The Cutterman’s Guide to Navigation Problems

Christopher D. Nolan

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Preface: How to Use This Guide

In the age of electronic navigation, older manual calculation methods have fallen out of favor. However esoteric it may seem, competent navigators must maintain proficiency with older navigation methods for three main reasons:

The first reason is that higher authority mandates it. Service navigation standards and national licensing require proficiency in solving many types of navigation problems.

The second reason is for potential electronic failure. Although rare, in the event of a GPS or other electronic signal disruption, older methods of position fixing are required. In an age where many watch officers seldom plot positions on paper charts; maintaining proficiency with manual navigation problems is crucial.

The third reason for familiarity with navigation problem solving is for personal satisfaction. Ship’s navigators are part of a heritage that goes back thousands of years. We are lucky to live in an age where navigation can be so easy, but tradition requires us to devote our energies to mastering our craft.

How to Use This Guide – For Everyone

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 Part features a brief introduction followed by a handful of example problems with detailed solutions, including snapshots from required publications or ephemerides. At the end of each Part are dozens of additional problems and answers for self-practice.

Most problems are taken directly from the US Coast Guard test database and therefore represent the types of problems expected on the 500-ton license exam.

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.

How to Use This Guide – Specifically For USCG Cuttermen or Naval Personnel

Certain USCG cutter classes are required to maintain proficiency in a range of navigation techniques, as set forth in the USCG Navigation Standards. Additionally, as professional mariners, deck watch officers and members of the boatswain mate and operations specialist ratings are required to meet certain qualification milestones.

This guide covers a majority of the required terrestrial and celestial tasks required by the Commandant's Navigation Standards, and serves to supplement on-the-job training for qualification as a deck watch officer or advancement in certain enlisted ratings.

How to Use This Guide – Specifically For Merchant Mariners

For certification as a 500-ton or 1600-ton Ocean or Near Coastal Master (and many other levels), the US Coast Guard still requires manual solutions to many navigation problems, including celestial navigation. The problems solved in this guide are taken directly from the US Coast Guard test database.

Each version of problem is solved in turn, so that license candidates can familiarize themselves with the nuances of the questions. After reviewing this guide, mariners should feel comfortable solving all problems on the TNAV or CNAV tests, in addition to most manual calculations on the NAV GEN test.

Regarding study strategy, it is highly recommended to purchase or download copies of the 1981 Training Nautical Almanac, the Sight Reduction Tables for Marine Navigation (Pub HO 229), the 1983 Tide and Tidal Current Tables, and Bowditch (Part 2) to familiarize themselves with the exam room materials. Additionally, online testing and training programs such as Lapware.com and other online training programs are indispensible when studying for a license or upgrade.

Organization

The Cutterman's Guide to Navigation Problems is organized as follows:

Sections divide the material into Terrestrial and Celestial areas of study. These do not, however, correlate directly to TNAV and CNAV on mariner exams…problems can come from both Sections.

Parts break down *Sections* into manageable study and testing topics.

Equations or ***Introductions*** introduce the required mathematics or process.

Problems are solved for each topic, including variations on wording or technique.

Additional Problems and Answers are taken from the USCG test database for further self-study and familiarization with problem wording.

About the Author

Christopher D. Nolan graduated with honors from the US Coast Guard Academy in 2002. He has over 8 years of sea-time aboard the 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.

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 holds a B.S. in Marine Science from the USCG Academy and a P.S.M. in Fisheries and Wildlife Administration from Oregon State University.

He is the co-author of "Eagle Seamanship – A Manual for Square Rigger Sailing" and the author of "The Bridge Navigation and Seamanship Refresher Guidebook," "The Cutterman's Guide to Maneuvering Boards," and "The Cutterman's Guide to Basic Celestial Navigation." Additionally, he maintains the training program website www.practicalnavigator.org and a YouTube channel dedicated to Navigation Training.

Preface: Basic Calculations

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.
$0.277 \times 60 = 16.62$ 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.
$0.62 \times 60 = 37.2$ 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**

Trigonometric Functions Involving Course Angle and Correct Sign

As described in further Parts of this text, "course angle" is related to actual course and is an important naming scheme during license exams. From Bowditch: "Course angle is the course measured from 0° at the reference direction clockwise or counter-clockwise 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."

Fortunately, the vagaries of trigonometry are forgiving of minor course error mistakes, provided the mariner uses common sense when figuring course angles.

For example, if a vessel were to head from California westward on course 250° T, the correct course angle would be N 110° W. When plugging this course angle into trigonometric values, 110° should be used to obtain the correct sign, as below:

$$\sin 110° = 0.9397$$
$$\cos 110° = -0.3420$$
$$\tan 110° = -0.27475$$

However, if the mariner were to plug in the given course instead (250°), the following results are obtained:

$$\sin 250° = \ -0.9397$$
$$\cos 250° = -0.3420$$
$$\tan 250° = 2.7475$$

Clearly, the absolute values are the same, but the signs are often different. This can be understood rapidly with a review of trigonometry, given in Bowditch or other texts. However for the purpose of marine calculations and merchant mariner exams, having the absolute value correct is usually sufficient *provided* the mariner uses common sense to determine differences in latitude, longitude, and other calculations.

For example, if a starting position of 145° W were given and Course Angle was used to determine a Difference of Longitude of (-10°), the correct ending longitude is 135° W. However, if course angle were improperly used, the Difference of Longitude value would be (+10°), leading the mariner to incorrectly suppose the secondary longitude was 155° W. However, given an inspection of the given information in the problem, it is usually clear whether the absolute value of Difference of Longitude should be added or subtracted. For example, the problem might state that the initial course was 080° T…clearly the longitude should be subtracted, regardless of the sign obtained.

It is definitely better to use Course Angle as described theoretically in navigation texts, but it can be a confusing topic and it is wise to use common sense when applying Departures, Differences in Latitude, and Differences in Longitude to initial positions when completing problems in Sailings, Time of Phenomenon, or other calculations involving trig functions.

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.

<u>Problem P-9</u>. 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 = <u>41° 37.3’</u>.

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 = <u>00:48:13</u>

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: <u>12° 03.3’ correction</u>

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 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.

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.

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

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 '	Corr '	v or d '	Corr '	v or d '	Corr '
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 '	Corr '	v or d '	Corr '	v or d '	Corr '
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 GHA 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).

The Cutterman's Guide to Navigation Problems

Section One: Terrestrial Navigation Problems

Contents

Part One: Fuel Consumption and Engine Problems

Fuel consumption problems are useful when calculating voyage efficiency or for logistics requirements.

There are two types of problems to solve. The first type of problem involves the relationship between speed, distance, and available fuel. The second type of problem involves the relationships between pitch, engine revolutions-per-minute, and speed.

Equations

There are five equations used to deal with in these problems:

(1) $$\frac{New\ Consumption}{Old\ Consumption} = \frac{New\ Speed^3}{Old\ Speed^3}$$

(2) $$\frac{New\ Consumption}{Old\ Consumption} = \frac{New\ Speed^2 \times New\ Distance}{Old\ Speed^2 \times Old\ Distance}$$

(3) $$Slip = \frac{Engine\ Speed - Observed\ Speed}{Engine\ Speed} \times 100$$

(4) $$Efficiency = 100\% - Slip$$

(5) $$Speed = \frac{RPM \times 60 \times Pitch \times Efficiency}{6080}$$

Speed, Distance, and Fuel Problems

These problems can take several forms, but all ultimately come down to the relationship between speed, distance and fuel. All problems use either equation (1) or equation (2).

Problem 1-1 (CG-632). The following question is taken directly from the USCG test bank and illustrates the use of equation (1).

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

Problem 1-2 (CG-809). The following question is taken directly from the USCG test bank and illustrates the use of equation (2).

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. Use equation (2) to solve for the new consumption. Since the speed is to remain the same, you can cancel the terms from the numerator and denominator.

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

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

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

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

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

Step 6: $\boldsymbol{New\ Consumption = 43.03\ tons\ per\ day}$

Pitch, RPM, and Speed Problems

These problems take many forms and sometimes require multiple equations to solve a single problem. They rely on equations (3), (4), and (5).

Problem 1-3. The following question illustrates the use of equation (3).

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, and it is crucial to watch the sign in later, more complex problems.

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: $Slip = 0.0388 \times 100$

Step 5: $\boldsymbol{Slip = +3.88\%}$

Problem 1-4 (CG-566). The following question is taken directly from the USCG test bank and illustrates the use of equations (3) and (5) together.

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 and unnecessary for the calculation. The goal is to calculate slip, so the "efficiency" portion of equation (5) 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: $Speed = \frac{122148}{6080}$

Step 4: $Speed = 20.09kts$

Step 5: 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 6: $Slip = \frac{Engine\ Speed - Observed\ Speed}{Engine\ Speed} \times 100$

Step 7: $Slip = \frac{20.09kts - 22.42kts}{20.09kts} \times 100$

Step 8: $Slip = \frac{-2.23kts}{20.09kts} \times 100$

Step 9: $Slip = -0.1159 \times 100$

Step 10: $\boldsymbol{Slip = -11.59\%}$

<u>Problem 1-5 (CG-146)</u>. The following question is taken directly from the USCG test bank and illustrates the use of equations (4) and (5) together.

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 use equation (5) 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: $\boldsymbol{RPM = 83.067}$

The purpose of the "60" in equation (5) is to turn RPM into an hourly figure. If a question gives a daily revolutions count, then the "60" is not required.

<u>Problem 1-6 (CG-127)</u>. The following question is taken directly from the USCG test bank and illustrates the concept of daily revolutions.

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 use equation (5) to calculate the required RPM of the shaft. Since the daily revolutions are given, the "60" in equation (5) is not necessary, and instead of "speed," the answer will be given in "day's run."

Step 6: $Speed = \frac{RPM \times 60 \times Pitch \times Efficiency}{6080}$ Equation (5)

Step 7: $Modified\ equation\ (5)\ to \rightarrow Day's\ Run = \frac{Revs \times Pitch \times Efficiency}{6080}$

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

Additional Problems and Answers

All of the following questions were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-621. 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*

Problem CG-624. 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*

Problem CG-625. While steaming 15 knots, your vessel burns 326 bbls of fuel oil per day. What will be the rate of fuel consumption if you decrease speed to 12.2 knots?

- *a) 175 bbls per day- correct*
- *b) 215 bbls per day*
- *c) 277 bbls per day*
- *d) 300 bbls per day*

Problem CG-812. You have steamed 201 miles and consumed 18.0 tons of fuel. If you maintain the same speed, how many tons of fuel will you consume while steaming 482 miles?

- *a) 25.2 tons*
- *b) 43.2 tons- correct*
- *c) 52.6 tons*
- *d) 103.5 tons*

Problem CG-817. 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

Problem CG-820. 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- correct
b) 14.3
c) 17.1
d) 18.2

Problem CG-826. 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

Problem CG-827. You have steamed 540 miles at 22 knots and burning 618 barrels of fuel oil per day. You must decrease your consumption to 372 barrels with 299 miles left in your voyage. What must you reduce your speed (kts) to in order to burn this amount of fuel?

a) 22.9- correct
b) 20.0
c) 19.1
d) 17.6

Problem CG-838. 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

Problem CG-902. 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 next port, 873 miles distant?

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

Problem CG-912. 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

Problem CG-90. At your current speed of 20 knots, you only have enough fuel remaining to travel 218 miles. You must travel 395 miles to reach your destination. What should you reduce your speed (knots) to in order to reach your destination?

a) 17.4
b) 16.2
c) 14.9- correct
d) 13.7

Problem CG-96. At your current speed of 23 knots, you only have enough fuel remaining to steam 386 miles. You must travel 785 miles to reach your destination. What should you reduce your speed (knots) to in order to reach your destination?

a) 19.3
b) 17.7
c) 16.1- correct
d) 14.5

Problem CG-635. While steaming at 19.5 knots, your vessel burns 297 bbls of fuel per day. What will be the rate of fuel consumption if you decrease speed to 15 knots?

a) 135 bbls- correct
b) 176 bbls
c) 229 bbls
d) 243 bbls

Problem CG-798. 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

Problem CG-126. 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*

Problem CG-132. 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*

Problem CG-136. 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*

Problem CG-139. 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*

Problem CG-140. 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*

Problem CG-144. 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

Problem CG-150. 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

Problem CG-562. 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%

Problem CG-565. 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%

Problem CG-561. 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

Problem CG-571. 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%

Problem CG-579. 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

Problem CG-730. 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

Problem CG-735. 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

Problem CG-991. 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%

Stability is a huge topic, and this document does not attempt to cover the spectrum of stability problems to be found in the pilothouse. These examples represent a portion of those encountered by the watch officer when preparing for qualification or licensure. Refer to standard nautical texts such as Ladage for further information.

Equations

The following equations are of use when making basic stability calculations:

(1) $$Roll\ Period = T = \frac{0.44 \times Beam}{\sqrt{GM}}$$

(2) $$Loll = \tan\ (\theta) = \sqrt{\frac{2GM}{BM}}$$

(3) $$Moment = KG \times Weight$$

(4) $$Total\ KG = \frac{Total\ Moment}{Total\ Weight}$$

(5) $$Shift = \frac{Weight \times Distance}{Displacement}$$

(6) $$KB = 0.53 \times Draft$$

(7) $$Parrallel\ Sinkage = \frac{Weight}{Tons\ Per\ Inch\ Immersion}$$

(8) $$Tons\ Per\ Inch\ Immersion = \frac{Waterplane}{420}$$

(9) $$Waterplane = Length \times Beam \times Coefficient$$

Deck Loading and Weight Shift Problems

Problem 2-1 (CG-5094). The following example is taken directly from the USCG test bank and illustrates how to determine the final center of gravity (CG) of a vessel after loading.

Your vessel displaces 479 tons. The existing deck cargo has a center of gravity of 3.0 feet above the deck and weighs 16.0 tons. If you load 23.0 tons of anchor and anchor chain with an estimated center of gravity of 9 inches above the deck, what is the final height of the CG above the deck?

Answer: 1.67 feet. To determine the total CG of a load, divide the total moment of the load by the total weight of the load.

Step 1: Set up a table to categorize the known information.

Category	Weight	Height of CG	Moment
Existing Cargo	16 tons	3 feet	
Anchor and Chain	23 tons	9 inches = .75 feet	
Total			

Step 2: Determine the individual moments of the loads.

Category	Weight	Height of CG	Moment
Existing Cargo	16 tons	3 feet	16 x 3 = **48**
Anchor and Chain	23 tons	9 inches = 0.75 feet	23 x 0.75 = **17.25**
Total			

Step 3: Determine the total weights and total moments of the loads.

Category	Weight	Height of CG	Moment
Existing Cargo	16 tons	3 feet	16 x 3 = 48
Anchor and Chain	23 tons	9 inches = 0.75 feet	23 x 0.75 = 17.25
Total	**39 tons**		**65.25**

Step 4: Divide the total moment by the total weight to determine the total height of the CG.
65.25 ÷ 39 = **1.673 feet.**

Problem 2-2 (CG-4827). The following example is taken directly from the USCG test bank and illustrates how to determine the final center of gravity (CG) of a vessel after loading.

You are on a supply run to an offshore drilling rig. On board is the listed cargo. What is the height above the main deck of the center of gravity of the cargo?

1. 50 drums of cement – each drum weighs 400 pounds and is stowed on end. Each drum is 28 inches in diameter and 32 inches high.
2. Crated piping and valves – 8 crates stowed 2 high. Each crate measures 8'H x 4'W x 6'L and weighs 640 pounds.
3. Stewards stores – 12 containers measuring 6'H x 6'W x 6'L. Each container weighs 960 pounds. The center of gravity of each container is 30 inches above the deck.
4. 20 lengths of drilling casing – 16 inches in diameter by 30 feet long. Each length weighs 1.72 long tons and is stowed in a single tier on deck.

Answer: 1.05 feet. To determine the total CG of a load, divide the total moment of the load by the total weight of the load.

Step 1: Organize the known information. Convert the given information to consistent terms of measure, height, and weight. Note that 1 ton = 2240 pounds.

1. 50 drums of cement – each drum weighs 400 pounds and is stowed on end. Each drum is 28 inches in diameter and 32 inches high.
   50 x 500 pounds = 20000 pounds = 8.93 tons
   32" high and stored on end = 32" ÷ 2 = 16" center of gravity

2. Crated piping and valves – 8 crates stowed 2 high. Each crate measures 8'H x 4'W x 6'L and weighs 640 pounds.
   8 x 640 pounds = 5120 pounds = 2.29 tons
   2.5' high and stored 2 high = 2.5' center of gravity

3. Stewards stores – 12 containers measuring 6'H x 6'W x 6'L. Each container weighs 960 pounds. The center of gravity of each container is 30 inches above the deck.
   12 x 960 pounds = 11520 pounds = 5.14 tons
   30" center of gravity (Given)

4. 20 lengths of drilling casing – 16 inches in diameter by 30 feet long. Each length weighs 1.72 long tons and is stowed in a single tier on deck.
   20 x 1.72 tons = 34.3 tons
   16 inch diameter = 8" center of gravity

Step 2: Set up a table to categorize the known information.

Category	Weight	Height of CG	Moment
Cement	8.9 tons	16" = 1.33 feet	
Piping and Valves	2.29 tons	2.5 feet	
Steward Stores	5.14 tons	30" = 2.5 feet	
Drill Casing	34.3 tons	8" = 0.67 feet	
Total			

Step 3: Determine the individual moments of the loads.

Category	Weight	Height of CG	Moment
Cement	8.9 tons	16" = 1.33 feet	8.9 x 1.33 =**11.84**
Piping and Valves	2.29 tons	2.5 feet	2.29 x 2.5 = **5.73**
Steward Stores	5.14 tons	30" = 2.5 feet	5.14 x 2.5 = **12.85**
Drill Casing	34.3 tons	8" = 0.67 feet	34.3 x 0.67 = **22.98**
Total			

Step 4: Determine the total weights and total moments of the loads.

Category	Weight	Height of CG	Moment
Cement	8.9 tons	16" = 1.33 feet	11.84
Piping and Valves	2.29 tons	2.5 feet	5.73
Steward Stores	5.14 tons	30" = 2.5 feet	12.85
Drill Casing	34.3 tons	8" = 0.67 feet	22.98
Total	**50.63 tons**		**53.40**

Step 5: Divide the total moment by the total weight to determine the total height of the CG.
53.40 ÷ 50.63 = **1.05 feet**

<u>Problem 2-3 (CG-4982)</u>. The following example is taken directly from the USCG test bank and illustrates how to solve weight shift problems.

You have approximately 16 tons of fish on deck. What will be the shift in the center of gravity after you shift the fish to the fish hold, a vertical distance of 8 feet? (Total displacement is 640 tons).

Answer: 0.2 feet.

Step 1: Use the weight shift formula to solve for shift in the center of gravity.

$$Shift = \frac{Weight \times Distance}{Displacement}$$

$$Shift = \frac{(16\ tons) \times (8\ vertical\ feet)}{640\ tons\ displacement}$$

$$Shift = \frac{128}{640}$$

$$\boldsymbol{Shift = 0.2\ feet}$$

Roll Period Problems

<u>Problem 2-4 (CG-5172)</u>. The following example is taken directly from the USCG test bank and illustrates how to solve roll period problems.

Your vessel measures 126 feet long by 21 feet in beam. If the natural rolling period at a draft of 8 feet is 6 seconds, what is the GM?

Answer: 2.37 feet

Step 1: Use the rolling period formula and the given information to solve for GM.

$$Roll\ Period = T = \frac{0.44 \times Beam}{\sqrt{GM}}$$

$$6\ seconds = \frac{0.44 \times (21\ feet)}{\sqrt{GM}}$$

$$6 = \frac{9.24}{\sqrt{GM}}$$

$$\sqrt{GM} = \frac{9.24}{6}$$

$$\sqrt{GM} = 1.54$$

$$GM = (1.54)^2$$

$$\boldsymbol{GM = 2.37}$$

Problem 2-5 (CG-5123). The following example is taken directly from the USCG test bank and illustrates how to solve roll period problems.

Your vessel has a displacement of 24,500 tons. It is 529 feet long and has a beam of 71 feet. You have timed your full charge rolling period to be 25.0 seconds. What is your vessel's approximate GM?

Answer: 1.56 feet. Much of the provided information is "distractor" information.

Step 1: Use the rolling period formula and the given information to solve for GM.

$$Roll\ Period = T = \frac{0.44 \times Beam}{\sqrt{GM}}$$
$$25\ seconds = \frac{0.44 \times (71\ feet)}{\sqrt{GM}}$$
$$25 = \frac{31.24}{\sqrt{GM}}$$
$$\sqrt{GM} = \frac{31.24}{25}$$
$$\sqrt{GM} = 1.25$$
$$GM = (1.25)^2$$
$$\boldsymbol{GM = 1.56}$$

Draft, Loading, and Immersion Problems

Problem 2-6 (CG-25). The following example is taken directly from the USCG test bank and illustrates how to solve tons-per-inch immersion problems.

A bulk freighter 680 feet in length, 60-foot beam, with a waterplane coefficient of 0.84 is floating in salt water at a draft of 21 feet. How many long tons would it take to increase the mean draft by 1 inch?

Answer: 81.6 tons.

Step 1: Use the waterplane formula to calculate the waterplane.

$$Waterplane = Length \times Beam \times Coefficient$$
$$Waterplane = 680\ feet \times 60\ feet \times 0.84$$
$$Waterplane = 34272$$

Step 2: Use the tons-per-inch immersion formula to calculate the TPI.

$$Tons\ Per\ Inch\ Immersion = \frac{Waterplane}{420}$$
$$Tons\ Per\ Inch\ Immersion = \frac{34272}{420}$$
$$Tons\ Per\ Inch\ Immersion = \mathbf{81.6\ tons}$$

<u>Problem 2-7 (CG-475)</u>. The following example is taken directly from the USCG test bank and illustrates how to solve draft problems given tons-per-inch immersion.

A vessel's mean draft is 29' 07". At this draft the TPI is 152. The mean draft after loading 1360 tons will be ______?

Answer: 30' 03.5".

Step 1: Use the parallel sinkage formula to calculate parallel sinkage.

$$Parallel\ Sinkage = \frac{Weight}{Tons\ Per\ Inch\ Immersion}$$

$$Parallel\ Sinkage = \frac{1360\ tons}{152}$$

$$Parallel\ Sinkage = 8.947''$$

Step 2: Use parallel sinkage to determine the new mean draft.
Old Mean Draft = 29' 07"
Sinkage = 8.947"
New Mean Draft = 29' 07" + 8.497" = 29' 15.497" = **30' 3.5"**

Additional Problems and Answers

All of the following questions were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-5092. Your vessel displaces 475 tons. The existing deck cargo has a center of gravity of 2.6 feet above the deck and weighs 22 tons. If you load 16 tons of ground tackle with an estimated center of gravity of 8 inches above the deck, what is the final height of the CG of the deck cargo?

a) *1.64 feet*
b) *1.79 feet- correct*
c) *1.96 feet*
d) *2.14 feet*

Problem CG-5097. Your vessel displaces 560 tons. The existing deck cargo has a center of gravity of 4.5 feet above the deck and weighs 34 tons. If you load 10 tons of ground tackle with an estimated center of gravity of 2.8 feet above the deck, what is the final height of the CG of the deck cargo?

a) *4.11 feet*
b) *4.36 feet*
c) *4.57 feet*
d) *4.78 feet*

Problem CG-4823. You are on a supply run to an offshore drilling rig. On board is the cargo listed. What is the height above the main deck of the center of gravity of the cargo?

I. Fifty drums of cement. Each drum weighs 600 pounds and is stowed on end. Each drum measures 28 inches in diameter and is 32 inches high.

II. Two reels of 1 inch diameter wire rope. Each reel contains 3000 linear feet of wire weighing 1.55 pounds per linear foot. The tare weight of each reel is 450 pounds. The reels are stowed on the flat and are 36 inches high.

III. Twelve pallets of general supplies. Each pallet measures 8'L x 4'W x 3'H. The pallets are stowed singly and weigh 580 pounds each.

IV. Twelve crates of machine parts and pipe fittings. Each weighs 880 pounds. Each crate measures 8'L x 3'W x 4'H and is stowed singly.

a) *1.50 feet- correct*
b) *1.96 feet*

c) *2.21 feet*
d) *2.78 feet*

Problem CG-4824. You are on a supply run to an offshore drilling rig. On board is the cargo listed. What is the height above the main deck of the center of gravity of the cargo?

I. Two reels of hoisting wire. Each reel is 8 feet in circumference, 4 feet wide and has 3000 feet of wire. Both reels are stowed on the flat. Wire weighs 1.55 pounds per linear foot. The tare weight of each reel is 500 pounds.

II. Eight pallets of case goods stowed singly. Each pallet is 8'L x 4'W x 4'H and weighs 1 long ton.

III. Twelve steel containers of cement. Each container weighs 1 1/2 tons. Each container is 8'L x 4'W x 4'H. The containers are stowed singly fore and aft.

IV. Ten crates of steward's stores. Each crate measures 4'L x 4'W 3'H and weighs 420 pounds. Each crate is stowed on deck.

a) *1.76 feet*
b) *1.97 feet- correct*
c) *2.21 feet*
d) *2.32 feet*

Problem CG-4826. You are on a supply run to an offshore drilling rig. On board is the cargo listed. What is the height above the main deck of the center of gravity of the cargo?

I. Fifty lengths of drill casing - stowed in a block 8 feet high. Each pipe weighs 326 lbs.

II. Ten crates of valves - stowed 2 high. Each crate is 36" L x 30" W x 15" H and weighs 1020 lbs.

III. Fourteen containers of dry stores - stowed 2 high. Each container weighs 2 long tons and measures 6'L x 6'W x 6'H.

IV. Four anchors - on deck. The center of gravity of each anchor is 9" from the deck and each weighs 6120 lbs.

a) *3.6 feet*
b) *4.2 feet- correct*
c) *4.4 feet*
d) *4.9 feet*

Problem CG-4981. You have approximately 15 tons of fish on deck. What will be the shift in the center of gravity after you shift the fish to the fish hold, a vertical distance of 8 feet (total displacement 300 tons)?

a) *0.1 foot*
b) *0.2 foot*
c) *0.3 foot*
d) *0.4 foot- correct*

Problem CG-4987. You have approximately 60 tons of fish on deck. What will be the shift in the center of gravity after you shift the fish to the fish hold, a vertical distance of 7 feet (total displacement 960 tons)?

a) *0.6 foot*
b) *0.5 foot- correct*
c) *0.4 foot*
d) *0.3 foot*

Problem CG-5168. Your vessel measures 114 feet long by 16 feet in beam. If the natural rolling period at a draft of 5' 05" is 6 seconds, what is the GM?

a) *1.38 feet- correct*
b) *1.53 feet*
c) *1.76 feet*
d) *1.98 feet*

Problem CG-5173. Your vessel measures 127 feet long by 17 feet in beam. If the natural rolling period at a draft of 7' 10" is 5 seconds, what is the GM?

a) *1.96 feet*
b) *2.24 feet- correct*
c) *2.45 feet*
d) *2.68 feet*

Problem CG-5175. Your vessel measures 131 feet long by 20 feet in beam. If the natural rolling period at a draft of 8' 03" is 6 seconds, what is the GM?

a) *1.26 feet*
b) *1.74 feet*
c) *1.93 feet*
d) *2.15 feet- correct*

Problem CG-4834. You are on a vessel that has a metacentric height of 1.0 foot and a beam of 40 feet. What can you expect the rolling period of the vessel to be?

a) *15.2 seconds*

b) 15.9 seconds
c) 17.0 seconds
d) 17.6 seconds- correct

Problem CG-5122. Your vessel has a displacement of 19,800 tons. It is 464 feet long and has a beam of 64 feet. You have timed its rolling period to be 21.0 seconds in still water. What is your vessel's approximate GM?

a) 1.1 feet
b) 1.3 feet
c) 1.6 feet
d) 1.8 feet- correct

Problem CG-5249. Your vessel has a beam of 40 feet and you observe a still water rolling period of 20 seconds. What is the vessel's metacentric height?

a) 0.3 feet
b) 0.5 feet
c) 0.8 feet- correct
d) 1.1 feet

Problem CG-24. A bulk freighter 580 feet in length, 60 feet in beam with a waterplane coefficient of 0.84 is floating in salt water at a draft of 21 feet. How many long tons would it take to increase the mean draft 1"?

a) 65.1
b) 69.6- correct
c) 74.3
d) 76.8

Problem CG-5124. Your vessel has a forward draft of 26' 11" and an after draft of 29' 07". How many tons of cargo can be loaded before the vessel reaches a mean draft of 28' 06" if the TPI is 69?

a) 204 tons
b) 207 tons- correct
c) 210 tons
d) 213 tons

Part Three: Chronometer and ETA Problems

This part describes how to correct a chronometer or watch for known error, and how to conduct time-tick corrections. Additionally it solves estimated time of arrival (ETA) problems for trans-oceanic voyages.

Chronometer Correction Problems

After observing a celestial body, one must first account for any error in the timepiece used when noting the time of observation. This is critical for all celestial navigation problems, and typically is given as a factor in navigation problems to increase complexity.

Problem 3-1. The following example illustrates the practice of correcting a chronometer for known error.

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

The procedure for translating the various sounds heard during radio time tick broadcasts is described well in Bowditch but is largely irrelevant for calculation purposes.

Problem 3-2 (CG-725). The following question is taken directly from the USCG test bank and illustrates how to solve time-tick problems.

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**

Problem 3-3 (CG-389). The following question is taken directly from the USCG test bank and illustrates how to solve time-tick problems for chronometer rate.

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)**

Long Distance ETA Problems

Calculating ETA is simply a problem of accurate timekeeping, chronometer corrections (if necessary), and management of time zones, longitude, and daylight savings time (if applicable).

Problem 3-4 (CG-43). The following question is taken directly from the USCG test bank and illustrates how to solve long distance ETA problems.

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**

<u>Problem 3-5 (CG-654)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve long distance ETA problems.

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. There are many ways to account for the bunkering delay, generally "delaying the departure" is an easy way to keep track of all times.

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).**

Additional Problems and Answers

All of the following questions labeled “CG” were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem 3-X1. 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*

Problem 3-X2. 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*

Problem CG-205. 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*

Problem CG-729. 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*

Problem CG-723. 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*

Problem CG-720. 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*

Problem CG-724. 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*

Problem CG-41. 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*

Problem CG-644. 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*

Problem CG-917. 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*

Problem CG-337. On 21 November, 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*

Problem CG-50. 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*

Part Four: Gnomonic Chart Problems

Gnomonic charts are used for ocean voyage planning and are oblique representations of the Earth's surface, with only one point of tangency.

Typically, waypoints are transferred from the gnomonic chart to the Mercator chart before a voyage. However, gnomonic charts are also useful for general decision making prior to a voyage. They provide a quick reference guide to trans-oceanic voyages.

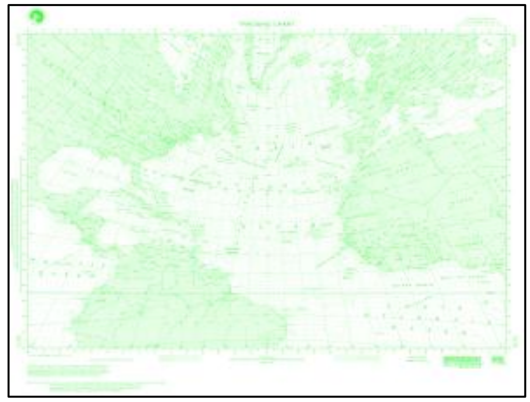


Chart WOCZX-5274 – provided in the USCG testing room or available for purchase online.

Gnomic Chart Problems

Problem 4-1 (CG-664). The following question is taken directly from the USCG test bank and illustrates how to solve qualitative gnomonic chart problems.

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.)

Problem 4-2 (CG-666). The following question is taken directly from the USCG test bank and illustrates how to solve qualitative gnomonic chart problems.

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.)

Additional Problems and Answers

All of the following questions labeled "CG" were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-1. 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*

Problem CG-545. 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*

Problem CG-546. 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*

Problem CG-541. 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 radiues of latitude 49° N, longitude 20° W*

Problem CG-593. 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.*

Problem CG-594. 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.*

Problem CG-656. 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.*

Problem CG-667. 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.*

Problem CG-672. You are planning a voyage from Jacksonville, FL to the Strait of Gibraltar. Using chart WOXZC 5274, determine which statement is true.

a) *All of the courses lie in the northeast quadrant of the compass.*
b) *You will be east of the Northern Hemisphere vertex during the entire voyage.*
c) *The great circle track approximates a rhumb line track because there is little difference in the latitudes.*
d) *None of the above are true- correct.*

Part Five: Great Circle and Sailings Problems

When planning a voyage of significant distance, the curvature of the earth must be accounted for. Additionally, great circle techniques allow a navigator to accurately dead-reckon to a location/time many hours in the future.

The ability to dead-reckon via mid-latitude or parallel sailing to a later location is critical to solving more complex problems such as time of phenomenon or celestial sight problems in later Parts of this text.

Definitions

Lat or *L* – Latitude.

L1 – the latitude of the point of departure.
L2 – the latitude of the destination.
Lm – the middle latitude ((L1 + L2) / 2)
Lv – the latitude of the vertex point (the point at the "peak" of the trackline).
Lx – the latitude of any point along the trackline.

DLat or *l* – the difference between two given latitudes.

m – Meridional parts. The actual length of an arc from the equator to a given latitude, given along a longitude/meridian line. Table 6 in Bowditch provides meridional parts.

m1 – the meridional parts of the point of departure.
m2 – the meridional parts of the destination.

λ or Long – Longitude.

Long1 – the longitude of the point of departure.
Long2 – the longitude of the destination.
λ V – the longitude of the vertex point (the point at the "peak" of the track).
λ X – the longitude of any point along a trackline.

DLo – the difference in two longitudes.

***p* or Dep** – Departure. The distance between two meridians at any given parallel of latitude.

C* or *Cn – Course angle. A course measured from 000° clockwise or anti-clockwise through 180° labeled with prefix and suffix directions to clarify the intended course. For example, a traditional course of 120° T would be expressed as a course angle of E120°N, while a traditional course of 330° T would be expressed as a course angle of

W30°N. Further discussion can be found in the Preface to this text, and even more can is available in Bowditch (in the glossary or in "The Sailings.")

Dist or *D* – Distance.

Trigonometric Identities and Inverse Functions

These formulae are also located in Bowditch, which is found on the bridge of most ocean-going vessels. Additionally, these formulae are provided via "Bowditch Volume II," which is located in the testing center for merchant mariner exams.

Trigonometric Identities:

$$\sin\theta = \frac{1}{\csc\theta} \qquad \tan\theta = \frac{1}{\cot\theta} \qquad \sec\theta = \frac{1}{\cos\theta}$$

$$\cos\theta = \frac{1}{\sec\theta} \qquad \csc\theta = \frac{1}{\sin\theta} \qquad \cot\theta = \frac{1}{\tan\theta}$$

Inverse Trigonometric Functions. Often, equivalent identities are expressed differently in different texts. Also, sometimes it is necessary to perform algebraic tasks on given formulae to solve for your desired value, necessitating inverse trig functions. As a refresher, all of the following are equivalent:

$$\sin\theta = x$$
$$\theta = \arcsin x$$
$$\theta = \sin^{-1} x$$

The Sailings Formulae

Note that the below formulae are re-created from Bowditch (available in merchant mariner test centers or vessel's bridges). They generally do not need to be memorized. Although listed under certain categories (e.g. "plane sailing" or "Mercator sailing"), they are often interchangeable, depending on the type of problem to be solved.

<u>The Plane Sailing Formulae</u>:

$$\cos C = \frac{l}{D} \qquad l = D \cos C$$

$$\sin C = \frac{p}{D} \qquad D = l \sec C$$

$$\tan C = \frac{p}{l} \qquad p = D \sin C$$

The Parallel Sailing Formulae:

$$DLo = p \ \sec l \quad - or - \quad DLo = \frac{p}{\cos l}$$

$$p = DLo \ \cos L$$

The Mid-Latitude Sailing Formulae:

$$DLo = p \ \sec Lm \quad - or - \quad DLo = \frac{p}{\cos Lm}$$

$$p = DLo \ \cos Lm$$

The Mercator Sailing Formulae:

$$\tan C = \frac{DLo}{m}$$

$$DLo = m \ \tan C$$

The Great Circle Distance and Course Angle Formulae:

$$D = \cos^{-1}((\sin L1)(\sin L2) + (\cos L1)(\cos L2)(\cos DLo))$$

$$C = \tan^{-1}(\frac{\sin DLo}{((\cos L1)(\tan L2)) - ((\sin L1)(\cos DLo))})$$

The Vertex Calculation Formulae:

$$Lv = \cos^{-1}((\cos L1)(\sin C))$$

$$DLo(v) = \sin^{-1}\left(\frac{\cos C}{\sin Lv}\right)$$

$$Dv = \sin^{-1}((\cos L1)(\sin DLo(v))$$

$$Lx = \tan^{-1}((\cos DLo(vx))(\tan Lv))$$

$$Lx = \sin^{-1}((\sin Lv)(\cos Dvx))$$

$$DLo(vx) = \sin^{-1}(\frac{\sin D(vx)}{\cos L(x)})$$

Course Angle Notation

Problem 5-1 (CG-452). The following question is taken directly from the USCG test bank and illustrates the concept of course angle.

From latitude 7° 12' N, longitude 80° 00'W to a position at latitude 47° 12' S, longitude 169° 18' E, the initial great circle course angle is 137.25°. How would you name this course?

Answer: N 137.25° W. From Bowditch (glossary): "Course angle is the course measured from 0° at the reference direction clockwise or counter-clockwise 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."
In this example, the vessel is proceeding from a point in the northern and western hemisphere (near the Panama Canal) to a point in the southern and eastern hemisphere. The course angle is given as 137.25°.

Since the reference hemisphere is north, the reference direction is north (000°). Since the vessel is heading southwest from the departure point to the arrival point, the course is measured "west of north" by the given 137.25°. The correct notation is therefore N 137.25° W. In standard notation (not asked for in this problem), the course would be 360° - 137.25° = 222.75° True.

Mid-Latitude Sailing Problems

Problem 5-2 (CG-7). The following question is taken directly from the USCG test bank and illustrates how to solve mid-latitude sailings problems.

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*).
$Lm = (20.0° \text{ N} + 24.67° \text{ N}) \div 2 = 22.33° \text{ N}$

Step 3: Determine the Difference of Latitude (*DLat*) 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: Apply mid-latitude formulae to 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) using the Mercator Formula.
$\tan C = \frac{p}{l}$
$\tan C = \frac{277.49}{280.2}$
$\tan C = 0.9903$
$C = \tan^{-1} 0.9903$
C = 44.722°

Step 7: Determine the distance given the Plane Sailing Formula.
$D = l\ \sec C$
$D = (280.2)\ \sec(44.722)$
$D = (280.2)(\frac{1}{\cos 44.722})$
$D = (280.2)(\frac{1}{0.7105})$
$\boldsymbol{D} =$ **394.4 nm**

Step 8: Determine the actual course given the solved Course Angle (C). 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°

<u>Problem 5-3 (CG-30)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve mid-latitude sailing problems.

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*) using the plane sailing formula 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*) using the plane sailing formula.
$p = D \sin C$
$p = (640) \sin 47°$
$p = (640)\,(0.7313)$
$p = 468.1'$

Step 6: Determine the Difference in Longitude (*DLo*) given the departure and mid-latitude.
$DLo = p \sec Lm$
$DLo = p \sec Lm = p\,(\frac{1}{\cos Lm})$
$DLo = p\,(\frac{1}{\cos Lm})$

$DLo = (468.1') (\frac{1}{\cos 38.388°})$
$DLo = (468.1') (\frac{1}{(0.7838)})$
$DLo = (468.1') (1.2758)$
$DLo = 597.2'$

Step 7: Convert the Difference in Longitude (DLo) to decimal notation and determine the arrival longitude. Convert to standard notation for partial problem answer.
$DLo = 597.2' \div 60$ = 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**

Mercator Sailing Problems

Problem 5-4 (CG-777). The following question is taken directly from the USCG test bank and illustrates how to solve Mercator Sailing problems for arrival location given an initial course and distance.

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. Use table 6 in Bowditch to obtain the necessary meridional parts.

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 Difference of Latitude (l) given the known course and distance using the Plane Sailing formula. Then convert the mileage to arc.
$l = D \cos C$
$l = (3365.6) \cos(118°)$
$l = (3365.6) (0.4695)$
$l = 1580.05'$
$l = 1580.05' \div 60 = 26.3342°$

Step 3: 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 4: Use Table 6 in Bowditch to obtain the meridional parts (*m1* and *m2*) for the given latitudes. Be sure to use the table correctly.

Latitude 1: 40° 42.0'
Meridional Parts 1: *m1* = 2662.8

Latitude 2: 14° 22.0'
Meridional Parts 2: *m2* = 865.4

Step 5: Determine the difference in meridional parts (*m*).
m1 – *m2* = *m*
2662.8 – 865.4 = *m* = 1797.4

Step 6: Determine the Difference in Longitude (*DLo*) using the Mercator Sailing formula. Convert the mileage to arc.
$DLo = m \ \tan C$
$DLo = (1797.4) \ \tan 118°$
$DLo = (1797.4)\ (1.8807)$
$DLo = 3380.42'$
$DLo = 3380.42' \div 60 = 56.34°$

Step 7: 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**

Problem 5-5 (CG-22). The following question is taken directly from the USCG test bank and illustrates how to solve Mercator Sailing problems for course and distance given a starting and ending location.

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. Use table 6 in Bowditch to obtain the necessary meridional parts.

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 Table 6 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) using the modified Mercator Sailing formula. Determine the actual course.
$DLo = m \tan C$
$$\tan C = \frac{DLo}{m}$$

$$\tan C = \frac{3736.02'}{1572.6}$$
$$\tan C = 2.3756$$
$$C = \tan^{-1} 2.3756$$
$$C = 67.172$$

Step 7: Determine the actual course steered given the solved course angle. Note that the vessel clearly 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.
$$D = l \sec C$$
$$D = l \left(\frac{1}{\cos C}\right)$$
$$D = (1279.98)\left(\frac{1}{\cos 247.2}\right)$$
$$D = (1279.98)\left(\frac{1}{(0.3875)}\right)$$
$$D = (1279.98)(2.5806)$$
$$\boldsymbol{D = 3303.2\ \mathbf{nm}}$$

Vertex Problems

Problem 5-6. The following question is modified from a question in the USCG test bank and illustrates how to find the latitude of the vertex. Finding the longitude of the vertex is given in the next problem.

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 of the vertex.

Answer: 37° 34.92' 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

Step 2: Determine the Latitude of the Vertex using the Vertex Formulae.

$$Lv = \cos^{-1}((\cos L1)(\sin C))$$
$$Lv = \cos^{-1}((\cos 25.834°)(\sin 61.7°))$$
$$Lv = \cos^{-1}(0.900060)(0.880477)$$
$$Lv = \cos^{-1}(0.792482)$$
$$Lv = 37.582°$$

Step 3: Convert the decimal longitude to standard notation.
37.582° N = **37° 34.92' N**

Problem 5-7 (CG-551). The following question is taken directly from the USCG test bank and illustrates how to find the longitude of the vertex of a Great Circle track. Note that the USCG test question provides the latitude of the vertex. Solving for the latitude of the vertex is shown in the previous problem.

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 latitude of the vertex is 37° 34.9' N. Determine the longitude of the vertex.

Answer: 025° 59.4' W

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° 34.9' N = 37.582° N

Step 2: Determine the Difference in Longitude of the Vertex *(DLo(v))* given the Vertex Formulae.

$$DLo(v) = \sin^{-1}\left(\frac{\cos C}{\sin Lv}\right)$$
$$DLo(v) = \sin^{-1}\left(\frac{\cos 61.7°}{\sin(37.582)}\right)$$
$$DLo(v) = \sin^{-1}\left(\frac{(0.4741)}{(0.6099)}\right)$$
$$DLo(v) = \sin^{-1}(0.7773)$$
$$DLo(v) = 51.01°$$

Step 3: 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) = 51.01°
Longitude of the Vertex = 77.00° - 51.01° = 25.99° W

Step 4: Convert the decimal longitude to standard notation.
25.99° W = **25° 59.4' W**

<u>Problem 5-8 (CG-552)</u>. The following question is taken directly from the USCG test bank and illustrates how to find the latitude intersecting the great circle track, away from the vertex. Note this example is a continuation of the previous two examples (having previously found the latitude and longitude of the vertex). Also note that the examples are slightly "off" due to rounding differences between this text and the official CG answers.

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° 34.9' N, 25° 59.0' W. Determine the latitude intersecting the great circle track 600 miles west of the vertex, along the great circle track.

Answer: 36° 54.9' 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° 34.9' N = 37.582° N
Longitude of the Vertex
25° 59.0' 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 using the Vertex Formulae. Note that "*D(vx)*" stands for the "distance from the vertex" and "*Lx*" stands for "latitude of any point along the great circle track."
$Lx = \sin^{-1}((\sin L(v))(\cos D(vx)))$
$Lx = \sin^{-1}((\sin(37.582°)(\cos(10°))$

$$Lx = \sin^{-1}((0.6099)(0.9848))$$
$$Lx = \sin^{-1}(0.6006)$$
$$Lx = 36.915°$$

Step 4: Convert the decimal latitude to standard notation.

$Lx = 36.915°$ = 36° + 0.915°

0.915° × 60 = 54.9’

$Lx = 36.915$ = **36° 54.9’ N**

Plane and Parallel Sailings Problems

Typically, these problems are part of larger problems. For example, when calculating a time of phenomenon problem (covered in Part 9) it is necessary to dead-reckon the ship’s future position.

Plane and parallel sailing formulas can be used to accurately calculate a future ship position, and these calculations are often incorporated into more complex time of phenomena problems later. The basic formulae for plane and parallel sailings are shown here, and this section should be reviewed before beginning the advanced problems in Part 9: Time of Phenomenon Problems.

There are several plane sailing formulae given in the “formulae” section above, as well as in Bowditch, but the main formulae necessary for most problems are:

$$l = D \cos C$$

$$D = l \sec C$$

$$p = D \sin C$$

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. The main parallel sailing formula needed is:

$$DLo = \frac{p}{\cos l}$$

Problem 5-9. The following question is modified from a question in the USCG test bank and illustrates how to solve for a second position given initial course, speed, and position.

You are on course 082° T, speed 19 knots. Your 0830 DR position is latitude 24° 14.8' N and longitude 133° 35.5' W. You wish to make a celestial observation at 1146 local time. What will the ship's position be at that time?

Answer: Latitude 2 = 24° 23.5' N, Longitude 2 = 132° 28.0' W

Step 1: Determine the transit time and the Distance (D) steamed over that time.
0830 to 1146 = 3 hours and 16 minutes = 3.27 hours.
3.27 hours at 19 knots = D = 62.13 nm covered

Step 2: Determine the Difference in Latitude (l) using the plane sailing formula.
$l = D\ \cos C$
$l = 62.13\ \cos(82°)$
$l = (62.13)\ (0.1392)$
$l = 8.65'$

Step 3: Determine latitude 2 given the initial position and the Difference in Latitude (l).
Lat1 = 24° 14.8' N
l = 0° 08.65'
Lat2 = 24° 14.8' + 0° 08.65' = **24° 23.5' N**

Step 4: Determine the Departure (p) using the plane sailing formula.
$p = D\ \sin C$
$p = (62.13)\ \sin(82°)$
$p = (62.13)(0.9903)$
$p = 61.53$

Step 5: Determine the mid-latitude and convert to decimal notation.
Lat1 = 24° 14.8' N
Lat2 = 24° 23.5' N
Lm = $\frac{(24°\ 23.5' + 24°\ 14.8)}{2}$ = 24° 19.15' N = 24.319°

Step 6: Determine the Difference in Longitude (DLo) using the parallel sailing formula. Then convert to arc.
$DLo = \frac{p}{\cos l}$
$DLo = \frac{61.53}{\cos(24.319°)}$
$DLo = \frac{61.53}{0.9113}$

DLo = 67.52' = 1° 07.5'

Step 7: Determine longitude 2 given the initial position and the Difference in Longitude (DLo).
Long 1 = 133° 35.5' W
DLo = 1° 07.5' (eastward given the initial course).
Long 2 = 133° 35.5' – 1° 07.5' = **132° 28.0' W**

Problem 5-10. The following question is modified from a question in the USCG test bank and illustrates how to solve for a second position given initial course, speed, and position.

Your ship's 0400 zone time DR position is 22° 31.'0 N and 031° 45.0' W. You are on course 240° T at 16.5 knots. Sunrise is at approximately 0505. What position will the ship be at that time?

Answer: Latitude 2 = 22° 22.1' N, Longitude 2 = 134° 01.7' W

Step 1: Determine the transit time and the Distance (D) steamed over that time.
0400 to 0505 = 1 hour and 05 minutes = 1.083 hours.
1.083 hours at 16.5 knots = D = 17.87 nm covered

Step 2: Determine the Difference in Latitude (l) using the plane sailing formula.
$l = D \cos C$
$l = 17.87 \cos(240°)$
$l = (17.87)\,(-0.5000)$
$l = -8.935'$

Step 3: Determine latitude 2 given the initial position and the Difference in Latitude (l).
Lat1 = 22° 31.0' N
l = - 0° 08.935'
Lat2 = 22° 31.0 + (-0° 08.935') = **22° 22.1' N**

Step 4: Determine the Departure (p) using the plane sailing formula.
$p = D \sin C$
$p = (17.87) \sin(240°)$
$p = (17.87)(-0.8660)$
$p = -15.475$

Step 5: Determine the mid-latitude and convert to decimal notation.
Lat1 = 22° 31.0' N
Lat2 = 22° 22.1' N

Lm = $\frac{(22° 31.0' + 22° 22.1)}{2}$ = 22° 26.55' N = 24.443°

Step 6: Determine the Difference in Longitude (*DLo*) using the parallel sailing formula. Then convert to arc.

$DLo = \frac{p}{\cos l}$

$DLo = \frac{-15.475}{\cos(22.443°)}$

$DLo = \frac{-15.475}{0.9243}$

$DLo =$ 16.742' = 0° 16.742'

Step 7: Determine longitude 2 given the initial position and the Difference in Longitude (*DLo*).

Long 1 = 031° 45.0' W

DLo = 0° 16.742' (westward given the initial course).

Long 2 = 133° 35.5' + 0° 16.742' = **133° 61.742' W = 134° 01.7' W**

<u>Problem 5-11 (CG-768)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve parallel sailing problems.

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 1: Convert standard latitude and longitudes to decimal form:
Departure Location
25° 54' N = 25.900° N
009° 38' E = 9.633° E

Step 2: Determine the Departure (p).
$p = D \ \sin C$
$p = (592) \ \sin(270°)$
$p = (592)\,(-1.0)$
$p = -592'$

Step 3: 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 4: Convert the Difference of Longitude (DLo) into decimal notation.
-658.1' ÷ 60 = -10.968° = 10.968° to the west.

Step 5: 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 6: Convert the arrival longitude to standard notation.
1.335° W = **001° 20.1' W**

Problem 5-12 (CG-775). The following question is taken directly from the USCG test bank and illustrates how to solve parallel sailing problems.

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.
$DLo = p \sec l = p\ (\frac{1}{\cos l})$
$DLo = (-1543')(\frac{1}{\cos 38.200°})$
$DLo = (-1543')(\frac{1}{0.7859})$
$DLo = (-1543')(1.2724)$
$DLo = -1963.3'$

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**

Additional Problems and Answers

All of the following questions were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-5. 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*

Problem CG-7. A vessel at latitude 20° 10' 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*

Problem CG-8. 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*

Problem CG-28. 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*

Problem CG-29. 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

Problem CG-30. 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

Problem CG-9. 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

Problem CG-13. 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

Problem CG-16. 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

Problem CG-6. 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*

Problem CG-3. 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*

Problem CG-24. 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*

Problem CG-26. 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*

Problem CG-779. 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*

Problem CG-914. 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

Problem CG-988. 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

Problem CG-100. 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

Problem CG-99. 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

Problem CG-765. 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

Problem CG-987. 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', 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

Problem CG-775. 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*

Problem CG-1006. The initial great circle course angle between latitude 23° S, longitude 42° W, and latitude 34° S, longitude 18° E is 063.8°. What is the true course?

- *a) 063.8° T*
- *b) 116.2° T- correct*
- *c) 243.8° T*
- *d) 296.2° T*

Problem CG-549. The great circle distance from latitude 24° N 25.3' W, longitude 83° 02.6' W to latitude 35° 57.2' N, longitude 5° 45.7' W is 3966.5 miles. Determine the latitude of the vertex.

- *a) 38° 46.2' N*
- *b) 38° 16.4' N*
- *c) 38° 09.4' N- correct*
- *d) 37° 57.3' N*

Problem CG-548. 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*

Problem CG-642. 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*

Problem CG-555. 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*

Problem CG-556. 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*

Problem CG-643. 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*

Problem CG-105. 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.

a) *3593 miles, 048.1° T- correct*
b) *3457 miles, 053.3° T*
c) *3389 miles, 042.4° T*
d) *3367 miles, 045.0° T*

Problem CG-108. 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*

Part Six: Compass Problems

Basic compass problems are usually a part of a much larger navigational problem, but the skills to correct and un-correct a compass can also be used in ship's logs or general navigational computations.

Many navigation problems are multi-part, with a compass calculation as a critical part of the solution.

Acronyms

When solving a compass problem, most people find it easiest to set up a grid, or their own type of system for solving each problem, and then sticking with it. Having a "system" reduces the chances for error in complex problems, provided it is used – every time.

A politically correct version of the most common acronym for solving compass problems is "True Vampires Make Dull Companions At Wakes." Or, in reverse, "Can Dead Men Vote Twice At Elections?"

In either case, here is what the acronym stands for:

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…***

Another acronym to use for some problems is "G-E-T." The acronym "G-E-T," which stands for "Gyro course + Easterly Error = True course" will help to solve problems involving gyro error. Note, however, that often times although gyro error is known or given, it is not necessary in calculations. Be careful in choosing applicable information when solving compass problems!

Definitions

True Course – the actual course between two points.
Variation – the difference in true north and magnetic north for the current location.
Magnetic Course – the actual magnetic course between two points.
Deviation – the difference in a magnetic course and the reading on a magnetic compass due to errors caused by adjustment or interference from the ship.
Compass Course – the course read directly off a steering compass.
Add East/Add West – this indicates to add easterly/westerly values (as the case may be) when moving in a certain direction. For example, when correcting (moving down), westerly values are added and easterly values are subtracted.
"per steering compass" or "per standard compass" – the course read off a magnetic compass.
"per gyro compass" – the course read off a gyroscopic compass.

Given these definitions and acronyms, all problems will be solved by first writing:
T
V
M
D
C
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).

Doing this process *for every calculation, no matter how mundane* drastically reduces the chance for errors. For example, a mariner could spend upwards of 30 minutes performing a course calculation on a chart plot exam or for a ship evaluation, only to ultimately get an incorrect answer because of an error in a 15 second compass calculation at the end.

Compass Correction Problems

Problem 6-1. The following question illustrates the use of the compass un-correction process (moving upwards in the table).

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)

<u>Problem 6-2</u>. The following question illustrates the use of the compass correction process (moving downwards in the table).

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)

Compass Correction Problems with Ancillary Information

Often, compass correction problems are simply part of larger problems, such as gyro error or leeway problems. Here are several examples of problems that incorporate compass corrections in them.

Problem 6-3 (CG-618). The following question is taken directly from the USCG test bank and illustrates the calculation of deviation using a charted range.

While proceeding up a channel on course 010° per gyro compass, you notice a pair of range lights in alignment with the masts of your vessel when viewed forward. A check of the chart shows the range to be 009° T and the variation to be 15° W. If the ship's course is 026° per steering compass, what is the deviation for the present heading?

Answer: 2° W

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).

Step 2: Fill in the known values:
T: 009° T (Given)
V: 15° W (Given)
M:
D:
C: 026° per steering compass (Given)

Step 3: Calculate the magnetic course and then the deviation using the known values:
T: 009° T (Given)
V: 15° W (Given)
M: 024° M (Calculated)
D: 2° W (Calculated)
C: 026° per steering compass (Given)

Problem 6-4 (CG-580). The following question is taken directly from the USCG test bank and illustrates the process of accounting for gyro error when choosing a course to steer per gyro compass.

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.

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)

Problem 6-5. The following question illustrates the use of gyro error calculations in larger compass calculation problems. The acronym "G-E-T," which stands for "Gyro course + Easterly Error = True course" will help to solve these problems.

The gyro compass is not functioning. You are steering 010° per standard magnetic compass. The variation is 5° E, the deviation is 2° W, and the gyro error is 1° E. At 2300, the gyro compass is repaired. What gyro course should you steer to maintain track?

Answer: 012° per gyro compass. The acronym "G-E-T," which stands for "Gyro course + Easterly Error = True course" will help to solve these problems.

Step 1: Write down the acronyms:
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).

G: (Gyro Course)
E: (Easterly Error Added)
T: (True Course)
The acronym "G-E-T," which stands for "Gyro course + Easterly Error = True course" will help to solve these problems.

Step 2: Fill in the known values:
T:
V: 5° E (Given)
M:
D: 2° W (Given)
C: 010° per steering compass (Given)

G:
E: 1° E (Given)
T:

Step 3: Calculate the magnetic course.
T:
V: 5° E (Given)
M: 008° M (Calculated)
D: 2° W (Given)
C: 010° per steering compass (Given)

G:
E: 1° E (Given)
T:

Step 4: Calculate the true course.
T: 013° T (Calculated)
V: 5° E (Given)
M: 008° M (Calculated)
D: 2° W (Given)
C: 010° per steering compass (Given)

G:
E: 1° E (Given)
T:

Step 5: Calculate the gyro course to steer to make good the previously calculated true course.

T: 013° T (Calculated)
V: 5° E (Given)
M: 008° M (Calculated)
D: 2° W (Given)
C: 010° per steering compass (Given)

G: 012° Per gyro compass (Calculated)
E: 1° E (Given)
T: 013° T (Carried over from "T" above)

Problem 6-6 (CG-786). The following question is taken directly from the USCG test bank and illustrates the calculation of a desired course to steer taking into account leeway. Additionally, it illustrates the incorporation of gyro error into the calculations.

You desire to make good a true course of 046° T. The variation is 6° E, magnetic compass deviation is 12° W, and the gyro compass error is 3° 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.

Leeway is treated as simply another error to be accounted for in the problem. In this case, "a northerly wind produces a 5° leeway." This means that the ship must steer 5° towards the wind (north/left in this case) in order to make good the desired course. Therefore once the compass course to steer has been calculated, the mariner must account for leeway, by subtracting 5° in this case.

Also note that although gyro error information is given in this problem, it is not necessary to solve the problem, so those calculations have been omitted in this example.

Step 1: Write down the acronyms:

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).

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

G:
E: 3° W (Given but not necessary. Further gyro error calculations are omitted.
T:

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)

--052° per steering compass
--Subtract 5° to account for leeway from a northerly (000° T) wind
--**047° per steering compass, taking into account leeway.**

Deviation Table Problems

Problem 6-7 (CG-868). The following question is taken directly from the USCG test bank and illustrates the use of a deviation table in compass correction problems.

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.

Table:

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°. Only the portions of the deviation table bracketing your headings are required. Construct TVMDC tables for each possible heading and interpolate.

Step 1: Write down the acronyms:
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).

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°

$\frac{4°}{30°} = \frac{x}{1.0°}$

$\boldsymbol{x = 0.133°}$**. Rounded to the nearest half-degree, answer is 0.0°**

Navigation Log Keeping Problems

Most CG cutters require frequent entries in the navigation log which feature compass correction problems. Here is the proper way to keep the cutter navigation log. The columns in the navigation log are laid out thus:

Time	Gyro Crs/Brg	Gyro Error	True Course/Brg	Var	Mag Compass	Dev	Steer Compass	Speed of Advance	Comments

Since most cutters steer by gyro compass exclusively, it is convenient to think of this log-keeping challenge as two separate problems. The first problem involves correcting the gyro compass in the boldfaced section below. Use the acronym "G-E-T" to solve these problems.

Time	**Gyro Crs/Brg**	**Gyro Error**	**True Course/Brg**	Var	Mag Compass	Dev	Steer Compass	Speed of Advance	Comments

The second problem involves using the corrected gyro course to solve a magnetic compass check in the boldfaced section below. Use the acronym "True Vampires Make Dull Companions (at wakes)" or "Can Dead Men Vote Twice (at elections" to solve these problems.

Time	Gyro Crs/Brg	Gyro Error	**True Course/Brg**	**Var**	**Mag Compass**	**Dev**	**Steer Compass**	Speed of Advance	Comments

The time, speed of advance, and comments columns are self explanatory.

<u>Problem 6-8</u>. The following question illustrates a typical log-keeping challenge while on watch in open ocean waters.

Your cutter is underway on patrol at 10 knots. At 0330, the quartermaster of the watch conducts a periodic compass check with the following information obtained:

The gyro compass course reads 045° per gyro compass.
The magnetic compass course reads 054° per steering compass.
The calculated gyro error is 1° E.
The charted variation for your location is 10° W.
The deviation table for your course indicates a magnetic deviation of 2° E.

Properly fill in the cutter navigation log.

Answer: as indicated below.

Step 1: First, use the gyro compass course and gyro error to calculate the true course, using the acronym "G-E-T," which stands for "Gyro course + Easterly Error = True course."

In this case, the gyro course is 045° pgc, the gyro error is 1° E, so the true course is therefore 046° T, as indicated in the log below.

Time	**Gyro Crs/Brg**	**Gyro Error**	**True Course/Brg**	Var	Mag Compass	Dev	Steer Compass	Speed of Advance	Comments
0330	**045°**	**1° E**	**046° T**					10.0kts	C/C

Step 2: Fill in the known information. Remember that the reading off the magnetic compass on the cutter's bridge is "Steering Compass" not "Magnetic Compass."

Time	Gyro Crs/Brg	Gyro Error	**True Course /Brg**	**Var**	Mag Compass	**Dev**	**Steer Compass**	Speed of Advance	Comments
0330	045°	1° E	**046° T**	**10° W**		**2° E**	**054° psc**	10.0 kts	C/C

Step 3: Use the true course that was just calculated, the given information and the acronym "True Vampires Make Dull Companions (at wakes)" to complete the navigation log.

Time	Gyro Crs/Brg	Gyro Error	True Course /Brg	Var	**Mag Compass**	Dev	Steer Compass	Speed of Advance	Comments
0330	045°	1° E	046° T	10° W	**056° M**	2° E	054° psc	10.0 kts	C/C

If the calculations do not work out perfectly, first double check the work, and second, consider that gyro error or deviation may have changed based on the existing conditions, and make log entries accordingly.

Additional Problems and Answers

All of the following questions were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-946. 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

Problem CG-948. 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

Problem CG-953. 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

Problem CG-592. 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

Problem CG-976. 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*

Problem CG-978. 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*

Problem CG-983. 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*

Problem CG-584. 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*

Problem CG-587. 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*

Problem CG-590. 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*

Problem CG-591. The true course from point A to point B is 317°. A SSW wind causes a 4° leeway, variation is 6° W, and deviation is 1° E. What is the magnetic compass course to steer to make good the true course?

- *a) 326° psc*
- *b) 318° psc- correct*
- *c) 313° psc*
- *d) 308° psc*

Problem CG-783. 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*

Problem CG-785. 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*

Problem CG-793. You desire to make good a true course of 223°. The variation is 2° E, magnetic compass deviation is 2° E, and gyrocompass error is 1° W. An east-southeast wind produces 3° leeway. What is the course to steer per standard magnetic compass to make the true course good?

- *a) 213° psc*
- *b) 216° psc- correct*
- *c) 220° psc*
- *d) 223° psc*

Problem CG-797. You desire to make good a true course of 347°. The variation is 11° E, magnetic compass deviation is 7° W, and gyrocompass error is 4° W. A north by east wind produces a leeway of 4°. What is the course to steer by standard magnetic compass to make the true course good?

a) *339° psc*
b) *343° psc*
c) *347° psc- correct*
d) *351° psc*

Problem CG-885. You wish to check the deviation of your standard magnetic compass. You find a natural range that you steer for and note that the gyrocompass heading is 034° and the heading by standard magnetic compass is 026°. The gyro error is 1° W. Variation is 9° E. What is the deviation for that heading?

a) *2° W- correct*
b) *0°*
c) *2° E*
d) *9° E*

Problem CG-869. 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 magnetic compass heading of 057°.

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

Problem CG-870. 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*

Problem CG-872. 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*

Problem CG-881. 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*

Problem CG-882. 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 319°.

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) *0.5° E*

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

Part Seven: Tide and Tidal Current Problems

Calculating tides and currents manually involves determining the height of tide or state of current at a reference station, determining offsets to your desired location, and then applying offsets to the reference station to find your exact values.

Problems are based on the 1983 tide tables and 1983 tidal current tables. Descriptions of these tables are located in the preface. Frequently utilized tables from the Tide Tables and Tidal Current Tables are reprinted at the end of this Part.

Tide Problems

Problem 7-1 (CG-703). The following question is taken directly from the USCG test bank and illustrates how to solve height of tide problems.

On 5 March, 1983, at 0630 EST (ZD +5), what will be the predicted height of tide at Ocracoke, Ocracoke Inlet, NC.

Answer: 0.1 foot.

Step 1: Locate the desired port in the Tide Tables and note the reference station and any offsets required.

NO.	PLACE	POSITION		DIFFERENCES				RANGES		Mean Tide Level
		Lat.	Long.	Time		Height		Mean	Spring	
				High Water	Low Water	High Water	Low Water			
	NORTH CAROLINA, Outer Coast									
2443	Currituck Beach Light	36 23	75 50	-1 46	-1 45	+1.1	0.0	3.6	4.3	1.8
2444	Albemarle and Pamlico Sounds <9>	- - -	- - -	- - -	- - -	- -	- -	- -	- -	- -
2445	Kitty Hawk (ocean)	36 06	75 43	-1 50	-1 49	+0.7	0.0	3.2	3.8	1.6
2446	Jennetts Pier (ocean)	35 55	75 36	-1 54	-1 50	+0.8	0.0	3.3	3.9	1.6
2447	Roanoke Sound Channel	35 48	75 35	+0 27	+0 37	-2.0	0.0	0.5	0.6	0.3
2448	Oregon Inlet Marina	35 48	75 33	-0 38	+0 26	-1.9	0.0	0.6	0.7	0.3
2449	Oregon Inlet	35 46	75 31	-1 13	-1 07	-0.5	0.0	2.0	2.4	1.0
2450	Oregon Inlet Bridge	35 46	75 32	-1 27	-1 35	-0.6	0.0	1.9	2.3	1.0
2451	Oregon Inlet Channel	35 46	75 34	-1 19	-1 14	-1.3	0.0	1.2	1.4	0.6
2452	Old House Channel	35 46	75 35	-0 36	-0 12	-1.8	0.0	0.7	0.8	0.4
2453	Oregon Inlet (USCG Station)	35 46	75 32	-1 40	-1 31	-0.8	0.0	1.7	2.0	0.9
2454	Davis Slough	35 45	75 33	-1 01	-0 41	-1.6	0.0	0.9	1.1	0.5
2455	Cape Hatteras	35 14	75 31	-1 54	-2 05	+1.1	0.0	3.6	4.3	1.8
2456	Hatteras (ocean)	35 12	75 42	-2 02	-2 05	+0.9	0.0	3.4	4.1	1.7
2457	Hatteras Inlet	35 12	75 44	-1 39	-1 39	-0.5	0.0	2.0	2.4	1.0
2458	Ocracoke Inlet	35 04	76 01	-1 38	-1 41	-0.6	0.0	1.9	2.3	0.9
2459	Ocracoke, Ocracoke Inlet	35 07	75 59	-1 23	-1 00	*0.40	*0.40	1.0	1.2	0.5
2461	Cape Lookout	34 37	76 32	-2 04	-2 13	+1.2	0.0	3.7	4.4	1.9
2463	Shell Point, Harkers Island	34 41	76 32	+0 12	+0 45	-1.2	0.0	1.3	1.6	0.6
2465	Beaufort (Pivers Island)	34 43	76 40	-1 01	-1 09	+0.5	0.0	3.0	3.6	1.5
2467	Morehead City	34 43	76 42	-0 58	-1 05	+0.4	0.0	2.9	3.5	1.4
2469	Atlantic Beach	34 42	76 43	-2 02	-2 03	+1.1	0.0	3.6	4.3	1.8
2471	Bogue Inlet	34 39	77 06	-1 34	-1 37	-0.3	0.0	2.2	2.6	1.1
2473	New River Inlet	34 32	77 20	-1 31	-1 35	+0.5	0.0	3.0	3.6	1.5
2475	New Topsail Inlet	34 22	77 38	-1 27	-0 52	+0.5	0.0	3.0	3.5	1.5

For Ocracoke, Ocracoke Inlet, NC (station 2459), the reference station is Hampton Roads, Virginia. The offsets are:

Time	High Water	Low Water	**Height**	High Water	Low Water
	-1:23	-1:00		*0.40	*0.40

Step 2: Find the tidal information for the reference station for the desired date.

For 5 March, 1983, the tidal information is:

0139: 2.5 feet
0800: 0.2 feet
1358: 2.0 feet
2003: 0.2 feet

MARCH

Day	Time h m	Height ft	Height m	Day	Time h m	Height ft	Height m
1 Tu	0435	-0.5	-0.2	16 W	0406	-0.3	-0.1
	1046	2.8	0.9		1013	2.2	0.7
	1658	-0.4	-0.1		1619	-0.3	-0.1
	2313	2.9	0.9		2233	2.4	0.7
2 W	0525	-0.3	-0.1	17 Th	0444	-0.3	-0.1
	1132	2.7	0.8		1048	2.2	0.7
	1741	-0.3	-0.1		1652	-0.2	-0.1
	2359	2.8	0.9		2311	2.5	0.8
3 Th	0613	-0.1	0.0	18 F	0524	-0.1	0.0
	1218	2.5	0.8		1125	2.2	0.7
	1826	-0.1	0.0		1728	-0.1	0.0
					2353	2.6	0.8
4 F	0049	2.7	0.8	19 Sa	0610	0.0	0.0
	0707	0.1	0.0		1210	2.2	0.7
	1308	2.2	0.7		1812	0.0	0.0
	1913	0.0	0.0				
5 Sa	0139	2.5	0.8	20 Su	0041	2.6	0.8
	0800	0.2	0.1		0703	0.2	0.1
	1358	2.0	0.6		1258	2.1	0.6
	2003	0.2	0.1		1903	0.1	0.0

Step 3: Determine if daylight savings time is in effect.

The problem states that times are to be determined in EST, which means daylight savings time is not in effect, and no correction to the tidal times is required.

Step 4: Create a table to compute tides at the desired location near the desired time.

Time	High Water	Low Water	**Height**	High Water	Low Water
Reference	01:39	08:00		2.0 feet	0.2 foot
Offsets	-1:23	-1:00		*0.40	*0.40
Ocracoke	**00:16**	**07:00**		**0.8 feet**	**0.1 foot**

Step 5: Answer the required questions regarding the state of tide.

The question asks the state of tide at 0630, which is 30 minutes before the time of low water. Refer to the "Height of Tide at any Time" table in the Tidal Tables (reprinted at the end of this Part).

TABLE 3.—HEIGHT OF TIDE AT ANY TIME 239

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
	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

The duration of rise or fall is 07:00 – 00:16 or <u>5 hours, 44 minutes.</u>
The time from nearest high water is <u>30 minutes.</u>

Entering the table with this data yields a height correction of 0.0 foot. Therefore there is no offset to the calculated tide, and the correct answer is **0.1 foot.**

<u>Problem 7-2 (CG-695).</u> The following question is taken directly from the USCG test bank and illustrates how to solve height of tide problems.

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?

Answer: 23.9 feet or 7.2 meters.

Step 1: Locate the desired port in the Tide Tables and note the reference station and any offsets required.

NO.	PLACE	POSITION Lat.	Long.	DIFFERENCES Time High Water	Time Low Water	Height High Water	Height Low Water	RANGES Mean	Spring	Mean Tide Level
	Hudson River <8>									
1513	Jersey City, Con Rail RR. Ferry, N. J...	40 43	74 02	+0 07						
1515	New York, Desbrosses Street.............	40 43	74 01	+0 10						
1517	New York, Chelsea Docks.................	40 45	74 01	+0 17						
1519	Hoboken, Castle Point, N. J.............	40 45	74 01	+0 17						
1521	Weehawken, Days Point, N. J.............	40 46	74 01	+0 24						
1523	New York, Union Stock Yards.............	40 47	74 00	+0 27						
1525	New York, 130th Street..................	40 49	73 58	+0 37						
1527	George Washington Bridge................	40 51	73 57	+0 46						
1529	Spuyten Duyvil, west of RR. bridge......	40 53	73 56	+0 58						
1531	Yonkers.................................	40 56	73 54	+1 09						

NEW YORK (The Battery), N.Y., 1983
Times and Heights of High and Low Waters

AUGUST

Day	Time h m	Height ft	Height m	Day	Time h m	Height ft	Height m
1	0029	4.2	1.3	16	0221	4.2	1.3
M	0626	0.7	0.2	Tu	0840	0.6	0.2
	1311	4.5	1.4		1454	4.9	1.5
	1931	1.2	0.4		2130	0.7	0.2
9	0234	-0.8	-0.2	24	0252	0.0	0.0
Tu	0836	5.1	1.6	W	0854	4.5	1.4
	1445	-0.5	-0.2		1459	0.4	0.1
	2054	6.0	1.8		2102	5.0	1.5
10	0322	-0.9	-0.3	25	0326	0.0	0.0
W	0931	5.3	1.6	Th	0929	4.6	1.4
	1536	-0.5	-0.2		1534	0.4	0.1
	2150	5.9	1.8		2134	4.9	1.5

For Weehawken, Days Point, NJ (station 1521), the reference station is New York. The offsets are:

Time	High Water	Low Water	**Height**	High Water	Low Water
	+0:24	+0:23		-0.3	0.0

Step 2: Find the tidal information for the reference station for the desired date.

For 10 August, 1983, the tidal information is:

0322	-0.9 foot
0931	5.3 feet
1536	-0.5 foot
2150	5.9 feet

Step 3: Determine if daylight savings time is in effect.

The problem states that times are to be determined in DST, which means daylight savings time is in effect, and one hour must be added to determine the correct times. The new tidal information is:

0422	-0.9 foot
1031	5.3 feet
1636	-0.5 foot
2250	5.9 feet

Step 4: Create a table to compute tides at the desired location near the desired time.

