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Practical Navigation

for Second Mates

BY

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PRACTICAL NAVIGATION FOR SECOND MATES

FOREWORD.

THE intention of this book is to serve as a companion volume to *Principles for Second Mates.* It is hoped that the two books will together cover the theoretical and practical work required for the Second Mate Examination in Navigation.

Explanatory matter has been kept to a minimum by giving only the steps in the problems, amplified by notes where necessary. Possibly criticism may be made of the fact that alternative methods of solving certain problems are not shown, for example:—Reduction to Soundings. It is felt, however, that it is better for the student to understand one method thoroughly, than to be confused by a multiplicity of methods and end by knowing none properly. In any event, those who know the alternative methods, should get the same results to the problems.

In spite of every care to avoid errors, it is always possible for them to occur, and apologies are made for any which may be found. Every endeavour has been made to attain a clear and concise arrangement of the examples; suggestions for any improvements will be welcomed.

Thanks are due to the many students, who, by using the notes and working the problems, have thus assisted in the production of the book, which, though primarily intended to cover the syllabus for the Second Mate Examination, should prove equally useful to those studying for Home Trade and Fishing Certificates.

BRISTOL. T. G. JONES.

ACKNOWLEDGEMENTS.

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CONTENTS.

Practical Navigation for Second Mates

EXERCISE 1

POSITION ON THE EARTH

Read pages 100, 101 and 102, *Principles for Second Mates*, and learn the definitions of:—latitude, longitude, d. lat., d. long., poles of the Earth, axis of the Earth, etc.

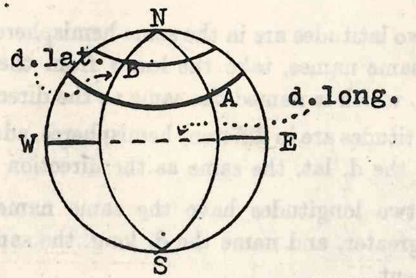
Notes.

1. **When the two latitudes are in the same hemisphere, *i.e.*, the latitudes have the same names, take the lesser from the greater to obtain the d. lat., which is named the same as the direction of movement.**
2. **When the latitudes are in different hemispheres, add the two latitudes, and name the d. lat. the same as the direction of movement.**
3. **When the two longitudes have the same names, take the lesser from the greater, and name the d. long. the same as the direction of movement.**
4. **When the two longitudes have different names, add them, and name the d. long. the same as the direction of movement; but if the sum exceeds 180° it must be subtracted from 360°, since the d. long. between two places is the lesser arc of the Equator between the meridians of the places.**
5. **If in doubt about naming the d. lat. or the d. long., draw a small figure as shown in the examples.**
6. **Where the factors d. lat. and d. long. are used in the "Sailing Problems," they must be expressed in minutes. To do this, multiply the degrees by 60, and add on the odd minutes. Positions will not usually contain seconds of arc, but should seconds be met with in the two factors, change them into decimals of a minute.**

Examples.

1. Find the d. lat. and d. long. between lat. 25° 46′ N., long. 15° 28′ W., and lat. 52° 56′ N., long. 39° 47′ W.

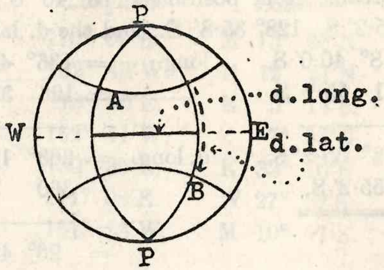
lat.	= 25° 46′ N.	long.	= 15° 28′ W.
lat.	= 52 56 N.	long.	= 39 47 W.
d. lat.	= 27° 10′ N.	d. long.	= 24° 19′ W.
	60		60
	= 1620		1440
	10		19
	= 1630′N.		= 1459′W.



The degrees are multiplied by 60 to change them into minutes and the odd minutes are added on.

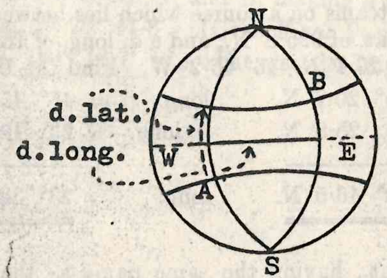
2. Find the d. lat. and d. long. between lat. 44° 25′ N., long. 75° 46′ W., and lat. 36° 19′ S., long. 09° 26′ W.

lat.	= 44° 25′ N.	long.	= 75° 46′ W.
lat.	= 36 19 S.	long.	= 09 26 W.
d. lat.	= 80° 44′ S.	d. long.	= 66° 20′ E.
	60		60
	= 4844′ S.		= 3980′ E.



3. Required the d. lat. and d. long. made good by a vessel which sails from position *A* 22° 10′ S., 09° 15′ W., to a position *B*, 15° 30′ N., 29° 30′ E.

A lat.	= 22° 10′ S.	long.	= 09° 15′ W.
B „	= 15. 30 N.	„	= 29 30 E.
d. lat.	= 37° 40′ N.	d. long.	= 38° 45′ E.
	= 2260′ N.		= 2325′ E.



This problem shows the usual method of arrangement. The minutes of arc are placed immediately under the degrees and minutes, the arithmetic involved being done mentally.

Notes.

1. The latitudes being of different names, they are added to obtain the d. lat.
2. The longitudes being of different names, they are added to obtain the d. long.

4. A vessel steams from position *P* 18° 40′ S., 136° 40·6′ W., to position *Q* 31° 15·2′ S., 128° 35·8′ E., find the d. lat. and the d. long.

P	lat.	= 18° 40·0′ S.	long.	=	136° 40·6′ W.
Q	,,	= 31 15·2 S.	,,	=	126 35·8 E.
	d. lat.	= 12° 35·2′ S.	d. long.	=	263° 16·4′
		= 755·2′ S.			360
				=	96° 43·6′ W.
				=	5803·6′ W.

Notes.

1. The longitudes are of different names, and are added together to obtain the d. long.
2. The sum of the longitudes exceeds 180°, and, as d. long. is defined as the lesser arc of the Equator between two meridians, this quantity must be subtracted from 360° to obtain the d. long.
3. In such cases as these, the d. long. will have the same name as the initial longitude.

5. A vessel steams on a course which lies between North and East, and makes a d. lat. of 925·8′ N., and a d. long. of 1392·6′ E. The initial position was 25° 20·7′ N., 46° 45·2′ W. Find the D.R. position.

lat.	= 25° 20·7′ N.	long.	= 46° 45·2′ W.
d. lat.	= 15 25·8 N.	d. long.	= 23 12·6 E.
D.R. lat.	= 40° 46·5′ N.	long.	= 23° 32·6′ W.

Note.—The d. lat., having the same name as the latitude, is added to it, while the d. long. being of opposite name to the longitude, is subtracted from it.

EXERCISE 1A ✓

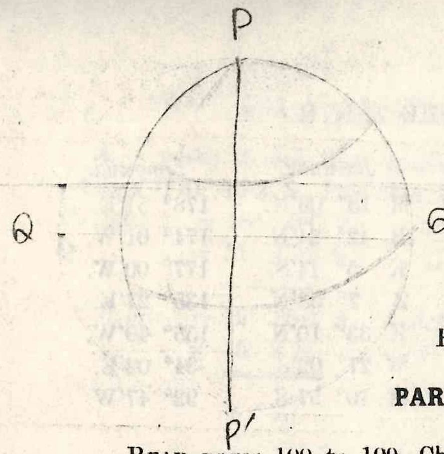
Find the d. lat. and d. long. between the following positions.

	Latitude	*Longitude*	*Latitude*	*Longitude*
1.	P 40° 10′N.	9° 25′W.	Q 47° 15′N.	21° 14′W.
2.	A 35° 15′N.	22° 12′W.	B 50° 25′N.	11° 37′W.
3.	X 10° 12′N.	5° 03′E.	Y 5° 18′S.	7° 18′W.

	Latitude	*Longitude*	*Latitude*	*Longitude*
4.	L 20° 40′S.	170° 09′E.	M 13° 06′N.	178° 51′E.
5.	A 30° 03′N.	152° 43′W.	B 42° 24′N.	174° 01′W.
6.	F 11° 31′N.	178° 00′E.	K 5° 14′S.	177° 00′W.
7.	A 8° 42′S.	162° 41′W.	Z 7° 53′N.	135° 27′E.
8.	B 15° 20′S.	130° 35′E.	K 33° 10′N.	155° 40′W.
9.	V 52° 10′S.	171° 08′E.	W 27° 02′S.	34° 02′E.
10.	L 60° 40′S.	151° 23′W.	M 10° 57·S.	92° 47′W.

EXERCISE 1B ✓

1. The initial longitude is 4° 30′ W. and the d. long is 104′ E. Find the final longitude.
2. Initial lat. = 20° 50′ S., long.=178° 49′ E., d. lat.=33° 14′ N., d. long.=15° 37′ E. Find the final position.
3. Initial lat.=39° 40′ N., long.=9° 21′ W., d. lat.=3° 57′ N., d. long.= 27° 07′ E. Find the final position.
4. Final position lat.=30° 10·6′ S., long.=4° 40·3′ E., d. lat. was 72° 18·8′ S., and d. long. was 38° 54·7′ E. What was the Initial position?
5. A ship steered a course between N. and E. making a d. lat. of 38° 55·5′ and a d. long. of 20° 41·8′. If the Final Position was lat. 21° 10·4′ N., long. 168° 18·7′ W., what was the Initial Position?



EXERCISE 2

PARALLEL SAILING

READ pages 100 to 109, Chapter 2, in *Principles for Second Mate* Learn and understand the definitions of the terms used, and lear the proof of the formulae. Note that the difference of longitude mus be expressed in minutes of arc.

Factors employed:—

(1) latitude. (2) d. long. in minutes.
(3) departure in nautical miles.

Formulae:—

1. **secant lat.** $= \dfrac{\text{d. long. in minutes}}{\text{dep. in nautical miles}}$
2. **cosine lat.** $= \dfrac{\text{dep. in nautical miles}}{\text{d. long. in minutes}}$
3. **d. long. in mins. = dep. in M. × secant lat.**
4. **dep. in M. = d. long. in mins. × cos lat.**

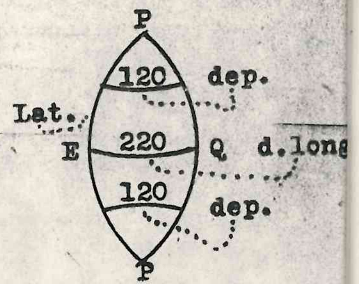
Figure.—An appropriate part of the sphere as shown in the example

Examples.

1. In what latitude will a d. long. of 3° 40′ correspond to a departu of 120 nautical miles?

$$\text{sec lat.} = \frac{\text{d. long. in mins.}}{\text{dep. in M.}}$$
$$= \frac{220}{120}$$
$$= 1{\cdot}8333$$

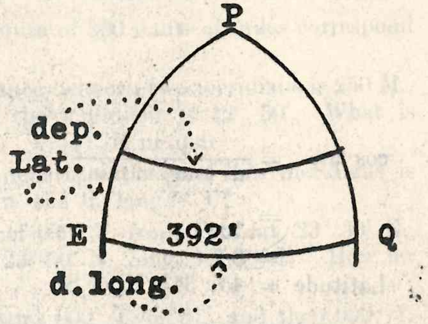
Latitude = 56° 56½′ N. or S.



2. A vessel steams 090° T. from long. 35° 25′ W. to long. 28° 53′ W. How far did she steam if the latitude was 41° 20·5′ N.?

Initial long. = 35° 25′ W.
Final long. = 28 53 W.

d. long. = 6° 32′ E.
= 392′ E.

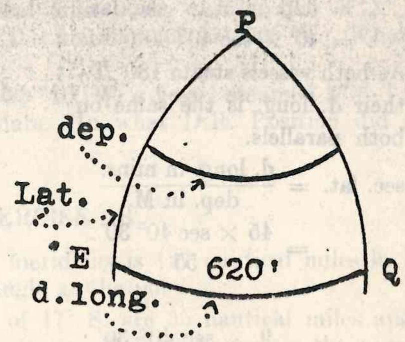


dep. in M.
= d. long. in mins × cos lat.
= 392 × cos 41° 20·5′
= 294·4
Dist. steamed = 294·4 M.

Number	Log
392	2·59329
cos 41° 20·5′	9·87552
	2·46881

3. The d. long. between two places *A* and *B* on the parallel of 51° 20′ N. is 10° 20′. What is the departure between *A* and *B*?

dep. in M.
= d. long. in mins. × cos lat.
= 620 × cos 51° 20′
= 387·3



Number	Log
620	2·79239
cos 51° 20′	9·79573
	2·58812

Dep. between *A* and *B* = 387·3 M.

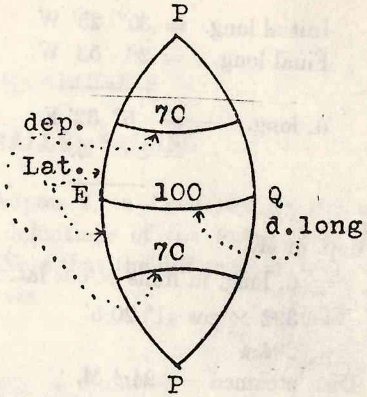
4. Two vessels are 70 nautical miles apart on a certain parallel. At the Equator the distance between their meridians is 100 nautical miles. What is the latitude of the vessels?

$$\cos \text{lat.} = \frac{\text{dep. in M.}}{\text{d. long. in mins.}}$$

$$= \frac{70}{100}$$

$$= 0{\cdot}7$$

Latitude $= 45° \ 34\tfrac{1}{2}'$ N. or S.



5. Two vessels 45 nautical miles apart on the parallel of 40° 30′ N. steam 180° T., at equal speeds, until the distance between them is 55 nautical miles. How far did each steam?

d. long. in mins.

$= \text{dep. in M.} \times \text{sec. lat.}$

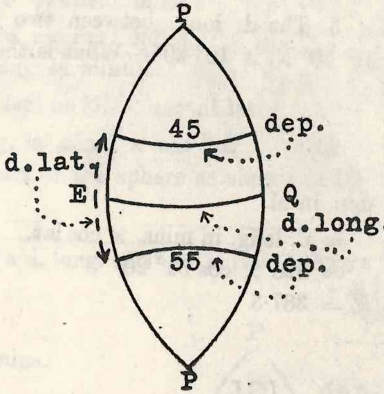
$= 45 \times \sec 40° \ 30'$

As both vessels steam 180° T., their d. long. is the same on both parallels.

$$\text{sec. lat.} = \frac{\text{d. long. in mins.}}{\text{dep. in M.}}$$

$$= \frac{45 \times \sec 40° \ 30'}{55}$$

$$= \frac{9 \times \sec 40° \ 30'}{11}$$



Number	Log
9	0·95424
sec 40° 30′	10·11895
	1·07319
11	1·04139
	10·03180

Final lat. = 21° 39·8′ N.
Initial lat. = 40 30·0 N.

d. lat. = 18° 50·2′
= 1130·2′

∴ Distance steamed = 1130·2 M.

EXERCISE 2A

Logarithms are not required in this exercise.

1. In what latitude will a departure of 300 nautical miles correspond to a d. long. of 6° 40′?
2. On a certain parallel the distance between two meridians is 250 M., while the d. long. between the meridians is 12° 30′. What is the latitude?
3. In latitude 50° 10′ N. the departure between two meridians is 360 nautical miles. What is the d. long.?
4. A vessel steams on a course of 090° T. from *P* in lat. 23° 30′ N., long. 59° 10′ E. to *A* in lat. 23° 30′ N., long. 65° 30′ E. How far did she steam?
5. From lat. X° N. a vessel steams 000° T. 50 M., and then 090° T. 100 M. If the difference of longitude is 185′, find lat. X.
6. From lat. 44° 15′ N., long. 10° 20′ W. a vessel steamed 270° T. for 550 nautical miles, and then 180° T. for 753 nautical miles. Find her final position.
7. On a certain parallel, the distance between two meridians is 150 nautical miles. On the Equator, the distance between the same two meridians is 235 nautical miles. What is the latitude of the parallel?
8. The distance between two meridians in lat. 48° 12′ N. is 250 M. What is the angle at the pole?
9. A vessel steams 470 nautical miles along the parallel of X° N. from long. 15° 35′ W. to the meridian of 27° 20′ W. What is the latitude of X?
10. From lat. 39° 00′ N., long. 33° 10′ W. a vessel steamed 270° T. at 10 knots for 3 days 8 hours. In what D.R. Position did she arrive?

EXERCISE 2B

1. The distance between two meridians is 427 nautical miles in lat. 50° 20′ N. What is the angle at the pole?
2. Two ships on the parallel of 17° S. are 55 nautical miles apart. What would be their distance apart if they were on the parallel of 40° N.?
3. Two ports *A* and *B* are in the Northern Hemisphere. On the parallel of *A*, the distance between their meridians is 250 M., on the parallel of *B* it is 350 M., and on the Equator it is 400 M. What are the latitudes of the ports?
4. At what rate does an observer in lat. 50° 20′ N. rotate? (Answer to be in knots.)

5. A vessel in latitude 48° 30′ N. steams 270° T. at 10 knots for 24 hours. By how much is the longitude changed?
6. In lat. 50° 20′ N. a vessel steams from long. 15° 46′ W. to long. 31° 18′ W. What distance was made good?
7. A ship steams 090° T. for 200 nautical miles in lat. 49° 10′ N. By how much will her clocks have to be advanced?
8. The distance between two meridians in the Northern Hemisphere is 240 M. On the Equator it is 400 M., and in the Southern Hemisphere it is 360 M. What is the d. lat. between the two parallels?
9. In what latitude is the departure in nautical miles five-sevenths the d. long. in minutes?
10. In lat. 48° 30′ N. a vessel is in long. 34° 30′ W.; at noon A.T.S. the course is set 270° T., and the following day at noon A.T.S. she is in long. 40° 30′ W. What was the vessel's average speed?
11. Two vessels 200 nautical miles apart on the same parallel steam, 180° T. to the parallel of 20° N., where their d. long. is found to be 5° 10′ How far did each steam?
12. A vessel leaves lat. 52° 21′ N., long. 30° 20′ W., and by steering 270° T. at 10 knots for 24 hours, arrives in lat. 52° 21′ N., long. 36° 00′ W. Find the set and drift.

EXERCISE 3

PLANE SAILING

Factors:—

(1) Course. (2) Distance. (3) Departure.
(4) Difference of latitude.

