CHARTWORK FOR FISHERMEN AND BOAT OPERATORS

G.A. Motte

FISHERIES AND MARINE TECHNOLOGY
SEA GRANT

University of Rhode Island
Marine Bulletin Number 7

ERRATA SHEET NO. 1

Chartwork for Fishermen and Boat Operators, G.A. Motte; University of Rhode Island Marine Bulletin Number 7, Kingston 1972

1. Page 7, diagram: change "PARALLEL OF LONG." to read "PARALLEL OF LAT.".

2. Page 7, diagram: change "EQUATOR LONG." to read "EQUATOR"

3. Page 29, line 17: change to read "NNE $022\frac{1}{2}°$ 7°E NNE $029\frac{1}{2}°$".

4. Page 29, line 22: redraw deviation curve to left of axis to show 1°W deviation on a course of SE.

5. Page 35, question no. 5: change end of first sentence to read "...recorded 30 fathoms.".

6. Page 66, diagram: change "FIRST BEARING 0650" to read "FIRST BEARING 0630".

7. Page 76, diagram: change "D. LAT." to read "DEPARTURE".

8. Page 76, diagram: change "DEPARTURE" to read "D. LAT.".

9. Page 81, line 2: change sixth word to read "measuring".

14 SEP 73

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THE AUTHOR

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Additional copies of this publication at $3.00 each may be obtained from the Marine Advisory Service, University of Rhode Island Narragansett Bay Campus, Narragansett, Rhode Island 02881.

Contents

Note: To keep the text as concise as possible, a working knowledge of logarithms, geometry and basic trigonometry has been assumed.

EXERCISES

In order to complete the exercises, you must have U.S. Coast and Geodetic Survey Charts 1, 71, 1210 and 1211 as well as a set of nautical tables, a pair of parallel rulers and dividers.

Introduction to Chartwork

In general terms, chartwork is used to plot a ship's progress in sight of land while navigation is a similar process used for ships out of sight of land. Chartwork applies basic geometric theories to a ship's course, speed, bearings and position lines. Navigation applies trigonometry to observations of celestial bodies and also obtains position lines from electronic aids to determine a vessel's position.

CARE OF THE CHART

The mariner uses his chart somewhat as a motorist uses a road map. The main difference is that at sea the navigator plots his own roads, or "courses to steer," on the chart. A chart often costs as little as a dollar, but circumstances often render a single chart the most important piece of equipment on board ship. A chart should never be abused nor used for any other purpose than that intended; the safety of your vessel and all aboard her may depend on a *single* chart.

The following rules should be adhered to:

1. Pencil courses and bearings on the chart lightly but firmly with a soft pencil.
2. Keep chart weighted down against gusts of wind which sometimes unexpectedly occur when a vessel alters course.
3. Keep charts flat in a drawer rather than rolled up.
4. Keep charts dry and do not place coffee cups or ashtrays on them.
5. Make sure that your charts are kept up to date by adding corrections published weekly in *Notices to Mariners* which are available in most ports from the Coast Guard or harbor authorities.

The charts available for a required route can be selected from a chart catalog. (See figures on pages 4-5.)

TYPES OF CHARTS

Charts are commonly termed large scale or small scale. When a certain distance on earth is represented by a relatively large distance on the chart, the chart is termed a large-scale chart. A chart requiring less detail, such as an ocean chart, would have the same distance represented by a comparatively small distance and, thus, be termed a small-scale chart.

Chart scale is represented by a ratio, such as 1:200,000, meaning 1 inch on the chart represents 200,000 inches, or about 2.74 nautical miles, on the surface of the earth. (Note that a nautical mile is taken as 6,080 feet.)

World Charts

These charts are on a very small scale and are used for plotting only main ocean routes. They are not generally used for navigation.

Ocean Charts

These are on a small scale, e.g., 1:3,000,000, and are used for deep sea navigation only. Ocean charts show a minimum of detail.

Coastal Charts

These are used for chartwork and are of a conveniently large scale, e.g., 1:200,000. A good coastal chart shows depth of water and the nature of the ocean floor, both in great detail. All lights and buoys, characteristic tidal streams and dangers to navigation also are clearly indicated.

Plan Charts

When minute detail is required and vessels may be maneuvering within only a few feet of shoals and rocks, a considerably larger scale must be used, e.g., 1:20,000. Such a scale is necessary for harbors, anchorages and their approaches.

Miscellaneous Charts

Charts marked with Loran or Decca position lines, meteorological charts and charts marked with lines of magnetic variation come under this category.

Some of the main fishing grounds of the world, such as the Dogger Bank, are specially charted on fishing charts which give such details as "hangups" and seasonal movement of various fish species. The "Kingfisher Charts," produced by the British White Fish Authority, are excellent fishing charts. However, this type of chart should *not* be used for coastal chartwork.

NOTE: $\text{Scale No.} = \dfrac{\text{Distance on Earth in Nautical Miles} \times 6080 \times 12}{\text{Representative Distance on Chart in Inches}}$

Exercise 1. CHART SCALES

1. What distance at sea does a length of 3 inches on a chart of scale 1:200,000 represent?

2. How many inches would be measured on a chart of scale 1:470,940 between two points 10 miles apart?

3. If 2 inches on the chart represent 7.3 miles on the earth, find the scale of that chart.

4. What distance at sea does 6 inches on a chart of scale 1:47,600 represent?

5. What distance on a chart of scale 1:80,000 would be covered by a vessel steaming 17 miles?

6. What scale of chart shows a distance of 12½ nautical miles as 3½ inches?

7. If 7¾ inches on the chart represents 54 miles steamed at sea, what would be the scale of this chart?

8. What scale of chart shows a distance of 23 miles as 4.6 inches?

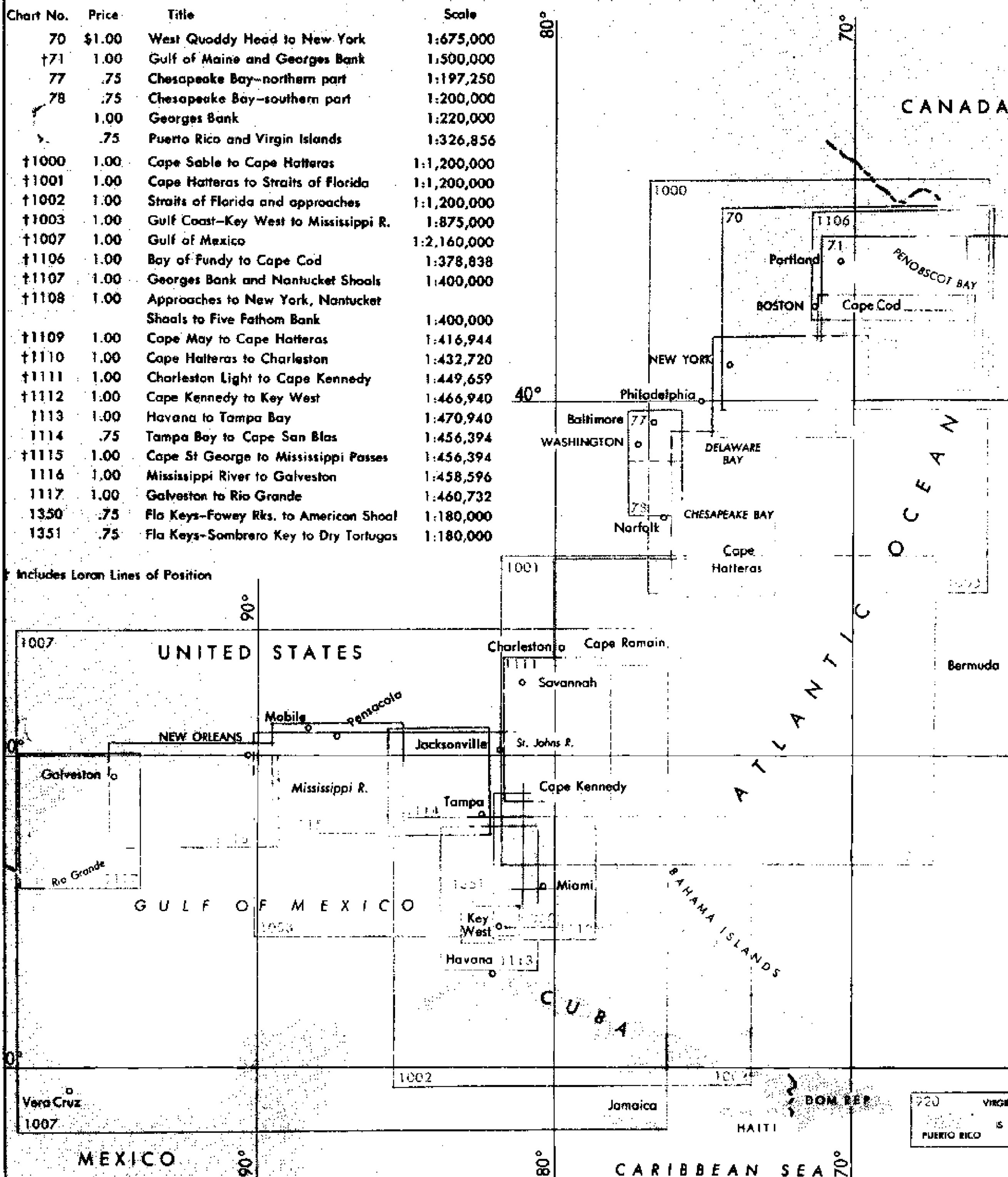
9. What distance would be steamed at sea between two positions 6 inches apart on a chart of scale 1:47,000?

10. If a vessel steams 840 miles, what distance would this be indicated by on a chart of scale 1:2,160,000?

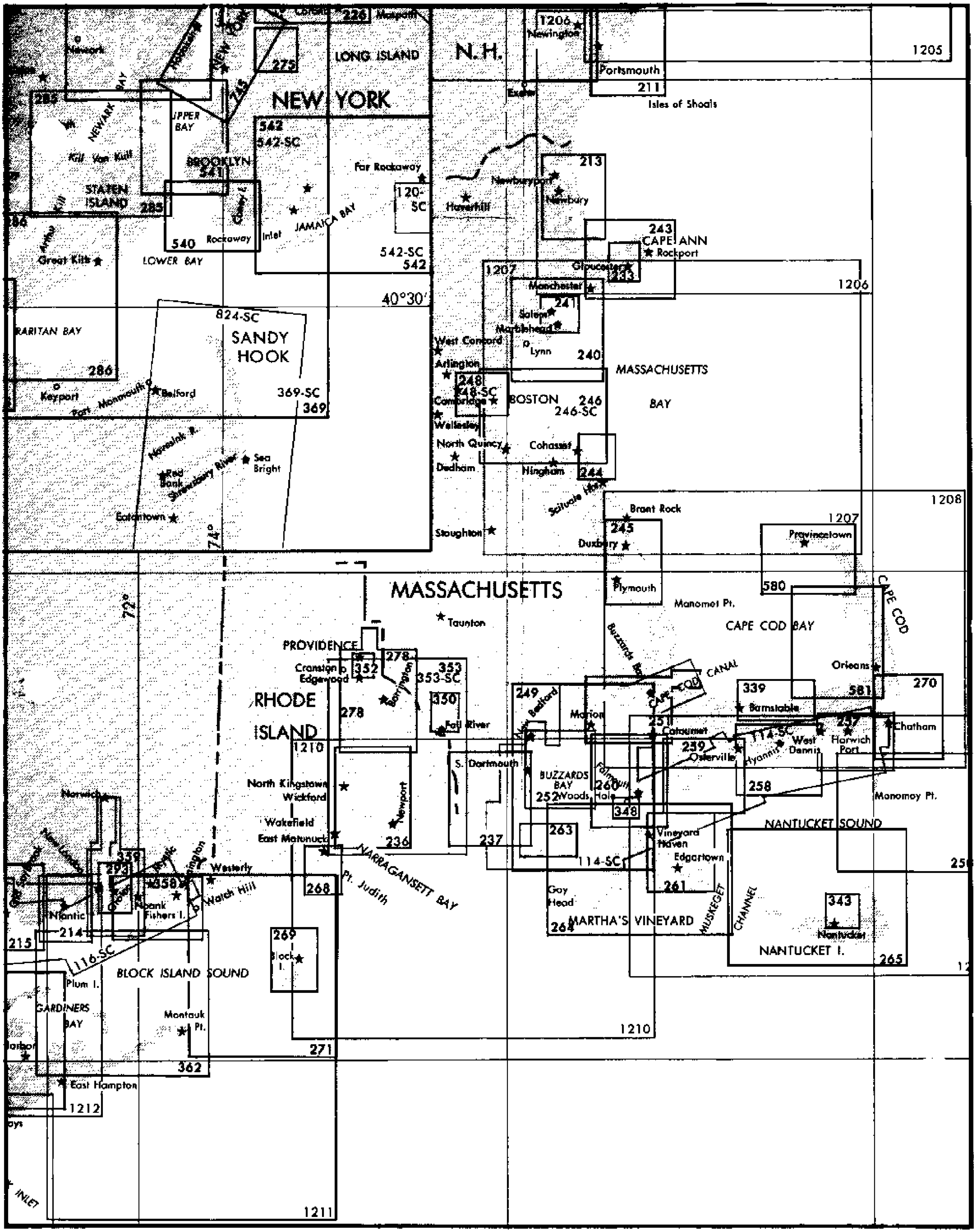
SAILING AND GENERAL CHARTS – ATLANTIC AND GULF COASTS

Chart No.	Price	Title	Scale
70	$1.00	West Quoddy Head to New York	1:675,000
†71	1.00	Gulf of Maine and Georges Bank	1:500,000
77	.75	Chesapeake Bay–northern part	1:197,250
78	.75	Chesapeake Bay–southern part	1:200,000
[illegible]	1.00	Georges Bank	1:220,000
[illegible]	.75	Puerto Rico and Virgin Islands	1:326,856
†1000	1.00	Cape Sable to Cape Hatteras	1:1,200,000
†1001	1.00	Cape Hatteras to Straits of Florida	1:1,200,000
†1002	1.00	Straits of Florida and approaches	1:1,200,000
†1003	1.00	Gulf Coast–Key West to Mississippi R.	1:875,000
†1007	1.00	Gulf of Mexico	1:2,160,000
†1106	1.00	Bay of Fundy to Cape Cod	1:378,838
†1107	1.00	Georges Bank and Nantucket Shoals	1:400,000
†1108	1.00	Approaches to New York, Nantucket Shoals to Five Fathom Bank	1:400,000
†1109	1.00	Cape May to Cape Hatteras	1:416,944
†1110	1.00	Cape Hatteras to Charleston	1:432,720
†1111	1.00	Charleston Light to Cape Kennedy	1:449,659
†1112	1.00	Cape Kennedy to Key West	1:466,940
1113	1.00	Havana to Tampa Bay	1:470,940
1114	.75	Tampa Bay to Cape San Blas	1:456,394
†1115	1.00	Cape St George to Mississippi Passes	1:456,394
1116	1.00	Mississippi River to Galveston	1:458,596
1117	1.00	Galveston to Rio Grande	1:460,732
1350	.75	Fla Keys–Fowey Rks. to American Shoal	1:180,000
1351	.75	Fla Keys–Sombrero Key to Dry Tortugas	1:180,000