Time	Low Water	High Water	**Height**	Low Water	High Water
Reference	16:36	22:50		-0.5 foot	5.9 feet
Offsets	+00:23	+00:24		0.0	-0.3
Weehaken	**16:59**	**23:14**		**-0.5 foot**	**5.6 feet**

Step 5: Answer the required questions regarding the state of tide.

The question asks for the height of water at the time of mooring (1800 DST). The height of water is MLLW + the height of tide. Using the Height of Tide at any Time table:

The duration of rise or fall is 14:59 – 21:14 or <u>6 hours, 13 minutes.</u>
The time from nearest high or low water is <u>1 hour, 1 minute.</u>
The range of tide is <u>6.1 feet.</u>

Entering the table with this data yields a height correction of 0.4 feet.

Since the nearest tide is low, the correction is applied from low water.

1659 to 1800:
-0.5 foot + 0.4 feet = -<u>0.1 feet.</u>

Since the height of tide at 1800 is -0.1 foot and the charted depth alongside is 24 feet, the correct depth of water at the pier at the time of mooring is **23.9 feet.**

TABLE 3.—HEIGHT OF TIDE AT ANY TIME 239

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
	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

Tidal Current Problems

Problem 7-3 (CG-1470). The following question is taken directly from the USCG test bank and illustrates how to solve tidal current speed problems.

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

Answer: 1.1 knots.

Step 1: Locate the desired location in the Tidal Current Tables and note the reference station and any offsets.

The reference station for Southwest Ledge (station 2211) is The Race.

TABLE 2. - CURRENT DIFFERENCES AND OTHER CONSTANTS, 1983

NO.	PLACE	METER DEPTH	POSITION Lat.	POSITION Long.	TIME DIFFERENCES Min. before Flood	Flood	Min. before Ebb	Ebb	SPEED RATIOS Flood	Ebb	AVERAGE SPEEDS AND DIRECTIONS Minimum before Flood knots	deg.	Maximum Flood knots	deg.	Minimum before Ebb knots	deg.	Maximum Ebb knots	deg.
		ft	° ' N	° ' W	h. m.	h. m.	h. m.	h. m.										
	NARRAGANSETT BAY <8> Time meridian, 75°W				on POLLOCK RIP CHANNEL, p.28													
2041	Patience Island, narrows east of........		41 39.5	71 21.2	-2 41	-2 29	-2 44	-2 37	0.4	0.5	0.0	- -	0.7	354	0.0	- -	0.9	157
2051	Patience I. and Warwick Neck, between...		41 39.8	71 22.4	-1 40	-1 21	-1 18	-1 13	0.3	0.5	0.0	- -	0.6	040	0.0	- -	0.8	224
2061	Warren River entrance..................		41 42.7	71 17.8	Current weak and variable						0.0	- -	0.4	020	0.0	- -	0.3	200
2071	Warren, Warren River...................		41 43.7	71 17.3	-0 14	+0 11	-0 22	-1 05	0.5	0.5	0.0	- -	1.0	358	0.0	- -	0.9	171
2081	Hog Island to Providence...............		- - - -	- - - -	Current weak and variable													
2091	India Point RR. Bridge, Seekonk R. <9>..		41 49.0	71 23.3	-1 48	-4 02 -2 30 -0 12	-1 31	-1 06	0.5 0.2 0.7	0.8	0.0	- -	1.0 0.4 1.3	020 020 020	0.0	- -	1.4	180
2101	Cold Spring Pt., Seekonk River <10>.....		41 49.6	71 22.8	-1 48	-4 14 -2 24 -0 26	-1 31	-1 02	0.4 0.1 0.6	0.8	0.0	- -	0.8 0.2 1.1	030 030 030	0.0	- -	1.4	210
	BLOCK ISLAND SOUND				on THE RACE, p.34													
	Point Judith																	
2106	Harbor of Refuge, south entrance.....		41 21.48	71 29.75	-2 23	-2 52	-2 26	-3 59 -2 41 -1 56	0.2	0.2 0.1 0.2	0.0	- -	0.6	329	0.0	- -	0.8 0.4 0.7	141 141 141
2111	Harbor of Refuge, west entrance......		41 22	71 31	See table 5.													
2116	Pond entrance........................		41 23	71 31	-3 23	-3 01	-3 16	-3 52	0.6	0.4	0.0	- -	1.8	351	0.0	- -	1.5	186
2121	2.4 miles southwest of...............		41 19.87	71 30.65	-0 48	-0 01	+0 18	-0 24	0.2	0.2	0.0	- -	0.7	258	0.0	- -	0.6	090
2126	4.5 miles southwest of...............		41 18	71 33	See table 5.													
	Block Island																	
2131	four miles north of..................		41 18	71 32	-0 30	+0 03	+0 35	+0 21	0.2	0.2	0.0	- -	0.8	285	0.0	- -	0.8	076
2136	Sandy Point, 2.1 miles NNE of........	15	41 15.85	71 34.00	+0 09	-0 53	-0 30	-0 43	0.4	0.5	0.0	- -	1.0	296	0.0	- -	1.7	066
2141	Sandy Pt., 1.5 miles north of........	7	41 15	71 34	-0 22	-0 30	-1 03	-0 50	0.6	0.5	0.0	- -	1.9	315	0.0	- -	2.1	063
2146	Clay Head, 1.2 miles ENE of..........	15	41 13.35	71 31.85	-2 20	-1 32	-0 37	-0 55	0.2	0.1	0.5	220	0.7	298	0.0	- -	0.5	164
2151	Old Harbor Pt., 0.5 mile southeast of		41 09	71 32	-0 10	-0 29	-0 34	+0 09	0.1	0.1	0.0	- -	0.2	336	0.0	- -	0.6	175
2156	Lewis Pt., 1.0 mile southwest of.....		41 08.20	71 37.30	-1 37	-1 08	-0 34	-1 13	0.7	0.5	0.0	- -	1.9	298	0.0	- -	1.8	136
2161	Lewis Pt., 1.5 miles west of.........		41 09	71 38	-1 31	-1 15	-0 44	-0 57	0.4	0.4	0.0	- -	1.4	318	0.0	- -	1.7	170
2166	Great Salt Pond entrance.............		41 11.97	71 35.50	-4 18	-3 35	-3 34	-4 22	0.1	0.1	0.0	- -	0.3	165	0.0	- -	0.3	326
2171	Great Salt Pond ent., 1 mile NW of...	7	41 12	71 36	-0 52	-0 58	-1 50	-0 32	0.1	0.1	0.0	- -	0.4	158	0.0	- -	0.4	035
2176	Sandy Point, 0.4 mile west of <11>...		41 13.80	71 35.13	- - -	-1 24	- - -	-1 35	- -	0.2	0.0	- -	- - -	- -	0.0	- -	0.7	011
2181	Green Hill Point, 1.1 miles south of....		41 20.90	71 35.77	-1 06	-0 47	-0 34	-0 55	0.2	0.1	0.0	- -	0.6	258	0.0	- -	0.4	070
2186	Sandy Point, 4.1 miles northwest of.....	15	41 17.10	71 38.00	-0 04	+0 11	+0 22	+0 04	0.2	0.2	0.0	- -	0.7	270	0.0	- -	0.6	084
2191	Grace Point, 2.0 miles northwest of.....		41 12	71 38	See table 5.													
2196	Quonochontaug Beach, 1.1 miles S of.....		41 18.80	71 42.82	-0 52	+0 06	+0 37	-0 20	0.4	0.1	0.0	- -	1.1	248	0.0	- -	0.4	078
2201	Quonochontaug Beach, 3.8 miles S of.....	15	41 16.35	71 43.00	-0 05	-0 06	+0 29	+0 08	0.2	0.2	0.0	- -	0.7	243	0.0	- -	0.6	058
2206	Lewis Point, 6.0 miles WNW of...........	15	41 11.60	71 44.20	+0 51	+0 40	+0 06	+0 35	0.2	0.3	0.0	- -	0.6	286	0.0	- -	1.2	097
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
2226	Watch Hill Point, 5.2 miles SSE of......	15	41 13.20	71 49.00	+0 26	+0 18	+0 29	+0 12	0.4	0.3	0.0	- -	1.2	265	0.0	- -	1.2	064
2231	Montauk Point, 5.4 miles NNE of.........	15	41 09.55	71 49.48	+0 25	-0 03	-0 47	+0 08	0.4	0.5	0.0	- -	1.1	279	0.0	- -	1.6	079
2236	Montauk Point, 1.2 miles east of........		41 04.50	71 49.80	-1 30	-1 09	-0 48	-1 53	1.0	0.8	0.0	- -	2.8	346	0.0	- -	2.8	162
2241	Montauk Point, 1 mile northeast of......		41 05	71 51	-2 02	-1 29	-1 10	-1 41	0.7	0.4	0.0	- -	2.4	356	0.0	- -	1.9	145

The offsets and tabular data are:

Minimum before Flood	Flood	Minimum before Ebb	Ebb	Speed ratio (Flood)	Speed ratio (Ebb)	Minimum before flood	Max Flood	Minimum before Ebb	Max Ebb
-0:33m	-0:33m	-0:10m	-0:08m	0.5	0.5	0/-	1.5kts/321°T	0/-	2.1 kts/ 141° T

Step 2: Determine the tidal current information for the reference station.

The reference station data are:

The Race	**Maximum**	**Velocity**
Slack Water	0212	4.8 Ebb
0525	0814	4.2 Flood
1119	1439	4.7 Ebb
1748	2037	4.3 Flood
2342		***The Race***

38 THE RACE, LONG ISLAND SOUND, 1983

F-Flood, Dir. 295° True E-Ebb, Dir. 100° True

SEPTEMBER

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
1		0232	2.3F
Th	0533	0855	2.5E
	1155	1454	2.6F
	1758	2137	3.2E
2	0056	0335	2.5F
F	0639	1002	2.7E
	1302	1555	2.9F
	1903	2237	3.5E
3	0157	0437	2.8F
Sa	0742	1106	3.2E
	1406	1700	3.2F
	2005	2336	3.9E
4	0253	0538	3.2F
Su	0841	1201	3.6E
	1506	1758	3.6F
	2103		
5		0030	4.3E
M	0346	0633	3.7F
	0936	1256	4.1E
	1602	1852	4.0F
	2158		
6		0123	4.6E
Tu	0436	0725	4.0F
	1028	1347	4.5E
	1655	1946	4.2F
	2251		
7		0212	4.8E
W	0525	0814	4.2F
	1119	1439	4.7E
	1748	2037	4.3F
	2342		

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
16	0132	0432	2.2F
F	0718	1031	2.5E
	1347	1650	2.2F
	1930	2256	3.0E
17	0225	0525	2.3F
Sa	0812	1122	2.7E
	1440	1739	2.4F
	2022	2345	3.2E
18	0312	0611	2.5F
Su	0858	1211	2.9E
	1526	1824	2.5F
	2108		
19		0031	3.3E
M	0353	0650	2.6F
	0939	1252	3.1E
	1608	1859	2.6F
	2149		
20		0112	3.4E
Tu	0431	0721	2.8F
	1015	1333	3.2E
	1647	1931	2.8F
	2227		
21		0149	3.4E
W	0506	0750	2.9F
	1049	1409	3.3E
	1723	2003	2.8F
	2304		
22		0228	3.4E
Th	0538	0818	2.9F
	1123	1447	3.4E
	1757	2037	2.9F
	2340		

OCT

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
1	0034	0314	2.6F
Sa	0621	0949	2.9E
	1251	1540	2.9F
	1846	2218	3.5E
2	0136	0418	2.9F
Su	0725	1050	3.4E
	1356	1644	3.2F
	1950	2318	3.9E
3	0233	0519	3.4F
M	0823	1145	3.9E
	1456	1745	3.6F
	2049		
4		0013	4.2E
Tu	0325	0614	3.8F
	0918	1239	4.4E
	1550	1840	3.9F
	2144		
5		0104	4.5E
W	0415	0705	4.1F
	1009	1330	4.7E
	1642	1931	4.1F
	2235		
6		0153	4.6E
Th	0503	0753	4.2F
	1057	1419	4.8E
	1733	2021	4.1F
	2325		
7		0242	4.5E
F	0550	0840	4.2F
	1145	1508	4.8E
	1822	2110	4.0F

Step 3: Determine if daylight savings time is in effect and adjust times as required.

The problem states that DST is in effect. To obtain DST times, one hour must be added. The corrected data are:

The Race	**Maximum**	**Velocity**
Slack Water	0312	4.8 Ebb
0625	0914	4.2 Flood
1219	1539	4.7 Ebb
1848	2137	4.3 Flood
0042		***The Race***

Step 4: Create a table to calculate the required information at the desired location.

The problem asks for the velocity of the tidal current, so only relevant data are included in the table.

	Max Flood Before Desired Time	**Velocity**	**Desired Time**	**Velocity**	**Slack After Desired Time**	**Velocity**
Reference Station	21:37	4.3 kts Flood			00:42	0 kts
Offsets	-0:33m	*0.5			-0:10	0 kts
Southwest Ledge	**21:04**	**2.2 kts**	**2230**	**TBD**	**00:32**	**0 kts**

Step 5: Answer the required questions.

The question asks for the velocity at a specific time (2330 DST). Table 3 in the Tidal Current Tables gives the velocity of the current at any time (Table 3 is reprinted at the end of this Part).

The interval between slack and desired time (2330) is:
2330 to 0032 = <u>1 hr, 02 m.</u>

The interval between slack and maximum current is:
2104 to 0032 = <u>3 hr, 28 m.</u>

Entering Table 3 yields a correction factor (f) of 0.5.

Per the instructions in Table 3, the factor (f) is multiplied by the maximum tidal current velocity to yield the tidal current at the desired time:
0.5 x 2.2 kts = **1.1 kts** at 2230 DST

190 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

<u>Problem 7-4 (CG-2066)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve tidal current problems for specific time windows.

You want to transit Hell Gate on 23 July 1983. What is the period of time around the AM (ZD +4) slack before ebb when the current will be less than 0.5 knot?

Answer: 0939 to 0957.

Step 1: Determine the tidal current information for the desired location.

Since Hell Gate is it's own reference station no offsets are required. The data are:

Hell Gate	**Maximum**	**Velocity**
Slack Water		
0252	0552	3.3 Flood
0848	1146	4.4 Ebb
1503	1809	3.5 Flood
2107		***Hell Gate***

JULY

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots	Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
				23 Sa	0252	0552	3.3F
					0848	1146	4.4E
					1503	1809	3.5F
					2107		

Step 2: Determine if daylight savings time applies and adjust times as required.

The problem states that DST is in effect. To obtain DST times, one hour must be added. The corrected data are:

Hell Gate	**Maximum**	**Velocity**
Slack Water		
0352	0652	3.3 Flood
0948	1246	4.4 Ebb
1603	1909	3.5 Flood
2207		***Hell Gate***

Step 3: Answer the required question.

a. The question asks for the period of time around the AM slack with current less than 0.5 knots. The AM slack is at 0948 (technically it could also be at 0352 but in this case the question seeks the 0948 slack).

b. To find the duration of slack water (the period around slack with a given current speed), utilize Table 4 in the Tidal Current Tables (Table 4 is reprinted at the end of this Part).

The maximum current is <u>4.4 knots</u> for the nearest flood, and <u>3.3 knots</u> for the nearest ebb.

The period sought is for a window of current <u>less than 0.5 knots.</u>

TABLE B

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	13	28	46	66	89
1.5	8	18	28	39	52
2.0	6	13	20	28	36
3.0	4	8	13	18	22
4.0	3	6	9	13	17
5.0	3	5	8	10	13

Utilize table B, because the question deals with Hell Gate.

The duration of slack (less than 0.5 knots) based on the nearest flood is <u>15 minutes.</u>

The duration of slack (less than 0.5 knots) based on the nearest ebb is <u>20 minutes.</u>

The average duration of slack based on both the nearest flood and nearest ebb is:
(15 min + 20 min) ÷ 2 = **18 minutes.**

Therefore, if slack is at 0948, the window of time with current less than 0.5 knots is 0948 +/- 9 minutes, or **0939 to 0957.**

Additional Problems and Answers

All of the following questions were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface). Tide and tidal current problems are located on the navigation general test.

Problem CG-107. Determine the height of the tide at 1430 EST (ZD +5) at New Bedford, MA, on 10 April 1983.

a) *1.1 feet*
b) *1.2 feet*
c) *1.4 feet- correct*
d) *1.7 feet*

Problem CG-408- 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)*

Problem CG-439. Find the height of the tide at Port Wentworth, GA, on 5 October 1983, at 1840 DST (ZD +4).

a) *3.0 feet*
b) *3.5 feet*
c) *4.0 feet*
d) *4.4 feet- correct*

Problem CG-447. For 3 November 1983, at 0830 EST (ZD +5) at Catskill, NY, what is the predicted height of tide?

a) *+0.1 foot*
b) *-0.6 foot- correct*
c) *+0.9 foot*
d) *-1.3 feet*

Problem CG-697. On 2 November 1983 at 1630 EST (ZD +5), what will be the predicted height of tide at Fulton, FL?

a) *2.8 feet- correct*
b) *3.4 feet*
c) *4.2 feet*
d) *5.6 feet*

Problem CG-1517. 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*

Problem CG-336. At what time after 1400 EST (ZD +5), on 4 January 1983, will the height of tide at Port Wentworth, GA be 3.0 feet?

a) *1612*
b) *1630*
c) *1653- correct*
d) *1718*

Problem CG-695. 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)*

Problem CG-2001. 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*

Problem CG-1470. 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*

Problem CG-1515. 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

Problem CG-1524. What will be the time of maximum flood current at the Sagamore Bridge on the Cape Cod Canal during the morning of 6 December 1983 (ZD +5)?

a) 0708- correct
b) 0712
c) 0716
d) 1020

Problem CG-1526. What will be the velocity and direction of the tidal current at Old Ferry Point, NY, at 1340 EST (ZD +5) on 5 February 1983?

a) 0.8 knot at 060° T
b) 0.8 knot at 240° T
c) 1.0 knot at 076° T
d) 1.4 knot at 076° T- correct

Problem CG-1536. What will be the velocity of the tidal current at Port Royal, VA at 1505 DST (ZD +4) on 4 June 1983?

a) 0.0 knot
b) 0.1 knot
c) 0.4 knot- correct
d) 0.7 knot

Problem CG-1537. What will be the velocity of the tidal current in Bolivar Roads, Texas, at a point 0.5 miles north of Ft. Point, on 23 November 1983 at 0330 CST (ZD +6)?

a) Slack water- correct
b) 0.8 kt
c) 1.2 kts
d) 3.4 kts

Problem CG-2069. You will be entering the Mystic River in Connecticut. What is the current at the Highway Bridge at 1900 EST (ZD +5) on 24 January 1983?

a) 2.2 knots flooding
b) Slack water

c) *Slight ebb- correct*
d) *2.5 knots ebbing*

Problem CG-2066. You want to transit Hell Gate on 23 July 1983. What is the period of time around the AM (ZD +4) slack before ebb when the current will be less than 0.5 knot?

a) *0939 to 0957- correct*
b) *0943 to 0953*
c) *0844 to 0852*
d) *0348 to 0356*

Problem CG-2068. You want to transit Pollack Rip Channel, MA on 6 April 1983. What is the period of time around the 0955 (ZD +5) slack water in which the current does not exceed 0.3 knot?

a) *0911 to 0955*
b) *0940 to 1010*
c) *0955 to 1044*
d) *0935 to 1017- correct*

Problem CG-409. 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*

Problem CG-405. 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*

Problem CG-1469. What is the period of time from around 1008 FST (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*

Problem CG-1148. 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*

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. 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
h. m.	*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. 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
h. m.	*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.

TABLE 4.—DURATION OF SLACK

The predicted times of slack water given in this publication indicate the instant of zero velocity, which is only momentary. There is a period each side of slack water, however, during which the current is so weak that for practical purposes it may be considered as negligible.

The following tables give, for various maximum currents, the approximate period of time during which weak currents not exceeding 0.1 to 0.5 knot will be encountered. This duration includes the last of the flood or ebb and the beginning of the following ebb or flood, that is, half of the duration will be before and half after the time of slack water.

Table A should be used for all places *except* those listed below for table B.

Table B should be used for **Cape Cod Canal, Hell Gate, Chesapeake and Delaware Canal,** and all stations in table 2 which are referred to them.

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

TABLE B

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	13	28	46	66	89
1.5	8	18	28	39	52
2.0	6	13	20	28	36
3.0	4	8	13	18	22
4.0	3	6	9	13	17
5.0	3	5	8	10	13

When there is a difference between the velocities of the maximum flood and ebb preceding and following the slack for which the duration is desired, it will be sufficiently accurate for practical purposes to find a separate duration for each maximum velocity and take the average of the two as the duration of the weak current.

Part Eight: Visibility and Distance Off Light Problems

There are two types of problems to solve involving lights: visibility of lights problems, and distance off of lights problems. Each relies on tables in Bowditch for solutions.

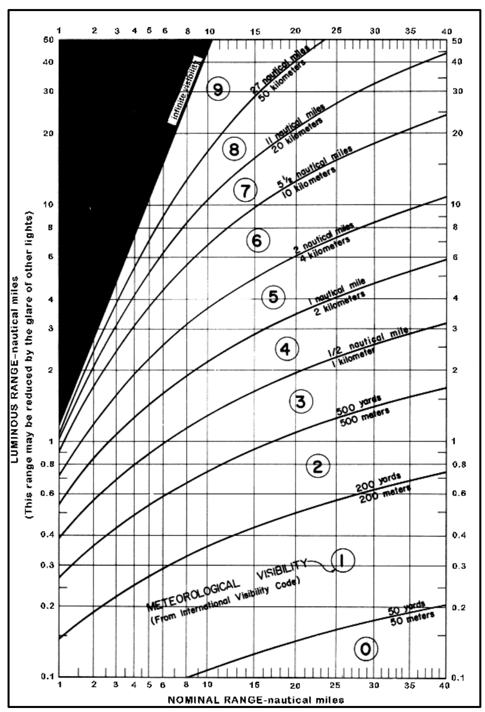
Visibility of Lights

Visibility of light problems involve completing two separate calculations (one for the existing meteorological visibility and another for the geographic range of the light) and determining which of the two are less. The luminous range diagram and Table 13 in Bowditch are used to solve these problems, and are re-created at the end of this part.

Problem 8-1 (CG-1026). The following question is taken directly from the USCG test bank and illustrates how to solve visibility of lights problems.

The Light List indicates that a light has a nominal range of 13 miles and is 36 feet high. If the visibility is 17 miles and your height of eye is 25 feet, at what approximate distance will you sight the light?

Answer: 12.86 miles.



Step 1: Determine the luminous range of the light.

a. Determine the nominal range of the light from the Light List or List of Lights (if necessary).

   The nominal range is given as 13 miles in the problem.

b. Enter the luminous range diagram with the nominal range and the meteorological visibility to determine the luminous range of the light. (The luminous range diagram is printed at full scale at the end of this part).

   In this case, the luminous range is determined to be approximately 20.0 nm.

Step 2: Determine the geographic range of the light.

a. Determine the height of the object and the height of eye of the observer.

The light is given as being 36 feet high, and the observer's height of eye is given as 25 feet.

Object Height		Height of eye of observer in feet and meters							
Feet		**7**	**10**	**13**	**16**	**20**	**23**	**26**	**30**
	Meters	2	3	4	5	6	7	8	9
		Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles
0	0	3.1	3.7	4.2	4.7	5.2	5.6	6.0	6.4
3	1	5.1	5.7	6.2	6.7	7.3	7.6	8.0	8.4
7	2	6.2	6.8	7.3	7.8	8.3	8.7	9.1	9.5
10	3	6.8	7.4	7.9	8.4	8.9	9.3	9.7	10.1
13	4	7.3	7.9	8.4	8.9	9.5	9.8	10.2	10.6
16	5	7.8	8.4	8.9	9.4	9.9	10.3	10.6	11.1
20	6	8.3	8.9	9.5	9.9	10.5	10.8	11.2	11.6
23	7	8.7	9.3	9.8	10.3	10.8	11.2	11.6	12.0
26	8	9.1	9.7	10.2	10.6	11.2	11.6	11.9	12.4
30	9	9.5	10.1	10.6	11.1	11.6	12.0	12.4	12.8
33	10	9.8	10.4	10.9	11.4	12.0	12.3	12.7	13.1
36	11	10.1	10.7	11.2	11.7	12.3	12.6	13.0	13.4

b. Enter Table 13 in Bowditch with the height of the light and the height of the observer.

c. Interpolate the geographic range.

In this case the geographic range is approximately 12.86 nautical miles.

Step 3: Compare the luminous range and geographic range to determine which is smaller. The smaller value is the actual visible range of the light.

The luminous range is 20.0 nm and the geographic range is 12.86 nm. The actual visibility of the light is **12.86 miles.**

Problem 8-2 (CG-1030). The following question is taken directly from the USCG test bank and illustrates how to solve visibility of lights problems.

Problem CG-1030. The Light List indicates that a light has a nominal range of 14 miles and is 42 feet high. If the visibility is 6 miles and your height of eye is 20 feet, at which distance will you sight the light?

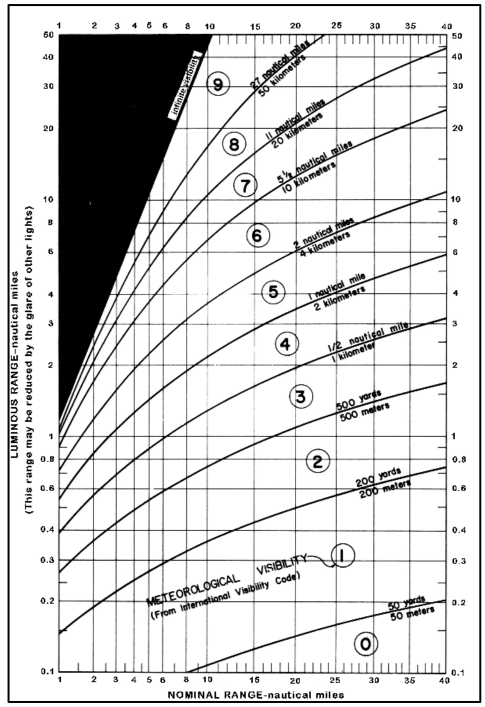
Answer: 10.0 miles.

Step 1: Determine the luminous range of the light.

a. Determine the nominal range of the light from the Light List or List of Lights (if necessary).

The nominal range is given as 14 miles in the problem.

b. Enter the luminous range diagram with the nominal range and the meteorological visibility to determine the luminous range of the light. (The luminous range diagram is printed at full scale at the end of this Part).



In this case, the luminous range is determined to be approximately 10.0 nm.

Step 2: Determine the geographic range of the light.

a. Determine the height of the object and the height of eye of the observer.

The light is given as being 42 feet high, and the observer's height of eye is given as 20 feet.

Object Height		Height of eye of observer in feet and meters							
Feet		**7**	**10**	**13**	**16**	**20**	**23**	**26**	**30**
	Meters	2	3	4	5	6	7	8	9
		Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles
0	0	3.1	3.7	4.2	4.7	5.2	5.6	6.0	6.4
3	1	5.1	5.7	6.2	6.7	7.3	7.6	8.0	8.4
7	2	6.2	6.8	7.3	7.8	8.3	8.7	9.1	9.5
10	3	6.8	7.4	7.9	8.4	8.9	9.3	9.7	10.1
13	4	7.3	7.9	8.4	8.9	9.5	9.8	10.2	10.6
16	5	7.8	8.4	8.9	9.4	9.9	10.3	10.6	11.1
20	6	8.3	8.9	9.5	9.9	10.5	10.8	11.2	11.6
23	7	8.7	9.3	9.8	10.3	10.8	11.2	11.6	12.0
26	8	9.1	9.7	10.2	10.6	11.2	11.6	11.9	12.4
30	9	9.5	10.1	10.6	11.1	11.6	12.0	12.4	12.8
33	10	9.8	10.4	10.9	11.4	12.0	12.3	12.7	13.1
36	11	10.1	10.7	11.2	11.7	12.3	12.6	13.0	13.4
39	12	10.4	11.0	11.5	12.0	12.5	12.9	13.3	13.7
43	13	10.8	11.4	11.9	12.4	12.9	13.3	13.6	14.1
46	14	11.0	11.6	12.2	12.6	13.2	13.5	13.9	14.3

b. Enter Table 13 in Bowditch with the height of the light and the height of the observer (Table 13 is printed at the end of this Part).

c. Interpolate the geographic range.

In this case the geographic range is approximately 12.8 nautical miles.

Step 3: Compare the luminous range and geographic range to determine which is smaller. The smaller value is the actual visible range of the light.

The luminous range is 10.0 nm and the geographic range is 12.8 nm. The actual visibility of the light is **10.0 miles.**

Distance Off of Lights

"Distance off" problems involve two bearings to one object at different times. By entering Table 18 in Bowditch with the difference between the course and each bearing, the distance off at the second bearing, or the distance off abeam can be calculated.

Problem 8-3 (CG-684). The following question is taken directly from the USCG test bank and illustrates how to solve distance off at the second bearing problems.

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?

Answer: 4.31 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
1122	114° T	077° T	114° T – 077° T = **37°**
1133	114° T	051° T	114° T – 051° T = **63°**

Step 2: Enter Table 18 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).

TABLE 18
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

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

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 18, 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

<u>Problem 8-4 (CG-933)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve distance off abeam and time abeam problems.

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: Enter Table 18 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.

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

	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

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 18, 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.
Since the second angle is 45° from the bow, and you already know the distance off, you can apply the bow/beam rule in reverse to determine time abeam.

The bow and beam rule states that when two bearings are taken (one at 45° and one at 90°), the distance run equals the distance 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), the distance run 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.**

Note that many of these distance off problems can be partially or completely solved by the special cases of bearing rules. They are not necessary to determine answers, but are listed here:

1. 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.

2. 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.

3. 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.

4. 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.

Additional Problems and Answers

All of the following questions were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface). Questions in this part are taken from both the Navigation General and Navigation Problems sections.

Problem CG-1023. The Light List indicates that a light has a nominal range of 10 miles and is 11 feet high. If the visibility is 15 miles and your height of eye is 20 feet, at what approximate distance will you sight the light?

- *a) 12.0 miles*
- *b) 11.0 miles*
- *c) 10.0 miles*
- *d) 9.0 miles- correct*

Problem CG-1029. The Light List indicates that a light has a nominal range of 14 miles and is 42 feet high. If the visibility is 16 miles and your height of eye is 20 feet, at which approximate distance will you sight the light?

- *a) 20.1 miles*
- *b) 16.0 miles*
- *c) 12.8 miles- correct*
- *d) 7.6 miles*

Problem CG-1030. The Light List indicates that a light has a nominal range of 14 miles and is 42 feet high. If the visibility is 6 miles and your height of eye is 20 feet, at which distance will you sight the light?

- *a) 20.1 miles*
- *b) 10.0 miles- correct*
- *c) 7.6 miles*
- *d) 6.0 miles*

Problem CG-1034. The Light List indicates that a light has a nominal range of 8 miles and is 48 feet high. If the visibility is 6 miles and your height of eye is 35 feet, at what approximate distance will you sight the light?

- *a) 15.0 nm*
- *b) 12.4 nm*
- *c) 8.0 nm*
- *d) 5.9 nm- correct*

Problem CG-96. A lighthouse is 120 feet high and the light has a nominal range of 18 miles. Your height of eye is 42 feet. If the visibility is 11 miles, approximately how far off the light will you be when the light becomes visible?

- *a) 12.5 miles*
- *b) 16.0 miles*
- *c) 19.0 miles- correct*
- *d) 23.5 miles*

Problem CG-404. Determine the approximate geographic visibility of an object with a height above the water of 85 feet, for an observer with a height of eye of 60 feet.

- *a) 18.4 nm*
- *b) 19.9 nm- correct*
- *c) 20.8 nm*
- *d) 21.5 nm*

Problem CG-1415. What is the approximate geographic range of Assateague Light, VA, if your height of eye is 52 feet? The Light List gives the height of the light as 156 feet.

- *a) 14.1 nm*
- *b) 21.8 nm*
- *c) 23.0 nm- correct*
- *d) 50.2 nm*

Problem CG-1416. What is the approximate geographic range of Fenwick Island Light, Delaware, if your height of eye is 37 feet? The Light List gives the height of the light as 83 feet.

- *a) 24.8 nm*
- *b) 17.8 nm- correct*
- *c) 15.9 nm*
- *d) 10.3 nm*

Problem CG-1419. What is the approximate geographic range of Point Judith Light, Rhode Island, if your height of eye is 62 feet? The Light List gives the height of the light as 65 feet.

- *a) 9.6 nm*
- *b) 16.5 nm*
- *c) 18.6 nm- correct*
- *d) 20.7 nm*

Problem CG-683. You are steaming on a course of 084° T at a speed of 13 knots. At 1919 a lighthouse bears 106.5° T. At 1957 the same lighthouse bears 129° T. What will be your distance off the lighthouse when abeam?

a) *4.3 miles*
b) *5.7 miles- correct*
c) *7.1 miles*
d) *8.2 miles*

Problem CG-686. 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*

Problem CG-687. 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*

Problem CG-689. 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*

Problem CG-961. 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*

Problem CG-964. 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

Problem CG-966. 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

Problem CG-696. You are steaming on course 168° T at a speed of 18 knots. At 1426 you sight a buoy bearing 144° T. At 1435 you sight the same buoy bearing 116° T. What is your distance off at the second bearing and predicted distance when abeam?

a) 2.3 miles at second bearing, 1.8 miles abeam- correct
b) 2.5 miles at second bearing, 2.8 miles abeam
c) 2.8 miles at second bearing, 1.8 miles abeam
d) 3.3 miles at second bearing, 2.8 miles abeam

Problem CG-920. 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

Problem CG-921. 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?

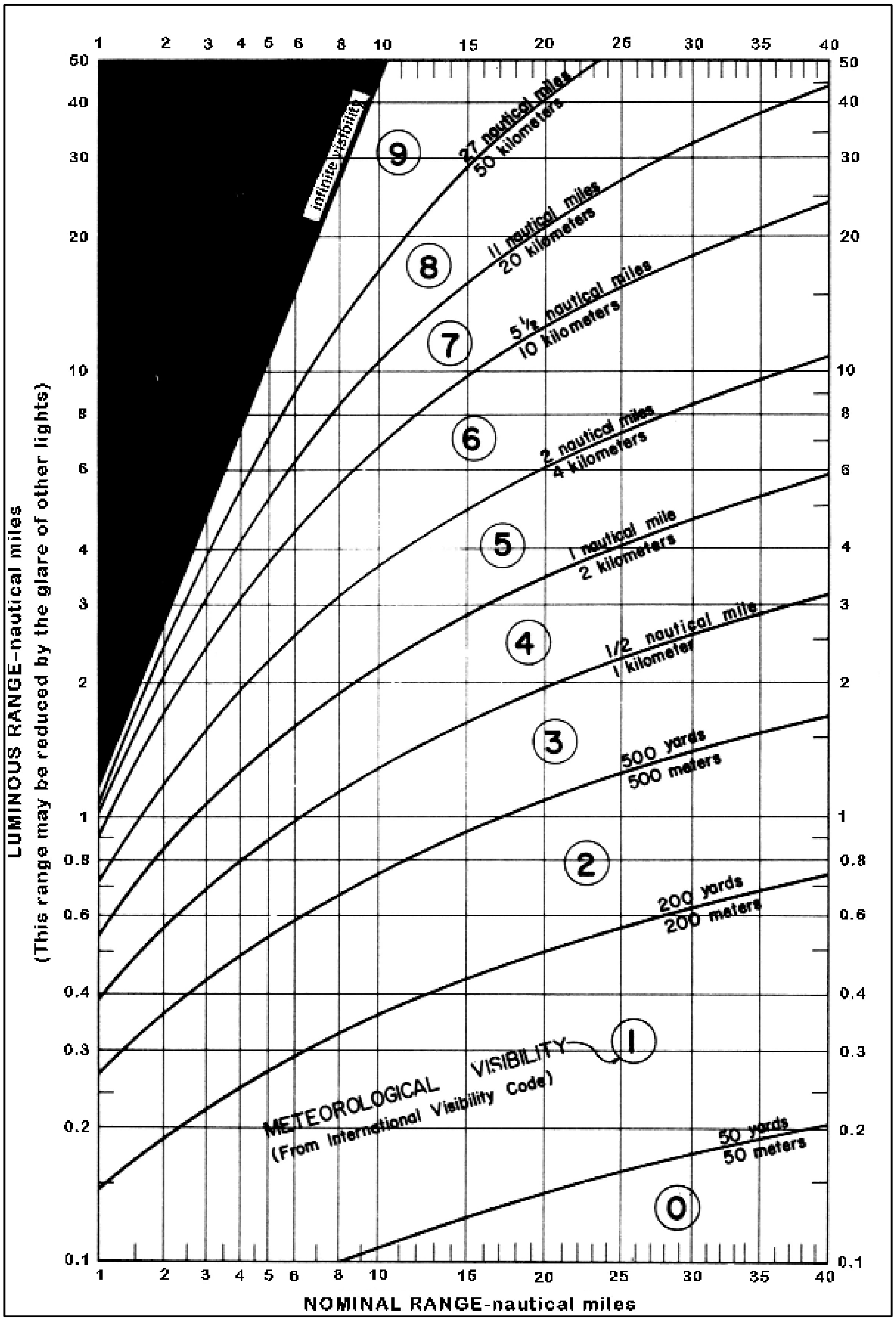
a) 0219, 2.3 miles
b) 0226, 3.1 miles- correct
c) 0233, 3.9 miles
d) 0242, 4.7 miles

Problem CG-922. 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

Problem CG-933. 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*



LUMINOUS RANGE-nautical miles
(This range may be reduced by the glare of other lights)
NOMINAL RANGE-nautical miles
infinite visibility
27 nautical miles
50 kilometers
11 nautical miles
20 kilometers
5 1/2 nautical miles
10 kilometers
2 nautical miles
4 kilometers
1 nautical mile
2 kilometers
1/2 nautical mile
1 kilometer
500 yards
500 meters
200 yards
200 meters
50 yards
50 meters
METEOROLOGICAL VISIBILITY
(From International Visibility Code)

TABLE 13
Geographic Range

Object Height (Feet)	Object Height (Meters)	7 ft / 2 m	10 ft / 3 m	13 ft / 4 m	16 ft / 5 m	20 ft / 6 m	23 ft / 7 m	26 ft / 8 m	30 ft / 9 m	33 ft / 10 m	36 ft / 11 m	Object Height (Meters)	Object Height (Feet)
		Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles		
0	0	3.1	3.7	4.2	4.7	5.2	5.6	6.0	6.4	6.7	7.0	0	**0**
3	1	5.1	5.7	6.2	6.7	7.3	7.6	8.0	8.4	8.7	9.0	1	**3**
7	2	6.2	6.8	7.3	7.8	8.3	8.7	9.1	9.5	9.8	10.1	2	**7**
10	3	6.8	7.4	7.9	8.4	8.9	9.3	9.7	10.1	10.4	10.7	3	**10**
13	4	7.3	7.9	8.4	8.9	9.5	9.8	10.2	10.6	10.9	11.2	4	**13**
16	5	7.8	8.4	8.9	9.4	9.9	10.3	10.6	11.1	11.4	11.7	5	**16**
20	6	8.3	8.9	9.5	9.9	10.5	10.8	11.2	11.6	12.0	12.3	6	**20**
23	7	8.7	9.3	9.8	10.3	10.8	11.2	11.6	12.0	12.3	12.6	7	**23**
26	8	9.1	9.7	10.2	10.6	11.2	11.6	11.9	12.4	12.7	13.0	8	**26**
30	9	9.5	10.1	10.6	11.1	11.6	12.0	12.4	12.8	13.1	13.4	9	**30**
33	10	9.8	10.4	10.9	11.4	12.0	12.3	12.7	13.1	13.4	13.7	10	**33**
36	11	10.1	10.7	11.2	11.7	12.3	12.6	13.0	13.4	13.7	14.0	11	**36**
39	12	10.4	11.0	11.5	12.0	12.5	12.9	13.3	13.7	14.0	14.3	12	**39**
43	13	10.8	11.4	11.9	12.4	12.9	13.3	13.6	14.1	14.4	14.7	13	**43**
46	14	11.0	11.6	12.2	12.6	13.2	13.5	13.9	14.3	14.7	15.0	14	**46**
49	15	11.3	11.9	12.4	12.9	13.4	13.8	14.2	14.6	14.9	15.2	15	**49**
52	16	11.5	12.1	12.7	13.1	13.7	14.0	14.4	14.8	15.2	15.5	16	**52**
56	17	11.9	12.5	13.0	13.4	14.0	14.4	14.7	15.2	15.5	15.8	17	**56**
59	18	12.1	12.7	13.2	13.7	14.2	14.6	15.0	15.4	15.7	16.0	18	**59**
62	19	12.3	12.9	13.4	13.9	14.4	14.8	15.2	15.6	15.9	16.2	19	**62**
66	20	12.6	13.2	13.7	14.2	14.7	15.1	15.5	15.9	16.2	16.5	20	**66**
72	22	13.0	13.6	14.1	14.6	15.2	15.5	15.9	16.3	16.6	16.9	22	**72**
79	24	13.5	14.1	14.6	15.1	15.6	16.0	16.4	16.8	17.1	17.4	24	**79**
85	26	13.9	14.5	15.0	15.5	16.0	16.4	16.8	17.2	17.5	17.8	26	**85**
92	28	14.3	14.9	15.4	15.9	16.5	16.8	17.2	17.6	17.9	18.2	28	**92**
98	30	14.7	15.3	15.8	16.3	16.8	17.2	17.5	18.0	18.3	18.6	30	**98**
115	35	15.6	16.2	16.8	17.2	17.8	18.2	18.5	19.0	19.3	19.6	35	**115**
131	40	16.5	17.1	17.6	18.1	18.6	19.0	19.4	19.8	20.1	20.4	40	**131**
148	45	17.3	17.9	18.5	18.9	19.5	19.8	20.2	20.6	21.0	21.3	45	**148**
164	50	18.1	18.7	19.2	19.7	20.2	20.6	20.9	21.4	21.7	22.0	50	**164**
180	55	18.8	19.4	19.9	20.4	20.9	21.3	21.7	22.1	22.4	22.7	55	**180**
197	60	19.5	20.1	20.6	21.1	21.7	22.0	22.4	22.8	23.1	23.4	60	**197**
213	65	20.2	20.8	21.3	21.8	22.3	22.7	23.0	23.5	23.8	24.1	65	**213**
230	70	20.8	21.4	22.0	22.4	23.0	23.4	23.7	24.2	24.5	24.8	70	**230**
246	75	21.4	22.1	22.6	23.0	23.6	24.0	24.3	24.8	25.1	25.4	75	**246**
262	80	22.0	22.6	23.2	23.6	24.2	24.5	24.9	25.3	25.7	26.0	80	**262**
279	85	22.6	23.2	23.8	24.2	24.8	25.2	25.5	26.0	26.3	26.6	85	**279**
295	90	23.2	23.8	24.3	24.8	25.3	25.7	26.1	26.5	26.8	27.1	90	**295**
312	95	23.8	24.4	24.9	25.3	25.9	26.3	26.6	27.1	27.4	27.7	95	**312**
328	100	24.3	24.9	25.4	25.9	26.4	26.8	27.2	27.6	27.9	28.2	100	**328**
361	110	25.3	25.9	26.4	26.9	27.5	27.8	28.2	28.6	29.0	29.3	110	**361**
394	120	26.3	26.9	27.4	27.9	28.5	28.8	29.2	29.6	29.9	30.2	120	**394**
427	130	27.3	27.9	28.4	28.9	29.4	29.8	30.1	30.6	30.9	31.2	130	**427**
459	140	28.2	28.8	29.3	29.7	30.3	30.7	31.0	31.5	31.8	32.1	140	**459**
492	150	29.0	29.7	30.2	30.6	31.2	31.6	31.9	32.4	32.7	33.0	150	**492**
525	160	29.9	30.5	31.0	31.5	32.0	32.4	32.8	33.2	33.5	33.8	160	**525**
558	170	30.7	31.3	31.9	32.3	32.9	33.2	33.6	34.0	34.4	34.7	170	**558**
591	180	31.5	32.1	32.7	33.1	33.7	34.1	34.4	34.9	35.2	35.5	180	**591**
623	190	32.3	32.9	33.4	33.9	34.4	34.8	35.2	35.6	35.9	36.2	190	**623**
656	200	33.1	33.7	34.2	34.6	35.2	35.6	35.9	36.4	36.7	37.0	200	**656**
722	220	34.5	35.1	35.7	36.1	36.7	37.0	37.4	37.8	38.2	38.5	220	**722**
787	240	35.9	36.5	37.0	37.5	38.1	38.4	38.8	39.2	39.5	39.8	240	**787**
853	260	37.3	37.9	38.4	38.9	39.4	39.8	40.1	40.6	40.9	41.2	260	**853**
919	280	38.6	39.2	39.7	40.1	40.7	41.1	41.4	41.9	42.2	42.5	280	**919**
984	300	39.8	40.4	40.9	41.4	41.9	42.3	42.7	43.1	43.4	43.7	300	**984**

TABLE 13
Geographic Range

Object Height (Feet)	Object Height (Meters)	39 ft / 12 m	43 ft / 13 m	46 ft / 14 m	49 ft / 15 m	52 ft / 16 m	56 ft / 17 m	59 ft / 18 m	62 ft / 19 m	66 ft / 20 m	69 ft / 21 m	Object Height (Meters)	Object Height (Feet)
		Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles		
0	0	7.3	7.7	7.9	8.2	8.4	8.8	9.0	9.2	9.5	9.7	0	**0**
3	1	9.3	9.7	10.0	10.2	10.5	10.8	11.0	11.2	11.5	11.7	1	**3**
7	2	10.4	10.8	11.0	11.3	11.5	11.9	12.1	12.3	12.6	12.8	2	**7**
10	3	11.0	11.4	11.6	11.9	12.1	12.5	12.7	12.9	13.2	13.4	3	**10**
13	4	11.5	11.9	12.2	12.4	12.7	13.0	13.2	13.4	13.7	13.9	4	**13**
16	5	12.0	12.4	12.6	12.9	13.1	13.4	13.7	13.9	14.2	14.4	5	**16**
20	6	12.5	12.9	13.2	13.4	13.7	14.0	14.2	14.4	14.7	15.0	6	**20**
23	7	12.9	13.3	13.5	13.8	14.0	14.4	14.6	14.8	15.1	15.3	7	**23**
26	8	13.3	13.6	13.9	14.2	14.4	14.7	15.0	15.2	15.5	15.7	8	**26**
30	9	13.7	14.1	14.3	14.6	14.8	15.2	15.4	15.6	15.9	16.1	9	**30**
33	10	14.0	14.4	14.7	14.9	15.2	15.5	15.7	15.9	16.2	16.4	10	**33**
36	11	14.3	14.7	15.0	15.2	15.5	15.8	16.0	16.2	16.5	16.7	11	**36**
39	12	14.6	15.0	15.2	15.5	15.7	16.1	16.3	16.5	16.8	17.0	12	**39**
43	13	15.0	15.3	15.6	15.9	16.1	16.4	16.7	16.9	17.2	17.4	13	**43**
46	14	15.2	15.6	15.9	16.1	16.4	16.7	16.9	17.1	17.4	17.7	14	**46**
49	15	15.5	15.9	16.1	16.4	16.6	16.9	17.2	17.4	17.7	17.9	15	**49**
52	16	15.7	16.1	16.4	16.6	16.9	17.2	17.4	17.6	17.9	18.2	16	**52**
56	17	16.1	16.4	16.7	16.9	17.2	17.5	17.7	18.0	18.3	18.5	17	**56**
59	18	16.3	16.7	16.9	17.2	17.4	17.7	18.0	18.2	18.5	18.7	18	**59**
62	19	16.5	16.9	17.1	17.4	17.6	18.0	18.2	18.4	18.7	18.9	19	**62**
66	20	16.8	17.2	17.4	17.7	17.9	18.3	18.5	18.7	19.0	19.2	20	**66**
72	22	17.2	17.6	17.9	18.1	18.4	18.7	18.9	19.1	19.4	19.6	22	**72**
79	24	17.7	18.1	18.3	18.6	18.8	19.2	19.4	19.6	19.9	20.1	24	**79**
85	26	18.1	18.5	18.7	19.0	19.2	19.5	19.8	20.0	20.3	20.5	26	**85**
92	28	18.5	18.9	19.2	19.4	19.7	20.0	20.2	20.4	20.7	20.9	28	**92**
98	30	18.9	19.3	19.5	19.8	20.0	20.3	20.6	20.8	21.1	21.3	30	**98**
115	35	19.9	20.2	20.5	20.7	21.0	21.3	21.5	21.8	22.1	22.3	35	**115**
131	40	20.7	21.1	21.3	21.6	21.8	22.1	22.4	22.6	22.9	23.1	40	**131**
148	45	21.5	21.9	22.2	22.4	22.7	23.0	23.2	23.4	23.7	24.0	45	**148**
164	50	22.3	22.7	22.9	23.2	23.4	23.7	24.0	24.2	24.5	24.7	50	**164**
180	55	23.0	23.4	23.6	23.9	24.1	24.5	24.7	24.9	25.2	25.4	55	**180**
197	60	23.7	24.1	24.4	24.6	24.9	25.2	25.4	25.6	25.9	26.1	60	**197**
213	65	24.4	24.7	25.0	25.3	25.5	25.8	26.1	26.3	26.6	26.8	65	**213**
230	70	25.1	25.4	25.7	25.9	26.2	26.5	26.7	27.0	27.2	27.5	70	**230**
246	75	25.7	26.0	26.3	26.5	26.8	27.1	27.3	27.6	27.9	28.1	75	**246**
262	80	26.2	26.6	26.9	27.1	27.4	27.7	27.9	28.2	28.4	28.7	80	**262**
279	85	26.8	27.2	27.5	27.7	28.0	28.3	28.5	28.8	29.0	29.3	85	**279**
295	90	27.4	27.8	28.0	28.3	28.5	28.9	29.1	29.3	29.6	29.8	90	**295**
312	95	28.0	28.3	28.6	28.9	29.1	29.4	29.7	29.9	30.2	30.4	95	**312**
328	100	28.5	28.9	29.1	29.4	29.6	29.9	30.2	30.4	30.7	30.9	100	**328**
361	110	29.5	29.9	30.2	30.4	30.7	31.0	31.2	31.4	31.7	31.9	110	**361**
394	120	30.5	30.9	31.2	31.4	31.7	32.0	32.2	32.4	32.7	32.9	120	**394**
427	130	31.5	31.8	32.1	32.4	32.6	32.9	33.2	33.4	33.7	33.9	130	**427**
459	140	32.4	32.7	33.0	33.3	33.5	33.8	34.1	34.3	34.6	34.8	140	**459**
492	150	33.3	33.6	33.9	34.1	34.4	34.7	34.9	35.2	35.5	35.7	150	**492**
525	160	34.1	34.5	34.7	35.0	35.2	35.6	35.8	36.0	36.3	36.5	160	**525**
558	170	34.9	35.3	35.6	35.8	36.1	36.4	36.6	36.9	37.1	37.4	170	**558**
591	180	35.7	36.1	36.4	36.6	36.9	37.2	37.4	37.7	37.9	38.2	180	**591**
623	190	36.5	36.9	37.1	37.4	37.6	38.0	38.2	38.4	38.7	38.9	190	**623**
656	200	37.3	37.6	37.9	38.2	38.4	38.7	39.0	39.2	39.5	39.7	200	**656**
722	220	38.7	39.1	39.4	39.6	39.9	40.2	40.4	40.7	40.9	41.2	220	**722**
787	240	40.1	40.5	40.8	41.0	41.3	41.6	41.8	42.0	42.3	42.5	240	**787**
853	260	41.5	41.8	42.1	42.4	42.6	42.9	43.2	43.4	43.7	43.9	260	**853**
919	280	42.8	43.1	43.4	43.7	43.9	44.2	44.5	44.7	45.0	45.2	280	**919**
984	300	44.0	44.4	44.6	44.9	45.1	45.5	45.7	45.9	46.2	46.4	300	**984**

TABLE 13
Geographic Range

Object Height (Feet)	Object Height (Meters)	72 ft / 22 m	75 ft / 23 m	79 ft / 24 m	82 ft / 25 m	85 ft / 26 m	89 ft / 27 m	92 ft / 28 m	95 ft / 29 m	98 ft / 30 m	115 ft / 35 m	Object Height (Meters)	Object Height (Feet)
		Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles		
0	0	9.9	10.2	10.4	10.6	10.8	11.0	11.2	11.4	11.6	12.5	0	**0**
3	1	12.0	12.2	12.4	12.6	12.8	13.1	13.2	13.4	13.6	14.6	1	**3**
7	2	13.0	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	15.6	2	**7**
10	3	13.6	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3	16.2	3	**10**
13	4	14.1	14.4	14.6	14.8	15.0	15.3	15.4	15.6	15.8	16.8	4	**13**
16	5	14.6	14.9	15.1	15.3	15.5	15.7	15.9	16.1	16.3	17.2	5	**16**
20	6	15.2	15.4	15.6	15.8	16.0	16.3	16.5	16.6	16.8	17.8	6	**20**
23	7	15.5	15.8	16.0	16.2	16.4	16.6	16.8	17.0	17.2	18.2	7	**23**
26	8	15.9	16.2	16.4	16.6	16.8	17.0	17.2	17.4	17.5	18.5	8	**26**
30	9	16.3	16.6	16.8	17.0	17.2	17.4	17.6	17.8	18.0	19.0	9	**30**
33	10	16.6	16.9	17.1	17.3	17.5	17.8	17.9	18.1	18.3	19.3	10	**33**
36	11	16.9	17.2	17.4	17.6	17.8	18.1	18.2	18.4	18.6	19.6	11	**36**
39	12	17.2	17.5	17.7	17.9	18.1	18.3	18.5	18.7	18.9	19.8	12	**39**
43	13	17.6	17.9	18.1	18.3	18.5	18.7	18.9	19.1	19.3	20.2	13	**43**
46	14	17.9	18.1	18.3	18.5	18.7	19.0	19.2	19.3	19.5	20.5	14	**46**
49	15	18.1	18.4	18.6	18.8	19.0	19.2	19.4	19.6	19.8	20.7	15	**49**
52	16	18.4	18.6	18.8	19.0	19.2	19.5	19.7	19.8	20.0	21.0	16	**52**
56	17	18.7	19.0	19.2	19.4	19.5	19.8	20.0	20.2	20.3	21.3	17	**56**
59	18	18.9	19.2	19.4	19.6	19.8	20.0	20.2	20.4	20.6	21.5	18	**59**
62	19	19.1	19.4	19.6	19.8	20.0	20.3	20.4	20.6	20.8	21.8	19	**62**
66	20	19.4	19.7	19.9	20.1	20.3	20.5	20.7	20.9	21.1	22.0	20	**66**
72	22	19.9	20.1	20.3	20.5	20.7	21.0	21.2	21.3	21.5	22.5	22	**72**
79	24	20.3	20.6	20.8	21.0	21.2	21.4	21.6	21.8	22.0	22.9	24	**79**
85	26	20.7	21.0	21.2	21.4	21.6	21.8	22.0	22.2	22.4	23.3	26	**85**
92	28	21.2	21.4	21.6	21.8	22.0	22.3	22.4	22.6	22.8	23.8	28	**92**
98	30	21.5	21.8	22.0	22.2	22.4	22.6	22.8	23.0	23.2	24.1	30	**98**
115	35	22.5	22.7	22.9	23.1	23.3	23.6	23.8	24.0	24.1	25.1	35	**115**
131	40	23.3	23.6	23.8	24.0	24.2	24.4	24.6	24.8	25.0	25.9	40	**131**
148	45	24.2	24.4	24.6	24.8	25.0	25.3	25.5	25.6	25.8	26.8	45	**148**
164	50	24.9	25.2	25.4	25.6	25.8	26.0	26.2	26.4	26.6	27.5	50	**164**
180	55	25.6	25.9	26.1	26.3	26.5	26.7	26.9	27.1	27.3	28.2	55	**180**
197	60	26.3	26.6	26.8	27.0	27.2	27.5	27.6	27.8	28.0	29.0	60	**197**
213	65	27.0	27.3	27.5	27.7	27.9	28.1	28.3	28.5	28.7	29.6	65	**213**
230	70	27.7	27.9	28.1	28.3	28.5	28.8	29.0	29.1	29.3	30.3	70	**230**
246	75	28.3	28.6	28.7	28.9	29.1	29.4	29.6	29.7	29.9	30.9	75	**246**
262	80	28.9	29.1	29.3	29.5	29.7	30.0	30.1	30.3	30.5	31.5	80	**262**
279	85	29.5	29.7	29.9	30.1	30.3	30.6	30.8	30.9	31.1	32.1	85	**279**
295	90	30.0	30.3	30.5	30.7	30.9	31.1	31.3	31.5	31.7	32.6	90	**295**
312	95	30.6	30.9	31.1	31.3	31.4	31.7	31.9	32.1	32.2	33.2	95	**312**
328	100	31.1	31.4	31.6	31.8	32.0	32.2	32.4	32.6	32.8	33.7	100	**328**
361	110	32.2	32.4	32.6	32.8	33.0	33.3	33.5	33.6	33.8	34.8	110	**361**
394	120	33.2	33.4	33.6	33.8	34.0	34.3	34.4	34.6	34.8	35.8	120	**394**
427	130	34.1	34.4	34.6	34.8	35.0	35.2	35.4	35.6	35.8	36.7	130	**427**
459	140	35.0	35.3	35.5	35.7	35.9	36.1	36.3	36.5	36.6	37.6	140	**459**
492	150	35.9	36.2	36.4	36.5	36.7	37.0	37.2	37.3	37.5	38.5	150	**492**
525	160	36.7	37.0	37.2	37.4	37.6	37.8	38.0	38.2	38.4	39.4	160	**525**
558	170	37.6	37.8	38.0	38.2	38.4	38.7	38.9	39.0	39.2	40.2	170	**558**
591	180	38.4	38.6	38.8	39.0	39.2	39.5	39.7	39.8	40.0	41.0	180	**591**
623	190	39.1	39.4	39.6	39.8	40.0	40.2	40.4	40.6	40.8	41.8	190	**623**
656	200	39.9	40.2	40.4	40.6	40.8	41.0	41.2	41.4	41.5	42.5	200	**656**
722	220	41.4	41.6	41.8	42.0	42.2	42.5	42.7	42.8	43.0	44.0	220	**722**
787	240	42.8	43.0	43.2	43.4	43.6	43.9	44.0	44.2	44.4	45.4	240	**787**
853	260	44.1	44.4	44.6	44.8	45.0	45.2	45.4	45.6	45.8	46.7	260	**853**
919	280	45.4	45.7	45.9	46.1	46.3	46.5	46.7	46.9	47.1	48.0	280	**919**
984	300	46.6	46.9	47.1	47.3	47.5	47.7	47.9	48.1	48.3	49.2	300	**984**

TABLE 18
Distance of an Object by Two Bearings

Difference between the course and second bearing °	Difference between the course and first bearing 20°		22°		24°		26°		28°		30°		32°	
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	2.88	1.85		
42	0.91	0.61	1.10	0.73	1.32	0.88	1.59	1.06	1.94	1.30	2.40	1.61	3.05	2.04
44	0.84	0.58	1.00	0.69	1.19	0.83	1.42	0.98	1.70	1.18	2.07	1.44	2.55	1.77
46	0.78	0.56	0.92	0.66	1.09	0.78	1.28	0.92	1.52	1.09	1.81	1.30	2.19	1.58
48	0.73	0.54	0.85	0.64	1.00	0.74	1.17	0.87	1.37	1.02	1.62	1.20	1.92	1.43
50	0.68	0.52	0.80	0.61	0.93	0.71	1.08	0.83	1.25	0.96	1.46	1.12	1.71	1.31
52	0.65	0.51	0.75	0.59	0.87	0.68	1.00	0.79	1.15	0.91	1.33	1.05	1.55	1.22
54	0.61	0.49	0.71	0.57	0.81	0.66	0.93	0.76	1.07	0.87	1.23	0.99	1.41	1.14
56	0.58	0.48	0.67	0.56	0.77	0.64	0.88	0.73	1.00	0.83	1.14	0.95	1.30	1.08
58	0.56	0.47	0.64	0.54	0.73	0.62	0.83	0.70	0.94	0.80	1.07	0.90	1.21	1.03
60	0.53	0.46	0.61	0.53	0.69	0.60	0.78	0.68	0.89	0.77	1.00	0.87	1.13	0.98
62	0.51	0.45	0.58	0.51	0.66	0.58	0.75	0.66	0.84	0.74	0.94	0.83	1.06	0.94
64	0.49	0.44	0.56	0.50	0.63	0.57	0.71	0.64	0.80	0.72	0.89	0.80	1.00	0.90
66	0.48	0.43	0.54	0.49	0.61	0.56	0.68	0.62	0.76	0.70	0.85	0.78	0.95	0.87
68	0.46	0.43	0.52	0.48	0.59	0.54	0.66	0.61	0.73	0.68	0.81	0.75	0.90	0.84
70	0.45	0.42	0.50	0.47	0.57	0.53	0.63	0.59	0.70	0.66	0.78	0.73	0.86	0.81
72	0.43	0.41	0.49	0.47	0.55	0.52	0.61	0.58	0.68	0.64	0.75	0.71	0.82	0.78
74	0.42	0.41	0.48	0.46	0.53	0.51	0.59	0.57	0.65	0.63	0.72	0.69	0.79	0.76
76	0.41	0.40	0.46	0.45	0.52	0.50	0.57	0.56	0.63	0.61	0.70	0.67	0.76	0.74
78	0.40	0.39	0.45	0.44	0.50	0.49	0.56	0.54	0.61	0.60	0.67	0.66	0.74	0.72
80	0.39	0.39	0.44	0.44	0.49	0.48	0.54	0.53	0.60	0.59	0.65	0.64	0.71	0.70
82	0.39	0.38	0.43	0.43	0.48	0.47	0.53	0.52	0.58	0.57	0.63	0.63	0.69	0.69
84	0.38	0.38	0.42	0.42	0.47	0.47	0.52	0.51	0.57	0.56	0.62	0.61	0.67	0.67
86	0.37	0.37	0.42	0.42	0.46	0.46	0.51	0.50	0.55	0.55	0.60	0.60	0.66	0.65
88	0.37	0.37	0.41	0.41	0.45	0.45	0.50	0.50	0.54	0.54	0.59	0.59	0.64	0.64
90	0.36	0.36	0.40	0.40	0.45	0.45	0.49	0.49	0.53	0.53	0.58	0.58	0.62	0.62
92	0.36	0.36	0.40	0.40	0.44	0.44	0.48	0.48	0.52	0.52	0.57	0.57	0.61	0.61
94	0.36	0.35	0.39	0.39	0.43	0.43	0.47	0.47	0.51	0.51	0.56	0.55	0.60	0.60
96	0.35	0.35	0.39	0.39	0.43	0.43	0.47	0.46	0.51	0.50	0.55	0.54	0.59	0.59
98	0.35	0.35	0.39	0.38	0.42	0.42	0.46	0.46	0.50	0.50	0.54	0.53	0.58	0.57
100	0.35	0.34	0.38	0.38	0.42	0.41	0.46	0.45	0.49	0.49	0.53	0.52	0.57	0.56
102	0.35	0.34	0.38	0.37	0.42	0.41	0.45	0.44	0.49	0.48	0.53	0.51	0.56	0.55
104	0.34	0.33	0.38	0.37	0.41	0.40	0.45	0.43	0.48	0.47	0.52	0.50	0.56	0.54
106	0.34	0.33	0.38	0.36	0.41	0.39	0.45	0.43	0.48	0.46	0.52	0.50	0.55	0.53
108	0.34	0.32	0.38	0.36	0.41	0.39	0.44	0.42	0.48	0.45	0.51	0.49	0.55	0.52
110	0.34	0.32	0.37	0.35	0.41	0.38	0.44	0.41	0.47	0.44	0.51	0.48	0.54	0.51
112	0.34	0.32	0.37	0.35	0.41	0.38	0.44	0.41	0.47	0.44	0.50	0.47	0.54	0.50
114	0.34	0.31	0.37	0.34	0.41	0.37	0.44	0.40	0.47	0.43	0.50	0.46	0.54	0.49
116	0.34	0.31	0.38	0.34	0.41	0.37	0.44	0.39	0.47	0.42	0.50	0.45	0.53	0.48
118	0.35	0.31	0.38	0.33	0.41	0.36	0.44	0.39	0.47	0.41	0.50	0.44	0.53	0.47
120	0.35	0.30	0.38	0.33	0.41	0.36	0.44	0.38	0.47	0.41	0.50	0.43	0.53	0.46
122	0.35	0.30	0.38	0.32	0.41	0.35	0.44	0.37	0.47	0.40	0.50	0.42	0.53	0.45
124	0.35	0.29	0.38	0.32	0.41	0.34	0.44	0.37	0.47	0.39	0.50	0.42	0.53	0.44
126	0.36	0.29	0.39	0.31	0.42	0.34	0.45	0.36	0.47	0.38	0.50	0.41	0.53	0.43
128	0.36	0.28	0.39	0.31	0.42	0.33	0.45	0.35	0.48	0.38	0.50	0.40	0.53	0.42
130	0.36	0.28	0.39	0.30	0.42	0.32	0.45	0.35	0.48	0.37	0.51	0.39	0.54	0.41
132	0.37	0.27	0.40	0.30	0.43	0.32	0.46	0.34	0.48	0.36	0.51	0.38	0.54	0.40
134	0.37	0.27	0.40	0.29	0.43	0.31	0.46	0.33	0.49	0.35	0.52	0.37	0.54	0.39
136	0.38	0.26	0.41	0.28	0.44	0.30	0.47	0.32	0.49	0.34	0.52	0.36	0.55	0.38
138	0.39	0.26	0.42	0.28	0.45	0.30	0.47	0.32	0.50	0.33	0.53	0.35	0.55	0.37
140	0.39	0.25	0.42	0.27	0.45	0.29	0.48	0.31	0.51	0.33	0.53	0.34	0.56	0.36
142	0.40	0.25	0.43	0.27	0.46	0.28	0.49	0.30	0.51	0.32	0.54	0.33	0.56	0.35
144	0.41	0.24	0.44	0.26	0.47	0.28	0.50	0.29	0.52	0.31	0.55	0.32	0.57	0.34
146	0.42	0.24	0.45	0.25	0.48	0.27	0.51	0.28	0.53	0.30	0.56	0.31	0.58	0.32
148	0.43	0.23	0.46	0.25	0.49	0.26	0.52	0.27	0.54	0.29	0.57	0.30	0.59	0.31
150	0.45	0.22	0.48	0.24	0.50	0.25	0.53	0.26	0.55	0.28	0.58	0.29	0.60	0.30
152	0.46	0.22	0.49	0.23	0.52	0.24	0.54	0.25	0.57	0.27	0.59	0.28	0.61	0.29
154	0.48	0.21	0.50	0.22	0.53	0.23	0.56	0.24	0.58	0.25	0.60	0.26	0.62	0.27
156	0.49	0.20	0.52	0.21	0.55	0.22	0.57	0.23	0.60	0.24	0.62	0.25	0.64	0.26
158	0.51	0.19	0.54	0.20	0.57	0.21	0.59	0.22	0.61	0.23	0.63	0.24	0.66	0.25
160	0.53	0.18	0.56	0.19	0.59	0.20	0.61	0.21	0.63	0.22	0.65	0.22	0.67	0.23

TABLE 18
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°		46°	
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	4.00	3.24		
56	1.49	1.24	1.72	1.42	1.99	1.65	2.33	1.93	2.77	2.29	3.34	2.77	4.14	3.43
58	1.37	1.17	1.57	1.33	1.80	1.53	2.08	1.76	2.43	2.06	2.87	2.44	3.46	2.93
60	1.28	1.10	1.45	1.25	1.64	1.42	1.88	1.63	2.17	1.88	2.52	2.18	2.97	2.57
62	1.19	1.05	1.34	1.18	1.51	1.34	1.72	1.52	1.96	1.73	2.25	1.98	2.61	2.30
64	1.12	1.01	1.25	1.13	1.40	1.26	1.58	1.42	1.79	1.61	2.03	1.83	2.33	2.09
66	1.06	0.96	1.18	1.07	1.31	1.20	1.47	1.34	1.65	1.51	1.85	1.69	2.10	1.92
68	1.00	0.93	1.11	1.03	1.23	1.14	1.37	1.27	1.53	1.42	1.71	1.58	1.92	1.78
70	0.95	0.89	1.05	0.99	1.16	1.09	1.29	1.21	1.43	1.34	1.58	1.49	1.77	1.66
72	0.91	0.86	1.00	0.95	1.10	1.05	1.21	1.15	1.34	1.27	1.48	1.41	1.64	1.56
74	0.87	0.84	0.95	0.92	1.05	1.01	1.15	1.10	1.26	1.21	1.39	1.34	1.53	1.47
76	0.84	0.81	0.91	0.89	1.00	0.97	1.09	1.06	1.20	1.16	1.31	1.27	1.44	1.40
78	0.80	0.79	0.88	0.86	0.96	0.94	1.04	1.02	1.14	1.11	1.24	1.22	1.36	1.33
80	0.78	0.77	0.85	0.83	0.92	0.91	1.00	0.98	1.09	1.07	1.18	1.16	1.28	1.27
82	0.75	0.75	0.82	0.81	0.89	0.88	0.96	0.95	1.04	1.03	1.13	1.12	1.22	1.21
84	0.73	0.73	0.79	0.79	0.86	0.85	0.93	0.92	1.00	0.99	1.08	1.07	1.17	1.16
86	0.71	0.71	0.77	0.77	0.83	0.83	0.89	0.89	0.96	0.96	1.04	1.04	1.12	1.12
88	0.69	0.69	0.75	0.75	0.80	0.80	0.86	0.86	0.93	0.93	1.00	1.00	1.08	1.07
90	0.67	0.67	0.73	0.73	0.78	0.78	0.84	0.84	0.90	0.90	0.97	0.97	1.04	1.04
92	0.66	0.66	0.71	0.71	0.76	0.76	0.82	0.82	0.87	0.87	0.93	0.93	1.00	1.00
94	0.65	0.64	0.69	0.69	0.74	0.74	0.79	0.79	0.85	0.85	0.91	0.90	0.97	0.97
96	0.63	0.63	0.68	0.67	0.73	0.72	0.78	0.77	0.83	0.82	0.88	0.88	0.94	0.93
98	0.62	0.62	0.67	0.66	0.71	0.70	0.76	0.75	0.81	0.80	0.86	0.85	0.91	0.90
100	0.61	0.60	0.65	0.64	0.70	0.69	0.74	0.73	0.79	0.78	0.84	0.83	0.89	0.88
102	0.60	0.59	0.64	0.63	0.68	0.67	0.73	0.71	0.77	0.76	0.82	0.80	0.87	0.85
104	0.60	0.58	0.63	0.61	0.67	0.65	0.72	0.69	0.76	0.74	0.80	0.78	0.85	0.82
106	0.59	0.57	0.63	0.60	0.66	0.64	0.70	0.68	0.74	0.72	0.79	0.76	0.83	0.80
108	0.58	0.55	0.62	0.59	0.66	0.62	0.69	0.66	0.73	0.70	0.77	0.74	0.81	0.77
110	0.58	0.54	0.61	0.57	0.65	0.61	0.68	0.64	0.72	0.68	0.76	0.71	0.80	0.75
112	0.57	0.53	0.61	0.56	0.64	0.59	0.68	0.63	0.71	0.66	0.75	0.69	0.79	0.73
114	0.57	0.52	0.60	0.55	0.63	0.58	0.67	0.61	0.70	0.64	0.74	0.68	0.78	0.71
116	0.56	0.51	0.60	0.54	0.63	0.57	0.66	0.60	0.70	0.63	0.73	0.66	0.77	0.69
118	0.56	0.50	0.59	0.52	0.63	0.55	0.66	0.58	0.69	0.61	0.72	0.64	0.76	0.67
120	0.56	0.49	0.59	0.51	0.62	0.54	0.65	0.57	0.68	0.59	0.72	0.62	0.75	0.65
122	0.56	0.47	0.59	0.50	0.62	0.53	0.65	0.55	0.68	0.58	0.71	0.60	0.74	0.63
124	0.56	0.46	0.59	0.49	0.62	0.51	0.65	0.54	0.68	0.56	0.71	0.58	0.74	0.61
126	0.56	0.45	0.59	0.48	0.62	0.50	0.64	0.52	0.67	0.54	0.70	0.57	0.73	0.59
128	0.56	0.44	0.59	0.46	0.62	0.49	0.64	0.51	0.67	0.53	0.70	0.55	0.73	0.57
130	0.56	0.43	0.59	0.45	0.62	0.47	0.64	0.49	0.67	0.51	0.70	0.53	0.72	0.55
132	0.56	0.42	0.59	0.44	0.62	0.46	0.64	0.48	0.67	0.50	0.70	0.52	0.72	0.54
134	0.57	0.41	0.59	0.43	0.62	0.45	0.64	0.46	0.67	0.48	0.69	0.50	0.72	0.52
136	0.57	0.40	0.60	0.41	0.62	0.43	0.65	0.45	0.67	0.47	0.70	0.48	0.72	0.50
138	0.58	0.39	0.60	0.40	0.63	0.42	0.65	0.43	0.67	0.45	0.70	0.47	0.72	0.48
140	0.58	0.37	0.61	0.39	0.63	0.40	0.65	0.42	0.68	0.43	0.70	0.45	0.72	0.46
142	0.59	0.36	0.61	0.38	0.63	0.39	0.66	0.41	0.68	0.42	0.70	0.43	0.72	0.45
144	0.60	0.35	0.62	0.36	0.64	0.38	0.66	0.39	0.68	0.40	0.71	0.41	0.73	0.43
146	0.60	0.34	0.63	0.35	0.65	0.36	0.67	0.37	0.69	0.39	0.71	0.40	0.73	0.41
148	0.61	0.32	0.63	0.34	0.66	0.35	0.68	0.36	0.70	0.37	0.72	0.38	0.74	0.39
150	0.62	0.31	0.64	0.32	0.66	0.33	0.68	0.34	0.70	0.35	0.72	0.36	0.74	0.37
152	0.63	0.30	0.65	0.31	0.67	0.32	0.69	0.33	0.71	0.33	0.73	0.34	0.75	0.35
154	0.65	0.28	0.67	0.29	0.68	0.30	0.70	0.31	0.72	0.32	0.74	0.32	0.76	0.33
156	0.66	0.27	0.68	0.28	0.70	0.28	0.72	0.29	0.73	0.30	0.75	0.30	0.77	0.31
158	0.67	0.25	0.69	0.26	0.71	0.27	0.73	0.27	0.74	0.28	0.76	0.28	0.78	0.29
160	0.69	0.24	0.71	0.24	0.73	0.25	0.74	0.25	0.76	0.26	0.77	0.26	0.79	0.27