Formulae:—

(1) distance = d. lat. × sec (course)
(2) distance = dep. × cosec (course)
(3) d. lat. = dist. × cos (course)
(4) d. lat. = dep. × cot (course)
(5) dep. = d. lat. × tan (course)
(6) dep. = dist. × sin (course)

(7) $\tan(\text{course}) = \dfrac{\text{dep.}}{\text{d. lat.}}$

(8) $\cot(\text{course}) = \dfrac{\text{d. lat.}}{\text{dep.}}$

(9) $\sin(\text{course}) = \dfrac{\text{dep.}}{\text{dist.}}$

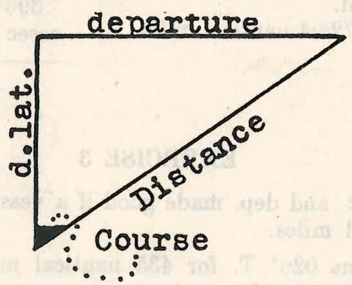
(10) $\cos(\text{course}) = \dfrac{\text{d. lat.}}{\text{dist.}}$

Figure.—The Plane Sailing Triangle as shown in Example 1.

For definitions of the terms used, proof of formulae, and further examples, see *Principles for Second Mates*, pages 100 to 113.

Examples.

1. The course and distance from *A* to *B* is 055° T. 720 nautical miles. Find the d. lat. and departure made good.



d. lat. = dist. × cos (course)
= 720 × cos 55°
= 412·98
= 5° 53′ N.

Number	Log
720	2·85733
cos 55°	9·75859
	2·61592

dep. = dist. × sin (course)
= 720 × sin 55°
= 589·74 M.

Number	Log
720	2·85733
sin 55°	9·91336
	2·77069

D. lat. = 5° 53′ N. dep. = 589·7 nautical miles

2. From lat. 50° 28′ N., a vessel steamed 156° T. 1550 nautical miles. Find the latitude in which she arrived.

d. lat. = dist. × cos (course)
= 1550 × cos 24°
= 1416′
= 23° 36′ S.

Number	Log
1550	3·19033
cos 24°	9·96073
	3·15106

Initial lat. = 50° 28·0′ N.
d. lat. = 23° 36·0′ S.

Final lat. = 26° 52·0′ N.

3. A vessel steers 327° T. and makes a departure of 396·7 nautical miles. How far did she steam?

Dist. = dep. × cosec (course)
= 396·7 × cosec 33°
= 728·43 M.
Dist. steamed = 728·4 nautical miles

Number	Log
396·7	2·59846
cosec 33°	10·26389
	2·86235

EXERCISE 3

1. Find the d. lat. and dep. made good if a vessel steams 248° T. for 1936 nautical miles.
2. A vessel steams 026° T. for 435 nautical miles. What was the d. lat. and departure?

3. A vessel steams 215° T. for 341 nautical miles. Find d. lat. and departure made good.
4. A vessel makes a d. lat. of 289·4′ N. and a departure of 203·2′ nautical miles. Find the course and distance.
5. A vessel steers a course of 146° T. from lat. 35° 10′ N. to lat. 8° 46′ N. How far did she steam?

EXERCISE 4

MERCATOR SAILING

Learn the definitions of:—d. lat., meridional parts, D.M.P. (or M.D. lat.), etc. Read pages 100 to 105, 109 to 112, 118 to 126, *Principles for Second Mates*.

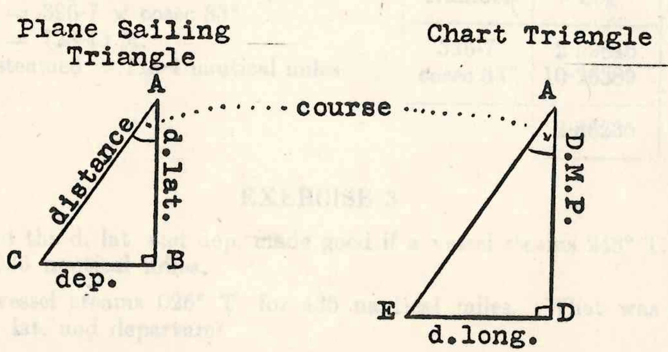
Factors employed:—

1. d. lat.
2. D.M.P.
3. course
4. d. long.
5. distance

Formulae:—

1. **tan (course)** $= \dfrac{\textbf{d. long. in mins.}}{\textbf{D.M.P.}}$
2. **distance = d. lat. × secant (course)**
3. **d. long. in mins. = D.M.P. × tan (course)**
4. **D.M.P. = d. long. in mins. × cot (course)**

The first two formulae may be considered the standard ones for all Mercator Sailing problems. In cases where the initial latitude is given to find the final latitude, and *vice versa*, it will be necessary to rearrange them, as in numbers 3 and 4.



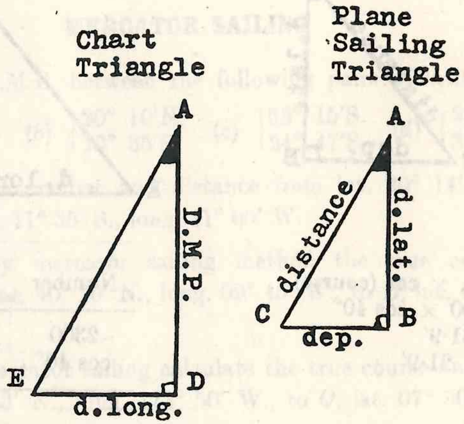
In all cases, draw a figure to illustrate the problem. It is better to deal separately with the two triangles involved, viz.:—the Plane Sailing Triangle and the Chart Triangle, although it is a common practice to combine the two.

In working out these problems, draw the figures approximately to scale. Also, use the Parts for the Terrestrial Spheroid.

Example.—

By Mercator Sailing find the true course and distance from *A*, lat. 49° 10′ N., long. 12° 30′ W., to *B*, lat. 25° 15′ N., long. 26° 50′ W.

A, lat.	= 49° 10′ N.	M.P.	= 3379·6	long.	= 12° 30′ W.
B, lat.	= 25° 15′ N.	M.P.	= 1556·6	long.	= 26° 50′ W.
d. lat.	= 23° 55′ S.	D.M.P.	= 1823·0	d. long.	= 14° 20′ W.
	= 1435′ S.				= 860′ W.



tan (course) $= \dfrac{\text{d. long.}}{\text{D.M.P.}} = \dfrac{860}{1823}$

Course = S.25° 15·3′ W.

Number	Log
860	2·93450
1823	3·26079
	9·67371

distance = d. lat. × sec (course)
= 1435 × sec 25° 15·3′
= 1586·6 M.

Number	Log
1435	3·15685
sec 25° 15·3′	10·04363
	3·20048

Course = 205° 15·3′ T., Dist. = 1586·6 M.

Example.

A vessel steams 220° T. for 2300 M., and arrives in 39° 37′ S., 47° 28′ W. Find the position sailed from.

Plane Sailing Triangle

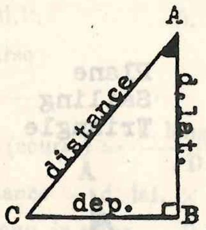
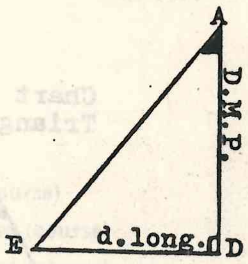


Chart Triangle



D. lat = dist. × cos (course)
= 2300 × cos 40°
= 1761·9′
= 29° 21·9′

Number	Log
2300	3·36173
cos 40°	9·88425
	3·24598

Final lat.	= 39° 37·0′ S.	M.P.	= 2577·8
d. lat.	= 29° 21·9′ N.		
Initial lat.	10° 15·1′ S.	M.P.	= 614·1
		D.M.P.	= 1963·7

D. long. = D.M.P. × tan (course)
= 1963·7 × tan 40°
= 1647·6
= 27° 27·6 E.

Number	Log
1963·7	3·29307
tan 40°	9·92381
	3·21688

Final long. = 47° 28·0′ W.
d. long. = 27° 27·6′ E.

Initial long. = 20° 00·4′ W.

Initial position:—
Lat. 10° 15·1′ S., long. 20° 00·4′ W.

EXERCISE 4

MERCATOR SAILING

1. Find the D.M.P. between the following pairs of latitudes:
(a) {40° 00′N. / 50° 00′N. (b) {20° 10′N. / 10° 35′S. (c) {53° 15′S. / 24° 47′S. (d) {22° 18′S. / 39° 53′N.

2. Find the true course and distance from lat. 20° 14′ N., long. 22° 17′ W., to Lat. 11° 35′ S., long. 41° 05′ W.

3. Calculate by mercator sailing method the true course and distance from *A*, lat. 40° 10′ N., long. 09° 45′ W., to *B*, lat. 10° 15′ N., long. 18° 11′ W.

4. By using mercator sailing calculate the true course and distance from *P*, lat. 41° 13′ N., long. 173° 50′ W., to *Q*, lat. 07° 50′ S., long. 79° 55′ W.

5. A vessel steams 210° T. 750 nautical miles from 29° 30′ N., 162° 20′ E. In what position did she arrive?

6. From lat. 10° 12′ S., long. 35° 05′ W., a vessel steers 017° T., and arrives in long. 28° 29′ W. What was the distance steamed and the latitude reached?

7. A vessel steams 225° T. 800 M., and then 135° T. 800 M. from lat. 10° 00′ S., long. 00° 00′. In what position did she arrive?

8. A vessel steams 065° T. 1850 M. from Lat. 20° 12′ N., long. 178° 40′ E. Find the latitude and longitude of the position in which she arrives.

9. Calculate the true course and distance from 05° 20′ N., 79° 05′ E., to 24° 20′ S., 112° 03′ E.

10. Calculate the true course and distance from 37° 03′ N., 13° 20′ E., to 31° 20′ N., 29° 55′ E.

EXERCISE 5

CORRECTIONS OF COURSE AND BEARINGS

General Notes.

There are three North points, viz:—Compass North, Magnetic North, and True North. Thus, a direction may be measured from any one of these north points, and, changed to the others by applying deviation and variation.

Deviation connects a compass direction and the corresponding magnetic direction.

Variation connects a magnetic direction and the corresponding true direction.

C. ↑ M. ↑ T.

Deviation Variation

The 3 figure notation—from 000° to 359°—can be used throughout to express directions, but the letter C., M., or T., must follow to denote whether it is a Compass, Magnetic, or True direction that is being dealt with.

Deviation.—Deviation is the angle between a compass direction and a magnetic direction.

Variation.—Variation is the angle between a magnetic direction and a true direction.

Error.—Error, or compass error, is the angle between a compass direction and a true direction, and, is therefore, the sum of the deviation and variation according to their names.

To apply deviation, variation and error.

The following rules apply, only if the 3 figure notation is used.

Compass to magnetic:—

Deviation East — *Add*
Deviation West — *Subtract*
Reverse for magnetic to compass

Magnetic to true:—

Variation East — *Add*
Variation West — *Subtract*
Reverse for true to magnetic

Compass to true:—

Error East — *Add*
Error West — *Subtract*
Reverse for true to compass

The following summarises the rules given:

C —(Dev. E+ W−)→ M —(Var. E+ W−)→ T   C —(Error E+ W−)→ T

T —(Var. E− W+)→ M —(Dev. E− W+)→ C   T —(Error E− W+)→ C

To change quadrantal directions to 3 figure notation.

Direction between N. and E. prefix by 0° or 00°
" " S. " E. take from 180°
" " S. " W. add 180°
" " N. " W. take from 360°

The prefix N. or S. and the suffix E. or W. is dropped.

Examples:—

N. 52° E., 052°: N. 6° E., 006°: S. 18° E., 162°: S. 54° W., 234°: N. 41° W., 319°.

Given deviation and variation to find the error.

Examples.

dev.	5° E.	dev.	3° W.	dev.	4° E.	dev.	6° W.
var.	10° E.	var.	20° W.	var.	15° W.	var.	18° E.
error	15° E.	error	23° W.	error	11° W.	error	12° E

From the examples it is seen that the error is simply the algebraic sum of the deviation and the variation.

EXERCISE 5A

Find the compass error given

1. Dev. 15° W., Var. 30° E. 6. Dev. 10° W., Var. 5° W.
2. " 14° E., " 5° E. 7. " 21° W. " 4° E.

3. " 3° W., " 30° W. 8. " 8° E., " 8° W.
4. " 5° W., " 25° W. 9. " 5° W. " 50° W.
5. " 6° W., " 20° E. 10. " 3° E., " 35° E.

Given the Error and the Variation to find the Deviation.

The error is the sum of the deviation and the variation according to their names. Therefore the variation must be subtracted from the error to find the deviation. This is done mentally, by changing the name of the variation as shown by the bracketed letter, and adding to the error according to the names.

Examples.—

error	20° W.	error	6° E.	error	10° W.
var.	15° W. (E.)	var.	20° E. (W.)	var.	15° E. (W.)
dev.	5° W.	dev.	14° W.	dev.	25° W.
error	10° E.	error	20° E.		
var.	15° W. (E.)	var.	6° E. (W.)		
dev.	25° E.	dev.	14° E.		

The variation being subtracted, its name is changed, as shown by the letter in brackets, and the error and variation are then added according to their names.

EXERCISE 5B

Find the deviation given

1. error 3° E., var. 21° W. 6. error 34° W., var. 39° W.
2. " 15° W., " 24° W. 7. " 2° W., " 12° W.
3. " 37° E., " 34° E. 8. " 7° E., " 9° W.
4. " 11° W. " 7° W. 9. " 24° W., " 30° W.
5. " 23° E., " 25° E. 10. " Nil " 5° E.

Given the true bearing and the compass bearing of a body, also the variation, to find the deviation.

Remember that if the error is East, it is added to a compass direction to obtain the true direction; it is then seen that the latter must be numerically greater than the former. Therefore, if the error is to be found, the rule is:—

True greater than Compass — Error is East
Compass greater than True — Error is West

If the figures in Examples 1 and 2 are referred to, the rule is obvious.

Example 1.—

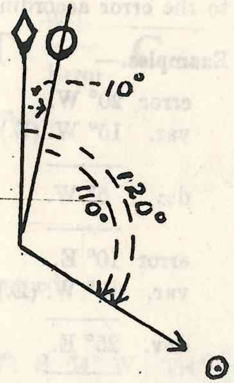
The Sun bore 120° T. and 110° C., find the compass error, and if the variation was 10° W., find the deviation.

☉ bearing = 110° C.
,, = 120° T.

Error = 10° E.
Var. = 10° W.

Dev. = 20° W.

Note.—T.>C. Error is East.



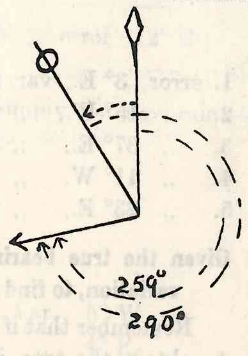
Example 2.—

The Sun's true amplitude is W. 10° 20′ S. and the observed amplitude W. 20° N. Find the compass error, and if the variation is 25° E. find the deviation.

W. 20° N. = 290°
W. 10° 20′ S. = 259° 40′
☉ bearing = 290° 00′ C.
,, = 259 40 T.

Error = 30 20 W.
var. = 25 00 W.

dev. = 5 20 W.



EXERCISE 5C

FIND THE DEVIATION

	Compass bearing	*True bearing*	*Variation*
1.	050° C.	060° T.	12° E.
2.	010° C.	005° T.	11° W.
3.	075° C.	060° T.	19° W.
4.	140° C.	115° T.	24° W.
5.	242° C.	248° T.	13° E.
6.	201° C.	201° T.	8° E.
7.	309° C.	322° T.	8° E.
8.	037° C.	022° T.	12° W.
9.	341° C.	320° T.	23° W.
10.	289° C.	310° T.	33° E.
11.	260° C.	294° T.	49° E.
12.	134° C.	120° T.	21° W.
13.	163° C.	200° T.	62° E.
14.	219° C.	175° T.	40° W.
15.	278° C.	262° T.	11° W.

To find the true course or the true bearing.

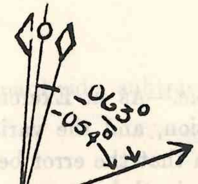
Given the compass direction, and, the deviation and variation, first obtain the error by combining, mentally, the deviation and the variation. Apply the error to the compass direction, using the rules previously mentioned.

Example.—

A vessel is steering 063° C., deviation 3° E., variation 12° W. Find the true course.

Course 063° C.
Error 9° W.

Course 054° T.



EXERCISE 5D

FIND THE TRUE COURSE OR TRUE BEARING.

	Course or bearing	Dev.	Var.
1.	226° C.	3° W.	16° W.
2.	010° C.	1° W.	18° W.
3.	358° C.	2° E.	15° W.
4.	267° C.	4° W.	20° E.
5.	034° C.	3° E.	15° W.
6.	332° C.	4° W.	10° W.
7.	116° C.	2° W.	8° W.
8.	218° C.	3° W.	11° W.
9.	084° C.	5° W.	17° E.
10.	178° C.	6° E.	11° E.

To find the compass course or the compass bearing.

Given:—the true direction, the deviation, and the variation.

Example:—A vessel is steering 156° T., the variation is 15° E., and the deviation is 3° W. Find the compass course.

Course = 156° T.
Error = 12° E.

Course = 144° C.

Note.—As in Exercise 5D, the Error is found mentally from the deviation, and the variation. Referring to the preliminary notes, it is seen that the error being East, it is subtracted from the true course to obtain the compass course.

EXERCISE 5E

	Course or bearing	Dev.	Var.
1.	222° T.	4° E.	15° E.
2.	356° T.	5° W.	20° W.
3.	172° T.	3° E.	18° W.
4.	200° T.	2° E.	1° W.
5.	005° T.	1° E.	5° E.
6.	086° T.	1° W.	Nil
7.	106° T.	2° W.	10° W.
8.	173° T.	3° E.	8° W.
9.	306° T.	2° W.	11° W.
10.	185° T.	3° W.	10° W.

GIVEN THE COMPASS COURSE, DEVIATION, VARIATION, AND LEEWAY WITH THE WIND DIRECTION.

To find the track.

The only new step in this problem after the previous work is that of applying the leeway. Until sufficient skill has been attained to do this mentally, it is best to use a small figure to decide the direction in which to apply the leeway. With the 3 figure notation, however, the following rule will make the finding of the track quite mechanical:

Wind on the Port side — add the leeway,

Wind on the Starboard side — subtract the leeway.

Examples.—

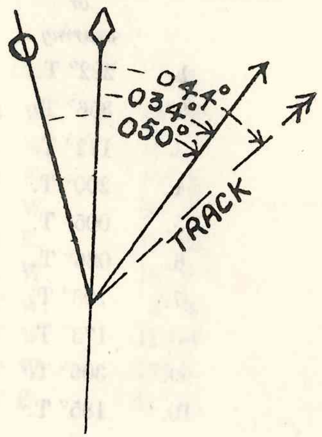
1. Given a vessel's course is 135° T., wind S.W., leeway 5°, find the track.

Course = 135° T.
Leeway = 5° (wind on the starboard side, subtract)

Track = 130° T.

2. A vessel is steering 050° C., deviation 3° E., variation 19° W., wind N.W. leeway 10, find the track.

Course	— 050° C.	
Error	— 16° W.	
Course	034° T.	
Leeway	10°	(wind on the port side, add)
Track	014° T.	