† Includes Loran Lines of Position



Sailing and General Charts

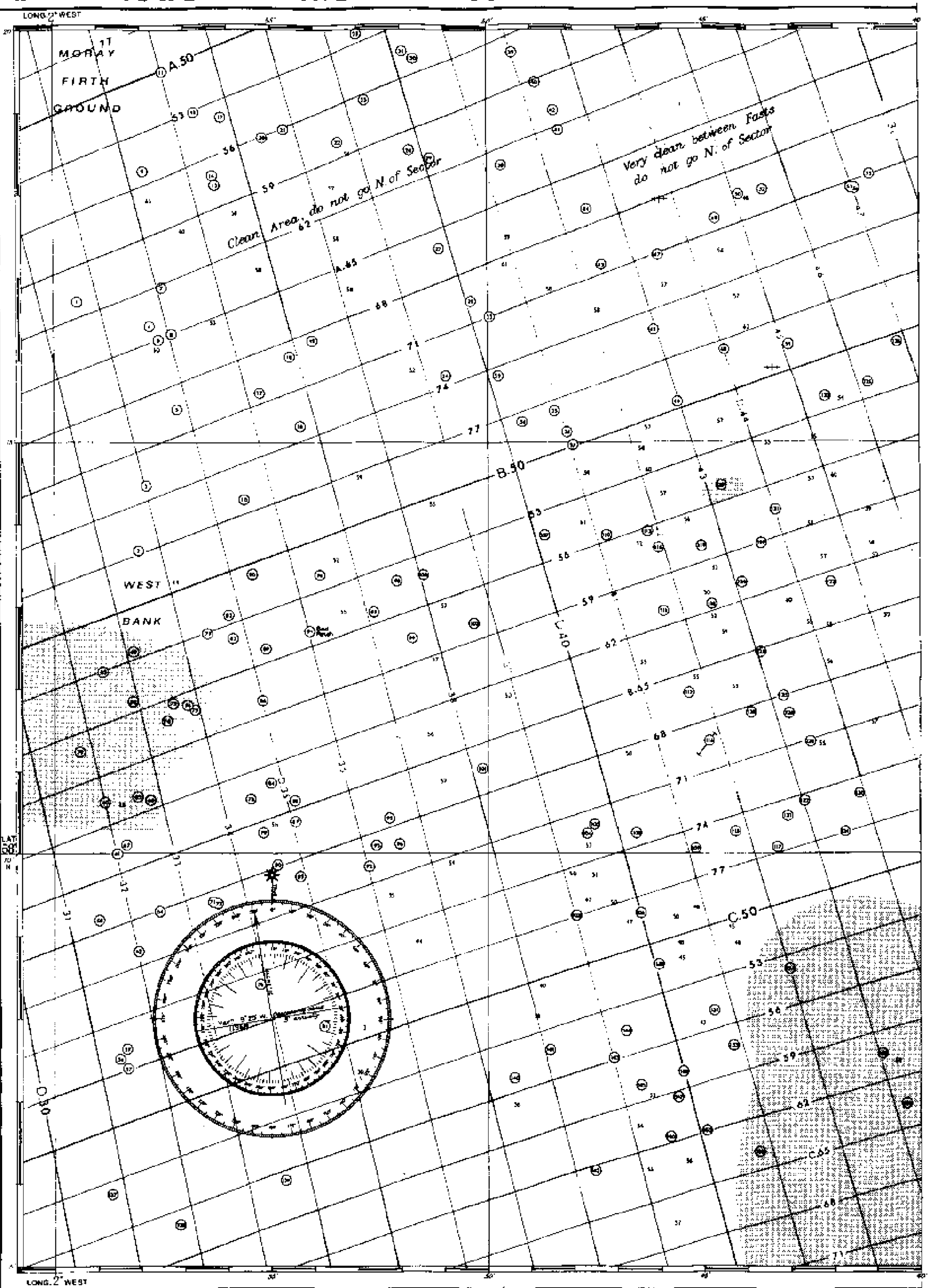


NEW YORK
LONG ISLAND
N.H.
Newark
NEWARK BAY
UPPER BAY
Kill Van Kull
STATEN ISLAND
BROOKLYN
Rockaway
Inlet
JAMAICA BAY
Far Rockaway
LOWER BAY
Great Kills
RARITAN BAY
SANDY HOOK
824-SC
369-SC
369
542
542-SC
540
541
285
286
275
226
745
120-SC
40°30'
Keyport
Port Monmouth
Belford
Navesink R.
Shrewsbury River
Red Bank
Sea Bright
Eatontown
74°
72°
1206
Newington
Portsmouth
211
Isles of Shoals
1205
Exeter
Newburyport
Newbury
213
Haverhill
243
CAPE ANN
Rockport
Gloucester
233
1207
Manchester
241
Salem
Marblehead
Lynn
240
West Concord
Arlington
248
248-SC
Cambridge
BOSTON
246
246-SC
Wellesley
North Quincy
Cohasset
Dedham
Hingham
244
Scituate Hbr.
Stoughton
MASSACHUSETTS BAY
1208
Brant Rock
245
Duxbury
Plymouth
Provincetown
580
Manomet Pt.
CAPE COD BAY
CAPE COD
MASSACHUSETTS
Taunton
PROVIDENCE
Cranston
Edgewood
352
278
353
353-SC
350
Fall River
Barrington
RHODE ISLAND
1210
North Kingstown
Wickford
Wakefield
East Matunuck
Newport
236
NARRAGANSETT BAY
Pt. Judith
268
S. Dartmouth
237
249
New Bedford
Marion
CAPE COD CANAL
251
Cataumet
259
Osterville
Hyannis
West Dennis
114-SC
257
Harwich Port
Chatham
270
339
Barnstable
Orleans
581
258
Monomoy Pt.
BUZZARDS BAY
252
Woods Hole
260
Falmouth
348
263
Vineyard Haven
Edgartown
261
NANTUCKET SOUND
Gay Head
264
MARTHA'S VINEYARD
MUSKEGET CHANNEL
343
Nantucket
NANTUCKET I.
265
Norwich
New London
Mystic
359
293
358
Westerly
Watch Hill
Noank
Fishers I.
Niantic
214
215
116-SC
BLOCK ISLAND SOUND
269
Block I.
Plum I.
GARDINERS BAY
Montauk Pt.
362
271
East Hampton
1212
1211

S.20 KINGFISHER SEINE NET CHART

Decca Readings of Reported Obstructions Numbered on West side of Chart

No.	Green D	Purple A	
1	33.80	[illegible]	Obs
2	33.60	76.76	..
3	34.00	73.00	..
4	34.70	66.00	..
5	34.70	60.30	..
6	34.80	[illegible]	..
7	35.68	82.20	..
8	35.06	[illegible]	S.V
9	35.35	[illegible]	Obs
10	35.60	76.00	..
11	36.00	80.30	S.V
12	36.20	70.30	Obs
13	36.40	85.10	..
14	36.40	67.00	S.V
15	36.41	67.60	Obs
16	36.70	73.00	..
17	36.80	63.90	..
18	36.86	[illegible]	..
19	37.31	[illegible]	..
20	37.40	[illegible]	..
21	37.80	66.67	..
22	38.05	[illegible]	S.V.
23	39.30	[illegible]	Obs
24	39.30	73.30	..
25	39.60	[illegible]	..
26	39.80	40.00	..
27	39.80	89.08	..
28	40.06	[illegible]	..
29	40.10	84.00	..
30	40.20	[illegible]	..
31	40.15	[illegible]	S.V.
32	40.14	74.90	Obs.
33	40.80	70.90	..
34	40.90	77.60	..
35	40.80	77.30	S.V
36	41.00	78.08	Obs
37	41.06	[illegible]	..
38	41.29	69.00	..
39	42.00	57.00	..
40	42.30	56.70	..
41	42.38	[illegible]	..
42	42.40	[illegible]	..
43	42.40	30.30	..
44	42.45	87.80	..
45	42.96	76.00	..
46	42.96	[illegible]	..
47	43.40	71.00	S.V
48	44.00	77.46	Obs
49	44.65	70.30	..
50	46.06	[illegible]	S.V
51	46.10	36.60	Obs
52	46.80	[illegible]	S.V
53	47.00	71.40	Obs
54	47.04	77.48	..
55	47.35	70.80	..
	D	B	
56	31.36	78.28	Obs
57	31.46	77.00	..
58	31.50	87.20	..
59	31.80	78.80	..
60	32.00	86.50	..
61	32.00	84.00	S.V
62	32.00	70.00	Obs
63	32.80	53.90	..
64	32.80	80.90	..
65	32.40	80.80	..
66	32.70	81.80	S.V
67	32.80	43.80	Obs.
68	32.87	86.30	..
69	33.10	[illegible]	..
70	33.40	57.18	..
71	33.46	[illegible]	..
72	33.80	[illegible]	..
73	33.50	[illegible]	..
74	33.80	[illegible]	..
75	33.90	59.10	..
76	33.90	74.80	..
77	34.40	83.80	..
78	34.48	63.50	..
79	34.00	30.00	..
80	34.90	47.90	..
81	34.75	78.80	S.V
82	34.80	92.48	Obs.
83	34.90	[illegible]	..
84	34.80	83.70	..
85	34.90	80.20	..
86	35.00	59.50	..
87	35.06	[illegible]	S.V
88	35.15	64.80	Obs
89	35.35	65.18	..
90	35.35	80.70	..
91	36.00	[illegible]	B.F
92	36.60	70.00	Obs.
93	36.20	[illegible]	..
94	36.40	[illegible]	S.V
95	36.50	67.60	Obs.
96	36.85	[illegible]	S.V
97	37.10	[illegible]	..
98	37.60	[illegible]	Obs
99	37.88	77.89	..
100	38.00	64.30	..
101	38.16	[illegible]	..
102	38.66	[illegible]	S.V
103	39.00	77.00	Obs
104	39.50	72.40	S.V
105	39.86	72.60	Obs
106	40.00	78.00	..
107	40.10	54.40	..
108	40.25	73.29	..
109	41.10	78.29	..
110	43.20	[illegible]	..
111	40.70	64.00	S.V.
112	41.70	58.00	Obs.
113	41.80	88.20	..
114	41.80	[illegible]	..
115	41.60	76.00	..
116	41.90	52.80	..
117	42.37	78.79	..
118	42.62	81.51	..
119	42.80	68.90	..
120	42.80	58.40	..
121	42.70	78.40	..
122	43.02	74.40	S.V
123	43.08	45.70	Obs.
124	43.12	[illegible]	..
125	43.20	88.10	..
126	43.20	69.10	..
127	43.25	65.60	..
128	43.40	75.00	..
129	43.60	[illegible]	S.V
130	43.80	74.28	Obs
131	44.02	87.48	S.V
132	44.60	49.50	Obs
133	46.40	93.80	..
134	42.50	79.90	..
135	46.10	92.00	..
136	49.65	90.80	..
	D	C	
137	30.30	[illegible]	Obs.
138	37.30	67.00	..
139	33.46	56.70	..
140	37.43	96.28	S.V
141	38.08	86.28	Obs
142	38.30	47.30	..
143	38.00	[illegible]	..
144	39.30	[illegible]	..
145	39.20	59.00	..
146	39.66	98.70	..
147	38.80	[illegible]	..
148	39.80	38.00	..
149	40.00	87.38	..
150	40.10	92.00	..
151	40.70	56.60	..
152	40.80	94.00	..
153	40.88	67.82	..
154	42.00	54.78	..
155	42.95	60.40	..
156	42.16	[illegible]	..



Edition Mar. 1966
Corrected to
24 AUG 1967

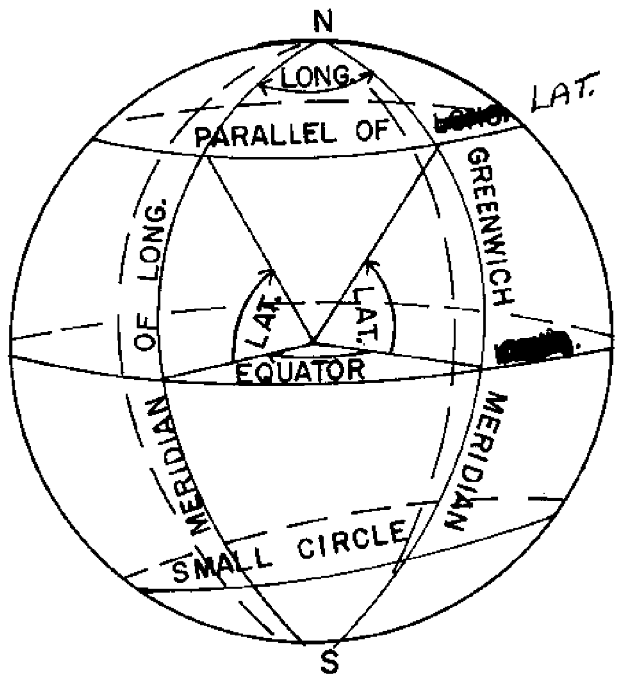
Compiled under the direction of Skipper E.S. Johnson, for the White Fish Authority. KINGFISHER CHARTS are published to record only dangers, obstructions and areas of foul ground which cause loss and damage to gear and loss of fishing time. They are not intended for purposes of general navigation. Where no depths or ground details are shown, there are no known dangers or obstructions on record.

SOUNDINGS in FATHOMS

Published in conjunction with the White Fish Authority by Imra

Compiled from information and based on British Admir Controller of H.M. Stationery

Basic Definitions for Position



For navigational purposes the earth is assumed to be a sphere. In fact the earth is an oblate spheroid, about 27 miles less in diameter between the poles than at the equator.

Great and Small Circles

A great circle is a circle on the surface of the earth the plane of which passes through the earth's center. If a sphere were cut along a great circle it would be divided into two equal halves. Should the plane of a circle not pass through the center of the sphere a small circle would have been drawn.

