correct column heading.
v:(10,7 factor) +/-Planets; +Moon. Corrn= +/-	+ 4,0'	Bottom of Planet column; or Moon, next to GHA; treat as d for Dec Corrn, Yellow p's.
Total GHA =	14 ° 10 ,3'	Sum of above lines.
- 360° if above line >360° -	° 00 ,0'	GHA must be between 0° and 360°.
Total GHA if different. =	° , '	GHA: angle, 0° westward, to meridian of GP.
SHA of Star +	° , '	Almanac, left day page, right hand column.
GHA of Celestial Body =	14 °10 ,3 '	Omit this and above line if not for a star.
Chosen Longitude (+E, -W) +/-	8 °49 ,7'	DR degrees; mins to make LHA whole number.
LHA of Celestial Body =	23 ° 00,0'	Angle, your meridian west to meridian of GP.
+/- 360° if necessary +/-	° 00,0'	LHA to be between 0° and 360°.
LHA Required =	23 ° 00,0'	Now we can start with the Sight Redn. Tables.

USE OF SIGHT REDUCTION TABLE (SRT) *By Henton Jaaback*

1. Select SRT page with above 'Chosen Lat' Under Lat , opposite LHA (as above):
[A°= 23° (nearest whole degree), A'= 38']
B = 79 °09', Z1= 85,8 (B/Z1 '-' if 90°<LHA<270°)
Dec = +/- 19 °58 'N/S ('+' SAME, '-' CONTRARY)
F = +/- 59 °11 '
(F°= +/- 59 °[nearest degree], F'= 11')

2. SRT page with A° value as column heading. Under A° opposite F°; H = 52 °06,0 '
P° = 50 °(nearest whole degree), Z2 = 57,0

3. Go to Auxiliary Table (pages 316/317). Under F' column opposite P° in left column, what is: Corrn 1 ? +/- 8 ,0' ('-' if F°<90° and F'>29', or if F°>90° and F'<30'. Otherwise '+')

4. Under A' column, opposite Z2 (right hand column), what is Corrn 2 ? +/- 12 ,0' ('-' if A'<30')

H = 52°06,0'
Corrn 1 = + 8,0'
Corrn 2 = + 12,0'
Hc = 52° 26,0'
Ho = 52 °14,5'
Intcpt = 11,5'

Z1 = 85,8 ° + or - as for B.
Z2 = 57 ,0 ° (If F°'-', use 180°-Z2). (Z2 is '-' if F°>90°).
Z = 142,8 ° Ignore '-' if applic.

IF DR in N LAT:
If LHA>180° Zn=Z
If LHA<180° Zn=360°-Z
IF DR in S LAT:
If LHA>180° Zn=180°-Z
If LHA<180° Zn=180°+Z

TOWARDS if Ho>Hc, **AWAY** if Hc >Ho   Zn = 323°T

Now here are some examples for you to do on your own - the answers, when you have finished or are 'stuck', are in the 'Solutions' section in Part 2.; see Solutions 24 and 25.

EXAMPLE 24. Using Air SRTs. (SRTs = Sight Reduction Tables.)

Date	:5 December 199x	DR: Lat 15°25' N, Long 26°05' W	IE: 1,7' on.
Dip	:Height of eye 3 m.	Clock time 19h07m48s.	Sextant angle 37°46,0'
Clock:	: Set to UTC, but 21 seconds fast.	Sight: Moon, LL	Course 130°M at 8 knots.

EXAMPLE 25. Using Almanac SRTs.

Date	: 27 February 199x.	DR: Lat 38°12' N, Long 80°15' E.	IE: 1,0' "ON".
Dip	: Height of eye 3,5m.	Clock Time : 00h37m06s.	Sextant angle: 9°31,7'.
Clock	: Set to UTC, but 42 seconds slow.	Sight : Moon, LL.	Course : 080°T at 7 knots.

Planets

All planets, of which the earth is one, have their own independent orbits around the sun. Each takes a different period of time, the earth's orbit taking a year. Planets are therefore sometimes called 'the wandering stars' - as opposed to the 'fixed' stars - stars remaining (almost) in the same place relative to each other.

There are nine principal planets but only four are suitable for navigation purposes. They are Venus (the brightest because it is nearer the sun than all other planets), Mars (the red-coloured planet), Jupiter - sometimes visible by day if a strong sextant telescope is used (same applies to Venus), and Saturn - the yellowish planet which is the least bright but is as bright as the brightest star.

When taking a sextant sight of a planet, you will notice that it is so small that no 'Upper' or 'Lower' Limb can be seen - it is just a 'dot' - set the sextant so that the 'dot' is on the horizon when the sextant is vertical.

Identifying Planets

Planets do not 'twinkle' like stars do. They are brighter than stars and when viewed through the sextant's telescope they appear as solid but very small 'round ball' lights. If we need to identify a planet, it can be done one of two ways.

Method 1. Take a sextant sight of the planet to be identified, noting the exact angle, time and the compass bearing converted to Azimuth (Zn) - the True bearing to the planet. Knowing your DR, look in the Air or Marine Sight Reduction Tables at the pages for your nearest latitude (whole number of degrees), 'SAME' and 'CONTRARY'. (If you are using the Almanac's Sight Reduction Tables, you will have to try calculating various combinations; a laborious exercise which is not recommended.) You will find only one combination of Hc and Z (convert from Zn) that will be the same as your sight. Look to the side columns to read off LHA and get two (one left hand column, one right and column) possible values. Now since

LHA = GHA + East Longitude, and
LHA = GHA - West Longitude,

GHA must be:

GHA = LHA - East Longitude, and
GHA = LHA + West Longitude.

So our two possibles for LHA become two possibles for GHA! Now look in the Almanac, left facing page on the day in question and look at the four planets' GHAs. At the hour of our sight, one planet's GHA will be the same or very close to the one we have just calculated.

Our Azimuth (magnetic converted to 'True') or Zn can also be related to the two possibles depending on which hemisphere we are in:

DR Lat 'North'... LHA > 180°, Zn = Z
LHA < 180°, Zn = 360°- Z ...

DR Lat 'South'... LHA > 180°, Zn = 180°- Z
LHA < 180°, Zn = 180°+ Z

If we are in the northern hemisphere, our Z could be one of two possibles, which when compared together with the sextant angle against the Hc and Z in the Tables, will serve as a confirmation check. A DR in the southern hemisphere is easier - if Zn is greater than 180°, Z must be Zn-180°. If Zn is less than 180°, Z must be 180° - Zn.

EXAMPLE 26. Let's do an example.

The date is 20 June 199x and we see a planet in the evening twilight. We note the magnetic bearing to be between 340° and 342°, and since the magnetic variation (as seen on our chart) at our DR (30°25' S, 26°10' W) is 21°W, the Azimuth is +/- 320° T. Our sextant angle is 28°52,8' when index error is 2' 'off' the scale and height of eye is 3,5m. Our clock set to UTC (GMT) is 1 second fast. The clock shows the time of the sight to be 19h52m12s. Our sextant angle is approximately equal to the Hc and is 28°52,8'.

Since we are 'South' and Zn = +/- 320° T, Z = 320° - 180° = 140°, we therefore look up in the Sight Reduction Tables on the pages for our DR Latitude (nearest degree), 30°, to find the nearest combination of Hc = +/- 28°52,8' and Z = +/- 140°. See Table 16 below.

N. Lat. {LHA greater than 180°....... Zn=Z; LHA less than 180°........... Zn=360—Z}

DECLINATION (15°-29°) CONTRARY N

LHA	15° Hc (° ')	15° d (')	15° Z (°)	16° Hc (° ')	16° d (')	16° Z (°)	17° Hc (° ')	17° d (')	17° Z (°)
69	09 49	35	114	09 14	34	115	08 40	35	115
68	10 36	35	114	10 01	34	115	09 27	35	116
67	11 23	35	115	10 48	35	116	10 13	35	117
66	12 10	35	116	11 35	35	116	11 00	36	117
65	12 57	-36	116	12 21	-35	117	11 46	-36	118
64	13 44	36	117	13 08	36	118	12 32	37	118
63	14 30	36	117	13 54	37	118	13 17	36	119
62	15 16	37	118	14 39	36	119	14 03	37	120
61	16 02	37	119	15 25	37	119	14 48	38	120
60	16 47	-37	119	16 10	-39	120	15 32	-37	121
59	17 33	38	120	16 55	38	121	16 17	38	121
58	18 18	38	120	17 40	39	121	17 01	38	122
57	19 02	38	121	18 24	39	122	17 45	39	123
56	19 47	39	122	19 08	39	123	18 29	40	123
55	20 31	-40	122	19 51	-39	123	19 12	-40	124
54	21 14	39	123	20 35	40	124	19 55	40	125
53	21 58	40	124	21 18	41	125	20 37	40	125
52	22 41	41	124	22 00	40	125	21 20	41	126
51	23 24	41	125	22 43	41	126	22 02	42	127
50	24 06	-41	126	23 25	-42	127	22 43	-42	127
49	24 48	42	127	24 06	42	127	23 24	42	128
48	25 29	42	127	24 47	42	128	24 05	43	129
47	26 10	42	128	25 28	43	129	24 45	43	130
46	26 51	43	129	26 08	43	130	25 25	44	130
45	27 31	-43	130	26 48	-44	130	26 04	-44	131
44	28 11	44	130	27 27	44	131	26 43	44	132
43	28 51	45	131	28 06	45	132	27 21	45	133
42	29 29	45	132	28 44	45	133	27 59	45	134
41	30 08	46	133	29 22	45	134	28 37	46	134
40	30 45	-45	134	30 00	-46	135	29 14	-47	135
39	31 23	47	135	30 36	46	135	29 50	47	136
38	31 59	46	136	31 13	47	136	30 26	48	137
37	32 36	48	136	31 48	47	137	31 01	48	138
36	33 11	48	137	32 23	48	138	31 35	48	139
35	33 46	-48	138	32 58	-49	139	32 09	-48	140
34	34 20	48	139	33 32	49	140	32 43	49	141
33	34 54	49	140	34 05	50	141	33 15	49	142
32	35 27	50	141	34 37	50	142	33 47	50	142
31	35 59	50	142	35 09	50	143	34 19	51	143
30	36 31	-51	143	35 40	-51	144	34 49	-51	144
29	37 02	51	144	36 11	52	145	35 19	51	145
28	37 32	52	145	36 40	52	146	35 48	52	146
27	38 01	52	146	37 09	52	147	36 17	53	147
26	38 30	53	147	37 37	53	148	36 44	52	149
25	38 57	-53	148	38 04	-53	149	37 11	-53	150
24	39 24	53	149	38 31	54	150	37 37	54	151
23	39 50	54	151	38 56	54	151	38 02	54	152
22	40 15	54	152	39 21	55	152	38 26	54	153
21	40 40	55	153	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	154
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

LHA	18° Hc (° ')	18° d (')	18° Z (°)	19° Hc (° ')	19° d (')	19° Z (°)	20° Hc (° ')	20° d (')	20° Z (°)
69	08 05	34	116	07 31	35	117	06 56	35	118
68	08 52	35	117	08 17	35	118	07 42	36	119
67	09 38	35	117	09 03	36	118	08 27	35	119
66	10 24	36	118	09 48	36	119	09 12	36	120
65	11 10	-36	119	10 34	-37	119	09 57	-36	120
64	11 55	36	119	11 19	37	120	10 42	36	121
63	12 41	37	120	12 04	37	121	11 27	37	121
62	13 26	38	120	12 48	37	121	12 11	37	122
61	14 10	37	121	13 33	38	122	12 55	38	123
60	14 55	-38	122	14 17	-38	122	13 39	-39	123
59	15 39	38	122	15 01	39	123	14 22	39	124
58	16 23	39	123	15 44	39	124	15 05	39	124
57	17 06	39	123	16 27	39	124	15 48	40	125
56	17 49	39	124	17 10	40	125	16 30	40	126
55	18 32	-40	125	17 52	-40	126	17 12	-40	126
54	19 15	41	125	18 34	40	126	17 54	41	127
53	19 57	41	126	19 16	41	127	18 35	41	128
52	20 39	41	127	19 58	42	128	19 16	41	128
51	21 20	41	128	20 39	42	128	19 57	42	129
50	22 01	-42	128	21 19	-42	129	20 37	-42	130
49	22 42	43	129	21 59	42	130	21 17	43	130
48	23 22	43	130	22 39	43	130	21 56	43	131
47	24 02	44	130	23 18	43	131	22 35	44	132
46	24 41	44	131	23 57	44	132	23 13	44	133
45	25 20	-44	132	24 36	-45	133	23 51	-44	133
44	25 59	45	133	25 14	45	133	24 29	45	134
43	26 36	45	134	25 51	45	134	25 06	46	135
42	27 14	44	134	26 28	46	135	25 42	46	136
41	27 51	46	135	27 05	47	136	26 18	46	137
40	28 27	-46	136	27 41	-47	137	26 54	-47	137
39	29 03	47	137	28 16	47	138	27 29	48	138
38	29 38	47	138	28 51	48	138	28 03	48	139
37	30 13	48	139	29 25	48	139	28 37	48	140
36	30 47	48	139	29 59	49	140	29 10	49	141
35	31 21	-49	140	30 32	-49	141	29 43	-50	142
34	31 54	50	141	31 04	49	142	30 15	50	143
33	32 26	50	142	31 36	50	143	30 46	50	143
32	32 57	50	143	32 07	51	144	31 16	50	144
31	33 28	51	144	32 37	51	145	31 46	51	145
30	33 58	-51	145	33 07	-51	146	32 16	-52	146
29	34 28	52	146	33 36	52	147	32 44	52	147
28	34 56	52	147	34 04	52	148	33 12	53	148
27	35 24	52	148	34 32	53	149	33 39	53	149
26	35 52	54	149	34 58	53	150	34 05	53	150
25	36 18	-54	150	35 24	-53	151	34 31	-54	151
24	36 43	54	151	35 49	54	152	34 55	54	152
23	37 08	54	152	36 14	55	153	35 19	55	153
22	37 32	55	153	36 37	55	154	[illegible]	[illegible]	[illegible]
21	37 55	56	154	36 59	55	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	156	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

LHA	21° Hc (° ')	21° d (')	21° Z (°)	22° Hc (° ')	22° d (')	22° Z (°)	23° Hc (° ')	23° d (')	23° Z (°)
69	06 21	35	119	05 46	35	120	05 11	35	120
68	07 06	35	119	06 31	35	120	05 56	36	121
67	07 52	36	120	07 16	36	121	06 40	36	121
66	08 36	36	120	08 00	36	121	07 24	36	122
65	09 21	-36	121	08 45	-37	122	08 08	-36	123
64	10 06	37	122	09 29	37	122	08 52	37	123
63	10 50	37	122	10 13	38	123	09 35	37	124
62	11 34	38	123	10 56	38	124	10 18	37	124
61	12 17	38	123	11 39	38	124	11 01	38	125
60	13 00	-38	124	12 22	-38	125	11 44	-39	126
59	13 43	38	125	13 05	39	125	12 26	39	126
58	14 26	39	125	13 47	39	126	13 08	40	127
57	15 08	39	126	14 29	40	127	13 49	40	127
56	15 50	40	126	15 10	40	127	14 30	40	128
55	16 32	-40	127	15 52	-41	128	15 11	-41	129
54	17 13	41	128	16 32	41	129	15 51	41	129
53	17 54	41	128	17 13	42	129	16 31	41	130
52	18 35	42	129	17 53	42	130	17 11	42	131
51	19 15	42	130	18 33	43	131	17 50	42	131
50	19 55	-43	131	19 12	-43	131	18 29	-43	132
49	20 34	43	131	19 51	43	132	19 08	44	133
48	21 13	44	132	20 29	43	133	19 46	44	133
47	21 51	44	133	21 07	44	133	20 23	44	134
46	22 29	44	133	21 45	45	134	21 00	45	135
45	23 07	-45	134	22 22	-45	135	21 37	-45	136
44	23 44	46	135	22 58	45	136	22 13	46	136
43	24 20	45	[illegible]	23 35	46	136	22 49	47	137
42	24 56	46	[illegible]	24 10	46	137	23 24	47	138
41	25 32	[illegible]	137	24 45	47	138	23 58	47	139
40	26 07	[illegible]	138	25 20	-48	139	24 32	-47	139
39	[illegible]	47	139	25 54	48	140	25 06	48	140
38	27 15	48	140	26 27	48	140	25 39	49	141
37	27 49	49	141	27 00	49	141	26 11	49	142
36	28 21	49	141	27 32	49	142	26 43	49	143
35	28 53	-49	142	28 04	-50	143	27 14	-50	144
34	29 25	50	143	28 35	50	144	27 45	51	144
33	29 56	51	144	29 05	50	145	28 15	51	145
32	30 26	51	145	29 35	51	146	28 44	51	146
31	30 55	51	146	30 04	52	147	29 12	51	147
30	31 24	-52	147	30 32	-52	147	29 40	-52	148
29	31 52	52	148	31 00	53	148	30 07	52	149
28	32 19	52	149	31 27	53	149	30 34	53	150
27	32 46	53	150	31 53	53	150	31 00	54	151
26	33 12	54	151	32 18	53	151	31 25	54	152
25	33 37	-54	152	32 43	-54	152	31 49	-54	153
24	34 01	54	153	33 07	55	153	32 12	54	154
23	34 24	54	154	33 30	55	154	32 35	55	155
22	[illegible]	[illegible]	155	33 52	56	155	32 56	55	156
21	[illegible]	[illegible]	[illegible]	[illegible]	56	156	33 17	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 16. APPLICABLE AIR SIGHT REDUCTIONS PAGE

The nearest we can get is on the Lat 30°, 'CONTRARY' page under the column for Declination 20°. As we are 'south' and Contrary applies, 'Dec' must be North. We need to look for a planet whose Dec is N 20°. The table's Hc is 28°37' and Z is 140°. In the side columns we see the LHA is either 37° (left hand column) or 323° (right hand column) . Our DR longitude is 26°10' W so the GHA must be:

GHA = LHA + W Longitude, so GHA = 37° + 26°10' = 63°10', or
GHA = 323° + 26°10' = 349°10'

Now we look in the Almanac on 20 June, opposite the UTC (GMT) time (hour value) of our sight and under the four planets' names and we see that Venus has a GHA of 49°26,4' (at 19h, -our sight was at 19h52 and as GHA changes about 15° per hour, this translates to a GHA at the time of our sight of 62°28,7') and Dec of N 20°33,9'. No other planet has a GHA or Dec anything like these figures so our planet is VENUS ! Knowing the Planet's name, we can now calculate, using any method we choose, the details for plotting the LOP. (See page 83, Solution 26 which uses the Almanac Sight Reduction Tables.)

Method 2. If we want to find a particular planet, for example Jupiter, we first need to know that at twilight, the LHA will be between 0° and 90° , or between 270° and 360°, otherwise it will be below our horizon:

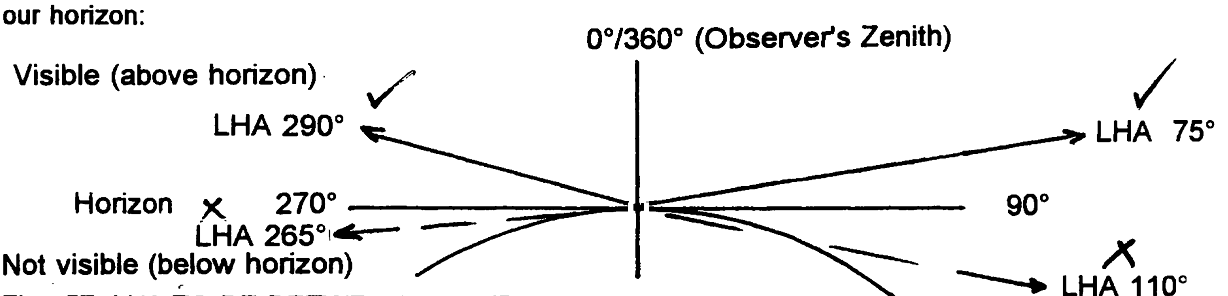


Fig. 57. LHA TO BE BETWEEN 0° AND 90° , OR 270° AND 360°.

We therefore convert our DR longitude to 'Time' (Arc to Time conversion table, see Table 3, page 17, or the first of the 'Yellow Pages' in your Almanac) and apply it to the GHA of Jupiter at the time (UTC) we expect twilight, and we get a LHA - is Jupiter going to be above our horizon?

<u>Twilight</u>

If we use the example earlier where the date is 20 June, our DR Long of 26°10' W = 1hr 45 mins (to the nearest minute), and the Almanac gives sunset at 30° South as 17h 08 local time which will be 18h53 UTC (17h08 + 1h45). Planets (normally) and stars can be seen only while the horizon is still adequately visible. This is between Sunset and Civil Twilight at night and between Civil Twilight and Sunrise in the mornings. There is normally a period of just over 20 minutes in which to take twilight sights. (Continued on page 84.)

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

Table 17. SUNSET AND TWILIGHT TABLES

Solution 26 to Example 26, page 81.

WORK SHEET FOR USE WITH ALMANAC'S SIGHT REDUCTION TABLES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 20/6 DR 30 °25 'N/S, 26 ° 10 'E/W; IE 2,0' 'on'/'off', Eye ht: 3,5 ft/m, Body VENUS UL/LL
Course 125 °T/M/C, Speed 6,5 knots. Clock error to UTC h m -1 s (-fast, +slow?),
Sight clock time 19 h 52 m 12 s, Sight Time Corrected to UTC(GMT) 19 h 52 m 11 s.

Ho		↓ → Apparent Altitude (AA)	28°51,6'
Sextant Angle (Hs)	28 °52,8'	Main Correction (Al'nac card) or(+/-) Moon Correction, back of Al'nac (+)	-1,8'
Index Error +/-	+2,0'	Planet Correction (Almanac card)(+)	+0,1'
DIP (Height of eye) (-)	-3,2'	Moon HP Corrn (Back of Al'nac) (+)	, '
Apparent Altitude (AA)	28°51,6→	↑ Moon UL Corrn (-30.0' only if UL) (-)	, '
Yachtmaster Ocean Services		**True Altitude (Ho)**	28°49,9'

DECLINATION 'Dec' as at day, hour of sight; Almanac.	N/S 20°34,5'	Increasing/Decreasing* hourly?
(d= ? at bottom of Dec column in Al'nac)	(d 0,7)	Not part of sum. See next line.
d Corrn, Yellow p's, Mins (time of sight)	+/- 0,6'	*+ if Dec increasing, - if decreasing
TOTAL DECLINATION	N/S 20°34,0'	Rounded off - nearest whole minute
Chosen Latitude	30°00,0' N/S	DR Lat rounded off, nearest degree
SAME or CONTRARY ?	Contrary	Dec and Lat, SAME hemisphere?

LHA		
GHA (hr)Cel'stial Body, Al'nac	49°26,4'	Date page, choose body's name column.
Increment, for mins/secs. +	13°02,8'	Yellow p's; NB: Use correct column heading.
v:(-0,6 factor) +/-Planets; +Moon. Corrn= +/-	-0,5'	Bottom of Planet column; or Moon, next to GHA; treat as d for Dec Corrn, Yellow p's.
Total GHA =	62°28,7'	Sum of above lines.
- 360° if above line >360° -	° 00 , 0'	GHA must be between 0° and 360°.
Total GHA if different. =	° , '	GHA: angle, 0° westward, to meridian of GP.
SHA of Star +	° , '	Almanac, left day page, right hand column.
GHA of Celestial Body =	62°28,7'	Omit this and above line if not for a star.
Chosen Longitude (+E, -W) +/-	-26°28,7'	DR degrees; mins to make LHA whole number.
LHA of Celestial Body =	36° 00,0'	Angle, your meridian west to meridian of GP.
+/- 360° if necessary +/-	° 00,0'	LHA to be between 0° and 360°.
LHA Required =	36° 00,0'	Now we can start with the Sight Redn. Tables.

USE OF SIGHT REDUCTION TABLE (SRT) *By Henton Jaaback*

1. Select SRT page with above 'Chosen Lat' Under Lat , opposite LHA (as above): [A°=31° (nearest whole degree), A'=36] B = 54°29', Z1=70,0° (B/Z1 '-' if 90°<LHA<270°)
Dec = +/- 20 °34 'N/S ('+' SAME, '-' CONTRARY)
F = +/- 33 °55'
(F°=+/-34 °[nearest degree], F'=55')

3. Go to Auxiliary Table (pages 316/317). Under F' column opposite P° in left column, what is: Corrn 1 ? +/- 4,0' ('-' if F°<90° and F'>29', or if F°>90° and F'<30'. Otherwise '+')

4. Under A' column, opposite Z2 (right hand column), what is Corrn 2 ? +/- 8,0' ('-' if A'<30')

2. SRT page with A° value as column heading. Under A° opposite F°; H = 28 °38, '
P° = 54 °(nearest whole degree), Z2 = 70,8°

H = 28°38,0'	Z1 = 70,0° + or - as for B.	**IF DR in N LAT:**
Corrn 1 = -4,0'	Z2 = 70,8° (If F°'-', use 180°-Z2).	If LHA>180° Zn=Z
Corrn 2 = +8,0'	(Z2 is '-' if F°>90°).	If LHA<180° Zn=360°-Z
Hc = 28°42,0'	Z = 140,8° Ignore '-'	**IF DR in S LAT:**
Ho = 28°49,9'	if applic.	If LHA>180° Zn=180°-Z
Intcpt = 7,9'		If LHA<180° Zn=180°+Z

TOWARDS if Ho>Hc, AWAY if Hc >Ho Zn = 321°T (To the nearest degree.)