EXERCISE 5F

	Course	*Dev.*	*Var.*	*Leeway*	*Wind*
1.	055° C.	3° E.	13° W.	4°	N.N.W
2.	140° C.	4° W.	10° W.	5°	S.W.
3.	246° C.	2° E.	15° E.	4°	N.W.
4.	330° C.	3° W.	8° W.	3°	S.W.
5.	104° C.	6° E.	12° W.	7°	N.E.
6.	084° C.	2° W.	20° E.	5°	North
7.	354° C.	5° W.	18° E.	6°	West
8.	190° C.	Nil	22° W.	10°	E.S.E.
9.	240° C.	3° E.	5° E.	8°	W.N.W.
10.	280° C.	1° W.	25° W.	4°	N.N.W.

EXERCISE 5G

Fill in the blanks

	Course or bearing	*Dev.*	*Course or bearing*	*Var.*	*Course or bearing*
1.	050° C.	—	056° M.	—	036° T.
2.	—	3° E.	220° M.	—	225° T.
3.	—	4° W.	280° M.	18° W.	—
4.	003° C.	—	358° M.	—	013° T.
5.	—	4° W.	241° M.	11° W.	—
6.	169° C.	3° E.	—	—	184° T.
7.	—	2° E.	—	20° E.	008° T.
8.	286° C.	6° W.	—	5° W.	—
9.	088° C.	—	091° M.	—	066° T.
10.	—	4° E.	205° M.	30° W.	—
11.	332° C.	—	332° M.	—	014° T.
12.	180° C.	—	178° M.	—	178° T.

EXERCISE 6

TRAVERSE TABLE

READ up notes on the Traverse Table in *Principles for Second Mates*, pages 40 to 45.

Note the formulae upon which the Traverse Table is based, viz.:—

$$\text{d. lat.} = \text{Dist.} \times \text{cosine (course)}$$
$$\text{dep.} = \text{Dist.} \times \text{sine (course)}$$

Examples:—

1. **Given:**—Course = 148° T., Dist. = 520 M., find the d. lat. and the dep.

Steps.—(1) Most users of the table find it more convenient to use the quadrantal notation when using the table. Therefore, change 148° T. into the quadrantal notation. 148° T. = S. 32° E. Find the page where the angle is 32° (the angle being less than 45°, it will be found at the top of the page).

(2) Move down the page in the dist. column to 520.

(3) Take out the d. lat. and dep. from the appropriate columns.

Answer.—Course S. 32° E. and dist. 520 M., d. lat. = 441′ S., dep. = 275·6 M. E.

2. **Given:**—d. lat. = 339·6′ N., dep. = 295·2 M. W., to find the course and distance.

Steps.—(1) Note that the d. lat. being greater than the dep. the angle will be less than 45°, and will therefore be found at the top of the page. Also, the values are near one another, so that the angle is approaching 45°.

(2) Open the table at about 35°, and look down the d. lat. and dep. columns. The given values are found to be widely separated, so, turn over a few pages, to 39°, and again look up the values. Here they are much closer, so continue to turn over the pages until they are found as near together as possible—this will be on the page headed 41°.

Answer:—With d. lat. 339·6′ N. and dep 295·2 M., W., course = N. 41° W. Dist. = 450 M.

The values may not always be found so easily as in the examples shown. It may be necessary to (1) interpolate or (2) use aliquot parts. Interpolation for the factors dist., d. lat., and dep. can be quite accurate,

since we are dealing with similar triangles; but for angles, the interpolation, though not exact, is within practical limits.

3. **Given:**—Course S. 62° W., dist. 47·4 M., find the d. lat. and dep.

Steps.—(1) Note that the angle is greater than 45° and will therefore be at the bottom of the page.

(2) The dist. column is the same whether we are dealing with the top or bottom of the page, but the columns headed d. lat. and dep. are reversed, since we are dealing with complementary angles.

(3) Turn to the page where the angle is 62°.

(4) Shift the decimal point on the distance given, and look up 474 in the dist. column.

(5) The d. lat. is 222·5 and the dep. is 418·5. Therefore the required d. lat. is 22·25 and the dep. is 41·85.

Answer:—Course S. 62° W. and distance 47·4 M. give d. lat. 22·25′ S. and dep. 41·85 M. W.

AC I O 1440

To change d. long. into dep. and vice versa.

The reasons why the traverse table can be used for this purpose are given on page 44, *Principles for Second Mates.*

Example.—Find the departure corresponding to a d. long. of 58·5′ in lat. 50° 24′ N.

Remember the rule:—*Take the latitude as course, then with the d. long. in the dist. column the departure is found in the d. lat. column.*

Note also that the columns are appropriately headed in *Norie's Tables*, while in *Burton's Tables* they are indicated by asterisks.

Now, under angle 50°, look up 585 in the dist. column, and this gives 376·0 in the d. lat. column.

Similarly, angle 51° and dist. 585 give 368·2 in the d. lat. column.

The dep. corresponding to the d. long. of 58·5 will therefore lie between 37·6 and 36·82. The interpolation is carried out thus, and, with practice it can be done mentally.

for angle 50° & dist. 585, d. lat. = 376·0
„ „ 51° & „ 585, d. lat. = 368·2
diff. for 1° = 7·8
× by 0·4 0·4
diff. for 0·4° 3·12

∴ angle 51·4° and dist. 585 give d. lat. 376·0 − 3·12 = 372·9.

Answer.—In lat. 50° 24′ N., d. long. 58·5′, dep. = 37·29 M.

If the dep. has to be changed into d. long., then the dep. is looked up in the d. lat. column, and the d. long. is found in the dist. column.

To find the course and distance between two places of known latitude and longitude.

This problem is simply a matter of finding the d. lat. and the d. long. between the two places, and, then with the mean latitude change the d. long. into dep. With the d. lat. and dep. find the course and distance.

Example:—

Find, by use of the traverse table, the course and distance from *A*, lat. 46° 30′ N., long. 15° 45′ W., to *B*, lat. 43° 50′ N., long. 25° 28′ W.

A, lat.	46° 30′ N.	long.	15° 45′ W.	46° 30′
B, lat.	43 50 N.	long.	25 28 W.	43 50
d. lat.	2° 40′ S.	d. long.	9° 43′ W.	2)90° 20′
	= 160′ S.		= 583′ W.	45° 10′

With m. lat. 45° 00′ & d. long. 583′, dep. = 412·2 diff.
,, ,, 46° 00′ & ,, 583′, ,, = 405·0 $\frac{7·2}{6}$ = 1·2
∴ ,, ,, 45° 10′ & ,, 583′ ,, = 410·0

d. lat. 160′ S. & dep. 410 M. W. give
Course S. 68¾° W. Distance 440 M.

If the set and drift is required, the method of obtaining it is precisely the same as above, since the set and drift is simply the course and distance from the D. R. Position to the Observed Position.

EXERCISE 6A

TRAVERSE TABLE

1. True co. = N.25°E., dist. = 238 M. Find the d. lat. and the dep.
2. ,, ,, = S. 10°E. ,, = 333 M. ,, ,, ,, ,, ,, ,,
3. ,, ,, = N.40°W. ,, = 505 M. ,, ,, ,, ,, ,, ,,
4. ,, ,, = S. 70°W. ,, = 214 M. ,, ,, ,, ,, ,, ,,
5. ,, ,, = 306° ,, = 176 M. ,, ,, ,, ,, ,, ,,
6. ,, ,, = 065° dep. = 173·3M. ,, ,, ,, ,, ,, dist.
7. ,, ,, = 148° d. lat. = 386·7′ ,, ,, dep. ,, ,, ,,

8. Dist. = 436 M. dep. = 262·4 M. ,, ,, course ,, ,, d.lat
9. d. lat. = 447·6′N. dep. = 198·3 M.E. ,, ,, ,, ,, ,, ,,
10. d. lat. = 353·1′ S. ,, = 229·3 M.W. ,, ,, ,, ,, ,, ,,
11. ,, = 44·6′ N. ,, = 14·5 M.E. ,, ,, ,, ,, ,, ,,
12. ,, = 312·3′S. ,, = 231·1 M.W. ,, ,, ,, ,, ,, ,,
13. ,, = 308·5′ N. ,, = 367·7 M.W. ,, ,, ,, ,, ,, ,,
14. ,, = 855·0′ S. ,, = 380·8 M.E. ,, ,, ,, ,, ,, ,,
15. True co. = 036° ,, = 723·0 M. ,, ,, dist. ,, ,, d.lat.

EXERCISE 6B

TO CHANGE DEP. INTO D. LONG. BY INSPECTION

Find the d. long., given:—

1.	Dep.	= 354·8 M.	Lat.	= 50° 00′ N.
2.	,,	= 261·8 M.	,,	= 35° 00′
3.	,,	= 246·0 M.	,,	= 42° 30′
4.	,,	= 197·0 M.	,,	= 38° 12′
5.	,,	= 348·4 M.	,,	= 27° 00′
6.	,,	= 361·2 M.	,,	= 75° 00′
7.	,,	= 294·6 M.	,,	= 52° 00′
8.	,,	= 326·9 M.	,,	= 36° 30′
9.	,,	= 444·4 M.	,,	= 19° 15′
10.	,,	= 258·7 M.	,,	= 50° 45′

EXERCISE 6C

TO CHANGE D. LONG. INTO DEP. BY INSPECTION.

Find the dep. given:

1.	d. long.	= 260·1′	Lat.	= 40° 00′
2.	,,	= 351·3′	,,	= 48° 15′
3.	,,	= 58·1′	,,	= 56° 00′
4.	,,	= 37·6′	,,	= 25° 00′
5.	,,	= 667·0′	,,	= 47° 30′
6.	,,	= 44·4′	,,	= 35° 15′
7.	,,	= 518·5′	,,	= 36° 30′
8.	,,	= 114·8′	,,	= 58° 30′
9.	,,	= 534·7′	,,	= 67° 30′
10.	,,	= 329·1′	,,	= 17° 30′

EXERCISE 6D

TO FIND THE COURSE AND DISTANCE

By inspection of the traverse table, find the course and distance.

	From			To	
1. A	lat.	50° 40′ N.	B	lat.	40° 50′ N.
	long.	40° 50′ W.		long.	50° 40, W.
2. P	lat.	35° 10′ N..	Q	lat.	37° 50′ N.
	long.	27° 18′ W.		long.	31° 08′ W.
3. D	lat.	25° 15′ S.	E	lat.	22° 47′ S.
	long.	156° 44′ E.		long.	159° 53′ E.
4. S	lat.	37° 53′ N.	T	lat.	38° 10′ N.
	long.	177° 50′ W.		long.	177° 50′ E.
5. L	lat.	10° 10′ N.	M	lat.	9° 00′ N.
	long.	31° 40′ W.		long.	29° 10′ W.

6. Find the set and drift, given:—

D.R. pos. lat. 50° 13′ N., long. 15° 15′ W. Pos. by obsn. lat. 50° 28′N. long. 14° 44′ W.

7. Given.—Initial position, lat. 40° 40′ N., long. 4° 04′ W.; course 214° T., dist. 100 M., find the D.R. position.

8. Find the true course and distance from 47° 06′ N., 39° 10′ W., to 48° 53·5′ N., 27° 04′ W.

9. Find the true course and distance from lat. 22° 33′ S., long. 96° 48′ E., to lat. 19° 43′ S., long. 92° 46′ E.

10. Find by inspection of the traverse table, the course and distance from 18° 35·7′ N., 39° 53′ E. to 22° 45·5′ N., 37° 15·5′ E.

EXERCISE 7

TRAVERSE SAILING

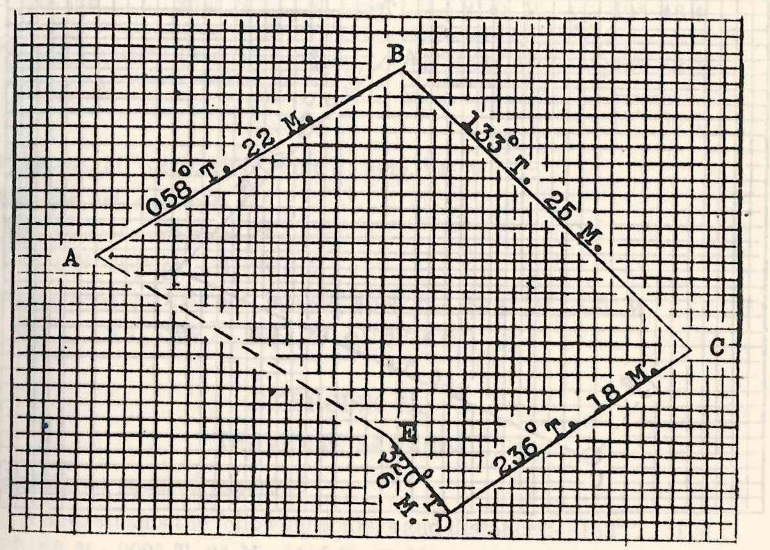
BY PLOTTING ON SQUARED PAPER

In these problems it is simply a matter of choosing a suitable scale, and then carefully drawing in the various directions and the distances.

If a position is to be taken off the plot, measure the d. lat. and dep. from the known position, and apply the d. lat. to the known latitude. Use the mean latitude to change the departure into d. long. which is then applied to the known longitude.

To plot a position, find the d. lat. and d. long. between the plotted position and the one to be plotted. Use the mean latitude to change the d. long. into departure. Measure the d. lat. and dep. from the plotted position and so plot the required position.

Examples:—



Scale 1sm. sq. = 1 M.

1. A vessel steams the following courses and distances:— 058° T. 22 M.; 133° T., 25 M.; 236° T., 18 M., and a current set 320° T., 6 M. Find the course and distance made good.

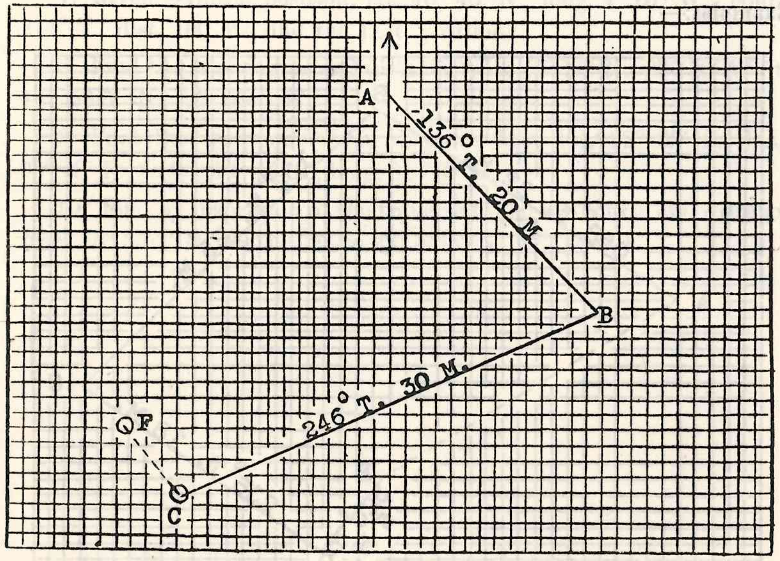
Description of figure.—*AB, BC, CD*, represent the courses and distances steamed, *DE* the set and drift, *A* the initial position, and *E* the final position of the ship. Then *AE* represents the course and distance made good.

By measurement, course 121° T., distance 21 nautical miles.

2. From lat. 50° 10′ N., long. 35° 15′ W., a vessel steamed 136° T., 20 M.; 246° T., 30 M., when the position by observation was lat. 49° 48′ N., long. 35° 43′ W. Find (1) the vessel's D.R. position, (2) the set and drift.

Steps in the problem.

1. Plot *A* to represent lat. 50° 10′ N. long. 35° 15′ W., and from this point, measure the courses and distances steamed. Then *C* is the D.R. position.



Scale 1 s.m. sq.— 1 M.

2. Find the d. lat. and d. long. between *A* and the position by observation. Use the mean latitude to change the d. long. into departure. Measure the d. lat. and dep. from *A* and so plot *F*, the position by observation.

3. For the set and drift, measure the course and distance from *C* to *F*.

4. To obtain the D.R. position, measure the d. lat. and dep. from *A* to *C*.

Apply the d. lat. to the latitude of *A*, and so obtain the latitude of *C*. Use the mean latitude to change the dep. into d. long. which is then applied to the longitude of *A*, thus giving the longitude of *C*.

To plot *F*.

A, lat.	50° 10·0′ N.	long.	35° 15·0′ W.
F, lat.	49 48·0′ N.	long.	35 42·0 W.
d. lat.	22·0′ S.	d. long.	27·0′ W.

Mean lat. 50°, d. long. 27′, give dep. 17·4.

To find *C* the D.R. position.—

By measurement from *A* to *C*, d. lat. 26·6′ S., dep. 13·5 M. W.

A, lat.	50° 10·0′ N.	long.	35° 15·0′ W.	50° 10·0′
d. lat.	26·6 S.	d. long.	21·0 W.	49° 43·4′
C, lat.	49° 43·4′ N.	long.	35° 36·0′ W.	2)99° 53·4′
				49° 56·7′

Mean lat. 50°, dep. 13·5′, give d. long. 21′ W.

To find the set and drift.—

By measurement from *C* to *F*,

Set N. 40½° W. Drift 6 M.

Answers.—(1) D.R. pos. lat. 49° 43·4′ N., long. 35° 36·0′ W.

(2) Set N. 40½° W. Drift 6 M.

EXERCISE 7A

TRAVERSE SAILINGS

By plotting on squared paper.—

1. A ship steams the following courses and distances:—162° T. 31 M.; 081° T. 53 M.; 202° T. 24 M.; 111° T. 60 M., and a current set 274° T. 14 M., throughout. Find the course and distance made good.

2. Find the course and distance made good if a ship steams:— 090° T. 20 M.; 153° T. 15 M.; 262° T. 17 ~~M.; 037° T.~~ 23 M., and a current sets 300° T. 8 M.

3. If a ship steams 305° T. 18 M.; 085° T. 17 M.; 153° T. 25 M.; 238° T. 22 M., in a current setting 180° T. 7 M., what is the course and distance made good?

4. A point of land bears 056° T. 10 M. From this position the vessel steams 180° T. 15 M.; 270° T. 12 M.; 152° T. 18 M., and a current sets 322° T. 5 M. Find the bearing and distance of the point of land at the end of the traverse.

5. From a starting buoy, a yacht sails:—S. 20° W. 18 M.; N. 84° E. 26 M.; N. 10° E. 17 M.; S. 33° E. 18 M. Find the course and distance to return to the starting buoy.

6. From lat. 44° 40′ N., long. 35° 10′ W., a ship steamed 036° T. 12 M.; 270° T. 23 M.; 222° T. 30 M., and a current set 115° T. 8 M. Find (1) the course and distance made good, (2) the estimated position.

