Navigation Problems for U.S. Coast Guard Exams

How to Solve Every Problem Type on Exams from 200 to Unlimited Tonnage
Near Coastal and Oceans

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How to Use This Textbook

This series of guides assumes that readers want to either refresh or master certain navigation techniques in order to pass an exam or meet other qualification requirements and is therefore written in a "no-nonsense" fashion.

Standard texts such as Bowditch and Dutton's do an excellent job of discussing navigation theory. What they lack are clear instructions on navigation problem solving to the level required for exams or problem solving. This guide attempts to furnish concrete example problems to help mariners master the techniques.

Each problem type features a brief introduction followed by a handful of cultivated example problems with detailed solutions, including snapshots from required publications or ephemerides. Most problems are taken directly from the US Coast Guard test database and therefore represent the types of problems expected on the Navigation Problems license exams. After the demonstration section are extra practice problems and answers that you can solve on your own.

When ephemeris data are required, all figures are taken from the 1981 Training Nautical Almanac, Sight Reduction Tables for Marine Navigation (Pub HO 229), or the 1983 Tide and Tidal Current Tables. All publications are available on the web or via the companion online course, available at https://practical-navigator-training.teachable.com/p/navigation-problems-for-uscg-exams.

Study Strategy for Your Exam

The main types of examinations are near coastal or oceans. On oceans exams, you may see traditional "near coastal" topics, so it pays to be proficient in all categories. It is recommended to start with near coastal problems and master those before moving on to oceans problems. Additionally, exam problems are often synthesized from several different skills. For example, chronometer problems are included in almost all oceans navigation problems involving celestial bodies.

Aside from the near coastal and oceans distinction, license levels each have their own knowledge requirements. For example, 200-ton ocean candidates are not required to be proficient in Gnomonic chart navigation, while 500-ton ocean masters are. Although required knowledge is found in 46 CFR 11.910, they are synthesized, re-ordered, and sometimes re-named for convenience in this text. However, the original CFR is also included below.

The best strategy for your exam is to master individual topics before moving on to new topics. You should be able to restate any required formulae, know the variety of problem types you may encounter, and routinely solve problems at a success rate over 95% before moving on. From there, it is simply a matter of repetition.

Study Strategy for Your Exam (Required Knowledge)

Source: 46 CFR 11.910

1 = Unlimited Master & Mate
2 = 500/1600 Ton Master
3 = Unlimited 2nd/3rd Mate and 500/1600 Ton Mate
4 = 200 Ton Master

Examination topics	1	2	3	4
Navigation and position determination:				
Ocean Track Plotting:				
Middle Latitude Sailing	1	1	1	
Mercator Sailing	X	X	X	7
Great Circle Sailing	1	1	1	7
Parallel Sailing	1	1	1	
Estimated Time of Arrival	X	X	X	
Piloting:				
Distance Off	X	X	X	X
Bearing Problems	X	X	X	X
Fix or Running Fix	X	X	X	X
Chart Navigation	X	X	X	X
Dead Reckoning	X	X	X	X
Celestial Observations:				
Latitude by Polaris	1	1	1	1
Latitude by Meridian Transit (Any Body)	1	1		
Latitude by Meridian Transit (Sun Only)			1	1
Fix or Running Fix (Any Body)	1	1	1	
Fix or Running Fix (Sun Only)				1
Star Identification	1	1	1	
Star Selection	1	1	1	
Times of Celestial Phenomena:				
Time of Meridian Transit (Any Body)	1	1		
Time of Meridian Transit (Sun Only)			1	1
Zone Time of Sun Rise/Set/Twilight	1	1	1	1
Speed by RPM	X	X	X	
Fuel Conservation	X	X		1

Examination topics	1	2	3	4
Electronic Navigation	X	X	X	X
Instruments & Accessories	X	X	X	X
Aids to Navigation	X	X	X	X
Charts, Navigation Publication, & Notices to Mariners	X	X	X	X
Nautical Astronomy & Navigation Definitions	1	1	1	1
Chart Sketch				
Seamanship:				
Marlinspike Seamanship			X	X
Purchases, Blocks, & Tackle			X	X
Watchkeeping:				
COLREGS	X	X	X	X
Inland Navigational Rules	X	X	X	X
Basic Principles, Watchkeeping	X	X	X	X
Navigation Safety Regulations (33 CFR 164)	X		X	
Compass - Magnetic & Gyro:				
Principles, Operation, and Maintenance of Gyro Compass	X	X	X	7
Principles of Magnetic Compass	X	X	X	X
Gyro Compass Error/Correction	X	X	X	7
Magnetic Compass Error/Correction	X	X	X	X
Determination of Compass Error:				
Azimuth (Any Body)	X	X	X	7
Azimuth (Sun Only)				
Amplitude (Any Body)	X	X	X	7
Amplitude (Sun Only)				
Terrestrial Observation	X	X	X	X

Study Strategy for Your Exam (Simplified Requirements with Module)

	Q108	Q116	Q126	Q141	Not Applicable
Navigation Problems: Near Coastal	Unlimited Master	2nd/3rd Unlimited	500/1600 Master	500/1600 Mate	200 Master/Mate
Mercator Sailing	x	x	x	x	
ETA	x	x	x	x	
Speed by RPM	x	x	x	x	
Fuel Conservation	x		x		
Electronic Navigation (Chronometer)	x	x	x	x	
Distance Off, Bearing, Dead Reckoning	x	x	x	x	
Gyro Error	x	x	x	x	
Magnetic Compass Error	x	x	x	x	
Azimuth	x	x	x	x	
Amplitude	x	x	x	x	
Tides and Currents	x	x	x	x	
	Q109	Q117	Q127	Q142	Q154
Navigation Problems: Oceans	Unlimited Master	2nd/3rd Unlimited	500/1600 Master	500/1600 Mate	200 Master/Mate
Middle Latitude Sailing	x	x	x	x	
Mercator Sailing	x	x	x	x	x
Great Circle Sailing	x	x	x	x	x
Parallel Sailing	x	x	x	x	
ETA	x	x	x	x	
Distance Off, Bearing, and Dead Reckoning	x	x	x	x	x
Chart Navigation (Gnomonic)	x		x		
Latitude by Polaris	x	x	x	x	x
Latitude by Meridian Transit	x	x	x	x	x
Sight Reduction	x	x	x	x	x
Sight Reduction (Fix or Running Fix)	x	x	x	x	x
Star Identification	x	x	x	x	
Star Selection	x	x	x	x	
Zone Time of Rise/Set/Twilight/Transit	x	x	x	x	x
Azimuth	x	x	x	x	
Amplitude	x	x	x	x	
Tides and Currents	x	x	x	x	

About the Author

Christopher D. Nolan graduated with honors from the U.S. Coast Guard Academy in 2002 with a bachelor's degree in Marine and Environmental Science. He also graduated from Oregon State University in 2016 with a master's degree in Fisheries and Wildlife Administration.

In the Coast Guard, he served aboard the following cutters:

ALEX HALEY (WMEC-39) – Kodiak, AK. First Lieutenant (3rd Mate)
DORADO (WPB-87306) – Crescent City, CA. Commanding Officer (Master)
EAGLE (WIX-327) – New London, CT. Navigator/Operations Officer (2nd Mate)
JEFFERSON ISLAND (WPB-1340) – Portland, ME. Commanding Officer (Master)

After completing service in the USCG, he sailed as a master of the sailing school vessels CORWITH CRAMER and ROBERT C. SEAMANS and taught as an assistant professor of Nautical Science with Sea Education Association in Woods Hole, MA. He also served as the master of the START OF INDIA, an engineless square rigger associated with the San Diego Maritime Museum.

After obtaining his original mariner's license in 2006, he now holds an STCW license as Master, less than 3000 GT and a domestic license as Master up to 1600 GRT upon oceans.

He is the co-author of *Eagle Seamanship – A Manual for Square Rigger Sailing* and the author of *The Cutterman's Guide to Passing the Rules of the Road Exam*, and *The Cutterman's Guide to Maneuvering Boards*, as well as *The Cutterman's Guide to Basic Celestial Navigation*.

Additionally, he teaches online and in-person professional maritime licensing courses as part of Practical Navigator Training www.practicalnavigator.org.

Basic Navigational Math Review

Certain basic calculations are necessary for successfully solving later, more advanced problems. This preface serves as a refresher for basic navigational calculations.

Converting Positions to and from Decimal Notation

Given a standard position in latitude and longitude, converting to decimal notation is completed by dividing the minutes of position by 60.

Problem P-1. Convert 24° 15.7’ N into decimal notation.

Step 1: Break the initial position into degrees and minutes of position.
24° 15.7’ = 24° + 15.7’

Step 2: Divide the minutes of position by 60.
$\frac{15.7'}{60}$ = 0.262°

Step 3: Combine the degrees and decimals of position into a final answer.
24° + 0.262° = **24.262° N**

Given a decimal position in latitude and longitude, converting to standard notation is completed by multiplying the decimal portion of the position by 60.

Problem P-2. Convert 133.673° W into standard notation.

Step 1: Break the initial position into degrees and decimals of position.
133.673° = 133° + 0.673°

Step 2: Multiply the decimal of position by 60.
0.673° × 60 = 40.38’

Step 3: Combine the degrees and minutes of position into a final answer.
133° + 40.38’ = **133° 40.38’ W**

Converting Time into Decimal Notation

Given a standard time, converting to decimal notation is completed by dividing the minutes by 60.

Problem P-3. Convert 3 hours and 16 minutes into decimal notation.

Step 1: Break the initial position into degrees and minutes of position.
3 hours, 16 minutes = 3 hours + 16 minutes.

Step 2: Divide the minutes of position by 60.
$\frac{16}{60}$ = 0.266 hours.

Step 3: Combine the degrees and decimals of position into a final answer.
3 hours + 0.266 hours = **3.266 hours**

Given a decimal time, converting to standard notation is completed by multiplying the decimal portion by 60.

Problem P-4. Convert 4.277 hours into standard notation of hours and minutes, and then again into hours, minutes, and seconds.

Step 1: Break the initial position into degrees and decimals of position.
4.277 hours = 4 hours + 0.277 hours.

Step 2: Multiply the decimal portion by 60.
0.277 × 60 = 16.62 minutes.

Step 3: Combine the degrees and minutes of position into a final answer.
4 hours + 16.62 minutes = **4 hours, 16.62 minutes.**

Step 4: If necessary, converting decimal minutes to seconds is accomplished the same way.
16.62 minutes = 16 minutes + 0.62 minutes.
0.62 × 60 = 37.2 seconds.
16.62 minutes = 16 minutes, 37.2 seconds.
Thus, the total answer would be **4 hours, 16 minutes, 37.2 seconds.**

Converting Time Between Zone Time and GMT

Depending on the problem, it is sometimes convenient to work exclusively in Zone Time or GMT. So if a problem describes times in multiple formats, it is necessary to convert to or from GMT.

Problem P-5. If the current ship time is 0834 and the ship is observing ZD (+4), what is the time in GMT?

Step 1: To correct zone time to GMT in the western hemisphere, add the zone descriptor to the ship time.
0834 + 0400 = **1234.**

Problem P-6. If the current ship time is 0834, and the ship is observing ZD (-4), what is the time in GMT?

Step 1: To correct zone time to GMT in the eastern hemisphere, subtract the zone descriptor from the ship time.
0834 - 0400 = **0434.**

Adding Degrees and Minutes

Adding degrees and minutes causes the most arithmetic errors when solving navigation problems, because the degree system is based on 60, not 100. It is usually best to complete the math in two steps:

Problem P-7. Add the following two latitudes. 23° 47.3' N and 11° 33.9' N.

Step 1: Add the whole degrees first and then the minutes.
23° 47.3 + 11° 33.9' = (23° + 11°) + (47.3' + 33.9') = 34° + 81.2'

Step 2: Convert the minutes into degrees and minutes.
81.2' = 1° + 21.2'

Step 3: Sum the parts.
34° + 1° + 21.2' = **35° 21.2' N**

<u>Problem P-8</u>. Sum the following two latitudes. 23° 17.3' N and 11° 33.9' S. Sometimes when subtracting minutes, it is helpful convert 1° to minutes (e.g. subtract 1° but add 60' to the minutes value).

Step 1: Subtract 1° and then add 60' to the first value to make the math easy.
<u>23° 17.3'</u> + (-11° 33.9') = <u>22° 77.3'</u> + (-11.33.9')

Step 2: Add the whole degrees first and then the minutes.
(22° + (-11°)) + (77.3' + (-33.9)) = 11° + 43.4'

Step 3: Sum the parts.
11° + 43.4' = **11° 43.4' N**

Interpolating for Values of Greenwich Hour Angle

In order to save space in the almanac, values of Greenwich Hour Angle in the Nautical Almanac are given only for whole hours. Unless observations are made on the hour, interpolation is necessary. This principle applies for all celestial bodies, and the correction is always added.

Problem P-9. It is 22 February and you make an observation of the sun at 15:48:13 UTC. The tabular value of GHA of the sun for 1500 UTC is 41° 37.3'. What is the calculated GHA of the sun for the time of observation?

Step 1: Note the tabular value of GHA for the next lower whole hour (1500 UTC in this case).
1500 UTC = 41° 37.3'.

22	00	176 36.1	S10 18.2
	01	191 36.2	17.3
	02	206 36.2	16.4
	03	221 36.3	·· 15.5
	04	236 36.4	14.6
	05	251 36.5	13.6
	06	266 36.6	S10 12.7
	07	281 36.6	11.8
	08	296 36.7	10.9
S	09	311 36.8	·· 10.0
U	10	326 36.9	09.1
N	11	341 37.0	08.2
D	12	356 37.1	S10 07.3
A	13	11 37.1	06.4
Y	14	26 37.2	05.4
	15	41 37.3	·· 04.5
	16	56 37.4	03.6
	17	71 37.5	02.7
	18	86 37.6	S10 01.8
	19	101 37.6	00.9
	20	116 37.7	10 00.0
	21	131 37.8	9 59.0
	22	146 37.9	58.1
	23	161 38.0	57.2

Step 2: Determine the difference in time between the time of observation and the next lower whole hour (1500 UTC in this case).
Observation – 15:48:13
Whole Hours – 15:00:00
Difference = 15:48:13 – 15:00:00 = 00:48:13

Step 3: Enter the Increments and Corrections pages in the Nautical Almanac and find the value for 48 minutes and 13 seconds in the "Sun/Planets" column.
48 minutes 13 seconds: 12° 03.3' correction

48m INCREMENTS AND CORRECTIONS 49m

48m (s)	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
	° '	° '	° '	'	'	'	'	'	'
00	12 00·0	12 02·0	11 27·2	0·0	0·0	6·0	4·9	12·0	9·7
01	12 00·3	12 02·2	11 27·4	0·1	0·1	6·1	4·9	12·1	9·8
02	12 00·5	12 02·5	11 27·7	0·2	0·2	6·2	5·0	12·2	9·9
03	12 00·8	12 02·7	11 27·9	0·3	0·2	6·3	5·1	12·3	9·9
04	12 01·0	12 03·0	11 28·2	0·4	0·3	6·4	5·2	12·4	10·0
05	12 01·3	12 03·2	11 28·4	0·5	0·4	6·5	5·3	12·5	10·1
06	12 01·5	12 03·5	11 28·6	0·6	0·5	6·6	5·3	12·6	10·2
07	12 01·8	12 03·7	11 28·9	0·7	0·6	6·7	5·4	12·7	10·3
08	12 02·0	12 04·0	11 29·1	0·8	0·6	6·8	5·5	12·8	10·3
09	12 02·3	12 04·2	11 29·3	0·9	0·7	6·9	5·6	12·9	10·4
10	12 02·5	12 04·5	11 29·6	1·0	0·8	7·0	5·7	13·0	10·5
11	12 02·8	12 04·7	11 29·8	1·1	0·9	7·1	5·7	13·1	10·6
12	12 03·0	12 05·0	11 30·1	1·2	1·0	7·2	5·8	13·2	10·7
13	12 03·3	12 05·2	11 30·3	1·3	1·1	7·3	5·9	13·3	10·8
14	12 03·5	12 05·5	11 30·5	1·4	1·1	7·4	6·0	13·4	10·8

49m (s)	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
	° '	° '	° '	'	'	'	'	'	'
00	12 15·0	12 17·0	11 41·5	0·0	0·0	6·0	5·0	12·0	9·9
01	12 15·3	12 17·3	11 41·8	0·1	0·1	6·1	5·0	12·1	10·0
02	12 15·5	12 17·5	11 42·0	0·2	0·2	6·2	5·1	12·2	10·1
03	12 15·8	12 17·8	11 42·2	0·3	0·2	6·3	5·2	12·3	10·1
04	12 16·0	12 18·0	11 42·5	0·4	0·3	6·4	5·3	12·4	10·2
05	12 16·3	12 18·3	11 42·7	0·5	0·4	6·5	5·4	12·5	10·3
06	12 16·5	12 18·5	11 42·9	0·6	0·5	6·6	5·4	12·6	10·4
07	12 16·8	12 18·8	11 43·2	0·7	0·6	6·7	5·5	12·7	10·5
08	12 17·0	12 19·0	11 43·4	0·8	0·7	6·8	5·6	12·8	10·6
09	12 17·3	12 19·3	11 43·7	0·9	0·7	6·9	5·7	12·9	10·6
10	12 17·5	12 19·5	11 43·9	1·0	0·8	7·0	5·8	13·0	10·7
11	12 17·8	12 19·8	11 44·1	1·1	0·9	7·1	5·9	13·1	10·8
12	12 18·0	12 20·0	11 44·4	1·2	1·0	7·2	5·9	13·2	10·9
13	12 18·3	12 20·3	11 44·6	1·3	1·1	7·3	6·0	13·3	11·0
14	12 18·5	12 20·5	11 44·9	1·4	1·2	7·4	6·1	13·4	11·1

Step 4: Apply the correction to the tabular GHA for whole hours. The correction is always added.
GHA for 1500 UTC = 41° 37.3'
Correction = 12° 03.3'
Total GHA = 41° 37.3' + 12° 03.3' = **53° 40.6'**

Interpolating for Values of Declination

In order to save space in the almanac, values of declination in the Nautical Almanac are given only for whole hours. Unless observations are made on the hour, interpolation is necessary. This principle applies for all celestial bodies. The correction is either added or subtracted, depending on the trend of hourly declination.

	h	GHA	Dec
22	00	176 36.1	S10 18.2
	01	191 36.2	17.3
	02	206 36.2	16.4
	03	221 36.3	· · 15.5
	04	236 36.4	14.6
	05	251 36.5	13.6
	06	266 36.6	S10 12.7
	07	281 36.6	11.8
	08	296 36.7	10.9
S	09	311 36.8	· · 10.0
U	10	326 36.9	09.1
N	11	341 37.0	08.2
D	12	356 37.1	S10 07.3
A	13	11 37.1	06.4
Y	14	26 37.2	05.4
	15	41 37.3	· · 04.5
	16	56 37.4	03.6
	17	71 37.5	02.7
	18	86 37.6	S10 01.8
	19	101 37.6	00.9
	20	116 37.7	10 00.0
	21	131 37.8	9 59.0
	22	146 37.9	58.1
	23	161 38.0	57.2
		S.D. 16.2	*d* 0.9

Typically, mental interpolation is sufficient, however, the concept of *d* correction ensures accuracy. The abbreviated process is to note the daily *d* value at the bottom of each daily page. Then, enter the Increments and Corrections pages for the minutes necessary, finding the appropriate *d* value on that page and noting the correction.

Problem P-10. It is 22 February and you make an observation of the sun at 15:48:13 UTC. The tabular value of declination of the sun at 1500 UTC is S 10° 04.5'. What is the calculated declination of the sun for the time of observation?

Step 1: Note the tabular value of declination for the next lower whole hour (1500 UTC in this case).
1500 UTC = S 10° 04.5'.

Step 2: Determine the difference in time between the time of observation and the next lower whole hour (1500 UTC in this case). Rounding to the nearest minute is sufficient.
Observation – 15:48:13
Whole Hours – 15:00:00
Difference = 15:48:13 – 15:00:00 = 48 min.

48m INCREMENTS AND CORRECTIONS

48m s	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
00	12 00.0	12 02.0	11 27.2	0.0	0.0	6.0	4.9	12.0	9.7
01	12 00.3	12 02.2	11 27.4	0.1	0.1	6.1	4.9	12.1	9.8
02	12 00.5	12 02.5	11 27.7	0.2	0.2	6.2	5.0	12.2	9.9
03	12 00.8	12 02.7	11 27.9	0.3	0.2	6.3	5.1	12.3	9.9
04	12 01.0	12 03.0	11 28.2	0.4	0.3	6.4	5.2	12.4	10.0
05	12 01.3	12 03.2	11 28.4	0.5	0.4	6.5	5.3	12.5	10.1
06	12 01.5	12 03.5	11 28.6	0.6	0.5	6.6	5.3	12.6	10.2
07	12 01.8	12 03.7	11 28.9	0.7	0.6	6.7	5.4	12.7	10.3
08	12 02.0	12 04.0	11 29.1	0.8	0.6	6.8	5.5	12.8	10.3
09	12 02.3	12 04.2	11 29.3	0.9	0.7	6.9	5.6	12.9	10.4
10	12 02.5	12 04.5	11 29.6	1.0	0.8	7.0	5.7	13.0	10.5
11	12 02.8	12 04.7	11 29.8	1.1	0.9	7.1	5.7	13.1	10.6
12	12 03.0	12 05.0	11 30.1	1.2	1.0	7.2	5.8	13.2	10.7
13	12 03.3	12 05.2	11 30.3	1.3	1.1	7.3	5.9	13.3	10.8
14	12 03.5	12 05.5	11 30.5	1.4	1.1	7.4	6.0	13.4	10.8

49m

49m s	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
00	12 15.0	12 17.0	11 41.5	0.0	0.0	6.0	5.0	12.0	9.9
01	12 15.3	12 17.3	11 41.8	0.1	0.1	6.1	5.0	12.1	10.0
02	12 15.5	12 17.5	11 42.0	0.2	0.2	6.2	5.1	12.2	10.1
03	12 15.8	12 17.8	11 42.2	0.3	0.2	6.3	5.2	12.3	10.1
04	12 16.0	12 18.0	11 42.5	0.4	0.3	6.4	5.3	12.4	10.2
05	12 16.3	12 18.3	11 42.7	0.5	0.4	6.5	5.4	12.5	10.3
06	12 16.5	12 18.5	11 42.9	0.6	0.5	6.6	5.4	12.6	10.4
07	12 16.8	12 18.8	11 43.2	0.7	0.6	6.7	5.5	12.7	10.5
08	12 17.0	12 19.0	11 43.4	0.8	0.7	6.8	5.6	12.8	10.6
09	12 17.3	12 19.3	11 43.7	0.9	0.7	6.9	5.7	12.9	10.6
10	12 17.5	12 19.5	11 43.9	1.0	0.8	7.0	5.8	13.0	10.7
11	12 17.8	12 19.8	11 44.1	1.1	0.9	7.1	5.9	13.1	10.8
12	12 18.0	12 20.0	11 44.4	1.2	1.0	7.2	5.9	13.2	10.9
13	12 18.3	12 20.3	11 44.6	1.3	1.1	7.3	6.0	13.3	11.0
14	12 18.5	12 20.5	11 44.9	1.4	1.2	7.4	6.1	13.4	11.1

Step 3: Note the *d* value at the bottom of the daily page.
d = 0.9

Step 4: Enter the Increments and Corrections pages in the Nautical Almanac and find the page for 48 minutes. On that page, find the "*v* or *d Corr*" column, and locate the heading for a *d* value of 0.9. Note the correction *d* value – 0.9.
Correction = 0.7'

Step 5: Apply the correction to the tabular declination for whole hours. In this case the correction is subtracted because the tabular values of declination are decreasing with time (winter and spring in the northern hemisphere).
Dec for 1500 UTC = S 10° 04.5' (decreasing)
d Correction = 0.7'
Total Dec = 10° 04.5' – 0.7'= **S 10° 03.8'**

Note – this value can be easily estimated with direct interpolation in most cases as follows:

a) The declination value for 1500 UTC is S 10° 04.5'
b) The declination value for 1600 UTC is S 10° 03.6', for a difference of 0.9' (same as the *d* value)
c) The time of observation is 15:48:13, or approximately 15.8 hours, for a difference of 0.8 hours.
d) $\frac{0.8\ hours}{1.0\ hours} = \frac{x\ minutes}{0.9\ minutes}$
e) $0.8 = \frac{x}{0.9}$
f) $x = \mathbf{0.7'}$ = declination correction to be applied.

Calculating the Local Hour Angle (LHA) of Any Body

Local Hour Angle (LHA) defines the angle between the observer and a celestial body. LHA ranges from 0° to 359° 59.9'.

In the western hemisphere, Local Hour Angle (LHA) is equal to Greenwich Hour Angle (GHA) minus the observer's longitude (or DR longitude).

In the eastern hemisphere, LHA is equal to GHA plus the observer's longitude (or DR longitude).

Magnetic Compass Problems

Magnetic Compass Error Problems

- Terms:
    - True – the true course between two points, as taken from a chart. Written as °T.
    - Variation – the angle between magnetic meridians and geographic meridians at any place expressed in degrees east or west to indicate the direction of magnetic north from true north. This depends on one's location on Earth. Written as °E or °W.
    - Magnetic – bearing relative to magnetic north; compass bearing corrected for deviation. Written as °M.
    - Deviation – the angle between a magnetic meridian and the axis of a compass card, expressed in degrees east or west to quantify the disturbing magnetic influences in the immediate vicinity of the compass. This depends on one's ship heading. Written as °E or °W.
    - Compass – the course indicated on a ship's compass. Written as °psc which means "per steering compass" or "per standard magnetic compass" or "per ship's compass."
- Deviation tables are constructed by "swinging" the ship through a circle and noting true/compass bearings to objects. The table can be entered with either °M or °psc if the values are relatively small. Otherwise it can only be entered with °M and residual deviation is interpolated for entry with °psc. For exam problems, entry into the table from either °M or °psc is sufficient and values can be rounded to the nearest 0.5°.
- Two memory aids are helpful for magnetic compass problems:
    - True Vampires Make Dull Companions (At Wakes).
    - Can Dead Men Vote Twice (At Elections)?
- Below is an example of using the compass correction acronyms:

Moving Down…	East	Elections
(Correcting)	Add	At
True	True Course	Twice
Vampires	Variation	Vote
Make	Magnetic Course	Men
Dull	Deviation	Dead
Companions	Compass Course	Can
At	Add	***(Un-correcting)***
Wakes	West	***Moving up…***

Course Made Good Problems

COM D1. Your vessel is steering 195° per standard magnetic compass. Variation is 12° west, and deviation is 4° east. What is the true course made good?

Answer: 187° True.

Step 1: Write down the acronym:
T (True Course)
V (Variation)
M (Magnetic Course)
D (Deviation)
C (Compass Course)
AW↓ (This indicates you should add westerly values moving down (correcting), reminding you that the opposite is also true – you should add easterly values when moving up (un-correcting). In this case we will be moving up (un-correcting), so easterly values will be added.

Step 2: Fill in the known values:
T:
V: 12° W
M:
D: 4° E
C: 195° (Steering)

Step 3: Correct or un-correct the compass as required to obtain the magnetic course. In this case, we are moving upwards, or un-correcting, so we will add easterly values and subtract westerly values proceeding **up** the table:
T:
V: 12° W (Given)
M: *199°*
D: 4° E (Given)
C: 195° (Steering)

Step 4: Determine the true course made good:
T: *187° T*
V: 12° W (Given)
M: 199° (Calculated)
D: 4° E (Given)
C: 195° (Steering)

COM D2. To clear an obstruction, your vessel must make good a true course of 330° true. Variation in the area is 15° east and the deviation table indicates a value of 2° west for your heading. What is the course to steer per standard magnetic compass?

Answer: 317° per standard magnetic compass.

Step 1: Write down the acronym:
T (True Course)
V (Variation)
M (Magnetic Course)
D (Deviation)
C (Compass Course)
AW↓ (This indicates you should add westerly values moving down (correcting), reminding you that the opposite is also true – you should add easterly values when moving up (un-correcting). In this case we will be moving down (correcting), so westerly values will be added.

Step 2: Fill in the known values:
T: 330° T (Course to make good)
V: 15° E (Given)
M:
D: 2° W (Given)
C:

Step 3: Correct or un-correct the compass as required to obtain the magnetic course. In this case, we are moving downwards, or correcting, so we will add westerly values and subtract easterly values proceeding down the table:
T: 330° T (Course to make good)
V: 15° E (Given)
M: *315° M*
D: 2° W (Given)
C:

Step 4: Determine the necessary course to steer:
T: 330° T (Course to make good
V: 15° E (Given)
M: 315° (Calculated)
D: 2° W (Given)
C: 317° (Necessary course to steer per standard magnetic compass)

Course Made Good with Leeway Problems

COM D3. You desire to make good a true course of 046° T. The variation is 6° E, magnetic compass deviation is 12° W. A northerly wind produces a 5° leeway. What is the course to steer per standard magnetic compass to make good the true course?

Answer: 047° per steering compass.

Step 1: Write down the acronyms:
T (True Course)
V (Variation)
M (Magnetic Course)
D (Deviation)
C (Compass Course)
AW↓ (Add West)

Step 2: Fill in the known values:
T: 046° T (Given – desired)
V: 6° E (Given)
M:
D: 12° W (Given)
C:

Step 3: Calculate the magnetic course.
T: 046° T (Given – desired)
V: 6° E (Given)
M: 040° M (Calculated)
D: 12° W (Given)
C:

Step 4: Calculate the course per steering compass.
T: 046° T (Given)
V: 6° E (Given)
M: 040° M (Calculated)
D: 12° W (Given)
C: 052° per steering compass (Calculated)

Step 5: Apply leeway to the calculated course to obtain a necessary course to steer.
T: 046° T (Given)
V: 6° E (Given)
M: 040° M (Calculated)
D: 12° W (Given)
C: 052° per steering compass (Calculated)

Step 6: Subtract 5° to account for leeway from a northerly (000° T) wind
047° per steering compass, taking into account leeway.

Deviation Table Problems

- See the Gyro Compass Problems section for more detail on gyro compass problems.

COM D4. You swung ship and compared the magnetic compass against the gyro compass to find deviation. Gyro error is 2° E. The variation is 8° W. Find the deviation on a gyro heading of 196° per gyro compass.

Heading		Heading		Heading	
PSC	PGC	PSC	PGC	PSC	PGC
358.5°	350°	122.5°	110°	239.5°	230°
030.5°	020°	152°	140°	269°	260°
061.5°	050°	181°	170°	298°	290°
092°	080°	210°	200°	327.5°	320°

Answer: 0.1°, rounded to nearest half-degree is 0.0°.

Step 1: Write down the acronyms:
T (True Course)
V (Variation)
M (Magnetic Course)
D (Deviation)
C (Compass Course)
AW↓ (Add West)

Step 2: Fill in the known values in table form for each gyro course bracketing the desired course.

	170° PGC	196° PGC	200° PGC
T			
V	8° W	8° W	8° W
M			
D			
C	181° PSC		210° PSC
G			
E	2° E	2° E	2° E
T			

Step 3: Solve the gyro error portion of the table.

	170° PGC	196° PGC	200° PGC
T			
V	8° W	8° W	8° W
M			
D			
C	181° PSC		210° PSC
G	170° PGC	196° PGC	200° PGC
E	2° E	2° E	2° E
T	**172° T**	**198° T**	**202° T**

Step 4: Transfer the solved gyro error portion of the table (T) to the True Course in the main table. The gyro error portion of the table has been omitted for the remainder of the problem.

	170° PGC	196° PGC	200° PGC
T	**172° T**	**198° T**	**202° T**
V	8° W	8° W	8° W
M			
D			
C	181° PSC		210° PSC

Step 5: Solve the table for the "Magnetic" course.

	170° PGC	196° PGC	200° PGC
T	172° T	198° T	202° T
V	8° W	8° W	8° W
M	**180° M**	**206° M**	**210° M**
D			
C	181° PSC		210° PSC

Step 6: Solve the table for the "Deviation" for the known PGC headings.

	170° PGC	196° PGC	200° PGC
T	172° T	198° T	202° T
V	8° W	8° W	8° W
M	180° M	206° M	210° M
D	**1° W**		**0°**
C	181° PSC		210° PSC

Step 7: Interpolate the known values of deviation to determine the deviation for the desired PGC heading.

	170° PGC	196° PGC	200° PGC
T	172° T	198° T	202° T
V	8° W	8° W	8° W
M	180° M	206° M	210° M
D	1° W	**TBD - X**	0°
C	181° PSC		210° PSC

Deviation for 170° PGC: 1.0° W
Deviation for 196° PGC: unknown = x
Deviation for 200° PGC: 0.0°

200° - 170° = 30°
200° - 196° = 4°
1.0° - 0.0° = 1.0°

$$\frac{4°}{30°} = \frac{x}{1.0°}$$

$x = 0.133°$. Rounded to the nearest half-degree, answer is 0.0°

Magnetic Compass Error Problems

Deviation by Range Problems

COM B1. Your vessel is proceeding down a channel and you see a pair of range lights that are in line dead ahead. The chart indicates that the direction of this pair of lights is 229° T, and the variation is 6° W. If the heading of your vessel at the time of the sighting was 232° per standard magnetic compass, what is the deviation?

a) 3° E - correct
b) 9° E
c) 3° W
d) 9° W

COM B2. Your vessel is proceeding up a channel and you see a pair of range lights that are in line ahead. The chart indicates that the direction of this pair of lights is 014° T and the variation is 11° E. If the heading of your vessel at the time of the sighting is 009° per standard magnetic compass, what is the correct deviation?

a) 5° E
b) 5° W
c) 6° E
d) 6° W - correct

COM B3. Your vessel is proceeding up a channel and you see a pair of range lights in line ahead. The chart indicates that the direction of this pair of lights is 352° T and the variation is 4° W. If the heading of your vessel at the time of the sighting is 359° per standard magnetic compass, what is the correct deviation?

a) 3° W - correct
b) 7° E
c) 11° E
d) 11° W

Course Made Good with Leeway Problems

COM B4. Your vessel is steering course 111° psc, variation for the area is 5° E, and deviation is 3° W. The wind is from the northwest, producing a 1° leeway. What true course are you making good?

a) 108° T
b) 110° T
c) 112° T
d) 114° T - correct

COM B5. Your vessel is steering course 166° psc, variation for the area is 8° W, and deviation is 3° W. The wind is from the WSW, producing a 2° leeway. What true course are you making good?

a) 153° T - correct
b) 157° T
c) 175° T
d) 179° T

COM B6. Your vessel is steering course 299° psc, variation for the area is 7° W, and deviation is 4° W. The wind is from the SW, producing a 3° leeway. What is the true course you are making good?

a) 291° T - correct
b) 296° T
c) 299° T
d) 313° T

COM B7. You desire to make good 152°. The magnetic compass deviation is 4° E, the variation is 5° E, and the gyro error is 3° E. A southwesterly wind produces a 4° leeway. Which course would you steer per standard compass to make good the true course?

a) 137° psc
b) 141° psc
c) 143° psc
d) 147° psc - correct

Com B8. You desire to make good a true course of 038°. The variation is 5° E, magnetic compass deviation is 4° W. A southeasterly wind produces a 4° leeway. What is the course to steer per standard magnetic compass to make the true course good?

a) 033° psc
b) 041° psc - correct
c) 043° psc
d) 047° psc

Deviation Table Problems

COM B9. You swung ship and compared the magnetic compass against the gyrocompass to find deviation. Gyro error is 2° E. The variation is 8° W. Find the deviation on a magnetic compass heading of 104°.

PSC	PGC	PSC	PGC	PSC	PGC
358.5°	350°	122.5°	110°	239.5°	230°
030.5°	020°	152.0°	140°	269.0°	260°
061.5°	050°	181.0°	170°	298.0°	290°
092.0°	080°	210.0°	200°	327.5°	320°

a) 1.8° E
b) 2.6° E
c) 2.2° W - correct
d) 2.7° W

COM B10. You swung ship and compared the magnetic compass against the gyrocompass to find deviation. Gyro error is 2° E. Variation is 8° W. Find the deviation on a magnetic compass heading of 234°.

PSC	PGC	PSC	PGC	PSC	PGC
358.5°	350°	122.5°	110°	239.5°	230°
030.5°	020°	152.0°	140°	269.0°	260°
061.5°	050°	181.0°	170°	298.0°	290°
092.0°	080°	210.0°	200°	327.5°	320°

a) 2.5° W
b) 2.5° E
c) 1.0° W
d) 0.5° E - correct

COM B11. You swung ship and compared the magnetic compass against the gyrocompass to find deviation. Gyro error is 2° W. Variation is 8° W. Find the deviation on a true heading of 236°.

PSC	PGC	PSC	PGC	PSC	PGC
358.5°	354°	122.5°	114°	239.5°	234°
030.5°	024°	152.0°	144°	269.0°	264°
061.5°	054°	181.0°	174°	298.0°	294°
092.0°	084°	210.0°	204°	327.5°	324°

a) 1.0° W
b) 0.5° E - correct
c) 1.5° E
d) 0.0

Gyro Compass Problems

- **Important Note**: Gyro compass error problems are often found as part of other problem types, the below demonstrations are not the only type of gyro related problem you will see on your test!

- "pgc" or "per gyro compass" – the course read off a gyroscopic compass.

- Leeway corrections are always applied into the wind (e.g. steer higher into the wind to counteract the wind).

GYR D1. The track line on a chart is 274° T. The gyro error is 1.5° E. What course would be steered by gyro compass to make good the desired course?

Answer: 272.5° pgc. In this case, the only acronym needed is "G-E-T." The acronym "G-E-T," which stands for "Gyro course + Easterly Error = True course" will help to solve these problems. Remember that when moving up the acronym, easterly errors are subtracted.

An alternative memory aid is "Gyro Best, Error West" or "Gyro Least, Error East." This means that if the gyro value is higher (or "best"), compass error is west. The opposite applies for east errors.

Step 1: Write down the acronym:
G: (Gyro Course)
E: (Add Easterly Error – when moving down the acronym)
T: (True Course)

Step 2: Fill in the known values:
G:
E: 1.5° E (Given)
T: 274° T (Given)

Step 3: Calculate the gyro course to steer.
G: 272.5° per gyro compass
E: 1.5° E (Given)
T: 274° T (Given)

GYR D2. The true course between two points is 057° T. Your gyrocompass has an error of 3° east, and you make an allowance for 1° of leeway for a north-northeast wind. Which gyro course should be steered to make good the true course?

Step 1: Write down the acronym:
G: (Gyro Course)
E: (Add Easterly Error – when moving down the acronym)
T: (True Course)

Step 2: Fill in the known values:
G:
E: 3° E (Given)
T: 057° T (Given)

Step 3: Calculate the gyro course to steer.
G: 054° per gyro compass
E: 3° E (Given)
T: 057° T (Given)

Step 4: Apply a leeway correction:
Gyro Course 054° pgc
Leeway 1° from the north-northeast.
Correction 1° to port (e.g. into the wind).
Gyro course to steer: 053° pgc.

Gyro Compass Error Problems

Important Note – Gyro Compass Problems are found as part of many other problem types.

Gyro Error by Range Problems

GYR B1. Two beacons form a range in the direction of 221.5° T. The range is seen in line from your vessel bearing 223° per gyro compass. The variation is the area is 4° E. What is the error of your gyro compass?

a) 1.5° W - correct
b) 2.5° W
c) 5.5° W
d) 2.5° E

GYR B2. While your vessel is proceeding down a channel, you notice a range of lights in line with your vessel's mast. If your vessel is on course 001° per gyro compass, and the charted value of the range of lights is 359° T, what is the gyro compass error?

a) 2.0° W - correct
b) 1.5° E
c) 1.5° W
d) 2.0° E

Course to Steer with Gyro Error Problems

GYR B3. The true course between two points is 194°. Your gyrocompass has an error of 2° W and you make an allowance of 1° leeway for a southeast wind. What gyro course should be steered to make the true course good?

a) 193° pgc
b) 195° pgc
c) 197° pgc - correct
d) 199° pgc

GYR B4. The true course between two points is 337°. Your gyrocompass has an error of 3° E and you make an allowance of 5° leeway for a west wind. Which gyro course should be steered to make the true course good?

a) 329° pgc - correct
b) 335° pgc
c) 339° pgc
d) 345° pgc

GYR B5. The true course between two points is 078°. Your gyrocompass has an error of 2° E. You make an allowance of 3° leeway for a north wind. What gyro course should be steered to make the true course good?

a) **073° pgc - correct**
b) 075° pgc
c) 077° pgc
d) 079° pgc

Electronic Navigation (Chronometer) Problems

- Although there are dedicated Chronometer (Electronic Navigation) problems you may encounter on your exam, Chronometer problems are most often a portion of other problem types.

Chronometer Problems as part of other Problem Types

CHR D1. According to your watch, you make an observation of the planet Venus at 15:43:30 Greenwich Mean Time. Your watch is known to be 1 minute and 20 seconds fast. At what time did you actually observe Venus?

Answer: 15:42:10 GMT. In order to correct for a known error, simply add or subtract the error, as appropriate, to the watch time to obtain the actual observed time.

Step 1: Watch Time: 15:43:30 GMT

Step 2: Known Error: 00:01:20 (Fast)

Step 3: Calculation: 15:43:30 – 00:01:20 = **15:42:10 GMT**

Time Tick Problems

CHR D2. You are taking a time-tick using the 2000 signal from Kauai, Hawaii (WWVH). You hear a series of 1-second dashes followed by a 9-second silent period, then a long 1.3 second dash. At the beginning of the long dash, your comparing watch reads 08h 00m 49s. When compared to the chronometer, the comparing watch reads 08h 01m 33s, and the chronometer reads 08h 00m 56s. What is the chronometer error?

Answer: 0m 12s fast. The portions regarding various sounds and lengths of time are distractor information. Note that the chronometer uses 12-hour clock (am and pm), versus the typical 24-hour clock; it is best to immediately correct all times to the 24 hour system to avoid error.

Step 1: Signal time: 20:00:00

Step 2: Comparing watch time at signal: 08:00:49 pm, or 20:00:49

Step 3: Calculate comparing watch error: 20:00:00 – 20:00:49 = 00:00:49 fast.

Step 4: Comparing watch (time 2): 20:01:33

Step 5: Corrected comparing watch (time 2): 20:01:33 – 00:00:49 = 20:00:44

Step 6: Chronometer (time 2): 20:00:56

Step 7: Chronometer error calculation: 20:00:44 – 08:00:56 = **00:00:12 fast**

Chronometer Rate Problems (this is the only problem in the database)

CHR D3. On 23 July you take a time tick using the 0900 GMT Capetown broadcast. You hear a repeating series of 59 dots followed by a dash. At the beginning of the fifth dash you start your stopwatch. The chronometer reads 08h 39m 16s at the time the stopwatch reads 01m 42s. The chronometer error at 0900 GMT on 22 July was 22m 24s. What is the chronometer rate?

Answer: Losing 00m 02s daily. The portions regarding various sounds and lengths of time are distractor information. Note that the chronometer has "lost" two seconds from the previous day, so the chronometer's rate is "losing." The opposite case would be "gaining."

Step 1: Signal time: 09:00:00

Step 2: Stopwatch at time of signal: 00:00:00.

Step 3: Stopwatch elapsed time: 00:01:42.

Step 4: Chronometer time after elapsed time: 08:39:16.

Step 5: Chronometer time at time of signal: 08:39:16 – 00:01:42 = 08:37:34.

Step 6: Chronometer error: 09:00:00 – 08:37:34 = 00:22:26.

Step 7: Chronometer error on 22 July: 00:22:24 (Given).
Chronometer error on 23 July: 00:22:26.
Difference/Rate = 00:22:24 – 00:22:26 = **- 00:00:02 (losing)**

Chronometer (Electronic Navigation) Problems

Chronometer Problems as a component of other Problems.

CHR B1. According to your watch, you make an observation of the sun at 11:27:35 Greenwich Mean Time. Your watch is known to be 2 minutes and 44 seconds fast. At what time did you actually observe the Sun?

a) 11:24:51 - correct
b) 11:29:51
c) 11:30:19

CHR B2. According to your watch, you make an observation of the moon at 23:37:12 Greenwich Mean Time. Your watch is known to be 47 seconds slow. At what time did you actually observe the moon?

a) 23:36:25
b) 23:27:59 - correct
c) 23:28:25

Time Tick Problems

CHR B3. On 12 November, you are taking a time tick using the 1600 GMT BBC broadcast. You hear five pulses followed by a longer pulse. At the start of the longer pulse, you start a stopwatch. You stop the stopwatch at the same time reading the chronometer, with the following results: stopwatch 03m 19s, chronometer 15h 59m 46s. What is the chronometer error?

a) 01m 14s slow
b) 03m 19s fast
c) 03m 33s slow - correct
d) 06m 54s slow

CHR B4. You are taking a time tick using the 2100 signal from Callao, Peru. You hear a series of 1-second dashes followed by a 9 second silent period, then a long 1.3 second dash. At the beginning of the long dash, your comparing watch reads 09h 00m 10s. When compared to the chronometer, the watch reads 09h 01m 20s, and the chronometer reads 08h 59m 22s. What is the chronometer error?

a) 1m 48 slow - correct
b) 0m 38s slow
c) 1m 10s fast
d) 0m 10s fast

CHR B5. You are taking a time tick using the 1930 signal from Rio de Janeiro, Brazil. You hear the preparatory signal CQ DE PPE repeated several times followed by a short dash (0.4 sec), 60 dots (0.1 sec each), and another short dash. At the beginning of the last dash, the comparing watch reads 07h 30m 08s. When compared to the chronometer, the watch reads 07h 31m 48s, and the chronometer reads 07h 32m 16s. What is the chronometer error?

a) 0m 28s slow
b) 1m 40s slow
c) 0m 08s fast
d) 0m 36s fast - correct

CHR B6. You are taking a time tick using the 1400 signal from Buenos Aires, Argentina. You hear a 0.4 second dash followed by a series of dots noting that the 29th dot and the 56th to 59th dots are omitted. At the start of the following 0.4 second dash (which is followed by an 8 second pulse), the comparing watch reads 01h 59m 57s. When compared to the chronometer, the watch reads 02h 00m 38s, and the chronometer reads 02h 01m 33s. What is the chronometer error?

a) 0m 03s slow
b) 0m 41s slow
c) 0m 52s fast - correct
d) 1m 36s fast

CHR B7. You are taking a time tick using the 2000 signal from Kekaha-Kaui, Hawaii (WWVH). You hear a series of 1 second dashes followed by a 9 second silent period, then a long 1.3 second dash. At the beginning of the long dash, your comparing watch reads 07h 59m 54s. When compared to the chronometer, the comparing watch reads 08h 00m 00s, and the chronometer reads 08h 00m 06s. What is the chronometer error?

a) 0m 06s slow
b) 0m 06 fast
c) 0m 12s fast
d) no error - correct

Estimated Time of Arrival Problems

Normal ETA Problems

- Keeping track of time zones (ZD) is the best way to solve these problems.
- Keeping time in GMT is a good strategy for the transit and then covert it to zone time at the end.
- You can find out how many days are in a month in the Nautical Almanac.

ETA D1. At 0600 zone time, on October 22, you depart Manila, latitude 14° 35.0’ N, longitude 120° 58.0’ E (ZD -8). You are bound for Los Angeles, latitude 33° 46.0’ N, longitude 118° 11.0’ W. You estimate your speed of advance to be 20.2 knots. The distance is 6385.9 miles. What is your estimated zone time of arrival in Los Angeles?

Answer: 1805, 3 November.

Step 1: Calculate the total time steaming:
6385.9 nm ÷ 20.2 knots = 316.13 hours.

Step 2: Convert the total time steaming into days and hours.
316.13 hours = 13.17 days = 13 days, 4 hours, 5 minutes.

Step 3: Convert departure times to GMT.
0600 ZT (-8); 22 October = 2200 GMT; 21 October.

Step 4: Add transit time to converted departure time.
2200 GMT; 21 October + 13 days, 4 hours, 5 minutes
= 0205 GMT; 4 November

Step 5: Determine the arrival zone descriptor and account for daylight savings time (not necessary in this case).
Arrival longitude = 118° 11.0’ W = 118.183°
118.183° ÷ 15 = 7.87 = -8 ZD

Step 6: Correct GMT arrival time to local time zone. It is easy and advisable to “backwards check” your work to ensure a correct answer.
0205 GMT; 4 November = **1805 ZT; 3 November**

ETA Problems with Delay

- ETA problems with stops (fueling, Panama Canal, etc.) are best accounted for by delaying the initial sailing time.

ETA D2. You are on a voyage from St. John's Canada, to Galveston, Texas. The distance is 2280 miles, and the speed of advance is 15.0 knots. You estimate 16.5 hours for bunkering en route at Ft. Lauderdale, Florida. If you sailed at 1642 hours (ZD +4) 27 February, what was your ETA (ZD +6) at Galveston?

Answer: 1512, 6 March.

Step 1: Calculate the total time steaming:
2280 nm ÷ 15 knots = 152 hours.

Step 2: Convert the total time steaming into days and hours.
152 hours = 6.33 days = 6 days, 8 hours.

Step 3: Convert departure time into GMT and account for "departure delay."
1642 ZT (+4), 27 February = 2042 GMT, 27 February

16:30 hour delay for bunkering en route.
2042 + 1630 = 36:72 = 12:72 + 1 day = 13:12 GMT, 28 February
Modified departure time = 1312 GMT, 28 February

Step 4: Add transit time to converted departure time.
1312 GMT, 28 February + 6 days, 8 hours
= 2112 GMT, 6 March

Step 5: Convert GMT arrival time into zone time (given as +6).
2112 GMT, 6 March = **1512, 6 March ZT (+6).**

Estimated Time of Arrival Problems

Normal ETA Problems

ETA B1. At 0530 zone time on 20 December, you depart Cape Town (ZD -1). You are bound for New York (ZD +5) and you estimate your speed of advance at 25 knots. The distance is 6,762 miles. What is your estimated zone time of arrival in New York?

a) 1200, 31 December
b) 1100, 31 December
c) 0700, 31 December
d) 0600, 31 December - correct

ETA B2. Your vessel departs Yokohama from position latitude 35° 27.0’ N, longitude 139° 39.0’ E (ZD -9) at 1330 ZT on 23 July. You are bound for Seattle at position latitude 47° 36.0’ N, longitude 122° 22.0’ W (ZD -8). The distance by great circle is 4,245 miles and you estimate that you will average 13.6 knots. What is your estimated ZT of arrival?

a) 0438, 4 August
b) 2038, 4 August - correct
c) 0438, 5 August
d) 1238, 5 August

ETA B3. On 21 November at 2100 zone time, you depart latitude 32° 12’ N, longitude 69° 26’ W en-route to position latitude 12° 05’ N, longitude 7° 32’ W. The distance is 3,519 miles and the average speed will be 12.5 knots. What is the zone time of arrival?

a) 1330, 3 December
b) 1530, 3 December
c) 1830, 3 December - correct
d) 1530, 4 December

ETA B4. At 0915 zone time on 7 April, you depart San Francisco, latitude 37° 48.5’ N, longitude 122° 24.0’ W (ZD -8). You are bound for Kobe, latitude 34° 40.0’ N, longitude 135° 12.0’ E. You estimate your speed of advance to be 17 knots. The distance is 4,819 miles. What is your estimated zone time of arrival at Kobe?

a) 0343, 18 April
b) 1243, 19 April
c) 2143, 19 April - correct
d) 0443, 20 April

ETA Problems with Delay

ETA B5. You are on a voyage from Baltimore, MD, to Seattle, WA. The distance from pilot to pilot is 5960 miles. The speed of advance is 16.0 knots. You estimate 16 hours for bunkering at Colon, and 12 hours for the Panama Canal transit. If you take departure at 0824 hours (ZD +5), 18 November, what is your ETA to Seattle (ZD +8)?

a) 1654, 5 December
b) 1354, 5 December
c) 2154, 4 December - correct
d) 1354, 4 December

ETA B6. You are on a voyage from Boston, MA to South Pass, LA. The distance is 1870 miles and the speed of advance is 13.6 knots. You estimate 16.5 hours for bunkering in Port Everglades, FL. If you sailed at 0836 (ZD +5), 26 February, what is your ETA at South Pass (ZD +6)?

a) 2336, 3 March
b) 1136, 4 March
c) 1236, 4 March
d) 1736, 4 March - correct

ETA B7. You are on a voyage from New York NY to San Francisco CA. The distance from pilot station to pilot station is 5132 miles and the speed of advance is 13.5 knots. You estimate 32 hours for bunkering at Colon and 14 hours for the Panama Canal transit. If you take departure at 0600 hours (ZD +4) on 16 May, what is your ETA at San Francisco (ZD +7)?

a) 0609, 1 June
b) 2109, 2 June - correct
c) 0009, 2 June
d) 0409, 2 June

Speed by RPM Problems

- Required formulas (these must be memorized).
  - $Slip = \frac{Engine\ Speed - Observed\ Speed}{Engine\ Speed}\ x\ 100$
  - $Efficiency = 100\% - Slip$
  - $Speed = \frac{RPM\ x\ 60\ x\ Pitch\ x\ Efficiency}{6080}$

- Pitch is the distance a propeller will move a ship forward in a fluid with one rotation. It is measured in feet.

- The number 6080 in the third equation comes from the fact that there are 6076 feet in a mile and is necessary because pitch is in terms of feet and necessary for units to cancel, resulting in nautical miles per hour. Generally the figure is rounded to 6080 to aid memorization.

- Revolutions per minute (RPM) is the number of turns a propeller (or shaft) makes in one minute.

- Slip is the difference between the speed of the engine and the speed of the ship. Slip values can be positive or negative and directly correlates to the efficiency of the system. For example, a following current could result in a negative slip, while a positive slip could come from hull fouling or mechanical issues. The “efficiency” figure in the third equation is usually used such that an efficiency of 107% would be noted as 1.07 and an efficiency of 97% would be noted as 0.97.

<u>Day's Run Problems</u>

RPM D1. If the pitch of the propeller is 19.7 feet and the revolutions per day are 86,178, calculate the day's run allowing 3% negative slip.

Answer 287.60 nautical miles.

Step 1: $Efficiency = 100\% - Slip$

Step 2: $Efficiency = 100\% - (-3\%)$

Step 3: $Efficiency = 103\%$

Step 4: $Efficiency = 1.03$

Step 5: After calculating the efficiency, the next step is to calculate the required RPM of the shaft. Since the daily revolutions are given, the "60" in the Speed Equation is not necessary, and instead of "speed," the answer will be given in "day's run."

Step 6: $Speed = \frac{RPM \times 60 \times Pitch \times Efficiency}{6080}$

Step 7: $Modified\ equation\ to \rightarrow Day's\ Run = \frac{Revs \times Pitch \times Efficiency}{6080}$

Step 8: $Day's\ Run = \frac{86{,}178\ \times 19.7ft \times 1.03}{6080}$

Step 9: $Day's\ Run = \frac{1{,}748{,}637.798}{6080}$

Step 10: $\boldsymbol{Day's\ Run = 287.60\ miles}$

Revolutions per Minute Problems

RPM D2. If the speed necessary for reaching port at a designated time is 18.5 knots and the pitch of the propeller is 21.7 feet, how many revolutions per minute will the shaft have to turn assuming a 4% negative slip?

Answer: 83.1 RPM.

Step 1: $Efficiency = 100\% - Slip$

Step 2: $Efficiency = 100\% - (-4\%)$

Step 3: $Efficiency = 104\%$

Step 4: $Efficiency = 1.04$

Step 5: After calculating the efficiency, the next step is to calculate the required RPM of the shaft.

Step 6: $Speed = \frac{RPM \times 60 \times Pitch \times Efficiency}{6080}$

Step 7: $18.5kts = \frac{RPM \times 60 \times 21.7ft \times 1.04}{6080}$

Step 8: $18.5kts = \frac{RPM \times 1354.08}{6080}$

Step 9: $112480 = RPM \times 1354.08$

Step 10: $\boldsymbol{RPM = 83.067}$

Engine Slip Problems

RPM D3. While turning for 18.0 knots, accounting for current and wind, the ship is observed to make good 17.3 knots. What is the apparent slip of the propeller?

Answer: +3.88%. The reason for multiplying the fractional value by 100 is to obtain an answer in percent form, the standard form for slip calculations. Note that positive slip and negative slip values can occur.

Step 1: $Slip = \frac{Engine\ Speed - Observed\ Speed}{Engine\ Speed} \times 100$

Step 2: $Slip = \frac{18.0kts - 17.3kts}{18.0kts} \times 100$

Step 3: $Slip = \frac{0.7kts}{18.0kts} \times 100$

Step 4: $Slip = 0.0388 \times 100$ = **+3.88%**

RPM D4. The propeller on a vessel has a diameter of 20.6 feet and a pitch of 23.4 feet. What would be the apparent slip if the vessel cruised 538 miles in a 24-hour day (observed distance) at an average RPM of 87?

Answer: -11.59%. The propeller diameter is "distractor" information. The goal is to calculate slip, so the "efficiency" portion of the speed equation is not required.

Step 1: $Speed = \frac{RPM \times 60 \times Pitch \times Efficiency}{6080}$

Step 2: $Speed = \frac{87RPM \times 60 \times 23.4ft \times Efficiency\ (irrelevant\ in\ this\ case)}{6080}$

Step 3: $Speed = \frac{122148}{6080}$ = 20.09 knots

Step 4: This gives us our engine speed for the next calculation. In the problem, the vessel cruised 538 miles in a 24-hour day. Therefore, from a basic speed=distance/time calculation, the observed speed is 22.42kts.

Step 5: $Slip = \frac{Engine\ Speed - Observed\ Speed}{Engine\ Speed} \times 100$

Step 6: $Slip = \frac{20.09kts - 22.42kts}{20.09kts} \times 100$

Step 7: $Slip = \frac{-2.23kts}{20.09kts} \times 100$

Step 8: $Slip = -0.1159 \times 100$ = **- 11.59%**

Speed Problems

RPM D5. You are turning for 90 RPM. The propeller pitch is 24 feet and the slip is -3%. What is the speed of advance?

Answer: 21.9 knots.

Step 1: $Efficiency = 100\% - Slip$

Step 2: $Efficiency = 100\% - (-3\%)$

Step 3: $Efficiency = 103\% = 1.03$

Step 4: $Speed = \frac{RPM \times 60 \times Pitch \times Efficiency}{6080}$

Step 5: $Speed = \frac{90RPM \times 60 \times 24ft \times 1.03}{6080}$

Step 6: $Speed = \frac{133488}{6080}$ = **21.96 knots**

Speed by RPM Problems

<u>Day's Run Problems</u>

RPM B1. If the pitch of the propeller is 19.4 feet, and the revolutions per day are 96,713, calculate the day's run allowing 6% positive slip.

a) 266.4 miles
b) 290.1 miles - correct
c) 308.6 miles
d) 327.1 miles

RPM B2. If the pitch of the propeller is 21.5 feet, and the revolutions per day are 96,666, calculate the day's run allowing 9% negative slip.

a) 311.1 miles
b) 341.8 miles
c) 357.9 miles
d) 372.6 miles - correct

RPM B3. If the pitch of the propeller is 25.1 feet, and the revolutions per day are 91,591, calculate the day's run allowing 7 % positive slip.

a) 351.6 miles - correct
b) 378.1 miles
c) 390.0 miles
d) 404.6 miles

Revolutions per Minute Problems

RPM B4. If the speed necessary for reaching port at a designated time is 12.6 knots and the pitch of the propeller is 13.6 feet, how many revolutions per minute will the shaft have to turn, assuming no slip?

a) 81
b) 85
c) 90
d) 94 - correct

RPM B5. If the speed necessary for reaching port at a designated time is 15.7 knots and the pitch of the propeller is 23.4 feet, how many revolutions per minute will the shaft have to turn, assuming a 6% negative slip?

a) 64 - correct
b) 68
c) 72
d) 76

RPM B6. If the speed necessary for reaching port at a designated time is 17.8 knots and the pitch of the propeller is 24.7 feet, how many revolutions per minute will the shaft have to turn, assuming a 7% positive slip?

a) 67
b) 71
c) 75
d) 79 - correct

RPM B7. If the speed necessary for reaching port at a designated time is 20.7 knots and the pitch of the propeller is 23.8 feet, how many revolutions per minute will the shaft have to turn, assuming a 3% negative slip?

a) 74
b) 79
c) 86 - correct
d) 98

Slip Problems

RPM B8. The propeller of a vessel has a pitch of 19.0 feet. If the vessel traveled 183.5 miles (observed distance) in 24 hours at an average of 44 RPM, what was the slip?

a) +7.4% - correct
b) -7.4%
c) +11.6%
d) -11.6%

RPM B8. The propeller on a vessel has a diameter of 20.2 feet and a pitch of 19.0 feet. What would be the apparent slip if the vessel cruised 367 miles (observed distance) in a 24-hour day at an average RPM of 84?

a) +2.9% - correct
b) -2.9%
c) +5.2%
d) -5.2%

RPM B9. The pitch of the propeller on your vessel is 19' 09". You estimate slip to be -3%. If you averaged 82 RPM for the day's run, how many miles did you steam?

a) 370.8
b) 373.6
c) 393.7
d) 395.3 - correct

RPM B10. The propeller on a vessel has a diameter of 24.0 feet and a pitch of 21.3 feet. What would be the slip if the vessel cruised 510 miles in a 24 hour day (observed distance) at an average RPM of 86?

a) -12.2%
b) +12.2%
c) -17.5% - correct
d) +17.5%

RPM B11. Your vessel's propeller has a pitch of 22'06". From 0530, 19 March, to 1930, 20 March, the average RPM was 82. The distance run by observation was 721.5 miles. What was the slip?

a) +4%
b) -4% - correct
c) +7%
d) -7%

Speed Problems

RPM B12. The speed of advance necessary to reach port at a designated time is 15.8 knots. The pitch of the propeller is 20.75 feet. You estimate positive 5% slip. How many RPM must you turn to make the necessary speed?

a) 73.5
b) 76.2
c) 79.9
d) 81.2 - correct

RPM B13. You are turning 100 RPM, with a propeller pitch of 25 feet, and an estimated slip of -5%. What is the speed of advance?

a) 24.7 kts
b) 23.5 kts
c) 25.9 kts - correct
d) 22.3 kts

RPM B14. You are turning 82 RPM, with a propeller pitch of 23 feet, and an estimated slip of +6%. What is the speed of advance?

a) 17.5 kts - correct
b) 17.9 kts
c) 18.4 kts
d) 19.7 kts

Fuel Conservation Problems

- Fuel conservation problems may appear in several formats, but they all rely on the same two formulae:
    - $\frac{New\ Consumption}{Old\ Consumption} = \frac{New\ Speed^3}{Old\ Speed^3}$
    - $\frac{New\ Consumption}{Old\ Consumption} = \frac{New\ Speed^2 \times New\ Distance}{Old\ Speed^2 \times Old\ Distance}$
- Depending on the information given in the problem, sometimes the formula should be modified by setting values to "1". For example, if no consumption information is given, it is assumed the consumption stays the same and can be set to 1/1. Proceed as normal with the formula from there.

Desired Speed (Change Consumption)

CON D1. While steaming 17.5 knots, your vessel consumes 378 barrels of fuel oil per day. In order to reduce consumption to 194 barrels of fuel oil per day, what is the maximum speed the vessel can turn for?

Answer: 14.01 knots. Use equation (1) to solve for the new speed required.

Step 1: $\frac{New\ Consumption}{Old\ Consumption} = \frac{New\ Speed^3}{Old\ Speed^3}$

Step 2: $\frac{194\ barrels\ per\ day}{378\ barrels\ per\ day} = \frac{New\ Speed^3}{(17.5kts)^3}$

Step 3: $0.5132 = \frac{New\ Speed^3}{5359.4}$

Step 4: $2750.4 = New\ Speed^3$

Step 5: $\mathbf{14.01\ kts = New\ Speed}$

Desired Speed (Remaining Fuel)

CON D2. You have steamed 369 miles at 16 knots and burned 326 barrels of fuel per day. You must decrease your consumption to 212 barrels per day with 271 miles left in your voyage. What must you reduce your speed to in order to burn this amount of fuel?

Answer: 15.1 knots

Step 1: $\frac{\text{New Consumption}}{\text{Old Consumption}} = \frac{\text{New Speed}^2 \times \text{New Distance}}{\text{Old Speed}^2 \times \text{Old Distance}}$

Step 2: $\frac{212}{326} = \frac{x^2 \times 271}{16^2 \times 369}$

Step 3: $0.6503 = \frac{271x^2}{94464}$

Step 4: $61429.9 = 271x^2$

Step 5: $226.7 = x^2$

Step 6: $\mathbf{New\ speed = 15.06\ knots}$

Desired Speed (Given Distance)

CON D3. At your current speed of 22 knots you have only enough fuel remaining to travel 440 miles. You must travel 618 miles to reach your destination. What speed should you reduce to in order to reach your destination?

Answer: 18.6 knots. If the consumption is not stated to change in the problem, you can set the value to 1/1 as a constant.

Step 1: $\frac{\text{New Consumption}}{\text{Old Consumption}} = \frac{\text{New Speed}^2 \times \text{New Distance}}{\text{Old Speed}^2 \times \text{Old Distance}}$

Step 2: $\frac{1}{1} = \frac{x^2 \times 618}{22^2 \times 440}$

Step 3: $1 = \frac{618x^2}{212960}$

Step 4: $212960 = 618x^2$

Step 5: $344.6 = x^2$

Step 6: $\mathbf{New\ speed = 18.6\ knots}$

Desired New Consumption (Change Speed)

CON D4. While steaming 14.0 knots, your vessel burns 276 barrels per day. What will be the rate of fuel consumption if you decrease speed to 11.7 knots?

Answer: 161.1 barrels per day

Step 1: $\frac{\text{New Consumption}}{\text{Old Consumption}} = \frac{\text{New Speed}^3}{\text{Old Speed}^3}$

Step 2: $\frac{\text{New Consumption}}{\text{276 barrels per day}} = \frac{(11.7\ \text{kts})^3}{(14.0\ \text{kts})^3}$

Step 3: $\frac{\text{New Consumption}}{\text{276 barrels per day}} = \frac{1601.613}{2744}$

Step 4: $\frac{\text{New Consumption}}{\text{276 barrels per day}} = 0.5837$

Step 5: $\mathbf{New\ Consumption = 161.1\ barrels\ per\ day}$

Desired New Consumption (Remaining Distance)

CON D5. You have steamed 174 miles and consumed 18.0 tons of fuel. If you maintain the same speed, how many tons of fuel will you consume while steaming 416 miles?

Answer: 43.03 tons. Since the speed is to remain the same, you can cancel the terms from the numerator and denominator.

Step 1: $\frac{\text{New Consumption}}{\text{Old Consumption}} = \frac{\text{New Speed}^2 \times \text{New Distance}}{\text{Old Speed}^2 \times \text{Old Distance}}$

Step 2: $\frac{\text{New Consumption}}{\text{18.0 tons per day}} = \frac{\text{Irrelevant Speed}^2 \times \text{416 miles}}{\text{Irrelevant Speed}^2 \times \text{174 miles}}$

Step 3: Cancel the speed terms from the numerator and denominator.

Step 4: $\frac{\text{New Consumption}}{\text{18.0 tons per day}} = \frac{\text{416 miles}}{\text{174 miles}}$

Step 5: $\frac{\text{New Consumption}}{\text{18.0 tons per day}} = 2.3908$

Step 6: $\textbf{New Consumption} = \textbf{43.03 tons}$

Desired New Distance

CON D6. You have steamed 607 miles at 17.0 knots and consumed 121 tons of fuel. If you have 479 tons of usable fuel remaining, how far can you steam at 14.5 knots?