If our sight is to be about 10 to 15 minutes after sunset, the sight time will be approximately 19h05 UTC. We can therefore look up the GHA of Jupiter at that time:

GHA hour value	340°39,2'	
Increment 5m 00s	+ 1°15,0'	
v +2,6 v corrn	+ 0,2'	(As this is always small, we could ignore it at this stage)
Total GHA	= 341°54,4'	

We can convert this to LHA by subtracting our West longitude:

GHA	= 341°54,4'
Chosen Longitude	-26°54,4'
LHA	= 315°00,0'
-360° if necessary	- N/A ° , '
LHA Required	= 315°00,0'

We will be able to see Mars- it will not be below the horizon.
Next to the GHA in the Almanac we see the Dec of Jupiter to be S 12°00,3'.

Knowing DR Lat, Dec and LHA, we can look up the Sight Reduction Tables (Same page because DR Lat and Dec are both south) to find Hc and Z. We see they are 44°40' and 104°.

Zn is therefore = 076° T. (S Lat; LHA>180°, Zn = 180° - Z)

We must therefore look in the approximate direction 075°T and at an altitude of about 45° at about 19h05 UTC to find Jupiter.

The Planet Sight

There is nothing special to taking a planet sight nor resolving for the applicable plotting information. The use of a work sheet also makes it very easy to do. Let's do some examples using the Air Sight Reduction Tables and Almanac's Sight Reduction Tables methods/work sheets.

EXAMPLE 27 (Air Sight Reduction Tables - planet's identity to be established.)

Date	: 20 June 199x. DR: Lat 30°25' S, Long 26°10' W.
Time	: 19h07m36s UTC per clock having a '4 seconds fast' error.
Sextant	: 45°11,8'. Compass bearing to planet at time of sight, converted to True : 075° T.
Dip	: 4,5m above sea level. Course: 320°M, 5 knots.
IE	: 3,7' 'off'.

First check GHA's/LHA's; only Venus and Jupiter will be visible/above the horizon. Resolve for both, one will become obviously wrong, the other right. (See the next page for the worked solution, Solution 27. Check that you can find all the values entered from the applicable Tables in Part 2.)

EXAMPLE 28. (Almanac's Sight Reduction Tables - planet's identity known.) (Solution 28, page 86.)

Date	: 5 December 199x. Morning twilight sight of the planet Mars.
DR	: Lat 15° 15' N, Long 80° 40' E. Course: 270°T 5 knots.
Time	: 00h07m16s UTC per clock. (Local time approx 05h30)
Clock error	15 seconds fast. Sextant : 85°21,3'. Bearing from compass : +/- 260° T.
Dip	: 3,5m above sea level. IE : 2,6' 'on'.

EXAMPLE 29. You try this one. See Solution 29 (in 'Solutions' in Part 2) which uses the Sine/Cosine method.
Date, 30 August, DR 38°20' N, 130°05' W, time of evening sighting of Venus 03h22m53s i.e. on 31 August UTC (but clock error was 24s fast), eye height 2,5 m, Index Error 3,2' off the scale. Sextant Angle 15°42'. Magnetic bearing +/-260°M when Variation was 18° West. Course 200°M, 9 knots, and Log 3456 M. Determine the intercept details (DR/CP Lat/Long, Zn, Intcpt, and Away/Towards).

Why is no navigation planet visible at 05h30 UT on the morning of 28 February 199x from the same DR as above? Answer: 1. Check their LHA's - they will all be below the horizon! (i.e. LHAs between 90° and 270°). 2. At that time and at that DR, 05h30 UT is +/- midday!

Solution 27 to Example 27, page 84.

AIR SIGHT REDUCTION TABLES WORK SHEET; ALL CELESTIAL BODIES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 20/6 IE:+/- 3,7 '(-On, +Off); Eye Ht: 4,5 ft/m; Clock error: h m -4 s(Fast/Slow?)
Course: 320 °T/M/C; Speed: 5 kns; Celestial Body/ies-UL/LL: Venus / Jupiter?

	VENUS	JUPITER	
DR Lat	30 ° 25 ' N/S	30 ° 25 ' N/S	° 'N/S
DR Long	26 ° 10 ' E/W	26 ° 10 ' E/W	° 'E/W
Chosen Lat	30 °00 ,0' N/S	30 °00 ,0' N/S	°00 ,0'N/S
TIME Clock time of sight	19 h 07 m 36 s	19 h 07 m 36 s	h m s
Clock error relative to UTC (-fast, + slow) ±	h m -4 s	h m -4 s	h m s
Corrected UTC time of sight =	19 h 07 m 32 s	19 h 07 m 32 s	h m s
LHA GHA as at day, hr of sight: Al'nac	64 ° 25,8 '	340 ° 39,2 '	° , '
Increments for mins/secs; Yellow pages +	1 ° 53,0 '	1 ° 53,0 '	° , '
v (?) ±Plnts; +Moon. Corrn.(Yellow p's) ±	(-0,6) -0,1 '	(2,6) +0,3 '	( ) , '
Total GHA as at exact time of sight =	66 ° 18,7 '	342 ° 32,5 '	° , '
-360° if nec; GHA to be between 0°/ 360° -	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
GHA Required =	° , '	° , '	° , '
SHA of star +	° , '	° , '	° , '
GHA of celestial body sighted =	66 ° 18,7 '	342 ° 32,5 '	° , '
Chosen Longitude (+E, -W) ±	-26 ° 18,7 '	-26 ° 32,5 '	° , '
LHA Required =	40 ° 0 0 , 0'	316 ° 0 0 , 0'	° 0 0 , 0'
+/- 360° if necessary ±	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
LHA of celestial body sighted =	40 ° 0 0 , 0'	316 ° 0 0 , 0'	° 0 0 , 0'
Declination day/hr of sight; next to GHA =	N/S 20° 34,5'	N/S 12 ° 00,3'	N/S ° , '
(d = ?)factor; bottom of/or in moon colmn	(d = -0,7)	(d = 0,0)	(d = ,)
d Corrn;Yellow p's(mins)(+if Dec incr'ng) ±	-0,1'	0,0'	, '
TOTAL DECLINATION at time of sight =	N/S 20° 34,4'	N/S 12° 00,3'	N/S ° , '
Lat/Dec **SAME** or **CONTRARY** (N/S) ?	Contrary	Same	
Hc: Hc, Sight Red Tables, 'C Lat' page:	*26 ° 54 '	45 ° 30 '	° '
(d± ?) Use with Dec's mins, Table 5.	(d = +/- 47)	(d = +/- 31)	(d =+/-)
d Correction, from Table 5 ±	-27 '	0 '	'
TOTAL Hc (Transfer to Intercept, ↓) =	26 ° 27 '	45 ° 30 '	° '
Z → Zn Top/bottom left corner SRT page.	Z = 137 ° Zn = 317 °	Z = 104 ° Zn = 076 °	Z = ° Zn = °
Ho; Sextant Angle (SA/Hs)Up./Low. Limb=	*Wrong: Must be Jupiter → (Hc and SA should be ± the same.)	45 ° 11,8 '	° , '
IE (-On, +Off) ±		+3,7 '	, '
DIP (Eye ht; Al'nac card/Page A2) -		-3,7 '	, '
Apparant Altitude (AA) =		45 ° 11,8 '	° '
Main corrn (Al'nac card), OR ±		-1,0 '	, '
Moon corrn (Back of Al'nac) +		° , '	° , '
Planet corrn (Al'nac card) +		NIL	° , '
Moon HP corrn (Back of Al'nac) +		° , '	° , '
Moon only, if UL, corrn (-30,0' if UL) -	° , '	° , '	° , '
TRUE ALTITUDE / Ho Ho =	° , '	45 ° 10,8 '	° . '
Intercept; Ho - Hc or Hc - Ho Hc =	° , 0'	45 ° 30 , 0'	° , 0'
Intcpt (Difference); ~	, '	19,2 '	, '
TOWARDS or AWAY? If Ho>Hc, Towards		Away	

Solution 28 to Example 28, page 84

WORK SHEET FOR USE WITH ALMANAC'S SIGHT REDUCTION TABLES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 5/12 DR 15 ° 15 'N/S, 80 ° 40 'E/W; IE 2,6 'on'/off, Eye ht: 3,5 ft/m, Body Mars UL/LL
Course 270°T/M/C, Speed 5 knots. Clock error to UTC h m -15 s (-fast, +slow?),
Sight clock time 00 h 07 m 16 s, Sight Time Corrected to UTC(GMT) 00 h 07 m 01 s.

Ho		↓ → Apparent Altitude (AA)	85 ° 15,5'
Sextant Angle (Hs)	85 ° 21,3 '	Main Correction (Al'nac card) or(+/-) Moon Correction, back of Al'nac (+)	-0,1 ° , '
Index Error +/-	- 2,6 '	Planet Correction (Almanac card)(+)	NIL '
DIP (Height of eye) (-)	- 3,2 '	Moon HP Corrn (Back of Al'nac) (+)	, '
Apparent Altitude (AA)	85 ° 15,5 →	↑ Moon UL Corrn (-30.0' only if UL) (-)	, '
Yachtmaster Ocean Services		**True Altitude (Ho)**	85° 15,4'

DECLINATION 'Dec' as at day, hour of sight; Almanac.	N/S 14 ° 30,8'	Increasing/Decreasing* hourly?
(d= ? at bottom of Dec column in Al'nac)	(d 0,2)	Not part of sum. See next line.
d Corrn, Yellow p's, Mins (time of sight)	+/- 0,0'	*+ if Dec increasing, - if decreasing
TOTAL DECLINATION	N/S 14 ° 31,0'	Rounded off - nearest whole minute
Chosen Latitude	15 °00,0' N/S	DR Lat rounded off, nearest degree
SAME or CONTRARY ?	Same	Dec and Lat, SAME hemisphere?

LHA		
GHA (hr)Cel'stial Body, Al'nac	282° 29,4'	Date page, choose body's name column.
Increment, for mins/secs. +	1° 45,3'	Yellow p's; NB: Use correct column heading.
v:(factor) +/-Planets; +Moon. Corrn= +/-	+ 0,2'	Bottom of Planet column; or Moon, next to GHA; treat as d for Dec Corrn, Yellow p's.
Total GHA =	284° 14,9'	Sum of above lines.
- 360° if above line >360° -	° 00,0'	GHA must be between 0° and 360°.
Total GHA if different. =	° , '	GHA: angle, 0° westward, to meridian of GP.
SHA of Star +	° , '	Almanac, left day page, right hand column.
GHA of Celestial Body =	284° 14,9'	Omit this and above line if not for a star.
Chosen Longitude (+E, -W) +/-	+80° 45,1'	DR degrees; mins to make LHA whole number.
LHA of Celestial Body =	365° 00,0'	Angle, your meridian west to meridian of GP.
+/- 360° if necessary +/-	360° 00,0'	LHA to be between 0° and 360°.
LHA Required =	5° 00,0'	Now we can start with the Sight Redn. Tables.

USE OF SIGHT REDUCTION TABLE (SRT) *By Henton Jaaback*

1. Select SRT page with above 'Chosen Lat' Under Lat , opposite LHA (as above):
[A°= 5 ° (nearest whole degree), A'=50]
B = 74 °57', Z1=88,7 (B/Z1 '-' if 90°<LHA<270°)
Dec =+/- 14°31 'N/S ('+' SAME, '-' CONTRARY)
F =+/- 89 °28'
(F°=+/-89°[nearest degree], F'=28')

2. SRT page with A° value as column heading. Under A° opposite F°; H =84 °54,0'
P° = 11 °(nearest whole degree), Z2 = 11 3°

3. Go to Auxiliary Table (pages 316/317). Under F' column opposite P° in left column, what is: Corrn 1 ? +/- 5,0' ('-' if F°<90° and F'>29', or if F°>90° and F'<30'. Otherwise '+')

4. Under A' column, opposite Z2 (right hand column), what is Corrn 2 ? +/-* 10,0' (*'-' if A'<30')

H = 84°54,0 ' Z1 = 88,7 ° + or - as for B.
Corrn 1 = + 5,0 ' Z2 = 11,3 ° (If F°'-', use 180°-Z2).
Corrn 2 = + 10,0 ' (Z2 is '-' if F°>90°).
Hc = 85°09,0 ' Z = 100,2 ° Ignore '-' if applic.
Ho = 85 °15,4 '
Intcpt = 6,4 '
TOWARDS if Ho>Hc, AWAY if Hc >Ho

IF DR in N LAT:
If LHA>180° Zn=Z
If LHA<180° Zn=360°-Z
IF DR in S LAT:
If LHA>180° Zn=180°-Z
If LHA<180° Zn=180°+Z

Zn = 260 °T (Rounded off to nearest degree.)

Stars

There are countless stars in the heavens but navigators only use some of the more prominent ones of which there are 57. Stars appear to occupy 'fixed' positions in the skies relative to each other - we regard them to be almost static as if painted on the inside of a very big ball - the celestial sphere of which earth is its centre. Just as we have an equator and meridians for navigation convenience on earth, we have a celestial equator and celestial meridians to aid charting our way around the heavens.

A belt 8° N to 8° S of the celestial equator is called the Zodiac which we have all heard of. Each star, whether in the Zodiac or not, can be 'pin-pointed' if its declination and longitude are known. We already know that declination means the angle measured at the centre of the earth in a vertical (north-south) plane between the equator and a line to the centre of the celestial body. The earth spinning on its axis has the Greenwich Meridian as a longitude reference while the celestial sphere remains static and has its own equivalent reference meridian, the 'First Point of Aries' or now just called 'Aries'. We use the symbol '♈' for Aries.

The celestial longitude of a star is stated as a number of degrees west of Aries, from 0° to 360°. This of course differs from our system on earth where we think in terms of being a number of degrees, up to 180°, east or west of Greenwich (the Greenwich Meridian).

Hour Angles we saw are also measured 0° to 360° west of Greenwich and so it is with stars - we think of the angle between the celestial meridians of the star and of Aries as an Hour Angle, just as we do for GHA and LHA. Our star hour angle is called the 'Sidereal Hour Angle' (SHA), and the stars used for navigation are listed in your Almanac in alphabetical order with their respective SHAs and Decs.

122 199· JUNE 18, 19, 20 (SAT., SUN., MON.)

UT (GMT)	ARIES	VENUS −4.0		MARS +1.2		JUPITER −2.3		SATURN +0.9		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. ° ′
18 00	266 00.4	140 0[illegible]	[illegible].0	219 45.6	N16 47.2	52 47.7	S12 01.7	281 34.[illegible]	[illegible]1.8	Acamar	315 29.5	S40 19.5
01	281 02.9	155 03.3	[illegible]1.4	234 46.3	47.7	67 50.3	01.7	296 37.0	31.8	Achernar	335 37.6	S57 15.6
02	296 05.3	170 02.7	20.7	249 46.9	48.3	82 52.9	01.7	311 39.5	31.8	Acrux	173 25.1	S63 04.5
03	311 07.8	185 02.1	· · 20.0	264 47.6	· · 48.8	97 55.4	· · 01.7	326 41.9	· · 31.8	Adhara	255 24.1	S28 58.0
04	326 10.3	200 01.5	19.3	279 48.2	49.3	112 58.0	01.6	341 44.3	31.8	Aldebaran	291 06.1	N16 29.8
05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Table 18. ALMANAC: GHA ARIES AND STARS' DETAILS LIST

To get the GHA of a star we look up the GHA of Aries in the Almanac (left column next to "hours" on the left page and increment in the yellow pages under the Aries column). We then add the SHA which we get from the right-hand column of the left page. The total of the two is the GHA of the star. If we now add our easterly (or subtract our westerly) longitude, we get the LHA (of the star) - just the same as we did for the sun, moon and planets.

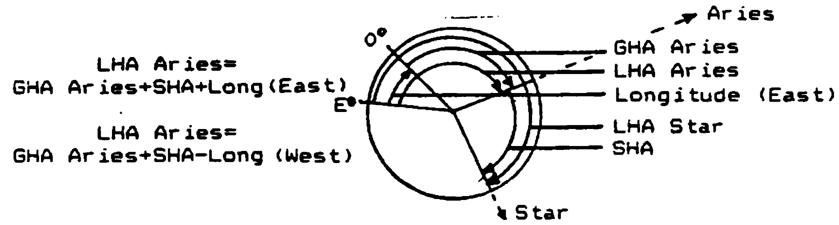


Fig. 58. LHA STAR FROM GHA ARIES AND SHA STAR

Once we have the LHA Star, and knowing the Chosen Lat and Long, and the Dec, we can find Hc and Zn. This can be done the same way as we did for the sun, moon, and planets.

Converting the sextant angle (SA or Hs) to a True Altitude (Ho) involves the only other variation when compared with a sun sight. The steps are the same but after getting the AA (Apparent Altitude), we get the 'main correction' from the middle section of the Almanac's card 'ALTITUDE CORRECTION TABLES 10°-90° -SUN, STARS, PLANETS'. The card detail is also printed on a page in the front of the Almanac in case the card gets lost!

Once we have Hc, Ho, and therefore the intercept, Zn, etc., we can plot the LOP.

BUT WHAT IF WE DO NOT KNOW ONE STAR FROM ANOTHER?

Relax! Help is on the way. I don't know which is which, either!

7 SELECTED STARS' - AIR SIGHT REDUCTION TABLES

Without doubt the easiest way to 'do' stars, the Air Navigation tables 'Publication No 249 Volume 1', 'SIGHT REDUCTION TABLES FOR AIR NAVIGATION (SELECTED STARS)' do not require the navigator to 'know' his stars. Instead, the names of the stars are revealed during the calculation process so you can go up on deck after getting your fix and make 'casual' comments to the effect that 'Acrux, Deneb and Regulus make a nice cocked hat tonight' - someone in the crew is bound to be impressed with the thought of having an astronomer (you!) on board.

To use these tables we need to know:

a. Chosen Lat.
b. LHA Aries.
c. Ho.
d. The true bearing to the star (Azimuth).

The procedure is simply to look up into the sky and pick out one of the brightest stars (not a planet). Take your sextant sight, noting the sextant angle, time AND the magnetic bearing to the star. This magnetic bearing is converted to 'True' by subtracting the (westerly) magnetic variation (add if variation east).

The sextant angle is converted to Ho as we did for the sun, moon and planets. We get the main correction from the centre column of the Almanac card (page 7, Table 1.).

From the time of the sight we can use the Almanac to find the GHA Aries and then apply our longitude to get LHA Aries.

Our DR Lat is rounded off to the nearest whole number of degrees to become our chosen latitude (C Lat).

We then go to the tables and open them to the facing pages for our C Lat. Each page has two vertically arranged halves for 90° of the possible 360° LHAs. Find the required LHA in the left column and look in the adjacent 7 columns to the right - one will have an Hc and Zn very close to the Ho and True bearing you obtained. At the top of that section of the column containing the matching Hc and Zn you will see the name of a star - Bingo!

LAT 33°S

LHA ♈	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn
	VEGA		ALTAIR		♦FOMALHAUT		ACHERNAR		♦RIGIL KENT.		ANTARES		♦Rasalhague	
270	17 43	007	40 36	037	27 51	109	15 45	149	47 28	214	69 11	282	44 02	351
271	17 50	007	41 06	036	28 39	109	16 11	149	47 00	214	68 21	281	43 53	350
272	17 55	006	41 35	035	29 26	108	16 37	149	46 32	214	67 32	281	43 44	349
273	18 00	005	42 04	034	30 14	108	17 04	148	46 04	214	66 43	280	43 34	347
274	18 04	004	42 31	032	31 02	107	17 30	148	45 36	214	65 53	279	43 22	346
275	18 07	003	42 58	031	31 50	107	17 57	148	45 07	215	65 03	278	43 09	345
276	18 10	003	43 23	030	32 38	107	18 24	147	44 38	215	64 13	277	42 55	343
277	16 12	002	43 48	029	33 27	106	18 51	147	44 10	215	63 23	276	42 41	342
278	18 13	001	44 12	027	34 15	106	19 19	147	43 41	215	62 33	276	42 25	341
279	18 14	000	44 34	026	35 04	105	19 47	146	43 12	215	61 43	275	42 08	340
280	18 13	359	44 56	025	35 52	105	20 15	146	42 43	215	60 53	274	41 49	338
281	18 12	358	45 17	024	36 41	105	20 43	146	42 14	215	60 03	274	41 30	337
282	18 11	358	45 36	022	37 29	104	21 11	146	41 45	215	59 13	273	41 10	336
283	18 08	357	45 55	021	38 18	104	21 40	145	41 16	215	58 22	272	40 49	335
284	18 05	356	46 12	020	39 07	103	22 09	145	40 46	215	57 32	272	40 27	333
	ALTAIR		Enif		♦FOMALHAUT		ACHERNAR		♦RIGIL KENT.		ANTARES		♦Rasalhague	
285	46 29	018	32 06	050	39 56	103	22 38	145	40 17	216	56 42	271	40 04	332
286	46 44	017	32 44	049	40 45	103	23 07	144	39 48	216	55 51	271	39 40	331
287	46 58	015	33 22	048	41 34	102	23 36	144	39 19	216	55 01	270	39 16	330
288	47 11	014	33 59	047	42 24	102	24 06	144	38 49	216	54 11	270	38 50	329
289	47 22	013	34 35	046	43 13	102	24 35	144	38 20	216	53 20	269	38 24	328
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 19. A SECTION FROM 'STARS' SIGHT REDUCTION TABLES

The difference between Hc and Ho is our intercept and the Zn is the direction to be used when plotting.

By sighting three* stars at about 120° apart in direction, and each being the brightest in its area, all within a few minutes of one another, we can get our cocked hat and therefore our fix - no advancing or transfering LOPs being involved, and no hours of waiting between taking sights.
* Warning: It may happen that one or two of the brightest stars you chose are not in fact from the seven listed for the LHA/time of your sights. It is therefore wise to take sights of a few extra - say six or seven altogether. Then you will be certain to get three of the seven as listed in the Sight Reduction Tables.

Planning Star Sights
Some navigators like to know in advance which stars they are going to use for taking sights. By knowing in what direction and height to look for the stars, no time will be wasted during the limited twilight period in deciding which stars to use. Planning will also avoid the remote possibility of one or more of the stars sighted not being among the seven!

The Procedure
Before twilight, calculate your DR as at the approximate time you think twilight will start. Then look up the Almanac to find out the time of sunset/sunrise and civil twilight at Greenwich - midway between sunset and civil twilight, or civil twilight and sunrise, will be the best time to plan for sight taking, if your DR is on the Greenwich Meridian. Convert your DR longitude to time (Arc to Time table - first of the yellow pages in the Almanac, or Table 3, page 17.) and if you are east subtract (add if west) this time from the Greenwich mid twilight, and you will have the UTC time of mid twilight at your DR.

Using this time look up the GHA Aries and apply your DR Long to get the LHA Aries.

Now open the Air Sight Reduction Tables - Seven Selected Stars, to the two facing pages labelled with the same 'Lat' as your chosen latitude and find the LHA value in one of the four LHA columns. To the right of the LHA are seven columns, each headed with a star's name and three of these have a diamond shape printed next to the name. These three are the stars recommended - they will be easy to find, brighter than surrounding stars and in directions that will result in a suitably shaped cocked hat - one which will make it easy for the navigator to find the centre, the 'fix' position.

The three stars' Hc's and Zn's can now be noted. Each Zn can be converted to a magnetic bearing and the Hc's used as the approximate sextant angles to find the stars when they become visible.

HINT: Take the sights of stars in the east first - they are the first to become visible at sunset and the first to disappear from view at sunrise.

(Star Finder. An alternative method of planning the taking of star sights is to use a "Star Finder and Identifier" - a set of round clear plastic discs and one white base disc. They are designed to be a quick, easy way of finding the approximate altitude and azimuth of any one of the 57 stars at a time and from a place. They are purchased with very easy to understand instructions how to use them.)

EXAMPLE 30. Now we will do an example. The date is 30 August 199x and DR at 16h00 LMT (local mean time) is 15°25' N, 130°25'W. What stars are the recommended stars for this evening's twilight, when will twilight start and end (UTC), and in which direction and at what height will each star be found?

The first fact we need to establish is 'time'. As our longitude is 130° 25'W, the time difference to GMT will be 8 hours 42 minutes behind (to the nearest minute). So when twilight starts at 0° Long/Greenwich (it will start with sunset at 18h14 - by interpolation), where we are we add our time equivalent of our west longitude, so it will be + 8h42, i.e. 26h56 = 02h56 UTC on 31 August!. Civil twilight lasts approximately 23 minutes so it will be from 02h56 to 03h19 UTC. If our sights are taken in the middle of twilight (average) they will be at approximately 03h07 UTC. So our LHA will be:

GHA Aries hour value	=	24°04,0'
Increment m s	+	1°45,3'
GHA Aries	=	25°49,3, '

To get LHA, being west, we subtract our longitude (DR Long with minutes changed to result in whole number of degrees for LHA - it becomes the chosen longitude, just as for the sun, moon and planets):

GHA Aries	=	25°49,3'
C Long (-W)	-	130°49,3'
LHA Aries	=	-105° 00,0'
+/- 360° if necessary	=	+360°00,0' (LHAs must be between 0° and 360°)
LHA Aries Required	=	255°00,0'

So 'time' lead us to LHA Aries.