TABLE 18
Distance of an Object by Two Bearings

Difference between the course and second bearing °	Difference between the course and first bearing 48°		50°		52°		54°		56°		58°		60°	
58	4.28	3.63												
60	3.57	3.10	4.41	3.82										
62	3.07	2.71	3.68	3.25	4.54	4.01								
64	2.70	2.42	3.17	2.85	3.79	3.41	4.66	4.19						
66	2.40	2.20	2.78	2.54	3.26	2.98	3.89	3.55	4.77	4.36				
68	2.17	2.01	2.48	2.30	2.86	2.65	3.34	3.10	3.99	3.71	4.88	4.53		
70	1.98	1.86	2.24	2.10	2.55	2.39	2.94	2.76	3.43	3.22	4.08	3.83	4.99	4.69
72	1.83	1.74	2.04	1.94	2.30	2.19	2.62	2.49	3.01	2.86	3.51	3.33	4.17	3.96
74	1.70	1.63	1.88	1.81	2.10	2.02	2.37	2.27	2.68	2.58	3.08	2.96	3.58	3.44
76	1.58	1.54	1.75	1.70	1.94	1.88	2.16	2.10	2.42	2.35	2.74	2.66	3.14	3.05
78	1.49	1.45	1.63	1.60	1.80	1.76	1.99	1.95	2.21	2.16	2.48	2.43	2.80	2.74
80	1.40	1.38	1.53	1.51	1.68	1.65	1.85	1.82	2.04	2.01	2.26	2.23	2.53	2.49
82	1.33	1.32	1.45	1.43	1.58	1.56	1.72	1.71	1.89	1.87	2.08	2.06	2.31	2.29
84	1.26	1.26	1.37	1.36	1.49	1.48	1.62	1.61	1.77	1.76	1.93	1.92	2.13	2.12
86	1.21	1.20	1.30	1.30	1.41	1.41	1.53	1.52	1.66	1.65	1.81	1.80	1.98	1.97
88	1.16	1.16	1.24	1.24	1.34	1.34	1.45	1.45	1.56	1.56	1.70	1.70	1.84	1.84
90	1.11	1.11	1.19	1.19	1.28	1.28	1.38	1.38	1.48	1.48	1.60	1.60	1.73	1.73
92	1.07	1.07	1.14	1.14	1.23	1.23	1.31	1.31	1.41	1.41	1.52	1.52	1.63	1.63
94	1.03	1.03	1.10	1.10	1.18	1.17	1.26	1.26	1.35	1.34	1.44	1.44	1.55	1.54
96	1.00	0.99	1.06	1.06	1.13	1.13	1.21	1.20	1.29	1.28	1.38	1.37	1.47	1.47
98	0.97	0.96	1.03	1.02	1.10	1.08	1.16	1.15	1.24	1.23	1.32	1.31	1.41	1.39
100	0.94	0.93	1.00	0.98	1.06	1.04	1.12	1.11	1.19	1.18	1.27	1.25	1.35	1.33
102	0.92	0.90	0.97	0.95	1.03	1.01	1.09	1.06	1.15	1.13	1.22	1.19	1.29	1.27
104	0.90	0.87	0.95	0.92	1.00	0.97	1.06	1.02	1.12	1.08	1.18	1.14	1.25	1.21
106	0.88	0.84	0.92	0.89	0.97	0.94	1.03	0.99	1.09	1.04	1.14	1.10	1.20	1.16
108	0.86	0.82	0.90	0.86	0.95	0.90	1.00	0.95	1.05	1.00	1.11	1.05	1.17	1.11
110	0.84	0.79	0.88	0.83	0.93	0.87	0.98	0.92	1.02	0.96	1.08	1.01	1.13	1.06
112	0.83	0.77	0.87	0.80	0.91	0.84	0.95	0.88	1.00	0.93	1.05	0.97	1.10	1.02
114	0.81	0.74	0.85	0.78	0.89	0.82	0.93	0.85	0.98	0.89	1.02	0.93	1.07	0.98
116	0.80	0.72	0.84	0.75	0.88	0.79	0.92	0.82	0.96	0.85	1.00	0.90	1.04	0.94
118	0.79	0.70	0.83	0.73	0.86	0.76	0.90	0.79	0.94	0.83	0.98	0.86	1.02	0.90
120	0.78	0.68	0.82	0.71	0.85	0.74	0.89	0.77	0.91	0.80	0.96	0.83	1.00	0.87
122	0.77	0.66	0.81	0.68	0.84	0.71	0.87	0.74	0.90	0.77	0.95	0.80	0.98	0.83
124	0.77	0.63	0.80	0.66	0.83	0.69	0.86	0.71	0.90	0.74	0.93	0.77	0.96	0.80
126	0.76	0.61	0.79	0.64	0.82	0.66	0.85	0.69	0.88	0.71	0.91	0.74	0.95	0.77
128	0.75	0.59	0.78	0.62	0.81	0.64	0.84	0.66	0.87	0.69	0.90	0.71	0.93	0.74
130	0.75	0.57	0.78	0.60	0.81	0.62	0.83	0.64	0.86	0.66	0.89	0.68	0.92	0.71
132	0.75	0.56	0.77	0.57	0.80	0.59	0.83	0.61	0.85	0.64	0.88	0.66	0.91	0.68
134	0.74	0.54	0.77	0.55	0.80	0.57	0.82	0.59	0.85	0.61	0.87	0.63	0.90	0.65
136	0.74	0.52	0.77	0.53	0.80	0.55	0.82	0.57	0.84	0.58	0.87	0.60	0.89	0.62
138	0.74	0.50	0.77	0.51	0.79	0.53	0.81	0.54	0.84	0.56	0.86	0.58	0.89	0.59
140	0.74	0.48	0.77	0.49	0.79	0.51	0.81	0.52	0.83	0.54	0.86	0.55	0.88	0.57
142	0.74	0.46	0.77	0.47	0.79	0.49	0.81	0.50	0.83	0.51	0.85	0.52	0.87	0.54
144	0.75	0.44	0.77	0.45	0.79	0.46	0.81	0.48	0.83	0.49	0.85	0.50	0.87	0.51
146	0.75	0.42	0.77	0.43	0.79	0.44	0.81	0.45	0.83	0.46	0.85	0.47	0.87	0.49
148	0.76	0.40	0.77	0.41	0.79	0.42	0.81	0.43	0.83	0.44	0.85	0.45	0.87	0.46
150	0.76	0.38	0.78	0.39	0.80	0.40	0.81	0.41	0.83	0.42	0.85	0.42	0.87	0.43
152	0.77	0.36	0.78	0.37	0.80	0.38	0.82	0.38	0.83	0.39	0.85	0.40	0.87	0.41
154	0.77	0.34	0.79	0.35	0.81	0.35	0.82	0.36	0.84	0.37	0.85	0.37	0.87	0.38
156	0.78	0.32	0.80	0.32	0.81	0.33	0.83	0.34	0.84	0.34	0.86	0.35	0.87	0.35
158	0.79	0.30	0.81	0.30	0.82	0.31	0.83	0.31	0.85	0.32	0.86	0.32	0.87	0.33
160	0.80	0.27	0.82	0.28	0.83	0.28	0.84	0.29	0.85	0.29	0.86	0.30	0.88	0.30

TABLE 18
Distance of an Object by Two Bearings

Difference between the course and second bearing °	Difference between the course and first bearing 62°		64°		66°		68°		70°		72°		74°		76°	
72	5.08	4.84														
74	4.25	4.08	5.18	4.98												
76	3.65	3.54	4.32	4.19	5.26	5.10										
78	3.20	3.13	3.72	3.63	4.39	4.30	5.34	5.22								
80	2.86	2.81	3.26	3.21	3.78	3.72	4.46	4.39	5.41	5.33						
82	2.58	2.56	2.91	2.88	3.31	3.28	3.83	3.80	4.52	4.48	5.48	5.42				
84	2.36	2.34	2.63	2.61	2.96	2.94	3.36	3.35	3.88	3.86	4.57	4.55	5.54	5.51		
86	2.17	2.17	2.40	2.39	2.67	2.66	3.00	2.99	3.41	3.40	3.93	3.92	4.62	4.61	5.59	5.57
88	2.01	2.01	2.21	2.21	2.44	2.44	2.71	2.71	3.04	3.04	3.45	3.45	3.97	3.97	4.67	4.66
90	1.88	1.88	2.05	2.05	2.25	2.25	2.48	2.48	2.75	2.75	3.08	3.08	3.49	3.49	4.01	4.01
92	1.77	1.76	1.91	1.91	2.08	2.08	2.28	2.28	2.51	2.51	2.78	2.78	3.11	3.11	3.52	3.52
94	1.67	1.66	1.80	1.79	1.95	1.94	2.12	2.11	2.31	2.30	2.54	2.53	2.81	2.80	3.14	3.13
96	1.58	1.57	1.70	1.69	1.83	1.82	1.97	1.96	2.14	2.13	2.34	2.33	2.57	2.55	2.84	2.82
98	1.50	1.49	1.61	1.59	1.72	1.71	1.85	1.84	2.00	1.98	2.17	2.15	2.36	2.34	2.59	2.56
100	1.43	1.41	1.53	1.51	1.63	1.61	1.75	1.72	1.88	1.85	2.03	2.00	2.19	2.16	2.39	2.35
102	1.37	1.34	1.46	1.43	1.55	1.52	1.66	1.62	1.77	1.73	1.90	1.86	2.05	2.00	2.21	2.16
104	1.32	1.28	1.40	1.36	1.48	1.44	1.58	1.53	1.68	1.63	1.79	1.74	1.92	1.87	2.07	2.01
106	1.27	1.22	1.34	1.29	1.42	1.37	1.51	1.45	1.60	1.54	1.70	1.63	1.81	1.74	1.94	1.87
108	1.23	1.17	1.29	1.23	1.37	1.30	1.44	1.37	1.53	1.45	1.62	1.54	1.72	1.63	1.83	1.74
110	1.19	1.12	1.25	1.17	1.32	1.24	1.39	1.30	1.46	1.37	1.54	1.45	1.64	1.54	1.74	1.63
112	1.15	1.07	1.21	1.12	1.27	1.18	1.33	1.24	1.40	1.30	1.48	1.37	1.56	1.45	1.65	1.53
114	1.12	1.02	1.17	1.07	1.23	1.12	1.29	1.18	1.35	1.24	1.42	1.30	1.50	1.37	1.58	1.44
116	1.09	0.98	1.14	1.03	1.19	1.07	1.25	1.12	1.31	1.17	1.37	1.23	1.44	1.29	1.51	1.36
118	1.07	0.94	1.11	0.98	1.16	1.02	1.21	1.07	1.26	1.12	1.32	1.17	1.38	1.22	1.45	1.28
120	1.04	0.90	1.08	0.94	1.13	0.98	1.18	1.02	1.23	1.06	1.28	1.11	1.34	1.16	1.40	1.21
122	1.02	0.86	1.06	0.90	1.10	0.93	1.15	0.97	1.19	1.01	1.24	1.05	1.29	1.10	1.35	1.14
124	1.00	0.83	1.04	0.86	1.08	0.89	1.12	0.93	1.16	0.96	1.21	1.00	1.25	1.04	1.31	1.08
126	0.98	0.79	1.02	0.82	1.05	0.85	1.09	0.88	1.13	0.92	1.18	0.95	1.22	0.99	1.27	1.02
128	0.97	0.76	1.00	0.79	1.03	0.82	1.07	0.84	1.11	0.87	1.15	0.90	1.19	0.94	1.23	0.97
130	0.95	0.73	0.98	0.75	1.02	0.78	1.05	0.80	1.09	0.83	1.12	0.86	1.16	0.89	1.20	0.92
132	0.94	0.70	0.97	0.72	1.00	0.74	1.03	0.77	1.06	0.79	1.10	0.82	1.13	0.84	1.17	0.87
134	0.93	0.67	0.96	0.69	0.99	0.71	1.01	0.73	1.04	0.75	1.08	0.77	1.11	0.80	1.14	0.82
136	0.92	0.64	0.95	0.66	0.97	0.68	1.00	0.69	1.03	0.71	1.06	0.74	1.09	0.76	1.12	0.78
138	0.91	0.61	0.94	0.63	0.96	0.64	0.99	0.66	1.01	0.68	1.04	0.70	1.07	0.72	1.10	0.74
140	0.90	0.58	0.93	0.60	0.95	0.61	0.97	0.63	1.00	0.64	1.03	0.66	1.05	0.68	1.08	0.69
142	0.90	0.55	0.92	0.57	0.94	0.58	0.96	0.59	0.99	0.61	1.01	0.62	1.04	0.64	1.06	0.65
144	0.89	0.52	0.91	0.54	0.93	0.55	0.96	0.56	0.98	0.57	1.00	0.59	1.02	0.60	1.05	0.62
146	0.89	0.50	0.91	0.51	0.93	0.52	0.95	0.53	0.97	0.54	0.99	0.55	1.01	0.57	1.03	0.58
148	0.89	0.47	0.90	0.48	0.92	0.49	0.94	0.50	0.96	0.51	0.98	0.52	1.00	0.53	1.02	0.54
150	0.88	0.44	0.90	0.45	0.92	0.46	0.94	0.47	0.95	0.48	0.97	0.49	0.99	0.50	1.01	0.50
152	0.88	0.41	0.90	0.42	0.92	0.43	0.93	0.44	0.95	0.45	0.97	0.45	0.98	0.46	1.00	0.47
154	0.88	0.39	0.90	0.39	0.91	0.40	0.93	0.41	0.94	0.41	0.96	0.42	0.98	0.43	0.99	0.43
156	0.89	0.36	0.90	0.37	0.91	0.37	0.93	0.38	0.94	0.38	0.96	0.39	0.97	0.39	0.99	0.40
158	0.89	0.33	0.90	0.34	0.91	0.34	0.93	0.35	0.94	0.35	0.95	0.36	0.97	0.36	0.98	0.37
160	0.89	0.30	0.90	0.31	0.91	0.31	0.93	0.32	0.94	0.32	0.95	0.33	0.96	0.33	0.98	0.33

TABLE 18

Distance of an Object by Two Bearings

Difference between the course and second bearing	Difference between the course and first bearing															
°	78°		80°		82°		84°		86°		88°		90°		92°	
88	5.63	5.63														
90	4.70	4.70	5.67	5.67												
92	4.04	4.04	4.74	4.73	5.70	5.70										
94	3.55	3.54	4.07	4.06	4.76	4.75	5.73	5.71								
96	3.17	3.15	3.57	3.55	4.09	4.07	4.78	4.76	5.74	5.71						
98	2.86	2.83	3.19	3.16	3.59	3.56	4.11	4.07	4.80	4.75	5.76	5.70				
100	2.61	2.57	2.88	2.84	3.20	3.16	3.61	3.55	4.12	4.06	4.81	4.73	5.76	5.67		
102	2.40	2.35	2.63	2.57	2.90	2.83	3.22	3.15	3.62	3.54	4.13	4.04	4.81	4.70	5.76	5.63
104	2.23	2.16	2.42	2.35	2.64	2.56	2.91	2.82	3.23	3.13	3.63	3.52	4.13	4.01	4.81	4.66
106	2.08	2.00	2.25	2.16	2.43	2.34	2.65	2.55	2.92	2.80	3.23	3.11	3.63	3.49	4.13	3.97
108	1.96	1.86	2.10	2.00	2.26	2.15	2.45	2.33	2.66	2.53	2.92	2.78	3.24	3.08	3.63	3.45
110	1.85	1.73	1.97	1.85	2.11	1.98	2.27	2.13	2.45	2.31	2.67	2.51	2.92	2.75	3.23	3.04
112	1.75	1.62	1.86	1.72	1.98	1.83	2.12	1.96	2.28	2.11	2.46	2.28	2.67	2.48	2.92	2.71
114	1.66	1.52	1.76	1.61	1.87	1.71	1.99	1.82	2.12	1.94	2.28	2.08	2.46	2.25	2.67	2.44
116	1.59	1.43	1.68	1.51	1.77	1.59	1.88	1.69	2.00	1.79	2.13	1.91	2.28	2.05	2.46	2.21
118	1.52	1.34	1.60	1.41	1.68	1.49	1.78	1.57	1.88	1.66	2.00	1.76	2.13	1.88	2.28	2.01
120	1.46	1.27	1.53	1.33	1.61	1.39	1.69	1.47	1.78	1.54	1.89	1.63	2.00	1.73	2.13	1.84
122	1.41	1.19	1.47	1.25	1.54	1.31	1.62	1.37	1.70	1.44	1.79	1.52	1.89	1.60	2.00	1.70
124	1.36	1.13	1.42	1.18	1.48	1.23	1.55	1.28	1.62	1.34	1.70	1.41	1.79	1.48	1.89	1.56
126	1.32	1.06	1.37	1.11	1.43	1.15	1.48	1.20	1.55	1.26	1.62	1.31	1.70	1.38	1.79	1.45
128	1.28	1.01	1.33	1.04	1.38	1.08	1.43	1.13	1.49	1.17	1.55	1.23	1.62	1.28	1.70	1.34
130	1.24	0.95	1.29	0.98	1.33	1.02	1.38	1.06	1.44	1.10	1.49	1.14	1.56	1.19	1.62	1.24
132	1.21	0.90	1.25	0.93	1.29	0.96	1.34	0.99	1.39	1.03	1.44	1.07	1.49	1.11	1.55	1.16
134	1.18	0.85	1.22	0.88	1.26	0.90	1.30	0.93	1.34	0.97	1.39	1.00	1.44	1.04	1.49	1.07
136	1.15	0.80	1.19	0.83	1.22	0.85	1.26	0.88	1.30	0.90	1.34	0.93	1.39	0.97	1.44	1.00
138	1.13	0.76	1.16	0.78	1.19	0.80	1.23	0.82	1.27	0.85	1.30	0.87	1.35	0.90	1.39	0.93
140	1.11	0.71	1.14	0.73	1.17	0.75	1.20	0.77	1.23	0.79	1.27	0.82	1.31	0.84	1.34	0.86
142	1.09	0.67	1.12	0.69	1.14	0.70	1.17	0.72	1.20	0.74	1.24	0.76	1.27	0.78	1.30	0.80
144	1.07	0.63	1.10	0.64	1.12	0.66	1.15	0.67	1.18	0.69	1.21	0.71	1.24	0.73	1.27	0.75
146	1.05	0.59	1.08	0.60	1.10	0.62	1.13	0.63	1.15	0.64	1.18	0.66	1.21	0.67	1.24	0.69
148	1.04	0.55	1.06	0.56	1.08	0.57	1.11	0.59	1.13	0.60	1.15	0.61	1.18	0.62	1.21	0.64
150	1.03	0.51	1.05	0.52	1.07	0.53	1.09	0.54	1.11	0.55	1.13	0.57	1.15	0.58	1.18	0.59
152	1.02	0.48	1.04	0.49	1.05	0.49	1.07	0.50	1.09	0.51	1.11	0.52	1.13	0.53	1.15	0.54
154	1.01	0.44	1.02	0.45	1.04	0.46	1.06	0.46	1.08	0.47	1.09	0.48	1.11	0.49	1.13	0.50
156	1.00	0.41	1.01	0.41	1.03	0.42	1.05	0.43	1.06	0.43	1.08	0.44	1.09	0.45	1.11	0.45
158	0.99	0.37	1.01	0.38	1.02	0.38	1.03	0.39	1.05	0.39	1.06	0.40	1.08	0.40	1.09	0.41
160	0.99	0.34	1.00	0.34	1.01	0.35	1.02	0.35	1.04	0.35	1.05	0.36	1.06	0.36	1.08	0.37
°	94°		96°		98°		100°		102°		104°		106°		108°	
104	5.74	5.57														
106	4.80	4.61	5.73	5.51												
108	4.12	3.92	4.78	4.55	5.70	5.42										
110	3.62	3.40	4.11	3.86	4.76	4.48	5.67	5.33								
112	3.23	2.99	3.61	3.35	4.09	3.80	4.74	4.40	5.63	5.22						
114	2.92	2.66	3.22	2.94	3.59	3.28	4.07	3.72	4.70	4.30	5.59	5.10				
116	2.66	2.39	2.91	2.61	3.20	2.88	3.57	3.21	4.04	3.63	4.67	4.19	5.54	4.98		
118	2.45	2.17	2.65	2.34	2.90	2.56	3.19	2.81	3.55	3.13	4.01	3.54	4.62	4.08	5.48	4.84
120	2.28	1.97	2.45	2.12	2.64	2.29	2.88	2.49	3.17	2.74	3.52	3.05	3.97	3.44	4.57	3.96
122	2.12	1.80	2.27	1.92	2.43	2.06	2.63	2.23	2.86	2.43	3.14	2.66	3.49	2.96	3.93	3.33
124	2.00	1.65	2.12	1.76	2.26	1.87	2.42	2.01	2.61	2.16	2.84	2.35	3.11	2.58	3.45	2.86
126	1.88	1.52	1.99	1.61	2.11	1.71	2.25	1.82	2.40	1.95	2.59	2.10	2.81	2.27	3.08	2.49
128	1.78	1.41	1.88	1.48	1.98	1.56	2.10	1.65	2.23	1.76	2.39	1.88	2.57	2.02	2.78	2.19
130	1.70	1.30	1.78	1.36	1.87	1.43	1.97	1.51	2.08	1.60	2.21	1.70	2.36	1.81	2.54	1.94
132	1.62	1.20	1.69	1.26	1.77	1.32	1.86	1.38	1.96	1.45	2.07	1.54	2.19	1.63	2.34	1.74
134	1.55	1.12	1.62	1.16	1.68	1.21	1.76	1.27	1.85	1.33	1.94	1.40	2.05	1.47	2.17	1.56
136	1.49	1.04	1.55	1.07	1.61	1.12	1.68	1.16	1.75	1.22	1.83	1.27	1.92	1.34	2.03	1.41
138	1.44	0.96	1.49	0.99	1.54	1.03	1.60	1.07	1.66	1.11	1.74	1.16	1.81	1.21	1.90	1.27
140	1.39	0.89	1.43	0.92	1.48	0.95	1.53	0.98	1.59	1.02	1.65	1.06	1.72	1.10	1.79	1.15
142	1.34	0.83	1.38	0.85	1.43	0.88	1.47	0.91	1.52	0.94	1.58	0.97	1.64	1.01	1.70	1.05
144	1.30	0.77	1.34	0.79	1.38	0.81	1.42	0.83	1.46	0.86	1.51	0.89	1.56	0.92	1.62	0.95
146	1.27	0.71	1.30	0.73	1.33	0.75	1.37	0.77	1.41	0.79	1.45	0.81	1.50	0.84	1.54	0.86
148	1.23	0.65	1.26	0.67	1.29	0.69	1.33	0.70	1.36	0.72	1.40	0.74	1.44	0.76	1.48	0.78
150	1.20	0.60	1.23	0.61	1.26	0.63	1.29	0.64	1.32	0.66	1.35	0.67	1.38	0.69	1.42	0.71
152	1.18	0.55	1.20	0.56	1.22	0.57	1.25	0.59	1.28	0.60	1.31	0.61	1.34	0.63	1.37	0.64
154	1.15	0.50	1.17	0.51	1.19	0.52	1.22	0.53	1.24	0.54	1.27	0.56	1.29	0.57	1.32	0.58
156	1.13	0.46	1.15	0.47	1.17	0.47	1.19	0.48	1.21	0.49	1.23	0.50	1.25	0.51	1.28	0.52
158	1.11	0.42	1.13	0.42	1.14	0.43	1.16	0.44	1.18	0.44	1.20	0.45	1.22	0.46	1.24	0.47
160	1.09	0.37	1.11	0.38	1.12	0.38	1.14	0.39	1.15	0.39	1.17	0.40	1.19	0.41	1.21	0.41

TABLE 18

Distance of an Object by Two Bearings

Difference between the course and second bearing	Difference between the course and first bearing													
°	110°		112°		114°		116°		118°		120°		122°	
120	5.41	4.69												
122	4.52	3.83	5.34	4.53										
124	3.88	3.22	4.46	3.70	5.26	4.36								
126	3.41	2.76	3.83	3.10	4.39	3.55	5.18	4.19						
128	3.04	2.40	3.36	2.65	3.78	2.98	4.32	3.41	5.08	4.01				
130	2.75	2.10	3.00	2.30	3.31	2.54	3.72	2.85	4.25	3.25	4.99	3.82		
132	2.51	1.86	2.71	2.01	2.96	2.20	3.26	2.42	3.65	2.71	4.17	3.10	4.88	3.63
134	2.31	1.66	2.48	1.78	2.67	1.92	2.91	2.09	3.20	2.30	3.58	2.57	4.08	2.93
136	2.14	1.49	2.28	1.58	2.44	1.69	2.63	1.83	2.86	1.98	3.14	2.18	3.51	2.44
138	2.00	1.34	2.12	1.42	2.25	1.50	2.40	1.61	2.58	1.73	2.80	1.88	3.08	2.06
140	1.88	1.21	1.97	1.27	2.08	1.34	2.21	1.42	2.36	1.52	2.53	1.63	2.74	1.76
142	1.77	1.09	1.85	1.14	1.95	1.20	2.05	1.26	2.17	1.34	2.31	1.42	2.48	1.53
144	1.68	0.99	1.75	1.03	1.83	1.07	1.91	1.13	2.01	1.18	2.13	1.25	2.26	1.33
146	1.60	0.89	1.66	0.93	1.72	0.96	1.80	1.01	1.88	1.05	1.98	1.10	2.08	1.17
148	1.53	0.81	1.58	0.84	1.63	0.87	1.70	0.90	1.77	0.94	1.84	0.98	1.93	1.03
150	1.46	0.73	1.51	0.75	1.55	0.78	1.61	0.80	1.67	0.83	1.73	0.87	1.81	0.90
152	1.40	0.66	1.44	0.68	1.48	0.70	1.53	0.72	1.58	0.74	1.63	0.77	1.70	0.80
154	1.35	0.59	1.39	0.61	1.42	0.62	1.46	0.64	1.50	0.66	1.55	0.68	1.60	0.70
156	1.31	0.53	1.33	0.54	1.37	0.56	1.40	0.57	1.43	0.58	1.47	0.60	1.52	0.62
158	1.26	0.47	1.29	0.48	1.32	0.49	1.34	0.50	1.37	0.51	1.41	0.53	1.44	0.54
160	1.23	0.42	1.25	0.43	1.27	0.43	1.29	0.44	1.32	0.45	1.35	0.46	1.38	0.47
	124°		126°		128°		130°		132°		134°		136°	
134	4.77	3.43												
136	3.99	2.77	4.66	3.24										
138	3.43	2.29	3.89	2.60	4.54	3.04								
140	3.01	1.93	3.34	2.15	3.79	2.44	4.41	2.84						
142	2.68	1.65	2.94	1.81	3.26	2.01	3.68	2.27	4.28	2.63				
144	2.42	1.42	2.62	1.54	2.86	1.68	3.17	1.86	3.57	2.10	4.14	2.43		
146	2.21	1.24	2.37	1.32	2.55	1.43	2.78	1.55	3.07	1.72	3.46	1.93	4.00	2.24
148	2.04	1.08	2.16	1.14	2.30	1.22	2.48	1.31	2.70	1.43	2.97	1.58	3.34	1.77
150	1.89	0.95	1.99	0.99	2.10	1.05	2.24	1.12	2.40	1.20	2.61	1.30	2.87	1.44
152	1.77	0.83	1.85	0.87	1.94	0.91	2.04	0.96	2.17	1.02	2.33	1.09	2.52	1.18
154	1.66	0.73	1.72	0.76	1.80	0.79	1.88	0.83	1.98	0.87	2.10	0.92	2.25	0.99
156	1.56	0.64	1.62	0.66	1.68	0.68	1.75	0.71	1.83	0.74	1.92	0.78	2.03	0.83
158	1.48	0.56	1.53	0.57	1.58	0.59	1.63	0.61	1.70	0.64	1.77	0.66	1.85	0.69
160	1.41	0.48	1.45	0.49	1.49	0.51	1.53	0.52	1.58	0.54	1.64	0.56	1.71	0.58
	138°		140°		142°		144°		146°		148°		150°	
148	3.85	2.04												
150	3.22	1.61	3.70	1.85										
152	2.77	1.30	3.09	1.45	3.55	1.66								
154	2.43	1.06	2.66	1.16	2.96	1.30	3.38	1.48						
156	2.17	0.88	2.33	0.95	2.54	1.04	2.83	1.15	3.22	1.31				
158	1.96	0.73	2.08	0.78	2.23	0.84	2.43	0.91	2.69	1.01	3.05	1.14		
160	1.79	0.61	1.88	0.64	1.99	0.68	2.13	0.73	2.31	0.79	2.55	0.87	2.88	0.98

Contents

Time of phenomenon calculations are critical to many navigation problems. Some problems involve solving for time itself, while others use a time solution as prerequisite for solving more complex problems.

Problems are divided into two major types: stationary and moving. Basic stationary time of phenomenon problems are typically an acceptable estimate, but more precision may be required for vessels in transit or for merchant mariner exams.

The 1981 Nautical Almanac is used for all applicable problems. Further information on this almanac is available in the preface.

Basic Sunrise, Sunset, and Local Apparent Noon Problems

Problem 9-1. The following question illustrates the process of calculating sunrise or sunset at a known location.

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?

Lat.	Twilight Naut.	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

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

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 arithmetic to do a manual calculation (ratios), or to use Table 1 in the Nautical Almanac. A portion of the table is re-created here, and the entire table is re-created at the end of this Part. Remember to mentally check the results to ensure addition/subtraction was performed correctly, as required.

Option 1: 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

Option 2: "Table 1" correction:

Tabular Interval 10°	5°	2°	Difference between the times for consecutive latitudes 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.

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. Use the Conversion of Arc to Time table in the Nautical Almanac. A portion of the table is re-created here, and the entire table is re-created at the end of this Part.

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

5° of arc to the west = 20 minutes (added, since difference is “to the west”).

Step 6: Apply the longitude correction to the latitude-corrected time to determine time of sunset.

0528 + 0020 = **0548**

Problem 9-2. The following question is modified from a question in the USCG test bank and illustrates how to calculate the time of a phenomenon at a known position.

Your ship's position is latitude 16° 03.1' N and longitude 031° 03.8' W. The ship is holding position and not moving. The date is 28 June. What is the zone time of sunset at your ship's location?

Answer: 18:39:45 zone time.

Step 1: Locate the tabular values in the Nautical Almanac.

N 40	19 33
35	19 18
30	19 05
20	18 43
N 10	18 24
0	18 07

The nearest bracketing latitudes are:
20° N: 1843
10° N: 1824

Note the tabular interval is 10°.

Step 2: Convert local latitude to decimal notation and identify the difference from the nearest bracketing latitudes.

20° N: 1843
16° 03.1' N = 16.052°: unknown
10° N: 1824

Differences:
10° N to 16.052° = 6.052°
10° N to 20° N = 19 minutes

Step 3: Complete the latitude correction (using mental interpolation or Table 1 in the Nautical Almanac, which is re-created in it's entirety at the end of this part).

$$\frac{x}{19\, minutes} = \frac{6.052°}{10°}$$
$$\frac{x}{19\, minutes} = 0.6052$$
$$x = (0.6052)\ (19)$$
$$x = 11.499 \text{ minutes (later)}$$

Latitude corrected time = 1824 (base) + 11.5 minutes = 18:35:30
Table 1 correction = 1824 (base) + approximately 12 min = 18:36

Step 4: Determine the difference in longitude from the standard meridian of the time being observed.

Longitude = 031° 03.8' W

The problem does not mention a specific time zone being observed, so assume that the vessel is observing (+2) = standard meridian of 30°.

031° 03.8' W – 30° = 1° 03.8' difference from standard meridian.

Step 5: Convert the difference in longitude arc to time (use the Conversion of Arc to Time in the Nautical Almanac, which is re-created in it's entirety at the end of this part).

1° 03.8' of arc to the west = 4 minutes 15 seconds (added).

Step 6: Apply the longitude correction to the latitude-corrected time to determine time of sunset.

18:35:30 + 00:04:15 = **18:39:45**

<u>Problem 9-3</u>. The following question is modified from a question in the USCG test bank and illustrates how to calculate the time of a phenomenon at a known position.

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: 11:38:26 zone time.

Step 1: Locate the tabular values in the Nautical Almanac.
The time of meridian passage for 15 July is 1206.

Step 2: No latitude correction is required due to the nature of local apparent noon calculations.

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

Tabular value = 1206
Latitude corrected value = 1206

Step 3: Determine the difference in longitude from the standard meridian of the time being observed.

Longitude = 128° 06.4 W

The problem gives a specific time zone being observed. 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 (use the Conversion of Arc to Time in the Nautical Almanac, which is re-created in it's entirety at the end of this part).

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 = **11:38:26**

Basic Moonrise and Moonset Problems

The key difference in moon calculations is that time calculations must be carried out for the day in question, as well as the following day (preceding day in eastern hemisphere) in order to use Table 2 in the Nautical Almanac. Moonrise and moonset are calculated in the same way.

Problem 9-4. The following question illustrates the process of calculating moonset.

Your ship's position is latitude 42° 30' N and longitude 070° 00' W. The ship is holding position and not moving. The date is 2 August and you are observing (+4) zone time. What is the zone time of moonset?

Answer: Approximately 2103

Lat.	Sunset	Twilight Civil	Twilight Naut.	Moonset 2	Moonset 3	Moonset 4
°	h m	h m	h m	h m	h m	h m
N 72	▭	▭	▭	22 23	22 09	21 56
N 70	22 24	////	////	22 10	22 02	21 56
68	21 44	////	////	21 58	21 57	21 55
66	21 17	23 10	////	21 49	21 53	21 55
64	20 56	22 18	////	21 41	21 49	21 55
62	20 39	21 47	////	21 35	21 45	21 54
60	20 26	21 24	23 16	21 29	21 42	21 54
N 58	20 14	21 06	22 29	21 24	21 40	21 54
56	20 04	20 51	22 00	21 19	21 37	21 54
54	19 55	20 38	21 39	21 15	21 35	21 54
52	19 47	20 27	21 22	21 11	21 33	21 53
50	19 40	20 18	21 07	21 08	21 31	21 53
45	19 24	19 58	20 40	21 00	21 28	21 53
N 40	19 12	19 42	20 19	20 54	21 24	21 53

Step 1: Locate the tabular values in the Nautical Almanac.

Locate the nearest tabular latitudes which bracket the desired position and record the time of moonset at each:

45° N: 2100

40° N: 2054

Note the tabular interval is 5°.

Step 2: Convert local latitude to decimal notation and identify the time difference between consecutive latitudes as well as the angular distance from the desired latitude to the base latitude.

45° N: 2100

42° 30' N = 42.5° = unknown value

40° N: 2054

Differences:

40° N to 42.5° = 2.5°

40° N to 45° N = 6 minutes

Step 3: Complete the latitude correction. The two options for this step are to use arithmetic to do a manual calculation (ratios), or to use Table 1 in the Nautical Almanac. A portion of the table is re-created here, and the entire table is re-created at the end of this Part. Remember to mentally check the results to ensure addition/subtraction was performed correctly, as required.

Option 1: Manual Calculation

$$\frac{x}{6\,minutes} = \frac{2.5°}{5°}$$

$$\frac{x}{6\,minutes} = 0.5$$

$x = (0.5)\,(6)$

$x = 3$ minutes (later)

Latitude corrected time = 2054 (base) + 3 minutes = 2057

Option 2: Table 1

Tabular Interval 10°	5°	2°	Difference between the times for consecutive latitudes 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 5°.
b. Proceed down the "Tabular Interval" column until you reach the difference between the tabular latitude and your desired latitude (2° 30' in this case).
c. The time difference determined in the previous step was 6 minutes. There is no "6 minutes" column in the "difference between the times for consecutive latitudes" section, so note the values for the nearest headings (5m and 10m). In this case, the necessary values are 2 and 5 minutes.
d. Mentally interpolate the actual value (3 minutes in this case).

Table 1 corrected time = 2054 + 3 minutes = 2057.

Step 4: Due to the moons proximity to the earth, its motions in the sky are complicated. In order to account for longitude, it is necessary to use Table 2 in the Nautical Almanac, which involves completing the above procedure a total of two times (once for the day in question, and once for the following day (western hemisphere) or preceding day (eastern hemisphere)).

The nearest bracketing latitudes for 3 August are:

45° N: 2128
42.5° = unknown value
40° N: 2124

Differences for 3 August:

40° N to 42.5° = 2.5°
40° N to 45° N = 4 minutes

$$\frac{x}{4\ minutes} = \frac{2.5°}{5°}$$
$$\frac{x}{4\ minutes} = 0.5$$
$$x = (0.5)\ (4)$$
$$x = 2 \text{ minutes (later)}$$

Corrections for 3 August:
Latitude corrected time = 2124 (base) + 2 minutes = 2126
Option 2: Table 1 correction = 2124 (base) + approx. 2 min = 2126

Step 5: Using the information for the two consecutive dates, use Table 2 in the Nautical Almanac (re-created in it's entirety here and at the end of this Part) to determine longitude correction.

Longitude: 070° W.
Nearest tabular longitude: 070°
Difference in moonset times between consecutive dates:
(3 Aug) – (4 Aug) = Difference
2126 – 2057 = 29 minutes
Using Table 2 (longitude of 70° and time difference of 29m), the correction is approximately <u>6 minutes</u>.

TABLE II—FOR LONGITUDE

Long. East or West	Difference between the times for given date and preceding date (for east longitude) or for given date and following date (for west longitude)																	
	10m	20m	30m	40m	50m	60m	1h + 10m	1h + 20m	1h + 30m	1h + 40m	1h + 50m	1h + 60m	2h 10m	2h 20m	2h 30m	2h 40m	2h 50m	3h 00m
°	m	m	m	m	m	m	m	m	m	m	m	m	h m	h m	h m	h m	h m	h m
0	0	0	0	0	0	0	0	0	0	0	0	0	0 00	0 00	0 00	0 00	0 00	0 00
10	0	1	1	1	1	2	2	2	2	3	3	3	04	04	04	04	05	05
20	1	1	2	2	3	3	4	4	5	6	6	7	07	08	08	09	09	10
30	1	2	2	3	4	5	6	7	7	8	9	10	11	12	12	13	14	15
40	1	2	3	4	6	7	8	9	10	11	12	13	14	16	17	18	19	20
50	1	3	4	6	7	8	10	11	12	14	15	17	0 18	0 19	0 21	0 22	0 24	0 25
60	2	3	5	7	8	10	12	13	15	17	18	20	22	23	25	27	28	30
70	2	4	6	8	10	12	14	16	17	19	21	23	25	27	29	31	33	35
80	2	4	7	9	11	13	16	18	20	22	24	27	29	31	33	36	38	40
90	2	5	7	10	12	15	17	20	22	25	27	30	32	35	37	40	42	45
100	3	6	8	11	14	17	19	22	25	28	31	33	0 36	0 39	0 42	0 44	0 47	0 50
110	3	6	9	12	15	18	21	24	27	31	34	37	40	43	46	49	0 52	0 55
120	3	7	10	13	17	20	23	27	30	33	37	40	43	47	50	53	0 57	1 00
130	4	7	11	14	18	22	25	29	32	36	40	43	47	51	54	0 58	1 01	1 05
140	4	8	12	16	19	23	27	31	35	39	43	47	51	54	0 58	1 02	1 06	1 10
150	4	8	13	17	21	25	29	33	38	42	46	50	0 54	0 58	1 03	1 07	1 11	1 15
160	4	9	13	18	22	27	31	36	40	44	49	53	0 58	1 02	1 07	1 11	1 16	1 20
170	5	9	14	19	24	28	33	38	42	47	52	57	1 01	1 06	1 11	1 16	1 20	1 25
180	5	10	15	20	25	30	35	40	45	50	55	60	1 05	1 10	1 15	1 20	1 25	1 30

Table II is for interpolating the L.M.T. of moonrise, moonset and the Moon's meridian passage for longitude. It is entered with longitude and with the difference between the times for the given date and for the preceding date (in east longitudes) or following date (in west longitudes). The correction is normally *added* for west longitudes and *subtracted* for east longitudes, but if, as occasionally happens, the times become earlier each day instead of later, the signs of the corrections must be reversed.

Step 6: Apply the Table 2 correction to the latitude-corrected time for the original date (2 August) to determine time of moonset. Corrections are typically added in the western hemisphere and subtracted in the eastern hemisphere, however there are occasional reversals, per the directions at the bottom of Table 2.

2057 + 6 minutes = **2103**

Problem 9-5. The following question illustrates the process of calculating moonrise.

Your ship's position is latitude 43° 12.7' N and longitude 069° 33.2' W. The ship is holding position and not moving. The date is 22 May and you are observing (+4) zone time. What is the zone time of moonrise?

Answer: Approximately 22:38:18 zone time.

Step 1: Locate the tabular values in the Nautical Almanac.

Lat.	Twilight Naut.	Twilight Civil	Sunrise	Mo… 22	23
°	h m	h m	h m	h m	h m
N 72	▭	▭	▭	■	■
N 70	▭	▭	▭	■	■
68	////	////	00 55	01 08	01 59
66	////	////	01 50	00 17	01 08
64	////	////	02 23	24 37	00 37
62	////	01 15	02 46	24 13	00 13
60	////	01 54	03 05	23 54	24 35
N 58	////	02 20	03 21	23 39	24 20
56	01 08	02 40	03 34	23 25	24 08
54	01 44	02 57	03 45	23 14	23 57
52	02 08	03 11	03 55	23 03	23 48
50	02 27	03 23	04 04	22 54	23 39
45	03 03	03 48	04 23	22 35	23 21
N 40	03 28	04 07	04 38	22 19	23 06

The nearest bracketing latitudes are:

45° N: 2235
40° N: 2219

Note the tabular interval is 5°.

Step 2: Convert local latitude to decimal notation and identify the difference from the nearest bracketing latitudes.

45° N: 2235
43° 12.7' N = 43.212° = unknown value
40° N: 2219

Differences:
40° N to 43.212° = 3.212°
40° N to 45° N = 16 minutes

Step 3: Complete the latitude correction (using mental interpolation or Table 1 in the Nautical Almanac, which is re-created in it's entirety at the end of this part).

$$\frac{x}{16\ minutes} = \frac{3.212°}{5°}$$
$$\frac{x}{16\ minutes} = 0.6424$$
$$x = (0.6424)\ (16)$$

$x = 10.278$ minutes (later)

Latitude corrected time = 2219 (base) + 10.3 minutes = 22:29:18
Table 1 correction = 2219 (base) + approximately 11 min = 22:30

Step 4: Complete the same calculation for the following day (note – use preceding day in eastern hemisphere problems).

The nearest bracketing latitudes for 23 May are:
45° N: 2321
43.212° = unknown value
40° N: 2306

Differences for 23 May:
40° N to 43.212° = 3.212°
40° N to 45° N = 15 minutes

$$\frac{x}{15\ minutes} = \frac{3.212°}{5°}$$
$$\frac{x}{15\ minutes} = 0.6424$$
$$x = (0.6424)\ (15)$$
$x = 9.636$ minutes (later)

Corrections for 23 May:
Latitude corrected time = 2306 (base) + 9.6 minutes = 23:15:36
Table 1 correction = (base) + 10 min = 23:16

Step 5: Use Table 2 in the Nautical Almanac (re-created in it's entirety at the end of this Part) to determine longitude correction.

Longitude: 069° 33.2
Nearest tabular longitude: 070°
Difference between consecutive dates: 23:15:36 – 22:29:18 = 00:46:18.
Tabular correction based on above information: approximately 9 min (added per directions in Table 2).

Step 6: Apply the Table 2 correction to the latitude-corrected time for the original date (22 May) to determine time of moonrise.

22:29:18 + 00:09:00 = **22:38:18**

Advanced Time of Phenomenon Problems Involving Moving Vessels

Since most navigators desire to determine the time of phenomenon at a point sometime in the future, the distance a moving vessel covers between time of calculation and phenomenon must be accounted for.

The process for calculating a future position with mid-latitude, parallel, or plane sailing is described in Part 5 (Great Circle and Sailings). The formulae are reproduced here for convenience with a brief description, below:

$$l = D\ \cos C$$

$$D = l\ \sec C$$

$$p = D\ \sin C$$

$$DLo = p\ \sec l \quad - or - \quad DLo = \frac{p}{\cos l}$$

$$DLo = p\ \sec Lm \quad - or - \quad DLo = \frac{p}{\cos Lm}$$

Variables:
p = Departure. The distance between two meridians at any given parallel of latitude.
D = Distance in miles
C = Course angle. Course angle. A course measured from 000° clockwise or anti-clockwise through 180° labeled with prefix and suffix directions to clarify the intended course. For example, a traditional course of 120° T would be expressed as a course angle of E120°N, while a traditional course of 330° T would be expressed as a course angle of W30°N. Further discussion can be found in Bowditch.
l = difference in latitude
DLo = Difference in Longitude

<u>Problem 9-6 (CG-312)</u>. The following question is taken directly from the USCG test bank and illustrates the process of solving a time of phenomenon problem using a first estimate of DR position.

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)?

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

Answer: 11:50:02 zone time.

Step 1: Locate the tabular values in the Nautical Almanac.
The time of meridian passage for 2 April is 1204.

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 time zone remains in effect regardless of travel).

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)
Latitude 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 (use the Conversion of Arc to Time in the Nautical Almanac, which is re-created in it’s entirety at the end of this part).

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**

<u>Problem 9-7 (CG-447)</u>. The following question is taken directly from the USCG test bank and illustrates the process of solving a time of phenomenon problem using a first estimate of DR position.

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: 18:39:18 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. 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

$$\frac{x}{19\,minutes} = \frac{6°}{10°}$$
$$\frac{x}{19\,minutes} = 0.6$$
$$x = (19)(0.6)$$
$x = 11.4$ 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 chart/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)
Latitude 2 = 31° W + 0.0773° = 31.0773° W

N 40	19 33
35	19 18
30	19 05
20	18 43
N 10	18 24
0	18 07

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

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

$$\frac{x}{19\,minutes} = \frac{6.0624°}{10°}$$

$$\frac{x}{19\,minutes} = 0.6062$$

$$x = (19)(0.6062)$$

$$x = 11.5 \text{ minutes (later)}$$

Latitude corrected time = 1824 (base) + 11.5 minutes = <u>1835.5</u>

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**

Problem 9-8 (CG 2012 database). The following example is taken directly from the 2012 USCG test bank (which has been since superseded and this type of problem removed) and illustrates the process of solving a time of phenomenon problem using a second estimate of DR position.

It is 19 October and you are keeping (+4) zone time. You are on course 275° T, speed 16 knots. Your 0800 DR position is latitude 25° 34.0' N, longitude 74° 36.0' W. What is the second estimate of the time of LAN by ship's clocks?

Answer: 12:49:06 zone time. This problem is similar to any other moving ship problem, however, *two* sets of calculations are required to refine the position to the required accuracy of a second estimate.

Step 1: Locate the tabular values in the Nautical Almanac.
The time of meridian passage for 19 October is 1145.

Step 2: Perform preliminary calculations.

Day	SUN Eqn. of Time 00ʰ	12ʰ	Mer. Pass.
	m s	m s	h m
19	14 56	15 01	11 45
20	15 07	15 12	11 45
21	15 17	15 22	11 45

0800 DR to 1145 = 3 hours, 45 minutes
3 hours, 45 minutes = 3.75 hours
3.75 hours at 16 knots = 60 nautical miles covered

The problem states that (+4) zone time is being observed, which has a standard meridian of 60° W.

Step 3: Determine the ship's DR position at 1145, based on steaming 275° T for 60 miles by mid-latitude sailing or using a chart/plotting sheet.

$l = D \ \cos C$
$l = (60) \ \cos 275°$
$l = (60)\ (0.0872)$
$l = 5.232'$

Latitude 1 = 25° 34.0' N = 25.566°
l = 5.232' = 0.0872° (to the north)
Latitude 2 = 25.566° + 0.0872° = 25.653° N = <u>25° 39.2' N</u>
$Lm = \frac{25.583° + 25.653°}{2}$ = 25.618° N

$p = D \ \sin C$
$p = (60) \ \sin 275°$
$p = (60)\ (-0.9962)$
$p = -59.772'$

$DLo = \frac{p}{\cos Lm}$

$DLo = \frac{-59.772}{\cos(25.618)}$
$DLo = \frac{-59.772}{0.9017}$
$DLo = -66.288'$

Longitude 1 = 74° 36.0’ W = 74.6° W
DLo = -66.288′= 1.1048° (to the west)
Latitude 2 = 74.6° W + 1.1048° = 75.705° = 75° 42.3’ W

Step 4: Determine the longitude difference for time of LAN.

1145 DR position:
25° 39.2’ N
75° 42.3’ W

Standard meridian in use = 60° W (given in problem)
75° 42.3’ W – 60° = 15° 42.3’ difference from standard meridian

Step 5: Convert the difference in longitude arc to time (use the Conversion of Arc to Time in the Nautical Almanac, which is re-created in it’s entirety at the end of this part).

15° 42.3’ of arc to the west = 1 hour, 2 minutes 49 seconds (added).

Step 6: Apply the longitude correction to the standard meridian transit time to determine time of local apparent noon.

11:45:00 + 01:02:49 = 12:47:49 first estimate

Second Estimate Steps:

Step 7: Perform preliminary calculations.

0800 DR to 12:47:49 = 4 hours, 47 minutes, 49 seconds
4 hours, 47 minutes, 49 seconds = 4.83 hours
4.83 hours at 16 knots = 77.3 nautical miles covered

The problem states that (+4) zone time is being observed, which has a standard meridian of 60° W.

Step 8: Determine the ship’s DR position at 1247, based on steaming 275° T for 77.3 miles by mid-latitude sailing or using a chart/plotting sheet.

$l = D \cos C$
$l = (77.3) \cos 275°$
$l = (77.3)\ (0.0872)$

$l = 6.741'$

Latitude 1 = 25° 34.0' N = 25.566°
l = 6.741 = 0.112° (to the north)
Latitude 2 = 25.566° + 0.112° = 25.678° N = 25° 40.7 N
$Lm = \frac{25.583° + 25.678°}{2} = 25.631°$ N

$p = D \ \sin C$
$p = (77.3) \ \sin 275°$
$p = (77.3)\ (-0.9962)$
$p = -77.006'$

$DLo = \frac{p}{\cos Lm}$
$DLo = \frac{-77.006}{\cos(25.631)}$
$DLo = \frac{-77.006}{0.9016}$
$DLo = -85.410'$

Longitude 1 = 74° 36.0' W = 74.6° W
DLo = -85.410′= 1.424° (to the west)
Latitude 2 = 74.6° W + 1.424° = 76.024° = 75° 01.4 W

Step 9: Determine the longitude difference for time of LAN.

1247 DR position:
25° 40.7 N
75° 01.4 W

Standard meridian in use = 60° W (given in problem)
76° 01.4 W – 60° = 16° 01.4' difference from standard meridian

Step 10: Convert the difference in longitude arc to time (use the Conversion of Arc to Time in the Nautical Almanac, which is re-created in it's entirety at the end of this part).

16° 01.4' of arc to the west = 1 hour, 4 minutes 06 seconds (added).

Step 11: Apply the longitude correction to the standard meridian transit time to determine time of local apparent noon.

11:45:00 + 01:04:06 = **12:49:06 second estimate**

Additional Problems and Answers

All of the following questions labeled "CG" were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem 9-X1. 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*

Problem 9-X2. 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*

Problem 9-X3. 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*

Problem 9-X4. It is 11 October and you are keeping zone time (+4). You are stationary in position latitude 42° 30.0' N, longitude 70° 00.0' W. What is the zone time of moonrise at your position?

- *a) 1606*
- *b) 1614*
- *c) 1621- correct*

Problem 9-X5. It is 22 July and you are keeping zone time (+9). You are stationary in position latitude 33° 12.5' N, longitude 139° 55.2' W. What is the zone time of moonset at your position?

- a) 1013
- b) 1038- correct

c) 1117

Problem CG-36. 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

Problem CG-39. 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

Problem CG-210. 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

Problem CG-291. On 17 May, your 0300 zone time DR position is latitude 27° 21.0' N, longitude 066° 48.0' 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

Problem CG-441. 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

Problem CG-256. 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*

Problem CG-68. 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*

Problem CG-74. 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*

Problem CG-162. 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*

Problem CG-300. 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*

Problem CG-191. 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*

Problem CG-193. 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*

Problem CG-234. 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*

Problem CG-260. On 16 January, your 0930 zone time DR position is latitude 26° 07.0' S, longitude 54° 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*

Problem CG-472. 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*

Problem 9-6X. It is 22 October and you are keeping zone time (+4). You are on course 083° T at a speed of 24 knots. Your 0820 DR position is latitude 26° 10.0' N, longitude 52° 20.0' W. What is the time of the second estimate of LAN by ship's clocks?

a) *10h 04m 36s*
b) *10h 04m 53s*
c) *11h 04m 37s*
d) *11h 08m 54s- correct*

Problem 9-7X. It is 25 February and you are keeping zone time (+4). You are on course 283° T at a speed of 22 knots. Your 0900 DR position is latitude 29° 10.3' N, longitude 72° 04.9' W. What is the time of the second estimate of LAN by ship's clocks?

a) *13h 08m 56s*
b) *13h 08m 02s- correct*
c) *12h 41m 36s*
d) *12h 08m 56s*

TABLES FOR INTERPOLATING SUNRISE, MOONRISE, ETC.

TABLE I—FOR LATITUDE

Tabular Interval 10°	5°	2°	Difference between the times for consecutive latitudes 5m	10m	15m	20m	25m	30m	35m	40m	45m	50m	55m	60m	1h 05m	1h 10m	1h 15m	1h 20m
° ′	° ′	° ′	m	m	m	m	m	m	m	m	m	m	m	m	h m	h 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	0 02	0 02
1 00	**0 30**	**0 12**	0	1	1	2	2	3	3	3	4	4	4	5	05	05	05	05
1 30	**0 45**	**0 18**	1	1	2	3	3	4	4	5	5	6	7	7	07	07	07	07
2 00	**1 00**	**0 24**	1	2	3	4	5	5	6	7	7	8	9	10	10	10	10	10
2 30	**1 15**	**0 30**	1	2	4	5	6	7	8	9	9	10	11	12	12	13	13	13
3 00	**1 30**	**0 36**	1	3	4	6	7	8	9	10	11	12	13	14	0 15	0 15	0 16	0 16
3 30	**1 45**	**0 42**	2	3	5	7	8	10	11	12	13	14	16	17	18	18	19	19
4 00	**2 00**	**0 48**	2	4	6	8	9	11	13	14	15	16	18	19	20	21	22	22
4 30	**2 15**	**0 54**	2	4	7	9	11	13	15	16	18	19	21	22	23	24	25	26
5 00	**2 30**	**1 00**	2	5	7	10	12	14	16	18	20	22	23	25	26	27	28	29
5 30	**2 45**	**1 06**	3	5	8	11	13	16	18	20	22	24	26	28	0 29	0 30	0 31	0 32
6 00	**3 00**	**1 12**	3	6	9	12	14	17	20	22	24	26	29	31	32	33	34	36
6 30	**3 15**	**1 18**	3	6	10	13	16	19	22	24	26	29	31	34	36	37	38	40
7 00	**3 30**	**1 24**	3	7	10	14	17	20	23	26	29	31	34	37	39	41	42	44
7 30	**3 45**	**1 30**	4	7	11	15	18	22	25	28	31	34	37	40	43	44	46	48
8 00	**4 00**	**1 36**	4	8	12	16	20	23	27	30	34	37	41	44	0 47	0 48	0 51	0 53
8 30	**4 15**	**1 42**	4	8	13	17	21	25	29	33	36	40	44	48	0 51	0 53	0 56	0 58
9 00	**4 30**	**1 48**	4	9	13	18	22	27	31	35	39	43	47	52	0 55	0 58	1 01	1 04
9 30	**4 45**	**1 54**	5	9	14	19	24	28	33	38	42	47	51	56	1 00	1 04	1 08	1 12
10 00	**5 00**	**2 00**	5	10	15	20	25	30	35	40	45	50	55	60	1 05	1 10	1 15	1 20

Table I is for interpolating the L.M.T. of sunrise, twilight, moonrise, etc., for latitude. It is to be entered, in the appropriate column on the left, with the difference between true latitude and the nearest tabular latitude which is *less* than the true latitude; and with the argument at the top which is the nearest value of the difference between the times for the tabular latitude and the next higher one; the correction so obtained is applied to the time for the tabular latitude; the sign of the correction can be seen by inspection. It is to be noted that the interpolation is not linear, so that when using this table it is essential to take out the tabular phenomenon for the latitude *less* than the true latitude.

TABLE II—FOR LONGITUDE

Long. East or West	Difference between the times for given date and preceding date (for east longitude) or for given date and following date (for west longitude) 10m	20m	30m	40m	50m	60m	1h + 10m	1h + 20m	1h + 30m	1h + 40m	1h + 50m	1h + 60m	2h 10m	2h 20m	2h 30m	2h 40m	2h 50m	3h 00m
°	m	m	m	m	m	m	m	m	m	m	m	m	h m	h m	h m	h m	h m	h m
0	0	0	0	0	0	0	0	0	0	0	0	0	0 00	0 00	0 00	0 00	0 00	0 00
10	0	1	1	1	1	2	2	2	2	3	3	3	04	04	04	04	05	05
20	1	1	2	2	3	3	4	4	5	6	6	7	07	08	08	09	09	10
30	1	2	2	3	4	5	6	7	7	8	9	10	11	12	12	13	14	15
40	1	2	3	4	6	7	8	9	10	11	12	13	14	16	17	18	19	20
50	1	3	4	6	7	8	10	11	12	14	15	17	0 18	0 19	0 21	0 22	0 24	0 25
60	2	3	5	7	8	10	12	13	15	17	18	20	22	23	25	27	28	30
70	2	4	6	8	10	12	14	16	17	19	21	23	25	27	29	31	33	35
80	2	4	7	9	11	13	16	18	20	22	24	27	29	31	33	36	38	40
90	2	5	7	10	12	15	17	20	22	25	27	30	32	35	37	40	42	45
100	3	6	8	11	14	17	19	22	25	28	31	33	0 36	0 39	0 42	0 44	0 47	0 50
110	3	6	9	12	15	18	21	24	27	31	34	37	40	43	46	49	0 52	0 55
120	3	7	10	13	17	20	23	27	30	33	37	40	43	47	50	53	0 57	1 00
130	4	7	11	14	18	22	25	29	32	36	40	43	47	51	54	0 58	1 01	1 05
140	4	8	12	16	19	23	27	31	35	39	43	47	51	54	0 58	1 02	1 06	1 10
150	4	8	13	17	21	25	29	33	38	42	46	50	0 54	0 58	1 03	1 07	1 11	1 15
160	4	9	13	18	22	27	31	36	40	44	49	53	0 58	1 02	1 07	1 11	1 16	1 20
170	5	9	14	19	24	28	33	38	42	47	52	57	1 01	1 06	1 11	1 16	1 20	1 25
180	5	10	15	20	25	30	35	40	45	50	55	60	1 05	1 10	1 15	1 20	1 25	1 30

Table II is for interpolating the L.M.T. of moonrise, moonset and the Moon's meridian passage for longitude. It is entered with longitude and with the difference between the times for the given date and for the preceding date (in east longitudes) or following date (in west longitudes). The correction is normally *added* for west longitudes and *subtracted* for east longitudes, but if, as occasionally happens, the times become earlier each day instead of later, the signs of the corrections must be reversed.

CONVERSION OF ARC TO TIME

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

The above table is for converting expressions in arc to their equivalent in time ; its main use in this Almanac is for the conversion of longitude for application to L.M.T. (*added* if *west*, *subtracted* if *east*) to give G.M.T. or vice versa, particularly in the case of sunrise, sunset, etc.

Part Ten: 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.

Abbreviated Concepts - For more detailed definitions, refer to the Bowditch glossary. These definitions are provided as simplified concepts only, to enable successful completion of required problems.

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° S.

Horizon – There are several different version 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 additional tables.

Basic Amplitude Problems

Problem 10-1. The following question illustrates how to solve basic amplitude problems involving the sun on the celestial horizon.

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.	SUN 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 in Bowditch with declination and latitude to determine the amplitude.
Declination: 20°
Latitude: 36°

TABLE 22
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. 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.**

Problem 10-2. The following question illustrates how to solve basic amplitude problems involving the sun on the visible horizon (using the Table 23 correction).

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° T, what is the gyro error?

Answers:

a) E 22.4° N

b) 112.4° T

c) 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 in Bowditch with declination and latitude to determine a correction due to the object's location on the visible horizon.

The correction is 1.0° (interpolated between the tabular values for 12° and 13° declination).

TABLE 23

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
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

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

TABLE 22

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
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

Step 5: Answer required questions.

a) Due to the object being on the visible horizon, the amplitude must be corrected.
   a. Amplitude from Table 22 = 21.4°
   b. Correction from Table 23 = 1.0°
   c. The correction must be applied *away from the elevated pole.* In other words, in the northern hemisphere, the correction should be added to sunrise values and subtracted from sunset values (in the southern hemisphere, the correction should be subtracted from sunrise values and added to sunset values).
   d. In this case, the sun is rising in the northern hemisphere. The correction is therefore 21.4° + 1.0° = **E 22.4° N**

b) Standard sunrise is 090° T. In the northern hemisphere in spring and summer, the sun rises north of east. Therefore the calculated sunrise is 090° - 22.4° = **67.6° T**

c) If the sun is observed rising at 065° T, while the calculated sunrise is 67.6° T, the gyro error is 67.6° - 65° = 2.6°. 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.**

<u>Problem 10-3.</u> The following question illustrates how to solve basic amplitude problems involving the sun.

It is 9 July. You have taken an observation of the setting 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 2100 UTC. Your latitude is 33° 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 setting at 300° T, what is the gyro error?

Answers:
a) W 27° N
b) 297° T
c) 3° W

Step 1: Determine the declination of the sun for the time of observation using the Nautical Almanac.
The declination at 2100 UTC is N 22° 17.5'.

G.M.T.	SUN G.H.A.	SUN Dec.
18	88 42.4	N22 18.4
19	103 42.3	18.1
20	118 42.2	17.8
21	133 42.2	· · 17.5
22	148 42.1	17.2
23	163 42.0	16.8

Step 2: Determine the ship's latitude at the time of observation.
Latitude – 33° N (given)

Step 3: Enter Table 22 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: 22° 17.5' = 22.3°
Latitude: 33°

TABLE 22
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

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

26. 2	26. 8
26. 9	27. 5

	Declination 22.0°	**Declination 22.3°**	Declination 22.5°
Latitude 32°	26.2°		26.8°
Latitude 33°		**Unknown value**	
Latitude 34°	26.9°		27.5°

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

	Declination 22.0°	Declination 22.3°	Declination 22.5°
Latitude 32°	26.2°	**26.6°**	26.8°
Latitude 33°	**26.6°**	Unknown value	**27.2°**
Latitude 34°	26.9°	**27.3°**	27.5°

c) Solve the interpolation for the desired value.

	Declination 22.0°	Declination 22.3°	Declination 22.5°
Latitude 32°	26.2°	26.6°	26.8°
Latitude 33°	26.6°	**27.0°**	27.2°
Latitude 34°	26.9°	27.3°	27.5°

Step 4: Answer required questions.

a) **Amplitude = W 27° N**
b) Standard sunset is 270° T. In the northern hemisphere in spring and summer, the sun sets north of west. Therefore the calculated sunrise is 270° + 27° = **297° T**
c) If the sun is observed setting at 300° T, while the calculated sunset is 297° T, the gyro error is 300° - 297° = 3.0°. 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.**

Problem 10-4. The following question illustrates how to solve basic amplitude problems involving the sun.

It is 22 February. You have taken an observation of the setting sun while it is on the celestial horizon. The time of observation is 2000 UTC. Your latitude is 30° N.

a) What is the amplitude of the sun?
b) What true bearing should the sunset be observed?
c) If you actually observe the sun setting at 260° T, what is the gyro error?

Answers:
a) W 11.6° S
b) 258.4° T
c) 1.6° W

Step 1: Determine the declination of the sun for the time of observation using the Nautical Almanac.
The declination at 2000 UTC is S 10° 00'.

G.M.T.	SUN G.H.A.	SUN Dec.
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 ship's latitude at the time of observation.
Latitude – 30° N (given)

Step 3: Enter Table 22 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: 10°
Latitude: 33°

TABLE 22
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

Step 4: Answer required questions.

a) **Amplitude = W 11.6° S**

b) Standard sunset is 270° T. In the northern hemisphere in fall and winter, the sun sets south of west. Therefore the calculated sunrise is 270° - 11.6° = **258.4° T**

c) If the sun is observed setting at 260° T, while the calculated sunset is 258.4° T, the gyro error is 360° - 258.4° = 1.6°. 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 **1.6° W.**

<u>Problem 10-5</u>. The following question illustrates how to solve basic amplitude problems involving the sun.

It is 23 February. You have taken an observation of the setting sun when the sun is on the celestial horizon. The time of observation is 1946 UTC. Your latitude is 33° 13.2' 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 setting at 300° T, what is the gyro error?

Answers:
a) W 11.5° S
b) 258.5° T
c) 0.5° E

Step 1: Determine the declination of the sun for the time of observation using the Nautical Almanac.

The declination at 1946 is not given in the Nautical Almanac and must be interpolated.

G.M.T.	SUN G.H.A.	SUN Dec.
18	86 39.6	S 9 39.8
19	101 39.7	38.9
20	116 39.8	37.9
21	131 39.9	· · 37.0
22	146 40.0	36.1
23	161 40.1	35.2
	S.D. 16.2	*d* 0.9

The base value for 1900 is S 9° 38.9' and decreasing.
The *d* value for 23 February is 0.9.

Enter the Increments and Corrections Page in the Nautical Almanac with the daily *d* value and a time of 46 minutes (the difference between the base declination and the observation time).

46m INCREMENTS AND CORRECTIONS **47m**

46m s	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corrn ′	v or d ′	Corrn ′	v or d ′	Corrn ′
00	11 30·0	11 31·9	10 58·6	0·0	0·0	6·0	4·7	12·0	9·3
01	11 30·3	11 32·1	10 58·8	0·1	0·1	6·1	4·7	12·1	9·4
02	11 30·5	11 32·4	10 59·0	0·2	0·2	6·2	4·8	12·2	9·5
03	11 30·8	11 32·6	10 59·3	0·3	0·2	6·3	4·9	12·3	9·5
04	11 31·0	11 32·9	10 59·5	0·4	0·3	6·4	5·0	12·4	9·6
05	11 31·3	11 33·1	10 59·8	0·5	0·4	6·5	5·0	12·5	9·7
06	11 31·5	11 33·4	11 00·0	0·6	0·5	6·6	5·1	12·6	9·8
07	11 31·8	11 33·6	11 00·2	0·7	0·5	6·7	5·2	12·7	9·8
08	11 32·0	11 33·9	11 00·5	0·8	0·6	6·8	5·3	12·8	9·9
09	11 32·3	11 34·1	11 00·7	0·9	0·7	6·9	5·3	12·9	10·0

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

Given a *d* value of 0.9, the declination correction factor is 0.7.

Since the declination is decreasing from hour to hour, the corrected declination for 23 February at 1946 is S 9° 38.9’ – 0.7’ = S 9° 38.2’.

Step 2: Determine the ship’s latitude at the time of observation.
Latitude – 33° 13.2’ N (given)

Step 3: Enter Table 22 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: S 9° 38.2’ = S 9.6°
Latitude: 33° 13.2’ = 33.2° N

TABLE 22
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.

11. 2	11. 8
11. 5	12. 1

	Declination 9.5°	**Declination 9.6°**	Declination 10°
Latitude 32°	11.2°		11.8°
Latitude 33.2°		**Unknown value**	
Latitude 34°	11.5°		12.1°

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

	Declination 9.5°	Declination 9.6°	Declination 10°
Latitude 32°	11.2°	**11.3°**	11.8°
Latitude 33.2°	**11.4°**	**Unknown value**	**12.0°**
Latitude 34°	11.5°	**11.6°**	12.1°

c) Solve the interpolation for the desired value.

	Declination 9.5°	Declination 9.6°	Declination 10°
Latitude 32°	11.2°	11.3°	11.8°
Latitude 33.2°	11.4°	**11.5°**	12.0°
Latitude 34°	11.5°	11.6°	12.1°

Step 4: Answer required questions.

a) **Amplitude = W 11.5° S**

b) Standard sunset is 270° T. In the northern hemisphere in autumn and winter, the sun sets south of west. Therefore the calculated sunrise is 270° - 11.5° = **258.5° T**

c) If the sun is observed setting at 258° T, while the calculated sunset is 258.5° T, the gyro error is 258.5° - 258° = 0.5°. 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 **0.5° E.**

Advanced Amplitude Problems

<u>Problem 10-6 (CG-400)</u>. The following problem is taken directly from the USCG test bank and illustrates how to solve advanced amplitude problems when the Sun is on the celestial horizon.

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 05:53, 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.

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

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.

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).

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

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’= N 11° 16.2’

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

Step 4: Enter Table 22 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: N 11° 16.2’ = N 10.3°
Latitude: 26° 49.4’ N = 26.8° N

TABLE 22
Amplitudes

Latitude	Declination 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	Latitude
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
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.

12.2	12.7
12.7	13.3

	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 explanation.*

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

-or –

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

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, 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

<u>Problem 10-7 (CG-183)</u>. The following problem is taken directly from the USCG test bank and illustrates how to solve advanced amplitude problems when the Sun is on the visible horizon (requiring a table 23 adjustment).

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.

58m s	SUN PLANETS ° '	ARIES ° '	MOON ° '	v or d '	Corrⁿ '	v or d '	Corrⁿ '	v or d '	Corrⁿ '
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

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).

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'= <u>N 17° 53.1'</u>

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 in Bowditch to obtain the Visible Horizon Correction.

TABLE 23
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. 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 Correction: + 0.6°
Total : 089° + 0.6° = 089.6° psc

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

TABLE 22
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 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 explanation.*

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

-or –

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

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 corrected for visible horizon using Table 23)

Deviation = 2.3° W

Problem 10-8 (CG-66). The following problem is taken directly from the USCG test bank and illustrates how to solve advanced amplitude problems when the Moon is on the visible horizon (requiring a table 23 adjustment).

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.

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.

v or d	Corr^n	v or d	Corr^n
′	′	′	′
0·0	0·0	6·0	2·5
0·1	0·0	6·1	2·5
0·2	0·1	6·2	2·5
0·3	0·1	6·3	2·6
0·4	0·2	6·4	2·6
0·5	0·2	6·5	2·7
0·6	0·2	6·6	2·7
0·7	0·3	6·7	2·7
0·8	0·3	6·8	2·8
0·9	0·4	6·9	2·8
1·0	0·4	7·0	2·9
1·1	0·4	7·1	2·9
1·2	0·5	7·2	2·9
1·3	0·5	7·3	3·0
1·4	0·6	7·4	3·0
1·5	0·6	7·5	3·1
1·6	0·7	7·6	3·1
1·7	0·7	7·7	3·1
1·8	0·7	7·8	3·2
1·9	0·8	7·9	3·2
2·0	0·8	8·0	3·3
2·1	0·9	8·1	3·3
2·2	0·9	8·2	3·3
2·3	0·9	8·3	3·4
2·4	1·0	8·4	3·4
2·5	1·0	8·5	3·5
2·6	1·1	8·6	3·5
2·7	1·1	8·7	3·6
2·8	1·1	8·8	3·6
2·9	1·2	8·9	3·6

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

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

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 8.4.

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 8.4 the declination correction is 3.4’.

Since the declination is increasing from hour to hour, the corrected declination for 14 June at 1724 is S 13° 22.6’ + 3.4’= S 13° 26.0’

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 in Bowditch to obtain the Visible Horizon Correction for the Moon.

TABLE 23
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>

Step 5: Enter Table 22 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

TABLE 22
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.

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 –

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

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

Problem 10-9 (CG-79). The following problem is taken directly from the USCG test bank and illustrates how to solve advanced amplitude problems when a planet is on the celestial horizon.

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.	22 26.5 (h m)	*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.

43m 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

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

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

b) 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°

c) 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 –

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

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 planetset 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°

Additional Problems and Answers

All of the following questions labeled "CG" were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the prefix).

Problem 10-X1. Using Table 22 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 – 080T, Sunset – 280T.

Problem 10-X2. Using Table 22 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 – 093T, Sunset 267T.

Problem 10-X3. Using Table 22 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 – 070T, Sunset - 290T.

Problem 10-X4. Your latitude is 10N. The declination of the sun is 12 degrees. What is the amplitude of the sun?

Answer: 12.2 degrees.

Problem CG-164. On 10 August you 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 standards 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*

Problem CG-166. 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

Problem CG-179. On 11 January, you 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

Problem CG-278. On 17 April you 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

Problem CG-171. 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

Problem CG-252. 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

Problem CG-503. 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*

Problem CG-329. 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*

Problem CG-64. 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*

Problem CG-57. 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*

Problem CG-58. 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

Problem CG-34. 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

Problem CG-65. 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

Problem CG-67. At 1538 ZT on 15 October, in DR position latitude 18° 12.8’ S, longitude 160° 48.4’ E, you observe an amplitude of the Moon. The center of the Moon is on the visible horizon and bears 276.2° psc. Variation is 10° E. What is the deviation?

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

Problem CG-80. 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

Problem CG-83. 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*

Problem CG-84. 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*

Problem CG-85. 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*

Part Eleven: Meridian Passage and Ex-Meridian Problems

Observations of bodies at meridian passage, or even ex-meridian sights, enable rapid computation of a line of position for latitude. These LOPs can be advanced or retarded to form fixes with other LOPs. All celestial bodies can be observed at meridian passage, and in some circumstances, bodies can be observed at both upper and lower transit.

Basic 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.

Problem 11-1 (CG-346). The following question is taken directly from the USCG test bank and illustrates how to solve basic meridian passage (local apparent noon) problems without advancing DR positions.