Answer: 3302.9 miles

Step 1: $\frac{\text{New Consumption}}{\text{Old Consumption}} = \frac{\text{New Speed}^2 \times \text{New Distance}}{\text{Old Speed}^2 \times \text{Old Distance}}$

Step 2: $\frac{479}{121} = \frac{14.5^2 \times \text{x}}{17^2 \times 607}$

Step 3: $3.959 = \frac{210.25\ \text{x}}{175423}$

Step 4: $694443 = 210.25\text{x}$

Step 5: $\textbf{New distance} = \textbf{3247 miles}$

Fuel Conservation Problems

Desired Speed (Change Consumption)

CON B1. While steaming 13.5 knots, your vessel consumes 251 barrels of fuel oil per day. In order to reduce consumption to 129 barrels of fuel oil per day, what is the maximum speed the vessel can turn for?

a) 6.9 kts
b) 9.7 kts
c) 10.8 kts - correct
d) 12.7 kts

CON B2. While steaming at 14.5 knots, your vessel consumes 319 barrels of fuel oil per day. In order to reduce consumption to 217 barrels of fuel oil per day, what is the maximum speed the vessel can turn for?

a) 9.8 kts
b) 11.9 kts
c) 12.8 kts - correct
d) 13.5 kts

CON B3. While steaming at 15.5 knots, your vessel consumes 333 barrels of fuel oil per day. In order to reduce consumption to 176 barrels of fuel oil per day, what is the maximum speed the vessel can turn for?

a) 11.3 kts
b) 12.5 kts - correct
c) 13.6 kts
d) 14.8 kts

Desired Speed (Remaining Fuel)

CON B4. You have steamed 449 miles at 19 knots and burning 476 barrels of fuel per day. You must decrease your consumption to 185 barrels per day with 362 miles left in your voyage. What must you reduce your speed (kts) to in order to burn this amount of fuel?

a) 13.2 kts - correct
b) 14.3 kts
c) 17.1 kts
d) 18.2 kts

CON B5. You have steamed 499 miles at 21 knots and burning 462 barrels of fuel per day. You must decrease your consumption to 221 barrels per day with 311 miles left in your voyage. What must you reduce your speed (kts) to in order to burn this amount of fuel?

a) 17.3 kts
b) 18.4 kts - correct
c) 19.1 kts
d) 20.0 kts

CON B6. At your current speed of 21 knots you only have sufficient fuel to travel 404 miles. You must travel 731 miles to reach your destination. What speed should you travel in order to reach your destination?

a) 18.9 kts
b) 17.8 kts
c) 16.7 kts
d) 15.6 kts - correct

<u>Desired Speed (Given Distance)</u>

CON B7. Your vessel arrives in port with sufficient fuel to steam 812 miles at 15 knots. If you are unable to take on bunkers at what speed must you proceed to reach your destination, 928 miles distant?

a) 13.6 kts
b) 14.0 kts - correct
c) 15.3 kts
d) 15.7 kts

CON B8. Your vessel arrives in port with sufficient fuel to steam 726 miles at 16 knots. If you are unable to take on bunkers at what speed must you proceed to reach your destination, 873 miles distant?

a) 14.6 kts - correct
b) 15.1 kts
c) 16.3 kts
d) 16.8 kts

CON B9. At your current speed of 21 knots you have only enough fuel remaining to travel 404 miles. You must travel 731 miles to reach your destination. What should you reduce your speed to in order to reach your destination?

a) 18.9 kts
b) 17.8 kts
c) 16.7 kts
d) 15.6 kts – correct

CON B10. At your current speed of 22 knots you have only enough fuel remaining to travel 422 miles. You must travel 844 miles to reach your destination. What should you reduce your speed to in order to reach your destination?

a) 19.8 kts
b) 18.4 kts
c) 17.0 kts
d) 15.6 kts – correct

Desired New Consumption (Change Speed)

CON B11. Your vessel consumes 274 barrels of fuel per day at a speed of 17.5 knots. What will the fuel consumption be at 13.5 knots?

a) 126 bbls - correct
b) 163 bbls
c) 211 bbls
d) 253 bbls

CON B12. Your vessel consumes 156 barrels of fuel per day at a speed of 13 knots. What will the fuel consumption be of your vessel at 16 knots?

a) 192 bbls
b) 236 bbls
c) 291 bbls - correct
d) 315 bbls

CON B13. Your vessel consumes 216 barrels of fuel per day at a speed of 15 knots. What will the fuel consumption be of your vessel at 17.5 knots?

a) 232 bbls
b) 252 bbls
c) 294 bbls
d) 343 bbls - correct

Desired New Consumption (Remaining Distance)

CON B14. You have steamed 300 miles and consumed 34 tons of fuel. If you maintain the same speed, how many tons of fuel will you consume while steaming 700 miles?

a) 79.3 tons - correct
b) 74.3 tons
c) 68.4 tons
d) 66.2 tons

CON B15. You have steamed 199 miles and consumed 23 tons of fuel. If you maintain the same speed, how many tons of fuel will you consume while steaming 410 miles?

a) 32.6 tons
b) 39.9 tons
c) 47.4 tons - correct
d) 97.6 tons

CON B16. You have steamed 916 miles at 13 knots and consumed 166 tons of fuel. If you have to steam 1325 miles to complete the voyage, how many tons of fuel will be consumed while steaming at 14 knots?

a) 133 tons
b) 181 tons
c) 207 tons
d) 278 tons - correct

CON B17. You have steamed 1175 miles at 19 knots and consumed 257 tons of fuel. If you have to steam 1341 miles to complete the voyage, how many tons of fuel will be consumed while steaming at 18 knots?

a) 293 tons
b) 263 tons - correct
c) 202 tons
d) 172 tons

Desired New Distance

CON B18. You have steamed 1124 miles at 21 knots and consumed 326 tons of fuel. If you have 210 tons of usable fuel remaining, how far can you steam at 17 knots?

a) 1096 miles
b) 1105 miles - correct
c) 1218 miles
d) 1304 miles

CON B19. You have steamed 525 miles at 16 knots and consumed 105 tons of fuel. If you have 308 tons of usable fuel remaining, how far can you steam at 19 knots?

a) 920 miles
b) 1092 miles - correct
c) 1297 miles
d) 2172 miles

CON B20. You have steamed 918 miles at 15 knots. The total fuel consumed is 183 tons. If you have 200 tons of fuel remaining how far can you steam at 12 knots?

a) 1021 miles
b) 1261 miles
c) 1568 miles - correct
d) 1960 miles

CON B21. You have steamed 701 miles at 18 knots. The total fuel consumed is 201 tons. If you have 259 tons of fuel remaining how far can you steam at 14.5 knots?

a) 838 miles
b) 903 miles
c) 1392 miles - correct
d) 1728 miles

CON B22. You have steamed 632 miles at 18.5 knots. The total fuel consumed is 197 tons. If you have 278 tons of fuel remaining how far can you steam at 15 knots?

a) 681 miles
b) 892 miles
c) 1100 miles
d) 1357 miles - correct

Distance Off, Bearing, & Dead Reckoning Problems

- Distance off problems can either involve distance when abeam or distance at second bearing. Table 7 in Bowditch provides tabulated results for most cases.

- There are some special case rules to know that may save time during an exam. The most common cases are the 7/10th's rule and the 26.5° - 45° rule:

  - Doubling the Angle on the Bow Rule: when the measured angle of an object doubles, the distance run between the bearings equals the distance from the object at the second bearing.

  - Bow and Beam Rule: When the first bearing is 45° and the second is 90°, the distance run between bearings and distance off are equal.

  - 7/10ths Rule: When the first bearing is 22.5° and the second is 45°, 0.7 times the distance run equals the distance abeam.

  - 26.5° - 45° Rule: When the first bearing is 26.5° and the second bearing is 45° the distance run equals the distance abeam.

  - 30/60/90 Rule: When the first bearing is 30° and the second is 60°, 0.875 times the distance run equals the distance abeam.

- Some problems are best solved with a Maneuvering Board, such as those involving a course to steer, time abeam a light, or those requiring a course change.

DIS D1. You are steaming on a course of 114° T at 17 knots. At 1122 you observe a lighthouse bearing 077° T. At 1133 the lighthouse bears 051° T. What is your distance off at the second bearing? What is your distance off when abeam?

Answer: 4.31 miles at second bearing, 3.84 miles when abeam.

Step 1: Create a table of data to determine the difference between ship's course and each bearing.

Time	Course	Bearing	Difference between course and bearing
1122	114° T	077° T	114° T – 077° T = **37°**
1133	114° T	051° T	114° T – 051° T = **63°**

Step 2: Enter Table 7 in Bowditch with the difference between the course and each bearing. Retrieve the tabular data, with bracketing values if exact values are not listed.

a. The bracketing values are:

	36°	**38°**
62°	1.34/1.18	1.51/1.34
64°	1.25/1.13	1.40/1.26

Distance of an Object by Two Bearings

Difference between the course and second bearing °	Difference between the course and first bearing 34°		36°		38°		40°		42°	
44	3.22	2.24								
46	2.69	1.93	3.39	2.43						
48	2.31	1.72	2.83	2.10	3.55	2.63				
50	2.03	1.55	2.43	1.86	2.96	2.27	3.70	2.84		
52	1.81	1.43	2.13	1.68	2.54	2.01	3.09	2.44	3.85	3.04
54	1.63	1.32	1.90	1.54	2.23	1.81	2.66	2.15	3.22	2.60
56	1.49	1.24	1.72	1.42	1.99	1.65	2.33	1.93	2.77	2.29
58	1.37	1.17	1.57	1.33	1.80	1.53	2.08	1.76	2.43	2.06
60	1.28	1.10	1.45	1.25	1.64	1.42	1.88	1.63	2.17	1.88
62	1.19	1.05	1.34	1.18	1.51	1.34	1.72	1.52	1.96	1.73
64	1.12	1.01	1.25	1.13	1.40	1.26	1.58	1.42	1.79	1.61
66	1.06	0.96	1.18	1.07	1.31	1.20	1.47	1.34	1.65	1.51
68	1.00	0.93	1.11	1.03	1.23	1.14	1.37	1.27	1.53	1.42

b. Interpolate for the desired value to the nearest hundredth.

	36°	**37°**	38°
62°	1.34/1.18		1.51/1.34
63°	**1.30/1.16**	?	**1.46/1.30**
64°	1.25/1.13		1.40/1.26

	36°	**37°**	38°
62°	1.34/1.18		1.51/1.34
63°	1.30/1.16	**1.38/1.23**	1.46/1.30
64°	1.25/1.13		1.40/1.26

The interpolated values for 37° and 63° are 1.38 and 1.23.

Step 3: Given the time between bearings and the ship speed, determine the distance run.
Bearing times: 1122 and 1133. 1133-1122 = 11 minutes run.
11 minutes = 0.183 hours at 17 knots = 3.12 miles run.

Step 4: Per the instructions in Bowditch for using Table 7, the distance run between bearings multiplied by the first number is equal to the distance at the second bearing, and the distance run multiplied by the second number is equal to the distance abeam.

Distance off at second bearing = 3.12 miles run x 1.38 = **4.31 miles**
Distance off abeam = 3.12 miles run x 1.23 = **3.84 miles**

DIS D2. Your vessel is on course 237° T at 18 knots. At 0404 a light bears 263.5° T and at 0430 the light bears 282° T. At what time and at what distance off will your vessel be when abeam of the light?

Answer: 0456, 7.8 miles.

Step 1: Create a table of data to determine the difference between ship's course and each bearing.

Time	Course	Bearing	Difference between course and bearing
0404	237° T	263.5° T	237° T – 263.5° T = **26.5°**
0430	237° T	282° T	237° T – 282° T = **45°**

Step 2: Because the first bearing is 26.5° and the second bearing is 45°, this is a special case rule which states that the distance run is equal to the distance abeam.

Step 3: Given the time between bearings and the ship speed, determine the distance run.
Bearing times: 0404 and 0430. 0430-0404 = 26 minutes run.
26 minutes = 0.433 hours at 18 knots = 7.8 miles run.

Step 4: Since the distance run is 7.8 miles, the distance abeam is also **7.8 miles.**

Step 5: When determining the time abeam, since the second bearing is 45° and the bearing abeam is 90°, the bow and beam rule states that the distance run between bearings and the distance abeam are the same.

a. Since we know the distance abeam is 7.8 miles, this also equals the distance run from 0430 until the time abeam.

b. Since the time between 0404 and 0430, and the time between 0430 and the time abeam will be the same, the time from 0430 to time abeam will be equal to 26 minutes. Therefore, the time abeam is 0430 + 26 = **0456.**

DIS D2A.Note this problem can also be solved using Table 7 in Bowditch if the special case is not recognized.

Resuming from step 1:

Step 1: Create a table of data to determine the difference between ship's course and each bearing.

Time	Course	Bearing	Difference between course and bearing
0404	237° T	263.5° T	237° T – 263.5° T = **26.5°**
0430	237° T	282° T	237° T – 282° T = **45°**

Step 2: Enter Table 7 in Bowditch with the difference between the course and each bearing. Retrieve the tabular data, with bracketing values if exact values are not listed (Table 18 is reproduced in it's entirety at the end of this Part).

Difference between the course and second bearing	Difference between the course and first bearing									
	20°		22°		24°		26°		28°	
°										
30	1.97	0.98								
32	1.64	0.87	2.16	1.14						
34	1.41	0.79	1.80	1.01	2.34	1.31				
36	1.24	0.73	1.55	0.91	1.96	1.15	2.52	1.48		
38	1.11	0.68	1.36	0.84	1.68	1.04	2.11	1.30	2.70	1.66
40	1.00	0.64	1.21	0.78	1.48	0.95	1.81	1.16	2.26	1.45
42	0.91	0.61	1.10	0.73	1.32	0.88	1.59	1.06	1.94	1.30
44	0.84	0.58	1.00	0.69	1.19	0.83	1.42	0.98	1.70	1.18
46	0.78	0.56	0.92	0.66	1.09	0.78	1.28	0.92	1.52	1.09
48	0.73	0.54	0.85	0.64	1.00	0.74	1.17	0.87	1.37	1.02

a. The bracketing values are:

	26°	**28°**
44°	1.42/0.98	1.70/1.18
46°	1.28/0.92	1.52/1.09

b. Interpolate for the desired value to the nearest hundredth.

	26°	**26.5°**	28°
44°	1.42/0.98		1.70/1.18
45°	**1.35/0.95**		**1.61/1.14**
46°	1.28/0.92		1.52/1.09

	26°	**26.5°**	28°
44°	1.42/0.98		1.70/1.18
45°	1.35/0.95	**1.42/1.00**	1.61/1.14
46°	1.28/0.92		1.52/1.09

The interpolated values for 26.5° and 45° are 1.42 and 1.00.

Step 3: Given the time between bearings and the ship speed, determine the distance run.
Bearing times: 0404 and 0430. 0430-0404 = 26 minutes run.
26 minutes = 0.433 hours at 18 knots = 7.8 miles run.

Step 4: Per the instructions in Bowditch for using Table 7, the distance run between bearings multiplied by the first number is equal to the distance at the second bearing, and the distance run multiplied by the second number is equal to the distance abeam.

Distance off at second bearing = 7.8 miles run x 1.42 = 11.08 miles
Distance off abeam = 7.8 miles run x 1.00 = **7.8 miles**

Step 5: Determine the time abeam.

The distance abeam was determined to be 7.8 miles in step 4.

With one bearing at 45° (the original, second bearing), and one bearing at 90° (abeam), this is a 45-45-90 right triangle, and therefore the distance run from the second bearing to the beam bearing and distance abeam are equal, so the distance run is 7.8 miles.

7.8 miles for 18 knots is 0.433 hours, or 26 minutes. The time of second bearing was 0430. 0430 + 26m = **0456.**

DIS 3. While on course 091° pgc, a light bears 014° off the port bow at a distance of 15.3 miles. What course should you steer to pass 1.5 miles abeam of the light, leaving it to port?

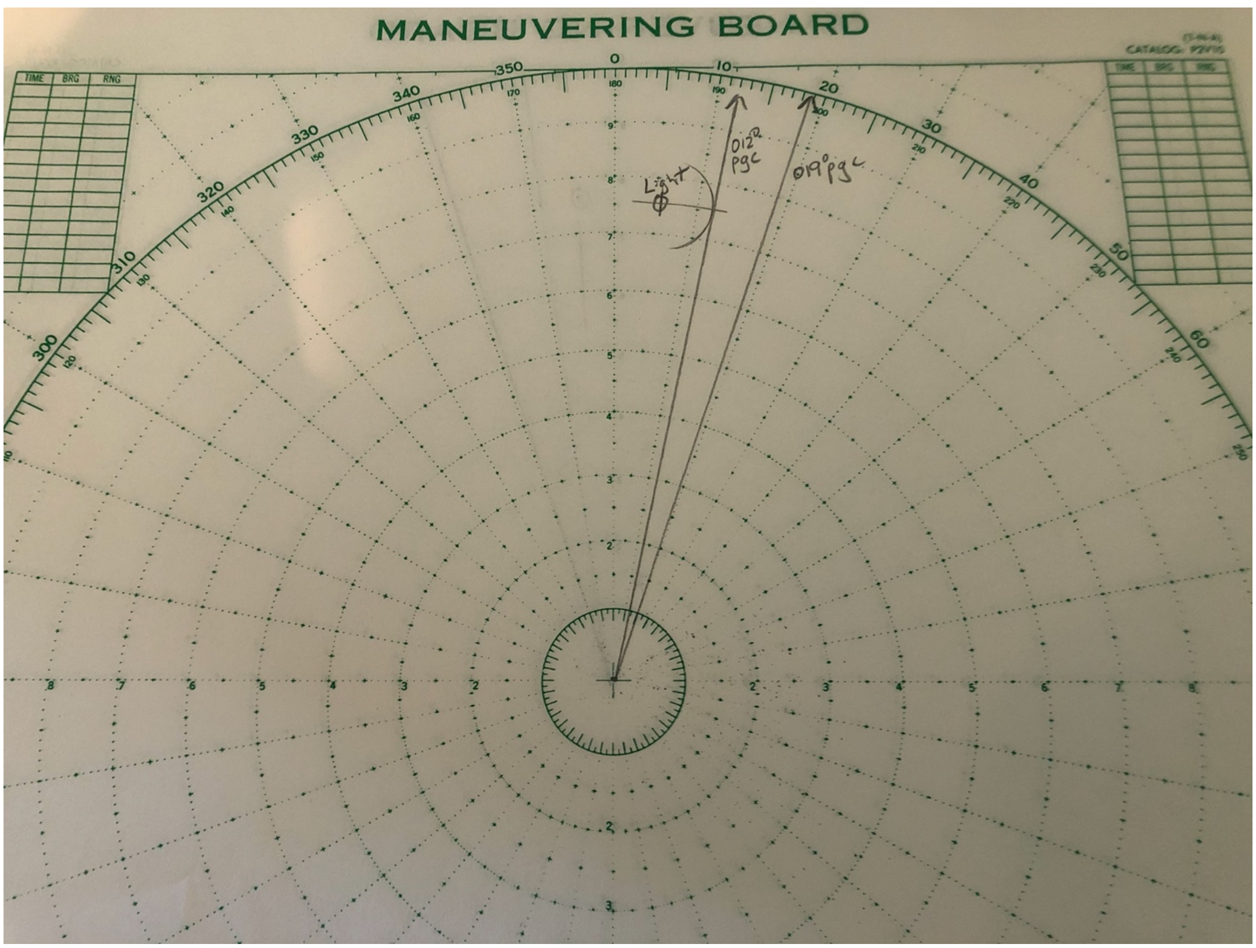
Answer: 012° pgc

Step 1: Plot the initial course on a Maneuvering Board.

Step 2: Plot the bearing and range to the light.

Step 3: Plot a circle of 1.5 miles around the light.

Step 4: Determine the course to steer with a tangent to the circle drawn in step 3.



DIS 4. You are steering 231° T and a light is picked up dead ahead at a distance of 12.3 miles at 0338. You change course to pass the light 4 miles off abeam to starboard. If you are making 16.5 knots, what is your ETA at the position 4 miles off the light?

Answer: 0420

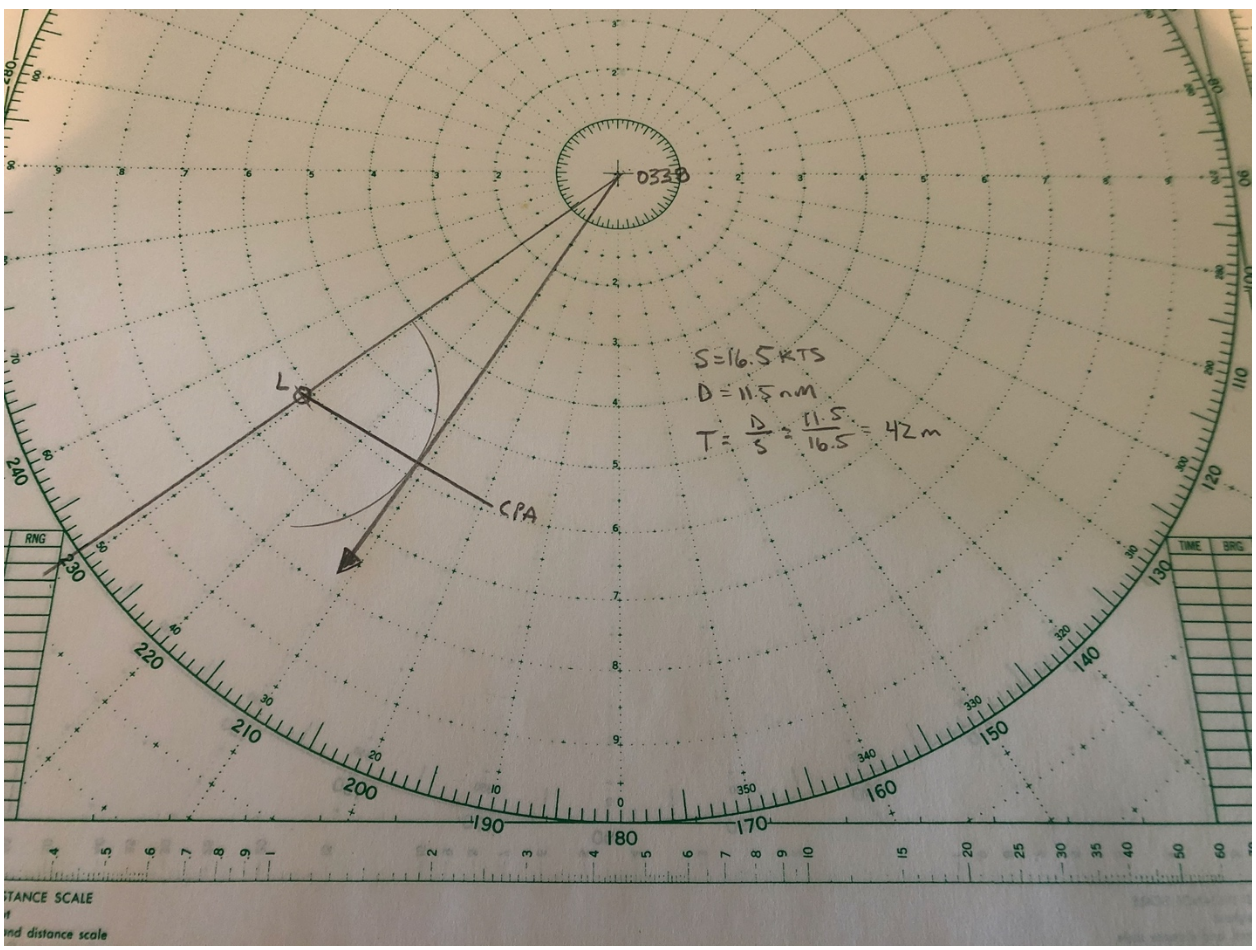
Step 1: Plot the initial course on a Maneuvering Board.

Step 2: Plot the bearing and range to the light.

Step 3: Plot a circle of 4 miles around the light.

Step 4: Determine the time abeam:

Draw a tangent line from the light to the course and mark it as the CPA.
Measure the distance from the origin to the CPA.
Time = D/S = 11.5nm/16.5kts = 42 minutes.
0338 + 42m = **0420**



DIS 5. You are underway on course 163° T at a speed of 15.8 knots. You sight a buoy bearing 161° T at a radar range of 5.5 miles at 1319. If you change course at 1325, what is the course to steer to leave the buoy abeam to starboard at 1.0 mile?

Answer: 145° T

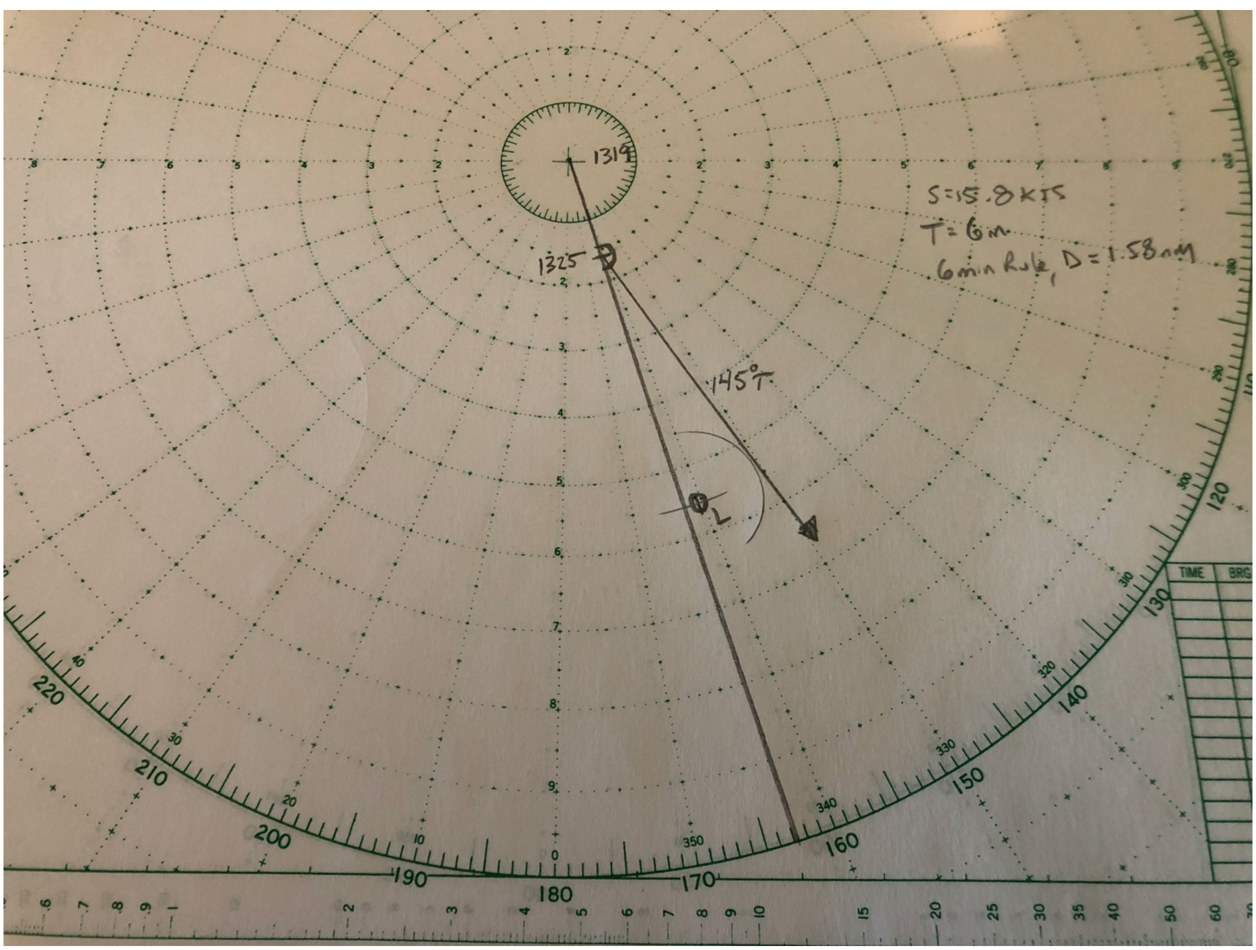
Step 1: Plot the initial course on a Maneuvering Board.

Step 2: Plot the bearing and range to the light.

Step 3: Plot a circle of 1.0 miles around the light.

Step 4: Determine the distance to the course change and mark the new 1325 position. Using the 6-minute rule, the distance is 1.58nm.

Step 5: Determine the course to steer with a tangent to the circle drawn in step 3.



Distance Off Problems

Distance at Second Bearing (Bowditch Table 7)

DIS B1. You are steaming on a course of 167° T at 19.5 knots. At 1837 you observe a lighthouse bearing 224° T. At 1904, the lighthouse bears 268° T. What is your distance off at the second bearing?

a) 8.8 miles
b) 9.5 miles
c) 10.4 miles - correct
d) 11.3 miles

DS B2. You are steaming on course 198° T at 18.5 knots. At 0316 you observe a lighthouse bearing 235° T. At 0348 the lighthouse bears 259° T. What is your distance off at the second bearing?

a) 14.8 miles - correct
b) 15.3 miles
c) 15.8 miles
d) 16.3 miles

DIS B3. You are steaming on a course of 211° T at 17 knots. At 0417 a light bears 184° T, and at 0428 the same light bears 168° T. What is the distance off the light at 0428?

a) 3.4 miles
b) 4.6 miles
c) 5.1 miles - correct
d) 5.6 miles

Distance Abeam (Bowditch Table 7)

DIS B4. Your vessel is steering 049° T at 15 knots. At 1914 a light bears 078° T and at 1951 the same light bears 116° T. What will be your distance off abeam?

a) **6.7 miles - correct**
b) 7.1 miles
c) 7.5 miles
d) 8.3 miles

DIS B5. Your vessel is steering 143° T at 16 knots. At 2147 a light bears 106° T and at 2206 the same light bears 078° T. What will be your distance off abeam?

a) 5.1 miles
b) 5.4 miles
c) **5.9 miles - correct**
d) 6.5 miles

DIS B6. Your vessel is steering 194° T at 13 knots. At 0116 a light bears 243° T and at 0147 the same light bears 267° T. What will be your distance off abeam?

a) 11.2 miles
b) 11.6 miles
c) **12.0 miles - correct**
d) 12.5 miles

Time and Distance Abeam (26.5° - 45° Special Case)

DIS B7. Your vessel is on a course of 052° T at 16 knots. At 0916 a light bears 078.5° T and at 0927 the light bears 097° T. At what time and at what distance off will your vessel be when abeam of the light?

a) 0929, 2.0 miles
b) 0932, 2.3 miles
c) 0935, 2.6 miles
d) 0938, 2.9 miles - correct

DIS B8. Your vessel is on a course of 079° T at 11 knots. At 0152 a light bears 105.5° T, and at 0209, the same light bears 124° T. At what time and at what distance off will your vessel be when abeam of the light?

a) 0219, 2.3 miles
b) 0226, 3.1 miles - correct
c) 0233, 3.9 miles
d) 0242, 4.7 miles

DIS B9. Your vessel is on course 237° T at 18 knots. At 0404 a light bears 263.5° T and at 0430 the light bears 282° T. At what time and at what distance off will your vessel be when abeam of the light?

a) 0448, 6.8 miles
b) 0452, 7.2 miles
c) 0456, 7.8 miles - correct
d) 0500, 8.4 miles

Time and Distance Abeam (22.5° - 45° Special Case)

DIS B10.Your vessel is on a course of 297° T at 11 knots. At 0019 a light bears 274.5° T and at 0048 the light bears 252° T. At what time and at what distance off will your vessel be when abeam of the light?

a) 0102, 2.6 miles
b) 0108, 3.7 miles - correct
c) 0057, 4.6 miles
d) 0117, 5.0 miles

DIS B11. Your vessel is on a course of 144° T at 16 knots. At 0126 a light bears 166.5° T and at 0152 the light bears 189° T. At what time and at what distance off will your vessel be when abeam of the light?

a) 0205, 4.1 miles
b) 0210, 4.8 miles - correct
c) 0215, 6.0 miles
d) 0220, 6.4 miles

DIS B12. Your vessel is on a course of 082° T at 19 knots. At 0255 a light bears 059.5° T and at 0312 the light bears 037° T. At what time and at what distance off will your vessel be when abeam of the light?

a) 0333, 5.1 miles
b) 0321, 4.7 miles
c) 0327, 4.3 miles
d) 0324, 3.8 miles - correct

Maneuvering Board Problems (Course to Steer)

DIS B13. While on course 034° pgc, a light bears 8° on the port bow at a distance of 8.8 miles. What course should you steer to pass 2.5 miles abeam of the light leaving it to port?

a) 035° pgc
b) 043° pgc - correct
c) 051° pgc
d) 059° pgc

DIS B14. While on course 066° pgc, a light bears 18° on the port bow at a distance of 12.3 miles. What course should you steer to pass 4 miles abeam of the light leaving it to port?

a) 067° pgc - correct
b) 072° pgc
c) 079° pgc
d) 085° pgc

DIS B15. While on course 283° pgc, a light bears 10° on the port bow at a distance of 8.3 miles. What course should you steer to pass 3.5 miles abeam of the light leaving it to port?

a) 289° pgc
b) 294° pgc
c) 298° pgc - correct
d) 302° pgc

DIS B16. While on course 159° T a light bears 11° on the starboard bow at a distance of 10.6 miles. What course should you steer to pass 2 miles abeam of the light leaving it to starboard?

a) 159° T - correct
b) 163° T
c) 167° T
d) 171° T

Maneuvering Board Problems (Time Abeam)

DIS B17. You are steering 163° T and a light is picked up dead ahead at a distance of 11 miles at 0142. You change course to pass the light 2 miles off abeam to starboard. If you are making 13 knots, what is your ETA at the position 2 miles off the light?

a) 0226
b) 0229
c) 0232 - correct
d) 0235

DIS B18. You are steering 115° T and a light is picked up dead ahead at a distance of 16.7 miles at 0522. You change course to pass the light 3.5 miles off abeam to port. If you are making 12 knots, what is your ETA at the position 3.5 miles off the light?

a) 0644 - correct
b) 0647
c) 0650
d) 0653

DIS B19. You are steering 349° T and a light is picked up dead ahead at a distance of 17.2 miles at 2122. You change course to pass the light 4.5 miles off abeam to port. If you are making 19.5 knots, what is your ETA at the position 4.5 miles off the light?

a) 2207
b) 2210
c) 2213 - correct
d) 2216

Maneuvering Board Problems (Course Changes)

DIS B20. You are underway on course 128° T at a speed of 17.6 knots. You sight a daymark bearing 126° T at a radar range of 4.3 miles at 1649. If you change course at 1654, what is the course to steer to leave the buoy abeam to starboard at 0.5 mile?

a) 113° T - correct
b) 116° T
c) 119° T
d) 121° T

DIS B21. You are underway on course 241° T at a speed of 18.2 knots. You sight a daymark bearing 241° T at a radar range of 3.9 miles at 1006. If you change course at 1009, what is the course to steer to leave the buoy abeam to starboard at 1.0 mile?

a) 218° T
b) 222° T - correct
c) 257° T
d) 260° T

DIS B22. You are underway on course 137° T at a speed of 16.2 knots. You sight a rock bearing 134° T at a radar range of 4.6 miles at 1508. If you change course at 1514, what is the course to steer to leave the buoy abeam to portat 1.5 mile?

a) 162° T - correct
b) 158° T
c) 154° T
d) 151° T

Tide and Tidal Current Problems

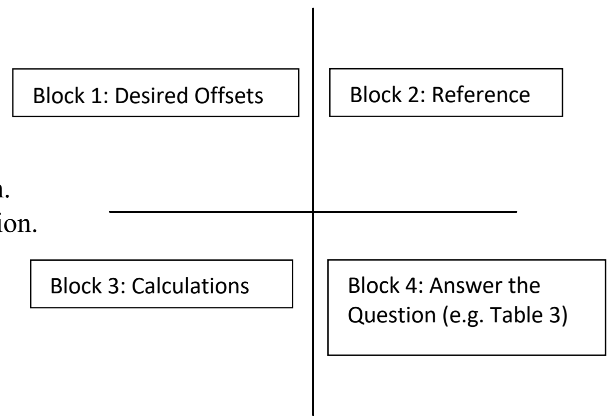
- Tide and current problems were traditionally tested in the Navigation General module but seem to be tested more often in the Navigation Problems section now. You should be prepared to see tide and current problems in either module.

- By using the below "method" for tide and current problems, you can generally stay organized and error trap effectively. This is helpful on a long test when you arrive at an incorrect answer and might save the day. However, there are many ways to complete tide and current problems.

- There are also several varieties of each type of problem. Having a fundamental understanding of tide and current problems will allow you to determine what the problem is asking and how to approach it. See the question bank for representations of all different problem types. For brevity, some are solved here, and some are simply provided with solutions.

Tide/Current Problems Method:

- Step 1: Find the desired station in Tables.
- Step 2: Find the reference station.
- Step 3: Note the times at reference station.
- Step 4: Apply corrections for desired station.
- Step 5: Answer the question, generally using Table 3.



TC D1. What is the height of tide at Three Mile Harbor Entrance, Gardiner's Bay on 14 November at 0700 (+5 ZD)?

Answer: 1.7 feet.

Station 1399

Hig	Low
+0:21	+0:02
-0.2ft	0.0ft

Reference: New London

High	Low
0453	1108
2.2ft	0.5ft

Three Mile Harbor Entrance

Hig	Low
0453	1108
+0:21	+0:02
0514	**1110**
2.2ft	0.5ft
-0.2ft	0.0ft
2.0ft	**0.5ft**

Desired Time: 0700

Duration of Rise/Fall: 5:56
Range of Tide: 1.5 ft
Time from **H**/L: 1:46

Correction to **High**: -0.3ft

2.0ft – 0.3ft = **1.7ft**

- Table 3 is included at the end of this document.

NEW LONDON, CONN., 1983

Times and Heights of High and Low Waters

NOVEMBER

14	0453	2.2	0.7
M	1108	0.5	0.2
	1658	2.2	0.7
	2326	0.2	0.1

NO.	PLACE	POSITION Lat.	POSITION Long.	DIFFERENCES Time High Water	DIFFERENCES Time Low Water	DIFFERENCES Height High Water	DIFFERENCES Height Low Water	RANGES Mean	RANGES Spring	Mean Tide Level
		° '	° '	h. m.	h. m.	ft	ft	ft	ft	ft
1393	New Suffolk	41 00	72 28	+2 26	+2 11	0.0	0.0	2.6	3.1	1.3
1395	South Jamesport	40 56	72 35	+2 32	+2 40	+0.1	0.0	2.7	3.2	1.3
1397	Shinnecock Canal	40 54	72 30	+2 33	+2 31	-0.2	0.0	2.4	2.9	1.2
1399	Threemile Harbor ent., Gardiners Bay	41 02	72 11	+0 21	+0 02	-0.2	0.0	2.4	2.9	1.2
1401	Promised Land, Napeague Bay	41 00	72 05	-0 14	-0 08	-0.3	0.0	2.3	2.7	1.1

TC D2. What is the height of tide at Falkner Island, CT, on 27 April at 1105 DST (+4 ZD)? Answer: 5.2 feet.

- Preliminary calculation: Tide tables are based on ZD +5. 1105 (+4 ZD) is the same as 1005 (+ 5ZD). We will solve the problem for 1005.

Station 1219

Hig	Low
-0:13	-0:27
-1.3ft	0.0ft

Reference: Bridgeport

High	Low
1115	0508
6.9ft	-1.2ft

Falkner Island

Hig	Low
1115	0508
-0:13	-0:27
1102	**0441**
6.9ft	-1.2ft
-1.3ft	0.0ft
5.6ft	**-1.2ft**

Desired Time: 1005

Duration of Rise/Fall: 6:21
Range of Tide: 6.8 ft
Time from **H**/L: 0:57

Correction to **High**: -0.4ft

5.6ft – 0.4ft = **5.2ft**

- Table 3 is included at the end of this document.

BRIDGEPORT, CONN., 1983

Times and Heights of High and Low Waters

27	0508	-1.2	-0.4
W	1115	6.9	2.1
	1721	-0.6	-0.2
	2329	7.6	2.3

NO.	PLACE	POSITION Lat.	POSITION Long.	DIFFERENCES Time High Water	DIFFERENCES Time Low Water	DIFFERENCES Height High Water	DIFFERENCES Height Low Water	RANGES Mean	RANGES Spring	Mean Tide Level
		° '	° '	h. m.	h. m.	ft	ft	ft	ft	ft
				on BRIDGEPORT, p.48						
1214	Westbrook, Duck Island Roads............	41 16	72 28	-0 23	-0 34	-2.6	0.0	4.1	4.7	2.0
1215	Duck Island............................	41 15	72 29	-0 25	-0 37	-2.2	0.0	4.5	5.2	2.2
1217	Madison................................	41 16	72 36	-0 20	-0 32	-1.8	0.0	4.9	5.6	2.4
1219	Falkner Island.........................	41 13	72 39	-0 13	-0 27	-1.3	0.0	5.4	6.2	2.7
1220	Sachem Head............................	41 15	72 42	-0 10	-0 17	-1.3	0.0	5.4	6.2	2.7

TC D3. What will be the time after 0800 EST (ZD +5) that the height of tide at South Freeport, ME will be 6.0 feet on 7 November?

Answer: 0952

Station 869

Hig	Low
+0:12	+0:10
-0.1ft	0.0ft

Reference: Portland

High	Low
1225	0613
10.1ft	-0.2ft

S. Freeport

Hig	Low	
1225	0613	
+0:12	+0:10	
1237	**0623**	
10.1ft	-0.2ft	
-0.1ft	0.0ft	
10.0ft	**-0.2ft**	
4.0ft	**6.2ft**	**Need Corr**

Desired Time: 1005

Duration of Rise/Fall: 6:14
Range of Tide: 10.2 ft
Correction **needed**: -4.0
10.0ft – 4.0ft = **6.0ft**

Reverse look up Time **H**/L: **2:45**

High: 1237 - 2:45 = **09:52**

- Table 3 is included at the end of this document.

PORTLAND, MAINE, 1983
Times and Heights of High and Low Waters
NOVEMBER

Day	Time h m	Height ft	Height m
7	0016	9.3	2.8
M	0613	-0.2	-0.1
	1225	10.1	3.1
	1850	-1.1	-0.3

NO.	PLACE	POSITION Lat.	POSITION Long.	DIFFERENCES Time High Water	DIFFERENCES Time Low Water	DIFFERENCES Height High Water	DIFFERENCES Height Low Water	RANGES Mean	RANGES Spring	Mean Tide Level
		° '	° '	h. m.	h. m.	ft	ft	ft	ft	ft
853	Small Point Harbor	43 44	69 51	-0 12	-0 09	-0.3	0.0	8.8	10.1	4.4
855	Cundy Harbor, New Meadows River	43 47	69 54	-0 01	-0 02	-0.2	0.0	8.9	10.2	4.4
857	Howard Point, New Meadows River	43 53	69 53	-0 05	+0 01	-0.1	0.0	9.0	10.3	4.5
859	Lowell Cove, Orrs Island	43 45	69 59	-0 07	-0 06	-0.3	0.0	8.8	10.1	4.4
861	Harpswell Harbor	43 46	70 00	-0 05	-0 05	-0.1	0.0	9.0	10.4	4.5
863	South Harpswell, Potts Harbor	43 44	70 01	+0 02	+0 01	-0.2	0.0	8.9	10.2	4.4
865	Wilson Cove, Middle Bay	43 49	69 59	+0 02	+0 02	0.0	0.0	9.1	10.5	4.5
867	Little Flying Point, Maquoit Bay	43 50	70 03	-0 01	-0 01	-0.1	0.0	9.0	10.3	4.5
869	South Freeport	43 49	70 06	+0 12	+0 10	-0.1	0.0	9.0	10.3	4.5

TC D4. What is the velocity of the tidal current at a point 2 miles west of Southwest Ledge RI on 7 September at 2330 EDT (ZD +4)?

Answer: 1.3 knots

- Preliminary calculation: Tide tables are based on ZD +5. 2330 (+4 ZD) is the same as 2230 (+ 5ZD). We will solve the problem for 2230.

Station 2216

Slack	Floo	Slack	Ebb
+0:02	+0:10	+0:01	-0:41
	x0.5		x0.5

Reference: The Race

Flood	Slack
2037	234
4.3kts	

2nm W. SW Ledge

Floo	Slack
2037	2342
+0:10	+0:01
2047	**2343**

4.3 kts
X0.5

2.15kts

Desired Time: 2230

Time Slack to Desired:1:13
Time Slack to Max: 2:56

Correction factor: 0.6

2.15kts x 0.6 = **1.3kts**

- Table 3 is included at the end of this document.

THE RACE, LONG ISLAND SOUND, 1983
F-Flood, Dir. 295° True E-Ebb, Dir. 100° True

SEPTEMBER

	Slack Water Time	Maximum Current Time	Vel.
7		0212	4.8E
W	0525	0814	4.2F
	1119	1439	4.7E
	1748	2037	4.3F
	2342		

NO.	PLACE	METER DEPTH	POSITION Lat.	Long.	TIME DIFFERENCES Min. before Flood	Flood	Min. before Ebb	Ebb	SPEED RATIOS Flood	Ebb	AVERAGE SPEEDS AND DIRECTIONS Minimum before Flood		Maximum Flood		Minimum before Ebb		Maximum Ebb	
2211	Southwest Ledge........................		41 07	71 42	-0 33	-0 33	-0 10	-0 08	0.5	0.5	0.0	- -	1.5	321	0.0	- -	2.1	141
2216	Southwest Ledge, 2.0 miles west of......	15	41 06.80	71 43.00	+0 02	+0 10	+0 01	-0 41	0.5	0.5	0.0	- -	1.5	354	0.0	- -	1.9	168
2221	Watch Hill Point, 2.2 miles east of.....		41 18.16	71 48.60	-0 37	-0 08	+0 35	-0 21	0.4	0.2	0.0	- -	1.2	260	0.0	- -	0.7	086

TC D5. Determine the duration of the first PM slack water on 3 March east of the Statue of Liberty, when the current is less than 0.1 knot.

Answer: 13 minutes

Station 3446

Slack	Floo	Slack	Ebb
+0:57	+0:58	+0:56	+0:59
	x0.8		x1.0

Reference: The Narrows

Flood	Slack	Ebb
0951	1251	1603
1.7kts		2.2kts

Statue of Liberty, East

Flood	Slac	Ebb
0951	1251	1603
+0:58	+0:56	+0:59
1049	1347	1702
1.7kts		2.2kts
x0.8		x1.0
1.4kts		**2.2kts**

Period of <0.1kts Slack, Table 4

Maximum current average:
(1.4+2.2)/2 = 1.8kts

Table 4:

Max	Period of Slack
1.5kts	15min
2.0kts	11 min

Interpolate answer to 13 min.

- Table 4 is included at the end of this document.

THE NARROWS, NEW YORK HARBOR, NEW YORK, 1983
F-Flood, Dir. 340° True E-Ebb, Dir. 160° True

MARCH

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
3	0035	0345	2.3E
Th	0722	0951	1.7F
	1251	1603	2.2E
	1939	2220	1.9F

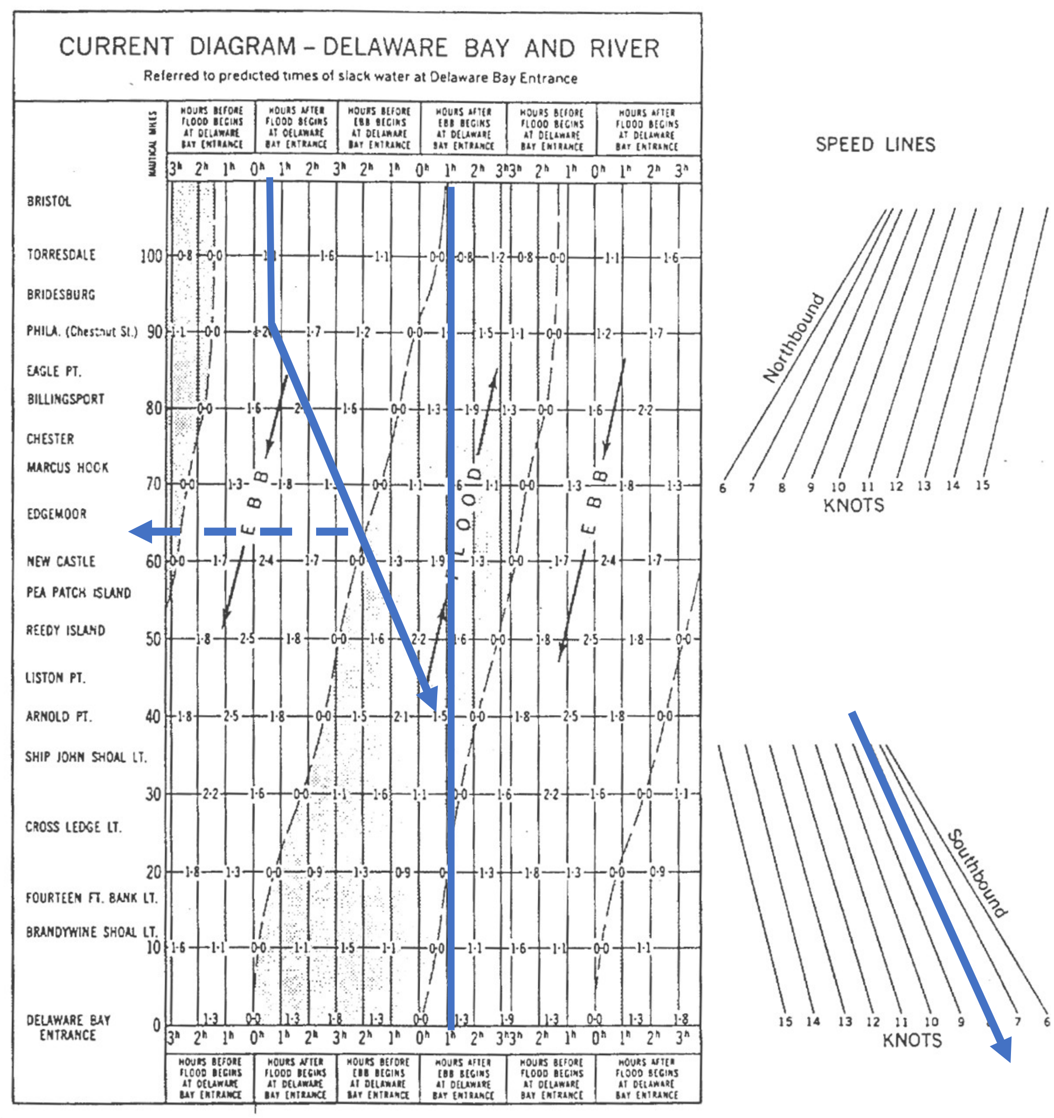
NO.	PLACE	METER DEPTH	POSITION Lat.	POSITION Long.	TIME DIFFERENCES Min. before Flood	TIME DIFFERENCES Flood	TIME DIFFERENCES Min. before Ebb	TIME DIFFERENCES Ebb	SPEED RATIOS Flood	SPEED RATIOS Ebb	Minimum before Flood		Maximum Flood		Minimum before Ebb		Maximum Ebb	
3416	Red Hook Channel........................		40 40.0	74 01.2	-1 03	-0 44	-0 08	-0 30	0.6	0.4	0.0	- -	1.0	353	0.0	- -	0.7	170
3426	Robbins Reef Light, east of.............		40 39.45	74 03.48	+0 16	+0 16	+0 02	+0 24	0.8	0.8	0.0	- -	1.3	016	0.0	- -	1.6	204
3436	Red Hook, 1 mile west of................		40 40.5	74 02.5	+0 41	+1 06	+0 47	+0 52	0.8	1.2	0.0	- -	1.3	024	0.0	- -	2.3	206
3446	Statue of Liberty, east of..............		40 41.4	74 01.8	+0 57	+0 58	+0 56	+0 59	0.8	1.0	0.0	- -	1.4	031	0.0	- -	1.9	205

TC D6. The predicted time that the flood begins at the entrance to Delaware Bay is 1526. You are anchored off Chestnut Street in Philadelphia. If you get underway bound for sea (southbound) at 1600 and make turns for 8 knots, at what point will you lose the ebb current?

Answer: Mile 63.

Time flood begins at Delaware Bay Entrance (given):	1526
Time underway:	1600
Departure time (difference between previous terms):	34m after flood begins at
Entrance Current Diagram:	8.0 knots southbound.

Use the current diagram with entering arguments of 8 knots southbound, Chester Street, and 34 minutes after the flood begins at Delaware Bay Entrance to find a **solution of mile 63.**



Duration of rise or fall, see footnote	Time from the nearest high water or low water														
h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
4 00	0 08	0 16	0 24	0 32	0 40	0 48	0 56	1 04	1 12	1 20	1 28	1 36	1 44	1 52	2 00
4 20	0 09	0 17	0 26	0 35	0 43	0 52	1 01	1 09	1 18	1 27	1 35	1 44	1 53	2 01	2 10
4 40	0 09	0 19	0 28	0 37	0 47	0 56	1 05	1 15	1 24	1 33	1 43	1 52	2 01	2 11	2 20
5 00	0 10	0 20	0 30	0 40	0 50	1 00	1 10	1 20	1 30	1 40	1 50	2 00	2 10	2 20	2 30
5 20	0 11	0 21	0 32	0 43	0 53	1 04	1 15	1 25	1 36	1 47	1 57	2 08	2 19	2 29	2 40
5 40	0 11	0 23	0 34	0 45	0 57	1 08	1 19	1 31	1 42	1 53	2 05	2 16	2 27	2 39	2 50
6 00	0 12	0 24	0 36	0 48	1 00	1 12	1 24	1 36	1 48	2 00	2 12	2 24	2 36	2 48	3 00
6 20	0 13	0 25	0 38	0 51	1 03	1 16	1 29	1 41	1 54	2 07	2 19	2 32	2 45	2 57	3 10
6 40	0 13	0 27	0 40	0 53	1 07	1 20	1 33	1 47	2 00	2 13	2 27	2 40	2 53	3 07	3 20
7 00	0 14	0 28	0 42	0 56	1 10	1 24	1 38	1 52	2 06	2 20	2 34	2 48	3 02	3 16	3 30
7 20	0 15	0 29	0 44	0 59	1 13	1 28	1 43	1 57	2 12	2 27	2 41	2 56	3 11	3 25	3 40
7 40	0 15	0 31	0 46	1 01	1 17	1 32	1 47	2 03	2 18	2 33	2 49	3 04	3 19	3 35	3 50
8 00	0 16	0 32	0 48	1 04	1 20	1 36	1 52	2 08	2 24	2 40	2 56	3 12	3 28	3 44	4 00
8 20	0 17	0 33	0 50	1 07	1 23	1 40	1 57	2 13	2 30	2 47	3 03	3 20	3 37	3 53	4 10
8 40	0 17	0 35	0 52	1 09	1 27	1 44	2 01	2 19	2 36	2 53	3 11	3 28	3 45	4 03	4 20
9 00	0 18	0 36	0 54	1 12	1 30	1 48	2 06	2 24	2 42	3 00	3 18	3 36	3 54	4 12	4 30
9 20	0 19	0 37	0 56	1 15	1 33	1 52	2 11	2 29	2 48	3 07	3 25	3 44	4 03	4 21	4 40
9 40	0 19	0 39	0 58	1 17	1 37	1 56	2 15	2 35	2 54	3 13	3 33	3 52	4 11	4 31	4 50
10 00	0 20	0 40	1 00	1 20	1 40	2 00	2 20	2 40	3 00	3 20	3 40	4 00	4 20	4 40	5 00
10 20	0 21	0 41	1 02	1 23	1 43	2 04	2 25	2 45	3 06	3 27	3 47	4 08	4 29	4 49	5 10
10 40	0 21	0 43	1 04	1 25	1 47	2 08	2 29	2 51	3 12	3 33	3 55	4 16	4 37	4 59	5 20

Range of tide, see footnote	Correction to height														
Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
1.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5
1.5	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8
2.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
2.5	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2
3.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.5
3.5	0.0	0.0	0.1	0.2	0.2	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.4	1.6	1.8
4.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.6	1.8	2.0
4.5	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2
5.0	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.8	1.0	1.2	1.5	1.7	2.0	2.2	2.5
5.5	0.0	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.1	1.4	1.6	1.9	2.2	2.5	2.8
6.0	0.0	0.1	0.1	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.7	3.0
6.5	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.1	1.3	1.6	1.9	2.2	2.6	2.9	3.2
7.0	0.0	0.1	0.2	0.3	0.5	0.7	0.9	1.2	1.4	1.8	2.1	2.4	2.8	3.1	3.5
7.5	0.0	0.1	0.2	0.3	0.5	0.7	1.0	1.2	1.5	1.9	2.2	2.6	3.0	3.4	3.8
8.0	0.0	0.1	0.2	0.3	0.5	0.8	1.0	1.3	1.6	2.0	2.4	2.8	3.2	3.6	4.0
8.5	0.0	0.1	0.2	0.4	0.6	0.8	1.1	1.4	1.8	2.1	2.5	2.9	3.4	3.8	4.2
9.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.5	1.9	2.2	2.7	3.1	3.6	4.0	4.5
9.5	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.6	2.0	2.4	2.8	3.3	3.8	4.3	4.8
10.0	0.0	0.1	0.2	0.4	0.7	1.0	1.3	1.7	2.1	2.5	3.0	3.5	4.0	4.5	5.0
10.5	0.0	0.1	0.3	0.5	0.7	1.0	1.3	1.7	2.2	2.6	3.1	3.6	4.2	4.7	5.2
11.0	0.0	0.1	0.3	0.5	0.7	1.1	1.4	1.8	2.3	2.8	3.3	3.8	4.4	4.9	5.5
11.5	0.0	0.1	0.3	0.5	0.8	1.1	1.5	1.9	2.4	2.9	3.4	4.0	4.6	5.1	5.8
12.0	0.0	0.1	0.3	0.5	0.8	1.1	1.5	2.0	2.5	3.0	3.6	4.1	4.8	5.4	6.0
12.5	0.0	0.1	0.3	0.5	0.8	1.2	1.6	2.1	2.6	3.1	3.7	4.3	5.0	5.6	6.2
13.0	0.0	0.1	0.3	0.6	0.9	1.2	1.7	2.2	2.7	3.2	3.9	4.5	5.1	5.8	6.5
13.5	0.0	0.1	0.3	0.6	0.9	1.3	1.7	2.2	2.8	3.4	4.0	4.7	5.3	6.0	6.8
14.0	0.0	0.2	0.3	0.6	0.9	1.3	1.8	2.3	2.9	3.5	4.2	4.8	5.5	6.3	7.0
14.5	0.0	0.2	0.4	0.6	1.0	1.4	1.9	2.4	3.0	3.6	4.3	5.0	5.7	6.5	7.2
15.0	0.0	0.2	0.4	0.6	1.0	1.4	1.9	2.5	3.1	3.8	4.4	5.2	5.9	6.7	7.5
15.5	0.0	0.2	0.4	0.7	1.0	1.5	2.0	2.6	3.2	3.9	4.6	5.4	6.1	6.9	7.8
16.0	0.0	0.2	0.4	0.7	1.1	1.5	2.1	2.6	3.3	4.0	4.7	5.5	6.3	7.2	8.0
16.5	0.0	0.2	0.4	0.7	1.1	1.6	2.1	2.7	3.4	4.1	4.9	5.7	6.5	7.4	8.2
17.0	0.0	0.2	0.4	0.7	1.1	1.6	2.2	2.8	3.5	4.2	5.0	5.9	6.7	7.6	8.5
17.5	0.0	0.2	0.4	0.8	1.2	1.7	2.2	2.9	3.6	4.4	5.2	6.0	6.9	7.8	8.8
18.0	0.0	0.2	0.4	0.8	1.2	1.7	2.3	3.0	3.7	4.5	5.3	6.2	7.1	8.1	9.0
18.5	0.1	0.2	0.5	0.8	1.2	1.8	2.4	3.1	3.8	4.6	5.5	6.4	7.3	8.3	9.2
19.0	0.1	0.2	0.5	0.8	1.3	1.8	2.4	3.1	3.9	4.8	5.6	6.6	7.5	8.5	9.5
19.5	0.1	0.2	0.5	0.8	1.3	1.9	2.5	3.2	4.0	4.9	5.8	6.7	7.7	8.7	9.8
20.0	0.1	0.2	0.5	0.9	1.3	1.9	2.6	3.3	4.1	5.0	5.9	6.9	7.9	9.0	10.0

Obtain from the predictions the high water and low water, one of which is before and the other after the time for which the height is required. The difference between the times of occurrence of these tides is the duration of rise or fall, and the difference between their heights is the range of tide for the above table. Find the difference between the nearest high or low water and the time for which the height is required.

Enter the table with the duration of rise or fall, printed in heavy-faced type, which most nearly agrees with the actual value, and on that horizontal line find the time from the nearest high or low water which agrees most nearly with the corresponding actual difference. The correction sought is in the column directly below, on the line with the range of tide.

When the nearest tide is high water, subtract the correction.

When the nearest tide is low water, add the correction.

TABLE 3.—VELOCITY OF CURRENT AT ANY TIME

TABLE A

Interval between slack and desired time	Interval between slack and maximum current													
h. m.	h. m. 1 20	h. m. 1 40	h. m. 2 00	h. m. 2 20	h. m. 2 40	h. m. 3 00	h. m. 3 20	h. m. 3 40	h. m. 4 00	h. m. 4 20	h. m. 4 40	h. m. 5 00	h. m. 5 20	h. m. 5 40
	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.
0 20	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0 40	0.7	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2
1 00	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3
1 20	1.0	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4
1 40	......	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4
2 00	......	......	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5
2 20	......	......	......	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.6	0.6
2 40	......	......	......	......	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.7
3 00	......	......	......	......	......	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.7
3 20	......	......	......	......	......	......	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8
3 40	......	......	......	......	......	......	......	1.0	1.0	1.0	0.9	0.9	0.9	0.9
4 00	......	......	......	......	......	......	......	......	1.0	1.0	1.0	1.0	0.9	0.9
4 20	......	......	......	......	......	......	......	......	......	1.0	1.0	1.0	1.0	0.9
4 40	......	......	......	......	......	......	......	......	......	......	1.0	1.0	1.0	1.0
5 00	......	......	......	......	......	......	......	......	......	......	......	1.0	1.0	1.0
5 20	......	......	......	......	......	......	......	......	......	......	......	......	1.0	1.0
5 40	......	......	......	......	......	......	......	......	......	......	......	......	......	1.0

TABLE B

Interval between slack and desired time	Interval between slack and maximum current													
h. m.	h. m. 1 20	h. m. 1 40	h. m. 2 00	h. m. 2 20	h. m. 2 40	h. m. 3 00	h. m. 3 20	h. m. 3 40	h. m. 4 00	h. m. 4 20	h. m. 4 40	h. m. 5 00	h. m. 5 20	h. m. 5 40
	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.
0 20	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
0 40	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
1 00	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4
1 20	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5
1 40	......	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6
2 00	......	......	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.6
2 20	......	......	......	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7
2 40	......	......	......	......	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.7
3 00	......	......	......	......	......	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.8	0.8
3 20	......	......	......	......	......	......	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8
3 40	......	......	......	......	......	......	......	1.0	1.0	1.0	1.0	0.9	0.9	0.9
4 00	......	......	......	......	......	......	......	......	1.0	1.0	1.0	1.0	0.9	0.9
4 20	......	......	......	......	......	......	......	......	......	1.0	1.0	1.0	1.0	0.9
4 40	......	......	......	......	......	......	......	......	......	......	1.0	1.0	1.0	1.0
5 00	......	......	......	......	......	......	......	......	......	......	......	1.0	1.0	1.0
5 20	......	......	......	......	......	......	......	......	......	......	......	......	1.0	1.0
5 40	......	......	......	......	......	......	......	......	......	......	......	......	......	1.0

Use table A for all places except those listed below for table B.
Use table B for Cape Cod Canal, Hell Gate, Chesapeake and Delaware Canal and all stations in table 2 which are referred to them.

1. From predictions find the time of slack water and the time and velocity of maximum current (flood or ebb), one of which is immediately before and the other after the time for which the velocity is desired.
2. Find the interval of time between the above slack and maximum current, and enter the top of table A or B with the interval which most nearly agrees with this value.
3. Find the interval of time between the above slack and the time desired, and enter the side of table A or B with the interval which most nearly agrees with this value.
4. Find, in the table, the factor corresponding to the above two intervals, and multiply the maximum velocity by this factor. The result will be the approximate velocity at the time desired.

Duration of weak current near time of slack water

TABLE A

Maximum current	Period with a velocity not more than—				
	0.1 knot	0.2 knot	0.3 knot	0.4 knot	0.5 knot
Knots	*Minutes*	*Minutes*	*Minutes*	*Minutes*	*Minutes*
1.0	23	46	70	94	120
1.5	15	31	46	62	78
2.0	11	23	35	46	58
3.0	8	15	23	31	38
4.0	6	11	17	23	29
5.0	5	9	14	18	23
6.0	4	8	11	15	19
7.0	3	7	10	13	16
8.0	3	6	9	11	14
9.0	3	5	8	10	13
10.0	2	5	7	9	11

Tide and Tidal Current Problems

Tide
Problems

TC B1. Determine the height of the tide at 2045 EST (ZD +5) at Augusta, ME, on 8 March 1983.

a) 1.4 feet (0.5 meter)
b) 1.9 feet (0.6 meter) - correct
c) 2.3 feet (0.7 meter)
d) 2.6 feet (0.8 meter)

TC B2. What will be the height of tide at Three Mile Harbor Entrance, Gardiner's Bay, NY, at 0700 (ZD +5) on 14 November 1983?

a) 1.1 feet
b) 1.7 feet - correct
c) 1.9 feet
d) 2.2 feet

TC B3. On 10 August 1983 you will dock near Days Point, Weehawken, on the Hudson River at 1800 DST (ZD +4). The charted depth alongside the pier is 24 feet (7.3 meters). What will be the depth of water when you dock?

a) 23.5 feet (7.1 m)
b) 23.9 feet (7.2m) - correct
c) 24.9 feet (7.5m)
d) 26.3 feet (8.0m)

TC B4. You are to sail from Elizabethport, NJ on 22 May 1983 with a maximum draft of 28 feet. You will pass over an obstruction with a charted depth of 27 feet. The steaming time from Elizabethport to the obstruction is 1h 40m. What is the earliest time (ZD +4) you can sail on the afternoon of 22 May and pass over the obstruction with 3 feet of clearance?

a) 1407 - correct
b) 1331
c) 1303
d) 1242

TC B5. What will be the time after 1000 EST (ZD +5), on 4 March 1983, that the height of the tide at City Island, NY, will be 2.4 feet?

a) 1228 - correct
b) 1240
c) 1244
d) 1248

Tidal Current Problems

TC B6. What is the predicted velocity of the tidal current 2 miles west of Southwest Ledge for 2330 DST (ZD +4) on 7 September 1983?

- **a) 1.3 knots - correct**
- **b)** 1.6 knots
- **c)** 1.9 knots
- **d)** 2.2 knots

TC B7. What will be the direction and velocity of the tidal current at Provincetown Harbor, MA at 1045 DST (ZD +4) on 5 May 1983?

- a) 0.0 knot at 135° T
- b) 0.2 knot at 135° T
- **c) 0.4 knot at 315° T - correct**
- d) 0.6 knot at 315° T

TC B8. What is the period of time from around 1008 EST (ZD +4) at Canapipsit Channel, MA on 7 August 1983, in which the current does not exceed 0.4 knots?

- a) 0945 to 1031
- b) 0950 to 1026
- **c) 0955 to 1021 - correct**
- d) 1000 to 1024

TC B9. The predicted time that the flood begins at the entrance to Delaware Bay is 1526. You are anchored off Chestnut Street in Philadelphia. If you get underway bound for sea at 1600 and turn for 8 knots, at what point will you lose the ebb current?

- a) Billingsport
- b) Marcus Hook
- **c) Mile 63 - correct**
- d) Mile 52

TC B10. Determine the duration of the first PM slack water on 3 March, 1983, east of the Statue of Liberty, when the current is less than 0.1 knot?

- a) 10 minutes
- **b) 13 minutes - correct**
- c) 16 minutes
- d) 19 minutes

TC B11. Determine the time after 0300 CST (ZD +6) when the velocity of the tidal current will be 0.5 knot on 16 April 1983 at Port Arthur Canal Entrance, TX.

a) 0436
b) 0507 - correct
c) 0538
d) 0554

TC B12. You are bound for the Chelsea docks in the Hudson River. The Captain wants to arrive at the docks at the first slack water on 28 July 1983. You are keeping daylight saving time. What time should you be at the docks?

a) 0215 - correct
b) 0530
c) 0811
d) 0911

Amplitude Problems

- Amplitude problems involve calculating the bearing at which an object *should* rise or set, and then comparing the calculation to actual observation in order to determine compass error. Amplitude is the easiest means of determining gyro error at sea, and can involve the sun, moon, or planets and stars.

- **Declination** - the angular distance north or south of the celestial equator, or the latitude of the point on earth directly beneath a celestial object. For example, if the sun's declination is 10° N, the sun is directly overhead at 10° N.

- **Amplitude** – the angular distance north or south of the equator of a celestial body on the horizon. Amplitudes are named based on the direction of the object and the difference from the equator. For example, if the sunset is observed at 280° T, the amplitude of the sun is W 10° N. If the sunrise is observed at 080° T, the amplitude of the sun is E 10° N. Amplitudes are found in Table 22 or Table 27 of Bowditch (depending on version used).

- **Horizon** – There are several different versions of "horizon" in celestial navigation. The simplest calculations are made when objects are on the "celestial" horizon as follows:
    - Sun – ideally when the sun's lower limb is 2/3 of a sun diameter (20 arc minutes) above the visual horizon.
    - Stars and Planets – ideally when the object is one sun diameter (30 arc minutes) above the visual horizon.
    - Moon – ideally when the upper limb of the moon is on the visual horizon.

- When objects are not on the "celestial" horizon, corrections must be made using Table 23 or Table 28 in Bowditch (depending on the version used). This correction has different rules depending on the body, season, and location.

Amplitude Problems of the Sun on the Celestial Horizon

AMP D1. It is 20 May. You have taken an observation of the rising sun when its lower limb is approximately 2/3 of a sun's diameter above the horizon (in other words the sun's center is on the celestial horizon). The time of observation is 1000 UTC. Your latitude is 36° N.

a) What is the amplitude of the sun?
b) What true bearing should the sunrise be observed?
c) If you actually observe the sun rising at 068° T, what is the gyro error?

Answers:
a) E 25° N
b) 065° T
c) 3° W

Step 1: Determine the declination of the sun for the time of observation using the Nautical Almanac. The declination at 1000 UTC is N 20° 00'.

G.M.T.		SUN	
		G.H.A.	Dec.
20	00	180 53.7	N19 54.8
	01	195 53.7	55.3
	02	210 53.6	55.8
	03	225 53.6	· · 56.3
	04	240 53.6	56.9
	05	255 53.5	57.4
	06	270 53.5	N19 57.9
W	07	285 53.5	58.4
E	08	300 53.4	59.0
D	09	315 53.4	19 59.5
N	10	330 53.4	20 00.0
E	11	345 53.3	00.5

Step 2: Determine the ship's latitude at the time of observation. Latitude – 36° N (given)

Step 3: Enter Table 22/27 in Bowditch with declination and latitude to determine the amplitude.
Declination: 20°
Latitude: 36°

Amplitudes

Latitude	Declination 18°0	18°5	19°0	19°5	20°0	20°5	21°0	21°5	22°0	22°5	23°0	23°5	24°0	Latitude
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	0
10	18.3	18.8	19.3	19.8	20.3	20.8	21.3	21.8	22.4	22.9	23.4	23.9	24.4	10
15	18.7	19.2	19.7	20.2	20.7	21.3	21.8	22.3	22.8	23.3	23.9	24.4	24.9	15
20	19.2	19.7	20.3	20.8	21.3	21.9	22.4	23.0	23.5	24.0	24.6	25.1	25.6	20
25	19.9	20.5	21.1	21.6	22.2	22.7	23.3	23.9	24.4	25.0	25.5	26.1	26.7	25
30	20.9	21.5	22.1	22.7	23.3	23.9	24.4	25.0	25.6	26.2	26.8	27.4	28.0	30
32	21.4	22.0	22.6	23.2	23.8	24.4	25.0	25.6	26.2	26.8	27.4	28.0	28.7	32
34	21.9	22.5	23.1	23.7	24.4	25.0	25.6	26.2	26.9	27.5	28.1	28.7	29.4	34
36	22.5	23.1	23.7	24.4	25.0	25.7	26.3	26.9	27.6	28.2	28.9	29.5	30.2	36
38	23.1	23.7	24.4	25.1	25.7	26.4	27.1	27.7	28.4	29.1	29.7	30.4	31.1	38

Step 4: Answer required questions.

a) **Amplitude = E 25° N**
b) Standard sunrise is 090° T. In the northern hemisphere in spring and summer, the sun rises north of east (e.g. the declination is North). Therefore, the calculated sunrise is 090° - 25° = **065° T**
c) If the sun is observed rising at 068° T, while the calculated sunrise is 065° T, the gyro error is 068° - 065° = 3°. To determine the direction of error, use the mnemonic "Gyro Best, Error West, Gyro Least, Error East." In this case, the gyro is higher (best) than the observation, so the error is **3° W.**

AMP D2. On 24 August in DR position latitude 26° 49.4' N, longitude 146° 19.4' E, you observe an amplitude of the Sun. The Sun's center is on the celestial horizon and bears 084° psc. The chronometer reads 07h 55m 06s and is 01m 11s fast. Variation in the area is 15° W. What is the deviation of the magnetic compass?

Answer: 8.2° E deviation.