7. Inistrahull Lt. (55° 26′ N., 07° 13·6′ W.) bore 180° T. 16 M., log reading 23. From this position, a vessel steamed 305° T. until the log read 41, 260° T., until the log read 64, 170° T., until the log read 91. Find the estimated position if a current set 073° T. 5·6 M.

8. From a position in lat. 39° 40′ N., long. 43° 15′ W., a vessel steamed 100° T. 20 M., 220° T. 30 M., 090° T. 25 M. Find the final position if the set and drift experienced was 060° T. 12 M.

9. From lat. 49° 57′ N., long. 06° 18·3′ W., a vessel steamed 150° T. 25 M., 065° T. 30 M., when a point of land (49° 57′ N., 05° 12′ W.) bore 010° T. 15 M. Find the set and drift experienced.

10. From lat. 50° 20′ N., long. 18° 35′ W., a vessel steamed 135° T. 20 M.; 250° T. 15 M.; 300° T. 23 M.; 286° T. 27 M. Find (1) the course and distance made good, (2) the D.R. position.

EXERCISE 7B

TRAVERSE SAILINGS

By use of traverse table.

Read pages 40 to 45 and 118 *Principles for Second Mates.*

Steps in the problem.—

These vary according to the information given and required, but in practically every case, the courses and distances steamed, with the

d. lat. and departure on each, must be tabulated. If a set and drift is experienced, it, also, is included in the traverse. If a bearing of a shore object is given, then, its true bearing must be reversed, but whether this is included in the tabled results or not, will depend on the information required. This is explained in Examples numbers 4 and 5.

The resultant d. lat. and departure are obtained by summation of the tabled results.

If the course and distance made is required, find, in the traverse table, the course and distance corresponding to the appropriate resultant d. lat. and departure. (Example 1.)

If either the D.R. position or the estimated position is required, the appropriate departure, *i.e.*, the departure from a known position, will have to be changed into d. long. This may be done by using the traverse table, or, where the figures are awkward, by using the formula:— d. long. = dep. in M. × sec mean lat.

If the set and drift is required, first find the D.R. position, the set and drift is then the course and distance from the D.R. position to the position by observation. (Example 2.)

Example 1.

A vessel steamed the following courses and distances:—165° T. 50 M.; 072° T. 63 M.; 112° T. 84 M.; 256° T. 58 M., and a current set 330° T. 10 M. Find the course and distance made good.

Course	*Dist. in M.*	*d. lat.*		*dep.*	
		N.	*S.*	*E.*	*W.*
S. 15° E.	50	—	48·3	12·9	—
N. 72° E.	63	19·5	—	59·9	—
S. 68° E.	84	—	31·5	77·9	—
S. 76° W.	58	—	14·0	—	56·3
N. 30° W.	10	05·0	—	—	08·7
		24·5	93·8	150·7	65·0
			24·5	65·0	
Resultant d. lat. & dep.	=		69·3S.	85·7 E.	

Course = S. 51° E. = 129° T., dist. = 110 M.

Notes.—

The course and distance made good is asked for, therefore, include in the traverse, the various courses, and the distance on each, and the set and drift, if any.

Example 2.

Given:—Initial position, courses and distances steamed, and position by Observation.

To find:—the set and drift.

A vessel steams the following courses and distances:—080° T. 62 M.; 168° T. 84 M.; 297° T. 56 M.; 312° T. 75 M., from lat. 41° 15′ N., long. 27° 18′ W. At the end of the traverse, the position by observation was lat. 41° 30′ N., long. 27° 40′ W. Find the set and drift experienced.

Course	*Dist. in M.*	*d. lat.* N.	*d. lat.* S.	*dep.* E.	*dep.* W.
080°	62	10·8	—	61·1	—
168°	84	—	82·2	17·5	—
297°	56	25·4	—	—	49·9
312°	75	50·2	—	—	55·7
		86·4	82·2	78·6	105·6
		82·2			78·6

resultant d. lat. = 4·2 N. dep. = 27·0 W.

Initial pos. lat. = 41° 15·0′N.	long. = 27° 18·0′W.		41° 15·0′
d. lat. = 4·2′N.	d. long. = 36·0′W.		41 19·2
D.R. Pos. lat. = 41° 19·2′N.	long. = 27° 54·0′W.		2)82 34·2
Obs. Pos. ,, = 41° 30·0′N.	,, = 27° 40·0′W.	m.l.	41 17·1
d. lat. = 10·8′N.	d. long. = 14·0′ E.		

dep. = 27·0M.
d. long. = 36·0′
m.l. 41° 24·6′
d. long. = 14·0′E.
dep. = 10·5 M.

To find the set and drift.—

d. lat. 10·8′ N., dep. 10·5 M. E.
Set = 044° T., drift = 15·1 M.

Notes.—

1. In changing the dep. on the traverse into d. long., use the mean latitude between the initial position and the D.R. position.
2. In changing into dep., the d. long. due to the set and drift, use the mean latitude between the D.R. and the observed positions.
3. In the traverse, use either the three figure or the quadrantal notation.

Example 3

Given :—The courses and distance on a traverse, and the final position.

To find:—the Initial Position.—A vessel steams the following courses and distances: 035° T. 42 M., 040° T. 152 M., 043° T. 178 M.

At one period she was stopped, due to engine trouble, when she drifted before the wind for 6 M., the wind direction being 140° T. At the end of the traverse, the position by observation was lat. 30° 10′ N., long. 165° 15′ E. Find the vessel's initial position.

Course	Dist. in M.	d. lat. N.	d. lat. S.	dep. E.	dep. W.
N. 35° E.	42	34·4	—	24·1	—
N. 40° E.	152	116·4	—	97·7	—
N. 43° E.	178	130·2	—	121·4	—
N. 40° W.	6	4·6	—		3·9
		295·6		243·2	
				3·9	

resultant d. lat. = 295·6′ N. dep. = 239·1E.

M.L. = 27° 42·2′

number	log
sec 27° 42·2′	0·05288
239·1	2·37858
	2·43146

Pos. by obs. lat. = 30° 10·0′ N.	long. = 165° 15·0′ E.
d. lat. = 4° 55·6′ S.	d. long. = 4° 30·0′ W.
Initial pos. lat. = 25° 14·4′ N.	long. = 160° 45·0′ E.

Notes.—

1. The drift before the wind is included in the traverse as a course and distance.
2. The wind direction is 140° T., therefore, the direction of movement of the vessel is 320° T.

3. The initial position of the vessel is required, therefore the names of the resultant d. lat. and dep. are reversed.
4. The dep. being large, it is better to change the dep. into d. long. by using the formula:—

   d. long. = dep. in M. × sec mean lat.

   and to use logarithms in the calculation.
5. Had the vessel's initial position been given, and the estimated position required, the problem would have been precisely the same except for the reversal of the names of the d. lat. and the dep.
6. Use either the 3 figure or the quadrantal notation, whichever is the more convenient, or whichever you can use the better, but in **correcting courses, as in later examples, always use the 3 figure notation.**

Example 4

Given:—The bearing of a lighthouse, course and distances steamed.

To find:—The D.R. position at the end of the traverse.

8th February, at 1500 hours, a lighthouse (50° 10·8′ N., 04° 15·9′ W.) bore 045° T., distant 15 M. Course was then set 220° C. (dev. 2° E., var. 11° W.), log reading 30. At 1730 hours, course was altered to 265° C (dev. nil, var. 11° W.), log reading 56. Find the vessel's D.R. position at 1850 hours, log reading 72.

Courses	(1) 220° C.	(2) 265° C.	Reversed brg. S. 45° W.
error	9° W.	11° W.	
courses	211° T.	254° T.	

Course	Dist. in M.	d. lat. N.	d. lat. S.	dep. E.	dep. W.
S. 45° W.	15	—	10·6	—	10·6
S. 31° W.	26	—	22·3	—	13·4
S. 74° W.	16	—	4·4	—	15·4

50° 10·8′
48° 33·5′
2)99° 44·3′
m.l. 49° 52′

resultant d. lat. = 37·3 dep. = 39·4

dep. = 39·4 M. W.
d. long. = 61·2′ W.

To find the D.R. position.

Lt. ho.	lat. =	50° 10·8′N.	long. =	4° 15·9′W.
	d. lat. =	37·3′S.	d. long. =	1° 01·2′W.
D.R. pos.	lat. =	49° 33·5′N.	long. =	5° 17·1′W.

Notes.—

1. The reversed bearing is included in the traverse, so that the resultant d. lat. and dep. from the known position—the latitude and longitude of the light-house—is obtained.
2. Interpolation for changing the departure into d. long. is carried out as shown in the examples on the use of the Traverse Table.
3. Compare this example with Example 5, where the course and distance made good on the run is asked for.

Example 5

Given:—the position and bearing of a point of land, courses and distances steamed, and a set and drift.

To find:—(1) the Estimated Position, (2) the course and distance made good on the run.

At 2200 hours, the Lizard Lt. (49° 58′ N., 5° 12′ W.) was abeam to starboard, distant 12 M., ship's head 282° C. (dev. 4° E., var. 11° W.).

The following courses and distances were then steamed:—
2200 hrs. to 0600 hrs. 236° C., dev. 3° E., var. 11° W., dist. 72 M.
0600 hrs. to 1200 hrs. 258° C., dev. 2° E., var. 11° W., dist. 60 M.
Throughout the run a current set 300° T. at 1 knot.

Find the estimated position at noon, and the course and distance made good on the run.

Bearing = 012° C.	courses	(1) = 236° C.	(2)	= 258° C.
Error = 7° W.		8° W.		9° W.
Bearing = 005° T.	courses	= 228° T.		249° T.
Reversed brg. = 185° T.				

Course	Dist. in M.	d. lat. N.	d. lat. S.	dep. E.	dep. W.
S. 48° W.	12	—	48·2	—	53·5
S. 69° W.	60	—	21·5	—	56·0
N. 60° W.	14	4·8	—	—	13·2
			69·7		122·7
			4·8		
			64·9		

rev. brg. = S. 5° W.
dist. = 12 M.
d. lat. = 12′ S.
dep. = 1 M. W.

∴ for course and dist., d. lat. = 64·9′ S. dep. = 122·7 W.
reversed bearing ,, = 12·0′ S. ,, = 1·0 W.

and for E.P. ,, = 76·9′ S. ,, = 123·7 W.

Lizard Lt. lat. = 49° 58·0′N.	long. = 5° 12·0′W.		49° 58′
d. lat. = 1° 16·9′S.	d. long. = 3° 09·8′W.		48° 41′
E.P. lat. = 48° 41·1′N.	long. = 8° 21·8′W.		2)98° 39′
			m.l. 49° 19½′
Course = 242° T. Dist. = 139 M.		dep.	= 123·7 M.
		d. long.	= 189·8′W.

Notes.—

1. The reversed bearing is not included in the traverse, since the course and distance made good on the run is required. The resultant d. lat. and dep. from the courses and distances steamed, and the set and drift experienced (if any) are used to find the course and distance.

   Had the course and distance made good from the point of land been required, then the reversed bearing would have been included in the traverse.

2. To find the estimated position—apply the d. lat. and dep. from the reversed bearing to the d. lat. and dep. on the run. Apply this d. lat. to the latitude of the departure point—this gives the latitude of the estimated position. Use the mean of these two latitudes to convert the dep. into d. long., which is then applied to the longitude of the departure point to obtain the longitude of the estimated position.

EXERCISE 7C

1. Find the resultant true course and distance, when the following traverse is sailed:—108° T. 12 M.; 012° T. 16 M.; 267° T. 23 M.; 340° T. 31 M.

2. Find the true course and distance made good by sailing the following traverse:—015° T. 60 M.; 090° T. 120 M.; 145° T. 120 M.

3. A vessel sails the following courses and distances:—165° T. 104 M.; 027° T. 120 M.; 070° T. 12 M. What was the course and distance made good?

4. A vessel sails as follows:—184° T. 16 M.; 071° T. 17 M.; 225° T. 16 M.; 130° T. 15 M.; 319° T. 9 M.; 095° T. 15 M.; 198° T. 28 M., and a current set 082° T. 23 M. Find the course and distance made good.

5. From lat. 51° 15′ N., long. 33° 17′ W., a vessel steamed 050° T. 53·5 M.; 072° T. 62 M.; 167° T. 48·4 M.; 233° T. 58·6 M.; 201° T. 40·2 M.; the set and drift experienced being 306° T. 10·7 M. Find the estimated position.

6. From a ship steering 250° T. a point of land (16° 10′ N., 25° 15′ W.) bore 330° T. 8 M. (log reading 10). The ship steamed on this course until the log showed 17, and was then stopped, when she drifted before the wind for 3 M. (wind direction 340° T.). Course was resumed, and continued until the log showed 62, when it was altered to 210° T. Find the estimated position, when the log showed 104.

7. From the following data, find the D.R. position at 2100 hours.
1415 hours Tuskar Rock (52° 12′ N., 06° 12·3′ W.) bore 290° C. distant 7 M. Course steered 200° C. (dev. 4° W., var. 16° W.) log reading 24.
1500 hours a/c 250° C. (dev. 6° W., var. 16° W.) log 32.
1600 ,, a/c 252° C. (dev. 6° W., var. 16° W.) log 43.
2100 ,, log 99.

8. The following is an extract as taken from a ship's log.
4 p.m. A point of land (50° 13′ N., 04° 47′ W.) bore 063° C. distant 10 M., course 220° C., error 18° W., speed 12 knots.
8 p.m. Course 220° C. error 18° W. speed 12 knots
Midnight ,, 180° C. ,, 15° W. ,, 13 ,,
4 a.m. ,, 180° C. ,, 15° W. ,, 13 ,,
8 a.m. ,, 050° C. ,, 23° W. ,, 15 ,,
Noon ,, 050° C. ,, 23° W. ,, 15 ,,
From midnight to 6 a.m., a current set 070° T. at 2 knots. Find the estimated position at noon.

9. 29th June, 1952, at 1200 hours, Cape Finisterre (42° 53′ N., 09° 15′ W.) was abeam to port, distant 12 M., ship's head 200° C., dev. 3° E., var. 10° W., log set to zero.
30th June at 0000 hours, a/c 199° C., dev. 2° E., var. 10° W., log 110.
0600 ,, required the estimated position, log 170.
A current was setting 270° T. at 2 knots throughout.

10. 9 p.m. Fastnet Rock (51° 23·3′ N., 09° 36·4′ W.) was abeam to starboard distant 7 M.
Course 235° C., dev. 6° E. wind W.N.W. leeway 5°, log 10
2 a.m. ,, 240° C. ,, 5° E. ,, N. ,, Nil ,, 62
6 a.m. ,, 245° C. ,, 4° E. ,, N. ,, 3° ,, 104
The magnetic variation throughout was 19° W.

From 9.50 p.m. to 10.40 p.m. the vessel was stopped, and drifted before the wind for 3 M. (wind direction 293° T.). A current set 090° T. at 1 knot throughout the run. Find the estimated position at 6 a.m.

11. At noon 24th February, 1952, a point of land (59° 04′ N., 04° 24′ W.) bore 102° C. distant 7 M. (compass error 25° W.).

1200 hours	set course	319° C.,	error 25° W.,	log set zero	
2000 ,,	a/c	315° C.	,, 24° W.	,, read	54
1200 ,,				,, ,,	194

The position by observation at noon 25th February was lat. 60° 23′ N., long. 10° 09′ W. Find the set and drift experienced.

12. From the following log extract, find the estimated position at noon, and the course and distance made good from noon to noon.

Noon—A point of land in lat. 50° 25′ S., long. 179° 40′ W., bore 338° C. distant 16 M., direction of ship's head 079° C.

	s/c 028° C.	dev. 6° E.	var. 12° E.	log Zero
4 p.m.	a/c 248° C.	,, 7° W.	,, 12° E.	,, 32
8 p.m.	a/c 079° C.	,, 14° E.	,, 12° E.	,, 62
Midnt.	a/c 343° C.	,, 4° W.	,, 14° E.	,, 96
4 a.m.	a/c 188° C.	,, 1° W.	,, 14° E.	,, 126
8 a.m.	a/c 051° C.	,, 8° E.	,, 14° E.	,, 157
Noon				,, 190

Throughout the day, a current set 082° T. at 1 knot.

13. From the following information, find the ship's position at 3 a.m. 12th January, the estimated position at noon 12th January and the course and distance made good from noon to noon.

11th January—

Noon to 8 p.m.—	course=307°C.	dev. = 5° E.	speed = 9 knots
8 p.m. to Midnt.—	,, =321°C.	,, = 3° E.	,, = 10

12th January—

Midnt. to 4 a.m.—	course=321°C.	dev. = 3°E.	speed = 10 knots
4 a.m. to 8 a.m.—	,, =328°C.	,, = 4°E.	,, = 9·5
8 a.m. to Noon—	,, =328°C.	,, = 4° E.	,, = 8 ,,

A current set 140° T. at 1 knot throughout the run, and the magnetic variation was 8° W. throughout.

At 3 a.m. 12th January, a lighthouse (47° 00′ N., 09° 00′ E.) bore 045° C. distant 8 nautical miles.

14. 1st August at noon, a point of land (50° 32′ N., 07° 10′ W.) bore 090° C. distant 21 M.; ship's head 277° C.; log set to Zero. From noon 1st August to noon 2nd August, the vessel steered 277° C., the deviation being 12° E. The magnetic variation was 24° W. until midnight (log 153), and was 22° W. for the ensuing 12 hours. At 0000 hours, stellar observations gave position lat. 50° 06′ N., long. 11° 35′ W.

Find (1) the estimated position at noon 2nd August, assuming throughout a current similar to that experienced in the earlier part of the run, (2) the course and distance made good from noon to noon (log reading at noon 2nd August being 312).

15. 9th January at noon, a light-house in lat. 57° 36′ N., long. 163° 15′ E., bore 114° C., distant 12 M. (ship's head 135° C.)

Until noon the following day, the course steered was 135° C., dev. 3° E., var. 5° W., speed 16 knots.

At 11 p.m. 9th January, observations gave the ship's position as lat. 55° 48·5′ N., long. 167° 18′ E.

Find (1) the estimated position at noon 10th, January, assuming throughout a current similar to that in the earlier part of the run, (2) the course and distance made good from noon to noon.

16. From the following log book extract, find the vessel's estimated position at midnight, also the course and distance made good.

4 p.m.—a point of land lat. 51° 33′ N., long. 131° 02′ W., bore 322° C. distance 12 M., course 207° C., log reading 44, wind 270° T., leeway 3°, deviation 7° E., variation 11° W.

Midnight—log showed 126.

A current set 255° T. at 1·5 knots throughout.

EXERCISE 8

FOUR POINT BEARING WITH LEEWAY AND CURRENT

These problems can be solved by:—

1. the use of the traverse table only,
2. the use of the sine formula and the traverse table,
3. scale drawing. The "Running Fix" as used in chartwork, could also be employed.

Scale drawing and the traverse table methods are shown here, since the problem is a navigational problem, and, the use of the sine formula is obvious if these two methods are understood. For further examples, see *Principles for Second Mates*, pages 48, 49, 59.