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?

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

Answer: 26° 31.4' S.

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 = 1447 GMT.

Step 2: Determine the declination of the sun for the GMT time of sight.

D CORRECTIONS 47m

47m	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° '	° '	° '	'	'	'	'	'	'
00	11 45·0	11 46·9	11 12·9	0·0	0·0	6·0	4·8	12·0	9·5
01	11 45·3	11 47·2	11 13·1	0·1	0·1	6·1	4·8	12·1	9·6
02	11 45·5	11 47·4	11 13·4	0·2	0·2	6·2	4·9	12·2	9·7
03	11 45·8	11 47·7	11 13·6	0·3	0·2	6·3	5·0	12·3	9·7
04	11 46·0	11 47·9	11 13·8	0·4	0·3	6·4	5·1	12·4	9·8
05	11 46·3	11 48·2	11 14·1	0·5	0·4	6·5	5·1	12·5	9·9
06	11 46·5	11 48·4	11 14·3	0·6	0·5	6·6	5·2	12·6	10·0
07	11 46·8	11 48·7	11 14·6	0·7	0·6	6·7	5·3	12·7	10·1
08	11 47·0	11 48·9	11 14·8	0·8	0·6	6·8	5·4	12·8	10·1
09	11 47·3	11 49·2	11 15·0	0·9	0·7	6·9	5·5	12·9	10·2

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' = S 10° 04.7'

Step 3: Determine the observed altitude of the body.
No corrections are required in this problem, since the (ho) is given as 73° 33.3’

Step 4: Determine the zenith distance of the sight.
ZD = 90° - observed altitude.
ZD = 90° - 73° 33.3’ = 16° 26.7’

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 = 16° 26.7’ + 10° 04.7’ = **26° 31.4’ S**

Problem 11-2 (CG-273). The following question is taken directly from the USCG test bank and illustrates how to solve basic meridian passage (local apparent noon) problems without advancing DR positions.

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.

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.

G.M.T.	SUN G.H.A.	SUN Dec.
d h	° '	° '
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 2: Determine the declination of the sun for the GMT time of sight.

D CORRECTIONS 27ᵐ

27ᵐ	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ	v or d	Corrⁿ	v or d	Corrⁿ
s	° '	° '	° '	'	'	'	'	'	'
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

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**

Problem 11-3 (CG-520). The following question is taken directly from the USCG test bank and illustrates how to solve basic meridian passage (local apparent noon) problems without advancing DR positions.

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

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.

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

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'

	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 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**

Meridian Passage Problems Involving Advanced/Retarded Lines of Position

Problem 11-4 (CG-216). The following question is taken directly from the USCG test bank and illustrates how to solve meridian passage problems involving an advanced or retarded line of position.

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. Note this problem asks for latitude at 1200 ZT, not LAN, requiring the LAN line of position to be advanced to 1200.

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.

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

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'

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 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

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.

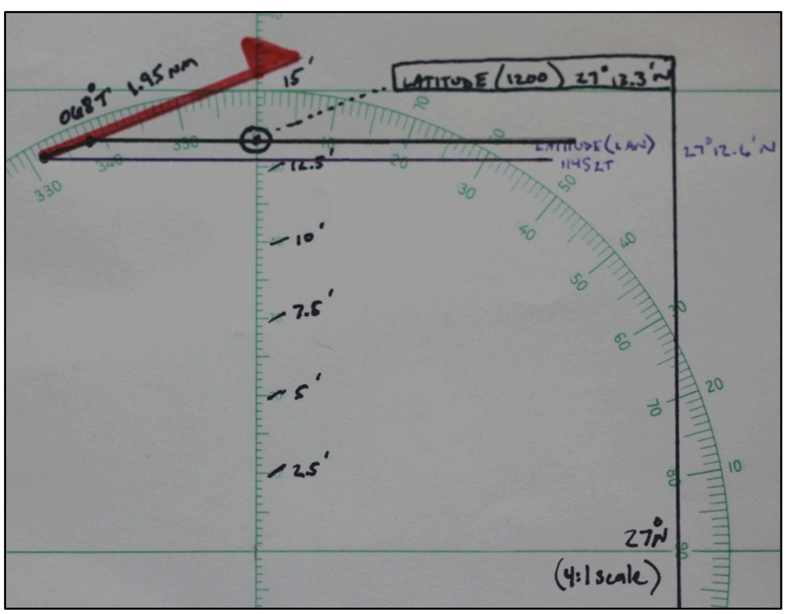
a. Method 1: Math. For more examples, see Part 5: Great Circle and Sailings Problems.

   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.
   $l = D \cos C$
   $l = 1.95 \cos(68°)$
   $l = (1.95)(0.3746)$
   $l = 0.73'$

   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. For more examples, see Part 16: Celestial Fix and Running Fix Problems.



Ex-Meridian Problems

Problem 11-5 (CG-236). The following question is taken directly from the USCG test bank and illustrates how to solve solar ex-meridian problems.

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

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 <u>01:29:52</u> (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 difference from meridian passage (LHA = 360°): 360 – 356° 22.4' = 3° 37.6'
LHA difference converted to time: 3° 37.6' = <u>14m 30s</u>

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

28ᵐ INCREMENTS AND CORRECTIONS 29ᵐ

28ᵐ s	SUN PLANETS ° '	ARIES ° '	MOON ° '	v or d '	Corrⁿ '	v or d '	Corrⁿ '	v or d '	Corrⁿ '
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 s	SUN PLANETS ° '	ARIES ° '	MOON ° '	v or d '	Corrⁿ '	v or d '	Corrⁿ '	v or d '	Corrⁿ '
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).

DIP		
Ht. of Eye	Corrn	Ht. of Eye
	−6.8	
15.1		49.8
	6.9	
15.5		51.3
	7.0	
16.0		52.8
	7.1	
16.5		54.3

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'

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 5: Note the DR latitude: 26° 24.0' S

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 table 24 in Bowditch to determine the altitude factor (a).

TABLE 24
Altitude Factor

a, the change of altitude in one minute from meridian transit.

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°	Latitude
°	"	"	"	"	"	"	"	"	"	"	"	"	"	°
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

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

Step 8: Enter table 25 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 = <u>9.0</u>

TABLE 25

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

Step 9: Apply the table 25 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’ = <u>49° 00.4’</u>

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**

<u>Problem 11-6 (CG-264).</u> The following question is taken directly from the USCG test bank and illustrates how to solve solar ex-meridian problems.

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 table 25 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

Step 2: 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.

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		

Step 3: 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’

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

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’

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

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

Step 4: 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 5: Note the DR latitude: 50° 57.0’ S

Step 6: Determine the declination of the body for the time of sight.
Declination (total): S 63° 00.0’

Step 7: Enter table 24 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.

No interpolation is necessary in this case. a = 0.6

TABLE 24
Altitude Factor

a, the change of altitude in one minute from meridian transit.

Latitude	51°	52°	53°	54°	55°	56°	57°	58°	59°	60°	61°	62°	63°	Latitude
	Declination **contrary** name to latitude, **upper** transit: **add** correction to observed altitude													

60°	61°	62°	63°	Latitude
				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

TABLE 25
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

Step 8: Enter table 25 in Bowditch to determine the altitude change correction.

Bracketing values:

	t = 13m 20s	t = 13m 22s	t = 13m 40s
a = .6	1.8	**Correction**	1.9

Interpolated value = 1.8’

Step 9: Apply the table 25 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 10: 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**

Additional Problems and Answers

All of the following questions labeled "CG" were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-520. 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*

Problem CG-445. 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*

Problem CG-346. 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*

Problem CG-273. 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

Problem CG-190. On 12 February your 0542 zone time (ZT) fix gives you a position of latitude 26° 42.0' N, longitude 60° 18.0' W. Your vessel is on course 300° T and your speed is 9.8 knots. Local apparent noon (LAN) occurs at 1220 ZT, at which time a meridian altitude of the Sun's lower limb is observed. The observed altitude (Ho) for this sight is 49° 10.0'. What is the calculated latitude at LAN?

a) 27° 13.5' N
b) 27° 16.3' N- correct
c) 27° 17.6' N
d) 27° 19.2' N

Problem CG-216. 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

Problem CG-444. 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

Problem CG-519. 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

Problem CG-172. On 10 March in DR position latitude 21° 42.0' S, longitude 57° 28.0' E, you take an ex-meridian observation of the Sun's lower limb. The chronometer time of the sight is 08h 28m 17s, and the chronometer error is 00m 00s. The sextant altitude (hs) is 72° 08.0'. The index error is 3.4' on the arc, and your height of eye is 52.7 feet. What is the latitude at meridian transit?

a) 21° 32.5' S
b) 21° 40.6' S
c) 21° 45.5' S- correct
d) 21° 50.2' S

Problem CG-236. 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.

a) 26° 32.6' S
b) 26° 51.6' S- correct
c) 26° 57.0' S
d) 27° 09.9' S

Problem CG-239. 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

Problem CG-439. 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*

Problem CG-295. 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*

Problem CG-264. 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*

Problem CG-343. 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*

Problem CG-461. On 29 October in DR position latitude 41° 12.0' N, longitude 50° 18.9' W, you take an ex-meridian observation of the Sun's lower limb, near upper transit. The chronometer time of the sight is 03h 21m 12s, and the chronometer error is 01m 50s slow. The sextant altitude (hs) is 34° 54.2'. The index error is 2.0' on the arc and your height of eye is 45 feet. What is the latitude at meridian transit?

a) *41° 12.0' N*
b) *41° 16.0' N- correct*
c) *41° 20.2' N*
d) *41° 23.6' N*

Problem CG-473. On 30 August in DR position latitude 26° 34.0' N, longitude 141° 36.0' W, you take an ex-meridian observation of the Sun's lower limb. The chronometer time of the sight is 09h 15m 26s and the chronometer error is 00m 00s. The sextant altitude (hs) is 71° 41.7'. The index error is 3.2' off the arc and your height of eye is 49.6 feet. What is the latitude at meridian transit?

a) *26° 41.9' N- correct*
b) *26° 44.6' N*
c) *26° 48.2' N*
d) *26° 52.3' N*

A2 ALTITUDE CORRECTION TABLES 10°-90°—SUN, STARS, PLANETS

SUN

OCT.—MAR. App. Alt.	Lower Limb	Upper Limb	APR.—SEPT. App. Alt.	Lower Limb	Upper Limb
° ′	′	′	° ′	′	′
9 34	+10.8	−21.5	9 39	+10.6	−21.2
9 45	+10.9	−21.4	9 51	+10.7	−21.1
9 56	+11.0	−21.3	10 03	+10.8	−21.0
10 08	+11.1	−21.2	10 15	+10.9	−20.9
10 21	+11.2	−21.1	10 27	+11.0	−20.8
10 34	+11.3	−21.0	10 40	+11.1	−20.7
10 47	+11.4	−20.9	10 54	+11.2	−20.6
11 01	+11.5	−20.8	11 08	+11.3	−20.5
11 15	+11.6	−20.7	11 23	+11.4	−20.4
11 30	+11.7	−20.6	11 38	+11.5	−20.3
11 46	+11.8	−20.5	11 54	+11.6	−20.2
12 02	+11.9	−20.4	12 10	+11.7	−20.1
12 19	+12.0	−20.3	12 28	+11.8	−20.0
12 37	+12.1	−20.2	12 46	+11.9	−19.9
12 55	+12.2	−20.1	13 05	+12.0	−19.8
13 14	+12.3	−20.0	13 24	+12.1	−19.7
13 35	+12.4	−19.9	13 45	+12.2	−19.6
13 56	+12.5	−19.8	14 07	+12.3	−19.5
14 18	+12.6	−19.7	14 30	+12.4	−19.4
14 42	+12.7	−19.6	14 54	+12.5	−19.3
15 06	+12.8	−19.5	15 19	+12.6	−19.2
15 32	+12.9	−19.4	15 46	+12.7	−19.1
15 59	+13.0	−19.3	16 14	+12.8	−19.0
16 28	+13.1	−19.2	16 44	+12.9	−18.9
16 59	+13.2	−19.1	17 15	+13.0	−18.8
17 32	+13.3	−19.0	17 48	+13.1	−18.7
18 06	+13.4	−18.9	18 24	+13.2	−18.6
18 42	+13.5	−18.8	19 01	+13.3	−18.5
19 21	+13.6	−18.7	19 42	+13.4	−18.4
20 03	+13.7	−18.6	20 25	+13.5	−18.3
20 48	+13.8	−18.5	21 11	+13.6	−18.2
21 35	+13.9	−18.4	22 00	+13.7	−18.1
22 26	+14.0	−18.3	22 54	+13.8	−18.0
23 22	+14.1	−18.2	23 51	+13.9	−17.9
24 21	+14.2	−18.1	24 53	+14.0	−17.8
25 26	+14.3	−18.0	26 00	+14.1	−17.7
26 36	+14.4	−17.9	27 13	+14.2	−17.6
27 52	+14.5	−17.8	28 33	+14.3	−17.5
29 15	+14.6	−17.7	30 00	+14.4	−17.4
30 46	+14.7	−17.6	31 35	+14.5	−17.3
32 26	+14.8	−17.5	33 20	+14.6	−17.2
34 17	+14.9	−17.4	35 17	+14.7	−17.1
36 20	+15.0	−17.3	37 26	+14.8	−17.0
38 36	+15.1	−17.2	39 50	+14.9	−16.9
41 08	+15.2	−17.1	42 31	+15.0	−16.8
43 59	+15.3	−17.0	45 31	+15.1	−16.7
47 10	+15.4	−16.9	48 55	+15.2	−16.6
50 46	+15.5	−16.8	52 44	+15.3	−16.5
54 49	+15.6	−16.7	57 02	+15.4	−16.4
59 23	+15.7	−16.6	61 51	+15.5	−16.3
64 30	+15.8	−16.5	67 17	+15.6	−16.2
70 12	+15.9	−16.4	73 16	+15.7	−16.1
76 26	+16.0	−16.3	79 43	+15.8	−16.0
83 05	+16.1	−16.2	86 32	+15.9	−15.9
90 00			90 00		

STARS AND PLANETS

App. Alt.	Corrⁿ
° ′	′
9 56	−5.3
10 08	−5.2
10 20	−5.1
10 33	−5.0
10 46	−4.9
11 00	−4.8
11 14	−4.7
11 29	−4.6
11 45	−4.5
12 01	−4.4
12 18	−4.3
12 35	−4.2
12 54	−4.1
13 13	−4.0
13 33	−3.9
13 54	−3.8
14 16	−3.7
14 40	−3.6
15 04	−3.5
15 30	−3.4
15 57	−3.3
16 26	−3.2
16 56	−3.1
17 28	−3.0
18 02	−2.9
18 38	−2.8
19 17	−2.7
19 58	−2.6
20 42	−2.5
21 28	−2.4
22 19	−2.3
23 13	−2.2
24 11	−2.1
25 14	−2.0
26 22	−1.9
27 36	−1.8
28 56	−1.7
30 24	−1.6
32 00	−1.5
33 45	−1.4
35 40	−1.3
37 48	−1.2
40 08	−1.1
42 44	−1.0
45 36	−0.9
48 47	−0.8
52 18	−0.7
56 11	−0.6
60 28	−0.5
65 08	−0.4
70 11	−0.3
75 34	−0.2
81 13	−0.1
87 03	0.0
90 00	

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	+0.4′
41	+0.5
Dec. 27-Dec. 31	
0°	
6	+0.5′
20	+0.6
31	+0.7
MARS	
Jan. 1-Dec. 31	
0°	
60	+0.1′

DIP

Ht. of Eye (m)	Corrⁿ	Ht. of Eye (ft.)
2.4	−2.8′	8.0
2.6	−2.9	8.6
2.8	−3.0	9.2
3.0	−3.1	9.8
3.2	−3.2	10.5
3.4	−3.3	11.2
3.6	−3.4	11.9
3.8	−3.5	12.6
4.0	−3.6	13.3
4.3	−3.7	14.1
4.5	−3.8	14.9
4.7	−3.9	15.7
5.0	−4.0	16.5
5.2	−4.1	17.4
5.5	−4.2	18.3
5.8	−4.3	19.1
6.1	−4.4	20.1
6.3	−4.5	21.0
6.6	−4.6	22.0
6.9	−4.7	22.9
7.2	−4.8	23.9
7.5	−4.9	24.9
7.9	−5.0	26.0
8.2	−5.1	27.1
8.5	−5.2	28.1
8.8	−5.3	29.2
9.2	−5.4	30.4
9.5	−5.5	31.5
9.9	−5.6	32.7
10.3	−5.7	33.9
10.6	−5.8	35.1
11.0	−5.9	36.3
11.4	−6.0	37.6
11.8	−6.1	38.9
12.2	−6.2	40.1
12.6	−6.3	41.5
13.0	−6.4	42.8
13.4	−6.5	44.2
13.8	−6.6	45.5
14.2	−6.7	46.9
14.7	−6.8	48.4
15.1	−6.9	49.8
15.5	−7.0	51.3
16.0	−7.1	52.8
16.5	−7.2	54.3
16.9	−7.3	55.8
17.4	−7.4	57.4
17.9	−7.5	58.9
18.4	−7.6	60.5
18.8	−7.7	62.1
19.3	−7.8	63.8
19.8	−7.9	65.4
20.4	−8.0	67.1
20.9	−8.1	68.8
21.4		70.5

Ht. of Eye	Corrⁿ
m	′
1.0	−1.8
1.5	−2.2
2.0	−2.5
2.5	−2.8
3.0	−3.0
See table ←	
m	′
20	−7.9
22	−8.3
24	−8.6
26	−9.0
28	−9.3
30	−9.6
32	−10.0
34	−10.3
36	−10.6
38	−10.8
40	−11.1
42	−11.4
44	−11.7
46	−11.9
48	−12.2
ft.	′
2	−1.4
4	−1.9
6	−2.4
8	−2.7
10	−3.1
See table ←	
ft.	′
70	−8.1
75	−8.4
80	−8.7
85	−8.9
90	−9.2
95	−9.5
100	−9.7
105	−9.9
110	−10.2
115	−10.4
120	−10.6
125	−10.8
130	−11.1
135	−11.3
140	−11.5
145	−11.7
150	−11.9
155	−12.1

CONVERSION OF ARC TO TIME

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

The above table is for converting expressions in arc to their equivalent in time; its main use in this Almanac is for the conversion of longitude for application to L.M.T. (*added* if *west*, *subtracted* if *east*) to give G.M.T. or vice versa, particularly in the case of sunrise, sunset, etc.

Part Twelve: Polaris Problems

The star Polaris can be used to solve directly for latitude, or can be used to determine a true azimuth for compass error problems.

Latitude by Polaris Problems

Problem 12-1 (CG-231). The following question is taken directly from the USCG test bank and illustrates how to solve latitude by Polaris problems.

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>

45m	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

Compass Problems Involving Polaris

Problem 12-2 (CG-496). The following question is taken directly from the USCG test bank and illustrates how to solve compass problems involving Polaris.

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?

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

Answer: 1.5° W. For instructions on solving standard compass problems, refer to Part 6: Compass Problems.

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' =
156° 05.7'

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 =
132° 17.7'

34

G.M.T. d h	ARIES G.H.A. ° '
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

20ᵐ

20ᵐ s	SUN PLANETS ° '	ARIES ° '
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: Enter the Polaris Tables with LHA (Aries), DR Latitude, and Month to determine the azimuth to Polaris (the full Polaris Tables are located at the end of this Part).
Azimuth (interpolated) = 358.7°

Step 5: Determine the gyro compass error (using the acronym G-E-T).
G (Gyro): 000.2° pgc
E (Error): TBD
T (True): 358.7° per azimuth tables
Gyro error = 1.5° W

Step 6: Determine the deviation (using a standard compass problem format).

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)

Additional Problems and Answers

All of the following questions labeled "CG" were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-170. 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*

Problem CG-177. On 11 February your 1832 zone time DR position is longitude 110° 52.6' W. At that time you observe Polaris with a sextant altitude (hs) of 26° 19.8'. The chronometer time of sight is 01h 34m 56s and the chronometer error is 02m 16s fast. The index error is 2.7' off the arc, and the height of eye is 60.2 feet. What is your latitude by Polaris?

a) *25° 27.2' N- correct*
b) *25° 34.2' N*
c) *26° 27.2' N*
d) *26° 34.2' N*

Problem CG-214. On 13 October at 1847 ZT, your vessel's DR position is latitude 42° 17.4' N, longitude 138° 46.2' W. AT approximately this time you obtain a sextant altitude (hs) of Polaris reading 42° 16.8', with an index error of 3.2' on the arc. Your chronometer reads 03h 45m 20s and is 01m 32s slow. What is your latitude by Polaris, given a height of eye of 44 feet?

a) *42° 09.1' N- correct*
b) *42° 12.5' N*
c) *42° 16.0' N*
d) *42° 19.5' N*

Problem CG-231. 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.*

a) *29° 11.7’ N*
b) *29° 15.5’ N*
c) *29° 18.0’ N*
d) *29° 21.3’ N- correct*

Problem CG-240. On 15 February at 0610 ZT in DR position latitude 56° 53.0’ N, longitude 157° 02.9’ E, you observe Polaris at a sextant altitude (hs) of 56° 10.4’. The index error is 2.5’ on the arc and the height of eye is 18 meters. What is the latitude?

a) *56° 41.8’ N- correct*
b) *56° 47.9’ N*
c) *56° 48.1’ N*
d) *57° 10.6’ N*

Problem CG-241. 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*

Problem CG-344. 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*

Problem CG-517. 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*

Problem CG-451. On 28 October at 1754 ZT, your vessel's DR position is latitude 28° 30' N, longitude 63° 24' W. At this time you obtain a sextant altitude (hs) of Polaris reading 28° 42.6' with an index error of 2.4' on the arc. Your chronometer reads 09h 50m 00s and is 4m 41s slow. What is your latitude by Polaris given a height of eye of 28 feet (8.5 meters)?

a) *28° 25.2' N*
b) *28° 30.6' N*
c) *28° 34.9' N- correct*
d) *28° 41.3' N*

Problem CG-178. 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*

Problem CG-306. 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*

Problem CG-387. 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*

Problem CG-469. On 3 October your 2122 ZT position is latitude 26° 32' N, longitude 84° 26' W. You observe Polaris bearing 359.8° pgc. At the time of observation, the helmsman noted that he was heading 106° pgc and 107° psc. The variation is 0°. What is the deviation for that heading?

a) *1° E*
b) *0° - correct*
c) *1° W*
d) *2° W*

Problem CG-470. 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*

POLARIS (POLE STAR) TABLES,

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	0°–9°	10°–19°	20°–29°	30°–39°	40°–49°	50°–59°	60°–69°	70°–79°	80°–89°	90°–99°	100°–109°	110°–119°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 17·8	0 13·7	0 10·9	0 09·7	0 09·9	0 11·7	0 14·9	0 19·5	0 25·3	0 32·1	0 39·7	0 47·9
1	17·3	13·3	10·7	09·6	10·1	12·0	15·3	20·0	25·9	32·8	40·5	48·7
2	16·9	13·0	10·6	09·6	10·2	12·2	15·7	20·6	26·6	33·5	41·3	49·6
3	16·4	12·7	10·4	09·6	10·3	12·5	16·2	21·1	27·2	34·3	42·1	50·4
4	16·0	12·4	10·3	09·6	10·5	12·8	16·6	21·7	27·9	35·0	42·9	51·3
5	0 15·6	0 12·1	0 10·1	0 09·6	0 10·6	0 13·1	0 17·1	0 22·3	0 28·6	0 35·8	0 43·7	0 52·1
6	15·2	11·9	10·0	09·7	10·8	13·5	17·5	22·8	29·3	36·6	44·6	53·0
7	14·8	11·6	09·9	09·7	11·0	13·8	18·0	23·4	29·9	37·3	45·4	53·8
8	14·4	11·4	09·8	09·8	11·2	14·2	18·5	24·0	30·6	38·1	46·2	54·7
9	14·0	11·2	09·7	09·8	11·5	14·5	19·0	24·7	31·4	38·9	47·0	55·5
10	0 13·7	0 10·9	0 09·7	0 09·9	0 11·7	0 14·9	0 19·5	0 25·3	0 32·1	0 39·7	0 47·9	0 56·4
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·5	0·6	0·6	0·6	0·6	0·5	0·5	0·4	0·3	0·3	0·2	0·2
10	·5	·6	·6	·6	·6	·6	·5	·4	·4	·3	·3	·2
20	·5	·6	·6	·6	·6	·6	·5	·5	·4	·4	·3	·3
30	·6	·6	·6	·6	·6	·6	·5	·5	·5	·4	·4	·4
40	0·6	0·6	0·6	0·6	0·6	0·6	0·6	0·5	0·5	0·5	0·5	0·5
45	·6	·6	·6	·6	·6	·6	·6	·6	·6	·5	·5	·5
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·6	·6	·6	·6	·6	·6	·6	·6	·7	·7	·7	·7
60	·6	·6	·6	·6	·6	·6	·7	·7	·7	·7	·8	·8
62	0·7	0·6	0·6	0·6	0·6	0·6	0·7	0·7	0·7	0·8	0·8	0·8
64	·7	·6	·6	·6	·6	·6	·7	·7	·8	·8	·9	0·9
66	·7	·6	·6	·6	·6	·7	·7	·8	·8	0·9	0·9	1·0
68	0·7	0·6	0·6	0·6	0·6	0·7	0·7	0·8	0·9	1·0	1·0	1·0
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·6	0·6	0·6
Feb.	·6	·6	·7	·7	·7	·7	·8	·8	·8	·8	·8	·8
Mar.	·5	·5	·6	·6	·7	·7	·8	·8	·8	·9	·9	·9
Apr.	0·3	0·4	0·4	0·5	0·5	0·6	0·7	0·7	0·8	0·8	0·9	0·9
May	·2	·2	·3	·3	·4	·5	·5	·6	·7	·7	·8	·9
June	·2	·2	·2	·2	·3	·3	·4	·5	·5	·6	·7	·7
July	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·6
Aug.	·3	·3	·3	·2	·2	·2	·2	·3	·3	·3	·4	·4
Sept.	·5	·5	·4	·4	·3	·3	·3	·3	·3	·3	·3	·3
Oct.	0·7	0·6	0·6	0·5	0·5	0·4	0·4	0·3	0·3	0·3	0·3	0·3
Nov.	0·9	0·8	·8	·7	·6	·6	·5	·5	·4	·3	·3	·3
Dec.	1·0	1·0	0·9	0·9	0·8	0·8	0·7	0·6	0·6	0·5	0·4	0·4
Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	0·4	0·3	0·1	0·0	359·8	359·7	359·6	359·5	359·4	359·3	359·2	359·2
20	0·4	0·3	0·1	0·0	359·8	359·7	359·5	359·4	359·3	359·2	359·2	359·1
40	0·5	0·3	0·2	0·0	359·8	359·6	359·4	359·3	359·2	359·1	359·0	358·9
50	0·6	0·4	0·2	0·0	359·7	359·5	359·3	359·1	359·0	358·9	358·8	358·7
55	0·7	0·5	0·2	0·0	359·7	359·5	359·2	359·0	358·9	358·7	358·6	358·6
60	0·8	0·5	0·2	0·0	359·7	359·4	359·1	358·9	358·7	358·5	358·4	358·4
65	0·9	0·6	0·3	359·9	359·6	359·3	359·0	358·7	358·4	358·3	358·1	358·1

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.*

POLARIS (POLE STAR) TABLES, 1981

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	120°–129°	130°–139°	140°–149°	150°–159°	160°–169°	170°–179°	180°–189°	190°–199°	200°–209°	210°–219°	220°–229°	230°–239°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 56·4	1 05·0	1 13·3	1 21·2	1 28·5	1 34·8	1 40·0	1 44·1	1 46·7	1 47·9	1 47·7	1 46·0
1	57·2	05·8	14·1	22·0	29·1	35·4	40·5	44·4	46·9	48·0	47·6	45·7
2	58·1	06·7	15·0	22·7	29·8	35·9	41·0	44·7	47·1	48·0	47·4	45·4
3	59·0	07·5	15·8	23·5	30·5	36·5	41·4	45·0	47·2	48·0	47·3	45·2
4	0 59·8	08·3	16·6	24·2	31·1	37·0	41·8	45·3	47·4	48·0	47·2	44·9
5	1 00·7	1 09·2	1 17·4	1 25·0	1 31·8	1 37·6	1 42·2	1 45·6	1 47·5	1 48·0	1 47·0	1 44·6
6	01·5	10·0	18·1	25·7	32·4	38·1	42·6	45·8	47·6	47·9	46·8	44·3
7	02·4	10·8	18·9	26·4	33·0	38·6	43·0	46·1	47·7	47·9	46·6	43·9
8	03·2	11·7	19·7	27·1	33·6	39·1	43·4	46·3	47·8	47·8	46·4	43·6
9	04·1	12·5	20·5	27·8	34·2	39·6	43·7	46·5	47·9	47·8	46·2	43·2
10	1 05·0	1 13·3	1 21·2	1 28·5	1 34·8	1 40·0	1 44·1	1 46·7	1 47·9	1 47·7	1 46·0	1 42·8
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·2	0·2	0·2	0·3	0·4	0·4	0·5	0·6	0·6	0·6	0·6	0·5
10	·2	·3	·3	·3	·4	·5	·5	·6	·6	·6	·6	·6
20	·3	·3	·3	·4	·4	·5	·5	·6	·6	·6	·6	·6
30	·4	·4	·4	·4	·5	·5	·6	·6	·6	·6	·6	·6
40	0·5	0·5	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·6	0·6
45	·5	·5	·5	·6	·6	·6	·6	·6	·6	·6	·6	·6
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·7	·7	·7	·7	·6	·6	·6	·6	·6	·6	·6	·6
60	·8	·8	·8	·7	·7	·7	·6	·6	·6	·6	·6	·6
62	0·8	0·8	0·8	0·8	0·7	0·7	0·7	0·6	0·6	0·6	0·6	0·6
64	0·9	0·9	·9	·8	·8	·7	·7	·6	·6	·6	·6	·6
66	1·0	1·0	0·9	·9	·8	·7	·7	·6	·6	·6	·6	·7
68	1·1	1·0	1·0	0·9	0·9	0·8	0·7	0·6	0·6	0·6	0·6	0·7
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·6	0·6	0·6	0·6	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5
Feb.	·8	·7	·7	·7	·7	·6	·6	·6	·5	·5	·5	·5
Mar.	·9	0·9	0·9	0·8	·8	·8	·7	·7	·6	·6	·5	·5
Apr.	0·9	1·0	1·0	1·0	0·9	0·9	0·9	0·8	0·8	0·7	0·7	0·6
May	·9	1·0	1·0	1·0	1·0	1·0	1·0	1·0	0·9	0·9	·8	·7
June	·8	0·9	0·9	1·0	1·0	1·0	1·0	1·0	1·0	1·0	0·9	0·9
July	0·7	0·7	0·8	0·9	0·9	0·9	1·0	1·0	1·0	1·0	1·0	1·0
Aug.	·5	·6	·6	·7	·7	·8	0·9	0·9	0·9	1·0	1·0	1·0
Sept.	·4	·4	·5	·5	·6	·6	·7	·7	·8	0·8	0·9	0·9
Oct.	0·3	0·3	0·3	0·3	0·4	0·4	0·5	0·6	0·6	0·7	0·7	0·8
Nov.	·2	·2	·2	·2	·3	·3	·3	·4	·4	·5	·6	·6
Dec.	0·3	0·3	0·2	0·2	0·2	0·2	0·2	0·2	0·3	0·3	0·4	0·4
Lat.	AZIMUTH											
°	°	°	°	°	°	°	°	°	°	°	°	°
0	359·2	359·2	359·2	359·3	359·4	359·5	359·6	359·7	359·9	0·0	0·2	0·3
20	359·1	359·1	359·2	359·3	359·4	359·5	359·6	359·7	359·9	0·0	0·2	0·3
40	358·9	359·0	359·0	359·1	359·2	359·3	359·5	359·7	359·8	0·0	0·2	0·4
50	358·7	358·8	358·8	358·9	359·1	359·2	359·4	359·6	359·8	0·0	0·3	0·5
55	358·6	358·6	358·7	358·8	358·9	359·1	359·3	359·6	359·8	0·0	0·3	0·5
60	358·4	358·4	358·5	358·6	358·8	359·0	359·2	359·5	359·8	0·0	0·3	0·6
65	358·1	358·1	358·2	358·4	358·6	358·8	359·1	359·4	359·7	0·1	0·4	0·7

ILLUSTRATION
On 1981 April 21 at G.M.T. $23^h 18^m 56^s$ in longitude W. 37° 14′ the apparent altitude (corrected for refraction), *Ho*, of

From the daily pages:	° ′
G.H.A. Aries (23^h)	194 55·4
Increment ($18^m 56^s$)	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

POLARIS (POLE STAR) TABLES,

FOR DETERMINING LATITUDE FROM SEXTANT ALTITUDE AND FOR AZIMUTH

L.H.A. ARIES	240°– 249°	250°– 259°	260°– 269°	270°– 279°	280°– 289°	290°– 299°	300°– 309°	310°– 319°	320°– 329°	330°– 339°	340°– 349°	350°– 359°
	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0	a_0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	1 42·8	1 38·4	1 32·8	1 26·1	1 18·6	1 10·5	1 02·1	0 53·5	0 45·0	0 37·0	0 29·7	0 23·2
1	42·5	37·9	32·1	25·4	17·8	09·7	01·2	52·6	44·2	36·3	29·0	22·6
2	42·1	37·4	31·5	24·7	17·0	08·8	1 00·3	51·8	43·4	35·5	28·3	22·0
3	41·6	36·8	30·9	23·9	16·2	08·0	0 59·5	50·9	42·6	34·7	27·6	21·5
4	41·2	36·3	30·2	23·2	15·4	07·2	58·6	50·1	41·8	34·0	27·0	20·9
5	1 40·8	1 35·7	1 29·6	1 22·5	1 14·6	1 06·3	0 57·8	0 49·2	0 41·0	0 33·3	0 26·3	0 20·4
6	40·3	35·2	28·9	21·7	13·8	05·5	56·9	48·4	40·2	32·5	25·7	19·8
7	39·9	34·6	28·2	20·9	13·0	04·6	56·0	47·5	39·4	31·8	25·0	19·3
8	39·4	34·0	27·5	20·2	12·2	03·8	55·2	46·7	38·6	31·1	24·4	18·8
9	38·9	33·4	26·8	19·4	11·3	02·9	54·3	45·9	37·8	30·4	23·8	18·3
10	1 38·4	1 32·8	1 26·1	1 18·6	1 10·5	1 02·1	0 53·5	0 45·0	0 37·0	0 29·7	0 23·2	0 17·8
Lat.	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1	a_1
°	′	′	′	′	′	′	′	′	′	′	′	′
0	0·5	0·4	0·3	0·3	0·2	0·2	0·2	0·2	0·2	0·3	0·4	0·4
10	·5	·4	·4	·3	·3	·2	·2	·3	·3	·3	·4	·5
20	·5	·5	·4	·4	·3	·3	·3	·3	·3	·4	·4	·5
30	·5	·5	·5	·4	·4	·4	·4	·4	·4	·4	·5	·5
40	0·6	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·6
45	·6	·6	·6	·5	·5	·5	·5	·5	·5	·6	·6	·6
50	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6	·6
55	·6	·6	·7	·7	·7	·7	·7	·7	·7	·7	·6	·6
60	·7	·7	·7	·7	·8	·8	·8	·8	·8	·7	·7	·7
62	0·7	0·7	0·7	0·8	0·8	0·8	0·8	0·8	0·8	0·8	0·7	0·7
64	·7	·7	·8	·8	·9	0·9	0·9	0·9	·9	·8	·8	·7
66	·7	·8	·8	0·9	0·9	1·0	1·0	1·0	0·9	·9	·8	·7
68	0·7	0·8	0·9	1·0	1·0	1·0	1·1	1·0	1·0	0·9	0·9	0·8
Month	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2	a_2
	′	′	′	′	′	′	′	′	′	′	′	′
Jan.	0·5	0·5	0·5	0·6	0·6	0·6	0·6	0·6	0·6	0·6	0·7	0·7
Feb.	·4	·4	·4	·4	·4	·4	·4	·5	·5	·5	·5	·6
Mar.	·4	·4	·4	·3	·3	·3	·3	·3	·3	·4	·4	·4
Apr.	0·5	0·5	0·4	0·4	0·3	0·3	0·3	0·2	0·2	0·2	0·3	0·3
May	·7	·6	·5	·5	·4	·3	·3	·2	·2	·2	·2	·2
June	·8	·7	·7	·6	·5	·5	·4	·3	·3	·2	·2	·2
July	0·9	0·9	0·8	0·8	0·7	0·6	0·5	0·5	0·4	0·3	0·3	0·3
Aug.	1·0	·9	·9	·9	·8	·8	·7	·6	·6	·5	·5	·4
Sept.	0·9	·9	·9	·9	·9	·9	·8	·8	·7	·7	·6	·6
Oct.	0·8	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·8	0·8
Nov.	·7	·7	·8	·9	·9	·9	1·0	1·0	1·0	1·0	0·9	0·9
Dec.	0·5	0·6	0·6	0·7	0·8	0·8	0·9	0·9	1·0	1·0	1·0	1.0
Lat.						AZIMUTH						
°	°	°	°	°	°	°	°	°	°	°	°	°
0	0·4	0·5	0·6	0·7	0·8	0·8	0·8	0·8	0·8	0·7	0·6	0·5
20	0·5	0·6	0·7	0·8	0·8	0·9	0·9	0·9	0·8	0·7	0·7	0·5
40	0·6	0·7	0·8	0·9	1·0	1·1	1·1	1·1	1·0	0·9	0·8	0·7
50	0·7	0·8	1·0	1·1	1·2	1·3	1·3	1·3	1·2	1·1	1·0	0·8
55	0·7	0·9	1·1	1·2	1·3	1·4	1·4	1·4	1·3	1·2	1·1	0·9
60	0·8	1·1	1·3	1·4	1·5	1·6	1·6	1·6	1·5	1·4	1·2	1·0
65	1·0	1·3	1·5	1·7	1·8	1·9	1·9	1·9	1·8	1·7	1·5	1·2

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*.

A2 ALTITUDE CORRECTION TABLES 10°-90°—SUN, STARS, PLANETS

SUN

OCT.—MAR. App. Alt.	Lower Limb	Upper Limb	APR.—SEPT. App. Alt.	Lower Limb	Upper Limb
° ′	′	′	° ′	′	′
9 34			9 39		
	+10.8	−21.5		+10.6	−21.2
9 45			9 51		
	+10.9	−21.4		+10.7	−21.1
9 56			10 03		
	+11.0	−21.3		+10.8	−21.0
10 08			10 15		
	+11.1	−21.2		+10.9	−20.9
10 21			10 27		
	+11.2	−21.1		+11.0	−20.8
10 34			10 40		
	+11.3	−21.0		+11.1	−20.7
10 47			10 54		
	+11.4	−20.9		+11.2	−20.6
11 01			11 08		
	+11.5	−20.8		+11.3	−20.5
11 15			11 23		
	+11.6	−20.7		+11.4	−20.4
11 30			11 38		
	+11.7	−20.6		+11.5	−20.3
11 46			11 54		
	+11.8	−20.5		+11.6	−20.2
12 02			12 10		
	+11.9	−20.4		+11.7	−20.1
12 19			12 28		
	+12.0	−20.3		+11.8	−20.0
12 37			12 46		
	+12.1	−20.2		+11.9	−19.9
12 55			13 05		
	+12.2	−20.1		+12.0	−19.8
13 14			13 24		
	+12.3	−20.0		+12.1	−19.7
13 35			13 45		
	+12.4	−19.9		+12.2	−19.6
13 56			14 07		
	+12.5	−19.8		+12.3	−19.5
14 18			14 30		
	+12.6	−19.7		+12.4	−19.4
14 42			14 54		
	+12.7	−19.6		+12.5	−19.3
15 06			15 19		
	+12.8	−19.5		+12.6	−19.2
15 32			15 46		
	+12.9	−19.4		+12.7	−19.1
15 59			16 14		
	+13.0	−19.3		+12.8	−19.0
16 28			16 44		
	+13.1	−19.2		+12.9	−18.9
16 59			17 15		
	+13.2	−19.1		+13.0	−18.8
17 32			17 48		
	+13.3	−19.0		+13.1	−18.7
18 06			18 24		
	+13.4	−18.9		+13.2	−18.6
18 42			19 01		
	+13.5	−18.8		+13.3	−18.5
19 21			19 42		
	+13.6	−18.7		+13.4	−18.4
20 03			20 25		
	+13.7	−18.6		+13.5	−18.3
20 48			21 11		
	+13.8	−18.5		+13.6	−18.2
21 35			22 00		
	+13.9	−18.4		+13.7	−18.1
22 26			22 54		
	+14.0	−18.3		+13.8	−18.0
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
27 52			28 33		
	+14.5	−17.8		+14.3	−17.5
29 15			30 00		
	+14.6	−17.7		+14.4	−17.4
30 46			31 35		
	+14.7	−17.6		+14.5	−17.3
32 26			33 20		
	+14.8	−17.5		+14.6	−17.2
34 17			35 17		
	+14.9	−17.4		+14.7	−17.1
36 20			37 26		
	+15.0	−17.3		+14.8	−17.0
38 36			39 50		
	+15.1	−17.2		+14.9	−16.9
41 08			42 31		
	+15.2	−17.1		+15.0	−16.8
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
54 49			57 02		
	+15.6	−16.7		+15.4	−16.4
59 23			61 51		
	+15.7	−16.6		+15.5	−16.3
64 30			67 17		
	+15.8	−16.5		+15.6	−16.2
70 12			73 16		
	+15.9	−16.4		+15.7	−16.1
76 26			79 43		
	+16.0	−16.3		+15.8	−16.0
83 05			86 32		
	+16.1	−16.2		+15.9	−15.9
90 00			90 00		

STARS AND PLANETS

App. Alt.	Corr^n
° ′	′
9 56	
	−5.3
10 08	
	−5.2
10 20	
	−5.1
10 33	
	−5.0
10 46	
	−4.9
11 00	
	−4.8
11 14	
	−4.7
11 29	
	−4.6
11 45	
	−4.5
12 01	
	−4.4
12 18	
	−4.3
12 35	
	−4.2
12 54	
	−4.1
13 13	
	−4.0
13 33	
	−3.9
13 54	
	−3.8
14 16	
	−3.7
14 40	
	−3.6
15 04	
	−3.5
15 30	
	−3.4
15 57	
	−3.3
16 26	
	−3.2
16 56	
	−3.1
17 28	
	−3.0
18 02	
	−2.9
18 38	
	−2.8
19 17	
	−2.7
19 58	
	−2.6
20 42	
	−2.5
21 28	
	−2.4
22 19	
	−2.3
23 13	
	−2.2
24 11	
	−2.1
25 14	
	−2.0
26 22	
	−1.9
27 36	
	−1.8
28 56	
	−1.7
30 24	
	−1.6
32 00	
	−1.5
33 45	
	−1.4
35 40	
	−1.3
37 48	
	−1.2
40 08	
	−1.1
42 44	
	−1.0
45 36	
	−0.9
48 47	
	−0.8
52 18	
	−0.7
56 11	
	−0.6
60 28	
	−0.5
65 08	
	−0.4
70 11	
	−0.3
75 34	
	−0.2
81 13	
	−0.1
87 03	
	0.0
90 00	

App. Alt.	Additional Corr^n
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	+ 0.4′
41	+ 0.5
Dec. 27-Dec. 31	
0°	
6	+ 0.5′
20	+ 0.6
31	+ 0.7
MARS	
Jan. 1-Dec. 31	
0°	
60	+ 0.1′

DIP

Ht. of Eye	Corr^n	Ht. of Eye
m	′	ft.
2.4		8.0
	−2.8	
2.6		8.6
	−2.9	
2.8		9.2
	−3.0	
3.0		9.8
	−3.1	
3.2		10.5
	−3.2	
3.4		11.2
	−3.3	
3.6		11.9
	−3.4	
3.8		12.6
	−3.5	
4.0		13.3
	−3.6	
4.3		14.1
	−3.7	
4.5		14.9
	−3.8	
4.7		15.7
	−3.9	
5.0		16.5
	−4.0	
5.2		17.4
	−4.1	
5.5		18.3
	−4.2	
5.8		19.1
	−4.3	
6.1		20.1
	−4.4	
6.3		21.0
	−4.5	
6.6		22.0
	−4.6	
6.9		22.9
	−4.7	
7.2		23.9
	−4.8	
7.5		24.9
	−4.9	
7.9		26.0
	−5.0	
8.2		27.1
	−5.1	
8.5		28.1
	−5.2	
8.8		29.2
	−5.3	
9.2		30.4
	−5.4	
9.5		31.5
	−5.5	
9.9		32.7
	−5.6	
10.3		33.9
	−5.7	
10.6		35.1
	−5.8	
11.0		36.3
	−5.9	
11.4		37.6
	−6.0	
11.8		38.9
	−6.1	
12.2		40.1
	−6.2	
12.6		41.5
	−6.3	
13.0		42.8
	−6.4	
13.4		44.2
	−6.5	
13.8		45.5
	−6.6	
14.2		46.9
	−6.7	
14.7		48.4
	−6.8	
15.1		49.8
	−6.9	
15.5		51.3
	−7.0	
16.0		52.8
	−7.1	
16.5		54.3
	−7.2	
16.9		55.8
	−7.3	
17.4		57.4
	−7.4	
17.9		58.9
	−7.5	
18.4		60.5
	−7.6	
18.8		62.1
	−7.7	
19.3		63.8
	−7.8	
19.8		65.4
	−7.9	
20.4		67.1
	−8.0	
20.9		68.8
	−8.1	
21.4		70.5

Ht. of Eye	Corr^n
m	′
1.0	− 1.8
1.5	− 2.2
2.0	− 2.5
2.5	− 2.8
3.0	− 3.0
See table ←	
m	′
20	− 7.9
22	− 8.3
24	− 8.6
26	− 9.0
28	− 9.3
30	− 9.6
32	− 10.0
34	− 10.3
36	− 10.6
38	− 10.8
40	− 11.1
42	− 11.4
44	− 11.7
46	− 11.9
48	− 12.2
ft.	′
2	− 1.4
4	− 1.9
6	− 2.4
8	− 2.7
10	− 3.1
See table ←	
ft.	′
70	− 8.1
75	− 8.4
80	− 8.7
85	− 8.9
90	− 9.2
95	− 9.5
100	− 9.7
105	− 9.9
110	− 10.2
115	− 10.4
120	− 10.6
125	− 10.8
130	− 11.1
135	− 11.3
140	− 11.5
145	− 11.7
150	− 11.9
155	− 12.1

App. Alt. = Apparent altitude = Sextant altitude corrected for index error and dip.
For daylight observations of Venus, see page 260.

The Starfinder (2102-D) is an instrument used for identifying stars and planets based on their azimuth (bearing) and altitude (height). Additionally, it can be used as a planning tool to identify the best stars and planets for fixes at a later time.

Star Identification Problems

Problem 13-1 (CG-289). The following question is taken directly from the USCG test bank and illustrates how to solve star identification problems using the Starfinder.

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?

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

Answer: Mirfak.

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>

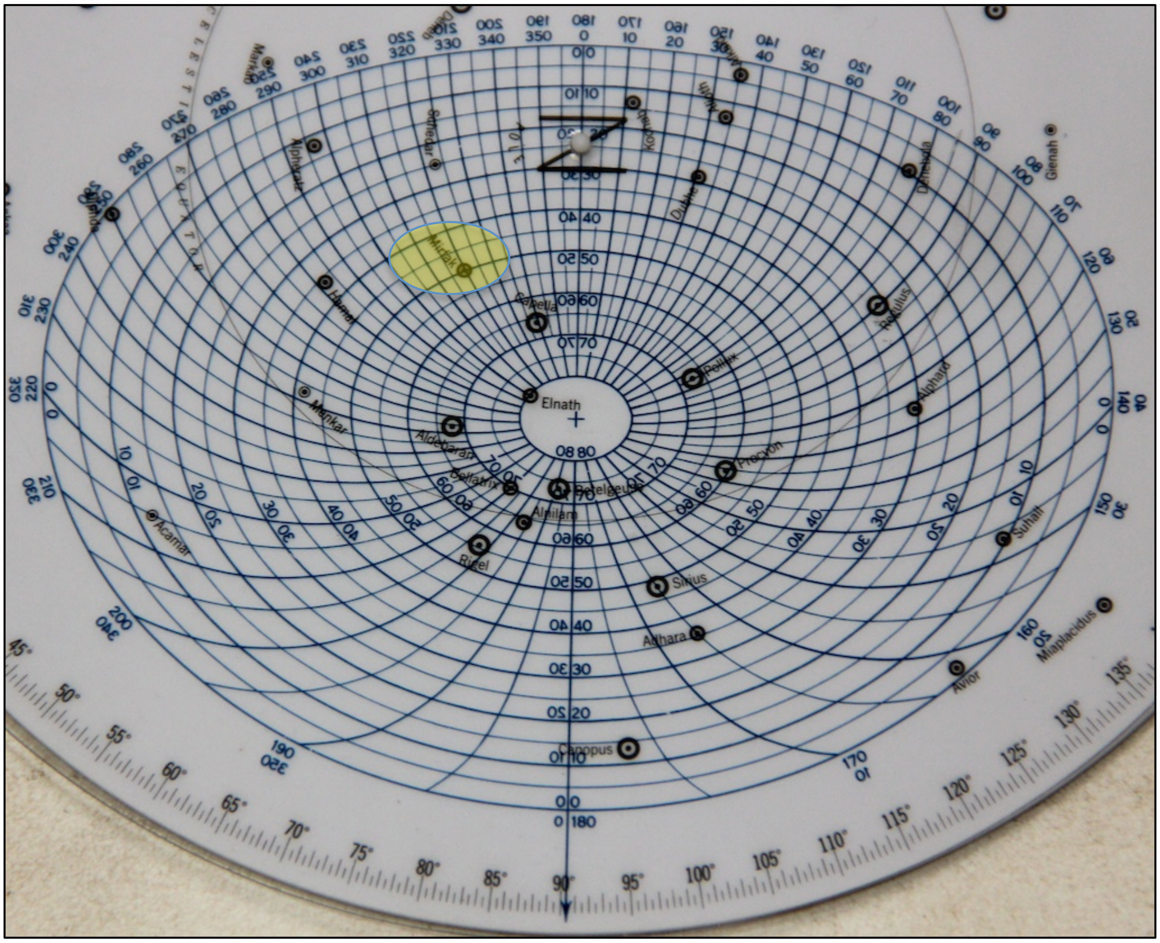
45m	SUN PLANETS	ARIES
55	11 28·8	11 30·6
56	11 29·0	11 30·9
57	11 29·3	11 31·1
58	11 29·5	11 31·4
59	11 29·8	11 31·6

Step 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'

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.

Problem 13-2 (CG-396). The following question is taken directly from the USCG test bank and illustrates how to solve star identification problems using a Starfinder.

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.

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

23 WEDNESDAY	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
	07	107 02.4
	08	122 04.9
	09	137 07.4
	10	152 09.8
	11	167 12.3
	12	182 14.7
	13	197 17.2
	14	212 19.7
	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 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: <u>07:36:06</u>

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'

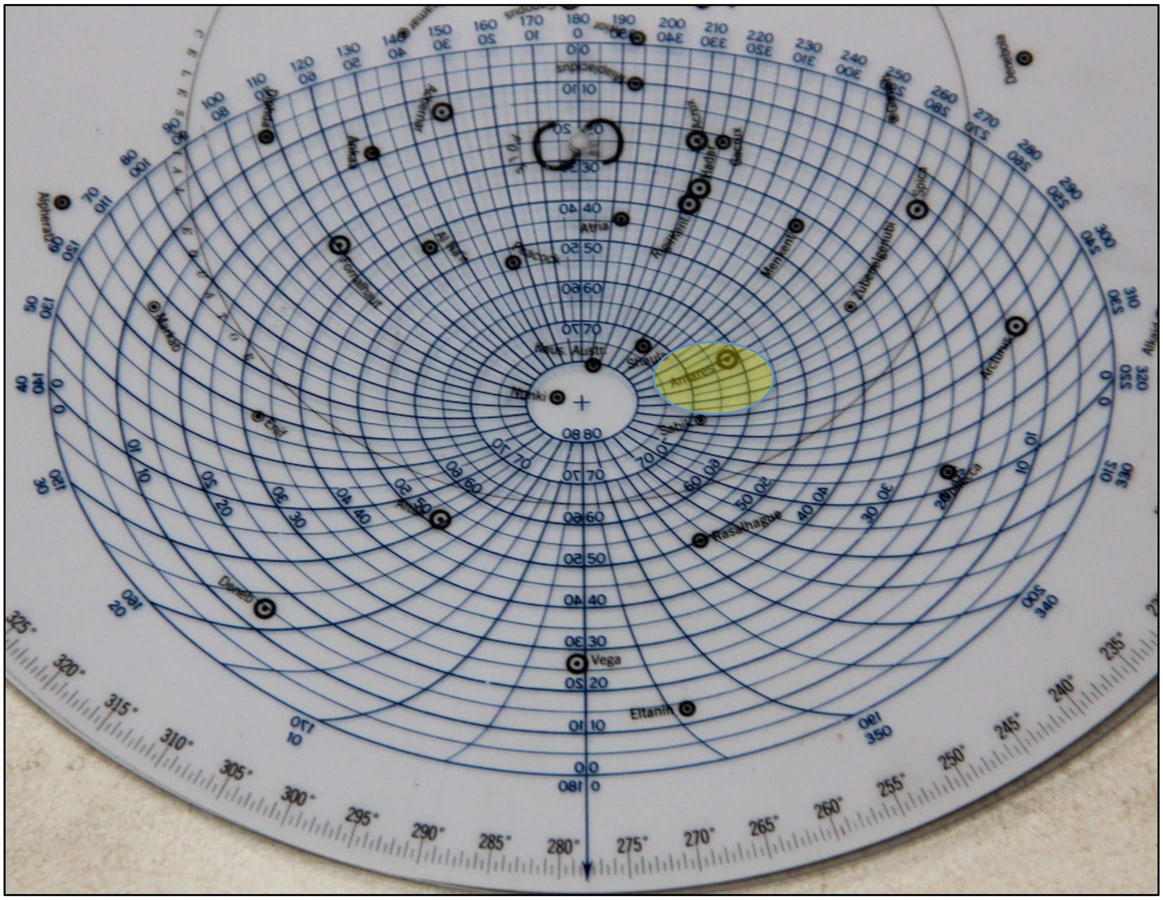
Step 4: Determine the LHA of Aries for the time of the sight.
GHA Aries: 116° 05.4'
DR Longitude: 162° 36.0' E (E longitude add, W longitude subtract)
LHA Aries: 116° 05.4' + 162° 36.0' W = <u>278° 41.4'</u>

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.



Fix Preparation Problems Involving Stars

Problem 13-3 (CG-443). The following question is taken directly from the USCG test bank and illustrates how to solve star fix preparation problems using the Starfinder.

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*

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'

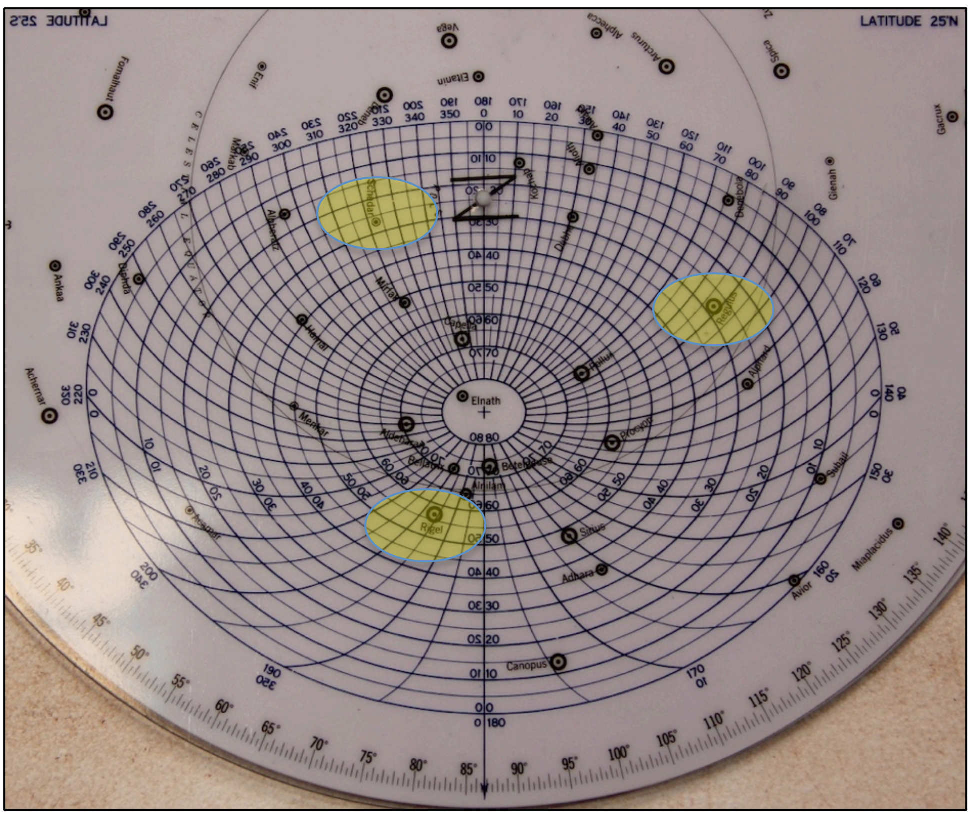
G.M.T.		ARIES G.H.A.
1 SUNDAY	00	158 42.6
	01	173 45.1
	02	188 47.5
	03	203 50.0
	04	218 52.5
	05	233 54.9
	06	248 57.4
	07	263 59.9
	08	279 02.3
	09	294 04.8
	10	309 07.3
	11	324 09.7
	12	339 12.2
	13	354 14.7
	14	9 17.1
	15	24 19.6
	16	39 22.0
	17	54 24.5
	18	69 27.0
	19	84 29.4
	20	99 31.9
	21	114 34.4
	22	129 36.8
	23	144 39.3

50m (s)	SUN PLANETS (° ')	ARIES (° ')
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.



<u>Problem 13-4 (CG-392)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve star fix preparation problems from a moving vessel using the Starfinder.

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?

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

a) *Arcturus, Regulus, Sirius*
b) *Procyon, Sirius, Capella*
c) <u>*Hamal, Rigel, Alphard- correct*</u>
d) *Betelgeuse, Dubhe, Regulus*

Step 1: Determine the approximate time of star time.
Based on the DR position, star time is closer to 1900 than 1600 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>

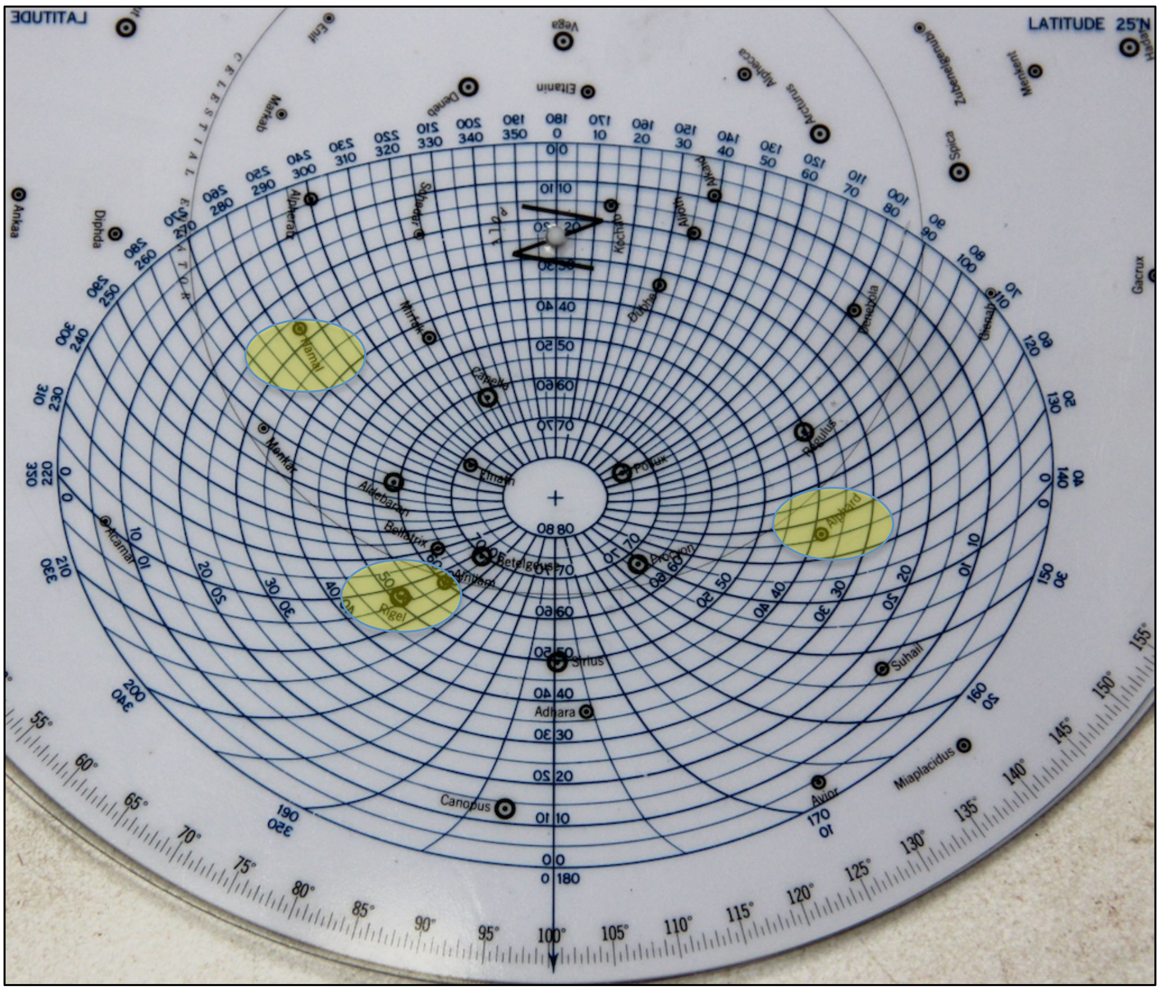
Step 4: Determine the GHA of Aries for the time of the sight.
GHA Aries (hours/total): 256° 35.1'

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. Arcturus, Regulus, Sirius: Arcturus is below the horizon.
b. Procyon, Sirius, Capella: Capella and Procyon are nearly opposite.
c. **Hamal, Rigel, Alphard: distributed at appropriate azimuths and altitudes.**
d. Betelgeuse, Dubhe, Regulus: Betelgeuse is too high in the sky and nearly opposite Dubhe.



Fix Preparation Problems Involving Stars and Planets

Problem 13-5 (CG-263). The following question is taken directly from the USCG test bank and illustrates how to solve star and planet fix preparation problems using the Starfinder.

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

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 3: Determine the GHA of Aries for the time of the sight.
GHA Aries (hours): 24° 58.5' (see next page for table)
GHA Aries (increment): 5° 00.8'
GHA Aries (Total): 24° 58.5 ' + 5° 00.8' = 29° 59.3'

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'

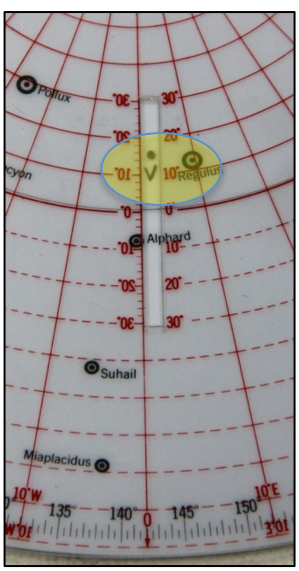
Saturn:
SHA = 175° 03.9’
RA = 360° - 175° 03.9 = 184° 56.1’
Declination = N 0° 23.2’

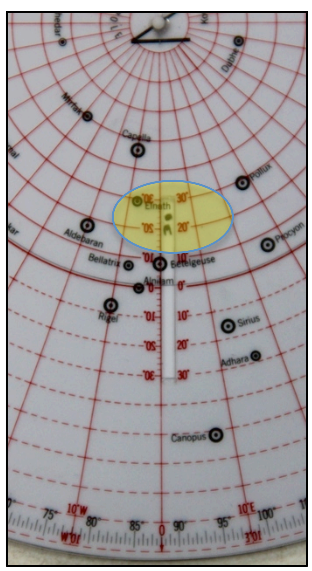
G.M.T. d h	ARIES G.H.A. ° ′	VENUS −3.3 G.H.A. ° ′	VENUS Dec. ° ′	MARS +1.7 G.H.A. ° ′	MARS Dec. ° ′	JUPITER −1.5 G.H.A. ° ′	JUPITER Dec. ° ′	SATURN +1.2 G.H.A. ° ′	SATURN Dec. ° ′
17 00	294 43.8	150 58.3	N16 05.2	205 44.6	N23 54.2	110 36.8	S 0 25.8	109 44.1	N 0 23.7
01	309 46.2	165 57.8	04.2	220 45.3	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.

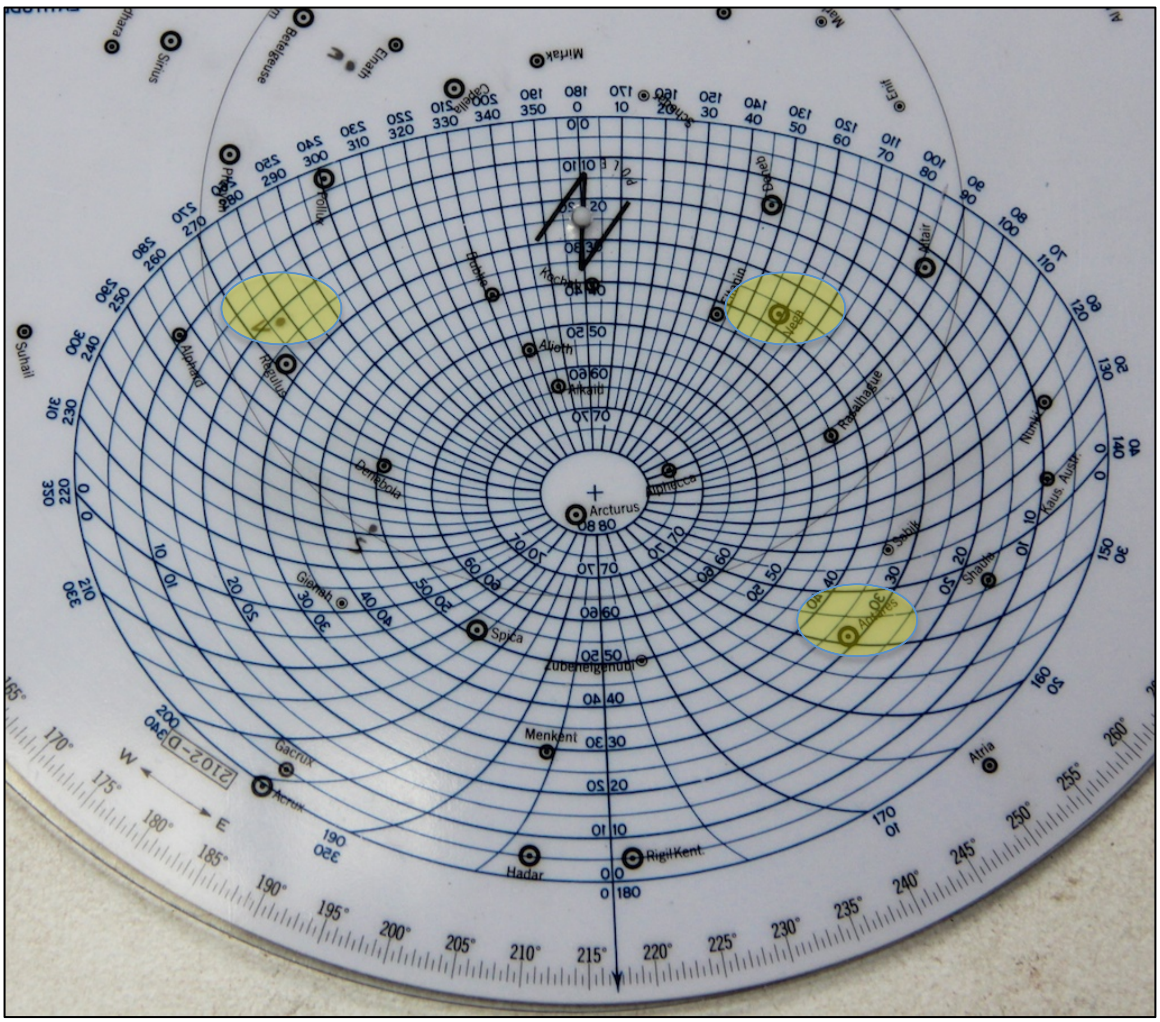




Step 7: Set up the Starfinder.
LHA Aries: 217° 40.4’
Observer’s latitude (nearest incremental degree): 25° N

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.



Additional Problems and Answers

All of the following questions labeled "CG" were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-40. 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*

Problem CG-77. 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*

Problem CG-203. 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?

Note- for this problem, it is necessary to use the SHA tables in the back of the nautical almanac.

- *a) Theta Carinae*
- *b) Epsilon Leonis*
- *c) Beta Librae- correct*
- *d) Zeta Puppis*

Problem CG-226. 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*

Problem CG-289. 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?

a) *Capella*
b) *Mirfak- correct*
c) *Pollux*
d) *Rigel*

Problem CG-341. 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*

Problem CG-396. 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?

a) *Antares- correct*
b) *Canopus*
c) *Achernar*
d) *Sirius*

Problem CG-185. 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*

Problem CG-263. 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*

Problem CG-282. 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*

Problem CG-313. 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*

Problem CG-328. 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*

Problem CG-392. 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) *Hamal, Rigel, Alphard- correct*
d) *Betelgeuse, Dubhe, Regulus*

Problem CG-403. 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*

Problem CG-443. 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*

Problem CG-455. 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*

By comparing a measured azimuth (bearing) to a celestial body with a computed azimuth, gyro compass error or deviation can be determined.

Azimuth Problems Involving the Sun

Problem 14-1 (CG-283). The following question is taken directly from the USCG test bank and illustrates how to solve azimuth problems involving the Sun.

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

G.M.T.	SUN G.H.A.	SUN 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

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'

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 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'

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)

Problem 14-2 (CG-208). The following question is taken directly from the USCG test bank and illustrates how to solve azimuth problems involving the Sun.

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?

G.M.T.		SUN G.H.A.	Dec.
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

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

36m	SUN PLANETS	ARIES	MOON	v or d	Corr
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 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 = <u>289° 47.9’</u>

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)

Azimuth Problems Involving Planets and Stars

Problem 14-3 (CG-86). The following question is taken directly from the USCG test bank and illustrates how to solve azimuth problems involving planets.

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?

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

G.M.T.		ARIES	VENUS −3.3		MARS +1.7		JUPITER −1.6	
d	h	G.H.A.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	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
	08	31 24.1	277 19.3	00.9	320 05.0	32.5	209 31.1	37.8
T	09	46 26.6	292 18.5	· · 00.4	335 05.6	· · 32.8	224 33.4	· · 37.7
U	10	61 29.1	307 17.7	23 00.0	350 06.2	33.0	239 35.7	37.6
E	11	76 31.5	322 16.8	22 59.6	5 06.8	33.3	254 37.9	37.5
S	12	91 34.0	337 16.0	N22 59.1	20 07.4	N22 33.5	269 40.2	N 0 37.4
D	13	106 36.5	352 15.2	58.7	35 08.0	33.8	284 42.5	37.4
A	14	121 38.9	7 14.4	58.2	50 08.6	34.0	299 44.8	37.3
Y	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.		h m 5 58.7	v −0.8	d 0.4	v 0.6	d 0.3	v 2.3	d 0.1

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: <u>09:25:48, 23 June</u>

Step 3: Determine the declination of Jupiter.
Declination (hours): N 0° 37.7'
(d number 0.1')
Declination (increment): 0
Declination (total): <u>N 0° 37.7'</u>

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): <u>231° 01.4'</u>

25^m	SUN PLANETS	ARIES	MOON	v or d	Corr^n
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 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 = <u>80° 57.4'</u>

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’**	

	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’**	

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°			24°			25°			26°		
	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	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°			28°			29°			30°			Dec.
Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
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°			24°			25°			26°		
	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	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°			28°			29°			30°			Dec.
Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
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°	**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° = <u>266.2°</u>
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)

<u>Problem 14-4 (CG-492)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve azimuth problems involving stars.

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: <u>12:07:06, 4 October</u>

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
05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

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’

7 m (s)	SUN PLANETS (° ′)	ARIES (° ′)
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 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’

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	**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’	

LATITUDE CONTRARY NAME TO DECLINATION L.H.A. 10°, 350°

24° Hc (° ′)	24° d (′)	24° Z (°)	25° Hc (° ′)	25° d (′)	25° Z (°)	26° Hc (° ′)	26° d (′)	26° Z (°)	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. (°)
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**

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**

	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° = +0.3°

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)

Additional Problems and Answers

All of the following questions labeled "CG" were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-276. 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*

Problem CG-333. 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*

Problem CG-406. 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*

Problem CG-161. 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

Problem CG-426. On 26 May, your 0723 zone time DR position is latitude 24° 50.0' N, longitude 38° 11.0' W. At that time you observe the Sun bearing 076.5° psc. The chronometer reads 10h 25m 43s, and the chronometer error is 02m 57s fast. The variation is 7° W. What is the deviation of the standard magnetic compass?

a) 3.3° E
b) 3.7° W
c) 8.3° W
d) 10.7° E- correct

Problem CG-208. 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?

a) 2.9° W
b) 3.2° E- correct
c) 3.9° E
d) 4.7° W

Problem CG-483. On 31 May, your vessel's 1420 zone time DR position is latitude 29° 06' N, longitude 120° 06' W, when an azimuth of the sun is observed. The bearing of the Sun per standard magnetic compass was 255.3°. The chronometer time of the observation is 10h 17m 24s. The chronometer error is 02m 32s slow. The variation for this area is 12.9° E. What is the deviation of the standard magnetic compass?

a) 2.5° W- correct
b) 2.9° W
c) 2.9° E
d) 3.2° E

Problem CG-497. 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

Problem CG-512. 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*

Problem CG-86. 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?

a) *3.0° W*
b) *3.5° W*
c) *1.5° E*
d) *2.3° E- correct*

Problem CG-446. 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*

Part Fifteen: Celestial Sight Reduction Problems

Certain celestial sight reduction problems can be solved mathematically and do not require a plotted solution. Additionally, some problems require uncommon corrections to the altitude tables due to non-standard observation conditions.