Step 1: Determine the actual time of observation.
07:55:06 chronometer time of observation
00:01:11 fast on GMT
07:55:06 – 00:01:11 = 07:53:55 correct chronometer time

146° 19.4’ E corresponds to a zone time of (-10). Since the approximate zone time is 07:53, the correct GMT is actually 19:53:55, on the 23rd of August.

Step 2: Determine the declination of the sun for the time of observation using the Nautical Almanac.

The declination at 19:53:55 is not given in the Nautical Almanac and must be interpolated.

The base value for 1900 is N 11° 17.0’ and decreasing.
The *d* value for 23-25 August is 0.9.

G.M.T.	SUN G.H.A.	SUN Dec.
18	89 22.5	N11 17.8
19	104 22.6	17.0
20	119 22.8	16.1
21	134 23.0	· · 15.3
22	149 23.1	14.4
23	164 23.3	13.6
	S.D. 15.8	*d* 0.9

Enter the Increments and Corrections Page in the Nautical Almanac with the daily *d* value and a time of 53 minutes, 55 seconds (the difference between the base declination and the observation time).

Given a *d* value of 0.9, the declination correction factor is 0.8.

Since the declination is decreasing from hour to hour, the corrected declination for 24 August at 19:53:55 is N 11° 17.0’ – 0.8’= <u>N 11° 16.2’</u>

53m	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° ′	° ′	° ′	′	′	′	′	′	′
00	13 15.0	13 17.2	12 38.8	0.0	0.0	6.0	5.4	12.0	10.7
01	13 15.3	13 17.4	12 39.0	0.1	0.1	6.1	5.4	12.1	10.8
02	13 15.5	13 17.7	12 39.3	0.2	0.2	6.2	5.5	12.2	10.9
03	13 15.8	13 17.9	12 39.5	0.3	0.3	6.3	5.6	12.3	11.0
04	13 16.0	13 18.2	12 39.7	0.4	0.4	6.4	5.7	12.4	11.1
05	13 16.3	13 18.4	12 40.0	0.5	0.4	6.5	5.8	12.5	11.1
06	13 16.5	13 18.7	12 40.2	0.6	0.5	6.6	5.9	12.6	11.2
07	13 16.8	13 18.9	12 40.5	0.7	0.6	6.7	6.0	12.7	11.3
08	13 17.0	13 19.2	12 40.7	0.8	0.7	6.8	6.1	12.8	11.4
09	13 17.3	13 19.4	12 40.9	0.9	0.8	6.9	6.2	12.9	11.5

Step 3: Determine the ship’s latitude at the time of observation.
Latitude – 26° 49.4’ N (given)

Step 4: Enter Table 22/27 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: N 11° 16.2’ = N 11.3°
Latitude: 26° 49.4’ N = 26.8° N

Amplitudes														
Latitude	Declination													Latitude
	6°.0	6°.5	7°.0	7°.5	8°.0	8°.5	9°.0	9°.5	10°.0	10°.5	11°.0	11°.5	12°.0	
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	0
10	6.1	6.6	7.1	7.6	8.1	8.6	9.1	9.6	10.2	10.7	11.2	11.7	12.2	10
15	6.2	6.7	7.2	7.8	8.3	8.8	9.3	9.8	10.4	10.9	11.4	11.9	12.4	15
20	6.4	6.9	7.5	8.0	8.5	9.0	9.6	10.1	10.6	11.2	11.7	12.2	12.8	20
25	6.6	7.2	7.7	8.3	8.8	9.4	9.9	10.5	11.0	11.6	12.2	12.7	13.3	25
30	6.9	7.5	8.1	8.7	9.2	9.8	10.4	11.0	11.6	12.1	12.7	13.3	13.9	30
32	7.1	7.7	8.3	8.9	9.4	10.0	10.6	11.2	11.8	12.4	13.0	13.6	14.2	32
34	7.2	7.8	8.5	9.1	9.7	10.3	10.9	11.5	12.1	12.7	13.3	13.9	14.5	34
36	7.4	8.0	8.7	9.3	9.9	10.5	11.1	11.8	12.4	13.0	13.6	14.3	14.9	36
38	7.6	8.3	8.9	9.5	10.2	10.8	11.5	12.1	12.7	13.4	14.0	14.7	15.3	38

a) Since the entering values are not whole numbers of declination or latitude, interpolation is required. Locate the bracketing values.

	Declination 11.0°	**Declination 11.3°**	Declination 11.5°
Latitude 25°	12.2°		12.7°
Latitude 26.8°		**Unknown value**	
Latitude 30°	12.7°		13.3°

b) Interpolate the bracketing values four ways to the nearest tenth.

	Declination 10.5°	**Declination 10.9°**	Declination 11°
Latitude 25°	12.2°	**12.6°**	12.7°
Latitude 26.8°	**12.4°**	**Unknown value**	**12.9°**
Latitude 30°	12.7°	**13.2°**	13.3°

c) Solve the interpolation for the desired value.

	Declination 10.5°	**Declination 10.9°**	Declination 11°
Latitude 25°	12.2°	12.6°	12.7°
Latitude 26.8°	12.4°	**12.8°**	12.9°
Latitude 30°	12.7°	13.2°	13.3°

**Note that the amplitude can also be solved directly using the instructions in the Bowditch table 22/27 explanation.*

$$\sin(Amplitude) = \sec(Latitude) \times \sin(Declination)$$

-or –

$$\sin(Amplitude) = \frac{\sin(Declination)}{\cos\,(Latitude)}$$

Step 5: Answer required questions.

Since the calculated amplitude is 12.8°, the sun is rising, and the season is summer in the northern hemisphere (e.g. the declination of the body is north), the correct notation for the amplitude is E 12.8° N, and the calculated compass bearing to sunrise should be:

090° - 12.8° = 77.2° T

Therefore, using a compass correction formula, the deviation of the compass is calculated as:

T: 77.2° T (Bearing to sunrise)
V: 15° W (Given)
M: 092.2° (Calculated)
D:
C: 084° psc (Given)

Deviation = 8.2° E

Amplitude Problems of the Sun on the Visible Horizon

AMP D3. It is 18 August. You have taken an observation of the rising sun when its center is on the visible horizon. The time of observation is 1500 UTC. Your latitude is 52° N.

a) What is the amplitude of the sun?
b) What true bearing should the sunrise be observed?
c) If you actually observe the sun rising at 065° pgc, what is the gyro error?

Answers:
a) Amplitude: E 21.4° N
b) True bearing: 068.6° T
c) Gyro error: 2.6° E

Step 1: Determine the declination of the sun for the time of observation using the Nautical Almanac.
The declination at 1500 UTC is N 13° 00’.

G.M.T.	SUN G.H.A.	SUN Dec.
12	359 03.3	N13 02.5
13	14 03.4	01.7
14	29 03.6	00.8
15	44 03.7	13 00.0
16	59 03.8	12 59.2
17	74 04.0	58.4

Step 2: Determine the ship’s latitude at the time of observation.
Latitude – 52° N (given)

Step 3: Enter Table 23/28 in Bowditch with declination and latitude to determine a correction due to the object’s location on the visible horizon.

Correction of Amplitude as Observed on the Visible Horizon

Declination 0°	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	Latitude
°	°	°	°	°	°	°	°	°	°	°	°	°	°
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	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	10
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	15
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	20
0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	25
0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	30
0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	32
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	34
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.6	36
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	38
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	40
0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	42
0.7	0.7	0.7	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	44
0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	46
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	48
0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.0	50
0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.0	1.1	1.1	1.1	51
0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.3	52
0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.2	1.2	1.3	53
1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.3	1.3	54

The correction is 1.0° (interpolated between the tabular values for 12° and 14° declination).

Step 4: Enter Table 22/27 in Bowditch with declination and latitude to determine the amplitude.
Declination: 13°
Latitude: 52°

Amplitudes

Latitude	Declination 12°0	12°5	13°0	13°5	14°0	14°5	15°0	15°5	16°0	16°5	17°0	17°5	18°0	Latitude
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	0
10	12.2	12.7	13.2	13.7	14.2	14.7	15.2	15.7	16.3	16.8	17.3	17.8	18.3	10
15	12.4	12.9	13.5	14.0	14.5	15.0	15.5	16.1	16.6	17.1	17.6	18.1	18.7	15
20	12.8	13.3	13.9	14.4	14.9	15.5	16.0	16.5	17.1	17.6	18.1	18.7	19.2	20
25	13.3	13.8	14.4	14.9	15.5	16.0	16.6	17.1	17.7	18.3	18.8	19.4	19.9	25
30	13.9	14.5	15.1	15.6	16.2	16.8	17.4	18.0	18.6	19.1	19.7	20.3	20.9	30
32	14.2	14.8	15.4	16.0	16.6	17.2	17.8	18.4	19.0	19.6	20.2	20.8	21.4	32
34	14.5	15.1	15.7	16.4	17.0	17.6	18.2	18.8	19.4	20.0	20.7	21.3	21.9	34
36	14.9	15.5	16.1	16.8	17.4	18.0	18.7	19.3	19.9	20.6	21.2	21.8	22.5	36
38	15.3	15.9	16.6	17.2	17.9	18.5	19.2	19.8	20.5	21.1	21.8	22.4	23.1	38
40	15.7	16.4	17.1	17.7	18.4	19.1	19.7	20.4	21.1	21.8	22.4	23.1	23.8	40
41	16.0	16.7	17.3	18.0	18.7	19.4	20.1	20.8	21.4	22.1	22.8	23.5	24.2	41
42	16.2	16.9	17.6	18.3	19.0	19.7	20.4	21.1	21.8	22.5	23.2	23.9	24.6	42
43	16.5	17.2	17.9	18.6	19.3	20.0	20.7	21.4	22.1	22.9	23.6	24.3	25.0	43
44	16.8	17.5	18.2	18.9	19.7	20.4	21.1	21.8	22.5	23.3	24.0	24.7	25.4	44
45	17.1	17.8	18.5	19.3	20.0	20.7	21.5	22.2	22.9	23.7	24.4	25.2	25.9	45
46	17.4	18.2	18.9	19.6	20.4	21.1	21.9	22.6	23.4	24.1	24.9	25.7	26.4	46
47	17.7	18.5	19.3	20.0	20.8	21.5	22.3	23.1	23.8	24.6	25.4	26.2	26.9	47
48	18.1	18.9	19.6	20.4	21.2	22.0	22.8	23.5	24.3	25.1	25.9	26.7	27.5	48
49	18.5	19.3	20.1	20.8	21.6	22.4	23.2	24.0	24.8	25.7	26.5	27.3	28.1	49
50	18.9	19.7	20.5	21.3	22.1	22.9	23.7	24.6	25.4	26.2	27.1	27.9	28.7	50
51	19.3	20.1	20.9	21.8	22.6	23.4	24.3	25.1	26.0	26.8	27.7	28.5	29.4	51
52	19.7	20.6	21.4	22.3	23.1	24.0	24.9	25.7	26.6	27.5	28.3	29.2	30.1	52
53	20.2	21.1	21.9	22.8	23.7	24.6	25.5	26.4	27.3	28.2	29.1	30.0	30.9	53
54	20.7	21.6	22.5	23.4	24.3	25.2	26.1	27.0	28.0	28.9	29.8	30.8	31.7	54

a) This yields an amplitude of 21.4° or (E 21.4° N).

Step 5: Answer required questions.

a) Due to the object being on the visible horizon, the observation must be corrected.
   - Correction from Table 23/28 = 1.0°
   - The correction must be applied to the observation (not the amplitude) *away from the elevated (nearest) pole.*
   - In this case, the ship is in the northern hemisphere, so the elevated pole is north. The initial observation is 065° pgc.
   - The corrected observation is 065° pgc + 1.0° = 066° pgc.

b) Standard sunrise is 090° T. In the northern hemisphere in spring and summer, the sun rises north of east. Therefore, using the amplitude (E 21.4° N) the calculated sunrise is 090° - 21.4° = **68.6° T**

c) If the sun (corrected) is observed rising at 066° pgc, while the calculated sunrise is 68.6° T, the gyro error is 68.6° - 66° = 2.6°.

d) To determine the direction of error, use the mnemonic "Gyro Best, Error West, Gyro Least, Error East." In this case, the gyro is lower (least) than the observation, so the error is **2.6° E.**

AMP D4. On 11 May, in DR position latitude 37° 06.0’ N, longitude 45° 45.0’ W, you observe an amplitude of the Sun. The Sun’s center is on the visible horizon and bears 089° psc. The chronometer reads 07h 57m 06s and is 1m 48s slow. Variation is 20.0° W. What is the deviation?

Answer: 2.3° W deviation.

Step 1: Determine the actual time of observation.
07:57:06 chronometer time of observation
00:01:48 slow on GMT
07:57:06 + 00:01:48 = 07:58:54 correct chronometer time

45° 45.0’ W corresponds to a zone time of (+3) and the correct GMT is 07:58:54.

Step 2: Determine the declination of the sun for the time of observation using the Nautical Almanac.

G.M.T.	SUN G.H.A.	SUN Dec.
06	270 55.2	N17 51.8
07	285 55.2	52.5
08	300 55.2	53.1
	S.D. 15.9	*d* 0.6

The declination at 07:58:54 is not given in the Nautical Almanac and must be interpolated.

The base value for 0700 is N 17° 52.5’ and increasing.
The d value for 10-12 May is 0.6.

Enter the Increments and Corrections Page in the Nautical Almanac with the daily d value and a time of 58 minutes (the difference between the base declination and the observation time).

58m	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	14 30·0	14 32·4	13 50·4	0·0	0·0	6·0	5·9	12·0	11·7
01	14 30·3	14 32·6	13 50·6	0·1	0·1	6·1	5·9	12·1	11·8
02	14 30·5	14 32·9	13 50·8	0·2	0·2	6·2	6·0	12·2	11·9
03	14 30·8	14 33·1	13 51·1	0·3	0·3	6·3	6·1	12·3	12·0
04	14 31·0	14 33·4	13 51·3	0·4	0·4	6·4	6·2	12·4	12·1
05	14 31·3	14 33·6	13 51·6	0·5	0·5	6·5	6·3	12·5	12·2
06	14 31·5	14 33·9	13 51·8	0·6	0·6	6·6	6·4	12·6	12·3
07	14 31·8	14 34·1	13 52·0	0·7	0·7	6·7	6·5	12·7	12·4
08	14 32·0	14 34·4	13 52·3	0·8	0·8	6·8	6·6	12·8	12·5
09	14 32·3	14 34·6	13 52·5	0·9	0·9	6·9	6·7	12·9	12·6

Given a d value of 0.6, the declination correction factor is 0.6.

Since the declination is increasing from hour to hour, the corrected declination for 11 May at 07:58:54 is N 17° 52.5’ + 0.6’= N 17° 53.1’

Step 3: Determine the ship’s latitude at the time of observation.
Latitude – 37° 06’ N (given)

Step 4: Since the body is observed on the visible horizon, enter Table 23/28 in Bowditch to obtain the Visible Horizon Correction.

Correction of Amplitude as Observed on the Visible Horizon													
Declination													Latitude
0°	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	
°	°	°	°	°	°	°	°	°	°	°	°	°	°
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	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	10
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	15
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	20
0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	25
0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	30
0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	32
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	34
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.6	36
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	38

By visual inspection, the correction is 0.6°.

Per the instructions at the bottom of the table, for the Sun, the correction is always applied away from the elevated pole and it is applied to the observed bearing and not to the Amplitude. Since the observer is in the northern hemisphere, the north pole is the elevated pole. Since the Sun is rising, the correction should be added.

Observed: 089° psc
Table 23/28 Correction: + 0.6°
Total: 089° + 0.6° = <u>089.6° psc</u>

Step 5: Enter Table 22/27 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: N 17° 53.1'= <u>N 17.9°</u>
Latitude: 37° 06.0' N = <u>37.1° N</u>

Amplitudes														
Latitude	Declination													Latitude
	12°0	12°5	13°0	13°5	14°0	14°5	15°0	15°5	16°0	16°5	17°0	17°5	18°0	
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	0
10	12.2	12.7	13.2	13.7	14.2	14.7	15.2	15.7	16.3	16.8	17.3	17.8	18.3	10
15	12.4	12.9	13.5	14.0	14.5	15.0	15.5	16.1	16.6	17.1	17.6	18.1	18.7	15
20	12.8	13.3	13.9	14.4	14.9	15.5	16.0	16.5	17.1	17.6	18.1	18.7	19.2	20
25	13.3	13.8	14.4	14.9	15.5	16.0	16.6	17.1	17.7	18.3	18.8	19.4	19.9	25
30	13.9	14.5	15.1	15.6	16.2	16.8	17.4	18.0	18.6	19.1	19.7	20.3	20.9	30
32	14.2	14.8	15.4	16.0	16.6	17.2	17.8	18.4	19.0	19.6	20.2	20.8	21.4	32
34	14.5	15.1	15.7	16.4	17.0	17.6	18.2	18.8	19.4	20.0	20.7	21.3	21.9	34
36	14.9	15.5	16.1	16.8	17.4	18.0	18.7	19.3	19.9	20.6	21.2	21.8	22.5	36
38	15.3	15.9	16.6	17.2	17.9	18.5	19.2	19.8	20.5	21.1	21.8	22.4	23.1	38

a) Since the entering values are not whole numbers of declination or latitude, interpolation is required. Locate the bracketing values.

21. 8	22. 5
22. 4	23. 1

	Declination 17.5°	**Declination 17.9°**	Declination 18.0°
Latitude 36°	21.8°		22.5°
Latitude 37.1°		**Unknown value**	
Latitude 38°	22.4°		23.1°

b) Interpolate the bracketing values four ways to the nearest tenth.

	Declination 17.5°	**Declination 17.9°**	Declination 18.0°
Latitude 36°	21.8°	**22.4°**	22.5°
Latitude 37.1°	**22.0°**	**Unknown value**	**22.6°**
Latitude 38°	22.4°	**23.0°**	23.1°

c) Solve the final interpolation for the desired value.

	Declination 17.5°	**Declination 17.9°**	Declination 18.0°
Latitude 36°	21.8°	22.4°	22.5°
Latitude 37.1°	22.0°	**22.7°**	22.6°
Latitude 38°	22.4°	23.0°	23.1°

*Note that the amplitude can also be solved directly using the instructions in the Bowditch table 22/27 explanation.

$$\sin(\text{Amplitude}) = \sec(\text{Latitude}) \times \sin(\text{Declination})$$

-or –

$$\sin(\text{Amplitude}) = \left(\frac{\sin(\text{Declination})}{\cos(\text{Latitude})}\right)$$

Step 6: Answer required questions.

Since the calculated amplitude is 22.7°, the sun is rising, and the season is spring in the northern hemisphere, the correct notation for the amplitude is E 22.7° N, and the calculated compass bearing to sunrise should be:
090° - 22.7° = 67.3° T

Therefore, using a compass correction formula, the deviation of the compass is calculated as:
T: 67.3° T (Bearing to sunrise)
V: 20° W (Given)
M: 087.3° (Calculated)
D:
C: 089.6° psc (Given and then corrected for visible horizon using Table 23/28)

Deviation = 2.3° W

Amplitude Problems of the Moon

- Celestial Horizon: Moon amplitude problems are calculated exactly like Sun problems when the moon is on the celestial horizon (e.g. when the upper limb is on the visible horizon).

- Visible Horizon: When the Moon's center is on the visible horizon, a correction is required. Moon amplitude problems are calculated differently than Sun problems when a Table 23/28 correction is required. Instead of the correction being applied away from the elevated pole (like the sun), the correction is applied such that half of the value is applied toward the elevated pole.

AMP D5. At 1524 ZT on 14 June in DR position latitude 30° 51' N, longitude 30° 02' W, you observe an amplitude of the Moon. The center of the Moon is on the visible horizon and bears 103.9 pgc. The variation is 10° W. What is the gyro error?

Answer: 2.0° E.

G.M.T.	SUN		MOON				
	G.H.A.	Dec.	G.H.A.	v	Dec.	d	H.P.
12	359 57.5	N23 16.3	214 55.5	14.4	S12 40.0	8.6	54.0
13	14 57.4	16.5	229 28.9	14.5	12 48.6	8.6	54.0
14	29 57.2	16.6	244 02.4	14.3	12 57.2	8.5	54.1
15	44 57.1	· · 16.7	258 35.7	14.4	13 05.7	8.5	54.1
16	59 57.0	16.8	273 09.1	14.3	13 14.2	8.4	54.1
17	74 56.8	16.9	287 42.4	14.2	13 22.6	8.4	54.1

Step 1: Determine the actual time of observation.
1524 chronometer time of observation

30° 02' W corresponds to a zone time of (+2), and the correct GMT is 1724.

Step 2: Determine the declination of the Moon for the time of observation using the Nautical Almanac.

The declination at 1724 is not given in the Nautical Almanac and must be interpolated.

The base value for 1700 is S 13° 22.6' and increasing.
The *d* value for the hour is 14.7.

Enter the Increments and Corrections Page in the Nautical Almanac with the daily *d* value and a time of 24 minutes (the difference between the base declination and the observation time).

Given a *d* value of 14.7 the declination correction is 6.0'.

Since the declination is increasing from hour to hour, the corrected declination for 14 June at 1724 is S 13° 22.6' + 6.0'= <u>S 13° 28.6'</u>

Step 3: Determine the ship's latitude at the time of observation.
Latitude – 30° 51' N (given)

Step 4: Since the body is observed on the visible horizon, enter Table 23/28 in Bowditch to obtain the Visible Horizon Correction for the Moon.

Correction of Amplitude as Observed on the Visible Horizon													
Declination													Latitude
0°	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	
°	°	°	°	°	°	°	°	°	°	°	°	°	°
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	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	10
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	15
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	20
0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	25
0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	30
0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	32
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	34
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.6	36
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	38

By visual inspection, the correction is 0.4°.

Per the instructions at the bottom of the table, for the Moon, the correction is always divided in 2 and applied toward the elevated pole. Since the observer is in the northern hemisphere, the north pole is the elevated pole. Since the Moon is rising, the correction should be subtracted.

Observed: 103.9° pgc
Table 23 Correction: - 0.2°
Total: 103.9° - 0.2° = <u>103.7° pgc</u>

Amplitudes														
Latitude	Declination													Latitude
	12°.0	12°.5	13°.0	13°.5	14°.0	14°.5	15°.0	15°.5	16°.0	16°.5	17°.0	17°.5	18°.0	
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	0
10	12.2	12.7	13.2	13.7	14.2	14.7	15.2	15.7	16.3	16.8	17.3	17.8	18.3	10
15	12.4	12.9	13.5	14.0	14.5	15.0	15.5	16.1	16.6	17.1	17.6	18.1	18.7	15
20	12.8	13.3	13.9	14.4	14.9	15.5	16.0	16.5	17.1	17.6	18.1	18.7	19.2	20
25	13.3	13.8	14.4	14.9	15.5	16.0	16.6	17.1	17.7	18.3	18.8	19.4	19.9	25
30	13.9	14.5	15.1	15.6	16.2	16.8	17.4	18.0	18.6	19.1	19.7	20.3	20.9	30
32	14.2	14.8	15.4	16.0	16.6	17.2	17.8	18.4	19.0	19.6	20.2	20.8	21.4	32
34	14.5	15.1	15.7	16.4	17.0	17.6	18.2	18.8	19.4	20.0	20.7	21.3	21.9	34
36	14.9	15.5	16.1	16.8	17.4	18.0	18.7	19.3	19.9	20.6	21.2	21.8	22.5	36
38	15.3	15.9	16.6	17.2	17.9	18.5	19.2	19.8	20.5	21.1	21.8	22.4	23.1	38

Step 5: Enter Table 22/27 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: S 13° 26.0'= N 13.4°
Latitude: 30° 51' N = 30.9° N

a) Since the entering values are not whole numbers of declination or latitude, interpolation is required. Locate the bracketing values.

15.1	15.6
15.4	16.0

	Declination 13.0°	**Declination 13.4°**	Declination 13.5°
Latitude 30°	15.1°		15.6°
Latitude 30.9°		**Unknown value**	
Latitude 32°	15.4°		16.0°

b) Interpolate the bracketing values four ways to the nearest tenth.

	Declination 13.0°	**Declination 13.4°**	Declination 13.5°
Latitude 30°	15.1°	**15.5°**	15.6°
Latitude 30.9°	**15.2°**	**Unknown value**	**15.8°**
Latitude 32°	15.4°	**15.9°**	16.0°

c) Solve the interpolation for the desired value.

	Declination 13.0°	**Declination 13.4°**	Declination 13.5°
Latitude 30°	15.1°	15.5°	15.6°
Latitude 30.9°	15.2°	**15.7°**	15.8°
Latitude 32°	15.4°	15.9°	16.0°

**Note that the amplitude can also be solved directly using the instructions in the Bowditch table 22 explanation.*

$$\sin(Amplitude) = \sec(Latitude) \times \sin(Declination)$$

-or –

$$\sin(Amplitude) = \left(\frac{\sin(Declination)}{\cos(Latitude)}\right)$$

Step 6: Answer required questions.

Since the calculated amplitude is 15.7°, the Moon is rising, and the declination is south, the correct notation for the amplitude is E 15.7° S, and the calculated compass bearing to moonrise should be:

090° + 15.7° = 105.7° T

Therefore, using a gyro error calculation, the gyro error is:
G: 103.7° pgc (Given)
E:
T: 105.7° T (Calculated)

Gyro Error = 2.0° E

Amplitude Problems of Planets

- Amplitudes of Planets are completed in the same manner as those for the sun. Planets are on the celestial horizon when they are approximately one sun diameter above the visible horizon.

AMP D6. At 2043 ZT on 13 October in DR position latitude 43° 57.3' S, longitude 147° 16.0' E, you observe an amplitude of Venus. The planet is about one sun's diameter above the horizon and bears 236.2° pgc. The variation is 15° E. What is the gyro error?

Answer: 0.0°.

Step 1: Determine the actual time of observation.
2043 chronometer time of observation

147° 16.0' E corresponds to a zone time of (-10), and the correct GMT is 1043 on 13 October.

Step 2: Determine the declination of the planet for the time of observation using the Nautical Almanac.

G.M.T.	ARIES G.H.A.	VENUS −3.8 G.H.A.	Dec.
06	111 42.7	229 23.3	S23 33.7
07	126 45.2	244 22.8	34.3
08	141 47.7	259 22.3	35.0
09	156 50.1	274 21.8	· · 35.6
10	171 52.6	289 21.3	36.3
11	186 55.1	304 20.8	36.9
Mer. Pass.	h m 22 26.5	*v* −0.5	*d* 0.6

The declination at 1043 is not given in the Nautical Almanac and must be interpolated.

The base value for 1000 is S 23° 36.3' and increasing.
The *d* value for 13 October is 0.6.

43^m^ s	SUN PLANETS ° '	ARIES ° '	MOON ° '	*v* or *d* '	Corr^n^ '	*v* or *d* '	Corr^n^ '	*v* or *d* '	Corr^n^ '
00	10 45·0	10 46·8	10 15·6	0·0	0·0	6·0	4·4	12·0	8·7
01	10 45·3	10 47·0	10 15·9	0·1	0·1	6·1	4·4	12·1	8·8
02	10 45·5	10 47·3	10 16·1	0·2	0·1	6·2	4·5	12·2	8·8
03	10 45·8	10 47·5	10 16·3	0·3	0·2	6·3	4·6	12·3	8·9
04	10 46·0	10 47·8	10 16·6	0·4	0·3	6·4	4·6	12·4	9·0
05	10 46·3	10 48·0	10 16·8	0·5	0·4	6·5	4·7	12·5	9·1
06	10 46·5	10 48·3	10 17·0	0·6	0·4	6·6	4·8	12·6	9·1
07	10 46·8	10 48·5	10 17·3	0·7	0·5	6·7	4·9	12·7	9·2
08	10 47·0	10 48·8	10 17·5	0·8	0·6	6·8	4·9	12·8	9·3
09	10 47·3	10 49·0	10 17·8	0·9	0·7	6·9	5·0	12·9	9·4

Enter the Increments and Corrections Page in the Nautical Almanac with the daily *d* value and a time of 43 minutes (the difference between the base declination and the observation time).

Given a *d* value of 0.6 the declination correction is 0.4'.

Since the declination is increasing from hour to hour, the corrected declination for 13 October at 1043 is S 23° 36.3' + 0.4'= <u>S 23° 36.7'</u>

Step 3: Determine the ship's latitude at the time of observation.
Latitude – 43° 57.3' S (given)

Step 4: Enter Table 22 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: S 23° 36.7'= S 23.6°
Latitude: 43° 57.3' S = 43.96° S

a) Since the entering values are not whole numbers of declination or latitude, interpolation is required.

Latitude	Declination													Latitude
	18°.0	18°.5	19°.0	19°.5	20°.0	20°.5	21°.0	21°.5	22°.0	22°.5	23°.0	23°.5	24°.0	
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	0
10	18.3	18.8	19.3	19.8	20.3	20.8	21.3	21.8	22.4	22.9	23.4	23.9	24.4	10
15	18.7	19.2	19.7	20.2	20.7	21.3	21.8	22.3	22.8	23.3	23.9	24.4	24.9	15
20	19.2	19.7	20.3	20.8	21.3	21.9	22.4	23.0	23.5	24.0	24.6	25.1	25.6	20
25	19.9	20.5	21.1	21.6	22.2	22.7	23.3	23.9	24.4	25.0	25.5	26.1	26.7	25
30	20.9	21.5	22.1	22.7	23.3	23.9	24.4	25.0	25.6	26.2	26.8	27.4	28.0	30
32	21.4	22.0	22.6	23.2	23.8	24.4	25.0	25.6	26.2	26.8	27.4	28.0	28.7	32
34	21.9	22.5	23.1	23.7	24.4	25.0	25.6	26.2	26.9	27.5	28.1	28.7	29.4	34
36	22.5	23.1	23.7	24.4	25.0	25.7	26.3	26.9	27.6	28.2	28.9	29.5	30.2	36
38	23.1	23.7	24.4	25.1	25.7	26.4	27.1	27.7	28.4	29.1	29.7	30.4	31.1	38
40	23.8	24.5	25.2	25.8	26.5	27.2	27.9	28.6	29.3	30.0	30.7	31.4	32.1	40
41	24.2	24.9	25.6	26.3	26.9	27.6	28.3	29.1	29.8	30.5	31.2	31.9	32.6	41
42	24.6	25.3	26.0	26.7	27.4	28.1	28.8	29.5	30.3	31.0	31.7	32.5	33.2	42
43	25.0	25.7	26.4	27.2	27.9	28.6	29.3	30.1	30.8	31.6	32.3	33.0	33.8	43
44	25.4	26.2	26.9	27.6	28.4	29.1	29.9	30.6	31.4	32.1	32.9	33.7	34.4	44

b) Locate the bracketing values.

33.0	33.8
33.7	34.4

	Declination 23.5°	**Declination 23.6°**	Declination 24°
Latitude 43°	33.0°		33.8°
Latitude 43.95°		**Unknown value**	
Latitude 44°	33.7°		34.4°

c) Interpolate the bracketing values four ways to the nearest tenth.

	Declination 23.5°	**Declination 23.6°**	Declination 24°
Latitude 43°	33.0°	**33.2°**	33.8°
Latitude 43.95°	**33.7°**	**Unknown value**	**34.4°**
Latitude 44°	33.7°	**33.8°**	34.4°

d) Solve the interpolation for the desired value.

	Declination 23.5°	**Declination 23.6°**	Declination 24°
Latitude 43°	33.0°	33.2°	33.8°
Latitude 43.95°	33.7°	**33.8°**	34.4°
Latitude 44°	33.7°	33.8°	34.4°

**Note that the amplitude can also be solved directly using the instructions in the Bowditch table 22 explanation.*

$$\sin(Amplitude) = \sec(Latitude) \times \sin(Declination)$$

-or –

$$\sin(Amplitude) = \left(\frac{\sin(Declination)}{\cos(Latitude)}\right)$$

Step 5: Answer required questions.

Since the calculated amplitude is 33.8°, the planet is setting, and the declination is south, the correct notation for the amplitude is W 33.8° S, and the calculated compass bearing to planet-set should be:

270° - 33.8° = 236.2° T

Therefore, using a gyro error calculation, the gyro error is:

G: 236.2° pgc (Given)
E:
T: 236.2° T (Calculated)

Gyro Error = 0.0°

Amplitude Problems

<u>Basic Concept Problems (non-USCG exams)</u>

AMP B1. Using the Amplitude Table in Bowditch, you have determined that the calculated amplitude of the sun is 10 degrees. It is August 15th and you are in the northern hemisphere. What is the calculated bearing of sunrise and sunset?

Answer: Sunrise – 080° T, Sunset – 280° T.

AMP B2. Using the Amplitude Table in Bowditch, you have determined that the calculated amplitude of the sun is 3 degrees. It is October 23rd and you are in the northern hemisphere. What is the calculated bearing of sunrise and sunset?

Answer: Sunrise – 093° T, Sunset 267° T.

AMP B3. Using the Amplitude Table in Bowditch, you have determined that the calculated amplitude of the sun is 20 degrees. It is August 15th and you are in the southern hemisphere. What is the calculated bearing of sunrise and sunset?

Answer: Sunrise – 070° T, Sunset – 290° T.

AMP B4. Your latitude is 10N. The declination of the sun is 12 degrees. What is the amplitude of the sun?

Answer: 12.2 degrees.

Amplitudes of the Sun (Celestial Horizon)

AMP B5. On 10 August your vessel's 0426 zone time DR position is latitude 52° 07' N, longitude 142° 16' E, when an amplitude of the Sun is observed. The Sun's lower limb is about 20 minutes of arc above the visible horizon and bears 074.5° per standard compass. Variation in the area is 12° W. The chronometer reads 07h 24m 19s and is 2m 34s fast. Which of the following is the deviation of the standard compass?

a) 0.0°
b) 1.3° W
c) 1.3° E – correct
d) 2.3° W

AMP B6. On 10 February in DR position latitude 25° 32.0' N, longitude 135° 15.0' E, you observe an amplitude of the Sun. The Sun's center is on the celestial horizon and bears 109° psc. The chronometer reads 09h 43m 25s and is 3m 20s fast. Variation in the area is 4.5° W. What is the deviation of the standard magnetic compass?

a) 1.6° E – correct
b) 2.9° W
c) 10.5° E
d) 30.5° W

AMP B7. On 11 January, your vessel's 0655 zone time DR position is latitude 24° 30' N, longitude 122° 02' W, when an amplitude of the Sun is observed. The Sun's center is on the celestial horizon and bears 101° per standard compass. Variation in the area is 11.6° E. The chronometer reads 02h 52m 48s and is 2m 12s slow. What is the deviation of the standard compass?

a) 1.4° E – correct
b) 1.4° W
c) 4.6° E
d) 4.6° W

AMP B8. On 17 April your vessel's position is latitude 21° 00' S, longitude 78° 30' W, when an amplitude of the Sun is observed. The Sun's center is on the celestial horizon and bears 082.7° per standard magnetic compass. Variation in the area is 2.0° W. The chronometer reads 10h 59m 24s and is 01m 24s fast. What is the deviation on the compass?

a) 2.0° W- correct
b) 3.0° W
c) 2.5° E
d) 3.0° E

Amplitudes of the Sun (Visible Horizon)

AMP B9. On 10 June you vessel's 0519 zone time DR position is latitude 27° 07.0' N, longitude 92° 10.0' W, when an amplitude of the Sun is observed. The Sun's center is on the visible horizon and bears 063.6° per standard magnetic compass. The variation in the area is 4.8° E. The chronometer reads 11h 17m 32s and is 1m 18s slow. What is the deviation of the compass?

a) 5.6° E
b) 4.8° E
c) 4.2° W
d) 4.8° W- correct

AMP B10. On 16 April in DR position latitude 28° 07.0' N, longitude 81° 47.0' W, you observe an amplitude of the Sun. The Sun's center is on the visible horizon and bears 073.5° psc. The chronometer reads 10h 53m 41s and is 2m 23s slow. Variation in the area is 11° E. What is the deviation of the magnetic compass?

a) 4.5° E
b) 4.9° W
c) 6.1° E
d) 6.5° W- correct

AMP B11. On 5 September in DR position latitude 23° 17.0' S, longitude 154° 35.0' E, you observe an amplitude of the Sun. The Sun's center is on the visible horizon and bears 275° per standard magnetic compass. The chronometer reads 7h 49m 26s and is 1m 52s fast. Variation in the area is 3° W. What is the deviation of the standard magnetic compass?

a) 2.1° E
b) 2.4° W
c) 5.1° E- correct
d) 5.4° W

AMP B12. On 20 June your vessel's 1955 ZT DR position is latitude 52° 38.9' N, longitude 3° 42.7' E, when an amplitude of the Sun is observed. The Sun's center is on the visible horizon and bears 311° per gyrocompass. Variation in the area is 6° W. At the time of the observation, the helmsman noted that she was heading 352° per gyrocompass and 358° per steering compass. What is the gyro error and deviation for that heading?

a) 1.3° W gyro error, 1.3°E deviation
b) 0.0° gyro error, 0.0° deviation
c) 1.3° W gyro error, 1.3° W deviation
d) 1.3° E gyro error, 1.3° E deviation – correct

Amplitudes of the Moon

AMP B13. At 1502 ZT on 4 August, in DR position latitude 11° 21.6 S, longitude 088° 14.3' E, you observe an amplitude of the Moon. The upper limb of the Moon is on the visible horizon and bears 289° psc. The variation is 15° W. What is the deviation?

a) 1.1° E
b) 1.1° W – correct
c) 1.9° E
d) 1.9° W

AMP B14. At 1318 ZT on 10 September, in DR position latitude 24° 05.8' N, longitude 058° 08.3' E, you observe an amplitude of the Moon. The upper limb of the Moon is on the visible horizon and bears 254° psc. Variation is 2° W. What is the deviation?

a) 8.0° W
b) 8.0° E
c) 4.0° W – correct
d) 4.0° E

AMP B15. At 1337 ZT on July 17, in DR position latitude 30° 56.8' S, longitude 039° 36.5' W, you observe an amplitude of the Moon. The upper limb of the Moon is on the visible horizon bearing 263° psc. The variation is 20° W. What is the deviation?

a) 2.6° E
b) 2.6° W
c) 3.6° E – correct
d) 3.6° W

AMP B16. At 1542 ZT on 23 October, in DR position latitude 37° 28.5' N, longitude 156° 17.3' E, you observe an amplitude of the Moon. The center of the Moon is on the visible horizon and bears 282.5° psc. The variation is 0.0°. What is the deviation?

a) 2.2° E – correct
b) 2.2° W
c) 1.2° E
d) 1.2° W

AMP B17. At 1523 ZT on 14 June, in DR position latitude 31° 58' S, longitude 48° 42' W, you observe an amplitude of the Moon. The center of the Moon is on the visible horizon and bears 118° psc. The variation is 10° W. What is the deviation?

a) 2.5° W
b) 2.1° W – correct
c) 1.7° W
d) 1.7° E

Amplitudes of Planets

AMP B18. At 2048 ZT on 13 October, you are in DR position latitude 44° 02.8' S, longitude 146° 58.3' E when you observe an amplitude of Venus. The planet is about one Sun's diameter above the visible horizon and bears 222.2° psc. The variation is 15° E. What is the deviation?

a) 0.0°
b) 1.1° E
c) 1.0° W – correct
d) 1.5° W

AMP B19. At 2232 ZT on 14 July you are in DR position latitude 33° 52 S, longitude 150° 03' W when you observe an amplitude of Jupiter. The planet is about one Sun's diameter above the visible horizon and bears 268.5° pgc. The variation is 15° E. What is the gyro error?

a) 1.0° E - correct
b) 0.5° E
c) 0.0°
d) 0.5° W

AMP B20. At 2234 ZT on 14 July you are in DR position latitude 34° 03' N, longitude 150° 16' W, when you observe an amplitude of Saturn. The planet is about one Sun's diameter above the visible horizon and bears 272.1° pgc. The variation is 14° E. What is the gyro error?

a) 0.5° W
b) 0.5° E
c) 1.5° W - correct
d) 2.5° E

AMP B21. At 2237 ZT on 14 July, you are in DR position latitude 33° 57' N, longitude 150° 32' W when you observe an amplitude of Saturn. The planet is about one Sun's diameter above the visible horizon and bears 258.6° psc. The variation is 14° E. What is the deviation?

a) 2.0° W – correct
b) 1.0° W
c) 0.0°
d) 1.0° E

Azimuth Problems

- "Azimuth" is the horizontal direction of a celestial point from a terrestrial point, expressed as an angular distance from a reference direction (usually 0°N). Most commonly it is measured using an azimuth ring on a compass repeater when making an observation of a celestial body.

- Azimuth problems generally involve determining the tabulated or computed azimuth value and comparing it to a gyro compass or a steering compass to determine compass error.

- To reduce the size of the sight reduction tables, some azimuth values that are repeated are eliminated from the tables, requiring an azimuth adjustment based on the rules found at the top or bottom of the tables. However, the azimuth rules may modify this azimuth value to a final azimuth (Zn) using the rules 360° - Z, 180° - Z, or 180° + Z in some cases.

- Azimuth values can be determined using tables or solved directly with the formula:

    - $Tan\ Z = \left(\frac{\cos d\ sin\ LHA}{((\cos L)(\sin d)-((\sin L)(\cos d)(\cos LHA))}\right)$, where:

      LHA is local hour angle
      L is latitude
      d is declination

Azimuth of the Sun Problems

AZI D1. On 17 June, your 0815 zone time DR position is latitude 25° 27.0’ N, longitude 47° 16.0’ W. At that time, you observe the Sun bearing 079.5° per standard magnetic compass. The chronometer reads 11h 15m 03s, and the chronometer error is 01m 15s fast. The variation is 3° E. What is the deviation of the standard magnetic compass?

Answer: 3.6° W

Step 1: Determine the correct chronometer time of the sight.
Chronometer: 11h 15m 03s
Chronometer error: 01m 15s fast
Correct chronometer time: 11h 15m 03s – 1m 15s = 11h 13m 48s

Step 2: Determine the GMT of the sight.
Ship time: 0815
Chronometer time: 11h 13m 48s
DR Longitude: 47° 16’ W – corresponds to (+3 ZD)
GMT of sight: 11:13:48, 17 June

Step 3: Determine the declination of the Sun.
Declination (hours): N 23° 23.1’ (d number 0.1’)
Declination (increment): 0
Declination (total): N 23° 23.1’

Step 4: Determine the GHA of the Sun.
GHA (hours): 344° 48.1’
GHA (increment): 3° 27.0’
GHA (total): 348° 15.1’

Step 5: Determine the LHA of the Sun.
GHA (Sun): 348° 15.1’
DR Longitude: 47° 16.0’ W (subtract west, add east)
LHA (Sun): 348° 15.1’ – 47° 16.0’ W = 300° 59.1’

G.M.T.		SUN G.H.A.	Dec.
17	00	179 49.6	N23 22.3
	01	194 49.4	22.3
	02	209 49.3	22.4
	03	224 49.2	·· 22.5
	04	239 49.0	22.6
	05	254 48.9	22.6
	06	269 48.8	N23 22.7
W	07	284 48.6	22.8
E	08	299 48.5	22.9
D	09	314 48.4	·· 22.9
N	10	329 48.2	23.0
E	11	344 48.1	23.1
S	12	359 48.0	N23 23.1
D	13	14 47.8	23.2
A	14	29 47.7	23.3
Y	15	44 47.5	·· 23.3
	16	59 47.4	23.4
	17	74 47.3	23.5
	18	89 47.1	N23 23.5
	19	104 47.0	23.6
	20	119 46.9	23.7
	21	134 46.7	·· 23.7
	22	149 46.6	23.8
	23	164 46.5	23.8
		S.D. 15.8	d 0.1

13m	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° ′	° ′	° ′	′	′	′	′	′	′
00	3 15·0	3 15·5	3 06·1	0·0	0·0	6·0	1·4	12·0	2·7
01	3 15·3	3 15·8	3 06·4	0·1	0·0	6·1	1·4	12·1	2·7
02	3 15·5	3 16·0	3 06·6	0·2	0·0	6·2	1·4	12·2	2·7
03	3 15·8	3 16·3	3 06·8	0·3	0·1	6·3	1·4	12·3	2·8
04	3 16·0	3 16·5	3 07·1	0·4	0·1	6·4	1·4	12·4	2·8
45	3 26·3	3 26·8	3 16·9	4·5	1·0	10·5	2·4	16·5	3·7
46	3 26·5	3 27·1	3 17·1	4·6	1·0	10·6	2·4	16·6	3·7
47	3 26·8	3 27·3	3 17·3	4·7	1·1	10·7	2·4	16·7	3·8
48	3 27·0	3 27·6	3 17·6	4·8	1·1	10·8	2·4	16·8	3·8
49	3 27·3	3 27·8	3 17·8	4·9	1·1	10·9	2·5	16·9	3·8

Step 6: Enter HO229 with whole values of latitude, declination (same in this case), and LHA. By increasing the value of each argument by 1 whole increment, triple interpolate for the exact values of each for the desired time/location.

	Base Value	Base Z	Next incremental Z	Difference in Z	**Increment**	Correction *(Diff Z x Increment) / 60*
Latitude – N	**25°**				**27.0’**	
Declination - N	**23°**				**23.1’**	
LHA	**300°**				**59.1’**	

	Base Value	**Base Z**	Next incremental Z	Difference in Z	Increment	Correction *(Diff Z x Increment) / 60*
Latitude	25°	**78.7°**			27.0’	
Declination	23°	**78.7°**			23.1’	
LHA	300°	**78.7°**			59.1’	

60°, 300° L.H.A. LATITUDE SAME NA

Dec.	23° Hc	d	Z	24° Hc	d	Z	25° Hc	d	Z	26° Hc	d	Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
0	27 24.2	+26.2	102.7	27 10.7	+27.3	103.2	26 56.8	+28.2	103.7	26 42.3	+29.2	104.2
1	27 50.4	+25.7	101.7	27 38.0	+26.7	102.2	27 25.0	+27.8	102.7	27 11.5	+28.9	103.2
2	28 16.1	+25.3	100.7	28 04.7	+26.4	101.2	27 52.8	+27.4	101.7	27 40.4	+28.4	102.2
3	28 41.4	+24.8	99.6	28 31.1	+25.8	100.2	28 20.2	+26.9	100.7	28 08.8	+27.9	101.2
4	29 06.2	+24.3	98.6	28 56.9	+25.4	99.1	28 47.1	+26.5	99.7	28 36.7	+27.6	100.2
5	29 30.5	+23.8	97.6	29 22.3	+25.0	98.1	29 13.6	+26.0	98.7	29 04.3	+27.0	99.2
6	29 54.3	+23.4	96.5	29 47.3	+24.4	97.1	29 39.6	+25.5	97.6	29 31.3	+26.6	98.2
7	30 17.7	+22.7	95.4	30 11.7	+23.9	96.0	30 05.1	+25.0	96.6	29 57.9	+26.1	97.2
8	30 40.4	+22.3	94.4	30 35.6	+23.4	94.9	30 30.1	+24.5	95.5	30 24.0	+25.6	96.1
9	31 02.7	+21.7	93.3	30 59.0	+22.8	93.9	30 54.6	+24.0	94.5	30 49.6	+25.1	95.1
10	31 24.4	+21.2	92.2	31 21.8	+22.3	92.8	31 18.6	+23.4	93.4	31 14.7	+24.5	94.0
11	31 45.6	+20.5	91.1	31 44.1	+21.7	91.7	31 42.0	+22.9	92.3	31 39.2	+24.0	92.9
12	32 06.1	+20.0	90.0	32 05.8	+21.2	90.6	32 04.9	+22.3	91.2	32 03.2	+23.5	91.9
13	32 26.1	+19.4	88.9	32 27.0	+20.6	89.5	32 27.2	+21.7	90.1	32 26.7	+22.9	90.8
14	32 45.5	+18.8	87.7	32 47.6	+20.0	88.4	32 48.9	+21.2	89.0	32 49.6	+22.3	89.7
15	33 04.3	+18.2	86.6	33 07.6	+19.3	87.3	33 10.1	+20.5	87.9	33 11.9	+21.7	88.6
16	33 22.5	+17.6	85.5	33 26.9	+18.8	86.1	33 30.6	+20.0	86.8	33 33.6	+21.2	87.5
17	33 40.1	+16.9	84.3	33 45.7	+18.1	85.0	33 50.6	+19.3	85.7	33 54.8	+20.5	86.3
18	33 57.0	+16.3	83.2	34 03.8	+17.5	83.8	34 09.9	+18.6	84.5	34 15.3	+19.8	85.2
19	34 13.3	+15.6	82.0	34 21.3	+16.8	82.7	34 28.5	+18.1	83.4	34 35.1	+19.2	84.0
20	34 28.9	+14.9	80.8	34 38.1	+16.1	81.5	34 46.6	+17.3	82.2	34 54.3	+18.6	82.9
21	34 43.8	+14.2	79.7	34 54.2	+15.5	80.3	35 03.9	+16.7	81.0	35 12.9	+17.9	81.7
22	34 58.0	+13.6	78.5	35 09.7	+14.7	79.2	35 20.6	+16.0	79.9	35 30.8	+17.2	80.6
23	35 11.6	+12.8	77.3	35 24.4	+14.1	78.0	35 36.6	+15.3	78.7	35 48.0	+16.5	79.4
24	35 24.4	+12.2	76.1	35 38.5	+13.4	76.8	35 51.9	+14.6	77.5	36 04.5	+15.8	78.2

59°, 301° L.H.A. LATITUDE SAME NA

Dec.	23° Hc	d	Z	24° Hc	d	Z	25° Hc	d	Z	26° Hc	d	Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
0	28 18.0	+26.4	103.2	28 04.0	+27.5	103.7	27 49.5	+28.5	104.2	27 34.5	+29.5	104.8
1	28 44.4	+26.0	102.2	28 31.5	+27.0	102.7	28 18.0	+28.0	103.3	28 04.0	+29.0	103.8
2	29 10.4	+25.4	101.2	28 58.5	+26.5	101.7	28 46.0	+27.6	102.2	28 33.0	+28.6	102.8
3	29 35.8	+25.0	100.1	29 25.0	+26.0	100.7	29 13.6	+27.1	101.2	29 01.6	+28.2	101.8
4	30 00.8	+24.4	99.1	29 51.0	+25.6	99.6	29 40.7	+26.6	100.2	29 29.8	+27.7	100.8
5	30 25.2	+24.0	98.0	30 16.6	+25.0	98.6	30 07.3	+26.1	99.2	29 57.5	+27.2	99.7
6	30 49.2	+23.4	97.0	30 41.6	+24.6	97.5	30 33.4	+25.7	98.1	30 24.7	+26.7	98.7
7	31 12.6	+22.9	95.9	31 06.2	+24.0	96.5	30 59.1	+25.1	97.1	30 51.4	+26.2	97.7
8	31 35.5	+22.3	94.8	31 30.2	+23.4	95.4	31 24.2	+24.6	96.0	31 17.6	+25.7	96.6
9	31 57.8	+21.8	93.7	31 53.6	+22.9	94.3	31 48.8	+24.0	94.9	31 43.3	+25.2	95.6
10	32 19.6	+21.2	92.6	32 16.5	+22.4	93.2	32 12.8	+23.5	93.9	32 08.5	+24.6	94.5
11	32 40.8	+20.6	91.5	32 38.9	+21.7	92.1	32 36.3	+22.9	92.8	32 33.1	+24.0	93.4
12	33 01.4	+20.0	90.4	33 00.6	+21.2	91.0	32 59.2	+22.4	91.7	32 57.1	+23.5	92.3
13	33 21.4	+19.3	89.2	33 21.8	+20.6	89.9	33 21.6	+21.7	90.6	33 20.6	+22.9	91.2
14	33 40.7	+18.8	88.1	33 42.4	+19.9	88.8	33 43.3	+21.1	89.4	33 43.5	+22.3	90.1
15	33 59.5	+18.1	87.0	34 02.3	+19.3	87.6	34 04.4	+20.5	88.3	34 05.8	+21.7	89.0
16	34 17.6	+17.5	85.8	34 21.6	+18.7	86.5	34 24.9	+19.9	87.2	34 27.5	+21.1	87.9
17	34 35.1	+16.8	84.7	34 40.3	+18.0	85.3	34 44.8	+19.2	86.0	34 48.6	+20.4	86.7
18	34 51.9	+16.1	83.5	34 58.3	+17.3	84.2	35 04.0	+18.6	84.9	35 09.0	+19.8	85.6
19	35 08.0	+15.4	82.3	35 15.6	+16.7	83.0	35 22.6	+17.9	83.7	35 28.8	+19.1	84.4
20	35 23.4	+14.7	81.1	35 32.3	+16.0	81.8	35 40.5	+17.2	82.5	35 47.9	+18.4	83.3
21	35 38.1	+14.1	79.9	35 48.3	+15.2	80.6	35 57.7	+16.4	81.4	36 06.3	+17.7	82.1
22	35 52.2	+13.3	78.7	36 03.5	+14.6	79.5	36 14.1	+15.8	80.2	36 24.0	+17.0	80.9
23	36 05.5	+12.6	77.5	36 18.1	+13.8	78.2	36 29.9	+15.1	79.0	36 41.0	+16.3	79.7
24	36 18.1	+11.8	76.3	36 31.9	+13.1	77.0	36 45.0	+14.3	77.8	36 57.3	+15.6	78.5

	Base Value	Base Z	**Next incremental Z**	**Difference in Z**	Increment	Correction *(Diff Z x Increment) / 60*
Latitude	25°	78.7°	**79.4°**	**0.7°**	27.0’	
Declination	23°	78.7°	**77.5°**	**-1.2°**	23.1’	
LHA	300°	78.7°	**79.0°**	**0.3°**	59.1’	

	Base Value	Base Z	Next incremental Z	Difference in Z	Increment	**Correction *(Diff Z x Increment) / 60***
Latitude	25°	78.7°	79.4°	0.7°	27.0’	**+0.32°**
Declination	23°	78.7°	77.5°	-1.2°	23.1’	**-0.46°**
LHA	300°	78.7°	79.0°	0.3°	59.1’	**+0.30°**

Total correction = 0.32° -0.46° + 0.30° = +0.2°

Step 7: Apply the correction to the base values to determine true azimuth.
Base azimuth: 078.7°
Correction: +0.2°
Corrected azimuth: 078.7° + 0.2° = 078.9°
Note - Check azimuth rules: if LHA greater than 180°, then zn = z.

Step 8: Answer the required questions.
T: 078.9° (Determine in Step 7)
V: 3.0° E (Given)
M: 075.9° (Calculated)
D: 3.6° W
C: 079.5° (Given)

Note this problem can be solved without the triple interpolation using the formula:

$$Tan\ Z = \left(\frac{\cos d\ sin\ LHA}{((\cos L)(\sin d) - ((\sin L)(\cos d)(\cos LHA))}\right)$$, where:

LHA is local hour angle
L is latitude
d is declination

AZI D2. On 12 September, your 0736 zone time DR position is latitude 28° 34’ S, longitude 174° 49’ E. At that time you observe the Sun bearing 084° per standard magnetic compass (psc). The chronometer reads 07h 38m 11s, and the chronometer error is 01m 46s fast. The variation is 11° W. What is the deviation of the standard magnetic compass?

Answer: 3.4° E

Step 1: Determine the correct chronometer time of the sight.
Chronometer: 07h 38m 11s
Chronometer error: 01m 46s fast
Correct chronometer time: 07h 38m 11s – 1m 46s = 07h 36m 25s

Step 2: Determine the GMT of the sight.
Ship time: 0736
Chronometer time: 07h 36m 25s
DR Longitude: 174° 49’ E – corresponds to (-12 ZD)
GMT of sight: 19:36:25, 11 September

11	00	180 48.4	N 4 40.7
	01	195 48.6	39.8
	02	210 48.8	38.8
	03	225 49.0	·· 37.9
	04	240 49.3	36.9
	05	255 49.5	36.0
	06	270 49.7	N 4 35.0
	07	285 49.9	34.1
	08	300 50.1	33.1
F	09	315 50.4	·· 32.2
R	10	330 50.6	31.2
I	11	345 50.8	30.3
D	12	0 51.0	N 4 29.3
A	13	15 51.2	28.3
Y	14	30 51.5	27.4
	15	45 51.7	·· 26.4
	16	60 51.9	25.5
	17	75 52.1	24.5
	18	90 52.3	N 4 23.6
	19	105 52.6	22.6
	20	120 52.8	21.7
	21	135 53.0	·· 20.7
	22	150 53.2	19.8
	23	165 53.4	18.8
		S.D. 15.9	d 1.0

Step 3: Determine the declination of the Sun.
Declination (hours): N 4° 22.6’
d number: -1.0’
Declination (increment): -0.6’
Declination (total): N 4° 22.0’

Step 4: Determine the GHA of the Sun.
GHA (hours): 105° 52.6’
GHA (increment): 9° 06.3’
GHA (total): 114° 58.9’

Step 5: Determine the LHA of the Sun.
GHA (Sun): 114° 58.9’
DR Longitude: 174° 49.0’ E (subtract west, add east)
LHA (Sun): 114° 58.9’ + 174° 49.0’ E = 289° 47.9’

36[m]	SUN PLANETS	ARIES	MOON	v or d	Corr[n]
s	° ′	° ′	° ′	′	′
00	9 00·0	9 01·5	8 35·4	0·0	0·0
01	9 00·3	9 01·7	8 35·6	0·1	0·1
02	9 00·5	9 02·0	8 35·9	0·2	0·1
03	9 00·8	9 02·2	8 36·1	0·3	0·2
04	9 01·0	9 02·5	8 36·4	0·4	0·2
05	9 01·3	9 02·7	8 36·6	0·5	0·3
06	9 01·5	9 03·0	8 36·8	0·6	0·4
07	9 01·8	9 03·2	8 37·1	0·7	0·4
08	9 02·0	9 03·5	8 37·3	0·8	0·5
09	9 02·3	9 03·7	8 37·5	0·9	0·5
10	9 02·5	9 04·0	8 37·8	1·0	0·6
11	9 02·8	9 04·2	8 38·0	1·1	0·7
12	9 03·0	9 04·5	8 38·3	1·2	0·7
13	9 03·3	9 04·7	8 38·5	1·3	0·8
14	9 03·5	9 05·0	8 38·7	1·4	0·9
15	9 03·8	9 05·2	8 39·0	1·5	0·9
16	9 04·0	9 05·5	8 39·2	1·6	1·0
17	9 04·3	9 05·7	8 39·5	1·7	1·0
18	9 04·5	9 06·0	8 39·7	1·8	1·1
19	9 04·8	9 06·2	8 39·9	1·9	1·2
20	9 05·0	9 06·5	8 40·2	2·0	1·2
21	9 05·3	9 06·7	8 40·4	2·1	1·3
22	9 05·5	9 07·0	8 40·6	2·2	1·3
23	9 05·8	9 07·2	8 40·9	2·3	1·4
24	9 06·0	9 07·5	8 41·1	2·4	1·5
25	9 06·3	9 07·7	8 41·4	2·5	1·5
26	9 06·5	9 08·0	8 41·6	2·6	1·6
27	9 06·8	9 08·2	8 41·8	2·7	1·6
28	9 07·0	9 08·5	8 42·1	2·8	1·7
29	9 07·3	9 08·7	8 42·3	2·9	1·8

Step 6: Enter HO229 with whole values of latitude, declination (contrary in this case), and LHA. By increasing the value of each argument by 1 whole increment, triple interpolate for the exact values of each for the desired time/location.

	Base Value	Base Z	Next incremental Z	Difference in Z	**Increment**	Correction *(Diff Z x Increment) / 60*
Latitude – S	**28°**				**34.0’**	
Declination - N	**4°**				**22.0’**	
LHA	**289°**				**47.9’**	

	Base Value	**Base Z**	Next incremental Z	Difference in Z	Increment	Correction *(Diff Z x Increment) / 60*
Latitude	28°	**102.8°**			34.0’	
Declination	4°	**102.8°**			22.0’	
LHA	289°	**102.8°**			47.9’	

TITUDE CONTRARY NAME TO DECLINATION L.H.A. 71°, 289°

25°			26°			27°			28°			29°			30°			
Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
17 09.7	−26.7	98.3	17 00.9	−27.6	98.6	16 51.8	−28.6	98.9	16 42.4	−29.6	99.2	16 32.6	−30.4	99.5	16 22.6	−31.4	99.8	0
16 43.0	−26.9	99.2	16 33.3	−27.9	99.5	16 23.2	−28.8	99.8	16 12.8	−29.7	100.1	16 02.2	−30.7	100.4	15 51.2	−31.6	100.7	1
16 16.1	−27.2	100.1	16 05.4	−28.1	100.4	15 54.4	−29.1	100.7	15 43.1	−30.0	101.0	15 31.5	−30.9	101.3	15 19.6	−31.8	101.5	2
15 48.9	−27.4	101.1	15 37.3	−28.4	101.4	15 25.3	−29.3	101.6	15 13.1	−30.2	101.9	15 00.6	−31.1	102.2	14 47.8	−32.0	102.4	3
15 21.5	−27.6	102.0	15 08.9	−28.5	102.3	14 56.0	−29.4	102.5	14 42.9	−30.4	102.8	14 29.5	−31.3	103.0	14 15.8	−32.2	103.3	4
14 53.9	−27.8	102.9	14 40.4	−28.8	103.2	14 26.6	−29.7	103.4	14 12.5	−30.6	103.7	13 58.2	−31.5	103.9	13 43.6	−32.3	104.2	5
14 26.1	−28.1	103.8	14 11.6	−29.0	104.1	13 56.9	−29.9	104.3	13 41.9	−30.8	104.6	13 26.7	−31.7	104.8	13 11.3	−32.6	105.0	6
13 58.0	−28.2	104.7	13 42.6	−29.2	105.0	13 27.0	−30.1	105.2	13 11.1	−30.9	105.4	12 55.0	−31.8	105.7	12 38.7	−32.7	105.9	7
13 29.8	−28.5	105.7	13 13.4	−29.3	105.9	12 56.9	−30.2	106.1	12 40.2	−31.2	106.3	12 23.2	−32.0	106.5	12 06.0	−32.9	106.7	8
13 01.3	−28.6	106.6	12 44.1	−29.5	106.8	12 26.7	−30.5	107.0	12 09.0	−31.3	107.2	11 51.2	−32.2	107.4	11 33.1	−33.0	107.6	9

TITUDE CONTRARY NAME TO DECLINATION L.H.A. 70°, 290°

25°			26°			27°			28°			29°			30°			
Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
18 03.5	−26.8	98.7	17 54.2	−27.8	99.1	17 44.6	−28.8	99.4	17 34.6	−29.7	99.7	17 24.3	−30.6	100.0	17 13.8	−31.6	100.3	0
17 36.7	−27.1	99.7	17 26.4	−28.0	100.0	17 15.8	−28.9	100.3	17 04.9	−29.9	100.6	16 53.7	−30.8	100.9	16 42.2	−31.7	101.2	1
17 09.6	−27.3	100.6	16 58.4	−28.3	100.9	16 46.9	−29.3	101.2	16 35.0	−30.1	101.5	16 22.9	−31.1	101.8	16 10.5	−32.0	102.1	2
16 42.3	−27.6	101.6	16 30.1	−28.5	101.8	16 17.6	−29.4	102.1	16 04.9	−30.4	102.4	15 51.8	−31.2	102.7	15 38.5	−32.2	103.0	3
16 14.7	−27.8	102.5	16 01.6	−28.8	102.8	15 48.2	−29.7	103.0	15 34.5	−30.6	103.3	15 20.6	−31.5	103.6	15 06.3	−32.3	103.8	4
15 46.9	−28.1	103.4	15 32.8	−29.0	103.7	15 18.5	−29.9	103.9	15 03.9	−30.8	104.2	14 49.1	−31.7	104.5	14 34.0	−32.6	104.7	5
15 18.8	−28.3	104.3	15 03.8	−29.1	104.6	14 48.6	−30.1	104.8	14 33.1	−31.0	105.1	14 17.4	−31.9	105.3	14 01.4	−32.8	105.6	6
14 50.5	−28.4	105.2	14 34.7	−29.4	105.5	14 18.5	−30.3	105.7	14 02.1	−31.2	106.0	13 45.5	−32.1	106.2	13 28.6	−32.9	106.4	7
14 22.1	−28.7	106.1	14 05.3	−29.6	106.4	13 48.2	−30.5	106.6	13 30.9	−31.3	106.9	13 13.4	−32.2	107.1	12 55.7	−33.1	107.3	8
13 53.4	−28.9	107.0	13 35.7	−29.8	107.3	13 17.7	−30.7	107.5	12 59.6	−31.6	107.7	12 41.2	−32.4	107.9	12 22.6	−33.3	108.2	9

	Base Value	Base Z	**Next incremental Z**	**Difference in Z**	Increment	Correction *(Diff Z x Increment) / 60*
Latitude	28°	102.8°	**103.0°**	**0.2°**	34.0’	
Declination	4°	102.8°	**103.7°**	**0.9°**	22.0’	
LHA	289°	102.8°	**103.3°**	**0.5°**	47.9’	

	Base Value	Base Z	Next incremental Z	Difference in Z	Increment	**Correction *(Diff Z x Increment) / 60***
Latitude	28°	102.8°	103.0°	0.2°	34.0’	**+0.11°**
Declination	4°	102.8°	103.7°	0.9°	22.0’	**+0.33°**
LHA	289°	102.8°	103.3°	0.5°	47.9’	**+0.40°**

Total correction = 0.11° + 0.33° + 0.40° = +0.8°

Step 7: Apply the correction to the base values to determine true azimuth.

Base azimuth: 102.8°
Correction: +0.8°
Corrected azimuth: 102.8° + 0.8° = 103.6°
Azimuth rules correction: 180° - 103.6° = 76.4°
Note - Check azimuth rules: if LHA greater than 180°, then zn =180° - z.

Step 8: Answer the required questions.
T: 076.4° (Determine in Step 7)
V: 11.0° W (Given)
M: 087.4° (Calculated)
D: 3.4° E
C: 084.0° (Given)

Note this problem can be solved without the triple interpolation using the formula:

$$Tan\ Z = \left(\frac{\cos d\ sin\ LHA}{((\cos L)(\sin d) - ((\sin L)(\cos d)(\cos LHA))}\right)$$, where:

LHA is local hour angle
L is latitude
d is declination

Azimuth of Stars/Planets Problems

AZI D3. At 2326 ZT on 22 June your vessel's position is latitude 28° 30' N, longitude 150° 04' W. An azimuth of the planet Jupiter is observed, and the standard compass bearing is 250.4°. The chronometer reads 09h 24m 36s and is 01m 12s slow. The variation of this area is 13.5° E. What is the deviation of the standard compass?

G.M.T.	ARIES G.H.A.	VENUS −3.3 G.H.A.	VENUS Dec.	MARS +1.7 G.H.A.	MARS Dec.	JUPITER −1.6 G.H.A.	JUPITER Dec.
23 00	271 04.4	157 25.8	N23 04.4	200 00.3	N22 30.5	89 12.7	N 0 38.4
01	286 06.9	172 25.0	03.9	215 00.9	30.8	104 15.0	38.4
02	301 09.4	187 24.2	03.5	230 01.5	31.0	119 17.3	38.3
03	316 11.8	202 23.3	·· 03.1	245 02.1	·· 31.3	134 19.6	·· 38.2
04	331 14.3	217 22.5	02.6	260 02.6	31.5	149 21.9	38.1
05	346 16.7	232 21.7	02.2	275 03.2	31.8	164 24.2	38.0
06	1 19.2	247 20.9	N23 01.8	290 03.8	N22 32.0	179 26.5	N 0 37.9
07	16 21.7	262 20.1	01.3	305 04.4	32.3	194 28.8	37.9
T 08	31 24.1	277 19.3	00.9	320 05.0	32.5	209 31.1	37.8
U 09	46 26.6	292 18.5	·· 00.4	335 05.6	·· 32.8	224 33.4	·· 37.7
E 10	61 29.1	307 17.7	23 00.0	350 06.2	33.0	239 35.7	37.6
S 11	76 31.5	322 16.8	22 59.6	5 06.8	33.3	254 37.9	37.5
D 12	91 34.0	337 16.0	N22 59.1	20 07.4	N22 33.5	269 40.2	N 0 37.4
A 13	106 36.5	352 15.2	58.7	35 08.0	33.8	284 42.5	37.4
Y 14	121 38.9	7 14.4	58.2	50 08.6	34.0	299 44.8	37.3
15	136 41.4	22 13.6	·· 57.8	65 09.2	·· 34.3	314 47.1	·· 37.2
16	151 43.9	37 12.8	57.3	80 09.8	34.5	329 49.4	37.1
17	166 46.3	52 12.0	56.9	95 10.3	34.8	344 51.7	37.0
18	181 48.8	67 11.2	N22 56.4	110 10.9	N22 35.0	359 54.0	N 0 36.9
19	196 51.2	82 10.4	56.0	125 11.5	35.3	14 56.3	36.8
20	211 53.7	97 09.6	55.5	140 12.1	35.5	29 58.6	36.8
21	226 56.2	112 08.8	·· 55.1	155 12.7	·· 35.7	45 00.9	·· 36.7
22	241 58.6	127 08.0	54.6	170 13.3	36.0	60 03.2	36.6
23	257 01.1	142 07.2	54.1	185 13.9	36.2	75 05.5	36.5
Mer. Pass.	5h 58.7m	v −0.8	d 0.4	v 0.6	d 0.3	v 2.3	d 0.1

Answer: 2.3° E

Step 1: Determine the correct chronometer time of the sight.
Chronometer: 09h 24m 36s
Chronometer error: 01m 12s slow
Correct chronometer time: 09h 24m 36s + 1m 12s = 09h 25m 48s

Step 2: Determine the GMT of the sight.
Ship time: 2326
Chronometer time: 09h 25m 48s
DR Longitude: 150° 04' W – corresponds to (+10 ZD)
GMT of sight: 09:25:48, 23 June

Step 3: Determine the declination of Jupiter.
Declination (hours): N 0° 37.7' (d number 0.1')
Declination (increment): 0
Declination (total): N 0° 37.7'

25m	SUN PLANETS	ARIES	MOON	v or d	Corrn
s	° '	° '	° '	'	'
00	6 15·0	6 16·0	5 57·9	0·0	0·0
01	6 15·3	6 16·3	5 58·2	0·1	0·0
02	6 15·5	6 16·5	5 58·4	0·2	0·1
03	6 15·8	6 16·8	5 58·6	0·3	0·1
04	6 16·0	6 17·0	5 58·9	0·4	0·2
45	6 26·3	6 27·3	6 08·7	4·5	1·9
46	6 26·5	6 27·6	6 08·9	4·6	2·0
47	6 26·8	6 27·8	6 09·1	4·7	2·0
48	6 27·0	6 28·1	6 09·4	4·8	2·0
49	6 27·3	6 28·3	6 09·6	4·9	2·1

Step 4: Determine the GHA of Jupiter.
GHA (hours): 224° 33.4'
GHA (increment): 6° 27.0' (v number 2.3)
GHA (v correction): +1.0'
GHA (total): 231° 01.4'

Step 5: Determine the LHA of Jupiter.
GHA (Jupiter): 231° 01.4'
DR Longitude: 150° 04' W (subtract west, add east)
LHA (Jupiter): 231° 01.4' – 150° 04.0' W = 80° 57.4'

Step 6: Enter HO229 with whole values of latitude, declination (same in this case), and LHA. By increasing the value of each argument by 1 whole increment, triple interpolate for the exact values of each for the desired time/location.