Now we go to the Sight Reduction Tables (7 Selected Stars) and open the book to the two facing pages with our chosen latitude (15° 00' N). Opposite LHA 255° we see:

LAT 15°N

LHA ♈	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	LHA ♈	Hc	Zn
			[illegible]	092	36 41	[illegible]							41 29	324			
	[illegible]	042	43 08	092	37 18	141	48 [illegible]				[illegible] 12	282	40 55	324	340	65 [illegible]	
[illegible]	55 42	041	44 06	092	37 54	142	48 25	185		245	54 16	282	40 20	323	341	66 06	0
252	56 19	040	45 04	092	38 29	143	48 20	186	33 17	246	53 19	282	39 46	323	342	66 50	0
253	56 56	039	46 02	093	39 03	144	48 12	188	32 24	246	52 23	282	39 11	323	343	67 34	0
254	57 32	038	47 00	093	39 37	145	48 04	189	31 31	247	51 26	282	38 35	322	344	68 16	0
	♦VEGA		ALTAIR		♦Nunki		ANTARES		SPICA		♦ARCTURUS		Alkaid			Schedar	
255	58 08	037	47 57	093	40 10	146	47 54	190	30 38	247	50 29	282	38 00	322	345	44 22	0
256	58 42	036	48 55	094	40 42	147	47 43	192	29 44	247	49 33	282	37 24	322	346	44 41	0
257	59 16	035	49 53	094	41 14	148	47 30	193	28 51	248	48 36	282	36 48	321	347	44 59	0
258	59 49	034	50 51	094	41 44	149	47 17	194	27 57	248	47 39	282	36 11	321	348	45 16	0
259	60 21	033	51 49	095	42 14	150	47 02	196	27 03	249	46 43	282	35 35	321	349	45 33	0
260	60 52	032	52 46	095	42 43	151	46 46	197	26 09	249	45 46	282	34 58	320	350	45 49	0
261	61 22	030	53 44	096	43 11	152	46 28	198	25 14	250	44 49	282	34 21	320	351	46 04	0
262	61 51	029	54 42	096	43 38	153	46 10	199	24 20	250	43 53	282	33 44	320	352	46 19	0
263	62 18	028	55 39	096	44 04	154	45 50	200	23 25	251	42 56	283	33 07	320	353	46 33	0
264	62 45	026	56 37	097	44 29	155	45 29	202	22 31	251	42 00	283	32 29	320	354	46 46	0
265	63 10	025	57 34	097	44 53	156	45 07	203	21 36	251	41 03	283	31 51	319	355	46 58	0
266	63 34	023	58 32	098	45 16	157	44 44	204	20 41	252	40 07	283	31 13	319	356	47 10	0
267	63 56	022	59 29	098	45 38	158	44 20	205	19 46	252	39 10	283	30 35	319	357	47 21	0
268	64 17	020	60 27	099	45 58	160	43 55	206	18 51	252	38 14	283	29 57	319	358	47 31	0
269	64 36	019	61 24	099	46 18	161	43 29	207	17 55	253	37 17	283	29 19	319	359	47 41	0

Zn	Hc	Zn	Hc	Zn
	♦ARCTURUS		Alkaid	
	[illegible]	283	28 41	318
		[illegible]	28 02	318
			[illegible] 24	318
				318

Table 20. 'STARS' SIGHT REDUCTION TABLE FOR 15° N/LHA 255°

The three stars with the diamond symbols are:

1. VEGA Hc 58°08', Zn 037°.
2. Nunki Hc 40°10', Zn 146°.
3. ARCTURUS Hc 50°29', Zn 282°.

QED !

Stars' names printed in capitals indicate a brightness or 'magnitude' greater than 1,5. The brightest, SIRIUS is -1,6 and the weakest, Acamar, is 3,1(+). 'Brightest' and 'weakest' here refers only to the 57 stars we use. (See magnitudes of stars on the reverse of the Almanac Card - also in our Almanac section in Part 2.)

Now let's complete the exercise. Assume we took the sights of those three stars and the sights' details are as follows:

Clock set to UTC but 6s slow. Same DR. IE 3,5' 'on'. Height of eye, 4 m.

Sights: (Hs = SA; Sextant Angle, or 'Height by sextant'.) 1: Hs 58° 50,5', clock time 03h07m18s.
2: Hs 40° 40,6', clock time 03h09m28s. 3: Hs 49° 00,1', clock time 03h11m46s.

Plot the fix. Sample 'star work sheets', the first with explanatory notes, appear on pages 91 and 92; the solution to this example is on pages 93 and 94 as Solution 30 (the use of the Work Sheet) and Solution 30 (Plotting).

Here are some more examples for you to try.

EXAMPLE 31. See Solution 31 in Part 2.

What time (UTC) is mid-twilight at that DR? What three stars are recommended for sighting during the morning twilight of 20 June 199x from DR 15°12' N, 26°45' W ? What are the expected Hc's and Zn's?

EXAMPLE 32. See Solution 32 in Part 2.

On 5 December 199x at DR 30°10' S, 8°50' E, when will evening twilight begin and end? What three stars are the recommended stars for sighting? The IE is 0,8' off, eye height 3,5 m, course 235°T, speed 5 knots, and Log 67 112 M. Clock error relative to UTC is 13 seconds slow. Sights taken were: 1. Hs 30°43,6' at 18h27m14s (per clock), 360°T. 2. Hs 14°27,7' at 18h29m51s, 090°T. 3. Hs 44°00,3' at 18h32m31s, 217°T. Plot the resulting fix and find the fix Latitude and Longitude.

EXPLAINED WORK SHEET FOR STAR SIGHTS: AIR SIGHT REDUCTION TABLES (SRTs): STARS

Date ,DR ° , 'N/S, ° , 'E/W, IE ,'on'/'off'. Clock error relative to UTC....h...m...s (-fast,+slow)
Ht of eye ft/m, Course °T, Speed Kns, Log Miles. CHOSEN LAT: ° , 'N/S. (This is standard)

Star Sight Planning Twilight on the Greenwich Meridian (0° Longitude):

Morning Twilight: Civil Twilight starts at	h m	Almanac, date page (right side), then
Sunrise is at	h m	estimate for your DR Lat.
Average of these times is mid twilight =	h m	* For use in the next box down.
Evening Twilight: Sunset is at	h m	Almanac, date page (right side), then
Civil Twilight ends at	h m	estimate for your DR Lat.
Average of these times is mid twilight =	h m	* For use in the next box down.

Best Time to take twilight sights: (and LHA)

Middle of twilight at Greenwich in UT +	h m	* From above determination.
DR Long converted to time; - E, + W ±	h m	Almanac, first Yellow page, 'Arc to Time'.
Take sights at approximately =	h m	UT of mid twilight at your DR.
GHA Aries as at the hour of taking sights	° , '	Almanac, date page, left side.
Increment for mins (0 seconds) of sight +	° , '	Al'nac, Yellow page for mins, opp 0 secs.
Total GHA Aries at time of mid twilight =	° , '	Sum of above two lines.
+ E, - W Chosen Longitude ±	° , '	DR Long's mins are changed so LHA is a
LHA Aries (+/- 360°if nec) =	° 00 ,0'	whole number of degrees, zero minutes.

Best Stars to Sight and their Locations ← 3 columns/3 stars →

Three Stars' names with ◆ shapes	....	From Star Sight Reduction Tables
Hc (as expected by tables/calculation)	° '	(SRTs), page for Chosen Lat, opp LHA
Zn (true direction to stars, as per Tables)	°T	Aries, as determined in above box.

Actual Sights' Data: ← 3 columns/3 stars →

Clock time of sight	h m s	As per clock/time piece used for timing
Clock error to UTC/GMT (+ slow, - fast) ±	h m s	sights. Its exact error relative to UTC
UTC (GMT) of sight =	h m s	must be known to get the correct time.
Direction bearing to star converted to True	°T	Use hand compass and convert to True.
GHA Aries at hour of sight	° , '	Almanac, Date page, left side.
Increment of GHA for mins and secs +	° , '	Al'nac, Yellow pages for mins, opp secs.
Total GHA Aries =	° , '	Sum of above two lines.
- 360° if necessary -	° , '	If sum exceeds 360°, minus to get GHA.
GHA Aries required =	° , '	Difference between above 2 lines, if nec.
Chosen Longitude (+ E, - W) ±	° , '	DR Long with mins changed for LHA°00'.
LHA	° 00 ,0'	Sum/difference of above 2 lines (+E,-W).
+/- 360° if necessary ±	° 00 ,0'	To make LHA be between 0°/360° if nec.
LHA Aries Required =	° 00 ,0'	To select row in SRT page "Chosen Lat".

From Sight Reduction Tables for Stars: ← 3 columns/3 stars →

Hc as per time of sight, at Chosen Posn.	° '	From SRTs, Chosen Lat page, opp LHA
Zn for plotting direction/compass check.	°T	Aries as above. Use for Intcpt/plotting.

True Altitude (TA/Ho) and Intercept: ← 3 columns/3 stars →

Sextant Angle (SA or Hs) taken at sight	° , '	The angle measured with the sextant.
Index Error ±	, '	Determined when calibrating the sextant.
DIP -	, '	Al'nac loose card (or page 1), right side.
Apparent Altitude (AA) =	° , '	Sum or difference of above three lines.
Star Correction -	, '	Al'nac loose card (or page 1), centre.
True Altitude Ho =	° , '	Difference between above two lines.
Intercept: Hc =	° , '	From above box, from Tables.
Ho - Hc or Hc - Ho, Intercept (difference)=	, '	Subtract the smaller from the larger.
Towards or Away? (Towards if Ho>Hc)		State 'T' or 'A' - 'Towards' if Ho larger.

To plot the fix, we need Chosen Lat and Long, Azimuth (Zn), the Intercept, and whether it is Away or Towards.

Table 21. THE EXPLAINED WORK SHEET FOR STAR SIGHTS; 'STAR SIGHT' TABLES.

WORK SHEET FOR STAR SIGHTS: AIR SIGHT REDUCTION TABLES (SRTs): 7 SELECTED STARS

By Henton Jaaback, Yachtmaster Ocean Services cc

Date ,DR ° 'N/S, ° 'E/W, CHOSEN LAT: °00' N/S. IE ' 'on'/'off'. Ht of eye ft/m,
Clock error relative to UTC.....h......m......s (-fast,+slow),Course °T, Speed Kns, Log Miles.

Star Sight Planning (Almanac.) Twilight on the Greenwich Meridian (0° Longitude):

Morning Twilight: Civil Twilight starts at	h m	Almanac, date page (right side), then
Sunrise is at	h m	estimate for your DR Lat.
Average of these times is mid twilight =	h m	* For use in the next box down.
Evening Twilight: Sunset is at	h m	Almanac, date page (right side), then
Civil Twilight ends at	h m	estimate for your DR Lat.
Average of these times is mid twilight =	h m	* For use in the next box down.

Best Time to take twilight sights: (and LHA) (Almanac.)

Middle of twilight at Greenwich in UT	+	h m	* From above determination.
DR Long converted to time; - E, + W	±	h m	Almanac, first Yellow page, 'Arc to Time'.
Take sights at approximately	=	h m	UT of mid twilight at your DR.
GHA Aries as at the hour of taking sights		° , '	Almanac, date page, left side.
Increment for mins (0 seconds) of sight	+	° , '	Al'nac, Yellow page for mins, opp 0 secs.
Total GHA Aries at time of mid twilight	=	° , '	Sum of above two lines.
+ E, - W Chosen Longitude	±	° , '	DR Long's mins are changed so LHA is a
LHA Aries (+/- 360°if nec)	=	° 00 ,0'	whole number of degrees, zero minutes.

Best Stars to Sight and their Locations (SRTs.)

Three Stars' names with ◆ shapes	....	....	....
Hc (as expected by tables/calculation)	° '	° '	° '
Zn (true direction to stars, as per Tables)	°T	°T	°T

Actual Sights' Data: (Almanac.)

Clock time of sight		h m s	h m s	h m s
Clock error to UTC/GMT (+ slow, - fast)	±	h m s	h m s	h m s
UTC (GMT) of sight	=	h m s	h m s	h m s
Direction bearing to star converted to True		°T	°T	°T
GHA Aries at hour of sight		° , '	° , '	° , '
Increment of GHA for mins and secs	+	° , '	° , '	° , '
Total GHA Aries	=	° , '	° , '	° , '
- 360° if necessary	-	° 00 , 0 '	° 00 , 0 '	° 00 , 0 '
GHA Aries required	=	° , '	° , '	° , '
Chosen Longitude (+ E, - W)	±	° , '	° , '	° 00 , 0 '
LHA	=	° 00 , 0 '	° 00 , 0 '	° 00 , 0 '
+/- 360° if necessary	±	° 00 , 0 '	° 00 , 0 '	° 00 , 0 '
LHA Aries Required	=	° 00 , 0 '	° 00 , 0 '	° 00 , 0 '

From Sight Reduction Tables for Stars: (SRTs.)

Hc as per time of sight, at Chosen Posn.	° '	° '	° '
Zn for plotting direction/compass check.	°T	°T	°T

True Altitude (TA/Ho) and Intercept: (Almanac.)

Sextant Angle (SA or Hs) taken at sight		° , '	° , '	° , '
Index Error	±	, '	, '	, '
DIP	-	, '	, '	, '
Apparent Altitude (AA)	=	° , '	° , '	° , '
Star Correction	-	, '	, '	, '
True Altitude Ho	=	° , '	° , '	° , '
Intercept: Hc	=	° , 0 '	° , 0 '	° , 0 '
Ho - Hc or Hc - Ho, Intercept (difference)	=	'	'	'
Towards or Away? (Towards if Ho>Hc)				

Work Sheet 6. STAR SIGHTS USING 'STAR TABLES' FOR SEVEN SELECTED STARS.

Solution 30 to Example 30, pages 89 and 90.

WORK SHEET FOR STAR SIGHTS: AIR SIGHT REDUCTION TABLES (SRTs): 7 SELECTED STARS

By Henton Jaaback, Yachtmaster Ocean Services cc

Date 30 Aug, DR 15°25'N/~~S~~, 130°25'~~E~~/W, CHOSEN LAT: 15°00' N/~~S~~. IE 3,5' 'on'/'~~off~~'. Ht of eye 4 ~~ft~~/m,
Clock error relative to UTC h m+6 s(~~-fast~~,+slow) Course 130 °T, Speed 5 Kns, Log 77 69 M.

Star Sight Planning (Almanac.) Twilight on the Greenwich Meridian (0° Longitude):

Morning Twilight: Civil Twilight starts at	h m	Almanac, date page (right side), then
Sunrise is at	h m	estimate for your DR Lat.
Average of these times is mid twilight =	h m	* For use in the next box down.
Evening Twilight: Sunset is at	18 h 14 m	Almanac, date page (right side), then
Civil Twilight ends at	18 h 36 m	estimate for your DR Lat.
Average of these times is mid twilight =	18 h 25 m	* For use in the next box down.

Best Time to take twilight sights: (and LHA) (Almanac.)

Middle of twilight at Greenwich in UT	+	18 h 25 m	* From above determination.
DR Long converted to time; ~~-E~~,+ W	±	8 h 42 m	Almanac, first Yellow page, 'Arc to Time'.
Take sights at approximately * 31/Aug	=	*03 h 07 m	UT of mid twilight at your DR.
GHA Aries as at the hour of taking sights		24 °04,0'	Almanac, date page, left side.
Increment for mins (0 seconds) of sight	+	1 °45,3'	Al'nac, Yellow page for mins, opp 0 secs.
Total GHA Aries at time of mid twilight	=	25 °49,3'	Sum of above two lines.
+ E, - W Chosen Longitude	±	-130 °49,3'	DR Long's mins are changed so LHA is a
LHA Aries (+/- 360°if nec) +360°	=	255 ° 00 ,0'	whole number of degrees, zero minutes.

Best Stars to Sight and their Locations (SRTs.)

Three Stars' names with ◆ shapes	VEGA	Nunki	ARCTURUS
Hc (as expected by tables/calculation)	58 ° 08 '	40 ° 10 '	50 ° 29 '
Zn (true direction to stars, as per Tables)	037 °T	146 °T	282 °T

Actual Sights' Data: (Almanac.)

Clock time of sight		03 h 07 m 18 s	03 h 09 m 28 s	03 h 11 m 46 s
Clock error to UTC/GMT (+ slow, - fast)	±	h m +6 s	h m +6 s	h m +6 s
UTC (GMT) of sight	=	03 h 07 m 24 s	03 h 09 m 34 s	03 h 11 m 52 s
Direction bearing to star converted to True		035 °T	145 °T	280 °T
GHA Aries at hour of sight		24 °04,0'	24 °04,0'	24 °04,0'
Increment of GHA for mins and secs	+	1 °51,3'	2 °23,9'	2 °58,5'
Total GHA Aries	=	25 °55,3'	26 °27,9'	27 °02,5'
- 360° if necessary	-	° 00 ,0'	° 00 ,0'	° 00 ,0'
GHA Aries required	=	25 °55,3'	26 °27,9'	27 °02,5'
Chosen Longitude (+ E, - W)	±	-130 °55,3'	-130 °27,9'	-130 °02,5'
LHA	=	-105 ° 00 ,0'	-104 ° 00 ,0'	-103 ° 00 ,0'
+/- 360° if necessary	±	+360 ° 00 ,0'	+360 ° 00 ,0'	+360 ° 00 ,0'
LHA Aries Required	=	255 ° 00 ,0'	256 ° 00 ,0'	257 ° 00 ,0'

From Sight Reduction Tables for Stars: (SRTs.)

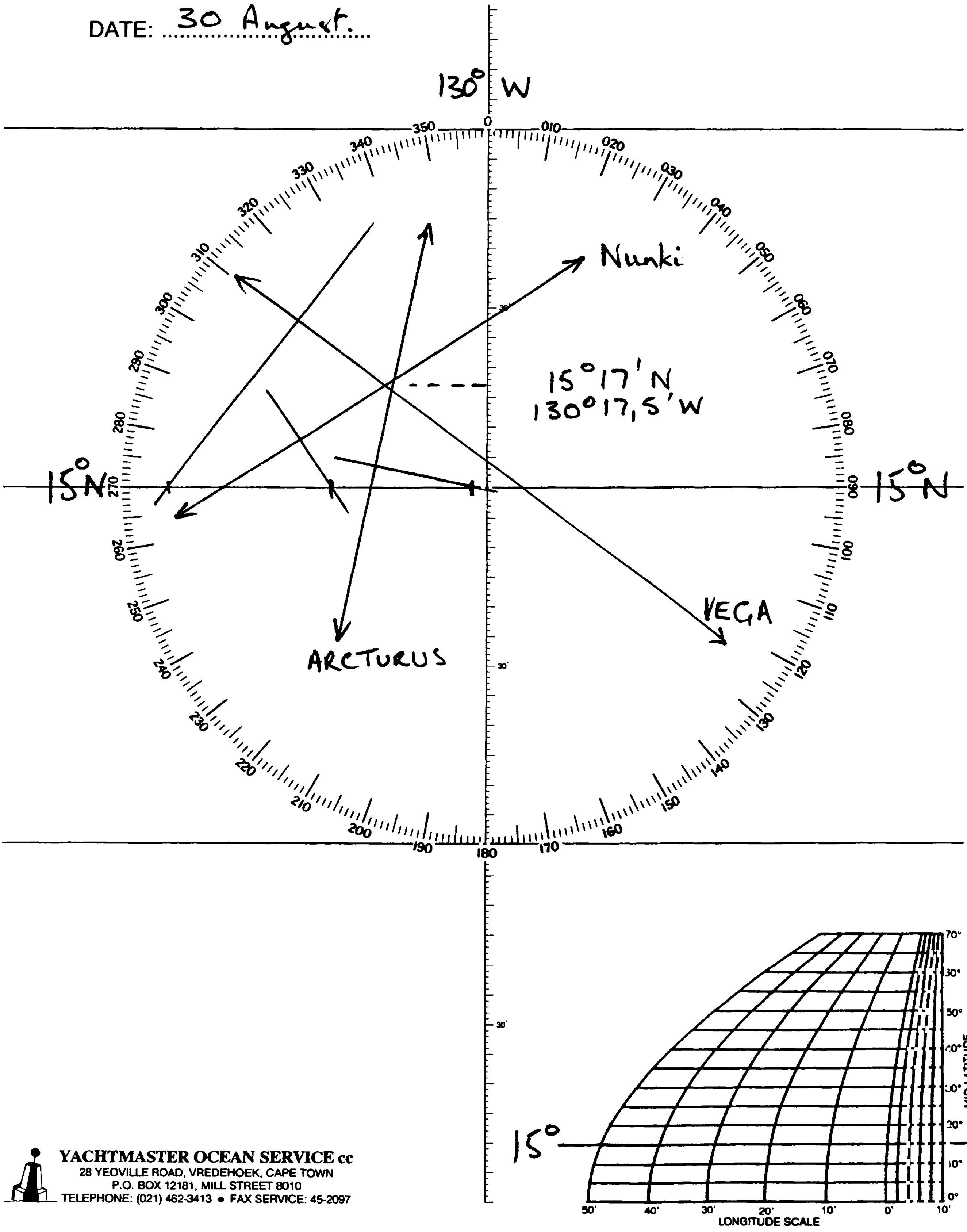
Hc as per time of sight, at Chosen Posn.	58 °08 '	40 °42 '	48 °36 '
Zn for plotting direction/compass check.	037 °T	147 °T	282 °T

True Altitude (TA/Ho) and Intercept: (Almanac.)

Sextant Angle (SA or Hs) taken at sight		58 °50,5'	40 °40,6'	49 °00,1'
Index Error	±	-3,5'	-3,5'	-3,5'
DIP	-	-3,5'	-3,5'	-3,5'
Apparent Altitude (AA)	=	58 °43,5'	40 °33,6'	48 °53,1'
Star Correction	-	-0,6'	-1,1'	-0,8'
True Altitude Ho	=	58 °42,9'	40 °32,5'	48 °52,3'
Intercept: Hc	=	58 °08,0'	40 °42,0'	48 °36,0'
Ho - Hc or Hc - Ho,(difference) Intercept	=	34,9'	9,5'	16,3'
Towards or Away? (Towards if Ho>Hc)		Towards	Away	Towards

Solution 30 (Plotting)

PLOTTING OF STAR SIGHTS: 30/31 AUGUST 199X; EXAMPLE 30



Solution 30 PLOTTING. THE PLOTTING OF THE STAR SIGHT; EXAMPLE 30.

Had we not done the star-sight planning in advance, we could simply have gone on deck with the sextant, clock and note pad and pencil before sunset and waited for the first stars in the east to become visible. During twilight we could then have taken sights of three (any three, preferably more 'in case') prominent stars as long as each was the brightest in its area of the sky and the three were suitably spaced around the 360° horizon so that the plotted triangle would be as near to equilateral as can be.

The only disadvantage in doing it this way is that sometimes one or two of the stars used may not be as per the '7 Selected Stars'. That, or those, sights are then useless! To overcome this problem, some navigators take sights on more than just three stars - maybe up to six, thereby ensuring that at least three will be among the seven listed for the appropriate LHA(s).

For the navigator who is able to look into the night sky and identify the individual stars, the work-sheet method as used for the sun, moon, and planets can be used. The only variation is the inclusion of "SHA Star" from the Almanac to be added to the GHA Aries to get "GHA Star". By knowing which star one is looking at, one knows which star's SHA to look up in the Almanac. If one can not easily identify stars and one does not have a copy of the "Sight Reduction Tables for the 7 Selected Stars", one could use a "Star Finder" or Star Atlas. It is then possible to do all the navigation with ONLY ONE reference book - the Nautical Almanac. Alternatively one can use the standard Air Tables (ONLY if Dec is < 30°).

<u>EXAMPLE 33</u>. Let's do an example using the SHA and the standard Air Tables (Volume 2).

Date : 27 February 199x.
DR : 38° 05' N, 26° 15' W.
IE : 2' "on".
DIP : 3 m.
Clock error : 2h00m29s fast relative to UTC (GMT).
Course : 040 T, 5,5 knots, Log 3579 M.

Sight 1. : Star POLLUX
SA(Hs) 49°28,4'
Clock Time 21h50m50s
Sight 2. : Star SIRIUS
SA(Hs) 27°32,9'
Clock Time 21h52m47s
Sight 3. : Star Hamal
SA(Hs) 54°30,7'
Clock Time 21h55m06s

Check the working on the work sheet over the page, Solution 33 using the AIR SRTs on page 96. We could use the Almanac's Sight Reduction Tables or the Sine/Cosine method. The answers will result in the same L.O.P. Then plot the fix. Your plotting can be compared to the solution in the Solutions section, 'Solution 33 Plotting'.

<u>EXAMPLE 34</u>. Now try a star sight on your own: You are the navigator on a cruising vessel approaching the island of Mauritius from the east. The date is 19 June 199x and your vessel's DR is 10°55' S, 80°40' E. It is early morning (still dark) and you decide to get a dawn fix using the stars.

When will civil twilight begin? When is sunrise? Which are the three recommended stars for this fix and where are they to be found (altitude and Azimuth)?

You take three star sights and the applicable detail is as follows:

IE 3,6' "off", height of eye 8 feet. Your navigation clock is set to UTC but is 17 seconds fast. Course 270°T, 6 knots, Log 2468 M.