Basic Celestial Sight Reduction Problems

Problem 15-1 (CG-488). The following question is taken directly from the USCG test bank and illustrates how to solve basic celestial sight reduction problems involving the Sun.

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'. The altitude correction tables are available at the end of this Part.

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'

DIP				
Ht. of Eye	Corrn	Ht. of Eye	Ht. of Eye	Corrn
13·8	−6·6	45·5	85	− 8·9
14·2	−6·7	46·9	90	− 9·2
14·7	−6·8	48·4	95	− 9·5
15·1		49·8		

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' = 25° 26.2'

OCT.—MAR. SUN			APR.—SEPT.		
App. Alt.	Lower Limb	Upper Limb	App. Alt.	Lower Limb	Upper Limb
24 21	+14·1	−18·2	24 53	+13·9	−17·9
25 26	+14·2	−18·1	26 00	+14·0	−17·8
26 36	+14·3	−18·0	27 13	+14·1	−17·7
	+14·4	17·9		+14·2	17·6

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'**

Problem 15-2 (CG-121). The following question is taken directly from the USCG test bank and illustrates how to solve basic celestial sight reduction problems involving planets and stars.

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'. The altitude correction tables are available at the end of this Part.

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' = <u>29° 35.1'</u>

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'**

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	+ 0·4'
41	+ 0·5
Dec. 27-Dec. 31	
0°	
6	+ 0·5'
20	+ 0·6
31	+ 0·7
MARS	
Jan. 1-Dec. 31	
0°	
60	+ 0·1'

DIP

Ht. of Eye	Corrⁿ	Ht. of Eye	Ht. of Eye	Corrⁿ
	−6·0		←	
11·8		38·9		
	−6·1		ft.	'
12·2		40·1		
	−6·2		70 —	8·1
12·6		41·5		
	−6·3		75 —	8·4
13·0		42·8		
	−6·4			

Celestial Sight Reduction Problems in Non-Standard Conditions

Problem 15-3 (CG-699-NG). The following question is taken directly from the USCG test bank and illustrates how to solve basic celestial sight reduction problems in non-standard atmospheric conditions.

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'. The complete altitude correction tables are available at the end of this Part.

DIP		
Ht. of Eye	Corrⁿ	Ht. of Eye
	−6·5	
13·8	−6·6	45·5
14·2	−6·7	46·9
14·7	−6·8	48·4
15·1		49·8

Step 1: Determine the sextant altitude (hs).
hs = 4° 06.9' (Given)

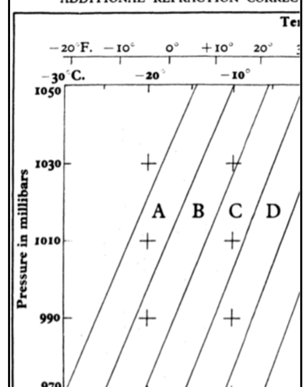
App. Alt.	OCT.–MAR. SUN Lower Limb	Upper Limb	APR.–SEPT. Lower Limb	Upper Limb
° '	'	'	'	'
3 30	+ 3·3	−29·0	+ 3·1	−28·7
35	3·6	28·7	3·3	28·5
40	3·8	28·5	3·5	28·3
45	4·0	28·3	3·7	28·1
50	4·2	28·1	3·9	27·9
3 55	4·4	27·9	4·1	27·7
4 00	+ 4·5	−27·8	+ 4·3	−27·5
05	4·7	27·6	4·5	27·3
10	4·9	27·4	4·6	27·2
15	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 2: Determine the index correction (IC).
Index error: 1.6' on the arc.
Index correction: -1.6'

Step 3: Determine the dip correction.
Height of eye: 47 feet.
Dip correction: -6.7'

Step 4: Determine the apparent altitude (ha).
Apparent altitude (ha) = hs ± IC ± dip
ha = 4° 06.9' – 1.6' – 6.7' = 3° 58.6'

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 5: Determine the main correction, using the altitude correction tables for altitudes less than 10°.
ha: 3° 58.6'
MC (Sun): + 4.5'

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'**

Problem 15-4 (CG-558-NG). The following question is taken directly from the USCG test bank and illustrates how to solve basic celestial sight reduction problems in non-standard atmospheric conditions.

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'. The complete altitude correction tables are available at the end of this Part.

DIP		
Ht. of Eye	Corrⁿ	Ht. of Eye
	−5·4	
9·5		31·5
	−5·5	
9·9		32·7
	5·6	
10·3		33·9
	−5·7	

Step 1: Determine the sextant altitude (hs).
hs = 3° 35.5' (Given)

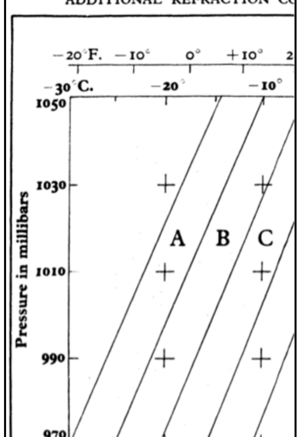
Step 2: Determine the index correction (IC).
Index error: none
Index correction: 0.0'

App. Alt.	SUN OCT.–MAR. Lower Limb	Upper Limb	SUN APR.–SEPT. Lower Limb	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 3: Determine the dip correction.
Height of eye: 32 feet.
Dip correction: - 5.5'

Step 4: Determine the apparent altitude (ha).
Apparent altitude (ha) = hs ± IC ± dip
ha = 3° 35.5' – 0.0' – 5.5' = 3° 30.0'

A4 ALTITUDE CORRECTION
ADDITIONAL REFRACTION CO



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 5: Determine the main correction, using the altitude correction tables for planet altitudes less than 10°.
ha: 3° 30.0'
MC (Planets): - 13.0'

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'

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'**

Celestial Sight Reduction of the Sun Problems

Problem 15-5. The following question is modified from a question in the USCG test bank and illustrates how to solve celestial sight reduction problems involving the Sun.

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 (for detailed instructions, see Part 5 or Part 9).

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° S

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

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	[illegible]	[illegible]		[illegible]
	S.D.	16.3	d	0.4

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° 56.2’

Step 4: Determine the observed altitude.

Apparent altitude (ha): 23° 56.2’

Main correction: +14.1’

Observed altitude (ho): 23° 56.2’ + 14.1’ = 24° 10.3’

15 m	SUN PLANETS	ARIES	MOON	v or d	Corrⁿ
s	° ′	° ′	° ′	′	′
00	3 45·0	3 45·6	3 34·8	0·0	0·0
01	3 45·3	3 45·9	3 35·0	0·1	0·0
02	3 45·5	3 46·1	3 35·2	0·2	0·1
03	3 45·8	3 46·4	3 35·5	0·3	0·1
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

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’

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° 11.5'
DR Longitude: 124° 11.5' 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° (increments solved in step 10 and 12)
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).

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 – 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’ = <u>36.7’</u>

Tabular hc: 23° 51.1’
Alt correction: -36.7’
hc: 23° 51.1’ – 36.7’ = **23° 14.4’**

Dec. Inc.	Altitude Difference (d) Tens					Decimals	Units									
	10′	20′	30′	40′	50′	⇓	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

<u>Problem 15-6 (CG-527)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve celestial sight reduction problems involving the Sun.

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 of the sight using the assumed position?

Answer: 38° 19.4', 048.4° T

Step 1: Determine the DR position of the ship for the time of the sight by mid-latitude sailing (for detailed instructions, see Part 5 or Part 9).

a. Perform preliminary calculations.
0545 fix position: 26° 16' S, 94° 16' E
Course/Speed: 346° T, 20 knots
Morning Sun sight: 0905
0545 to 0905 = 3 hours 20 minutes = 3.33 hours
3.33 hours at 20 knots = D = 66.66 miles covered.

b. Determine the difference in latitude (l).
$l = D\ \cos C$
$l = (66.66)\ \cos(346°)$
$l = (66.66)\ (0.9703)$
$l = 64.68$ = 1.078°

c. Determine the mid-latitude (Lm) and the 0905 DR latitude position.
Latitude 1 = 26° 16' S = 26.266° S
l = 64.68' = 1.078° (to the north)
Latitude 2 = 26.266° S - 1.078° = 25.188° S = <u>25° 11.2' S</u>
$Lm = \frac{26.266° + 25.188°}{2}$ = 25.727° S

d. Determine the departure (p).
$p = D\ \sin C$
$p = (66.66)\ \sin 346°$
$p = (66.66)\ (-0.2419)$
$p = -16.125$

e. Determine the difference in longitude (DLo) and the 0905 DR longitude position.
$DLo = \frac{p}{\cos Lm}$

$DLo = \frac{-16.125}{\cos(25.188)}$

$DLo = \frac{-16.125}{0.9049}$

$DLo = -17.82'$ = 0.298° (to the west)

Longitude 1 = 94° 16' E = 94.266° E

Longitude 2 = 94.266° E – 0.298° = 93.968° E = 93° 58.1' E

0915 DR position: 25° 11.2' S, 93° 58.1' E

G.M.T. d h	SUN G.H.A. ° '	Dec. ° '
8 00	178 35.4	N16 13.9
01	193 35.5	13.2
02	208 35.6	12.4
03	223 35.6	·· 11.7
04	238 35.7	11.0
05	253 35.8	10.3
06	268 35.9	N16 09.6
07	283 36.0	08.9
S 08	298 36.0	08.2
A 09	313 36.1	·· 07.5
T 10	328 36.2	06.8
U 11	343 36.3	06.1
R 12	358 36.4	N16 05.3
D 13	13 36.5	04.6
A 14	28 36.5	03.9
Y 15	43 36.6	·· 03.2
16	58 36.7	02.5
17	73 36.8	01.8
18	88 36.9	N16 01.1
19	103 37.0	16 00.4
20	118 37.0	15 59.6
21	133 37.1	·· 58.9
22	148 37.2	58.2
23	163 37.3	57.5
	S.D. 15.8	*d* 0.7

Step 2: Determine the GMT of the sight.
Chronometer time: 03h 02m 52s
Chronometer error: 02m 17s slow
Correct chronometer time: 03h 05m 09s
Ship time of sight: 0905 zone time
DR Longitude: 94° 16' E corresponds to (-6 ZD).
GMT of sight: 03:05:09 GMT, 8 August

Step 3: Given the sextant altitude (hs), index error and height of eye, determine the apparent altitude (ha).
hs: 38° 07.5' (Given)
Index error/(Index correction): 5.2' off the arc (+5.2' correction)
Height of eye/(dip correction): 72 feet (-8.1' correction)
Apparent altitude (ha): 38° 07.5' + 5.2' – 8.1' = 38° 04.6'

Step 4: Determine the observed altitude.
Apparent altitude (ha): 38° 04.6'
Main correction: +14.8'
Observed altitude (ho): 38° 04.6' + 14.8' = **38° 19.4'**

Step 5: Determine the declination of the Sun for the time of sight.
Declination (hours): N 16° 11.7' (d number = 0.7')
Declination (increments): -0.1'
Declination (total): N 16° 11.7' – 0.1' = N 16° 11.6'

5m s	SUN PLANETS ° '	ARIES ° '	MOON ° '	v or d '	Corrⁿ '
00	1 15·0	1 15·2	1 11·6	0·0	0·0
01	1 15·3	1 15·5	1 11·8	0·1	0·0
02	1 15·5	1 15·7	1 12·1	0·2	0·0
03	1 15·8	1 16·0	1 12·3	0·3	0·0
04	1 16·0	1 16·2	1 12·5	0·4	0·0
05	1 16·3	1 16·5	1 12·8	0·5	0·0
06	1 16·5	1 16·7	1 13·0	0·6	0·1
07	1 16·8	1 17·0	1 13·3	0·7	0·1
08	1 17·0	1 17·2	1 13·5	0·8	0·1
09	1 17·3	1 17·5	1 13·7	0·9	0·1

Step 6: Determine the GHA of the Sun for the time of sight.
GHA (hours): 223° 35.8'
GHA (increment): 1° 17.3'
GHA (total): 223° 35.8' + 1° 17.3' = 224° 53.1'

Step 7: Determine the assumed position (AP) of the ship.
DR latitude based on nearest whole latitude: 25° S
DR long chosen such that GHA + long. is a whole value: 94° 06.9' E

Step 8: Determine the LHA of the Sun for the time of sight and AP.
GHA (Sun): 224° 53.1'
DR Longitude: 94° 06.9' W

LHA = 224° 53.1’ + 94° 06.9’ E = <u>319</u>° (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: 25° S
Declination: N 16° (increments solved in step 10 and 12)
LHA: 319° (Contrary Pages)

HO 229 values:

Computed altitude (hc): 32° 45.2’
Altitude difference (d): -42.6’
Azimuth (z): 131.4°

LATITUDE CONTRARY NAME TO DECLINATION — L.H.A. 41°, 319°

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	44 00.3	−33.0	114.2	43 35.2	−34.0	115.1	43 09.4	−35.1	115.9	42 42.8	−36.1	116.8
1	43 27.3	−33.6	115.4	43 01.2	−34.7	116.2	42 34.3	−35.7	117.0	42 06.7	−36.7	117.8
2	42 53.7	−34.3	116.5	42 26.5	−35.3	117.3	41 58.6	−36.3	118.1	41 30.0	−37.3	118.9
3	42 19.4	−34.9	117.6	41 51.2	−35.9	118.4	41 22.3	−36.9	119.2	40 52.7	−37.8	119.9
4	41 44.5	−35.6	118.7	41 15.3	−36.5	119.5	40 45.4	−37.4	120.2	40 14.9	−38.4	121.0
5	41 08.9	−36.1	119.8	40 38.8	−37.1	120.5	40 08.0	−38.0	121.3	39 36.5	−38.8	122.0
6	40 32.8	−36.7	120.8	40 01.7	−37.6	121.6	39 30.0	−38.5	122.3	38 57.7	−39.4	123.0
7	39 56.1	−37.2	121.9	39 24.1	−38.1	122.6	38 51.5	−39.0	123.3	38 18.3	−39.8	123.9
8	39 18.9	−37.8	122.9	38 46.0	−38.6	123.6	38 12.5	−39.4	124.2	37 38.5	−40.3	124.9
9	38 41.1	−38.3	123.9	38 07.4	−39.1	124.5	37 33.1	−40.0	125.2	36 58.2	−40.7	125.8
10	38 02.8	−38.7	124.9	37 28.3	−39.6	125.5	36 53.1	−40.3	126.1	36 17.5	−41.1	126.7
11	37 24.1	−39.2	125.8	36 48.7	−40.0	126.4	36 12.8	−40.8	127.0	35 36.4	−41.5	127.6
12	36 44.9	−39.7	126.8	36 08.7	−40.4	127.4	35 32.0	−41.1	127.9	34 54.9	−41.9	128.5
13	36 05.2	−40.1	127.7	35 28.3	−40.8	128.3	34 50.9	−41.6	128.8	34 13.0	−42.2	129.4
14	35 25.1	−40.4	128.6	34 47.5	−41.3	129.2	34 09.3	−41.9	129.7	33 30.8	−42.6	130.2
15	34 44.7	−40.9	129.5	34 06.2	−41.5	130.1	33 27.4	−42.2	130.6	32 48.2	−42.9	131.1
16	34 03.8	−41.3	130.4	33 24.7	−42.0	130.9	32 45.2	−42.6	131.4	32 05.3	−43.3	131.9
17	33 22.5	−41.6	131.3	32 42.7	−42.3	131.8	32 02.6	−43.0	132.3	31 22.0	−43.5	132.7
18	32 40.9	−42.0	132.2	32 00.4	−42.6	132.6	31 19.6	−43.2	133.1	30 38.5	−43.8	133.5
19	31 58.9	−42.3	133.0	31 17.8	−42.9	133.5	30 36.4	−43.5	133.9	29 54.7	−44.2	134.3

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.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
42 15.4	−37.1	117.6	41 47.2	−38.0	118.4	41 18.4	−39.0	119.1	40 48.8	−39.9	119.9	0
41 38.3	−37.7	118.6	41 09.2	−38.6	119.4	40 39.4	−39.5	120.2	40 08.9	−40.4	120.9	1
41 00.6	−38.2	119.7	40 30.6	−39.1	120.4	39 59.9	−40.0	121.1	39 28.5	−40.8	121.9	2
40 22.4	−38.7	120.7	39 51.5	−39.6	121.4	39 19.9	−40.5	122.1	38 47.7	−41.3	122.8	3
39 43.7	−39.3	121.7	39 11.9	−40.1	122.4	38 39.4	−40.9	123.1	38 06.4	−41.7	123.7	4
39 04.4	−39.7	122.7	38 31.8	−40.6	123.3	37 58.5	−41.4	124.0	37 24.7	−42.2	124.6	5
38 24.7	−40.2	123.6	37 51.2	−41.0	124.3	37 17.1	−41.7	124.9	36 42.5	−42.5	125.5	6
37 44.5	−40.6	124.6	37 10.2	−41.4	125.2	36 35.4	−42.2	125.8	36 00.0	−42.9	126.4	7
37 03.9	−41.0	125.5	36 28.8	−41.8	126.1	35 53.2	−42.5	126.7	35 17.1	−43.2	127.3	8
36 22.9	−41.5	126.4	35 47.0	−42.2	127.0	35 10.7	−42.9	127.6	34 33.9	−43.6	128.1	9
35 41.4	−41.8	127.3	35 04.8	−42.6	127.9	34 27.8	−43.3	128.4	33 50.3	−44.0	128.9	10
34 59.6	−42.3	128.2	34 22.2	−42.9	128.7	33 44.5	−43.6	129.2	33 06.3	−44.2	129.8	11
34 17.3	−42.5	129.0	33 39.3	−43.2	129.6	33 00.9	−43.9	130.1	32 22.1	−44.5	130.6	12
33 34.8	−43.0	129.9	32 56.1	−43.6	130.4	32 17.0	−44.2	130.9	31 37.6	−44.9	131.3	13
32 51.8	−43.2	130.7	32 12.5	−43.9	131.2	31 32.8	−44.5	131.7	30 52.7	−45.1	132.1	14
32 08.6	−43.6	131.5	31 28.6	−44.2	132.0	30 48.3	−44.8	132.5	30 07.6	−45.4	132.9	15
31 25.0	−43.8	132.4	30 44.4	−44.4	132.8	30 03.5	−45.0	133.2	29 22.2	−45.6	133.6	16
30 41.2	−44.2	133.2	30 00.0	−44.8	133.6	29 18.5	−45.4	134.0	28 36.6	−45.8	134.4	17
29 57.0	−44.4	133.9	29 15.2	−45.0	134.3	28 33.1	−45.5	134.7	27 50.8	−46.1	135.1	18
29 12.6	−44.7	134.7	28 30.2	−45.2	135.1	27 47.6	−45.8	135.5	27 04.7	−46.3	135.8	19

S. Lat. { L.H.A. greater than 180° ....Zn=180°−Z
L.H.A. less than 180°............Zn=180°+Z

Step 10: Determine the azimuth correction for the sight (to account for increments of declination ignored in step 9).

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	25°	131.4°	-	-	00.0’	0
Declination – N	16°	131.4°	132.3°	0.9’	11.6’	0.17°
LHA	319°	131.4°	-	-	00.0’	0

Total correction = <u>0.2°</u>

Step 11: Apply the correction to the base values to determine true azimuth.
Base azimuth: 131.4°
Correction: +0.2°
Corrected azimuth: 131.4° + 0.2° = 131.6°
Note - Check azimuth rules: if LHA greater than 180°, then zn = 180° - z.
Corrected azimuth: 180° - 131.6°= **048.4°**

Celestial Sight Reduction of the Moon and Planets Problems

Problem 15-7 (CG-415). The following question is taken directly from the USCG test bank and illustrates how to solve celestial sight reduction problems involving the Moon.

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: <u>23:22:06 GMT, 24 February</u>

Step 2: Determine the sextant altitude (hs).
hs = 59° 58.6' (Given)

G.M.T.	SUN G.H.A.	SUN Dec.	MOON G.H.A.	v	MOON Dec.	d	H.P.
d h	° '	° '	° '	'	° '	'	'
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 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' = <u>59° 48.6'</u>

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 = ha ± MC
Observed altitude = 59° 48.6’ + 11.8’ = <u>60° 00.4’</u>

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>

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

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>

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

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)

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°

25°, 335° L.H.A. **LATITUDE SAME NAME AS DECLINATION**

S. Lat. {L.H.A. greater than 180° ....Zn=180°–Z
L.H.A. less than 180°............Zn=180°+Z

	23°			24°			25°			26°		
Dec.	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z
°	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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

	27°			28°			29°			30°			
	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	Dec.
	° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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 14: Determine the azimuth correction for the sight (to account for increments of declination ignored in step 13).

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	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’

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

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.

Problem 15-8 (CG-419). The following question is taken directly from the USCG test bank and illustrates how to solve celestial sight reduction problems involving planets.

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?

Answer: 290.3° T. Note that several steps (involving the sextant measurement) are not technically 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

Step 2: Determine the apparent altitude (ha).
hs = 12° 53.4' (Given)
Index error: 4.5' off the arc (index correction = +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'

G.M.T.		ARIES	VENUS −3.4	
		G.H.A.	G.H.A.	Dec.
d	h	° '	° '	° '
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. 7h 44.8m	v −0.9	d 0.4

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)

57m	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn
s	° '	° '	° '	'	'	'	'
00	14 15·0	14 17·3	13 36·1	0·0	0·0	6·0	5·8
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 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}

Dec.	15°			16°			17°			18°		
	Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z
°	° '	'	°	° '	'	°	° '	'	°	° '	'	°
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
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
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
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
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
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	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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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

19°			20°			21°			22°			Dec.
Hc	d	Z	Hc	d	Z	Hc	d	Z	Hc	d	Z	
° '	'	°	° '	'	°	° '	'	°	° '	'	°	°
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
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
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
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
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
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 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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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).

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 – 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 = -<u>0.2°</u>

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’ = +<u>4.0’</u>

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

Tabular hc: 12° 24.7’
Altitude difference correction: +4.0’
hc: 12° 24.7’ + 4.0’ = <u>12° 28.7’</u>

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’ = <u>17.9’</u>
If ho is greater, intercept is <u>towards.</u>

Additional Problems and Answers

All of the following questions labeled “CG” were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface). The problems labeled (NG) come from the Navigation General test bank.

Problem CG-315. 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’*

Problem CG-488. On 4 July you observer 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)?

a) *25° 37.1’*
b) *25° 40.2’- correct*
c) *25° 42.8’*
d) *25° 44.3’*

Problem CG-845. 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’*

Problem CG-459. 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’*

Problem CG-121. 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?

a) *29° 34.1'- correct*
b) *29° 36.0'*
c) *29° 36.3'*
d) *29° 38.2'*

Problem CG-696 (NG). On 16 January you take a sight of a star. The sextant altitude (hs) is 4° 33.0'. The temperature is 10° C and the barometer reads 992 millibars. The height of eye is 42 feet. The index error is 1.9' off the arc. What is the observed altitude (ho)?

a) *4° 10.2'*
b) *4° 14.3'*
c) *4° 17.0'- correct*
d) *4° 24.1'*

Problem CG-322 (NG). 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'*

Problem CG-558 (NG). 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)?

a) *03° 14.5'*
b) *03° 15.8'- correct*
c) *03° 16.2'*
d) *03° 28.8'*

Problem CG-699 (NG). 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?

a) *3° 57.4'*
b) *4° 01.9'- correct*
c) *4° 02.5'*

d) 4° 03.4’

Problem CG-122. During twilight on 28 December around 1800 GMT, in DR position latitude 4° 00’ N, longitude 0° 06’ W, the sextant altitude (hs) of Venus was 30° 46.8’. The height of eye was 36 feet, and the index error was 2.0’ on the arc. The temperature was 68° F. The barometer read 1030mb. Calculate the observed altitude (ho).

a) 30° 35.2’
b) 30° 37.1’
c) 30° 38.1’- correct
d) 30° 40.3’

Problem CG-44. 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

Problem CG-45. At 0800 zone time on 29 June your DR position is latitude 26° 00.0’ N, longitude 75° 29.5’ W. Given a chronometer time of 01h 00m 00s, determine the computed altitude (hc) of the Sun for the assumed position nearest to the above given latitude and longitude.

a) hc 34° 38.6’
b) hc 34° 48.6’
c) hc 34° 58.6’- correct
d) hc 35° 18.6’

Problem CG-53. 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

Problem CG-167. 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) *131.9° T- correct*
d) *133.6° T*

Problem CG-188. 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*

Problem CG-265. 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*

Problem CG-527. 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

Problem CG-336. 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

Problem CG-415. 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?

a) zn = 305.4° T, a = 4.2' towards- correct
b) zn = 234.6° T, a = 4.2' away
c) zn = 305.4° T, a = 1.5' towards
d) zn = 305.4° T, a = 9.2' away

Problem CG-419. On 25 May your vessel's 1858 zone time 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?

a) 069.6° T
b) 110.4° T
c) 249.6° T
d) 290.4° T- correct

Problem CG-420. 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?

a) 143.8° T
b) 147.3° T- correct
c) 148.7° T
d) 149.9° T

Problem CG-427. 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

SUN

OCT.—MAR.

App. Alt.	Lower Limb	Upper Limb
9 34		
	+10.8	-21.5
9 45		
	+10.9	-21.4
9 56		
	+11.0	-21.3
10 08		
	+11.1	-21.2
10 21		
	+11.2	-21.1
10 34		
	+11.3	-21.0
10 47		
	+11.4	-20.9
11 01		
	+11.5	-20.8
11 15		
	+11.6	-20.7
11 30		
	+11.7	-20.6
11 46		
	+11.8	-20.5
12 02		
	+11.9	-20.4
12 19		
	+12.0	-20.3
12 37		
	+12.1	-20.2
12 55		
	+12.2	-20.1
13 14		
	+12.3	-20.0
13 35		
	+12.4	-19.9
13 56		
	+12.5	-19.8
14 18		
	+12.6	-19.7
14 42		
	+12.7	-19.6
15 06		
	+12.8	-19.5
15 32		
	+12.9	-19.4
15 59		
	+13.0	-19.3
16 28		
	+13.1	-19.2
16 59		
	+13.2	-19.1
17 32		
	+13.3	-19.0
18 06		
	+13.4	-18.9
18 42		
	+13.5	-18.8
19 21		
	+13.6	-18.7
20 03		
	+13.7	-18.6
20 48		
	+13.8	-18.5
21 35		
	+13.9	-18.4
22 26		
	+14.0	-18.3
23 22		
	+14.1	-18.2
24 21		
	+14.2	-18.1
25 26		
	+14.3	-18.0
26 36		
	+14.4	-17.9
27 52		
	+14.5	-17.8
29 15		
	+14.6	-17.7
30 46		
	+14.7	-17.6
32 26		
	+14.8	-17.5
34 17		
	+14.9	-17.4
36 20		
	+15.0	-17.3
38 36		
	+15.1	-17.2
41 08		
	+15.2	-17.1
43 59		
	+15.3	-17.0
47 10		
	+15.4	-16.9
50 46		
	+15.5	-16.8
54 49		
	+15.6	-16.7
59 23		
	+15.7	-16.6
64 30		
	+15.8	-16.5
70 12		
	+15.9	-16.4
76 26		
	+16.0	-16.3
83 05		
	+16.1	-16.2
90 00		

APR.—SEPT.

App. Alt.	Lower Limb	Upper Limb
9 39		
	+10.6	-21.2
9 51		
	+10.7	-21.1
10 03		
	+10.8	-21.0
10 15		
	+10.9	-20.9
10 27		
	+11.0	-20.8
10 40		
	+11.1	-20.7
10 54		
	+11.2	-20.6
11 08		
	+11.3	-20.5
11 23		
	+11.4	-20.4
11 38		
	+11.5	-20.3
11 54		
	+11.6	-20.2
12 10		
	+11.7	-20.1
12 28		
	+11.8	-20.0
12 46		
	+11.9	-19.9
13 05		
	+12.0	-19.8
13 24		
	+12.1	-19.7
13 45		
	+12.2	-19.6
14 07		
	+12.3	-19.5
14 30		
	+12.4	-19.4
14 54		
	+12.5	-19.3
15 19		
	+12.6	-19.2
15 46		
	+12.7	-19.1
16 14		
	+12.8	-19.0
16 44		
	+12.9	-18.9
17 15		
	+13.0	-18.8
17 48		
	+13.1	-18.7
18 24		
	+13.2	-18.6
19 01		
	+13.3	-18.5
19 42		
	+13.4	-18.4
20 25		
	+13.5	-18.3
21 11		
	+13.6	-18.2
22 00		
	+13.7	-18.1
22 54		
	+13.8	-18.0
23 51		
	+13.9	-17.9
24 53		
	+14.0	-17.8
26 00		
	+14.1	-17.7
27 13		
	+14.2	-17.6
28 33		
	+14.3	-17.5
30 00		
	+14.4	-17.4
31 35		
	+14.5	-17.3
33 20		
	+14.6	-17.2
35 17		
	+14.7	-17.1
37 26		
	+14.8	-17.0
39 50		
	+14.9	-16.9
42 31		
	+15.0	-16.8
45 31		
	+15.1	-16.7
48 55		
	+15.2	-16.6
52 44		
	+15.3	-16.5
57 02		
	+15.4	-16.4
61 51		
	+15.5	-16.3
67 17		
	+15.6	-16.2
73 16		
	+15.7	-16.1
79 43		
	+15.8	-16.0
86 32		
	+15.9	-15.9
90 00		

STARS AND PLANETS

App. Alt.	Corrⁿ
9 56	
	-5.3
10 08	
	-5.2
10 20	
	-5.1
10 33	
	-5.0
10 46	
	-4.9
11 00	
	-4.8
11 14	
	-4.7
11 29	
	-4.6
11 45	
	-4.5
12 01	
	-4.4
12 18	
	-4.3
12 35	
	-4.2
12 54	
	-4.1
13 13	
	-4.0
13 33	
	-3.9
13 54	
	-3.8
14 16	
	-3.7
14 40	
	-3.6
15 04	
	-3.5
15 30	
	-3.4
15 57	
	-3.3
16 26	
	-3.2
16 56	
	-3.1
17 28	
	-3.0
18 02	
	-2.9
18 38	
	-2.8
19 17	
	-2.7
19 58	
	-2.6
20 42	
	-2.5
21 28	
	-2.4
22 19	
	-2.3
23 13	
	-2.2
24 11	
	-2.1
25 14	
	-2.0
26 22	
	-1.9
27 36	
	-1.8
28 56	
	-1.7
30 24	
	-1.6
32 00	
	-1.5
33 45	
	-1.4
35 40	
	-1.3
37 48	
	-1.2
40 08	
	-1.1
42 44	
	-1.0
45 36	
	-0.9
48 47	
	-0.8
52 18	
	-0.7
56 11	
	-0.6
60 28	
	-0.5
65 08	
	-0.4
70 11	
	-0.3
75 34	
	-0.2
81 13	
	-0.1
87 03	
	0.0
90 00	

App. Alt. — Additional Corrⁿ

1981

VENUS

App. Alt.	Additional Corrⁿ
Jan. 1-Sept. 27	
0°	
	+0.1′
42	
Sept. 28-Nov. 13	
0°	
	+0.2′
47	
Nov. 14-Dec. 10	
0°	
	+0.3′
46	
Dec. 11-Dec. 26	
0°	
	+0.4′
11	
	+0.5
41	
Dec. 27-Dec. 31	
0°	
	+0.5′
6	
	+0.6
20	
	+0.7
31	

MARS

App. Alt.	Additional Corrⁿ
Jan. 1-Dec. 31	
0°	
	+0.1′
60	

DIP

Ht. of Eye (m)	Corrⁿ	Ht. of Eye (ft.)
2.4		8.0
	-2.8	
2.6		8.6
	-2.9	
2.8		9.2
	-3.0	
3.0		9.8
	-3.1	
3.2		10.5
	-3.2	
3.4		11.2
	-3.3	
3.6		11.9
	-3.4	
3.8		12.6
	-3.5	
4.0		13.3
	-3.6	
4.3		14.1
	-3.7	
4.5		14.9
	-3.8	
4.7		15.7
	-3.9	
5.0		16.5
	-4.0	
5.2		17.4
	-4.1	
5.5		18.3
	-4.2	
5.8		19.1
	-4.3	
6.1		20.1
	-4.4	
6.3		21.0
	-4.5	
6.6		22.0
	-4.6	
6.9		22.9
	-4.7	
7.2		23.9
	-4.8	
7.5		24.9
	-4.9	
7.9		26.0
	-5.0	
8.2		27.1
	-5.1	
8.5		28.1
	-5.2	
8.8		29.2
	-5.3	
9.2		30.4
	-5.4	
9.5		31.5
	-5.5	
9.9		32.7
	-5.6	
10.3		33.9
	-5.7	
10.6		35.1
	-5.8	
11.0		36.3
	-5.9	
11.4		37.6
	-6.0	
11.8		38.9
	-6.1	
12.2		40.1
	-6.2	
12.6		41.5
	-6.3	
13.0		42.8
	-6.4	
13.4		44.2
	-6.5	
13.8		45.5
	-6.6	
14.2		46.9
	-6.7	
14.7		48.4
	-6.8	
15.1		49.8
	-6.9	
15.5		51.3
	-7.0	
16.0		52.8
	-7.1	
16.5		54.3
	-7.2	
16.9		55.8
	-7.3	
17.4		57.4
	-7.4	
17.9		58.9
	-7.5	
18.4		60.5
	-7.6	
18.8		62.1
	-7.7	
19.3		63.8
	-7.8	
19.8		65.4
	-7.9	
20.4		67.1
	-8.0	
20.9		68.8
	-8.1	
21.4		70.5

Ht. of Eye	Corrⁿ
m	′
1.0	-1.8
1.5	-2.2
2.0	-2.5
2.5	-2.8
3.0	-3.0
See table ←	
m	′
20	-7.9
22	-8.3
24	-8.6
26	-9.0
28	-9.3
30	-9.6
32	-10.0
34	-10.3
36	-10.6
38	-10.8
40	-11.1
42	-11.4
44	-11.7
46	-11.9
48	-12.2
ft.	′
2	-1.4
4	-1.9
6	-2.4
8	-2.7
10	-3.1
See table ←	
ft.	′
70	-8.1
75	-8.4
80	-8.7
85	-8.9
90	-9.2
95	-9.5
100	-9.7
105	-9.9
110	-10.2
115	-10.4
120	-10.6
125	-10.8
130	-11.1
135	-11.3
140	-11.5
145	-11.7
150	-11.9
155	-12.1

App. Alt. = Apparent altitude = Sextant altitude corrected for index error and dip.

For daylight observations of Venus, see page 260.

App. Alt.	0°–4° Corrⁿ	5°–9° Corrⁿ	10°–14° Corrⁿ	15°–19° Corrⁿ	20°–24° Corrⁿ	25°–29° Corrⁿ	30°–34° Corrⁿ	App. Alt.
′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	′
00	0 33·8	5 58·2	10 62·1	15 62·8	20 62·2	25 60·8	30 58·9	00
10	35·9	58·5	62·2	62·8	62·1	60·8	58·8	10
20	37·8	58·7	62·2	62·8	62·1	60·7	58·8	20
30	39·6	58·9	62·3	62·8	62·1	60·7	58·7	30
40	41·2	59·1	62·3	62·8	62·0	60·6	58·6	40
50	42·6	59·3	62·4	62·7	62·0	60·6	58·5	50
00	1 44·0	6 59·5	11 62·4	16 62·7	21 62·0	26 60·5	31 58·5	00
10	45·2	59·7	62·4	62·7	61·9	60·4	58·4	10
20	46·3	59·9	62·5	62·7	61·9	60·4	58·3	20
30	47·3	60·0	62·5	62·7	61·9	60·3	58·2	30
40	48·3	60·2	62·5	62·7	61·8	60·3	58·2	40
50	49·2	60·3	62·6	62·7	61·8	60·2	58·1	50
00	2 50·0	7 60·5	12 62·6	17 62·7	22 61·7	27 60·1	32 58·0	00
10	50·8	60·6	62·6	62·6	61·7	60·1	57·9	10
20	51·4	60·7	62·6	62·6	61·6	60·0	57·8	20
30	52·1	60·9	62·7	62·6	61·6	59·9	57·8	30
40	52·7	61·0	62·7	62·6	61·5	59·9	57·7	40
50	53·3	61·1	62·7	62·6	61·5	59·8	57·6	50
00	3 53·8	8 61·2	13 62·7	18 62·5	23 61·5	28 59·7	33 57·5	00
10	54·3	61·3	62·7	62·5	61·4	59·7	57·4	10
20	54·8	61·4	62·7	62·5	61·4	59·6	57·4	20
30	55·2	61·5	62·8	62·5	61·3	59·6	57·3	30
40	55·6	61·6	62·8	62·4	61·3	59·5	57·2	40
50	56·0	61·6	62·8	62·4	61·2	59·4	57·1	50
00	4 56·4	9 61·7	14 62·8	19 62·4	24 61·2	29 59·3	34 57·0	00
10	56·7	61·8	62·8	62·3	61·1	59·3	56·9	10
20	57·1	61·9	62·8	62·3	61·1	59·2	56·9	20
30	57·4	61·9	62·8	62·3	61·0	59·1	56·8	30
40	57·7	62·0	62·8	62·2	60·9	59·1	56·7	40
50	57·9	62·1	62·8	62·2	60·9	59·0	56·6	50

H.P.	L U	L U	L U	L U	L U	L U	L U	H.P.
′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′
54·0	0·3 0·9	0·3 0·9	0·4 1·0	0·5 1·1	0·6 1·2	0·7 1·3	0·9 1·5	54·0
54·3	0·7 1·1	0·7 1·2	0·7 1·2	0·8 1·3	0·9 1·4	1·1 1·5	1·2 1·7	54·3
54·6	1·1 1·4	1·1 1·4	1·1 1·4	1·2 1·5	1·3 1·6	1·4 1·7	1·5 1·8	54·6
54·9	1·4 1·6	1·5 1·6	1·5 1·6	1·6 1·7	1·6 1·8	1·8 1·9	1·9 2·0	54·9
55·2	1·8 1·8	1·8 1·8	1·9 1·9	1·9 1·9	2·0 2·0	2·1 2·1	2·2 2·2	55·2
55·5	2·2 2·0	2·2 2·0	2·3 2·1	2·3 2·1	2·4 2·2	2·4 2·3	2·5 2·4	55·5
55·8	2·6 2·2	2·6 2·2	2·6 2·3	2·7 2·3	2·7 2·4	2·8 2·4	2·9 2·5	55·8
56·1	3·0 2·4	3·0 2·5	3·0 2·5	3·0 2·5	3·1 2·6	3·1 2·6	3·2 2·7	56·1
56·4	3·4 2·7	3·4 2·7	3·4 2·7	3·4 2·7	3·4 2·8	3·5 2·8	3·5 2·9	56·4
56·7	3·7 2·9	3·7 2·9	3·8 2·9	3·8 2·9	3·8 3·0	3·8 3·0	3·9 3·0	56·7
57·0	4·1 3·1	4·1 3·1	4·1 3·1	4·1 3·1	4·2 3·1	4·2 3·2	4·2 3·2	57·0
57·3	4·5 3·3	4·5 3·3	4·5 3·3	4·5 3·3	4·5 3·3	4·5 3·4	4·6 3·4	57·3
57·6	4·9 3·5	4·9 3·5	4·9 3·5	4·9 3·5	4·9 3·5	4·9 3·5	4·9 3·6	57·6
57·9	5·3 3·8	5·3 3·8	5·2 3·8	5·2 3·7	5·2 3·7	5·2 3·7	5·2 3·7	57·9
58·2	5·6 4·0	5·6 4·0	5·6 4·0	5·6 4·0	5·6 3·9	5·6 3·9	5·6 3·9	58·2
58·5	6·0 4·2	6·0 4·2	6·0 4·2	6·0 4·2	6·0 4·1	5·9 4·1	5·9 4·1	58·5
58·8	6·4 4·4	6 4 4·4	6·4 4·4	6·3 4·4	6·3 4·3	6·3 4·3	6·2 4·2	58·8
59·1	6·8 4·6	6·8 4·6	6·7 4·6	6·7 4·6	6·7 4·5	6·6 4·5	6·6 4·4	59·1
59·4	7·2 4·8	7·1 4·8	7·1 4·8	7·1 4·8	7·0 4·7	7·0 4·7	6·9 4·6	59·4
59·7	7·5 5·1	7·5 5·0	7·5 5·0	7·5 5·0	7·4 4·9	7·3 4·8	7·2 4·7	59·7
60·0	7·9 5·3	7·9 5·3	7·9 5·2	7·8 5·2	7·8 5·1	7·7 5·0	7·6 4·9	60·0
60·3	8·3 5·5	8·3 5·5	8·2 5·4	8·2 5·4	8·1 5·3	8·0 5·2	7·9 5·1	60·3
60·6	8·7 5·7	8·7 5·7	8·6 5·7	8·6 5·6	8·5 5·5	8·4 5·4	8·2 5·3	60·6
60·9	9·1 5·9	9·0 5·9	9·0 [illegible]	8·9 5·8	8·8 5·7	8·7 5·6	8·6 5·4	60·9
61·2	9·5 6·2	9·4 6·1	9·4 6·1	9·3 6·0	9·2 5·9	9·1 5·8	8·9 5·6	61·2
61·5	9·8 6·4	9·8 6·3	9·7 6·3	9·7 6·2	9·5 6·1	9·4 5·9	9·2 5·8	61·5

DIP

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

MOON CORRECTION TABLE

The correction is in two parts; the first correction is taken from the upper part of the table with argument apparent altitude, and the second from the lower part, with argument H.P., in the same column as that from which the first correction was taken. Separate corrections are given in the lower part for lower (L) and upper (U) limbs. All corrections are to be **added** to apparent altitude, *but 30′ is to be subtracted from the altitude of the upper limb.*

For corrections for pressure and temperature see page A4.

For bubble sextant observations ignore dip, take the mean of upper and lower limb corrections and subtract 15′ from the altitude.

App. Alt. - Apparent altitude - Sextant altitude corrected for index error and dip.

ALTITUDE CORRECTION TABLES 35°-90°—MOON

App. Alt.	35°-39° Corrⁿ	40°-44° Corrⁿ	45°-49° Corrⁿ	50°-54° Corrⁿ	55°-59° Corrⁿ	60°-64° Corrⁿ	65°-69° Corrⁿ	70°-74° Corrⁿ	75°-79° Corrⁿ	80°-84° Corrⁿ	85°-89° Corrⁿ	App. Alt.
′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	′
00	**35** 56.5	**40** 53.7	**45** 50.5	**50** 46.9	**55** 43.1	**60** 38.9	**65** 34.6	**70** 30.1	**75** 25.3	**80** 20.5	**85** 15.6	00
10	56.4	53.6	50.4	46.8	42.9	38.8	34.4	29.9	25.2	20.4	15.5	10
20	56.3	53.5	50.2	46.7	42.8	38.7	34.3	29.7	25.0	20.2	15.3	20
30	56.2	53.4	50.1	46.5	42.7	38.5	34.1	29.6	24.9	20.0	15.1	30
40	56.2	53.3	50.0	46.4	42.5	38.4	34.0	29.4	24.7	19.9	15.0	40
50	56.1	53.2	49.9	46.3	42.4	38.2	33.8	29.3	24.5	19.7	14.8	50
00	**36** 56.0	**41** 53.1	**46** 49.8	**51** 46.2	**56** 42.3	**61** 38.1	**66** 33.7	**71** 29.1	**76** 24.4	**81** 19.6	**86** 14.6	00
10	55.9	53.0	49.7	46.0	42.1	37.9	33.5	29.0	24.2	19.4	14.5	10
20	55.8	52.8	49.5	45.9	42.0	37.8	33.4	28.8	24.1	19.2	14.3	20
30	55.7	52.7	49.4	45.8	41.8	37.7	33.2	28.7	23.9	19.1	14.1	30
40	55.6	52.6	49.3	45.7	41.7	37.5	33.1	28.5	23.8	18.9	14.0	40
50	55.5	52.5	49.2	45.5	41.6	37.4	32.9	28.3	23.6	18.7	13.8	50
00	**37** 55.4	**42** 52.4	**47** 49.1	**52** 45.4	**57** 41.4	**62** 37.2	**67** 32.8	**72** 28.2	**77** 23.4	**82** 18.6	**87** 13.7	00
10	55.3	52.3	49.0	45.3	41.3	37.1	32.6	28.0	23.3	18.4	13.5	10
20	55.2	52.2	48.8	45.2	41.2	36.9	32.5	27.9	23.1	18.2	13.3	20
30	55.1	52.1	48.7	45.0	41.0	36.8	32.3	27.7	22.9	18.1	13.2	30
40	55.0	52.0	48.6	44.9	40.9	36.6	32.2	27.6	22.8	17.9	13.0	40
50	55.0	51.9	48.5	44.8	40.8	36.5	32.0	27.4	22.6	17.8	12.8	50
00	**38** 54.9	**43** 51.8	**48** 48.4	**53** 44.6	**58** 40.6	**63** 36.4	**68** 31.9	**73** 27.2	**78** 22.5	**83** 17.6	**88** 12.7	00
10	54.8	51.7	48.2	44.5	40.5	36.2	31.7	27.1	22.3	17.4	12.5	10
20	54.7	51.6	48.1	44.4	40.3	36.1	31.6	26.9	22.1	17.3	12.3	20
30	54.6	51.5	48.0	44.2	40.2	35.9	31.4	26.8	22.0	17.1	12.2	30
40	54.5	51.4	47.9	44.1	40.1	35.8	31.3	26.6	21.8	16.9	12.0	40
50	54.4	51.2	47.8	44.0	39.9	35.6	31.1	26.5	21.7	16.8	11.8	50
00	**39** 54.3	**44** 51.1	**49** 47.6	**54** 43.9	**59** 39.8	**64** 35.5	**69** 31.0	**74** 26.3	**79** 21.5	**84** 16.6	**89** 11.7	00
10	54.2	51.0	47.5	43.7	39.6	35.3	30.8	26.1	21.3	16.5	11.5	10
20	54.1	50.9	47.4	43.6	39.5	35.2	30.7	26.0	21.2	16.3	11.4	20
30	54.0	50.8	47.3	43.5	39.4	35.0	30.5	25.8	21.0	16.1	11.2	30
40	53.9	50.7	47.2	43.3	39.2	34.9	30.4	25.7	20.9	16.0	11.0	40
50	53.8	50.6	47.0	43.2	39.1	34.7	30.2	25.5	20.7	15.8	10.9	50
H.P.	**L U**	**L U**	**L U**	**L U**	**L U**	**L U**	**L U**	**L U**	**L U**	**L U**	**L U**	**H.P.**
′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′ ′	′
54.0	1.1 1.7	1.3 1.9	1.5 2.1	1.7 2.4	2.0 2.6	2.3 2.9	2.6 3.2	2.9 3.5	3.2 3.8	3.5 4.1	3.8 4.5	54.0
54.3	1.4 1.8	1.6 2.0	1.8 2.2	2.0 2.5	2.3 2.7	2.5 3.0	2.8 3.2	3.0 3.5	3.3 3.8	3.6 4.1	3.9 4.4	54.3
54.6	1.7 2.0	1.9 2.2	2.1 2.4	2.3 2.6	2.5 2.8	2.7 3.0	3.0 3.3	3.2 3.5	3.5 3.8	3.7 4.1	4.0 4.3	54.6
54.9	2.0 2.2	2.2 2.3	2.3 2.5	2.5 2.7	2.7 2.9	2.9 3.1	3.2 3.3	3.4 3.5	3.6 3.8	3.9 4.0	4.1 4.3	54.9
55.2	2.3 2.3	2.5 2.4	2.6 2.6	2.8 2.8	3.0 2.9	3.2 3.1	3.4 3.3	3.6 3.5	3.8 3.7	4.0 4.0	4.2 4.2	55.2
55.5	2.7 2.5	2.8 2.6	2.9 2.7	3.1 2.9	3.2 3.0	3.4 3.2	3.6 3.4	3.7 3.5	3.9 3.7	4.1 3.9	4.3 4.1	55.5
55.8	3.0 2.6	3.1 2.7	3.2 2.8	3.3 3.0	3.5 3.1	3.6 3.3	3.8 3.4	3.9 3.6	4.1 3.7	4.2 3.9	4.4 4.0	55.8
56.1	3.3 2.8	3.4 2.9	3.5 3.0	3.6 3.1	3.7 3.2	3.8 3.3	4.0 3.4	4.1 3.6	4.2 3.7	4.4 3.8	4.5 4.0	56.1
56.4	3.6 2.9	3.7 3.0	3.8 3.1	3.9 3.2	3.9 3.3	4.0 3.4	4.1 3.5	4.3 3.6	4.4 3.7	4.5 3.8	4.6 3.9	56.4
56.7	3.9 3.1	4.0 3.1	4.1 3.2	4.1 3.3	4.2 3.3	4.3 3.4	4.3 3.5	4.4 3.6	4.5 3.7	4.6 3.8	4.7 3.8	56.7
57.0	4.3 3.2	4.3 3.3	4.3 3.3	4.4 3.4	4.4 3.4	4.5 3.5	4.5 3.5	4.6 3.6	4.7 3.6	4.7 3.7	4.8 3.8	57.0
57.3	4.6 3.4	4.6 3.4	4.6 3.4	4.6 3.5	4.7 3.5	4.7 3.5	4.7 3.6	4.8 3.6	4.8 3.6	4.8 3.7	4.9 3.7	57.3
57.6	4.9 3.6	4.9 3.6	4.9 3.6	4.9 3.6	4.9 3.6	4.9 3.6	4.9 3.6	4.9 3.6	5.0 3.6	5.0 3.6	5.0 3.6	57.6
57.9	5.2 3.7	5.2 3.7	5.2 3.7	5.2 3.7	5.2 3.7	5.1 3.6	5.1 3.6	5.1 3.6	5.1 3.6	5.1 3.6	5.1 3.6	57.9
58.2	5.5 3.9	5.5 3.8	5.5 3.8	5.4 3.8	5.4 3.7	5.4 3.7	5.3 3.7	5.3 3.6	5.2 3.6	5.2 3.5	5.2 3.5	58.2
58.5	5.9 4.0	5.8 4.0	5.8 3.9	5.7 3.9	5.6 3.8	5.6 3.8	5.5 3.7	5.5 3.6	5.4 3.6	5.3 3.5	5.3 3.4	58.5
58.8	6.2 4.2	6.1 4.1	6.0 4.1	6.0 4.0	5.9 3.9	5.8 3.8	5.7 3.7	5.6 3.6	5.5 3.5	5.4 3.5	5.3 3.4	58.8
59.1	6.5 4.3	6.4 4.3	6.3 4.2	6.2 4.1	6.1 4.0	6.0 3.9	5.9 3.8	5.8 3.6	5.7 3.5	5.6 3.4	5.4 3.3	59.1
59.4	6.8 4.5	6.7 4.4	6.6 4.3	6.5 4.2	6.4 4.1	6.2 3.9	6.1 3.8	6.0 3.7	5.8 3.5	5.7 3.4	5.5 3.2	59.4
59.7	7.1 4.6	7.0 4.5	6.9 4.4	6.8 4.3	6.6 4.1	6.5 4.0	6.3 3.8	6.2 3.7	6.0 3.5	5.8 3.3	5.6 3.2	59.7
60.0	7.5 4.8	7.3 4.7	7.2 4.5	7.0 4.4	6.9 4.2	6.7 4.0	6.5 3.9	6.3 3.7	6.1 3.5	5.9 3.3	5.7 3.1	60.0
60.3	7.8 5.0	7.6 4.8	7.5 4.7	7.3 4.5	7.1 4.3	6.9 4.1	6.7 3.9	6.5 3.7	6.3 3.5	6.0 3.2	5.8 3.0	60.3
60.6	8.1 5.1	7.9 5.0	7.7 4.8	7.6 4.6	7.3 4.4	7.1 4.2	6.9 3.9	6.7 3.7	6.4 3.4	6.2 3.2	5.9 2.9	60.6
60.9	8.4 5.3	8.2 5.1	8.0 4.9	7.8 4.7	7.6 4.5	7.3 4.2	7.1 4.0	6.8 3.7	6.6 3.4	6.3 3.2	6.0 2.9	60.9
61.2	8.7 5.4	8.5 5.2	8.3 5.0	8.1 4.8	7.8 4.5	7.6 4.3	7.3 4.0	7.0 3.7	6.7 3.4	6.4 3.1	6.1 2.8	61.2
61.5	9.1 5.6	8.8 5.4	8.6 5.1	8.3 4.9	8.1 4.6	7.8 4.3	7.5 4.0	7.2 3.7	6.9 3.4	6.5 3.1	6.2 2.7	61.5

ALTITUDE CORRECTION TABLES 0°–10°—SUN, STARS, PLANETS A3

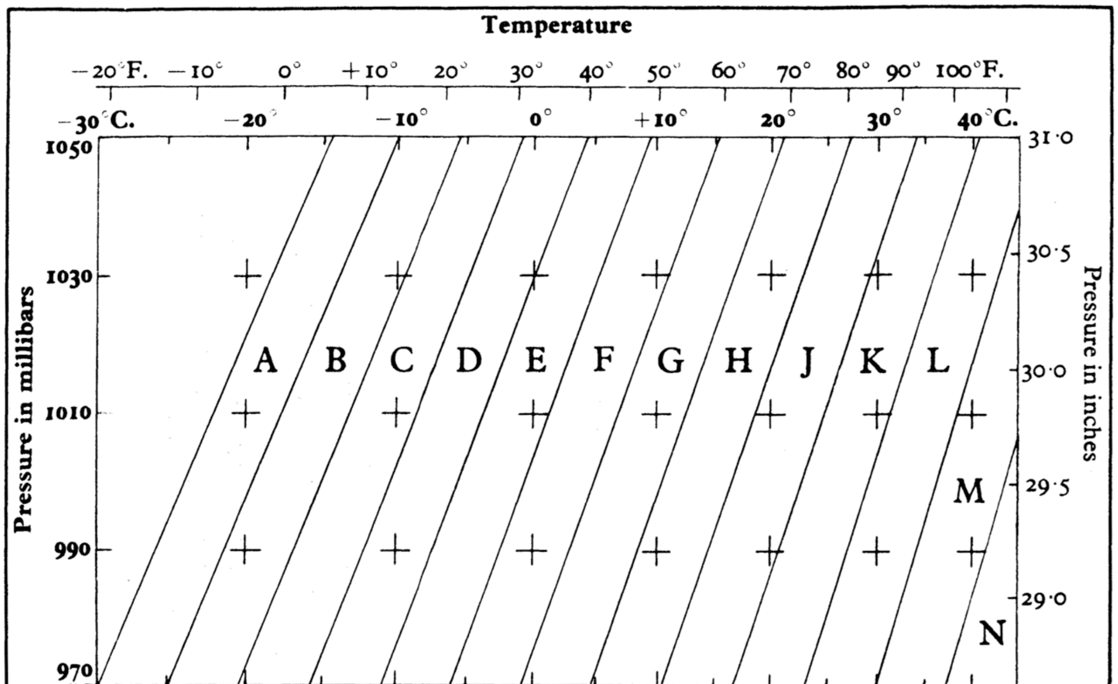
App. Alt.	SUN Oct.–Mar. Lower Limb	SUN Oct.–Mar. Upper Limb	SUN Apr.–Sept. Lower Limb	SUN Apr.–Sept. Upper Limb	STARS PLANETS
° ′	′	′	′	′	′
0 00	−18·2	−50·5	−18·4	−50·2	−34·5
03	17·5	49·8	17·8	49·6	33·8
06	16·9	49·2	17·1	48·9	33·2
09	16·3	48·6	16·5	48·3	32·6
12	15·7	48·0	15·9	47·7	32·0
15	15·1	47·4	15·3	47·1	31·4
0 18	−14·5	−46·8	−14·8	−46·6	−30·8
21	14·0	46·3	14·2	46·0	30·3
24	13·5	45·8	13·7	45·5	29·8
27	12·9	45·2	13·2	45·0	29·2
30	12·4	44·7	12·7	44·5	28·7
33	11·9	44·2	12·2	44·0	28·2
0 36	−11·5	−43·8	−11·7	−43·5	−27·8
39	11·0	43·3	11·2	43·0	27·3
42	10·5	42·8	10·8	42·6	26·8
45	10·1	42·4	10·3	42·1	26·4
48	9·6	41·9	9·9	41·7	25·9
51	9·2	41·5	9·5	41·3	25·5
0 54	−8·8	−41·1	−9·1	−40·9	−25·1
0 57	8·4	40·7	8·7	40·5	24·7
1 00	8·0	40·3	8·3	40·1	24·3
03	7·7	40·0	7·9	39·7	24·0
06	7·3	39·6	7·5	39·3	23·6
09	6·9	39·2	7·2	39·0	23·2
1 12	−6·6	−38·9	−6·8	−38·6	−22·9
15	6·2	38·5	6·5	38·3	22·5
18	5·9	38·2	6·2	38·0	22·2
21	5·6	37·9	5·8	37·6	21·9
24	5·3	37·6	5·5	37·3	21·6
27	4·9	37·2	5·2	37·0	21·2
1 30	−4·6	−36·9	−4·9	−36·7	−20·9
35	4·2	36·5	4·4	36·2	20·5
40	3·7	36·0	4·0	35·8	20·0
45	3·2	35·5	3·5	35·3	19·5
50	2·8	35·1	3·1	34·9	19·1
1 55	2·4	34·7	2·6	34·4	18·7
2 00	−2·0	−34·3	−2·2	−34·0	−18·3
05	1·6	33·9	1·8	33·6	17·9
10	1·2	33·5	1·5	33·3	17·5
15	0·9	33·2	1·1	32·9	17·2
20	0·5	32·8	0·8	32·6	16·8
25	−0·2	32·5	0·4	32·2	16·5
2 30	+0·2	−32·1	−0·1	−31·9	−16·1
35	0·5	31·8	+0·2	31·6	15·8
40	0·8	31·5	0·5	31·3	15·5
45	1·1	31·2	0·8	31·0	15·2
50	1·4	30·9	1·1	30·7	14·9
2 55	1·6	30·7	1·4	30·4	14·7
3 00	+1·9	−30·4	+1·7	−30·1	−14·4
05	2·2	30·1	1·9	29·9	14·1
10	2·4	29·9	2·1	29·7	13·9
15	2·6	29·7	2·4	29·4	13·7
20	2·9	29·4	2·6	29·2	13·4
25	3·1	29·2	2·9	28·9	13·2
3 30	+3·3	−29·0	+3·1	−28·7	−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
4 00	+4·5	−27·8	+4·3	−27·5	−11·8
05	4·7	27·6	4·5	27·3	11·6
10	4·9	27·4	4·6	27·2	11·4
15	5·1	27·2	4·8	27·0	11·2
20	5·2	27·1	5·0	26·8	11·1
25	5·4	26·9	5·1	26·7	10·9
4 30	+5·6	−26·7	+5·3	−26·5	−10·7
35	5·7	26·6	5·5	26·3	10·6
40	5·9	26·4	5·6	26·2	10·4
45	6·0	26·3	5·8	26·0	10·3
50	6·2	26·1	5·9	25·9	10·1
4 55	6·3	26·0	6·0	25·8	10·0
5 00	+6·4	−25·9	+6·2	−25·6	−9·9
05	6·6	25·7	6·3	25·5	9·7
10	6·7	25·6	6·4	25·4	9·6
15	6·8	25·5	6·6	25·2	9·5
20	6·9	25·4	6·7	25·1	9·4
25	7·1	25·2	6·8	25·0	9·2
5 30	+7·2	−25·1	+6·9	−24·9	−9·1
35	7·3	25·0	7·0	24·8	9·0
40	7·4	24·9	7·2	24·6	8·9
45	7·5	24·8	7·3	24·5	8·8
50	7·6	24·7	7·4	24·4	8·7
5 55	7·7	24·6	7·5	24·3	8·6
6 00	+7·8	−24·5	+7·6	−24·2	−8·5
10	8·0	24·3	7·8	24·0	8·3
20	8·2	24·1	8·0	23·8	8·1
30	8·4	23·9	8·1	23·7	7·9
40	8·6	23·7	8·3	23·5	7·7
6 50	8·7	23·6	8·5	23·3	7·6
7 00	+8·9	−23·4	+8·6	−23·2	7·4
10	9·1	23·2	8·8	23·0	7·2
20	9·2	23·1	9·0	22·8	7·1
30	9·3	23·0	9·1	22·7	7·0
40	9·5	22·8	9·2	22·6	6·8
7 50	9·6	22·7	9·4	22·4	6·7
8 00	+9·7	−22·6	+9·5	−22·3	−6·6
10	9·9	22·4	9·6	22·2	6·4
20	10·0	22·3	9·7	22·1	6·3
30	10·1	22·2	9·8	22·0	6·2
40	10·2	22·1	10·0	21·8	6·1
8 50	10·3	22·0	10·1	21·7	6·0
9 00	+10·4	−21·9	+10·2	−21·6	−5·9
10	10·5	21·8	10·3	21·5	5·8
20	10·6	21·7	10·4	21·4	5·7
30	10·7	21·6	10·5	21·3	5·6
40	10·8	21·5	10·6	21·2	5·5
9 50	10·9	21·4	10·6	21·2	5·4
10 00	+11·0	−21·3	+10·7	−21·1	−5·3

Additional corrections for temperature and pressure are given on the following page.
For bubble sextant observations ignore dip and use the star corrections for Sun, planets, and stars.

A4 ALTITUDE CORRECTION TABLES—ADDITIONAL CORRECTIONS

ADDITIONAL REFRACTION CORRECTIONS FOR NON-STANDARD CONDITIONS



App. Alt.	A	B	C	D	E	F	G	H	J	K	L	M	N	App. Alt.
° ′	′	′	′	′	′	′	′	′	′	′	′	′	′	° ′
0 00	−6·9	−5·7	−4·6	−3·4	−2·3	−1·1	0·0	+1·1	+2·3	+3·4	+4·6	+5·7	+6·9	0 00
0 30	5·2	4·4	3·5	2·6	1·7	0·9	0·0	0·9	1·7	2·6	3·5	4·4	5·2	0 30
1 00	4·3	3·5	2·8	2·1	1·4	0·7	0·0	0·7	1·4	2·1	2·8	3·5	4·3	1 00
1 30	3·5	2·9	2·4	1·8	1·2	0·6	0·0	0·6	1·2	1·8	2·4	2·9	3·5	1 30
2 00	3·0	2·5	2·0	1·5	1·0	0·5	0·0	0·5	1·0	1·5	2·0	2·5	3·0	2 00
2 30	−2·5	−2·1	−1·6	−1·2	−0·8	−0·4	0·0	+0·4	+0·8	+1·2	+1·6	+2·1	+2·5	2 30
3 00	2·2	1·8	1·5	1·1	0·7	0·4	0·0	0·4	0·7	1·1	1·5	1·8	2·2	3 00
3 30	2·0	1·6	1·3	1·0	0·7	0·3	0·0	0·3	0·7	1·0	1·3	1·6	2·0	3 30
4 00	1·8	1·5	1·2	0·9	0·6	0·3	0·0	0·3	0·6	0·9	1·2	1·5	1·8	4 00
4 30	1·6	1·4	1·1	0·8	0·5	0·3	0·0	0·3	0·5	0·8	1·1	1·4	1·6	4 30
5 00	−1·5	−1·3	−1·0	−0·8	−0·5	−0·2	0·0	+0·2	+0·5	+0·8	+1·0	+1·3	+1·5	5 00
6	1·3	1·1	0·9	0·6	0·4	0·2	0·0	0·2	0·4	0·6	0·9	1·1	1·3	6
7	1·1	0·9	0·7	0·6	0·4	0·2	0·0	0·2	0·4	0·6	0·7	0·9	1·1	7
8	1·0	0·8	0·7	0·5	0·3	0·2	0·0	0·2	0·3	0·5	0·7	0·8	1·0	8
9	0·9	0·7	0·6	0·4	0·3	0·1	0·0	0·1	0·3	0·4	0·6	0·7	0·9	9
10 00	−0·8	−0·7	−0·5	−0·4	−0·3	−0·1	0·0	+0·1	+0·3	+0·4	+0·5	+0·7	+0·8	10 00
12	0·7	0·6	0·5	0·3	0·2	0·1	0·0	0·1	0·2	0·3	0·5	0·6	0·7	12
14	0·6	0·5	0·4	0·3	0·2	0·1	0·0	0·1	0·2	0·3	0·4	0·5	0·6	14
16	0·5	0·4	0·3	0·3	0·2	0·1	0·0	0·1	0·2	0·3	0·3	0·4	0·5	16
18	0·4	0·4	0·3	0·2	0·2	0·1	0·0	0·1	0·2	0·2	0·3	0·4	0·4	18
20 00	−0·4	−0·3	−0·3	−0·2	−0·1	−0·1	0·0	+0·1	+0·1	+0·2	+0·3	+0·3	+0·4	20 00
25	0·3	0·3	0·2	0·2	0·1	−0·1	0·0	+0·1	0·1	0·2	0·2	0·3	0·3	25
30	0·3	0·2	0·2	0·1	0·1	0·0	0·0	0·0	0·1	0·1	0·2	0·2	0·3	30
35	0·2	0·2	0·1	0·1	0·1	0·0	0·0	0·0	0·1	0·1	0·1	0·2	0·2	35
40	0·2	0·1	0·1	0·1	−0·1	0·0	0·0	0·0	+0·1	0·1	0·1	0·1	0·2	40
50 00	−0·1	−0·1	−0·1	−0·1	0·0	0·0	0·0	0·0	0·0	+0·1	+0·1	+0·1	+0·1	50 00

The graph is entered with arguments temperature and pressure to find a zone letter; using as arguments this zone letter and apparent altitude (sextant altitude corrected for dip), a correction is taken from the table. This correction is to be applied to the sextant altitude in addition to the corrections for standard conditions (for the Sun, stars and planets from page A2 and for the Moon from pages xxxiv and xxxv).

INTERPOLATION TABLE

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff. and Corr.
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	0.0 / 0.0 / 48.2
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	0.0	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	0.0	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	0.0	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	0.0	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	0.0	0.1	0.1	0.1	16.2 / 0.1 / 48.6
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	0.0	0.1	0.1	0.1	
0.7	0.1	0.2	0.4	0.5	0.6	.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	
0.8	0.1	0.3	0.4	0.5	0.7	.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.1	0.1	0.1	
1.0	0.1	0.3	0.5	0.6	0.8	.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	8.2 / 0.1 / 24.6 / 0.2 / 41.0
1.1	0.2	0.3	0.5	0.7	0.9	.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
1.2	0.2	0.4	0.6	0.8	1.0	.2	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
1.3	0.2	0.4	0.6	0.9	1.1	.3	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
1.4	0.2	0.5	0.7	0.9	1.2	.4	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
1.5	0.3	0.5	0.8	1.0	1.3	.5	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
1.6	0.3	0.5	0.8	1.1	1.3	.6	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
1.7	0.3	0.6	0.9	1.2	1.4	.7	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
1.8	0.3	0.6	0.9	1.2	1.5	.8	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
1.9	0.4	0.7	1.0	1.3	1.6	.9	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	
2.0	0.3	0.6	1.0	1.3	1.6	.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	5.0 / 0.1 / 15.0 / 0.2 / 25.0 / 0.3 / 35.1
2.1	0.3	0.7	1.0	1.4	1.7	.1	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	
2.2	0.3	0.7	1.1	1.4	1.8	.2	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	
2.3	0.4	0.8	1.1	1.5	1.9	.3	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	
2.4	0.4	0.8	1.2	1.6	2.0	.4	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	
2.5	0.4	0.8	1.3	1.7	2.1	.5	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	
2.6	0.4	0.9	1.3	1.7	2.2	.6	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	
2.7	0.5	0.9	1.4	1.8	2.3	.7	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	
2.8	0.5	1.0	1.4	1.9	2.4	.8	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	
2.9	0.5	1.0	1.5	2.0	2.5	.9	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	
3.0	0.5	1.0	1.5	2.0	2.5	.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	3.6 / 0.1 / 10.9 / 0.2 / 18.2 / 0.3 / 25.5 / 0.4 / 32.8 / 0.5 / 40.1
3.1	0.5	1.0	1.5	2.0	2.6	.1	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	
3.2	0.5	1.0	1.6	2.1	2.6	.2	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	
3.3	0.5	1.1	1.6	2.2	2.7	.3	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	
3.4	0.6	1.1	1.7	2.3	2.8	.4	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	
3.5	0.6	1.2	1.8	2.3	2.9	.5	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	
3.6	0.6	1.2	1.8	2.4	3.0	.6	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	
3.7	0.6	1.3	1.9	2.5	3.1	.7	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	
3.8	0.7	1.3	1.9	2.6	3.2	.8	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	
3.9	0.7	1.3	2.0	2.6	3.3	.9	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	
4.0	0.6	1.3	2.0	2.6	3.3	.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	2.9 / 0.1 / 8.6 / 0.2 / 14.4 / 0.3 / 20.2 / 0.4 / 25.9 / 0.5 / 31.7 / 0.6 / 37.5
4.1	0.7	1.3	2.0	2.7	3.4	.1	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	
4.2	0.7	1.4	2.1	2.8	3.5	.2	0.0	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	
4.3	0.7	1.4	2.1	2.9	3.6	.3	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	
4.4	0.7	1.5	2.2	2.9	3.7	.4	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	
4.5	0.8	1.5	2.3	3.0	3.8	.5	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	
4.6	0.8	1.5	2.3	3.1	3.8	.6	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	
4.7	0.8	1.6	2.4	3.2	3.9	.7	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.7	
4.8	0.8	1.6	2.4	3.2	4.0	.8	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	
4.9	0.9	1.7	2.5	3.3	4.1	.9	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	
5.0	0.8	1.6	2.5	3.3	4.1	.0	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	2.4 / 0.1 / 7.2 / 0.2 / 12.0 / 0.3 / 16.8 / 0.4 / 21.6 / 0.5 / 26.4 / 0.6 / 31.2 / 0.7 / 36.0
5.1	0.8	1.7	2.5	3.4	4.2	.1	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	
5.2	0.8	1.7	2.6	3.4	4.3	.2	0.0	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	
5.3	0.9	1.8	2.6	3.5	4.4	.3	0.0	0.1	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	
5.4	0.9	1.8	2.7	3.6	4.5	.4	0.0	0.1	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	
5.5	0.9	1.8	2.8	3.7	4.6	.5	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	
5.6	0.9	1.9	2.8	3.7	4.7	.6	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
5.7	1.0	1.9	2.9	3.8	4.8	.7	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
5.8	1.0	2.0	2.9	3.9	4.9	.8	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
5.9	1.0	2.0	3.0	4.0	5.0	.9	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
6.0	1.0	2.0	3.0	4.0	5.0	.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	2.1 / 0.1 / 6.2 / 0.2 / 10.4 / 0.3 / 14.5 / 0.4 / 18.6 / 0.5 / 22.8 / 0.6 / 26.9 / 0.7 / 31.1 / 0.8 / 35.2
6.1	1.0	2.0	3.0	4.0	5.1	.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
6.2	1.0	2.0	3.1	4.1	5.1	.2	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
6.3	1.0	2.1	3.1	4.2	5.2	.3	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	
6.4	1.1	2.1	3.2	4.3	5.3	.4	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	
6.5	1.1	2.2	3.3	4.3	5.4	.5	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	
6.6	1.1	2.2	3.3	4.4	5.5	.6	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	
6.7	1.1	2.3	3.4	4.5	5.6	.7	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	
6.8	1.2	2.3	3.4	4.6	5.7	.8	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
6.9	1.2	2.3	3.5	4.6	5.8	.9	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
7.0	1.1	2.3	3.5	4.6	5.8	.0	0.0	0.1	0.2	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.8 / 0.1 / 5.5 / 0.2 / 9.1 / 0.3 / 12.8 / 0.4 / 16.5 / 0.5 / 20.1 / 0.6 / 23.8 / 0.7 / 27.4 / 0.8 / 31.1 / 0.9 / 34.7
7.1	1.2	2.3	3.5	4.7	5.9	.1	0.0	0.1	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
7.2	1.2	2.4	3.6	4.8	6.0	.2	0.0	0.1	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1	
7.3	1.2	2.4	3.6	4.9	6.1	.3	0.0	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	
7.4	1.2	2.5	3.7	4.9	6.2	.4	0.0	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	
7.5	1.3	2.5	3.8	5.0	6.3	.5	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.1	
7.6	1.3	2.5	3.8	5.1	6.3	.6	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.1	
7.7	1.3	2.6	3.9	5.2	6.4	.7	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1	
7.8	1.3	2.6	3.9	5.2	6.5	.8	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1	
7.9	1.4	2.7	4.0	5.3	6.6	.9	0.1	0.2	0.3	0.4	0.5	0.7	0.8	0.9	1.0	1.1	

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff. and Corr.
8.0	1.3	2.6	4.0	5.3	6.6	.0	0.0	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.6 / 0.1 / 4.8 / 0.2 / 8.0 / 0.3 / 11.2 / 0.4 / 14.5 / 0.5 / 17.7 / 0.6 / 20.9 / 0.7 / 24.1 / 0.8 / 27.3 / 0.9 / 30.5 / 1.0 / 33.7 / 1.1 / 36.9
8.1	1.3	2.7	4.0	5.4	6.7	.1	0.0	0.2	0.3	0.4	0.6	0.7	0.9	1.0	1.1	1.3	
8.2	1.3	2.7	4.1	5.4	6.8	.2	0.0	0.2	0.3	0.5	0.6	0.7	0.9	1.0	1.2	1.3	
8.3	1.4	2.8	4.1	5.5	6.9	.3	0.0	0.2	0.3	0.5	0.6	0.8	0.9	1.0	1.2	1.3	
8.4	1.4	2.8	4.2	5.6	7.0	.4	0.1	0.2	0.3	0.5	0.6	0.8	0.9	1.0	1.2	1.3	
8.5	1.4	2.8	4.3	5.7	7.1	.5	0.1	0.2	0.4	0.5	0.6	0.8	0.9	1.1	1.2	1.3	
8.6	1.4	2.9	4.3	5.7	7.2	.6	0.1	0.2	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.4	
8.7	1.5	2.9	4.4	5.8	7.3	.7	0.1	0.2	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.4	
8.8	1.5	3.0	4.4	5.9	7.4	.8	0.1	0.3	0.4	0.5	0.7	0.8	1.0	1.1	1.2	1.4	
8.9	1.5	3.0	4.5	6.0	7.5	.9	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4	
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	1.4 / 0.1 / 4.2 / 0.2 / 7.1 / 0.3 / 9.9 / 0.4 / 12.7 / 0.5 / 15.5 / 0.6 / 18.4 / 0.7 / 21.2 / 0.8 / 24.0 / 0.9 / 26.8 / 1.0 / 29.7 / 1.1 / 32.5 / 1.2 / 35.3
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	1.3 / 0.1 / 3.8 / 0.2 / 6.3 / 0.3 / 8.9 / 0.4 / 11.4 / 0.5 / 14.0 / 0.6 / 16.5 / 0.7 / 19.0 / 0.8 / 21.6 / 0.9 / 24.1 / 1.0 / 26.7 / 1.1 / 29.2 / 1.2 / 31.7 / 1.3 / 34.3
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	1.2 / 0.1 / 3.5 / 0.2 / 5.8 / 0.3 / 8.1 / 0.4 / 10.5 / 0.5 / 12.8 / 0.6 / 15.1 / 0.7 / 17.4 / 0.8 / 19.8 / 0.9 / 22.1 / 1.0 / 24.4 / 1.1 / 26.7 / 1.2 / 29.1 / 1.3 / 31.4 / 1.4 / 33.7 / 1.5 / 36.0
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	
14.0	2.3	4.6	7.0	9.3	11.6	.0	0.0	0.2	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	1.1 / 0.1 / 3.2 / 0.2 / 5.3 / 0.3 / 7.5 / 0.4 / 9.6 / 0.5 / 11.7 / 0.6 / 13.9 / 0.7 / 16.0 / 0.8 / 18.1 / 0.9 / 20.3 / 1.0 / 22.4 / 1.1 / 24.5 / 1.2 / 26.7 / 1.3 / 28.8 / 1.4 / 30.9 / 1.5 / 33.1 / 1.6 / 35.2
14.1	2.3	4.7	7.0	9.4	11.7	.1	0.0	0.3	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	
14.2	2.3	4.7	7.1	9.4	11.8	.2	0.0	0.3	0.5	0.8	1.0	1.3	1.5	1.7	2.0	2.2	
14.3	2.4	4.8	7.1	9.5	11.9	.3	0.1	0.3	0.6	0.8	1.0	1.3	1.5	1.8	2.0	2.2	
14.4	2.4	4.8	7.2	9.6	12.0	.4	0.1	0.3	0.6	0.8	1.1	1.3	1.5	1.8	2.0	2.3	
14.5	2.4	4.8	7.3	9.7	12.1	.5	0.1	0.4	0.6	0.8	1.1	1.3	1.6	1.8	2.1	2.3	
14.6	2.4	4.9	7.3	9.7	12.2	.6	0.1	0.4	0.6	0.9	1.1	1.4	1.6	1.8	2.1	2.3	
14.7	2.5	4.9	7.4	9.8	12.3	.7	0.2	0.4	0.7	0.9	1.1	1.4	1.6	1.9	2.1	2.3	
14.8	2.5	5.0	7.4	9.9	12.4	.8	0.2	0.4	0.7	0.9	1.2	1.4	1.6	1.9	2.1	2.4	
14.9	2.5	5.0	7.5	10.0	12.5	.9	0.2	0.5	0.7	0.9	1.2	1.4	1.7	1.9	2.2	2.4	
15.0	2.5	5.0	7.5	10.0	12.5	.0	0.0	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.1	2.3	
15.1	2.5	5.0	7.5	10.0	12.6	.1	0.0	0.3	0.5	0.8	1.1	1.3	1.6	1.8	2.1	2.4	
15.2	2.5	5.0	7.6	10.1	12.6	.2	0.1	0.3	0.6	0.8	1.1	1.3	1.6	1.9	2.1	2.4	
15.3	2.5	5.1	7.6	10.2	12.7	.3	0.1	0.3	0.6	0.9	1.1	1.4	1.6	1.9	2.1	2.4	
15.4	2.6	5.1	7.7	10.3	12.8	.4	0.1	0.4	0.6	0.9	1.1	1.4	1.7	1.9	2.2	2.4	
15.5	2.6	5.2	7.8	10.3	12.9	.5	0.1	0.4	0.6	0.9	1.2	1.4	1.7	1.9	2.2	2.5	
15.6	2.6	5.2	7.8	10.4	13.0	.6	0.2	0.4	0.7	0.9	1.2	1.4	1.7	2.0	2.2	2.5	
15.7	2.6	5.3	7.9	10.5	13.1	.7	0.2	0.4	0.7	1.0	1.2	1.5	1.7	2.0	2.2	2.5	
15.8	2.7	5.3	7.9	10.6	13.2	.8	0.2	0.5	0.7	1.0	1.2	1.5	1.8	2.0	2.3	2.5	
15.9	2.7	5.3	8.0	10.6	13.3	.9	0.2	0.5	0.7	1.0	1.3	1.5	1.8	2.0	2.3	2.6	

The Double-Second-Difference correction (Corr.) is always to be added to the tabulated altitude.