All meridians of longitude are great circles which pass through the poles. The prime meridian passes through the Greenwich Observatory in England and longitude is measured east or west of this prime meridian.

All parallels of latitude are small circles drawn parallel to the equator. The equator is a great circle midway between the poles.

Latitude

The latitude of an object on the earth's surface is the angle at the center of the earth between the equator and the object, measured from 0-90 degrees north or south of the equator along the meridian passing through the object.

Longitude

The longitude of an object on the earth's surface is the angle at the pole between the prime meridian and the meridian passing through the object, measured from 0-180 degrees east or west of the prime meridian.

Position

An object is positioned on earth by its latitude and longitude in that order or by true bearing and distance from some reference point nearby; e.g. the whistle buoy in lat. 41°20′.0 N long. 71°28′.5 W is also 170° T × 1.7 miles from Point Judith. (See Chart 1210.)

Difference of Latitude (D. Lat.)

D. Lat. is the angle at the center of the earth between the parallels of latitude passing through the two points considered.

Difference of Longitude (D. Long.)

D. Long. is the angle at the pole between the meridians passing through the two points considered.

Note that distance is always measured on the latitude scale of the chart. *One minute of latitude equals one nautical mile.* This will be discussed later.

Exercise 2. POSITION (Chart 1210 and 1211)

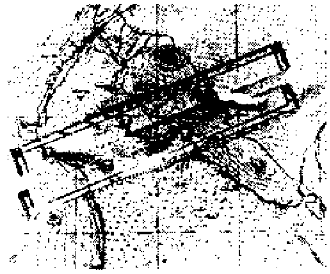
1. Find the true bearing and distance of a vessel in 41°31′ N 70°53′ W from Round Hill Pt.
2. In what position would a vessel 6.9 miles due south of Beavertail Lt. be?
3. How would you refer a vessel in 41°22.9′ N 71°5′ W to Buzzards Horn Radio Bn.?
4. In what position would a vessel having Southeast Pt. bearing 231°T × 7.6 miles be?
5. How would a vessel in 41°22.8′ N 71°16.4′ W be positioned from Sakonnet Pt.?
6. In what position would a vessel 162° T × 5 miles from Montauk Pt. be?
7. Position a vessel in 41°14.2′ N 72°10.8′ W with reference to Little Gull I.
8. In what position would a vessel 8.2 miles due west of Sandy Pt. be?
9. How would a vessel in 41°10.3′ N 71°57.7′ W be positioned relative to Race Pt.?
10. In what position would a vessel 096° T × 16.6 miles from Montauk Pt. lie?

Check that the following buoys and light vessels are positioned as for 1970. Discrepancies in answers may result if the position of a buoy has been changed.

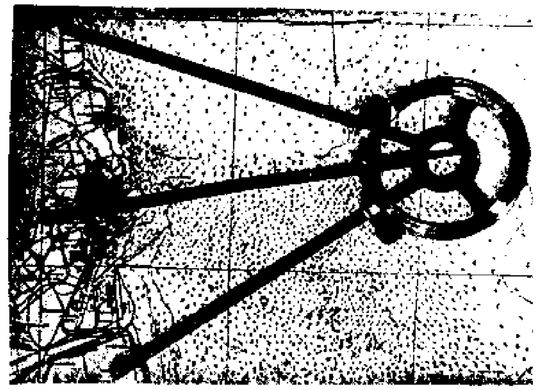
1. Qk. Fl. Whistle Buoy S.E. Buzzards Bn. 41°22.6′N × 71°00.2′W
2. S. Nomans No. 2 Whistle Buoy 41°12.2′ N × 70°50′ W
3. Davis S. Shoal Buoy 40°57.3′ N × 69°55′ W
4. Nantucket Shoals Lt. V/L. 40°30′ N × 69°28′ W
5. Cashes Ledge Buoy 42°53.4′ N × 68°55.7′ W
6. Jeffreys Ledge Buoy 43°00.9′ N × 70°02.8′ W
7. Brazil Rk. Whistle Buoy 43°21′ N × 65°26.5′ W
8. Gull Rk. Whistle Buoy 43°36.6′N × 65°02.5′W
9. R. "10" Whistle Buoy 40°59.1′ N × 69°06′ W
10. Nomans Land Bell Buoy 41°15.7′ N × 70°46.1′ W
11. Pollock Rip Lt. Buoy 41°36.1′ N × 69°51.1° W
12. Cultivator Shoal Buoy 41°40.2′ N × 68°12.3′ W
13. Gannet Rk. Buoy 43°36.6′ N × 66°12.4′ W
14. Lurcher Shoal Lt. V/L. 43°48.2′ N × 66°31.8′ W 56 ft.
15. R. "4" Davis Bank Buoy 41°07.7′ N × 69°42.5′ W
16. Fl. G. Buoy S. of Negro Ledge 41°31.8′ N × 70°50.9′ W

CHARTWORK INSTRUMENTS

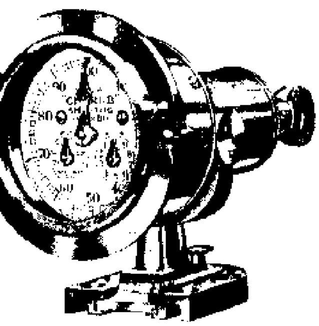
Dividers



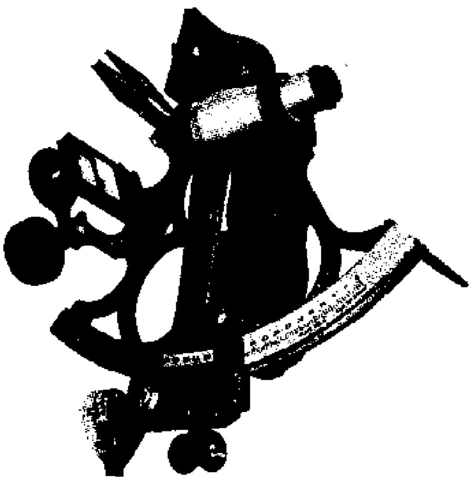
Parallel Rules



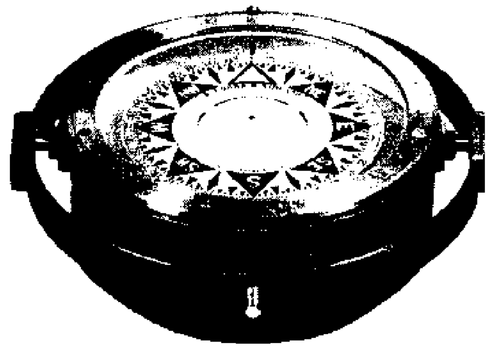
Station Pointer



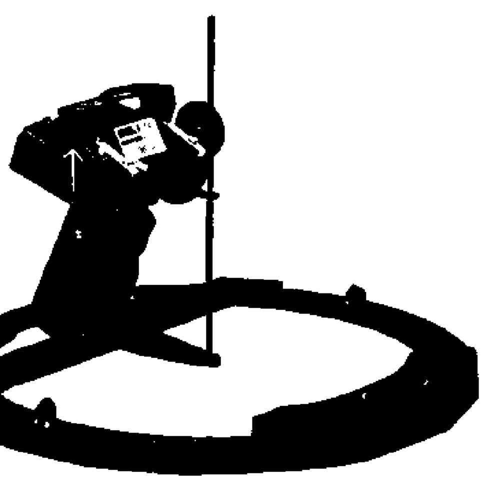
Log Clock



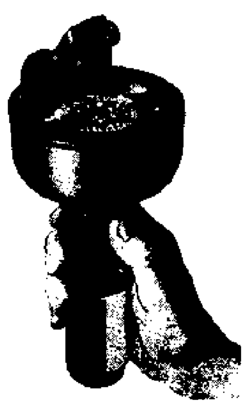
Marine Sextant



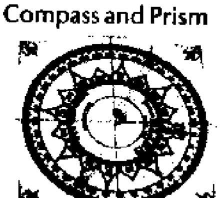
Compass



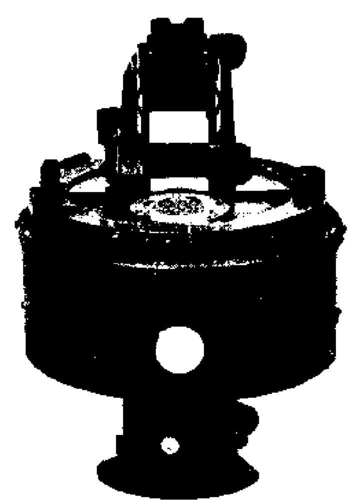
Azimuth Mirror



Hand-bearing
Compass and Prism



Pelorus Card



Liquid Compass
with Combined Azimuth
and Steering Prism

Fixing Position Near Land

The position of a vessel should be constantly fixed, or determined, by as many different means as possible. This is best done by checking positions obtained from crossed bearings of shore objects with information from radar, the radio direction finder, the echo sounder and other navigational instruments.

Bearings are obtained by looking across the top of the compass card at a shore object through a sighting vane or through a reflecting prism mounted on a rotatable frame over the compass; this device is called an azimuth mirror.

Sometimes hand bearing compasses or pelorus cards are used to take bearings. A hand compass has a handle underneath it and a prism on top. The bearing of a shore object is noted and the difference in direction of the hand compass and ship's compass is noted and applied. A pelorus is simply a small compass card which is set up in the fore and aft line to coincide with the ship's compass. A bearing can be taken by means of a set of two vanes which move on a diameter across the card.

A single bearing gives only a position line, somewhere along which the vessel must be situated. A fix is obtained when additional information determines just where on the position line the vessel lies. Another bearing, a radar distance from the land, or a sounding would give this information and complete the fix.

When two bearings are crossed for a fix their angle of intersection should be as near to 90 degrees as possible. When the angle is very small a slight error in the bearing may give a large error in position. For accuracy a fix should be checked with a third position line bearing. Often the three bearings will not meet at a single point but will form a small triangle known as a "cocked hat." In this case it is advisable to position the vessel in the corner of the cocked hat nearest to danger.

Exercise 3. FIXING POSITION (Chart 1211)

1. Find the position and depth of water of a vessel having Montauk Pt. bearing 302° T and Southeast Pt. bearing 044° T.

2. Find the position and depth of water when Watch Hill Pt. bears 306° T and Sandy Pt. Lt. bears 073° T.

3. Give position of a vessel having East Hampton Spire and Flagstaff in transit and Aero Lt. bearing due north.

4. Find position of a vessel with Montauk Pt. bearing 331° T in 30 fathoms of water.

5. Find the position of a vessel with Montauk Lake Breakwater Lts. in transit and Eastern Plain Pt. bearing 310° T. What sounding would you expect in this position?

6. Give the position of a vessel having Watch Hill Pt. bearing 295° T, Point Judith Lt. bearing 055° T and Sandy Pt. bearing 099° T.

7. What sounding would you expect in a position with Point Judith Lt. bearing 065° T on Loran position line 5820 from Loran station 3 H.4? What distance from the nearest land should the radar indicate?

8. Give position of a vessel with Montauk Pt. bearing 318° T if the radar gives the distance from nearest land as 9 miles.

9. A vessel steering due north, true course, observes Montauk Pt. Lt. 30° on the st'b'd bow while crossing the 20-fathom line. Find her position.

10. Where would you position a vessel having Race Pt. Lt. bearing 035° T, Great Gull I. Tower bearing 007° T and Plum I. Flagpole bearing 309° T?

Reading a Chart

The navigator reads a chart in much the same way a soldier interprets a land survey map. The general shape of the seabed and the nature of the bottom are particularly important to fishermen. A good chart will have a high density of sounding and bottom information,but the technique of applying this to a particular fishing operation is perfected only with considerable experience.

In order to understand a chart become very familiar with the symbols and abbreviations. These symbols are itemized and explained on Chart No. 1 and this chart should be well studied in the initial stages of learning about chartwork.

SOME OF THE MORE IMPORTANT SYMBOLS

1. Exposed Rock; Elevation in Feet above Mean High Water

 (25).

2. Rock which Covers and Uncovers; in Feet above Chart Datum

 (6)

3. Rock Awash at Chart Datum

Note: When 2 or 3 is surrounded by a dotted circle, the rock is considered a danger to navigation.

4. Sunken Danger with Depth Swept by Wire Drag; in Feet or Fathoms

4 OBSTR.

5. Snags or Submerged Stumps

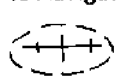
 Snags

6. Foul Ground

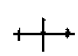
(Foul)

7. Wreck, Part of which is Visible above Chart Datum

8. Sunken Wreck, Possibly Dangerous to Navigation



9. Sunken Wreck, not Dangerous to Navigation



10. Radio Direction Finding Station

 R.D.F.

11. Radar Reflector

 Ra Ref

12. Radar Responder Beacon

 Racon.

13. R St'b'd Hand Buoy "2" Entering from Seaward  R "2"

14. Port Hand Buoy "1" Entering from Seaward  "1"

SOME OF THE MORE IMPORTANT ABBREVIATIONS

Lt. Ho.	Lighthouse	S.	Sand	wh.	White
Bn.	Light beacon	M.	Mud	bk.	Black
F.	Fixed light	St.	Stones	bu.	Blue
Occ.	*Occulting light	Rk.	Rocky	gn.	Green
Fl.	Flashing light	Sh.	Shells	yl.	Yellow
Qk. Fl.	Quick flashing light	Oys.	Oysters	rd.	Red
Gp. Fl.	Group flashing light	Ms.	Mussels	br.	Brown
OBSC.	Obscured light	Wd.	Seaweed	gy.	Gray

Note that all soundings are given in fathoms and/or feet at chart datum. Thus 11_4 would be a sounding of 11 fathoms and 4 feet at chart datum. Chart datum is most simply described as: *The level below which the tide seldom falls.* Chart datum is mean low water on the eastern seaboard of the United States.

Heights of land or conspicuous objects are given in feet above mean high water level unless otherwise stated in notes below the chart title. The depth contour lines as laid out in Chart No. 1 should be noted.