	Base Value	Base Z	Next incremental Z	Difference in Z	**Increment**	Correction *(Diff Z x Increment) / 60*
Latitude – N	**28°**				**30.0’**	
Declination - N	**0°**				**37.7’**	
LHA	**80°**				**57.4’**	

80°, 280° 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.	23° Hc	23° d	23° Z	24° Hc	24° d	24° Z	25° Hc	25° d	25° Z	26° Hc	26° d	26° Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
0	9 11.9	+23.6	93.9	9 07.7	+24.6	94.1	9 03.3	+25.6	94.3	8 58.7	+26.6	94.4
1	9 35.5	+23.6	93.0	9 32.3	+24.5	93.2	9 28.9	+25.5	93.3	9 25.3	+26.4	93.5
2	9 59.1	+23.3	92.1	9 56.8	+24.4	92.3	9 54.4	+25.3	92.4	9 51.7	+26.3	92.6
3	10 22.4	+23.3	91.1	10 21.2	+24.1	91.3	10 19.7	+25.1	91.5	10 18.0	+26.1	91.7
4	10 45.7	+23.0	90.2	10 45.3	+24.1	90.4	10 44.8	+25.0	90.6	10 44.1	+26.0	90.8
5	11 08.7	+22.9	89.3	11 09.4	+23.8	89.5	11 09.8	+24.8	89.7	11 10.1	+25.8	89.9
6	11 31.6	+22.6	88.3	11 33.2	+23.7	88.5	11 34.6	+24.7	88.7	11 35.9	+25.6	88.9
7	11 54.2	+22.5	87.4	11 56.9	+23.5	87.6	11 59.3	+24.4	87.8	12 01.5	+25.4	88.0
8	12 16.7	+22.3	86.4	12 20.4	+23.2	86.6	12 23.7	+24.3	86.9	12 26.9	+25.3	87.1
9	12 39.0	+22.1	85.5	12 43.6	+23.1	85.7	12 48.0	+24.1	85.9	12 52.2	+25.0	86.2

27° Hc	27° d	27° Z	28° Hc	28° d	28° Z	29° Hc	29° d	29° Z	30° Hc	30° d	30° Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
8 54.0	+27.5	94.6	8 49.2	+28.4	94.7	8 44.1	+29.4	94.9	8 39.0	+30.2	95.0	**0**
9 21.5	+27.4	93.7	9 17.6	+28.3	93.8	9 13.5	+29.2	94.0	9 09.2	+30.2	94.2	**1**
9 48.9	+27.2	92.8	9 45.9	+28.2	92.9	9 42.7	+29.1	93.1	9 39.4	+30.0	93.3	**2**
10 16.1	+27.1	91.9	10 14.1	+28.0	92.0	10 11.8	+29.0	92.2	10 09.4	+29.9	92.4	**3**
10 43.2	+26.9	91.0	10 42.1	+27.9	91.2	10 40.8	+28.8	91.3	10 39.3	+29.7	91.5	**4**
11 10.1	+26.8	90.1	11 10.0	+27.7	90.2	11 09.6	+28.7	90.4	11 09.0	+29.6	90.6	**5**
11 36.9	+26.6	89.1	11 37.7	+27.5	89.3	11 38.3	+28.4	89.5	11 38.6	+29.4	89.8	**6**
12 03.5	+26.4	88.2	12 05.2	+27.4	88.4	12 06.7	+28.3	88.7	12 08.0	+29.3	88.9	**7**
12 29.9	+26.2	87.3	12 32.6	+27.1	87.5	12 35.0	+28.2	87.7	12 37.3	+29.0	88.0	**8**
12 56.1	+26.0	86.4	12 59.7	+27.0	86.6	13 03.2	+27.9	86.8	13 06.3	+28.9	87.1	**9**

81°, 279° 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.	23° Hc	23° d	23° Z	24° Hc	24° d	24° Z	25° Hc	25° d	25° Z	26° Hc	26° d	26° Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
0	8 16.8	+23.6	93.5	8 13.0	+24.6	93.7	8 09.0	+25.6	93.8	8 05.0	+26.5	94.0
1	8 40.4	+23.5	92.6	8 37.6	+24.4	92.8	8 34.6	+25.4	92.9	8 31.5	+26.3	93.1
2	9 03.9	+23.3	91.7	9 02.0	+24.4	91.8	9 00.0	+25.3	92.0	8 57.8	+26.3	92.2
3	9 27.2	+23.2	90.7	9 26.4	+24.1	90.9	9 25.3	+25.2	91.1	9 24.1	+26.1	91.2
4	9 50.4	+23.1	89.8	9 50.5	+24.1	90.0	9 50.5	+24.9	90.2	9 50.2	+26.0	90.3
5	10 13.5	+22.9	88.9	10 14.6	+23.8	89.1	10 15.4	+24.9	89.2	10 16.2	+25.8	89.4
6	10 36.4	+22.7	87.9	10 38.4	+23.7	88.1	10 40.3	+24.7	88.3	10 42.0	+25.6	88.5
7	10 59.1	+22.5	87.0	11 02.1	+23.5	87.2	11 05.0	+24.5	87.4	11 07.6	+25.5	87.6
8	11 21.6	+22.4	86.0	11 25.6	+23.4	86.2	11 29.5	+24.3	86.5	11 33.1	+25.3	86.7
9	11 44.0	+22.1	85.1	11 49.0	+23.2	85.3	11 53.8	+24.1	85.5	11 58.4	+25.1	85.7

27° Hc	27° d	27° Z	28° Hc	28° d	28° Z	29° Hc	29° d	29° Z	30° Hc	30° d	30° Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
8 00.7	+27.5	94.1	7 56.4	+28.3	94.3	7 51.8	+29.3	94.4	7 47.2	+30.2	94.5	**0**
8 28.2	+27.3	93.2	8 24.7	+28.3	93.4	8 21.1	+29.2	93.5	8 17.4	+30.1	93.7	**1**
8 55.5	+27.2	92.3	8 53.0	+28.1	92.5	8 50.3	+29.1	92.6	8 47.5	+30.0	92.8	**2**
9 22.7	+27.1	91.4	9 21.1	+28.0	91.6	9 19.4	+28.9	91.7	9 17.5	+29.9	91.9	**3**
9 49.8	+26.9	90.5	9 49.1	+27.9	90.7	9 48.3	+28.8	90.9	9 47.4	+29.7	91.0	**4**
10 16.7	+26.7	89.6	10 17.0	+27.7	89.8	10 17.1	+28.7	90.0	10 17.1	+29.6	90.1	**5**
10 43.4	+26.6	88.7	10 44.7	+27.6	88.9	10 45.8	+28.5	89.1	10 46.7	+29.4	89.3	**6**
11 10.0	+26.5	87.8	11 12.3	+27.3	88.0	11 14.3	+28.3	88.2	11 16.1	+29.3	88.4	**7**
11 36.5	+26.2	86.9	11 39.6	+27.3	87.1	11 42.6	+28.2	87.3	11 45.4	+29.1	87.5	**8**
12 02.7	+26.1	85.9	12 06.9	+27.0	86.2	12 10.8	+28.0	86.4	12 14.5	+28.9	86.6	**9**

	Base Value	Base Z	Next incremental Z	Difference in Z	**Increment**	Correction *(Diff Z x Increment) / 60*
Latitude	**28°**	**94.7°**			**30.0’**	
Declination	**0°**	**94.7°**			**37.7’**	
LHA	**80°**	**94.7°**			**57.4’**	

	Base Value	Base Z	**Next incremental Z**	**Difference in Z**	Increment	Correction *(Diff Z x Increment) / 60*
Latitude	28°	94.7°	**94.9°**	**0.2°**	30.0’	
Declination	0°	94.7°	**93.8°**	**-0.9°**	37.7’	
LHA	80°	94.7°	**94.3°**	**-0.4°**	57.4’	

	Base Value	Base Z	Next incremental Z	Difference in Z	Increment	**Correction *(Diff Z x Increment) / 60***
Latitude	28°	94.7°	94.9°	0.2°	30.0’	**+0.10°**
Declination	0°	94.7°	93.8°	-0.9°	37.7’	**-0.57°**
LHA	80°	94.7°	94.3°	-0.4°	57.4’	**-0.38°**

Total correction = 0.10° -0.57° - 0.38° = -0.9°

Step 7: Apply the correction to the base values to determine true azimuth.
Base azimuth: 094.7°
Correction: -0.9°
Corrected azimuth: 094.7° - 0.9° = 093.8°
Azimuth rules correction: 360° - 93.8° = 266.2°
Note - Check azimuth rules: if LHA less than 180°, then zn =360° - z.

Step 8: Answer the required questions.
T: 266.2° (Determine in Step 7)
V: 13.5° E (Given)
M: 252.7° (Calculated)
D: 2.3° E
C: 250.4° (Given)

Note this problem can be solved without the triple interpolation using the formula:

$$Tan\ Z = \left(\frac{\cos d\ sin\ LHA}{((\cos L)(\sin d) - ((\sin L)(\cos d)(\cos LHA))}\right)$$, where:

LHA is local hour angle
L is latitude
d is declination

AZI D4. On 4 October your 1907 zone time DR position is latitude 25° 15.0’ S, longitude 105° 44.0’ E. At that time, you observe Deneb bearing 011.5° psc. The chronometer reads 00h 07m 42s and the chronometer error is 00m 36s fast. The variation is 7.5° W. What is the deviation of the standard compass?

Answer: 3.2° E

Step 1: Determine the correct chronometer time of the sight.
Chronometer: 00h 07m 42s
Chronometer error: 00m 36s fast
Correct chronometer time: 00h 07m 42s – 36s = 00h 07m 06s

Step 2: Determine the GMT of the sight.
Ship time: 1907
Chronometer time: 00h 07m 06s
DR Longitude: 105° 44’ E – corresponds to (-7 ZD)
GMT of sight: 12:07:06, 4 October

Step 3: Determine the declination of Deneb.
Declination (total): N 45° 13.2’

Step 4: Determine the GHA of Deneb.
GHA (Aries - hours): 193° 05.3’
GHA (Aries - increment): 1° 46.8’
GHA (Aries - total): 194° 52.1’
SHA (Deneb): 49° 47.8’
GHA (Deneb): 244° 39.9’

Step 5: Determine the LHA of Deneb.
GHA (Deneb): 244° 39.9’
DR Longitude: 105° 44.0’ E (subtract west, add east)
LHA (Deneb): 244° 39.9’ + 105° 44.0’ E = 350° 23.9’

G.M.T.	ARIES	VENUS −3.7		MARS +1.7		JUPITER −1.2		SATURN +1.0		STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
d h	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		° ′	° ′
4 00	12 35.7	141 09.3	S20 45.7	229 55.9	N16 05.3	175 04.4	S 6 15.6	180 10.5	S 2 55.6	Acamar	315 36.3	S40 22.6
01	27 38.2	156 08.9	46.5	244 56.8	04.8	190 06.4	15.8	195 12.6	55.7	Achernar	335 44.1	S57 19.7
02	42 40.6	171 08.5	47.4	259 57.8	04.4	205 08.4	16.0	210 14.8	55.8	Acrux	173 37.2	S62 59.7
03	57 43.1	186 08.0	· · 48.3	274 58.7	· · 03.9	220 10.3	· · 16.2	225 17.0	· · 56.0	Adhara	255 31.6	S28 56.6
04	72 45.6	201 07.6	49.1	289 59.7	03.5	235 12.3	16.4	240 19.2	56.1	Aldebaran	291 17.0	N16 28.4
05	87 48.0	216 07.1	50.0	305 00.7	03.0	250 14.2	16.6	255 21.4	56.2			
06	102 50.5	231 06.7	S20 50.8	320 01.6	N16 02.6	265 16.2	S 6 16.8	270 23.5	S 2 56.3	Alioth	166 42.4	N56 03.7
07	117 53.0	246 06.2	51.7	335 02.6	02.1	280 18.2	17.0	285 25.7	56.4	Alkaid	153 18.4	N49 24.5
08	132 55.4	261 05.8	52.5	350 03.6	01.6	295 20.1	17.2	300 27.9	56.6	Al Na'ir	28 13.7	S47 03.1
S 09	147 57.9	276 05.3	· · 53.4	5 04.5	· · 01.2	310 22.1	· · 17.4	315 30.1	· · 56.7	Alnilam	276 10.8	S 1 12.7
U 10	163 00.3	291 04.9	54.2	20 05.5	00.7	325 24.1	17.6	330 32.3	56.8	Alphard	218 20.1	S 8 34.5
N 11	178 02.8	306 04.4	55.1	35 06.5	16 00.3	340 26.0	17.8	345 34.4	56.9			
D 12	193 05.3	321 04.0	S20 55.9	50 07.4	N15 59.8	355 28.0	S 6 18.0	0 36.6	S 2 57.0	Alphecca	126 31.8	N26 46.9
A 13	208 07.7	336 03.5	56.7	65 08.4	59.4	10 29.9	18.2	15 38.8	57.1	Alpheratz	358 08.2	N28 59.4
Y 14	223 10.2	351 03.1	57.6	80 09.3	58.9	25 31.9	18.5	30 41.0	57.3	Altair	62 31.8	N 8 49.3
15	238 12.7	6 02.6	· · 58.4	95 10.3	· · 58.5	40 33.9	· · 18.7	45 43.2	· · 57.4	Ankaa	353 39.1	S42 24.3
16	253 15.1	21 02.2	20 59.3	110 11.3	58.0	55 35.8	18.9	60 45.4	57.5	Antares	112 56.2	S26 23.4
17	268 17.6	36 01.7	21 00.1	125 12.2	57.6	70 37.8	19.1	75 47.5	57.6			
18	283 20.1	51 01.3	S21 01.0	140 13.2	N15 57.1	85 39.7	S 6 19.3	90 49.7	S 2 57.7	Arcturus	146 18.1	N19 16.9
19	298 22.5	66 00.8	01.8	155 14.2	56.6	100 41.7	19.5	105 51.9	57.9	Atria	108 20.1	S68 59.9
20	313 25.0	81 00.4	02.6	170 15.1	56.2	115 43.7	19.7	120 54.1	58.0	Avior	234 28.2	S59 26.7
21	328 27.5	95 59.9	· · 03.5	185 16.1	· · 55.7	130 45.6	· · 19.9	135 56.3	· · 58.1	Bellatrix	278 57.9	N 6 20.1
22	343 29.9	110 59.5	04.3	200 17.1	55.3	145 47.6	20.1	150 58.4	58.2	Betelgeuse	271 27.4	N 7 24.3
23	358 32.4	125 59.0	05.1	215 18.0	54.8	160 49.6	20.3	166 00.6	58.3			
5 00	13 34.8	140 58.6	S21 06.0	230 19.0	N15 54.4	175 51.5	S 6 20.5	181 02.8	S 2 58.5	Canopus	264 06.8	S52 40.8
01	28 37.3	155 58.1	06.8	245 20.0	53.9	190 53.5	20.7	196 05.0	58.6	Capella	281 10.1	N45 58.7
02	43 39.8	170 57.7	07.7	260 20.9	53.4	205 55.4	20.9	211 07.2	58.7	Deneb	49 47.8	N45 13.2
03	58 42.2	185 57.2	· · 08.5	275 21.9	· · 53.0	220 57.4	· · 21.1	226 09.3	· · 58.8	Denebola	182 58.6	N14 40.7
04	73 44.7	200 56.8	09.3	290 22.9	52.5	235 59.4	21.3	241 11.5	58.9	Diphda	349 19.8	S18 05.2

m 7	SUN PLANETS	ARIES
s	° ′	° ′
00	1 45·0	1 45·3
01	1 45·3	1 45·5
02	1 45·5	1 45·8
03	1 45·8	1 46·0
04	1 46·0	1 46·3
05	1 46·3	1 46·5
06	1 46·5	1 46·8
07	1 46·8	1 47·0
08	1 47·0	1 47·3
09	1 47·3	1 47·5

Step 6: Enter HO229 with whole values of latitude, declination (contrary in this case), and LHA. By increasing the value of each argument by 1 whole increment, triple interpolate for the exact values of each for the desired time/location.

LATITUDE CONTRARY NAME TO DECLINATION — L.H.A. 9°, 351°

24°			25°			26°			27°			28°			29°			30°			
Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
21 30.1	−59.3	173.1	20 30.5	−59.3	173.1	19 30.9	−59.3	173.1	18 31.4	−59.4	173.2	17 31.8	−59.4	173.2	16 32.2	−59.4	173.3	15 32.6	−59.4	173.3	44
20 30.8	−59.3	173.2	19 31.2	−59.3	173.3	18 31.6	−59.3	173.3	17 32.0	−59.4	173.3	16 32.4	−59.4	173.4	15 32.8	−59.4	173.4	14 33.2	−59.4	173.4	45
19 31.5	−59.4	173.4	18 31.9	−59.4	173.4	17 32.3	−59.4	173.5	16 32.6	−59.3	173.5	15 33.0	−59.4	173.5	14 33.4	−59.4	173.6	13 33.8	−59.4	173.6	46
18 32.1	−59.3	173.5	17 32.5	−59.3	173.6	16 32.9	−59.4	173.6	15 33.3	−59.4	173.6	14 33.6	−59.3	173.7	13 34.0	−59.4	173.7	12 34.4	−59.5	173.7	47
17 32.8	−59.3	173.7	16 33.2	−59.4	173.7	15 33.5	−59.3	173.8	14 33.9	−59.4	173.8	13 34.3	−59.4	173.8	12 34.6	−59.4	173.8	11 34.9	−59.4	173.9	48
16 33.5	−59.3	173.9	15 33.8	−59.3	173.9	14 34.2	−59.4	173.9	13 34.5	−59.4	173.9	12 34.9	−59.4	174.0	11 35.2	−59.4	174.0	10 35.5	−59.4	174.0	49
15 34.2	−59.4	174.0	14 34.5	−59.4	174.0	13 34.8	−59.3	174.1	12 35.1	−59.3	174.1	11 35.5	−59.4	174.1	10 35.8	−59.4	174.1	9 36.1	−59.4	174.1	50

LATITUDE CONTRARY NAME TO DECLINATION — L.H.A. 10°, 350°

24°			25°			26°			27°			28°			29°			30°			
Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
21 23.1	−59.2	172.3	20 23.6	−59.2	172.3	19 24.1	−59.1	172.4	18 24.7	−59.2	172.4	17 25.2	−59.2	172.5	16 25.7	−59.3	172.5	15 26.2	−59.3	172.6	44
20 23.9	−59.1	172.5	19 24.4	−59.1	172.5	18 25.0	−59.2	172.6	17 25.5	−59.3	172.6	16 26.0	−59.3	172.6	15 26.4	−59.2	172.7	14 26.9	−59.2	172.7	45
19 24.8	−59.2	172.7	18 25.3	−59.2	172.7	17 25.8	−59.2	172.7	16 26.2	−59.2	172.8	15 26.7	−59.2	172.8	14 27.2	−59.3	172.8	13 27.7	−59.3	172.9	46
18 25.6	−59.1	172.8	17 26.1	−59.2	172.9	16 26.6	−59.2	172.9	15 27.0	−59.2	172.9	14 27.5	−59.3	173.0	13 27.9	−59.2	173.0	12 28.4	−59.3	173.0	47
17 26.5	−59.2	173.0	16 26.9	−59.2	173.0	15 27.4	−59.2	173.1	14 27.8	−59.2	173.1	13 28.2	−59.2	173.1	12 28.7	−59.3	173.2	11 29.1	−59.3	173.2	48
16 27.3	−59.2	173.2	15 27.7	−59.2	173.2	14 28.2	−59.3	173.2	13 28.6	−59.3	173.3	12 29.0	−59.3	173.3	11 29.4	−59.3	173.3	10 29.8	−59.3	173.3	49
15 28.1	−59.1	173.3	14 28.5	−59.2	173.4	13 28.9	−59.2	173.4	12 29.3	−59.2	173.4	11 29.7	−59.2	173.5	10 30.1	−59.3	173.5	9 30.5	−59.3	173.5	50

	Base Value	Base Z	Next incremental Z	Difference in Z	**Increment**	Correction *(Diff Z x Increment) / 60*
Latitude – S	**25°**				**15.0’**	
Declination - N	**45°**				**13.2’**	
LHA	**350°**				**23.9’**	

	Base Value	**Base Z**	Next incremental Z	Difference in Z	Increment	Correction *(Diff Z x Increment) / 60*
Latitude	25°	**172.5°**			15.0’	
Declination	45°	**172.5°**			13.2’	
LHA	350°	**172.5°**			23.9’	

	Base Value	Base Z	**Next incremental Z**	**Difference in Z**	Increment	Correction *(Diff Z x Increment) / 60*
Latitude	25°	172.5°	**172.6°**	**0.1°**	15.0’	
Declination	45°	172.5°	**172.7°**	**0.2°**	13.2’	
LHA	350°	172.5°	**173.3°**	**0.8°**	23.9’	

	Base Value	Base Z	Next incremental Z	Difference in Z	Increment	**Correction *(Diff Z x Increment) / 60***
Latitude	25°	172.5°	172.6°	0.1°	15.0’	**+0.00°**
Declination	45°	172.5°	172.7°	0.2°	13.2’	**+0.00°**
LHA	350°	172.5°	173.3°	0.8°	23.9’	**+0.32°**

Total correction = 0.0° + 0.0° + 0.32° = <u>+0.3°</u>

Step 7: Apply the correction to the base values to determine true azimuth.
Base azimuth: 172.5°
Correction: +0.3°
Corrected azimuth: 172.5° + 0.3° = 172.8°
Azimuth rules correction: 180° - 172.8° = 007.2°
Note - Check azimuth rules: if LHA greater than 180°, then zn =180° - z.

Step 8: Answer the required questions.
T: 007.2° (Determine in Step 7)
V: 7.5° W (Given)
M: 14.7° (Calculated)
D: 3.2° E
C: 011.5° (Given)

Note this problem can be solved without the triple interpolation using the formula:

$$Tan\ Z = \left(\frac{\cos d\ sin\ LHA}{((\cos L)(\sin d) - ((\sin L)(\cos d)(\cos LHA))}\right)$$, where:

LHA is local hour angle
L is latitude
d is declination

Azimuth of Polaris Problems

- Refer to the Latitude by Polaris section for more detail on theory regarding Local Hour Angle (LHA) and Polaris problems in general.

AZI D5. On 5 February your 2320 ZT position is latitude 52° 28’ N, longitude 23° 48’ W. You observe Polaris bearing 000.2° pgc. At the time of observation, the helmsman noted that she was heading 224° pgc and 244° psc. The variation is 20° W. What is the deviation for that heading?

34		ARIES
G.M.T.		G.H.A.
d	h	° ′
6	00	136 02.4
	01	151 04.9
	02	166 07.4
	03	181 09.8
	04	196 12.3
	05	211 14.8

Answer: 1.5° W.

Step 1: Determine the GMT of the sight.
DR Longitude: 23° 48’ W - corresponds to ZD (+2).
Local time of observation: 2320 ZT
GMT time of observation = 2320 ZT + 2 hours = 0120 GMT (6 Feb).

Step 2: Determine the GHA of Aries for the time of sight.
GHA (Aries), whole hours: 151° 04.9’
GHA (Aries), increment: 5° 00.8’
GHA (Aries), total: 151° 04.9’ + 5° 00.8’ = <u>156° 05.7’</u>

20m		
20 m	SUN PLANETS	ARIES
s	° ′	° ′
00	5 00·0	5 00·8
01	5 00·3	5 01·1
02	5 00·5	5 01·3
03	5 00·8	5 01·6
04	5 01·0	5 01·8

Step 3: Determine the LHA of Aries.
GHA (Aries): 156° 05.7’
DR Longitude: 23° 48’ W
LHA (Aries) = 156° 05.7’ – 23° 48’ W = <u>132° 17.7’</u>

Step 4: Enter the Polaris Tables with LHA (Aries), DR Latitude, and Month to determine the azimuth to Polaris
<u>Azimuth (interpolated) = 358.7°</u>

Step 5: Determine the gyro compass error.
G (Gyro): 000.2° pgc
E (Error): TBD
T (True): 358.7° per azimuth tables
Gyro error = <u>1.5° W</u>

L.H.A. ARIES	120°– 129°	130°– 139°
Lat.		
°	°	°
0	359·2	359·2
20	359·1	359·1
40	358·9	359·0
50	358·7	358·8
55	358·6	358·6

Step 6: Determine the deviation.
G: 224° pgc (Given)
E: 1.5° W (Determine in step 5)
T: 222.5° (Calculated)
V: 20° W (Given)
M: 242.5° (Calculated)
D: 1.5° W (Calculated)
C: 244° per steering compass (Given)

Azimuth Problems

Azimuth of the Sun

AZI B1. On 17 April your 1610 zone time DR position is latitude 22° 07.0’ N, longitude 158° 16.0’ W. At that time, you observe the Sun bearing 271° psc. The chronometer reads 03h 08m 52s and the chronometer error is 01m 16s slow. The variation is 4° E. What is the deviation of the standard magnetic compass?

a) 1.1° W
b) 1.7° E
c) 2.3° W - correct
d) 2.9° E

AZI B2. On 21 April, your 1542 zone time DR position is latitude 28° 54.0’ S. Longitude 19° 07.0’ W. At that time, you observe the Sun bearing 299° psc. The chronometer reads 04h 44m 11s and the chronometer error is 01m 54s fast. The variation is 3° E. What is the deviation of the standard compass?

a) 0.3° W - correct
b) 0.4° E
c) 2.7° W
d) 2.7° E

AZI B3. On 1 September your 1115 zone time DR position is latitude 25° 20’ N, longitude 28° 24’ W. At that time, you observe the Sun bearing 160.5° psc. The chronometer reads 01h 14m 58s and the chronometer error is 01m 17s fast. The variation is 13.5° W. What is the deviation of the standard compass?

a) 2.1° E - correct
b) 4.1° E
c) 11.0° W
d) 11.0° E

AZI B4. On 24 May, your vessel’s 1000 ZT position is latitude 25° 36.0’ N, longitude 118° 39.5’ W, when you observe an azimuth of the Sun. Determine the gyro error using the azimuth information:
Chronometer time: 06h 21m 48s
Chronometer error: Fast 01m 36s
Gyro bearing: 099.4°
Variation: 11.1° E

a) 0.3° W
b) 1.3° W - correct
c) 1.8° E
d) 2.4° E

Azimuth of Stars/Planets Problems

AZI B5. On 5 June your 0420 zone time DR position is latitude 26° 47.0’ N, longitude 133° 19.5’ W. At that time, you observer Vega bearing 298.1° psc. The chronometer reads 01h 21m 17s, and the chronometer error is 02m 25s fast. The variation is 3.5° E. What is the deviation of the standard compass?

a) 1.8° E
b) 5.2° E
c) 1.8° W - correct
d) 5.2° W

AZI B6. On 6 October your 0416 zone time DR position is latitude 25° 16.0’ N, longitude 130° 25.0’ E. At that time, you observe Mars bearing 083° psc. The chronometer reads 07h 16m 22s and the chronometer error is 10s fast. The variation is 1.5° E. What is the deviation of the standard compass?

a) 0.4° E
b) 1.2° W - correct
c) 3.5° E
d) 19.0° E

AZI B7. On 28 July your 1937 zone time DR position is latitude 26° 13.0’ N, longitude 78° 27.0’ E. At that time, you observe Deneb bearing 048.7° pgc. The chronometer reads 02h 37m 42s and the chronometer error is 00m 15s fast. The variation is 4° W. What is the gyro error?

a) 2.4° W
b) 2.8° E - correct
c) 3.6° W
d) 3.6° E

AZI B8. On 2 March your 2216 zone time DR position is latitude 21° 20.0’ S, longitude 17° 10.0’ W. At that time, you observe Saturn bearing 078° psc. The chronometer reads 11h 14m 04s and the chronometer error is 02m 20s slow. The variation is 4.5° W. What is the deviation of the standard compass?

a) 1.5° W
b) 1.6° E
c) 2.9° W
d) 3.6° E - correct

Azimuth of Polaris Problems

AZI B9. On 11 January your 0450 ZT position is latitude 38° 42' N, longitude 14° 16' W. You observe Polaris bearing 358.5° pgc. At the time of observation, the helmsman noted he was heading 160° pgc and 173° psc. The variation is 9° W. What is the deviation for that heading?

a) 1° E
b) 1° W
c) 3° W - correct
d) 13° W

AZI B10. On 19 November, your 0146 ZT position is latitude 33° 48' N, longitude 25° 22' E. You observe Polaris bearing 359.8° pgc. At the time of observation, the helmsman noted that he was heading 224° pgc and 222.5° psc. The variation is 2° E. What is the deviation for that heading?

a) 2.0° E
b) 0.5° E
c) 1.0° W - correct
d) 1.5° W

AZI B11. On 23 July, your 2100 ZT position is latitude 36° 43.0' N, longitude 16° 09.8' W, when you observe an azimuth of Polaris to determine compass error. Polaris bears 359.0° per gyrocompass. At the time of the observation, the helmsman noted that he was heading 319° per gyrocompass and 331° per standard compass. Variation is 12.0° W. Which of the following statements is TRUE?

a) The gyro error is 0.7° E
b) The gyro error is 1.7° W
c) The deviation is 1.7° E - correct
d) The compass error is 13.7° W

AZI B12. On 3 October your 0330 zone time (ZD +5) DR position is latitude 47° 41' N, longitude 86° 49' W. At that time, you observe Polaris bearing 357.5° pgc. The chronometer time of observation is 08h 32m 04s and the chronometer is 0m 27s slow. The variation is 5.5° W. What is the gyro error?

a) 7.5° E
b) 5.0° E
c) 3.5° E
d) 2.0° E - correct

Mercator Sailing Problems

- Terms:
  - DLo – the difference in two longitudes.
  - L is latitude.
  - DLat or *l* is the difference between two latitudes.
  - Cn or C is the course/course angle. Course angle is the course measured from 0° at the reference direction clockwise or counterclockwise through 90° or 180°. It is labeled with the reference direction as a prefix and the direction of measurement from the reference direction as a suffix. For example, a true course of 330° T would be noted as N 30° W.
  - D is distance in nautical miles.
  - m is the Meridional parts. The actual length of an arc from the equator to a given latitude, given along a longitude/meridian line. The Meridional Parts Table in Bowditch provides this value.
    - m1 – the meridional parts of the point of departure.
    - m2 – the meridional parts of the destination.
- The main Mercator sailing formula needed are:
  - $l = D \ \cos C$, which can be restated as $D = l \ (\frac{1}{\cos C})$
  - $DLo = m \ tan\, C$
  - $\tan C = \frac{DLo}{m}$

Mercator Latitude and Longitude Problems

MER D1. You depart latitude 40° 42.0' N, longitude 074° 01.0' W and steam 3365.6 miles on course 118° T. What is the longitude of your arrival by Mercator Sailing?

Answer: 17° 40.62' W.

Step 1: Convert standard latitude and longitudes to decimal form:
Departure Location
40° 42.0' N = 40.70° N
74° 01.0' W = 74.02° W

Step 2: Determine the Course Angle:
Course = 118° T
Course Angle = S 62° E

Step 3: Determine the Difference of Latitude (*l*) given the known course and distance. Then convert the mileage to arc.

$l = D\ \cos C$
$l = (3365.6)\ \cos(62°)$
$l = (3365.6)\ (0.4695)$
$l = 1580.05'$
$l = 1580.05' \div 60 = 26.3342°$

Step 4: Given that the initial course was to the southeast, subtract the Difference of Latitude (*l*) from the initial latitude to determine the arrival latitude.

Departure Latitude: 40.70° N
Difference of Latitude: -26.3342°
Arrival Latitude = 40.70° - 26.3342° = 14.366° = 14° 22.0' N

Step 5: Use the Meridional Parts Table in Bowditch to obtain the meridional parts (*m1* and *m2*) for the given latitudes.

Latitude 1: 40° 42.0'
Meridional Parts 1: *m1* = 2662.8

Latitude 2: 14° 22.0'
Meridional Parts 2: *m2* = 865.4

Step 6: Determine the difference in meridional parts (*m*).
m1 – *m2* = *m*
2662.8 – 865.4 = *m* = 1797.4

Step 7: Determine the Difference in Longitude (*DLo*). Convert the mileage to arc.

$DLo = m\ \tan C$
$DLo = (1797.4)\ \tan 62°$
$DLo = (1797.4)\ (1.8807)$
$DLo = 3380.42'$
$DLo = 3380.42' \div 60 = 56.34°$

Step 8: Determine the arrival longitude using the Difference of Longitude (*DLo*).

Departure Longitude: 74.017° = 74° 01.0' W
Difference of Longitude: 56.34° = 56° 20.4'
Arrival Longitude = 74.017° - 56.34° = 17.677° = **17° 40.62' N**

Mercator Course and Distance Problems

MER D2. A vessel at latitude 45° 36.0’ N, longitude 011° 36.0 W heads for a destination at latitude 24° 16.0’ N, longitude 073° 52.0’ W. Determine the true course and distance by Mercator sailing.

Answer: 247.2° T, 3299.2 nm.

Step 1: Convert standard latitude and longitudes to decimal form:
Departure Location
45° 36.0’ N = 45.600° N
11° 36.0’ W = 11.600° W
Arrival Location
24° 16.0’ N = 24.267° N
73° 52.0’ W = 73.867° W

Step 2: Determine the Difference of Latitude (l). Convert to minutes of arc.
l = 45.600° N - 24.267° N = 21.333°
l = 21.333° × 60 = 1279.98’

Step 3: Determine the Difference in Longitude (*DLo*). Convert to minutes of arc.
DLo = 11.600° W - 73.867° W = 62.267°
DLo = 62.267° × 60 = 3736.02’

Step 4: Use the Meridional Parts Table in Bowditch to obtain the meridional parts (*m1* and *m2*) for the given latitudes.

Latitude 1: 45° 36.0’
Meridional Parts 1: *m1* = 3064.7

Latitude 2: 24° 16.0’
Meridional Parts 2: *m2* = 1492.1

Step 5: Determine the difference in meridional parts (*m*).
m1 – m2 = m
3064.7– 1492.1 = *m* = 1572.6

Step 6: Determine the Course Angle (C).

$$DLo = m \tan C$$
$$\tan C = \frac{DLo}{m}$$
$$\tan C = \frac{3736.02'}{1572.6}$$
$$\tan C = 2.3756$$
$$C = \tan^{-1} 2.3756$$
$$C = 67.172$$

Step 7: Determine the actual course steered given the solved course angle. Note that the vessel headed in a SW direction given the initial and final positions. Therefore, the course angle 67.172° is expressed as S 67.172° W. You can round final answers to nearest tenth.

C = S 67.172° W
180° + 67.172° W = **247.172° T = 247.2° T**

Step 8: Determine the distance travelled using the Plane Sailing formula.

$$l = D \cos C$$
$$D = l \left(\frac{1}{\cos C}\right)$$
$$D = (1279.98)\left(\frac{1}{\cos 247.2}\right)$$
$$D = (1279.98)\left(\frac{1}{(0.3875)}\right)$$
$$D = (1279.98)(2.5806)$$
$$\boldsymbol{D = 3303.2 \text{ nm}}$$

Mercator Sailing Problems

Mercator Latitude and Longitude

MER B1. A vessel steams 1082 miles on course 047° T from latitude 37° 18.0’ N, longitude 24° 40.0’ W. What is the latitude and longitude of the point of arrival by Mercator sailing?

a) 49° 30’ N, 6° 22’ W
b) 49° 33’ N, 6° 25’ W
c) 49° 36’ N, 6° 28’ W - correct
d) 49° 39’ N, 6° 31’ W

MER B2. A vessel steams 1650 miles on course 077° T from latitude 12° 47’ N, longitude 45° 10’ E. What is the latitude and longitude of the point of arrival by Mercator sailing?

a) 18° 54’ N, 72° 58’ E
b) 18° 58’ N, 72° 52’ E - correct
c) 19° 02’ N, 72° 44’ E
d) 19° 06’ N, 72° 36’ E

MER B3. You depart latitude 49° 45.0’ N, longitude 6° 35.0’ W and steam 3599 miles on course 246.5° T. What is the longitude of your arrival by Mercator sailing?

a) 76° 36.2’ W
b) 77° 02.8’ W - correct
c) 78° 14.0’ W
d) 78° 22.6’ W

Mercator Course and/or Distance

MER B4. Your vessel departs latitude 32° 45’ N, longitude 79° 50’ W, and is bound for latitude 34° 21’ S, longitude 18° 29’ E. Determine the distance by Mercator sailing.

a) 5,021 miles
b) 6,884 miles - correct
c) 6,954 miles
d) 7,002 miles

MER B5. Your vessel receives a distress call from a vessel reporting her position as latitude 35° 01’ S, longitude 18° 51’ W. Your position is latitude 30° 18’ S, longitude 21° 42’ W. Determine the true course from your vessel to the vessel in distress by Mercator sailing.

a) 135° T
b) 149° T
c) 153° T - correct
d) 160° T

MER B6. A vessel at latitude 32° 14.7’ N, longitude 66° 28.9’ W heads for a destination at latitude 36° 58.7’ N, longitude 75° 42.2’ W. Determine the true course by Mercator sailing.

a) 058.2° T
b) 235.2° T
c) 301.8° T - correct
d) 348.3° T

MER B7. A vessel at latitude 10° 22’ S, longitude 7° 18’ E heads for a destination at latitude 6° 54’ N, longitude 57° 23’ W. Determine the course and distance by Mercator sailing.

a) 285° T, 3825.3 miles
b) 285° T, 4025.7 miles - correct
c) 296° T, 3825.3 miles
d) 296° T, 4025.7 miles

MER B8. A vessel at latitude 18° 54’ N, longitude 73° 00’ E heads for a destination at latitude 13° 12’ N, longitude 54° 00’ E. Determine the true course and distance by Mercator sailing.

a) 247° T, 1161 miles
b) 250° T, 1172 miles
c) 253° T, 1154 miles - correct
d) 256° T, 1136 miles

MER B9. A vessel at latitude 21° 18.5’ N, longitude 157° 52.2’ W heads for a destination at latitude 8° 53.0’ N, longitude 79° 31.0’ W. Determine the true course and distance by Mercator sailing.

a) 081° T, 4617.5 miles
b) 081° T, 4915.8 miles
c) 099° T, 4617.5 miles - correct
d) 099° T, 4915.8 miles

MER B10. A vessel at latitude 29° 38.0’ N, longitude 93° 49.0’ W heads for a destination at latitude 24° 38.0’ N, longitude 82° 55.2’ W. Determine the true course and distance by Mercator sailing.

a) 115° T, 637 miles
b) 117° T, 658 miles - correct
c) 122° T, 648 miles
d) 126° T, 665 miles

Middle Latitude Sailing Problems

- Terms:
  - DLo is the difference in two longitudes.
  - λ1 is the starting longitude.
  - λ2 is the ending longitude.
  - p is departure. The distance between two meridians at any given parallel of latitude.
  - L1 is the starting latitude.
  - L2 is the ending latitude.
  - DLat or *l* is the difference between two latitudes.
  - Lm is the middle latitude, the average of the starting and ending latitudes.
  - Cn or C is the course/course angle. Course angle is the course measured from 0° at the reference direction clockwise or counterclockwise through 90° or 180°. It is labeled with the reference direction as a prefix and the direction of measurement from the reference direction as a suffix. For example, a true course of 330° T would be noted as N 30° W.
  - D is distance in nautical miles.
- The main formula needed are:
  - $l = D \cos C$
  - $p = D \sin C$
  - $DLo = \frac{p}{\cos Lm}$
  - $\tan C = \frac{p}{l}$
- Mid Latitude Sailing involves the use of the mid (or middle) latitude for converting departure (p) to difference in longitude (DLo) when the course is not due east or west, and it is assumed such course is steered at the mid latitude.
- Bowditch article 1006 provides background knowledge on this task and is available during Coast Guard exams.

Mid Latitude Sailings Course and Distance

MLS D1. A vessel in latitude 20° 00’ N, longitude 107° 30’ W is to proceed to latitude 24° 40’ N, longitude 112° 30’ W. What is the course and distance by mid-latitude sailing?

Answer: Course 315.27° T, 394.4 nm.

Step 1: Convert standard latitude and longitudes to decimal form:
Departure Location
20° 00’ N = 20.0° N
107° 30’ W = 107.5° W
Arrival Location
24° 40’ N = 24.67° N
112° 30’W = 112.5° W

Step 2: Determine the mid-latitude (*Lm*).
Lm = (20.0° N + 24.67° N) ÷ 2 = 22.33° N

Step 3: Determine the Difference of Latitude (*l*) and convert to arc minutes to determine l.
DLat = 24.67° - 20.0° = 4.67°
l = 4.67° × 60 = 280.2’

Step 4: Determine the Difference of Longitude (*DLo*) and convert to arc minutes.
112.5° W – 107.5° W = 5.0° = 300’

Step 5: Determine the Departure (*p*).
$p = DLo \ \cos Lm$
$p = 300' \ \cos(22.33)$
$p = (300)\ (0.9250)$
$p = 277.49'$

Step 6: Determine the Course Angle (*C*).
$\tan C = \frac{p}{l}$
$\tan C = \frac{277.49}{280.2}$
$\tan C = 0.9903$
$C = \tan^{-1} 0.9903$
$C = 44.722°$

Step 7: Determine the distance.

$D = l \sec C$

$D = (280.2) \sec(44.722)$

$D = (280.2)(\frac{1}{\cos 44.722})$

$D = (280.2)(\frac{1}{0.7105})$

$\boldsymbol{D =}$ **394.4 nm**

Step 8: Determine the actual course given the solved Course Angle (*C*). Also note that the vessel clearly headed in a northwesterly direction based on the origin and destination points. Therefore, the course is given by:

Course = 360° - *C*
Course = 360° - 44.722°
Course = 315.278°

Mid Latitude Sailings Arrival Position

MLS D2. A vessel steams 640 miles on course 047° T from latitude 34° 45’ N, longitude 140° 00’ E. What are the latitude and longitude of arrival by mid-latitude sailing?

Answer: 42° 01.5’ N, 149° 57.2’ E

Step 1: Convert standard latitude and longitudes to decimal form:
Departure Location
34° 45’ N = 34.750° N
140° 00’ E = 140.000° E

Step 2: Determine the Difference in Latitude (l) and convert to decimal notation.
$l = D\ \cos C$
$l = (640)\ \cos(047°)$
$l = (640)\ (0.6820)$
$l = 436.5'$
436.5’ ÷ 60 = 7.275° (to the north based on initial course).

Step 3: Determine the arrival latitude using the Difference in Latitude (l). Convert to standard notation for partial problem answer.
Latitude 1 = 34.750° N
Difference in Latitude = 7.275° to the north.
Latitude 2 = 34.750° + 7.275° = 42.025° N = **42° 01.5’ N**

Step 4: Determine the mid latitude using the Difference in Latitude (l) and arrival latitude.
Latitude 1 = 34.750° N
Latitude 2 = 42.025° N
Mid Lat = $\frac{34.750°+42.025°}{2} = 38.388°$

Step 5: Determine the Departure (p).
$p = D\ \sin C$
$p = (640)\ \sin 47°$
$p = (640)\ (0.7313)$
$p = 468.1'$

Step 6: Determine the Difference in Longitude (*DLo*) given the departure and mid-latitude.

$DLo = p\ (\frac{1}{\cos Lm})$
$DLo = p\ (\frac{1}{\cos Lm})$
$DLo = (468.1')\ (\frac{1}{\cos 38.388°})$
$DLo = (468.1')\ (\frac{1}{(0.7838)})$
$DLo = (468.1')\ (1.2758)$
$DLo = 597.2'$

Step 7: Convert the Difference in Longitude (*DLo*) to decimal notation and determine the arrival longitude. Convert to standard notation for partial problem answer.

$DLo = 597.2'$ ÷ 60 = 9.953° (to the east based on initial course).
Longitude 1 = 140.000° E
Difference in Longitude = 9.953° to the east.
Longitude 2 = 140.000° + 9.953° = 149.953° E
149.953° E = **149° 57.2' E**

Mid Latitude Sailings Problems

Mid Latitude Sailings Course and Distance

MLS B1. A vessel at latitude 14° 10'N, longitude 61° 00'W is to proceed to latitude 10° 00' N, longitude 53° 23' W. What is the course and distance by mid-latitude sailing?

a) 117.3° T for 503 miles
b) 117.9° T for 504 miles
c) 118.6° T for 508 miles
d) 119.2° T for 512 miles - correct

MLS B2. A vessel at latitude 20° 00' N, longitude 107° 30'W is to proceed to latitude 24° 40' N, longitude 112° 30' W. What is the course and distance by mid-latitude sailing?

a) 314.0° T for 389 miles
b) 315.3° T for 394 miles - correct
c) 317.2° T for 397 miles
d) 318.3° T for 399 miles

MLS B3. A vessel at latitude 20° 10' N, longitude 122° 00' E is to proceed to latitude 26° 18' N, longitude 128° 20' E. What are the course and distance by mid-latitude sailing?

a) 041.2° T for 501 miles
b) 041.9° T for 503.6 miles
c) 043.5° T for 507.3 miles - correct
d) 044.7° T for 509.7 miles

Mid Latitude Sailings Arrival

MLS B4. A vessel steams 576 miles on course 260° T from latitude 40° 36’N, longitude 50° 24’ W. What are the latitude and longitude of the point of arrival by mid-latitude sailing?

a) 39° 12’ N, 62° 28’ W
b) 39° 06’ N, 62° 34’ W
c) 39° 02’ N, 62° 37’ W
d) 38° 56’ N, 62° 42’ W - correct

MLS B5. A vessel steams 580 miles on course 083° T from latitude 13° 12’ N, 71° 12’ W. What are the latitude and longitude of the point of arrival by mid-latitude sailing?

a) 14° 17’ N, 61° 23’ W
b) 14° 20’ N, 61° 21’ W
c) 14° 23’ N, 61° 19’ W - correct
d) 14° 25’ N, 61° 17’ W

MLS B6. A vessel steams 640 miles on course 047° T from latitude 34° 45’ N, longitude 140° 00’ E. What are the latitude and longitude of the point of arrival by mid-latitude sailing?

a) 41° 57’ N, 150° 02’ E
b) 42° 01’ N, 149° 57’ E - correct
c) 42° 06’ N, 149° 53’ E
d) 42° 09’ N, 149° 50’ E

Parallel Sailing Problems

- Terms:
  - DLo – the difference in two longitudes.
  - p is departure. The distance between two meridians at any given parallel of latitude.
  - L is latitude. For parallel sailing problems, the latitude does not change since the course is either 090° T or 270° T.
- The main parallel sailing formula needed is:
  - $DLo = \frac{p}{\cos l}$ which can be re-arranged as $p = DLo\ \cos L$
- The main parallel sailing formula is identical to the mid-latitude formula, given that when determining Difference in Longitude (DLo), it is assumed a vessel is proceeding along a parallel, e.g. parallel sailing.

PAR D1. You depart latitude 52° 01'N longitude176° 09'E to latitude 52° 01'N, 178° 46'W. what are the course and distance by parallel sailing?

Answer: 090° T, 188 miles.

Step 1: Convert standard latitude and longitudes to decimal form:

Departure Location
52° 01' N = 52.017° N
176° 09' E = 176.150° E

Arrival Longitude
178° 46'W = 178.766° W

Step 2: Determine the Course and Difference of Longitude (DLo).

Long 1 = 176.150° E
Long 2 = 178.766° W

Eastern Hemisphere Distance (180° - 176.150°) = 3.85° to the east
Western Hemisphere Distance (180° – 178.766°) = 1.234° to the east

Total DLo = 3.85° + 1.234° =5.084° to the east **(e.g. course 090° T)**

DLo converted to minutes = 5.084° x 60 = 305'

Step 3: Determine the Departure (same as distance for parallel sailing problems) using the parallel sailing formula.

$\mathrm{DLo} = \mathrm{p} \sec \mathrm{l} = \mathrm{p}\ (\frac{1}{\cos \mathrm{L}})$
$\mathrm{p} = (\mathrm{DLo})(\mathrm{CosL})$ - Rearranged terms
$\mathrm{p} = (305')(\mathrm{Cos}\ 52.017°)$
$\mathrm{p} = (305')(0.6154)$
$\mathbf{p = 187.7\ miles}$

PAR D2. You depart latitude 25° 54’ N, longitude 009° 38’ E and steam 592 miles on course 270° T. What is the longitude of arrival?

Answer 001° 20.1’ W. Since the course is 270°, this is strictly a parallel sailing problem.

Step 4: Convert standard latitude and longitudes to decimal form:
Departure Location
25° 54’ N = 25.900° N
009° 38’ E = 9.633° E

Step 5: Determine the Departure (p).
$p = D \sin C$
$p = (592)\ \sin(270°)$
$p = (592)\ (-1.0)$
$p = -592'$

Step 6: Determine the Difference of Longitude (DLo) using the parallel sailing formula.
$DLo = p \sec l = p\ (\frac{1}{\cos l})$
$DLo = (-592')(\frac{1}{\cos 25.900°})$
$DLo = (-592')(\frac{1}{0.8996})$
$DLo = (-592')(1.1116)$
$DLo = -658.1'$

Step 7: Convert the Difference of Longitude (DLo) into decimal notation.
-658.1’ ÷ 60 = -10.968° = 10.968° to the west.

Step 8: Sum the longitudes to determine the final longitude.
Departure longitude = 9.633° E
Difference in longitude = 10.968° to the west.
Arrival longitude = 9.633° E – 10.968° to the west = -1.335°
-1.335° = 1.335° W

Step 9: Convert the arrival longitude to standard notation.
1.335° W = **001° 20.1’ W**

PAR D3. You depart latitude 38° 12’ S, longitude 012° 06’ W and steam 1543 miles on course 270° T. What is the longitude of arrival?

Answer: 044° 49.3’ W. Since the course is 270°, this is strictly a parallel sailing problem.

Step 1: Convert standard latitude and longitudes to decimal form:
Departure Location
38° 12’ S = 38.200° S
012° 06’ W = 12.100° W

Step 2: Determine the Departure (p).
$p = D \sin C$
$p = (1543) \sin(270°)$
$p = (1543)(-1.0)$
$p = -1543'$

Step 3: Determine the Difference of Longitude (DLo) using the parallel sailing formula.
$DLo = p \sec l = p \left(\frac{1}{\cos l}\right)$
$DLo = (-1543')\left(\frac{1}{\cos 38.200°}\right)$
$DLo = (-1543')\left(\frac{1}{0.7859}\right)$
$DLo = (-1543')(1.2724)$
$DLo = -1963.3'$

Step 4: Convert the Difference of Longitude (DLo) into decimal notation.
-1963.3’ ÷ 60 = -32.722° = 32.722° to the west.

Step 5: Sum the longitudes to determine the final longitude.
Departure longitude = 12.100° W
Difference in longitude = 32.722° to the west.
Arrival longitude = 12.100° W + 32.722° to the west = 44.822° W

Step 6: Convert the arrival longitude to standard notation.
44.822° W = **044° 49.3’ W**

Parallel Sailings Problems

Parallel Distance

PAR B1. Determine the distance from latitude 59° 12’ N, longitude 14° 00’ W to latitude 59° 12’ N, longitude 03° 20’ W by parallel sailing.

a) 324.2 miles
b) 325.4 miles
c) 327.7 miles- correct
d) 328.9 miles

PAR B2. Determine the distance from latitude 34° 18’ S, longitude 172° 40’ E to latitude 34° 18’ S, longitude 152° 38’ E by parallel sailing.

a) 993.0 miles- correct
b) 995.2 miles
c) 996.4 miles
d) 998.6 miles

PAR B3. Determine the distance from 19° 54’N, 166° 36’E to 19° 54’N, 157° 54’W by parallel sailing.

a) 2204.6 miles
b) 2006.9 miles
c) 2002.8 miles - correct
d) 1990.6 miles

Parallel Course and Distance

PAR B4. Your vessel receives a distress call from a vessel reporting her position as latitude 35° 01.0’ S, longitude 18° 51.0’ W. Your position is latitude 35° 01.0’S, longitude 21° 42.0’ W. Determine the true course and distance from your vessel to the vessel in distress by parallel sailing.

a) 090° T, 140.0 miles- correct
b) 090° T, 189.2 miles
c) 270° T, 140.0 miles
d) 270° T, 189.2 miles

Parallel Longitude of Arrival

PAR B5. You depart latitude 15° 48' N, longitude 174° 06' E and steam 905 miles on course 090° T. What is the longitude of arrival?

a) 165° 41' W
b) 170° 13' W- correct
c) 172° 47' W
d) 179° 06' E

PAR B6. You depart latitude 38° 12' S, longitude 12° 06' W and steam 1543 miles on course 270° T. What is the longitude of arrival?

a) 44° 49' W- correct
b) 45° 12' W
c) 45° 37' W
d) 45° 42' W

PAR B7. You depart latitude 25° 54' S, longitude 9° 38' E and steam 592 miles on course 270° T. What is the longitude of arrival?

a) 1° 20' E
b) 0° 40' E
c) 0° 40' W
d) 1° 20' W - correct

Great Circle Sailing Problems

Great Circle Sailings Problems

- Terms:
  - DLo is the difference in two longitudes.
  - λ1 is the starting longitude.
  - λ2 is the ending longitude.
  - L1 is the starting latitude.
  - L2 is the ending latitude.
  - Vertex is the most poleward position along the great circle route.
  - Lv is the latitude of the vertex.
  - λv is the longitude of the vertex.
  - Lx is the latitude of any spot along the great circle route.
  - DLo(v) is the difference in longitude from the vertex to a point on the great circle route.
  - Cn or C is the course/course angle. Course angle is the course measured from 0° at the reference direction clockwise or counterclockwise through 90° or 180°. It is labeled with the reference direction as a prefix and the direction of measurement from the reference direction as a suffix. For example, a true course of 330° T would be noted as N 30° W.
  - D is distance in nautical miles.

- The main formula needed are: <u>Bowditch Formula:</u>

  - $Sin\ C = \frac{((Sin\ DLo)(Cos\ L2))}{Sin\ D}$ Formula 24
  - $Cos\ Lv = (Cos\ L1)(Sin\ C)$ Formula 25
  - $Sin\ DLo(v) = \frac{Cos\ C}{Sin\ Lv}$ Formula 27
  - $Tan\ Lx = ((Cos\mathrm{DLo(v)})(\mathrm{Tan\ Lv}))$ Formula 31
  - $Csc\ Lx = (CscLv)(SecDVx)$ Formula 32
  - $Cos\ D = ((\sin L1)(\sin L2) + (\cos L1)(\cos L2)(\cos DLo))$ Formula 36
  - $Tan\ C = (\frac{\sin DLo}{((\cos L1)(\tan L2))-((\sin L1)(\cos DLo))})$ Formula 37

Great Circle Sailings Problems

- Bowditch article 1016 provides background knowledge on this task and is available during Coast Guard exams. Additionally, all of Bowditch chapter X is useful for this topic.

- See the article in Bowditch or in this text regarding basic trigonometric functions and particularly how to take the inverse Sin, Cos, and Tan when solving equations.

- Great Circle Sailings questions can come in three main varieties:
  - Seeking the course and/or distance.
  - Seeking the latitude and/or longitude of the vertex.
  - Seeking a position along the great circle route.

<u>Initial Course and/or Distance</u>

GRC D1. Determine the distance and initial course along a great circle route from 33° 53.3'S, 18° 23.1'E to a position 40° 27.0'N, 73° 49.4'W.

Answer: 6762.7 nm, 304.5° T

Step 1: Convert standard latitude and longitudes to decimal form:
Departure Location
33° 53.3' S = 33.888° S
18° 23.1' E = 18.385° E
Arrival Location
40° 27.0' N = 40.450° N
73° 49.4' W = 73.823° W

Step 2: Determine the Difference in Longitude.

λ1 = 18.385° E
λ2 = 73.823° W
DLo = 18.385° + 73.823° = 92.208° to the west.

Step 3: Determine the Distance.

$$Cos\ D = ((\sin L1)(\sin L2) + (\cos L1)(\cos L2)(\cos DLo))$$

$$Cos\ D = ((\sin 33.888°)(\sin -40.450°) + (\cos 33.888°)(\cos -40.450°)(\cos 92.208°))$$

$$Cos\ D = ((0.5576)(-0.6488) + (0.8301)(0.7610)(-0.0385))$$

$$Cos\ D = ((-0.3618) + (-0.0243))$$

$$Cos\ D = -0.3861$$

$$D = 112.7° = \mathbf{6762.7nm}$$

Step 4: Determine the Course Angle.

$$Sin\ C = \frac{((Sin\ DLo)(Cos\ L2))}{Sin\ D}$$

$$Sin\ C = \frac{((Sin\ 92.208°)(Cos\ 40.450°))}{Sin\ 112.7°}$$

$$Sin\ C = \frac{(0.9993)(0.7610)}{(.9225)}$$

$$Sin\ C = \frac{(0.7605)}{(.9225)}$$

$$Sin\ C = 0.8244$$

$$C = 55.5°$$

Because of the departure from the southern hemisphere, the elevated pole is the south pole and the correct course angle notation is S 55.5° W.

However due to the change in hemispheres, the prefix must be reversed, so the correct course angle is N 55.5° W, or **304.5° T.**

Great Circle Sailings Problems

Latitude and Longitude of the Vertex Problems

GRC D2. The great circle distance from latitude 25° 50.0’ N, longitude 077° 00.0’ W to latitude 35° 56.0’ N, longitude 006° 15.0’ W is 3616 nautical miles. The initial course is 061.7° T. Determine the latitude and longitude of the vertex.

Answer: 37° 35’ N, 025° 59’ W

Step 1: Convert standard latitude and longitudes to decimal form:
Departure Location
25° 50.0’ N = 25.833° N
77° 00.0’ W = 77.000° W
Arrival Location
35° 56.0’ N = 35.933° N
06° 15.0’ W = 06.250° W

Step 2: Determine the Latitude of the Vertex.

$$Lv = \cos^{-1}((\cos L1)(\sin C))$$
$$Lv = \cos^{-1}((\cos 25.833°)(\sin 61.7°))$$
$$Lv = \cos^{-1}(0.9000)(0.8805)$$
$$Lv = \cos^{-1}(0.7924)$$
$$Lv = 37.587°$$

Step 3: Convert the decimal longitude to standard notation.
37.587° N = **37° 35’ N**

Step 4: Determine the Difference in Longitude of the Vertex *(DLo(v))*

$$DLo(v) = \sin^{-1}\left(\frac{\cos C}{\sin Lv}\right)$$
$$DLo(v) = \sin^{-1}\left(\frac{\cos 61.7°}{\sin(37.587)}\right)$$
$$DLo(v) = \sin^{-1}\left(\frac{(0.4741)}{(0.6099)}\right)$$
$$DLo(v) = \sin^{-1}(0.7773)$$
$$DLo(v) = 51.02°$$

Step 5: Determine the Longitude of the Vertex given the initial longitude and the direction of travel (easterly in this case based on given positions).
Longitude 1 = 77.000° W
Difference of Long(vx) = 51.02°
Longitude of the Vertex = 77.00° - 51.02° = 25.98° W

Step 6: Convert the decimal longitude to standard notation.
25.98° W = **25° 59’ W**

Great Circle Sailings Problems

Positions Along the Great Circle Route

GRC D3. The great circle distance from latitude 25° 50.0' N, longitude 077° 00.0' W to latitude 35° 56.0' N, longitude 006° 15.0' W is 3616 nautical miles. The initial course is 061.7° T. The position of the vertex is 37° 35' N, 25° 59' W. Determine the latitude intersecting the great circle track 600 miles west of the vertex, along the great circle track.

Answer: 37° 09' N

Step 1: Convert standard latitude and longitudes to decimal form:
Departure Location
25° 50.0' N = 25.834° N
77° 00.0' W = 77.000° W
Arrival Location
35° 56.0' N = 35.934° N
06° 15.0' W = 06.250° W
Latitude of the Vertex
37° 35' N = 37.583° N
Longitude of the Vertex
25° 59' W = 25.983° W

Step 2: Convert 600 miles to arc.
600 ÷ 60 = 10°

Step 3: Determine the latitude at a position 600 miles (10° of arc) west of the vertex along the great circle track.

$$Tan\ Lx = \left((Cos\,\mathrm{DLo(v)})(\mathrm{Tan\ Lv})\right)$$

$$Tan\ Lx = \left((Cos(10°))(\mathrm{Tan}\ 37.583)\right)$$

$$Tan\ Lx = \left((0.9848)(0.7696)\right)$$

$$Tan\ Lx = (0.7579)$$

$$Lx = 37.158°$$

Step 4: Convert the decimal latitude to standard notation.
$Lx =$ 37.158° = **37° 09' N**

Great Circle Sailing Problems

Great Circle Initial Course and/or Distance

GRC B1. Determine the great circle initial course from 29° 46’S, 30° 26’E, to 31° 52’S, 115° 22’E.

a) 074° T
b) 113° T
c) 117° T - correct
d) 121° T

GRC B2. Determine the great circle initial course from 07° 05’N, 81° 45’W, to 21° 15’N, 157° 40’W.

a) 128° T
b) 217° T
c) 290° T - correct
d) 326° T

GRC B3. Determine the great circle distance and initial course from latitude 24° 52.0’ N, longitude 78° 27.0’ W to latitude 47° 19.0’ N, longitude 6° 42.0’ W.

e) 3593 miles, 048.1° T- correct
f) 3457 miles, 053.3° T
g) 3389 miles, 042.4° T
h) 3367 miles, 045.0° T

GRC B4. Determine the great circle distance and initial course from latitude 26° 00’ S, longitude 56° 00’ W to latitude 34° 00’ S, longitude 18° 15.0’ E.

a) 3705 miles, 153° T
b) 3841 miles, 068° T
c) 3849 miles, 248° T
d) 3805 miles, 117° T - correct

GRC B5. Determine the great circle distance and initial course from latitude 38° 42’ N, longitude 09° 10.5’ W to latitude 32° 05’ N, longitude 81° 05’ W.

a) 3402.0 miles, 072.5° T
b) 3412.6 miles, 085.8° T
c) 3432.0 miles, 278.3° T
d) 3449.4 miles, 287.2° T – correct

Great Circle Latitude or Longitude of the Vertex

GRC B6. The great circle distance from latitude 08° 50' N, 80° 21' W, to a position 12° 36' N, 128° 16' E is 8664 miles and the initial course is 306.6° T. Determine the latitude of the vertex.

a) 38° 46.2' N
b) 38° 16.4' N
c) 37° 30.2 N - correct
d) 37° 05.3' N

GRC B7. The great circle distance from latitude 35° 08' S, longitude 19° 26' E to latitude 33° 16' S, longitude 115° 36' E is 4559 miles and the initial course is 121° T. Determine the latitude of the vertex.

a) 44° 29.1' S
b) 45° 30.9' S - correct
c) 46° 18.2' S
d) 43° 41.8' S

GRC B8. The great circle distance from latitude 38° 17' N, longitude 123° 16' W to latitude 35° 01' N, longitude 142° 21' W is 4330 miles and the initial course is 300.9° T. Determine the latitude of the vertex.

a) 46° 54.8' N
b) 47° 24.7' N
c) 47° 35.2' N
d) 47° 40.5' N - correct

GRC B9. The great circle distance from latitude 8° 50.0' N, longitude 80° 21.0' W to latitude 22° 36.0' N, longitude 128° 16.0' E is 7801 miles and the initial course is 318° 45' T. The latitude of the vertex is 49° 20.6' N. What is the longitude of the vertex?

a) 156° 43' W
b) 162° 41' W - correct
c) 159° 32' W
d) 161° 18' W

GRC B10. The great circle distance from latitude 35° 08' S, longitude 19° 26' E to latitude 33° 16' S, longitude 115° 36' E is 4559 miles and the initial course is 121° T. Determine the longitude of the vertex.

a) 26° 50.9' E
b) 65° 45.9' E - correct
c) 69° 19.1' E
d) 72° 18.3' E

GRC B11. The great circle distance from latitude 38° 17.0’ N, longitude 123° 16.0’ W to latitude 35° 01.0’ N, longitude 142° 21.0’ E is 4330 miles and the initial course is 300.9° T. The latitude of the vertex is 47° 40.5’ N. What is the longitude of the vertex?

a) 173° 04.6’ E
b) 167° 18.0’ E
c) 173° 04.6’ W
d) 167° 18.5’ W - correct

Points Along the Great Circle Route

GRC B12. You are on a great circle track departing latitude 25° 50’ N, longitude 77° 00’ W, and your initial course is 061.7° T. The position of the vertex is latitude 37° 35.6’ N, longitude 25° 57.8’ W. What is the distance along the great circle track between the point of departure and the vertex?

a) 2735.1 miles
b) 2664.9 miles- correct
c) 2583.2 miles
d) 2420.0 miles

GRC B13. You are on a great circle track departing from position latitude 25° 50’ N, longitude 77° 00’ W. The position of the vertex is latitude 37° 35.6’ N, longitude 25° 57.8’ W. The distance along the great circle track from the vertex to a point (x) is 600 miles westward. Determine the position of point (x) on the great circle track.

a) 36° 47.5’ N, 38° 21.8’ W
b) 36° 50.4’ N, 38° 25.6’ W
c) 36° 55.6’ N, 38° 30.0’ W- correct
d) 37° 02.3’ N, 38° 34.4’ W

GRC B14. The great circle distance from latitude 25° 50’ N, longitude 77° 00’ W to latitude 35° 56’N, longitude 06° 15’ W is 3616nm and the initial course is 061.7° T. The position of the vertex is latitude 37° 34.9’ N, longitude 25° 59.0’W. The difference of longitude from the vertex to a point (X) on the great circle route is 10° W. Determine the latitude which intersects the great circle at point X.

a) 37° 02.5’ N
b) 37° 09.5’ N - correct
c) 37° 15.6’ N
d) 37° 21.2’ N

Zone Time (Rise/Set/Twilight/LAN) Problems

- Time problems can either be dedicated problems asking for the time of rise/set/transit or could be a part of larger problems.

- Although the Coast Guard requirements indicated required competence at zone time of twilight problems, there are none currently in the problem database. Only rise/set/transit are found currently.

- Using the Nautical Almanac, values for time of phenomena are given for standard latitudes (various frequencies) and longitudes (every 15°). The most efficient process is to correct times for latitude first, using the nautical almanac, and then to correct for the difference in longitude from the standard meridian being observed.

<u>Basic Time of Rise/Set Concept Problems</u>

TOP D1. Your ship's position is latitude 25° 00.0' N and longitude 65° 00.0' W. The ship is holding position and is not moving. The date is 4 August and you are observing (+4) zone time. What is the zone time of sunrise at your ship's location?

Answer: 0548.

Step 1: Locate the tabular values in the Nautical Almanac.

Find the latitudes which bracket the desired latitude and note the time of sunrise at those latitudes:

30° N: 0520
20° N: 0536

Lat.	Twilight Naut.	Twilight Civil	Sunrise
°	h m	h m	h m
N 72	[ ]	[ ]	[ ]
N 70	////	////	01 42
68	////	////	02 24
66	////	00 51	02 52
64	////	01 50	03 14
62	////	02 22	03 31
60	00 46	02 46	03 45
N 58	01 39	03 04	03 57
56	02 09	03 19	04 07
54	02 31	03 32	04 16
52	02 49	03 44	04 24
50	03 03	03 53	04 32
45	03 32	04 14	04 47
N 40	03 53	04 30	05 00
35	04 09	04 43	05 11
30	04 23	04 54	05 20
20	04 45	05 13	05 36
N 10	05 02	05 28	05 50
0	05 16	05 41	06 03

Note that the interval between the bracketing latitudes is 10°.

Step 2: Identify the latitude difference between the bracketing latitudes and the desired latitude, and the time difference between the tabular latitudes.

30° N: 0520
25° N: this is the unknown value you seek.
20° N: 0536

Differences:
Latitude difference: 20° N to 25° = 5°
Time difference: 20° N to 30° N = 0536 – 0520 = 16 minutes.

Step 3: Complete the latitude correction. The two options for this step are to use table 1 in the back of the Nautical Almanac, or for values that are relatively small and at relatively low latitudes, an arithmetic or mental interpolation is sufficient.

- Option 1: "Table 1" correction:

Tabular Interval			Difference between the times for consecutive latitudes													
10°	5°	2°	5m	10m	15m	20m	25m	30m	35m	40m	45m	50m	55m	60m	1h 05m	1h 10m
° ′	° ′	° ′	m	m	m	m	m	m	m	m	m	m	m	m	h m	h m
0 30	0 15	0 06	0	0	1	1	1	1	1	2	2	2	2	2	0 02	0 02
1 00	0 30	0 12	0	1	1	2	2	3	3	3	4	4	4	5	05	05
1 30	0 45	0 18	1	1	2	3	3	4	4	5	5	6	7	7	07	07
2 00	1 00	0 24	1	2	3	4	5	5	6	7	7	8	9	10	10	10
2 30	1 15	0 30	1	2	4	5	6	7	8	9	9	10	11	12	12	13
3 00	1 30	0 36	1	3	4	6	7	8	9	10	11	12	13	14	0 15	0 15
3 30	1 45	0 42	2	3	5	7	8	10	11	12	13	14	16	17	18	18
4 00	2 00	0 48	2	4	6	8	9	11	13	14	15	16	18	19	20	21
4 30	2 15	0 54	2	4	7	9	11	13	15	16	18	19	21	22	23	24
5 00	2 30	1 00	2	5	7	10	12	14	16	18	20	22	23	25	26	27

a. Note that the tabular interval is 10°.

b. Proceed down the "Tabular Interval" column until you reach the difference between the tabular latitude and your desired latitude (5° in this case).

c. The time difference determined in the previous step was 16 minutes. There is no "16 minutes" column in the "difference between the times for consecutive latitudes" section, so note the values for the nearest headings (15m and 20m). In this case, the necessary values are 7 and 10 minutes.

d. Mentally interpolate the actual value (8 minutes in this case).

Table 1 corrected time = 0536 – 8 minutes = 0528.

- Option 2: manual calculation:

$$\frac{x}{16\,minutes} = \frac{5°}{10°}$$

$$\frac{x}{16\,minutes} = 0.500$$

$$x = (0.5000)\,(16)$$

$x = 8$ minutes (earlier than base latitude)

Calculated corrected time = 0536 – 8 minutes = 0528

Step 4: Determine the difference in longitude from the standard meridian of the time being observed.

Longitude = 065° W.

If you are observing (+4) zone time, the associated standard meridian is 60° W.