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff. and Corr.
16.0	2.6	5.3	8.0	10.6	13.3	.0	0.0	0.3	0.5	0.8	1.1	1.4	1.6	1.9	2.2	2.5	1.0 / 0.1 / 3.0 / 0.2 / 4.9 / 0.3 / 6.9 / 0.4 / 8.9 / 0.5 / 10.8 / 0.6 / 12.8 / 0.7 / 14.8 / 0.8 / 16.7 / 0.9 / 18.7 / 1.0 / 20.7 / 1.1 / 22.7 / 1.2 / 24.6 / 1.3 / 26.6 / 1.4 / 28.6 / 1.5 / 30.5 / 1.6 / 32.5 / 1.7 / 34.5
16.1	2.7	5.3	8.0	10.7	13.4	.1	0.0	0.3	0.6	0.9	1.1	1.4	1.7	2.0	2.2	2.5	
16.2	2.7	5.4	8.1	10.8	13.5	.2	0.1	0.3	0.6	0.9	1.2	1.4	1.7	2.0	2.3	2.5	
16.3	2.7	5.4	8.1	10.9	13.6	.3	0.1	0.4	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	
16.4	2.7	5.5	8.2	10.9	13.7	.4	0.1	0.4	0.7	0.9	1.2	1.5	1.8	2.0	2.3	2.6	
16.5	2.8	5.5	8.3	11.0	13.8	.5	0.1	0.4	0.7	1.0	1.2	1.5	1.8	2.1	2.3	2.6	
16.6	2.8	5.5	8.3	11.1	13.8	.6	0.2	0.4	0.7	1.0	1.3	1.5	1.8	2.1	2.4	2.6	
16.7	2.8	5.6	8.4	11.2	13.9	.7	0.2	0.5	0.7	1.0	1.3	1.6	1.8	2.1	2.4	2.7	
16.8	2.8	5.6	8.4	11.2	14.0	.8	0.2	0.5	0.8	1.0	1.3	1.6	1.9	2.1	2.4	2.7	
16.9	2.9	5.7	8.5	11.3	14.1	.9	0.2	0.5	0.8	1.1	1.3	1.6	1.9	2.2	2.4	2.7	
17.0	2.8	5.6	8.5	11.3	14.1	.0	0.0	0.3	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	
17.1	2.8	5.7	8.5	11.4	14.2	.1	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	
17.2	2.8	5.7	8.6	11.4	14.3	.2	0.1	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	
17.3	2.9	5.8	8.6	11.5	14.4	.3	0.1	0.4	0.7	1.0	1.3	1.5	1.8	2.1	2.4	2.7	
17.4	2.9	5.8	8.7	11.6	14.5	.4	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.4	2.7	
17.5	2.9	5.8	8.8	11.7	14.6	.5	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.5	2.8	
17.6	2.9	5.9	8.8	11.7	14.7	.6	0.2	0.5	0.8	1.0	1.3	1.6	1.9	2.2	2.5	2.8	
17.7	3.0	5.9	8.9	11.8	14.8	.7	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.2	2.5	2.8	
17.8	3.0	6.0	8.9	11.9	14.9	.8	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9	
17.9	3.0	6.0	9.0	12.0	15.0	.9	0.3	0.6	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9	
18.0	3.0	6.0	9.0	12.0	15.0	.0	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.2	2.5	2.8	0.9 / 0.1 / 2.8 / 0.2 / 4.6 / 0.3 / 6.5 / 0.4 / 8.3 / 0.5 / 10.2 / 0.6 / 12.0 / 0.7 / 13.9 / 0.8 / 15.7 / 0.9 / 17.6 / 1.0 / 19.4 / 1.1 / 21.3 / 1.2 / 23.1 / 1.3 / 25.0 / 1.4 / 26.8 / 1.5 / 28.7 / 1.6 / 30.5 / 1.7 / 32.3 / 1.8 / 34.2
18.1	3.0	6.0	9.0	12.0	15.1	.1	0.0	0.3	0.6	1.0	1.3	1.6	1.9	2.2	2.5	2.8	
18.2	3.0	6.0	9.1	12.1	15.1	.2	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.5	2.8	
18.3	3.0	6.1	9.1	12.2	15.2	.3	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.3	2.6	2.9	
18.4	3.1	6.1	9.2	12.3	15.3	.4	0.1	0.4	0.7	1.0	1.4	1.7	2.0	2.3	2.6	2.9	
18.5	3.1	6.2	9.3	12.3	15.4	.5	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9	
18.6	3.1	6.2	9.3	12.4	15.5	.6	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.3	2.7	3.0	
18.7	3.1	6.3	9.4	12.5	15.6	.7	0.2	0.5	0.8	1.1	1.4	1.8	2.1	2.4	2.7	3.0	
18.8	3.2	6.3	9.4	12.6	15.7	.8	0.2	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	
18.9	3.2	6.3	9.5	12.6	15.8	.9	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.1	
19.0	3.1	6.3	9.5	12.6	15.8	.0	0.0	0.3	0.6	1.0	1.3	1.6	1.9	2.3	2.6	2.9	
19.1	3.2	6.3	9.5	12.7	15.9	.1	0.0	0.4	0.7	1.0	1.3	1.7	2.0	2.3	2.6	3.0	
19.2	3.2	6.4	9.6	12.8	16.0	.2	0.1	0.4	0.7	1.0	1.4	1.7	2.0	2.3	2.7	3.0	
19.3	3.2	6.4	9.6	12.9	16.1	.3	0.1	0.4	0.7	1.1	1.4	1.7	2.0	2.4	2.7	3.0	
19.4	3.2	6.5	9.7	12.9	16.2	.4	0.1	0.5	0.8	1.1	1.4	1.8	2.1	2.4	2.7	3.1	
19.5	3.3	6.5	9.8	13.0	16.3	.5	0.2	0.5	0.8	1.1	1.5	1.8	2.1	2.4	2.8	3.1	
19.6	3.3	6.5	9.8	13.1	16.3	.6	0.2	0.5	0.8	1.2	1.5	1.8	2.1	2.5	2.8	3.1	
19.7	3.3	6.6	9.9	13.2	16.4	.7	0.2	0.6	0.9	1.2	1.5	1.9	2.2	2.5	2.8	3.2	
19.8	3.3	6.6	9.9	13.2	16.5	.8	0.3	0.6	0.9	1.2	1.6	1.9	2.2	2.5	2.9	3.2	
19.9	3.4	6.7	10.0	13.3	16.6	.9	0.3	0.6	0.9	1.3	1.6	1.9	2.2	2.6	2.9	3.2	
20.0	3.3	6.6	10.0	13.3	16.6	.0	0.0	0.3	0.7	1.0	1.4	1.7	2.0	2.4	2.7	3.1	0.9 / 0.1 / 2.6 / 0.2 / 4.4 / 0.3 / 6.2 / 0.4 / 7.9 / 0.5 / 9.7 / 0.6 / 11.4 / 0.7 / 13.2 / 0.8 / 14.9 / 0.9 / 16.7 / 1.0 / 18.5 / 1.1 / 20.2 / 1.2 / 22.0 / 1.3 / 23.7 / 1.4 / 25.5 / 1.5 / 27.3 / 1.6 / 29.0 / 1.7 / 30.8 / 1.8 / 32.5 / 1.9 / 34.3
20.1	3.3	6.7	10.0	13.4	16.7	.1	0.0	0.4	0.7	1.1	1.4	1.7	2.1	2.4	2.8	3.1	
20.2	3.3	6.7	10.1	13.4	16.8	.2	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.5	2.8	3.1	
20.3	3.4	6.8	10.1	13.5	16.9	.3	0.1	0.4	0.8	1.1	1.5	1.8	2.2	2.5	2.8	3.2	
20.4	3.4	6.8	10.2	13.6	17.0	.4	0.1	0.5	0.8	1.2	1.5	1.8	2.2	2.5	2.9	3.2	
20.5	3.4	6.8	10.3	13.7	17.1	.5	0.2	0.5	0.9	1.2	1.5	1.9	2.2	2.6	2.9	3.2	
20.6	3.4	6.9	10.3	13.7	17.2	.6	0.2	0.5	0.9	1.2	1.6	1.9	2.3	2.6	2.9	3.3	
20.7	3.5	6.9	10.4	13.8	17.3	.7	0.2	0.6	0.9	1.3	1.6	1.9	2.3	2.6	3.0	3.3	
20.8	3.5	7.0	10.4	13.9	17.4	.8	0.3	0.6	1.0	1.3	1.6	2.0	2.3	2.7	3.0	3.3	
20.9	3.5	7.0	10.5	14.0	17.5	.9	0.3	0.6	1.0	1.3	1.7	2.0	2.4	2.7	3.0	3.4	
21.0	3.5	7.0	10.5	14.0	17.5	.0	0.0	0.4	0.7	1.1	1.4	1.8	2.1	2.5	2.9	3.2	
21.1	3.5	7.0	10.5	14.0	17.6	.1	0.0	0.4	0.8	1.1	1.5	1.8	2.2	2.5	2.9	3.3	
21.2	3.5	7.0	10.6	14.1	17.6	.2	0.1	0.4	0.8	1.1	1.5	1.9	2.2	2.6	2.9	3.3	
21.3	3.5	7.1	10.6	14.2	17.7	.3	0.1	0.5	0.8	1.2	1.5	1.9	2.3	2.6	3.0	3.3	
21.4	3.6	7.1	10.7	14.3	17.8	.4	0.1	0.5	0.9	1.2	1.6	1.9	2.3	2.7	3.0	3.4	
21.5	3.6	7.2	10.8	14.3	17.9	.5	0.2	0.5	0.9	1.3	1.6	2.0	2.3	2.7	3.0	3.4	
21.6	3.6	7.2	10.8	14.4	18.0	.6	0.2	0.6	0.9	1.3	1.6	2.0	2.4	2.7	3.1	3.4	
21.7	3.6	7.3	10.9	14.5	18.1	.7	0.3	0.6	1.0	1.3	1.7	2.0	2.4	2.8	3.1	3.5	
21.8	3.7	7.3	10.9	14.6	18.2	.8	0.3	0.6	1.0	1.4	1.7	2.1	2.4	2.8	3.2	3.5	
21.9	3.7	7.3	11.0	14.6	18.3	.9	0.3	0.7	1.0	1.4	1.8	2.1	2.5	2.8	3.2	3.5	
22.0	3.6	7.3	11.0	14.6	18.3	.0	0.0	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.4	0.8 / 0.1 / 2.5 / 0.2 / 4.2 / 0.3 / 5.9 / 0.4 / 7.6 / 0.5 / 9.3 / 0.6 / 11.0 / 0.7 / 12.7 / 0.8 / 14.4 / 0.9 / 16.1 / 1.0 / 17.8 / 1.1 / 19.5 / 1.2 / 21.2 / 1.3 / 22.8 / 1.4 / 24.5 / 1.5 / 26.2 / 1.6 / 27.9 / 1.7 / 29.6 / 1.8 / 31.3 / 1.9 / 33.0 / 2.0 / 34.7
22.1	3.7	7.3	11.0	14.7	18.4	.1	0.0	0.4	0.8	1.2	1.5	1.9	2.3	2.7	3.0	3.4	
22.2	3.7	7.4	11.1	14.8	18.5	.2	0.1	0.4	0.8	1.2	1.6	1.9	2.3	2.7	3.1	3.4	
22.3	3.7	7.4	11.1	14.9	18.6	.3	0.1	0.5	0.9	1.2	1.6	2.0	2.4	2.7	3.1	3.5	
22.4	3.7	7.5	11.2	14.9	18.7	.4	0.1	0.5	0.9	1.3	1.6	2.0	2.4	2.8	3.1	3.5	
22.5	3.8	7.5	11.3	15.0	18.8	.5	0.2	0.6	0.9	1.3	1.7	2.1	2.4	2.8	3.2	3.6	
22.6	3.8	7.5	11.3	15.1	18.8	.6	0.2	0.6	1.0	1.3	1.7	2.1	2.5	2.8	3.2	3.6	
22.7	3.8	7.6	11.4	15.2	18.9	.7	0.3	0.6	1.0	1.4	1.8	2.1	2.5	2.9	3.3	3.6	
22.8	3.8	7.6	11.4	15.2	19.0	.8	0.3	0.7	1.0	1.4	1.8	2.2	2.5	2.9	3.3	3.7	
22.9	3.9	7.7	11.5	15.3	19.1	.9	0.3	0.7	1.1	1.5	1.8	2.2	2.6	3.0	3.3	3.7	
23.0	3.8	7.6	11.5	15.3	19.1	.0	0.0	0.4	0.8	1.2	1.6	2.0	2.3	2.7	3.1	3.5	
23.1	3.8	7.7	11.5	15.4	19.2	.1	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	
23.2	3.8	7.7	11.6	15.4	19.3	.2	0.1	0.5	0.9	1.3	1.6	2.0	2.4	2.8	3.2	3.6	
23.3	3.9	7.8	11.6	15.5	19.4	.3	0.1	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.6	
23.4	3.9	7.8	11.7	15.6	19.5	.4	0.2	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.7	
23.5	3.9	7.8	11.8	15.7	19.6	.5	0.2	0.6	1.0	1.4	1.8	2.2	2.5	2.9	3.3	3.7	
23.6	3.9	7.9	11.8	15.7	19.7	.6	0.2	0.6	1.0	1.4	1.8	2.2	2.6	3.0	3.4	3.8	
23.7	4.0	7.9	11.9	15.8	19.8	.7	0.3	0.7	1.1	1.4	1.8	2.2	2.6	3.0	3.4	3.8	
23.8	4.0	8.0	11.9	15.9	19.9	.8	0.3	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.4	3.8	
23.9	4.0	8.0	12.0	16.0	20.0	.9	0.4	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.5	3.9	

The Double-Second-Difference correction (Corr.) ...

TION TABLE

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff. and Corr.
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′ ′
24.0	4.0	8.0	12.0	16.0	20.0	.0	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.9	3.3	3.7	0.8 0.1 2.5 0.2 4.1 0.3 5.8 0.4 7.4 0.5 9.1 0.6 10.7 0.7 12.3 0.8 14.0 0.9 15.6 1.0 17.3 1.1 18.9 1.2 20.6 1.3 22.2 1.4 23.9 1.5 25.5 1.6 27.2 1.7 28.8 1.8 30.4 1.9 32.1 2.0 33.7 2.1 35.4
24.1	4.0	8.0	12.0	16.0	20.1	.1	0.0	0.4	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.7	
24.2	4.0	8.0	12.1	16.1	20.1	.2	0.1	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.8	
24.3	4.0	8.1	12.1	16.2	20.2	.3	0.1	0.5	0.9	1.3	1.8	2.2	2.6	3.0	3.4	3.8	
24.4	4.1	8.1	12.2	16.3	20.3	.4	0.2	0.6	1.0	1.4	1.8	2.2	2.6	3.0	3.4	3.8	
24.5	4.1	8.2	12.3	16.3	20.4	.5	0.2	0.6	1.0	1.4	1.8	2.2	2.7	3.1	3.5	3.9	
24.6	4.1	8.2	12.3	16.4	20.5	.6	0.2	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.5	3.9	
24.7	4.1	8.3	12.4	16.5	20.6	.7	0.3	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.6	4.0	
24.8	4.2	8.3	12.4	16.6	20.7	.8	0.3	0.7	1.1	1.6	2.0	2.4	2.8	3.2	3.6	4.0	
24.9	4.2	8.3	12.5	16.6	20.8	.9	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	
25.0	4.1	8.3	12.5	16.6	20.8	.0	0.0	0.4	0.8	1.3	1.7	2.1	2.5	3.0	3.4	3.8	
25.1	4.2	8.3	12.5	16.7	20.9	.1	0.0	0.5	0.9	1.3	1.7	2.2	2.6	3.0	3.4	3.9	
25.2	4.2	8.4	12.6	16.8	21.0	.2	0.1	0.5	0.9	1.4	1.8	2.2	2.6	3.1	3.5	3.9	
25.3	4.2	8.4	12.6	16.9	21.1	.3	0.1	0.6	1.0	1.4	1.8	2.3	2.7	3.1	3.5	4.0	
25.4	4.2	8.5	12.7	16.9	21.2	.4	0.2	0.6	1.0	1.4	1.9	2.3	2.7	3.1	3.6	4.0	
25.5	4.3	8.5	12.8	17.0	21.3	.5	0.2	0.6	1.1	1.5	1.9	2.3	2.8	3.2	3.6	4.0	
25.6	4.3	8.5	12.8	17.1	21.3	.6	0.3	0.7	1.1	1.5	2.0	2.4	2.8	3.2	3.7	4.1	
25.7	4.3	8.6	12.9	17.2	21.4	.7	0.3	0.7	1.1	1.6	2.0	2.4	2.8	3.3	3.7	4.1	
25.8	4.3	8.6	12.9	17.2	21.5	.8	0.3	0.8	1.2	1.6	2.0	2.5	2.9	3.3	3.7	4.2	
25.9	4.4	8.7	13.0	17.3	21.6	.9	0.4	0.8	1.2	1.7	2.1	2.5	2.9	3.4	3.8	4.2	
26.0	4.3	8.6	13.0	17.3	21.6	.0	0.0	0.4	0.9	1.3	1.8	2.2	2.6	3.1	3.5	4.0	0.8 0.1 2.4 0.2 4.0 0.3 5.7 0.4 7.3 0.5 8.9 0.6 10.5 0.7 12.1 0.8 13.7 0.9 15.4 1.0 17.0 1.1 18.6 1.2 20.2 1.3 21.8 1.4 23.4 1.5 25.1 1.6 26.7 1.7 28.3 1.8 29.9 1.9 31.5 2.0 33.1 2.1 34.7
26.1	4.3	8.7	13.0	17.4	21.7	.1	0.0	0.5	0.9	1.4	1.8	2.3	2.7	3.1	3.6	4.0	
26.2	4.3	8.7	13.1	17.4	21.8	.2	0.1	0.5	1.0	1.4	1.9	2.3	2.7	3.2	3.6	4.1	
26.3	4.4	8.8	13.1	17.5	21.9	.3	0.1	0.6	1.0	1.5	1.9	2.3	2.8	3.2	3.7	4.1	
26.4	4.4	8.8	13.2	17.6	22.0	.4	0.2	0.6	1.1	1.5	1.9	2.4	2.8	3.3	3.7	4.2	
26.5	4.4	8.8	13.3	17.7	22.1	.5	0.2	0.7	1.1	1.5	2.0	2.4	2.9	3.3	3.8	4.2	
26.6	4.4	8.9	13.3	17.7	22.2	.6	0.3	0.7	1.1	1.6	2.0	2.5	2.9	3.4	3.8	4.2	
26.7	4.5	8.9	13.4	17.8	22.3	.7	0.3	0.8	1.2	1.6	2.1	2.5	3.0	3.4	3.8	4.3	
26.8	4.5	9.0	13.4	17.9	22.4	.8	0.4	0.8	1.2	1.7	2.1	2.6	3.0	3.4	3.9	4.3	
26.9	4.5	9.0	13.5	18.0	22.5	.9	0.4	0.8	1.3	1.7	2.2	2.6	3.0	3.5	3.9	4.4	
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	2.3	2.7	3.2	3.6	4.1	4.5	
28.0	4.6	9.3	14.0	18.6	23.3	.0	0.0	0.5	0.9	1.4	1.9	2.4	2.8	3.3	3.8	4.3	0.8 0.1 2.4 0.2 4.0 0.3 5.6 0.4 7.2 0.5 8.8 0.6 10.4 0.7 12.0 0.8 13.6 0.9 15.2 1.0 16.8 1.1 18.4 1.2 20.0 1.3 21.6 1.4 23.2 1.5 24.8 1.6 26.4 1.7 28.0 1.8 29.6 1.9 31.2 2.0 32.8 2.1 34.4
28.1	4.7	9.3	14.0	18.7	23.4	.1	0.0	0.5	1.0	1.5	1.9	2.4	2.9	3.4	3.8	4.3	
28.2	4.7	9.4	14.1	18.8	23.5	.2	0.1	0.6	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4	
28.3	4.7	9.4	14.1	18.9	23.6	.3	0.1	0.6	1.1	1.6	2.0	2.5	3.0	3.5	3.9	4.4	
28.4	4.7	9.5	14.2	18.9	23.7	.4	0.2	0.7	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5	
28.5	4.8	9.5	14.3	19.0	23.8	.5	0.2	0.7	1.2	1.7	2.1	2.6	3.1	3.6	4.0	4.5	
28.6	4.8	9.5	14.3	19.1	23.8	.6	0.3	0.8	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6	
28.7	4.8	9.6	14.4	19.2	23.9	.7	0.3	0.8	1.3	1.8	2.2	2.7	3.2	3.7	4.1	4.6	
28.8	4.8	9.6	14.4	19.2	24.0	.8	0.4	0.9	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7	
28.9	4.9	9.7	14.5	19.3	24.1	.9	0.4	0.9	1.4	1.9	2.3	2.8	3.3	3.8	4.2	4.7	
29.0	4.8	9.6	14.5	19.3	24.1	.0	0.0	0.5	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4	
29.1	4.8	9.7	14.5	19.4	24.2	.1	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	
29.2	4.8	9.7	14.6	19.4	24.3	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5	
29.3	4.9	9.8	14.6	19.5	24.4	.3	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6	
29.4	4.9	9.8	14.7	19.6	24.5	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6	
29.5	4.9	9.8	14.8	19.7	24.6	.5	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7	
29.6	4.9	9.9	14.8	19.7	24.7	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7	
29.7	5.0	9.9	14.9	19.8	24.8	.7	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8	
29.8	5.0	10.0	14.9	19.9	24.9	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.8	
29.9	5.0	10.0	15.0	20.0	25.0	.9	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9	
30.0	5.0	10.0	15.0	20.0	25.0	.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.6	4.1	4.6	0.8 0.1 2.4 0.2 4.0 0.3 5.6 0.4 7.2 0.5 8.8 0.6 10.4 0.7 12.0 0.8 13.6 0.9 15.2 1.0 16.8 1.1 18.4 1.2 20.0 1.3 21.6 1.4 23.2 1.5 24.8 1.6 26.4 1.7 28.0 1.8 29.6 1.9 31.2 2.0 32.8 2.1 34.4
30.1	5.0	10.0	15.0	20.0	25.1	.1	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6	
30.2	5.0	10.0	15.1	20.1	25.1	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.2	3.7	4.2	4.7	
30.3	5.0	10.1	15.1	20.2	25.2	.3	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7	
30.4	5.1	10.1	15.2	20.3	25.3	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8	
30.5	5.1	10.2	15.3	20.3	25.4	.5	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8	
30.6	5.1	10.2	15.3	20.4	25.5	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9	
30.7	5.1	10.3	15.4	20.5	25.6	.7	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9	
30.8	5.2	10.3	15.4	20.6	25.7	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0	
30.9	5.2	10.3	15.5	20.6	25.8	.9	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	
31.0	5.1	10.3	15.5	20.6	25.8	.0	0.0	0.5	1.0	1.6	2.1	2.6	3.1	3.7	4.2	4.7	
31.1	5.2	10.3	15.5	20.7	25.9	.1	0.1	0.6	1.1	1.6	2.2	2.7	3.2	3.7	4.3	4.8	
31.2	5.2	10.4	15.6	20.8	26.0	.2	0.1	0.6	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8	
31.3	5.2	10.4	15.6	20.9	26.1	.3	0.2	0.7	1.2	1.7	2.3	2.8	3.3	3.8	4.4	4.9	
31.4	5.2	10.5	15.7	20.9	26.2	.4	0.2	0.7	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9	
31.5	5.3	10.5	15.8	21.0	26.3	.5	0.3	0.8	1.3	1.8	2.4	2.9	3.4	3.9	4.5	5.0	
31.6	5.3	10.5	15.8	21.1	26.3	.6	0.3	0.8	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0	
31.7	5.3	10.6	15.9	21.2	26.4	.7	0.4	0.9	1.4	1.9	2.5	3.0	3.5	4.0	4.6	5.1	
31.8	5.3	10.6	15.9	21.2	26.5	.8	0.4	0.9	1.5	2.0	2.5	3.0	3.6	4.1	4.6	5.1	
31.9	5.4	10.7	16.0	21.3	26.6	.9	0.5	1.0	1.5	2.0	2.6	3.1	3.6	4.1	4.7	5.2	
	10′	20′	30′	40′	50′		0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	

is always to be added to the tabulated altitude.

INTERPOLATION TABLE

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff. and Corr.
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′ ′
28.0	4.6	9.3	14.0	18.6	23.3	.0	0.0	0.5	0.9	1.4	1.9	2.4	2.8	3.3	3.8	4.3	0.8 0.1 2.4 0.2 4.0 0.3 5.6 0.4 7.2 0.5 8.8 0.6 10.4 0.7 12.0 0.8 13.6 0.9 15.2 1.0 16.8 1.1 18.4 1.2 20.0 1.3 21.6 1.4 23.2 1.5 24.8 1.6 26.4 1.7 28.0 1.8 29.6 1.9 31.2 2.0 32.8 2.1 34.4
28.1	4.7	9.3	14.0	18.7	23.4	.1	0.0	0.5	1.0	1.5	1.9	2.4	2.9	3.4	3.8	4.3	
28.2	4.7	9.4	14.1	18.8	23.5	.2	0.1	0.6	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4	
28.3	4.7	9.4	14.1	18.9	23.6	.3	0.1	0.6	1.1	1.6	2.0	2.5	3.0	3.5	3.9	4.4	
28.4	4.7	9.5	14.2	18.9	23.7	.4	0.2	0.7	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5	
28.5	4.8	9.5	14.3	19.0	23.8	.5	0.2	0.7	1.2	1.7	2.1	2.6	3.1	3.6	4.0	4.5	
28.6	4.8	9.5	14.3	19.1	23.8	.6	0.3	0.8	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6	
28.7	4.8	9.6	14.4	19.2	23.9	.7	0.3	0.8	1.3	1.8	2.2	2.7	3.2	3.7	4.1	4.6	
28.8	4.8	9.6	14.4	19.2	24.0	.8	0.4	0.9	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7	
28.9	4.9	9.7	14.5	19.3	24.1	.9	0.4	0.9	1.4	1.9	2.3	2.8	3.3	3.8	4.2	4.7	
29.0	4.8	9.6	14.5	19.3	24.1	.0	0.0	0.5	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4	
29.1	4.8	9.7	14.5	19.4	24.2	.1	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	
29.2	4.8	9.7	14.6	19.4	24.3	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5	
29.3	4.9	9.8	14.6	19.5	24.4	.3	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6	
29.4	4.9	9.8	14.7	19.6	24.5	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6	
29.5	4.9	9.8	14.8	19.7	24.6	.5	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7	
29.6	4.9	9.9	14.8	19.7	24.7	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7	
29.7	5.0	9.9	14.9	19.8	24.8	.7	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8	
29.8	5.0	10.0	14.9	19.9	24.9	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.8	
29.9	5.0	10.0	15.0	20.0	25.0	.9	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9	
30.0	5.0	10.0	15.0	20.0	25.0	.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.6	4.1	4.6	0.8 0.1 2.4 0.2 4.0 0.3 5.6 0.4 7.2 0.5 8.8 0.6 10.4 0.7 12.0 0.8 13.6 0.9 15.2 1.0 16.8 1.1 18.4 1.2 20.0 1.3 21.6 1.4 23.2 1.5 24.8 1.6 26.4 1.7 28.0 1.8 29.6 1.9 31.2 2.0 32.8 2.1 34.4
30.1	5.0	10.0	15.0	20.0	25.1	.1	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6	
30.2	5.0	10.0	15.1	20.1	25.1	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.2	3.7	4.2	4.7	
30.3	5.0	10.1	15.1	20.2	25.2	.3	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7	
30.4	5.1	10.1	15.2	20.3	25.3	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8	
30.5	5.1	10.2	15.3	20.3	25.4	.5	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8	
30.6	5.1	10.2	15.3	20.4	25.5	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9	
30.7	5.1	10.3	15.4	20.5	25.6	.7	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9	
30.8	5.2	10.3	15.4	20.6	25.7	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0	
30.9	5.2	10.3	15.5	20.6	25.8	.9	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	
31.0	5.1	10.3	15.5	20.6	25.8	.0	0.0	0.5	1.0	1.6	2.1	2.6	3.1	3.7	4.2	4.7	
31.1	5.2	10.3	15.5	20.7	25.9	.1	0.1	0.6	1.1	1.6	2.2	2.7	3.2	3.7	4.3	4.8	
31.2	5.2	10.4	15.6	20.8	26.0	.2	0.1	0.6	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8	
31.3	5.2	10.4	15.6	20.9	26.1	.3	0.2	0.7	1.2	1.7	2.3	2.8	3.3	3.8	4.4	4.9	
31.4	5.2	10.5	15.7	20.9	26.2	.4	0.2	0.7	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9	
31.5	5.3	10.5	15.8	21.0	26.3	.5	0.3	0.8	1.3	1.8	2.4	2.9	3.4	3.9	4.5	5.0	
31.6	5.3	10.5	15.8	21.1	26.3	.6	0.3	0.8	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0	
31.7	5.3	10.6	15.9	21.2	26.4	.7	0.4	0.9	1.4	1.9	2.5	3.0	3.5	4.0	4.6	5.1	
31.8	5.3	10.6	15.9	21.2	26.5	.8	0.4	0.9	1.5	2.0	2.5	3.0	3.6	4.1	4.6	5.1	
31.9	5.4	10.7	16.0	21.3	26.6	.9	0.5	1.0	1.5	2.0	2.6	3.1	3.6	4.1	4.7	5.2	
32.0	5.3	10.6	16.0	21.3	26.6	.0	0.0	0.5	1.1	1.6	2.2	2.7	3.2	3.8	4.3	4.9	0.8 0.1 2.4 0.2 4.0 0.3 5.7 0.4 7.3 0.5 8.9 0.6 10.5 0.7 12.1 0.8 13.7 0.9 15.4 1.0 17.0 1.1 18.6 1.2 20.2 1.3 21.8 1.4 23.4 1.5 25.1 1.6 26.7 1.7 28.3 1.8 29.9 1.9 31.5 2.0 33.1 2.1 34.7
32.1	5.3	10.7	16.0	21.4	26.7	.1	0.1	0.6	1.1	1.7	2.2	2.8	3.3	3.8	4.4	4.9	
32.2	5.3	10.7	16.1	21.4	26.8	.2	0.1	0.6	1.2	1.7	2.3	2.8	3.4	3.9	4.4	5.0	
32.3	5.4	10.8	16.1	21.5	26.9	.3	0.2	0.7	1.2	1.8	2.3	2.9	3.4	4.0	4.5	5.0	
32.4	5.4	10.8	16.2	21.6	27.0	.4	0.2	0.8	1.3	1.8	2.4	2.9	3.5	4.0	4.5	5.1	
32.5	5.4	10.8	16.3	21.7	27.1	.5	0.3	0.8	1.4	1.9	2.4	3.0	3.5	4.1	4.6	5.1	
32.6	5.4	10.9	16.3	21.7	27.2	.6	0.3	0.9	1.4	1.9	2.5	3.0	3.6	4.1	4.7	5.2	
32.7	5.5	10.9	16.4	21.8	27.3	.7	0.4	0.9	1.5	2.0	2.5	3.1	3.6	4.2	4.7	5.3	
32.8	5.5	11.0	16.4	21.9	27.4	.8	0.4	1.0	1.5	2.1	2.6	3.1	3.7	4.2	4.8	5.3	
32.9	5.5	11.0	16.5	22.0	27.5	.9	0.5	1.0	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.4	
33.0	5.5	11.0	16.5	22.0	27.5	.0	0.0	0.6	1.1	1.7	2.2	2.8	3.3	3.9	4.5	5.0	
33.1	5.5	11.0	16.5	22.0	27.6	.1	0.1	0.6	1.2	1.7	2.3	2.8	3.4	4.0	4.5	5.1	
33.2	5.5	11.0	16.6	22.1	27.6	.2	0.1	0.7	1.2	1.8	2.3	2.9	3.5	4.0	4.6	5.1	
33.3	5.5	11.1	16.6	22.2	27.7	.3	0.2	0.7	1.3	1.8	2.4	3.0	3.5	4.1	4.6	5.2	
33.4	5.6	11.1	16.7	22.3	27.8	.4	0.2	0.8	1.3	1.9	2.5	3.0	3.6	4.1	4.7	5.2	
33.5	5.6	11.2	16.8	22.3	27.9	.5	0.3	0.8	1.4	2.0	2.5	3.1	3.6	4.2	4.7	5.3	
33.6	5.6	11.2	16.8	22.4	28.0	.6	0.3	0.9	1.5	2.0	2.6	3.1	3.7	4.2	4.8	5.4	
33.7	5.6	11.3	16.9	22.5	28.1	.7	0.4	0.9	1.5	2.1	2.6	3.2	3.7	4.3	4.9	5.4	
33.8	5.7	11.3	16.9	22.6	28.2	.8	0.4	1.0	1.6	2.1	2.7	3.2	3.8	4.4	4.9	5.5	
33.9	5.7	11.3	17.0	22.6	28.3	.9	0.5	1.1	1.6	2.2	2.7	3.3	3.9	4.4	5.0	5.5	
34.0	5.6	11.3	17.0	22.6	28.3	.0	0.0	0.6	1.1	1.7	2.3	2.9	3.4	4.0	4.6	5.2	0.8 0.1 2.5 0.2 4.1 0.3 5.8 0.4 7.4 0.5 9.1 0.6 10.7 0.7 12.3 0.8 14.0 0.9 15.6 1.0 17.3 1.1 18.9 1.2 20.6 1.3 22.2 1.4 23.9 1.5 25.5 1.6 27.2 1.7 28.8 1.8 30.4 1.9 32.1 2.0 33.7 2.1 35.4
34.1	5.7	11.3	17.0	22.7	28.4	.1	0.1	0.6	1.2	1.8	2.4	2.9	3.5	4.1	4.7	5.2	
34.2	5.7	11.4	17.1	22.8	28.5	.2	0.1	0.7	1.3	1.8	2.4	3.0	3.6	4.1	4.7	5.3	
34.3	5.7	11.4	17.1	22.9	28.6	.3	0.2	0.7	1.3	1.9	2.5	3.0	3.6	4.2	4.8	5.3	
34.4	5.7	11.5	17.2	22.9	28.7	.4	0.2	0.8	1.4	2.0	2.5	3.1	3.7	4.3	4.8	5.4	
34.5	5.8	11.5	17.3	23.0	28.8	.5	0.3	0.9	1.4	2.0	2.6	3.2	3.7	4.3	4.9	5.5	
34.6	5.8	11.5	17.3	23.1	28.8	.6	0.3	0.9	1.5	2.1	2.6	3.2	3.8	4.4	4.9	5.5	
34.7	5.8	11.6	17.4	23.2	28.9	.7	0.4	1.0	1.6	2.1	2.7	3.3	3.9	4.4	5.0	5.6	
34.8	5.8	11.6	17.4	23.2	29.0	.8	0.5	1.0	1.6	2.2	2.8	3.3	3.9	4.5	5.1	5.6	
34.9	5.9	11.7	17.5	23.3	29.1	.9	0.5	1.1	1.7	2.2	2.8	3.4	4.0	4.5	5.1	5.7	
35.0	5.8	11.6	17.5	23.3	29.1	.0	0.0	0.6	1.2	1.8	2.4	3.0	3.5	4.1	4.7	5.3	
35.1	5.8	11.7	17.5	23.4	29.2	.1	0.1	0.7	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	
35.2	5.8	11.7	17.6	23.4	29.3	.2	0.1	0.7	1.3	1.9	2.5	3.1	3.7	4.3	4.9	5.4	
35.3	5.9	11.8	17.6	23.5	29.4	.3	0.2	0.8	1.4	2.0	2.5	3.1	3.7	4.3	4.9	5.5	
35.4	5.9	11.8	17.7	23.6	29.5	.4	0.2	0.8	1.4	2.0	2.6	3.2	3.8	4.4	5.0	5.6	
35.5	5.9	11.8	17.8	23.7	29.6	.5	0.3	0.9	1.5	2.1	2.7	3.3	3.8	4.4	5.0	5.6	
35.6	5.9	11.9	17.8	23.7	29.7	.6	0.4	0.9	1.5	2.1	2.7	3.3	3.9	4.5	5.1	5.7	
35.7	6.0	11.9	17.9	23.8	29.8	.7	0.4	1.0	1.6	2.2	2.8	3.4	4.0	4.6	5.1	5.7	
35.8	6.0	12.0	17.9	23.9	29.9	.8	0.5	1.1	1.7	2.2	2.8	3.4	4.0	4.6	5.2	5.8	
35.9	6.0	12.0	18.0	24.0	30.0	.9	0.5	1.1	1.7	2.3	2.9	3.5	4.1	4.7	5.3	5.9	
	10′	20′	30′	40′	50′		0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff. and Corr.
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′ ′
36.0	6.0	12.0	18.0	24.0	30.0	.0	0.0	0.6	1.2	1.8	2.4	3.0	3.6	4.3	4.9	5.5	0.8 0.1 2.5 0.2 4.2 0.3 5.9 0.4 7.6 0.5 9.3 0.6 11.0 0.7 12.7 0.8 14.4 0.9 16.1 1.0 17.8 1.1 19.5 1.2 21.2 1.3 22.8 1.4 24.5 1.5 26.2 1.6 27.9 1.7 29.6 1.8 31.3 1.9 33.0 2.0 34.7
36.1	6.0	12.0	18.0	24.0	30.1	.1	0.1	0.7	1.3	1.9	2.5	3.1	3.7	4.3	4.9	5.5	
36.2	6.0	12.0	18.1	24.1	30.1	.2	0.1	0.7	1.3	1.9	2.6	3.2	3.8	4.4	5.0	5.6	
36.3	6.0	12.1	18.1	24.2	30.2	.3	0.2	0.8	1.4	2.0	2.6	3.2	3.8	4.4	5.0	5.7	
36.4	6.1	12.1	18.2	24.3	30.3	.4	0.2	0.9	1.5	2.1	2.7	3.3	3.9	4.5	5.1	5.7	
36.5	6.1	12.2	18.3	24.3	30.4	.5	0.3	0.9	1.5	2.1	2.7	3.3	4.0	4.6	5.2	5.8	
36.6	6.1	12.2	18.3	24.4	30.5	.6	0.4	1.0	1.6	2.2	2.8	3.4	4.0	4.6	5.2	5.8	
36.7	6.1	12.3	18.4	24.5	30.6	.7	0.4	1.0	1.6	2.3	2.9	3.5	4.1	4.7	5.3	5.9	
36.8	6.2	12.3	18.4	24.6	30.7	.8	0.5	1.1	1.7	2.3	2.9	3.5	4.1	4.7	5.4	6.0	
36.9	6.2	12.3	18.5	24.6	30.8	.9	0.5	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	
37.0	6.1	12.3	18.5	24.6	30.8	.0	0.0	0.6	1.2	1.9	2.5	3.1	3.7	4.4	5.0	5.6	
37.1	6.2	12.3	18.5	24.7	30.9	.1	0.1	0.7	1.3	1.9	2.6	3.2	3.8	4.4	5.1	5.7	
37.2	6.2	12.4	18.6	24.8	31.0	.2	0.1	0.7	1.4	2.0	2.6	3.2	3.9	4.5	5.1	5.7	
37.3	6.2	12.4	18.6	24.9	31.1	.3	0.2	0.8	1.4	2.1	2.7	3.3	3.9	4.6	5.2	5.8	
37.4	6.2	12.5	18.7	24.9	31.2	.4	0.2	0.9	1.5	2.1	2.7	3.4	4.0	4.6	5.2	5.9	
37.5	6.3	12.5	18.8	25.0	31.3	.5	0.3	0.9	1.6	2.2	2.8	3.4	4.1	4.7	5.3	5.9	
37.6	6.3	12.5	18.8	25.1	31.3	.6	0.4	1.0	1.6	2.2	2.9	3.5	4.1	4.7	5.4	6.0	
37.7	6.3	12.6	18.9	25.2	31.4	.7	0.4	1.1	1.7	2.3	2.9	3.6	4.2	4.8	5.4	6.1	
37.8	6.3	12.6	18.9	25.2	31.5	.8	0.5	1.1	1.7	2.4	3.0	3.6	4.2	4.9	5.5	6.1	
37.9	6.4	12.7	19.0	25.3	31.6	.9	0.6	1.2	1.8	2.4	3.1	3.7	4.3	4.9	5.6	6.2	
38.0	6.3	12.6	19.0	25.3	31.6	.0	0.0	0.6	1.3	1.9	2.6	3.2	3.8	4.5	5.1	5.8	0.9 0.1 2.6 0.2 4.4 0.3 6.2 0.4 7.9 0.5 9.7 0.6 11.4 0.7 13.2 0.8 14.9 0.9 16.7 1.0 18.5 1.1 20.2 1.2 22.0 1.3 23.7 1.4 25.5 1.5 27.3 1.6 29.0 1.7 30.8 1.8 32.5 1.9 34.3
38.1	6.3	12.7	19.0	25.4	31.7	.1	0.1	0.7	1.3	2.0	2.6	3.3	3.9	4.6	5.2	5.8	
38.2	6.3	12.7	19.1	25.4	31.8	.2	0.1	0.8	1.4	2.1	2.7	3.3	4.0	4.6	5.3	5.9	
38.3	6.4	12.8	19.1	25.5	31.9	.3	0.2	0.8	1.5	2.1	2.8	3.4	4.0	4.7	5.3	6.0	
38.4	6.4	12.8	19.2	25.6	32.0	.4	0.3	0.9	1.5	2.2	2.8	3.5	4.1	4.7	5.4	6.0	
38.5	6.4	12.8	19.3	25.7	32.1	.5	0.3	1.0	1.6	2.2	2.9	3.5	4.2	4.8	5.5	6.1	
38.6	6.4	12.9	19.3	25.7	32.2	.6	0.4	1.0	1.7	2.3	3.0	3.6	4.2	4.9	5.5	6.2	
38.7	6.5	12.9	19.4	25.8	32.3	.7	0.4	1.1	1.7	2.4	3.0	3.7	4.3	4.9	5.6	6.2	
38.8	6.5	13.0	19.4	25.9	32.4	.8	0.5	1.2	1.8	2.4	3.1	3.7	4.4	5.0	5.6	6.3	
38.9	6.5	13.0	19.5	26.0	32.5	.9	0.6	1.2	1.9	2.5	3.1	3.8	4.4	5.1	5.7	6.4	
39.0	6.5	13.0	19.5	26.0	32.5	.0	0.0	0.7	1.3	2.0	2.6	3.3	3.9	4.6	5.3	5.9	
39.1	6.5	13.0	19.5	26.0	32.6	.1	0.1	0.7	1.4	2.0	2.7	3.4	4.0	4.7	5.3	6.0	
39.2	6.5	13.0	19.6	26.1	32.6	.2	0.1	0.8	1.4	2.1	2.8	3.4	4.1	4.7	5.4	6.1	
39.3	6.5	13.1	19.6	26.2	32.7	.3	0.2	0.9	1.5	2.2	2.8	3.5	4.1	4.8	5.5	6.1	
39.4	6.6	13.1	19.7	26.3	32.8	.4	0.3	0.9	1.6	2.2	2.9	3.6	4.2	4.9	5.5	6.2	
39.5	6.6	13.2	19.8	26.3	32.9	.5	0.3	1.0	1.6	2.3	3.0	3.6	4.3	4.9	5.6	6.3	
39.6	6.6	13.2	19.8	26.4	33.0	.6	0.4	1.1	1.7	2.4	3.0	3.7	4.3	5.0	5.7	6.3	
39.7	6.6	13.3	19.9	26.5	33.1	.7	0.5	1.1	1.8	2.4	3.1	3.8	4.4	5.1	5.7	6.4	
39.8	6.7	13.3	19.9	26.6	33.2	.8	0.5	1.2	1.8	2.5	3.2	3.8	4.5	5.1	5.8	6.5	
39.9	6.7	13.3	20.0	26.6	33.3	.9	0.6	1.3	1.9	2.6	3.2	3.9	4.5	5.2	5.9	6.5	
40.0	6.6	13.3	20.0	26.6	33.3	.0	0.0	0.7	1.3	2.0	2.7	3.4	4.0	4.7	5.4	6.1	0.9 0.1 2.8 0.2 4.6 0.3 6.5 0.4 8.3 0.5 10.2 0.6 12.0 0.7 13.9 0.8 15.7 0.9 17.6 1.0 19.4 1.1 21.3 1.2 23.1 1.3 25.0 1.4 26.8 1.5 28.7 1.6 30.5 1.7 32.3 1.8 34.2
40.1	6.7	13.3	20.0	26.7	33.4	.1	0.1	0.7	1.4	2.1	2.8	3.4	4.1	4.8	5.5	6.1	
40.2	6.7	13.4	20.1	26.8	33.5	.2	0.1	0.8	1.5	2.2	2.8	3.5	4.2	4.9	5.5	6.2	
40.3	6.7	13.4	20.1	26.9	33.6	.3	0.2	0.9	1.6	2.2	2.9	3.6	4.3	4.9	5.6	6.3	
40.4	6.7	13.5	20.2	26.9	33.7	.4	0.3	0.9	1.6	2.3	3.0	3.6	4.3	5.0	5.7	6.3	
40.5	6.8	13.5	20.3	27.0	33.8	.5	0.3	1.0	1.7	2.4	3.0	3.7	4.4	5.1	5.7	6.4	
40.6	6.8	13.5	20.3	27.1	33.8	.6	0.4	1.1	1.8	2.4	3.1	3.8	4.5	5.1	5.8	6.5	
40.7	6.8	13.6	20.4	27.2	33.9	.7	0.5	1.1	1.8	2.5	3.2	3.8	4.5	5.2	5.9	6.5	
40.8	6.8	13.6	20.4	27.2	34.0	.8	0.5	1.2	1.9	2.6	3.2	3.9	4.6	5.3	5.9	6.6	
40.9	6.9	13.7	20.5	27.3	34.1	.9	0.6	1.3	2.0	2.6	3.3	4.0	4.7	5.3	6.0	6.7	
41.0	6.8	13.6	20.5	27.3	34.1	.0	0.0	0.7	1.4	2.1	2.8	3.5	4.1	4.8	5.5	6.2	
41.1	6.8	13.7	20.5	27.4	34.2	.1	0.1	0.8	1.5	2.1	2.8	3.5	4.2	4.9	5.6	6.3	
41.2	6.8	13.7	20.6	27.4	34.3	.2	0.1	0.8	1.5	2.2	2.9	3.6	4.3	5.0	5.7	6.4	
41.3	6.9	13.8	20.6	27.5	34.4	.3	0.2	0.9	1.6	2.3	3.0	3.7	4.4	5.0	5.7	6.4	
41.4	6.9	13.8	20.7	27.6	34.5	.4	0.3	1.0	1.7	2.4	3.0	3.7	4.4	5.1	5.8	6.5	
41.5	6.9	13.8	20.8	27.7	34.6	.5	0.3	1.0	1.7	2.4	3.1	3.8	4.5	5.2	5.9	6.6	
41.6	6.9	13.9	20.8	27.7	34.7	.6	0.4	1.1	1.8	2.5	3.2	3.9	4.6	5.3	5.9	6.6	
41.7	7.0	13.9	20.9	27.8	34.8	.7	0.5	1.2	1.9	2.6	3.3	3.9	4.6	5.3	6.0	6.7	
41.8	7.0	14.0	20.9	27.9	34.9	.8	0.6	1.2	1.9	2.6	3.3	4.0	4.7	5.4	6.1	6.8	
41.9	7.0	14.0	21.0	28.0	35.0	.9	0.6	1.3	2.0	2.7	3.4	4.1	4.8	5.5	6.2	6.8	
42.0	7.0	14.0	21.0	28.0	35.0	.0	0.0	0.7	1.4	2.1	2.8	3.5	4.2	5.0	5.7	6.4	1.0 0.1 3.0 0.2 4.9 0.3 6.9 0.4 8.9 0.5 10.8 0.6 12.8 0.7 14.8 0.8 16.7 0.9 18.7 1.0 20.7 1.1 22.7 1.2 24.6 1.3 26.6 1.4 28.6 1.5 30.5 1.6 32.5 1.7 34.5
42.1	7.0	14.0	21.0	28.0	35.1	.1	0.1	0.8	1.5	2.2	2.9	3.6	4.3	5.0	5.7	6.4	
42.2	7.0	14.0	21.1	28.1	35.1	.2	0.1	0.8	1.6	2.3	3.0	3.7	4.4	5.1	5.8	6.5	
42.3	7.0	14.1	21.1	28.2	35.2	.3	0.2	0.9	1.6	2.3	3.0	3.8	4.5	5.2	5.9	6.6	
42.4	7.1	14.1	21.2	28.3	35.3	.4	0.3	1.0	1.7	2.4	3.1	3.8	4.5	5.2	5.9	6.7	
42.5	7.1	14.2	21.3	28.3	35.4	.5	0.4	1.1	1.8	2.5	3.2	3.9	4.6	5.3	6.0	6.7	
42.6	7.1	14.2	21.3	28.4	35.5	.6	0.4	1.1	1.8	2.5	3.3	4.0	4.7	5.4	6.1	6.8	
42.7	7.1	14.3	21.4	28.5	35.6	.7	0.5	1.2	1.9	2.6	3.3	4.0	4.7	5.5	6.2	6.9	
42.8	7.2	14.3	21.4	28.6	35.7	.8	0.6	1.3	2.0	2.7	3.4	4.1	4.8	5.5	6.2	6.9	
42.9	7.2	14.3	21.5	28.6	35.8	.9	0.6	1.3	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0	
43.0	7.1	14.3	21.5	28.6	35.8	.0	0.0	0.7	1.4	2.2	2.9	3.6	4.3	5.1	5.8	6.5	
43.1	7.2	14.3	21.5	28.7	35.9	.1	0.1	0.8	1.5	2.2	3.0	3.7	4.4	5.1	5.9	6.6	
43.2	7.2	14.4	21.6	28.8	36.0	.2	0.1	0.9	1.6	2.3	3.0	3.8	4.5	5.2	5.9	6.7	
43.3	7.2	14.4	21.6	28.9	36.1	.3	0.2	0.9	1.7	2.4	3.1	3.8	4.6	5.3	6.0	6.7	
43.4	7.2	14.5	21.7	28.9	36.2	.4	0.3	1.0	1.7	2.5	3.2	3.9	4.6	5.4	6.1	6.8	
43.5	7.3	14.5	21.8	29.0	36.3	.5	0.4	1.1	1.8	2.5	3.3	4.0	4.7	5.4	6.2	6.9	
43.6	7.3	14.5	21.8	29.1	36.3	.6	0.4	1.2	1.9	2.6	3.3	4.1	4.8	5.5	6.2	7.0	
43.7	7.3	14.6	21.9	29.2	36.4	.7	0.5	1.2	2.0	2.7	3.4	4.1	4.9	5.6	6.3	7.0	
43.8	7.3	14.6	21.9	29.2	36.5	.8	0.6	1.3	2.0	2.8	3.5	4.2	4.9	5.7	6.4	7.1	
43.9	7.4	14.7	22.0	29.3	36.6	.9	0.7	1.4	2.1	2.8	3.6	4.3	5.0	5.7	6.5	7.2	
	10′	20′	30′	40′	50′		0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	

The Double-Second-Difference correction (Corr.) is always to be added to the tabulated altitude.

INTERPOLATION TABLE

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff.	and Corr.
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
44.0	7.3	14.6	22.0	29.3	36.6	**.0**	0.0	0.7	1.5	2.2	3.0	3.7	4.4	5.2	5.9	6.7	1.1 3.2 5.3 7.5 9.6 11.7 13.9 16.0 18.1 20.3 22.4 24.5 26.7 28.8 30.9 33.1 35.2	0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
44.1	7.3	14.7	22.0	29.4	36.7	**.1**	0.1	0.8	1.6	2.3	3.0	3.8	4.5	5.3	6.0	6.7		
44.2	7.3	14.7	22.1	29.4	36.8	**.2**	0.1	0.9	1.6	2.4	3.1	3.9	4.6	5.3	6.1	6.8		
44.3	7.4	14.8	22.1	29.5	36.9	**.3**	0.2	1.0	1.7	2.4	3.2	3.9	4.7	5.4	6.2	6.9		
44.4	7.4	14.8	22.2	29.6	37.0	**.4**	0.3	1.0	1.8	2.5	3.3	4.0	4.7	5.5	6.2	7.0		
44.5	7.4	14.8	22.3	29.7	37.1	**.5**	0.4	1.1	1.9	2.6	3.3	4.1	4.8	5.6	6.3	7.0		
44.6	7.4	14.9	22.3	29.7	37.2	**.6**	0.4	1.2	1.9	2.7	3.4	4.2	4.9	5.6	6.4	7.1		
44.7	7.5	14.9	22.4	29.8	37.3	**.7**	0.5	1.3	2.0	2.7	3.5	4.2	5.0	5.7	6.5	7.2		
44.8	7.5	15.0	22.4	29.9	37.4	**.8**	0.6	1.3	2.1	2.8	3.6	4.3	5.0	5.8	6.5	7.3		
44.9	7.5	15.0	22.5	30.0	37.5	**.9**	0.7	1.4	2.2	2.9	3.6	4.4	5.1	5.9	6.6	7.3		
45.0	7.5	15.0	22.5	30.0	37.5	**.0**	0.0	0.8	1.5	2.3	3.0	3.8	4.5	5.3	6.1	6.8		
45.1	7.5	15.0	22.5	30.0	37.6	**.1**	0.1	0.8	1.6	2.4	3.1	3.9	4.6	5.4	6.1	6.9		
45.2	7.5	15.0	22.6	30.1	37.6	**.2**	0.2	0.9	1.7	2.4	3.2	3.9	4.7	5.5	6.2	7.0		
45.3	7.5	15.1	22.6	30.2	37.7	**.3**	0.2	1.0	1.7	2.5	3.3	4.0	4.8	5.5	6.3	7.1		
45.4	7.6	15.1	22.7	30.3	37.8	**.4**	0.3	1.1	1.8	2.6	3.3	4.1	4.9	5.6	6.4	7.1		
45.5	7.6	15.2	22.8	30.3	37.9	**.5**	0.4	1.1	1.9	2.7	3.4	4.2	4.9	5.7	6.4	7.2		
45.6	7.6	15.2	22.8	30.4	38.0	**.6**	0.5	1.2	2.0	2.7	3.5	4.2	5.0	5.8	6.5	7.3		
45.7	7.6	15.3	22.9	30.5	38.1	**.7**	0.5	1.3	2.0	2.8	3.6	4.3	5.1	5.8	6.6	7.4		
45.8	7.7	15.3	22.9	30.6	38.2	**.8**	0.6	1.4	2.1	2.9	3.6	4.4	5.2	5.9	6.7	7.4		
45.9	7.7	15.3	23.0	30.6	38.3	**.9**	0.7	1.4	2.2	3.0	3.7	4.5	5.2	6.0	6.7	7.5		
46.0	7.6	15.3	23.0	30.6	38.3	**.0**	0.0	0.8	1.5	2.3	3.1	3.9	4.6	5.4	6.2	7.0	1.2 3.5 5.8 8.1 10.5 12.8 15.1 17.4 19.8 22.1 24.4 26.7 29.1 31.4 33.7 36.0	0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
46.1	7.7	15.3	23.0	30.7	38.4	**.1**	0.1	0.9	1.6	2.4	3.2	4.0	4.7	5.5	6.3	7.1		
46.2	7.7	15.4	23.1	30.8	38.5	**.2**	0.2	0.9	1.7	2.5	3.3	4.0	4.8	5.6	6.4	7.1		
46.3	7.7	15.4	23.1	30.9	38.6	**.3**	0.2	1.0	1.8	2.6	3.3	4.1	4.9	5.7	6.4	7.2		
46.4	7.7	15.5	23.2	30.9	38.7	**.4**	0.3	1.1	1.9	2.6	3.4	4.2	5.0	5.7	6.5	7.3		
46.5	7.8	15.5	23.3	31.0	38.8	**.5**	0.4	1.2	1.9	2.7	3.5	4.3	5.0	5.8	6.6	7.4		
46.6	7.8	15.5	23.3	31.1	38.8	**.6**	0.5	1.2	2.0	2.8	3.6	4.3	5.1	5.9	6.7	7.4		
46.7	7.8	15.6	23.4	31.2	38.9	**.7**	0.5	1.3	2.1	2.9	3.6	4.4	5.2	6.0	6.7	7.5		
46.8	7.8	15.6	23.4	31.2	39.0	**.8**	0.6	1.4	2.2	2.9	3.7	4.5	5.3	6.0	6.8	7.6		
46.9	7.9	15.7	23.5	31.3	39.1	**.9**	0.7	1.5	2.2	3.0	3.8	4.6	5.3	6.1	6.9	7.7		
47.0	7.8	15.6	23.5	31.3	39.1	**.0**	0.0	0.8	1.6	2.4	3.2	4.0	4.7	5.5	6.3	7.1		
47.1	7.8	15.7	23.5	31.4	39.2	**.1**	0.1	0.9	1.7	2.5	3.2	4.0	4.8	5.6	6.4	7.2		
47.2	7.8	15.7	23.6	31.4	39.3	**.2**	0.2	0.9	1.7	2.5	3.3	4.1	4.9	5.7	6.5	7.3		
47.3	7.9	15.8	23.6	31.5	39.4	**.3**	0.2	1.0	1.8	2.6	3.4	4.2	5.0	5.8	6.6	7.4		
47.4	7.9	15.8	23.7	31.6	39.5	**.4**	0.3	1.1	1.9	2.7	3.5	4.3	5.1	5.9	6.6	7.4		
47.5	7.9	15.8	23.8	31.7	39.6	**.5**	0.4	1.2	2.0	2.8	3.6	4.4	5.1	5.9	6.7	7.5	1.3 3.8 6.3 8.9 11.4 14.0 16.5 19.0 21.6 24.1 26.7 29.2 31.7 34.3	0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3
47.6	7.9	15.9	23.8	31.7	39.7	**.6**	0.5	1.3	2.1	2.8	3.6	4.4	5.2	6.0	6.8	7.6		
47.7	8.0	15.9	23.9	31.8	39.8	**.7**	0.6	1.3	2.1	2.9	3.7	4.5	5.3	6.1	6.9	7.7		
47.8	8.0	16.0	23.9	31.9	39.9	**.8**	0.6	1.4	2.2	3.0	3.8	4.6	5.4	6.2	7.0	7.8		
47.9	8.0	16.0	24.0	32.0	40.0	**.9**	0.7	1.5	2.3	3.1	3.9	4.7	5.5	6.3	7.0	7.8		
48.0	8.0	16.0	24.0	32.0	40.0	**.0**	0.0	0.8	1.6	2.4	3.2	4.0	4.8	5.7	6.5	7.3		
48.1	8.0	16.0	24.0	32.0	40.1	**.1**	0.1	0.9	1.7	2.5	3.3	4.1	4.9	5.7	6.5	7.4		
48.2	8.0	16.0	24.1	32.1	40.1	**.2**	0.2	1.0	1.8	2.6	3.4	4.2	5.0	5.8	6.6	7.4		
48.3	8.0	16.1	24.1	32.2	40.2	**.3**	0.2	1.1	1.9	2.7	3.5	4.3	5.1	5.9	6.7	7.5		
48.4	8.1	16.1	24.2	32.3	40.3	**.4**	0.3	1.1	1.9	2.7	3.6	4.4	5.2	6.0	6.8	7.6		
48.5	8.1	16.2	24.3	32.3	40.4	**.5**	0.4	1.2	2.0	2.8	3.6	4.4	5.3	6.1	6.9	7.7		
48.6	8.1	16.2	24.3	32.4	40.5	**.6**	0.5	1.3	2.1	2.9	3.7	4.5	5.3	6.1	7.0	7.8		
48.7	8.1	16.3	24.4	32.5	40.6	**.7**	0.6	1.4	2.2	3.0	3.8	4.6	5.4	6.2	7.0	7.8		
48.8	8.2	16.3	24.4	32.6	40.7	**.8**	0.6	1.5	2.3	3.1	3.9	4.7	5.5	6.3	7.1	7.9		
48.9	8.2	16.3	24.5	32.6	40.8	**.9**	0.7	1.5	2.3	3.2	4.0	4.8	5.6	6.4	7.2	8.0		
49.0	8.1	16.3	24.5	32.6	40.8	**.0**	0.0	0.8	1.6	2.5	3.3	4.1	4.9	5.8	6.6	7.4	1.4 4.2 7.1 9.9 12.7 15.5 18.4 21.2 24.0 26.8 29.7 32.5 35.3	0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2
49.1	8.2	16.3	24.5	32.7	40.9	**.1**	0.1	0.9	1.7	2.6	3.4	4.2	5.0	5.9	6.7	7.5		
49.2	8.2	16.4	24.6	32.8	41.0	**.2**	0.2	1.0	1.8	2.6	3.5	4.3	5.1	5.9	6.8	7.6		
49.3	8.2	16.4	24.6	32.9	41.1	**.3**	0.2	1.1	1.9	2.7	3.5	4.4	5.2	6.0	6.8	7.7		
49.4	8.2	16.5	24.7	32.9	41.2	**.4**	0.3	1.2	2.0	2.8	3.6	4.5	5.3	6.1	6.9	7.8		
49.5	8.3	16.5	24.8	33.0	41.3	**.5**	0.4	1.2	2.1	2.9	3.7	4.5	5.4	6.2	7.0	7.8		
49.6	8.3	16.5	24.8	33.1	41.3	**.6**	0.5	1.3	2.1	3.0	3.8	4.6	5.4	6.3	7.1	7.9		
49.7	8.3	16.6	24.9	33.2	41.4	**.7**	0.6	1.4	2.2	3.1	3.9	4.7	5.5	6.4	7.2	8.0		
49.8	8.3	16.6	24.9	33.2	41.5	**.8**	0.7	1.5	2.3	3.1	4.0	4.8	5.6	6.4	7.3	8.1		
49.9	8.4	16.7	25.0	33.3	41.6	**.9**	0.7	1.6	2.4	3.2	4.0	4.9	5.7	6.5	7.3	8.2		
50.0	8.3	16.6	25.0	33.3	41.6	**.0**	0.0	0.8	1.7	2.5	3.4	4.2	5.0	5.9	6.7	7.6		
50.1	8.3	16.7	25.0	33.4	41.7	**.1**	0.1	0.9	1.8	2.6	3.5	4.3	5.1	6.0	6.8	7.7		
50.2	8.3	16.7	25.1	33.4	41.8	**.2**	0.2	1.0	1.9	2.7	3.5	4.4	5.2	6.1	6.9	7.7		
50.3	8.4	16.8	25.1	33.5	41.9	**.3**	0.3	1.1	1.9	2.8	3.6	4.5	5.3	6.1	7.0	7.8		
50.4	8.4	16.8	25.2	33.6	42.0	**.4**	0.3	1.2	2.0	2.9	3.7	4.5	5.4	6.2	7.1	7.9		
50.5	8.4	16.8	25.3	33.7	42.1	**.5**	0.4	1.3	2.1	2.9	3.8	4.6	5.5	6.3	7.2	8.0	1.6 4.8 8.0 11.2 14.5 17.7 20.9 24.1 27.3 30.5 33.7 36.9	0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
50.6	8.4	16.9	25.3	33.7	42.2	**.6**	0.5	1.3	2.2	3.0	3.9	4.7	5.6	6.4	7.2	8.1		
50.7	8.5	16.9	25.4	33.8	42.3	**.7**	0.6	1.4	2.3	3.1	4.0	4.8	5.6	6.5	7.3	8.2		
50.8	8.5	17.0	25.4	33.9	42.4	**.8**	0.7	1.5	2.4	3.2	4.0	4.9	5.7	6.6	7.4	8.2		
50.9	8.5	17.0	25.5	34.0	42.5	**.9**	0.8	1.6	2.4	3.3	4.1	5.0	5.8	6.6	7.5	8.3		
51.0	8.5	17.0	25.5	34.0	42.5	**.0**	0.0	0.9	1.7	2.6	3.4	4.3	5.1	6.0	6.9	7.7		
51.1	8.5	17.0	25.5	34.0	42.6	**.1**	0.1	0.9	1.8	2.7	3.5	4.4	5.2	6.1	7.0	7.8		
51.2	8.5	17.0	25.6	34.1	42.6	**.2**	0.2	1.0	1.9	2.7	3.6	4.5	5.3	6.2	7.0	7.9		
51.3	8.5	17.1	25.6	34.2	42.7	**.3**	0.3	1.1	2.0	2.8	3.7	4.5	5.4	6.3	7.1	8.0		
51.4	8.6	17.1	25.7	34.3	42.8	**.4**	0.3	1.2	2.1	2.9	3.8	4.6	5.5	6.4	7.2	8.1		
51.5	8.6	17.2	25.8	34.3	42.9	**.5**	0.4	1.3	2.1	3.0	3.9	4.7	5.6	6.4	7.3	8.2		
51.6	8.6	17.2	25.8	34.4	43.0	**.6**	0.5	1.4	2.2	3.1	3.9	4.8	5.7	6.5	7.4	8.2		
51.7	8.6	17.3	25.9	34.5	43.1	**.7**	0.6	1.5	2.3	3.2	4.0	4.9	5.8	6.6	7.5	8.3		
51.8	8.7	17.3	25.9	34.6	43.2	**.8**	0.7	1.5	2.4	3.3	4.1	5.0	5.8	6.7	7.6	8.4		
51.9	8.7	17.3	26.0	34.6	43.3	**.9**	0.8	1.6	2.5	3.3	4.2	5.1	5.9	6.8	7.6	8.5		
	10′	**20′**	**30′**	**40′**	**50′**		**0′**	**1′**	**2′**	**3′**	**4′**	**5′**	**6′**	**7′**	**8′**	**9′**		

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff.	and Corr.
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
52.0	8.6	17.3	26.0	34.6	43.3	**.0**	0.0	0.9	1.7	2.6	3.5	4.4	5.2	6.1	7.0	7.9	1.8 5.5 9.1 12.8 16.5 20.1 23.8 27.4 31.1 34.7	0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
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	2.1 6.2 10.4 14.5 18.6 22.8 26.9 31.1 35.2	0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
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		
54.0	9.0	18.0	27.0	36.0	45.0	**.0**	0.0	0.9	1.8	2.7	3.6	4.5	5.4	6.4	7.3	8.2	2.4 7.2 12.0 16.8 21.6 26.4 31.2 36.0	0.1 0.2 0.3 0.4 0.5 0.6 0.7
54.1	9.0	18.0	27.0	36.0	45.1	**.1**	0.1	1.0	1.9	2.8	3.7	4.6	5.5	6.4	7.4	8.3		
54.2	9.0	18.0	27.1	36.1	45.1	**.2**	0.2	1.1	2.0	2.9	3.8	4.7	5.6	6.5	7.4	8.4		
54.3	9.0	18.1	27.1	36.2	45.2	**.3**	0.3	1.2	2.1	3.0	3.9	4.8	5.7	6.6	7.5	8.4		
54.4	9.1	18.1	27.2	36.3	45.3	**.4**	0.4	1.3	2.2	3.1	4.0	4.9	5.8	6.7	7.6	8.5		
54.5	9.1	18.2	27.3	36.3	45.4	**.5**	0.5	1.4	2.3	3.2	4.1	5.0	5.9	6.8	7.7	8.6		
54.6	9.1	18.2	27.3	36.4	45.5	**.6**	0.5	1.5	2.4	3.3	4.2	5.1	6.0	6.9	7.8	8.7		
54.7	9.1	18.3	27.4	36.5	45.6	**.7**	0.6	1.5	2.5	3.4	4.3	5.2	6.1	7.0	7.9	8.8		
54.8	9.2	18.3	27.4	36.6	45.7	**.8**	0.7	1.6	2.5	3.5	4.4	5.3	6.2	7.1	8.0	8.9		
54.9	9.2	18.3	27.5	36.6	45.8	**.9**	0.8	1.7	2.6	3.5	4.5	5.4	6.3	7.2	8.1	9.0		
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	2.9 8.6 14.4 20.2 25.9 31.7 37.5	0.1 0.2 0.3 0.4 0.5 0.6
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		
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	3.6 10.9 18.2 25.5 32.8 40.1	0.1 0.2 0.3 0.4 0.5
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		
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		
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		
56.5	9.4	18.8	28.3	37.7	47.1	**.5**	0.5	1.4	2.4	3.3	4.2	5.2	6.1	7.1	8.0	8.9		
56.6	9.4	18.9	28.3	37.7	47.2	**.6**	0.6	1.5	2.4	3.4	4.3	5.3	6.2	7.2	8.1	9.0		
56.7	9.5	18.9	28.4	37.8	47.3	**.7**	0.7	1.6	2.5	3.5	4.4	5.4	6.3	7.3	8.2	9.1		
56.8	9.5	19.0	28.4	37.9	47.4	**.8**	0.8	1.7	2.6	3.6	4.5	5.5	6.4	7.3	8.3	9.2		
56.9	9.5	19.0	28.5	38.0	47.5	**.9**	0.8	1.8	2.7	3.7	4.6	5.6	6.5	7.4	8.4	9.3		
57.0	9.5	19.0	28.5	38.0	47.5	**.0**	0.0	1.0	1.9	2.9	3.8	4.8	5.7	6.7	7.7	8.6	5.0 15.0 25.0 35.1	0.1 0.2 0.3
57.1	9.5	19.0	28.5	38.0	47.6	**.1**	0.1	1.1	2.0	3.0	3.9	4.9	5.8	6.8	7.8	8.7		
57.2	9.5	19.0	28.6	38.1	47.6	**.2**	0.2	1.1	2.1	3.1	4.0	5.0	5.9	6.9	7.9	8.8		
57.3	9.5	19.1	28.6	38.2	47.7	**.3**	0.3	1.2	2.2	3.2	4.1	5.1	6.0	7.0	8.0	8.9		
57.4	9.6	19.1	28.7	38.3	47.8	**.4**	0.4	1.3	2.3	3.3	4.2	5.2	6.1	7.1	8.0	9.0		
57.5	9.6	19.2	28.8	38.3	47.9	**.5**	0.5	1.4	2.4	3.4	4.3	5.3	6.2	7.2	8.1	9.1		
57.6	9.6	19.2	28.8	38.4	48.0	**.6**	0.6	1.5	2.5	3.4	4.4	5.4	6.3	7.3	8.2	9.2		
57.7	9.6	19.3	28.9	38.5	48.1	**.7**	0.7	1.6	2.6	3.5	4.5	5.5	6.4	7.4	8.3	9.3		
57.8	9.7	19.3	28.9	38.6	48.2	**.8**	0.8	1.7	2.7	3.6	4.6	5.6	6.5	7.5	8.4	9.4		
57.9	9.7	19.3	29.0	38.6	48.3	**.9**	0.9	1.8	2.8	3.7	4.7	5.7	6.6	7.6	8.5	9.5		
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	8.2 24.6 41.0	0.1 0.2
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		
59.0	9.8	19.6	29.5	39.3	49.1	**.0**	0.0	1.0	2.0	3.0	4.0	5.0	5.9	6.9	7.9	8.9	16.2 48.6	0.1
59.1	9.8	19.7	29.5	39.4	49.2	**.1**	0.1	1.1	2.1	3.1	4.1	5.1	6.0	7.0	8.0	9.0		
59.2	9.8	19.7	29.6	39.4	49.3	**.2**	0.2	1.2	2.2	3.2	4.2	5.2	6.1	7.1	8.1	9.1		
59.3	9.9	19.8	29.6	39.5	49.4	**.3**	0.3	1.3	2.3	3.3	4.3	5.3	6.2	7.2	8.2	9.2		
59.4	9.9	19.8	29.7	39.6	49.5	**.4**	0.4	1.4	2.4	3.4	4.4	5.4	6.3	7.3	8.3	9.3		
59.5	9.9	19.8	29.8	39.7	49.6	**.5**	0.5	1.5	2.5	3.5	4.5	5.5	6.4	7.4	8.4	9.4	0.0 48.2	0.0
59.6	9.9	19.9	29.8	39.7	49.7	**.6**	0.6	1.6	2.6	3.6	4.6	5.6	6.5	7.5	8.5	9.5		
59.7	10.0	19.9	29.9	39.8	49.8	**.7**	0.7	1.7	2.7	3.7	4.7	5.7	6.6	7.6	8.6	9.6		
59.8	10.0	20.0	29.9	39.9	49.9	**.8**	0.8	1.8	2.8	3.8	4.8	5.8	6.7	7.7	8.7	9.7		
59.9	10.0	20.0	30.0	40.0	50.0	**.9**	0.9	1.9	2.9	3.9	4.9	5.9	6.8	7.8	8.8	9.8		
	10′	**20′**	**30′**	**40′**	**50′**		**0′**	**1′**	**2′**	**3′**	**4′**	**5′**	**6′**	**7′**	**8′**	**9′**		

The Double-Second-Difference correction (Corr.) is always to be added to the tabulated altitude.