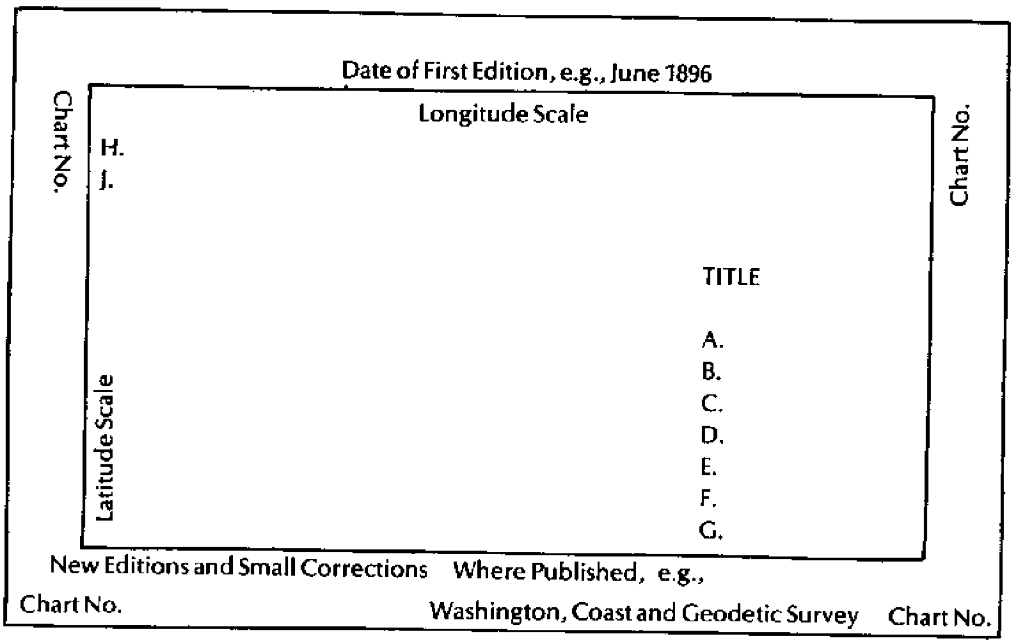
Fishermen usually plot "snags" and "hangups" as they are encountered during fishing operations. Such obstructions are also often listed in a fishing logbook together with details of seasonal movement of fish species, water temperature, etc.

*Occulting light has a greater period of flash than darkness between flashes.

Exercise 4. CHART SYMBOLS (Chart 1211 and 71)

1. List the positions of three different types of wreck symbols on Chart No. 1211.
2. Itemize four different types of buoys on Chart No. 1211.
3. Explain the reason why Area C to the north of Gardiners I. is listed as a Danger Area.
4. Interpret the characteristics of the following lights: Point Judith, Watch Hill Pt., Montauk Pt.
5. Explain the dashed lines around Long Island.
6. List the positions of four different abbreviations for the nature of the bottom on Chart No. 1211.
7. Explain the current diagrams used on Chart No. 71 for computing direction and velocity of tidal drift.
8. How does Chart No. 71 help to protect fishermen from damaging their nets in the Gulf of Maine region?
9. List the symbols for submarine cables. What precautions should be taken when trawling in the vicinity of submarine cables?
10. Interpret the characteristics of the following lights: Cape Cod, Cape Sable, Seal I.

General Chart Layout



A. Type of projection used to transfer the curved section of surface area of the earth onto the flat surface of the chart, e.g., Mercator.

B. Scale of the chart, e.g., 1:80,000.

C. Sounding datum and whether depths are given in fathoms or feet, e.g., soundings in feet at mean low water, or M.L.W.

D. Level from which heights are given, e.g., heights in feet above M.H.W.

E. Cautions, hazards and dangers to navigation; e.g., heavy tide rips may be experienced in a certain position at a given state of tide. These clauses must be well studied before using the chart.

F. An explanation of the tidal information contained on the chart, e.g., a series of vector diagrams superimposed on the chart showing tide strength and direction for each hour after H.W. at a given port.

G. A short summary of Loran or Decca navigator information available in the region.

H. Submarine cable and pipeline information and warnings.

J. Dumping grounds, firing or torpedo ranges, and protected fishing grounds.

Some of the warnings and cautions printed on the chart may refer to the *Coast Pilot Book* for the region concerned. These pilot books give a highly detailed description of all factors relevant to the safe navigation of the zone covered and should be used in conjunction with the chart. Many interesting historical features are also related. Details about lights and beacons are contained in volumes of the *Light List*.

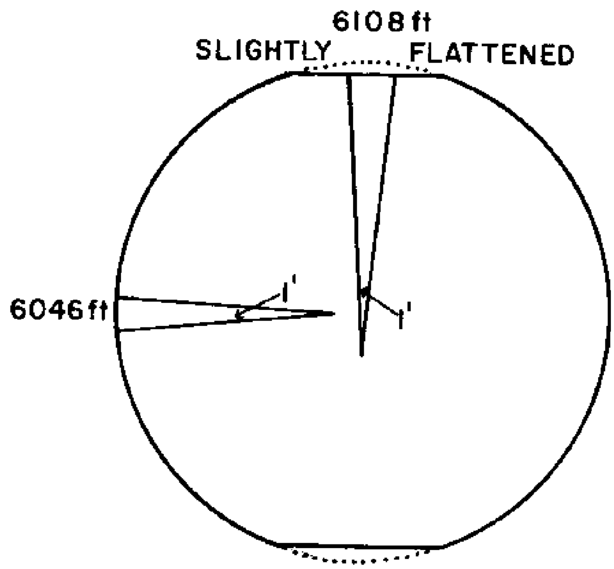
Note the date of a new edition as the accuracy of modern electronic surveying equipment improves the reliability of the chart.

Care should be taken when transferring a position from one chart to the next. The observed position should be checked as soon as possible on the new chart. The scale of the chart may differ greatly from the first one used, and it is important to "double-check" the distance scale used. For this reason it is advisable to have only one chart in use at a time.

CHART CONSTRUCTION

Prominent objects are positioned by extending a framework of angles and bearings from the known position of established points, called triangulation stations. Further detail is superimposed and lines of soundings are run off. Position of wrecks, rocks, shoals and all other important features are closely checked and rechecked. This information is presented on a field chart which is engraved onto a copper plate. This is copied in zinc, and the copper original is filed for future reference. Besides preserving the copper original, the use of the zinc plate for printing gives a lithographic impression which may be regarded as free of distortion. Modern hydrographic offices substitute certain plastics for the copper plate and employ sophisticated photographic processes in the lithographic system.

Distance



The nautical mile (n.m.) is the arc of a meridian subtended by an angle of 1 minute at the center of curvature of that section. As previously mentioned, the earth is slightly flattened at the poles. Therefore, the center of curvature in this region will be at a greater distance from the surface than it will be near the equator. This results in the distance subtended by 1 minute at the center of curvature, being 6108 feet at the poles and 6046 feet at the equator. A mean of 6080 feet is assumed for the nautical mile, this being the value in about lat. 49° N and S.

It is common practice to divide the nautical mile into ten equal parts which are called cables. For this purpose the length of a nautical mile is further approximated to 6000 feet, thus giving the cable a value of 600 feet.

The unit of speed used at sea is the knot. One knot is 1 nautical mile travelled in 1 hour. This should not be confused with distance used as purely a unit to indicate velocity.

Exercise 5. TRUE COURSE AND DISTANCE (Chart 1210)

1. Find the true course and distance from a position 41°10′ N 71°30′ W to 41°20′ N 71° 00′ W.

2. Find the true course and distance from Sakonnet Pt. bearing due north at 3 miles to Gay Head bearing due east by 2 miles. How close to Buzzards Bn. will you pass?

3. A vessel steers 200° T at 8 knots from Vineyard Sound Whistle Buoy. In what longitude will she cross the 20-fathom line to the south of Cox Ledge and how long will this take?

4. A vessel fishing in 41°05′ N 71°21′.7 W hauls up and proceeds to Pt. Judith at 9 knots. What true course should be made good, and how long will it take before she passes the East Breakwater?

5. A vessel leaves position 41°10′ N 71°20′ W at 1800 hours steaming at 9½ knots. What course should be made good to the No. 26 Bell Buoy south of Nobska Pt. and what is the estimated time of arrival (E.T.A.)?

6. A fishing vessel passing close to Brenton Reef Bn. hears of good catches being made near the 24-fathom patch to the north of Cox Ledge. How soon can she be there at 7 knots and what course should be made good?

7. From the 24-fathom patch north of Cox Ledge the vessel, slowed to 6 knots by a head wind, proceeds to Pt. Judith. What course should be made good and how long will it take to reach the East Breakwater?

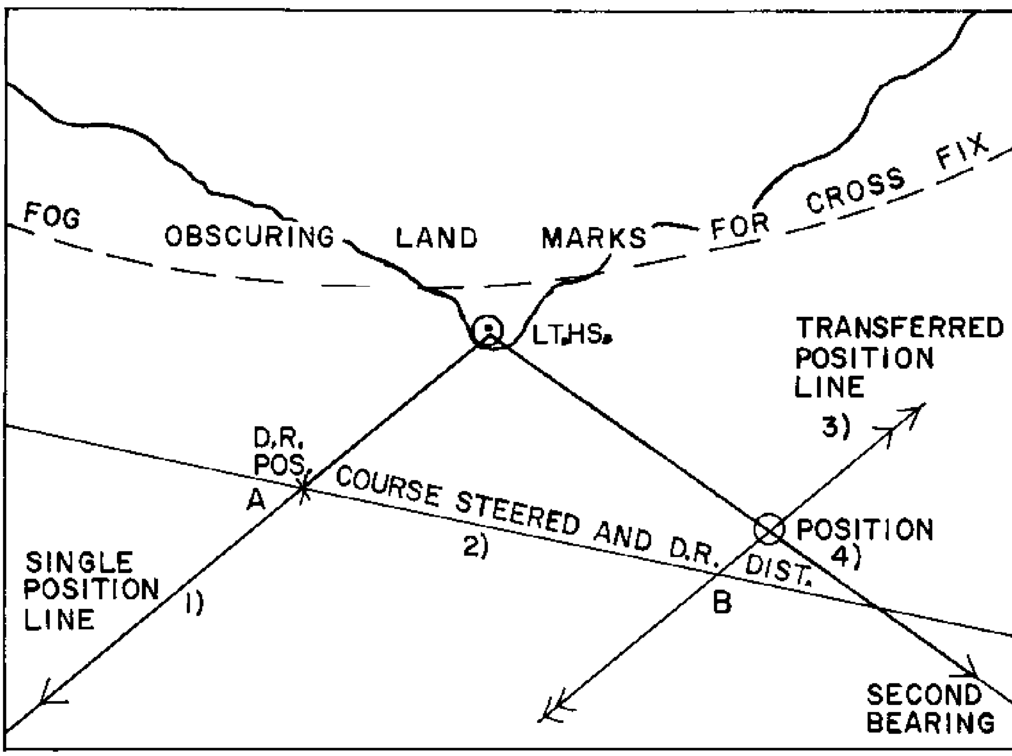
8. Find the true course and distance from 3 miles abeam of Southeast Pt. to 2 miles abeam of Gay Head. (To find beam position draw distance circles from the point and lay off course line tangential to these circles. The abeam position will be where a perpendicular to the course line from the point intersects the course line.)

9. From a position with Cuttyhunk I. Lt. bearing 040° T and Gay Head bearing 088° T. find the true course and distance to the bell buoy at the entrance to Block I. Old Hbr.

10. From a position with Beavertail Pt. Lt. in transit with Pt. Judith Lt. in 15 fathoms, find the true course and distance to a position just north of Sakonnet River Whistle Buoy, keeping Aband. Lt. Ho. Tower right ahead.

The Running Fix

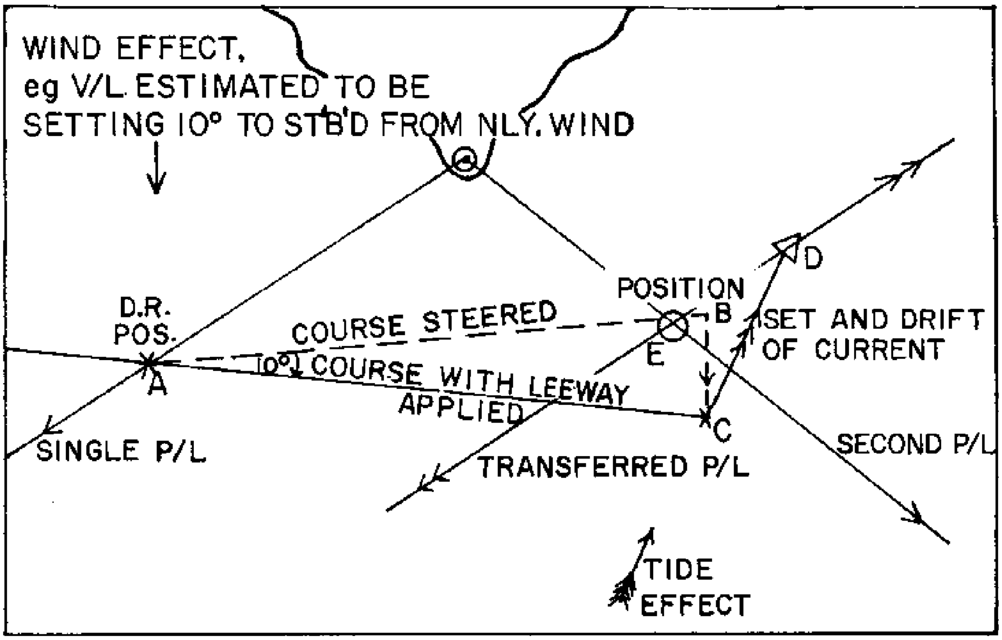
As previously stated, a single bearing gives only a position line somewhere along which the vessel must be situated. If a cross fix cannot be obtained, the "running fix" will give a reasonable estimation of the vessel's position by transferring the initial bearing through a future estimated position and crossing this with another bearing of the same or another object at that time. This principle of the transferred position line is described below in four steps.



1. Lay off the first bearing.
2. Anywhere on this bearing fix dead reckoning (D.R.) position A, and project course steered and D.R. distance AB.
3. Transfer first bearing through B. It is reasonable to assume, providing course and distance AB are not in appreciable error, the vessel must now lie somewhere along this transferred position line.

4. At time of position B, take a second bearing of the same or another object. The point where this bearing crosses the transferred position line will be a reasonably accurate reading of position.

It should be emphasized that the accuracy of the running fix depends on a correct estimation of the run between bearings. The wind (or leeway) effect and tide or (set and drift) effect can be allowed for as indicated in the next diagram.



1. A is fixed as D.R. position somewhere on first bearing and course steered AB is laid off.
2. In this case 10 degrees of leeway is estimated for a northerly wind; this is shown as BC. Thus, AC is course with leeway applied.
3. The set, or direction of current and drift, which is the distance the ship is affected by the current between bearings, is estimated and applied as CD.
4. D is the estimated position through which the transferred position line is drawn.
5. Where the second bearing intersects the transferred position line is the vessel's observed position, E. The second position line can be from any other source, e.g., Loran or radio direction finder.