65° W – 60° W = 5° difference (to the west) from standard meridian.

Step 5: Convert the difference in longitude arc to time using the Conversion of Arc to Time table in the Nautical Almanac.

5° of arc to the west = 20 minutes (added, since difference is "to the west").

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

Step 6: Apply the longitude correction to the latitude-corrected time to determine time of sunset.

0528 + 0020 = **0548**

Basic Time of Meridian Transit (Local Apparent Noon) Concept Problems

TOP D2. Your ship's position is latitude 25° 31.5' N and longitude 128° 06.4' W. The ship is holding position and not moving. The date is 15 July and you are observing (+9) zone time. What is the zone time of local apparent noon at your ship's location?

Answer: 11:38 zone time.

Step 1: Locate the tabular values in the Nautical Almanac. The time of meridian passage for 15 July is 1206.

Day	SUN Eqn. of Time 00ʰ	12ʰ	Mer. Pass.
	m s	m s	h m
15	05 49	05 52	12 06
16	05 55	05 58	12 06
17	06 01	06 03	12 06

Step 2: No latitude correction is required due to the nature of local apparent noon calculations.

Step 3: Determine the difference in longitude from the standard meridian of the time being observed.

Longitude = 128° 06.4 W

The vessel is observing (+9) = standard meridian of 135°.

135° W – 128° 06.4' W = 6° 53.6' difference from standard meridian.

Step 4: Convert the difference in longitude arc to time using the Conversion of Arc to Time in the Nautical Almanac.

6° 53.6' of arc to the east = 27 minutes 34 seconds (subtracted).

Step 5: Apply the longitude correction to the latitude-corrected time to determine time of local apparent noon.

12:06:00 - 00:27:34 = **11:38**

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
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

Advanced Time of Rise/Set/Passage Problems

TOP D3. On 28 June, your 1820 ZT DR position is latitude 16° 00.0’ N, longitude 31° 00.0’ W. You are on course 310° at a speed of 18 knots. What will be the zone time of sunset at your vessel?

Answer: 18:39 zone time. The calculation involves two phases. First determine the approximate time of sunset for your current position and determine how far you will travel between the current time and the calculated time. Some schools recommend assuming 0600 ZT for sunrise, 1800 for sunset, and 1200 for meridian passage. Second, complete a sunset calculation for the new DR location.

Step 1: Locate the tabular values in the Nautical Almanac.
The nearest bracketing latitudes and their associated sunset times are:

N 40	19 33
35	19 18
30	19 05
20	18 43
N 10	18 24
0	18 07

10° N = 1824
16° N = unknown value
20° N = 1843

Step 2: Determine the approximate time of sunset for your current DR position using either manual calculation or Table 1 in the Nautical Almanac.

Differences:
10° N to 20° N = 10°
10° N to 16° N = 6°
10° N time to 20° N time = 1843 – 1824 = 19 minutes

Using direct calculation is reasonable for this interpolation because the latitude is small, and the intervals are short. Table 1 is always available as an option.

$$\frac{x}{19\,minutes} = \frac{6°}{10°} = 0.6$$

$x = (19)(0.6) =$ 11.4 minutes (later)

Latitude corrected time (calculation method) = 1824 (base) + 11.4 = 1835.4

Longitude 1 = 31° W.
Observed standard meridian (assumed from problem text) = 30° W.
Difference between actual and standard meridian = 31° - 30° = 1° (to the west).

Conversion of 1° arc to time = 4 minutes (to the west, or later).

Latitude corrected time = 1835.4
Longitude correction = 4 minutes (later)
Sunset at original DR position (16° N and 31° W) = 1835.4 + 4 = <u>1839.4</u>

Step 3: Perform other preliminary calculations.

1820 DR to 1839.4 = 19.4 minutes
19.4 minutes = 0.323 hours
0.323 hours at 18 knots = 5.82 nautical miles covered

Step 4: Determine the ship's DR position at 1839.4, based on steaming 310° T for 5.82 miles by mid-latitude sailing or using a universal plotting sheet.

$l = D \ \cos C$
$l = (5.82) \ \cos 310°$
$l = (5.82)\ (0.6428)$
$l = 3.741$

Latitude 1 = 16° 00.0' N
l = 3.741' = 0.0624° (to the north)
Latitude 2 = 16° N + 0.0624° (to the north) = 16.0624° N
$Lm = \frac{16° + 16.0624°}{2} = 16.0312°$

$p = D \ \sin C$
$p = (5.82) \ \sin 310°$
$p = (5.82)\ (-0.7660)$
$p = -4.4584$

$DLo = \frac{p}{\cos Lm}$
$DLo = \frac{-4.4584}{\cos(16.0312)}$
$DLo = \frac{-4.4584}{0.9611}$
$DLo = -4.639$

Longitude 1 = 31° W
DLo = -4.639' = 0.0773° (to the west)
Longitude 2 = 31° W + 0.0773° = 31.0773° W

Step 5: Determine the latitude corrected time of sunset at the new DR position.

1839.4 DR position:
16.0624° N = 16° 03.7’ N
31.0773° W = 31° 04.6’ W

N 40	19 33
35	19 18
30	19 05
20	18 43
N 10	18 24
0	18 07

Tabular values for nearest bracketing latitudes:

10° N = 1824
16.0624° N = unknown
20° N = 1843

Differences:
10° N to 20° N = 10°
10° N to 16.0624° N = 6.0624°
10° N time to 20° N time = 1843 – 1824 = 19 minutes

$$\frac{x}{19\,minutes} = \frac{6.0624°}{10°}$$

$$\frac{x}{19\,minutes} = 0.6062$$

$$x = (19)(0.6062)$$

$x = 11.5$ minutes (later)

Latitude corrected time = 1824 (base) + 11.5 minutes = 1835.5

Step 6: Determine the longitude corrected time of sunset at the new DR position using the Conversion of Arc to Time in the Nautical Almanac.

31° 04.6’ W – 30° W = 1° 04.6’ difference from standard meridian.
1° 04.6’ of arc to the west = 4 minutes 18 seconds (added).

Step 7: Apply the longitude correction to the latitude-corrected time to determine time of local apparent noon.

18:35:30 – 00:04:18 = **18:39:18**

Note: this is a long, tedious process for minimal gain in this particular problem, but is illustrative of the process recommended for all problems for maximum accuracy. See the next problem for an example in which the changed DR position is critical.

TOP D4. On 2 April, your 0900 zone time DR position is latitude 28° 04.0' S and longitude 94° 14.0' E. Your vessel is on course 316° T at a speed of 18.5 knots. What is the zone time of local apparent noon (LAN)?

Answer: 11:50 zone time.

Step 1: Locate the tabular values in the Nautical Almanac. The time of meridian passage for 2 April is 1204.

Day	SUN Eqn. of Time 00ʰ	12ʰ	Mer. Pass.
	m s	m s	h m
1	04 02	03 53	12 04
2	03 44	03 35	12 04
3	03 26	03 18	12 03

Step 2: Perform preliminary calculations.

0900 DR to 1204 = 3 hours, 4 minutes
3 hours, 4 minutes = 3.067 hours
3.067 hours at 18.5 knots = 56.740 nautical miles covered

Longitude 094° 14.0' E = zone descriptor (-6) = 90° E standard meridian being observed (no other information stated in problem, so assume this zone time).

Step 3: Determine the ship's DR position at 1204, based on steaming 316° T for 56.740 miles by mid-latitude sailing or using a chart/plotting sheet.

$l = D \cos C$
$l = (56.740) \cos 316°$
$l = (56.740)\,(0.7193)$
$l = 40.813$

Latitude 1 = 28° 04.0' S = 28.067° S
l = 40.813' = 0.680° (to the north)
Latitude 2 = 28.067° S – 0.680° = 27.387° = <u>27° 23.22' S</u>
$Lm = \frac{28.067°+27.387°}{2} = 27.727°$

$p = D \sin C$
$p = (56.740) \sin 316°$
$p = (56.740)\,(-0.6947)$
$p = -39.417$

$DLo = \frac{p}{\cos Lm}$
$DLo = \frac{-39.417}{\cos(27.727)}$
$DLo = \frac{-39.417}{0.8852}$
$DLo = -44.529'$

Longitude 1 = 94° 14.0' E = 94.233° E
DLo = -44.529' = 0.742° (to the west)
Longitude 2 = 94.233° E - 0.742° = 93.491° = <u>93° 29.46' E</u>

Step 4: Determine the time of LAN at the new DR position.

1204 DR position:

27° 23.22’ S
93° 29.46’ E

93° 29.46’ E – 90° E = 3° 29.46’ difference from standard meridian.

Step 5: Convert the difference in longitude arc to time using the Conversion of Arc to Time Table.

3° 29.46’ of arc to the east = 13 minutes 58 seconds (subtracted).

Step 6: Apply the longitude correction to the latitude-corrected time to determine time of local apparent noon.

12:04:00 - 00:13:58 = **11:50:02**

Zone Time of Rise/Set/Transit Problems

Basic Time of Phenomena Calculations (For Practice Only, Not on USCG Exams)

TOP B1. It is 3 March and you are keeping zone time (+6). You are stationary in position latitude 26° 26.0'N, longitude 94° 06.0' W. What is the zone time of sunrise at your location?

a) **0638 - correct**
b) 0645
c) 0649

TOP B2. It is 12 June and you are keeping zone time (+9). You are stationary in position latitude 44° 13.0' N, longitude 138° 14.0' W. What is the zone time of sunset at your position?

a) 1950
b) **1957 - correct**
c) 2009

TOP B3. It is 22 February and you are keeping zone time (+9). You are stationary in position latitude 16° 45.0' N, longitude 130° 00.0' W. What is the zone time of local apparent noon at your position?

a) **1154 - correct**
b) 1214
c) 1234

Zone Time of Sunrise/Sunset Problems

TOP B4. At 0327 zone time on 29 May, your DR position is latitude 25° 00.0' N, longitude 064° 15.0' W. You are steering 270° T at a speed of 13.6 knots. What is the zone time of sunrise?

a) 0521
b) 0529 – correct
c) 0536
d) 0548

TOP B5. At 0500 zone time on 21 August, your DR position is latitude 47° 00.0' N, longitude 125° 15.0' W. You are steering 000° T at a speed of 9.8 knots. What is the zone time of sunrise?

a) 0525 – correct
b) 0529
c) 0531
d) 0535

TOP B6. On 13 February at 0325 zone time, your DR position is latitude 23° 20.0 N, longitude 155° 15.0' W. You are steering 240° T at a speed of 13.6 knots. What is the zone time of sunrise?

a) 0652
b) 0657 – correct
c) 0706
d) 0711

TOP B7. On 17 May, your 0300 zone time DR position is latitude 27° 21.0' N, longitude 146° 14.0' E. You are on course 107° T at a speed of 18 knots. What will be the zone time of sunrise at your vessel?

a) 0457
b) 0511
c) 0519
d) 0522 - correct

TOP B8. On 27 September, your 0345 zone time DR position is latitude 26° 18.0' S, longitude 004° 18.0' W. You are on course 271° at a speed of 15 knots. What will be the zone time of sunrise at your vessel?

a) 0525
b) 0545
c) 0555
d) 0605 – correct

TOP B9. On 16 February, your 0300 zone time DR position is latitude 28° 32.0’ S, longitude 176° 49.0’ E. You are on course 082° T at a speed of 21 knots. What will be the zone time of sunrise at your vessel?

a) 0534
b) 0552 - correct
c) 0631
d) 0645

TOP B10. At 1544 zone time on 5 October, your DR position is latitude 25° 00.0’ N, longitude 60° 15.0’ W. You are steering 270° T at a speed of 6.8 knots. What is the zone time of sunset?

a) 1728
b) 1737
c) 1741
d) 1745 - correct

TOP B11. At 1800 zone time on 7 December, your DR position is latitude 22° 48.0’ S, longitude 91° 26.0’ W. You are steering 320° T at a speed of 14 knots. What is the zone time of sunset?

a) 1830
b) 1836
c) 1842 – correct
d) 1852

TOP B12. On 10 April, your 1630 zone time DR position is latitude 21° 03.0’ N, longitude 63° 11.0’ W. You are on course 324° T at a speed of 22 knots. What will be the zone time of sunset at your vessel?

a) 1805
b) 1814
c) 1818
d) 1833 - correct

TOP B13. On 18 October, your 1330 zone time DR position is latitude 27° 32.0’ N, longitude 154° 47.0’ W. You are on course 115° T at a speed of 20 knots. What will be the zone time of sunset at your vessel?

a) 1715
b) 1729
c) 1742 - correct
d) 1751

Zone Time of Meridian Transit (Local Apparent Noon)

TOP B14. On 12 February, your 0900 zone time DR position is latitude 16° 43.0' N, longitude 51° 42.0' W. Your vessel is on course 093° T at a speed of 18.5 knots. What is the zone time of local apparent noon?

a) 1237 - correct
b) 1233
c) 1230
d) 1226

TOP B15. On 12 July your 0800 zone time DR position is latitude 24° 15.0' N, longitude 132° 30.0' W. Your vessel is on course 045° T at a speed of 15 knots. What is the zone time of local apparent noon?

a) 1146
b) 1148
c) 1152 - correct
d) 1159

TOP B16. On 14 October your 0800 zone time DR position is latitude 28° 22.0' N, longitude 161° 17.0' E. Your vessel is on course 116° T at a speed of 17.5 knots. What is the zone time of local apparent noon?

a) 1142
b) 1148
c) 1152
d) 1156 - correct

TOP B17. On 16 January, your 0930 zone time DR position is latitude 26° 07.0' S, longitude 51° 43.0' E. Your vessel is on course 238° T at a speed of 17 knots. What is the zone time of local apparent noon?

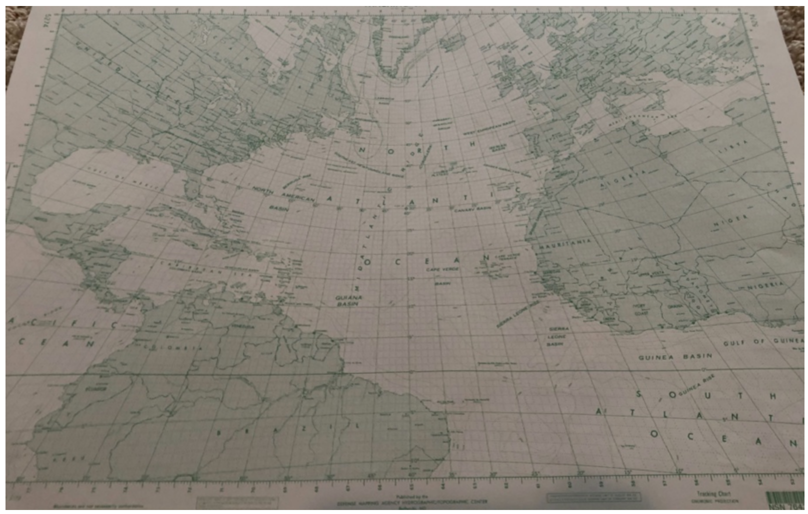
a) 1145 - correct
b) 1148
c) 1152
d) 1156

TOP B18. On 3 October, your 0830 zone time DR position is latitude 26° 15.0' S, longitude 73° 16.0' E. Your vessel is on course 280° T at a speed of 19 knots. What is the zone time of local apparent noon?

a) 1151
b) 1154
c) 1158
d) 1201 - correct

Gnomonic Chart Navigation Problems

- These charts are used for planning ocean voyages and are oblique representations of the Earth's surface.
- Great Circles on a Gnomonic chart are straight lines, enabling easy voyage planning and later transfer of waypoints to a Mercator projection chart.
- Problems generally seek to test your plotting skills (use the latitude/longitude scales along the borders of the chart) or your ability to understand the benefits of Great Circles over Rhumb Lines.
- Generally, voyages that cross a large number of meridians (longitude lines) and latitude lines are best served with a Great Circle route. Voyages that transit north/south along a meridian or east/west near the equator are not significantly different than a Rhumb Line.



GNO D1. You are planning a voyage by great circle from latitude 38° 00' N, longitude 73° 00' W to latitude 49° 00' N, longitude 06° 00' W. Which of the following statements are true? Use Gnomonic tracking chart WOXZC 5274).

Answer: The shoals with a 25-mile radius around Sable Island will be a hazard.

Step 1: Plot the origin and arrival positions on the tracking chart and draw the trackline.

Step 2: Read each answer option carefully to eliminate all but the correct answer.

a. You will pass to the south of icebergs reported extending to 100 miles south of Cape Race, Newfoundland. (Incorrect – You will pass through the iceberg area)

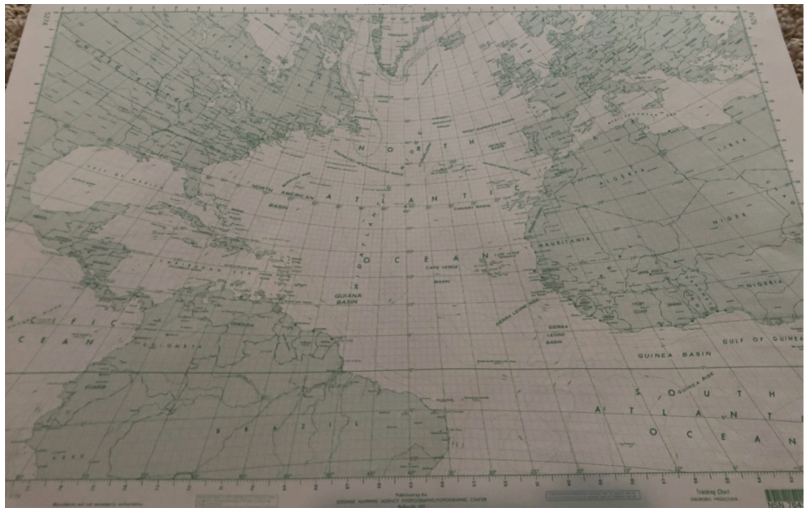
b. **The shoals with a 25 mile radius around Sable Island will be a hazard.** (Correct – The track passes within the shoal area)

c. You will reach the maximum northerly latitude at longitude 29° 45' W. (Incorrect – The maximum northerly latitude will be significantly further north than the stated position.)

d. The distance is measured in 60-mile segments using the length of a degree of latitude at the vertex. (Incorrect – Gnomonic charts are not used in this way.)

You are planning a voyage by great circle from Reykjavik (latitude 63° 30’ N, longitude 24° 00’ W) to the Azores (latitude 39° 30’ N, longitude 29° 00’ W). Which of the following statements are true? Use Gnomonic tracking chart WOXZC 5274).

Answer: The great circle track is not appreciably shorter than a rhumb line track.



Step 1: Plot the origin and arrival positions on the tracking chart and draw the trackline.

Step 2: Read each answer option carefully to eliminate all but the correct answer.

a. The distance is measured in sixty-mile segments based on the length of a degree of latitude at the mid-latitude and mid-longitude positions. (Incorrect – Gnomonic charts are not used in this way.)

b. The northern hemisphere vertex lies south of Reykjavik. (Incorrect – The course is virtually North/South, so the vertexes would be near the poles.)

c. **The great circle track is not appreciably shorter than a rhumb line track.** (Correct – The course is virtually North/South, yielding no significant savings by great circle.)

d. When plotted on a Mercator chart, the great circle track will be convex to the British Isles. (Incorrect – The course would be concave to the British Isles.)

Gnomonic Chart Navigation Problems

Atlantic Chart - 5274

GNO B1. A great circle track would be most advantageous when compared to the rhumb line track on which route? (Use gnomonic tracking chart WOXZC 5274).

a) Cayenne (4° 40' N, 52° 15' W) to Sao Tome (0° 00', 6° 45' E)
b) Palm Beach, FL to the English Channel- correct
c) Natal, Brazil, to Reykjavik, Iceland
d) Recife, Brazil, to Monrovia

GNO B2. On which voyage would a great circle track be significantly shorter than a rhumb line track? (Use gnomonic tracking chart WOXZC 5274).

a) Savannah, GA to Lisbon, Portugal- correct
b) Dublin, Ireland (Irish Sea) to La Coruna, Spain (latitude 43° 22' N, longitude 8° 24' W)
c) Reykjavik, Iceland to Lisbon, Portugal
d) Boston to Sable Island

GNO B3. On a voyage via the southern tip of Nova Scotia (latitude 43° 20' N, longitude 65° 35' W), you wish to sail the shortest route to La Coruna, Spain (latitude 43° 20' N, longitude 8° 24' W). Which of the following will require you to plot a composite sailing? (Use gnomonic tracking chart WOXZC 5274).

a) Shoals extending 15 miles from Sable Island
b) Sea ice reported 68 miles ESE of St. John's, Newfoundland
c) Icebergs reported extending west to west-northwest from latitude 47° N, longitude 35° W- correct
d) Naval exercises using live ammunition being conducted with a 150-mile radius of latitude 49° N, longitude 20° W

GNO B4. You are planning a voyage by great circle from the mouth of the Delaware River (latitude 38° 40' N, longitude 75° W to Lisbon, Portugal. Which statement is true? (Use gnomonic tracking chart WOXZC 5274).

a) You will reach the northernmost latitude of the voyage in the vicinity of longitude 42° 30' W- correct
b) The Northern Hemisphere vertex lies to the east of Lisbon.
c) You must plot a composite sailing to remain south of icebergs reported north of 44° N.
d) The distance is measured in 60-mile segments using the length of the degree of latitude crossed by the track line.

Pacific Chart - 5270

GNO B5. On which voyage would a great circle track provide a significant savings in distance to steam, when compared to a rhumb line track? (Use gnomonic tracking chart WOXZC 5270).

a) Valdez, AK to the Marquesas Islands (latitude 8° S, longitude 140° W)
b) San Francisco to Kodiak, AK
c) Christmas Island (latitude 2° N, longitude 157° 30' W) to Singapore via latitude 3° N, longitude 126° E
d) Guam (latitude 14° N, longitude 145° E) to Seattle via latitude 47° 30' N, longitude 125° 20' W- correct

GNO B6. Using gnomonic tracking chart WOXZC 5270, determine which of the following statements about a voyage from San Francisco to San Bernardino Strait (latitude 13° N, longitude 125° 30' E) is true.

a) A composite sailing should be used to avoid the Bonin Islands.
b) Distance is measured using the length of a degree of longitude at the point of tangency.
c) You will cross the Northern Hemisphere vertex at the approximate longitude of 159° W- correct
d) The entire track line is west of the Northern Hemisphere vertex.

GNO B7. Using gnomonic tracking chart WOXZC 5270, determine which of the following statements about a voyage from Valdez, AK to Hilo, HI is true.

a) A great circle track is not significantly shorter than a rhumb line track- correct
b) You will cross the Northern Hemisphere vertex where the track line crosses latitude 45° N.
c) Distance is measured using the length of a degree of longitude at the mid-latitude line.
d) When plotted on a Mercator chart, the track line will be convex to San Francisco.

GNO B8. You are on a voyage via position latitude 44° N, longitude 150° E to latitude 46° 15' N, longitude 124° W. Using gnomonic tracking chart WOXZC 5270, determine which statement is true.

a) A composite sailing with a limiting latitude of 51° N will clear the Aleutian Islands- correct
b) The northern hemisphere vertex is east of the arrival position.
c) The Aleutian Islands are not a navigational hazard on the direct great circle track.
d) The final course angle lies in the northeast quadrant.

Latitude by Polaris Problems

- LHA (Local Hour Angle) of Aries is found using the Nautical Almanac to determine the GHA of Aries for the given time. Then, add (E Hem) or subtract (W Hem) the DR longitude to determine LHA of Aries.

- The formula for determining latitude by Polaris are located in the Nautical Almanac, on the same page as the Polaris corrections and therefore do not need to be memorized.

POL D1. On 14 March at 1845 ZT, you take a sextant observation of Polaris. Your DR position is latitude 29° 10’ N, longitude 154° 30’ W. Your sextant reads 29° 53.5’. Your chronometer reads 04h 42m 36s, and the chronometer error is 02m 24s slow. Your height of eye is 24 feet and the index error is 1.3’ off the arc. Determine the latitude by Polaris.

Answer: 29° 21.3’ N

Step 1: Determine the correct chronometer time of sight.
Chronometer time of observation: 04h 42m 36s
Chronometer error: 02m 24s slow
Correct chronometer time of observation: 04h 42m 36s + 2m 24s = 04:45:00.

Step 2: Determine the correct GMT of the sight
DR Longitude: 154° 30’ W - corresponds to ZD (+10).
Local time of observation: 1845 ZT
GMT time of observation = 1845 ZT + 10 hours = 0445 GMT (15 Mar).

Step 3: Determine the observed altitude of the body using the correction tables in the Nautical Almanac (reproduced at the end of this Part).
Sextant altitude (hs): 29° 53.5’
Index error (1.3’ off the arc): IC = + 1.3’
Height of eye (24 feet): dip = - 4.8’
Apparent altitude (ha) = 29° 53.5’ + 1.3’ – 4.8’ = 29° 50.0’
Apparent altitude (stars/planets) correction: -1.7’
Observed altitude (ho) = 29° 50’ – 1.7’ = <u>29° 48.3’</u>

15	00	172 30.6
	01	187 33.0
	02	202 35.5
	03	217 38.0
	04	232 40.4
	05	247 42.9

Step 4: Determine the GHA of Aries for the time of sight.
GHA (Aries), whole hours: 232° 40.4’
GHA (Aries), increment: 11° 16.8’
GHA (Aries), total: 232° 40.4’ + 11° 16.8’ =
<u>243° 57.2’</u>

m 45	SUN PLANETS	ARIES	MOON
s	° ′	° ′	° ′
00	11 15·0	11 16·8	10 44·3
01	11 15·3	11 17·1	10 44·5
02	11 15·5	11 17·3	10 44·7
03	11 15·8	11 17·6	10 45·0
04	11 16·0	11 17·9	10 45·2

Step 5: Determine the LHA of Aries.
GHA (Aries): 243° 57.2’
DR Longitude: 154° 30 W
LHA (Aries) = 243° 57.2’ – 154° 30’ W =
<u>89° 27.2’</u>

Step 6: Enter the Polaris Tables with LHA (Aries), DR Latitude, and Month to determine the A0, A1, and A2 correction factors (The complete Polaris Tables are located at the end of this Part).
A0 (LHA correction): 0° 31.7'
A1 (Latitude correction): 0.5'
A2 (Month correction): 0.8'

Step 7: Calculate latitude using the Polaris Formula, provided at the bottom of the Polaris Tables.
Latitude = Observed altitude – 1° + A0 + A1 + A2
Lat = 29° 48.3' – 1° + 31.7' + 0.5' + 0.8' = **29° 21.3' N**

L.H.A. ARIES	80°– 89°
	a_0
°	° ′
0	0 25·3
1	25·9
2	26·6
3	27·2
4	27·9
5	0 28·6
6	29·3
7	29·9
8	30·6
9	31·4
10	0 32·1
Lat.	a_1
°	′
0	0·3
10	·4
20	·4
30	·5
40	0·5
45	·6
50	·6
55	·7
60	·7
62	0·7
64	·8
66	·8
68	0·9
Month	a_2
	′
Jan.	0·7
Feb.	·8
Mar.	·8
Apr.	0·8
May	·7
June	·5
July	0·4
Aug.	·3
Sept.	·3
Oct.	0·3
Nov.	·4
Dec.	0·6

Latitude = Apparent altitude (corrected for refraction) $- 1° + a_0 + a_1 + a_2$

The table is entered with L.H.A. Aries to determine the column to be used; each column refers to a range of 10°. a_0 is taken, with mental interpolation, from the upper table with the units of L.H.A. Aries in degrees as argument; a_1, a_2 are taken, without interpolation, from the second and third tables with arguments latitude and month respectively. a_0, a_1, a_2 are always positive. The final table gives the azimuth of *Polaris*.

ILLUSTRATION
On 1981 April 21 at G.M.T. 23h 18m 56s in longitude W. 37° 14′ the apparent altitude (corrected for refraction), *Ho*, of

From the daily pages:	° ′
G.H.A. Aries (23h)	194 55·4
Increment (18m 56s)	4 44·8
Longitude (west)	−37 14

	° ′
Ho	49 31·6
a_0 (argument 162° 26′)	1 30·1
a_1 (lat. 50° approx.)	0·6
a_2 (April)	0·9

Latitude by Polaris Problems

POL B1. On 22 August your 1852 zone time DR position is longitude 155° 54' E. At that time, you observe Polaris with a sextant altitude (Hs) of 27° 36.9'. The chronometer time of observation is 08h 54m 06s and the chronometer error is 02m 20s fast. The index error is 3.6' off the arc and the height of eye is 61.5 feet. What is your latitude by Polaris?

a) 27° 05.5' N
b) 27° 31.0' N
c) 28° 05.9' N - correct
d) 28° 09.5' N

POL B2. On 15 July at 0447 ZT, your vessel's DR position is latitude 22° 42' N, longitude 126° 36' E. At approximately that time, you obtain a sextant altitude (Hs) of Polaris reading 23° 46.2' with an index error of 1.6' off the arc. Your chronometer reads 08h 48m 28s and is 1m 16s fast. What is your latitude by Polaris, given a height of eye of 33 feet?

a) 22° 44.1' N
b) 22° 46.2' N
c) 22° 50.2' N
d) 22° 54.1' N - correct

POL B3. On 7 March at 1838 ZT in DR position latitude 34° 26.9' N, longitude 58° 16.2' W, you observe Polaris for latitude. The sextant altitude (Hs) is 35° 08.4'. The index error is 2.5' off the arc. The height of eye is 54 feet. What is the latitude at the time of sight?

a) 34° 29.8' N
b) 34° 33.4' N - correct
c) 34° 34.8' N
d) 34° 36.8' N

POL B4. On 10 June your 2010 zone time DR position is latitude 41° 10.0' N, longitude 61° 15.0' W. At that time, you observe Polaris with a sextant altitude (Hs) of 40° 35.8'. The chronometer time of observation is 00h 08m 18s, and the chronometer error is 01m 45s slow. The index error is 2.0' on the arc, and the height of eye is 40 feet. What is your latitude by Polaris?

a) 41° 10.6' N
b) 41° 15.0' N - correct
c) 41° 18.3' N
d) 41° 21.2' N

Latitude by Meridian Passage Problems

- The key to basic meridian passage (local apparent noon) problems is identifying the relationship between the observer and the body.
    - If the observer is in the opposite hemisphere as the body, the formula is Latitude = Zenith Distance - Declination.
    - If the observer is in the same hemisphere but closer to the equator than the body, the formula is Latitude = Declination – Zenith Distance.
    - If the observer is in the same hemisphere as the body, but further away from the equator, the formula is Latitude = Zenith Distance + Declination.
- Zenith Distance is 90 – the Observed Altitude (Ho).
- Declination is obtained from the Nautical Almanac.
- Advancing/retarding lines of position is covered in more detail in the Running Fix section.
- Ex-meridian sights are those in which the observer was unable to make an observation at the appropriate time of phenomena. However, sights shortly before or shortly after the appropriate time of phenomena can be corrected yielding a line of latitude. In real practice, it is more accurate to simply do a full sight reduction rather than try to correct a flawed meridian passage sight.

Latitude at LAN Problems

MER D1. On 22 February your 0612 zone time fix gives you a position of latitude 27° 16.2’ S, longitude 37° 41.6’ W. Your vessel is on course 298° T at 14.2 knots. Local apparent noon (LAN) occurs at 1147 zone time, at which time a meridian altitude of the Sun’s lower limb is observed. The observed altitude (Ho) for this sight is 73° 33.3’. What is the calculated latitude at LAN?

Answer: 26° 31.4’ S.

	22 00	176 36.1	S10	18.2
	01	191 36.2		17.3
	02	206 36.2		16.4
	03	221 36.3	· ·	15.5
	04	236 36.4		14.6
	05	251 36.5		13.6
	06	266 36.6	S10	12.7
	07	281 36.6		11.8
	08	296 36.7		10.9
S	09	311 36.8	· ·	10.0
U	10	326 36.9		09.1
N	11	341 37.0		08.2
D	12	356 37.1	S10	07.3
A	13	11 37.1		06.4
Y	14	26 37.2		05.4
	15	41 37.3	· ·	04.5
	16	56 37.4		03.6
	17	71 37.5		02.7
	18	86 37.6	S10	01.8
	19	101 37.6		00.9
	20	116 37.7	10	00.0
	21	131 37.8	9	59.0
	22	146 37.9		58.1
	23	161 38.0		57.2

Step 1: Determine the GMT of the sight.
DR longitude (0612): 37° 41.6’ W, which corresponds to (+3 ZD).
1147 zone time +3 hours = <u>1447 GMT.</u>

Step 2: Determine the declination of the sun for the GMT time of sight.
At 1447 GMT:
Declination (hours): S 10° 05.4’ (decreasing)
d number: 0.9
Declination (increments): - 0.7’
Declination (total): S 10° 05.4’ – 0.7’ = <u>S 10° 04.7’</u>

Step 3: Determine the observed altitude of the body.
No corrections are required in this problem, since the (ho) is given as <u>73° 33.3’</u>

Step 4: Determine the zenith distance of the sight.
ZD = 90° - observed altitude.
ZD = 90° - 73° 33.3’ = <u>16° 26.7’</u>

Step 5: Determine the latitude.

Since the observer is in the same hemisphere as the body, but further away from the equator (as evidenced by the DR latitude), the formula is:
Latitude = Zenith Distance + Declination
Latitude = 16° 26.7’ + 10° 04.7’ = **26° 31.4’ S**

D CORRECTIONS 47m

47m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	11 45·0	11 46·9	11 12·9	0·0	0·0	6·0	4·8	12·0	9·5
01	11 45·3	11 47·2	11 13·1	0·1	0·1	6·1	4·8	12·1	9·6
02	11 45·5	11 47·4	11 13·4	0·2	0·2	6·2	4·9	12·2	9·7
03	11 45·8	11 47·7	11 13·6	0·3	0·2	6·3	5·0	12·3	9·7
04	11 46·0	11 47·9	11 13·8	0·4	0·3	6·4	5·1	12·4	9·8
05	11 46·3	11 48·2	11 14·1	0·5	0·4	6·5	5·1	12·5	9·9
06	11 46·5	11 48·4	11 14·3	0·6	0·5	6·6	5·2	12·6	10·0
07	11 46·8	11 48·7	11 14·6	0·7	0·6	6·7	5·3	12·7	10·1
08	11 47·0	11 48·9	11 14·8	0·8	0·6	6·8	5·4	12·8	10·1
09	11 47·3	11 49·2	11 15·0	0·9	0·7	6·9	5·5	12·9	10·2

MER D2. On 16 September your 0600 ZT fix gives you a position of latitude 29° 47.2’ N, longitude 65° 28.4’ W. Your vessel is on course 242° T and your speed is 13.5 knots. Local apparent noon (LAN) occurs at 1227 ZT, at which time a meridian altitude of the Sun’s lower limb is observed. The observed altitude (Ho) for this sight is 63° 25.3’. What is the calculated latitude at LAN?

Answer: 29° 04.6’ N.

G.M.T. (d h)	SUN G.H.A. (° ′)	SUN Dec. (° ′)
16 00	181 15.0	N 2 45.9
01	196 15.2	44.9
02	211 15.4	43.9
03	226 15.7	· · 43.0
04	241 15.9	42.0
05	256 16.1	41.0
06	271 16.3	N 2 40.1
W 07	286 16.6	39.1
E 08	301 16.8	38.2
D 09	316 17.0	· · 37.2
N 10	331 17.2	36.2
E 11	346 17.4	35.3
S 12	1 17.7	N 2 34.3
D 13	16 17.9	33.3
A 14	31 18.1	32.4
Y 15	46 18.3	· · 31.4
16	61 18.6	30.4
17	76 18.8	29.5
18	91 19.0	N 2 28.5
19	106 19.2	27.5
20	121 19.5	26.6
21	136 19.7	· · 25.6
22	151 19.9	24.6
23	166 20.1	23.7

Step 1: Determine the GMT of the sight.
DR longitude (0600): 65° 28.4’ W, which corresponds to (+4 ZD).
1227 zone time +4 hours = 1627 GMT.

Step 2: Determine the declination of the sun for the GMT time of sight.
At 1627 GMT:
Declination (hours): N 2° 30.4’ (decreasing)
d number: 1.0
Declination (increments): - 0.5’
Declination (total): N 2° 30.4’ – 0.5’ =
S 2° 29.9’

Step 3: Determine the observed altitude of the body.
No corrections are required in this problem, since the (ho) is given as 63° 25.3’

Step 4: Determine the zenith distance of the sight.
ZD = 90° - observed altitude.
ZD = 90° - 63° 25.3’ = 26° 34.7’

Step 5: Determine the latitude.

Since the observer is in the same hemisphere as the body, but further away from the equator (as evidenced by the DR latitude), the formula is:
Latitude = Zenith Distance + Declination
Latitude = 26° 34.7’ + 2° 29.9’ = **26° 04.6’ N**

D CORRECTIONS 27m

27m (s)	SUN PLANETS (° ′)	ARIES (° ′)	MOON (° ′)	v or d (′)	Corr^n (′)	v or d (′)	Corr^n (′)	v or d (′)	Corr^n (′)
00	6 45·0	6 46·1	6 26·6	0·0	0·0	6·0	2·8	12·0	5·5
01	6 45·3	6 46·4	6 26·8	0·1	0·0	6·1	2·8	12·1	5·5
02	6 45·5	6 46·6	6 27·0	0·2	0·1	6·2	2·8	12·2	5·6
03	6 45·8	6 46·9	6 27·3	0·3	0·1	6·3	2·9	12·3	5·6
04	6 46·0	6 47·1	6 27·5	0·4	0·2	6·4	2·9	12·4	5·7
05	6 46·3	6 47·4	6 27·7	0·5	0·2	6·5	3·0	12·5	5·7
06	6 46·5	6 47·6	6 28·0	0·6	0·3	6·6	3·0	12·6	5·8
07	6 46·8	6 47·9	6 28·2	0·7	0·3	6·7	3·1	12·7	5·8
08	6 47·0	6 48·1	6 28·5	0·8	0·4	6·8	3·1	12·8	5·9
09	6 47·3	6 48·4	6 28·7	0·9	0·4	6·9	3·2	12·9	5·9
10	6 47·5	6 48·6	6 28·9	1·0	0·5	7·0	3·2	13·0	6·0

MER D3. On 7 November your 0830 zone time fix gives you a position of latitude 27° 36.0’ N, longitude 163° 19.0’ W. Your vessel is on course 289° T and your speed is 19.0 knots. Local apparent noon (LAN) occurs at 1138 zone time, at which time a meridian altitude of the Sun’s lower limb is observed. The observed altitude (Ho) for this sight is 45° 35.0’. What is the calculated latitude at LAN?

Answer: 27° 57.2’ N

7	00	184	04.6	S16	11.2
	01	199	04.6		12.0
	02	214	04.6		12.7
	03	229	04.6	··	13.5
	04	244	04.5		14.2
	05	259	04.5		14.9
	06	274	04.5	S16	15.7
	07	289	04.4		16.4
S	08	304	04.4		17.1
A	09	319	04.3	··	17.9
T	10	334	04.3		18.6
U	11	349	04.3		19.4
R	12	4	04.2	S16	20.1
D	13	19	04.2		20.8
A	14	34	04.2		21.6
Y	15	49	04.1	··	22.3
	16	64	04.1		23.0
	17	79	04.1		23.8
	18	94	04.0	S16	24.5
	19	109	04.0		25.2
	20	124	03.9		26.0
	21	139	03.9	··	26.7
	22	154	03.9		27.4
	23	169	03.8		28.2

Step 1: Determine the GMT of the sight.
DR longitude (0830): 163° 19.0’ W, which corresponds to (+11 ZD).
1138 zone time +11 hours = 2238 GMT.

Step 2: Determine the declination of the sun for the GMT time of sight.
At 2238 GMT:
Declination (hours): S 16° 27.4’ (increasing)
d number: 0.7
Declination (increments): +0.4’
Declination (total): S 16° 27.4’ + 0.4’ =
S 16° 27.8’

Step 3: Determine the observed altitude of the body.
No corrections are required in this problem, since the (ho) is given as 45° 35.0’

Step 4: Determine the zenith distance of the sight.
ZD = 90° - observed altitude.
ZD = 90° - 45° 35.0’ = 44° 25.0’

Step 5: Determine the latitude.

Since the observer is in the opposite hemisphere as the body (as evidenced by the DR latitude), the formula is:
Latitude = Zenith Distance - Declination
Latitude = 44° 25.0’ - 16° 27.8’ = **27° 57.2’ N**

38m INCREMENTS AN

38m	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	0·8	0·5	6·8	4·4	12·8	8·2
09	9 32·3	9 33·8	9 06·2	0·9	0·6	6·9	4·4	12·9	8·3

Latitude at 1200 (Advance/Retard LOP)

MER D4. On 13 October your 0515 zone time fix gives you a position of latitude 26° 53.0' N, longitude 90° 05.0' W. Your vessel is on course 068° T and your speed is 7.8 knots. Local apparent noon (LAN) occurs at 1145 zone time, at which time a meridian altitude of the Sun's lower limb is observed. The observed altitude (Ho) for this sight is 54° 51.5'. What is the latitude at 1200 ZT?

Answer: 27° 13.3' N.

G.M.T.	SUN G.H.A.	SUN Dec.
d h	° '	° '
13 00	183 24.5	S 7 39.3
01	198 24.6	40.2
02	213 24.8	41.2
03	228 24.9	· · 42.1
04	243 25.1	43.1
05	258 25.2	44.0
06	273 25.4	S 7 44.9
07	288 25.5	45.9
08	303 25.7	46.8
T 09	318 25.8	· · 47.7
U 10	333 26.0	48.7
E 11	348 26.1	49.6
S 12	3 26.3	S 7 50.5
D 13	18 26.4	51.5
A 14	33 26.6	52.4
Y 15	48 26.7	· · 53.3
16	63 26.9	54.3
17	78 27.0	55.2

Step 1: Determine the GMT of the sight.
DR longitude (0515): 90° 05.0' W, which corresponds to (+6 ZD).
1145 zone time + 6 hours = 1745 GMT.

Step 2: Determine the declination of the sun for the GMT time of sight.
At 1745 GMT:
Declination (hours): S 7° 55.2' (increasing)
d number: 0.9
Declination (increments): +0.7'
Declination (total): S 7° 55.2' + 0.7' =
S 7° 55.9'

Step 3: Determine the observed altitude of the body.
No corrections are required in this problem, since the (ho) is given as 54° 51.5'

Step 4: Determine the zenith distance of the sight.
ZD = 90° - observed altitude.
ZD = 90° - 54° 51.5' = 35° 08.5'

Step 5: Determine the latitude.

Since the observer is in the opposite hemisphere as the body (as evidenced by the DR latitude), the formula is:
Latitude = Zenith Distance - Declination
Latitude = 35° 08.5' - 7° 55.9' = 27° 12.6' N

D CORRECTIONS 45m

45m	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° '	° '	° '	'	'	'	'	'	'
00	11 15·0	11 16·8	10 44·3	0·0	0·0	6·0	4·6	12·0	9·1
01	11 15·3	11 17·1	10 44·5	0·1	0·1	6·1	4·6	12·1	9·2
02	11 15·5	11 17·3	10 44·7	0·2	0·2	6·2	4·7	12·2	9·3
03	11 15·8	11 17·6	10 45·0	0·3	0·2	6·3	4·8	12·3	9·3
04	11 16·0	11 17·9	10 45·2	0·4	0·3	6·4	4·9	12·4	9·4
05	11 16·3	11 18·1	10 45·4	0·5	0·4	6·5	4·9	12·5	9·5
06	11 16·5	11 18·4	10 45·7	0·6	0·5	6·6	5·0	12·6	9·6
07	11 16·8	11 18·6	10 45·9	0·7	0·5	6·7	5·1	12·7	9·6
08	11 17·0	11 18·9	10 46·2	0·8	0·6	6·8	5·2	12·8	9·7
09	11 17·3	11 19·1	10 46·4	0·9	0·7	6·9	5·2	12·9	9·8

Step 6: Advance or retard the latitude line of position to the desired time. Note this task can be accomplished by math (via mid-latitude sailing) or by plotting sheet. This example shows both methods.

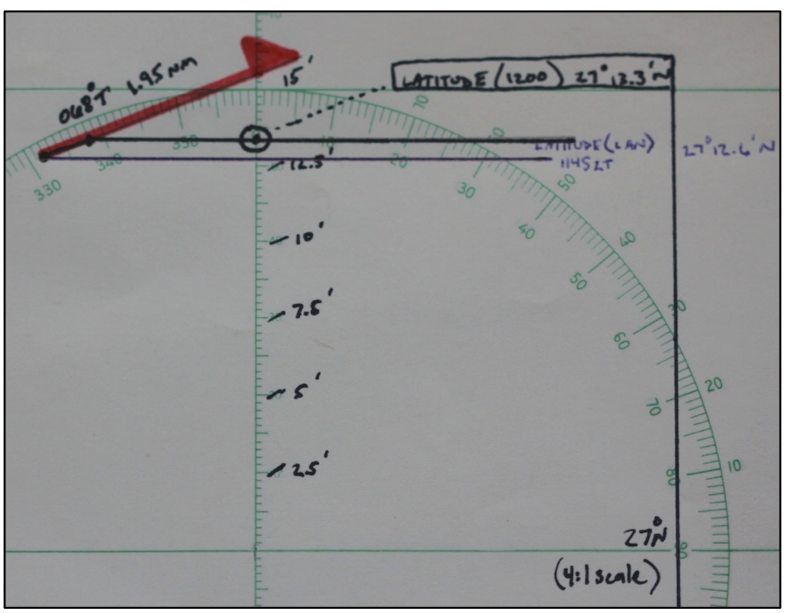
a. Method 1: Mid Latitude Sailings.

i. Determine the transit time and distance (D) steamed over that time.
1145 (LAN) to 1200 (desired fix) = 15 minutes = 0.25 hours
7.8 knots for 0.25 hours = 1.95 miles. (Course = 068° T)

ii. Determine the Difference in Latitude (*l*) using the plane sailing formula.
$l = \text{D} \ \cos \text{C}$
$l = 1.95 \ \cos(68°)$
$l = (1.95)\ (0.3746)$
$l = 0.73'$

iii. Determine latitude 2 given the initial position and the Difference in Latitude (*l*).
Lat1 (LAN) = 27° 12.6' N
l = + 0.73'
Lat2 (1200) = 27° 12.6' + 0.73' = **27° 13.3' N**

b. Method 2: Plotting Sheet.



Ex-Meridian Problems

MER D5. On 15 August an ex-meridian altitude of the Sun's lower limb at upper transit was observed at 1130 ZT. Your DR position is latitude 26° 24.0' S, longitude 155° 02.0' E and your sextant altitude (hs) is 48° 45.9'. The index error is 2.6' on the arc and your height of eye is 51.5 feet. The chronometer time of the observation is 01h 27m 38s, and the chronometer error is 02m 14s slow. Find the latitude at meridian passage from the ex-meridian observation.

Answer: 26° 51.7' S.

Step 1: Determine the chronometer time of sight based on chronometer error.
Chronometer time: 01h 27m 38s
Chronometer error: 00h 02m 14s slow
Correct sight time: 01h 27m 38s + 00h 02m 14s = 01h 29m 52s

G.M.T.	SUN G.H.A.	SUN Dec.
15 00	178 52.3	N14 09.1
01	193 52.4	08.3
02	208 52.6	07.5
	S.D. 15.8	d 0.8

Step 2: Determine the GMT of the sight.
DR longitude: 155° 02.0' E (corresponds to -10 ZT)
Clock time of sight: 1130 ZT
1130 – 10 (ZT) = 0130. Therefore, the chronometer time of 01:29:52 (15 August) is correct and used for the sight.

Step 3: Determine the time difference from meridian passage to the time of observation.
Time of sight: 01:29:52 GMT
GHA (hours): 193° 52.4'
GHA (increment): 7° 28.0'
GHA (total): 193° 52.4' + 7° 28.0' = 201° 20.4'
DR longitude: 155° 02.0' E
LHA (sun): 201° 20.4' + 155° 02.0' E = 356° 22.4'
LHA diff. from meridian passage (LHA = 360°): 360 – 356° 22.4' = 3° 37.6'
LHA difference converted to time: 3° 37.6' = 14m 30s

28m INCREMENTS AND CORRECTIONS

28m s	SUN PLANETS ° '	ARIES ° '	MOON ° '	v or d '	Corr^n '	v or d '	Corr^n '	v or d '	Corr^n '
00	7 00·0	7 01·1	6 40·9	0·0	0·0	6·0	2·9	12·0	5·7
01	7 00·3	7 01·4	6 41·1	0·1	0·0	6·1	2·9	12·1	5·7
02	7 00·5	7 01·7	6 41·3	0·2	0·1	6·2	2·9	12·2	5·8
03	7 00·8	7 01·9	6 41·6	0·3	0·1	6·3	3·0	12·3	5·8
04	7 01·0	7 02·2	6 41·8	0·4	0·2	6·4	3·0	12·4	5·9
05	7 01·3	7 02·4	6 42·1	0·5	0·2	6·5	3·1	12·5	5·9
06	7 01·5	7 02·7	6 42·3	0·6	0·3	6·6	3·1	12·6	6·0
07	7 01·8	7 02·9	6 42·5	0·7	0·3	6·7	3·2	12·7	6·0
08	7 02·0	7 03·2	6 42·8	0·8	0·4	6·8	3·2	12·8	6·1
09	7 02·3	7 03·4	6 43·0	0·9	0·4	6·9	3·3	12·9	6·1

29m

29m s	SUN PLANETS ° '	ARIES ° '	MOON ° '	v or d '	Corr^n '	v or d '	Corr^n '	v or d '	Corr^n '
00	7 15·0	7 16·2	6 55·2	0·0	0·0	6·0	3·0	12·0	5·9
01	7 15·3	7 16·4	6 55·4	0·1	0·0	6·1	3·0	12·1	5·9
02	7 15·5	7 16·7	6 55·7	0·2	0·1	6·2	3·0	12·2	6·0
03	7 15·8	7 16·9	6 55·9	0·3	0·1	6·3	3·1	12·3	6·0
04	7 16·0	7 17·2	6 56·1	0·4	0·2	6·4	3·1	12·4	6·1
05	7 16·3	7 17·4	6 56·4	0·5	0·2	6·5	3·2	12·5	6·1
06	7 16·5	7 17·7	6 56·6	0·6	0·3	6·6	3·2	12·6	6·2
07	7 16·8	7 17·9	6 56·9	0·7	0·3	6·7	3·3	12·7	6·2
08	7 17·0	7 18·2	6 57·1	0·8	0·4	6·8	3·3	12·8	6·3
09	7 17·3	7 18·4	6 57·3	0·9	0·4	6·9	3·4	12·9	6·3

Step 4: Determine the observed altitude for the sight using the correction tables in the Nautical Almanac (also provided at the end of this Part).

Sextant altitude (hs): 48° 45.9’

Corrections:

Index error: 2.6’ on the arc (-2.6’ index correction)

Height of eye: 51.5’ (-7.0’ dip correction)

Apparent altitude (ha) = 48° 45.9’ – 2.6’ – 7.0’ = 48° 36.3’

Apparent altitude correction: +15.1’

Observed altitude (ho) = 48° 36.3’ + 15.1’ = 48° 51.4’

DIP		
Ht. of Eye	Corrⁿ	Ht. of Eye
15·1		49·8
	6·9	
15·5		51·3
	7·0	
16·0		52·8
	7·1	
16·5		54·3

Step 5: Note the DR latitude: 26° 24.0’ S

OCT.—MAR. SUN			APR.—SEPT.		
App. Alt.	Lower Limb	Upper Limb	App. Alt.	Lower Limb	Upper Limb
43 59			45 31		
	+15·3	−17·0		+15·1	−16·7
47 10			48 55		
	+15·4	−16·9		+15·2	−16·6
50 46			52 44		
	+15·5	−16·8		+15·3	−16·5

Step 6: Determine the declination of the body for the time of sight.

Declination (hours): N 14° 08.3

Declination (increments): d = -0.8, therefore increment = -0.4’

Declination (total): N 14° 08.3 – 0.4 = N 14° 07.9’

Step 7: Enter Altitude Factor Table in Bowditch to determine the altitude factor (a).

Bracketing values:

	14° N	14° 07.9’	**15° N**
26° S	**2.7**		**2.6**
26°24’S		**a**	
27° S	**2.6**		**2.5**

Interpolation:

	14° N	**14.13°**	15° N
26° S	2.7	2.69	2.6
26.4° S	2.66	**a**	2.56
27° S	2.6	2.59	2.5

Interpolated value: a = 2.63

Altitude Factor

a, the change of altitude in one minute from meridian transit.

Latitude	Declination **contrary** name to latitude, **upper** transit: **add** correction to observed altitude													Latitude
	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	
°	"	"	"	"	"	"	"	"	"	"	"	"	"	°
0	9.2	8.5	7.9	7.3	6.8	6.4	6.0	5.7	5.4	5.1	4.9	4.6	4.4	0
1	8.5	7.9	7.4	6.9	6.5	6.1	5.7	5.4	5.1	4.9	4.7	4.4	4.2	1
2	7.9	7.4	6.9	6.5	6.1	5.8	5.5	5.2	4.9	4.7	4.5	4.3	4.1	2
3	7.4	6.9	6.5	6.1	5.8	5.5	5.2	4.9	4.7	4.5	4.3	4.1	3.9	3
4	7.0	6.5	6.2	5.8	5.5	5.2	5.0	4.7	4.5	4.3	4.1	4.0	3.8	4
5	6.5	6.2	5.8	5.5	5.2	5.0	4.8	4.5	4.3	4.2	4.0	3.8	3.7	5
6	6.2	5.8	5.5	5.3	5.0	4.8	4.6	4.4	4.2	4.0	3.9	3.7	3.6	6
7	5.9	5.6	5.3	5.0	4.8	4.6	4.4	4.2	4.0	3.9	3.7	3.6	3.5	7
8	5.6	5.3	5.0	4.8	4.6	4.4	4.2	4.0	3.9	3.7	3.6	3.5	3.4	8
9	5.3	5.0	4.8	4.6	4.4	4.2	4.1	3.9	3.8	3.6	3.5	3.4	3.3	9
10	5.0	4.8	4.6	4.4	4.2	4.1	3.9	3.8	3.6	3.5	3.4	3.3	3.2	10
11	4.8	4.6	4.4	4.2	4.1	3.9	3.8	3.6	3.5	3.4	3.3	3.2	3.1	11
12	4.6	4.4	4.3	4.1	3.9	3.8	3.7	3.5	3.4	3.3	3.2	3.1	3.0	12
13	4.4	4.3	4.1	3.9	3.8	3.7	3.5	3.4	3.3	3.2	3.1	3.0	2.9	13
14	4.2	4.1	3.9	3.8	3.7	3.5	3.4	3.3	3.2	3.1	3.0	2.9	2.8	14
15	4.1	3.9	3.8	3.7	3.5	3.4	3.3	3.2	3.1	3.0	2.9	2.8	2.8	15
16	3.9	3.8	3.7	3.5	3.4	3.3	3.2	3.1	3.0	2.9	2.8	2.8	2.7	16
17	3.8	3.7	3.5	3.4	3.3	3.2	3.1	3.0	2.9	2.8	2.8	2.7	2.6	17
18	3.7	3.5	3.4	3.3	3.2	3.1	3.0	2.9	2.9	2.8	2.7	2.6	2.5	18
19	3.5	3.4	3.3	3.2	3.1	3.0	2.9	2.9	2.8	2.7	2.6	2.6	2.5	19
20	3.4	3.3	3.2	3.1	3.0	2.9	2.9	2.8	2.7	2.6	2.6	2.5	2.4	20
21	3.3	3.2	3.1	3.0	2.9	2.8	2.8	2.7	2.6	2.6	2.5	2.4	2.4	21
22	3.2	3.1	3.0	2.9	2.8	2.8	2.7	2.6	2.6	2.5	2.4	2.4	2.3	22
23	3.1	3.0	2.9	2.8	2.8	2.7	2.6	2.6	2.5	2.4	2.4	2.3	2.3	23
24	3.0	2.9	2.8	2.8	2.7	2.6	2.5	2.5	2.4	2.4	2.3	2.3	2.2	24
25	2.9	2.8	2.7	2.7	2.6	2.5	2.5	2.4	2.4	2.3	2.3	2.2	2.2	25
26	2.8	2.7	2.7	2.6	2.5	2.5	2.4	2.4	2.3	2.3	2.2	2.1	2.1	26
27	2.7	2.7	2.6	2.5	2.5	2.4	2.4	2.3	2.2	2.2	2.1	2.1	2.1	27
28	2.6	2.6	2.5	2.5	2.4	2.3	2.3	2.2	2.2	2.1	2.1	2.1	2.0	28
29	2.6	2.5	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.1	2.0	2.0	2.0	29

Step 8: Enter Change in Altitude Table in Bowditch to determine the altitude change correction.

Bracketing values:

	t = 14m 20s	t = 14m 30 s	**t = 14m 40s**
a = 2.0	**6.8**		**7.2**
a = 2.63		**Correction**	
a = 3.0	**10.3**		**10.8**

Interpolation:

	t = 14m 20s	**t = 14m 30 s**	t = 14m 40s
a = 2.0	6.8	**7.0**	7.2
a = 2.63	**9.01**	**Correction**	**9.47**
a = 3.0	10.3	**10.55**	10.8

Interpolated value = 9.0

Step 9: Apply the Change in Altitude correction to the observed altitude (ho) to determine the corrected altitude.
Observed altitude (ho): 48° 51.4'
Correction: +9.0'
Corrected altitude (ho (corr)): 48° 51.4' + 9.0' = 49° 00.4'

Step 10: Complete the meridian transit (LAN) calculation.
Altitude: 49° 00.4' (to the north)
Zenith Distance (90-Alt) = 40° 59.6'
Declination: 14° 07.9' N
Latitude (ZD – Dec in this case): 40° 59.6' – 14° 07.9' = **26° 51.7' S**

Change of Altitude in Given Time from Meridian Transit

a (table 24)	t, meridian angle														*a* (table 24)
	3° 35′	3° 40′	3° 45′	3° 50′	3° 55′	4° 00′	4° 05′	4° 10′	4° 15′	4° 20′	4° 25′	4° 30′	4° 35′	4° 40′	
	$14^m 20^s$	$14^m 40^s$	$15^m 00^s$	$15^m 20^s$	$15^m 40^s$	$16^m 00^s$	$16^m 20^s$	$16^m 40^s$	$17^m 00^s$	$17^m 20^s$	$17^m 40^s$	$18^m 00^s$	$18^m 20^s$	$18^m 40^s$	
″	′	′	′	′	′	′	′	′	′	′	′	′	′	′	″
0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.1
0.2	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	0.2
0.3	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.7	0.3
0.4	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.2	2.3	0.4
0.5	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	0.5
0.6	2.1	2.2	2.2	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.4	3.5	0.6
0.7	2.4	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.8	3.9	4.1	0.7
0.8	2.7	2.9	3.0	3.1	3.3	3.4	3.6	3.7	3.9	4.0	4.2	4.3	4.5	4.6	0.8
0.9	3.1	3.2	3.4	3.5	3.7	3.8	4.0	4.2	4.3	4.5	4.7	4.9	5.0	5.2	0.9
1.0	3.4	3.6	3.8	3.9	4.1	4.3	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	1.0
2.0	6.8	7.2	7.5	7.8	8.2	8.5	8.9	9.3	9.6	10.0	10.4	10.8	11.2	11.6	2.0
3.0	10.3	10.8	11.3	11.8	12.3	12.8	13.3	13.9	14.4	15.0	15.6	16.2	16.8	17.4	3.0
4.0	13.7	14.3	15.0	15.7	16.4	17.1	17.8	18.5	19.3	20.0	20.8	21.6	22.4	23.2	4.0
5.0	17.1	17.9	18.8	19.6	20.5	21.3	22.2	23.1	24.1	25.0	26.0	27.0	28.0	29.0	5.0
6.0	20.5	21.5	22.5	23.5	24.5	25.6	26.7	27.8							6.0
7.0	24.0	25.1	26.3	27.4											7.0
8.0	27.4	28.7	30.0												8.0

MER D5. On 16 June in DR position latitude 50° 57.0’ S, longitude 53° 03.9’ W (ZD +4), you take an ex-meridian observation of Acrux at lower transit. The chronometer time of the sight is 10h 08m 18s, and the chronometer error is 02m 12s fast. The sextant altitude (hs) is 23° 49.0’. The index error is 1.1’ off the arc and your height of eye is 26 feet. What is the latitude at meridian transit?

Answer: 50° 41.1’ S. In certain cases, depending on the observer’s latitude, stars and planets can be circumpolar – they never set. In these cases, meridian transits can be observed twice per day. When the object is at its lowest point in the sky, it is called a lower transit. The calculations are the same as a typical meridian passage, with the exception of the LHA correction, the altitude factor table correction, and the latitude determination, each of which require a lower transit correction.

Step 1: Determine the chronometer time of sight based on chronometer error.
Chronometer time: 10h 08m 18s
Chronometer error: 00h 02m 12s fast
Correct sight time: 10h 08m 18s - 00h 02m 12s = 10h 06m 06s
Determine the GMT of the sight.
The correct zone descriptor is given in the problem, and the chronometer time of 10h 06m 06s is the correct GMT.

Step 2: Determine the time difference from meridian passage to the time of observation.
Time of sight: 10:06:06 GMT
GHA (Aries - hours): 54° 35.1’
GHA (Aries - increment): 1° 31.8’
GHA (Aries - total): 54° 35.1’ + 1° 31.8’ = 56° 06.9’

SHA (Acrux): 173° 36.5’
GHA (Aries): 56° 06.9’
GHA (Acrux): 173° 36.5’ + 56° 06.9’ = 229° 43.4’
Lower transit correction: -180°
GHA (Acrux – lower transit) = 229° 38.4 – 180° = 49° 38.4’

DR longitude: 53° 03.9’ W
LHA (Acrux): 49° 38.4’ - 53° 03.9’ W = 356° 39.5’
LHA difference from meridian passage (LHA = 360°): 360 – 356° 39.5’ = 3° 20.5’
LHA difference converted to time: 3° 20.5’ = 13m 22s

G.M.T.		ARIES G.H.A.
	08	24 30.2
T	09	39 32.6
U	10	54 35.1
E	11	69 37.6
S		

6m INCREMENTS AN

6m s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corrn ′	v or d ′	Corrn ′	v or d ′	Corrn ′
00	1 30·0	1 30·2	1 25·9	0·0	0·0	6·0	0·7	12·0	1·3
01	1 30·3	1 30·5	1 26·1	0·1	0·0	6·1	0·7	12·1	1·3
02	1 30·5	1 30·7	1 26·4	0·2	0·0	6·2	0·7	12·2	1·3
03	1 30·8	1 31·0	1 26·6	0·3	0·0	6·3	0·7	12·3	1·3
04	1 31·0	1 31·2	1 26·9	0·4	0·0	6·4	0·7	12·4	1·3
05	1 31·3	1 31·5	1 27·1	0·5	0·1	6·5	0·7	12·5	1·4
06	1 31·5	1 31·8	1 27·3	0·6	0·1	6·6	0·7	12·6	1·4
07	1 31·8	1 32·0	1 27·6	0·7	0·1	6·7	0·7	12·7	1·4
08	1 32·0	1 32·3	1 27·8	0·8	0·1	6·8	0·7	12·8	1·4
09	1 32·3	1 32·5	1 28·0	0·9	0·1	6·9	0·7	12·9	1·4

STARS

Name	S.H.A. ° ′	Dec. ° ′
Acamar	315 37.2	S40 22.7
Achernar	335 45.2	S57 19.7
Acrux	173 36.5	S63 00.0
Adhara	255 32.1	S28 56.9
Aldebaran	291 17.8	N16 28.2

Step 3: Determine the observed altitude for the sight using the correction tables in the Nautical Almanac (provided at the end of this Part).
Sextant altitude (hs): 23° 49.0’
Corrections:
Index error: 1.1’ off the arc (+1.1’ index correction)
Height of eye: 26’ (-5.0’ dip correction)
Apparent altitude (ha) = 23° 49.0’ + 1.1’ – 5.0’ = 23° 45.1’
Apparent altitude correction: -2.2’
Observed altitude (ho) = 23° 45.1’ -2.2’ = 23° 42.9’

Step 4: Note the DR latitude: 50° 57.0’ S

Step 5: Determine the declination of the body for the time of sight.
Declination (total): S 63° 00.0’

Step 6: Enter the Altitude Factor table in Bowditch to determine the altitude factor (a). Because it is a lower transit problem, be sure to use the correct table (lower portion of the “contrary” table). Refer to the tabular instructions in Bowditch if in doubt.

Altitude Factor

a, the change of altitude in one minute from meridian transit.

Lati-tude	Declination contrary name to latitude, upper transit: add correction to observed altitude													Lati-tude
	51°	52°	53°	54°	55°	56°	57°	58°	59°	60°	61°	62°	63°	
														30
														31
														32
													0. 8	33
												0. 8	0. 7	34
											0. 8	0. 8	0. 7	35
										0. 8	0. 8	0. 8	0. 7	36
										0. 8	0. 8	0. 7	0. 7	37
										0. 8	0. 8	0. 7	0. 7	38
										0. 8	0. 8	0. 7	0. 7	39
										0. 8	0. 8	0. 7	0. 7	40
										0. 8	0. 7	0. 7	0. 7	41
										0. 8	0. 7	0. 7	0. 7	42
										0. 7	0. 7	0. 7	0. 7	43
										0. 7	0. 7	0. 7	0. 7	44
										0. 7	0. 7	0. 7	0. 7	45
										0. 7	0. 7	0. 7	0. 7	46
										0. 7	0. 7	0. 7	0. 6	47
										0. 7	0. 7	0. 7	0. 6	48
										0. 7	0. 7	0. 6	0. 6	49
										0. 7	0. 7	0. 6	0. 6	50
										0. 7	0. 7	0. 6	0. 6	51
										0. 7	0. 6	0. 6	0. 6	52

No interpolation is necessary in this case. a = 0.6

Step 7: Enter Change in Altitude table in Bowditch to determine the altitude change correction.

Change of Altitude in Given Time from Meridian Transit

t, meridian angle												a (table 24)
2° 35′	2° 40′	2° 45′	2° 50′	2° 55′	3° 00′	3° 05′	3° 10′	3° 15′	3° 20′	3° 25′	3° 30′	
10m 20s	10m 40s	11m 00s	11m 20s	11m 40s	12m 00s	12m 20s	12m 40s	13m 00s	13m 20s	13m 40s	14m 00s	
′	′	′	′	′	′	′	′	′	′	′	′	″
0. 2	0. 2	0. 2	0. 2	0. 2	0. 2	0. 3	0. 3	0. 3	0. 3	0. 3	0. 3	0. 1
0. 4	0. 4	0. 4	0. 4	0. 5	0. 5	0. 5	0. 5	0. 6	0. 6	0. 6	0. 7	0. 2
0. 5	0. 6	0. 6	0. 6	0. 7	0. 7	0. 8	0. 8	0. 8	0. 9	0. 9	1. 0	0. 3
0. 7	0. 8	0. 8	0. 9	0. 9	1. 0	1. 0	1. 1	1. 1	1. 2	1. 2	1. 3	0. 4
0. 9	0. 9	1. 0	1. 1	1. 1	1. 2	1. 3	1. 3	1. 4	1. 5	1. 6	1. 6	0. 5
1. 1	1. 1	1. 2	1. 3	1. 4	1. 4	1. 5	1. 6	1. 7	1. 8	1. 9	2. 0	0. 6

Bracketing values:

	t = 13m 20s	t = 13m 22s	t = 13m 40s
a = .6	1.8	**Correction**	1.9

Interpolated value = 1.8’

Step 8: Apply the Change in Altitude correction to the observed altitude (ho) to determine the corrected altitude.
Observed altitude (ho): 23° 42.9’
Correction: -1.8’ (lower transit corrections are subtracted)
Corrected altitude (ho (corr)): 23° 42.9’ – 1.8’ = 23° 41.1’

Step 9: Complete the meridian transit calculation.
Altitude: 23° 41.1’ (to the north)
Zenith Distance (90-Alt) = 66° 18.9’
Declination: 63° 00.0’ S
Latitude (ZD + Dec in this case): 66° 18.9’ + 63° 00.0’ = 129° 18.9’ S
Lower Transit correction: -180°
Latitude = 129° 18.9’ – 180° = **50° 41.1’ S**

Latitude by Meridian Passage Problems

Latitude at LAN

MER B1. On 7 November your 0830 zone time fix gives you a position of latitude 27° 36.0’ N, longitude 163° 19.0’ W. Your vessel is on course 289° T and your speed is 19.0 knots. Local apparent noon (LAN) occurs at 1138 zone time, at which time a meridian altitude of the Sun’s lower limb is observed. The observed altitude (Ho) for this sight is 45° 35.0’. What is the calculated latitude at LAN?

a) 27° 52.3’ N
b) 27° 53.4’ N
c) 27° 55.1’ N
d) 27° 57.2’ N - correct

MER B2. On 28 July your 0800 zone time fix gives you a position of latitude 25° 16.0’ N, longitude 71° 19.0’ W. Your vessel is on course 026° T and your speed is 17.5 knots. Local apparent noon (LAN) occurs at 1149 zone time, at which time a meridian altitude of the Sun’s lower limb is observed. The observed altitude (Ho) for this sight is 82° 28.7’. What is the calculated latitude at LAN?

a) 26° 21.9’ N
b) 26° 23.4’ N
c) 26° 25.0’ N - correct
d) 26° 27.7’ N

MER B3. On 22 February your 0612 zone time fix gives you a position of latitude 27° 16.2’ S, longitude 37° 41.6’ W. Your vessel is on course 298° T at 14.2 knots. Local apparent noon (LAN) occurs at 1147 zone time, at which time a meridian altitude of the Sun’s lower limb is observed. The observed altitude (Ho) for this sight is 73° 33.3’. What is the calculated latitude at LAN?

a) 26° 31.4’ S - correct
b) 26° 29.5’ S
c) 26° 27.1’ S
d) 26° 24.8’ S

MER B4. On 16 September your 0600 ZT fix gives you a position of latitude 29° 47.2’ N, longitude 65° 28.4’ W. Your vessel is on course 242° T and your speed is 13.5 knots. Local apparent noon (LAN) occurs at 1227 ZT, at which time a meridian altitude of the Sun’s lower limb is observed. The observed altitude (Ho) for this sight is 63° 25.3’. What is the calculated latitude at LAN?

a) 29° 07.9 N
b) 29° 06.1’ N
c) 29° 04.7’ N - correct
d) 29° 01.6’ N

Latitude at 1200 (Advance/Retard LAN)

MER B5. On 13 October your 0515 zone time fix gives you a position of latitude 26° 53.0' N, longitude 90° 05.0' W. Your vessel is on course 068° T and your speed is 7.8 knots. Local apparent noon (LAN) occurs at 1145 zone time, at which time a meridian altitude of the Sun's lower limb is observed. The observed altitude (Ho) for this sight is 54° 51.5'. What is the latitude at 1200 ZT?

a) 27° 13.3' N - correct
b) 27° 14.6' N
c) 27° 15.7' N
d) 27° 16.8' N

MER B6. On 28 July your 0800 zone time (ZT) fix gives you a position of latitude 25° 16.0' N, longitude 71° 19.0' W. Your vessel is on course 026° T at 17.5 knots. Local apparent noon (LAN) occurs at 1150 ZT, at which time a meridian altitude of the Sun's lower limb is observed. The observed altitude (Ho) for this sight is 82° 28.7'. What is the latitude at 1200 ZT?

a) 26° 25.0' N
b) 26° 27.6' N - correct
c) 26° 29.8' N
d) 26° 32.0' N

MER B7. On 7 November your 0830 zone time fix gives you a position of latitude 27° 36.0' N, longitude 162° 19.0' W. Your vessel is on course 289° T and your speed is 19.0 knots. Local apparent noon (LAN) occurs at 1138 zone time, at which time a meridian altitude of the Sun's lower limb is observed. The observed altitude (Ho) for this sight is 45° 35.0'. What is the latitude at 1200 ZT?

a) 27° 55.1' N
b) 27° 57.2' N
c) 27° 59.5' N - correct
d) 28° 01.9' N

Latitude from Ex-Meridian Sights

MER B8. On 15 December in DR position latitude 23° 24.0' N, longitude 55° 36.0' W, you take an ex-meridian observation of the Sun's lower limb. The chronometer time of the sight is 03h 45m 19s, and there is no chronometer error. The sextant altitude (hs) is 43° 02.3'. The index error is 2.6' on the arc and your height of eye is 65.0 feet. What is the latitude at meridian transit?

a) **23° 33.5' N - correct**
b) 23° 35.8' N
c) 23° 38.1' N
d) 23° 40.6' N

MER B9. On 27 March in DR position latitude 32° 31.0' N, longitude 76° 25.0' W, you take an ex-meridian observation of the Sun's lower limb. The chronometer time of the sight is 05h 23m 32s and the chronometer error is 01m 30s fast. The sextant altitude (hs) is 59° 59.0'. The index error is 1.8' off the arc, and your height of eye is 52 feet. What is the latitude at meridian transit?

a) 32° 21.6' N
b) **32° 29.5' N - correct**
c) 32° 37.6' N
d) 32° 46.2' N

MER B10. On 17 November in DR position latitude 01° 14.4' S, longitude 148° 45.5' E, you take an ex-meridian observation of the planet Venus at upper transit. The chronometer time of the sight is 05h 31m 42s and the chronometer error is 01m 50s fast. The sextant altitude (hs) is 64° 41.1'. The index error is 1.8' off the arc and your height of eye is 50 feet. What is the latitude at meridian transit?

a) 01° 14.4' S
b) 01° 16.3' S
c) **01° 18.0' S - correct**
d) 01° 20.2' S

MER B11. On 16 June in DR position latitude 50° 57.0' S, longitude 53° 03.9' W (ZD +4), you take an ex-meridian observation of Acrux at lower transit. The chronometer time of the sight is 10h 08m 18s, and the chronometer error is 02m 12s fast. The sextant altitude (hs) is 23° 49.0'. The index error is 1.1' off the arc and your height of eye is 26 feet. What is the latitude at meridian transit?

a) **50° 41.2' S - correct**
b) 51° 02.2' S
c) 51° 33.0' S
d) 51° 41.2' S

MER B12. On 22 August in DR position latitude 29° 41.8’ N, longitude 33° 15.5’ W, you take an ex-meridian observation of the Moon’s upper limb at upper transit. The chronometer time of the sight is 08h 00m 02s and the chronometer error is 2m 20s slow. The sextant altitude (hs) is 74° 32.4’. The index error is 1.5’ off the arc and your height of eye is 48 feet. What is the latitude at meridian transit?

a) 29° 39.3’ N
b) 29° 41.3’ N
c) 29° 47.8’ N - correct
d) 29° 49.7’ N

Star Identification Problems

- The Starfinder (2102-D) is an instrument used for identifying stars and planets based on their azimuth (bearing) and altitude (height).