Example.

A vessel, steaming at 12 knots on a course 210° C., observes a point of land to bear four points on the port bow. One hour later, the point was abeam. In the interval a current set 080° T. at 3 knots, the wind being N.W. and leeway 5°. Find the vessel's distance off the point when it was abeam. Deviation was 10° W. and variation 4° E.

By scale drawing

Steps in the problem.

1. Correct the compass course, and find the true course.
2. Apply the leeway and find the track.
3. Apply 45° to the true course to find the 4 point bearing.
4. Decide upon the point to represent the first position of the ship, and draw in the direction of the true course, the track and the 4 point bearing.
5. Measure the distance along the track, and from this point lay off the set and drift.
6. Lay off the beam bearing (at right angles to the true course) through the end of the set and drift.

Course	210° C.
error	6° W.
course	204° T.
leeway	5°
Track	199° T.

4 point bearing
= 159° T.

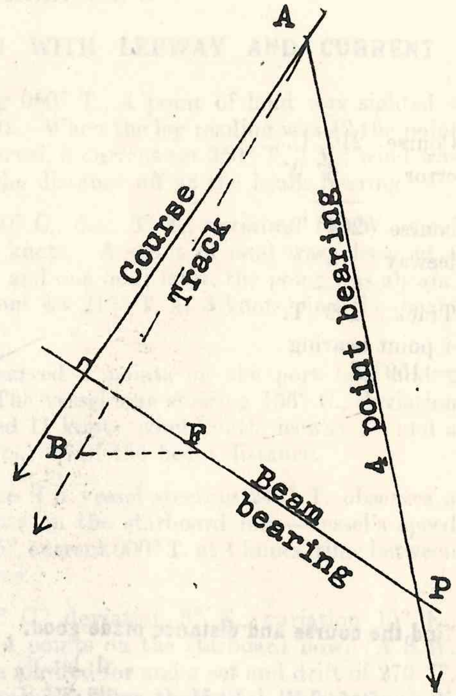
Description of figure:—

A is the ship's initial position

P the point of land

F the ship's position

Beam distance = 6·7 nautical miles.



By Traverse Table

Steps in the problem.

1. From the compass course and the error find the true course, and by applying the leeway, find the TRACK.

2. From the true course and the true four-point bearing. If the beam position is required, find also the beam bearing.

3. With the track and distance, and the set and drift, enter the traverse table. Then, from the resultant d. lat. and dep. find the course and distance made good between the bearings.

4. Solve the triangle *APF* (vide figure 8·1) by means of the traverse table. To do this, draw the perpendicular *FD*, and solve the two right angled triangles *AFD* and *FPD*.

Course	210° C.
error	6° W.
course	204° T.
leeway	5°
Track	199° T.
4 point bearing	= 159° T.

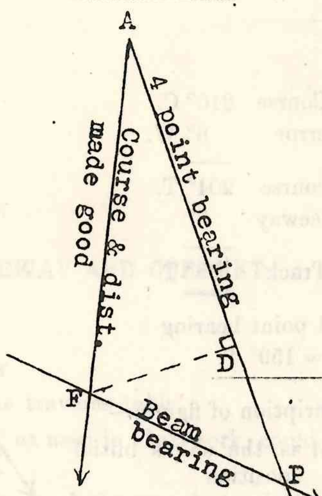


Figure 8.1

To find the course and distance made good.

		d. lat.	dep.
S. 19° W.	12 M.	11·35′ S.	3·91 W.
N. 80° E.	3 M.	0·53′ N.	2·95 E.
		10·83′ S.	0·96 W.

Course = S. 5° W. Distance = 10·9 M.

In triangle *AFD*

Angle *FAD* is the angle between the course made good and the 4 point bearing, *i.e.*, between 185° T. and 159° T., so that angle *FAD*= 26°. Side *AF* is the distance made good, namely, 10·9 M. Enter the traverse table with angle 26°, and distance 10·9, and take out the dep., which is found as 4·78. Thus side *FD*=4·78.

In triangle *FDP*.

Angle *FPD* = 45°, the angle between the 4 point and beam bearings. Side *FD* = 4·78. Therefore, with 45° as course, and 4·78 as dep., enter the traverse table and take out *FP* as distance. *FP* = 6·76.

Beam distance = 6·76 nautical miles.

EXERCISE 8

FOUR POINT BEARING WITH LEEWAY AND CURRENT

1. From a vessel steering 050° T., a point of land was sighted 4 points on the port bow, log 50. When the log reading was 42 the point was abeam. During the interval, a current set 350° T. 3 M.; wind was S.E. and leeway 4°. Find the distance off at the beam bearing.

2. A vessel is steering 050° C., dev. 3° E., variation 15° W., wind N.W., leeway 10°, speed 12 knots. A point of land was observed 4 points on the starboard bow, and one hour later, the point was abeam. If during the interval a current set 212° T. at 3 knots, find the beam distance.

3. A light-house was observed 4 points on the port bow and 2 hours later it was abeam. The vessel was steering 136° C., deviation 3° W., variation 12° W., speed 11 knots, wind South, leeway 8°, and a current set 090° T. at 3 knots. Find the beam distance.

4. Find the beam distance if a vessel steering 246° T. observes a point of land to bear 4 points on the starboard bow—vessel's speed 12 knots, wind N.W., leeway 5°, current 000° T. at 4 knots, time between the bearings 1 hour 50 minutes.

5. A vessel steering 320° C., deviation 5° E., variation 15° E., sighted a lighthouse bearing 4 points on the starboard bow. A S.W. wind causing 8° of leeway was allowed for and a set and drift of 270° T. 4 nautical miles was experienced. After the vessel had steamed 25 nautical miles, the lighthouse was abeam. Find the beam distance.

EXERCISE 9.

W/T BEARINGS

Read up notes on convergency, pages 131 to 135, *Principles for Second Mates.*

Note that all long distance bearings must be corrected for convergency.

Formula:—

Convergency = **d. long. × sine mean latitude**
Correction = **½ Convergency**
= **½ d. long. × sine mean latitude**

The correction and the half-d. long. are in the same units, *i.e.*, if the half-d. long. is in minutes, the correction is in minutes; if the half-d. long. is in degrees, the correction is in degrees.

To apply the Correction.

In the Northern Hemisphere—

Bearing less than 180° add the correction
Bearing more than 180° subtract the correction

In the Southern Hemisphere—

Reverse the above rules.

The rule for applying the correction may also be stated as, "always apply the correction towards the Equator."

Note:—The above rules will always apply, whether the bearing is of the ship from a station or *vice versa.*

If a relative bearing is given.—

Apply the relative bearing to the true direction of the ship's head and thus obtain the great circle bearing, to which the correction is then applied, to obtain the Mercator bearing.

To find the correction by use of the traverse table:—

Take the mean latitude as the course (or angle), look up the d. long. in minutes in the distance column, and the convergency in minutes is found in the departure column.

Example:—

From a ship in lat. 50° 04′ N., long. 01° 40′ W. a station in lat. 50° 32′ N., long. 02° 28′ W., bore 306° by W/T D.F. Find the Mercator bearing for plotting on a chart.

Ship lat.	=	50° 04′ N.	long.	=	01° 40′ W.
Station lat.	=	50° 32′ N.	long.	=	02° 28′ W.
Mean lat.	=	50° 18′ N.	d. long.	=	48′

Corr. = ½ d. long. × sine mean lat.
= 24 × sine 50° 18′
= 18·46′
= 0·3°

Number	log
24	1·38021
sine 50° 18′	9·88615
	1·26636

W/T bearing = 306°
Corr. = 0·3°

Mercator bearing = 305·7° T.

If a relative bearing were given.

From a ship in lat. 50° 04′ N., long. 01° 40′ W., and steering 083° C., the relative bearing of a W/T D.F. station in lat. 50° 32′ N., long. 02° 28′ W. was 230°. Find the bearing to plot on a mercator chart. Deviation was 3° E. and the variation 10° W.

Course = 083° C.
Error 7° W.

Course = 076° T.
Bearing = 230° (relative)

Bearing = 306° (W/T)

The remainder of the problem is then the same as above.

EXERCISE 9

1. A station in lat. 48° 28′ N., long. 05° 05′ W., bore 218·5° by W/T D.F. from a ship in D.R. position lat. 49° 30′ N., long. 03° 50′ W. Find the bearing to plot on a mercator chart.

2. From a ship in D.R. position lat. 50° 11′ N., long. 02° 47′ W., a station in lat. 50° 35′ N., long. 01° 18′ W. bore 066° by W/T D.F. Find the mercator bearing of the station.

3. From a vessel steering 306° C., dev. 3° W., var. 10° W., the relative bearing of a W/T station in lat. 49° 58′ N., long. 05° 12′ W. was 114°. Find the bearing to plot on a mercator chart, the D.R. position of the ship being lat. 49° 42′ N., long. 06° 00′ W.

4. A ship in D.R. position lat. 44° 10′ S., long. 144° 50′ E. bore 235° from a W/T D.F. station in lat. 42° 53′ S., long. 147° 14′ E. Find the mercator bearing.

5. From a W/T D.F. station in lat. 40° 42′ S., long. 144° 43′ E., a ship in D.R. position lat. 41° 10′ S., long. 143° 15′ E. bore 265°. Find the mercator bearing to plot on the chart.

EXERCISE 10

MISCELLANEOUS SAILINGS.

1. A vessel in latitude 55° 12′ N. steamed on a course 270° T., and made a d. long. of 21° 36·6′. If the time taken was 3 days 2 hours, find the vessel's speed.

2. A vessel steams 385 nautical miles, making a d. long. of 6° 40′. Between what parallels did she steam?

3. From a position lat. 49° 27′ N., long. 07° 50′ W., a vessel steamed 080° T. 25 M.; 034° T. 20 M.; 070° T. 15 M.; 162° T. 10 M. At the end of the run, the position by observation was Bishop Rock (49° 52′ N., 06° 27′ W.) bearing 020° T. 15 M. Find the set and drift.

4. Two ships, *A*, in lat. 30° 00′ N., long. 150° 00′ E., and *B*, in lat. 30° 00′ N., long. 160° 00′ E. are stopped. They drift 300 M. before a current setting 040° T. Find their final distance apart.

5. Two ships *A* and *B*, which are 40 M. apart on the Equator, steam due North to the 20th parallel. What is the distance between them in this latitude.

6. Find the true course and distance to steam from lat. 50° 10′ N., long. 09° 20′ W., to lat. 35° 15′ N., long. 26° 17′ W.

7. Starting from the Equator, a vessel made a d. lat. of 3° N., and a d. long. of 1° W. Find the true course steered.

8. A ship left lat. 35° 00′ S., long. 54° 15′ W., and steered 090° T. 154 M. Find the position arrived at.

9. Two vessels *A* and *B* are on the parallel of 49° 50′ N., *A* steering 090° T. and *B* 270° T. At noon, A.T.S. by *B*'s clock they were 349 M. apart, when their clocks were set to the apparent time of their respective meridians. At 10.15 p.m. by *B*'s clock they collide. What was the time by *A*'s clock, neither clock having been altered since noon?

10. Two vessels *A* and *B* leave lat. 38° 02′ N., long. 28° 38′ W., for a position in lat. 44° 40′ N., long. 63° 35′ W. *A* steams 000° T., and then 270° T. *B* steams 270° T., and then 000° T. Which arrives the earlier and by how much is her distance the shorter, their speeds being the same.

11. On a certain parallel, a vessel must steam one nautical mile to alter her longitude by two minutes. What is the latitude of the parallel?

12. A vessel leaves lat. 38° 27′ S., long. 176° 31·1′ E., and steams 345° T. 1400 M. Find the position arrived at.

13. Find the true course and distance from lat. 38° 22′ S., long. 36° 37′ W., to lat. 23° 01′ S., long. 42° 00′ W.

14. A vessel is steering 080° C., variation 15° 15′ W., deviation 3° 15′ E. Find the true course and illustrate by a correct figure.

15. In steaming 400 M. a vessel makes a departure of 315·2 M., and a d. long. of 7°. Between what parallels did she steam?

16. Two ships *A* and *B* are in positions, *A*, lat. 17° 00′ S., long. 00°, and *B*, lat. 18° 00′ S., long. 01° 00′ W. *A* steams 270° T. for 4 hours at 17 knots. Find the course and speed of *B* to reach *A* at the end of the 4 hours.

17. Two vessels left the same port at the same time. One steered 252° T. at 11 knots, and the other steered 180° T. for one hour and then 270° T. at 14 knots. Find the distance between the two vessels after 5 hours all told. (Use the traverse table only.)

18. (*a*) A yacht encounters a head wind when 30 nautical miles from her destination, and finds that she can make 7 knots when she lies $6\frac{3}{4}$ points off the wind and 9 knots if she falls off a further $\frac{1}{2}$ point. Using the traverse table only, solve which will be her better course.

(*b*) Explain clearly what is meant by leeway.

19. A ship *A* is 75 nautical miles due East of a ship *B*. *A* sails 270° T. at 9 knots and *B*, 180° T. at 12 knots. Find their least distance apart, and the time when this occurs.

20. Assuming it is possible, a vessel on the 60th parallel of latitude sails due West from Greenwich at noon 1st, January, and makes a departure of 216 nautical miles in 24 hours. Find the number of days it will take to circumnavigate the 60th parallel, also the time and date she will regain the meridian of Greenwich.

21. A vessel leaves lat. 00° 00′, long. 40° 00′ W., and steams the following courses and distances:—045° T. 900 M.; 315° T. 1800 M.; 045° T. 900 M. Find her final position.

22. From the Equator, a vessel steams on a course 240° T. and makes a d. long. of 12° 20′. By use of meridional parts, find the latitude in which she arrives and the distance steamed.

23. Given lat. 37° 10′ S., course 210° T., d. long. 11° 30′, find the latitude reached and the distance steamed.

24. Given initial position is lat. 50° 00′ S., long. 70° 00′ E., course 050° T., distance 1000 M., find the final position.

25. Two ships are on the Equator, 183 M. apart. Both steam 000° T. at the same speed, until the d. lat. = $\frac{3}{4}$ M.D. lat. How far are they now apart?

26. A vessel steers a course of 060° T., making a d. lat. of 31′ and a d. long. of 1° 16′. Find the latitude reached.

27. A ship *A* is on the Equator steering 090° T. at 16 knots; a ship *B* is on a parallel of North latitude, steering 270° T. at 12 knots. When *A* makes a d. long. of 1°, *B* makes a d. long. of 48′. Calculate the latitude of *B*.

28. From lat. 51° 00′ N. a vessel steams 060° T. at 24 knots. At what rate does she change her longitude?

29. A ship in lat. 59° 40′ sailed on a certain course until the M.D. lat. was twice the d. lat. Calculate the latitude reached.

EXERCISE 11

ELEMENTS FROM THE "NAUTICAL ALMANAC."

Before commencing the exercise, read pages 151 to 173, *Principles for Second Mates*. Learn the definitions of the different terms used, and study the Time Formulae—it will be necessary to learn the proofs. Look through the *Nautical Almanac*, and note its arrangement, which is entirely different from any arrangement prior to 1952.

The G.H.A. and declination of the Sun, the Moon, and the four navigational planets, Mars, Venus, Jupiter and Saturn, are tabulated on one page for each day of the year. The G.H.A. of Aries is also tabulated on each page. These elements are given for every hour of G.M.T., and extensive Interpolation Tables are provided so that the increment for minutes and seconds of time can be easily obtained. Note also the Calendar, page 7; the Equation of Time, page 10; the Moon's Upper Meridian Passage, page 11; the Conversion of Arc to Time, page 408; etc. Amongst other data found on the daily pages are the times of sunrise and sunset; these are Local Mean Times, and apply to the two days on which they are given. The use of these times and those of morning and evening twilight is for making up morning and evening programmes of star observations. Another quantity to be noted on each page is the quantity given at the foot of the column headed Sun—this quantity is the L.M.T. of the Sun's meridian passage, to the nearest minute. It will be used in problems on finding the latitude by the Meridian Altitude of the Sun.

Note on G.H.A.

The mean rate of increase of the G.H.A. of the Sun is 15°, and it is upon this quantity that the Interpolation Tables for the Sun are based, the slight variations in value which occur, being allowed for in the hourly values of the G.H.A. of the True Sun.

The hourly increase in the G.H.A. of the planets is, with the exception of that of Venus, always greater than 15°. The Sun tables are then used for interpolation, and the excess over 15° is allowed for by the v correction, which is found at the foot of each column for each planet. The actual value of v to apply to the hourly value of the G.H.A. is given on each page of the Interpolation Tables. When taking out

the increment for the minutes and seconds of time, look down the v correction table, which is on the right hand side of the page, until the value of v from the daily page is found; abreast of it will be found the actual value of v. When dealing with Venus, note if the correction is plus or minus. With the other three planets it is always plus.

Change in H.A. of the Moon varies from 14° 19′ to 14° 37′ per hour. The Interpolation Tables give the increment for every minute and second of time for the minimum increase of 14° 19′, and the v correction is the excess over this amount. It is given for every hour on the daily page, and it is always plus. Interpolation for v is the same as for the planets.

For Aries, the hourly increase in G.H.A. is a constant of 15° 02·46′, and upon this quantity the Interpolation Tables are based.

Declination.

The declination for each of the bodies mentioned is given for each hour of G.M.T., and the variation in hourly value is given as the d correction. The increment for minutes and seconds of time can be obtained from the Interpolation Tables, or mentally.

Example.

Required the G.H.A. and the declination of the Sun on 15th January, 1952, at 18h 46m 17s G.M.T.

d.p.	= 87° 40·6′		d.p.	= 21° 13·2′ S.
incr.	= 11 34·3		d	= 00·3
G.H.A.	= 99° 14·9′		Dec.	= 21° 12·9′ S.

Notes:—

1. The G.H.A. for 18h 00m is obtained from the daily page for the date of G.M.T.
2. The declination is taken out at the same time.
3. The increment is for 46m 17s, and is taken from the Interpolation Tables. Turn to the page headed 46m, and proceeding down the page to 17s, the increment will be found under the column headed Sun. The increment is always added.
4. The correction to the declination is found by proceeding down the column headed v or d correction to the value of d, and taking out the quantity abreast of it, interpolating if necessary. Note from the values of the declination whether d is plus or minus.

Exercise.

Find the G.H.A. and declination of the sun on:

1. 17th January 1952, at 10h 50m 00s G.M.T.
2. 18th September, 1952, at 15h 40m 00s G.M.T.
3. 20th December, 1952, at 11h 58m 25s G.M.T.
4. 29th August 1952, at 17h 53m 34s G.M.T.
5. 6th October 1952, at 04h 16m 47s G.M.T.

Answers.

	G.H.A.	Dec.
1.	340° 01·9′	20° 54·2′ S.
2.	56° 29·4′	1° 43·7′ N.
3.	00° 10·9′	23° 26·4′ S.
4.	88° 11·7′	9° 12·0′ N.
5.	247° 08·9′	5° 04·6′ S.