Celestial Running Fix Problems Involving the Sun

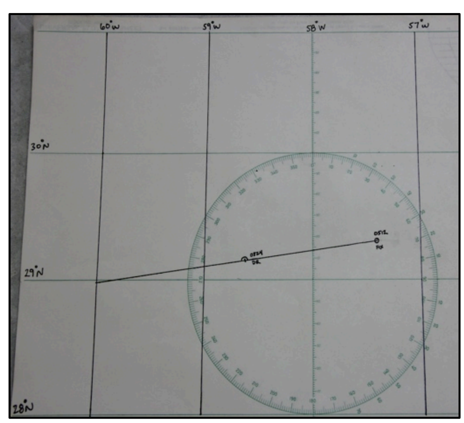
Problem 16-1 (CG-237). The following question is taken directly from the USCG test bank and illustrates how to solve celestial running fix problems.

On 15 August, your 0512 zone time position was latitude 29° 18' N, longitude 57° 24' W. Your vessel was steaming on course 262° T at 20 knots. An observation of the Sun's lower limb was made at 0824 zone time. The chronometer read 00h 22m 24s and was slow 01m 34s. The observed altitude (ho) was 38° 16.7'. LAN occurred at 1204 zone time and the observed altitude (ho) was 74° 58.0'. What was the longitude of your 1204 zone time running fix?

Answer: 59° 59' W

Step 1: Determine the GMT of the morning Sun sight.
Chronometer time: 00h 22m 24s
Chronometer error: 01m 34s slow
Correct chronometer time: 00h 22m 24s + 01m 34s = 00h 23m 58s
Ship time of sight: 0824 ZT
DR longitude: 57° 24' W corresponds to (+4 ZD)
GMT of sight: <u>12:23:58 GMT, 15 August</u>

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 (see Part 5 or Part 9).
Original fix time: 0512 ZT or 0912 GMT
Original fix position: 29° 18' N, 57° 24' W.
Morning observation time: 0824 ZT or 1224 GMT
Course and speed: 262° T at 20 knots
Time underway: 0824 ZT – 0512 ZT = 3 hours, 12 minutes, or 3.2 hours
Distance travelled: 3.2 hours for 20 knots = 64.0 miles covered
Morning DR position (original fix advanced 64 miles in direction 262°):
<u>29° 09' N, 58° 37' W</u>



Step 3: Determine the observed altitude of the morning Sun sight.
ho: 38° 16.7’ (Given)

G.M.T.		SUN G.H.A.	Dec.
15	00	178 52.3	N14 09.1
	01	193 52.4	08.3
	02	208 52.6	07.5
	03	223 52.7	·· 06.8
	04	238 52.8	06.0
	05	253 52.9	05.2
	06	268 53.0	N14 04.4
	07	283 53.2	03.6
S	08	298 53.3	02.9
A	09	313 53.4	·· 02.1
T	10	328 53.5	01.3
U	11	343 53.7	14 00.5
R	12	358 53.8	N13 59.7
D	13	13 53.9	59.0
A	14	28 54.0	58.2
Y	15	43 54.2	·· 57.4
	16	58 54.3	56.6
	17	73 54.4	55.8
	18	88 54.5	N13 55.0
	19	103 54.7	54.3
	20	118 54.8	53.5
	21	133 54.9	·· 52.7
	22	148 55.0	51.9
	23	163 55.2	51.1
		S.D. 15.8	d 0.8

Step 4: Determine the declination of the Sun for the morning Sun sight.
Declination (hours): N 13° 59.7’ (d number 0.8)
Declination (increments): + 0.3’
Declination (total): N 14° 00.0’

Step 5: Determine the GHA of the Sun for the morning Sun sight.
GHA (hours): 358° 53.8’
GHA (increments): 5° 59.5’
GHA (total): 364° 53.3’ (-360°) = 4° 53.3’

Step 6: Determine the assumed position of the ship.
DR latitude: 29° 09’ N
Assumed latitude: 29° N
DR longitude: 58° 37’ W
Assumed longitude (to ensure whole number of LHA): 58° 53.3’ W

23m	SUN PLANETS	ARIES	MOON	v or d	Corrn	v or d	Corrn	v or d	Corrn
s	° ′	° ′	° ′	′	′	′	′	′	′
00	5 45·0	5 45·9	5 29·3	0·0	0·0	6·0	2·4	12·0	4·7
01	5 45·3	5 46·2	5 29·5	0·1	0·0	6·1	2·4	12·1	4·7
02	5 45·5	5 46·4	5 29·8	0·2	0·1	6·2	2·4	12·2	4·8
03	5 45·8	5 46·7	5 30·0	0·3	0·1	6·3	2·5	12·3	4·8
04	5 46·0	5 46·9	5 30·2	0·4	0·2	6·4	2·5	12·4	4·9
05	5 46·3	5 47·2	5 30·5	0·5	0·2	6·5	2·5	12·5	4·9
06	5 46·5	5 47·4	5 30·7	0·6	0·2	6·6	2·6	12·6	4·9
07	5 46·8	5 47·7	5 31·0	0·7	0·3	6·7	2·6	12·7	5·0
08	5 47·0	5 48·0	5 31·2	0·8	0·3	6·8	2·7	12·8	5·0
09	5 47·3	5 48·2	5 31·4	0·9	0·4	6·9	2·7	12·9	5·1
56	5 59·0	6 00·0	5 42·6	5·6	2·2	11·6	4·5	17·6	6·9
57	5 59·3	6 00·2	5 42·9	5·7	2·2	11·7	4·6	17·7	6·9
58	5 59·5	6 00·5	5 43·1	5·8	2·3	11·8	4·6	17·8	7·0
59	5 59·8	6 00·7	5 43·4	5·9	2·3	11·9	4·7	17·9	7·0
60	6 00·0	6 01·0	5 43·6	6·0	2·4	12·0	4·7	18·0	7·1

Step 7: Determine the LHA of the Sun for the morning Sun sight.
GHA (Sun): 4° 53.3’ W
Assumed longitude: 58° 53.3’ W
LHA 4° 53.3’ (+360°) – 58° 53.3’ W = 306° (subtract west, add 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: 29° N
Declination: N 14° (no increments in this problem)
LHA: 306° (Same Pages)

HO 229 values:

Computed altitude (hc): 38° 01.9’
Altitude difference (d): +26.1’
Azimuth (z): 94.7° T

54°, 306° 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	32 45.3	+27.7	105.8	32 28.7	+28.6	106.5	32 11.3	+29.8	107.1	31 53.4	+30.8	107.7
1	33 13.0	+27.0	104.8	32 57.3	+28.2	105.4	32 41.1	+29.2	106.0	32 24.2	+30.2	106.7
2	33 40.0	+26.5	103.7	33 25.5	+27.6	104.4	33 10.3	+28.6	105.0	32 54.4	+29.7	105.6
3	34 06.5	+26.0	102.6	33 53.1	+27.0	103.3	33 38.9	+28.2	103.9	33 24.1	+29.3	104.6
4	34 32.5	+25.3	101.5	34 20.1	+26.5	102.2	34 07.1	+27.6	102.9	33 53.4	+28.6	103.5
5	34 57.8	+24.8	100.4	34 46.6	+25.9	101.1	34 34.7	+27.0	101.8	34 22.0	+28.1	102.5
6	35 22.6	+24.1	99.3	35 12.5	+25.2	100.0	35 01.7	+26.4	100.7	34 50.1	+27.6	101.4
7	35 46.7	+23.5	98.2	35 37.7	+24.7	98.9	35 28.1	+25.8	99.6	35 17.7	+26.9	100.3
8	36 10.2	+22.8	97.1	36 02.4	+24.0	97.8	35 53.9	+25.2	98.5	35 44.6	+26.4	99.2
9	36 33.0	+22.2	95.9	36 26.4	+23.4	96.7	36 19.1	+24.5	97.4	36 11.0	+25.7	98.1
10	36 55.2	+21.4	94.8	36 49.8	+22.7	95.5	36 43.6	+23.9	96.3	36 36.7	+25.1	97.0
11	37 16.6	+20.8	93.6	37 12.5	+22.0	94.3	37 07.5	+23.3	95.1	37 01.8	+24.5	95.9
12	37 37.4	+20.1	92.4	37 34.5	+21.3	93.2	37 30.8	+22.5	93.9	37 26.3	+23.7	94.7
13	37 57.5	+19.3	91.2	37 55.8	+20.6	92.0	37 53.3	+21.9	92.8	37 50.0	+23.1	93.5
14	38 16.8	+18.6	90.0	38 16.4	+19.9	90.8	38 15.2	+21.1	91.6	38 13.1	+22.4	92.4

27° Hc	d	Z	28° Hc	d	Z	29° Hc	d	Z	30° Hc	d	Z	Dec.
° ′	′	°	° ′	′	°	° ′	′	°	° ′	′	°	°
31 34.9	+31.8	108.3	31 15.8	+32.8	108.8	30 56.2	+33.7	109.4	30 36.0	+34.6	110.0	0
32 06.7	+31.2	107.3	31 48.6	+32.2	107.9	31 29.9	+33.2	108.4	31 10.6	+34.2	109.0	1
32 37.9	+30.8	106.2	32 20.8	+31.8	106.9	32 03.1	+32.8	107.5	31 44.8	+33.8	108.1	2
33 08.7	+30.3	105.2	32 52.6	+31.3	105.8	32 35.9	+32.4	106.5	32 18.6	+33.4	107.1	3
33 39.0	+29.7	104.2	33 23.9	+30.8	104.8	33 08.3	+31.8	105.5	32 52.0	+32.8	106.1	4
34 08.7	+29.2	103.1	33 54.7	+30.3	103.8	33 40.1	+31.3	104.4	33 24.8	+32.4	105.1	5
34 37.9	+28.7	102.1	34 25.0	+29.8	102.8	34 11.4	+30.9	103.4	33 57.2	+31.8	104.1	6
35 06.6	+28.1	101.0	34 54.8	+29.2	101.7	34 42.3	+30.2	102.4	34 29.0	+31.4	103.1	7
35 34.7	+27.5	99.9	35 24.0	+28.6	100.6	35 12.5	+29.7	101.3	35 00.4	+30.8	102.0	8
36 02.2	+26.8	98.8	35 52.6	+28.0	99.5	35 42.2	+29.2	100.3	35 31.2	+30.3	101.0	9
36 29.0	+26.3	97.7	36 20.6	+27.4	98.5	36 11.4	+28.6	99.2	36 01.5	+29.6	99.9	10
36 55.3	+25.6	96.6	36 48.0	+26.8	97.3	36 40.0	+27.9	98.1	36 31.1	+29.1	98.8	11
37 20.9	+25.0	95.5	37 14.8	+26.2	96.2	37 07.9	+27.3	97.0	37 00.2	+28.5	97.7	12
37 45.9	+24.3	94.3	37 41.0	+25.5	95.1	37 35.2	+26.7	95.9	37 28.7	+27.9	96.6	13
38 10.2	+23.6	93.2	38 06.5	+24.8	93.9	38 01.9	+26.1	94.7	37 56.6	+27.2	95.5	14

Step 9: Determine the azimuth correction for the sight. In this problem there are no corrections required, but the step is shown for training purposes.

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 – N	29°	94.7°	-	-	00.0’	0
Declination – N	14°	94.7°	-	-	00.0’	0
LHA	306°	94.7°	-	-	00.0’	0

Total correction = 0.0°

Step 10: Apply the correction to the base values to determine true azimuth.
Base azimuth: 94.7°
Correction: 0.0°
Corrected azimuth: 94.7°
Note - Check azimuth rules: if LHA greater than 180°, then zn = z.
Corrected azimuth: 94.7°

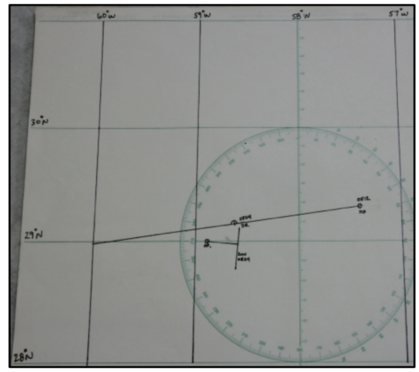
Step 11: Determine the computed altitude. In this problem the altitude difference correction is not necessary, but is shown for training purposes.
Tabular computed altitude (hc): 38° 01.9’
Altitude difference (d): +26.1’
Declination: N 14° 00.0’
Declination increments: 00.0’

Altitude difference correction:
Tens: 00.0’
Units/decimals: 0.0’
Total correction: 00.0’

Tabular hc: 38° 01.9’
Alt correction: 00.0’
hc: 38° 01.9’

Step 12: Determine the intercept (a).
Observed altitude: 38° 16.7’
Computed altitude: 38° 01.9’
Intercept (a): 38° 16.7’ – 38° 01.9’ = 14.8’
If observed altitude is greater, intercept is towards.

Step 13: Plot the morning Sun sight.
Assumed position: 29° N, 58° 53.3’ W
Azimuth: 094.7’
Intercept: 14.8’ towards



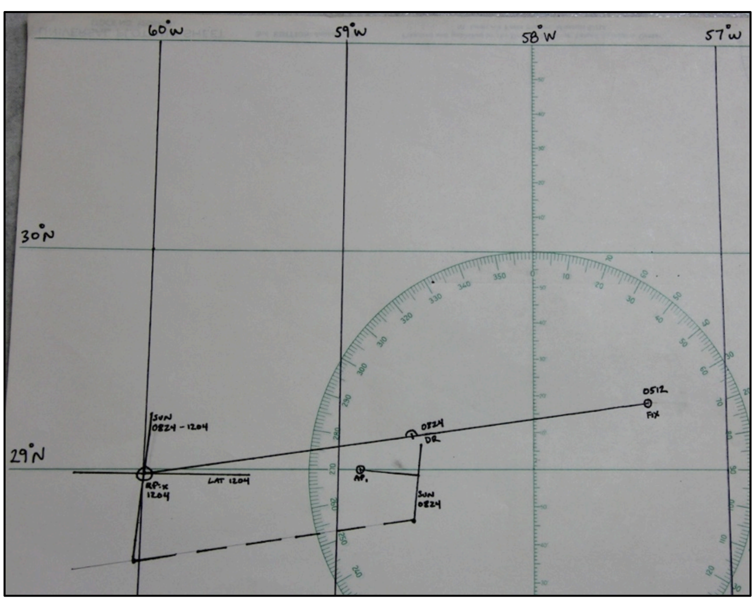
Step 14: Calculated the latitude at meridian passage (see Part 11).
Time of meridian passage sight: 1204 zone time or 1604 GMT
Observed altitude: 74° 58.0’
Zenith Distance: 90° 00.0 – 74° 58.0’ = <u>15° 02.0’</u>
Declination (Sun – hours): 13° 56.6’ N (d number = 0.8)
Declination (Sun – increments): +0.1’
Declination (Sun – total): <u>13° 56.7’</u>
Latitude at meridian passage = zenith distance + declination =
15° 02.0’ N + 13° 56.7’ N = <u>28° 58.7’ N</u>

4 m	SUN PLANETS	ARIES	MOON	v or d	Corr^n	v or d	Corr^n	v or d	Corr^n
s	° ′	° ′	° ′	′	′	′	′	′	′
00	1 00·0	1 00·2	0 57·3	0·0	0·0	6·0	0·5	12·0	0·9
01	1 00·3	1 00·4	0 57·5	0·1	0·0	6·1	0·5	12·1	0·9
02	1 00·5	1 00·7	0 57·7	0·2	0·0	6·2	0·5	12·2	0·9
03	1 00·8	1 00·9	0 58·0	0·3	0·0	6·3	0·5	12·3	0·9
04	1 01·0	1 01·2	0 58·2	0·4	0·0	6·4	0·5	12·4	0·9
05	1 01·3	1 01·4	0 58·5	0·5	0·0	6·5	0·5	12·5	0·9
06	1 01·5	1 01·7	0 58·7	0·6	0·0	6·6	0·5	12·6	0·9
07	1 01·8	1 01·9	0 58·9	0·7	0·1	6·7	0·5	12·7	1·0
08	1 02·0	1 02·2	0 59·2	0·8	0·1	6·8	0·5	12·8	1·0
09	1 02·3	1 02·4	0 59·4	0·9	0·1	6·9	0·5	12·9	1·0

Step 15: Plot the meridian passage latitude.
Latitude: 28° 58.7’ N

Step 16: Advance the morning Sun sight (0824 zone time) to the meridian passage latitude to determine the running fix.
0824 zone time to 1204 zone time = 3 hours 40 minutes = 3.67 hours
3.67 hours at 20 knots = 73.34 miles covered (course 262° T)

Step 17: Answer the required question.
Longitude = **59° 59’ W**



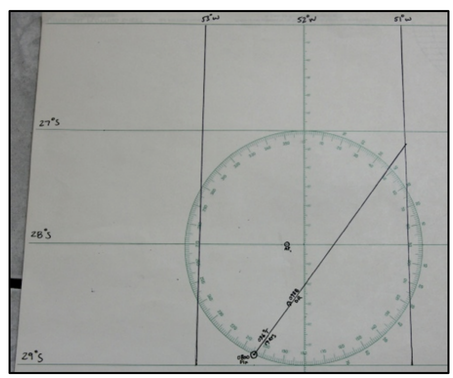
<u>Problem 16-2 (CG-530)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve celestial running fix problems.

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: <u>12:38:47 GMT, 8 February</u>

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 (see Part 5 or Part 9).
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°):
<u>28° 30' S, 52° 06' W</u>



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): <u>S 14° 55.0'</u>

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°) = <u>6° 08.2’</u>

	G.M.T.	SUN G.H.A.	SUN Dec.
	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

Step 6: Determine the assumed position of the ship.
DR latitude: 28° 30’ S
Assumed latitude: <u>28° S</u>
DR longitude: 52° 06’ W
Assumed longitude (to ensure whole number of LHA): <u>52° 08.2’ W</u>

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 = <u>314°</u>
(subtract west, add east)

38 m (s)	SUN PLANETS ° ′	ARIES ° ′	MOON ° ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′	v or d ′	Corrⁿ ′
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 ° ′	23° d ′	23° Z °	24° Hc ° ′	24° d ′	24° Z °	25° Hc ° ′	25° d ′	25° Z °	26° Hc ° ′	26° d ′	26° 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 ° ′	27° d ′	27° Z °	28° Hc ° ′	28° d ′	28° Z °	29° Hc ° ′	29° d ′	29° Z °	30° Hc ° ′	30° d ′	30° 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>

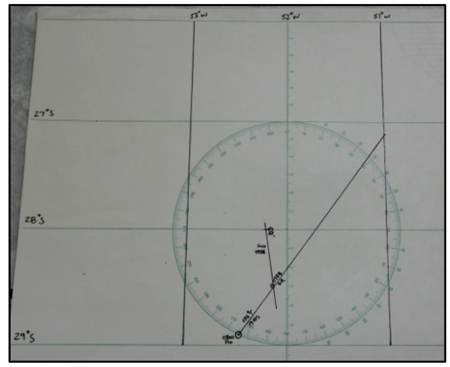
Tabular hc: 45° 07.8’
Alt correction: +23.5’
hc: <u>45° 31.3’</u>

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

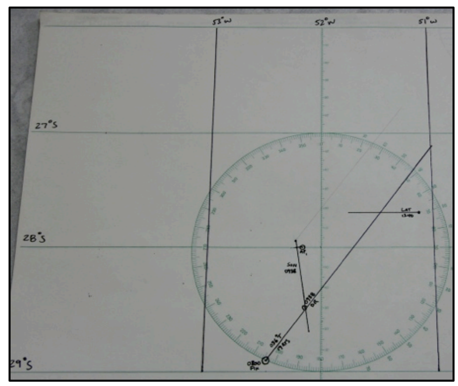
Step 12: Determine the intercept (a).
Observed altitude: 45° 29.2’
Computed altitude: 45° 31.3’
Intercept (a): 45° 31.3’ – 45° 29.2’ = <u>2.1’</u>
If computed altitude is greater, intercept is <u>away.</u>

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 (see Part 11).
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>



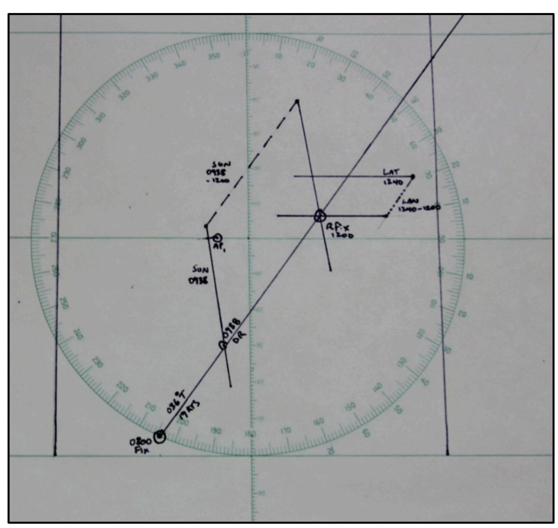
Step 15: Plot the meridian passage latitude.
Latitude: 27° 42.1’ S

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**



<u>Problem 16-3 (CG-35)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve celestial running fix problems.

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 (see Part 5 or Part 9).

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°**

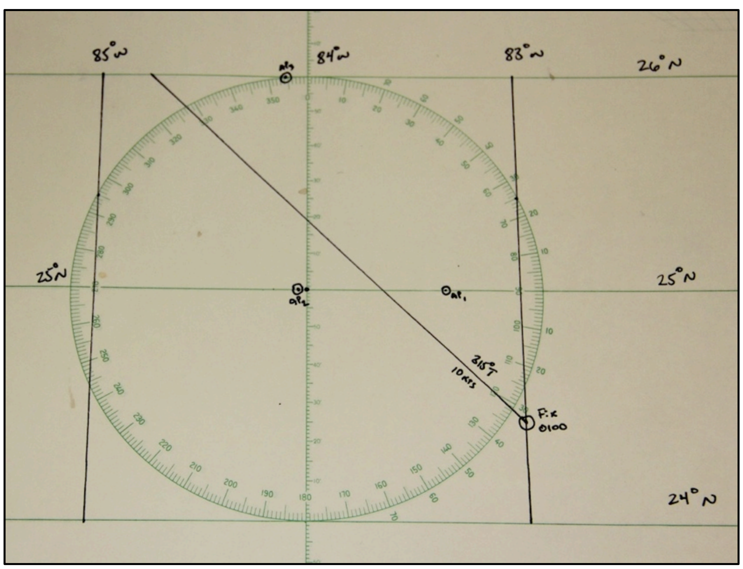
Step 5: Given the tabular HO229 information in step 3 determine the correct computed altitude (hc) for the three Sun sights.

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.

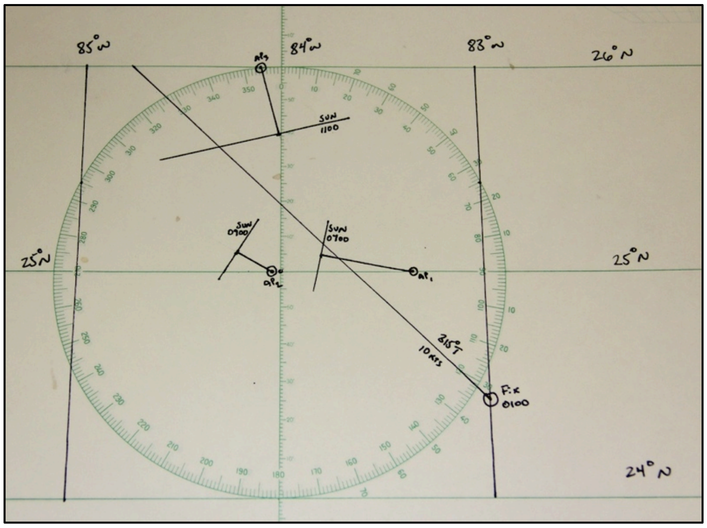
Sight		*Sun (0700)*	*Sun (0900)*	*Sun (1100)*
Observed altitude (ho)	*Given*	21° 09.0’	46° 05.0’	63° 16.1’
Correct computed altitude (hc)	*From step 5*	21° 33.5’	46° 15.0’	62° 55.2’
Intercept (a)	*hc – ho*	**24.5’**	**10.0’**	**20.9’**
Towards/Away	*If hc is greater, intercept is “away”*	**Away**	**Away**	**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.

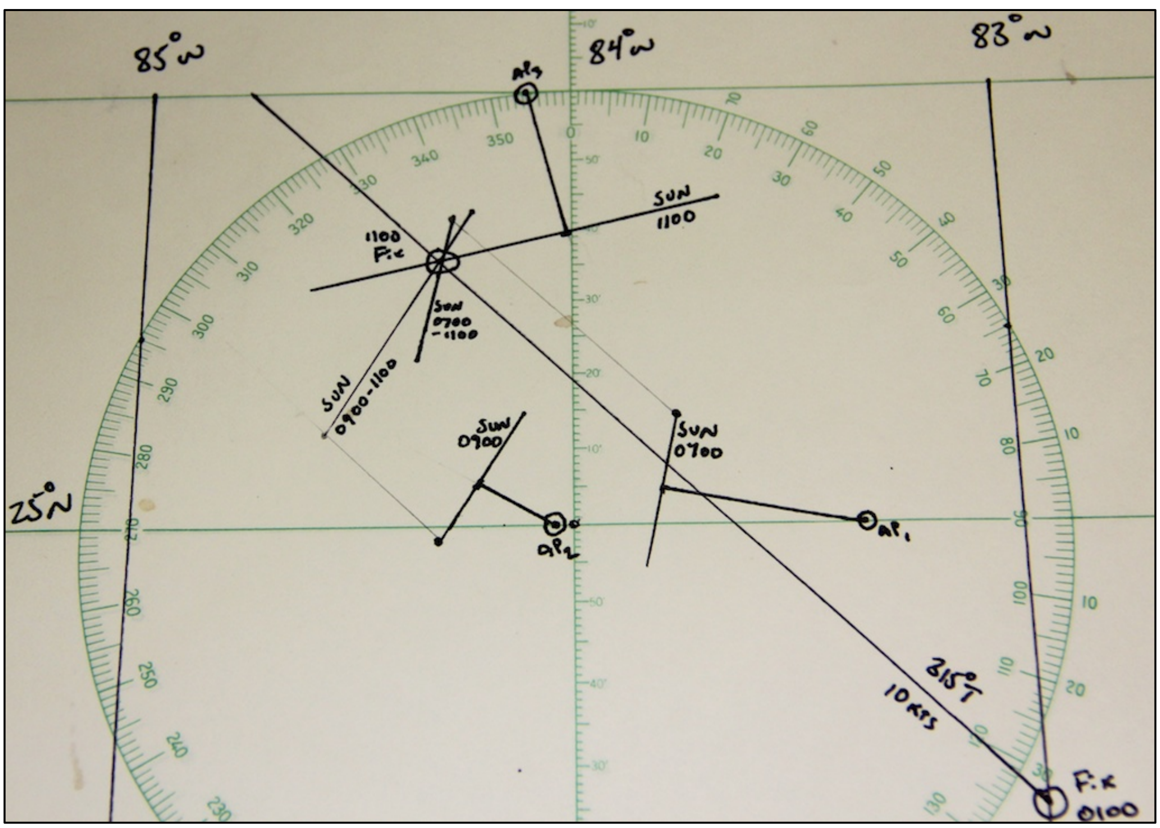


Dec. Inc.	Altitude Difference (d)															
	Tens					Decimals	Units									
	10′	20′	30′	40′	50′	⇓	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
9.0	1.5	3.0	4.5	6.0	7.5	**.0**	0.0	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.4
9.1	1.5	3.0	4.5	6.0	7.6	**.1**	0.0	0.2	0.3	0.5	0.6	0.8	1.0	1.1	1.3	1.4
9.2	1.5	3.0	4.6	6.1	7.6	**.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



Celestial Running Fix Problems Involving Stars

Problem 16-4 (CG-505). The following question is taken directly from the USCG test bank and illustrates how to solve celestial running fix problems.

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 (see Part 5 or Part 9).

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	99.5	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

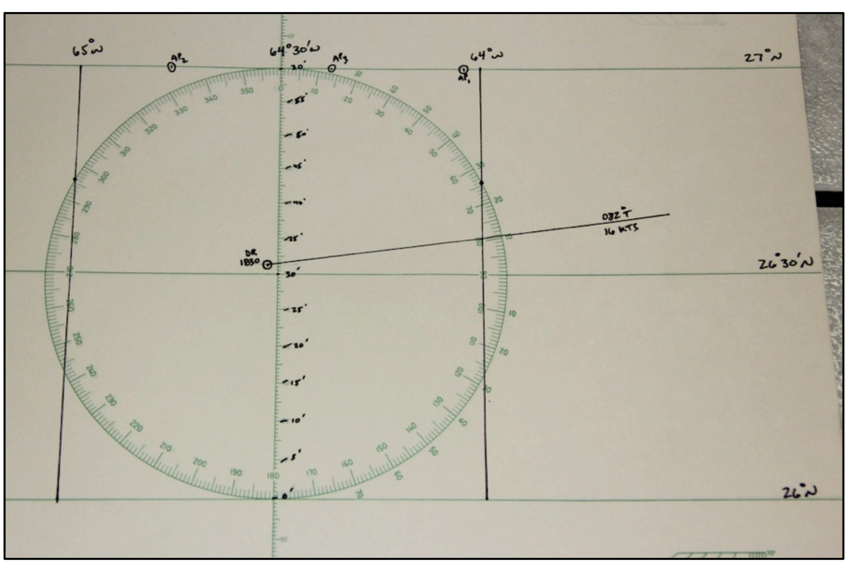
Step 5: Given the tabular HO229 information in step 3, determine the correct computed altitude (hc) for the three star sights.

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'**

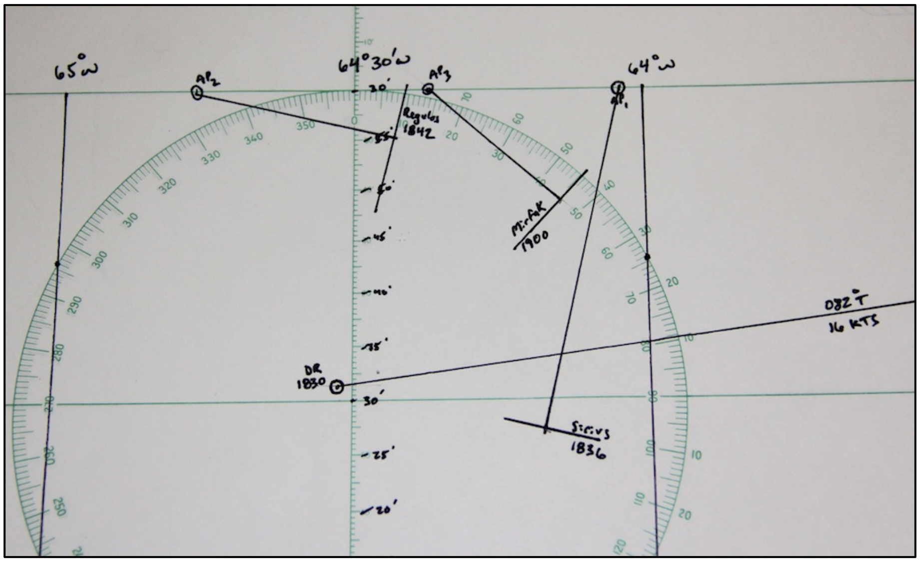
Step 6: Compare the observed altitudes (given) with the computed altitudes (determined in step 5), to compute intercepts (a) for the three star sights.

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°

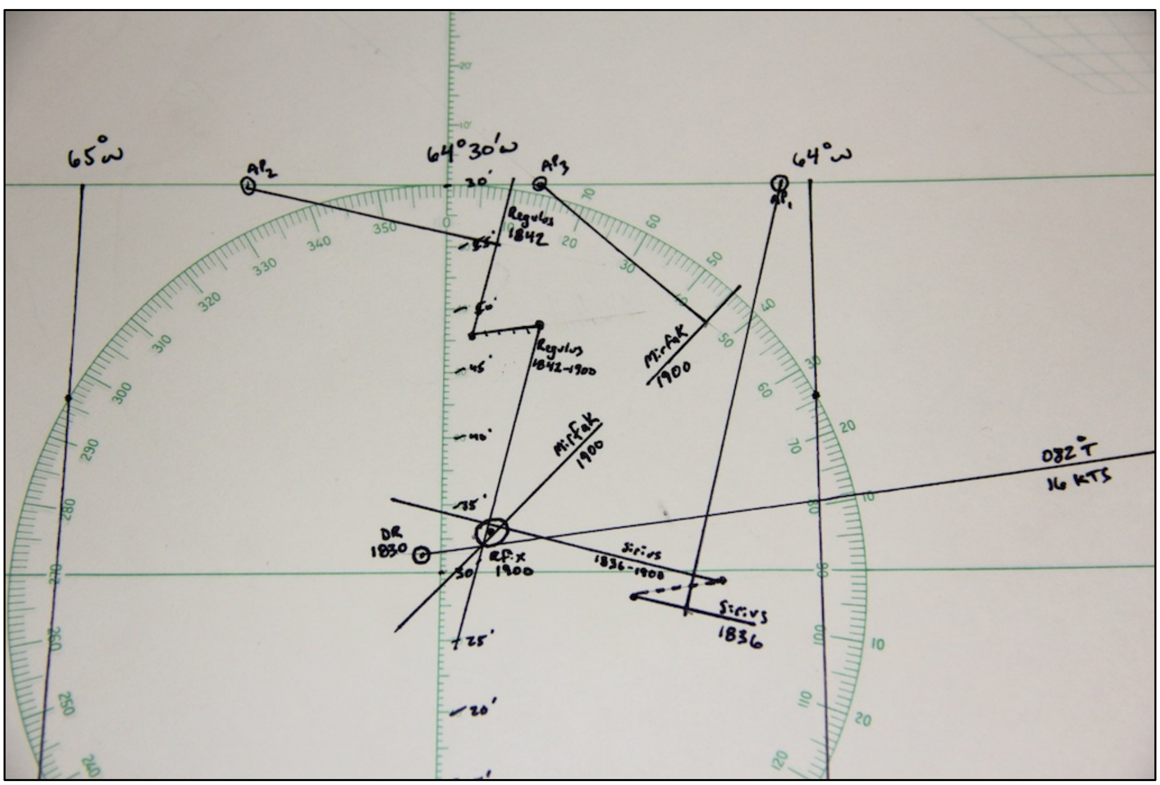
Step 7: Plot the assumed positions for each star sight.



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



<u>Problem 16-5 (CG-418)</u>. The following question is taken directly from the USCG test bank and illustrates how to solve celestial running fix problems.

On 25 March, your 0500 zone time DR position is latitude 28° 14.0' S, longitude 93° 17.0' E. You are on course 291° T at a speed of 16 knots. You observe 3 celestial bodies. Determine the latitude and longitude of your 0550 running fix.

Body	*Zone Time*	*GHA*	*Observed Altitude*	*Declination*
Peacock	*0520*	*226° 18.5'*	*49° 42.9'*	*S 56° 47.6'*
Altair	*0535*	*238° 38.2'*	*43° 53.1'*	*N 8° 48.9'*
Spica	*0550*	*338° 48.5'*	*21° 11.7'*	*S 11° 03.8'*

Answer: 28° 16' S, 92° 57' E

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 (see Part 5 or Part 9).

Sight	*Original DR (0500)*	*Peacock (0520)*	*Altair (0535)*	*Spica (0550)*
Course/Speed	291°, 16 knots	Same	Same	Same
Time difference	-	20 minutes	35 minutes	50 minutes
Distance covered	-	5.33 miles	9.33 miles	13.33 miles
DR latitude	28° 14.0' S	**28° 12' S**	**28° 11' S**	**28° 09' S**
DR longitude	93° 17.0' E	**93° 11' E**	**93° 07' E**	**93° 03' E**

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	*Original DR (0500)*	*Peacock (0520)*	*Altair (0535)*	*Spica (0550)*
DR latitude		28° 12' S	28° 11' S	28° 09' S
DR longitude		93° 11' E	93° 07' E	93° 03' E
Assumed latitude		**28° S**	**28° S**	**28° S**
GHA (total)	*Given*	226° 18.5'	238° 38.2'	338° 48.5'
Assumed longitude	*To ensure whole value of LHA*	**92° 41.5' E**	**93° 21.8' E**	**93° 11.5' E**
LHA	*Subtract west, add east (±360°)*	**319°**	**332°**	**72°**

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		*Peacock (0520)*	*Altair (0535)*	*Spica (0550)*
Assumed latitude		28° S	28° S	28° S
Declination		S 56° 47.6’	N 8° 48.9’	S 11° 03.8’
LHA		319° Same	332° Contrary	72° Same
Computed altitude (hc)	*From HO229*	**49° 37.6’**	**44° 57.9’**	**20° 56.5’**
Altitude difference (d)	*From HO229*	**-27.3’**	**-48.8’**	**26.1’**
Azimuth (z)	*From HO229*	**34.5°**	**138.9°**	**88.4°**

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}

	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.
55	45 56.0	−30.1	32.8	46 46.3	−29.4	33.3	47 36.3	−28.7	33.9	48 25.9	−28.0	34.6	49 15.1	−27.2	35.2	50 03.9	−26.3	35.9	50 52.3	−25.5	36.6	51 40.3	−24.6	37.4	55
56	45 25.9	−31.0	31.5	46 16.9	−30.3	32.1	47 07.6	−29.6	32.6	47 57.9	−28.8	33.2	48 47.9	−28.1	33.8	49 37.6	−27.3	34.5	50 26.8	−26.5	35.2	51 15.7	−25.7	35.9	56
57	44 54.9	−31.7	30.3	45 46.6	−31.1	30.8	46 38.0	−30.4	31.4	47 29.1	−29.8	31.9	48 19.8	−29.0	32.5	49 10.3	−28.3	33.1	50 00.3	−27.5	33.8	50 50.0	−26.7	34.5	57
58	44 23.2	−32.4	29.1	45 15.5	−31.8	29.6	46 07.6	−31.3	30.1	46 59.3	−30.6	30.6	47 50.8	−29.9	31.2	48 42.0	−29.3	31.8	49 32.8	−28.5	32.4	50 23.3	−27.8	33.0	58
59	43 50.8	−33.2	27.9	44 43.7	−32.6	28.4	45 36.3	−32.0	28.9	46 28.7	−31.3	29.4	47 20.9	−30.8	29.9	48 12.7	−30.0	30.5	49 04.3	−29.4	31.0	49 55.5	−28.6	31.7	59

LATITUDE CONTRARY NAME TO DECLINATION **L.H.A. 28°, 332°**

	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	54 22.0	−40.7	126.3	53 46.0	−41.7	127.4	53 09.1	−42.6	128.5	52 31.3	−43.5	129.5	51 52.8	−44.5	130.5	51 13.4	−45.2	131.4	50 33.3	−46.0	132.4	49 52.6	−46.8	133.2	0
1	53 41.3	−41.4	127.6	53 04.3	−42.3	128.6	52 26.5	−43.3	129.6	51 47.8	−44.2	130.6	51 08.3	−45.0	131.6	50 28.2	−45.8	132.5	49 47.3	−46.5	133.4	49 05.8	−47.3	134.2	1
2	52 59.9	−42.1	128.8	52 22.0	−43.1	129.8	51 43.2	−44.0	130.8	51 03.6	−44.7	131.7	50 23.3	−45.5	132.6	49 42.4	−46.3	133.5	49 00.8	−47.1	134.3	48 18.5	−47.7	135.1	2
3	52 17.8	−42.8	130.0	51 38.9	−43.7	130.9	50 59.2	−44.5	131.9	50 18.9	−45.4	132.8	49 37.8	−46.1	133.6	48 56.1	−46.8	134.5	48 13.7	−47.4	135.3	47 30.8	−48.1	136.0	3
4	51 35.0	−43.4	131.1	50 55.2	−44.2	132.0	50 14.7	−45.0	132.9	49 33.5	−45.8	133.8	48 51.7	−46.5	134.6	48 09.3	−47.3	135.4	47 26.3	−47.9	136.2	46 42.7	−48.5	136.9	4
5	50 51.6	−44.0	132.2	50 11.0	−44.8	133.1	49 29.7	−45.6	133.9	48 47.7	−46.3	134.8	48 05.2	−47.0	135.6	47 22.0	−47.6	136.3	46 38.4	−48.3	137.1	45 54.2	−48.9	137.8	5
6	50 07.6	−44.6	133.3	49 26.2	−45.4	134.1	48 44.1	−46.1	134.9	48 01.4	−46.8	135.7	47 18.2	−47.5	136.5	46 34.4	−48.1	137.2	45 50.1	−48.7	137.9	45 05.3	−49.2	138.6	6
7	49 23.0	−45.1	134.3	48 40.8	−45.9	135.1	47 58.0	−46.6	135.9	47 14.6	−47.2	136.7	46 30.7	−47.8	137.4	45 46.3	−48.4	138.1	45 01.4	−49.0	138.8	44 16.1	−49.5	139.4	7
8	48 37.9	−45.7	135.3	47 54.9	−46.3	136.1	47 11.4	−47.0	136.8	46 27.4	−47.6	137.6	45 42.9	−48.2	138.3	44 57.9	−48.8	138.9	44 12.4	−49.3	139.6	43 26.6	−49.9	140.2	8
9	47 52.2	−46.1	136.3	47 08.6	−46.8	137.0	46 24.4	−47.4	137.7	45 39.8	−48.0	138.4	44 54.7	−48.6	139.1	44 09.1	−49.2	139.7	43 23.1	−49.7	140.4	42 36.7	−50.2	140.9	9

72°, 288° 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	16 31.6	+24.3	97.2	16 23.9	+25.3	97.5	16 15.8	+26.3	97.8	16 07.5	+27.3	98.1	15 58.9	+28.2	98.4	15 50.0	+29.2	98.7	15 40.8	+30.1	99.0	15 31.3	+31.1	99.2	0
1	16 55.9	+24.0	96.3	16 49.2	+25.0	96.6	16 42.1	+26.1	96.9	16 34.8	+27.0	97.2	16 27.1	+28.0	97.5	16 19.2	+28.9	97.8	16 10.9	+29.9	98.1	16 02.4	+30.8	98.3	1
2	17 19.9	+23.8	95.3	17 14.2	+24.8	95.6	17 08.2	+25.7	95.9	17 01.8	+26.8	96.2	16 55.1	+27.7	96.5	16 48.1	+28.7	96.8	16 40.8	+29.6	97.1	16 33.2	+30.6	97.4	2
3	17 43.7	+23.5	94.4	17 39.0	+24.5	94.7	17 33.9	+25.5	95.0	17 28.6	+26.4	95.3	17 22.8	+27.5	95.6	17 16.8	+28.4	95.9	17 10.4	+29.4	96.2	17 03.8	+30.3	96.5	3
4	18 07.2	+23.2	93.4	18 03.5	+24.2	93.7	17 59.4	+25.3	94.0	17 55.0	+26.3	94.4	17 50.3	+27.2	94.7	17 45.2	+28.2	95.0	17 39.8	+29.2	95.3	17 34.1	+30.1	95.6	4
5	18 30.4	+22.9	92.4	18 27.7	+23.9	92.8	18 24.7	+24.9	93.1	18 21.3	+25.9	93.4	18 17.5	+26.9	93.8	18 13.4	+27.9	94.1	18 09.0	+28.8	94.4	18 04.2	+29.8	94.7	5
6	18 53.3	+22.6	91.4	18 51.6	+23.7	91.8	18 49.6	+24.6	92.1	18 47.2	+25.6	92.5	18 44.4	+26.7	92.8	18 41.3	+27.6	93.1	18 37.8	+28.6	93.5	18 34.0	+29.6	93.8	6
7	19 15.9	+22.3	90.5	19 15.3	+23.3	90.8	19 14.2	+24.4	91.2	19 12.8	+25.4	91.5	19 11.1	+26.3	91.9	19 08.9	+27.4	92.2	19 06.4	+28.4	92.6	19 03.6	+29.3	92.9	7
8	19 38.2	+22.0	89.5	19 38.6	+23.0	89.8	19 38.6	+24.0	90.2	19 38.2	+25.0	90.6	19 37.4	+26.1	90.9	19 36.3	+27.0	91.3	19 34.8	+28.0	91.6	19 32.9	+29.0	92.0	8
9	20 00.2	+21.6	88.5	20 01.6	+22.7	88.9	20 02.6	+23.7	89.2	20 03.2	+24.7	89.6	20 03.5	+25.7	89.9	20 03.3	+26.8	90.3	20 02.8	+27.7	90.7	20 01.9	+28.7	91.0	9
10	20 21.8	+21.3	87.5	20 24.3	+22.3	87.9	20 26.3	+23.4	88.2	20 27.9	+24.4	88.6	20 29.2	+25.4	89.0	20 30.1	+26.4	89.4	20 30.5	+27.5	89.7	20 30.6	+28.4	90.1	10
11	20 43.1	+21.0	86.5	20 46.6	+22.0	86.9	20 49.7	+23.0	87.3	20 52.3	+24.1	87.6	20 54.6	+25.1	88.0	20 56.5	+26.1	88.4	20 58.0	+27.1	88.8	20 59.0	+28.1	89.2	11
12	21 04.1	+20.6	85.5	21 08.6	+21.6	85.9	21 12.7	+22.7	86.3	21 16.4	+23.7	86.7	21 19.7	+24.7	87.0	21 22.6	+25.7	87.4	21 25.1	+26.7	87.8	21 27.1	+27.8	88.2	12
13	21 24.7	+20.2	84.5	21 30.2	+21.3	84.9	21 35.4	+22.3	85.3	21 40.1	+23.4	85.7	21 44.4	+24.4	86.1	21 48.3	+25.5	86.5	21 51.8	+26.5	86.9	21 54.9	+27.5	87.3	13
14	21 44.9	+19.9	83.5	21 51.5	+20.9	83.9	21 57.7	+22.0	84.3	22 03.5	+23.0	84.7	22 08.8	+24.1	85.1	22 13.8	+25.0	85.5	22 18.3	+26.1	85.9	22 22.4	+27.1	86.3	14

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		*Peacock (0520)*	*Altair (0535)*	*Spica (0550)*
Base Azimuth (Z)	*From HO229*	34.5°	138.9°	88.4°
Next incremental Z		33.1°	139.7°	87.4°
Difference		-1.4°	+0.8°	-1.0°
Declination Increment	*From given declination*	47.6'	48.9'	03.8'
Correction (Diff Z x Increment) / 60		-1.1°	+0.7°	-0.1°
Corrected azimuth (Z)		33.4°	139.6°	88.3°
Azimuth rules corrected azimuth (Zn)	*Check azimuth rules for LHA on top/bottom of HO229 pages*	**146.6°**	**40.5°**	**268.3°**

Dec. Inc.	Altitude Difference (d) Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
3.0	0.5	1.0	1.5	2.0	2.5	**.0**	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5
3.1	0.5	1.0	1.5	2.0	2.6	**.1**	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5
3.2	0.5	1.0	1.6	2.1	2.6	**.2**	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5
3.3	0.5	1.1	1.6	2.2	2.7	**.3**	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.5
3.4	0.6	1.1	1.7	2.3	2.8	**.4**	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.5
3.5	0.6	1.2	1.8	2.3	2.9	**.5**	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6
3.6	0.6	1.2	1.8	2.4	3.0	**.6**	0.0	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6
3.7	0.6	1.3	1.9	2.5	3.1	**.7**	0.0	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6
3.8	0.7	1.3	1.9	2.6	3.2	**.8**	0.0	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6
3.9	0.7	1.3	2.0	2.6	3.3	**.9**	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6
47.0	7.8	15.6	23.5	31.3	39.1	**.0**	0.0	0.8	1.6	2.4	3.2	4.0	4.7	5.5	6.3	7.1
47.1	7.8	15.7	23.5	31.4	39.2	**.1**	0.1	0.9	1.7	2.5	3.2	4.0	4.8	5.6	6.4	7.2
47.2	7.8	15.7	23.6	31.4	39.3	**.2**	0.2	0.9	1.7	2.5	3.3	4.1	4.9	5.7	6.5	7.3
47.3	7.9	15.8	23.6	31.5	39.4	**.3**	0.2	1.0	1.8	2.6	3.4	4.2	5.0	5.8	6.6	7.4
47.4	7.9	15.8	23.7	31.6	39.5	**.4**	0.3	1.1	1.9	2.7	3.5	4.3	5.1	5.9	6.6	7.4
47.5	7.9	15.8	23.8	31.7	39.6	**.5**	0.4	1.2	2.0	2.8	3.6	4.4	5.1	5.9	6.7	7.5
47.6	7.9	15.9	23.8	31.7	39.7	**.6**	0.5	1.3	2.1	2.8	3.6	4.4	5.2	6.0	6.8	7.6
47.7	8.0	15.9	23.9	31.8	39.8	**.7**	0.6	1.3	2.1	2.9	3.7	4.5	5.3	6.1	6.9	7.7
47.8	8.0	16.0	23.9	31.9	39.9	**.8**	0.6	1.4	2.2	3.0	3.8	4.6	5.4	6.2	7.0	7.8
47.9	8.0	16.0	24.0	32.0	40.0	**.9**	0.7	1.5	2.3	3.1	3.9	4.7	5.5	6.3	7.0	7.8
48.0	8.0	16.0	24.0	32.0	40.0	**.0**	0.0	0.8	1.6	2.4	3.2	4.0	4.8	5.7	6.5	7.3
48.1	8.0	16.0	24.0	32.0	40.1	**.1**	0.1	0.9	1.7	2.5	3.3	4.1	4.9	5.7	6.5	7.4
48.2	8.0	16.0	24.1	32.1	40.1	**.2**	0.2	1.0	1.8	2.6	3.4	4.2	5.0	5.8	6.6	7.4
48.3	8.0	16.1	24.1	32.2	40.2	**.3**	0.2	1.1	1.9	2.7	3.5	4.3	5.1	5.9	6.7	7.5
48.4	8.1	16.1	24.2	32.3	40.3	**.4**	0.3	1.1	1.9	2.7	3.6	4.4	5.2	6.0	6.8	7.6
48.5	8.1	16.2	24.3	32.3	40.4	**.5**	0.4	1.2	2.0	2.8	3.6	4.4	5.3	6.1	6.9	7.7
48.6	8.1	16.2	24.3	32.4	40.5	**.6**	0.5	1.3	2.1	2.9	3.7	4.5	5.3	6.1	7.0	7.8
48.7	8.1	16.3	24.4	32.5	40.6	**.7**	0.6	1.4	2.2	3.0	3.8	4.6	5.4	6.2	7.0	7.8
48.8	8.2	16.3	24.4	32.6	40.7	**.8**	0.6	1.5	2.3	3.1	3.9	4.7	5.5	6.3	7.1	7.9
48.9	8.2	16.3	24.5	32.6	40.8	**.9**	0.7	1.5	2.3	3.2	4.0	4.8	5.6	6.4	7.2	8.0

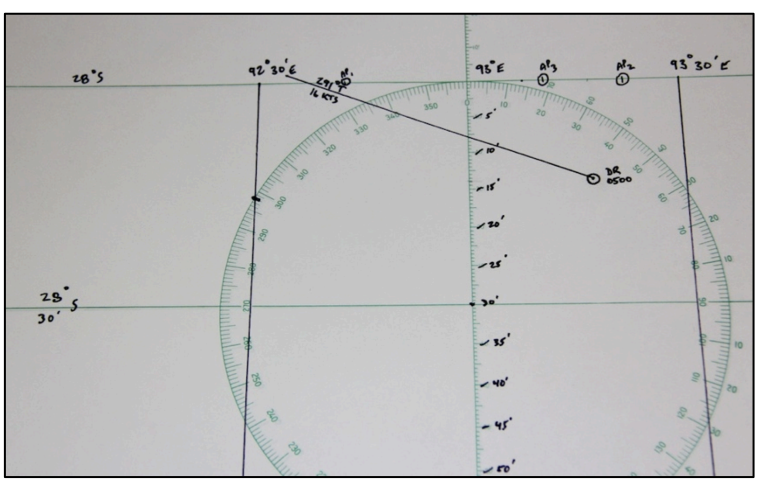
Step 5: Given the tabular HO229 information in step 3, determine the correct computed altitude (hc) for the three star sights.

Sight		*Peacock (0520)*	*Altair (0535)*	*Spica (0550)*
Tabular computed altitude	*From step 3*	49° 37.6'	44° 57.9'	20° 56.5'
Altitude difference (d)	*From step 3*	-27.3'	-48.8'	+26.1'
Declination increment	*From given declination*	47.6'	48.9'	03.8'
Altitude difference	*From HO229 interpolation table*	-21.7'	-39.8'	+1.7'
Correct computed altitude		**49° 15.9'**	**44° 18.1'**	**20° 58.2'**

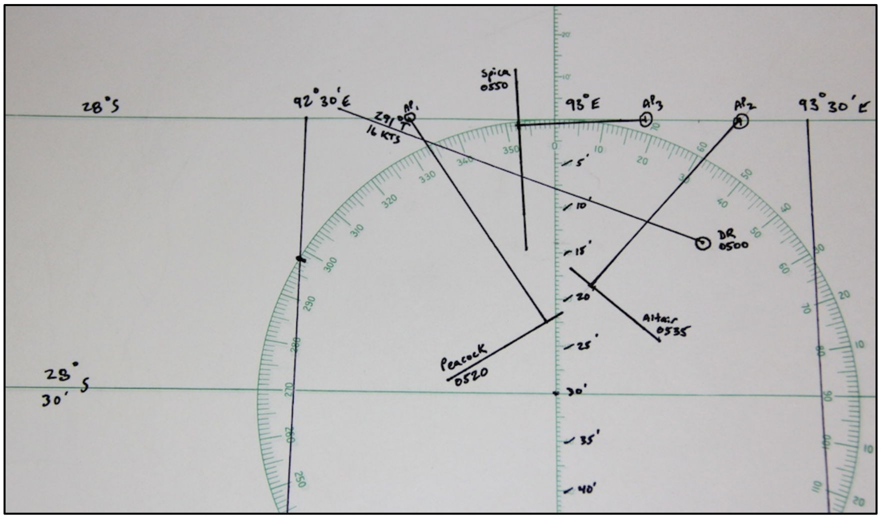
Step 6: Compare the observed altitudes (given) with the computed altitudes (determined in step 5), to compute intercepts (a) for the three star sights.

Sight		*Peacock (0520)*	*Altair (0535)*	*Spica (0550)*
Observed altitude (ho)	*Given*	49° 42.9'	43° 53.1'	21° 11.7'
Correct computed altitude (hc)	*From step 5*	**49° 15.9'**	**44° 18.1'**	**20° 58.2'**
Intercept (a)	*hc – ho*	**27.0'**	**25.0'**	**13.5'**
Towards/Away	*If hc is greater, intercept is "away"*	**Towards**	**Away**	**Towards**
Azimuth	*Repeated from step 4*	146.6°	40.5°	268.3°

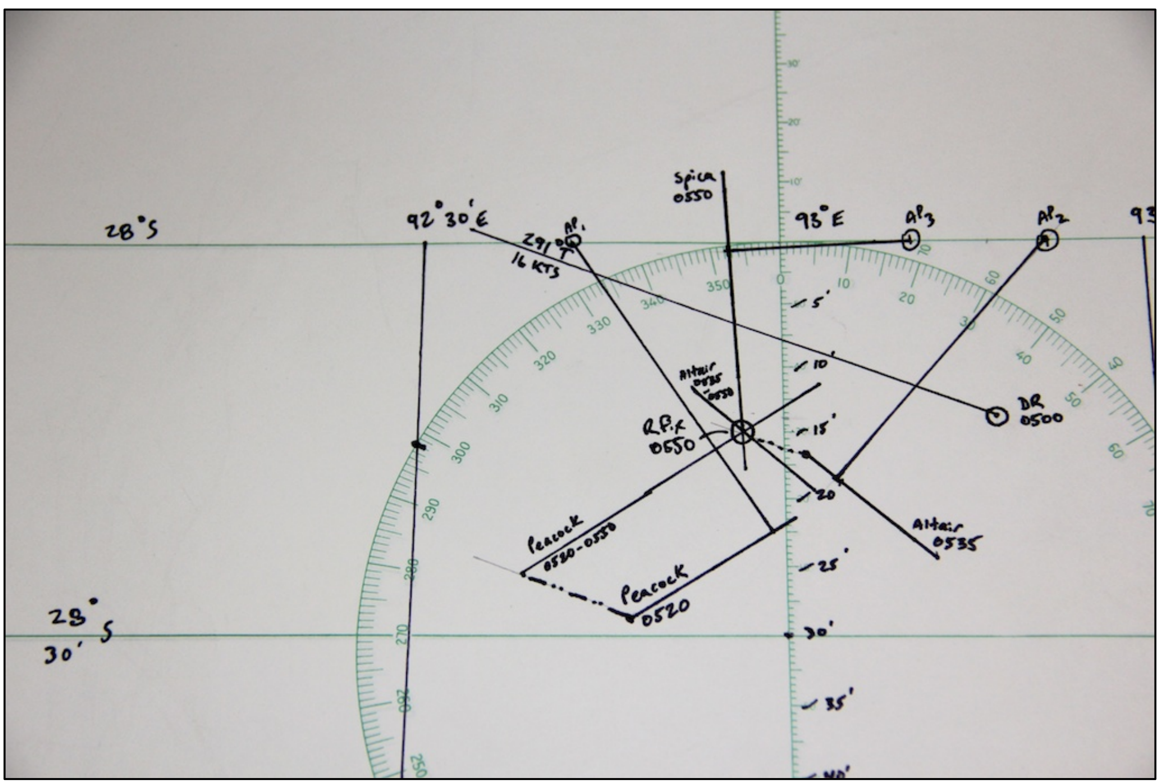
Step 7: Plot the assumed positions for each star sight.



Step 8: Plot each star sight's line of position.



Step 9: Advance the 0520 and 0535 Sun lines of position to 0550 to determine the running fix at **23° 16'S, 092° 57'E.**



Additional Problems and Answers

All of the following questions labeled "CG" were taken directly from the 2013 USCG test bank and illustrate the concepts in this Part. Note – not all problems have been worked and are subject to occasional errors in the database. For more problems and answers, see the USCG database of questions (database information located in the preface).

Problem CG-280. 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*

Problem CG-297. On 18 May your 1030 zone time DR position is latitude 18° 30' N, longitude 62° 31' W. You are on course 286° T, speed 24 knots. Determine your 1200 position using the following observations of the Sun:

Zone time	*GHA*	*Declination*	*ho*
1204	*61° 54.6'*	*N 19° 37.6'*	*88° 39.7'*
1210	*63° 24.6'*	*N 19° 37.7'*	*88° 59.2'*

a) *18° 33.6' N, 62° 54.3' W*
b) *18° 35.2' N, 62° 49.7' W*
c) *18° 38.7' N, 62° 59.2' W*
d) *18° 41.1' N, 62° 53.9' W- correct*

Problem CG-311. 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*

Problem CG-404. 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*

Problem CG-456. 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*

Problem CG-347. 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*

Problem CG-206. 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*	*Declination*

			Altitude	
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

Problem CG-235. On 14 September your 1810 zone time DR position is latitude 27° 12.0' S, longitude 71° 10.0' E. You are on course 060° T at a speed of 15 knots. You observe 3 celestial bodies. Determine the latitude and longitude of your 1822 running fix.

Body	*Zone Time*	*GHA*	*Observed Altitude*	*Declination*
Venus	*1810*	*341° 03.4'*	*38° 48.9'*	*S 12° 48.1'*
Altair	*1816*	*255° 00.4'*	*41° 20.3'*	*N 8° 49.3'*
Peacock	*1822*	*247° 55.8'*	*48° 39.5'*	*S 56° 47.8'*

a) 27° 04.5' S, 71° 22.4' E
b) 27° 07.5' S, 71° 18.6' E
c) 27° 09.2' S, 71° 11.3' E
d) 27° 11.0' S, 71° 14.5' E- correct

Problem CG-238. 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

Problem CG-253. 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

INTERPOLATION TABLE

Altitude Difference (d)

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff.	and Corr.
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	0.0	0.0
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	48.2	
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	16.2	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	48.6	
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		
1.0	0.1	0.3	0.5	0.6	0.8	.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2		
1.1	0.2	0.3	0.5	0.7	0.9	.1	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2		
1.2	0.2	0.4	0.6	0.8	1.0	.2	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2		
1.3	0.2	0.4	0.6	0.9	1.1	.3	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2		
1.4	0.2	0.5	0.7	0.9	1.2	.4	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	8.2	0.1
1.5	0.3	0.5	0.8	1.0	1.3	.5	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	24.6	0.2
1.6	0.3	0.5	0.8	1.1	1.3	.6	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	41.0	
1.7	0.3	0.6	0.9	1.2	1.4	.7	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2		
1.8	0.3	0.6	0.9	1.2	1.5	.8	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2		
1.9	0.4	0.7	1.0	1.3	1.6	.9	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2		
2.0	0.3	0.6	1.0	1.3	1.6	.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4		
2.1	0.3	0.7	1.0	1.4	1.7	.1	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4		
2.2	0.3	0.7	1.1	1.4	1.8	.2	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4		
2.3	0.4	0.8	1.1	1.5	1.9	.3	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	5.0	0.1
2.4	0.4	0.8	1.2	1.6	2.0	.4	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	15.0	0.2
2.5	0.4	0.8	1.3	1.7	2.1	.5	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	25.0	0.3
2.6	0.4	0.9	1.3	1.7	2.2	.6	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	35.1	
2.7	0.5	0.9	1.4	1.8	2.3	.7	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4		
2.8	0.5	1.0	1.4	1.9	2.4	.8	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4		
2.9	0.5	1.0	1.5	2.0	2.5	.9	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4		
3.0	0.5	1.0	1.5	2.0	2.5	.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5		
3.1	0.5	1.0	1.5	2.0	2.6	.1	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5		
3.2	0.5	1.0	1.6	2.1	2.6	.2	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	3.6	0.1
3.3	0.5	1.1	1.6	2.2	2.7	.3	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.5	10.9	0.2
3.4	0.6	1.1	1.7	2.3	2.8	.4	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.5	18.2	0.3
3.5	0.6	1.2	1.8	2.3	2.9	.5	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	25.5	0.4
3.6	0.6	1.2	1.8	2.4	3.0	.6	0.0	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	32.8	0.5
3.7	0.6	1.3	1.9	2.5	3.1	.7	0.0	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	40.1	
3.8	0.7	1.3	1.9	2.6	3.2	.8	0.0	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6		
3.9	0.7	1.3	2.0	2.6	3.3	.9	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6		
4.0	0.6	1.3	2.0	2.6	3.3	.0	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7		
4.1	0.7	1.3	2.0	2.7	3.4	.1	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7		
4.2	0.7	1.4	2.1	2.8	3.5	.2	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	2.9	0.1
4.3	0.7	1.4	2.1	2.9	3.6	.3	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	8.6	0.2
4.4	0.7	1.5	2.2	2.9	3.7	.4	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	14.4	0.3
4.5	0.8	1.5	2.3	3.0	3.8	.5	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	20.2	0.4
4.6	0.8	1.5	2.3	3.1	3.8	.6	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	25.9	0.5
4.7	0.8	1.6	2.4	3.2	3.9	.7	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	31.7	0.6
4.8	0.8	1.6	2.4	3.2	4.0	.8	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	37.5	
4.9	0.9	1.7	2.5	3.3	4.1	.9	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7		
5.0	0.8	1.6	2.5	3.3	4.1	.0	0.0	0.1	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8		
5.1	0.8	1.7	2.5	3.4	4.2	.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8	2.4	0.1
5.2	0.8	1.7	2.6	3.4	4.3	.2	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	7.2	0.2
5.3	0.9	1.8	2.6	3.5	4.4	.3	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	12.0	0.3
5.4	0.9	1.8	2.7	3.6	4.5	.4	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	16.8	0.4
5.5	0.9	1.8	2.8	3.7	4.6	.5	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	21.6	0.5
5.6	0.9	1.9	2.8	3.7	4.7	.6	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	26.4	0.6
5.7	1.0	1.9	2.9	3.8	4.8	.7	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	31.2	0.7
5.8	1.0	2.0	2.9	3.9	4.9	.8	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	36.0	
5.9	1.0	2.0	3.0	4.0	5.0	.9	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9		
6.0	1.0	2.0	3.0	4.0	5.0	.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	2.1	0.1
6.1	1.0	2.0	3.0	4.0	5.1	.1	0.0	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0	6.2	0.2
6.2	1.0	2.0	3.1	4.1	5.1	.2	0.0	0.1	0.2	0.3	0.5	0.6	0.7	0.8	0.9	1.0	10.4	0.3
6.3	1.0	2.1	3.1	4.2	5.2	.3	0.0	0.1	0.2	0.4	0.5	0.6	0.7	0.8	0.9	1.0	14.5	0.4
6.4	1.1	2.1	3.2	4.3	5.3	.4	0.0	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	18.6	0.5
6.5	1.1	2.2	3.3	4.3	5.4	.5	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	22.8	0.6
6.6	1.1	2.2	3.3	4.4	5.5	.6	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	26.9	0.7
6.7	1.1	2.3	3.4	4.5	5.6	.7	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1	31.1	0.8
6.8	1.2	2.3	3.4	4.6	5.7	.8	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	35.2	
6.9	1.2	2.3	3.5	4.6	5.8	.9	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.1		
7.0	1.1	2.3	3.5	4.6	5.8	.0	0.0	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.8	0.1
7.1	1.2	2.3	3.5	4.7	5.9	.1	0.0	0.1	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1	5.5	0.2
7.2	1.2	2.4	3.6	4.8	6.0	.2	0.0	0.1	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1	9.1	0.3
7.3	1.2	2.4	3.6	4.9	6.1	.3	0.0	0.2	0.3	0.4	0.5	0.7	0.8	0.9	1.0	1.2	12.8	0.4
7.4	1.2	2.5	3.7	4.9	6.2	.4	0.0	0.2	0.3	0.4	0.5	0.7	0.8	0.9	1.0	1.2	16.5	0.5
7.5	1.3	2.5	3.8	5.0	6.3	.5	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.1	1.2	20.1	0.6
7.6	1.3	2.5	3.8	5.1	6.3	.6	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.1	1.2	23.8	0.7
7.7	1.3	2.6	3.9	5.2	6.4	.7	0.1	0.2	0.3	0.5	0.6	0.7	0.8	1.0	1.1	1.2	27.4	0.8
7.8	1.3	2.6	3.9	5.2	6.5	.8	0.1	0.2	0.3	0.5	0.6	0.7	0.8	1.0	1.1	1.2	31.1	0.9
7.9	1.4	2.7	4.0	5.3	6.6	.9	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2	34.7	

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff.	and Corr.
8.0	1.3	2.6	4.0	5.3	6.6	.0	0.0	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3		
8.1	1.3	2.7	4.0	5.4	6.7	.1	0.0	0.2	0.3	0.4	0.6	0.7	0.9	1.0	1.1	1.3		
8.2	1.3	2.7	4.1	5.4	6.8	.2	0.0	0.2	0.3	0.5	0.6	0.7	0.9	1.0	1.2	1.3	1.6	0.1
8.3	1.4	2.8	4.1	5.5	6.9	.3	0.0	0.2	0.3	0.5	0.6	0.8	0.9	1.0	1.2	1.3	4.8	0.2
8.4	1.4	2.8	4.2	5.6	7.0	.4	0.1	0.2	0.3	0.5	0.6	0.8	0.9	1.0	1.2	1.3	8.0	0.3
8.5	1.4	2.8	4.3	5.7	7.1	.5	0.1	0.2	0.4	0.5	0.6	0.8	0.9	1.1	1.2	1.3	11.2	0.4
8.6	1.4	2.9	4.3	5.7	7.2	.6	0.1	0.2	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.4	14.5	0.5
8.7	1.5	2.9	4.4	5.8	7.3	.7	0.1	0.2	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.4	17.7	0.6
8.8	1.5	3.0	4.4	5.9	7.4	.8	0.1	0.3	0.4	0.5	0.7	0.8	1.0	1.1	1.2	1.4	20.9	0.7
8.9	1.5	3.0	4.5	6.0	7.5	.9	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4	24.1	0.8
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	27.3	0.9
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	30.5	1.0
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	33.7	1.1
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	36.9	
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	1.4	0.1
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	4.2	0.2
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	7.1	0.3
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	9.9	0.4
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	12.7	0.5
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	15.5	0.6
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	18.4	0.7
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	21.2	0.8
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	24.0	0.9
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	26.8	1.0
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	29.7	1.1
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	32.5	1.2
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	35.3	
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	1.3	0.1
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	3.8	0.2
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	6.3	0.3
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	8.9	0.4
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	11.4	0.5
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	14.0	0.6
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	1.8	16.5	0.7
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	19.0	0.8
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	21.6	0.9
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	24.1	1.0
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	26.7	1.1
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	29.2	1.2
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	31.7	1.3
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	34.3	
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	1.2	0.1
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	3.5	0.2
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	5.8	0.3
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	8.1	0.4
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	10.5	0.5
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	12.8	0.6
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	15.1	0.7
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	17.4	0.8
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	19.8	0.9
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	22.1	1.0
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	24.4	1.1
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	26.7	1.2
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	29.1	1.3
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	31.4	1.4
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	33.7	1.5
14.0	2.3	4.6	7.0	9.3	11.6	.0	0.0	0.2	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	36.0	
14.1	2.3	4.7	7.0	9.4	11.7	.1	0.0	0.3	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2		
14.2	2.3	4.7	7.1	9.4	11.8	.2	0.0	0.3	0.5	0.8	1.0	1.3	1.5	1.7	2.0	2.2	1.1	0.1
14.3	2.4	4.8	7.1	9.5	11.9	.3	0.1	0.3	0.6	0.8	1.0	1.3	1.5	1.8	2.0	2.3	3.2	0.2
14.4	2.4	4.8	7.2	9.6	12.0	.4	0.1	0.3	0.6	0.8	1.1	1.3	1.5	1.8	2.0	2.3	5.3	0.3
14.5	2.4	4.8	7.3	9.7	12.1	.5	0.1	0.4	0.6	0.8	1.1	1.3	1.6	1.8	2.1	2.3	7.5	0.4
14.6	2.4	4.9	7.3	9.7	12.2	.6	0.1	0.4	0.6	0.9	1.1	1.4	1.6	1.8	2.1	2.3	9.6	0.5
14.7	2.5	4.9	7.4	9.8	12.3	.7	0.2	0.4	0.7	0.9	1.1	1.4	1.6	1.9	2.1	2.4	11.7	0.6
14.8	2.5	5.0	7.4	9.9	12.4	.8	0.2	0.4	0.7	0.9	1.2	1.4	1.6	1.9	2.1	2.4	13.9	0.7
14.9	2.5	5.0	7.5	10.0	12.5	.9	0.2	0.5	0.7	0.9	1.2	1.4	1.7	1.9	2.2	2.4	16.0	0.8
15.0	2.5	5.0	7.5	10.0	12.5	.0	0.0	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.1	2.3	18.1	0.9
15.1	2.5	5.0	7.5	10.0	12.6	.1	0.0	0.3	0.5	0.8	1.1	1.3	1.6	1.8	2.1	2.4	20.3	1.0
15.2	2.5	5.0	7.6	10.1	12.6	.2	0.1	0.3	0.6	0.8	1.1	1.3	1.6	1.9	2.1	2.4	22.4	1.1
15.3	2.5	5.1	7.6	10.2	12.7	.3	0.1	0.3	0.6	0.9	1.1	1.4	1.6	1.9	2.1	2.4	24.5	1.2
15.4	2.6	5.1	7.7	10.3	12.8	.4	0.1	0.4	0.6	0.9	1.1	1.4	1.7	1.9	2.2	2.4	26.7	1.3
15.5	2.6	5.2	7.8	10.3	12.9	.5	0.1	0.4	0.6	0.9	1.2	1.4	1.7	1.9	2.2	2.5	28.8	1.4
15.6	2.6	5.2	7.8	10.4	13.0	.6	0.2	0.4	0.7	0.9	1.2	1.4	1.7	2.0	2.2	2.5	30.9	1.5
15.7	2.6	5.3	7.9	10.5	13.1	.7	0.2	0.4	0.7	1.0	1.2	1.5	1.7	2.0	2.2	2.5	33.1	1.6
15.8	2.7	5.3	7.9	10.6	13.2	.8	0.2	0.5	0.7	1.0	1.2	1.5	1.8	2.0	2.3	2.5	35.2	
15.9	2.7	5.3	8.0	10.6	13.3	.9	0.2	0.5	0.7	1.0	1.3	1.5	1.8	2.0	2.3	2.6		

The Double-Second-Difference correction (Corr.) is always to be added to the tabulated altitude.