- The key to star identification problems is three-fold:

    - Use the correct hemisphere on the backing plate (North or South)
    - Use the correct plate based on latitude (all USCG Problems use the 25° plate).
    - Find the LHA of Aries (based on the GHA of Aries and your DR longitude).

- The vast majority of problems on USCG exams are of major navigational stars. However, there are some problems in the database seeking minor stars. For these minor star problems, the procedure is the same but requires an extra step at the end of looking up the star's right ascension (RA) and declination (dec) in the back of the Nautical Almanac.

SID D1. On 17 March your 1845 DR position is latitude 25° 10.0' N, longitude 66° 48.0' W. You observe an unidentified star bearing 320° T at an observed altitude (ho) of 50° 02.9'. The chronometer reads 10h 47m 49s and is 1m 54s fast. What star did you observe?

Answer: Mirfak.

G.M.T. d h	ARIES G.H.A. ° '
17 00	174 28.8
01	189 31.3
02	204 33.8
03	219 36.2
04	234 38.7
05	249 41.2
06	264 43.6
07	279 46.1
T 08	294 48.6
U 09	309 51.0
E 10	324 53.5
S 11	339 55.9
D 12	354 58.4
A 13	10 00.9
Y 14	25 03.3
15	40 05.8
16	55 08.3
17	70 10.7
18	85 13.2
19	100 15.7
20	115 18.1
21	130 20.6
22	145 23.1
23	160 25.5

Step 1: Determine the correct chronometer time of the sight.
Chronometer: 10h 47m 49s
Chronometer error: 1m 54s fast
Correct chronometer time: 10:47:49 – 00:01:54 = 10:45:55

Step 2: Determine the GMT of the sight.
Chronometer: 10h 45m 55s
1845 ZT DR Longitude: 66° 48.0' W corresponds to (+4 ZD)
GMT of sight: <u>22:45:55</u>

Step 3: Determine the GHA of Aries for the time of the sight.
GHA Aries (hours): 145° 23.1'
GHA Aries (increment): 11° 30.6'
GHA Aries (Total): 145° 23.1' + 11° 30.6' = 156° 53.7'

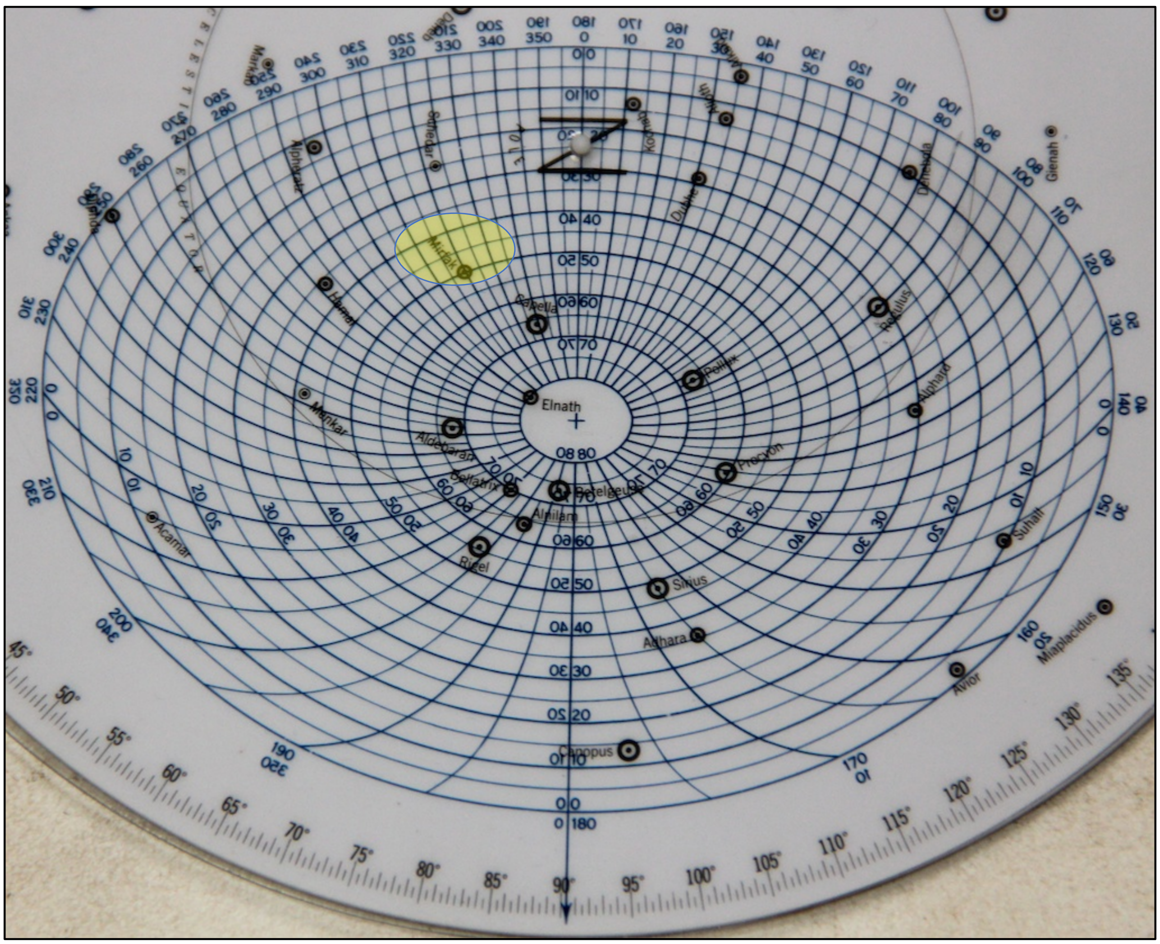
45m	SUN PLANETS	ARIES
55	11 28·8	11 30·6
56	11 29·0	11 30·9
57	11 29·3	11 31·1
58	11 29·5	11 31·4
59	11 29·8	11 31·6

Step 4: Determine the LHA of Aries for the time of the sight.
GHA Aries: 156° 53.7'
DR Longitude: 66° 48.0' W (W longitude subtract, E longitude add)
LHA Aries: 156° 53.7' – 66° 48.0' W = <u>90° 05.7'</u>

Step 5: Set up the Starfinder.
LHA Aries: 90° 05.7’
Observer’s Latitude (nearest incremental degree): 25° N

Step 6: Search the Starfinder field based on the given altitude and azimuth.
Observed altitude (ho): 50° 02.9’
Observed azimuth: 320° T

Step 7: Identify the observed body.
Mirfak is the closest body to the observed altitude and azimuth.



SID D2. On 23 September, while taking stars for an evening fix, an unidentified star is observed bearing 261° T at an observed altitude (ho) of 61° 35’. Your 1836 zone time DR position is latitude 25° 18’ S, longitude 162° 36’ E. The chronometer reads 07h 34m 12s, and the chronometer error is 1m 54s slow. Your vessel is steaming on a course of 230° T at a speed of 18 knots. What star did you observe?

Answer: Antares.

23	00	1 45.2
	01	16 47.6
	02	31 50.1
	03	46 52.6
	04	61 55.0
	05	76 57.5
	06	92 00.0
W	07	107 02.4
E	08	122 04.9
D	09	137 07.4
N	10	152 09.8
E	11	167 12.3
S	12	182 14.7
D	13	197 17.2
A	14	212 19.7
Y	15	227 22.1
	16	242 24.6
	17	257 27.1
	18	272 29.5
	19	287 32.0
	20	302 34.5
	21	317 36.9
	22	332 39.4
	23	347 41.9

Step 1: Determine the correct chronometer time of the sight.
Chronometer: 7h 34m 12s
Chronometer error: 1m 54s slow
Correct chronometer time: 07:34:12 + 00:01:54 = 07:36:06

Step 2: Determine the GMT of the sight.
Chronometer: 07h 36m 06s
1836 ZT DR Longitude: 162° 36.0’ E corresponds to (-11 ZD)
GMT of sight: 07:36:06

Step 3: Determine the GHA of Aries for the time of the sight.
GHA Aries (hours): 107° 02.4’
GHA Aries (increment): 9° 03.0’
GHA Aries (Total): 107° 02.4’ + 9° 03.0’ = 116° 05.4’

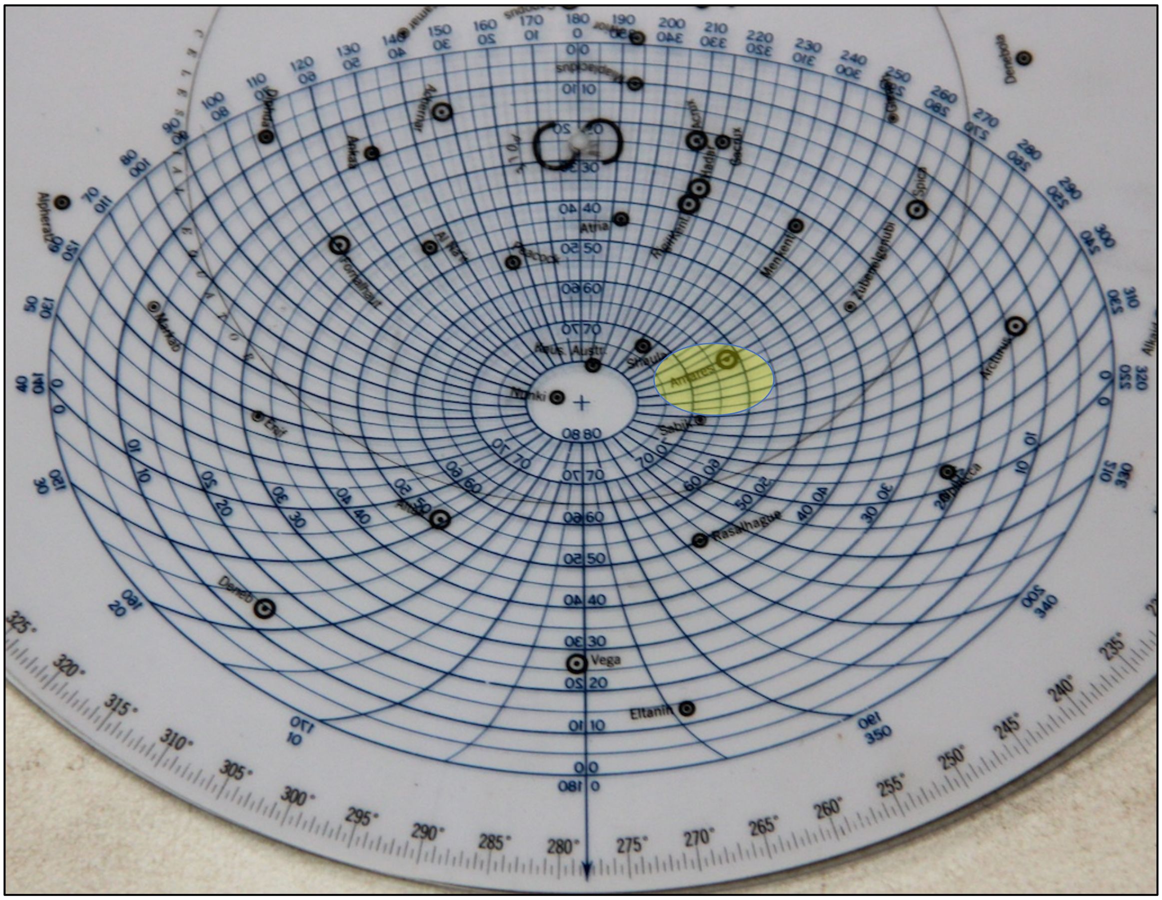
Step 4: Determine the LHA of Aries for the time of the sight.
GHA Aries: 116° 05.4’
DR Longitude: 162° 36.0’ E (E longitude add, W longitude subtract)
LHA Aries: 116° 05.4’ + 162° 36.0’ W = 278° 41.4’

36 m	SUN PLANETS	ARIES
s	° ′	° ′
00	9 00·0	9 01·5
01	9 00·3	9 01·7
02	9 00·5	9 02·0
03	9 00·8	9 02·2
04	9 01·0	9 02·5
05	9 01·3	9 02·7
06	9 01·5	9 03·0
07	9 01·8	9 03·2
08	9 02·0	9 03·5
09	9 02·3	9 03·7

Step 5: Set up the Starfinder.
LHA Aries: 278° 41.4’
Observer’s Latitude (nearest incremental degree): 25° S

Step 6: Search the Starfinder field based on the given altitude and azimuth.
Observed altitude (ho): 61° 35.0’
Observed azimuth: 261° T

Step 7: Identify the observed body.
Antares is the closest body to the observed altitude and azimuth.


Vega
Eltanin
Rasalhague
Nunki
Atria
Antares
Sabik
Deneb
Peacock
Menkent
Arcturus
Spica

SID D3. On 12 June 1981, your DR 1845 position is LAT 21° 47' N, LONG 46° 52'W when you observe a faint unidentifiable star through a break in the clouds. The star bears 313° T at a sextant altitude (Hs) of 14° 56.3'. The index error is 0.5' on the arc and the height of eye is 45 feet. The chronometer reads 09:43:27 and the chronometer error is 1m 46s slow. What star did you observe?

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G.M.T. (d h)	ARIES G.H.A. (° ')
12 00	260 13.9
01	275 16.4
02	290 18.8
03	305 21.3
04	320 23.8
05	335 26.2
06	350 28.7
07	5 31.1
08	20 33.6
F 09	35 36.1
R 10	50 38.5
I 11	65 41.0
D 12	80 43.5
A 13	95 45.9
Y 14	110 48.4
15	125 50.9
16	140 53.3
17	155 55.8
18	170 58.3
19	186 00.7
20	201 03.2
21	216 05.6
22	231 08.1
23	246 10.6

45m (s)	SUN PLANETS (° ')
00	11 15·0
01	11 15·3
02	11 15·5
03	11 15·8
04	11 16·0
05	11 16·3
06	11 16·5
07	11 16·8
08	11 17·0
09	11 17·3
10	11 17·5
11	11 17·8
12	11 18·0
13	11 18·3
14	11 18·5

Answer: Menkalinan (Minor Star)

Step 1: Determine the correct chronometer time of the sight.
Chronometer: 9h 43m 27s
Chronometer error: 1m 46s slow
Correct chronometer time: 09:45:13

Step 2: Determine the GMT of the sight.
1845 ZT DR Longitude: 46° 52'W corresponds to (+3 ZD)
GMT of sight: <u>21:45:13</u>

Step 3: Determine the GHA of Aries for the time of the sight.
GHA Aries (hours): 216° 05.6'
GHA Aries (increment): 11° 20.1'
GHA Aries (Total): 227° 25.7'

Step 4: Determine the LHA of Aries for the time of the sight.
GHA Aries: 227° 25.7'
DR Longitude: 46° 52'W (E longitude add, W longitude subtract)
LHA Aries: 180° 33.7'

Step 5: Set up the Starfinder.
LHA Aries: 180° 33.7'
Observer's Latitude (nearest incremental degree): 25° S

Step 6: Determine the Height Observed (Ho) by applying index error, height of eye and apparent altitude corrections.

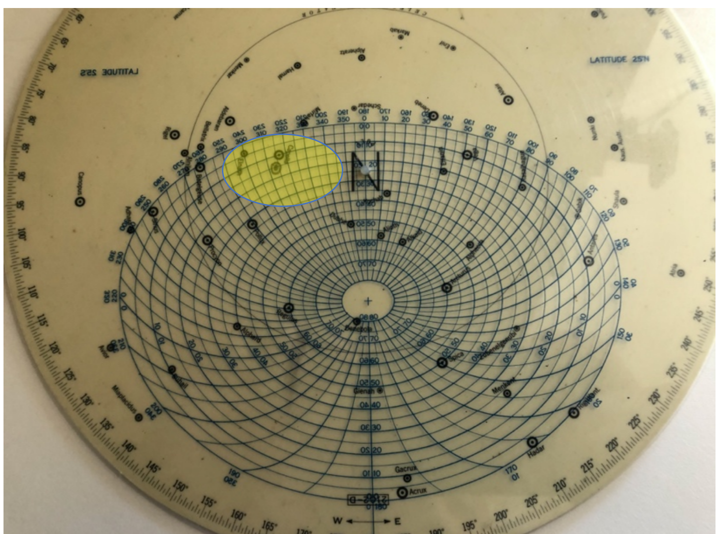
Hs = 14° 56.3'
IC = +0.5'
Dip = -6.5'
<u>Ha = 14° 50.3'</u>
Alt Corr = -3.6'
<u>Ho = 14° 46.7'</u>

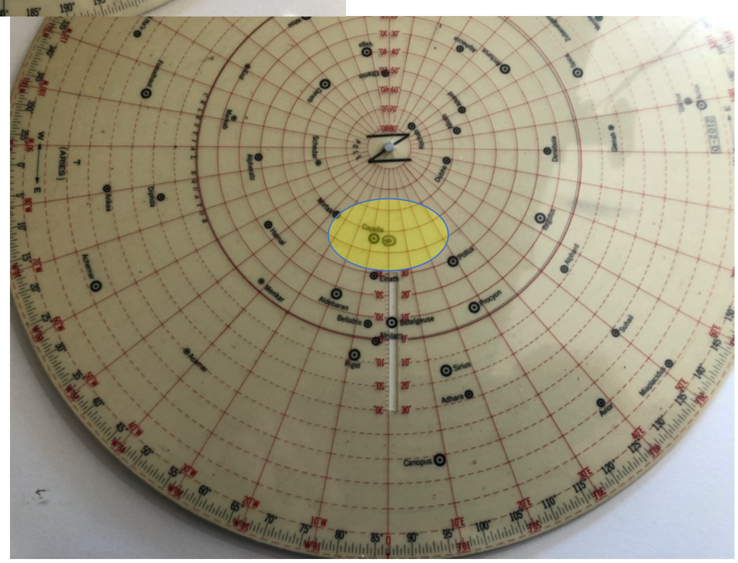
Step 7: Make a mark on the Starfinder plate at the appropriate Ho and Azimuth.
Observed altitude (ho): 14° 46.7’
Observed azimuth: 313° T

Step 8: Find the Right Ascension and Declination of the body.
Put the red template on the Starfinder.
Align 0° line with mark you made in Step 8.
RA is the outer number on the Starfinder = 87°
Declination is based on location on the red plate = 45° N

Step 9: Find the SHA.
SHA = 360-RA = 273°

Step 10: Look in the back of the Nautical Almanac for the best match (note more accuracy can be obtained by averaging the 25° and 15° plate, which is rarely necessary to answer the exam question).
B Auriga, or Menkalinan.





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Mag.	Name and Number		S.H.A.							Dec.						
				JAN.	FEB.	MAR.	APR.	MAY	JUNE		JAN.	FEB.	MAR.	APR.	MAY	JUNE
			°	′	′	′	′	′	′	°	′	′	′	′	′	′
1·6	α Geminorum		**246**	39·0	39·0	39·1	39·2	39·4	39·4	**N. 31**	55·7	55·8	55·8	55·9	55·9	55·8
3·3	σ Puppis		**247**	50·2	50·2	50·4	50·6	50·8	50·9	**S. 43**	15·9	16·0	16·1	16·1	16·1	16·0
3·1	β Canis Minoris		**248**	28·0	28·0	28·1	28·2	28·3	28·4	**N. 8**	19·6	19·6	19·5	19·6	19·6	19·6
2·4	η Canis Majoris		**249**	09·6	09·6	09·7	09·9	10·0	10·1	**S. 29**	16·1	16·2	16·3	16·3	16·2	16·1
2·7	π Puppis		**250**	52·6	52·6	52·8	53·0	53·1	53·2	**S. 37**	03·9	04·0	04·1	04·1	04·1	04·0
2·0	δ Canis Majoris		**253**	05·5	05·5	05·6	05·8	05·9	06·0	**S. 26**	21·9	22·0	22·1	22·1	22·0	21·9
3·1	ο Canis Majoris		**254**	26·3	26·3	26·4	26·6	26·7	26·8	**S. 23**	48·4	48·6	48·6	48·6	48·6	48·5
1·6	ε Canis Majoris	19	**255**	31·6	31·6	31·7	31·9	32·0	32·1	**S. 28**	56·9	57·0	57·1	57·1	57·0	56·9
2·8	τ Puppis		**257**	37·6	37·7	37·9	38·1	38·4	38·5	**S. 50**	35·7	35·8	35·9	35·9	35·8	35·7
−1·6	α Canis Majoris	18	**258**	55·2	55·2	55·3	55·5	55·6	55·6	**S. 16**	41·6	41·7	41·7	41·7	41·6	41·5
1·9	γ Geminorum		**260**	50·6	50·7	50·8	50·9	51·0	51·0	**N. 16**	24·9	24·9	24·9	24·9	24·9	24·9
−0·9	α Carinæ	17	**264**	06·6	06·7	06·9	07·2	07·4	07·5	**S. 52**	41·3	41·4	41·5	41·5	41·4	41·3
2·0	β Canis Majoris		**264**	31·9	31·9	32·0	32·2	32·3	32·3	**S. 17**	56·9	57·0	57·1	57·0	57·0	56·9
2·7	θ Aurigæ		**270**	23·4	23·5	23·7	23·8	23·9	23·9	**N. 37**	12·7	12·7	12·7	12·7	12·7	12·7
2·1	β Aurigæ		**270**	27·8	27·9	28·0	28·2	28·3	28·3	**N. 44**	56·8	56·8	56·9	56·8	56·8	56·7
Var.‡	α Orionis	16	**271**	27·7	27·8	27·9	28·0	28·1	28·1	**N. 7**	24·1	24·1	24·1	24·1	24·1	24·2
2·2	κ Orionis		**273**	17·0	17·1	17·2	17·4	17·4	17·4	**S. 9**	40·7	40·8	40·8	40·8	40·7	40·6
1·9	ζ Orionis		**275**	02·9	02·9	03·1	03·2	03·3	03·2	**S. 1**	57·3	57·3	57·3	57·3	57·3	57·2
2·8	α Columbæ		**275**	15·4	15·5	15·6	15·8	15·9	15·9	**S. 34**	05·3	05·4	05·4	05·4	05·3	05·1
3·0	ζ Tauri		**275**	52·2	52·3	52·4	52·6	52·6	52·6	**N. 21**	07·8	07·8	07·8	07·8	07·8	07·8

Star and Planet Identification Problems

Star Identification of Navigational Stars

SID B1. At 0520 zone time, on 17 March while taking stars for a morning fix, you observe an unidentified star bearing 050° T at an observed altitude (ho) of 45° 00.0'. Your DR position at the time of the sight is latitude 27° 23.0' N, longitude 39° 42.0' W. The chronometer time of the sight is 08h 22m 15s and the chronometer error is 1m 45s fast. Your vessel is steaming on a course of 300° T at a speed of 18 knots. What star did you observe?

a) Altair
b) Alkaid
c) Arcturus
d) Deneb - correct

SID B2. At 1845 zone time on 17 March, while taking stars for an evening fix, you observe an unidentified star bearing 200° T at an observed altitude of 53° 45.0'. Your DR position at the time of the sight is latitude 25° 10.0' N, longitude 66° 48.0' W. The chronometer time of the sight is 10h 47m 49s and the chronometer error is 1m 54s fast. Your vessel is steaming on a course of 290° at a speed of 18 knots. What star did you observe?

a) Altair
b) Mirfak
c) Pollux
d) Rigel - correct

SID B3. On 14 January your 0550 zone time DR position is latitude 25° 26.0' N, longitude 38° 16.0' W. You observe an unidentifiable star bearing 004.5° T, at an observed altitude (ho) of 40° 10.0'. The chronometer reads 08h 48m 51s and is 01m 22s slow. What star did you observe?

a) Gienah
b) Kochab - correct
c) Gacrux
d) Eltanin

SID B4. On 22 April, your 1852 zone time DR position is latitude 23° 54.5' N, longitude 117° 36.8' W. You observe an unidentifiable star bearing 259° T at an observed altitude (ho)of 41° 15.2'. The chronometer reads 02h 54m 53s and is 02m 51s fast. What star did you observe?

a) Diphda
b) Betelgeuse - correct
c) Gienah
d) Arcturus

Star Identification of Minor Stars

SID B5. On 12 June, your 1945 DR position is latitude 21° 47.0’ N, longitude 46° 52.0’ W when you observe a faint unidentifiable star through a break in the clouds. The star bears 130° T at a sextant altitude (hs) of 45° 21.2’ The index error is 0.5’ on the arc and the height of eye is 45 feet. The chronometer reads 10h 43m 27s and the chronometer error is 1m 46s slow. What star did you observe?

a) Theta Carinae
b) Epsilon Leonis
c) Beta Librae - correct
d) Zeta Puppis

SID B6. On 12 June, your 1845 DR position is latitude 21° 47.0’ N, longitude 46° 52.0’ W when you observe a faint unidentifiable star through a break in the clouds. The star bears 162° T at a sextant altitude (hs) of 28° 36.5’ The index error is 0.5’ on the arc and the height of eye is 45 feet. The chronometer reads 09h 43m 27s and the chronometer error is 1m 46s slow. What star did you observe?

a) Gamma Virginis
b) Iota Centauri - correct
c) Spica
d) Mimosa

SID B7. On 12 June, your 1845 DR position is latitude 21° 47.0’ N, longitude 46° 52.0’ W when you observe a faint unidentifiable star through a break in the clouds. The star bears 031° T at a sextant altitude (hs) of 70° 10.3’ The index error is 0.5’ on the arc and the height of eye is 45 feet. The chronometer reads 09h 43m 27s and the chronometer error is 1m 46s slow. What star did you observe?

a) Sheratan
b) Ruchbah
c) Mimosa
d) Cor Caroli - correct

Star Selection Problems

- When selecting stars for a fix, look for objects equally distributed throughout the sky in terms of azimuth, and at an elevation between about 20° - 60°. Remember that objects on opposite azimuths will yield similar lines of position.

- Planets and the Moon move at different rates across the background celestial sphere compared to planets. When solving problems involving planets or the moon using the Starfinder, the red RA/Dec template is necessary to plot the bodies on the white template.

SSL D1. On 28 February, your 1850 zone time DR position is latitude 27° 49.0' N, longitude 159° 24.0' W. Considering their magnitude, azimuth, and altitude, which group includes the three stars best suited for a fix at star time?

a) Rigel, Schedar, Regulus- correct
b) Sirius, Mirfak, Elnath
c) Hamal, Alkaid, Canopus
d) Bellatrix, Vega, Regulus

G.M.T.		ARIES G.H.A.
1	00	158 42.6
	01	173 45.1
	02	188 47.5
	03	203 50.0
	04	218 52.5
	05	233 54.9
	06	248 57.4
	07	263 59.9
	08	279 02.3
S	09	294 04.8
U	10	309 07.3
N	11	324 09.7
D	12	339 12.2
A	13	354 14.7
Y	14	9 17.1
	15	24 19.6
	16	39 22.0
	17	54 24.5
	18	69 27.0
	19	84 29.4
	20	99 31.9
	21	114 34.4
	22	129 36.8
	23	144 39.3

Step 1: Determine the approximate time of star time.
In this problem, no course or speed is given, so you may assume that star time is approximately 1850 ZT.

Step 2: Determine the GMT of the sight.
Chronometer: 1850 ZT
DR Longitude: 159° 24.0' W corresponds to (+11 ZD)
GMT of sight: 0550 GMT, 1 March

Step 3: Determine the GHA of Aries for the time of the sight.
GHA Aries (hours): 233° 54.9'
GHA Aries (increment): 12° 32.1'
GHA Aries (Total): 233° 54.9' + 12° 32.1' = 246° 27.0'

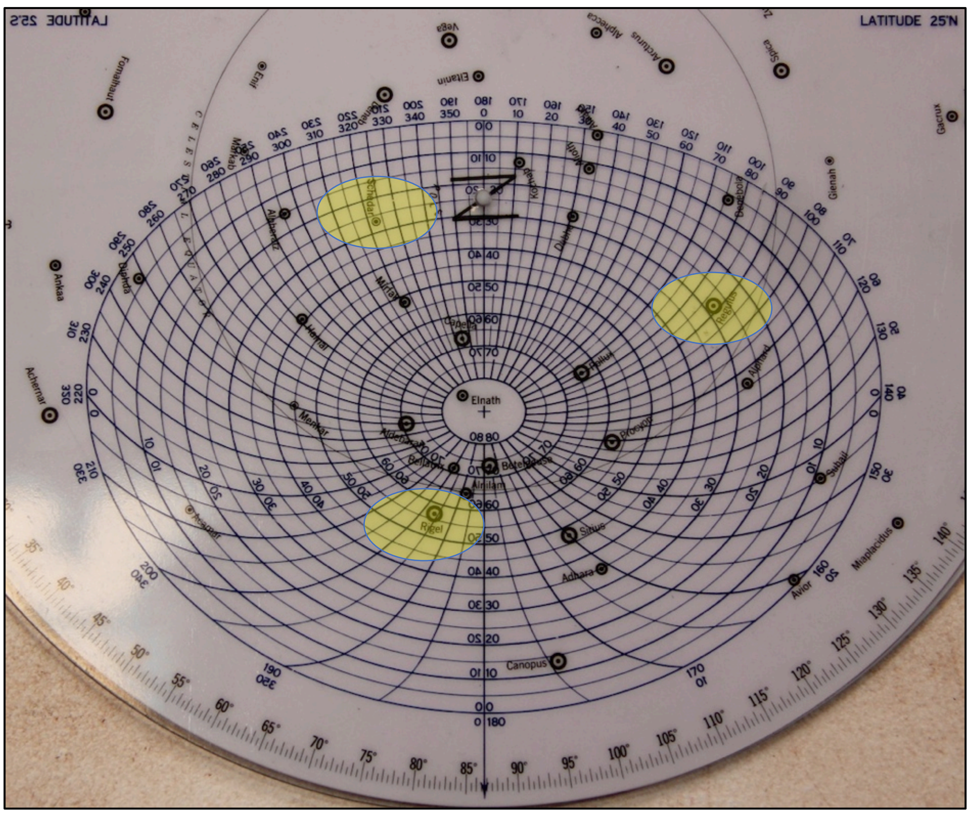
Step 4: Determine the LHA of Aries for the time of the sight.
GHA Aries: 246° 27.0'
DR Longitude: 159° 24.0' W (W longitude subtract, E longitude add)
LHA Aries: 246° 27.0' - 159° 24.0' W = 87° 03.0'

50m	SUN PLANETS	ARIES
s	° '	° '
00	12 30·0	12 32·1
01	12 30·3	12 32·3
02	12 30·5	12 32·6
03	12 30·8	12 32·8
04	12 31·0	12 33·1

Step 5: Set up the Starfinder.
LHA Aries: 87° 03.0’
Observer’s Latitude (nearest incremental degree): 25° N

Step 6: Examine the given stars on the Starfinder and make the best selection.

a. **<u>Rigel, Schedar, Regulus:</u> distributed at appropriate azimuths and altitudes.**
b. <u>Sirius, Mirfak, Elnath</u>: Elnath is too high in the sky, and Sirius/Mirfak are nearly exactly opposite in the sky.
c. <u>Hamal, Alkaid, Canopus</u>: Canopus is too low in the sky and Alkaid is on the horizon.
d. <u>Bellatrix, Vega, Regulus</u>: Bellatrix is too high in the sky and Vega is below the horizon.



SSL D2. On 23 March, your 1600 zone time DR position is latitude 27° 16.3’ N, longitude 156° 48.2’ W. You are on course 063° T at a speed of 18 knots. Considering their magnitude, azimuth, and altitude, which group includes the three best stars suited for a fix at star time?

a) Arcturus, Regulus, Sirius
b) Procyon, Sirius, Capella
c) <u>Hamal, Rigel, Alphard- correct</u>
d) Betelgeuse, Dubhe, Regulus

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

Step 1: Determine the approximate time of star time.
Based on the DR position, star time is close to 1900 for 23 March.

Step 2: Advance the ship’s DR position from 1600 to 1900 (for detailed explanation, see Part 5, Great Circles and Sailings Problems, or Part 9, Time of Phenomenon Problems).
1600 DR position: 27° 16.3’ N, 156° 48.2’ W
1900 DR position: 27° 40.8’ N, 155° 54.0’ W

24	00	181 22.8
	01	196 25.3
	02	211 27.7
	03	226 30.2
	04	241 32.7
	05	256 35.1
	06	271 37.6
	07	286 40.1
	08	301 42.5
T	09	316 45.0
U	10	331 47.5
E	11	346 49.9
S	12	1 52.4
D	13	16 54.8
A	14	31 57.3
Y	15	46 59.8
	16	62 02.2
	17	77 04.7
	18	92 07.2
	19	107 09.6
	20	122 12.1
	21	137 14.6
	22	152 17.0
	23	167 19.5

Step 3: Determine the GMT of the sight.
Chronometer: 1900 ZT
DR Longitude: 155° 54.0’ W corresponds to (+10 ZD)
GMT of sight: <u>0500 GMT, 24 March</u>

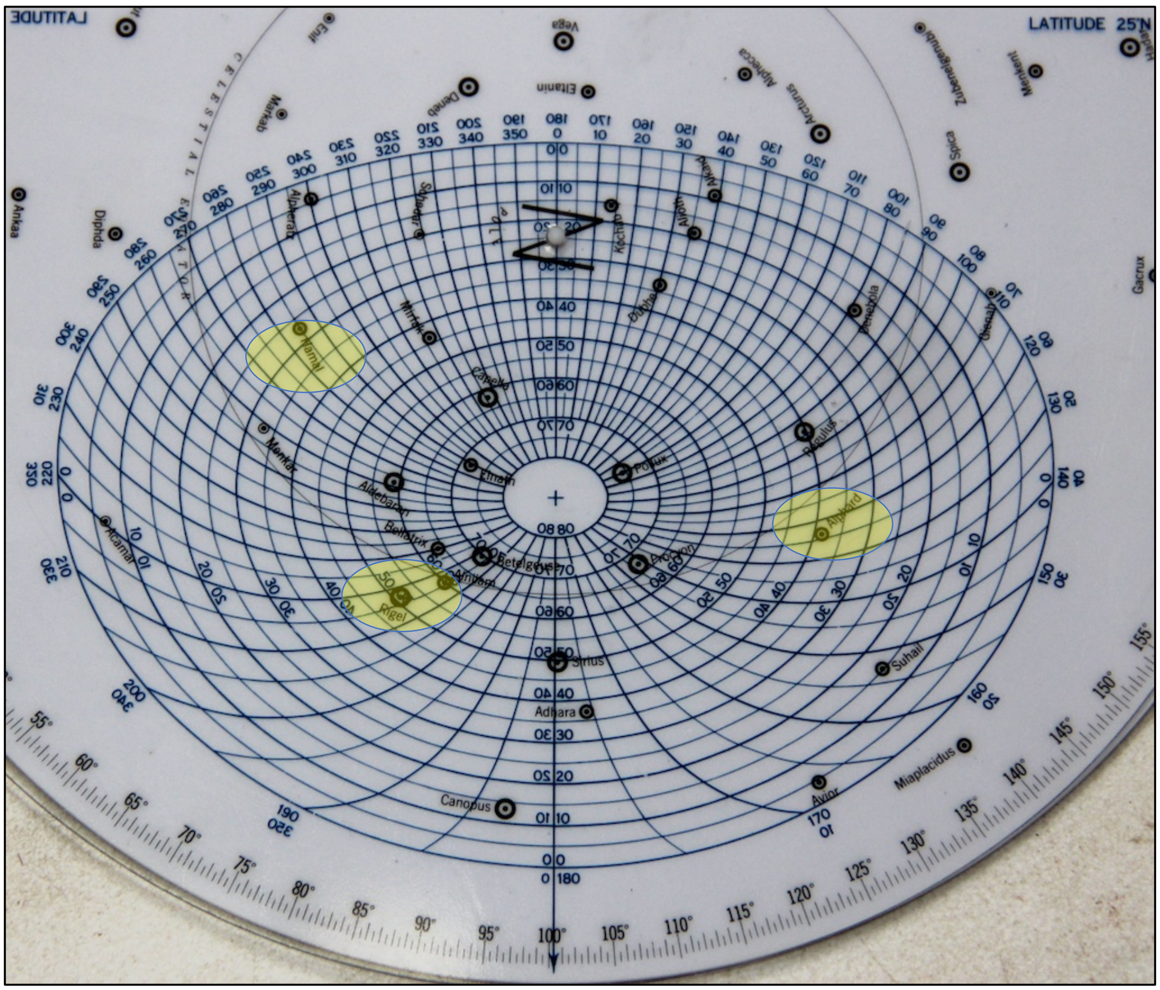
Step 4: Determine the GHA of Aries for the time of the sight.
GHA Aries (hours/total): 256° 35.1’

Step 5: Determine the LHA of Aries for the time of the sight.
GHA Aries: 256° 35.1’
DR Longitude: 155° 54.0’ W (W longitude subtract, E longitude add)
LHA Aries: 256° 35.1’ - 155° 54.0’ W = <u>100° 41.1’</u>

Step 6: Set up the Starfinder.
LHA Aries: 100° 41.1’
Observer’s Latitude (nearest incremental degree): 25° N

Step 7: Examine the given stars on the Starfinder and make the best selection.

a. <u>Arcturus, Regulus, Sirius:</u> Arcturus is below the horizon.
b. <u>Procyon, Sirius, Capella</u>: Capella and Procyon are nearly opposite.
c. <u>Hamal, Rigel, Alphard</u>: distributed at appropriate azimuths and altitudes.
d. <u>Betelgeuse, Dubhe, Regulus</u>: Betelgeuse is too high in the sky and nearly opposite Dubhe.



SSL D3. On 16 July, your 1920 zone time DR position is latitude 25° 36.0’ N, longitude 172° 18.9’ W. Considering their magnitude, azimuth, and altitude, which group includes the three bodies best suited for a fix at star time?

a) Rassalhague, Spica, Arcturus
b) Venus, Antares, Vega- correct
c) Vega, Mars, Antares
d) Saturn, Acrux, Spica

Step 1: Determine the approximate time of star time.
In this problem, no course or speed is given, so you may assume that star time is approximately 1920 ZT.

Step 2: Determine the GMT of the sight.
Chronometer: 1920 ZT
DR Longitude: 172° 18.9’ W corresponds to (+11 ZD)
GMT of sight: 0620 GMT, 17 July

Step 3: Determine the GHA of Aries for the time of the sight.
GHA Aries (hours): 24° 58.5’
GHA Aries (increment): 5° 00.8’
GHA Aries (Total): 24° 58.5’ + 5° 00.8’ = 29° 59.3’

20m	SUN PLANETS	ARIES
s	° '	° '
00	5 00·0	5 00·8
01	5 00·3	5 01·1
02	5 00·5	5 01·3
03	5 00·8	5 01·6
04	5 01·0	5 01·8

Step 4: Determine the LHA of Aries for the time of the sight.
GHA Aries: 29° 59.3’
DR Longitude: 172° 18.9’ W (W longitude subtract, E longitude add)
LHA Aries: 29° 59.3’ (+360°) - 172° 18.9’ W = 217° 40.4’

Step 5: Determine the SHA, Right Ascension and Declination of each planet listed.

Venus:
SHA = 217° 26.2’
RA = 360° - 217° 26.2’ = 142° 33.8’
Declination = N 15° 58.9’

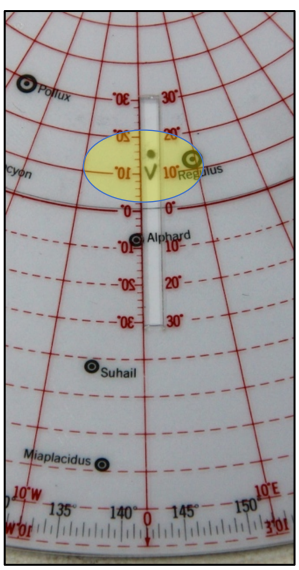
Mars:
SHA = 271° 45.4’
RA = 360 – 271° 45.4 = 88° 14.6’
Declination = N 23° 54.4’

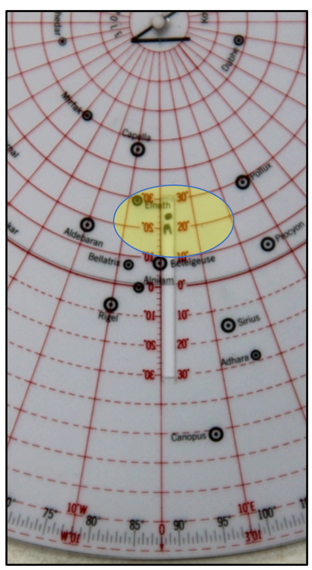
Saturn:
SHA = 175° 03.9’
RA = 360° - 175° 03.9 = 184° 56.1’
Declination = N 0° 23.2’

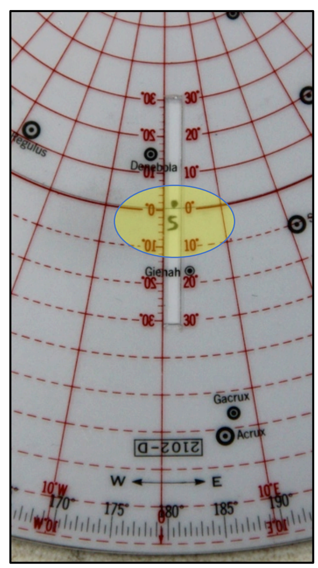
G.M.T.	ARIES	VENUS −3.3		MARS +1.7		JUPITER −1.5		SATURN +1.2	
d h	G.H.A. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	Dec. ° ′
17 00	294 43.8	150 58.3	N16 05.2	205 44.6	N23 54.2	110 36.8	S 0 25.8	109 44.1	N 0 23.7
01	309 46.2	165 57.8	04.2	220 45.3	54.3	125 39.0	25.9	124 46.4	23.6
02	324 48.7	180 57.3	03.2	235 45.9	54.3	140 41.2	26.0	139 48.8	23.5
03	339 51.1	195 56.8	· · 02.3	250 46.5	· · 54.3	155 43.3	· · 26.2	154 51.1	· · 23.4
04	354 53.6	210 56.2	01.3	265 47.1	54.4	170 45.5	26.3	169 53.4	23.4
05	9 56.1	225 55.7	16 00.3	280 47.7	54.4	185 47.7	26.5	184 55.7	23.3
06	24 58.5	240 55.2	N15 59.3	295 48.3	N23 54.4	200 49.8	S 0 26.6	199 58.0	N 0 23.2
07	40 01.0	255 54.7	58.3	310 48.9	54.5	215 52.0	26.7	215 00.3	23.1
08	55 03.5	270 54.2	57.3	325 49.5	54.5	230 54.2	26.9	230 02.7	23.1
F 09	70 05.9	285 53.7	· · 56.3	340 50.2	· · 54.6	245 56.3	· · 27.0	245 05.0	· · 23.0
R 10	85 08.4	300 53.2	55.3	355 50.8	54.6	260 58.5	27.1	260 07.3	22.9
I 11	100 10.9	315 52.7	54.3	10 51.4	54.6	276 00.7	27.3	275 09.6	22.8
D 12	115 13.3	330 52.2	N15 53.4	25 52.0	N23 54.7	291 02.8	S 0 27.4	290 11.9	N 0 22.8
A 13	130 15.8	345 51.7	52.4	40 52.6	54.7	306 05.0	27.6	305 14.2	22.7
Y 14	145 18.2	0 51.2	51.4	55 53.2	54.7	321 07.2	27.7	320 16.5	22.6
15	160 20.7	15 50.6	· · 50.4	70 53.8	· · 54.8	336 09.3	· · 27.8	335 18.9	· · 22.6
16	175 23.2	30 50.1	49.4	85 54.5	54.8	351 11.5	28.0	350 21.2	22.5
17	190 25.6	45 49.6	48.4	100 55.1	54.8	6 13.6	28.1	5 23.5	22.4
18	205 28.1	60 49.1	N15 47.4	115 55.7	N23 54.9	21 15.8	S 0 28.3	20 25.8	N 0 22.3
19	220 30.6	75 48.6	46.4	130 56.3	54.9	36 18.0	28.4	35 28.1	22.3
20	235 33.0	90 48.1	45.4	145 56.9	54.9	51 20.1	28.5	50 30.4	22.2
21	250 35.5	105 47.6	· · 44.4	160 57.5	· · 54.9	66 22.3	· · 28.7	65 32.7	· · 22.1
22	265 38.0	120 47.1	43.4	175 58.1	55.0	81 24.5	28.8	80 35.1	22.0
23	280 40.4	135 46.6	42.4	190 58.8	55.0	96 26.6	28.9	95 37.4	22.0
Mer. Pass.	h m 4 24.3	v −0.5	d 1.0	v 0.6	d 0.0	v 2.2	d 0.1	v 2.3	d 0.1

Mirfak	309 15.5	N49 47.5
Nunki	76 28.1	S26 19.2
Peacock	53 56.9	S56 47.6
Pollux	243 57.9	N28 04.3
Procyon	245 25.5	N 5 16.4
Rasalhague	96 28.8	N12 34.5
Regulus	208 09.7	N12 03.6
Rigel	281 35.7	S 8 13.4
Rigil Kent.	140 24.8	S60 45.6
Sabik	102 40.2	S15 42.1
Schedar	350 08.2	N56 25.8
Shaula	96 54.6	S37 05.4
Sirius	258 55.5	S16 41.4
Spica	158 56.9	S11 03.8
Suhail	223 10.8	S43 21.5
Vega	80 55.0	N38 46.1
Zuben'ubi	137 32.3	S15 57.9
	S.H.A. ° ′	Mer. Pass. h m
Venus	217 26.2	13 56
Mars	271 45.4	10 18
Jupiter	176 00.1	16 39
Saturn	175 03.9	16 42

Step 6: Plot the planets on the Starfinder using the planet disk.



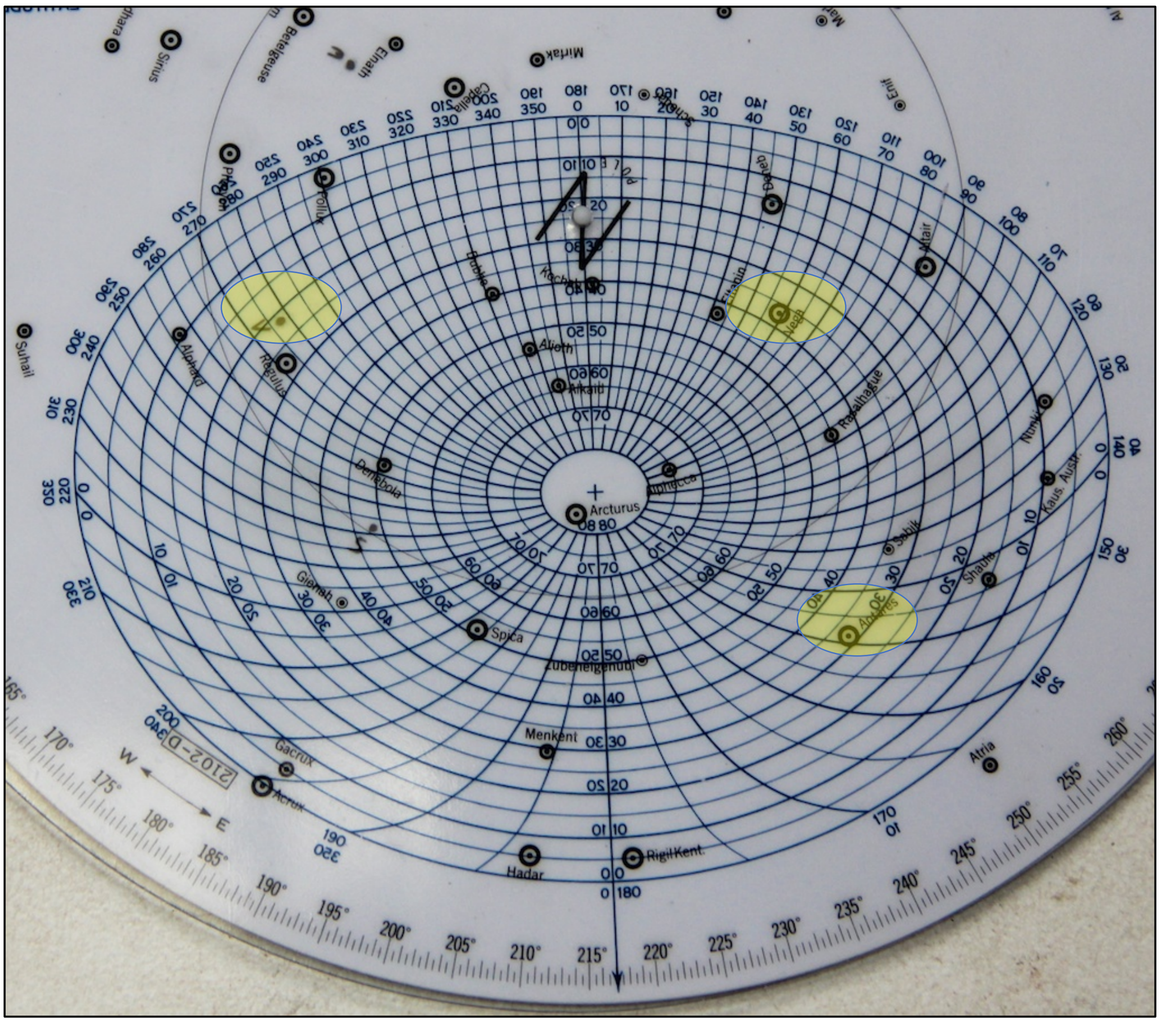




Step 7: Set up the Starfinder.
LHA Aries: 217° 40.4’
Observer’s latitude (nearest incremental degree): 25° N

Step 8: Use the Starfinder to make the best selection.

a. <u>Rassalhague, Spica, Arcturus</u>: Arcturus is too high in the sky.
b. <u>Venus, Antares, Vega</u>: distributed at appropriate altitudes and azimuths.
c. <u>Vega, Mars, Antares</u>: Mars is below the horizon.
d. <u>Saturn, Acrux, Spica</u>: Acrux is below the horizon.



Star Selection Problems

Star Selection Problems

SSL B1. On 20 June, your 1742 zone time DR position is latitude 24° 55.0' S, longitude 8° 19.6' E. Considering their magnitude, azimuth, and altitude, which three stars are best suited for a fix at star time?

a) **Regulus, Canopus, Antares - correct**
b) Spica, Arcturus, Alioth
c) Arcturus, Achernar, Pollux
d) Avoir, Sabik, Formalhaut

SSL B2. On 24 July your 1912 zone time DR position is latitude 24° 28.0' N, longitude 73° 46.5' W. Considering their magnitude, azimuth, and altitude, which group includes the three stars best suited for a fix at star time?

a) Fomalhaut, Rigel, Pollux
b) Arcturus, Acrux, Hadar
c) **Spica, Altair, Alioth - correct**
d) Vega, Deneb, Regulus

SSL B3. On 4 September, your 1813 zone time DR position is latitude 24° 18.0' S, longitude 95° 16' E. Considering their magnitude, azimuth, and altitude, which group includes the three stars best suited for a fix at star time?

a) Enif, Miaplacidus, Alkaid
b) Betelgeuse, Acrux, Hamal
c) **Rasalhague, Fomalhaut, Spica - correct**
d) Deneb, Altair, Vega

SSL B4. On 28 October, morning twilight will occur around 0524 ZT in position latitude 25° 25' N, longitude 32° 33.3' W. Which group will be the three best stars to observe for a star fix at star time?

a) Sirius, Hamal, Denebola
b) Sirius, Denebola, Dubhe
c) **Sirius, Capella, Denebola - correct**
d) Sirius, Mirfak, Hamal

Star Selection Problems with Planets/Moon

SSL B5. On 11 November, your 0200 zone time DR position is latitude 26° 32’ S, longitude 154° 16’ E. You are on course 058° T at a speed of 21 knots. Considering their magnitude, azimuth, and altitude, which group includes the three bodies best suited for a fix at star time?

a) Polaris, Regulus, Rigel
b) Jupiter, Spica, Canopus
c) Saturn, Peacock, Rigel
d) Mars, Betelgeuse, Miaplacidus - correct

SSL B6. On 17 July your 1951 zone time DR position is latitude 24° 26.0’ N, longitude 51° 16.0’ W. Considering their magnitude, azimuth, and altitude, which group includes the three bodies best suited for a fix at star time?

a) Hadar, Deneb, Alphard
b) Regulus, Venus, Antares
c) Mars, Vega, Dubhe
d) Kochab, Jupiter, Rasalhague - correct

SSL B7. On 2 February your 0400 zone time DR position is latitude 24° 14.0’ N, longitude 163° 28.0’ W. You are on course 322° T at a speed of 22 knots. Considering their magnitude, azimuth, and altitude, which group includes the three bodies best suited for a fix at star time?

a) Saturn, Antares, Rasalhague - correct
b) Jupiter, Saturn, Polaris
c) Saturn, Polaris, Zubenelgenubi
d) Jupiter, Spica, Denebola

SSL B8. On 29 April your 0300 zone time DR position is latitude 28° 39’ N, longitude 168° 03’ E. You are on course 108° T at a speed of 22 knots. Considering their magnitude, azimuth, and altitude, which group includes the three bodies best suited for a fix at star time?

a) Moon, Alpheratz, Polaris - correct
b) Deneb, Dubhe, Zubenelgenubi
c) Venus, Polaris, Arcturus
d) Moon, Altair, Sabik

Sight Reduction (Individual) Problems

- For more details on any portion of these sights, see the applicable sections such as mid-latitude sailings, sextant basics, or refer to Bowditch's glossary.
- Apparent Altitude Correction is also termed "Main Correction" in this text.

<u>Sextant Correction (Hs to Ho) Problems</u>

RED D1. On 4 July you observe the lower limb of the Sun at a sextant altitude (hs) of 25° 29.8'. The index error is 3.1' off the arc. The height of eye is 48 feet. What is the observed altitude (ho)?

Answer: 25° 40.2'.

Step 1: Determine the sextant altitude (hs).
hs = 25° 29.8' (Given)

Step 2: Determine the index correction (IC).
Index error: 3.1' off the arc.
Index correction: +3.1'

Step 3: Determine the dip correction.
Height of eye: 48 feet.
Dip correction: -6.7'

Step 4: Determine the apparent altitude (ha).
Apparent altitude (ha) = hs ± IC ± dip
ha = 25° 29.8' +3.1' – 6.7' = <u>25° 26.2'</u>

Step 5: Determine the main correction.
ha = 25° 26.2'
MC = +14.0'

Step 6: Determine the observed altitude (ho).
Observed altitude = ha ± MC
Observed altitude = 25° 26.2' + 14.0' = **25° 40.2'**

DIP

Ht. of Eye	Corrⁿ	Ht. of Eye	Ht. of Eye	Corrⁿ
13·8		45·5	85	— 8·9
	— 6·6			
14·2		46·9	90	— 9·2
	— 6·7			
14·7		48·4	95	— 9·5
	— 6·8			
15·1		49·8		

OCT.—MAR. SUN APR.—SEPT.

App. Alt.	Lower Limb	Upper Limb	App. Alt.	Lower Limb	Upper Limb
23 22			23 51		
	+14·1	— 18·2		+13·9	— 17·9
24 21			24 53		
	+14·2	— 18·1		+14·0	— 17·8
25 26			26 00		
	+14·3	— 18·0		+14·1	— 17·7
26 36			27 13		
	+14·4	17·9		+14·2	17·6

RED D2. During evening twilight on 28 December, a sextant altitude (hs) of the planet Venus was 29° 43.2’. The height of eye was 40 feet and the index error was 2.0’ on the arc. What was the observed altitude?

Answer: 29° 34.1’.

Step 1: Determine the sextant altitude (hs).
hs = 29° 43.2’ (Given)

Step 2: Determine the index correction (IC).
Index error: 2.0’ on the arc.
Index correction: -2.0’

Step 3: Determine the dip correction.
Height of eye: 40 feet.
Dip correction: -6.1’

Step 4: Determine the apparent altitude (ha).
Apparent altitude (ha) = hs ± IC ± dip
ha = 29° 43.2’ -2.0’ – 6.1’ = 29° 35.1’

Step 5: Determine the main correction.
ha = 29° 35.1’
MC (stars and planets): -1.7’
Additional Venus correction: +0.7’
MC =-1.7’ + 0.7’ = -1.0’

Step 6: Determine the observed altitude (ho).
Observed altitude = ha ± MC
Observed altitude = 29° 35.1’ - 1.0’ = **29° 34.1’**

DIP

Ht. of Eye	Corrn	Ht. of Eye	Ht. of Eye	Corrn
	-6.0		←	
11.8		38.9		
	-6.1			
12.2		40.1	ft.	′
	-6.2			
12.6		41.5	70	-8.1
	-6.3			
13.0		42.8	75	-8.4
	-6.4			

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

App. Alt.	Additional Corrn
1981 VENUS	
Jan. 1-Sept. 27	
0° 42	+ 0.1′
Sept. 28-Nov. 13	
0° 47	+ 0.2′
Nov. 14-Dec. 10	
0° 46	+ 0.3′
Dec. 11-Dec. 26	
0° 11 41	+ 0.4′ + 0.5
Dec. 27-Dec. 31	
0° 6 20 31	+ 0.5′ + 0.6 + 0.7
MARS	
Jan. 1-Dec. 31	
0° 60	+ 0.1′

RED D3. On 25 December you observe the Sun's lower limb. The sextant altitude (hs) is 4° 06.9'. The height of eye is 47 feet and the index error is 1.6' on the arc. The temperature is 19° F and the barometer reads 1030.8 millibars. What is the observed altitude?

Answer: 4° 01.9'.

Step 1: Determine the sextant altitude (hs).
hs = 4° 06.9' (Given)

Step 2: Determine the index correction (IC).
Index error: 1.6' on the arc.
Index correction: -1.6'

DIP		
Ht. of Eye	Corrⁿ	Ht. of Eye
	−6·5	
13·8		45·5
	−6·6	
14·2		46·9
	−6·7	
14·7		48·4
	−6·8	
15·1		49·8

Step 3: Determine the dip correction.
Height of eye: 47 feet.
Dip correction: -6.7'

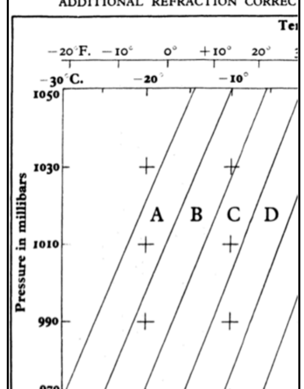
App. Alt.	OCT.–MAR. SUN Lower Limb	OCT.–MAR. SUN Upper Limb	APR.–SEPT. Lower Limb	APR.–SEPT. Upper Limb
° '	'	'	'	'
3 30	+ 3·3	− 29·0	+ 3·1	− 28·7
35	3·6	28·7	3·3	28·5
40	3·8	28·5	3·5	28·3
45	4·0	28·3	3·7	28·1
50	4·2	28·1	3·9	27·9
3 55	4·4	27·9	4·1	27·7
4 00	+ 4·5	− 27·8	+ 4·3	− 27·5
05	4·7	27·6	4·5	27·3
10	4·9	27·4	4·6	27·2
15	5·1	27·2	4·8	27·0
20	5·2	27·1	5·0	26·8
25	5·4	26·9	5·1	26·7

Step 4: Determine the apparent altitude (ha).
Apparent altitude (ha) = hs ± IC ± dip
ha = 4° 06.9' – 1.6' – 6.7' = 3° 58.6'

Step 5: Determine the main correction, using the altitude correction tables for altitudes less than 10°.
ha: 3° 58.6'
MC (Sun): + 4.5'

A4 ALTITUDE CORRECTION TA

ADDITIONAL REFRACTION CORREC



App. Alt.	A	B	C	D	E	F
° '	'	'	'	'	'	'
0 00	−6·9	−5·7	−4·6	−3·4	−2·3	−1·1
0 30	5·2	4·4	3·5	2·6	1·7	0·9
1 00	4·3	3·5	2·8	2·1	1·4	0·7
1 30	3·5	2·9	2·4	1·8	1·2	0·6
2 00	3·0	2·5	2·0	1·5	1·0	0·5
2 30	−2·5	−2·1	−1·6	−1·2	−0·8	−0·4
3 00	2·2	1·8	1·5	1·1	0·7	0·4
3 30	2·0	1·6	1·3	1·0	0·7	0·3
4 00	1·8	1·5	1·2	0·9	0·6	0·3
4 30	1·6	1·4	1·1	0·8	0·5	0·3

Step 6: Determine the additional correction for non-standard conditions.
Temperature: 19° F
Barometer: 1030.8mb
Additional correction category: C
Apparent altitude : 3° 58.6'
Additional correction: -1.2'

Step 7: Determine the observed altitude (ho).
Observed altitude = ha ± MC ± Additional Correction
Observed altitude = 3° 58.6' + 4.5' – 1.2' = **4° 01.9'**

RED D4. In the Bay of Fundy, during twilight, you take a sight of Mars. The sextant altitude (hs) is 3° 35.5’. Your height of eye is 32 feet and there is no index error. The air temperature is -10° C and the barometer reads 1010 millibars. What is the observed altitude (ho)?

Answer: 03° 15.7’.

Step 1: Determine the sextant altitude (hs).
hs = 3° 35.5’ (Given)

Step 2: Determine the index correction (IC).
Index error: none
Index correction: 0.0’

Step 3: Determine the dip correction.
Height of eye: 32 feet.
Dip correction: - 5.5’

DIP		
Ht. of Eye	Corrn	Ht. of Eye
9·5	−5·4	31·5
9·9	−5·5	32·7
10·3	5·6	33·9
	−5·7	

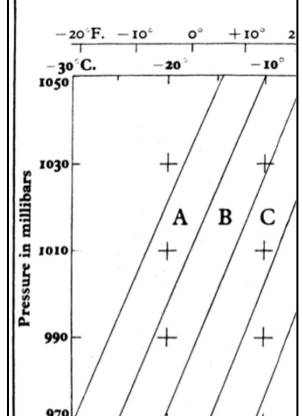
Step 4: Determine the apparent altitude (ha).
Apparent altitude (ha) = hs ± IC ± dip
ha = 3° 35.5’ – 0.0’ – 5.5’ = 3° 30.0’

Step 5: Determine the main correction, using the altitude correction tables for planet altitudes less than 10°.
ha: 3° 30.0’
MC (Planets): - 13.0’

App. Alt.	SUN Oct.–Mar. Lower Limb	SUN Oct.–Mar. Upper Limb	SUN Apr.–Sept. Lower Limb	SUN Apr.–Sept. Upper Limb	STARS PLANETS
° ′	′	′	′	′	′
3 30	+ 3·3	−29·0	+ 3·1	−28·7	−13·0
35	3·6	28·7	3·3	28·5	12·7
40	3·8	28·5	3·5	28·3	12·5
45	4·0	28·3	3·7	28·1	12·3
50	4·2	28·1	3·9	27·9	12·1
3 55	4·4	27·9	4·1	27·7	11·9

Step 6: Determine the additional correction for non-standard conditions.
Temperature: 10° C
Barometer: 1010mb
Additional correction category: C
Apparent altitude: 3° 30.0’
Additional correction: -1.3’

A4 ALTITUDE CORRECTION
ADDITIONAL REFRACTION C



App. Alt.	A	B	C	D	E
° ′	′	′	′	′	′
0 00	−6·9	−5·7	−4·6	−3·4	−2·3
0 30	5·2	4·4	3·5	2·6	1·7
1 00	4·3	3·5	2·8	2·1	1·4
1 30	3·5	2·9	2·4	1·8	1·2
2 00	3·0	2·5	2·0	1·5	1·0
2 30	−2·5	−2·1	−1·6	−1·2	−0·8
3 00	2·2	1·8	1·5	1·1	0·7
3 30	2·0	1·6	1·3	1·0	0·7
4 00	1·8	1·5	1·2	0·9	0·6
4 30	1·6	1·4	1·1	0·8	0·5

Step 7: Determine the observed altitude (ho).
Observed altitude = ha ± MC ± Additional Correction
Observed altitude = 3° 30.0’ – 13.0’ – 1.3’ = **3° 15.7’**

<u>Sight Reduction of the Sun Problems</u>

RED D5. On 10 January at 0550 zone time, morning stars were observed, and the vessels position was determined to be latitude 25° 16' N, longitude 123° 18' W. Your vessel is steaming at 22 knots on a course of 295° T. A sextant observation of the Sun's lower limb is made at 0915 zone time. The chronometer reads 05h 14m 02s and the sextant altitude is 24° 00.7'. The index error is 2.6' off the arc, and the chronometer error is 01m 34s slow. Your height of eye on the bridge is 55 feet. What is the azimuth (zn) and computed altitude (hc) of this sight?

Answer: zn = 131.4° T, hc = 23° 14.4'.

Step 1: Determine the DR position of the ship for the time of the sight by mid-latitude sailing.

a. Perform preliminary calculations.
0550 fix position: 25° 16' N, 123° 18' W
Course/Speed: 295° T, 22 knots
Morning Sun sight: 0915
0550 to 0915 = 3 hours 25 minutes = 3.42 hours
3.42 hours at 22 knots = D = 75.24 miles covered.

b. Determine the difference in latitude (*l*).
$l = D \cos C$
$l = (75.24) \cos (295°)$
$l = (75.24)(0.4226)$
$l = 31.796$ = 0.5299°

c. Determine the mid-latitude (*Lm*) and the 0915 DR latitude position.
Latitude 1 = 25° 16' N = 25.266° N
l = 31.796' = 0.5299° (to the north)
Latitude 2 = 25.266° N + 0.5299° = 25.796° N = <u>25° 47.8' N</u>
$Lm = \frac{25.266° + 25.796°}{2}$ = 25.531° N

d. Determine the departure (*p*).
$p = D \sin C$
$p = (75.24) \sin 295°$
$p = (75.24)(-0.9063)$
$p = -68.190$

e. Determine the difference in longitude (*DLo*) and the 0915 DR longitude position.