To find the G.H.A. and declination of the Moon.

This is done in precisely the same way as for the Sun, except that the *v* correction must be applied to the G.H.A. Follow the steps in the example.

Example.

15th January 1952, at 19h 24m 36s G.M.T., find the G.H.A. and dec. of the Moon.

d.p.	243° 51·4′	d.p.	10° 00·7′ N.	*v*	+ 16·2′
incr.	5° 52·2′	*d*	— 5·5′	*d*	— 13·4′
v	+ 6·6′				
		Dec.	9° 55·2′ N.		
G.H.A.	249° 50·2′				

To find the G.H.A. and declination of a Planet.

Follow the same steps as for the Moon, but the increment for minutes and seconds of time is found in the Interpolation Tables by using the Sun table.

Example.

15th September 1952, at 21h 37m 45s G.M.T., find the G.H.A. and dec. of the planet Venus.

d.p.	115° 15·7′	d.p.	5° 22·0′ S.	*v*	— 0·3′
incr.	9° 26·3′	*d*	+ 0·8′	*d*	+ 1·3′
v	— 0·2′				
		Dec.	5° 22·8′ S.		
G.H.A.	124° 41·8′				

Note :—In this example *v* is minus.

Exercise.

Find the G.H.A. and declination of:—

1. The Moon, 16th January 1952, at 02h 50m 20s G.M.T.
2. The Moon, 15th September 1952, at 08h 50m 40s G.M.T.
3. The Moon, 21st December 1952, at 06h 35m 42s G.M.T.
4. Venus, 18th September 1952, at 11h 45m 10s G.M.T.
5. Mars, 18th September 1952, at 21h 51m 20s G.M.T.
6. Jupiter, 16th January 1952, at 20h 31m 20s G.M.T.

Answers.

	G.H.A.	Dec.
1.	358° 12·0′	8° 14·6′ N.
2.	354° 45·3′	18° 56·5′ N.
3.	221° 07·5′	11° 53·6′ S.
4.	336° 10·9′	6° 41·3′ S.
5.	73° 14·0′	24° 28·6′ S.
6.	55° 17·5′	2° 00·5′ N.

To find the G.H.A. of a star.

The G.H.A. of Aries must first be found, and this is done in precisely the same way as for the Sun. The Star's S.H.A. is added to the G.H.A. of Aries to obtain the star's G.H.A.

* G.H.A. = G.H.A. Aries + * S.H.A. (−360° where necessary).

Example.

Required the G.H.A. of the star Canopus 17, at 16h 50m 10s G.M.T. 17th January 1952.

d.p.	356° 01·7′
incr.	12° 34·6′
S.H.A.	264° 16·1′
sum	632° 52·4′
	360°
G.H.A.	272° 52·4′

Note.

It is not necessary actually to find the G.H.A. of Aries.

Be careful to take out the star's S.H.A. for the proper month.

The star's declination is taken from the same page as the star's S.H.A., either from the catalogues of stars at the back of the *Nautical Almanac*, or from the book-mark giving a list of selected stars.

To find the Local Hour Angle (L.H.A.) of a body.

First find the G.H.A. of the body, then apply the longitude of the observer.

$$\text{L.H.A.} = \text{G.H.A.} \begin{matrix} +\text{ long. E.} \\ -\text{ long. W.} \end{matrix}$$

Exercise.

Find the L.H.A. in each case

	Date	*G.M.T.*	*Body*	*Longitude*
1.	23rd December 1952	08h 25m 30s	Sun	125° 10·0′ E.
2.	18th September 1952	21h 18m 57s	Sun	72° 18·3′ W.
3.	18th September 1952	03h 50m 41s	Aries	140° 10·2′ W.
4.	17th December 1952	20h 10m 40s	Arcturus	164° 16·2′ E.
5.	18th December 1952	21h 10m 14s	Kochab	38° 20·2′ W.
6.	15th September 1952	18h 20m 40s	Sun	162° 20·0′ W.
7.	29th August 1952	20h 00m 12s	Aries	17° 33·0′ W.
8.	18th September 1952	20h 31m 20s	Betelgeuse	162° 00·0′ W.

Answers.
1. 71° 45·6′. 2. 68° 56·7′. 3. 274° 30·8′. 4. 339° 57·0′.
5. 143° 56·8′. 6. 294° 04·1′. 7. 260° 27·8′. 8. 55° 22·6′.

Equation of Time

The Equation of Time is given for every 12 hours G.M.T. for each day of the year, on page 10 of the *Nautical Almanac*. Interpolation for the given G.M.T. can be done mentally. For definition and notes on Equation of Time read pages 159,160, *Principles for Second Mates*.

Example.

16th January 1952 G.M.T. 18h 00m 00s, required the Equation of Time.

E.T. @ 12h 00m	9m	33s
diff.		5
Equation of Time	9	38 + to Apparent Time

Exercise.

Find the Equation of Time

1. 29th August 1952 at 05h 20m 00s G.M.T.
2. 15th September 1952 at 20h 28m 10s G.M.T.
3. 23rd December 1952 at 07h 40m 00s G.M.T.

Answers.
1. 0m 57s + 2. 4m 58s — 3. 0m 54s —

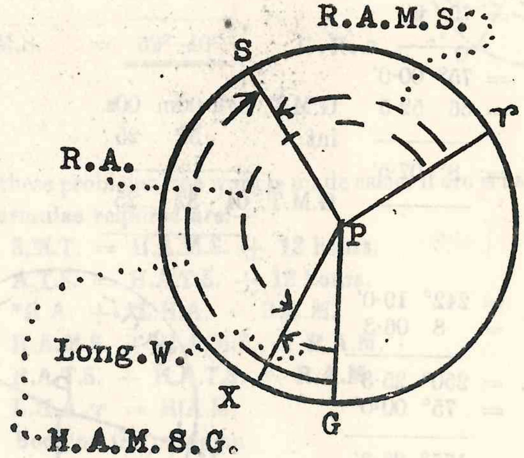
Miscellaneous

These problems depend on the various time formulae, *which must be known.*

Examples.

1. In longitude 15° 00′ W. at 22h 08m 07s G.M.T., the longitude of the geographical position of a star was 24° 32·5′ W. The R.A.M.S. was 05h 46m 03s. Find the star's R.A.

R.A.M.S. 05h 46m 03s	=	86°	30·75′
H.A.M.S. 10h 08m 03s	=	152	09·75
R.A.M.G.	=	238°	41·5′
Long. of star's G.P.	=	24°	32·5′
Star's R.A.	=	214°	09·0′



In all problems of this type, involving time formulae, always draw a small figure, as shown.

2. To find the G.M.T. of the Moon's Meridian Passage.

16th January 1952, find the G.M.T. of the Moon's meridian passage to an observer in long. 150° 10′ W.

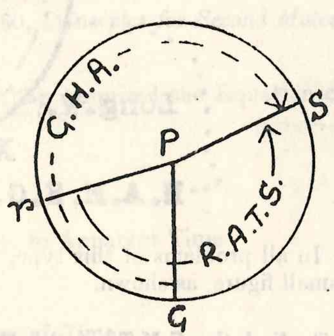
Mer. pass.		02h	58m	00s
long. corr.	+		16	20
L.M.T.		03	14	20
long. W.		10	00	40
G.M.T.		13	15	00 (16th)

Notes.

1. Refer to page 145, *Principles for Second Mates.*
2. Note why . . . appear against certain dates, and also how to obtain G.M.T.
3. The longitude correction in the example has been taken from Table 11, page 409, in the *Nautical Almanac.* It may also be obtained as explained on page referred to in 1.

3. 28th September 1952, Aries is on the meridian of 75° W. What will be the R.A.T.S.?

♈L.H.A.	= 00° 00·0′			
long. W.	= 75 00			
♈G.H.A.	= 75° 00·0′			
♈d.p.	= 66 52·5	G.M.T. 04h 00m 00s		
		int.	32	25
incr.	= 8° 07·5′			
		G.M.T. 04	32	25
☉d.p.	= 242° 19·0′			
incr.	= 8 06·3			
☉G.H.A.	= 250° 25·3′			
long. W.	= 75° 00·0′			
☉L.H.A.	= 175° 25·3′			
R.A.M.	= 360 00·0			
R.A.T.S.	= 184° 34·7′			



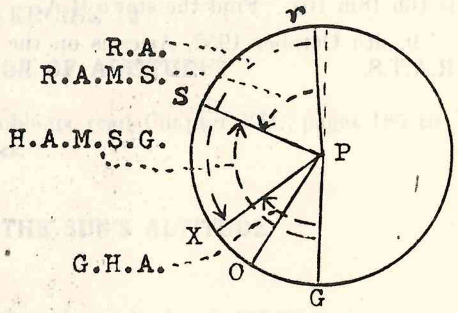
Notes.—

1. Find the G.M.T. as shown—the interval corresponding to the increment is found in the Interpolation Tables.
2. The Sun's L.H.A. being found, and Aries being on the meridian, subtract the L.H.A. from 360°, since the R.A. is measured *Eastwards* from Aries. A small figure as shown, will make this quite clear.
3. In the figure, *P*♈ is both the meridian of Aries and of the observer in long. 75° W. Further, since Aries is on the meridian the R.A.M. is either 000° or 360°.

4. The formula used is:—H.A.T.S. + R.A.T.S. = R.A.M. (See page 164, *Principles for Second Mates.*)

4. In long. 30° W. the L.H.A. of a star was 20° 15′. The R.A. was 8h 20m 00s and the G.M.T. was 19h 30m 20s. Find the R.A.M.S.

* L.H.A.	= 20° 15′
long. W.	= 30 00
* G.H.A.	= 50° 15′
* R.A.	= 125° 00′
R.A.M.G.	= 175° 15′
H.A.M.S.G.	= 112 35
R.A.M.S.	= 62° 40′



Notes.—

1. In all these problems, the work is made easier if arc is used throughout.
2. **The formulae required are:—**
   1. **S.M.T. = H.A.M.S. ± 12 hours.**
   2. **A.T.S. = H.A.T.S. ± 12 hours.**
   3. ***R.A. + *L.H.A. = R.A.M.**
   4. **R.A.M.S. + H.A.M.S. = R.A.M.**
   5. **R.A.T.S. + H.A.T.S. = R.A.M.**
   6. **L.H.A.♈ = R.A.M.**
   7. **Body on the meridian**
      R.A. = R.A.M.

EXERCISE 11A

TIME FORMULAE

1. 28th September 1952, Aries was on the meridian of 75° W. Find the R.A.T.S.
2. 6th October 1952, Aries was on the meridian of 80° W. Find the Sun's R.A.
3. 16th January 1952, at 09h 52m 10s G.M.T., find the R.A.M.S.
4. 29th August 1952, Aries is on the meridian of 70° E. Find the R.A.M.S.
5. 15th January 1952, find the R.A.M.S. at 08h 52m 40s G.M.T.
6. 20th December 1952, in Long. 20° W., the H.A.T.S.=1h 20m. Find the R.A. of the true Sun.

7. G.M.T. is 15h 25m 00s, R.A.M.S. is 7h 18m 10s. The longitude of a star's geographical position is 70° W. Find the star's right ascension.

8. An observer is in longitude 35° E. at 04h 04m 04s G.M.T. The longitude of a star's geographical position is 43° W., and the R.A.M.S. is 16h 18m 10s. Find the star's R.A.

9. 6th October 1952, Aries is on the meridian of 80° E. Find the R.A.T.S.

EXERCISE 12

CORRECTION OF ALTITUDES

Before commencing the problems, read Chapter VII., pages 185 to 206, *Principles for Second Mates.*

CORRECTION OF THE SUN'S ALTITUDE

Example.

The sextant altitude of the Sun's lower limb was 45° 20′, index error 1·2′ on the arc; height of eye 50 ft.; Sun's semi-diameter 15·9′. Find the true altitude of the Sun's centre.

Sext. alt.		45° 20·0′
I.E.	—	1·2
Obs. alt.		45° 18·8′
dip	—	6·93
		45° 11·87′
S.D.	+	15·9′
App. alt.		45° 27·77′
ref.	—	0·96′
		45° 26·81′
par.	+	0·1
True alt.		45° 26·91′

Notes.—

1. The corrections for dip, refraction, and parallax-in-altitude are obtained from the appropriate tables in *Nories, Burtons,* etc.
2. The Sun's semi-diameter is obtained from the daily page for the given date in the *Nautical Almanac.*
3. The corrections for index error, dip, and semi-diameter must be made in the order shown. Whether the correction for refraction is applied before the correction for parallax-in-altitude, or *vice versa,* is immaterial.

CORRECTION OF AN ALTITUDE BY "BACK ANGLE," OR "REVERSE HORIZON".

Example.

The sextant altitude of the Sun's lower limb by back angle, was 102° 00′, index error 4′ 30″ on the arc; height of eye 22 feet; Sun's semi-diameter 16·1′. Find the true altitude of the Sun's centre.

Sext. alt.		102° 00·0′
I.E.	—	4·5′
Obs. alt.		101° 55·5′
dip	—	4·6′
		101° 50·9′
S.D.	+	16·1′
App. alt.		102° 07·0′
		180°
		77° 53·0′
ref.	—	0·2′
		77° 52·8′
par.	+	0·0′
True alt.		77° 52·8′

Notes.—

1. The corrections for index error, dip, and semi-diameter are applied in the usual way.
2. By subtracting the apparent altitude fom 180°, the corrections for refraction and parallax-in-altitude can then be applied in the usual way.

ALTITUDE OF THE SUN BY ARTIFICIAL HORIZON.

Read pages 204 to 205, *Principles for Second Mates.*

Example.

The sextant altitude of the Sun's lower limb by artificial horizon was 107° 41·5′; index error 2·5′ on the arc; Sun's semi-diameter 16·0′.

Find the true altitude of the Sun's centre.

Sext. alt.		107° 41·5′
Ind. err.	—	2·5′
		2)107° 39·0′
		53° 49·5′
Semi-dia.	+	16·0′
		54° 05·5′
ref.	—	0·7′
		54° 04·8′
par-in-alt.	+	0·1′
True alt.		54° 04·9′

Notes.—

1. The angle obtained after applying index error is divided by two, since the image appears as far behind the surface of the mirror as the Sun is in front of the reflecting surface.
2. The artificial horizon is a horizontal surface which lies in the plane of the celestial horizon, so that no correction for height of eye is applied.

EXERCISE 12A

CORRECTION OF THE SUN'S ALTITUDE

These examples are to be worked *fully* (as shown), as if they occurred in a Principles paper.

Find the true altitude of the Sun's centre, given.

1. The sextant altitude of the Sun's lower limb was 52° 31·2,; index error 2·2′ on the arc; height of eye 28 feet; Sun's semi-diameter 16·1′.

2. The sextant altitude of the Sun's L.L. 33° 10′ 50″; I.E. 1·0′ off the arc; H.E. 40 feet; S.D. 15·9′.

3. Sextant altitude U.L. 71° 53′ 30″; index error 1′ 50″ off the arc; H.E. 36 feet; S.D. 16·0′.

4. The observed altitude of the Sun's upper limb was 27° 46′ 40″; height of eye 25 feet; semi-diameter 15·8′.

5. Sextant alt. L.L. 62° 34·3′; I.E. 2·2′ off the arc; H.E. 30 feet; S.D. 16·1′.

6. Sextant altitude of the Sun's upper limb was 55° 55′ 50″, index error 1′ 00″ on the arc; height of eye 24 feet; semi-diameter 16·3′.

7. The sextant altitude of the Sun's lower limb by back angle was 110° 51·6'; index error 2·2' off the arc; H.E. 38 feet; semi-diameter 16·2'.

8. The sextant altitude of the Sun's upper limb by reverse horizon was 98° 24·4'; index error 1·2' off the arc; height of eye 34 feet; semi-diameter 16·1'.

9. Sextant altitude of the Sun's lower limb by artificial horizon was 96° 37' 10"; index error 1' 20" on the arc; semi-diameter 16·0'; height of eye 40 feet.

10. The sextant altitude of the Sun's upper limb by artificial horizon was 103° 56·4'; index error on the arc was 2·4'; height of eye 50 feet; semi-diameter 15·8'.

CORRECTION OF THE MOON'S ALTITUDE

Read pages 191 to 198, *Principles for Second Mates*. Note why the Moon's semi-diameter is augmented, and why the horizontal parallax is reduced for latitude. Also note why the parallax in altitude is added to the apparent altitude to obtain the true altitude, these points are most important.

Example.

The sextant altitude of the Moon's lower limb was 16° 58·2', index error 0·8' off the arc, height of eye 18 feet, semi-diameter 15·2', horizontal parallax 55·7', and latitude 12° 50' N. Find the true altitude of the Moon's centre.

Sextant altitude		16° 58·2'
Index error	+	0·8'
Observed alt.		16° 59·0'
dip	—	4·16'
		16° 54·84'
Semi-diameter	+	15·27'
Apparent alt.		17° 10·11'
par.-in-alt.	+	53·22'
		18° 03·33'
refraction	—	3·05'
True altitude		18° 00·28'

Semi-diameter	15·2'	
augmentation	0·07'	
Augmented S.D.	15·27'	
Hor. par.	55·7'	
reduction	Nil	
Reduced H.P.	55·7'	
par.-in-alt.		logs
= R.H.P. × cos app. alt.		1·74586
=55·7' × cos 17° 10·11'		9·98021
=53·22'		1·72607

Notes.—

1. When the semi-diameter and horizontal parallax are taken from the *Nautical Almanac*, interpolate for G.M.T., where necessary.
2. The corrections for augmentation of the Moon's semi-diameter, and the reduction for latitude to apply to the Equatorial horizontal parallax, are taken from tables D and E, respectively; these tables being given in *Burton's*, *Norie's*, etc.
3. Working to the second place of decimals, as shown, is not necessary—it is done here, as a check on your working.

EXERCISE 12B

CORRECTION OF THE MOON'S ALTITUDE

From the following information, find the true altitude of the Moon's centre.

	Obs. limb	Sext. Alt.	Index Error	Ht. of eye	S.D.	H.P.	Lat.
1.	L.L.	63° 12·8'	1·6' off the arc	24 ft.	15·3'	56·0'	50° N.
2.	L.L.	34° 14·8'	2·2' on the arc	42 ft.	15·1'	55·4'	39° S.
3.	U.L.	58° 16·2'	1·0' on the arc	34 ft.	16·1'	59·2'	44° N.
4.	U.L.	77° 51·6'	1·2' off the arc	30 ft.	14·8'	54·5'	22° N.
5.	L.L.	21° 38·8'	3·4' on the arc	38 ft.	15·8'	58·1'	00
6.	L.L.	38° 21·8'	2·4' off the arc	30 ft.	16·3'	59·7'	41° 10'S.
7.	U.L.	51° 17·0'	1·6' on the arc	52 ft.	14·9'	54·6'	37° 20'N.
8.	L.L.	43° 18·4'	Nil	45 ft.	16·6'	61·0'	25° 15'S.