In order to avoid confusion in the construction of the running fix, or any other chartwork for that matter, it is advisable to adopt a uniform set of symbols for practical use, as suggested below:

X	D.R. Position	↗	Single Position Line
△	Estimated Position	↗↗	Transferred Position Line
⊙	Observed Position	↗↗↗	Set and Drift of Current

Exercise 6. RUNNING FIX (Chart 1210)

1. At 0600 Southeast Pt. Lt. bore 023° T, with the vessel steaming at 7 knots on a course of 070° T. At 0700 the same light was bearing 305° T. Find the vessel's position at 0700. What should the depth sounder indicate at this time?

2. The southeast point of Noman's Land bore 310° T to a vessel steering 243° T at 8 knots. One-and-a-quarter hours later the same point bore due true north. Find the vessel's position at the time of the second bearing.

3. At 1030 Buzzards Bn. bore 052° T to a vessel steaming 276° T at 12 knots. At 1115 Brenton Reef Bn. bore 310° T. Find the position at this time.

4. At 1400 Gay Head bore 030° T to a ship steaming at 11 knots on a course of 297° T. Half-an-hour later Buzzards Bn. was bearing 336° T. Find the position at 1430 and the true course to steer to Sakonnet River Whistle Buoy.

5. At 1000 Loran ceased to operate with a final reading of 3H4 6100. The vessel then proceeded at a reduced speed of 3 knots in fog, steering 055° T into Vineyard Sound. Nothing was seen until 1240 when Robinson's Hole Bell Buoy was observed *50° on the port bow.* Find the position at this time by the transferred position line method.

6. A vessel proceeding NNW into Rhode Island Sound after fishing to the southward crossed the 20-fathom line in an estimated longitude of 70°50′ W. Using this depth contour as a transferred position line, find the vessel's position one hour later when Gay Head Lt. was seen 4 points on the st'b'd bow and the vessel was steaming at 8 knots. At what longitude do you estimate the vessel actually did cross the 20-fathom line? (Note that the compass card is divided into 32 points; 1 point=11¼°.)

7. At 0400 Southeast Pt. Lt. was bearing 010° T and the vessel was steering 070° T at 8½ knots. Find the vessel's position at 0500 when Southeast Pt. Lt. bore 282° T, if a current was estimated to be setting 030° T at 2½ knots.

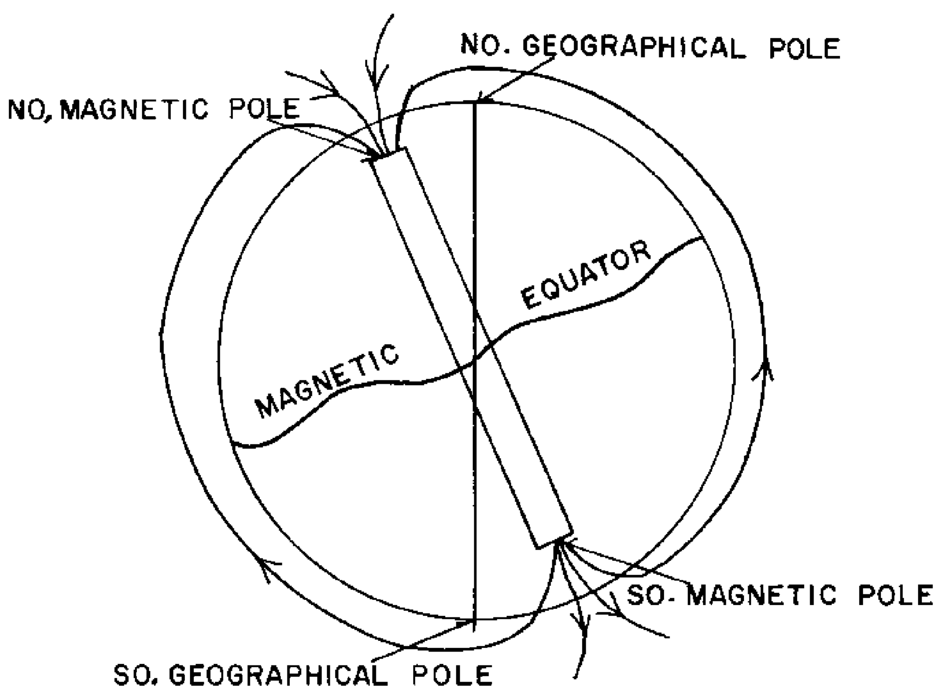
8. At 1130 Pt. Judith Lt. was in transit with No. 2 Whistle Buoy and the vessel was steering 305° T at 6 knots. Find the position at 1230 if Pt. Judith Lt. bore 065° T and a current was estimated to be setting NE at 2 knots.

9. At 1530 West I. near Sakonnet Pt. was bearing 322° T to a vessel steaming 290° T at 7 knots. A northerly wind was estimated to be giving 8° leeway and an ebb tide was believed to be setting 140° T at 2 knots. Find the vessel's position at 1630 when Point Judith Lt. bore 249° T.

10. At 1900 Buzzards Bn. bore 033° T to a vessel steaming 15 knots at 060° T, making an estimated 12° leeway for a strong NNWly wind. A current was estimated to be setting 050° T at 2½ knots. Find the vessel's position at 1948 if Gay Head Lt. was bearing 170° T.

Earth's Magnetism

So far we have only been concerned with courses and bearings as laid down on the chart, that is true courses and bearings related to the true, or geographical, north pole. Unfortunately, the north-seeking end of the magnetic compass needle does not seek the true north pole, but is attracted toward the magnetic north pole.



For all practical purposes the earth's magnetic effect can be likened to that of a bar magnet running along a diameter of the earth. The blue end of this magnet is situated somewhere beneath the Northern Hudson Bay Region and constitutes the north magnetic pole while the red end of the magnet is about 1800 miles south of Tasmania to give the south magnetic pole.

The compass needle is merely a small, freely suspended bar magnet. Following the first basic law of magnetism, "opposite poles attract," it will attempt to align itself, red pole pointing toward magnetic north and blue pole toward magnetic south.

The Magnetic Equator

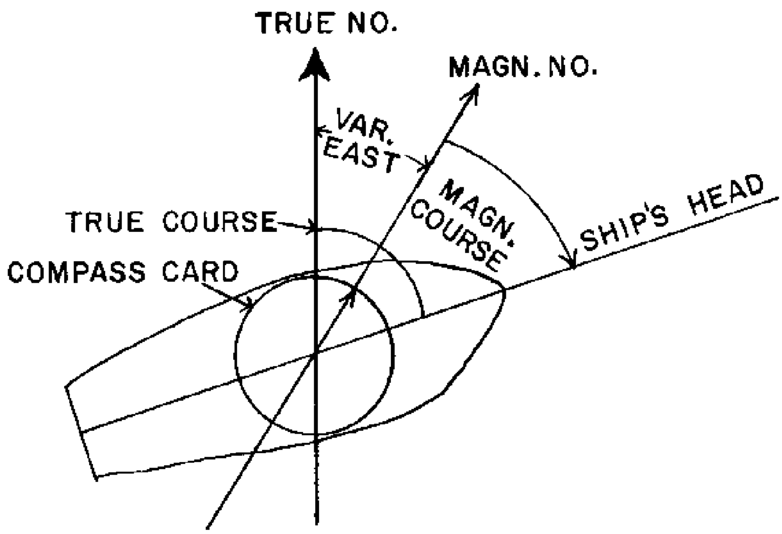
About midway between the magnetic poles, there will be equal attraction of the blue end of the compass needle for the south magnetic pole and of the red end of the needle for the north magnetic pole. In this position the compass needle will lie horizontally. If the needle were moved toward a pole its one end would be more strongly attracted than the other. It would dip out of the horizontal until the pole was reached and a maximum angle of dip of 90 degrees would result. This feature renders the magnetic compass useless near either magnetic pole. The region surrounding earth (roughly midway between the magnetic poles) where there is no horizontal dip of a compass needle is known as the magnetic equator, or aclinic line.

Magnetic Meridian

A freely suspended compass needle, when subjected to the earth's magnetic influence alone, will line up with a meridian passing through the magnetic poles.

Variation

Variation is the angle between the true and magnetic meridians at the place considered. It is the number of degrees that the compass needle is deflected east or west of the true meridian due to the effect of earth's magnetism alone.



Note in the diagram that the compass card remains steady. The magnetic course is altered by applying helm and allowing the fore and aft lines to move around the compass card.

From the diagram it is easily seen that easterly variation will give a magnetic course smaller than the true course. It follows that westerly variation must be added to the true course to obtain the magnetic course.

True Course

The true course is the angle between the true meridian passing through the vessel and the vessel's fore and aft line.

Magnetic Course

The magnetic course is the angle between the magnetic meridian passing through the vessel and the vessel's fore and aft line.

Secular Change

The positions of the magnetic poles change slightly each year so there is a consequent small change in the value of magnetic variation. This annular change is not a constant value and is itself subject to change. Therefore, when updating variation values by applying secular change from information printed on the compass roses of old charts, caution should be taken. If possible take the variation value for the area concerned from an up-to-date isogonic chart.

Isogonic Lines

Isogonic lines are lines passing through places having the same magnetic variation.

Agonic Line

Agonic line is the isogonic line representing zero variation.

Isallogonic Lines

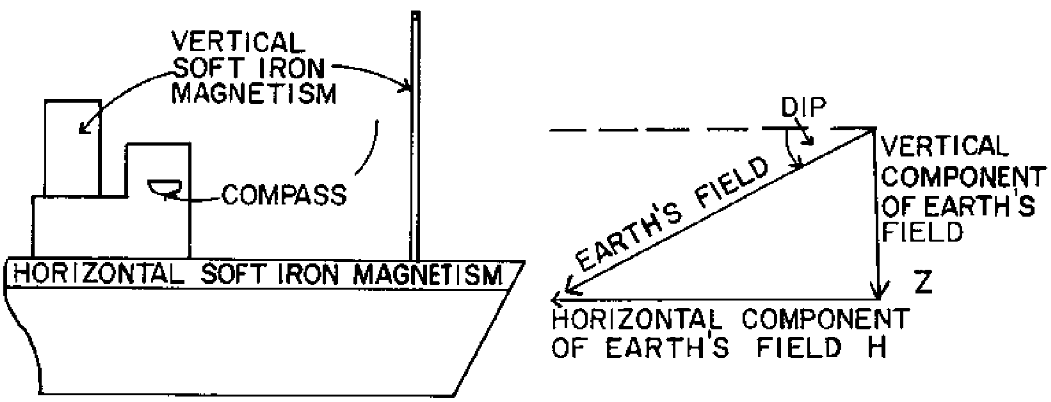
Isallogonic lines are lines passing through places having the same secular change in variation.

Exercise 7. VARIATION AND MAGNETIC COURSE (Chart 1211)

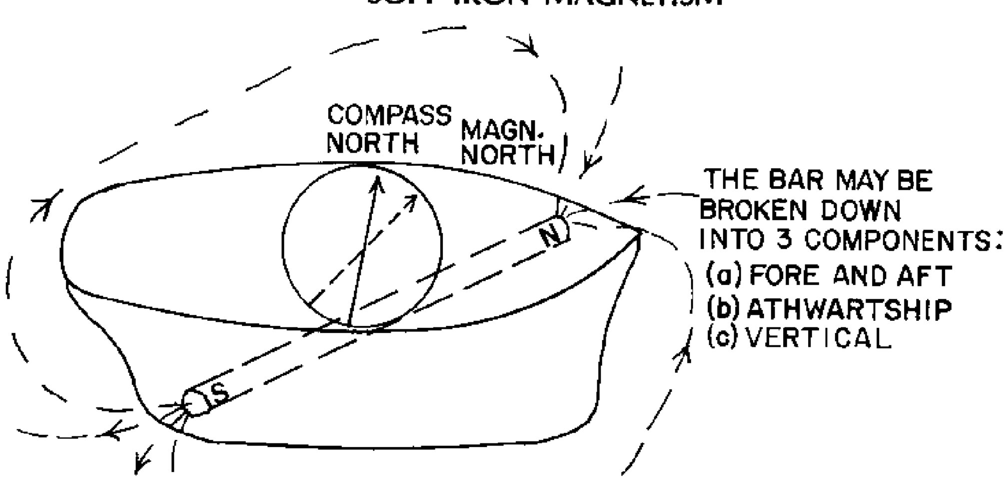
1. True course and variation given, state magnetic course:
   - (a) 035° T, Var. 17° W,
   - (b) 097° T, Var. 12° E,
   - (c) 268° T, Var. 28° W,
   - (d) 348° T, Var. 15° E,
   - (e) 357° T, Var. 12° W,
2. Magnetic bearing and variation given, state true bearing:
   - (a) 078° M, Var. 23° W,
   - (b) 143° M, Var. 16° E,
   - (c) 289° M, Var. 31° W,
   - (d) 356° M, Var. 14° E,
   - (e) 011° M, Var. 17° W,
3. True and magnetic bearings given, state variation:
   - (a) 089° T, 058° M,
   - (b) 158° T, 187° M,
   - (c) 197° T, 164° M,
   - (d) 289° T, 298° M,
   - (e) 357° T, 017° M,
4. Find the magnetic course from Southwest Ledge Bell Buoy to Cerberus Shoal Whistle Buoy.
5. Find the magnetic course from Watch Hill Pt. to pass 3 miles off Montauk Pt. when a-beam.

Ship's Magnetism

The effect of the earth's magnetic properties on the compass needle is complicated by the effects of magnetic fields set up by the iron contained in the ship itself. This text will not discuss in detail the various components of a ship's magnetic properties, but they may be broadly regarded in two groups: Permanent, or hard iron, magnetism induced into the ship's structure during building and variable, or soft iron, magnetism which varies according to the intensity of the component of the earth's field that induces it.