$DLo = \frac{p}{\cos Lm}$

$DLo = \frac{-68.190}{\cos(25.531)}$

$DLo = \frac{-68.190}{0.9024}$

$DLo = -75.57$’ = 1.260° (to the west)

Longitude 1 = 123° 18’ W = 123.300° W

Longitude 2 = 123.300° W + 1.260° = 124.560° W = 124° 33.6’ W

0915 DR position: 25° 47.8’ N, 124° 33.6’ W

Step 2: Determine the GMT of the sight.
Chronometer time: 05h 14m 02s
Chronometer error: 01m 34s slow
Correct chronometer time: 05h 15m 36s
Ship time of sight: 0915 zone time
DR Longitude: 124° 33.6’ W corresponds to (+8 ZD).
GMT of sight: 17:15:36, 10 January

Step 3: Given the sextant altitude (hs), index error and height of eye, determine the apparent altitude (ha).
hs: 24° 00.7’ (Given)
Index error (Index correction): 2.6’ off the arc (+2.6’ correction)
Height of eye (dip correction): 55 feet (-7.2’ correction)
Apparent altitude (ha): 24° 00.7’ + 2.6’ – 7.2’ = 23° 56.1’

Step 4: Determine the observed altitude.
Apparent altitude (ha): 23° 56.1’
Main correction: +14.1’
Observed altitude (ho): 23° 56.1’ + 14.1’ = 24° 10.2’

Step 5: Determine the declination of the Sun for the time of sight.
Declination (hours): S 21° 53.6’ (d number = 0.4’)
Declination (increments): -0.1’
Declination (total): S 21° 53.6’ – 0.1’ = S 21° 53.5’

Step 6: Determine the GHA of the Sun for the time of sight.
GHA (hours): 73° 04.5’
GHA (increment): 3° 54.0’
GHA (total): 73° 04.5’ + 3° 54.0’ = 76° 58.5’

15^m	SUN PLANETS	ARIES	MOON	v or d	Corr^n
32	3 53·0	3 53·6	3 42·4	3·2	0·8
33	3 53·3	3 53·9	3 42·6	3·3	0·9
34	3 53·5	3 54·1	3 42·9	3·4	0·9
35	3 53·8	3 54·4	3 43·1	3·5	0·9
36	3 54·0	3 54·6	3 43·3	3·6	0·9
37	3 54·3	3 54·9	3 43·6	3·7	1·0
38	3 54·5	3 55·1	3 43·8	3·8	1·0
39	3 54·8	3 55·4	3 44·1	3·9	1·0
40	3 55·0	3 55·6	3 44·3	4·0	1·0

G.M.T.		SUN G.H.A.		SUN Dec.	
d	h	°	′	°	′
10	00	178	08.8	S21	59.9
	01	193	08.5		59.6
	02	208	08.3		59.2
	03	223	08.0	· ·	58.8
	04	238	07.8		58.5
	05	253	07.5		58.1
	06	268	07.2	S21	57.7
	07	283	07.0		57.4
S	08	298	06.7		57.0
A	09	313	06.5	· ·	56.6
T	10	328	06.2		56.2
U	11	343	06.0		55.9
R	12	358	05.7	S21	55.5
D	13	13	05.5		55.1
A	14	28	05.2		54.7
Y	15	43	05.0	· ·	54.4
	16	58	04.7		54.0
	17	73	04.5		53.6
	18	88	04.2	S21	53.2
	19	103	04.0		52.8
	20	118	03.7		52.4
	21	133	03.5	· ·	52.1
	22	148	03.2		51.7
	23	163	03.0		51.3
		S.D.	16.3	d	0.4

Step 7: Determine the assumed position (AP) of the ship.
DR latitude based on nearest whole latitude: 26° N
DR long chosen such that GHA – long. is a whole value: 124° 58.5' W

Step 8: Determine the LHA of the Sun for the time of sight and AP.
GHA (Sun): 76° 58.5'
DR Longitude: 124° 58.5' W
LHA = 76° 58.5' (+360°) – 124° 58.5' = 312° (subtract west, add east).

Step 9: Entering publication HO229 with assumed latitude, declination, and LHA, retrieve the computed altitude (hc), altitude difference (d), and azimuth (z) for the assumed position.
Assumed latitude: 26° N
Declination: S 21°
LHA: 312° (Contrary Pages)

HO 229 values:

Computed altitude (hc): 23° 51.1'
Altitude difference (d): -41.1'
Azimuth (z): 130.7°

LATITUDE CONTRARY NAME TO DECLINATION — L.H.A. 48°, 312°

Dec.	23° Hc	23° d	23° Z	24° Hc	24° d	24° Z	25° Hc	25° d	25° Z	26° Hc	26° d	26° Z
°	° '	'	°	° '	'	°	° '	'	°	° '	'	°
0	38 01.2	−30.1	109.4	37 40.9	−31.1	110.1	37 19.9	−32.1	110.8	36 58.3	−33.2	111.5
1	37 31.1	−30.6	110.5	37 09.8	−31.7	111.2	36 47.8	−32.8	111.9	36 25.1	−33.8	112.6
2	37 00.5	−31.3	111.6	36 38.1	−32.3	112.3	36 15.0	−33.2	112.9	35 51.3	−34.2	113.6
3	36 29.2	−31.8	112.6	36 05.8	−32.8	113.3	35 41.8	−33.8	114.0	35 17.1	−34.7	114.6
4	35 57.4	−32.3	113.7	35 33.0	−33.3	114.3	35 08.0	−34.3	115.0	34 42.4	−35.3	115.6
5	35 25.1	−32.9	114.7	34 59.7	−33.8	115.4	34 33.7	−34.7	116.0	34 07.1	−35.6	116.6
6	34 52.2	−33.4	115.7	34 25.9	−34.3	116.4	33 59.0	−35.3	117.0	33 31.5	−36.2	117.6
7	34 18.8	−33.8	116.7	33 51.6	−34.8	117.3	33 23.7	−35.7	117.9	32 55.3	−36.5	118.5
8	33 45.0	−34.4	117.7	33 16.8	−35.3	118.3	32 48.0	−36.1	118.9	32 18.8	−37.0	119.5
9	33 10.6	−34.8	118.7	32 41.5	−35.6	119.3	32 11.9	−36.5	119.8	31 41.8	−37.3	120.4
10	32 35.8	−35.2	119.7	32 05.9	−36.1	120.2	31 35.4	−36.9	120.8	31 04.5	−37.8	121.3
11	32 00.6	−35.7	120.7	31 29.8	−36.5	121.2	30 58.5	−37.3	121.7	30 26.7	−38.1	122.2
12	31 24.9	−36.0	121.6	30 53.3	−36.9	122.1	30 21.2	−37.7	122.6	29 48.6	−38.5	123.1
13	30 48.9	−36.5	122.5	30 16.4	−37.3	123.0	29 43.5	−38.1	123.5	29 10.1	−38.8	124.0
14	30 12.4	−36.9	123.5	29 39.1	−37.6	123.9	29 05.4	−38.4	124.4	28 31.3	−39.1	124.8
15	29 35.5	−37.2	124.4	29 01.5	−38.0	124.8	28 27.0	−38.7	125.3	27 52.2	−39.5	125.7
16	28 58.3	−37.6	125.3	28 23.5	−38.4	125.7	27 48.3	−39.1	126.1	27 12.7	−39.8	126.6
17	28 20.7	−37.9	126.1	27 45.1	−38.6	126.6	27 09.2	−39.3	127.0	26 32.9	−40.0	127.4
18	27 42.8	−38.2	127.0	27 06.5	−39.0	127.4	26 29.9	−39.7	127.8	25 52.9	−40.3	128.2
19	27 04.6	−38.6	127.9	26 27.5	−39.2	128.3	25 50.2	−39.9	128.7	25 12.6	−40.6	129.0
20	26 26.0	−38.9	128.8	25 48.3	−39.6	129.1	25 10.3	−40.3	129.5	24 32.0	−40.9	129.9
21	25 47.1	−39.1	129.6	25 08.7	−39.8	130.0	24 30.0	−40.4	130.3	23 51.1	−41.1	130.7
22	25 08.0	−39.5	130.4	24 28.9	−40.1	130.8	23 49.6	−40.8	131.1	23 10.0	−41.4	131.5
23	24 28.5	−39.7	131.3	23 48.8	−40.3	131.6	23 08.8	−40.9	131.9	22 28.6	−41.5	132.2
24	23 48.8	−40.0	132.1	23 08.5	−40.6	132.4	22 27.9	−41.2	132.7	21 47.1	−41.8	133.0

27° Hc	27° d	27° Z	28° Hc	28° d	28° Z	29° Hc	29° d	29° Z	30° Hc	30° d	30° Z	Dec.
° '	'	°	° '	'	°	° '	'	°	° '	'	°	°
36 35.9	−34.2	112.2	36 12.9	−35.2	112.9	35 49.2	−36.1	113.6	35 24.9	−37.1	114.2	0
36 01.7	−34.7	113.3	35 37.7	−35.7	113.9	35 13.1	−36.6	114.6	34 47.8	−37.5	115.2	1
35 27.0	−35.2	114.3	35 02.0	−36.1	114.9	34 36.5	−37.1	115.5	34 10.3	−37.9	116.1	2
34 51.8	−35.7	115.2	34 25.9	−36.6	115.9	33 59.4	−37.4	116.5	33 32.4	−38.3	117.1	3
34 16.1	−36.1	116.2	33 49.3	−37.0	116.8	33 22.0	−37.9	117.4	32 54.1	−38.7	118.0	4
33 40.0	−36.6	117.2	33 12.3	−37.4	117.8	32 44.1	−38.3	118.3	32 15.4	−39.2	118.9	5
33 03.4	−37.0	118.1	32 34.9	−37.9	118.7	32 05.8	−38.7	119.3	31 36.2	−39.4	119.8	6
32 26.4	−37.4	119.1	31 57.0	−38.2	119.6	31 27.1	−39.0	120.2	30 56.8	−39.9	120.7	7
31 49.0	−37.8	120.0	31 18.8	−38.6	120.5	30 48.1	−39.4	121.0	30 16.9	−40.1	121.5	8
31 11.2	−38.1	120.9	30 40.2	−39.0	121.4	30 08.7	−39.8	121.9	29 36.8	−40.5	122.4	9
30 33.1	−38.6	121.8	30 01.2	−39.3	122.3	29 28.9	−40.0	122.8	28 56.3	−40.9	123.3	10
29 54.5	−38.9	122.7	29 21.9	−39.6	123.2	28 48.9	−40.4	123.6	28 15.4	−41.1	124.1	11
29 15.6	−39.2	123.6	28 42.3	−40.0	124.0	28 08.5	−40.7	124.5	27 34.3	−41.4	124.9	12
28 36.4	−39.6	124.4	28 02.3	−40.3	124.9	27 27.8	−41.0	125.3	26 52.9	−41.7	125.7	13
27 56.8	−39.8	125.3	27 22.0	−40.6	125.7	26 46.8	−41.3	126.1	26 11.2	−41.9	126.5	14
27 17.0	−40.2	126.1	26 41.4	−40.8	126.5	26 05.5	−41.5	126.9	25 29.3	−42.2	127.3	15
26 36.8	−40.5	127.0	26 00.6	−41.2	127.4	25 24.0	−41.8	127.7	24 47.1	−42.4	128.1	16
25 56.3	−40.7	127.8	25 19.4	−41.4	128.2	24 42.2	−42.0	128.5	24 04.7	−42.7	128.9	17
25 15.6	−41.0	128.6	24 38.0	−41.6	129.0	24 00.2	−42.3	129.3	23 22.0	−42.9	129.7	18
24 34.6	−41.2	129.4	23 56.4	−41.9	129.8	23 17.9	−42.5	130.1	22 39.1	−43.1	130.4	19
23 53.4	−41.5	130.2	23 14.5	−42.1	130.5	22 35.4	−42.7	130.9	21 56.0	−43.3	131.2	20
23 11.9	−41.8	131.0	22 32.4	−42.4	131.3	21 52.7	−43.0	131.6	21 12.7	−43.5	131.9	21
22 30.1	−41.9	131.8	21 50.0	−42.5	132.1	21 09.7	−43.1	132.4	20 29.2	−43.7	132.6	22
21 48.2	−42.2	132.5	21 07.5	−42.7	132.8	20 26.6	−43.3	133.1	19 45.5	−43.9	133.4	23
21 06.0	−42.4	133.3	20 24.8	−43.0	133.6	19 43.3	−43.5	133.8	19 01.6	−44.0	134.1	24

Step 10: Determine the azimuth correction for the sight (to account for increments of declination ignored in step 9).

	Base Value	Base Z	Next incremental Z	Difference in Z	Increment	Correction *(Diff Z x Increment) / 60*
Latitude – N	26°	130.7°	-	-	00.0’	0
Declination - S	21°	130.7°	131.5°	0.8’	53.5’	0.71°
LHA	312°	130.7°	-	-	00.0’	0

Total correction = 0.7°

Step 11: Apply the correction to the base values to determine true azimuth.
Base azimuth: 130.7°
Correction: +0.7°
Corrected azimuth: 130.7° + 0.7° = **131.4°**
Note - Check azimuth rules: if LHA greater than 180°, then zn = z.

Step 12: Determine the computed altitude.
Tabular computed altitude (Hc): 23° 51.1’
Altitude difference (d): -41.1
Declination: S 21° 53.5’
Declination increments: 53.5’

Altitude difference correction:
Tens: 35.7’
Units/decimals: 1.0’
Total correction: 35.7’+1.0’ = 36.7’

Dec. Inc.	Altitude Difference (d) Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
52.0	8.6	17.3	26.0	34.6	43.3	**.0**	0.0	0.9	1.7	2.6	3.5	4.4	5.2	6.1	7.0	7.9
52.1	8.7	17.3	26.0	34.7	43.4	**.1**	0.1	1.0	1.8	2.7	3.6	4.5	5.3	6.2	7.1	8.0
52.2	8.7	17.4	26.1	34.8	43.5	**.2**	0.2	1.0	1.9	2.8	3.7	4.5	5.4	6.3	7.2	8.0
52.3	8.7	17.4	26.1	34.9	43.6	**.3**	0.3	1.1	2.0	2.9	3.8	4.6	5.5	6.4	7.3	8.1
52.4	8.7	17.5	26.2	34.9	43.7	**.4**	0.3	1.2	2.1	3.0	3.8	4.7	5.6	6.5	7.3	8.2
52.5	8.8	17.5	26.3	35.0	43.8	**.5**	0.4	1.3	2.2	3.1	3.9	4.8	5.7	6.6	7.4	8.3
52.6	8.8	17.5	26.3	35.1	43.8	**.6**	0.5	1.4	2.3	3.1	4.0	4.9	5.8	6.6	7.5	8.4
52.7	8.8	17.6	26.4	35.2	43.9	**.7**	0.6	1.5	2.4	3.2	4.1	5.0	5.9	6.7	7.6	8.5
52.8	8.8	17.6	26.4	35.2	44.0	**.8**	0.7	1.6	2.4	3.3	4.2	5.1	5.9	6.8	7.7	8.6
52.9	8.9	17.7	26.5	35.3	44.1	**.9**	0.8	1.7	2.5	3.4	4.3	5.2	6.0	6.9	7.8	8.7
53.0	8.8	17.6	26.5	35.3	44.1	**.0**	0.0	0.9	1.8	2.7	3.6	4.5	5.3	6.2	7.1	8.0
53.1	8.8	17.7	26.5	35.4	44.2	**.1**	0.1	1.0	1.9	2.8	3.7	4.5	5.4	6.3	7.2	8.1
53.2	8.8	17.7	26.6	35.4	44.3	**.2**	0.2	1.1	2.0	2.9	3.7	4.6	5.5	6.4	7.3	8.2
53.3	8.9	17.8	26.6	35.5	44.4	**.3**	0.3	1.2	2.1	2.9	3.8	4.7	5.6	6.5	7.4	8.3
53.4	8.9	17.8	26.7	35.6	44.5	**.4**	0.4	1.2	2.1	3.0	3.9	4.8	5.7	6.6	7.5	8.4
53.5	8.9	17.8	26.8	35.7	44.6	**.5**	0.4	1.3	2.2	3.1	4.0	4.9	5.8	6.7	7.6	8.5
53.6	8.9	17.9	26.8	35.7	44.7	**.6**	0.5	1.4	2.3	3.2	4.1	5.0	5.9	6.8	7.7	8.6
53.7	9.0	17.9	26.9	35.8	44.8	**.7**	0.6	1.5	2.4	3.3	4.2	5.1	6.0	6.9	7.8	8.6
53.8	9.0	18.0	26.9	35.9	44.9	**.8**	0.7	1.6	2.5	3.4	4.3	5.2	6.1	7.0	7.8	8.7
53.9	9.0	18.0	27.0	36.0	45.0	**.9**	0.8	1.7	2.6	3.5	4.4	5.3	6.2	7.0	7.9	8.8

Note this step can be completed without the interpolation table by using the formula:

$$Correction = (Altitude\ Difference\ (d))\frac{Declination\ Increment}{60}$$

Tabular Hc: 23° 51.1’
Alt correction: -36.7’
hc: 23° 51.1’ – 36.7’ = **23° 14.4’**

S. Lat. { L.H.A. greater than 180° ....Zn=180°–Z
L.H.A. less than 180°............Zn=180°+Z }

Sight Reduction of the Moon Problems

RED D6. On 25 February at 0622 zone time, you observe the upper limb of the Moon with a sextant altitude of 59° 58.6’. Your DR position is latitude 30° 28.3’ S, longitude 102° 39.3’ E. The chronometer reading at the time of the sight is 11h 21m 18s and the chronometer is 48s slow. The height of eye is 59 feet and the index error is 2.5’ on the arc. What are the azimuth (Zn) and intercept (a) of this sight using the assumed position?

Answer: Zn = 304.1° T, a = 4.2’ towards.

Step 1: Determine the GMT of the sight.
Chronometer time: 11h 21m 18s
Chronometer error: 48s slow
Correct chronometer time: 11h 21m 18s + 48s = 11:22:06
Ship time: 0622 zone time.
DR longitude: 102° 39.3’ E corresponds to (-7 ZD)
GMT of sight: 23:22:06 GMT, 24 February

Step 2: Determine the sextant altitude (hs).
hs = 59° 58.6’ (Given)

Step 3: Determine the index correction (IC).
Index error: 2.5’ on the arc.
Index correction: -2.5’

Step 4: Determine the dip correction.
Height of eye: 59 feet.
Dip correction: -7.5’

Step 5: Determine the apparent altitude (ha).
Apparent altitude (ha) = hs ± IC ± dip
ha = 59° 58.6’ – 2.5’ – 7.5’ = 59° 48.6’

G.M.T.		SUN		MOON				
d	h	G.H.A. ° ′	Dec. ° ′	G.H.A. ° ′	v ′	Dec. ° ′	d ′	H.P. ′
24	00	176 40.2	S 9 34.3	302 07.8	15.3	S 7 19.3	9.7	54.2
	01	191 40.3	33.3	316 42.1	15.2	7 29.0	9.6	54.2
	02	206 40.4	32.4	331 16.3	15.2	7 38.6	9.6	54.2
	03	221 40.5	·· 31.5	345 50.5	15.2	7 48.2	9.6	54.2
	04	236 40.6	30.6	0 24.7	15.1	7 57.8	9.6	54.2
	05	251 40.6	29.6	14 58.8	15.2	8 07.4	9.5	54.2
	06	266 40.7	S 9 28.7	29 33.0	15.1	S 8 16.9	9.5	54.2
	07	281 40.8	27.8	44 07.1	15.1	8 26.4	9.4	54.2
	08	296 40.9	26.9	58 41.2	15.1	8 35.8	9.4	54.2
T	09	311 41.0	·· 26.0	73 15.3	15.1	8 45.2	9.4	54.2
U	10	326 41.1	25.0	87 49.4	15.1	8 54.6	9.3	54.2
E	11	341 41.2	24.1	102 23.5	15.0	9 03.9	9.3	54.2
S	12	356 41.3	S 9 23.2	116 57.5	15.0	S 9 13.2	9.3	54.2
D	13	11 41.4	22.3	131 31.5	15.0	9 22.5	9.2	54.2
A	14	26 41.5	21.3	146 05.5	15.0	9 31.7	9.1	54.2
Y	15	41 41.6	·· 20.4	160 39.5	14.9	9 40.8	9.2	54.2
	16	56 41.7	19.5	175 13.4	14.9	9 50.0	9.1	54.2
	17	71 41.8	18.6	189 47.3	14.9	9 59.1	9.0	54.2
	18	86 41.9	S 9 17.6	204 21.2	14.9	S10 08.1	9.1	54.2
	19	101 42.0	16.7	218 55.1	14.9	10 17.2	8.9	54.2
	20	116 42.1	15.8	233 29.0	14.8	10 26.1	9.0	54.2
	21	131 42.2	·· 14.8	248 02.8	14.8	10 35.1	8.8	54.2
	22	146 42.3	13.9	262 36.6	14.7	10 43.9	8.9	54.2
	23	161 42.4	13.0	277 10.3	14.8	10 52.8	8.8	54.2

Step 6: Determine the horizontal parallax (HP) of the Moon.
For 24 February at 2322, the HP is 54.2’

Step 7: Determine main correction.
Apparent altitude: 59° 48.6’
Apparent altitude correction 1: +39.1’
Horizontal parallax: 54.2’
Limb observed (correction): Upper (-30’)
Apparent altitude correction 2: +2.7’
Total altitude correction: 39.1’ + 2.7’ – 30.0’ = +11.8’

Step 8: Determine the observed altitude (ho).
Observed altitude = 59° 48.6’ + 11.8’ = 60° 00.4’

Step 9: Determine the declination of the Moon.
Declination (hours): S 10° 52.8’ (d number: 8.8)
Declination (increment): 3.3’
Declination (total): 10° 52.8’ + 3.3’ = <u>S 10° 56.1’</u>

Step 10: Determine the GHA of the Moon.
GHA (hours): 277° 10.3’ (v number: 14.8)
GHA (increment): 5° 16.4’
GHA (v correction): 5.6’
GHA (total): 277° 10.3 + 5° 16.4’ + 5.6’ = <u>282° 32.3’</u>

Step 11: Determine the assumed position of the ship.
DR latitude: 30° 28.3’ S
Assumed latitude: <u>30° S</u>
DR longitude: 102° 39.3’ E
Assumed longitude (to ensure whole number of LHA): <u>102° 27.7’ E</u>

Step 12: Determine the LHA for the Moon for the time of sight.
GHA (Moon): 282° 32.3’
Assumed longitude: 102° 27.7’ E
LHA (Moon): 282° 32.3’ + 102° 27.7’ E (-360°) = <u>25°</u> (-west, +east)

22m	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	5 30·0	5 30·9	5 15·0	0·0	0·0	6·0	2·3	12·0	4·5
01	5 30·3	5 31·2	5 15·2	0·1	0·0	6·1	2·3	12·1	4·5
02	5 30·5	5 31·4	5 15·4	0·2	0·1	6·2	2·3	12·2	4·6
03	5 30·8	5 31·7	5 15·7	0·3	0·1	6·3	2·4	12·3	4·6
04	5 31·0	5 31·9	5 15·9	0·4	0·2	6·4	2·4	12·4	4·7
05	5 31·3	5 32·2	5 16·2	0·5	0·2	6·5	2·4	12·5	4·7
06	5 31·5	5 32·4	5 16·4	0·6	0·2	6·6	2·5	12·6	4·7
07	5 31·8	5 32·7	5 16·6	0·7	0·3	6·7	2·5	12·7	4·8
08	5 32·0	5 32·9	5 16·9	0·8	0·3	6·8	2·6	12·8	4·8
09	5 32·3	5 33·2	5 17·1	0·9	0·3	6·9	2·6	12·9	4·8
10	5 32·5	5 33·4	5 17·4	1·0	0·4	7·0	2·6	13·0	4·9
11	5 32·8	5 33·7	5 17·6	1·1	0·4	7·1	2·7	13·1	4·9
12	5 33·0	5 33·9	5 17·8	1·2	0·5	7·2	2·7	13·2	5·0
13	5 33·3	5 34·2	5 18·1	1·3	0·5	7·3	2·7	13·3	5·0
14	5 33·5	5 34·4	5 18·3	1·4	0·5	7·4	2·8	13·4	5·0
15	5 33·8	5 34·7	5 18·5	1·5	0·6	7·5	2·8	13·5	5·1
16	5 34·0	5 34·9	5 18·8	1·6	0·6	7·6	2·9	13·6	5·1
17	5 34·3	5 35·2	5 19·0	1·7	0·6	7·7	2·9	13·7	5·1
18	5 34·5	5 35·4	5 19·3	1·8	0·7	7·8	2·9	13·8	5·2
19	5 34·8	5 35·7	5 19·5	1·9	0·7	7·9	3·0	13·9	5·2
20	5 35·0	5 35·9	5 19·7	2·0	0·8	8·0	3·0	14·0	5·3
21	5 35·3	5 36·2	5 20·0	2·1	0·8	8·1	3·0	14·1	5·3
22	5 35·5	5 36·4	5 20·2	2·2	0·8	8·2	3·1	14·2	5·3
23	5 35·8	5 36·7	5 20·5	2·3	0·9	8·3	3·1	14·3	5·4
24	5 36·0	5 36·9	5 20·7	2·4	0·9	8·4	3·2	14·4	5·4
25	5 36·3	5 37·2	5 20·9	2·5	0·9	8·5	3·2	14·5	5·4
26	5 36·5	5 37·4	5 21·2	2·6	1·0	8·6	3·2	14·6	5·5
27	5 36·8	5 37·7	5 21·4	2·7	1·0	8·7	3·3	14·7	5·5
28	5 37·0	5 37·9	5 21·6	2·8	1·1	8·8	3·3	14·8	5·6
29	5 37·3	5 38·2	5 21·9	2·9	1·1	8·9	3·3	14·9	5·6

ALTITUDE CORRECTI

App. Alt.	35°–39° Corrⁿ	40°–44° Corrⁿ	45°–49° Corrⁿ	50°–54° Corrⁿ	55°–59° Corrⁿ
′	° ′	° ′	° ′	° ′	° ′
00	35 56·5	40 53·7	45 50·5	50 46·9	55 43·1
10	56·4	53·6	50·4	46·8	42·9
20	56·3	53·5	50·2	46·7	42·8
30	56·2	53·4	50·1	46·5	42·7
40	56·2	53·3	50·0	46·4	42·5
50	56·1	53·2	49·9	46·3	42·4
00	36 56·0	41 53·1	46 49·8	51 46·2	56 42·3
10	55·9	53·0	49·7	46·0	42·1
20	55·8	52·8	49·5	45·9	42·0
30	55·7	52·7	49·4	45·8	41·8
40	55·6	52·6	49·3	45·7	41·7
50	55·5	52·5	49·2	45·5	41·6
00	37 55·4	42 52·4	47 49·1	52 45·4	57 41·4
10	55·3	52·3	49·0	45·3	41·3
20	55·2	52·2	48·8	45·2	41·2
30	55·1	52·1	48·7	45·0	41·0
40	55·0	52·0	48·6	44·9	40·9
50	55·0	51·9	48·5	44·8	40·8
00	38 54·9	43 51·8	48 48·4	53 44·6	58 40·6
10	54·8	51·7	48·2	44·5	40·5
20	54·7	51·6	48·1	44·4	40·3
30	54·6	51·5	48·0	44·2	40·2
40	54·5	51·4	47·9	44·1	40·1
50	54·4	51·2	47·8	44·0	39·9
00	39 54·3	44 51·1	49 47·6	54 43·9	59 39·8
10	54·2	51·0	47·5	43·7	39·6
20	54·1	50·9	47·4	43·6	39·5
30	54·0	50·8	47·3	43·5	39·4
40	53·9	50·7	47·2	43·3	39·2
50	53·8	50·6	47·0	43·2	39·1
H.P.	L U	L U	L U	L U	L U
′	′ ′	′ ′	′ ′	′ ′	′ ′
54·0	1·1 1·7	1·3 1·9	1·5 2·1	1·7 2·4	2·0 2·6
54·3	1·4 1·8	1·6 2·0	1·8 2·2	2·0 2·5	2·3 2·7
54·6	1·7 2·0	1·9 2·2	2·1 2·4	2·3 2·6	2·5 2·8
54·9	2·0 2·2	2·2 2·3	2·3 2·5	2·5 2·7	2·7 2·9
55·2	2·3 2·3	2·5 2·4	2·6 2·6	2·8 2·8	3·0 2·9

25°, 335° 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}

	23°			24°			25°			26°			27°			28°			29°			30°			
Dec. °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Dec. °
0	56 32.3	+42.2	130.0	55 53.3	+43.2	131.1	55 13.5	+44.1	132.2	54 32.8	+45.0	133.2	53 51.3	+45.9	134.2	53 09.1	+46.7	135.2	52 26.2	+47.4	136.1	51 42.6	+48.2	137.0	0
1	57 14.5	+41.2	128.7	56 36.5	+42.3	129.8	55 57.6	+43.4	131.0	55 17.8	+44.3	132.1	54 37.2	+45.2	133.1	53 55.8	+46.1	134.1	53 13.6	+47.0	135.1	52 30.8	+47.7	136.0	1
2	57 55.7	+40.4	127.3	57 18.8	+41.6	128.5	56 41.0	+42.6	129.7	56 02.1	+43.7	130.9	55 22.4	+44.6	132.0	54 41.9	+45.5	133.0	54 00.6	+46.3	134.1	53 18.5	+47.1	135.0	2
3	58 36.1	+39.4	125.9	58 00.4	+40.6	127.2	57 23.6	+41.8	128.4	56 45.8	+42.8	129.6	56 07.0	+43.9	130.8	55 27.4	+44.8	131.9	54 46.9	+45.7	133.0	54 05.6	+46.6	134.0	3
4	59 15.5	+38.4	124.4	58 41.0	+39.7	125.8	58 05.4	+40.9	127.1	57 28.6	+42.1	128.4	56 50.9	+43.1	129.6	56 12.2	+44.2	130.7	55 32.6	+45.1	131.8	54 52.2	+46.0	132.9	4
5	59 53.9	+37.3	122.9	59 20.7	+38.7	124.3	58 46.3	+39.9	125.7	58 10.7	+41.2	127.0	57 34.0	+42.3	128.3	56 56.4	+43.3	129.5	56 17.7	+44.4	130.6	55 38.2	+45.4	131.8	5
6	60 31.2	+36.2	121.3	59 59.4	+37.6	122.8	59 26.2	+39.0	124.3	58 51.9	+40.2	125.6	58 16.3	+41.5	126.9	57 39.7	+42.6	128.2	57 02.1	+43.7	129.4	56 23.6	+44.6	130.6	6
7	61 07.4	+34.9	119.7	60 37.0	+36.4	121.3	60 05.2	+37.8	122.7	59 32.1	+39.2	124.2	58 57.8	+40.5	125.6	58 22.3	+41.7	126.9	57 45.8	+42.8	128.2	57 08.2	+43.9	129.4	7
8	61 42.3	+33.6	118.0	61 13.4	+35.2	119.6	60 43.0	+36.8	121.2	60 11.3	+38.2	122.7	59 38.3	+39.5	124.1	59 04.0	+40.8	125.5	58 28.6	+42.0	126.8	57 52.1	+43.2	128.1	8
9	62 15.9	+32.2	116.2	61 48.6	+33.9	117.9	61 19.8	+35.5	119.5	60 49.5	+37.0	121.1	60 17.8	+38.5	122.6	59 44.8	+39.8	124.1	59 10.6	+41.1	125.4	58 35.3	+42.3	126.8	9
10	62 48.1	+30.8	114.4	62 22.5	+32.5	116.2	61 55.3	+34.2	117.8	61 26.5	+35.8	119.5	60 56.3	+37.3	121.0	60 24.6	+38.8	122.6	59 51.7	+40.1	124.0	59 17.6	+41.3	125.4	10
11	63 18.9	+29.2	112.5	62 55.0	+31.1	114.3	62 29.5	+32.8	116.1	62 02.3	+34.5	117.8	61 33.6	+36.1	119.4	61 03.4	+37.6	121.0	60 31.8	+39.1	122.5	59 58.9	+40.4	124.0	11
12	63 48.1	+27.5	110.6	63 26.1	+29.5	112.4	63 02.3	+31.4	114.3	62 36.8	+33.2	116.0	62 09.7	+34.8	117.7	61 41.0	+36.5	119.4	61 10.9	+37.9	121.0	60 39.3	+39.4	122.5	12
13	64 15.6	+25.8	108.5	63 55.6	+27.8	110.5	63 33.7	+29.8	112.4	63 10.0	+31.6	114.2	62 44.5	+33.5	116.0	62 17.5	+35.1	117.7	61 48.8	+36.8	119.3	61 18.7	+38.3	120.9	13
14	64 41.4	+23.9	106.4	64 23.4	+26.1	108.4	64 03.5	+28.1	110.4	63 41.6	+30.1	112.3	63 18.0	+32.0	114.1	62 52.6	+33.8	115.9	62 25.6	+35.4	117.6	61 57.0	+37.0	119.3	14

Step 13: Entering publication HO229 with assumed latitude, declination, and LHA, retrieve the computed altitude (hc), altitude difference (d), and azimuth (z) for the assumed position.

Assumed latitude: 30° S
Declination: S 10° (increments solved in step 14)
LHA: 25° (Same Pages)

HO 229 values:

Computed altitude (hc): 59° 17.6’
Altitude difference (d): + 41.3’
Azimuth (z): 125.4°

Step 14: Determine the azimuth correction for the sight (to account for increments of declination ignored in step 13).

	Base Value	Base Z	Next incremental Z	Difference in Z	Increment	Correction *(Diff Z x Increment) / 60*
Latitude – S	30°	125.4°	-	-	00.0’	0
Declination – S	10°	125.4°	124.0°	-1.4’	56.1’	-1.3°
LHA	25°	125.4°	-	-	00.0’	0

Total correction = -1.3°

Step 15: Apply the correction to the base values to determine true azimuth.
Base azimuth: 125.4°
Correction: -1.3°
Corrected azimuth: 125.4° - 1.3° = 124.1°
Note - Check azimuth rules: if LHA less than 180°, then zn = 180° + z.
Corrected azimuth: 180° + 124.1° = **304.1° T**

Step 16: Determine the computed altitude (hc).
Tabular computed altitude: 59° 17.6’
Altitude difference (d): +41.3’
Declination: S 10° 56.1’
Declination increments: 56.1’

Altitude difference correction:
Tens: 37.4’
Units/decimals: 1.2’
Total correction: 37.4’+1.2’ = 38.6’

Tabular hc: 59° 17.6’
Altitude difference correction: +38.6’
hc: 59° 17.6’ + 38.6’ = 59° 56.2’

Step 17: Determine the intercept (a).
Computed altitude (hc): 59° 56.2’
Observed altitude (ho): 60° 00.4’
Intercept (a): ho - hc = 60° 00.4’ – 59° 56.2’ = **4.2’**
If ho is greater, intercept is **towards.**
If hc is greater, intercept is away.

Dec. Inc.	Altitude Difference (d)																Double Second Diff. and Corr.	
	Tens					Decimals	Units											
	10′	20′	30′	40′	50′	⇓	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′		
56.0	9.3	18.6	28.0	37.3	46.6	**.0**	0.0	0.9	1.9	2.8	3.8	4.7	5.6	6.6	7.5	8.5		
56.1	9.3	18.7	28.0	37.4	46.7	**.1**	0.1	1.0	2.0	2.9	3.9	4.8	5.7	6.7	7.6	8.6		
56.2	9.3	18.7	28.1	37.4	46.8	**.2**	0.2	1.1	2.1	3.0	4.0	4.9	5.8	6.8	7.7	8.7	3.6	
56.3	9.4	18.8	28.1	37.5	46.9	**.3**	0.3	1.2	2.2	3.1	4.0	5.0	5.9	6.9	7.8	8.8	10.9	0.1
56.4	9.4	18.8	28.2	37.6	47.0	**.4**	0.4	1.3	2.3	3.2	4.1	5.1	6.0	7.0	7.9	8.9	18.2	0.2
																		0.3

RED D7. On 25 May your vessel's 1858 zone time DR position is latitude 21° 05' N, longitude 143° 27' E. At that time a sextant observation of the planet Venus was made. The sextant altitude is 12° 53.4' and the chronometer reads 08h 59m 15s. The index error is 4.5' off the arc and the chronometer error is 1m 25s fast. Your height of eye is determined to be 55 feet. What is the azimuth (Zn) of the sight using the assumed position?

G.M.T. d	h	ARIES G.H.A. ° '	VENUS −3.4 G.H.A. ° '	Dec. ° '
25	00	242 29.4	167 32.4	N23 09.5
	01	257 31.9	182 31.6	09.9
	02	272 34.3	197 30.7	10.3
	03	287 36.8	212 29.9	· · 10.8
	04	302 39.3	227 29.0	11.2
	05	317 41.7	242 28.2	11.6
	06	332 44.2	257 27.4	N23 12.0
	07	347 46.7	272 26.5	12.4
	08	2 49.1	287 25.7	12.8
M	09	17 51.6	302 24.8	· · 13.2
O	10	32 54.0	317 24.0	13.6
N	11	47 56.5	332 23.1	14.0
D	12	62 59.0	347 22.3	N23 14.4
A	13	78 01.4	2 21.4	14.8
Y	14	93 03.9	17 20.6	15.2
	15	108 06.4	32 19.7	· · 15.6
	16	123 08.8	47 18.9	16.0
	17	138 11.3	62 18.0	16.4
	18	153 13.8	77 17.2	N23 16.8
	19	168 16.2	92 16.4	17.2
	20	183 18.7	107 15.5	17.6
	21	198 21.2	122 14.7	· · 18.0
	22	213 23.6	137 13.8	18.4
	23	228 26.1	152 13.0	18.8
Mer. Pass.		h m 7 44.8	v −0.9	d 0.4

Answer: 290.3° T. *Note that several steps are not required to answer the specific question posed but are shown here for training purposes.*

Step 1: Determine the GMT of the sight.
Chronometer time: 08h 59m 15s
Chronometer error: 1m 25s fast
Correct chronometer time: 08h 59m 15s – 1m 25s = 08:57:50
Ship time: 1858 zone time.
DR longitude: 143° 27' E corresponds to (-10 ZD)
GMT of sight: 08:57:50 GMT, 25 May

57m s	SUN PLANETS ° '	ARIES ° '	MOON ° '	v or d '	Corrn '	v or d '	Corrn '
00	14 15·0	14 17·3	13 36·1	0·0	0·0	6·0	5·8
01	14 15·3	14 17·6	13 36·3	0·1	0·1	6·1	5·8
02	14 15·5	14 17·8	13 36·5	0·2	0·2	6·2	5·9
03	14 15·8	14 18·1	13 36·8	0·3	0·3	6·3	6·0
04	14 16·0	14 18·3	13 37·0	0·4	0·4	6·4	6·1
05	14 16·3	14 18·6	13 37·2	0·5	0·5	6·5	6·2
06	14 16·5	14 18·8	13 37·5	0·6	0·6	6·6	6·3
07	14 16·8	14 19·1	13 37·7	0·7	0·7	6·7	6·4
08	14 17·0	14 19·3	13 38·0	0·8	0·8	6·8	6·5
09	14 17·3	14 19·6	13 38·2	0·9	0·9	6·9	6·6
50	14 27·5	14 29·9	13 48·0	5·0	4·8	11·0	10·5
51	14 27·8	14 30·1	13 48·2	5·1	4·9	11·1	10·6
52	14 28·0	14 30·4	13 48·5	5·2	5·0	11·2	10·7
53	14 28·3	14 30·6	13 48·7	5·3	5·1	11·3	10·8
54	14 28·5	14 30·9	13 48·9	5·4	5·2	11·4	10·9

Step 2: Determine the apparent altitude (ha).
hs = 12° 53.4' (Given)
Index error: 4.5' off the arc (IC = +4.5')
Height of eye: 55 ft (dip correction = -7.2')
ha = 12° 53.4 + 4.5' – 7.2' = 12° 50.7'

Step 3: Determine observed altitude.
Apparent altitude: 12° 50.7'
Apparent altitude correction: - 4.2'
Additional Venus correction: +0.1'
Total main correction: -4.2' + 0.1' = -4.1'
Observed altitude (ho): 12° 50.7' – 4.1' = 12° 46.6'

Step 4: Determine the declination of Venus.
Declination (hours): N 23° 12.8' (d number: +0.4)
Declination (increment): +0.4'
Declination (total): N 23° 12.8' + 0.4' = N 23° 13.2'

Step 5: Determine the GHA of Venus.
GHA (hours): 287° 25.7' (v number: -0.9)
GHA (increment): 14° 27.5'
GHA (v correction): -0.9'
GHA (total): 287° 25.7 + 14° 27.5' – 0.9' = 301° 52.3'

Step 6: Determine the assumed position of the ship.
DR latitude: 21° 05’ N
Assumed latitude: 21° N
DR longitude: 143° 27’ E
Assumed longitude (to ensure whole number of LHA): 143° 07.7’ E

Step 7: Determine the LHA for Venus for the time of sight.
GHA (Venus): 301° 52.3’
Assumed longitude: 143° 07.7’ E
LHA (Moon): 301° 52.3’ + 143° 07.7’ E (-360°) = 85° (-west, +east)

Step 8: Entering publication HO229 with assumed latitude, declination, and LHA, retrieve the computed altitude (hc), altitude difference (d), and azimuth (z) for the assumed position.
Assumed latitude: 21° N
Declination: N 23° (increments solved in step 9)
LHA: 85° (Same Pages)

HO 229 values:
Computed altitude (hc): 12° 24.7’
Altitude difference (d): + 18.2’
Azimuth (z): 69.9°

85°, 275° 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}

	15°			16°			17°			18°			19°			20°			21°			22°			
Dec. °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Dec. °
0	4 49.8	+15.5	91.3	4 48.4	+16.5	91.4	4 46.9	+17.5	91.5	4 45.3	+18.5	91.5	4 43.6	+19.6	91.6	4 41.9	+20.5	91.7	4 40.0	+21.6	91.8	4 38.1	+22.5	91.9	0
1	5 05.3	+15.5	90.3	5 04.9	+16.5	90.4	5 04.4	+17.5	90.5	5 03.8	+18.5	90.6	5 03.2	+19.5	90.7	5 02.4	+20.5	90.8	5 01.6	+21.4	90.9	5 00.6	+22.5	90.9	1
2	5 20.8	+15.3	89.4	5 21.4	+16.4	89.5	5 21.9	+17.4	89.5	5 22.3	+18.4	89.6	5 22.7	+19.3	89.7	5 22.9	+20.4	89.8	5 23.0	+21.4	89.9	5 23.1	+22.3	90.0	2
3	5 36.1	+15.3	88.4	5 37.8	+16.2	88.5	5 39.3	+17.3	88.6	5 40.7	+18.3	88.7	5 42.0	+19.3	88.8	5 43.3	+20.3	88.9	5 44.4	+21.3	89.0	5 45.4	+22.3	89.1	3
4	5 51.4	+15.2	87.4	5 54.0	+16.2	87.5	5 56.6	+17.2	87.6	5 59.0	+18.2	87.7	6 01.3	+19.2	87.8	6 03.6	+20.2	87.9	6 05.7	+21.1	88.0	6 07.7	+22.1	88.1	4
5	6 06.6	+15.0	86.4	6 10.2	+16.1	86.5	6 13.8	+17.1	86.7	6 17.2	+18.1	86.8	6 20.5	+19.1	86.9	6 23.8	+20.0	87.0	6 26.8	+21.1	87.1	6 29.8	+22.1	87.2	5
6	6 21.6	+15.0	85.5	6 26.3	+16.0	85.6	6 30.9	+16.9	85.7	6 35.3	+18.0	85.8	6 39.6	+19.0	85.9	6 43.8	+20.0	86.0	6 47.9	+21.0	86.2	6 51.9	+21.9	86.3	6
7	6 36.6	+14.8	84.5	6 42.3	+15.8	84.6	6 47.8	+16.9	84.7	6 53.3	+17.9	84.8	6 58.6	+18.9	85.0	7 03.8	+19.9	85.1	7 08.9	+20.8	85.2	7 13.8	+21.9	85.3	7
8	6 51.4	+14.7	83.5	6 58.1	+15.8	83.6	7 04.7	+16.7	83.8	7 11.2	+17.7	83.9	7 17.5	+18.7	84.0	7 23.7	+19.7	84.1	7 29.7	+20.8	84.3	7 35.7	+21.7	84.4	8
9	7 06.1	+14.6	82.5	7 13.9	+15.6	82.7	7 21.4	+16.7	82.8	7 28.9	+17.6	82.9	7 36.2	+18.7	83.1	7 43.4	+19.6	83.2	7 50.5	+20.6	83.3	7 57.4	+21.6	83.5	9
10	7 20.7	+14.5	81.6	7 29.5	+15.4	81.7	7 38.1	+16.5	81.8	7 46.5	+17.5	82.0	7 54.9	+18.4	82.1	8 03.0	+19.5	82.2	8 11.1	+20.4	82.4	8 19.0	+21.4	82.5	10
11	7 35.2	+14.3	80.6	7 44.9	+15.4	80.7	7 54.6	+16.3	80.9	8 04.0	+17.4	81.0	8 13.3	+18.4	81.1	8 22.5	+19.4	81.3	8 31.5	+20.4	81.4	8 40.4	+21.3	81.6	11
12	7 49.5	+14.2	79.6	8 00.3	+15.2	79.7	8 10.9	+16.2	79.9	8 21.4	+17.2	80.0	8 31.7	+18.2	80.2	8 41.9	+19.2	80.3	8 51.9	+20.2	80.5	9 01.7	+21.2	80.6	12
13	8 03.7	+14.1	78.6	8 15.5	+15.1	78.8	8 27.1	+16.1	78.9	8 38.6	+17.1	79.1	8 49.9	+18.1	79.2	9 01.1	+19.0	79.4	9 12.1	+20.0	79.5	9 22.9	+21.0	79.7	13
14	8 17.8	+13.9	77.6	8 30.6	+14.9	77.8	8 43.2	+15.9	77.9	8 55.7	+16.9	78.1	9 08.0	+17.9	78.2	9 20.1	+18.9	78.4	9 32.1	+19.9	78.6	9 43.9	+20.9	78.7	14
15	8 31.7	+13.8	76.7	8 45.5	+14.8	76.8	8 59.1	+15.8	77.0	9 12.6	+16.7	77.1	9 25.9	+17.7	77.3	9 39.0	+18.7	77.4	9 52.0	+19.7	77.6	10 04.8	+20.7	77.8	15
16	8 45.5	+13.6	75.7	9 00.3	+14.6	75.8	9 14.9	+15.6	76.0	9 29.3	+16.6	76.1	9 43.6	+17.6	76.3	9 57.7	+18.6	76.5	10 11.7	+19.5	76.6	10 25.5	+20.5	76.8	16
17	8 59.1	+13.5	74.7	9 14.9	+14.4	74.8	9 30.5	+15.4	75.0	9 45.9	+16.5	75.2	10 01.2	+17.4	75.3	10 16.3	+18.4	75.5	10 31.2	+19.4	75.7	10 46.0	+20.3	75.9	17
18	9 12.6	+13.3	73.7	9 29.3	+14.3	73.9	9 45.9	+15.3	74.0	10 02.4	+16.2	74.2	10 18.6	+17.3	74.4	10 34.7	+18.2	74.5	10 50.6	+19.2	74.7	11 06.3	+20.2	74.9	18
19	9 25.9	+13.1	72.7	9 43.6	+14.1	72.9	10 01.2	+15.1	73.0	10 18.6	+16.1	73.2	10 35.9	+17.0	73.4	10 52.9	+18.1	73.6	11 09.8	+19.0	73.8	11 26.5	+20.0	73.9	19
20	9 39.0	+13.0	71.7	9 57.7	+14.0	71.9	10 16.3	+14.9	72.1	10 34.7	+15.9	72.2	10 52.9	+16.9	72.4	11 11.0	+17.8	72.6	11 28.8	+18.8	72.8	11 46.5	+19.7	73.0	20
21	9 52.0	+12.8	70.7	10 11.7	+13.8	70.9	10 31.2	+14.8	71.1	10 50.6	+15.7	71.3	11 09.8	+16.7	71.4	11 28.8	+17.7	71.6	11 47.6	+18.6	71.8	12 06.2	+19.6	72.0	21
22	10 04.8	+12.6	69.7	10 25.5	+13.5	69.9	10 46.0	+14.5	70.1	11 06.3	+15.5	70.3	11 26.5	+16.5	70.5	11 46.5	+17.4	70.6	12 06.2	+18.5	70.8	12 25.8	+19.4	71.1	22
23	10 17.4	+12.4	68.7	10 39.0	+13.4	68.9	11 00.5	+14.4	69.1	11 21.8	+15.4	69.3	11 43.0	+16.3	69.5	12 03.9	+17.3	69.7	12 24.7	+18.2	69.9	12 45.2	+19.2	70.1	23
24	10 29.8	+12.2	67.8	10 52.4	+13.2	67.9	11 14.9	+14.2	68.1	11 37.2	+15.1	68.3	11 59.3	+16.1	68.5	12 21.2	+17.0	68.7	12 42.9	+18.0	68.9	13 04.4	+18.9	69.1	24

Step 9: Determine the azimuth correction for the sight (to account for increments of declination ignored in step 8).

	Base Value	Base Z	Next incremental Z	Difference in Z	Increment	Correction *(Diff Z x Increment) / 60*
Latitude – N	21°	69.9°	-	-	00.0’	0
Declination – N	23°	69.9°	68.9°	-1.0’	13.2’	-0.2°
LHA	85°	69.9°	-	-	00.0’	0

Total correction = -0.2°

Step 10: Apply the correction to the base values to determine true azimuth.
Base azimuth: 69.9°
Correction: -0.2°
Corrected azimuth: 69.9° - 0.2° = 69.7°
Note - Check azimuth rules: if LHA less than 180°, then zn = 360° - z.
Corrected azimuth: 360° - 69.7° = **290.3° T**

Step 11: Determine the computed altitude (hc).
Tabular computed altitude: 12° 24.7’
Altitude difference (d): 18.2’
Declination: N 23° 13.2’
Declination increments: 13.2’

Altitude difference correction:
Tens: 2.2’
Units/decimals: 1.9’
Total correction: 2.2’+1.8’ = +4.0’

Tabular hc: 12° 24.7’
Altitude difference correction: +4.0’
hc: 12° 24.7’ + 4.0’ = 12° 28.7’

Step 12: Determine the intercept (a).
Computed altitude (hc): 12° 28.7’
Observed altitude (ho): 12° 46.6’
Intercept (a): 12° 46.6’ – 12° 28.7’ = 17.9’
If ho is greater, intercept is towards.

Dec. Inc.	Altitude Difference (d)															
	Tens					Decimals	Units									
	10′	20′	30′	40′	50′	⇓	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
13.0	2.1	4.3	6.5	8.6	10.8	**.0**	0.0	0.2	0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0
13.1	2.2	4.3	6.5	8.7	10.9	**.1**	0.0	0.2	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.0
13.2	2.2	4.4	6.6	8.8	11.0	**.2**	0.0	0.3	0.5	0.7	0.9	1.2	1.4	1.6	1.8	2.1
13.3	2.2	4.4	6.6	8.9	11.1	**.3**	0.1	0.3	0.5	0.7	1.0	1.2	1.4	1.6	1.9	2.1
13.4	2.2	4.5	6.7	8.9	11.2	**.4**	0.1	0.3	0.5	0.8	1.0	1.2	1.4	1.7	1.9	2.1

Sight Reduction (Individual) Problems

Hs to Ho Problems

RED B1. On 2 January you observe the lower limb of the Sun at a sextant altitude (hs) or 35° 50.4'. The index error is 0.8' on the arc. The height of eye is 24 feet. What is the observed altitude?

a) 35° 50.3'
b) 35° 54.7'
c) 35° 59.7' - correct
d) 36° 05.6'

RED B2. You observe the lower limb of the Sun at a sextant altitude (hs) of 28° 24.7' on 17 May. The index error is 1.5' off the arc. The height of eye is 86 feet. What is the observed altitude (ho)?

a) 28° 29.7'
b) 28° 30.6'
c) 28° 31.5' - correct
d) 28° 32.9'

RED B3. On 29 June you observe the star Achernar at a sextant altitude (hs) of 54° 18.9'. The index error is 4.7' off the arc. The height of eye is 58 feet. What is the observed altitude?

a) 54° 06.1'
b) 54° 15.5' - correct
c) 54° 31.5'
d) 54° 43.7'

RED B4. At about 1436 GMT on 3 December, the lower limb of the Moon is observed. The sextant has an index error of 2.5' on the arc. The height of eye is 32 feet. The sextant altitude (hs) is 3° 38.8'. What is the observed altitude?

a) 4° 18.6'
b) 4° 29.1' - correct
c) 4° 36.3'
d) 4° 42.2'

Sight Reduction of the Sun Problems

RED B5. At 0600 zone time on 24 July, your DR position is latitude 22° 37’ N, longitude 32° 45’ W. You are steering 185° T at 20 knots. Determine the computed altitude (hc) and azimuth (zn) for an observation of the Sun’s lower limb taken at 1030 ZT. At this time the chronometer reads 00h 30m 16s and is 31s slow.

a) hc 64° 27.5’, zn 092.3° T
b) hc 64° 30.8’, zn 090.1° T
c) hc 64° 41.7’, zn 087.8° T - correct
d) hc 64° 44.2’, zn 094.7° T

RED B6. At 1000 zone time on 21 October, your DR position is latitude 29° 00’ N, longitude 134° 40’ E. Determine the computed altitude (hc) of the Sun for the assumed position (AP) nearest to the above given latitude and longitude, given a chronometer time of 01h 00m 00s.

a) hc 42° 30.6’
b) hc 42° 32.1’
c) hc 42° 34.2’
d) hc 42° 35.7’ - correct

RED B7. On 10 January at 0550 zone time, morning stars were observed, and the vessels position was determined to be latitude 25° 16’ N, longitude 123° 18’ W. Your vessel is steaming at 22 knots on a course of 295° T. A sextant observation of the Sun’s lower limb is made at 0915 zone time. The chronometer reads 05h 14m 02s and the sextant altitude is 24° 00.7’. The index error is 2.6’ off the arc, and the chronometer error is 01m 34s slow. Your height of eye on the bridge is 55 feet. What is the azimuth (zn) of this sight using the assumed position?

a) 127.8° T
b) 129.8° T
c) 131.4° T – correct, note official CG correct answer is 131.9° T in the databank.
d) 133.6° T

RED B8. On 12 April at 0515 zone time, morning stars were observed and the vessel’s position was determined to be latitude 21° 05’ S, longitude 16° 30’ W. Your vessel is steaming at 19 knots on course 278° T. A sextant observation of the Sun’s lower limb is made at 0930 zone time. The chronometer reads 10h 28m 25s and the sextant altitude (hs) is 40° 15.9’. The index error is 2.5’ off the arc and the chronometer error is 2m 15s slow. Your height of eye on the bridge is 57 feet. What are the intercept (a), and azimuth (zn) from the assumed position?

a) zn = 057.7° T, a = 15.4’ towards
b) zn = 057.0° T, a = 17.7’ away - correct
c) zn = 122.3° T, a = 17.7’ away
d) zn = 123.0° T, a = 22.7’ away

RED B9. On 16 June at 0612 zone time, morning stars were observed. The vessel's position was latitude 27° 23.0' S, longitude 56° 22.0' W. The vessel is steaming at 16 knots on a course of 212° T. A sextant observation of the Sun's lower limb is made at 0850 zone time. The chronometer reads 00h 53m 19s and the sextant altitude (hs) is 22° 58.6'. The index error is 2.0' off the arc and the chronometer error is 02m 43s fast. Your height of eye is 61 feet. What is the azimuth (zn) of the sight using the assumed position?

a) 044.3° T - correct
b) 052.6° T
c) 136.1° T
d) 148.4° T

RED B10. On 8 August at 0545 zone time morning stars were observed and the vessel's position was determined to be latitude 26° 16' S, longitude 94° 16' E. Your vessel is steaming at 20 knots on a course of 346° T. A sextant observation of the Sun's lower limb is made at 0905 zone time. The chronometer reads 03h 02m 52s, and the sextant altitude (hs) is 38° 07.5'. The index error is 5.2' off the arc, and the chronometer error is 2m 17s slow. Your height of eye on the bridge is 72 feet. What is the observed altitude (ho) and azimuth (zn) of the sight using the assumed position?

a) 38° 19.4', 048.4° T - correct
b) 38° 19.4', 131.6° T
c) 38° 54.9', 048.4° T
d) 38° 54.9', 131.6° T

RED B11. On 21 November at 0430 zone time, morning stars were observed, and the vessel's position was latitude 22° 14.0' S, longitude 79° 23.0' E. Your vessel is steaming at 14.5 knots on a course of 246° T. A sextant observation of the Sun's lower limb is made at 0816 zone time. The chronometer reads 03h 14m 16s, and the sextant altitude (hs) is 44° 29.2' The index error is 1.0' on the arc and the chronometer error is 01m 47s slow. Your height of eye is 61 feet. What is the azimuth (zn) and intercept (a) of this sight using the assumed position?

a) zn = 084.2° T, a = 6.6' away
b) zn = 084.2° T, a = 6.6' towards
c) zn = 095.6° T, a = 6.6' away
d) zn = 095.6° T, a = 6.6' towards - correct

Sight Reduction of the Moon, Stars and Planets Problems (very few problems in database)

RED B12. On 22 July, at 0720 ZT in your DR position latitude 20° 38.2'N, longitude 87° 16.0'W, you observe the Moon's lower limb. The sextant altitude (Hs) is 38° 32.6' and the chronometer reads 01h 18m 14s. The chronometer is 01m 28s slow and the index error is 3.1' off the arc. The height of eye is 68 feet. What is the azimuth (Zn) and intercept (a) of this sight from the assumed position?

a) Zn 291.4°, a 5.2' A
b) Zn 111.4°, a 8.7' A
c) Zn 248.6°, a 5.0' T - correct
d) Zn 068.6°, a 6.5' T

RED B13. On 25 May your vessel's 1917 zone time position is latitude 24° 16' N, longitude 17° 26' W. At that time a sextant observation of the planet Saturn was made. The sextant altitude is 63° 05.1' and the chronometer reads 08h 18m 24s. The index error is 4.5' off the arc and the chronometer error is 1m 05s fast. Your height of eye is determined to be 62 feet. What is the azimuth (zn) of the sight using the assumed position?

e) 143.8° T
f) 147.3° T - correct
g) 148.7° T
h) 149.9° T

RED B14. On 26 May your vessel's 1906 zone time position is latitude 27° 16' N, longitude 24° 37' W. At that time a sextant observation of the planet Jupiter was made. The sextant altitude is 63° 27.6' and the chronometer reads 09h 05m 16s. The index error is 5.2' on the arc and the chronometer error is 1m 25s slow. Your height of eye is determined to be 52.6 feet. What is the azimuth (zn) of the sight using the assumed position?

a) 011.3° T
b) 168.7° T - correct
c) 191.3° T
d) 348.7° T

RED B15. On 28 April your vessel's 0515 zone time position is latitude 23° 26' S, longitude 95° 30' E. At that time a sextant observation of Rigil Kentaurus was made. The Ho is 24° 51.4'. Your chronometer reads 11h 16m 36s and is 01m 18s fast. What is the intercept (a) based on the assumed position?

a) 30.9 miles
b) 32.3 miles
c) 33.1 miles
d) 34.4 miles - correct

Sight Reduction (Running Fix) Problems

Sun Problems

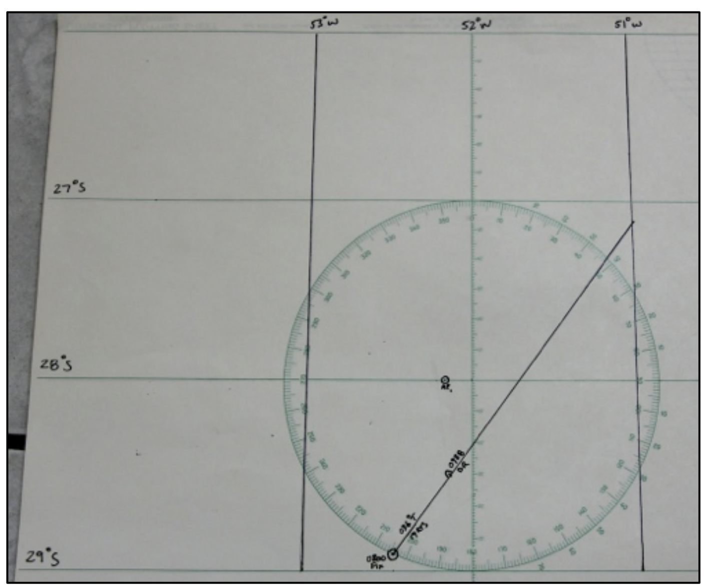
FIX D1. On 8 February, your 0800 zone time position was latitude 28° 55.0’ S, longitude 52° 27’ W. Your vessel was steaming on course 036° T at a speed of 19 knots. An observation of the Sun’s lower limb was made at 0938 zone time. The chronometer read 12h 37m 23s and was slow 01m 24s. The observed altitude (ho) was 45° 29.2’. Local apparent noon (LAN) occurred at 1240 zone time. The observed altitude (ho) was 77° 10.5’. What was the longitude of your 1200 zone time running fix?

Answer: 51° 36.0’ W

Step 1: Determine the GMT of the morning Sun sight.
Chronometer time: 12h 37m 23s
Chronometer error: 01m 24s slow
Correct chronometer time: 12h 37m 23s + 01m 24s = 12h 38m 47s
Ship time of sight: 0938 ZT
DR longitude: 52° 27’ W corresponds to (+3 ZD)
GMT of sight: 12:38:47 GMT, 8 February

Step 2: Advance the original fix location to the morning Sun sight. Note this solution uses a plotting sheet, but the position may also be advanced by mid-latitude sailing.

Original fix time: 0800 ZT or 1100 GMT
Original fix position: 28° 55’ S, 52° 27’ W.
Morning observation time: 0938 ZT or 1238 GMT
Course and speed: 036 T at 19 knots
Time underway: 0800 ZT – 0938 ZT = 1 hours, 38 minutes, or 1.6 hrs
Distance travelled: 1.6 hours for 19 knots = 31.0 miles covered
Morning DR position (original fix advanced 31 miles in direction 036°):
28° 30’ S, 52° 06’ W



Step 3: Determine the observed altitude of the morning Sun sight.
ho: 45° 29.2’ (Given)

Step 4: Determine the declination of the Sun for the morning Sun sight.
Declination (hours): S 14° 55.5’ (d number -0.8)
Declination (increments): - 0.5’
Declination (total): S 14° 55.0’

Step 5: Determine the GHA of the Sun for the morning Sun sight.
GHA (hours): 356° 26.4’
GHA (increments): 9° 41.8’
GHA (total): 366° 08.2’ (-360°) = 6° 08.2’

Step 6: Determine the assumed position of the ship.
DR latitude: 28° 30’ S
Assumed latitude: 28° S
DR longitude: 52° 06’ W
Assumed longitude (to ensure whole number of LHA): 52° 08.2’ W

Step 7: Determine the LHA of the Sun for the morning Sun sight.
GHA (Sun): 6° 08.2’ W
Assumed longitude: 52° 08.2’ W
LHA 6° 08.2’ (+360°) – 52° 08.2’ W = 314° (subtract west, add east)

G.M.T.		SUN G.H.A.	SUN Dec.
d h		° ′	° ′
8	00	176 26.7	S15 05.0
	01	191 26.7	04.2
	02	206 26.7	03.4
	03	221 26.7	· · 02.7
	04	236 26.6	01.9
	05	251 26.6	01.1
	06	266 26.6	S15 00.3
	07	281 26.5	14 59.5
	08	296 26.5	58.7
S	09	311 26.5	· · 57.9
U	10	326 26.5	57.1
N	11	341 26.4	56.3
D	12	356 26.4	S14 55.5
A	13	11 26.4	54.7
Y	14	26 26.4	53.9
	15	41 26.4	· · 53.1
	16	56 26.3	52.3
	17	71 26.3	51.5
	18	86 26.3	S14 50.8
	19	101 26.3	50.0
	20	116 26.2	49.2
	21	131 26.2	· · 48.4
	22	146 26.2	47.6
	23	161 26.2	46.8
		S.D. 16.2	d 0.8

38m	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	0·8	0·5	6·8	4·4	12·8	8·2
09	9 32·3	9 33·8	9 06·2	0·9	0·6	6·9	4·4	12·9	8·3
45	9 41·3	9 42·8	9 14·8	4·5	2·9	10·5	6·7	16·5	10·6
46	9 41·5	9 43·1	9 15·0	4·6	3·0	10·6	6·8	16·6	10·7
47	9 41·8	9 43·3	9 15·2	4·7	3·0	10·7	6·9	16·7	10·7
48	9 42·0	9 43·6	9 15·5	4·8	3·1	10·8	6·9	16·8	10·8
49	9 42·3	9 43·8	9 15·7	4·9	3·1	10·9	7·0	16·9	10·8

Step 8: Entering publication HO229 with assumed latitude, declination, and LHA, retrieve the computed altitude (hc), altitude difference (d), and azimuth (z) for the assumed position.
Assumed latitude: 28° S
Declination: S 14° (increments solved in step 9)
LHA: 314° (Same Pages)

HO 229 values:
Computed altitude (hc): 45° 07.8’
Altitude difference (d): +25.7’
Azimuth (z): 98.4° T

46°, 314° 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.	23° Hc	d	Z	24° Hc	d	Z	25° Hc	d	Z	26° Hc	d	Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
0	39 45.0	+30.2	110.7	39 23.4	+31.3	111.4	39 01.1	+32.4	112.2	38 38.1	+33.4	112.9
1	40 15.2	+29.5	109.5	39 54.7	+30.6	110.3	39 33.5	+31.7	111.1	39 11.5	+32.8	111.9
2	40 44.7	+28.8	108.4	40 25.3	+30.0	109.2	40 05.2	+31.1	110.0	39 44.3	+32.1	110.8
3	41 13.5	+28.1	107.2	40 55.3	+29.2	108.1	40 36.3	+30.4	108.9	40 16.4	+31.6	109.7
4	41 41.6	+27.3	106.1	41 24.5	+28.6	106.9	41 06.7	+29.7	107.7	40 48.0	+30.8	108.6
5	42 08.9	+26.6	104.9	41 53.1	+27.8	105.7	41 36.4	+29.0	106.6	41 18.8	+30.2	107.4
6	42 35.5	+25.9	103.6	42 20.9	+27.1	104.5	42 05.4	+28.3	105.4	41 49.0	+29.5	106.3
7	43 01.4	+25.0	102.4	42 48.0	+26.3	103.3	42 33.7	+27.6	104.2	42 18.5	+28.8	105.1
8	43 26.4	+24.2	101.2	43 14.3	+25.5	102.1	43 01.3	+26.7	103.0	42 47.3	+28.0	103.9
9	43 50.6	+23.4	99.9	43 39.8	+24.7	100.8	43 28.0	+26.0	101.8	43 15.3	+27.2	102.7
10	44 14.0	+22.4	98.6	44 04.5	+23.8	99.6	43 54.0	+25.1	100.5	43 42.5	+26.5	101.5
11	44 36.4	+21.6	97.3	44 28.3	+22.9	98.3	44 19.1	+24.3	99.3	44 09.0	+25.6	100.2
12	44 58.0	+20.7	96.0	44 51.2	+22.1	97.0	44 43.4	+23.4	98.0	44 34.6	+24.7	99.0
13	45 18.7	+19.7	94.7	45 13.3	+21.1	95.7	45 06.8	+22.5	96.7	44 59.3	+23.9	97.7
14	45 38.4	+18.8	93.3	45 34.4	+20.2	94.4	45 29.3	+21.6	95.4	45 23.2	+23.0	96.4
15	45 57.2	+17.8	92.0	45 54.6	+19.2	93.0	45 50.9	+20.7	94.0	45 46.2	+22.0	95.1
16	46 15.0	+16.8	90.6	46 13.8	+18.3	91.6	46 11.6	+19.7	92.7	46 08.2	+21.1	93.7
17	46 31.8	+15.8	89.2	46 32.1	+17.2	90.3	46 31.3	+18.7	91.3	46 29.3	+20.2	92.4
18	46 47.6	+14.7	87.8	46 49.3	+16.2	88.9	46 50.0	+17.6	89.9	46 49.5	+19.1	91.0
19	47 02.3	+13.7	86.4	47 05.5	+15.2	87.5	47 07.6	+16.7	88.5	47 08.6	+18.1	89.6

27° Hc	d	Z	28° Hc	d	Z	29° Hc	d	Z	30° Hc	d	Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
38 14.3	+34.5	113.7	37 49.9	+35.4	114.4	37 24.8	+36.4	115.1	36 59.0	+37.4	115.8	0
38 48.8	+33.8	112.6	38 25.3	+34.9	113.4	38 01.2	+35.8	114.1	37 36.4	+36.8	114.8	1
39 22.6	+33.2	111.6	39 00.2	+34.3	112.3	38 37.0	+35.3	113.1	38 13.2	+36.3	113.8	2
39 55.8	+32.7	110.5	39 34.5	+33.6	111.3	39 12.3	+34.8	112.0	38 49.5	+35.7	112.8	3
40 28.5	+31.9	109.4	40 08.1	+33.1	110.2	39 47.1	+34.1	111.0	39 25.2	+35.2	111.7	4
41 00.4	+31.4	108.3	40 41.2	+32.5	109.1	40 21.2	+33.6	109.9	40 00.4	+34.6	110.7	5
41 31.8	+30.6	107.1	41 13.7	+31.8	108.0	40 54.8	+32.9	108.8	40 35.0	+34.0	109.6	6
42 02.4	+30.0	106.0	41 45.5	+31.1	106.8	41 27.7	+32.3	107.7	41 09.0	+33.4	108.5	7
42 32.4	+29.2	104.8	42 16.6	+30.4	105.7	42 00.0	+31.6	106.6	41 42.4	+32.8	107.4	8
43 01.6	+28.5	103.6	42 47.0	+29.7	104.5	42 31.6	+30.8	105.4	42 15.2	+32.0	106.3	9
43 30.1	+27.7	102.4	43 16.7	+29.0	103.3	43 02.4	+30.2	104.2	42 47.2	+31.4	105.1	10
43 57.8	+26.9	101.2	43 45.7	+28.2	102.1	43 32.6	+29.4	103.1	43 18.6	+30.6	104.0	11
44 24.7	+26.1	99.9	44 13.9	+27.3	100.9	44 02.0	+28.7	101.8	43 49.2	+29.9	102.8	12
44 50.8	+25.2	98.7	44 41.2	+26.6	99.6	44 30.7	+27.8	100.6	44 19.1	+29.1	101.6	13
45 16.0	+24.3	97.4	45 07.8	+25.7	98.4	44 58.5	+27.0	99.4	44 48.2	+28.3	100.4	14
45 40.3	+23.5	96.1	45 33.5	+24.8	97.1	45 25.5	+26.2	98.1	45 16.5	+27.5	99.1	15
46 03.8	+22.5	94.8	45 58.3	+23.9	95.8	45 51.7	+25.3	96.8	45 44.0	+26.7	97.8	16
46 26.3	+21.6	93.4	46 22.2	+23.0	94.5	46 17.0	+24.3	95.5	46 10.7	+25.7	96.5	17
46 47.9	+20.6	92.1	46 45.2	+22.0	93.1	46 41.3	+23.5	94.2	46 36.4	+24.8	95.2	18
47 08.5	+19.5	90.7	47 07.2	+21.0	91.8	47 04.8	+22.4	92.8	47 01.2	+23.9	93.9	19

Step 9: Determine the azimuth correction for the sight (to account for increments of declination ignored in step 8).