Sight 1. Sextant Angle 41°57,4', Clock time 00h38m51s,
Bearing to the star 045° T
Sight 2. Sextant Angle 39°18,3', Clock time 00h40m20s,
Bearing to the star 160° T
Sight 3. Sextant Angle 26°36,2', Clock time 00h42m23s
Bearing to the star 285° T

What is the resulting fix position ? See Solutions section, Solution 34 (Work Sheet) and Solution 34 (Plotting).

Solution 33 to Example 33, page 95.

AIR SIGHT REDUCTION TABLES WORK SHEET; ALL CELESTIAL BODIES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: 27/2 IE:+/- 2,0'(-On, +Off); Eye Ht: 3 ft/m; Clock error: 2 h 00 m 29 s(Fast/Slow?)
Course: 040 °T/M/C; Speed: 5,5 kns; Celestial Body/ies-UL/LL: Stars:

	POLLUX	SIRIUS	Hamal
Log	3579 M	M	M
DR Lat	38°05 'N/S	Same 'N/S	Same 'N/S
DR Long	26°15 'E/W	'E/W	'E/W
Chosen Lat	38°00,0'N/S	°00,0'N/S	°00,0'N/S
TIME Clock time of sight	21h 50m 50s	21h 52m 47s	21h 55m 06s
Clock error relative to UTC (-fast, + slow)±	-2h 00m 29s	-2h 00m 29s	-2h 00m 29s
Corrected UTC time of sight =	19h 50m 21s	19h 52m 18s	19h 54m 37s
LHA GHA as at day, hr of sight: Al'nac	82°22,8'	82°22,8'	82°22,8'
Increments for mins/secs; Yellow pages +	12°37,3'	13°06,6'	13°41,5'
v (?) ±Plnts; +Moon. Corr.(Yellow p's) ±	( ) ° , '	( ) ° , '	( ) ° , '
Total GHA as at exact time of sight =	95°00,1'	95°29,4'	96°04,3'
-360° if nec; GHA to be between 0°/ 360° -	°00,0'	°00,0'	°00,0'
GHA Required =	95°00,1'	95°29,4'	96°04,3'
SHA of star +	243°45,1'	258°42,2'	328°17,3'
GHA of celestial body sighted =	338°45,2'	354°11,6'	424°21,6'
Chosen Longitude (+E, -W) ±	-26°45,2'	-26°11,6'	-26°21,6'
LHA Required =	312°00,0'	328°00,0'	398°00,0'
+/- 360° if necessary ±	°00,0'	°00,0'	-360°00,0'
LHA of celestial body sighted =	312°00,0'	328°00,0'	38°00,0'
Declination day/hr of sight; next to GHA =	N/S ° , '	N/S ° , '	N/S ° , '
(d = ?)factor; bottom of/or in moon colmn	(d= ,)	(d= ,)	(d= ,)
d Corr;Yellow p's(mins)(+if Dec incr'ng) ±	'	'	'
TOTAL DECLINATION at time of sight =	N/S 28°02,3'	N/S 16°42,8'	N/S 23°26,1'
Lat/Dec **SAME** or **CONTRARY** (N/S) ?	Same	Contrary	Same
Hc: Hc, Sight Red Tables, 'C Lat' page:	48°59'	28°13'	54°18'
(d± ?) Use with Dec's mins, Table 5.	(d =+/-27)	(d =+/-53)	(d =+/-33)
d Correction, from Table 5 ±	+1'	-38'	+14'
TOTAL Hc (Transfer to Intercept, ↓) =	49°00'	27°35'	54°32'
Z → Zn Top/bottom left corner SRT page.	Z = 90°	Z = 145°	Z = 104°
	Zn = 090°	Zn = 145°	Zn = 256°
Ho; Sextant Angle (SA/Hs)Up./Low. Limb=	49°28,4'	27°32,9'	54°30,7'
IE (-On, +Off) ±	-2,0'	-2,0'	-2,0'
DIP (Eye ht; Al'nac card/Page A2) -	-3,0'	-3,0'	-3,0'
Apparant Altitude (AA) =	49°23,4'	27°27,9'	54°25,7'
Main corrn (Al'nac card), OR ±	-0,8'	-1,9'	-0,7'
Moon corrn (Back of Al'nac) +	° , '	° , '	° , '
Planet corrn (Al'nac card) +	° , '	° , '	° , '
Moon HP corrn (Back of Al'nac) +	° , '	° , '	° , '
Moon only, if UL, corrn (-30,0' if UL) -	'	° , '	° , '
TRUE ALTITUDE / Ho Ho =	49°22,6'	27°26,0'	54°25,0'
Intercept; Ho - Hc or Hc - Ho Hc =	49°00,0'	27°35,0'	54°32,0'
Intcpt (Difference); ~	22,6'	9'	7'
TOWARDS or AWAY? If Ho>Hc, Towards	Towards	Away	Away

Precession and Nutation

As the earth spins on its axis and progresses on its orbit around the sun, it "wobbles".

Precession

The earth's orbit path is not a smooth eliptic curve as it moves in small 'curls'; see Figure 59.

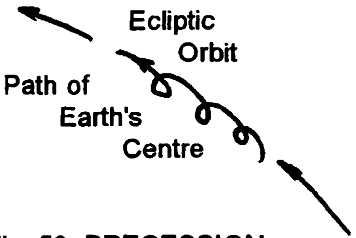


Fig. 59. PRECESSION

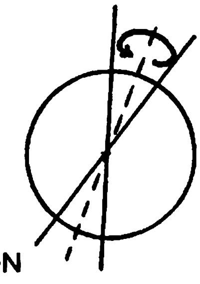


Fig. 60. NUTATION

Nutation

The axis of the earth also wobbles, pivoting on its centre so that a plot of the axis at the poles shows the axis moving around a small circle; see Figure 60 above.

Correction

Our Tables (Volume 1-"7 Selected Stars") are published every five years with the "Epoch" - the middle year of the five - being stated on the cover. During this Epoch the Tables are correct and no further allowance need be made. Inside the book's back cover are correction tables for other years. Our latitude and the LHA Aries enable us to see from these tables how far and in what direction to advance or transfer our fix obtained from the stars LOPs, to allow for the effects of Precession and Nutation (only for stars as they are so far away.)

A section of the applicable table, 'TABLE 5 - CORRECTION FOR PRECESSION AND NUTATION' is shown below as Table 22. As an example of its use, if we were near the equator (latitude near 0° - say 3°15' S) in the year 19.., we would look down the centre vertical column, under the year concerned, to the row nearest to our LHA for Aries, say 181°. Along the 180° row we see (under 0° for Lat) the numbers " 3' and 290° ". This means that the fix must be moved 3' in the direction 290°T. This change in the fix position will allow for the errors due to Precession and Nutation during the applicable year.

TABLE 5—CORRECTION FOR PRECESSION AND NUTATION

LHA ♈	North latitudes N 89°	N 80°	N 70°	N 60°	N 50°	N 40°	N 20°	0°	South latitudes S 20°	S 40°	S 50°	S 60°	S 70°	S 80°	S 89°	LHA ♈
								19..								
°	′ °	′ °	′ °	′ °	′ °	′ °	′ °	′ °	′ °	′ °	′ °	′ °	′ °	′ °	′ ° °	
0	1 190	1 210	2 220	2 230	2 240	3 240	3 250	3 250	3 240	2 240	2 230	2 230	1 210	1 200	1 180	0
30	1 220	2 230	2 240	2 240	3 250	3 250	3 250	3 250	3 250	2 240	2 230	1 220	1 200	1 170	1 150	30
60	1 250	2 250	2 260	2 260	3 260	3 260	3 260	3 260	2 260	2 250	1 240	1 220	1 170	1 130	1 110	60
90	1 280	2 270	2 270	2 270	3 270	3 270	3 270	3 270	2 270	1 280	1 280	0 —	0 —	1 080	1 080	90
120	1 300	2 300	2 290	2 290	3 290	3 280	3 280	3 280	2 290	2 300	1 300	1 320	1 000	1 030	1 050	120
150	1 330	1 320	2 310	2 300	2 300	3 290	3 290	3 290	3 290	2 300	2 310	1 320	1 340	1 000	1 020	150
180	1 000	1 340	1 330	2 310	2 310	2 300	3 300	3 290	3 290	3 300	2 300	2 310	2 320	1 330	1 350	180
210	1 030	1 010	1 340	1 320	2 310	2 300	3 290	3 290	3 290	3 290	3 290	2 300	2 300	2 310	1 320	210
240	1 070	1 050	1 010	1 320	1 300	2 290	2 280	3 280	3 280	3 280	3 280	2 280	2 280	2 290	1 290	240
270	1 100	1 100	0 —	0 —	1 260	1 260	2 270	3 270	3 270	3 270	3 270	2 270	2 270	2 270	1 260	270
300	1 130	1 150	1 180	1 220	1 240	2 240	2 250	3 260	3 260	3 260	3 250	2 250	2 250	2 240	1 240	300
330	1 160	1 180	1 200	1 220	2 230	2 240	3 250	3 250	3 250	3 250	2 240	2 240	2 230	1 220	1 210	330
360	1 190	1 210	2 220	2 230	2 240	3 240	3 250	3 250	3 240	2 240	2 230	2 230	1 210	1 200	1 180	360
								19..+1								
0	1 190	1 210	1 220	1 230	2 240	2 240	2 250	2 250	2 240	2 240	1 230	1 230	1 210	1 190	1 170	0
30	1 220	1 230	1 240	2 250	2 250	2 250	2 250	2 250	2 250	1 240	1 230	1 220	1 190	1 160	1 140	30
60	1 250	1 260	1 260	2 260	2 260	2 260	2 260	2 260	2 260	1 250	1 240	0 —	0 —	1 120	1 110	60
90	1 280	1 280	1 280	2 270	2 270	2 270	2 270	2 270	2 280	1 280	1 280	0 —	0 —	1 070	1 080	90

Table 22.

NOTES

POLARIS

The Pole Star

This star, Polaris, is without doubt the most useful natural navigation aid to all who sail in the northern hemisphere. It is located (almost) directly over the North Pole. There is, therefore, a permanent 'North' reference to mariners, but more importantly there is also a continuous (by night) ability to check latitude. (This assumes the horizon is adequately visible at night between twilights for the taking of sights - which it seldom is.) The star itself is located in the group of stars known as URSA MINOR (commonly called 'The Little Bear' and although not a bright star with a magnitude of 2,1 ,it is the brightest of this group and can easily be found at the 'handle' end of the soup-ladle shape formed by the group.

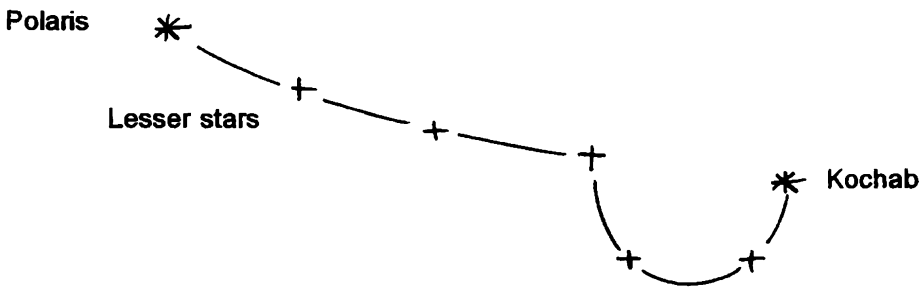


Fig. 61. URSA MINOR AND POLARIS

The more conspicuous group of stars, URSA MAJOR, also forms a spoon shape and the last two, Merak and Dubhe at the opposite end from the handle are known as the 'pointers' as they are almost in line with and point to Polaris. The front cover of your Nautical Almanac shows both groups of stars quite clearly. The URSA MAJOR group have their declinations between approximately 50° North and 63° North.

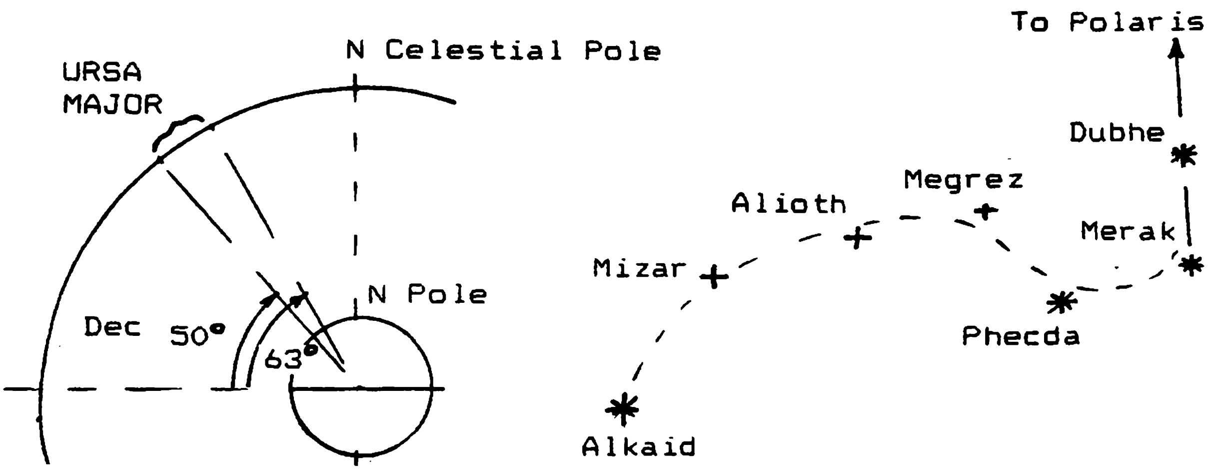
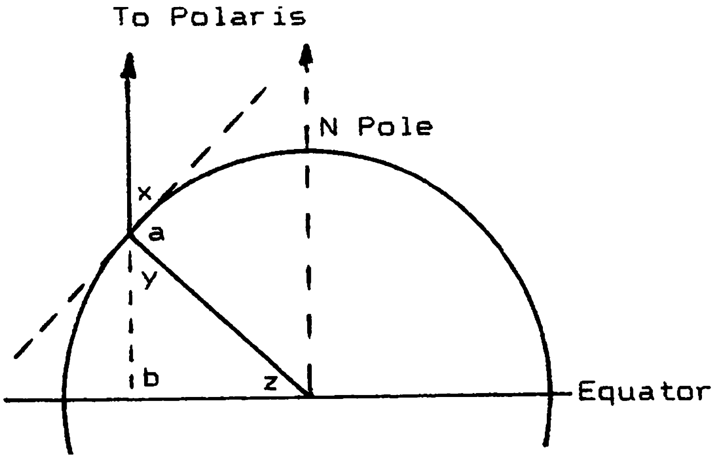


Fig. 62. URSA MAJOR: ITS LOCATION AND APPEARANCE

The Logic

Polaris is not in fact exactly over the North Pole. It is very nearly but can be up to nearly 2° off the axis. It varies with time and the way the earth 'wobbles'. Luckily the wobble pattern has been computed and adjustments (corrections) are now available in the Almanac. Assume though for the moment that it is directly over the North Pole. Look at Fig. 29 on page 28. The corrected sextant angle from your position (looking north) to the Pole Star will be the same as the angle formed at the earth's centre between the equator and a line from the earth's centre to where you are - which is your latitude:



'a' and 'b' are 90°.
'a'+'x'+'y' = 180°.
'b'+'y'+'z' = 180°.
'a' = 'b'
'x' = 'z'
'x' = SA(Ho)
'z' = Lat ,
therefore Lat = SA(Ho)

Fig. 63. SEXTANT ANGLE (CORRECTED) SAME AS LATITUDE

The Procedure

We all know that the sextant angle needs corrections to become the True Altitude, Ho. Since we want to find the corrected angle knowing that Polaris is NOT EXACTLY over the North Pole, our correction must take this fact into account. To do this we use tables computed for the purpose which we find in the Almanac just before the Sight Reduction Tables section, at pages 274 to 276.

To be able to use the tables, we need to know the LHA Aries as at the time of the sight. By now we know how to do this:

Convert exact time of sight to corrected UTC (GMT).
Using this time, from the Almanac daily pages, find the

GHA Aries (hour value)	° , '
Increment (mins/secs, '+')	° , ' (Yellow pages)
Total GHA Aries	° , '
Longitude (+East, -West)	° , '
+/-360° if necessary	°00,0'
LHA Aries	° , '

We can now start to correct the sextant angle:

Sextant angle	° , '
Index error (+/-)	, '
Dip (-)	, '
Apparent Altitude	° , '
Main corrn, stars (-)	° , '
Corrected AA = Ho	° , '

To proceed we must now look at the Polaris Tables and select the page (example opposite) with our LHA Aries - note that there are three pages, each having 120° of LHA. Each page has four sections, the top three are for corrections to the 'Ho' to get 'Lat':

1. The first (top) section correction has the symbol 'a_0' and is only concerned with our LHA Aries.
2. The next section's correction, 'a_1', is determined by our DR Lat and LHA Aries.
3. The third section is a correction for monthly variations and depends on our LHA Aries. It is called 'a_2'.

These corrections are '+' because of the way these corrections have been computed using 'constants'. The fact that the constants add up to 1° and the way they have been used in the computation, means that we must finally subtract 1° to get the final answer - our latitude. So the final look at our 'sums'!

Ho		° , '
a_0	(+)	° , '
a_1	(+)	° , '
a_2	(+)	° , '
-1°		-1° 00 ,0'
Latitude (North) =		° , ' N

POLARIS (POLE STAR) TABLES, 199

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

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

ILLUSTRATION

On 199· April 21 at 23ʰ 18ᵐ 56ˢ UT in longitude W 37° 14′ the apparent altitude (corrected for refraction), H_O, of *Polaris* was 49° 31′·6

From the daily pages:	° ′		° ′
GHA Aries (23ʰ)	194 47·0	H_O	49 31·6
Increment (18ᵐ 56ˢ)	4 44·8	a_0 (argument 162° 18′)	1 25·6
Longitude (west)	−37 14	a_1 (Lat 50° approx.)	0·6
		a_2 (April)	0·9
LHA Aries	162 18	Sum − 1° = Lat =	49 58·7

Table 23. A PAGE FROM 'POLARIS' TABLES

The fourth section at the bottom of the tables enables the navigator to determine very accurately, the direction or Azimuth to the Pole Star from his or her position at the time of the sight.

EXAMPLE 35. Let's do the following example:

Date	:	30 August 199x.
DR	:	Lat 23°45' N, 15°30' W.
Clock	:	Set to UTC (GMT) but 4 s slow.
IE	:	4' 'on' the scale.
Dip	:	3 metres height of eye.
Time	:	Sextant sight at 19h22m16s.
Sextant	:	23°37,2'

So:

Clock time	19h22m16s
Error (+slow)	+ 4s
UTC (GMT)	19h22m20s

and;

GHA Aries 19h	263°44,3'
Increment 22m20s	5°35,9'
Total GHA Aries	269°20,2'

Therefore: GHA Aries 269°20,2'
DR Long (-W) - 15°30,0' W
LHA Aries 253°50,2' = 254° to the nearest degree.

But:

Sextant angle	23°37,2'	
IE	-4,0'	
Dip	-3,0'	
Apparent Altitude	23°30,2'	
Main Corrn (Star)	- 2,2'	(From Almanac's card, centre column; Refraction correction.)
Corrected AA: Ho=	23°28,0'	

From the Almanac's Polaris Tables (third page) under the LHAs column headed '250°-259°' and opposite '4°' (for 254°):

ao	=	1° 35,2'
a1	=	0,5'
a2	=	0,9'
-1°	=	-1° 00,0'
Total corrections	=	0° 36,6'
Latitude is therefore: Ho	=	23°28,0'
Corrns	= +	0°36,6'
Lat	=	24°04,6' North

At the bottom of the page of the tables is a heading "Azimuth". This tells us the true direction of Polaris at the time of our sight. If we had checked to see the compass bearing to/from Polaris when we took the sight, we could convert the compass bearing to to true - does it agree with the Azimuth. If it does not, there is deviation/the deviation card is not correct. Deviation can be calculated.

We can even make a work sheet for this type of Polaris sight - see the next page (page 103 - top).

EXAMPLE 36. Now follows our worked example using a work sheet.
The date is 5 December 199x, height of eye 7 metres, index error 3,5' 'on', clock error relative to UTC (GMT) is 7 seconds fast, DR Lat 47°45' N, Long 169°50' E, Sextant angle 47°59,1', time per clock 05h22m26s. Compass bearing to Polaris 015°, magnetic variation (assumed) 14° West. Course 265°M, speed 6 knots. What is the correct latitude ? What is the compass deviation, if any?
Note: Because the UTC (GMT) is 05h22 most people will tend to think in terms of morning twilight. As our Longitude is 169° East, this is in fact an evening twilight sight of Polaris.

Our worked solution, Solution 36, is at the bottom half of page 103. You try these. (Answers are in the Solutions section as Solutions 37 and 38.)

EXAMPLE 37. Date, 18 June 199x; DR 16°20' N, 67°35' W; Course 265°T, 6 knots, Log 2534. I.E. 4,0' 'off'; Eye height 3,5 m.; S.A. 15°43,5'; Time of sight 23 h 08 m 12 s by clock which is 31 s fast. Polaris direction 015°C. Assumed magnetic variation 14° West.

EXAMPLE 38. Date 4 December 199x, DR 48°05' N, 12°45' W; I.E. 0,8' 'on'; Eye height 2 m; S.A. 48°05'; Time of sight 17 h 06 m 27 s by clock which is 47 s slow. Course 310°T, speed 5 knots, Log 1245, compass direction to Polaris 013°C (variation assumed 16° West).

WORK SHEET FOR LATITUDE FROM POLARIS

By Henton Jaaback, *Yachtmaster Ocean Services*

Date: DR ° , ' N, ° , ' E/W; IE , ' 'on'/'off';
Height of eye ft/m, Clock error relative to UTC (GMT) h m s(-fast,+slow),
Course: °T/M/C, Speed Knots, Compass bearing to Polaris = °C

Clock time of sight = h m s
Clock error to UTC (+ Slow, - Fast) = h m s
Correct UTC time of sight = h m s

GHA Aries, hour of sight = ° , ' Al'nac, daily page, left page/side.
Increment, mins and secs (+) = ° , ' Yellow pages, 'minutes'.
Total GHA Aries = ° , '
Longitude (+ East, - West) = ° , '
+/- 360° if necessary = ° , ' (LHA to be between 0° - 360°).
LHA Aries = ° , '

Sextant angle = ° , '
I.E. = , '
Dip = , '
Apparent Altitude = ° , '
Star corrn (-) = , '
Ho = ° , '
a_0 = ° , '
a_1 = , '
a_2 = , '
-1° = - 1° 00.0'
LATITUDE = ° , ' N

Azimuth (True direction to Polaris) per Tables = °T
+ West, - East Variation = ± °Var
Magnetic Direction = °M
Compass Bearing to Polaris = °C
Difference (°M/°C)(= Dev) = °

If:
Compass > Magnetic, Deviation is "West".
Compass < Magnetic, Deviation is "East".

Work Sheet 7.

Solution 36 to Example 36, page 102.

WORK SHEET FOR LATITUDE FROM POLARIS

By Henton Jaaback, *Yachtmaster Ocean Services*

Date: 5/12 DR 47 ° 45 ' N, 169 ° 50 ' E/~~W~~; IE 3 , 5 ' 'on'/~~'off'~~;
Height of eye 7 ~~ft~~/m, Clock error relative to UTC (GMT) h m -7 s(-fast,~~+slow~~),
Course: 265 °T/~~M/C~~, Speed 6 Knots, Compass bearing to Polaris = 015 °C

Clock time of sight = 05 h 22 m 26 s
Clock error to UTC (+ Slow, - Fast) = h m -7 s
Correct UTC time of sight = 05 h 22 m 19 s

GHA Aries, hour of sight = 148 ° 46 , 3 ' Al'nac, daily page, left page/side.
Increment, mins and secs (+) = 5 ° 35 , 7 ' Yellow pages, 'minutes'.
Total GHA Aries = 154 ° 22 , 0 '
Longitude (+ East, - West) = +169 ° 50 , 0 '
+/- 360° if necessary = ° , ' (LHA to be between 0° - 360°).
LHA Aries = 324 ° 12 , 0 '

Sextant angle = 47 ° 59 , 1 '
I.E. = - 3 , 5 '
Dip = - 4 , 7 '
Apparent Altitude = 47 ° 50 , 9 '
Star Corrn (-) = - 0 , 9 '
Ho = 47 ° 50 , 0 '
a_0 = + 0 ° 45 , 5 '
a_1 = + 0 , 5 '
a_2 = + 1 , 0 '
-1° = - 1° 00.0'
LATITUDE = 47 ° 37 , 0 ' N

Azimuth (True direction to Polaris) per Tables = °T
+ West, - East Variation = ± °Var
Magnetic Direction = °M
Compass Bearing to Polaris = °C
Difference (°M/°C)(= Dev) = °

If:
Compass > Magnetic, Deviation is "West".
Compass < Magnetic, Deviation is "East".

NOTES

GREAT CIRCLE SAILING

A 'Great Circle' is, by definition, any circle around the earth whose centre is the centre of the earth. All meridians and the equator are therefore great circles, and any circle whose plane is at an angle to the plane of the equator and which has its centre at the centre of the earth, is a great circle.