SOFT IRON MAGNETISM



HARD IRON MAGNETISM

DEVIATION

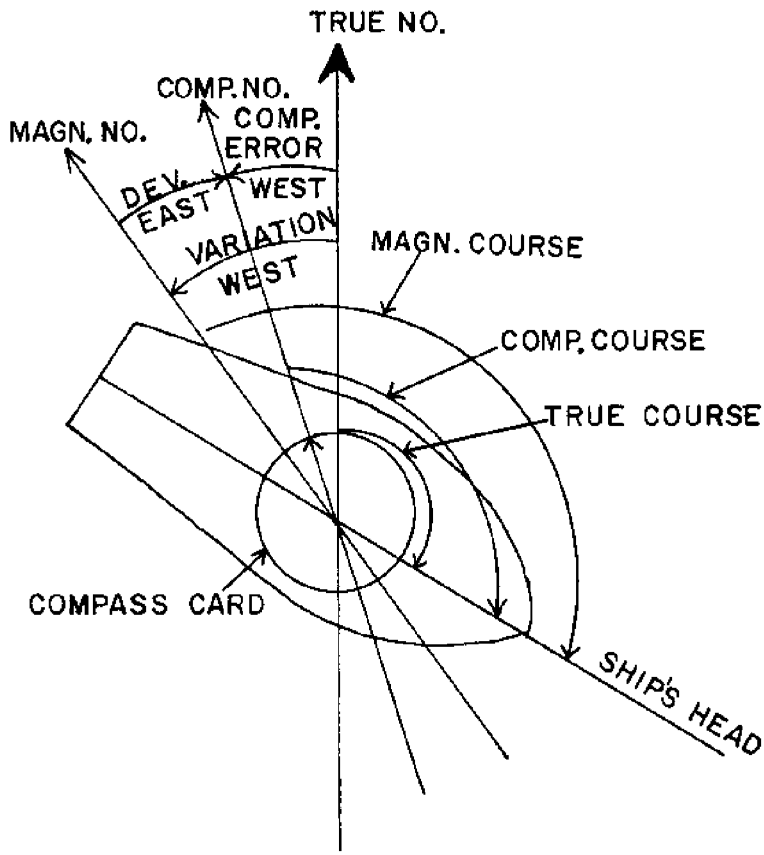
Deviation is the amount that the compass needle is deflected from the magnetic meridian due to the effects of the ship's iron. It can be clearly seen from the preceding diagram that as the vessel alters course, around the steady card its various magnetic poles will be presented at differing angles to the compass needle. Thus, deviation is not a constant error; its value changes with alteration of course.

COMPASS CORRECTION

The ship's magnetic disturbing effects are compensated for as much as possible by placing correctors of equal and opposite effect near the compass. The basic principle observed in compass correction is: "Like cures like."

Fore and aft hard iron magnetism is compensated for by a fore and aft magnet of equal and opposite effect, and athwartship hard iron magnetism is opposed by an athwartship magnet of equal and opposite effect. The soft iron disturbing fields are compensated for by two athwartship soft iron balls and a vertical soft iron bar called the "Flinder's Bar," which is placed in the fore and aft line usually forward of the compass.

The process of compass correction is done by practical experiment. The ship is "swung" through 360° of the compass and steadied on various headings in order to note the deviation by observing the difference between the compass bearing of a distant object and its known magnetic bearing. These deviations are then reduced as much as possible by the compensation process, and any remaining deviations are observed and plotted in table form for practical use at sea. Examples of deviation tables and curves follow.



COMPASS COURSE AND COMPASS ERROR

Compass course is the angle between compass north and the ship's head. Compass error is the amount that a compass needle is deflected out of the true meridan due to the combined effects of variation and deviation.

Compass Error = Variation ± Deviation.

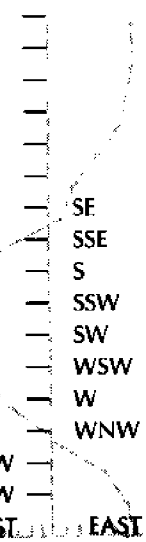
It can be seen from the above diagram that if variation and deviation are of opposite name they are to be subtracted to give the compass error. If variation and deviation are the same name they are added to give the compass error.

Also note from the same diagram that if the compass error is west then the compass course is greater than the true course. Similarly, if the deviation is west then the compass course is greater than the magnetic course.

Compass error, or deviation west, then compass course best;
compass error, or deviation east, then compass course least.

DEVIATION CARD I

Compass	Course	Deviation	Curve	Magnetic Course
N	000°	7° E	N	007°
NNE	~~002½°~~ 022½	7° E	NNE	029½°
NE	045°	6½° E	NE	051½°
ENE	067½°	6° E	ENE	073½°
E	090°	4° E	E	094°
ESE	112½°	2° E	ESE	114½°
SE	135°	1° W	SE	134°
SSE	157½°	4° W	SSE	153½°
S	180°	6° W	S	174°
SSW	202½°	7½° W	SSW	195°
SW	225°	7° W	SW	218°
WSW	247½°	6° W	WSW	241½°
W	270°	3½° W	W	266½°
WNW	292½°	Nil	WNW	292½°
NW	315°	4° E	NW	319°
NNW	337½°	6° E	NNW	343½°
N	000°	7° E	WEST EAST	007°



Deviations for intermediate directions of the ship's head can be quickly calculated from the rate of change of deviation between the nearest known points, or it can be taken directly from the curve.

Example A

Find Deviation for 256° C from Deviation Card I.

256° C is 8½° beyond WSW toward W where deviation changes 2½° in 22½° of course alteration

$$\text{Deviation on } 256°\text{ C} = 6°\text{ W} - \left(\frac{8\frac{1}{2}}{22\frac{1}{2}} \times 2\frac{1}{2}\right)$$

Deviation on 256° C = 6° W − .94° (Deviation is decreasing)

For all practical purposes, Deviation = 5° W

Example B

Find Deviation for 130° C from Deviation Card I.

130° C is 5° from SE back toward ESE where deviation changes 3° in 22½° of course alteration

Deviation on 130° C = 1° W $- \left(\frac{5}{22\frac{1}{2}} \times 3\right)$

Deviation on 130° C = 1° W - 2/3° (Deviation is decreasing)

For all practical purposes, Deviation = nil.

In examples A and B we have found the deviation for a given Compass Course. Deviation is used more often in a reverse manner, being applied to a known magnetic course required to be steered between two given points.

Example C

A course of 125° T is required where variation is 18° W. Find the Compass Course to Steer using Deviation Card I.

125° T with Var. 18° W gives 143° M.

143° M lies between 134° M and 153½° M on Deviation Card I. In this region the deviation changes from 1° W to 4° W in 19½° magnetic. 143° is 9° beyond 134° with deviation increasing from 1° W.

Deviation for 143° M = 1° W $+ \left(\frac{9}{19\frac{1}{2}} \times 3\right)$

Deviation for 143° M = 1° W + 1.4° (Deviation is increasing)

Deviation for 143° M = 2.4° W.

Compass Course to Steer = 145° C.

In a nutshell, variation (the effect of the earth's magnetic properties) is applied to the true course to obtain the magnetic course, and deviation (the effect of the ship's magnetic properties) is applied to the magnetic course to obtain the compass course to steer.

Exercise 8. DEVIATION, COMPASS COURSE AND COMPASS ERROR

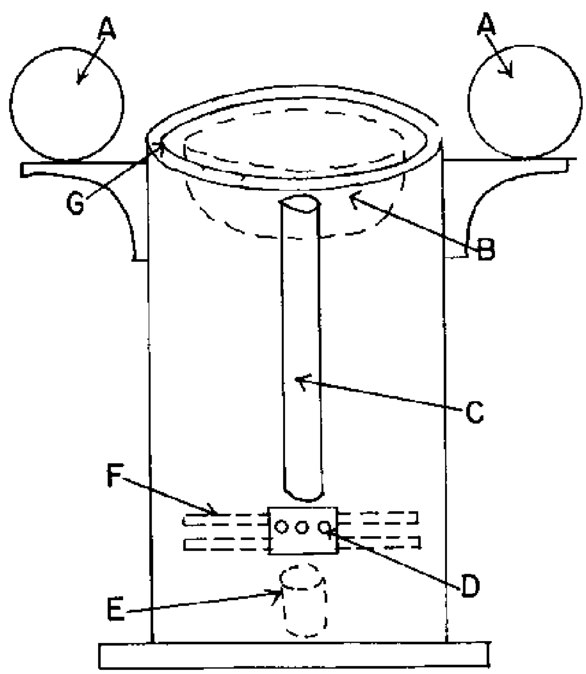
Given the following information:

Compass Course	Deviation
N	5 W
NNE	5 W
NE	5 W
ENE	4½ W
E	4 W
ESE	3 W
SE	2 W
SSE	Nil
S	1½ E
SSW	2½ E
SW	3½ E
WSW	3½ E
W	3 E
WNW	1½ E
NW	1 W
NNW	3 W

1. Compile Deviation Card II together with curve of deviations to scale.
2. From Deviation Card II find the deviation for the following compass courses, by both calculation and consulting the curve:
   057° C, 129° C, 168° C, 239° C, 307° C.
3. Using Deviation Card II find the deviation for the following magnetic courses:
   038° M, 167° M, 232° M, 280° M, 307° M.
4. From Deviation Card I find the deviation for the following compass courses:
   079° C, 127° C, 174° C, 284° C, 307° C.
5. From Deviation Card I find the deviation for the following magnetic courses:
   089° M, 127° M, 188° M, 281° M, 331° M.
6. Fill in the blanks in this table.

	True Course	Variation	Magnetic Course	Deviation	Compass Error	Compass Course
a)	128° T	28° W		3° E		
b)	207° T			6° W	24° W	
c)		18° E	256° M	3° W		
d)			306° M	7° E	22° W	
e)		21° E			17° E	016° C
f)		18° W		5° W		337° C
g)	196° T		174° M			181° C
h)				2° E	2° W	010° C
i)	232° T	27°E			30° E	
j)		18° W	154° M		14° W	
k)	352° T			6° W	37° E	
l)		19° E	218° M			223° C
m)		36° W			25° W	176° C
n)				9° E	14° W	256° C
o)	018° T		357° M			000°C
p)	359° T			1° E	18° W	
q)		24° E	295° M	6° W		
r)	006° T		347° M	11° E		
s)	001° T	11° E		11° W		
t)		27° W			14° E	346° C

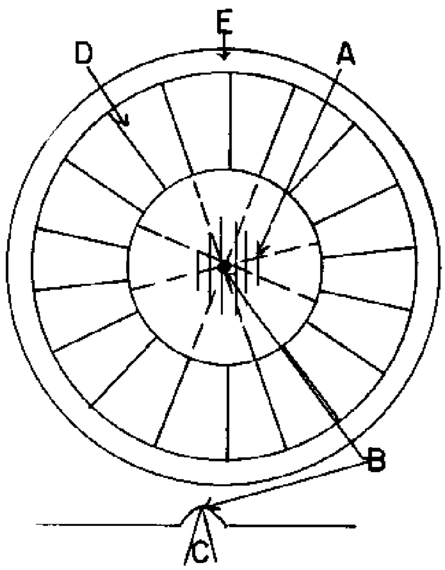
The Compass



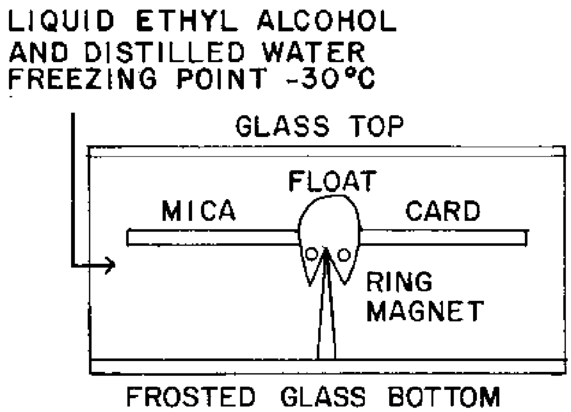
COMPASS BINNACLE

KEY TO COMPASS BINNACLE

A. Athwartship Soft Iron Correctors
B. Compass Bowl (painted white with black Fore and Aft Lubber Line to steer by)
C. Flinder's Bar, Fore and Aft Soft Iron Corrector
D. Fore and Aft Permanent Corrector Magnets
E. Bucket which contains Vertical Corrector Magnets and which also helps to correct for disturbing forces created when ship heels
F. Athwartship Permanent Correct Magnets
G. Gimbals and Antivibrational Springs and Mountings



DRY CARD



LIQUID COMPASS CARD

KEY TO DRY CARD

A. Set of Needle Magnets of cobalt steel held in place by silk threads
B. Center Sapphire Jeweled Bearing
C. Iridium Pivot
D. Card made in sections of rice paper to allow for any expansion or contraction
E. Aluminum Outer Ring

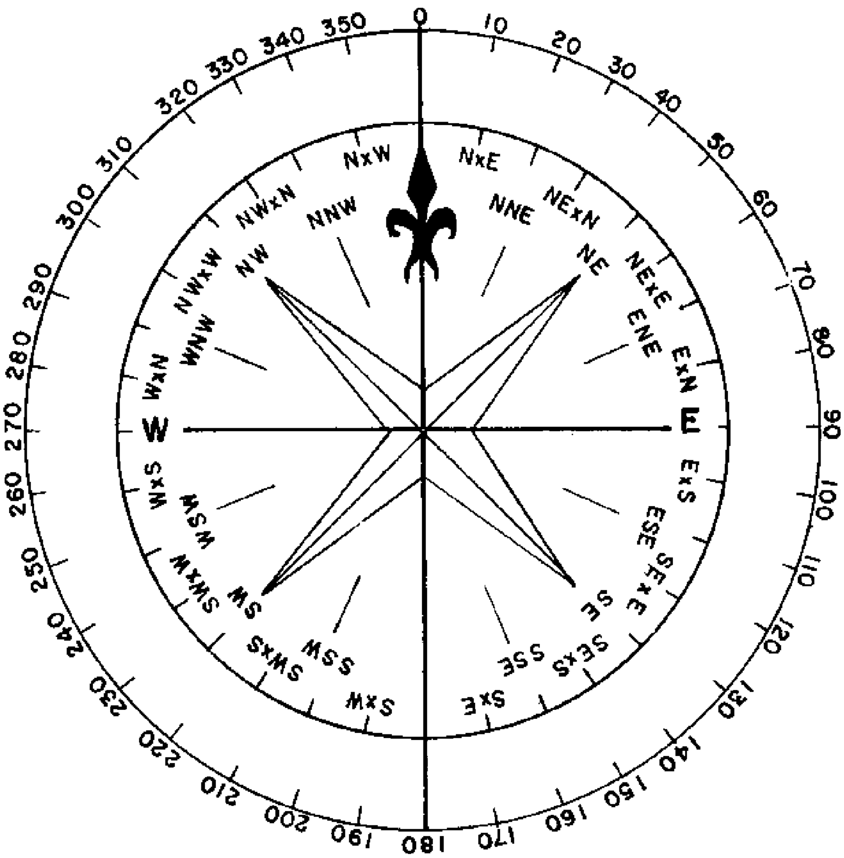
NOTE ON LIQUID COMPASS CARD

In general the liquid card is much more stable than the dry card because the liquid quickly "damps out" oscillations of the card due to motion of the ship. Such a "dead beat" type of compass is generally preferred.