By increasing the value of each argument by 1 whole increment, triple interpolate for the exact values of azimuth (for detailed instructions see Part 14).

	Base Value	Base Z	Next incremental Z	Difference in Z	Increment	Correction *(Diff Z x Increment) / 60*
Latitude – S	28°	98.4°	-	-	00.0’	0
Declination – S	14°	98.4°	97.1°	-1.3°	55.0’	-1.19°
LHA	314°	98.4°	-	-	00.0’	0

Total correction = -<u>1.2°</u>

Step 10: Apply the correction to the base values to determine true azimuth.
Base azimuth: 98.4°
Correction: -1.2°
Corrected azimuth: 97.2°
Note - Check azimuth rules: if LHA greater than 180°, then zn = 180° z.
Corrected azimuth: 180° - 97.2° = <u>82.8° T</u>

Step 11: Determine the computed altitude.
Tabular computed altitude (hc): 45° 07.8’
Altitude difference (d): +25.7’
Declination: S 14° 55.0’
Declination increments: 55.0’

Altitude difference correction:
Tens: +18.3’
Units/decimals: +5.2’
Total correction: +<u>23.5’</u>

Tabular hc: 45° 07.8’
Alt correction: +23.5’
hc: <u>45° 31.3’</u>

Dec. Inc.	Altitude Difference (d) Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
55.0	9.1	18.3	27.5	36.6	45.8	**.0**	0.0	0.9	1.8	2.8	3.7	4.6	5.5	6.5	7.4	8.3
55.1	9.2	18.3	27.5	36.7	45.9	**.1**	0.1	1.0	1.9	2.9	3.8	4.7	5.6	6.6	7.5	8.4
55.2	9.2	18.4	27.6	36.8	46.0	**.2**	0.2	1.1	2.0	3.0	3.9	4.8	5.7	6.7	7.6	8.5
55.3	9.2	18.4	27.6	36.9	46.1	**.3**	0.3	1.2	2.1	3.1	4.0	4.9	5.8	6.8	7.7	8.6
55.4	9.2	18.5	27.7	36.9	46.2	**.4**	0.4	1.3	2.2	3.1	4.1	5.0	5.9	6.8	7.8	8.7
55.5	9.3	18.5	27.8	37.0	46.3	**.5**	0.5	1.4	2.3	3.2	4.2	5.1	6.0	6.9	7.9	8.8
55.6	9.3	18.5	27.8	37.1	46.3	**.6**	0.6	1.5	2.4	3.3	4.3	5.2	6.1	7.0	8.0	8.9
55.7	9.3	18.6	27.9	37.2	46.4	**.7**	0.6	1.6	2.5	3.4	4.3	5.3	6.2	7.1	8.0	9.0
55.8	9.3	18.6	27.9	37.2	46.5	**.8**	0.7	1.7	2.6	3.5	4.4	5.4	6.3	7.2	8.1	9.1
55.9	9.4	18.7	28.0	37.3	46.6	**.9**	0.8	1.8	2.7	3.6	4.5	5.5	6.4	7.3	8.2	9.2

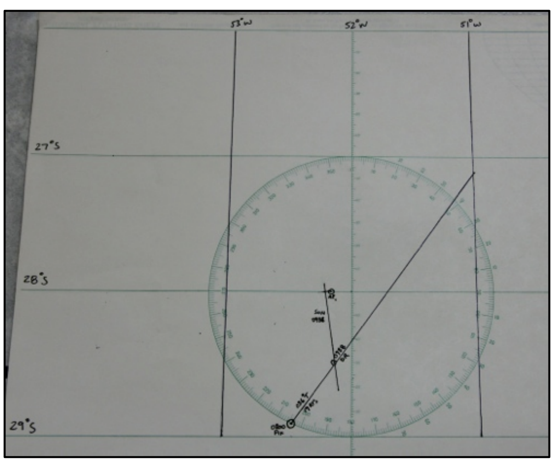
Step 12: Determine the intercept (a).
Observed altitude: 45° 29.2’
Computed altitude: 45° 31.3’
Intercept (a): 45° 31.3’ – 45° 29.2’ = <u>2.1’</u>
If computed altitude is greater, intercept is <u>away.</u>

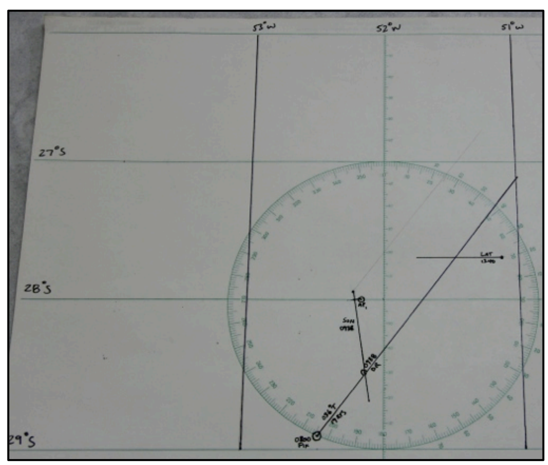
40m	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′	′	′	′	′
00	10 00·0	10 01·6	9 32·7	0·0	0·0	6·0	4·1	12·0	8·1
01	10 00·3	10 01·9	9 32·9	0·1	0·1	6·1	4·1	12·1	8·2
02	10 00·5	10 02·1	9 33·1	0·2	0·1	6·2	4·2	12·2	8·2
03	10 00·8	10 02·4	9 33·4	0·3	0·2	6·3	4·3	12·3	8·3
04	10 01·0	10 02·6	9 33·6	0·4	0·3	6·4	4·3	12·4	8·4
05	10 01·3	10 02·9	9 33·9	0·5	0·3	6·5	4·4	12·5	8·4
06	10 01·5	10 03·1	9 34·1	0·6	0·4	6·6	4·5	12·6	8·5
07	10 01·8	10 03·4	9 34·3	0·7	0·5	6·7	4·5	12·7	8·6
08	10 02·0	10 03·6	9 34·6	0·8	0·5	6·8	4·6	12·8	8·6
09	10 02·3	10 03·9	9 34·8	0·9	0·6	6·9	4·7	12·9	8·7

Step 13: Plot the morning Sun sight.
Assumed position: 28° S, 52° 08.2’ W
Azimuth: 082.8’
Intercept: 2.1’ away

Step 14: Calculated the latitude at meridian passage.
Time of meridian passage sight: 1240 zone time or 1540 GMT
Observed altitude: 77° 10.5’
Zenith Distance: 90° 00.0 – 77° 10.5’ = <u>12° 49.5’</u>
Declination (Sun – hours): 14° 53.1’ S (d number = -0.8)
Declination (Sun – increments): -0.5’
Declination (Sun – total): <u>14° 52.6’</u>
Latitude at meridian passage = zenith distance + declination =
12° 49.5’ N + 14° 52.6’ N = <u>27° 42.1’ S</u>

Step 15: Plot the meridian passage latitude.
Latitude: 27° 42.1’ S



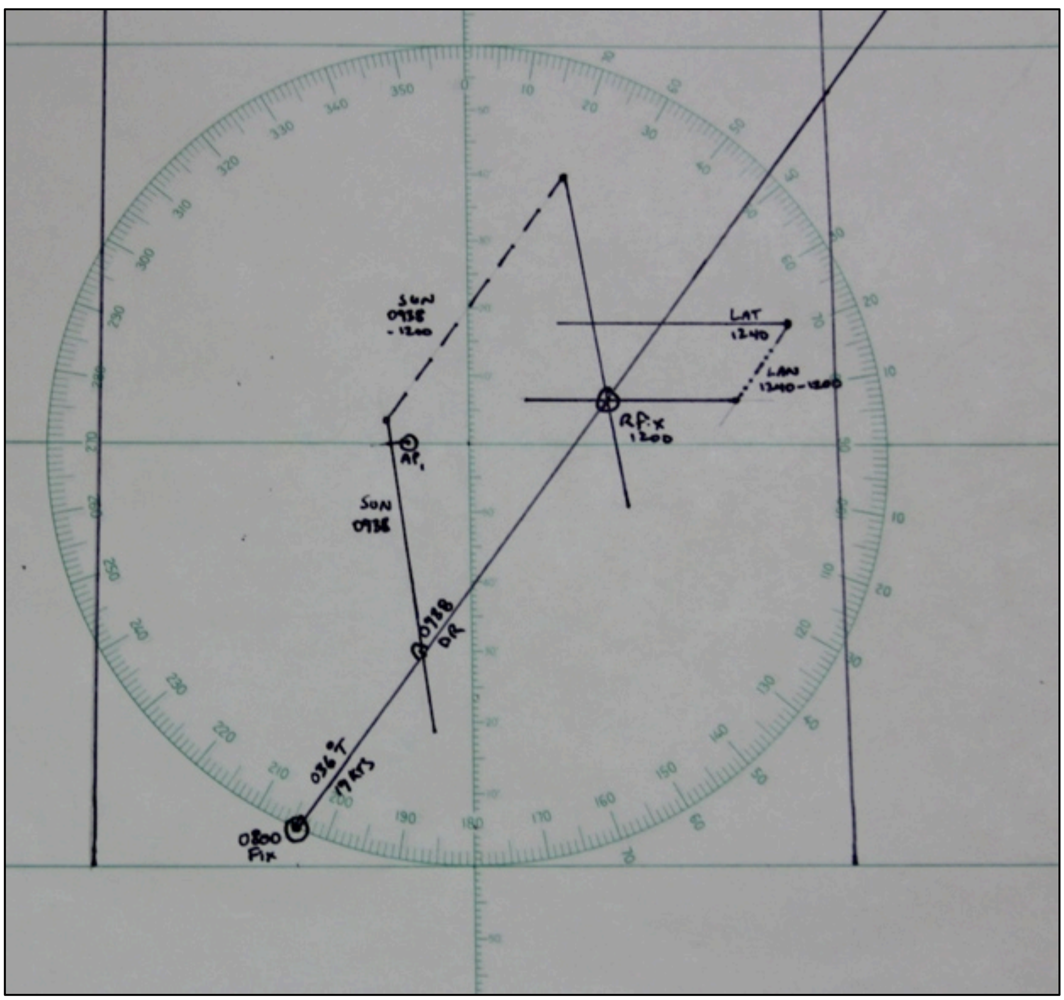


Step 16: Advance the morning Sun sight (0938 zone time) and retard the meridian passage latitude (1240 zone time) both to 1200 zone time to determine the running fix.

a. Morning Sun sight: 0938 zone time to 1200 zone time = 2 hours 22 minutes = 2.36 hours
2.36 hours at 19 knots = 44.8 miles covered (course 036° T)

b. Meridian passage latitude: 1240 zone time to 1200 = 40 minutes = 0.67 hours.
0.67 hours at 19 knots = 12.67 miles covered (course 036° T reciprocal)

Step 17: Answer the required question.
Longitude = **51° 36.0’ W**



FIX D2. At 0100 zone time on 23 September, your DR position is latitude 24° 25' N, longitude 83° 00' W. You are steering course 315° T. The speed over ground is 10 knots. You observe 3 morning sun lines. Determine the latitude and longitude of your 1100 running fix.

Body	Zone Time	GHA	Observed Altitude	Declination
Sun	0700	17° 20.1'	21° 09.0'	S 00° 09.7'
Sun	0900	47° 03.0'	46° 05.0'	S 00° 11.6'
Sun	1100	77° 06.4'	63° 16.1'	S 00° 13.5'

Answer: 25° 35' N, 84° 17' W

Step 1: Determine the DR position of the ship for each Sun sight. Note this solution uses a plotting sheet, but the position may also be advanced by mid-latitude sailing.

Sight	*Original Fix (0100)*	*Sun (0700)*	*Sun (0900)*	*Sun (1100)*
Course/Speed	315°, 10 knots	Same	Same	Same
Time difference	-	06 hours	08 hours	10 hours
Distance covered	-	60 miles	80 miles	100 miles
DR latitude	24° 25.0' N	**25° 07' N**	**25° 22' N**	**25° 36' N**
DR longitude	83° 00.0' W	**83° 47' W**	**84° 02' W**	**84° 18' W**

Step 2: Given the GHA information presented in the question, determine the assumed position of the ship and the LHA for each Sun sight.

Sight		*Sun (0700)*	*Sun (0900)*	*Sun (1100)*
DR latitude		25° 07' N	25° 22' N	25° 36' N
DR longitude		83° 47' W	84° 02' W	84° 18' W
Assumed latitude		**25° N**	**25° N**	**26° N**
GHA (total)	*Given*	17° 20.1 '	47° 03.0'	77° 06.4'
Assumed longitude	*To ensure whole value of LHA*	**83° 20.1' W**	**84° 03.0' W**	**84° 06.4' W**
LHA	*Subtract west, add east (±360°)*	**294°**	**323°**	**353°**

Step 3: Given the declination and altitude information presented in the question, as well as the LHA information determined in step 2, enter publication HO229 and construct a table with computed altitude (hc), altitude difference (a), and azimuth (zn).

Sight		*Sun (0700)*	*Sun (0900)*	*Sun (1100)*
Assumed latitude		25° N	25° N	26° N
Declination		S 0° 09.7’	S 0° 11.6’	S 0° 13.5’
LHA		294° Contrary	323° Contrary	353° Contrary
Computed altitude (hc)	*From HO229*	**21° 37.9’**	**46° 22.2’**	**63° 08.3’**
Altitude difference (d)	*From HO229*	**-27.5’**	**-37.1’**	**-58.3’**
Azimuth (z)	*From HO229*	**100.7°**	**119.3°**	**164.4°**

LATITUDE CONTRARY NAME TO DECLINATION L.H.A. 66°, 294°

	23°			24°			25°			26°			27°			28°			29°			30°			
Dec. °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Dec. °
0	21 59.2	−25.4	99.9	21 48.8	−26.5	100.3	21 37.9	−27.5	100.7	21 26.6	−28.4	101.0	21 14.9	−29.4	101.4	21 02.8	−30.3	101.8	20 50.3	−31.2	102.2	20 37.5	−32.2	102.6	0
1	21 33.8	−25.8	100.8	21 22.3	−26.8	101.2	21 10.4	−27.7	101.6	20 58.2	−28.8	102.0	20 45.5	−29.7	102.4	20 32.5	−30.7	102.7	20 19.1	−31.6	103.1	20 05.3	−32.5	103.5	1
2	21 08.0	−26.1	101.8	20 55.5	−27.1	102.2	20 42.7	−28.1	102.6	20 29.4	−29.0	102.9	20 15.8	−30.0	103.3	20 01.8	−30.9	103.6	19 47.5	−31.8	104.0	19 32.8	−32.7	104.3	2
3	20 41.9	−26.5	102.8	20 28.4	−27.4	103.1	20 14.6	−28.4	103.5	20 00.4	−29.3	103.9	19 45.8	−30.2	104.2	19 30.9	−31.1	104.6	19 15.7	−32.1	104.9	19 00.1	−33.0	105.2	3
4	20 15.4	−26.7	103.7	20 01.0	−27.7	104.1	19 46.2	−28.6	104.4	19 31.1	−29.6	104.8	19 15.6	−30.5	105.1	18 59.8	−31.5	105.5	18 43.6	−32.3	105.8	18 27.1	−33.2	106.1	4

LATITUDE CONTRARY NAME TO DECLINATION L.H.A. 37°, 323°

	23°			24°			25°			26°			27°			28°			29°			30°			
Dec. °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Dec. °
0	47 19.2	−35.0	117.4	46 51.1	−36.0	118.4	46 22.2	−37.1	119.3	45 52.4	−38.1	120.2	45 21.9	−39.1	121.1	44 50.5	−40.0	121.9	44 18.4	−40.9	122.8	43 45.6	−41.8	123.6	0
1	46 44.2	−35.7	118.6	46 15.1	−36.8	119.5	45 45.1	−37.7	120.4	45 14.3	−38.7	121.3	44 42.8	−39.7	122.1	44 10.5	−40.6	123.0	43 37.5	−41.5	123.8	43 03.8	−42.3	124.6	1
2	46 08.5	−36.3	119.8	45 38.3	−37.3	120.7	45 07.4	−38.4	121.5	44 35.6	−39.3	122.4	44 03.1	−40.2	123.2	43 29.9	−41.1	124.0	42 56.0	−41.9	124.8	42 21.5	−42.8	125.5	2
3	45 32.2	−37.1	120.9	45 01.0	−38.1	121.8	44 29.0	−39.0	122.6	43 56.3	−39.9	123.4	43 22.9	−40.8	124.2	42 48.8	−41.6	125.0	42 14.1	−42.4	125.7	41 38.7	−43.2	126.5	3
4	44 55.1	−37.7	122.0	44 22.9	−38.6	122.9	43 50.0	−39.5	123.7	43 16.4	−40.4	124.5	42 42.1	−41.3	125.2	42 07.2	−42.1	126.0	41 31.7	−42.9	126.7	40 55.5	−43.6	127.4	4

LATITUDE CONTRARY NAME TO DECLINATION L.H.A. 7°, 353°

	23°			24°			25°			26°			27°			28°			29°			30°			
Dec. °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Hc ° ′	d ′	Z °	Dec. °
0	66 00.8	−57.7	162.6	65 03.5	−58.0	163.2	64 06.0	−58.2	163.8	63 08.3	−58.3	164.4	62 10.4	−58.4	164.9	61 12.4	−58.5	165.3	60 14.3	−58.6	165.8	59 16.1	−58.7	166.2	0
1	65 03.1	−57.9	163.2	64 05.5	−58.0	163.8	63 07.8	−58.2	164.4	62 10.0	−58.4	164.9	61 12.0	−58.5	165.3	60 13.9	−58.6	165.8	59 15.7	−58.7	166.2	58 17.4	−58.9	166.6	1
2	64 05.2	−58.1	163.8	63 07.5	−58.3	164.4	62 09.6	−58.4	164.9	61 11.6	−58.5	165.4	60 13.5	−58.6	165.8	59 15.3	−58.7	166.2	58 17.0	−58.8	166.6	57 18.5	−58.8	167.0	2
3	63 07.1	−58.2	164.4	62 09.2	−58.3	164.9	61 11.2	−58.4	165.4	60 13.1	−58.5	165.8	59 14.9	−58.7	166.2	58 16.6	−58.8	166.6	57 18.2	−58.9	167.0	56 19.7	−59.0	167.3	3
4	62 08.9	−58.3	164.9	61 10.9	−58.4	165.4	60 12.8	−58.5	165.8	59 14.6	−58.7	166.2	58 16.2	−58.7	166.6	57 17.8	−58.8	167.0	56 19.3	−58.9	167.3	55 20.7	−58.9	167.7	4

Step 4: Given the azimuth information in step 3 (which does not account for increments of declination), construct a table to determine correct azimuths.

Sight		*Sun (0700)*	*Sun (0900)*	*Sun (1100)*
Base Azimuth (Z)	*From HO229*	100.7°	119.3°	164.4°
Next incremental Z		101.6°	120.4°	164.9°
Difference		0.9°	1.1°	0.5°
Declination Increment	*From given declination*	09.7’	11.6’	13.5’
Correction (Diff Z x Increment) / 60		+0.15°	+0.21°	+0.11°
Corrected azimuth (Z)		100.9°	119.5°	164.5°
Azimuth rules corrected azimuth (Zn)	*If LHA greater than 180°, Zn = z*	**100.9°**	**119.5°**	**164.5°**

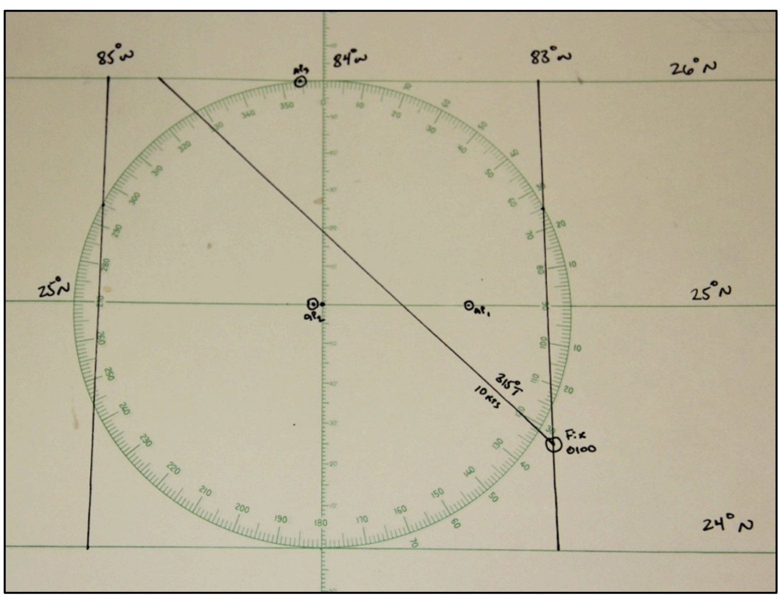
Step 5: Given the tabular HO229 information in step 3 determine the correct computed altitude (hc) for the three Sun sights.

Sight		*Sun (0700)*	*Sun (0900)*	*Sun (1100)*
Tabular computed altitude	*From step 3*	**21° 37.9’**	**46° 22.2’**	**63° 08.3’**
Altitude difference (d)	*From step 3*	**-27.5’**	**-37.1’**	**-58.3’**
Declination increment	*From given declination*	09.7’	11.6’	13.5’
Altitude difference	*From HO229 interpolation table*	-4.4’	-7.2’	-13.1’
Correct computed altitude		**21° 33.5’**	**46° 15.0’**	**62° 55.2’**

Step 6: Compare the observed altitudes (given) with the computed altitudes (determined in step 5), to compute intercepts (a) for the three Sun sights.

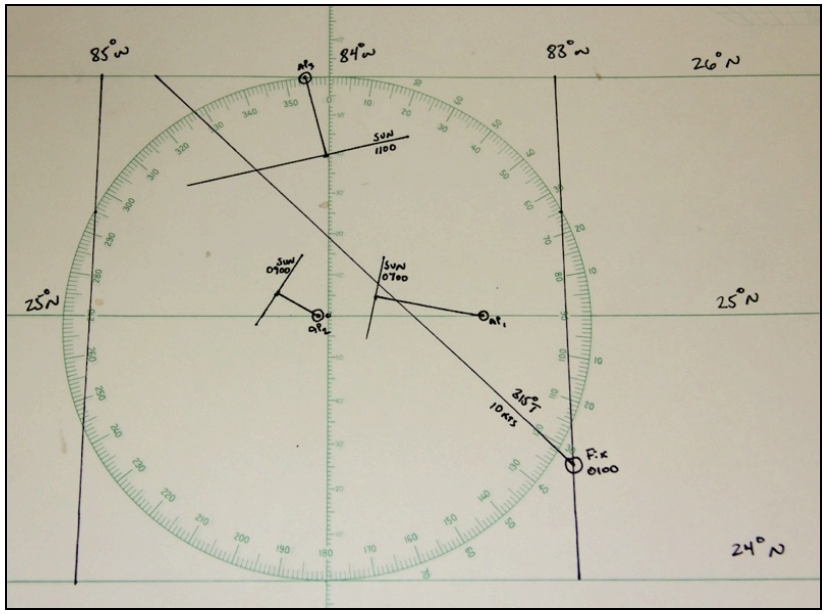
Sight		*Sun (0700)*	*Sun (0900)*	*Sun (1100)*
Observed altitude (ho)	*Given*	21° 09.0’	46° 05.0’	63° 16.1’
Correct computed altitude (hc)	*From step 5*	21° 33.5’	46° 15.0’	62° 55.2’
Intercept (a)	*hc – ho*	**24.5’**	**10.0’**	**20.9’**
Towards/Away	*If hc is greater, intercept is “away”*	**Away**	**Away**	**Towards**
Azimuth	*Repeated from step 4*	100.9° T	119.5° T	164.5° T

Step 7: Plot the assumed positions for each Sun sight.

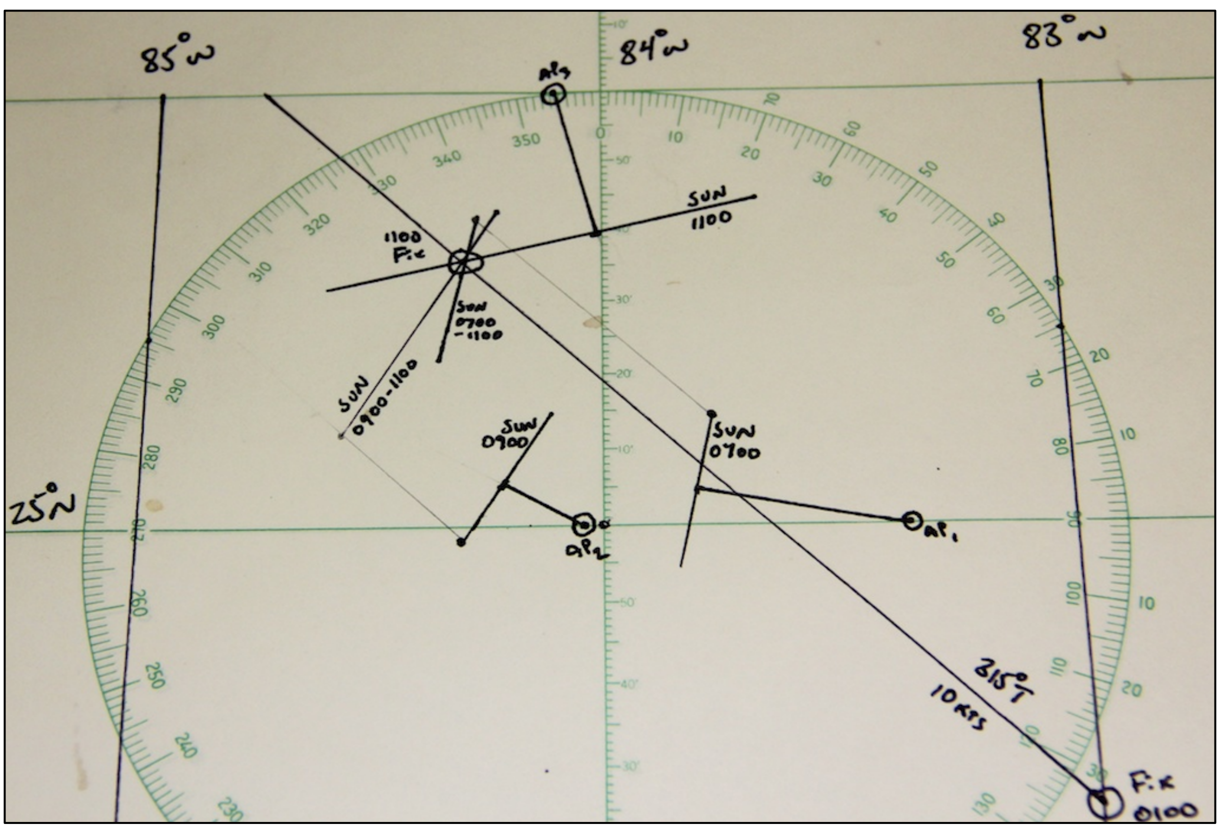


Dec. Inc.	Altitude Difference (d)															
	Tens					Decimals	Units									
	10′	20′	30′	40′	50′	⇓	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
9.0	1.5	3.0	4.5	6.0	7.5	**.0**	0.0	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.4
9.1	1.5	3.0	4.5	6.0	7.6	**.1**	0.0	0.2	0.3	0.5	0.6	0.8	1.0	1.1	1.3	1.4
9.2	1.5	3.0	4.6	6.1	7.6	**.2**	0.0	0.2	0.3	0.5	0.7	0.8	1.0	1.1	1.3	1.5
9.3	1.5	3.1	4.6	6.2	7.7	**.3**	0.0	0.2	0.4	0.5	0.7	0.8	1.0	1.2	1.3	1.5
9.4	1.6	3.1	4.7	6.3	7.8	**.4**	0.1	0.2	0.4	0.5	0.7	0.9	1.0	1.2	1.3	1.5
9.5	1.6	3.2	4.8	6.3	7.9	**.5**	0.1	0.2	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5
9.6	1.6	3.2	4.8	6.4	8.0	**.6**	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.4	1.5
9.7	1.6	3.3	4.9	6.5	8.1	**.7**	0.1	0.3	0.4	0.6	0.7	0.9	1.1	1.2	1.4	1.5
9.8	1.7	3.3	4.9	6.6	8.2	**.8**	0.1	0.3	0.4	0.6	0.8	0.9	1.1	1.2	1.4	1.6
9.9	1.7	3.3	5.0	6.6	8.3	**.9**	0.1	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.4	1.6
10.0	1.6	3.3	5.0	6.6	8.3	**.0**	0.0	0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.6
10.1	1.7	3.3	5.0	6.7	8.4	**.1**	0.0	0.2	0.4	0.5	0.7	0.9	1.1	1.2	1.4	1.6
10.2	1.7	3.4	5.1	6.8	8.5	**.2**	0.0	0.2	0.4	0.6	0.7	0.9	1.1	1.3	1.4	1.6
10.3	1.7	3.4	5.1	6.9	8.6	**.3**	0.1	0.2	0.4	0.6	0.8	0.9	1.1	1.3	1.5	1.6
10.4	1.7	3.5	5.2	6.9	8.7	**.4**	0.1	0.2	0.4	0.6	0.8	0.9	1.1	1.3	1.5	1.6
10.5	1.8	3.5	5.3	7.0	8.8	**.5**	0.1	0.3	0.4	0.6	0.8	1.0	1.1	1.3	1.5	1.7
10.6	1.8	3.5	5.3	7.1	8.8	**.6**	0.1	0.3	0.5	0.6	0.8	1.0	1.2	1.3	1.5	1.7
10.7	1.8	3.6	5.4	7.2	8.9	**.7**	0.1	0.3	0.5	0.6	0.8	1.0	1.2	1.3	1.5	1.7
10.8	1.8	3.6	5.4	7.2	9.0	**.8**	0.1	0.3	0.5	0.7	0.8	1.0	1.2	1.4	1.5	1.7
10.9	1.9	3.7	5.5	7.3	9.1	**.9**	0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.6	1.7
11.0	1.8	3.6	5.5	7.3	9.1	**.0**	0.0	0.2	0.4	0.6	0.8	1.0	1.1	1.3	1.5	1.7
11.1	1.8	3.7	5.5	7.4	9.2	**.1**	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.7
11.2	1.8	3.7	5.6	7.4	9.3	**.2**	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
11.3	1.9	3.8	5.6	7.5	9.4	**.3**	0.1	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
11.4	1.9	3.8	5.7	7.6	9.5	**.4**	0.1	0.3	0.5	0.7	0.8	1.0	1.2	1.4	1.6	1.8
11.5	1.9	3.8	5.8	7.7	9.6	**.5**	0.1	0.3	0.5	0.7	0.9	1.1	1.2	1.4	1.6	1.8
11.6	1.9	3.9	5.8	7.7	9.7	**.6**	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.6	1.8
11.7	2.0	3.9	5.9	7.8	9.8	**.7**	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9
11.8	2.0	4.0	5.9	7.9	9.9	**.8**	0.2	0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9
11.9	2.0	4.0	6.0	8.0	10.0	**.9**	0.2	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.9
12.0	2.0	4.0	6.0	8.0	10.0	**.0**	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.5	1.7	1.9
12.1	2.0	4.0	6.0	8.0	10.1	**.1**	0.0	0.2	0.4	0.6	0.9	1.1	1.3	1.5	1.7	1.9
12.2	2.0	4.0	6.1	8.1	10.1	**.2**	0.0	0.2	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9
12.3	2.0	4.1	6.1	8.2	10.2	**.3**	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9
12.4	2.1	4.1	6.2	8.3	10.3	**.4**	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.7	2.0
12.5	2.1	4.2	6.3	8.3	10.4	**.5**	0.1	0.3	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.0
12.6	2.1	4.2	6.3	8.4	10.5	**.6**	0.1	0.3	0.5	0.7	1.0	1.2	1.4	1.6	1.8	2.0
12.7	2.1	4.3	6.4	8.5	10.6	**.7**	0.1	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
12.8	2.2	4.3	6.4	8.6	10.7	**.8**	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
12.9	2.2	4.3	6.5	8.6	10.8	**.9**	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.9	2.1
13.0	2.1	4.3	6.5	8.6	10.8	**.0**	0.0	0.2	0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0
13.1	2.2	4.3	6.5	8.7	10.9	**.1**	0.0	0.2	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.0
13.2	2.2	4.4	6.6	8.8	11.0	**.2**	0.0	0.3	0.5	0.7	0.9	1.2	1.4	1.6	1.8	2.1
13.3	2.2	4.4	6.6	8.9	11.1	**.3**	0.1	0.3	0.5	0.7	1.0	1.2	1.4	1.6	1.9	2.1
13.4	2.2	4.5	6.7	8.9	11.2	**.4**	0.1	0.3	0.5	0.8	1.0	1.2	1.4	1.7	1.9	2.1
13.5	2.3	4.5	6.8	9.0	11.3	**.5**	0.1	0.3	0.6	0.8	1.0	1.2	1.5	1.7	1.9	2.1
13.6	2.3	4.5	6.8	9.1	11.3	**.6**	0.1	0.4	0.6	0.8	1.0	1.3	1.5	1.7	1.9	2.2
13.7	2.3	4.6	6.9	9.2	11.4	**.7**	0.2	0.4	0.6	0.8	1.1	1.3	1.5	1.7	2.0	2.2
13.8	2.3	4.6	6.9	9.2	11.5	**.8**	0.2	0.4	0.6	0.9	1.1	1.3	1.5	1.8	2.0	2.2
13.9	2.4	4.7	7.0	9.3	11.6	**.9**	0.2	0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2

Step 8: Plot each Sun sight's line of position.



Step 9: Advance the 0700 and 0900 Sun lines of position to 1100 to determine the running fix.
Fix: 25° 35' N, 84° 17' W



Any Celestial Body Fixes

FIX D3. On 6 April your 1830 zone time DR position is latitude 26° 33’ N, longitude 64° 31’ W. You are on course 082° T at a speed of 16 knots. You observe 3 celestial bodies. Determine the latitude and longitude of your 1900 running fix.

Body	Zone Time	GHA	Observed Altitude	Declination
Sirius	1836	73° 02.7’	46° 00.5’	S 16° 41.7’
Regulus	1842	23° 46.9’	49° 07.2’	N 12° 03.5’
Mirfak	1900	129° 24.3’	35° 51.6’	N 49° 47.7’

Answer: 26° 33’ N, 64° 27’ W

Step 1: Determine the DR position of the ship for each star sight. Note this solution uses a plotting sheet, but the position may also be advanced by mid-latitude sailing.

Sight	*Original DR (1830)*	*Sirius (1836)*	*Regulus (1842)*	*Mirfak (1900)*
Course/Speed	082°, 16 knots	Same	Same	Same
Time difference	-	6 minutes	12 minutes	30 minutes
Distance covered	-	1.6 nm	3.2 nm	8 nm
DR latitude	26° 33.0’ N	**26° 33’ N**	**26° 33 N**	**26° 34’ N**
DR longitude	64° 31.0’ W	**64° 29’ W**	**64° 28’ W**	**64° 22’ W**

Step 2: Given the GHA information presented in the question, determine the assumed position of the ship and the LHA for each star sight.

Sight		*Sirius (1836)*	*Regulus (1842)*	*Mirfak (1900)*
DR latitude		26° 33’ N	26° 33 N	26° 34’ N
DR longitude		64° 29’ W	64° 28’ W	64° 22’ W
Assumed latitude		**27° N**	**27° N**	**27° N**
GHA (total)	*Given*	73° 02.7	23° 46.9’	129° 24.3’
Assumed longitude	*To ensure whole value of LHA*	**64° 02.7’ W**	**64° 46.9’ W**	**64° 24.3’ W**
LHA	*Subtract west, add east (±360°)*	**9°**	**319°**	**65°**

Step 3: Given the declination and altitude information presented in the question, as well as the LHA information determined in step 2, enter publication HO229 and construct a table with computed altitude (hc), altitude difference (a), and azimuth (zn).

Sight		*Sirius (1836)*	*Regulus (1842)*	*Mirfak (1900)*
Assumed latitude		27° N	27° N	27° N
Declination		S 16° 41.7'	N 12° 03.5'	N 49° 47.7'
LHA		9° Contrary	319° Same	65° Same
Computed altitude (hc)	*From HO229*	**46° 07.3'**	**48° 46.6'**	**36° 08.0'**
Altitude difference (d)	*From HO229*	**-58.8'**	**27.2'**	**0.7'**
Azimuth (z)	*From HO229*	**167.5°**	**103.1°**	**47.4°**

LATITUDE CONTRARY NAME TO DECLINATION L.H.A. 9°, 351°

Dec.	23°			24°			25°			26°			27°			28°			29°			30°			Dec.
	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	
°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	°
0	65 23.5	−56.5	157.9	64 27.7	−56.7	158.7	63 31.7	−57.0	159.5	62 35.4	−57.3	160.1	61 38.8	−57.4	160.8	60 42.1	−57.7	161.4	59 45.1	−57.8	161.9	58 48.0	−58.0	162.4	0
1	64 27.0	−56.6	158.7	63 31.0	−57.0	159.5	62 34.7	−57.2	160.1	61 38.1	−57.4	160.8	60 41.4	−57.6	161.4	59 44.4	−57.7	161.9	58 47.3	−57.9	162.4	57 50.0	−58.1	162.9	1
2	63 30.4	−56.9	159.5	62 34.0	−57.1	160.2	61 37.5	−57.4	160.8	60 40.7	−57.5	161.4	59 43.8	−57.7	161.9	58 46.7	−57.9	162.4	57 49.4	−58.1	162.9	56 51.9	−58.1	163.4	2
3	62 33.5	−57.1	160.2	61 36.9	−57.3	160.8	60 40.1	−57.5	161.4	59 43.2	−57.7	162.0	58 46.1	−57.9	162.5	57 48.8	−58.0	162.9	56 51.3	−58.1	163.4	55 53.8	−58.3	163.8	3
4	61 36.4	−57.3	160.8	60 39.6	−57.5	161.4	59 42.6	−57.6	162.0	58 45.5	−57.8	162.5	57 48.2	−58.0	163.0	56 50.8	−58.1	163.4	55 53.2	−58.2	163.8	54 55.5	−58.3	164.2	4
5	60 39.1	−57.4	161.5	59 42.1	−57.6	162.0	58 45.0	−57.8	162.5	57 47.7	−57.9	163.0	56 50.2	−58.0	163.4	55 52.7	−58.2	163.9	54 55.0	−58.4	164.3	53 57.2	−58.5	164.6	5
6	59 41.7	−57.6	162.0	58 44.5	−57.7	162.6	57 47.2	−57.9	163.0	56 49.8	−58.1	163.5	55 52.2	−58.2	163.9	54 54.5	−58.3	164.3	53 56.6	−58.3	164.7	52 58.7	−58.5	165.0	6
7	58 44.1	−57.7	162.6	57 46.8	−57.9	163.1	56 49.3	−58.0	163.5	55 51.7	−58.1	163.9	54 54.0	−58.3	164.3	53 56.2	−58.4	164.7	52 58.3	−58.5	165.1	52 00.2	−58.5	165.4	7
8	57 46.4	−57.8	163.1	56 48.9	−58.0	163.6	55 51.3	−58.1	164.0	54 53.6	−58.2	164.4	53 55.7	−58.3	164.7	52 57.8	−58.4	165.1	51 59.8	−58.5	165.4	51 01.7	−58.6	165.7	8
9	56 48.6	−58.0	163.6	55 50.9	−58.0	164.0	54 53.2	−58.2	164.4	53 55.4	−58.3	164.8	52 57.4	−58.4	165.1	51 59.4	−58.5	165.5	51 01.3	−58.6	165.8	50 03.1	−58.7	166.1	9
10	55 50.6	−58.0	164.1	54 52.9	−58.2	164.5	53 55.0	−58.3	164.8	52 57.1	−58.4	165.2	51 59.0	−58.5	165.5	51 00.9	−58.6	165.8	50 02.7	−58.7	166.1	49 04.4	−58.8	166.4	10
11	54 52.6	−58.2	164.5	53 54.7	−58.2	164.9	52 56.7	−58.3	165.2	51 58.7	−58.5	165.6	51 00.5	−58.5	165.9	50 02.3	−58.6	166.2	49 04.0	−58.7	166.4	48 05.6	−58.7	166.7	11
12	53 54.4	−58.2	164.9	52 56.5	−58.4	165.3	51 58.4	−58.4	165.6	51 00.2	−58.5	165.9	50 02.0	−58.6	166.2	49 03.7	−58.7	166.5	48 05.3	−58.7	166.8	47 06.9	−58.8	167.0	12
13	52 56.2	−58.3	165.4	51 58.1	−58.4	165.7	51 00.0	−58.5	166.0	50 01.7	−58.6	166.3	49 03.4	−58.7	166.5	48 05.0	−58.7	166.8	47 06.6	−58.8	167.1	46 08.1	−58.9	167.3	13
14	51 57.9	−58.3	165.7	50 59.7	−58.4	166.0	50 01.5	−58.6	166.3	49 03.1	−58.6	166.6	48 04.7	−58.7	166.9	47 06.3	−58.8	167.1	46 07.8	−58.9	167.3	45 09.2	−58.9	167.6	14
15	50 59.6	−58.5	166.1	50 01.3	−58.6	166.4	49 02.9	−58.6	166.7	48 04.5	−58.7	166.9	47 06.0	−58.7	167.2	46 07.5	−58.8	167.4	45 08.9	−58.9	167.6	44 10.3	−59.0	167.8	15
16	50 01.1	−58.5	166.5	49 02.7	−58.5	166.7	48 04.3	−58.6	167.0	47 05.8	−58.7	167.2	46 07.3	−58.8	167.5	45 08.7	−58.9	167.7	44 10.0	−58.9	167.9	43 11.3	−58.9	168.1	16
17	49 02.6	−58.6	166.8	48 04.2	−58.7	167.1	47 05.7	−58.8	167.3	46 07.1	−58.8	167.5	45 08.5	−58.9	167.8	44 09.8	−58.9	168.0	43 11.1	−58.9	168.2	42 12.4	−59.0	168.3	17
18	48 04.0	−58.6	167.1	47 05.5	−58.7	167.4	46 06.9	−58.7	167.6	45 08.3	−58.8	167.8	44 09.6	−58.8	168.0	43 10.9	−58.9	168.2	42 12.2	−59.0	168.4	41 13.4	−59.1	168.6	18
19	47 05.4	−58.6	167.5	46 06.8	−58.7	167.7	45 08.2	−58.8	167.9	44 09.5	−58.9	168.1	43 10.8	−58.9	168.3	42 12.0	−59.0	168.5	41 13.2	−59.0	168.7	40 14.3	−59.0	168.8	19

41°, 319° 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.	23°			24°			25°			26°			27°			28°			29°			30°			Dec.
	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	
°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	°
0	44 00.3	+32.2	114.2	43 35.2	+33.4	115.1	43 09.4	+34.4	115.9	42 42.8	+35.5	116.8	42 15.4	+36.5	117.6	41 47.2	+37.5	118.4	41 18.4	+38.4	119.1	40 48.8	+39.4	119.9	0
1	44 32.5	+31.5	113.0	44 08.6	+32.6	113.9	43 43.8	+33.8	114.8	43 18.3	+34.8	115.7	42 51.9	+35.9	116.5	42 24.7	+36.9	117.3	41 56.8	+37.9	118.1	41 28.2	+38.8	118.9	1
2	45 04.0	+30.7	111.8	44 41.2	+31.9	112.7	44 17.6	+33.0	113.6	43 53.1	+34.2	114.5	43 27.8	+35.2	115.4	43 01.6	+36.3	116.2	42 34.7	+37.3	117.1	42 07.0	+38.3	117.9	2
3	45 34.7	+29.9	110.6	45 13.1	+31.2	111.6	44 50.6	+32.4	112.5	44 27.3	+33.4	113.4	44 03.0	+34.6	114.3	43 37.9	+35.7	115.2	43 12.0	+36.7	116.0	42 45.3	+37.7	116.8	3
4	46 04.6	+29.1	109.4	45 44.3	+30.3	110.3	45 23.0	+31.5	111.3	45 00.7	+32.8	112.2	44 37.6	+33.9	113.1	44 13.6	+35.0	114.0	43 48.7	+36.1	114.9	43 23.0	+37.1	115.8	4
5	46 33.7	+28.3	108.1	46 14.6	+29.5	109.1	45 54.5	+30.8	110.1	45 33.5	+31.9	111.0	45 11.5	+33.1	112.0	44 48.6	+34.3	112.9	44 24.8	+35.4	113.8	44 00.1	+36.5	114.7	5
6	47 02.0	+27.4	106.8	46 44.1	+28.7	107.8	46 25.3	+29.9	108.8	46 05.4	+31.2	109.8	45 44.6	+32.4	110.8	45 22.9	+33.5	111.7	45 00.2	+34.7	112.7	44 36.6	+35.8	113.6	6
7	47 29.4	+26.4	105.5	47 12.8	+27.8	106.5	46 55.2	+29.1	107.6	46 36.6	+30.4	108.6	46 17.0	+31.6	109.6	45 56.4	+32.8	110.5	45 34.9	+34.0	111.5	45 12.4	+35.2	112.4	7
8	47 55.8	+25.5	104.2	47 40.6	+26.9	105.2	47 24.3	+28.2	106.3	47 07.0	+29.5	107.3	46 48.6	+30.8	108.3	46 29.2	+32.1	109.3	46 08.9	+33.2	110.3	45 47.6	+34.4	111.3	8
9	48 21.3	+24.6	102.8	48 07.5	+25.9	103.9	47 52.5	+27.3	105.0	47 36.5	+28.6	106.0	47 19.4	+30.0	107.1	47 01.3	+31.2	108.1	46 42.1	+32.5	109.1	46 22.0	+33.7	110.1	9
10	48 45.9	+23.5	101.4	48 33.4	+25.0	102.5	48 19.8	+26.4	103.6	48 05.1	+27.8	104.7	47 49.4	+29.0	105.8	47 32.5	+30.4	106.8	47 14.6	+31.6	107.9	46 55.7	+32.9	108.9	10
11	49 09.4	+22.5	100.0	48 58.4	+24.0	101.2	48 46.2	+25.4	102.3	48 32.9	+26.8	103.4	48 18.4	+28.2	104.5	48 02.9	+29.5	105.6	47 46.2	+30.9	106.6	47 28.6	+32.0	107.7	11
12	49 31.9	+21.5	98.6	49 22.4	+22.9	99.8	49 11.6	+24.4	100.9	48 59.7	+25.8	102.0	48 46.6	+27.2	103.1	48 32.4	+28.6	104.3	48 17.1	+29.9	105.3	48 00.6	+31.3	106.4	12
13	49 53.4	+20.3	97.2	49 45.3	+21.9	98.3	49 36.0	+23.3	99.5	49 25.5	+24.8	100.6	49 13.8	+26.3	101.8	49 01.0	+27.6	102.9	48 47.0	+29.0	104.0	48 31.9	+30.4	105.1	13
14	50 13.7	+19.3	95.7	50 07.2	+20.7	96.9	49 59.3	+22.3	98.1	49 50.3	+23.8	99.2	49 40.1	+25.2	100.4	49 28.6	+26.7	101.6	49 16.0	+28.1	102.7	49 02.3	+29.4	103.8	14

65°, 295° 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.	23°			24°			25°			26°			27°			28°			29°			30°			Dec.
	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	
°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	° '	'	°	°
0	22 53.6	+25.3	100.3	22 42.7	+26.2	100.7	22 31.3	+27.2	101.1	22 19.5	+28.2	101.6	22 07.2	+29.3	102.0	21 54.6	+30.2	102.3	21 41.6	+31.1	102.7	21 28.1	+32.1	103.1	0
1	23 18.9	+24.9	99.3	23 08.9	+25.9	99.8	22 58.5	+27.0	100.2	22 47.7	+27.9	100.6	22 36.5	+28.9	101.0	22 24.8	+29.9	101.4	22 12.7	+30.9	101.8	22 00.2	+31.8	102.2	1
2	23 43.8	+24.5	98.3	23 34.8	+25.6	98.8	23 25.5	+26.5	99.2	23 15.6	+27.6	99.6	23 05.4	+28.5	100.1	22 54.7	+29.5	100.5	22 43.6	+30.5	100.9	22 32.0	+31.5	101.3	2
3	24 08.3	+24.1	97.3	24 00.4	+25.1	97.8	23 52.0	+26.2	98.2	23 43.2	+27.2	98.7	23 33.9	+28.2	99.1	23 24.2	+29.2	99.5	23 14.1	+30.2	100.0	23 03.5	+31.1	100.4	3
4	24 32.4	+23.7	96.3	24 25.5	+24.8	96.8	24 18.2	+25.8	97.2	24 10.4	+26.8	97.7	24 02.1	+27.9	98.1	23 53.4	+28.9	98.6	23 44.3	+29.8	99.0	23 34.6	+30.8	99.4	4
45	33 27.7	−0.3	50.2	34 05.9	+0.7	50.7	34 43.6	+1.7	51.2	35 21.0	+2.7	51.8	35 57.9	+3.7	52.4	36 34.3	+4.7	52.9	37 10.2	+5.7	53.5	37 45.6	+6.8	54.2	45
46	33 27.4	−1.0	49.0	34 06.6	0.0	49.5	34 45.3	+1.0	50.0	35 23.7	+1.9	50.6	36 01.6	+2.9	51.1	36 39.0	+3.9	51.7	37 15.9	+5.0	52.3	37 52.4	+6.0	52.9	46
47	33 26.4	−1.6	47.8	34 06.6	−0.8	48.3	34 46.3	+0.2	48.8	35 25.6	+1.2	49.3	36 04.5	+2.1	49.9	36 42.9	+3.2	50.4	37 20.9	+4.1	51.0	37 58.4	+5.1	51.6	47
48	33 24.8	−2.3	46.6	34 05.8	−1.4	47.1	34 46.5	−0.5	47.6	35 26.8	+0.4	48.1	36 06.6	+1.4	48.6	36 46.1	+2.3	49.2	37 25.0	+3.4	49.8	38 03.5	+4.4	50.4	48
49	33 22.5	−3.0	45.4	34 04.4	−2.1	45.9	34 46.0	−1.2	46.4	35 27.2	−0.3	46.9	36 08.0	+0.7	47.4	36 48.4	+1.6	48.0	37 28.4	+2.5	48.5	38 07.9	+3.5	49.1	49
50	33 19.5	−3.8	44.2	34 02.3	−2.8	44.7	34 44.8	−2.0	45.2	35 26.9	−1.0	45.7	36 08.7	−0.2	46.2	36 50.0	+0.8	46.7	37 30.9	+1.8	47.3	38 11.4	+2.8	47.8	50
51	33 15.7	−4.3	43.0	33 59.5	−3.6	43.5	34 42.8	−2.6	43.9	35 25.9	−1.8	44.4	36 08.5	−0.9	44.9	36 50.8	0.0	45.5	37 32.7	+0.9	46.0	38 14.2	+1.9	46.6	51
52	33 11.4	−5.1	41.8	33 55.9	−4.2	42.3	34 40.2	−3.4	42.7	35 24.1	−2.6	43.2	36 07.6	−1.6	43.7	36 50.8	−0.7	44.2	37 33.6	+0.2	44.7	38 16.1	+1.0	45.3	52
53	33 06.3	−5.8	40.6	33 51.7	−5.0	41.1	34 36.8	−4.2	41.5	35 21.5	−3.2	42.0	36 06.0	−2.5	42.5	36 50.1	−1.6	43.0	37 33.8	−0.7	43.5	38 17.1	+0.3	44.0	53
54	33 00.5	−6.4	39.4	33 46.7	−5.6	39.9	34 32.6	−4.8	40.3	35 18.3	−4.1	40.8	36 03.5	−3.1	41.2	36 48.5	−2.3	41.7	37 33.1	−1.4	42.2	38 17.4	−0.6	42.7	54

Step 4: Given the azimuth information in step 3 (which does not account for increments of declination), construct a table to determine correct azimuths.

Sight		*Sirius (1836)*	*Regulus (1842)*	*Mirfak (1900)*
Base Azimuth (Z)	*From HO229*	167.5°	103.1°	47.4°
Next incremental Z		167.8°	101.8°	46.2°
Difference		0.3°	-1.3°	-1.2°
Declination Increment	*From given declination*	41.7’	3.5’	47.7’
Correction (Diff Z x Increment) / 60		+0.2°	-0.1°	-1.0°
Corrected azimuth (Z)		167.7°	103.0°	46.5°
Azimuth rules corrected azimuth (Zn)	*Check azimuth rules for LHA on top/bottom of HO229 pages*	**192.3°**	**103.0°**	**313.6°**

Dec. Inc.	Altitude Difference (d)															
	Tens					Decimals	Units									
	10′	20′	30′	40′	50′	⇓	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
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	0.1	0.1
0.1	0.0	0.0	0.0	0.0	0.1	**.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
0.2	0.0	0.0	0.1	0.1	0.1	**.2**	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
0.3	0.0	0.1	0.1	0.2	0.2	**.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
0.4	0.1	0.1	0.2	0.3	0.3	**.4**	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
0.5	0.1	0.2	0.3	0.3	0.4	**.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
0.6	0.1	0.2	0.3	0.4	0.5	**.6**	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
0.7	0.1	0.3	0.4	0.5	0.6	**.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
0.8	0.2	0.3	0.4	0.6	0.7	**.8**	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
0.9	0.2	0.3	0.5	0.6	0.8	**.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
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
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
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
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
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
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
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
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
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
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
58.0	9.6	19.3	29.0	38.6	48.3	**.0**	0.0	1.0	1.9	2.9	3.9	4.9	5.8	6.8	7.8	8.8
58.1	9.7	19.3	29.0	38.7	48.4	**.1**	0.1	1.1	2.0	3.0	4.0	5.0	5.9	6.9	7.9	8.9
58.2	9.7	19.4	29.1	38.8	48.5	**.2**	0.2	1.2	2.1	3.1	4.1	5.1	6.0	7.0	8.0	9.0
58.3	9.7	19.4	29.1	38.9	48.6	**.3**	0.3	1.3	2.2	3.2	4.2	5.2	6.1	7.1	8.1	9.1
58.4	9.7	19.5	29.2	38.9	48.7	**.4**	0.4	1.4	2.3	3.3	4.3	5.3	6.2	7.2	8.2	9.2
58.5	9.8	19.5	29.3	39.0	48.8	**.5**	0.5	1.5	2.4	3.4	4.4	5.4	6.3	7.3	8.3	9.3
58.6	9.8	19.5	29.3	39.1	48.8	**.6**	0.6	1.6	2.5	3.5	4.5	5.5	6.4	7.4	8.4	9.4
58.7	9.8	19.6	29.4	39.2	48.9	**.7**	0.7	1.7	2.6	3.6	4.6	5.6	6.5	7.5	8.5	9.5
58.8	9.8	19.6	29.4	39.2	49.0	**.8**	0.8	1.8	2.7	3.7	4.7	5.7	6.6	7.6	8.6	9.6
58.9	9.9	19.7	29.5	39.3	49.1	**.9**	0.9	1.9	2.8	3.8	4.8	5.8	6.7	7.7	8.7	9.7

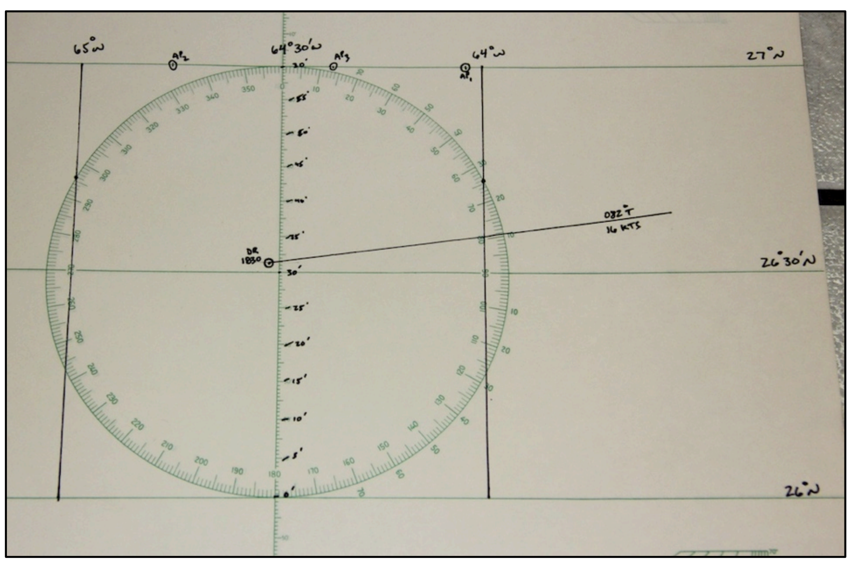
Step 5: Given the tabular HO229 information in step 3, determine the correct computed altitude (hc) for the three-star sights.

Sight		*Sirius (1836)*	*Regulus (1842)*	*Mirfak (1900)*
Tabular computed altitude	*From step 3*	**46° 07.3’**	**48° 46.6’**	**36° 08.0’**
Altitude difference (d)	*From step 3*	**-58.8’**	**27.2’**	**0.7’**
Declination increment	*From given declination*	41.7’	3.5’	47.7’
Altitude difference	*From HO229 interpolation table*	-40.9’	+1.6’	+0.6’
Correct computed altitude		**45° 26.4**	**48° 48.2’**	**36° 08.6’**

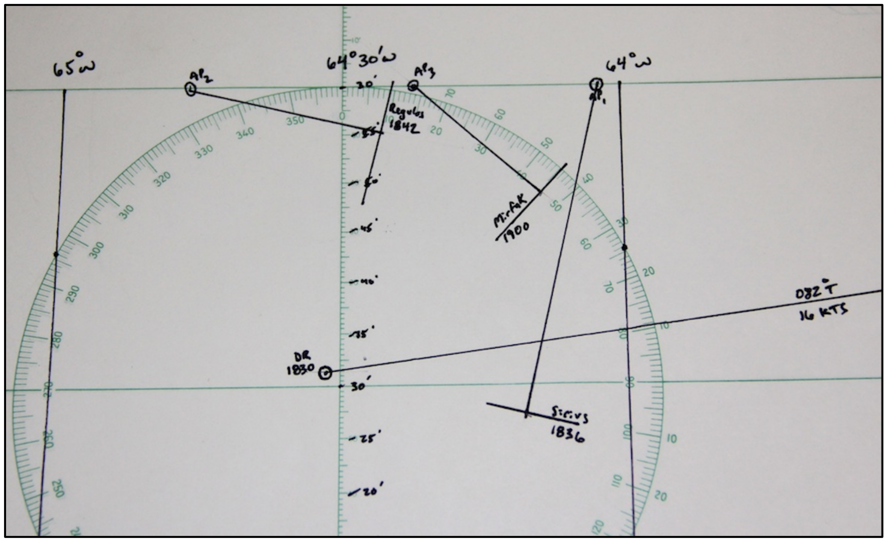
Step 6: Compare the observed altitudes (given) with the computed altitudes (determined in step 5), to compute intercepts (a) for the three-star sights.

Sight		*Sirius (1836)*	*Regulus (1842)*	*Mirfak (1900)*
Observed altitude (ho)	*Given*	46° 00.5’	49° 07.2’	35° 51.6’
Correct computed altitude (hc)	*From step 5*	**45° 26.4’**	**48° 48.2’**	**36° 08.6’**
Intercept (a)	*hc – ho*	**34.1’**	**19.0’**	**17.0’**
Towards/Away	*If hc is greater, intercept is “away”*	**Towards**	**Towards**	**Away**
Azimuth	*Repeated from step 4*	192.3°	103.0°	313.6°

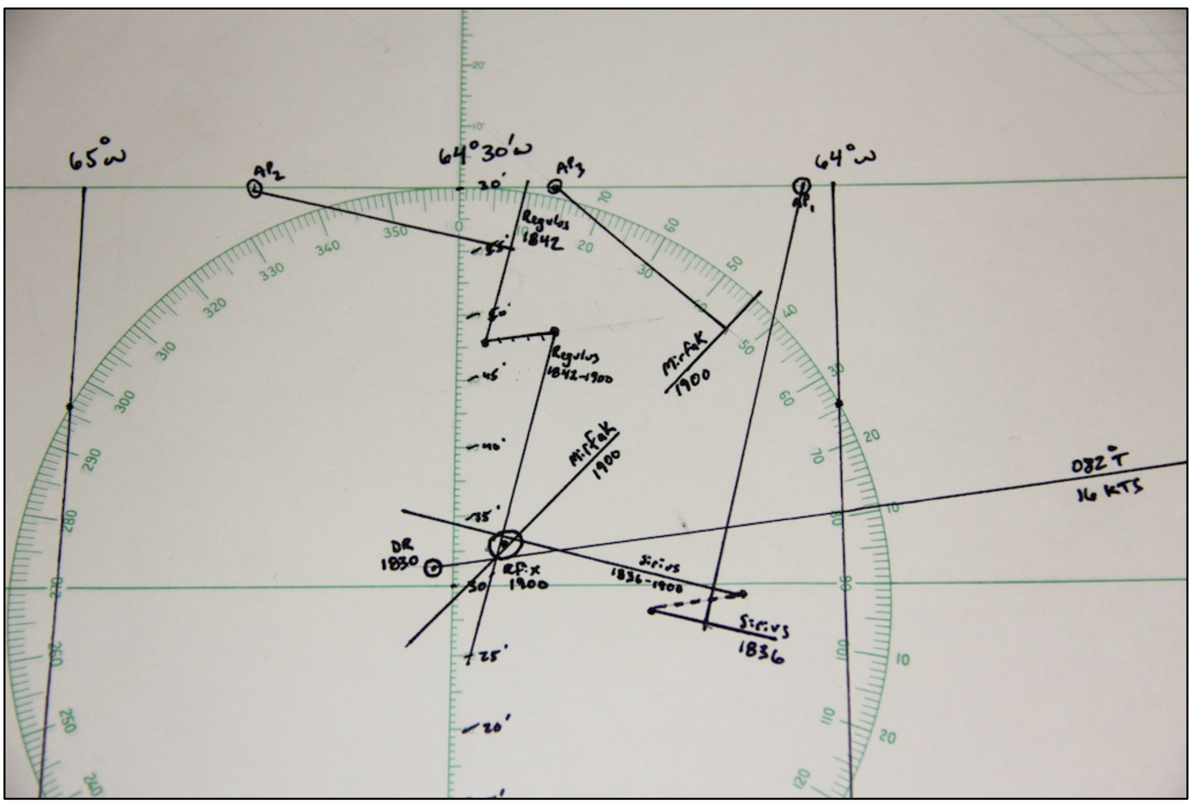
Step 7: Plot the assumed positions for each star sight.



Step 8: Plot each star sight's line of position.



Step 9: Advance the 1836 and 1842 star lines of position to 1900 to determine the running fix.
Fix: 26° 33' N, 64° 27' W



Celestial Fix and Running Fix Problems

Sun Problems

FIX B1. On 2 April your 0830 zone time fix gives you a position of latitude 20° 16.0’ S, longitude 004° 12’ E. Your vessel is steaming on a course of 143° T at a speed of 18 knots. An observation of the Sun’s upper limb is made at 0903 zone time, and the observed altitude (ho) is 42° 39.6’. The chronometer reads 09h 05m 40s and the chronometer error is 2m 15s fast. Local apparent noon occurs at 1145 zone time and a meridian altitude of the Sun’s lower limb is observed. The observed altitude (ho) for this sight is 63° 46.2’. Determine the vessel’s 1200 position.

a) 21° 10.1’ S, 004° 53.9’ E
b) 21° 14.0’ S, 004° 55.0’ E
c) 21° 18.0’ S, 005° 00.5’ E - correct
d) 22° 42.0’ S, 004° 57.0’ E

FIX B2. On 17 January your 0730 zone time fix gives you a position of latitude 22° 26.0’ S, longitude 152° 17.0’ E. Your vessel is steaming on a course of 116° T at a speed of 17 knots. An observation of the Sun’s lower limb is made at 1015 zone time. The chronometer reads 00h 13m 23s and the chronometer error is 1m 49s slow. The observed altitude (ho) is 66° 02.1’. LAN occurs at 1152 zone time and a meridian altitude of the Sun’s lower limb is made. The observed altitude (ho) is 87° 54.2’. Determine the vessel’s 1200 zone time position.

a) 22° 53.8’ S, 153° 25.6’ E - correct
b) 22° 53.8’ S, 153° 28.8’ E
c) 22° 56.3’ S, 153° 25.6’ E
d) 22° 56.3’ S, 153° 28.8’ E

FIX B3. On 24 March your 0800 zone time fix gives you a position of latitude 22° 16’ N, longitude 31° 45’ W. Your vessel is steaming on a course of 285° T at a speed of 16.5 knots. An observation of the Sun’s upper limb is made at 0938 zone time, and the observed altitude (ho) is 46° 32.2’. The chronometer reads 11h 41m 01s and the chronometer error is 02m 50s fast. Local apparent noon occurs at 1214 zone time and a meridian altitude of the Sun’s lower limb is made. The observed altitude (ho) for this sight is 68° 55.8’. Determine the vessel’s 1200 zone time position.

a) 22° 35.0’ N, 30° 29.0’ W
b) 22° 35.0’ N, 32° 51.0’ W - correct
c) 22° 36.0’ N, 32° 10.5’ W
d) 22° 36.0’ N, 32° 55.2’ W

FIX B4. On 29 April your 0530 zone time position was latitude 23° 04.0’ S, longitude 162° 12.0’ E. Your vessel was steaming on course 120° T at a speed of 9 knots. An observation of the Sun’s upper limb was made at 0830 zone time. The chronometer read 09h 27m 32s and was slow 2m 24s. The observed altitude (ho) was 24° 58.0’. LAN occurred at 1205 zone time. The observed altitude (ho) was 52° 04.0’. What was the longitude of your 1200 zone time running fix?

a) 163° 02.1’ E
b) 163° 06.0’ E - correct
c) 163° 09.5’ E
d) 163° 11.3’ E

FIX B5. On 22 February, your 0800 zone time position is latitude 24° 16’ S, longitude 95° 37’ E. Your vessel is on course 126° T at a speed of 14 knots. An observation of the Sun’s lower limb is made at 0945 zone time. The chronometer reads 03h 47m 22s and the chronometer error is 02m 37s fast. The observed altitude (ho) is 57° 02.1’. LAN occurs at 1148 zone time, and a meridian altitude of the Sun’s lower limb is made. The observed meridian altitude (ho) is 75° 22.3’. Determine the vessel’s 1200 zone time position.

a) 24° 49.3’ S, 96° 24.0’ E
b) 24° 49.3’ S, 96° 27.2’ E
c) 24° 52.2’ S, 96° 24.0’ E - correct
d) 24° 52.2’ S, 96° 27.2’ E

Any Celestial Body Problems

FIX B6. On 15 August your vessel is en route from Bombay to San Francisco. You are steering course 020° T and making a speed of 20 knots. Your 1830 zone time DR is latitude 26° 13.0’ N, longitude 135° 18.0’ W. You observe 3 celestial bodies. Determine the latitude and longitude of your 1935 running fix.

Body	Zone Time	GHA	Observed Altitude	Declination
Spica	1848	180° 24.3’	32° 21.4’	S 11° 03.8’
Altair	1910	89° 29.8’	43° 06.3’	N 8° 49.3’
Kochab	1935	170° 33.4’	39° 12.0’	N 74° 14.3’

a) 26° 15.9’ N, 135° 03.6’ W
b) 26° 35.3’ N, 135° 24.8’ W
c) 26° 40.5’ N, 135° 21.6’ W
d) 26° 48.1’ N, 135° 20.7’ W - correct

FIX B7. On 16 April your 0200 zone time DR position is latitude 17° 18’ S, longitude 168° 46’ E. You are on course 236° T at a speed of 16 knots. You observe 3 celestial bodies. Determine the latitude and longitude of your 0600 running fix.

Body	Zone Time	GHA	Observed Altitude	Declination
Fomalhaut	0523	133° 27.1’	35° 40.4’	S 29° 43.4’
Peacock	0527	172° 33.9’	48° 28.6’	S 56° 47.6’
Antares	0531	232° 32.3’	51° 43.9’	S 26° 23.4’

a) 17° 54.9’ S, 167° 48.7’ E
b) 17° 55.6’ S, 167° 45.1’ E
c) 17° 56.8’ S, 167° 52.4’ E
d) 18° 00.4’ S, 167° 49.2’ E - correct

FIX B8. On 12 October, your vessel is on course 081° T, speed 20 knots. Your 1800 zone time DR position is latitude 26° 11.0’ S, longitude 77° 18.0’ E. You observe 3 celestial bodies. Determine the latitude and longitude of your 1835 zone time running fix.

Body	Zone Time	GHA	Observed Altitude	Declination
Vega	1810	299° 26.6’	23° 08.7’	N 38° 46.3’
Fomalhaut	1823	237° 37.0’	50° 23.9’	S 29° 43.2’
Antares	1835	337° 43.4’	40° 53.1’	S 26° 23.4’

a) 26° 05.5’ S, 77° 14.5’ E
b) 26° 07.5’ S, 77° 34.0’ E
c) 26° 09.0’ S, 77° 27.5’ E
d) 26° 12.0’ S, 77° 31.0’ E- correct

FIX B9. On 20 Nov, your 1030 ZT DR position is LAT 27° 16.0’N, LONG 157° 18.6’E. You are on course 060° T at a speed of 20 knots. You observe three celestial bodies. Determine the latitude and longitude of your 1200 running fix.

Body	Zone Time	GHA	Observed Altitude	Declination
Moon	1030	259° 24.4’	34° 01.5’	N 9° 47.3’
Sun	1116	202° 30.5’	43° 00.0’	S 19° 38.0’
Venus	1200	162° 57.7’	24° 26.9’	S 26° 02.4’

a) 27° 16.8’ N, 157° 30.5’ E
b) 27° 22.6’ N, 157° 37.8’ E
c) 27° 29.7’ N, 157° 43.0’ E - correct
d) 27° 33.4’ N, 157° 48.2’ E

FIX B10. On 22 Nov, your vessel is en route from Accra Ghana to Montevideo, Uruguay. You are on course 240° T and making a speed of 15 knots. Your 1129 DR position is LAT 28° 25’S, LONG 42° 40W. You observe three celestial bodies. Determine the latitude and longitude of your 1137 running fix.

Body	Zone Time	GHA	Observed Altitude	Declination
Venus	1129	350° 00.1’	43° 26.8’	S 25° 41.8’
Moon	1134	082° 54.7’	43° 15.0’	S 01° 46.5’
Sun	1137	042° 38.0’	81° 44.7’	S 20° 11.7’

a) 28° 27.0’ S, 42° 38.0’ W - correct
b) 28° 25.2’ S, 42° 40.0’ W
c) 28° 25.0’ S, 42° 36.0’ W
d) 28° 23.4’ S, 42° 42.0’ W