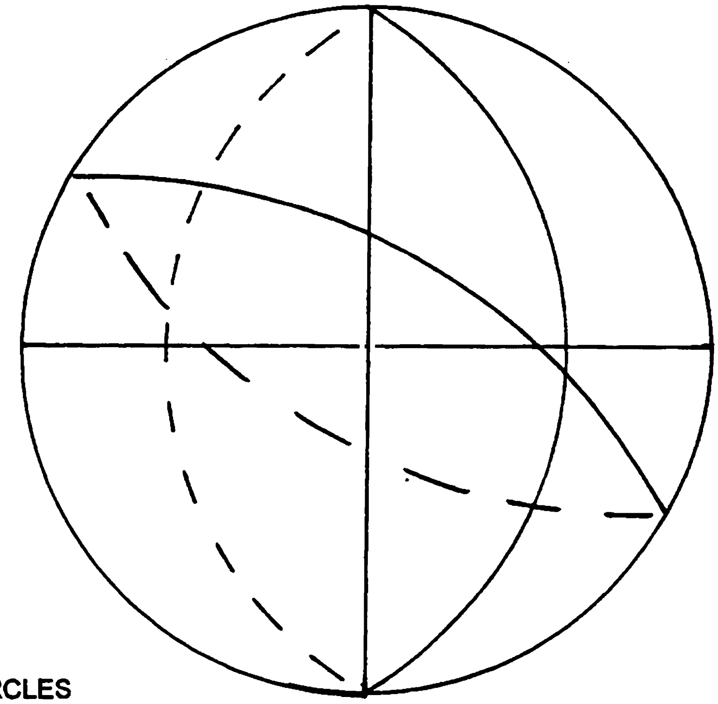


Fig. 64. GREAT CIRCLES

A nautical mile, by definition, is the length on the earth's surface of an arc of a great circle formed by an angle at the centre of the earth of 1'. The shortest route between two places on earth is the arc of a great circle which passes through both those places. (That is, providing you don't go the long way round!)

Unless one is sailing due east or west on the equator or due north or south on a meridian, one's course will curve so that as it crosses successive meridians, the angle formed between the course line and the meridian will be constantly changing. Look at the illustration in Figure 65 on page 106. Notice how the curve requires a turn towards the equator. Notice, too, that the navigator will have to update his vessel's position regularly and plot a new course to steer for the helmsman as the vessel follows the curve. The course direction changes.

For journeys of less than +/-500 miles a Rhumb Line course is steered. A Rhumb Line is a straight-line course between the start and end points of a journey, or one leg of a journey, and appears as a straight line on a Mercator Projection chart. No change of course to steer is necessary, but it is not the shortest route.

The Logic

Think back to the discussion on the Spherical or Navigation Triangle (page 49 and onwards). 'Co altitude' (also called Zenith Distance) is the side of the navigation triangle from the observer to the GP of the celestial body (see Figure 65). The direction from the observer to the GP, the side of the spherical triangle, is Zn, the Azimuth. The distance, observer to GP, is the ZD. $ZD = 90° - Hc$

The position of the GP was stated as its declination and GHA, which 'equate' to latitude and longitude. The observer's position was stated as (chosen) latitude and (chosen) longitude (which affected LHA). With these 'knowns' we are able to look up in the Sight Reduction Tables or calculate, using the Sine/Cosine formula method, the Hc and Zn.

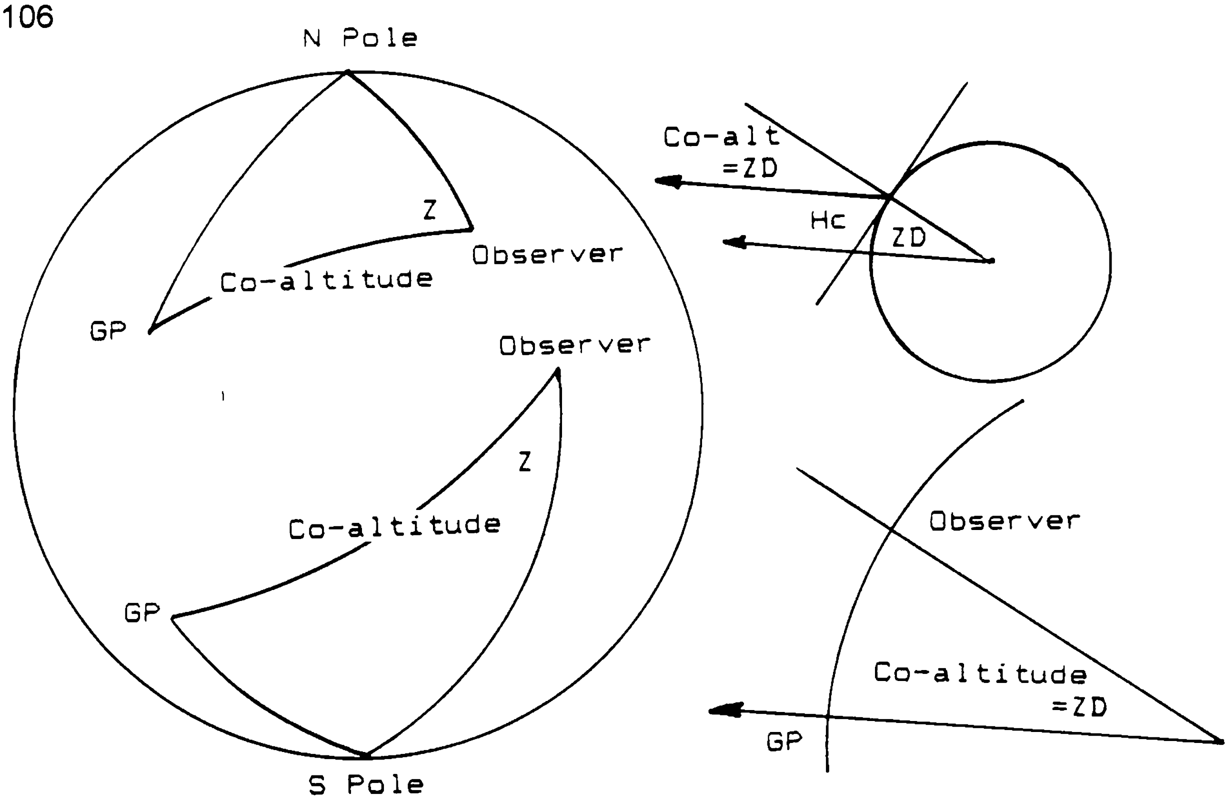


Fig. 65. CO-ALTITUDE IS THE DIRECTION (Zn/AZIMUTH) AND DISTANCE TO THE GP.

If we are to replace the GP's position, declination and hour angle, with the latitude and longitude of our destination, we can get an Hc, which subtracted from 90°, is the distance from our position to the destination, and a Zn which will be the great circle course to steer from our position towards the destination. As we move along this course, being on the arc of a great circle, the course to steer (Zn) will be changing (unless we are sailing east/west on the equator, or north/south) so regular updates of one's fix position and new calculations of the great circle course to steer will be necessary.

(Henton's Note: This is all very well in theory and in certain purists' view, such as those involved in ocean racing. In practice, cruising yachts do not normally concern themselves with great circle sailing because one tends to change course to sail on comfortable tacks depending on the wind direction. In addition, the difference in distance sailed between vessels crossing the ocean, one sailing a great circle course and the other a Rhumb Line course, is not regarded by most cruising skippers as significant. However, if for any reason (e.g. medical treatment) one has to get to a destination as quickly as possible, one may then go on to a great circle course).

Mercator Projection

The Mercator Projection is the technique employed for the production of the charts most commonly used for day-to-day, and ocean crossing, navigation. See Figure 53 on page 59 and note that the horizontal scale around the equator is not changed but the vertical scale increases the further one moves from the equator. This is the method used to get a section of a sphere correctly drawn on a flat piece of paper with a known and measurable distortion so that both the horizontal and vertical scale proportions remain correct. The result is that the meridians are parallel lines running north/south and a course line ruled on this chart as a straight line will intersect all meridians with the same angle. The equivalent great circle course will appear as a curve, although it is the shorter route. See Figure 66 on the next page.

Gnomonic charts are used to show great circle courses as straight lines, and if a Rhumb Line course is to be added, it will appear as the curved line course. Note how the angles between the course line and the meridians are still constantly changing in the case of the great circle course but in the case of the Rhumb Line course the angles with the meridians remain the same. See Figure 67 on page 107.

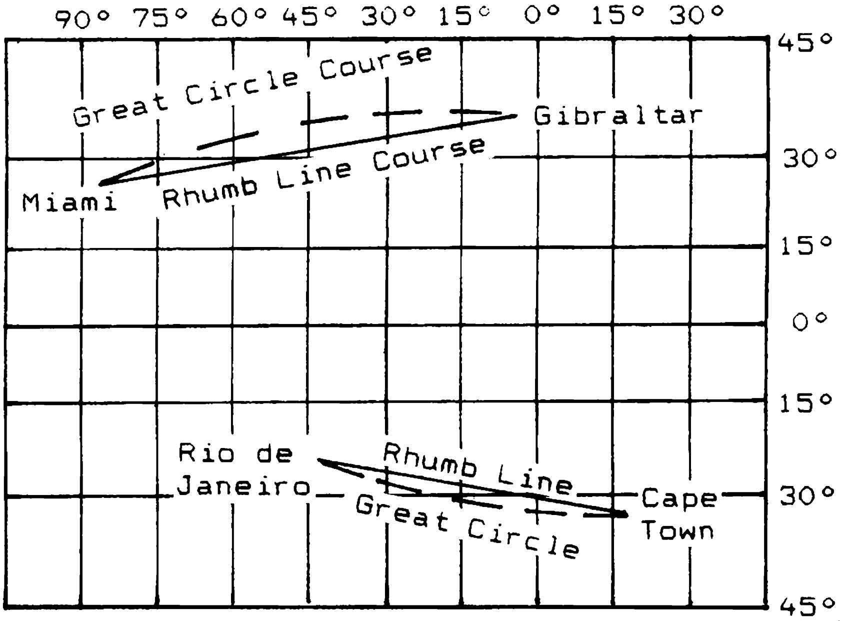


Fig. 66. RHUMB LINE AND GREAT CIRCLE COURSES ON A MERCATOR CHART

For great circle course-planning purposes, a special chart is available, namely chart 5029. It is intended for 'Air Navigation' but it is suitable for yachtsmen. The British Admiralty produce great circle planning charts as a series (e.g. 5095 A, B, C, 5096 A, B, C, 5097, etc.), each chart for different latitudes. A great circle planning chart allows the navigator to rule a straight line for the great circle course and then to take co-ordinates of latitude and longitude at regular distances along this course which can then be plotted on the Mercator chart as a curved course line (actually a series of Rhumb Line 'legs'). See Figure 66 above.

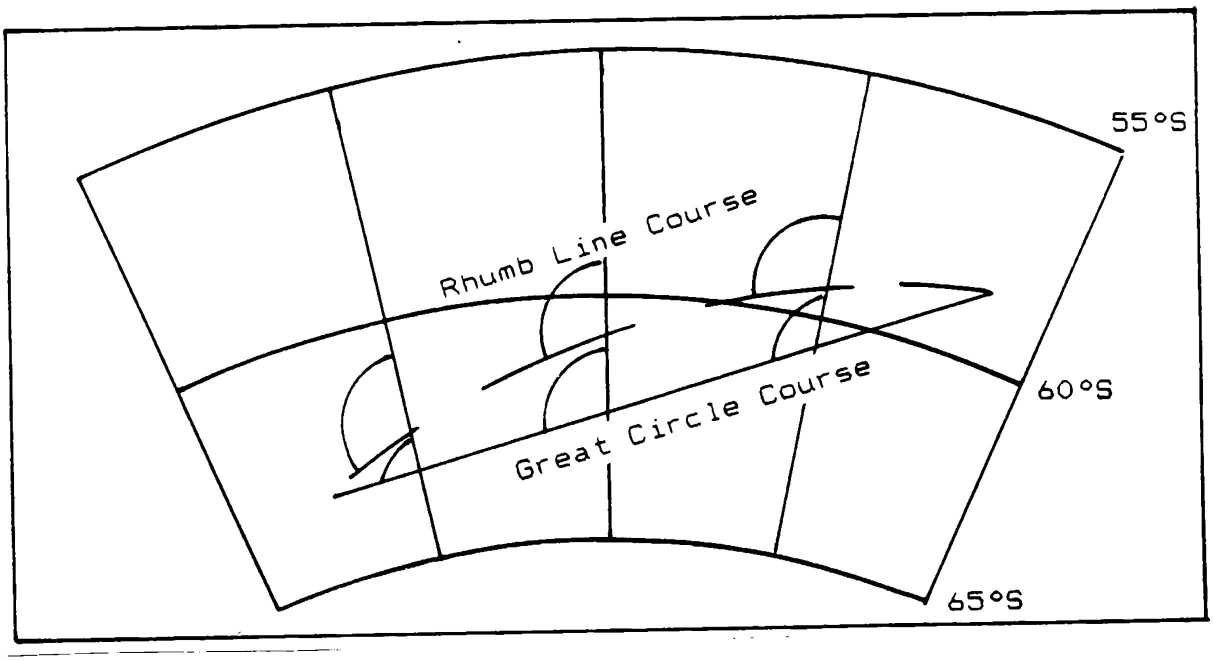


Fig. 67. A GNOMONIC GREAT CIRCLE PLANNING CHART, 5029.

We will do an example, once using the Air Sight Reduction Tables method, and then repeat the same example using the Sine/Cosine formula method.

EXAMPLE 39.

We require to know the great circle course to steer from Cape Town (33°55' S, 18°25' E) to Rio de Janeiro (24°25' S, 43°30' W).

(Although Rio is some 9°30' closer to the equator than is Cape Town, we will see that the great circle course out of Cape Town will not be north of west but south of west! There is no yachtsman or -woman that I know who would sail from Cape Town to Rio along this great circle course - it will be against the dominant winds and currents and contrary to all the recommendations in the pilot books, Ocean Passages of the World, World Cruising Routes, and of experienced yachtsmen.)

We need: 1. LHA: Difference in longitudes 43°30' W
+18°25' E
L HA = 61°55'(62° nearest)
2. Dec: Lat of Rio 24°24'S
3. Lat: Lat of observer (Cape Town) 34° S(nearest)
4. SAME or CONTRARY? (Both S) SAME

From the Tables:
Hc 35°40' d +26 Z 83°
From Table 5 when d is 26 and Dec minutes is 25', the d correction is 11'. 'd' was '+' so it is +11'.
Hc is therefore 35°40' + 11' = 35°51'.
ZD = 90° - 35°51' = 54°09'.
54° x 60' = 3 240' 3 240' + 09' = 3 249' or Nautical Miles
Zn = 180° + Z = 180°+ 83° = 263°T

(which is 7° south of due west, 270°). As you can see it is in fact very simple. There is, however, one disadvantage to this method and it is a limitation of the Tables. The Tables do not provide for 'Dec's', i.e. destinations, over 30°00,0', so no destination latitude over 30° can be resolved using this method.

If we use a work sheet for the method of our choice, it is so much easier. See the Work Sheets 2, 3, and 4 (pages 38, 41 and 55) for the Air Sight Reduction Tables method, the Almanac's Sight Reduction Tables method, and the Sine/Cosine method respectively.

Assume that we do not have these tables but wish to get the same answers using a scientific calculator:

$$Hc = \sin^{-1}\{(\sin Lat \times \sin Dec) + (\cos Lat \times \cos Dec \times \cos LHA)\}$$

where:
Lat = Lat of departure point (Cape Town). It is 'negative' because it is South.
Dec = Lat of destination (Rio). It is 'negative' because it is South.
LHA = The angle measured WESTWARD from the observer's meridian, to the meridian of the Destination's longitude.

Hc = $\sin^{-1}$ {(sin 33°55' x sin 24°25) + (cos 33°55' x cos 24°25' x cos 61°55')}
= $\sin^{-1}$ {(sin 33,916° x sin 24,416°) + (cos 33,916° x cos 24,416° x cos 61,916°)}
= $\sin^{-1}$ {(0,558 x 0,413) + (0,830 x 0,911 x 0,471)}
= $\sin^{-1}$ {(0,230) + (0,356)}
= $\sin^{-1}$ {0,586} ('+' because Dec and Lat are both negative; - x - = +).
= 35,874°
= 35°52' (Which is 1' different from the Tables method).

D = 90° - Hc = 90° - 35°52' = 54°08'
54° x 60' = 3 240' 3 240' + 08' = 3 248' or nautical miles
(Which is 1 mile more than the Tables method!)

$$Z = \sin^{-1} \frac{(\cos Dec \times \sin LHA)}{\cos Hc}$$

$$= \sin^{-1} \frac{(\cos 24{,}416° \times \sin 61{,}916°)}{\cos 35{,}874°}$$

$$= \sin^{-1} \frac{(0{,}911 \times 0{,}882)}{(0{,}810)} = \sin^{-1} \frac{(0{,}804)}{(0{,}810)} = \sin^{-1} 0{,}993 = \underline{83°} \text{ (to the nearest degree)}$$

Since Lat is South and LHA < 180°, Zn = 180°+ Z = 263°T. (Same as the Tables method.)

NOTE :
If we had been coming from Rio to Cape Town, the LHA determination would have been as follows:

Longitude of Rio = 40°30' W
Longitude of Cape Town = 18°25' E

We need LHA. Look at it diagrammatically:

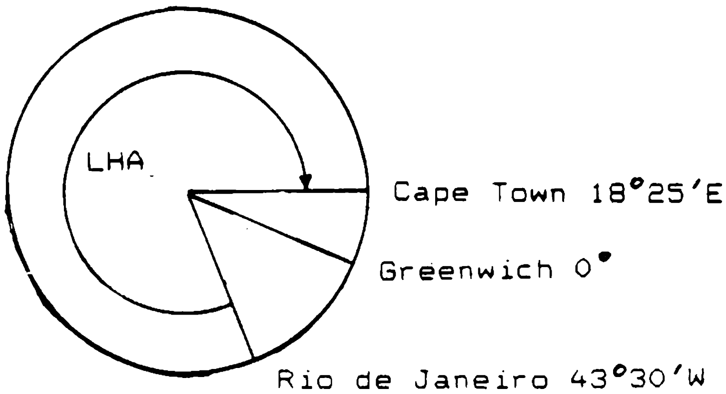


Fig. 68. LHA WHEN LONGITUDE EAST OR WEST.

From the above diagram:
Longitude West, from Rio to Cape Town:
LHA = 360°- 43°30' - 18°25' = 298°05' = 298° (to the nearest °). In the Tables, where 298° appears in the right-hand column for LHA, the left column of LHA shows 62°. The sum of the two places' longitudes is 62° (to the nearest degree). So either one (62° or 298°) will get us on to the correct row in the Tables. But we need the correct LHA when we convert Z to Zn:
Longitude East, Cape Town to Rio:
LHA = 18•25' (E) + 43°30' (W) = 62° (to the nearest degree).
Remember how we change Z to Zn: (See page 52, Figures 47 to 50 for the explanation.)

If (Departure Point) Latitude is North:
- LHA > 180°: Zn = Z
- LHA < 180°: Zn = 360° - Z

If (Departure Point) Latitude is South:
- LHA > 180°: Zn = 180° - Z
- LHA < 180°: Zn = 180° + Z

In our example, Rio to Cape Town, Lat is South and the LHA is 298° (i.e. LHA > 180°):

$$Zn = 180° - Z$$

But Z $= \sin^{-1} \dfrac{(\cos 33{,}914° \times \sin 62°)}{\cos 35{,}850°}$

$= \sin^{-1} \dfrac{(0{,}830 \times 0{,}883)}{0{,}811}$

$= \sin^{-1} \dfrac{0{,}733}{0{,}811}$

$= \sin^{-1} 0{,}904$

= 65° (to the nearest)

Therefore Zn = 180° - 65° = 115° T -the True course to steer on leaving Rio for Cape Town.

If we use a work sheet, it will be so much easier.

We can use the Air Sight Reduction Tables method IF the destination (which we regard as Declination) is not greater than 30°; these tables do not allow for declinations greater than that. We must also make allowance, after the calculation, for the fact that our start point Lat has been rounded off to the nearest degree.

WORK SHEET FOR GREAT CIRCLE SAILING: AIR SIGHT REDUCTION TABLES

By Henton Jaaback, *Yachtmaster Ocean Services cc*

Departure Lat: ....°................' N/S   Destination Lat: ....°................' N/S
Departure Long: ....°................' E/W   Destination Long: ....°................' E/W

Declination = Destination's Lat = ...°........' N/S
Chosen Lat = Departure,s Lat = ...°..00..' N/S (or present Lat/latest fix's Lat). (Nearest°)
SAME or CONTRARY? .... In SAME or different [CONTRARY] hemispheres?
LHA = Angle WESTWARD from departure's meridian/longitude to destination's longitude:

1. Departure Long 'E', Destination Long 'W';
   LHA = E Long of Departure + W Long of Destination, or
2. Departure Long 'E', Destination 'E' but less 'E';
   LHA = E Long of Departure - W Long of Destination, or
3. Departure Long 'E', Destination 'E' but further 'E';
   LHA = {360° - (Destination's E long - Departure's E Long)}, or
4. Departure Long 'W', Destination Long 'E';
   LHA = {360° - (Destination's 'E' Long + Departure's 'W' Long)}, or
5. Departure Long 'W', Destination Long 'W' but less 'W';
   LHA = {360° - (Departure's 'W' Long - Destination's 'W' Long)}, or
6. Departure Long 'W', Destination Long 'W' but further 'W';
   LHA = Destination's 'W' Long - Departure's 'W' long.

LHA = ...°..........'
= ....°...00...' (To nearest whole number of degrees)

Hc → ZD (= DISTANCE)

Tables Hc value ° ' Select 'Tables' page for Chosen Lat/Dec/SAME or CONTRARY/LHA as obtained above.
'd' (+/-..............) For use with mins of Dec in Table 5 to get next line...
d Correction (+/-) ______' From Table 5-see above lines
Hc Required ___°___' Sum/difference of above.
90 ° 00 , 0 '
Hc - ......°.... , ..'
ZD = ...°.... , ..'
ZD's degrees x 60 = '
Plus ZD's minutes = +__________'
Minutes = n.m. = ___________ n.m.

NB: Make allowance for the rounding off to whole numbers of Departure Lat and LHA (the effect on Longitude); add or subtract minutes/miles in proportion.

Distance = ___________ n.m.

Zn

Tables value for Z: °. Found with Hc and d in Sight Reduction Tables.
Convert to Zn = °T. See the tables, outside the page margin, top and bottom left side,
e.g. Top: "(If DR) N Lat, LHA > 180°, Zn = Z; LHA < 180°, Zn = 360° - Z."
Bottom: "(If DR) S Lat, LHA > 180°, Zn=180°- Z; LHA < 180°, Zn = 180° + Z."
Course to steer when leaving Destination (or from latest fix/present position)

Steer = ________ °True

Work Sheet 8.

We can opt to use the Sine/Cosine method which has a double bonus advantage. We do not have to round off the start point latitude, and therefore no estimating/allowance adjustment is required after the calculation; and there is no limit to the destination latitude (Declination). So the results will be accurate.

WORK SHEET FOR GREAT CIRCLE SAILING:SINE/COSINE METHOD

By Henton Jaaback, *Yachtmaster Ocean Services cc*

Departure Lat: ....°................' N/S   Destination Lat: ....°................' N/S
Departure Long: ....°................' E/W   Destination Long: ....°................' E/W

Declination = Destination's Lat = ...°........' N/S
DR Lat = Departure,s Lat = ...°........' N/S (or present Lat/latest fix's Lat).
LHA = Angle WESTWARD from departure's meridian/longitude to destination's longitude:

1. Departure Long 'E', Destination Long 'W';
   LHA = E Long of Departure + W Long of Destination, or
2. Departure Long 'E', Destination 'E' but less 'E';
   LHA = E Long of Departure - W Long of Destination, or
3. Departure Long 'E', Destination 'E' but further 'E';
   LHA = {360° - (Destination's E long - Departure's E Long)}, or
4. Departure Long 'W', Destination Long 'E';
   LHA = {360° - (Destination's 'E' Long + Departure's 'W' Long)}, or
5. Departure Long 'W', Destination Long 'W' but less 'W';
   LHA = {360° - (Departure's 'W' Long - Destination's 'W' Long)}, or
6. Departure Long 'W', Destination Long 'W' but further 'W';
   LHA = Destination's 'W' Long - Departure's 'W' long.

LHA = ...°..........'

DISTANCE VIA GREAT CIRCLE ROUTE

Distance = ZD = 90° 00,0' - Hc = ______, n.m.

NB: Dec and Lat are negative if South.

Hc = $\sin^{-1}$ {(sin Dec x sin Lat) + (cos Dec x cos Lat x cos LHA)}
= $\sin^{-1}$ {(sin ° ' x sin ° ') + (cos ° ' x cos ° ' x cos ° ')}
= $\sin^{-1}$ {(sin , ° x sin , °) + (cos , ° x cos , ° x cos , °)}
= $\sin^{-1}$ {(x) + (x x)}
= $\sin^{-1}$ { + }
= $\sin^{-1}$ { }
= , ° = ____°____'

ZD = 90° 00,0' - Hc = ° , '

ZD's degrees x 60 = '
Plus ZD's minutes = +__________'
Minutes = n.m. = __________ **n.m. = Great Circle Distance**

Great Circle COURSE TO STEER

Zn = Azimuth = direction from observer (place of Departure/present position) to GP (Destination)

If LHA > 180° : Zn = $\cos^{-1}$ X
If LHA < 180° : Zn = 360° - $\cos^{-1}$ X   **Zn = Course to Steer = ______ °T**

Where X = (sin Dec x cos Lat) - (cos Dec x cos LHA x sin Lat) / (cos Hc)   NB:Dec/Lat are '-' if South.