THE GYRO COMPASS

The gyro compass consists of a heavy wheel, called the rotor, which is rotated at high speed by an electric motor. The property of gyroscopic inertia in a spinning gyro allows the axis to remain rigid in its direction no matter how its supporting frame is moved. This principle is utilized by applying a gravity control to the axis, causing it to oscillate about the true meridian. The oscillation is further controlled by a damping system which causes the axis to settle, usually within 1 degree of the true meridian. The danger of incorrect application of variation, deviation or both is removed.

Modern gyro compasses are sturdy, compact and efficient and lend themselves well to such refinements as automatic helmsman and course-stabilized radar display. However, the cost of such equipment is beyond the means of most smaller boat operators.



COMPASS CARD GRADUATION

When converting from one notation to the other, remember 1 point = 11¼ degrees.

Exercise 9. COMPASS COURSES AND BEARINGS (Chart 1211)

1. Using Deviation Card I and variation from the compass rose, find the position of a vessel steering 020°C when Southeast Pt. was bearing 035°C and Montauk Pt. was bearing 312° C.

2. The Tall Building south of Fort Pond bore 041°C and East Hampton Spire bore 297°C. Find the vessel's position using Deviation Card II if she was steering 145°C.

3. Watch Hill Pt. was bearing due north by compass while Race Pt. was bearing 308°C. Find the position if the vessel was steering 072°C, using Deviation Card I.

4. The measured-mile markers at Grace Pt. on Block I. were in transit bearing 140°C. By observation of their true transit bearing, compute the deviation of the vessel's compass at this time. If Sandy Pt. was bearing 060°C, how far off the land would the vessel be?

5. The vessel was steering 142°C and, using Deviation Card I, Race Pt. bore 306°C while the depth sounder recorded 30 fathoms. What should the compass bearing of Little Gull I. Lt. have been at this time?

6. Pt. Judith west breakwaters were in line bearing due north compass. Find the deviation of the compass at that time and, if Sandy Pt. Lt. was bearing 250°C, how many miles off the east breakwater entrance was the vessel?

7. Find the compass course to steer from Gardiners Pt. Bell Buoy to pass 1 mile to the northward of Shagwong Reef Buoy. Use Deviation Card II.

8. Find the compass course and distance from a position 4 cables* southwest of Race Pt. to the No. "3" gong buoy off Montauk Pt. Also find the compass course necessary to steer due south true from the gong buoy. Use Deviation Card I.

9. Montauk Pt. Lt. bore 032°C to a vessel steering 048°C at 9 knots. One hour later the same light was bearing 354°C. Using Deviation Card I. find the vessel's position at the time of the second bearing.

10. At 0630 Watch Hill Pt. Lt. was bearing 322°C to a vessel steaming 254°C at 7½ knots. A northerly wind was giving the vessel an estimated 5° leeway and the tide was estimated to be setting 030° T at 2 knots. Find the vessel's position at 0730 if Watch Hill Pt. Lt. was then bearing 042°C. Use Deviation Card II. What compass course should now be steered to pass through "The Race" 4 cables off the Lt. Bn. off Race Pt.?

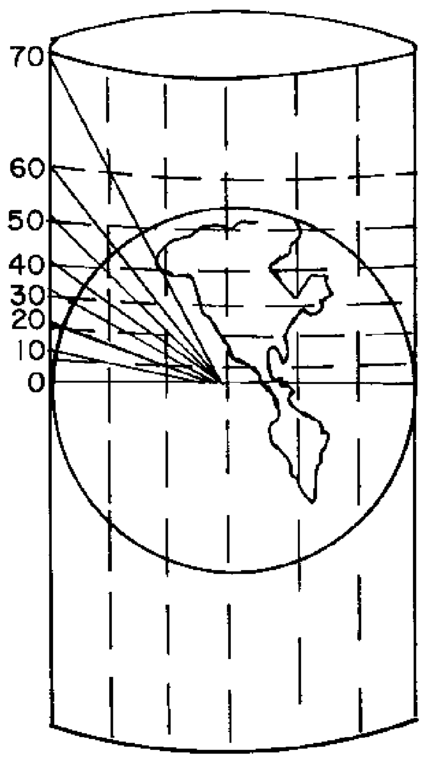
*One cable is one-tenth of a nautical mile.

Chart Projections

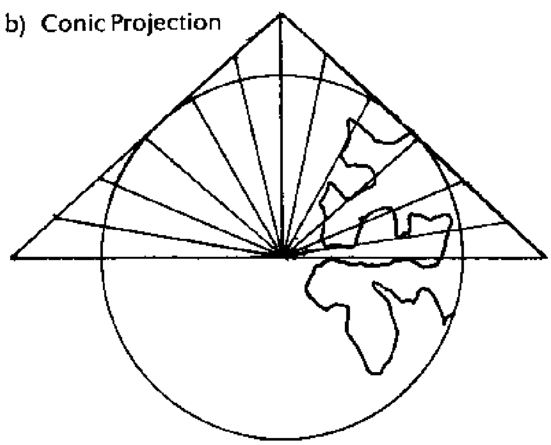
There are numerous methods used for transferring all or part of the surface of a sphere onto a plane surface.

A section of a sphere cannot be flattened out without distortion. Because of this "undevelopable" property, either a cylinder, a cone, or a tangential plane is used to represent the section. These are developable surfaces in that they can be flattened into chart form without distortion.

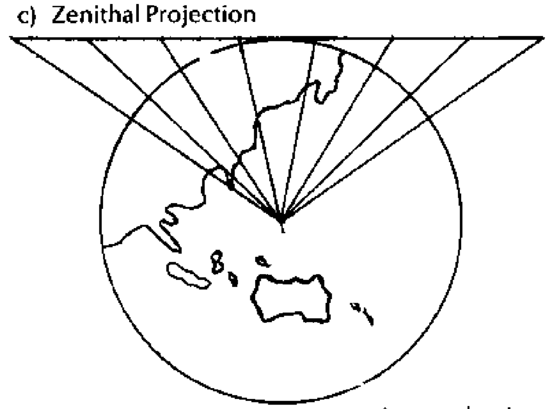
a) Cylindrical Projection



b) Conic Projection



c) Zenithal Projection



A discussion of one of each of these projections and its importance in the production of charts follows. Any projection will have some degree of proportion, scale or angular distortion, but in some cases this feature of a projection can be used to the navigator's advantage.

THE MERCATOR PROJECTION

The projection most favored and used to produce a great majority of charts is the Mercator projection which is effected by projecting from the center of the earth through certain positions on the earth's surface onto the inner surface of a circumscribing cylinder. It can be easily visualized that meridians of longitude will thus be represented as parallel straight lines. However, we know that on the globe they converge to meet at the poles. That is to say, 1 minute of longitude, which equals approximately 1 minute of latitude at the equator, gradually decreases to zero value at the poles. Thus we can say that the distance value of 1 minute of longitude varies as to the cosine of the latitude concerned. On the Mercator projection we have removed this convergency of the meridians; therefore, theoretically we have cancelled the cosine value with secant value;

$$\text{i.e., Dist. Value of Long.} = \text{Long.} \times \cancel{\text{Cos. of Lat.}} \times \frac{1}{\cancel{\text{Cos. of Lat.}}}$$

Therefore, in order to keep the area represented in the correct relative porportion it is also necessary to increase the distance between parallels of latitude by the same degree, that is, by the secant of the mean latitude. For this reason Mercator charts are of no value in the polar regions, the natural secant of 90 degrees being infinity. Also this is why it is important to measure distance on the latitude scale of the chart only in the immediate latitude concerned. The distance value, in nautical miles, for any given difference of longitude in a given latitude is known as *departure*.

THE GNOMIC PROJECTION

The gnomic projection is a zenithal projection which is of particular value for portraying the polar regions. For a polar gnomic chart the pole itself is the point of tangency of the plane, and points on the earth's surface are projected onto its underside by means of straight lines from the center of the earth. Meridians of longitude will therefore appear as spokes from the center and parallels of latitude, as concentric circles. The gnomic chart is also commonly called a great circle chart because straight lines laid off on such a chart will be great circles.

This property allows a relatively inexperienced navigator to take advantage of great circle sailing without going through the more difficult calculations necessitated by the mathematical approach to it. While a straight line is the shortest distance between two points on a plane surface, the arc of a great circle is the shortest distance between two points on the surface of a sphere. A straight line tracked out by a vessel steering a steady course on the earth's surface will result in a spiral or loxodromic curve which cuts all meridians at the same angle. Such a curve is commonly called a *rhumb line*.

Note that a rhumb line appears as a straight line on a Mercator chart but will be a curve on a gnomic chart while the converse will apply to a great circle.

A considerable distance can be saved by sailing a great circle track instead of a straight rhumb-line course on long ocean passages. This is easily accomplished by transferring so many positions through which a straight line on a gnomic chart passes onto a Mercator chart of the same region. The interval of these positions is usually approximately a day or a half-day of normal steaming distance and the positions are joined by a series of straight rhumb lines which combine to give the nearest practical approximation to a great circle.

THE POLYCONIC PROJECTION

The simple conic projection is only accurate near the latitude of tangency of the cone. Considerable distortion will result at appreciable distances from this standard parallel. This fault can be overcome by the use of a series of cones (so that each latitude is the base of a tangent cone) and because many, or "poly," cones are used, the projection is termed polyconic.

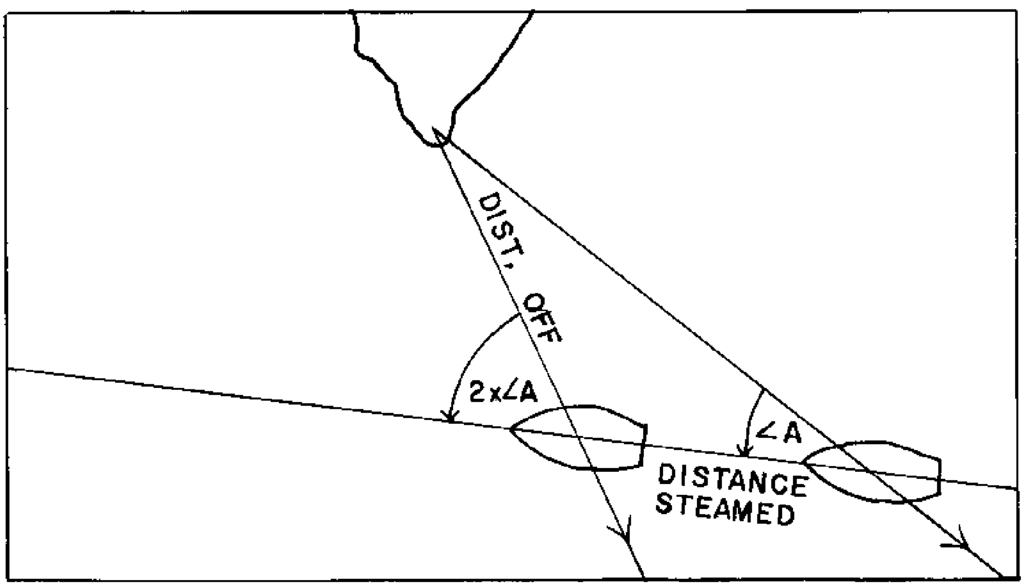
Parallels of latitude appear as nonconcentric circles and meridians are curved slightly concave toward a central, straight meridian. The scale is true along the central meridian and any parallel of latitude.

This type of projection is used extensively for maps of large land areas because a number of small maps are easily fitted into a large coverage. For this reason charts produced from this projection are sometimes used in navigating lakes or inland waterways.

Practical Chartwork

SPECIAL CASES OF THE RUNNING FIX

A. Doubling the Angle on the Bow



If the angle between the ship's head and an object ashore is doubled by steaming a certain distance, then, because the exterior angle of a triangle is equal to the two interior opposite angles, the interior angles are equal. In other words, an isosceles triangle has been formed and the sides opposite the equal angles must also be equal.

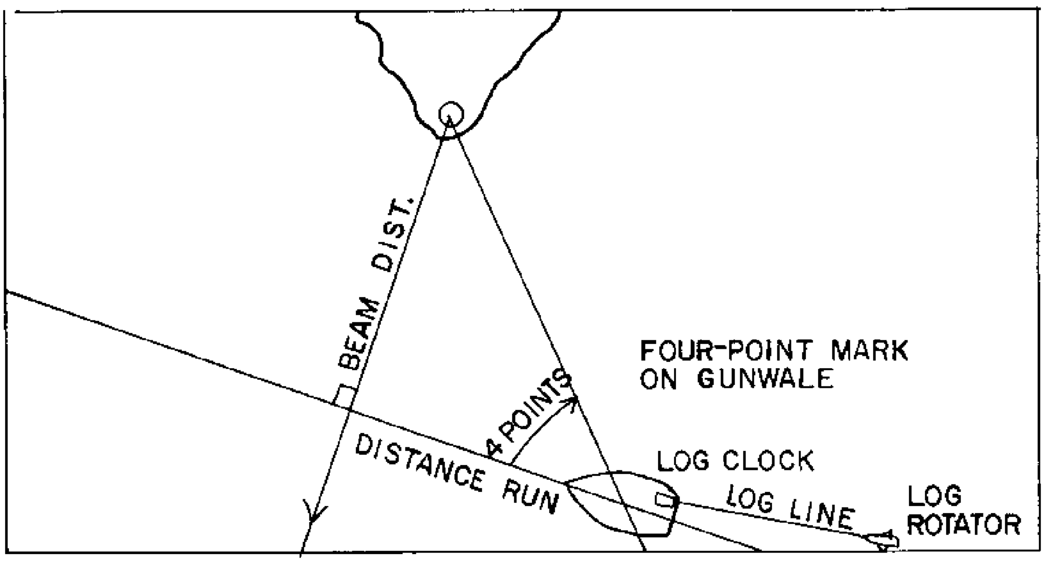
Therefore, Distance Steamed = Distance Off At Second Bearing

Any appreciable set and drift of current will render this method of fixing inaccurate. Also error is likely if very small angles are used.

B. The Four-Point Problem

A convenient application of doubling the angle on the bow, which serves as a good practical method of approximating position in small craft, uses the four-point bearing. A steady course is steered and the bearing of a shore mark is observed until it is four points (45 degrees) on the bow. The vessel continues on a steady course and speed until the mark is abeam. Then the distance off abeam will be the distance steamed between the four-point bearing and the beam bearing. It is handy to have a small paint mark on the gunwale on each side of the bow at four points to the helmsman. These marks can be set up accurately while the vessel is alongside. It is important to have a good idea of the vessel's speed through the water for any type of running fix; perhaps, the best way of determining this is from a patent log. The log gear consists of a rotator which is towed behind the vessel and is attached by a log line to a critically geared clock which is graduated in nautical miles. The accuracy of the log can be improved by adjusting the length of log line until the distance recorded on the clock corresponds to that determined by fixed observations. Various, more sophisticated logs, more permanent in nature, are available, but are more expensive.