Dec. Inc.	Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff.	and Corr.
16.0	2.6	5.3	8.0	10.6	13.3	.0	0.0	0.3	0.5	0.8	1.1	1.4	1.6	1.9	2.2	2.5		
16.1	2.7	5.3	8.0	10.7	13.4	.1	0.0	0.3	0.6	0.9	1.1	1.4	1.7	2.0	2.2	2.5		
16.2	2.7	5.4	8.1	10.8	13.5	.2	0.1	0.3	0.6	0.9	1.2	1.4	1.7	2.0	2.3	2.5	1.0	0.1
16.3	2.7	5.4	8.1	10.9	13.6	.3	0.1	0.4	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	3.0	0.2
16.4	2.7	5.5	8.2	10.9	13.7	.4	0.1	0.4	0.7	0.9	1.2	1.5	1.8	2.0	2.3	2.6	4.9	0.3
16.5	2.8	5.5	8.3	11.0	13.8	.5	0.1	0.4	0.7	1.0	1.2	1.5	1.8	2.1	2.3	2.6	6.9	0.4
16.6	2.8	5.5	8.3	11.1	13.8	.6	0.2	0.4	0.7	1.0	1.3	1.5	1.8	2.1	2.4	2.6	8.9	0.5
16.7	2.8	5.6	8.4	11.2	13.9	.7	0.2	0.5	0.7	1.0	1.3	1.6	1.8	2.1	2.4	2.7	10.8	0.6
16.8	2.8	5.6	8.4	11.2	14.0	.8	0.2	0.5	0.8	1.0	1.3	1.6	1.9	2.1	2.4	2.7	12.8	0.7
16.9	2.9	5.7	8.5	11.3	14.1	.9	0.2	0.5	0.8	1.1	1.3	1.6	1.9	2.2	2.4	2.7	14.8	0.8
17.0	2.8	5.6	8.5	11.3	14.1	.0	0.0	0.3	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	16.7	0.9
17.1	2.8	5.7	8.5	11.4	14.2	.1	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	18.7	1.0
17.2	2.8	5.7	8.6	11.4	14.3	.2	0.1	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	20.7	1.1
17.3	2.9	5.8	8.6	11.5	14.4	.3	0.1	0.4	0.7	1.0	1.3	1.5	1.8	2.1	2.4	2.7	22.7	1.2
17.4	2.9	5.8	8.7	11.6	14.5	.4	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.4	2.7	24.6	1.3
17.5	2.9	5.8	8.8	11.7	14.6	.5	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.5	2.8	26.6	1.4
17.6	2.9	5.9	8.8	11.7	14.7	.6	0.2	0.5	0.8	1.0	1.3	1.6	1.9	2.2	2.5	2.8	28.6	1.5
17.7	3.0	5.9	8.9	11.8	14.8	.7	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.2	2.5	2.8	30.5	1.6
17.8	3.0	6.0	8.9	11.9	14.9	.8	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9	32.5	1.7
17.9	3.0	6.0	9.0	12.0	15.0	.9	0.3	0.6	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9	34.5	
18.0	3.0	6.0	9.0	12.0	15.0	.0	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.2	2.5	2.8		
18.1	3.0	6.0	9.0	12.0	15.1	.1	0.0	0.3	0.6	1.0	1.3	1.6	1.9	2.2	2.5	2.8	0.9	0.1
18.2	3.0	6.0	9.1	12.1	15.1	.2	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.5	2.8	2.8	0.2
18.3	3.0	6.1	9.1	12.2	15.2	.3	0.1	0.4	0.7	1.0	1.3	1.6	1.9	2.3	2.6	2.9	4.6	0.3
18.4	3.1	6.1	9.2	12.3	15.3	.4	0.1	0.4	0.7	1.0	1.4	1.7	2.0	2.3	2.6	2.9	6.5	0.4
18.5	3.1	6.2	9.3	12.3	15.4	.5	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9	8.3	0.5
18.6	3.1	6.2	9.3	12.4	15.5	.6	0.2	0.5	0.8	1.1	1.4	1.7	2.0	2.3	2.7	3.0	10.2	0.6
18.7	3.1	6.3	9.4	12.5	15.6	.7	0.2	0.5	0.8	1.1	1.4	1.8	2.1	2.4	2.7	3.0	12.0	0.7
18.8	3.2	6.3	9.4	12.6	15.7	.8	0.2	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	13.9	0.8
18.9	3.2	6.3	9.5	12.6	15.8	.9	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.1	15.7	0.9
19.0	3.1	6.3	9.5	12.6	15.8	.0	0.0	0.3	0.6	1.0	1.3	1.6	1.9	2.3	2.6	2.9	17.6	1.0
19.1	3.2	6.3	9.5	12.7	15.9	.1	0.0	0.4	0.7	1.0	1.3	1.7	2.0	2.3	2.6	3.0	19.4	1.1
19.2	3.2	6.4	9.6	12.8	16.0	.2	0.1	0.4	0.7	1.0	1.4	1.7	2.0	2.3	2.7	3.0	21.3	1.2
19.3	3.2	6.4	9.6	12.9	16.1	.3	0.1	0.4	0.7	1.1	1.4	1.7	2.0	2.4	2.7	3.0	23.1	1.3
19.4	3.2	6.5	9.7	12.9	16.2	.4	0.1	0.5	0.8	1.1	1.4	1.8	2.1	2.4	2.7	3.1	25.0	1.4
19.5	3.3	6.5	9.8	13.0	16.3	.5	0.2	0.5	0.8	1.1	1.5	1.8	2.1	2.4	2.8	3.1	26.8	1.5
19.6	3.3	6.5	9.8	13.1	16.3	.6	0.2	0.5	0.8	1.2	1.5	1.8	2.1	2.5	2.8	3.1	28.7	1.6
19.7	3.3	6.6	9.9	13.2	16.4	.7	0.2	0.6	0.9	1.2	1.5	1.9	2.2	2.5	2.8	3.2	30.5	1.7
19.8	3.3	6.6	9.9	13.2	16.5	.8	0.3	0.6	0.9	1.2	1.6	1.9	2.2	2.5	2.9	3.2	32.3	1.8
19.9	3.4	6.7	10.0	13.3	16.6	.9	0.3	0.6	0.9	1.3	1.6	1.9	2.2	2.6	2.9	3.2	34.2	
20.0	3.3	6.6	10.0	13.3	16.6	.0	0.0	0.3	0.7	1.0	1.4	1.7	2.0	2.4	2.7	3.1	0.9	0.1
20.1	3.3	6.7	10.0	13.4	16.7	.1	0.0	0.4	0.7	1.1	1.4	1.7	2.1	2.4	2.8	3.1	2.6	0.2
20.2	3.3	6.7	10.1	13.4	16.8	.2	0.1	0.4	0.8	1.1	1.4	1.8	2.1	2.5	2.8	3.1	4.4	0.3
20.3	3.4	6.8	10.1	13.5	16.9	.3	0.1	0.4	0.8	1.1	1.5	1.8	2.2	2.5	2.8	3.2	6.2	0.4
20.4	3.4	6.8	10.2	13.6	17.0	.4	0.1	0.5	0.8	1.2	1.5	1.8	2.2	2.5	2.9	3.2	7.9	0.5
20.5	3.4	6.8	10.3	13.7	17.1	.5	0.2	0.5	0.9	1.2	1.5	1.9	2.2	2.6	2.9	3.2	9.7	0.6
20.6	3.4	6.9	10.3	13.7	17.2	.6	0.2	0.5	0.9	1.2	1.6	1.9	2.3	2.6	2.9	3.3	11.4	0.7
20.7	3.5	6.9	10.4	13.8	17.3	.7	0.2	0.6	0.9	1.3	1.6	1.9	2.3	2.6	3.0	3.3	13.2	0.8
20.8	3.5	7.0	10.4	13.9	17.4	.8	0.3	0.6	1.0	1.3	1.6	2.0	2.3	2.7	3.0	3.3	14.9	0.9
20.9	3.5	7.0	10.5	14.0	17.5	.9	0.3	0.6	1.0	1.3	1.7	2.0	2.4	2.7	3.0	3.4	16.7	1.0
21.0	3.5	7.0	10.5	14.0	17.5	.0	0.0	0.4	0.7	1.1	1.4	1.8	2.1	2.5	2.9	3.2	18.5	1.1
21.1	3.5	7.0	10.5	14.0	17.6	.1	0.0	0.4	0.8	1.1	1.5	1.8	2.2	2.5	2.9	3.3	20.2	1.2
21.2	3.5	7.0	10.6	14.1	17.6	.2	0.1	0.4	0.8	1.1	1.5	1.9	2.2	2.6	2.9	3.3	22.0	1.3
21.3	3.5	7.1	10.6	14.2	17.7	.3	0.1	0.5	0.8	1.2	1.5	1.9	2.3	2.6	3.0	3.3	23.7	1.4
21.4	3.6	7.1	10.7	14.3	17.8	.4	0.1	0.5	0.9	1.2	1.6	1.9	2.3	2.7	3.0	3.4	25.5	1.5
21.5	3.6	7.2	10.8	14.3	17.9	.5	0.2	0.5	0.9	1.3	1.6	2.0	2.3	2.7	3.0	3.4	27.3	1.6
21.6	3.6	7.2	10.8	14.4	18.0	.6	0.2	0.6	0.9	1.3	1.6	2.0	2.4	2.7	3.1	3.4	29.0	1.7
21.7	3.6	7.3	10.9	14.5	18.1	.7	0.3	0.6	1.0	1.3	1.7	2.0	2.4	2.8	3.1	3.5	30.8	1.8
21.8	3.7	7.3	10.9	14.6	18.2	.8	0.3	0.6	1.0	1.4	1.7	2.1	2.4	2.8	3.2	3.5	32.5	1.9
21.9	3.7	7.3	11.0	14.6	18.3	.9	0.3	0.7	1.0	1.4	1.8	2.1	2.5	2.8	3.2	3.5	34.3	
22.0	3.6	7.3	11.0	14.6	18.3	.0	0.0	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.4	0.8	0.1
22.1	3.7	7.3	11.0	14.7	18.4	.1	0.0	0.4	0.8	1.2	1.5	1.9	2.3	2.7	3.0	3.4	2.5	0.2
22.2	3.7	7.4	11.1	14.8	18.5	.2	0.1	0.4	0.8	1.2	1.6	1.9	2.3	2.7	3.1	3.4	4.2	0.3
22.3	3.7	7.4	11.1	14.9	18.6	.3	0.1	0.5	0.9	1.2	1.6	2.0	2.4	2.7	3.1	3.5	5.9	0.4
22.4	3.7	7.5	11.2	14.9	18.7	.4	0.1	0.5	0.9	1.3	1.6	2.0	2.4	2.8	3.1	3.5	7.6	0.5
22.5	3.8	7.5	11.3	15.0	18.8	.5	0.2	0.6	0.9	1.3	1.7	2.1	2.4	2.8	3.2	3.6	9.3	0.6
22.6	3.8	7.5	11.3	15.1	18.8	.6	0.2	0.6	1.0	1.3	1.7	2.1	2.5	2.8	3.2	3.6	11.0	0.7
22.7	3.8	7.6	11.4	15.2	18.9	.7	0.3	0.6	1.0	1.4	1.8	2.1	2.5	2.9	3.3	3.6	12.7	0.8
22.8	3.8	7.6	11.4	15.2	19.0	.8	0.3	0.7	1.0	1.4	1.8	2.2	2.5	2.9	3.3	3.7	14.4	0.9
22.9	3.9	7.7	11.5	15.3	19.1	.9	0.3	0.7	1.1	1.5	1.8	2.2	2.6	3.0	3.3	3.7	16.1	1.0
23.0	3.8	7.6	11.5	15.3	19.1	.0	0.0	0.4	0.8	1.2	1.6	2.0	2.3	2.7	3.1	3.5	17.8	1.1
23.1	3.8	7.7	11.5	15.4	19.2	.1	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	19.5	1.2
23.2	3.8	7.7	11.6	15.4	19.3	.2	0.1	0.5	0.9	1.3	1.6	2.0	2.4	2.8	3.2	3.6	21.2	1.3
23.3	3.9	7.8	11.6	15.5	19.4	.3	0.1	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.6	22.8	1.4
23.4	3.9	7.8	11.7	15.6	19.5	.4	0.2	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.7	24.5	1.5
23.5	3.9	7.8	11.8	15.7	19.6	.5	0.2	0.6	1.0	1.4	1.8	2.2	2.5	2.9	3.3	3.7	26.2	1.6
23.6	3.9	7.9	11.8	15.7	19.7	.6	0.2	0.6	1.0	1.4	1.8	2.2	2.6	3.0	3.4	3.8	27.9	1.7
23.7	4.0	7.9	11.9	15.8	19.8	.7	0.3	0.7	1.1	1.4	1.8	2.2	2.6	3.0	3.4	3.8	29.6	1.8
23.8	4.0	8.0	11.9	15.9	19.9	.8	0.3	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.4	3.8	31.3	1.9
23.9	4.0	8.0	12.0	16.0	20.0	.9	0.4	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.5	3.9	33.0 34.7	2.0

The Double-Second-Difference correction (Corr

(INTERPOLA)TION TABLE

Altitude Difference (d)

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
24.0	4.0	8.0	12.0	16.0	20.0	.0	0.0	0.4	0.8	1.2	1.6	2.0	2.4	2.9	3.3	3.7
24.1	4.0	8.0	12.0	16.0	20.1	.1	0.0	0.4	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.7
24.2	4.0	8.0	12.1	16.1	20.1	.2	0.1	0.5	0.9	1.3	1.7	2.1	2.5	2.9	3.3	3.8
24.3	4.0	8.1	12.1	16.2	20.2	.3	0.1	0.5	0.9	1.3	1.8	2.2	2.6	3.0	3.4	3.8
24.4	4.1	8.1	12.2	16.3	20.3	.4	0.2	0.6	1.0	1.4	1.8	2.2	2.6	3.0	3.4	3.8
24.5	4.1	8.2	12.3	16.3	20.4	.5	0.2	0.6	1.0	1.4	1.8	2.2	2.7	3.1	3.5	3.9
24.6	4.1	8.2	12.3	16.4	20.5	.6	0.2	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.5	3.9
24.7	4.1	8.3	12.4	16.5	20.6	.7	0.3	0.7	1.1	1.5	1.9	2.3	2.7	3.1	3.6	4.0
24.8	4.2	8.3	12.4	16.6	20.7	.8	0.3	0.7	1.1	1.6	2.0	2.4	2.8	3.2	3.6	4.0
24.9	4.2	8.3	12.5	16.6	20.8	.9	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
25.0	4.1	8.3	12.5	16.6	20.8	.0	0.0	0.4	0.8	1.3	1.7	2.1	2.5	3.0	3.4	3.8
25.1	4.2	8.3	12.5	16.7	20.9	.1	0.0	0.5	0.9	1.3	1.7	2.2	2.6	3.0	3.4	3.9
25.2	4.2	8.4	12.6	16.8	21.0	.2	0.1	0.5	0.9	1.4	1.8	2.2	2.6	3.1	3.5	3.9
25.3	4.2	8.4	12.6	16.9	21.1	.3	0.1	0.6	1.0	1.4	1.8	2.3	2.7	3.1	3.5	4.0
25.4	4.2	8.5	12.7	16.9	21.2	.4	0.2	0.6	1.0	1.4	1.9	2.3	2.7	3.1	3.6	4.0
25.5	4.3	8.5	12.8	17.0	21.3	.5	0.2	0.6	1.1	1.5	1.9	2.3	2.8	3.2	3.6	4.0
25.6	4.3	8.5	12.8	17.1	21.3	.6	0.3	0.7	1.1	1.5	2.0	2.4	2.8	3.2	3.7	4.1
25.7	4.3	8.6	12.9	17.2	21.4	.7	0.3	0.7	1.1	1.6	2.0	2.4	2.8	3.3	3.7	4.1
25.8	4.3	8.6	12.9	17.2	21.5	.8	0.3	0.8	1.2	1.6	2.0	2.5	2.9	3.3	3.7	4.2
25.9	4.4	8.7	13.0	17.3	21.6	.9	0.4	0.8	1.2	1.7	2.1	2.5	2.9	3.4	3.8	4.2

Double Second Diff.	Corr.
0.8	0.1
2.5	0.2
4.1	0.3
5.8	0.4
7.4	0.5
9.1	0.6
10.7	0.7
12.3	0.8
14.0	0.9
15.6	1.0
17.3	1.1
18.9	1.2
20.6	1.3
22.2	1.4
23.9	1.5
25.5	1.6
27.2	1.7
28.8	1.8
30.4	1.9
32.1	2.0
33.7	2.1
35.4	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
26.0	4.3	8.6	13.0	17.3	21.6	.0	0.0	0.4	0.9	1.3	1.8	2.2	2.6	3.1	3.5	4.0
26.1	4.3	8.7	13.0	17.4	21.7	.1	0.0	0.5	0.9	1.4	1.8	2.3	2.7	3.1	3.6	4.0
26.2	4.3	8.7	13.1	17.4	21.8	.2	0.1	0.5	1.0	1.4	1.9	2.3	2.7	3.2	3.6	4.1
26.3	4.4	8.8	13.1	17.5	21.9	.3	0.1	0.6	1.0	1.5	1.9	2.3	2.8	3.2	3.7	4.1
26.4	4.4	8.8	13.2	17.6	22.0	.4	0.2	0.6	1.1	1.5	1.9	2.4	2.8	3.3	3.7	4.2
26.5	4.4	8.8	13.3	17.7	22.1	.5	0.2	0.7	1.1	1.5	2.0	2.4	2.9	3.3	3.8	4.2
26.6	4.4	8.9	13.3	17.7	22.2	.6	0.3	0.7	1.1	1.6	2.0	2.5	2.9	3.4	3.8	4.2
26.7	4.5	8.9	13.4	17.8	22.3	.7	0.3	0.8	1.2	1.6	2.1	2.5	3.0	3.4	3.8	4.3
26.8	4.5	9.0	13.4	17.9	22.4	.8	0.4	0.8	1.2	1.7	2.1	2.6	3.0	3.4	3.9	4.3
26.9	4.5	9.0	13.5	18.0	22.5	.9	0.4	0.8	1.3	1.7	2.2	2.6	3.0	3.5	3.9	4.4
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

Double Second Diff.	Corr.
0.8	0.1
2.4	0.2
4.0	0.3
5.7	0.4
7.3	0.5
8.9	0.6
10.5	0.7
12.1	0.8
13.7	0.9
15.4	1.0
17.0	1.1
18.6	1.2
20.2	1.3
21.8	1.4
23.4	1.5
25.1	1.6
26.7	1.7
28.3	1.8
29.9	1.9
31.5	2.0
33.1	2.1
34.7	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
28.0	4.6	9.3	14.0	18.6	23.3	.0	0.0	0.5	0.9	1.4	1.9	2.4	2.8	3.3	3.8	4.3
28.1	4.7	9.3	14.0	18.7	23.4	.1	0.0	0.5	1.0	1.5	1.9	2.4	2.9	3.4	3.8	4.3
28.2	4.7	9.4	14.1	18.8	23.5	.2	0.1	0.6	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4
28.3	4.7	9.4	14.1	18.9	23.6	.3	0.1	0.6	1.1	1.6	2.0	2.5	3.0	3.5	3.9	4.4
28.4	4.7	9.5	14.2	18.9	23.7	.4	0.2	0.7	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5
28.5	4.8	9.5	14.3	19.0	23.8	.5	0.2	0.7	1.2	1.7	2.1	2.6	3.1	3.6	4.0	4.5
28.6	4.8	9.5	14.3	19.1	23.8	.6	0.3	0.8	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6
28.7	4.8	9.6	14.4	19.2	23.9	.7	0.3	0.8	1.3	1.8	2.2	2.7	3.2	3.7	4.1	4.6
28.8	4.8	9.6	14.4	19.2	24.0	.8	0.4	0.9	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7
28.9	4.9	9.7	14.5	19.3	24.1	.9	0.4	0.9	1.4	1.9	2.3	2.8	3.3	3.8	4.2	4.7
29.0	4.8	9.6	14.5	19.3	24.1	.0	0.0	0.5	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4
29.1	4.8	9.7	14.5	19.4	24.2	.1	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
29.2	4.8	9.7	14.6	19.4	24.3	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5
29.3	4.9	9.8	14.6	19.5	24.4	.3	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6
29.4	4.9	9.8	14.7	19.6	24.5	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6
29.5	4.9	9.8	14.8	19.7	24.6	.5	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7
29.6	4.9	9.9	14.8	19.7	24.7	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7
29.7	5.0	9.9	14.9	19.8	24.8	.7	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8
29.8	5.0	10.0	14.9	19.9	24.9	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.8
29.9	5.0	10.0	15.0	20.0	25.0	.9	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9

Double Second Diff.	Corr.
0.8	0.1
2.4	0.2
4.0	0.3
5.6	0.4
7.2	0.5
8.8	0.6
10.4	0.7
12.0	0.8
13.6	0.9
15.2	1.0
16.8	1.1
18.4	1.2
20.0	1.3
21.6	1.4
23.2	1.5
24.8	1.6
26.4	1.7
28.0	1.8
29.6	1.9
31.2	2.0
32.8	2.1
34.4	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
30.0	5.0	10.0	15.0	20.0	25.0	.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.6	4.1	4.6
30.1	5.0	10.0	15.0	20.0	25.1	.1	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6
30.2	5.0	10.0	15.1	20.1	25.1	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.2	3.7	4.2	4.7
30.3	5.0	10.1	15.1	20.2	25.2	.3	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7
30.4	5.1	10.1	15.2	20.3	25.3	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8
30.5	5.1	10.2	15.3	20.3	25.4	.5	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8
30.6	5.1	10.2	15.3	20.4	25.5	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9
30.7	5.1	10.3	15.4	20.5	25.6	.7	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9
30.8	5.2	10.3	15.4	20.6	25.7	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0
30.9	5.2	10.3	15.5	20.6	25.8	.9	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
31.0	5.1	10.3	15.5	20.6	25.8	.0	0.0	0.5	1.0	1.6	2.1	2.6	3.1	3.7	4.2	4.7
31.1	5.2	10.3	15.5	20.7	25.9	.1	0.1	0.6	1.1	1.6	2.2	2.7	3.2	3.7	4.3	4.8
31.2	5.2	10.4	15.6	20.8	26.0	.2	0.1	0.6	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8
31.3	5.2	10.4	15.6	20.9	26.1	.3	0.2	0.7	1.2	1.7	2.3	2.8	3.3	3.8	4.4	4.9
31.4	5.2	10.5	15.7	20.9	26.2	.4	0.2	0.7	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9
31.5	5.3	10.5	15.8	21.0	26.3	.5	0.3	0.8	1.3	1.8	2.4	2.9	3.4	3.9	4.5	5.0
31.6	5.3	10.5	15.8	21.1	26.3	.6	0.3	0.8	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0
31.7	5.3	10.6	15.9	21.2	26.4	.7	0.4	0.9	1.4	1.9	2.5	3.0	3.5	4.0	4.6	5.1
31.8	5.3	10.6	15.9	21.2	26.5	.8	0.4	0.9	1.5	2.0	2.5	3.0	3.6	4.1	4.6	5.1
31.9	5.4	10.7	16.0	21.3	26.6	.9	0.5	1.0	1.5	2.0	2.6	3.1	3.6	4.1	4.7	5.2

Double Second Diff.	Corr.
0.8	0.1
2.4	0.2
4.0	0.3
5.6	0.4
7.2	0.5
8.8	0.6
10.4	0.7
12.0	0.8
13.6	0.9
15.2	1.0
16.8	1.1
18.4	1.2
20.0	1.3
21.6	1.4
23.2	1.5
24.8	1.6
26.4	1.7
28.0	1.8
29.6	1.9
31.2	2.0
32.8	2.1
34.4	

is always to be added to the tabulated altitude.

INTERPOLATION TABLE

Altitude Difference (d)

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
28.0	4.6	9.3	14.0	18.6	23.3	.0	0.0	0.5	0.9	1.4	1.9	2.4	2.8	3.3	3.8	4.3
28.1	4.7	9.3	14.0	18.7	23.4	.1	0.0	0.5	1.0	1.5	1.9	2.4	2.9	3.4	3.8	4.3
28.2	4.7	9.4	14.1	18.8	23.5	.2	0.1	0.6	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4
28.3	4.7	9.4	14.1	18.9	23.6	.3	0.1	0.6	1.1	1.6	2.0	2.5	3.0	3.5	3.9	4.4
28.4	4.7	9.5	14.2	18.9	23.7	.4	0.2	0.7	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5
28.5	4.8	9.5	14.3	19.0	23.8	.5	0.2	0.7	1.2	1.7	2.1	2.6	3.1	3.6	4.0	4.5
28.6	4.8	9.5	14.3	19.1	23.8	.6	0.3	0.8	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6
28.7	4.8	9.6	14.4	19.2	23.9	.7	0.3	0.8	1.3	1.8	2.2	2.7	3.2	3.7	4.1	4.6
28.8	4.8	9.6	14.4	19.2	24.0	.8	0.4	0.9	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7
28.9	4.9	9.7	14.5	19.3	24.1	.9	0.4	0.9	1.4	1.9	2.3	2.8	3.3	3.8	4.2	4.7
29.0	4.8	9.6	14.5	19.3	24.1	.0	0.0	0.5	1.0	1.5	2.0	2.5	2.9	3.4	3.9	4.4
29.1	4.8	9.7	14.5	19.4	24.2	.1	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
29.2	4.8	9.7	14.6	19.4	24.3	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5
29.3	4.9	9.8	14.6	19.5	24.4	.3	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6
29.4	4.9	9.8	14.7	19.6	24.5	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.1	3.6	4.1	4.6
29.5	4.9	9.8	14.8	19.7	24.6	.5	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7
29.6	4.9	9.9	14.8	19.7	24.7	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.2	3.7	4.2	4.7
29.7	5.0	9.9	14.9	19.8	24.8	.7	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8
29.8	5.0	10.0	14.9	19.9	24.9	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.8
29.9	5.0	10.0	15.0	20.0	25.0	.9	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9

Double Second Diff.	Corr.
0.8	0.1
2.4	0.2
4.0	0.3
5.6	0.4
7.2	0.5
8.8	0.6
10.4	0.7
12.0	0.8
13.6	0.9
15.2	1.0
16.8	1.1
18.4	1.2
20.0	1.3
21.6	1.4
23.2	1.5
24.8	1.6
26.4	1.7
28.0	1.8
29.6	1.9
31.2	2.0
32.8	2.1
34.4	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
30.0	5.0	10.0	15.0	20.0	25.0	.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.6	4.1	4.6
30.1	5.0	10.0	15.0	20.0	25.1	.1	0.1	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6
30.2	5.0	10.0	15.1	20.1	25.1	.2	0.1	0.6	1.1	1.6	2.1	2.6	3.2	3.7	4.2	4.7
30.3	5.0	10.1	15.1	20.2	25.2	.3	0.2	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7
30.4	5.1	10.1	15.2	20.3	25.3	.4	0.2	0.7	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8
30.5	5.1	10.2	15.3	20.3	25.4	.5	0.3	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8
30.6	5.1	10.2	15.3	20.4	25.5	.6	0.3	0.8	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9
30.7	5.1	10.3	15.4	20.5	25.6	.7	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.9
30.8	5.2	10.3	15.4	20.6	25.7	.8	0.4	0.9	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0
30.9	5.2	10.3	15.5	20.6	25.8	.9	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
31.0	5.1	10.3	15.5	20.6	25.8	.0	0.0	0.5	1.0	1.6	2.1	2.6	3.1	3.7	4.2	4.7
31.1	5.2	10.3	15.5	20.7	25.9	.1	0.1	0.6	1.1	1.6	2.2	2.7	3.2	3.7	4.3	4.8
31.2	5.2	10.4	15.6	20.8	26.0	.2	0.1	0.6	1.2	1.7	2.2	2.7	3.3	3.8	4.3	4.8
31.3	5.2	10.4	15.6	20.9	26.1	.3	0.2	0.7	1.2	1.7	2.3	2.8	3.3	3.8	4.4	4.9
31.4	5.2	10.5	15.7	20.9	26.2	.4	0.2	0.7	1.3	1.8	2.3	2.8	3.4	3.9	4.4	4.9
31.5	5.3	10.5	15.8	21.0	26.3	.5	0.3	0.8	1.3	1.8	2.4	2.9	3.4	3.9	4.5	5.0
31.6	5.3	10.5	15.8	21.1	26.3	.6	0.3	0.8	1.4	1.9	2.4	2.9	3.5	4.0	4.5	5.0
31.7	5.3	10.6	15.9	21.2	26.4	.7	0.4	0.9	1.4	1.9	2.5	3.0	3.5	4.0	4.6	5.1
31.8	5.3	10.6	15.9	21.2	26.5	.8	0.4	0.9	1.5	2.0	2.5	3.0	3.6	4.1	4.6	5.1
31.9	5.4	10.7	16.0	21.3	26.6	.9	0.5	1.0	1.5	2.0	2.6	3.1	3.6	4.1	4.7	5.2

Double Second Diff.	Corr.
0.8	0.1
2.4	0.2
4.0	0.3
5.6	0.4
7.2	0.5
8.8	0.6
10.4	0.7
12.0	0.8
13.6	0.9
15.2	1.0
16.8	1.1
18.4	1.2
20.0	1.3
21.6	1.4
23.2	1.5
24.8	1.6
26.4	1.7
28.0	1.8
29.6	1.9
31.2	2.0
32.8	2.1
34.4	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
32.0	5.3	10.6	16.0	21.3	26.6	.0	0.0	0.5	1.1	1.6	2.2	2.7	3.2	3.8	4.3	4.9
32.1	5.3	10.7	16.0	21.4	26.7	.1	0.1	0.6	1.1	1.7	2.2	2.8	3.3	3.8	4.4	4.9
32.2	5.3	10.7	16.1	21.4	26.8	.2	0.1	0.6	1.2	1.7	2.3	2.8	3.4	3.9	4.4	5.0
32.3	5.4	10.8	16.1	21.5	26.9	.3	0.2	0.7	1.2	1.8	2.3	2.9	3.4	3.9	4.5	5.0
32.4	5.4	10.8	16.2	21.6	27.0	.4	0.2	0.8	1.3	1.8	2.4	2.9	3.5	4.0	4.5	5.1
32.5	5.4	10.8	16.3	21.7	27.1	.5	0.3	0.8	1.4	1.9	2.4	3.0	3.5	4.1	4.6	5.1
32.6	5.4	10.9	16.3	21.7	27.2	.6	0.3	0.9	1.4	1.9	2.5	3.0	3.6	4.1	4.7	5.2
32.7	5.5	10.9	16.4	21.8	27.3	.7	0.4	0.9	1.5	2.0	2.5	3.1	3.6	4.2	4.7	5.2
32.8	5.5	11.0	16.4	21.9	27.4	.8	0.4	1.0	1.5	2.1	2.6	3.1	3.7	4.2	4.8	5.3
32.9	5.5	11.0	16.5	22.0	27.5	.9	0.5	1.0	1.6	2.1	2.7	3.2	3.7	4.3	4.8	5.4
33.0	5.5	11.0	16.5	22.0	27.5	.0	0.0	0.6	1.1	1.7	2.2	2.8	3.3	3.9	4.5	5.0
33.1	5.5	11.0	16.5	22.0	27.6	.1	0.1	0.6	1.2	1.7	2.3	2.8	3.4	4.0	4.5	5.1
33.2	5.5	11.0	16.6	22.1	27.6	.2	0.1	0.7	1.2	1.8	2.3	2.9	3.5	4.0	4.6	5.1
33.3	5.5	11.1	16.6	22.2	27.7	.3	0.2	0.7	1.3	1.8	2.4	3.0	3.5	4.1	4.6	5.2
33.4	5.6	11.1	16.7	22.3	27.8	.4	0.2	0.8	1.3	1.9	2.5	3.0	3.6	4.1	4.7	5.2
33.5	5.6	11.2	16.8	22.3	27.9	.5	0.3	0.8	1.4	2.0	2.5	3.1	3.6	4.2	4.7	5.3
33.6	5.6	11.2	16.8	22.4	28.0	.6	0.3	0.9	1.5	2.0	2.6	3.1	3.7	4.2	4.8	5.4
33.7	5.6	11.3	16.9	22.5	28.1	.7	0.4	0.9	1.5	2.1	2.6	3.2	3.7	4.3	4.9	5.4
33.8	5.7	11.3	16.9	22.6	28.2	.8	0.4	1.0	1.6	2.1	2.7	3.2	3.8	4.4	4.9	5.5
33.9	5.7	11.3	17.0	22.6	28.3	.9	0.5	1.1	1.6	2.2	2.7	3.3	3.9	4.4	5.0	5.5

Double Second Diff.	Corr.
0.8	0.1
2.4	0.2
4.0	0.3
5.7	0.4
7.3	0.5
8.9	0.6
10.5	0.7
12.1	0.8
13.7	0.9
15.4	1.0
17.0	1.1
18.6	1.2
20.2	1.3
21.8	1.4
23.4	1.5
25.1	1.6
26.7	1.7
28.3	1.8
29.9	1.9
31.5	2.0
33.1	2.1
34.7	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
34.0	5.6	11.3	17.0	22.6	28.3	.0	0.0	0.6	1.1	1.7	2.3	2.9	3.4	4.0	4.6	5.2
34.1	5.7	11.3	17.0	22.7	28.4	.1	0.1	0.6	1.2	1.8	2.4	2.9	3.5	4.1	4.7	5.2
34.2	5.7	11.4	17.1	22.8	28.5	.2	0.1	0.7	1.3	1.8	2.4	3.0	3.6	4.1	4.7	5.3
34.3	5.7	11.4	17.1	22.9	28.6	.3	0.2	0.7	1.3	1.9	2.5	3.0	3.6	4.2	4.8	5.3
34.4	5.7	11.5	17.2	22.9	28.7	.4	0.2	0.8	1.4	2.0	2.5	3.1	3.7	4.3	4.8	5.4
34.5	5.8	11.5	17.3	23.0	28.8	.5	0.3	0.9	1.4	2.0	2.6	3.2	3.7	4.3	4.9	5.5
34.6	5.8	11.5	17.3	23.1	28.8	.6	0.3	0.9	1.5	2.1	2.6	3.2	3.8	4.4	4.9	5.5
34.7	5.8	11.6	17.4	23.2	28.9	.7	0.4	1.0	1.6	2.1	2.7	3.3	3.9	4.4	5.0	5.6
34.8	5.8	11.6	17.4	23.2	29.0	.8	0.5	1.0	1.6	2.2	2.8	3.3	3.9	4.5	5.1	5.6
34.9	5.9	11.7	17.5	23.3	29.1	.9	0.5	1.1	1.7	2.2	2.8	3.4	4.0	4.5	5.1	5.7
35.0	5.8	11.6	17.5	23.3	29.1	.0	0.0	0.6	1.2	1.8	2.4	3.0	3.5	4.1	4.7	5.3
35.1	5.8	11.7	17.5	23.4	29.2	.1	0.1	0.7	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4
35.2	5.8	11.7	17.6	23.4	29.3	.2	0.1	0.7	1.3	1.9	2.5	3.1	3.7	4.3	4.9	5.5
35.3	5.9	11.8	17.6	23.5	29.4	.3	0.2	0.8	1.4	2.0	2.5	3.1	3.7	4.3	4.9	5.5
35.4	5.9	11.8	17.7	23.6	29.5	.4	0.2	0.8	1.4	2.0	2.6	3.2	3.8	4.4	5.0	5.6
35.5	5.9	11.8	17.8	23.7	29.6	.5	0.3	0.9	1.5	2.1	2.7	3.3	3.8	4.4	5.0	5.6
35.6	5.9	11.9	17.8	23.7	29.7	.6	0.4	0.9	1.5	2.1	2.7	3.3	3.9	4.5	5.1	5.7
35.7	6.0	11.9	17.9	23.8	29.8	.7	0.4	1.0	1.6	2.2	2.8	3.4	4.0	4.6	5.1	5.7
35.8	6.0	12.0	17.9	23.9	29.9	.8	0.5	1.1	1.7	2.2	2.8	3.4	4.0	4.6	5.2	5.8
35.9	6.0	12.0	18.0	24.0	30.0	.9	0.5	1.1	1.7	2.3	2.9	3.5	4.1	4.7	5.3	5.9

Double Second Diff.	Corr.
0.8	0.1
2.5	0.2
4.1	0.3
5.8	0.4
7.4	0.5
9.1	0.6
10.7	0.7
12.3	0.8
14.0	0.9
15.6	1.0
17.3	1.1
18.9	1.2
20.6	1.3
22.2	1.4
23.9	1.5
25.5	1.6
27.2	1.7
28.8	1.8
30.4	1.9
32.1	2.0
33.7	2.1
35.4	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
36.0	6.0	12.0	18.0	24.0	30.0	.0	0.0	0.6	1.2	1.8	2.4	3.0	3.6	4.3	4.9	5.5
36.1	6.0	12.0	18.0	24.0	30.1	.1	0.1	0.7	1.3	1.9	2.5	3.1	3.7	4.3	4.9	5.5
36.2	6.0	12.0	18.1	24.1	30.1	.2	0.1	0.7	1.3	1.9	2.6	3.2	3.8	4.4	5.0	5.6
36.3	6.0	12.1	18.1	24.2	30.2	.3	0.2	0.8	1.4	2.0	2.6	3.2	3.8	4.4	5.0	5.7
36.4	6.1	12.1	18.2	24.3	30.3	.4	0.2	0.9	1.5	2.1	2.7	3.3	3.9	4.5	5.1	5.7
36.5	6.1	12.2	18.3	24.3	30.4	.5	0.3	0.9	1.5	2.1	2.7	3.3	4.0	4.6	5.2	5.8
36.6	6.1	12.2	18.3	24.4	30.5	.6	0.4	1.0	1.6	2.2	2.8	3.4	4.0	4.6	5.2	5.8
36.7	6.1	12.3	18.4	24.5	30.6	.7	0.4	1.0	1.6	2.3	2.9	3.5	4.1	4.7	5.3	5.9
36.8	6.2	12.3	18.4	24.6	30.7	.8	0.5	1.1	1.7	2.3	2.9	3.5	4.1	4.7	5.4	6.0
36.9	6.2	12.3	18.5	24.6	30.8	.9	0.5	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0
37.0	6.1	12.3	18.5	24.6	30.8	.0	0.0	0.6	1.2	1.9	2.5	3.1	3.7	4.4	5.0	5.6
37.1	6.2	12.3	18.5	24.7	30.9	.1	0.1	0.7	1.3	1.9	2.6	3.2	3.8	4.4	5.1	5.7
37.2	6.2	12.4	18.6	24.8	31.0	.2	0.1	0.7	1.4	2.0	2.6	3.2	3.9	4.5	5.1	5.7
37.3	6.2	12.4	18.6	24.9	31.1	.3	0.2	0.8	1.4	2.1	2.7	3.3	3.9	4.6	5.2	5.8
37.4	6.2	12.5	18.7	24.9	31.2	.4	0.2	0.9	1.5	2.1	2.7	3.4	4.0	4.6	5.2	5.9
37.5	6.3	12.5	18.8	25.0	31.3	.5	0.3	0.9	1.6	2.2	2.8	3.4	4.1	4.7	5.3	5.9
37.6	6.3	12.5	18.8	25.1	31.3	.6	0.4	1.0	1.6	2.2	2.9	3.5	4.1	4.7	5.4	6.0
37.7	6.3	12.6	18.9	25.2	31.4	.7	0.4	1.1	1.7	2.3	2.9	3.6	4.2	4.8	5.4	6.1
37.8	6.3	12.6	18.9	25.2	31.5	.8	0.5	1.1	1.7	2.4	3.0	3.6	4.2	4.9	5.5	6.1
37.9	6.4	12.7	19.0	25.3	31.6	.9	0.6	1.2	1.8	2.4	3.1	3.7	4.3	4.9	5.6	6.2

Double Second Diff.	Corr.
0.8	0.1
2.5	0.2
4.2	0.3
5.9	0.4
7.6	0.5
9.3	0.6
11.0	0.7
12.7	0.8
14.4	0.9
16.1	1.0
17.8	1.1
19.5	1.2
21.2	1.3
22.8	1.4
24.5	1.5
26.2	1.6
27.9	1.7
29.6	1.8
31.3	1.9
33.0	2.0
34.7	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
38.0	6.3	12.6	19.0	25.3	31.6	.0	0.0	0.6	1.3	1.9	2.6	3.2	3.8	4.5	5.1	5.8
38.1	6.3	12.7	19.0	25.4	31.7	.1	0.1	0.7	1.3	2.0	2.6	3.3	3.9	4.6	5.2	5.8
38.2	6.3	12.7	19.1	25.4	31.8	.2	0.1	0.8	1.4	2.1	2.7	3.3	4.0	4.6	5.3	5.9
38.3	6.4	12.8	19.1	25.5	31.9	.3	0.2	0.8	1.5	2.1	2.8	3.4	4.0	4.7	5.3	6.0
38.4	6.4	12.8	19.2	25.6	32.0	.4	0.3	0.9	1.5	2.2	2.8	3.5	4.1	4.7	5.4	6.0
38.5	6.4	12.8	19.3	25.7	32.1	.5	0.3	1.0	1.6	2.2	2.9	3.5	4.2	4.8	5.5	6.1
38.6	6.4	12.9	19.3	25.7	32.2	.6	0.4	1.0	1.7	2.3	3.0	3.6	4.2	4.9	5.5	6.2
38.7	6.5	12.9	19.4	25.8	32.3	.7	0.4	1.1	1.7	2.4	3.0	3.7	4.3	4.9	5.6	6.2
38.8	6.5	13.0	19.4	25.9	32.4	.8	0.5	1.2	1.8	2.4	3.1	3.7	4.4	5.0	5.6	6.3
38.9	6.5	13.0	19.5	26.0	32.5	.9	0.6	1.2	1.9	2.5	3.1	3.8	4.4	5.1	5.7	6.4
39.0	6.5	13.0	19.5	26.0	32.5	.0	0.0	0.7	1.3	2.0	2.6	3.3	3.9	4.6	5.3	5.9
39.1	6.5	13.0	19.5	26.0	32.6	.1	0.1	0.7	1.4	2.0	2.7	3.4	4.0	4.7	5.3	6.0
39.2	6.5	13.0	19.6	26.1	32.6	.2	0.1	0.8	1.4	2.1	2.8	3.4	4.1	4.7	5.4	6.1
39.3	6.5	13.1	19.6	26.2	32.7	.3	0.2	0.9	1.5	2.2	2.8	3.5	4.1	4.8	5.5	6.1
39.4	6.6	13.1	19.7	26.3	32.8	.4	0.3	0.9	1.6	2.2	2.9	3.6	4.2	4.9	5.5	6.2
39.5	6.6	13.2	19.8	26.3	32.9	.5	0.3	1.0	1.6	2.3	3.0	3.6	4.3	4.9	5.6	6.3
39.6	6.6	13.2	19.8	26.4	33.0	.6	0.4	1.1	1.7	2.4	3.0	3.7	4.3	5.0	5.7	6.3
39.7	6.6	13.3	19.9	26.5	33.1	.7	0.5	1.1	1.8	2.4	3.1	3.8	4.4	5.1	5.7	6.4
39.8	6.7	13.3	19.9	26.6	33.2	.8	0.5	1.2	1.8	2.5	3.2	3.8	4.5	5.1	5.8	6.5
39.9	6.7	13.3	20.0	26.6	33.3	.9	0.6	1.3	1.9	2.6	3.2	3.9	4.5	5.2	5.9	6.5

Double Second Diff.	Corr.
0.9	0.1
2.6	0.2
4.4	0.3
6.2	0.4
7.9	0.5
9.7	0.6
11.4	0.7
13.2	0.8
14.9	0.9
16.7	1.0
18.5	1.1
20.2	1.2
22.0	1.3
23.7	1.4
25.5	1.5
27.3	1.6
29.0	1.7
30.8	1.8
32.5	1.9
34.3	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
40.0	6.6	13.3	20.0	26.6	33.3	.0	0.0	0.7	1.3	2.0	2.7	3.4	4.0	4.7	5.4	6.1
40.1	6.7	13.3	20.0	26.7	33.4	.1	0.1	0.7	1.4	2.1	2.8	3.4	4.1	4.8	5.5	6.1
40.2	6.7	13.4	20.1	26.8	33.5	.2	0.1	0.8	1.5	2.2	2.8	3.5	4.2	4.9	5.5	6.2
40.3	6.7	13.4	20.1	26.9	33.6	.3	0.2	0.9	1.6	2.2	2.9	3.6	4.3	4.9	5.6	6.3
40.4	6.7	13.5	20.2	26.9	33.7	.4	0.3	0.9	1.6	2.3	3.0	3.6	4.3	5.0	5.7	6.3
40.5	6.8	13.5	20.3	27.0	33.8	.5	0.3	1.0	1.7	2.4	3.0	3.7	4.4	5.1	5.7	6.4
40.6	6.8	13.5	20.3	27.1	33.8	.6	0.4	1.1	1.8	2.4	3.1	3.8	4.5	5.1	5.8	6.5
40.7	6.8	13.6	20.4	27.2	33.9	.7	0.5	1.1	1.8	2.5	3.2	3.8	4.5	5.2	5.9	6.5
40.8	6.8	13.6	20.4	27.2	34.0	.8	0.5	1.2	1.9	2.6	3.2	3.9	4.6	5.3	5.9	6.6
40.9	6.9	13.7	20.5	27.3	34.1	.9	0.6	1.3	2.0	2.6	3.3	4.0	4.7	5.3	6.0	6.7
41.0	6.8	13.6	20.5	27.3	34.1	.0	0.0	0.7	1.4	2.1	2.8	3.5	4.1	4.8	5.5	6.2
41.1	6.8	13.7	20.5	27.4	34.2	.1	0.1	0.8	1.5	2.1	2.8	3.5	4.2	4.9	5.6	6.3
41.2	6.8	13.7	20.6	27.4	34.3	.2	0.1	0.8	1.5	2.2	2.9	3.6	4.3	5.0	5.7	6.4
41.3	6.9	13.8	20.6	27.5	34.4	.3	0.2	0.9	1.6	2.3	3.0	3.7	4.4	5.0	5.7	6.4
41.4	6.9	13.8	20.7	27.6	34.5	.4	0.3	1.0	1.7	2.4	3.0	3.7	4.4	5.1	5.8	6.5
41.5	6.9	13.8	20.8	27.7	34.6	.5	0.3	1.0	1.7	2.4	3.1	3.8	4.5	5.2	5.9	6.6
41.6	6.9	13.9	20.8	27.7	34.7	.6	0.4	1.1	1.8	2.5	3.2	3.9	4.6	5.3	5.9	6.6
41.7	7.0	13.9	20.9	27.8	34.8	.7	0.5	1.2	1.9	2.6	3.3	3.9	4.6	5.3	6.0	6.7
41.8	7.0	14.0	20.9	27.9	34.9	.8	0.6	1.2	1.9	2.6	3.3	4.0	4.7	5.4	6.1	6.8
41.9	7.0	14.0	21.0	28.0	35.0	.9	0.6	1.3	2.0	2.7	3.4	4.1	4.8	5.5	6.2	6.8

Double Second Diff.	Corr.
0.9	0.1
2.8	0.2
4.6	0.3
6.5	0.4
8.3	0.5
10.2	0.6
12.0	0.7
13.9	0.8
15.7	0.9
17.6	1.0
19.4	1.1
21.3	1.2
23.1	1.3
25.0	1.4
26.8	1.5
28.7	1.6
30.5	1.7
32.3	1.8
34.2	

Dec. Inc.	10′	20′	30′	40′	50′	Decimals	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′
42.0	7.0	14.0	21.0	28.0	35.0	.0	0.0	0.7	1.4	2.1	2.8	3.5	4.2	5.0	5.7	6.4
42.1	7.0	14.0	21.0	28.0	35.1	.1	0.1	0.8	1.5	2.2	2.9	3.6	4.3	5.0	5.7	6.4
42.2	7.0	14.0	21.1	28.1	35.1	.2	0.1	0.8	1.6	2.3	3.0	3.7	4.4	5.1	5.8	6.5
42.3	7.0	14.1	21.1	28.2	35.2	.3	0.2	0.9	1.6	2.3	3.0	3.8	4.5	5.2	5.9	6.6
42.4	7.1	14.1	21.2	28.3	35.3	.4	0.3	1.0	1.7	2.4	3.1	3.8	4.5	5.2	5.9	6.7
42.5	7.1	14.2	21.3	28.3	35.4	.5	0.4	1.1	1.8	2.5	3.2	3.9	4.6	5.3	6.0	6.7
42.6	7.1	14.2	21.3	28.4	35.5	.6	0.4	1.1	1.8	2.5	3.3	4.0	4.7	5.4	6.1	6.8
42.7	7.1	14.3	21.4	28.5	35.6	.7	0.5	1.2	1.9	2.6	3.3	4.0	4.7	5.5	6.2	6.9
42.8	7.2	14.3	21.4	28.6	35.7	.8	0.6	1.3	2.0	2.7	3.4	4.1	4.8	5.5	6.2	6.9
42.9	7.2	14.3	21.5	28.6	35.8	.9	0.6	1.3	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0
43.0	7.1	14.3	21.5	28.6	35.8	.0	0.0	0.7	1.4	2.2	2.9	3.6	4.3	5.1	5.8	6.5
43.1	7.2	14.3	21.5	28.7	35.9	.1	0.1	0.8	1.5	2.2	3.0	3.7	4.4	5.1	5.9	6.6
43.2	7.2	14.4	21.6	28.8	36.0	.2	0.1	0.9	1.6	2.3	3.0	3.8	4.5	5.2	5.9	6.7
43.3	7.2	14.4	21.6	28.9	36.1	.3	0.2	0.9	1.7	2.4	3.1	3.8	4.6	5.3	6.0	6.7
43.4	7.2	14.5	21.7	28.9	36.2	.4	0.3	1.0	1.7	2.5	3.2	3.9	4.6	5.4	6.1	6.8
43.5	7.3	14.5	21.8	29.0	36.3	.5	0.4	1.1	1.8	2.5	3.3	4.0	4.7	5.4	6.2	6.9
43.6	7.3	14.5	21.8	29.1	36.3	.6	0.4	1.2	1.9	2.6	3.3	4.1	4.8	5.5	6.2	7.0
43.7	7.3	14.6	21.9	29.2	36.4	.7	0.5	1.2	2.0	2.7	3.4	4.1	4.9	5.6	6.3	7.0
43.8	7.3	14.6	21.9	29.2	36.5	.8	0.6	1.3	2.0	2.8	3.5	4.2	4.9	5.7	6.4	7.1
43.9	7.4	14.7	22.0	29.3	36.6	.9	0.7	1.4	2.1	2.8	3.6	4.3	5.0	5.7	6.5	7.2

Double Second Diff.	Corr.
1.0	0.1
3.0	0.2
4.9	0.3
6.9	0.4
8.9	0.5
10.8	0.6
12.8	0.7
14.8	0.8
16.7	0.9
18.7	1.0
20.7	1.1
22.7	1.2
24.6	1.3
26.6	1.4
28.6	1.5
30.5	1.6
32.5	1.7
34.5	

The Double-Second-Difference correction (Corr.) is always to be added to the tabulated altitude.

INTERPOLATION TABLE

Dec. Inc.	Altitude Difference (d) Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff. and Corr.
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′ ′
44.0	7.3	14.6	22.0	29.3	36.6	.0	0.0	0.7	1.5	2.2	3.0	3.7	4.4	5.2	5.9	6.7	1.1 0.1 3.2 0.2 5.3 0.3 7.5 0.4 9.6 0.5 11.7 0.6 13.9 0.7 16.0 0.8 18.1 0.9 20.3 1.0 22.4 1.1 24.5 1.2 26.7 1.3 28.8 1.4 30.9 1.5 33.1 1.6 35.2
44.1	7.3	14.7	22.0	29.4	36.7	.1	0.1	0.8	1.6	2.3	3.0	3.8	4.5	5.3	6.0	6.7	
44.2	7.3	14.7	22.1	29.4	36.8	.2	0.1	0.9	1.6	2.4	3.1	3.9	4.6	5.3	6.1	6.8	
44.3	7.4	14.8	22.1	29.5	36.9	.3	0.2	1.0	1.7	2.4	3.2	3.9	4.7	5.4	6.2	6.9	
44.4	7.4	14.8	22.2	29.6	37.0	.4	0.3	1.0	1.8	2.5	3.3	4.0	4.7	5.5	6.2	7.0	
44.5	7.4	14.8	22.3	29.7	37.1	.5	0.4	1.1	1.9	2.6	3.3	4.1	4.8	5.6	6.3	7.0	
44.6	7.4	14.9	22.3	29.7	37.2	.6	0.4	1.2	1.9	2.7	3.4	4.2	4.9	5.6	6.4	7.1	
44.7	7.5	14.9	22.4	29.8	37.3	.7	0.5	1.3	2.0	2.7	3.5	4.2	5.0	5.7	6.5	7.2	
44.8	7.5	15.0	22.4	29.9	37.4	.8	0.6	1.3	2.1	2.8	3.6	4.3	5.0	5.8	6.5	7.3	
44.9	7.5	15.0	22.5	30.0	37.5	.9	0.7	1.4	2.2	2.9	3.6	4.4	5.1	5.9	6.6	7.3	
45.0	7.5	15.0	22.5	30.0	37.5	.0	0.0	0.8	1.5	2.3	3.0	3.8	4.5	5.3	6.1	6.8	
45.1	7.5	15.0	22.5	30.0	37.6	.1	0.1	0.8	1.6	2.4	3.1	3.9	4.6	5.4	6.1	6.9	
45.2	7.5	15.0	22.6	30.1	37.6	.2	0.2	0.9	1.7	2.4	3.2	3.9	4.7	5.5	6.2	7.0	
45.3	7.5	15.1	22.6	30.2	37.7	.3	0.2	1.0	1.7	2.5	3.3	4.0	4.8	5.5	6.3	7.1	
45.4	7.6	15.1	22.7	30.3	37.8	.4	0.3	1.1	1.8	2.6	3.3	4.1	4.9	5.6	6.4	7.1	
45.5	7.6	15.2	22.8	30.3	37.9	.5	0.4	1.1	1.9	2.7	3.4	4.2	4.9	5.7	6.4	7.2	
45.6	7.6	15.2	22.8	30.4	38.0	.6	0.5	1.2	2.0	2.7	3.5	4.2	5.0	5.8	6.5	7.3	
45.7	7.6	15.3	22.9	30.5	38.1	.7	0.5	1.3	2.0	2.8	3.6	4.3	5.1	5.8	6.6	7.4	
45.8	7.7	15.3	22.9	30.6	38.2	.8	0.6	1.4	2.1	2.9	3.6	4.4	5.2	5.9	6.7	7.4	
45.9	7.7	15.3	23.0	30.6	38.3	.9	0.7	1.4	2.2	3.0	3.7	4.5	5.2	6.0	6.7	7.5	
46.0	7.6	15.3	23.0	30.6	38.3	.0	0.0	0.8	1.5	2.3	3.1	3.9	4.6	5.4	6.2	7.0	1.2 0.1 3.5 0.2 5.8 0.3 8.1 0.4 10.5 0.5 12.8 0.6 15.1 0.7 17.4 0.8 19.8 0.9 22.1 1.0 24.4 1.1 26.7 1.2 29.1 1.3 31.4 1.4 33.7 1.5 36.0
46.1	7.7	15.3	23.0	30.7	38.4	.1	0.1	0.9	1.6	2.4	3.2	4.0	4.7	5.5	6.3	7.1	
46.2	7.7	15.4	23.1	30.8	38.5	.2	0.2	0.9	1.7	2.5	3.3	4.0	4.8	5.6	6.4	7.1	
46.3	7.7	15.4	23.1	30.9	38.6	.3	0.2	1.0	1.8	2.6	3.3	4.1	4.9	5.7	6.4	7.2	
46.4	7.7	15.5	23.2	30.9	38.7	.4	0.3	1.1	1.9	2.6	3.4	4.2	5.0	5.7	6.5	7.3	
46.5	7.8	15.5	23.3	31.0	38.8	.5	0.4	1.2	1.9	2.7	3.5	4.3	5.0	5.8	6.6	7.4	
46.6	7.8	15.5	23.3	31.1	38.8	.6	0.5	1.2	2.0	2.8	3.6	4.3	5.1	5.9	6.7	7.4	
46.7	7.8	15.6	23.4	31.2	38.9	.7	0.5	1.3	2.1	2.9	3.6	4.4	5.2	6.0	6.7	7.5	
46.8	7.8	15.6	23.4	31.2	39.0	.8	0.6	1.4	2.2	2.9	3.7	4.5	5.3	6.0	6.8	7.6	
46.9	7.9	15.7	23.5	31.3	39.1	.9	0.7	1.5	2.2	3.0	3.8	4.6	5.3	6.1	6.9	7.7	
47.0	7.8	15.6	23.5	31.3	39.1	.0	0.0	0.8	1.6	2.4	3.2	4.0	4.7	5.5	6.3	7.1	
47.1	7.8	15.7	23.5	31.4	39.2	.1	0.1	0.9	1.7	2.5	3.2	4.0	4.8	5.6	6.4	7.2	
47.2	7.8	15.7	23.6	31.4	39.3	.2	0.2	0.9	1.7	2.5	3.3	4.1	4.9	5.7	6.5	7.3	
47.3	7.9	15.8	23.6	31.5	39.4	.3	0.2	1.0	1.8	2.6	3.4	4.2	5.0	5.8	6.6	7.4	
47.4	7.9	15.8	23.7	31.6	39.5	.4	0.3	1.1	1.9	2.7	3.5	4.3	5.1	5.9	6.6	7.4	
47.5	7.9	15.8	23.8	31.7	39.6	.5	0.4	1.2	2.0	2.8	3.6	4.4	5.1	5.9	6.7	7.5	1.3 0.1 3.8 0.2 6.3 0.3 8.9 0.4 11.4 0.5 14.0 0.6 16.5 0.7 19.0 0.8 21.6 0.9 24.1 1.0 26.7 1.1 29.2 1.2 31.7 1.3 34.3
47.6	7.9	15.9	23.8	31.7	39.7	.6	0.5	1.3	2.1	2.8	3.6	4.4	5.2	6.0	6.8	7.6	
47.7	8.0	15.9	23.9	31.8	39.8	.7	0.6	1.3	2.1	2.9	3.7	4.5	5.3	6.1	6.9	7.7	
47.8	8.0	16.0	23.9	31.9	39.9	.8	0.6	1.4	2.2	3.0	3.8	4.6	5.4	6.2	7.0	7.8	
47.9	8.0	16.0	24.0	32.0	40.0	.9	0.7	1.5	2.3	3.1	3.9	4.7	5.5	6.3	7.0	7.8	
48.0	8.0	16.0	24.0	32.0	40.0	.0	0.0	0.8	1.6	2.4	3.2	4.0	4.8	5.7	6.5	7.3	
48.1	8.0	16.0	24.0	32.0	40.1	.1	0.1	0.9	1.7	2.5	3.3	4.1	4.9	5.7	6.5	7.4	
48.2	8.0	16.0	24.1	32.1	40.1	.2	0.2	1.0	1.8	2.6	3.4	4.2	5.0	5.8	6.6	7.4	
48.3	8.0	16.1	24.1	32.2	40.2	.3	0.2	1.1	1.9	2.7	3.5	4.3	5.1	5.9	6.7	7.5	
48.4	8.1	16.1	24.2	32.3	40.3	.4	0.3	1.1	1.9	2.7	3.6	4.4	5.2	6.0	6.8	7.6	
48.5	8.1	16.2	24.3	32.3	40.4	.5	0.4	1.2	2.0	2.8	3.6	4.4	5.3	6.1	6.9	7.7	
48.6	8.1	16.2	24.3	32.4	40.5	.6	0.5	1.3	2.1	2.9	3.7	4.5	5.3	6.1	7.0	7.8	
48.7	8.1	16.3	24.4	32.5	40.6	.7	0.6	1.4	2.2	3.0	3.8	4.6	5.4	6.2	7.0	7.8	
48.8	8.2	16.3	24.4	32.6	40.7	.8	0.6	1.5	2.3	3.1	3.9	4.7	5.5	6.3	7.1	7.9	
48.9	8.2	16.3	24.5	32.6	40.8	.9	0.7	1.5	2.3	3.2	4.0	4.8	5.6	6.4	7.2	8.0	
49.0	8.1	16.3	24.5	32.6	40.8	.0	0.0	0.8	1.6	2.5	3.3	4.1	4.9	5.8	6.6	7.4	1.4 0.1 4.2 0.2 7.1 0.3 9.9 0.4 12.7 0.5 15.5 0.6 18.4 0.7 21.2 0.8 24.0 0.9 26.8 1.0 29.7 1.1 32.5 1.2 35.3
49.1	8.2	16.3	24.5	32.7	40.9	.1	0.1	0.9	1.7	2.6	3.4	4.2	5.0	5.9	6.7	7.5	
49.2	8.2	16.4	24.6	32.8	41.0	.2	0.2	1.0	1.8	2.6	3.5	4.3	5.1	5.9	6.8	7.6	
49.3	8.2	16.4	24.6	32.9	41.1	.3	0.2	1.1	1.9	2.7	3.5	4.4	5.2	6.0	6.8	7.7	
49.4	8.2	16.5	24.7	32.9	41.2	.4	0.3	1.2	2.0	2.8	3.6	4.5	5.3	6.1	6.9	7.8	
49.5	8.3	16.5	24.8	33.0	41.3	.5	0.4	1.2	2.1	2.9	3.7	4.5	5.4	6.2	7.0	7.8	
49.6	8.3	16.5	24.8	33.1	41.3	.6	0.5	1.3	2.1	3.0	3.8	4.6	5.4	6.3	7.1	7.9	
49.7	8.3	16.6	24.9	33.2	41.4	.7	0.6	1.4	2.2	3.1	3.9	4.7	5.5	6.4	7.2	8.0	
49.8	8.3	16.6	24.9	33.2	41.5	.8	0.7	1.5	2.3	3.1	4.0	4.8	5.6	6.4	7.3	8.1	
49.9	8.4	16.7	25.0	33.3	41.6	.9	0.7	1.6	2.4	3.2	4.0	4.9	5.7	6.5	7.3	8.2	
50.0	8.3	16.6	25.0	33.3	41.6	.0	0.0	0.8	1.7	2.5	3.4	4.2	5.0	5.9	6.7	7.6	
50.1	8.3	16.7	25.0	33.4	41.7	.1	0.1	0.9	1.8	2.6	3.5	4.3	5.1	6.0	6.8	7.7	
50.2	8.3	16.7	25.1	33.4	41.8	.2	0.2	1.0	1.9	2.7	3.5	4.4	5.2	6.1	6.9	7.7	
50.3	8.4	16.8	25.1	33.5	41.9	.3	0.3	1.1	1.9	2.8	3.6	4.5	5.3	6.1	7.0	7.8	
50.4	8.4	16.8	25.2	33.6	42.0	.4	0.3	1.2	2.0	2.9	3.7	4.5	5.4	6.2	7.1	7.9	
50.5	8.4	16.8	25.3	33.7	42.1	.5	0.4	1.3	2.1	2.9	3.8	4.6	5.5	6.3	7.2	8.0	1.6 0.1 4.8 0.2 8.0 0.3 11.2 0.4 14.5 0.5 17.7 0.6 20.9 0.7 24.1 0.8 27.3 0.9 30.5 1.0 33.7 1.1 36.9
50.6	8.4	16.9	25.3	33.7	42.2	.6	0.5	1.3	2.2	3.0	3.9	4.7	5.6	6.4	7.2	8.1	
50.7	8.5	16.9	25.4	33.8	42.3	.7	0.6	1.4	2.3	3.1	4.0	4.8	5.6	6.5	7.3	8.2	
50.8	8.5	17.0	25.4	33.9	42.4	.8	0.7	1.5	2.4	3.2	4.0	4.9	5.7	6.6	7.4	8.2	
50.9	8.5	17.0	25.5	34.0	42.5	.9	0.8	1.6	2.4	3.3	4.1	5.0	5.8	6.6	7.5	8.3	
51.0	8.5	17.0	25.5	34.0	42.5	.0	0.0	0.9	1.7	2.6	3.4	4.3	5.1	6.0	6.9	7.7	
51.1	8.5	17.0	25.5	34.0	42.6	.1	0.1	0.9	1.8	2.7	3.5	4.4	5.2	6.1	7.0	7.8	
51.2	8.5	17.0	25.6	34.1	42.6	.2	0.2	1.0	1.9	2.7	3.6	4.5	5.3	6.2	7.0	7.9	
51.3	8.5	17.1	25.6	34.2	42.7	.3	0.3	1.1	2.0	2.8	3.7	4.5	5.4	6.3	7.1	8.0	
51.4	8.6	17.1	25.7	34.3	42.8	.4	0.3	1.2	2.1	2.9	3.8	4.6	5.5	6.4	7.2	8.1	
51.5	8.6	17.2	25.8	34.3	42.9	.5	0.4	1.3	2.1	3.0	3.9	4.7	5.6	6.4	7.3	8.2	
51.6	8.6	17.2	25.8	34.4	43.0	.6	0.5	1.4	2.2	3.1	3.9	4.8	5.7	6.5	7.4	8.2	
51.7	8.6	17.3	25.9	34.5	43.1	.7	0.6	1.5	2.3	3.2	4.0	4.9	5.8	6.6	7.5	8.3	
51.8	8.7	17.3	25.9	34.6	43.2	.8	0.7	1.5	2.4	3.3	4.1	5.0	5.8	6.7	7.6	8.4	
51.9	8.7	17.3	26.0	34.6	43.3	.9	0.8	1.6	2.5	3.3	4.2	5.1	5.9	6.8	7.6	8.5	
	10′	20′	30′	40′	50′		0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	

Dec. Inc.	Altitude Difference (d) Tens 10′	20′	30′	40′	50′	Decimals ⇓	Units 0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	Double Second Diff. and Corr.
′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′ ′
52.0	8.6	17.3	26.0	34.6	43.3	.0	0.0	0.9	1.7	2.6	3.5	4.4	5.2	6.1	7.0	7.9	1.8 0.1 5.5 0.2 9.1 0.3 12.8 0.4 16.5 0.5 20.1 0.6 23.8 0.7 27.4 0.8 31.1 0.9 34.7
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	2.1 0.1 6.2 0.2 10.4 0.3 14.5 0.4 18.6 0.5 22.8 0.6 26.9 0.7 31.1 0.8 35.2
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	
54.0	9.0	18.0	27.0	36.0	45.0	.0	0.0	0.9	1.8	2.7	3.6	4.5	5.4	6.4	7.3	8.2	2.4 0.1 7.2 0.2 12.0 0.3 16.8 0.4 21.6 0.5 26.4 0.6 31.2 0.7 36.0
54.1	9.0	18.0	27.0	36.0	45.1	.1	0.1	1.0	1.9	2.8	3.7	4.6	5.5	6.4	7.4	8.3	
54.2	9.0	18.0	27.1	36.1	45.1	.2	0.2	1.1	2.0	2.9	3.8	4.7	5.6	6.5	7.4	8.4	
54.3	9.0	18.1	27.1	36.2	45.2	.3	0.3	1.2	2.1	3.0	3.9	4.8	5.7	6.6	7.5	8.4	
54.4	9.1	18.1	27.2	36.3	45.3	.4	0.4	1.3	2.2	3.1	4.0	4.9	5.8	6.7	7.6	8.5	
54.5	9.1	18.2	27.3	36.3	45.4	.5	0.5	1.4	2.3	3.2	4.1	5.0	5.9	6.8	7.7	8.6	
54.6	9.1	18.2	27.3	36.4	45.5	.6	0.5	1.5	2.4	3.3	4.2	5.1	6.0	6.9	7.8	8.7	
54.7	9.1	18.3	27.4	36.5	45.6	.7	0.6	1.5	2.5	3.4	4.3	5.2	6.1	7.0	7.9	8.8	
54.8	9.2	18.3	27.4	36.6	45.7	.8	0.7	1.6	2.5	3.5	4.4	5.3	6.2	7.1	8.0	8.9	
54.9	9.2	18.3	27.5	36.6	45.8	.9	0.8	1.7	2.6	3.5	4.5	5.4	6.3	7.2	8.1	9.0	
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	2.9 0.1 8.6 0.2 14.4 0.3 20.2 0.4 25.9 0.5 31.7 0.6 37.5
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	
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	3.6 0.1 10.9 0.2 18.2 0.3 25.5 0.4 32.8 0.5 40.1
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	
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	
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	
56.5	9.4	18.8	28.3	37.7	47.1	.5	0.5	1.4	2.4	3.3	4.2	5.2	6.1	7.1	8.0	8.9	
56.6	9.4	18.9	28.3	37.7	47.2	.6	0.6	1.5	2.4	3.4	4.3	5.3	6.2	7.2	8.1	9.0	
56.7	9.5	18.9	28.4	37.8	47.3	.7	0.7	1.6	2.5	3.5	4.4	5.4	6.3	7.3	8.2	9.1	
56.8	9.5	19.0	28.4	37.9	47.4	.8	0.8	1.7	2.6	3.6	4.5	5.5	6.4	7.3	8.3	9.2	
56.9	9.5	19.0	28.5	38.0	47.5	.9	0.8	1.8	2.7	3.7	4.6	5.6	6.5	7.4	8.4	9.3	
57.0	9.5	19.0	28.5	38.0	47.5	.0	0.0	1.0	1.9	2.9	3.8	4.8	5.7	6.7	7.7	8.6	5.0 0.1 15.0 0.2 25.0 0.3 35.1
57.1	9.5	19.0	28.5	38.0	47.6	.1	0.1	1.1	2.0	3.0	3.9	4.9	5.8	6.8	7.8	8.7	
57.2	9.5	19.0	28.6	38.1	47.6	.2	0.2	1.1	2.1	3.1	4.0	5.0	5.9	6.9	7.9	8.8	
57.3	9.5	19.1	28.6	38.2	47.7	.3	0.3	1.2	2.2	3.2	4.1	5.1	6.0	7.0	8.0	8.9	
57.4	9.6	19.1	28.7	38.3	47.8	.4	0.4	1.3	2.3	3.3	4.2	5.2	6.1	7.1	8.0	9.0	
57.5	9.6	19.2	28.8	38.3	47.9	.5	0.5	1.4	2.4	3.4	4.3	5.3	6.2	7.2	8.1	9.1	
57.6	9.6	19.2	28.8	38.4	48.0	.6	0.6	1.5	2.5	3.4	4.4	5.4	6.3	7.3	8.2	9.2	
57.7	9.6	19.3	28.9	38.5	48.1	.7	0.7	1.6	2.6	3.5	4.5	5.5	6.4	7.4	8.3	9.3	
57.8	9.7	19.3	28.9	38.6	48.2	.8	0.8	1.7	2.7	3.6	4.6	5.6	6.5	7.5	8.4	9.4	
57.9	9.7	19.3	29.0	38.6	48.3	.9	0.9	1.8	2.8	3.7	4.7	5.7	6.6	7.6	8.5	9.5	
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	8.2 0.1 24.6 0.2 41.0
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	
59.0	9.8	19.6	29.5	39.3	49.1	.0	0.0	1.0	2.0	3.0	4.0	5.0	5.9	6.9	7.9	8.9	16.2 0.1 48.6
59.1	9.8	19.7	29.5	39.4	49.2	.1	0.1	1.1	2.1	3.1	4.1	5.1	6.0	7.0	8.0	9.0	
59.2	9.8	19.7	29.6	39.4	49.3	.2	0.2	1.2	2.2	3.2	4.2	5.2	6.1	7.1	8.1	9.1	
59.3	9.9	19.8	29.6	39.5	49.4	.3	0.3	1.3	2.3	3.3	4.3	5.3	6.2	7.2	8.2	9.2	
59.4	9.9	19.8	29.7	39.6	49.5	.4	0.4	1.4	2.4	3.4	4.4	5.4	6.3	7.3	8.3	9.3	
59.5	9.9	19.8	29.8	39.7	49.6	.5	0.5	1.5	2.5	3.5	4.5	5.5	6.4	7.4	8.4	9.4	0.0 0.0 48.2
59.6	9.9	19.9	29.8	39.7	49.7	.6	0.6	1.6	2.6	3.6	4.6	5.6	6.5	7.5	8.5	9.5	
59.7	10.0	19.9	29.9	39.8	49.8	.7	0.7	1.7	2.7	3.7	4.7	5.7	6.6	7.6	8.6	9.6	
59.8	10.0	20.0	29.9	39.9	49.9	.8	0.8	1.8	2.8	3.8	4.8	5.8	6.7	7.7	8.7	9.7	
59.9	10.0	20.0	30.0	40.0	50.0	.9	0.9	1.9	2.9	3.9	4.9	5.9	6.8	7.8	8.8	9.8	
	10′	20′	30′	40′	50′		0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	

The Double-Second-Difference correction (Corr.) is always to be added to the tabulated altitude.

Student Notes

Student Notes

Student Notes

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Dedicated to U.S. Coast Guard Cuttermen.