= (sin ° , ' x cos ° , ') - (cos ° , ' x cos ° , ' x sin ° , ') / (cos ° , ')

= (sin , ° x cos , °) - (cos , ° x cos , ° x sin , °) / (cos , °)

= (x) - (x x) / ( )

= ( ) - ( ) / ( ) = ( ) / ( ) = __________

BUT: If X > +1, make X = 1; If X < -1, make X = -1. (i.e. X must be between -1 and +1.)

Work Sheet 9.

This method has only one disadvantage; allowance has to be made after the calculation for the fact that the start point latitude was rounded off to the nearest degree.

WORK SHEET FOR GREAT CIRCLE SAILING: ALMANAC SRTs METHOD

By Henton Jaaback, Yachtmaster Ocean Services cc

Departure/Start/Present Location/Last Fix: = ° , 'N/S, ° , 'E/W;
Destination (Treat as 'Declination') = ° , 'N/S, ° , 'E/W.

DESTINATION LAT (=DECLINATION)	N/S ° , '	
Chosen Latitude	°00,0' N/S	Nearest whole degree.
SAME or CONTRARY ?		Dec and Lat, SAME hemisphere?

LHA

LHA = Angle WESTWARD from departure's meridian/longitude to destination's longitude:

1. Departure Long 'E', Destination Long 'W';
   LHA = E Long of Departure + W Long of Destination, or
2. Departure Long 'E', Destination 'E' but less 'E';
   LHA = E Long of Departure - W Long of Destination, or
3. Departure Long 'E', Destination 'E' but further 'E';
   LHA = {360° - (Destination's E long - Departure's E Long)}, or
4. Departure Long 'W', Destination Long 'E';
   LHA = {360° - (Destination's 'E' Long + Departure's 'W' Long)}, or
5. Departure Long 'W', Destination Long 'W' but less 'W';
   LHA = {360° - (Departure's 'W' Long - Destination's 'W' Long)}, or
6. Departure Long 'W', Destination Long 'W' but further 'W';
   LHA = Destination's 'W' Long - Departure's 'W' long.

LHA = ...°..........'
= ....°...00...' (to the whole nearest degree.)

USE OF SIGHT REDUCTION TABLE (SRT)

By Henton Jaaback

1. Select SRT page with above 'Chosen Lat' Under Lat , opposite LHA (as above):
[A°= ° (nearest whole degree), A'= ']
B = ° ', Z1= , ° (B/Z1 '-' if 90°<LHA<270°)
Dec =+/- ° 'N/S ('+' SAME, '-' CONTRARY)
F =+/- ° '
(F°=+/- °[nearest degree], F'= ')

2. SRT page with A° value as column heading. Under A° opposite F°; H = ° , '
P° = °(nearest whole degree), Z2 = , °

3. Go to Auxiliary Table (pages 316/317). Under F' column opposite P° in left column, what is: Corrn 1 ? +/- , ' ('-' if F°<90° and F'>29', or if F°>90° and F'<30'. Otherwise '+')

4. Under A' column, opposite Z2 (right hand column), what is Corrn 2 ? +/-* , ' ('*-' if A'<30')

Hc = ° , '
Corrn 1 = , '
Corrn 2 = , '
Hc = ° , '

Z1 = , ° + or - as for B.
Z2 = , ° (If F°'-', use 180°-Z2). (Z2 is '-' if F°>90°).
Z = , ° Ignore '-' if applicable.

IF DR in N LAT:
If LHA>180° Zn=Z
If LHA<180° Zn=360°-Z
IF DR in S LAT:
If LHA>180° Zn=180°-Z
If LHA<180° Zn=180°+Z

90° 00 , 0 '
-Hc = ° , '
ZD = ° , '

GC Course = Zn = °T

ZD degrees x 60, + ZD minutes = , '/n.m. = GC Distance

Work Sheet 10.

Here are some exercises for you to try:

<u>EXAMPLE 40</u>. You are about to leave Gibraltar waters en route for the island of St Thomas in the Caribbean. What is the great circle course to steer from the western exit of the Medterranean Sea 36°05' North, 5°30' West to the distant island at 18° 15' North, 65° 00' West? What will be the initial great circle course to steer? (See 'Solutions' in Part 2, Solution 40, which - has used the Air Sight Reduction Tables method, i.e. Work Sheet 2.)

(In practice it seems crazy to attempt to sail this route, initially against the currents and prevailing winds, and then into the middle of the 'Azores High' where good sailing wind is rare. The sailing yachts will prefer to sail in the 'right' direction around the High, in which case a series of shorter great circle courses may be considered. If one is in a powered vessel however, the great circle course is the best.)

<u>EXAMPLE 41</u>. Having spent the last two years sailing around the Caribbean, Bahamas, and south-eastern USA coast, passing through the Panama Canal and sailing up the west coast, you are now ready to depart from San Diego headed for Tokyo. The two sets of co-ordinates are:

San Diego	32° 45' North, 117° 15' West.
Tokyo	35° 30' North, 140° 00' East.

What is the great circle course to steer on leaving San Diego and what is the great circle distance? (See 'Solutions' in Part 2, Solution 41 - it uses the sine/cosine method, i.e. Work Sheet 10.)

(The comment after the first question, above, applies here too! One would be sailing against the current and prevailing westerlies. Both of these two questions are therefore very definitely 'hypothetical'!)

NOTES

COMPASS CHECKING

Throughout the Yachtmaster Ocean syllabus, ALL our sights' resolutions involve calculations which at some stage supply us with the True direction (Azimuth) to the applicable celestial body. The Meridian Passage sight can only give us the maximum sextant angle for that day when the sun is directly due North (360°) or South (180°) of the observer. All other sights, whether they be sun, moon, planets, or stars all give us "Zn" - the Azimuth or True direction from the observer to the celestial body as at the time of the sight.

Even if the navigator has not been very accurate with the use of the sextant, and the resulting intercept is a few miles away from where it should be, the Zn will nevertheless be accurate to the degree. To check this for yourself, look at the Arc to Time conversion table - how much time must elapse for the earth to turn one degree on its axis? The answer is 4 minutes. So any LHA to be used in Sight Reduction Tables will be the same for a 4 minute period. Now if you look at any page for any combination of Lat, Dec, SAME or CONTRARY, and LHA, you will see that the rate of change of Z, and therefore the rate of change of Zn, is very seldom more than 1° per degree change of LHA - often the Z value remains unchanged for several consecutive degrees of LHA. **However**: where Dec and Lat are the SAME and the Dec is Larger than Lat, this does not apply if the LHAs are within +/- 15° of 360°, i.e. between 345° through 360° to 15°, so be warned! The Z/Zn rate of change accelerates near 360°.

When taking a sight, we always note the exact time. If we are to also note the heading on the ship's steering compass and that compass's direction to the celestial body, we can determine compass error. We take the compass reading to the celestial body, and subtract any westerly or add any easterly Variation as stated on the chart, to get the True equivalent. Once we have done the sight calculation and obtained Zn, Zn and our true bearing to the celestial body as per compass, should be the same. Any difference is compass error, and is called Deviation. As with Variation, it can be east or west.

Assume our vessel's course is South by the compass, i.e. 180°C. If we take an accurate bearing from that compass on the sun and find it to be, say, 330°C, and if the chart indicates that the magnetic variation where we are is 21° West, the true bearing appears to be 330° - 21° = 309° True. When we do the sight resolution, if the Zn differs from 309°, there is Deviation. Imagine that Zn is:

a. 305°. Zn is a 'True' direction. If we add West or subtract East Variation, we get the correct magnetic bearing to the sun at that moment from that place. We can compare this correct magnetic direction with the compass bearing we recorded. Any difference is Deviation. If the compass number is bigger than the magnetic number, the deviation is West; if the compass number is smaller than the magnetic number, the deviation is East. So:

T V M But: 'True' + W 'Var' = Magnetic, + W/ -E 'Dev' = Compass
305° + 21°W = 326°

So: T V M D C
305°T + 21° W = 326°M, ? = 330°C
(+ 4°W)

i.e. Deviation is 4° W on a compass heading of 180°. Check the ship's Deviation card - is it the same? If not, use this new Deviation ONLY UNTIL you can get the compass re-swung.

b. 312°. T V M D C
312°T + 21°W = 333°M, ? = 330°C
(- 3°E)

i.e. Deviation is 3°E when on a compass heading of 180°C. Is the Deviation card in agreement?

These errors are "Deviation" and they will be different on different headings of the vessel. While sailing on a heading and doing a spot check on a compass, the bearing to a celestial body compared to the Zn, if the same, or if the deviation is the same, will tend to indicate there has been no change in the compass's accuracy. If there is a difference or if there is any other reason to doubt the accuracy of the deviation information, one should check the deviation on each of many headings around the compass rose's 360°, say at 30° intervals. On each of the headings, note the time accurately as you also note the compass bearing to the celestial body. In each case work out the LHA and find Z to get Zn and apply the variation to get the magnetic bearing as it should be. The difference between this calculated magnetic bearing and the compass bearing will be the deviation - if the compass number is bigger it is west, the deviation is west, it must be added to the magnetic reading to become the correct compass bearing. If it is a smaller number it is east, we must subtract it from the magnetic number to get the correct compass equivalent.

With deviation values for ship's headings every 30° around the compass rose we are able to make up or correct our deviation card or graph.

THE RISING OR SETTING SUN'S AMPLITUDE

Some reference books have what are called Amplitude Tables. These tables tell one, depending on one's latitude and the date, how many degrees north or south of east the sun will appear at sunrise, or how many degrees off west it will be at sunset. If, at a place on a date the amplitude was seen to be 6° North at sunrise, it means it will be 6° north of east which will be 084°True. By adding 'west' variation we get what the compass bearing to the sun will be if there is no deviation. Any difference noted when taking the bearing to the rising sun will be the deviation (on that heading). We can do a similar check with the setting sun.

To be strictly correct, the bearing by compass from/to the sun at sunrise or sunset should be when the bottom arc of the sun's circumference is one radius (half the sun's diameter) above the horizon.

The date enables us to find the declination on that day, to the nearest degree. Our Latitude can be rounded off to the nearest whole number of degrees. With these two numbers, we can look up the tables, (see Table 24, page 117), to find an angle which is called the Amplitude of the Celestial Body (i.e. the sun in our case).

The 'Rising Amplitude' refers to the angle, as seen by the observer (you/the navigator) between true east and the direction of the sun, north or south of true east (the sun rises in the east). If we know this angle, we can determine the true direction of the sun in terms of the 360° notation. For example, if our DR is 28°15' N, 57°50' W on 18 June at sunrise, we can look up the Declination of the sun in the Almanac and see that it is, to the nearest degree, N 23°. Our latitude to the nearest degree is 28°N. When we look up the Amplitude Tables, we see (next page) the angle is 26° (when Dec is 23° and Lat is 28°).

(Note that whether Dec and/or Lat are North or South is of no relevance in the make up of the tables.)

This means the direction (True) to the sun from that latitude, is 26° north (because Declination is North) of east, i.e. 26° north of 090° = 064°. If the Declination had been South, this angle, and therefore the direction to the sun, would be south of east, i.e. 116°True (090° + 26°).

Knowing the true direction and the magnetic variation from the chart for the area, we can compare the magnetic direction with the observed compass direction to the sun at that time - if the compass and magnetic directions are the same, there is no deviation. If they are not the same, there is Deviation; the Deviation is the difference between the two values. If the compass value is the larger. the Deviation is 'West'. If the magnetic number is the larger, the Deviation is 'East'.

The Amplitude Angle of the setting sun can be as useful a check of your compass deviation. From the same DR and date above, i.e. when the Amplitude Angle is 26°. the true direction to the sun will be 244° if Declination is South (270° - 26°), or 296° if Declination is North (270° + 26°).

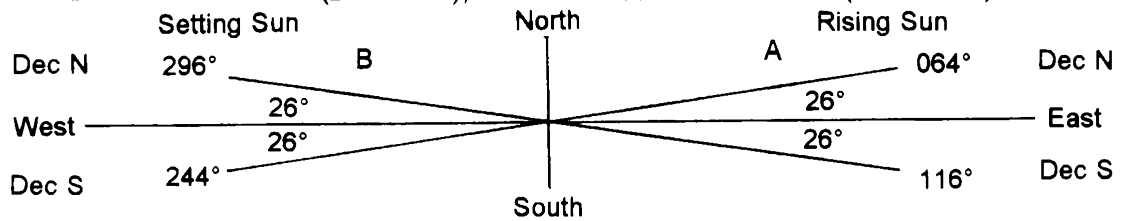


Fig. 69. TRUE DIRECTION OF THE RISING (A) AND THE SETTING (B) SUN.

AMPLITUDE OF THE RISING AND SETTING SUN: LATITUDES UP TO 57° N/S

By Henton Jaaback

Lat °	Declination° (nearest degree) North or South																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0-5	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
6	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
7	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
8	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
9	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
10	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
11	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24
12	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24
13	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	19	20	21	22	23	24
14	0	1	2	3	4	5	6	7	8	9	10	11	12	14	14	16	17	18	19	20	21	22	23	24
15	0	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24
16	0	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	22	23	24
17	0	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	21	22	23	24
18	0	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
19	0	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
20	0	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24	25
21	0	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20	22	23	24	25
22	0	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25
23	0	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	19	20	21	22	23	24	25
24	0	1	2	3	4	6	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22	23	24	25
25	0	1	2	3	4	6	7	8	9	10	11	12	13	14	16	17	18	19	20	21	22	23	24	26
26	0	1	2	3	4	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	24	25	26
27	0	1	2	3	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	23	24	25	26
28	0	1	2	3	5	6	7	8	9	10	11	13	14	15	16	17	18	19	21	22	23	24	25	26
29	0	1	2	3	5	6	7	8	9	10	11	13	14	15	16	17	18	20	21	22	23	24	25	27
30	0	1	2	4	5	6	7	8	9	10	12	13	14	15	16	17	18	20	21	22	23	25	26	27
31	0	1	2	4	5	6	7	8	9	11	12	13	14	15	16	18	19	20	21	22	24	25	26	27
32	0	1	2	4	5	6	7	8	9	11	12	13	14	15	17	18	19	20	21	23	24	25	26	27
33	0	1	2	4	5	6	7	8	10	11	12	13	14	16	17	18	19	20	22	23	24	25	27	28
34	0	1	2	4	5	6	7	9	10	11	12	13	15	16	17	18	19	21	22	23	24	26	27	28
35	0	1	3	4	5	6	7	9	10	11	12	14	15	16	17	18	20	21	22	23	25	26	27	29
36	0	1	3	4	5	6	7	9	10	11	12	14	16	16	17	19	20	21	23	24	25	26	28	29
37	0	1	3	4	5	6	8	9	10	11	13	14	16	16	18	19	20	22	23	24	25	27	28	29
38	0	1	3	4	5	6	8	9	10	12	13	14	16	17	18	19	21	22	23	24	26	27	28	30
39	0	1	3	4	5	6	8	9	10	12	13	14	16	17	18	20	21	22	23	25	26	28	29	30
40	0	1	3	4	5	7	8	9	11	12	13	14	16	17	18	20	21	22	24	25	27	28	29	31
41	0	1	3	4	5	7	8	9	11	12	13	15	16	17	19	20	21	23	24	26	27	28	30	31
42	0	1	3	4	5	7	8	9	11	12	14	15	16	18	19	20	22	23	25	26	27	29	30	32
43	0	1	3	4	6	7	8	10	11	12	14	15	17	18	19	21	22	24	25	26	28	29	31	32
44	0	1	3	4	6	7	8	10	11	13	14	15	17	18	20	21	23	24	25	27	28	30	31	33
45	0	1	3	4	6	7	9	10	11	13	14	16	17	19	20	22	23	24	26	27	29	31	32	34
46	0	1	3	4	6	7	9	10	12	13	15	16	17	19	20	22	23	25	26	28	30	31	33	34
47	0	2	3	4	6	7	9	10	12	13	15	16	18	19	21	22	24	25	27	29	30	32	33	35
48	0	2	3	5	6	8	9	11	12	14	15	17	18	20	21	23	24	26	28	29	31	32	34	36
49	0	2	3	5	6	8	9	11	12	14	15	17	19	20	22	23	25	27	28	30	31	33	35	37
50	0	2	3	5	6	8	9	11	13	14	16	17	19	21	22	24	25	27	29	30	32	34	36	37
51	0	2	3	5	6	8	10	11	13	14	16	18	19	20	23	24	26	28	29	31	33	35	37	38
52	0	2	3	5	7	8	10	11	13	15	16	18	20	20	23	25	27	28	30	32	34	36	38	39
53	0	2	3	5	7	8	10	12	13	15	17	19	20	22	24	26	27	29	31	33	35	37	39	41
54	0	2	3	5	7	9	10	12	14	15	17	19	21	23	25	26	28	30	32	34	36	38	40	42
55	0	2	4	5	7	9	11	12	14	16	18	19	21	24	25	27	29	30	33	35	37	39	41	43
56	0	2	4	5	7	9	11	12	14	16	18	20	22	24	25	27	29	30	33	36	38	40	42	44
57	0	2	4	5	7	9	11	12	14	16	19	20	22	25	26	28	30	31	34	37	39	41	43	45

Table 24.

In practice we all know that a yacht 'zig zags' at sea - it is impossible to keep her on a perfectly straight course, and the bigger the swell or rougher the sea, the worse it is. So this exercise could only be done in relatively calm conditions.

A well adjusted compass will have no or small amounts of deviation which for practical purposes can be ignored - we cannot steer to an accuracy of a degree or two anyway. DO NOT leave on a voyage when the vessel's compass deviation involves large numbers. Something is wrong. Get it professionally checked.

NOTES

APPENDIX A

USE OF MARINE SIGHT REDUCTION TABLES

Sight Reduction Tables allow the navigator to look up the Hc and Zn applicable to the sight. The Hc is compared with Ho to get the Intercept, and the Zn is also needed for the plotting.

During the process of resolving a sight for the LOP, we determine the Declination and the LHA, and along the way we decide on the Assumed or Chosen Latitude, the calculation reveals the Chosen Longitude to be used, and we see whether 'SAME' or 'CONTRARY' applies. All these elements are common to any sight calculation we have done (except Meridian Passage).

With Air Sight Reduction Tables, the navigator turns to the page in the Tables applicable to the Chosen Latitude. With the Marine Sight Reduction Tables, the book (volume - one per 15° of latitude) is chosen according to the navigator's latitude, and the page is selected according to the LHA (as well as 'SAME' or 'CONTRARY', and Assumed or Chosen Latitude). See the example page, Table 25, from the Marine Sight Reduction Tables on page 120.

Note that the column headings are Latitude (the Assumed or Chosen Latitude) and that the horizontal rows are Declination (whole numbers of degrees only). Notice also that the relationship between Z and ZN appears, just as it did in the Air Sight Reduction Tables, above the top margin (for 'Lat North') and below the bottom margin (for 'Lat South'). We are able, therefore to read off the Hc, d, and Z. Converting Z to Zn is the same as the Air Tables.

Using the 'd' number (+ or -) and with the balance of the Declination (the minutes part of the Declination) we look inside the front and back covers of the book, at the 'Interpolation Table'. The horizontal rows represent the increment of Declination. An example Interpolation Table is on page 121 (Table 26).

Next to the Declination increment selected, we see five columns os 'tens' corrections, then a 'Decimals' column, and then ten columns for the units. If our Declination increment was 24,7' and the 'd' number from the tables was +48,3', we would look in the front section, right hand page, opposite 24,7' in the bold/dark print under the 'Dec Inc' column. Then under the 'Tens' section, under 40' for the 48,3', we see 16,5' - call it 'd1', i.e. correction 1, or d1 = + 16,5'. ('+' because 48,3 for the value of 'd' in the Tables, was '+').

The second correction for 'd', or 'd2', uses the units and the decimals part of the value for d from the Tables, i.e. 8,3'. Opposite the 24,7' we go to the right to the decimals column, then up, or down if nearer, to the nearest decimal of the same value as the one we have i.e. ,3. Then go further right along the ,3 row to under the 8 units to get 3,4'. 3,4' is '+' for the same reason as d1.

Hc required = Hc from the Tables, ± d1 ± d2.

('Double Second Difference' tables - right hand column - involve very small corrections when Hc is over 60° - we ignore them.)

A sample Work Sheet (Work Sheet 11) for use with the Marine Sight Reduction Tables is shown on page 122. Note that the only difference, when compared to the Air Sight Reduction Tables, is in the Hc block.