CORRECTION OF THE ALTITUDE OF A STAR OR A PLANET

Read page 202, *Principles for Second Mates*. Note why, in the correcting of these altitudes, the corrections for semi-diameter and parallax-in-altitude are not applied.

Example.

Find the true altitude of the star Rigel 11, the sextant altitude of the star being 29° 17·2', index error 1·8' off the arc, and height of eye 46 feet.

Sext. Alt.	29°	17·2′
I.E.	+	1·8′
Obs. alt.	29°	19·0′
dip	—	6·6′
	29°	12·4′
ref.	—	1·7′
True alt.	29°	10·7′

EXERCISE 12C

FIND THE TRUE ALTITUDE OF THE FOLLOWING BODIES

	Sext. Alt.	*Ind. Error*	*Ht. of eye*	*Body*
1.	47° 29·6′	1·0′ on the arc	37 feet	Altair
2.	32° 24·4′	0·8′ on the arc	24 feet	Canopus
3.	21° 13·6′	0·4′ off the arc	38 feet	Arcturus
4.	47° 15·8′	1·4′ on the arc	50 feet	Polaris
5.	37° 10·4′	1·8′ on the arc	28 feet	Gruis
6.	12° 17·0′	2·0′ off the arc	46 feet	Saturn
7.	53° 20·2′	0·6′ on the arc	25 feet	Venus
8.	23° 14·0′	2·2′ off the arc	36 feet	Jupiter
9.	51° 56·0′	0·4′ on the arc	56 feet	Mars
10.	14° 38·2′	2·8′ on the arc	32 feet	Venus

EXERCISE 13

LATITUDE BY MERIDIAN ALTITUDE OF A STAR

Read pages 225 to 229, *Principles for Second Mates*; see also pages 260, 261, for figure drawing.

Steps in the problem.

1. Take out the star's declination for the appropriate month, in the *Nautical Almanac*.

2. Correct the sextant altitude for:—
   (*a*) Index error (on the arc is minus; off the arc is plus).
   (*b*) Height of eye. (H.E.) } from tables on the inside of the
   (*c*) Main correction. } cover of the *Nautical Almanac*.

3. Take the true altitude from 90° to obtain the zenith distance (reverse the name of the bearing, and apply to it).

4. Apply the declination to the zenith distance to obtain the latitude.

5. The bearing is either 000° T. or 180° T., so that the P.L. trends 090° T.—270° T. through position lat. (by observation), long. (by D.R.)

Note.—

If the bearing of the star on the meridian is given, reverse the name and apply to the zenith distance, then to obtain the latitude:—

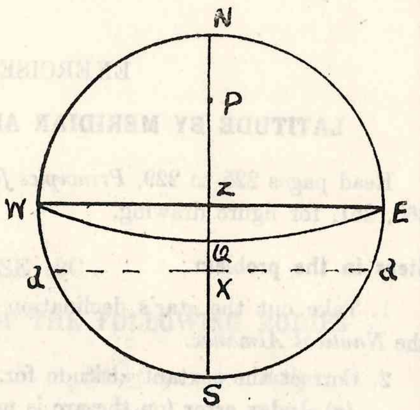
Zenith distance and declination the same names—ADD
" " " " different names—take their difference, and name the latitude the same as the greater.

This applies in all meridian altitude problems, and ex-meridian altitude problems except latitude by Polaris, and latitude by a star on the meridian below the Pole.

Example.

18th December 1952, the sextant altitude of the star *Diphda* 4 on the meridian, bearing 180° T., was 46° 15·4′, index error 1·4′ on the arc, height of eye 40 feet, D.R. position lat. 25° 33′ N., long. 33° 52′ W. Find the latitude and P.L.

Sext. alt.	46° 15·4′ S.	Dec. 18° 14·7′ S.	
ind. err. —	1·4		
Obs. alt.	46 14·0		
dip —	6·3		
	46 07·7		
main corr. —	0·9		
True alt.	46 06·8 S.		
	90		
zen. dist.	43° 53·2′ N.		
dec.	18° 14·7′ S.		
lat.	25° 38·5′ N.		



P.L. trends 090° T. — 270° T. through lat. 25° 38·5′ N., long. 33° 52′ W.

EXERCISE 13A

1. 28th September 1952, to an observer in long. 42° 10′ W., the sextant altitude of *Mirfak* 9, on the meridian, was 63° 18·6′, index error 1·4′ off the arc, height of eye 48 feet, the star bearing 000° T. Find the latitude and P.L.

2. 16th December 1952, the sextant altitude of *Diphda* 4 on the meridian, and bearing 180° T. to an observer in long. 18° 30′ W., was 57° 10·8′, index error 1·2′ off the arc, height of eye 35 feet. Find the P.L. and latitude of the point through which it is drawn.

3. 16th January 1952, in D.R. position lat. 01° 30′ N. long. 42° 10′ W. the sextant altitude of the star *Acrux* 30, on the meridian, was 25° 52·4′, index error 0·6′ on the arc, height of eye 50 feet. Find the latitude and the P.L.

4. 10th September 1952, β *Ophiuchi* was observed on the meridian bearing 180° T., sextant altitude 45° 15·8′, index error 0·4′ on the arc, height of eye 48 feet. Find the latitude and P.L.

5. 29th August 1952. Find the latitude of an observer, given:— sextant altitude of *Capella* 12, on the meridian, was 32° 06·4′, bearing 000° T., index error 1·8′ off the arc, height of eye 39 feet.

LATITUDE BY A STAR ON THE MERIDIAN BELOW THE POLE

Steps in the problem.

1. Take out the star's declination for the month, from the *Nautical Almanac*.
2. Subtract the declination from 90° to obtain the Polar distance.
3. Correct the altitude of the star.
4. Add the Polar distance to the true altitude to obtain the latitude.
5. Name the latitude the same as the declination.

Note.

When a body is on the meridian below the Pole:

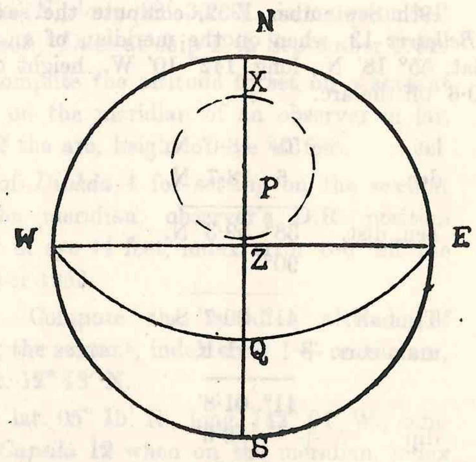
lat. = true alt. + Polar dist.

(See page 227, *Principles for Second Mates*, for proof.)

Example.

18th September 1952, the sextant altitude of *Eltanin* 47 on the meridian below the pole, was 12° 26·4′, index error 0·8′ on the arc, height of eye 32 feet. Find the latitude.

Sext. alt.	12° 26·4′	Dec.	51° 29·8′ N.
ind. err. —	0·8′		90
Obs. alt.	12° 25·6′	Polar dist.	38° 30·2′
dip —	5·7′		
	12° 19·9′		
main corr. —	4·3′		
True alt.	12° 15·6′		
Polar dist.	38° 30·2′		
lat.	50° 45·8′N.		



EXERCISE 13B

1. The sextant altitude of *Dubhe* 27 on the meridian below the pole, on 18th December 1952, was 33° 26·8′, index error 2·2′ on the arc, height of eye 42 feet. Find the latitude.

2. 16th December 1952, find the latitude by *Vega* 49 on the meridian below the pole, sextant altitude 13° 10·0′, index error 2·4′ on the arc, height of eye 42 feet.

3. 17th January 1952, the sextant altitude of *Acrux* 30 on the meridian below the pole was 26° 18·4′, index error 0·8′ off the arc, height of eye 44 feet. Find the latitude.

4. 5th October 1952, the star *Atria* was observed at its lower transit, sextant altitude 23° 15·8′, index error 1·2′ off the arc, height of eye 46 feet. Find the latitude.

5. 2nd August 1952, the sextant altitude of *Kochab* 40, on the meridian below the pole, was 33° 08·6′, index error 1·4′ on the arc, height of eye 41 feet. Find the latitude.

COMPUTING THE ALTITUDE OF A STAR ON THE MERIDIAN

This problem arises when it is desired to obtain the latitude by meridian altitude of a star. A suitable star is chosen and its altitude is computed. The angle is clamped on the sextant, and the horizon is swept until the star is picked up, after which its meridian altitude is observed.

Example.

19th September 1952, compute the sextant altitude of the star *Bellatrix* 13, when on the meridian of an observer in D.R. position lat. 55° 18′ N., long. 142° 10′ W., height of eye 44 feet, index error 0·6′ off the arc.

lat.		55° 18·0′ N.
dec.		6 18·7 N.
Zen. dist.		38° 59·3′ N.
		90°
True alt.		41° 00·7′ S.
main corr.	+	1·1′
		41° 01·8′
dip	+	6·6′
Obs. alt.		41° 08·4′
I.E.	—	0·6′
Sext. alt.		41° 07·8′ S.

Computed sext. alt. 41° 07·8′, star bearing 180° T.

Steps in the problem.

1. Obtain the zenith distance from the latitude and declination. To do this, mentally change the name of the declination and add the two quantities, for example:—

lat. 15° N. dec. 40° N. (S), zenith distance = 25° S.
,, 35° N. ,, 10° N. (S), zenith distance = 25° N.
,, 34° S. ,, 15° N. (S), zenith distance = 49° S.
,, 50° N. ,, 6° S. (N), zenith distance = 56° N.

2. Subtract the zenith distance from 90° to obtain the true altitude, giving it the *opposite* name to the zenith distance.

3. Apply the main correction, dip correction, and the index error with reversed signs to obtain the sextant altitude; the name will be the bearing of the star when on the meridian. Alternatively, obtain the bearing by means of a small figure.

EXERCISE 13C

1. Compute the sextant altitude of *Eltanin* on the meridian to an observer in E.P. lat. 35° 50′ N., long. 22° 30′ W., index error 0·4′ off the arc, height of eye 28 feet. Date at ship 19th September 1952.

2. 16th January 1952: Compute the altitude to set on a sextant for observation of *Acrux* 30 on the meridian of an observer in lat. 35° 10′ S., index error 1·2′ off the arc, height of eye 40 feet.

3. Compute the altitude of *Diphda* 4 for setting on the sextant for observation when on the meridian, observer's D.R. position 39° 20′ N., 35° 10′ W., height of eye 44 feet, index error 0·6′ off the arc, date at ship 15th December 1952.

4. 23rd September 1952. Compute the meridian altitude of *Mirfak* 9 as a guide to setting the sextant, index error 1·8′ on the arc, height of eye 54 feet, D.R. lat. 12° 18′ N.

5. 25th August 1952, E.P. lat. 05° 15′ N., long. 142° 04′ W., compute the sextant altitude of *Capella* 12 when on the meridian, index error 2·2′ off the arc, height of eye 57 feet.

LATITUDE BY MERIDIAN ALTITUDE OF THE SUN

The Sun is on the meridian of any observer at 12h 00m 00s A.T.S. To take the Sun's declination from the *Nautical Almanac*, the G.M.T.

of observation is required. From the A.T.S. the G.M.T. can be found as follows:—

		h m s	
A.T.S.	=		
long. in time	=		(long. E. subtract, W. add)
A.T.G.	=		
Eq. of Time	=		(use A.T.G. and interpolate for Equ. of Time on page 10 of the *N.A.* Note the sign of application, which is to apparent time.)
G.M.T.	=		

This process is followed in all cases where A.T.S. is given, and G.M.T. is required. When dealing with the time of transit of the Sun however, there is no need to use the above process, since on each daily page of the *Nautical Almanac*, there is tabulated at the foot of the column headed Sun, a quantity T, which is the mean time of apparent noon (to the nearest minute) for the day. Therefore, to find the G.M.T. in this problem, proceed thus:—

		h m	
T	=		
long. in time	=		(long. E. subtract, W. add)
G.M.T.			

Note:—In practice, the G.M.T. will be obtained from the chronometer time.

Steps in the problem.

1. Find the G.M.T.
2. Take out the declination for the G.M.T.
3. Correct the altitude.
4. Take the true altitude from 90° to obtain the zenith distance.
5. latitude = zenith distance $\pm$ Dec.
6. State the answer at the end.

Notes.—

Put the bearing of the Sun, *i.e.*, N. or S. after the sextant altitude and the true altitude. Apply the reverse name to the zenith distance, then,

lat. = zen. dist. + dec. (if the names are the same)

lat. = zen. dist. $\sim$ dec. (if the names are different, and name the lat. the same as the greater)

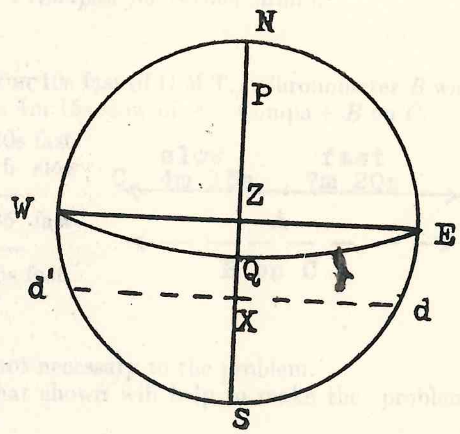
If the bearing is not given, it can easily be found from the D.R. lat. and the dec. For example, if the lat. is 50° N. and the dec. is 20° N., then the Sun's bearing is 180° T.

Example.

15th December 1952, in D.R. position 22° 05′ N., 154° 20′ W., the sextant altitude of the Sun's L.L. on the meridian was 44° 20·8′, index error 0·4′ off the arc, height of eye 50 feet. Find the latitude and P.L.

T	=	11h 55m 00s	Dec. 23° 18·4′ S.
long. in time	=	10 17 20	
G.M.T.	=	22 12 20 (15th)	

Sext. alt.		44° 20·8′ S.
I.E.	+	0·4′
obs. alt.		44° 21·2′
dip.	—	7·0′
		44° 14·2′
main corr.	+	15·3′
True alt.		44° 29·5′ S.
		90
zen. dist.		45° 30·5′ N.
dec.		23 18·4 S.
latitude		22° 12·1′ N.



P.L. trends 090° T. — 270° T. through lat. 22° 12·1′ N., long. 154° 20′ W.

EXERCISE 13D

1. 18th December 1952, in D.R. position lat. 00° 20′ N., long. 162° 20′ W., the sextant altitude of the Sun's lower limb on the meridian was 66° 10·4′ bearing South, index error 1·2′ on the arc, height of eye 44 feet. Find the latitude and P.L.

2. 29th August 1952, the sextant altitude of the Sun's lower limb when on the meridian was 41° 26·4′, index error 2·4′ off the arc, height of eye 24 feet. The D.R. position of the observer was lat. 39° 10′ S., long. 40° 20′ W. Find the latitude and P.L.

3. 16th January 1952, an observation of the Sun on the meridian by an observer in E.P. 49° 50′ S., 96° 35′ W., gave the sextant altitude

of the Sun's upper limb 61° 25′, index error was 1·4′ on the arc, height of eye 38 feet. Find the latitude and P.L.

4. From the following data, find the latitude and P.L.
Date at ship, 14th December 1952.
Observer's E.P. lat. 35° 10′ N., long. 165° 30′ E.
Body observed:—the Sun on the meridian, bearing 180° T., sextant altitude of the lower limb 31° 22·4′, index error 1·6′ off the arc, height of eye 46 feet.

5. 17th January 1952, an observation of the Sun on the meridian bearing 180° T., gave the sext. alt. of the Sun's lower limb as 32° 10·4′, index error 1·6′ off the arc, height of eye 42 feet. The D.R. long. was 141° 10·8′ E.

Find the latitude and position line.

EXERCISE 14

CHRONOMETER RATES AND ERRORS

Treat these problems as purely commonsense. Do not attempt them by stereotyped methods. The following examples and problems do not cover every possible variation in the problems, but they will present some clear ideas, which can be utilised when attempting problems.

Read pages 270 to 273, *Principles for Second Mates*.

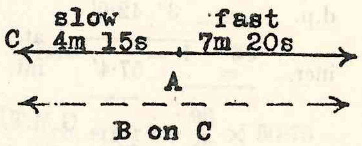
Examples.

1. Chronometer *A* was 25m 10s fast of G.M.T. Chronometer *B* was 7m 20s fast of *A*, and *C* was 4m 15s slow of *A*. Compare *B* on *C*.

B on *A*, error = 7m 20s fast
C on *A*, error = 4 15 slow

B on *C*, error = 11 35 fast

B's error on *C* = 11m 35s fast.

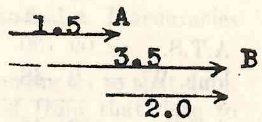


Notes.

1. Error of *A* on G.M.T. is not necessary to the problem.
2. A small figure such as that shown will help to make the problem clear.

2. Chronometer *A* is gaining 1·5s daily. Chronometer *B* is gaining 3·5s daily. *A* is 15m 2s fast of *B*. What will be the error of *B* on *A* at the end of a further 40 days?

A's daily rate = 1·5s gain
B's ,, ,, = 3·5 ,,



B apparent ,, = 2·0 ,, on *A*
× 40

∴ *B*'s gain on *A* = 80·0

B's 1st error on *A* = 15m 2s slow
B's accumulated error on *A* } = 1 20 gain

∴ *B*'s error on *A* = 13m 42s slow

Note.—

The daily rate of *A* and of *B* is known. Therefore the apparent rate of *B* on *A* can be found. From this, the accumulated error of *B* on *A* is obtained.

3. 18th October 1952, in long. 42° 10′ W. at 0920 hours approximate time ship, an observation was taken, which gave Sun's L.H.A. 322° 30′. The time shown by a chronometer was 00h 18m 40s. Find the chronometer error.

Chron. time	12h	18m	40s

Approx. T.S.	09h	20m	00s
long. W.	2	48	40
Approx. T.G.	12	08	40

☉L.H.A. =	322° 30·0′						
long W. =	42° 10·0′						
☉G.H.A. =	364° 40·0′						
	360°						
☉G.H.A. =	4° 40·0′						
d.p. =	3° 42·6′	at	12h	00m	00s	G.M.T.	
incr. =	57·4′	int.		3	50		
		G.M.T. =	12	03	50		
		Chron. time =	12	18	40		
		error =		14	50	fast of G.M.T.	

Alternative.

☉L.H.A. =	322° 30′		
∴ H.A.T.S. =	21h	30m	00s
	12		
A.T.S. =	09	30	00
long. W. =	2	48	40
A.T.G. =	12	18	40
E.T. =	—	14	50
G.M.T. =	12	03	50
Chron. =	12	18	40
Error =		14	50 fast of G.M.T.