A PAGE FROM MARINE SIGHT REDUCTION TABLES

42°, 318° 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	15° d	15° Z	16° Hc	16° d	16° Z	17° Hc	17° d	17° Z	18° Hc	18° d	18° Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
0	45 52.5	+21.8	106.0	45 35.4	+23.2	107.0	45 17.4	+24.5	108.0	44 58.4	+25.8	108.9
1	46 14.3	20.9	104.7	45 58.6	22.3	105.7	45 41.9	23.6	106.7	45 24.2	24.9	107.7
2	46 35.2	19.9	103.3	46 20.9	21.3	104.4	46 05.5	22.6	105.4	45 49.1	24.0	106.4
3	46 55.1	18.9	102.0	46 42.2	20.3	103.0	46 28.1	21.7	104.0	46 13.1	23.1	105.0
4	47 14.0	17.9	100.6	47 02.5	19.3	101.6	46 49.8	20.8	102.7	46 36.2	22.1	103.7
5	47 31.9	+16.8	99.2	47 21.8	+18.3	100.2	47 10.6	+19.7	101.3	46 58.3	+21.2	102.3
6	47 48.7	15.8	97.7	47 40.1	17.2	98.8	47 30.3	18.7	99.9	47 19.5	20.1	101.0
7	48 04.5	14.6	96.3	47 57.3	16.2	97.4	47 49.0	17.7	98.5	47 39.6	19.1	99.6
8	48 19.1	13.6	94.8	48 13.5	15.1	96.0	48 06.7	16.6	97.1	47 58.7	18.1	98.2
9	48 32.7	12.4	93.4	48 28.6	13.9	94.5	48 23.3	15.5	95.6	48 16.8	17.0	96.7
10	48 45.1	+11.3	91.9	48 42.5	+12.9	93.0	48 38.8	+14.4	94.2	48 33.8	+16.0	95.3
11	48 56.4	10.1	90.4	48 55.4	11.7	91.5	48 53.2	13.2	92.7	48 49.8	14.7	93.8
12	49 06.5	8.9	88.9	49 07.1	10.5	90.0	49 06.4	12.1	91.2	49 04.5	13.7	92.4
13	49 15.4	7.8	87.4	49 17.6	9.3	88.5	49 18.5	10.9	89.7	49 18.2	12.5	90.9
14	49 23.2	6.5	85.9	49 26.9	8.1	87.0	49 29.4	9.7	88.2	49 30.7	11.3	89.4
15	49 29.7	+5.3	84.3	49 35.0	+7.0	85.5	49 39.1	+8.6	86.7	49 42.0	+10.1	87.8
16	49 35.0	4.1	82.8	49 42.0	5.7	84.0	49 47.7	7.3	85.1	49 52.1	8.9	86.3
17	49 39.1	2.9	81.3	49 47.7	4.4	82.4	49 55.0	6.0	83.6	50 01.0	7.7	84.8
18	49 42.0	1.6	79.7	49 52.1	3.3	80.9	50 01.0	4.9	82.0	50 08.7	6.5	83.2
19	49 43.6	+0.5	78.2	49 55.4	2.0	79.3	50 05.9	3.6	80.5	50 15.2	5.2	81.7
20	49 44.1	−0.9	76.6	49 57.4	+0.7	77.8	50 09.5	+2.3	78.9	50 20.4	+3.9	80.1
21	49 43.2	2.0	75.1	49 58.1	−0.5	76.2	50 11.8	+1.1	77.4	50 24.3	2.7	78.6
22	49 41.2	3.3	73.5	49 57.6	1.7	74.7	50 12.9	−0.2	75.8	50 27.0	1.4	77.0
23	49 37.9	4.6	72.0	49 55.9	3.0	73.1	50 12.7	1.4	74.3	50 28.4	+0.2	75.4
24	49 33.3	5.7	70.4	49 52.9	4.3	71.6	50 11.3	2.7	72.7	50 28.6	−1.2	73.8
25	49 27.6	−7.0	68.9	49 48.6	−5.4	70.0	50 08.6	−3.9	71.1	50 27.4	−2.4	72.3
26	49 20.6	8.1	67.4	49 43.2	6.7	68.5	50 04.7	5.2	69.6	50 25.0	3.6	70.7
27	49 12.5	9.4	65.9	49 36.5	7.9	66.9	49 59.5	6.4	68.0	50 21.4	4.9	69.1
28	49 03.1	10.5	64.4	49 28.6	9.1	65.4	49 53.1	7.7	66.5	50 16.5	6.2	67.6
29	48 52.6	11.7	62.9	49 19.5	10.3	63.9	49 45.4	8.8	64.9	50 10.3	7.4	66.0
30	48 40.9	−12.8	61.4	49 09.2	−11.4	62.4	49 36.6	−10.1	63.4	50 02.9	−8.6	64.5
31	48 28.1	13.9	59.9	48 57.8	12.6	60.9	49 26.5	11.2	61.9	49 54.3	9.8	62.9
32	48 14.2	15.0	58.4	48 45.2	13.8	59.4	49 15.3	12.4	60.4	49 44.5	11.1	61.4
33	47 59.2	16.2	57.0	48 31.4	14.8	57.9	49 02.9	13.6	58.9	49 33.4	12.2	59.9
34	47 43.0	17.2	55.5	48 16.6	16.0	56.5	48 49.3	14.7	57.4	49 21.2	13.4	58.4
35	47 25.8	−18.2	54.1	48 00.6	−17.0	55.0	48 34.6	−15.8	55.9	49 07.8	−14.5	56.9
36	47 07.6	19.2	52.7	47 43.6	18.1	53.6	48 18.8	16.9	54.5	48 53.3	15.7	55.4
37	46 48.4	20.3	51.3	47 25.5	19.1	52.2	48 01.9	17.9	53.0	48 37.6	16.7	54.0
38	46 28.1	21.2	50.0	47 06.4	20.1	50.8	47 44.0	19.0	51.6	48 20.9	17.9	52.5
39	46 06.9	22.2	48.6	46 46.3	21.1	49.4	47 25.0	20.0	50.2	48 03.0	18.9	51.1
40	45 44.7	−23.0	47.3	46 25.2	−22.1	48.0	47 05.0	−21.0	48.8	47 44.1	−19.9	49.7
41	45 21.7	24.0	45.9	46 03.1	23.0	46.7	46 44.0	22.0	47.5	47 24.2	20.9	48.3
42	44 57.7	24.9	44.6	45 40.1	23.9	45.4	46 22.0	22.9	46.1	47 03.3	21.9	46.9
43	44 32.8	25.7	43.4	45 16.2	24.8	44.1	45 59.1	23.9	44.8	46 41.4	22.9	45.5
44	44 07.1	26.5	42.1	44 51.4	25.6	42.8	45 35.2	24.7	43.5	46 18.5	23.8	44.2
45	43 40.6	−27.3	40.9	44 25.8	−26.5	41.5	45 10.5	−25.6	42.2	45 54.7	−24.7	42.8
46	43 13.3	28.1	39.6	43 59.3	27.3	40.2	44 44.9	26.5	40.9	45 30.0	25.6	41.5
47	42 45.2	28.9	38.4	43 32.0	28.1	39.0	44 18.4	27.2	39.6	45 04.4	26.4	40.3
48	42 16.3	29.5	37.2	43 03.9	28.8	37.8	43 51.2	28.1	38.4	44 38.0	27.3	39.0
49	41 46.8	30.3	36.1	42 35.1	29.5	36.6	43 23.1	28.8	37.2	44 10.7	28.0	37.7
50	41 16.5	−31.0	34.9	42 05.6	−30.3	35.4	42 54.3	−29.6	36.0	43 42.7	−28.9	36.5
51	40 45.5	31.6	33.8	41 35.3	31.0	34.3	42 24.7	30.3	34.8	43 13.8	29.5	35.3
52	40 13.9	32.2	32.7	41 04.3	31.6	33.1	41 54.4	30.9	33.6	42 44.3	30.3	34.1
53	39 41.7	32.9	31.6	40 32.7	32.3	32.0	41 23.5	31.7	32.5	42 13.9	31.0	32.9
54	39 08.8	33.4	30.5	40 00.4	32.9	30.9	40 51.8	32.3	31.3	41 42.9	31.7	31.8
55	38 35.4	−34.0	29.4	39 27.5	−33.4	29.8	40 19.5	−32.9	30.2	41 11.2	−32.3	30.7
56	38 01.4	34.6	28.4	38 54.1	34.1	28.7	39 46.6	33.6	29.1	40 38.9	33.0	29.5
57	37 26.8	35.1	27.3	38 20.0	34.6	27.7	39 13.0	34.1	28.1	40 05.9	33.6	28.5
58	36 51.7	35.6	26.3	37 45.4	35.2	26.6	38 38.9	34.7	27.0	39 32.3	34.2	27.4
59	36 16.1	36.2	25.3	37 10.2	35.6	25.6	38 04.2	35.2	26.0	38 58.1	34.7	26.3
60	35 39.9	−36.5	24.3	36 34.6	−36.2	24.6	37 29.0	−35.7	24.9	38 23.4	−35.3	25.3
61	35 03.4	37.1	23.3	35 58.4	36.7	23.6	36 53.3	36.3	23.9	37 48.1	35.9	24.2
62	34 26.3	37.5	22.4	35 21.7	37.1	22.7	36 17.0	36.7	22.9	37 12.2	36.3	23.2
63	33 48.8	37.9	21.4	34 44.6	37.5	21.7	35 40.3	37.2	22.0	36 35.9	36.8	22.2
64	33 10.9	38.3	20.5	34 07.1	38.0	20.8	35 03.1	37.6	21.0	35 59.1	37.3	21.3
65	32 32.6	−38.7	19.6	33 29.1	−38.4	19.8	34 25.5	−38.1	20.0	35 21.8	−37.7	20.3
66	31 53.9	39.1	18.7	32 50.7	38.8	18.9	33 47.4	38.5	19.1	34 44.1	38.2	19.3
67	31 14.8	39.5	17.8	32 11.9	39.2	18.0	33 08.9	38.9	18.2	34 05.9	38.6	18.4
68	30 35.3	39.8	16.9	31 32.7	39.5	17.1	32 30.0	39.3	17.3	33 27.3	39.0	17.5
69	29 55.5	40.1	16.1	30 53.2	39.9	16.2	31 50.7	39.6	16.4	32 48.3	39.4	16.6
70	29 15.4	−40.5	15.2	30 13.3	−40.3	15.4	31 11.1	−40.0	15.5	32 08.9	−39.8	15.7
71	28 34.9	40.7	14.4	29 33.0	40.5	14.5	30 31.1	40.3	14.6	31 29.1	40.1	14.8
72	27 54.2	41.1	13.5	28 52.5	40.9	13.7	29 50.8	40.7	13.8	30 49.0	40.4	13.9
73	27 13.1	41.4	12.7	28 11.6	41.2	12.8	29 10.1	41.0	12.9	30 08.6	40.8	13.1
74	26 31.7	41.6	11.9	27 30.4	41.4	12.0	28 29.1	41.3	12.1	29 27.8	41.1	12.2
75	25 50.1	−41.9	11.1	26 49.0	−41.7	11.2	27 47.8	−41.5	11.3	28 46.7	−41.4	11.4
76	25 08.2	42.1	10.3	26 07.3	42.0	10.4	27 06.3	41.9	10.5	28 05.3	41.7	10.6
77	24 26.1	42.4	9.5	25 25.3	42.3	9.6	26 24.4	42.1	9.7	27 23.6	42.0	9.8
78	23 43.7	42.6	8.7	24 43.0	42.5	8.8	25 42.3	42.4	8.9	26 41.6	42.3	9.0
79	23 01.1	42.8	8.0	24 00.5	42.7	8.0	24 59.9	42.6	8.1	25 59.3	42.5	8.2
80	22 18.3	−43.0	7.2	23 17.8	−42.9	7.3	24 17.3	−42.8	7.3	25 16.8	−42.7	7.4
81	21 35.3	43.3	6.5	22 34.9	43.2	6.5	23 34.5	43.1	6.6	24 34.1	43.0	6.6
82	20 52.0	43.4	5.7	21 51.7	43.3	5.8	22 51.4	43.3	5.8	23 51.1	43.2	5.8
83	20 08.6	43.6	5.0	21 08.4	43.6	5.0	22 08.1	43.4	5.1	23 07.9	43.4	5.1
84	19 25.0	43.8	4.3	20 24.8	43.7	4.3	21 24.7	43.7	4.3	22 24.5	43.6	4.3
85	18 41.2	−43.9	3.5	19 41.1	−43.9	3.6	20 41.0	−43.9	3.6	21 40.9	−43.9	3.6
86	17 57.3	44.1	2.8	18 57.2	44.1	2.8	19 57.1	44.0	2.8	20 57.0	44.0	2.9
87	17 13.2	44.3	2.1	18 13.1	44.2	2.1	19 13.1	44.2	2.1	20 13.0	44.1	2.1
88	16 28.9	44.4	1.4	17 28.9	44.4	1.4	18 28.9	44.4	1.4	19 28.9	44.4	1.4
89	15 44.5	44.5	0.7	16 44.5	44.5	0.7	17 44.5	44.5	0.7	18 44.5	44.5	0.7
90	15 00.0	−44.7	0.0	16 00.0	−44.7	0.0	17 00.0	−44.7	0.0	18 00.0	−44.7	0.0
	15°			16°			17°			18°		

19° Hc	19° d	19° Z	20° Hc	20° d	20° Z	21° Hc	21° d	21° Z	22° Hc	22° d	22° Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
44 38.4	+27.1	109.9	44 17.6	+28.3	110.8	43 55.8	+29.5	111.7	43 33.2	+30.7	112.6	0
45 05.5	26.2	108.6	44 45.9	27.4	109.6	44 25.3	28.7	110.5	44 03.9	29.8	111.4	1
45 31.7	25.3	107.3	45 13.3	26.6	108.3	44 54.0	27.9	109.3	44 33.7	29.2	110.2	2
45 57.0	24.4	106.0	45 39.9	25.8	107.0	45 21.9	27.0	108.0	45 02.9	28.2	109.0	3
46 21.4	23.5	104.7	46 05.7	24.8	105.7	45 48.9	26.2	106.7	45 31.1	27.5	107.7	4
46 44.9	+22.6	103.4	46 30.5	+24.0	104.4	46 15.1	+25.3	105.4	45 58.6	+26.6	106.4	5
47 07.5	21.6	102.0	46 54.5	22.9	103.1	46 40.4	24.3	104.1	46 25.2	25.7	105.1	6
47 29.1	20.6	100.7	47 17.4	22.0	101.7	47 04.7	23.4	102.8	46 50.9	24.8	103.8	7
47 49.7	19.5	99.3	47 39.4	21.1	100.3	47 28.1	22.5	101.4	47 15.7	23.8	102.5	8
48 09.2	18.5	97.8	48 00.5	19.9	98.9	47 50.6	21.4	100.0	47 39.5	22.9	101.1	9
48 27.7	+17.5	96.4	48 20.4	+19.0	97.5	48 12.0	+20.4	98.6	48 02.4	+21.9	99.7	10
48 45.2	16.3	95.0	48 39.4	17.8	96.1	48 32.4	19.4	97.2	48 24.3	20.8	98.3	11
49 01.5	15.2	93.5	48 57.2	16.8	94.7	48 51.8	18.2	95.8	48 45.1	19.8	96.9	12
49 16.7	14.0	92.0	49 14.0	15.6	93.2	49 10.0	17.2	94.3	49 04.9	18.7	95.5	13
49 30.7	12.9	90.5	49 29.6	14.5	91.7	49 27.2	16.0	92.9	49 23.6	17.6	94.0	14
49 43.6	+11.8	89.0	49 44.1	+13.3	90.2	49 43.2	+14.9	91.4	49 41.2	+16.4	92.6	15
49 55.4	10.5	87.5	49 57.4	12.1	88.7	49 58.1	13.7	89.9	49 57.6	15.3	91.1	16
50 05.9	9.3	86.0	50 09.5	10.9	87.2	50 11.8	12.5	88.4	50 12.9	14.1	89.6	17
50 15.2	8.0	84.4	50 20.4	9.6	85.6	50 24.3	11.3	86.8	50 27.0	12.9	88.0	18
50 23.2	6.8	82.9	50 30.0	8.5	84.1	50 35.6	10.1	85.3	50 39.9	11.7	86.5	19
50 30.0	+5.6	81.3	50 38.5	+7.2	82.5	50 45.7	+8.8	83.7	50 51.6	+10.4	85.0	20
50 35.6	4.3	79.7	50 45.7	5.9	81.0	50 54.5	7.5	82.2	51 02.0	9.2	83.4	21
50 39.9	3.0	78.2	50 51.6	4.6	79.4	51 02.0	6.3	80.6	51 11.2	7.9	81.8	22
50 42.9	1.8	76.6	50 56.2	3.4	77.8	51 08.3	5.0	79.0	51 19.1	6.6	80.2	23
50 44.7	+0.4	75.0	50 59.6	2.0	76.2	51 13.3	3.6	77.4	51 25.7	5.3	78.6	24
50 45.1	−0.8	73.4	51 01.6	+0.8	74.6	51 16.9	+2.4	75.8	51 31.0	+4.0	77.0	25
50 44.3	2.1	71.9	51 02.4	−0.5	73.0	51 19.3	+1.1	74.2	51 35.0	2.7	75.4	26
50 42.2	3.4	70.3	51 01.9	1.8	71.4	51 20.4	−0.3	72.6	51 37.7	+1.4	73.8	27
50 38.8	4.6	68.7	51 00.1	3.2	69.9	51 20.1	1.5	71.0	51 39.1	0.0	72.2	28
50 34.2	5.9	67.1	50 56.9	4.4	68.3	51 18.6	2.9	69.4	51 39.1	−1.3	70.6	29
50 28.3	−7.2	65.6	50 52.5	−5.6	66.7	51 15.7	−4.1	67.8	51 37.8	−2.6	69.0	30
50 21.1	8.4	64.0	50 46.9	7.0	65.1	51 11.6	5.5	66.2	51 25.2	3.9	67.4	31
50 12.7	9.6	62.5	50 39.9	8.2	63.5	51 06.1	6.7	64.6	51 31.3	5.2	65.8	32
50 03.1	10.9	60.9	50 31.7	9.4	62.0	50 59.4	8.0	63.1	51 26.1	6.6	64.2	33
49 52.2	12.0	59.4	50 22.3	10.7	60.4	50 51.4	9.3	61.5	51 19.5	7.8	62.6	34
49 40.2	−13.3	57.9	50 11.6	−11.9	58.9	50 42.1	−10.5	59.9	51 11.7	−9.1	61.0	35
49 26.9	14.4	56.4	49 59.7	13.1	57.4	50 31.6	11.7	58.4	51 02.6	10.3	59.4	36
49 12.5	15.5	54.9	49 46.6	14.2	55.8	50 19.9	12.9	56.8	50 52.3	11.6	57.9	37
48 57.0	16.6	53.4	49 32.4	15.4	54.3	50 07.0	14.2	55.3	50 40.7	12.9	56.3	38
48 40.4	17.7	52.0	49 17.0	16.5	52.9	49 52.8	15.3	53.8	50 27.8	14.0	54.8	39
48 22.7	−18.8	50.5	49 00.5	−17.7	51.4	49 37.5	−16.4	52.3	50 13.8	−15.2	53.3	40
48 03.9	19.9	49.1	48 42.8	18.7	49.9	49 21.1	17.6	50.8	49 58.6	16.4	51.7	41
47 44.0	20.9	47.7	48 24.1	19.8	48.5	49 03.5	18.7	49.4	49 42.2	17.5	50.3	42
47 23.1	21.8	46.3	48 04.3	20.8	47.1	48 44.8	19.7	47.9	49 24.7	18.6	48.8	43
47 01.3	22.8	44.9	47 43.5	21.8	45.7	48 25.1	20.8	46.5	49 06.1	19.7	47.3	44
46 38.5	−23.8	43.6	47 21.7	−22.8	44.3	48 04.3	−21.8	45.1	48 46.4	−20.8	45.9	45
46 14.7	24.7	42.2	46 58.9	23.8	42.9	47 42.5	22.8	43.7	48 25.6	21.8	44.5	46
45 50.0	25.6	40.9	46 35.1	24.7	41.6	47 19.7	23.7	42.3	48 03.8	22.8	43.1	47
45 24.4	26.4	39.6	46 10.4	25.6	40.3	46 56.0	24.7	41.0	47 41.0	23.8	41.7	48
44 58.0	27.3	38.3	45 44.8	26.4	39.0	46 31.3	25.6	39.6	47 17.2	24.7	40.3	49
44 30.7	−28.1	37.1	45 18.4	−27.3	37.7	46 05.7	−26.5	38.3	46 52.5	−25.6	39.0	50
44 02.6	28.8	35.9	44 51.1	28.1	36.4	45 39.2	27.4	37.0	46 26.9	26.6	37.7	51
43 33.8	29.7	34.6	44 23.0	28.9	35.2	45 11.8	28.1	35.8	46 00.3	27.4	36.4	52
43 04.1	30.3	33.5	43 54.1	29.7	34.0	44 43.7	29.0	34.5	45 32.9	28.2	35.1	53
42 33.8	31.1	32.3	43 24.4	30.4	32.8	44 14.7	29.8	33.3	45 04.7	29.1	33.8	54
42 02.7	−31.7	31.1	42 54.0	−31.2	31.6	43 44.9	−30.5	32.1	44 35.6	−29.8	32.6	55
41 31.0	32.5	30.0	42 22.8	31.8	30.4	43 14.4	31.2	30.9	44 05.8	30.6	31.4	56
40 58.5	33.0	28.9	41 51.0	32.5	29.3	42 43.2	31.9	29.7	43 35.2	31.4	30.2	57
40 25.5	33.7	27.8	41 18.5	33.2	28.2	42 11.3	32.6	28.6	43 03.8	32.0	29.0	58
39 51.8	34.3	26.7	40 45.3	33.7	27.1	41 38.7	33.3	27.5	42 31.8	32.7	27.9	59
39 17.5	−34.8	25.6	40 11.6	−34.4	26.0	41 05.4	−33.9	26.4	41 59.1	−33.4	26.7	60
38 42.7	35.4	24.6	39 37.2	34.9	24.9	40 31.5	34.4	25.3	41 25.7	34.0	25.6	61
38 07.3	35.9	23.5	39 02.3	35.5	23.9	39 57.1	35.1	24.2	40 51.7	34.6	24.5	62
37 31.4	36.4	22.5	38 26.8	36.1	22.8	39 22.0	35.6	23.1	40 17.1	35.2	23.5	63
36 55.0	37.0	21.5	37 50.7	36.5	21.8	38 46.4	36.2	22.1	39 41.9	35.8	22.4	64
36 18.0	−37.4	20.5	37 14.2	−37.1	20.8	38 10.2	−36.7	21.1	39 06.1	−36.3	21.4	65
35 40.6	37.8	19.6	36 37.1	37.5	19.8	37 33.5	37.2	20.1	38 29.8	36.8	20.3	66
35 02.8	38.3	18.6	35 59.6	38.0	18.9	36 56.3	37.6	19.1	37 53.0	37.3	19.3	67
34 24.5	38.7	17.7	35 21.6	38.4	17.9	36 18.7	38.2	18.1	37 15.7	37.9	18.4	68
33 45.8	39.2	16.8	34 43.2	38.9	17.0	35 40.5	38.5	17.2	36 37.8	38.3	17.4	69
33 06.6	−39.5	15.9	34 04.3	−39.2	16.0	35 02.0	−39.0	16.2	35 59.5	−38.7	16.4	70
32 27.1	39.9	15.0	33 25.1	39.7	15.1	34 23.0	39.4	15.3	35 20.8	39.2	15.5	71
31 47.2	40.2	14.1	32 45.4	40.0	14.2	33 43.6	39.9	14.4	34 41.6	39.5	14.6	72
31 07.0	40.6	13.2	32 05.4	40.4	13.4	33 03.7	40.1	13.5	34 02.1	40.0	13.7	73
30 26.4	40.9	12.4	31 25.0	40.7	12.5	32 23.6	40.6	12.6	33 22.1	40.4	12.8	74
29 45.5	−41.3	11.5	30 44.3	−41.1	11.6	31 43.0	−40.9	11.7	32 41.7	−40.7	11.9	75
29 04.2	41.5	10.7	30 03.2	41.4	10.8	31 02.1	41.2	10.9	32 01.0	41.0	11.0	76
28 22.7	41.9	9.9	29 21.8	41.7	9.9	30 20.9	41.6	10.0	31 20.0	41.5	10.1	77
27 40.8	42.1	9.0	28 40.1	42.0	9.1	29 39.3	41.8	9.2	30 38.5	41.7	9.3	78
26 58.7	42.4	8.2	27 58.1	42.3	8.3	28 57.5	42.2	8.4	29 56.8	42.0	8.5	79
26 16.3	−42.6	7.4	27 15.8	−42.5	7.5	28 15.3	−42.4	7.6	29 14.8	−42.4	7.7	80
25 33.7	42.9	6.7	26 33.3	42.8	6.7	27 32.9	42.7	6.8	28 32.4	42.6	6.8	81
24 50.8	43.1	5.9	25 50.5	43.1	5.9	26 50.2	43.0	6.0	27 49.8	42.9	6.0	82
24 07.7	43.4	5.1	25 07.4	43.3	5.2	26 07.2	43.2	5.2	27 06.9	43.1	5.3	83
23 24.3	43.6	4.4	24 24.1	43.5	4.4	25 24.0	43.5	4.4	26 23.8	43.4	4.5	84
22 40.7	−43.7	3.6	23 40.6	−43.7	3.7	24 40.5	−43.7	3.7	25 40.4	−43.7	3.7	85
21 57.0	44.0	2.9	22 56.9	43.9	2.9	23 56.8	43.9	2.9	24 56.7	43.8	3.0	86
21 13.0	44.2	2.2	22 13.0	44.2	2.2	23 12.9	44.1	2.2	24 12.9	44.1	2.2	87
20 28.8	44.3	1.4	21 28.8	44.3	1.4	22 28.8	44.3	1.4	23 28.8	44.3	1.5	88
19 44.5	44.5	0.7	20 44.5	44.5	0.7	21 44.5	44.5	0.7	22 44.5	44.5	0.7	89
19 00.0	−44.7	0.0	20 00.0	−44.7	0.0	21 00.0	−44.7	0.0	22 00.0	−44.7	0.0	90
19°			20°			21°			22°			

42°, 318° L.H.A. **LATITUDE SAME NAME AS DECLINATION**

Table 25.

INTERPOLATION TABLES: SAMPLE PAGE FROM INSIDE FRONT COVER

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.
16.0	2.6	5.3	8.0	10.6	13.3	.0	0.0	0.3	0.5	0.8	1.1	1.4	1.6	1.9	2.2	2.5	
16.1	2.7	5.3	8.0	10.7	13.4	.1	0.0	0.3	0.6	0.9	1.1	1.4	1.7	2.0	2.2	2.5	
16.2	2.7	5.4	8.1	10.8	13.5	.2	0.1	0.3	0.6	0.9	1.2	1.4	1.7	2.0	2.3	2.5	1.0
16.3	2.7	5.4	8.1	10.9	13.6	.3	0.1	0.4	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	0.1 3.0
16.4	2.7	5.5	8.2	10.9	13.7	.4	0.1	0.4	0.7	0.9	1.2	1.5	1.8	2.0	2.3	2.6	0.2 4.9
16.5	2.8	5.5	8.3	11.0	13.8	.5	0.1	0.4	0.7	1.0	1.2	1.5	1.8	2.1	2.3	2.6	0.3 6.9
16.6	2.8	5.5	8.3	11.1	13.8	.6	0.2	0.4	0.7	1.0	1.3	1.5	1.8	2.1	2.4	2.6	0.4 8.9
16.7	2.8	5.6	8.4	11.2	13.9	.7	0.2	0.5	0.7	1.0	1.3	1.6	1.8	2.1	2.4	2.7	0.5 10.8
16.8	2.8	5.6	8.4	11.2	14.0	.8	0.2	0.5	0.8	1.0	1.3	1.6	1.9	2.1	2.4	2.7	0.6 12.8
16.9	2.9	5.7	8.5	11.3	14.1	.9	0.2	0.5	0.8	1.1	1.3	1.6	1.9	2.2	2.4	2.7	0.7 14.8 0.8 16.7
17.0	2.8	5.6	8.5	11.3	14.1	.0	0.0	0.3	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	0.9 18.7
17.1	2.8	5.7	8.5	11.4	14.2	.1	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	1.0 20.7
17.2	2.8	5.7	8.6	11.4	14.3	.2	0.1	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	1.1 22.7
17.3	2.9	5.8	8.6	11.5	14.4	.3	0.1	0.4	0.7	1.0	1.3	1.5	1.8	2.1	2.4	2.7	1.2 24.6
17.4	2.9	5.8	8.7	11.6	14.5	.4	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.4	2.7	1.3 26.6 1.4 28.6
17.5	2.9	5.8	8.8	11.7	14.6	.5	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.5	2.8	1.5 30.5
17.6	2.9	5.9	8.8	11.7	14.7	.6	0.2	0.5	0.8	1.0	1.3	1.6	1.9	2.2	2.5	2.8	1.6 32.5
17.7	3.0	5.9	8.9	11.8	14.8	.7	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.2	2.5	2.8	1.7 34.5
17.8	3.0	6.0	8.9	11.9	14.9	.8	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9	
17.9	3.0	6.0	9.0	12.0	15.0	.9	0.3	0.6	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9	
18.0	3.0	6.0	9.0	12.0	15.0	.0	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.2	2.5	2.8	
18.1	3.0	6.0	9.0	12.0	15.1	.1	0.0	0.3	0.6	1.0	1.3	1.6	1.9	2.2	2.5	2.8	0.9
18.2	3.0	6.0	9.1	12.1	15.1	.2	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.5	2.8	0.1 2.8
18.3	3.0	6.1	9.1	12.2	15.2	.3	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.3	2.6	2.9	0.2 4.6
18.4	3.1	6.1	9.2	12.3	15.3	.4	0.1	0.4	0.7	1.0	1.4	1.7	2.0	2.3	2.6	2.9	0.3 6.5
18.5	3.1	6.2	9.3	12.3	15.4	.5	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9	0.4 8.3
18.6	3.1	6.2	9.3	12.4	15.5	.6	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.3	2.7	3.0	0.5 10.2
18.7	3.1	6.3	9.4	12.5	15.6	.7	0.2	0.5	0.8	1.1	1.4	1.8	2.1	2.4	2.7	3.0	0.6 12.0
18.8	3.2	6.3	9.4	12.6	15.7	.8	0.2	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	0.7 13.9
18.9	3.2	6.3	9.5	12.6	15.8	.9	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.1	0.8 15.7 0.9 17.6
19.0	3.1	6.3	9.5	12.6	15.8	.0	0.0	0.3	0.6	1.0	1.3	1.6	1.9	2.3	2.6	2.9	1.0 19.4
19.1	3.2	6.3	9.5	12.7	15.9	.1	0.0	0.4	0.7	1.0	1.3	1.7	2.0	2.3	2.6	3.0	1.1 21.3
19.2	3.2	6.4	9.6	12.8	16.0	.2	0.1	0.4	0.7	1.0	1.4	1.7	2.0	2.3	2.7	3.0	1.2 23.1
19.3	3.2	6.4	9.6	12.9	16.1	.3	0.1	0.4	0.7	1.1	1.4	1.7	2.0	2.4	2.7	3.0	1.3 25.0
19.4	3.2	6.5	9.7	12.9	16.2	.4	0.1	0.5	0.8	1.1	1.4	1.8	2.1	2.4	2.7	3.1	1.4 26.8
19.5	3.3	6.5	9.8	13.0	16.3	.5	0.2	0.5	0.8	1.1	1.5	1.8	2.1	2.4	2.8	3.1	1.5 28.7
19.6	3.3	6.5	9.8	13.1	16.3	.6	0.2	0.5	0.8	1.2	1.5	1.8	2.1	2.5	2.8	3.1	1.6 30.5
19.7	3.3	6.6	9.9	13.2	16.4	.7	0.2	0.6	0.9	1.2	1.5	1.9	2.2	2.5	2.8	3.2	1.7 32.3
19.8	3.3	6.6	9.9	13.2	16.5	.8	0.3	0.6	0.9	1.2	1.6	1.9	2.2	2.5	2.9	3.2	1.8 34.2
19.9	3.4	6.7	10.0	13.3	16.6	.9	0.3	0.6	0.9	1.3	1.6	1.9	2.2	2.6	2.9	3.2	
20.0	3.3	6.6	10.0	13.3	16.6	.0	0.0	0.3	0.7	1.0	1.4	1.7	2.0	2.4	2.7	3.1	
20.1	3.3	6.7	10.0	13.4	16.7	.1	0.0	0.4	0.7	1.1	1.4	1.7	2.1	2.4	2.8	3.1	0.9
20.2	3.3	6.7	10.1	13.4	16.8	.2	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.5	2.8	3.1	0.1 2.6
20.3	3.4	6.8	10.1	13.5	16.9	.3	0.1	0.4	0.8	1.1	1.5	1.8	2.2	2.5	2.8	3.2	0.2 4.4
20.4	3.4	6.8	10.2	13.6	17.0	.4	0.1	0.5	0.8	1.2	1.5	1.8	2.2	2.5	2.9	3.2	0.3 6.2
20.5	3.4	6.8	10.3	13.7	17.1	.5	0.2	0.5	0.9	1.2	1.5	1.9	2.2	2.6	2.9	3.2	0.4 7.9
20.6	3.4	6.9	10.3	13.7	17.2	.6	0.2	0.5	0.9	1.2	1.6	1.9	2.3	2.6	2.9	3.3	0.5 9.7
20.7	3.5	6.9	10.4	13.8	17.3	.7	0.2	0.6	0.9	1.3	1.6	1.9	2.3	2.6	3.0	3.3	0.6 11.4
20.8	3.5	7.0	10.4	13.9	17.4	.8	0.3	0.6	1.0	1.3	1.6	2.0	2.3	2.7	3.0	3.3	0.7 13.2
20.9	3.5	7.0	10.5	14.0	17.5	.9	0.3	0.6	1.0	1.3	1.7	2.0	2.4	2.7	3.0	3.4	0.8 14.9 0.9 16.7
21.0	3.5	7.0	10.5	14.0	17.5	.0	0.0	0.4	0.7	1.1	1.4	1.8	2.1	2.5	2.9	3.2	1.0 18.5
21.1	3.5	7.0	10.5	14.0	17.6	.1	0.0	0.4	0.8	1.1	1.5	1.8	2.2	2.5	2.9	3.3	1.1 20.2
21.2	3.5	7.0	10.6	14.1	17.6	.2	0.1	0.4	0.8	1.1	1.5	1.9	2.2	2.6	2.9	3.3	1.2 22.0
21.3	3.5	7.1	10.6	14.2	17.7	.3	0.1	0.5	0.8	1.2	1.5	1.9	2.3	2.6	3.0	3.3	1.3 23.7
21.4	3.6	7.1	10.7	14.3	17.8	.4	0.1	0.5	0.9	1.2	1.6	1.9	2.3	2.7	3.0	3.4	1.4 25.5 1.5 27.3
21.5	3.6	7.2	10.8	14.3	17.9	.5	0.2	0.5	0.9	1.3	1.6	2.0	2.3	2.7	3.0	3.4	1.6 29.0
21.6	3.6	7.2	10.8	14.4	18.0	.6	0.2	0.6	0.9	1.3	1.6	2.0	2.4	2.7	3.1	3.4	1.7 30.8
21.7	3.6	7.3	10.9	14.5	18.1	.7	0.3	0.6	1.0	1.3	1.7	2.0	2.4	2.8	3.1	3.5	1.8 32.5
21.8	3.7	7.3	10.9	14.6	18.2	.8	0.3	0.6	1.0	1.4	1.7	2.1	2.4	2.8	3.2	3.5	1.9 34.3
21.9	3.7	7.3	11.0	14.6	18.3	.9	0.3	0.7	1.0	1.4	1.8	2.1	2.5	2.8	3.2	3.5	
22.0	3.6	7.3	11.0	14.6	18.3	.0	0.0	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.4	0.8
22.1	3.7	7.3	11.0	14.7	18.4	.1	0.0	0.4	0.8	1.2	1.5	1.9	2.3	2.7	3.0	3.4	0.1 2.5
22.2	3.7	7.4	11.1	14.8	18.5	.2	0.1	0.4	0.8	1.2	1.6	1.9	2.3	2.7	3.1	3.4	0.2 4.2
22.3	3.7	7.4	11.1	14.9	18.6	.3	0.1	0.5	0.9	1.2	1.6	2.0	2.4	2.7	3.1	3.5	0.3 5.9
22.4	3.7	7.5	11.2	14.9	18.7	.4	0.1	0.5	0.9	1.3	1.6	2.0	2.4	2.8	3.1	3.5	0.4 7.6
22.5	3.8	7.5	11.3	15.0	18.8	.5	0.2	0.6	0.9	1.3	1.7	2.1	2.4	2.8	3.2	3.6	0.5 9.3
22.6	3.8	7.5	11.3	15.1	18.8	.6	0.2	0.6	1.0	1.3	1.7	2.1	2.5	2.8	3.2	3.6	0.6 11.0
22.7	3.8	7.6	11.4	15.2	18.9	.7	0.3	0.6	1.0	1.4	1.8	2.1	2.5	2.9	3.3	3.6	0.7 12.7
22.8	3.8	7.6	11.4	15.2	19.0	.8	0.3	0.7	1.0	1.4	1.8	2.2	2.5	2.9	3.3	3.7	0.8 14.4
22.9	3.9	7.7	11.5	15.3	19.1	.9	0.3	0.7	1.1	1.5	1.8	2.2	2.6	3.0	3.3	3.7	0.9 16.1 1.0 17.8
23.0	3.8	7.6	11.5	15.3	19.1	.0	0.0	0.4	0.8	1.2	1.6	2.0	2.3	2.7	3.1	3.5	1.1 19.5
23.1	3.8	7.7	11.5	15.4	19.2	.1	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	1.2 21.2
23.2	3.8	7.7	11.6	15.4	19.3	.2	0.1	0.5	0.9	1.3	1.6	2.0	2.4	2.8	3.2	3.6	1.3 22.8
23.3	3.9	7.8	11.6	15.5	19.4	.3	0.1	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.6	1.4 24.5
23.4	3.9	7.8	11.7	15.6	19.5	.4	0.2	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.7	1.5 26.2 1.6 27.9
23.5	3.9	7.8	11.8	15.7	19.6	.5	0.2	0.6	1.0	1.4	1.8	2.2	2.5	2.9	3.3	3.7	1.7 29.6
23.6	3.9	7.9	11.8	15.7	19.7	.6	0.2	0.6	1.0	1.4	1.8	2.2	2.6	3.0	3.4	3.8	1.8 31.3
23.7	4.0	7.9	11.9	15.8	19.8	.7	0.3	0.7	1.1	1.4	1.8	2.2	2.6	3.0	3.4	3.8	1.9 33.0
23.8	4.0	8.0	11.9	15.9	19.9	.8	0.3	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.4	3.8	2.0 34.7
23.9	4.0	8.0	12.0	16.0	20.0	.9	0.4	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.5	3.9	
24.0	4.0	8.0	12.0	16.0	20.0	.0	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.9	3.3	3.7	0.8
24.1	4.0	8.0	12.0	16.0	20.1	.1	0.0	0.4	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.7	0.1 2.5
24.2	4.0	8.0	12.1	16.1	20.1	.2	0.1	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.8	0.2 4.1
24.3	4.0	8.1	12.1	16.2	20.2	.3	0.1	0.5	0.9	1.3	1.8	2.2	2.6	3.0	3.4	3.8	0.3 5.8
24.4	4.1	8.1	12.2	16.3	20.3	.4	0.2	0.6	1.0	1.4	1.8	2.2	2.6	3.0	3.4	3.8	0.4 7.4
24.5	4.1	8.2	12.3	16.3	20.4	.5	0.2	0.6	1.0	1.4	1.8	2.2	2.7	3.1	3.5	3.9	0.5 9.1 0.6 10.7
24.6	4.1	8.2	12.3	16.4	20.5	.6	0.2	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.5	3.9	0.7 12.3
24.7	4.1	8.3	12.4	16.5	20.6	.7	0.3	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.6	4.0	0.8 14.0
24.8	4.2	8.3	12.4	16.6	20.7	.8	0.3	0.7	1.1	1.6	2.0	2.4	2.8	3.2	3.6	4.0	0.9 15.6
24.9	4.2	8.3	12.5	16.6	20.8	.9	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	1.0 17.3 1.1 18.9
25.0	4.1	8.3	12.5	16.6	20.8	.0	0.0	0.4	0.8	1.3	1.7	2.1	2.5	3.0	3.4	3.8	1.2 20.6
25.1	4.2	8.3	12.5	16.7	20.9	.1	0.0	0.5	0.9	1.3	1.7	2.2	2.6	3.0	3.4	3.9	1.3 22.2
25.2	4.2	8.4	12.6	16.8	21.0	.2	0.1	0.5	0.9	1.4	1.8	2.2	2.6	3.1	3.5	3.9	1.4 23.9
25.3	4.2	8.4	12.6	16.9	21.1	.3	0.1	0.6	1.0	1.4	1.8	2.3	2.7	3.1	3.5	4.0	1.5 25.5
25.4	4.2	8.5	12.7	16.9	21.2	.4	0.2	0.6	1.0	1.4	1.9	2.3	2.7	3.1	3.6	4.0	1.6 27.2
25.5	4.3	8.5	12.8	17.0	21.3	.5	0.2	0.6	1.1	1.5	1.9	2.3	2.8	3.2	3.6	4.0	1.7 28.8
25.6	4.3	8.5	12.8	17.1	21.3	.6	0.3	0.7	1.1	1.5	2.0	2.4	2.8	3.2	3.7	4.1	1.8 30.4
25.7	4.3	8.6	12.9	17.2	21.4	.7	0.3	0.7	1.1	1.6	2.0	2.4	2.8	3.3	3.7	4.1	1.9 32.1
25.8	4.3	8.6	12.9	17.2	21.5	.8	0.3	0.8	1.2	1.6	2.0	2.5	2.9	3.3	3.7	4.2	2.0 33.7
25.9	4.4	8.7	13.0	17.3	21.6	.9	0.4	0.8	1.2	1.7	2.1	2.5	2.9	3.4	3.8	4.2	2.1 35.4
26.0	4.3	8.6	13.0	17.3	21.6	.0	0.0	0.4	0.9	1.3	1.8	2.2	2.6	3.1	3.5	4.0	0.8
26.1	4.3	8.7	13.0	17.4	21.7	.1	0.0	0.5	0.9	1.4	1.8	2.3	2.7	3.1	3.6	4.0	0.1 2.4
26.2	4.3	8.7	13.1	17.4	21.8	.2	0.1	0.5	1.0	1.4	1.9	2.3	2.7	3.2	3.6	4.1	0.2 4.0
26.3	4.4	8.8	13.1	17.5	21.9	.3	0.1	0.6	1.0	1.5	1.9	2.3	2.8	3.2	3.7	4.1	0.3 5.7
26.4	4.4	8.8	13.2	17.6	22.0	.4	0.2	0.6	1.1	1.5	1.9	2.4	2.8	3.3	3.7	4.2	0.4 7.3
26.5	4.4	8.8	13.3	17.7	22.1	.5	0.2	0.7	1.1	1.5	2.0	2.4	2.9	3.3	3.8	4.2	0.5 8.9
26.6	4.4	8.9	13.3	17.7	22.2	.6	0.3	0.7	1.1	1.6	2.0	2.5	2.9	3.4	3.8	4.2	0.6 10.5
26.7	4.5	8.9	13.4	17.8	22.3	.7	0.3	0.8	1.2	1.6	2.1	2.5	3.0	3.4	3.8	4.3	0.7 12.1
26.8	4.5	9.0	13.4	17.9	22.4	.8	0.4	0.8	1.2	1.7	2.1	2.6	3.0	3.4	3.9	4.3	0.8 13.7
26.9	4.5	9.0	13.5	18.0	22.5	.9	0.4	0.8	1.3	1.7	2.2	2.6	3.0	3.5	3.9	4.4	0.9 15.4 1.0 17.0
27.0	4.5	9.0	13.5	18.0	22.5	.0	0.0	0.5	0.9	1.4	1.8	2.3	2.7	3.2	3.7	4.1	1.1 18.6
27.1	4.5	9.0	13.5	18.0	22.6	.1	0.0	0.5	1.0	1.4	1.9	2.3	2.8	3.3	3.7	4.2	1.2 20.2
27.2	4.5	9.0	13.6	18.1	22.6	.2	0.1	0.5	1.0	1.5	1.9	2.4	2.8	3.3	3.8	4.2	1.3 21.8
27.3	4.5	9.1	13.6	18.2	22.7	.3	0.1	0.6	1.1	1.5	2.0	2.4	2.9	3.3	3.8	4.3	1.4 23.4
27.4	4.6	9.1	13.7	18.3	22.8	.4	0.2	0.6	1.1	1.6	2.0	2.5	2.9	3.4	3.8	4.3	1.5 25.1 1.6 26.7
27.5	4.6	9.2	13.8	18.3	22.9	.5	0.2	0.7	1.1	1.6	2.1	2.5	3.0	3.4	3.9	4.4	1.7 28.3
27.6	4.6	9.2	13.8	18.4	23.0	.6	0.3	0.7	1.2	1.6	2.1	2.6	3.0	3.5	3.9	4.4	1.8 29.9
27.7	4.6	9.3	13.9	18.5	23.1	.7	0.3	0.8	1.2	1.7	2.2	2.6	3.1	3.5	4.0	4.4	1.9 31.5
27.8	4.7	9.3	13.9	18.6	23.2	.8	0.4	0.8	1.3	1.7	2.2	2.7	3.1	3.6	4.0	4.5	2.0 33.1
27.9	4.7	9.3	14.0	18.6	23.3	.9	0.4	0.9	1.3	1.8	2.2	2.7	3.2	3.6	4.1	4.5	2.1 34.7
28.0	4.6	9.3	14.0	18.6	23.3	.0	0.0	0.5	0.9	1.4	1.9	2.4	2.8	3.3	3.8	4.3	0.8
28.1	4.7	9.3	14.0	18.7	23.4	.1	0.0	0.5	1.0	1.5	1.9	2.4	2.9	3.4	3.8	4.3	0.1 2.4
28.2	4.7	9.4	14.1	18.8	23.5	.2	0.1	0.6	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4	0.2 4.0
28.3	4.7	9.4	14.1	18.9	23.6	.3	0.1	0.6	1.1	1.6	2.0	2.5	3.0	3.5	3.9	4.4	0.3 5.6
28.4	4.7	9.5	14.2	18.9	23.7	.4	0.2	0.7	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5	0.4 7.2
28.5	4.8	9.5	14.3	19.0	23.8	.5	0.2	0.7	1.2	1.7	2.1	2.6	3.1	3.6	4.0	4.5	0.5 8.8
28.6	4.8	9.5	14.3	19.1	23.8	.6	0.3	0.8	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6	0.6 10.4
28.7	4.8	9.6	14.4	19.2	23.9	.7	0.3	0.8	1.3	1.8	2.2	2.7	3.2	3.7	4.1	4.6	0.7 12.0
28.8	4.8	9.6	14.4	19.2	24.0	.8	0.4	0.9	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7	0.8 13.6
28.9	4.9	9.7	14.5	19.3	24.1	.9	0.4	0.9	1.4	1.9	2.3	2.8	3.3	3.8	4.2	4.7	0.9 15.2 1.0 16.8
29.0	4.8	9.6	14.5	19.3	24.1	.0	0.0	0.5	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4	1.1 18.4
29.1	4.8	9.7	14.5	19.4	24.2	.1	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	1.2 20.0
29.2	4.8	9.7	14.6	19.4	24.3	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5	1.3 21.6
29.3	4.9	9.8	14.6	19.5	24.4	.3	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6	1.4 23.2
29.4	4.9	9.8	14.7	19.6	24.5	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6	1.5 24.8 1.6 26.4
29.5	4.9	9.8	14.8	19.7	24.6	.5	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7	1.7 28.0
29.6	4.9	9.9	14.8	19.7	24.7	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7	1.8 29.6
29.7	5.0	9.9	14.9	19.8	24.8	.7	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8	1.9 31.2
29.8	5.0	10.0	14.9	19.9	24.9	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.8	2.0 32.8
29.9	5.0	10.0	15.0	20.0	25.0	.9	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9	2.1 34.4
30.0	5.0	10.0	15.0	20.0	25.0	.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.6	4.1	4.6	0.8
30.1	5.0	10.0	15.0	20.0	25.1	.1	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6	0.1 2.4
30.2	5.0	10.0	15.1	20.1	25.1	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.2	3.7	4.2	4.7	0.2 4.0
30.3	5.0	10.1	15.1	20.2	25.2	.3	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7	0.3 5.6
30.4	5.1	10.1	15.2	20.3	25.3	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8	0.4 7.2
30.5	5.1	10.2	15.3	20.3	25.4	.5	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8	0.5 8.8
30.6	5.1	10.2	15.3	20.4	25.5	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9	0.6 10.4
30.7	5.1	10.3	15.4	20.5	25.6	.7	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9	0.7 12.0
30.8	5.2	10.3	15.4	20.6	25.7	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0	0.8 13.6
30.9	5.2	10.3	15.5	20.6	25.8	.9	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	0.9 15.2 1.0 16.8
31.0	5.1	10.3	15.5	20.6	25.8	.0	0.0	0.5	1.0	1.6	2.1	2.6	3.1	3.7	4.2	4.7	1.1 18.4
31.1	5.2	10.3	15.5	20.7	25.9	.1	0.1	0.6	1.1	1.6	2.2	2.7	3.2	3.7	4.3	4.8	1.2 20.0
31.2	5.2	10.4	15.6	20.8	26.0	.2	0.1	0.6	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8	1.3 21.6
31.3	5.2	10.4	15.6	20.9	26.1	.3	0.2	0.7	1.2	1.7	2.3	2.8	3.3	3.8	4.4	4.9	1.4 23.2
31.4	5.2	10.5	15.7	20.9	26.2	.4	0.2	0.7	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9	1.5 24.8 1.6 26.4
31.5	5.3	10.5	15.8	21.0	26.3	.5	0.3	0.8	1.3	1.8	2.4	2.9	3.4	3.9	4.5	5.0	1.7 28.0
31.6	5.3	10.5	15.8	21.1	26.3	.6	0.3	0.8	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0	1.8 29.6
31.7	5.3	10.6	15.9	21.2	26.4	.7	0.4	0.9	1.4	1.9	2.5	3.0	3.5	4.0	4.6	5.1	1.9 31.2
31.8	5.3	10.6	15.9	21.2	26.5	.8	0.4	0.9	1.5	2.0	2.5	3.0	3.6	4.1	4.6	5.1	2.0 32.8
31.9	5.4	10.7	16.0	21.3	26.6	.9	0.5	1.0	1.5	2.0	2.6	3.1	3.6	4.1	4.7	5.2	2.1 34.4
	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.

Table 26.

MARINE SIGHT REDUCTION TABLES WORK SHEET; ALL CELESTIAL BODIES

By Henton Jaaback, Yachtmaster Ocean Services cc

Date: IE:+/- , '(-On, +Off); Eye Ht: ft/m; Clock error: h m s(Fast/Slow?)
Course: °T/M/C; Speed: kns; Celestial Body/ies-UL/LL:

Log			
DR Lat	° 'N/S	° 'N/S	° 'N/S
DR Long	° 'E/W	° 'E/W	° 'E/W
Chosen Lat	° 00,0'N/S	° 00,0'N/S	° 00,0'N/S
TIME Clock time of sight	h m s	h m s	h m s
Clock error relative to UTC (-fast, + slow) ±	h m s	h m s	h m s
Corrected UTC time of sight =	h m s	h m s	h m s
LHA GHA as at day, hour of sight: Al'nac	° , '	° , '	° , '
Increments for mins/secs; Yellow pages +	° , '	° , '	° , '
v (?) ±Planets; +Moon. Corrn.(Yellow p's) ±	( ) , '	( ) , '	( ) , '
Total GHA as at exact time of sight =	° , '	° , '	° , '
-360° if nec; GHA to be between 0°/ 360° -	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
GHA Required =	° , '	° , '	° , '
SHA of star +	° , '	° , '	° , '
GHA of celestial body sighted =	° , '	° , '	° , '
Chosen Longitude (+E, -W) ±	° , '	° , '	° , '
LHA Required =	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
+/- 360° if necessary ±	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
LHA of celestial body sighted =	° 0 0 , 0'	° 0 0 , 0'	° 0 0 , 0'
Declination day/hr of sight; next to GHA =	N/S ° , '	N/S ° , '	N/S ° , '
(d = ?)factor; bottom of/or in moon column 'd'	(d = ,)	(d = ,)	(d = ,)
Corrn;Yellow p's(mins)(+ if Dec increasing) ±	, '	, '	, '
TOTAL DECLINATION at time of sight =	N/S ° , '	N/S ° , '	N/S ° , '
Lat/Dec **SAME** or **CONTRARY** (N/S) ?			
Hc: SRTs,'LHA' page,(Lat° column,opp Dec°)	° , '	° , '	° , '
(d± ?) (use with Dec's mins, Interpolat.Table.)	(d =+/-)	(d =+/-)	(d =+/-)
d1, First correction, from Interpolation Table. ±	, '	, '	, '
d2,Second correction, Interpolation Table. ±	, '	, '	, '
TOTAL Hc (Transfer to Intercept, ↓) =	° , '	° , '	° , '
Z → Zn Top of SRT page if Lat North.	Z = °	Z = °	Z = °
Bottom of SRT page if Lat South.	Zn = °	Zn = °	Zn = °
Ho; Sextant Angle (SA/Hs)Up./Low. Limb =	° , '	° , '	° , '
IE (- On, + Off) ±	, '	, '	, '
DIP (Eye ht; Almanac card/Page A2) -	, '	, '	, '
Apparent Altitude (AA) =	° , '	° , '	° , '
Main corrn (Almanac card), OR ±	, '	, '	, '
Moon corrn (Back of Almanac) +	° , '	° , '	° , '
Planet corrn (Almanac card) +	, '	, '	, '
Moon HP corrn (Back of Almanac) +	° , '	° , '	° , '
Moon only, if UL, corrn (-30,0' if UL) -	, '	, '	, '
TRUE ALTITUDE / Ho Ho =	° , '	° , '	° , '
Intercept; Hc =	° , '	° , '	° , '
Intcpt (Difference); Ho - Hc or Hc - Ho. ~	, '	, '	, '
TOWARDS or AWAY? If Ho>Hc, Towards			

Work Sheet 11.

NOTES