4. 22nd August 1952, in 52° 00′ N., 162° 00′ W., at about 1900 hours at ship, a chronometer showed 05h 40m 10s. On 17th May the chronometer was 4m 10s fast of G.M.T., and on 3rd July it was 2m 32s fast of G.M.T. (all comparisons at 1200 hours G.M.T.). Find the correct G.M.T.

Approx. T.S. =	19h	00m	00s	(22nd)
long. in time =	10	48	00	
Approx. T.G. =	05	48	00	(23rd)

1st No. of days	*2nd No. of days*
138·5	185·5
185·5	236·25
47·0	50·75

Chron. Time =	05h	40m	10s	
2nd Error =	— 2		32	
	05	37	38	
Acc. error =	+	1	45·8	
G.M.T. =	05	39	23·8	(23rd)

1st Error =	4m	10s	(fast)
2nd ,, =	2	32	,,
Loss =	1	38	

$$\text{Acc. error} = \frac{98}{47} \times 50{\cdot}75$$
$$= 105{\cdot}8 \text{ (loss)}$$

Notes.—

1. For finding the number of days in the given period, use the number appropriate to the day, as given in the *Nautical Almanac.* The number of hours in any time is used as a decimal of a day, *e.g.*, 05h 48m = 0·25 days. There will be a constant error of 1 day in each figure, but the final results are unaffected.
2. Unless the daily rate is asked for, do not bother to find it. Inaccuracies may result.
3. Apply the 2nd error, which will correct the chronometer to that date, then apply the error which has accumulated from that date to the given date and time.
4. In all problems where the chronometer time is given, be certain, always, to find the approximate time at Greenwich, so that the correct number of hours, and date can be used in the chronometer time, and thus, the G.M.T.
5. Observations gave a vessel's longitude as 17° 06′ E. She then steamed 090° T. 50 M., when a point of land (34° 21′ S., 18° 29′ E.)

bore 060° T. 10 M. Find the chronometer error, if the error used was 3m 10s fast.

Position of point	34° 21′ S.	18° 29′ E.	
from bearing	05′ S.	10·5′ W.	(S.60°W. 10M., d. lat. =5′S., dep.=8·7M.)
	34° 26′ S.	18° 18·5′ E.	
from course & dist.		1° 00·0′ W.	(090°T. 50M., dep. = 50 M.)
Ship's actual pos.	34° 26′ S.	17° 18·5′ E.	
Calculated long.		17° 06·0′ E.	
Error		12·5′ W.	
		— 50 seconds (of time)	

Estimated chron. error	3m 10s	(fast)
error	50	
Actual chron. error	4m 00s	fast of G.M.T.

Notes.—

1. In this problem, it is best to calculate the ship's actual position at the time of observation, and, so obtain the error in longitude.
2. Change the longitude error into time.
3. In this case the G.M.T. used, was obviously too large. The chronometer error must have been too small, since it was fast.

EXERCISE 14

1. Chronometer *A* was 32m 28s fast of G.M.T. Chronometer *B* was 11m 35s slow of *A*, and *C* was 23m 00s slow of *A*. Compare *B* and *C*.

2. Chronometer *A* was 3m 10s slow of G.M.T. Chronometer *B* was 15m 42s fast of *A*, and *C* was 27m 10s slow of *B*. Compare *C* with *A*.

3. Chronometer *A* is losing 2 seconds daily, *B* is gaining 3·2 seconds daily. *A* is 10m 15s fast of *B*. What will be their difference after 20 days?

4. Chronometer *A* is 2m 31s fast of *B*, and its daily rate is 2·5 seconds gaining. At the end of 20 days, *A* is 3m 1s fast of *B*. Find the daily rate of B.

5. Chronometer *A* is losing 2 seconds daily, *B* is gaining 3·2 seconds daily. *A* is 10m 15s slow of *B*. What will be the error of *B* on *A* at the end of 20 days?

6. A chronometer while in port gained 2·7 seconds daily. At sea on 10th June, it was 15m 52s fast of G.M.T. by W/T time signal. On 20th June it was 16m 35s fast of G.M.T. by the same time signal. Compare the port and sea rates.

7. 26th March 1952, a chronometer showed 08h 50m 20s. On 6th January 1952, the chronometer was 2m 12s slow of G.M.T., and on 5th March it was 0m 14s slow of G.M.T. Find the correct G.M.T., all comparisons being made at 1200 hours G.M.T.

8. On 1st May, 1952, at about 1900 hours at ship, in long. 45° 10′ E., the time shown by a chronometer was 3h 17m 58s. On 2nd January, it was 1m 58s slow, and on 29th February, it was 1m 58s fast of G.M.T. the comparisons being made at 1200 hours G.M.T. Find the correct G.M.T.

9. 16th September 1952, in long. 32° 50′ E. the Sun's L.H.A. was 47° 47·5′, the time shown by a chronometer was 01h 34m 20s. Find the chronometer error.

10. At a position on the meridian of 23° 10′ E., on 28th September 1952, the calculated L.H.A. of the Sun was 47° 49·5′, when a chronometer showed 1h 38m 39s. Find the chronometer error.

11. 29th August 1952, in long. 40° 00′ W., the L.H.A. of the Sun was 76° 22·5′, when a chronometer showed 7h 44m 05s. Find the chronometer error.

12. At 12h 00m 00s G.M.T. on 1st May 1952, chronometer *A* was 32m 5s fast of G.M.T., while *B* was 10m 30s slow of *A*. At 12h 00m 00s G.M.T. on 31st May, *A* was 29m 15s fast of G.M.T., while *B* was 9m 3s slow of *A*. What entries should be made in the *Chronometer Journal* on 10th June 1952 at 12h 00m 00s G.M.T.?

13. 1st November 1952, in long. 43° 15′ W., at 0930 hours approximate S.M.T., an observation was taken when the chronometer showed 00h 15m 11s. The chronometer was correct on 10th July, and its daily rate was 2·1 seconds gaining. Find the correct G.M.T. at the time of observation.

14. Chronometer *A* is gaining 1·5 seconds daily, and chronometer *B* is losing 2 seconds daily. On 22nd March 1952, *A* was 5m 15s slow on G.M.T., while *B* was correct on G.M.T. What was the error of *B* on *A* on 11th April 1952?

15. On 1st March 1952, chronometer *B* was 1m 25s slow of *A*, and on 26th March it was 15 secs. fast of *A*. If the daily rate of *A* is 1·5 secs. losing, find the daily rate of *B*.

16. 13th July 1952, approximate time at ship 1750, in long. 40° 00′W., a chronometer showed 8h 30m 40s. On 28th February it was 1m 7s slow of G.M.T., and on 15th April, it was 1m 14s fast of G.M.T. (all comparisons being made at 12h 00m 00s G.M.T.). Find the correct G.M.T.

17. 2nd June 1952, chronometer B was 1m 11s slow of A, and again, on 30th June, B was 2m 22s slow of A. If the daily rate of A was 2 secs. gaining, what was the daily rate of chronometer B?

18. Chronometer A is 4m 20s fast of G.M.T., and chronometer B is 5m 24s slow of A. An observation worked with the time by B, gave long. 30° 17′ W. If the error on B was omitted when the observation was worked out, what was the actual longitude?

EXERCISE 15

AMPLITUDES

General.

The observing of the amplitude of a celestial body (Sun, Moon, or a planet), *i.e.*, the bearing of the body when rising or setting, is one of the methods used at sea for finding the deviation of the compass for the direction of the ship's head at the time of taking the observation.

It must be remembered that the true altitude of the body's centre should be 00° 00′ at the time of observation, so that in practical work, due allowance must be made for—height of eye, S.D., parallax and refraction. (See *Principles for Second Mates*, pages 187, 201, 205). In problems for exercise, it is always assumed that the true altitude is 00° 00′.

Before attempting problems, be certain that you understand and know the meaning of each and every term used. Further, realise why the terms deviation, variation and error arise, viz:—because there are three north points—compass, magnetic, and true. Brief definitions have already been given in the section on correction of courses.

Amplitude.—The amplitude of a body is the angle between the east point and the body when rising, and the west point and the body when setting. (Read page 187, *Principles for Second Mates.*)

Steps in the problem.

1. From the time given, ascertain the G.M.T., and its date.
2. From the *Nautical Almanac*, take out the Sun's declination.
3. Obtain the true amplitude of the body. This may be done by any one of three methods:—
   (*a*) Calculation, by using the formula:
   sine true amplitude = sine dec. × sec. lat.
   (*b*) The amplitude table in nautical tables such as *Norie's*, *Burton's*, etc.
   (*c*) Alt-azimuth tables.
4. Name the amplitude:
   E. if a rising body and W. if a setting body — N. or S. according to the name of the declination.
5. Change both the true amplitude and the observed amplitude into bearings in the 3 figure notation.

6. Find the error.
7. Find the deviation.

The last steps have been dealt with in Exercise 5—correction of courses—therefore, only a brief recapitulation should be necessary.

Dev. = error − var.

Treat the E. and W. signs as though they were plus and minus signs. That is, mentally or as shown in the examples, change the name of the variation, then apply to the error, using the "Rule of signs".

Error	12° W.	10° E.	20° W.	8° W.
Var.	5 W(E)	15 E.(W)	30 W.(E)	6 E.(W)
Dev.	7° W.	5° W.	10° E.	14° W.

Note.—See page 262, *Principles for Second Mates* for figure drawing.

Example.

27th October 1952, in D.R. position lat. 36° 10′ N., long. 28° 20′ W., at 06h 17m 30s S.M.T., the Sun rose bearing 112° C. Find the true amplitude, and, if the variation was 18° W., find the deviation for the direction of the ship's head.

S.M.T.	06h	17m	30s	d.p.	12°	48·3′ S.
long. W.	1	53	20	d		0·1
G.M.T.	08	10	50 (27th)	Dec.	12	48·4 S.

sine true amp. = sine dec. × sec lat.
= sine 12° 48·4′ × sec 36° 10′

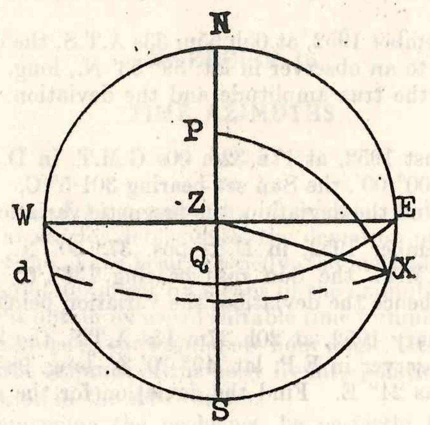
True amp.	=	E. 15° 56·2′ S.
Bearing	=	105° 56·2′ T.
,,	=	112 00·0 C.
Error	=	6 03·8 W.
Var.	=	18 00·0 W.
Dev.	=	11° 56·2′ E.

number	log
sin 12° 48·4′	9·34569
sec 36° 10′	10·09296
	9·43865

Notes.

1. It does not matter whether the body observed is the Sun, the Moon, or a planet, the above problem is typical. (See page 201, *Principles for Second Mates*, on time at which amplitudes should be taken.)
2. When the declination is 00° the body rises 090° T., and sets 270° T.
3. When the latitude is 00°, the true amplitude = declination.

4. It may happen that no time is stated in the problem; in such a case, use the times of Sunrise and Sunset given in the *Nautical Almanac*.



Example.

Find the G.M.T. of Sunrise, 16th September 1952, in lat. 47° 10′ N., long. 38° 20′ W.

S.M.T. sunrise	05h	38m	00s	(for lat. 45° N.)
lat. corr.	—	1	00	(diff. for 5° = 2m)
S.M.T. sunrise	05	37	00	(for lat. 47° 10′ N.)
long. in time W.	2	33	20	
G.M.T.	08	10	20	

The time of Sunrise is taken out for the 15th September, this being to the nearest minute, the mean of the times of Sunrise for the two days 15th and 16th September. The times of Sunset given on the 16th September, similarly apply to the two days.

Interpolation for the latitude only is necessary, and this can be done mentally, or by use of the table on page 409 in the *Nautical Almanac*. The difference in times of Sunrise and of Sunset on successive days is so small, that interpolation for longitude is not necessary.

5. If the alt.-azimuth tables are used, note that the azimuth, and not the amplitude, is obtained.

EXERCISE 15

1. 6th October 1952, in D.R. position lat. 20° 52′ N., long. 153° 10′ W. at 06h 03m 00s A.T.S., the Sun rose bearing E. 11·5° N. by compass. Find the true amplitude and the deviation, the variation in the locality being 11° E.

2. 23rd September 1952, at 05h 55m 33s A.T.S. the observed amplitude of the Sun to an observer in lat. 39° 53′ N., long. 51° 00′ E., was E. 5° N. Find the true amplitude and the deviation. The variation was 5° E.

3. 29th August 1952, at 17h 32m 00s G.M.T. in D.R. position lat. 40° 20′ S., long. 00° 00′, the Sun set bearing 301·5° C. Find the Sun's true amplitude and the deviation, the magnetic variation being 26° W.

4. 20th December 1952, in D.R. pos. 37° 30′ N., 32° 15′ W. at 07h 11m 00s S.M.T., the Sun rose bearing 138° C. Find the true amplitude and thence the deviation, the variation being 21° W.

5. 16th January 1952, at 20h 37m 13s A.T.S. the Sun set bearing 258° C. to an observer in E.P. lat. 49° 10′ S., long. 98° 45′ W., where the variation was 24° E. Find the deviation for the direction of the ship's head.

6. 29th August 1952, the Sun rose bearing 102° C. to an observer in D.R. position lat. 42° 10′ N., long. 42° 10′ W. Find the deviation of the compass, the variation in the locality being 24·8° W.

EXERCISE 16

TIME AZIMUTHS

General Notes.

The observing of time azimuths of celestial bodies is one of the methods used at sea for determining the deviation of the compass for the direction of the ship's head. Briefly, the method is to observe the compass bearing of an object by means of the azimuth mirror; note the time, and from it obtain by use of suitable time formulae, the hour angle of the body, then using the arguments hour angle, latitude and declination, find the true azimuth of the body by interpolation in the altitude-azimuth tables, or in the ABC tables.

Before commencing the problems, be perfectly familiar with the time formulae likely to be needed, viz:—

1. Longitude = G.M.T. $\sim$ S.M.T.
2. Longitude = A.T.G. $\sim$ A.T.S.
3. L.H.A. = G.H.A. $\left.\begin{matrix}+\text{E.}\\-\text{W.}\end{matrix}\right\}$ longitude
4. *G.H.A. = G.H.A. ♈ + *S.H.A.
5. *L.H.A. = *G.H.A. $\left.\begin{matrix}+\text{E.}\\-\text{W.}\end{matrix}\right\}$ longitude
6. S.M.T. = A.T.S. ± Equation of Time

Read pages 153 to 168, 187, *Principles for Second Mates*, for the definitions of the above terms, and, proofs of the formulae.

From the following figures, note how altitude increases with azimuth (Figs. 16.1, 16.2), but, when the declination is greater than the latitude, the names being the same, the altitude increases the azimuth increases, attains a maximum (the angle of position is then 90°), and then decreases. Thus, in Figure 16.3 the maximum azimuth is attained when the body is at *M*, so that the angle *M* is 90° in the spherical triangle *PZM*.

Steps in the problem.

1. Ascertain the G.M.T. and date from the time given.
2. Take out the necessary elements from the *Nautical Almanac*:—
   for the Sun — the declination and G.H.A.
   for a star — the declination, *S.H.A., and G.H.A. ♈

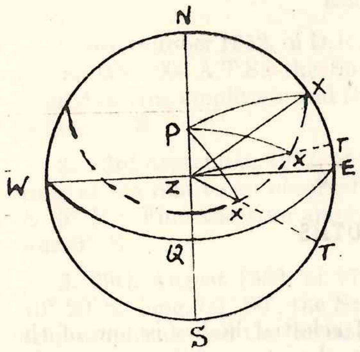


Fig. 16.1

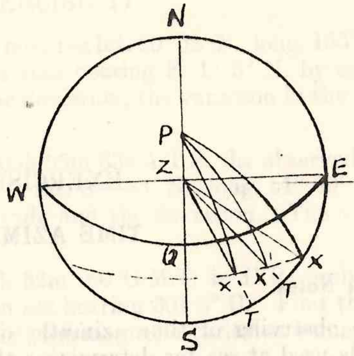


Fig. 16.2

3. By use of time formulae derive the H.A. of the body—use the lesser hour angle, *i.e.*, when the L.H.A. is greater than 180°, subtract from 360° to obtain the H.A.E.

4. Convert the arc into time for entering the altitude-azimuth tables; in the ABC tables arc is used.

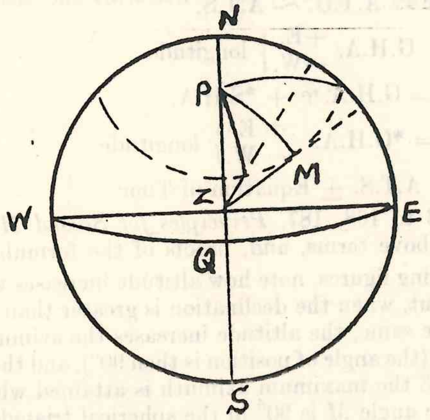


Fig. 16.3

5. With the arguments:—H.A., declination and latitude, enter the appropriate altitude-azimuth table (the tables extend from lat. 30° N. to lat. 30° S. and from lat. 30° to lat. 60° N. or S., with declination from 0° to 21°, additional tables cover latitudes and declinations outside these

limits). Note whether the latitude and declination are of the same or opposite names.

6. To interpolate—first put down three headings—H.A., declination and latitude—then enter the tables:—

(*a*) With the lesser hour angle, the lesser declination, and the lesser latitude take out the azimuth, and put down the value under each of the three headings. The hour angle may be given for 4 minute or 8 minute intervals—the figures in dark type are altitudes, the figures in light type are the azimuths.

(*b*) With the greater hour angle, the lesser declination, and the lesser latitude take out the azimuth and place it under the hour angle heading.

(*c*) With the lesser hour angle and the greater declination and the lesser latitude take out the azimuth and place it under the declination heading.

(*d*) With the lesser hour angle, the lesser declination and the greater latitude take out the azimuth, and place it under the latitude heading.

(*e*) Work out the differences—total them—apply to the "standard" and so obtain the angle at the zenith.

(*f*) Name the azimuth the same as the latitude and the hour angle.

Note:—In using the altitude-azimuth tables, ignore the term A.T.S.—use only the right hand side of the pages, and hour angle. The same methods will apply with all time azimuth problems. Further, do not use the rules on the bottom of each page, use (*f*) above.

7. To find the error and the deviation, the procedure is the same as in the amplitude problems.

8. For figure drawing see page 263, *Principles for Second Mates*.

Example 1.

Given L.H.A. = 3h 15m, lat. = 40° 42′ N., dec. = 16° 20′ S.

To find the true azimuth.

Notice that the lat. and declination are of contrary names. Now enter the tables with lat. 40°, and where the lat. and declination are contrary names. Turn to the page where the hour angle is 3 hours,