One of these relies on the amount of power recorded by a small generator activated by a tiny propellor projecting beneath the hull. The amount of power depends on the revolutions of the propellor which, in turn, vary directly according to the vessel's speed relative to the water. Other logs rely on the pressure of water on a tube or tubes extending from the hull.



The distance run between an angle on the bow of 63½ degrees and the four-point bearing will give half the distance off when abeam.

C. Distance Off Abeam Equals the Distance Run Between Set Bearings

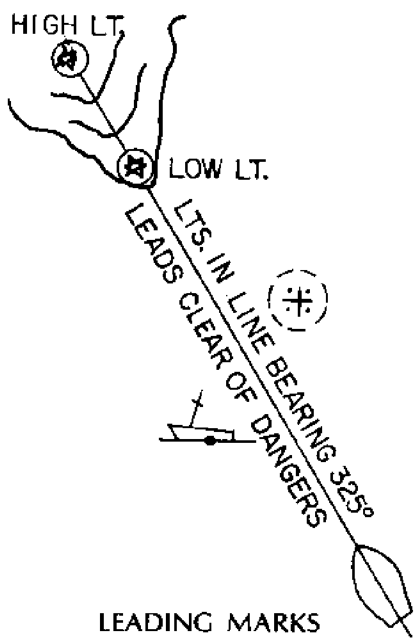
If the relative bearing of a shore object is increased as indicated in this table, then the distance run between the two bearings will be the distance off the object when it is abeam.

Relative bearings in degrees from ship's head

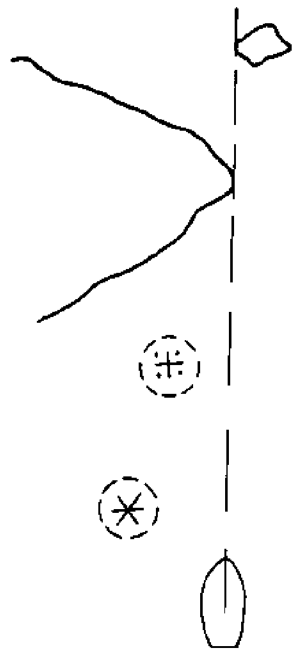
22°	- 34°
25°	- 41°
26½°	- 45°
32°	- 59°
35°	- 67°
37°	- 72°

LEADING AND CLEARING MARKS

Leading and clearing marks,which may be natural or man-made, are extremely useful aids to chartwork when handling a ship in confined waters. Many helpful clearing and leading marks, which are not marked on the chart, can be discovered as the navigator gradually acquires local knowledge of a particular area. Various church towers, rocks, taverns, etc., when kept in line with a more conventional navigation mark, such as a buoy, beacon or lighthouse, lead the vessel clear of rocks, shoals and dangers.



LEADING MARKS



CLEARING MARKS

Exercise 10. DOUBLING THE ANGLE ON THE BOW (Chart 1210)

1. A vessel steering due true north at 11 knots observed Gay Head Lt. bearing northeast. What distance will she be off the light when it is abeam some 22 minutes later?

2. A vessel steering 326° C observed Buzzards Bn. four points on the st'b'd bow with the log reading 36. Give the latitude and longitude of the beam position if the log was reading 41.3 at this time. Use Deviation Card I.

3. A vessel steering 214° C sights the No. 2 Whistle Buoy to the south of Nomans Land 30° on the port bow with the log reading 97½. Some time later the buoy is 60° on the port bow and the log reads 101. Find the distance off at the time of the second bearing and also the distance off abeam. Use Deviation Card I.

4. A vessel steering 202° C sights Southeast Pt. Lt. 27° on the st'b'd bow. Some time later Southeast Pt' Lt. bore 256° C. If the total number of engine revolutions made between bearings indicated that the vessel had travelled 5 miles, give the vessel's position at the time of the second bearing. Use Deviation Card I.

5. Brenton Reef Bn. was 35° on the st'b'd bow of a vessel steering 316° C with the log reading 47. When the log was reading 49 the Brenton Reef Bn. was found to be 67° on the st'b'd bow. How far will the vessel be from Brenton Reef Bn. when it is abeam if the present course and speed are maintained?

FIRST GENERAL CHARTWORK EXERCISE (Use Deviation Card I)

For the purpose of this exercise you are skipper of a trawler fishing out of New Bedford in the Gulf of Maine area working as far east as Liverpool, Nova Scotia.

1. List the charts you will require, using the chart catalog inserts. State what you will look for when checking these charts and list the allied publications you will carry.

2. You pass through New Bedford Outer Breakwater at 0400 Monday morning and proceed at 6 knots on various courses until you reach the Gong Buoy at Negro Ledge. Increase speed to 9 knots and alter course down Buzzards Bay to the Qk. Fl. Whistle Buoy to the southeast of Buzzards Bn. State the compass course and the least depth of water encountered on that course.

3. From the Whistle Buoy alter course to pass a mile to the northward of the No. 2 Whistle Buoy to the south of Nomans Land. A little later Gay Head Lt. was bearing 094° C and half-an-hour after this the same light was bearing 032° C. From this position adjust the course allowing 5° leeway for a southerly wind. State the initial and final compass courses and give the vessel's position at the time of the second bearing.

4. Assuming that this course is maintained, transfer the abeam position of the vessel at the No. 2 Whistle Buoy from Chart 1210 to Chart 71. What is the compass beam bearing of the buoy, and at what time should it be abeam?

5. At this position alter course to pass 4 miles off Davis South Shoal Buoy and "stream" the log, setting it at zero. The buoy was not sighted but some time later when the log was reading 65, Nantucket Lt. V/L was observed four points on the st'b'd bow. If the light vessel was abeam when the log was reading 76, state the compass course steered and give any alteration of course necessary to maintain the vessel on this course line.

6. Continue on this course until the 40-fathom line is reached, then alter course due east magnetic to begin fishing. It is estimated that an average advance speed of 2½ knots is made for the next full day's fishing in a general east magnetic direction. At the end of this time a good catch has been made and the course is set for Boston. The sounding at this time being 47 fathoms, state the compass course necessary in order to alter course 3 miles to the east of Cape Cod Lt. Give the course from this position to the Graves Lt. Bn. At what time do you expect to arrive off The Graves if a speed of 10 knots is maintained?

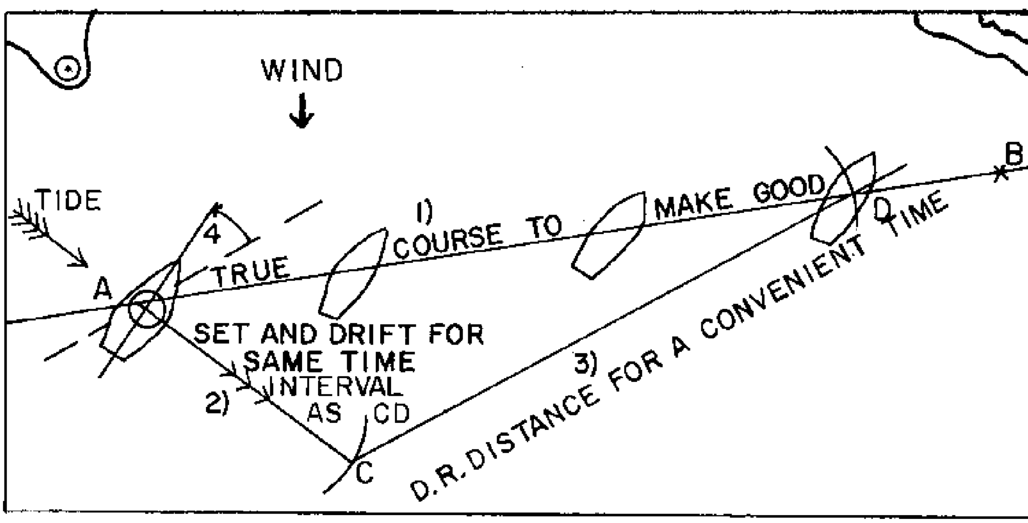
Check that the Buoys and Lt. Vessel are positioned as for 1970:

a. Qk. Fl. Whistle Buoy S.E. of Buzzards Bn. 41°22.'6 N 71°00.'2 W.
b. S. Nomans No. 2 Whistle Buoy 41°12.'2 N 70°50' W.
c. Davis S. Shoal Buoy 40°57.'3 N 69°55' W.
d. Nantucket Shoals Lt. Vl. 40°30' N 69°28' W.

Allowing for Wind and Tide

A current setting directly ahead or astern of a vessel will only affect the speed made good through the water and will not cause the vessel to be set from her course line. If the current is setting at any angle to the projected course line it is necessary to alter course toward the current in order to make the course good. The amount of alteration obviously must vary according to the strength and relative direction of the current as well as the speed of the ship.

It is first necessary to estimate the set and rate of the current and allow for this as indicated in the following diagram. Any wind effect can be allowed for after this is done.



1. Lay off the course required to be made good, AB.
2. From A also lay off the estimated set and drift of current for any convenient time, usually 1 hour or 2 hours, AC.
3. With center C and radius equal to the D.R. distance for this convenient time, cut off CD on the line AB. Then CD is the course to steer to combat the current and AD is the distance made good. If AD is greater than CD, the current is said to be favorable, otherwise it is unfavorable.
4. Finally, leeway is counteracted by altering course into the wind. The amount of compensation for a given force of wind varies considerably for different conditions of draught and trim for one particular vessel. The accuracy of estimation of leeway improves with experience.

A helpful fact is that a 1-degree set to port or st'b'd of the course steered will give an error of about 100 feet in a distance of 1 mile run.

Exercise 11. ALLOWING FOR WIND AND TIDE (Chart 71)

Use Deviation Card I throughout.

1. Find the compass course to steer from Jeffreys Ledge Whistle Buoy to Cashes Ledge Whistle Buoy in order to combat a current setting south at 2 knots if the vessel is steaming at 10 knots. What speed will the vessel make good? (Four to five hours is probably the best time factor to use in this case.)

2. Find the compass course to steer from Brazil Rk. Whistle Buoy to Gull Rk. Fl.R. Whistle Buoy to counteract a current setting 260° T at 3 knots. What speed will the vessel make good if her D.R. speed is 11 knots?

3. Give the compass course to steer from 42°45′ N 67°00′ W to the R "10" Whistle Buoy marking the Great South Channel in order to combat a 2½-knot current setting from the south. If the vessel is steaming at 9 knots what speed should she make good?

4. Find the compass course to steer from 42°05′ N 69°07′ W to a position 1 mile south of Eastern Pt. at the approaches to Gloucester. The current is estimated to be setting 300° T at 2 knots and 5° leeway is to be allowed for a southwesterly wind. The vessel has a D.R. speed of 12 knots.

5. Give the compass course and speed made good for a vessel steaming at 10 knots from Nomans Land Bell Buoy to Nantucket Lt. V/L and counteracting a current setting 050° T at 2½ knots. Nine degrees leeway is to be allowed for a northerly wind.

6. A vessel 1 mile to the east of Pollock Rip Lt. Buoy wishes to pick up Cultivator Shoal Whistle Buoy ahead. What compass course should she steer to counteract a current setting 070° T at 3 knots and a northerly wind estimated to be giving 8° leeway? The vessel has a steaming speed of 8 knots.

7. A vessel wishes to make good a course from Gannet Rk. Bell Buoy to 42°10′ N 65°18′ W. The mean time of the passage will be 8 hours after the time of maximum flood at Pollock Rip Channel. Using the current diagram in 42°50′ N 65°56′ W find the compass course to steer and the speed made good if the vessel is steaming at 7 knots.

8. Using the current diagram in 43°16′ N 66°00′ W find the compass course to steer from 42°35′ N 65°22′ W to pass 1 mile to the eastward of Lurcher Shoal Lt. V/L. The mean time of passage is the time of maximum flood at Pollock Rip Channel and the vessel is steaming at 11 knots. How long will it take before the light vessel is abeam?

9. A vessel leaves 40°54′ N 67°47′ W to pick up the Cultivator Shoal Whistle Buoy ahead. Find the compass course to steer to combat the current indicated by the vector near Cultivator Shoal for 8 hours after time of maximum flood at Pollock Rip Channel for the full moon period. Also allow 10° leeway for a westerly wind. If the vessel is steaming at 8 knots what speed will she make good?

10. A vessel steaming at 10 knots leaves 41°15′ N 68°55′ W with the tide flooding and the moon at first quarter. What compass course should be steered to make the R"4" Flashing Buoy near Davis Bank allowing 10° for a southerly wind?

SECOND GENERAL CHARTWORK EXERCISE (Chart 1210)

Use Deviation Card I and assume your vessel's steaming speed is 10 knots and towing speed 3 knots throughout.)

1. You leave Pt. Judith East Breakwater Entrance at 0400 to fish within the 25-fathom "deep hole" 12 miles eastward of Block Island. You are required to set the gear where the 3H4-5950 Loran position line crosses the 25-fathom line. Give the compass course to steer to combat the flood tide estimated to be setting 350° T at 2 knots and a southerly wind estimated to be giving 5° leeway.

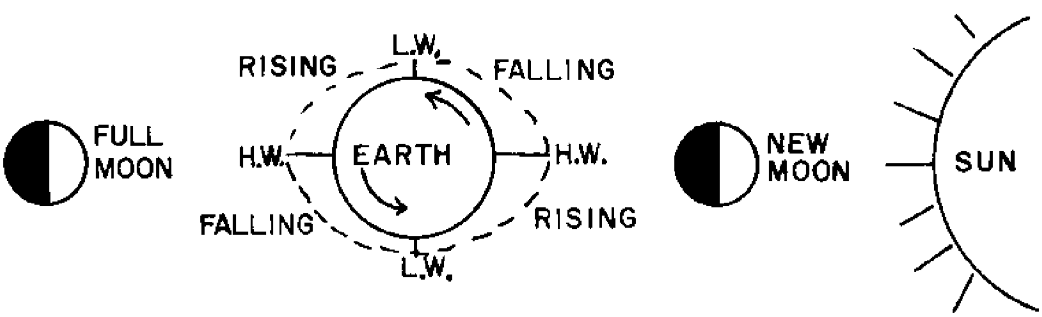
2. Two 2-hour drags are made toward the 30-fathom patch in the southwest leg of the "deep hole," taking about 20 minutes between sets and keeping to this course line as much as possible to avoid known snags on each side. The 25-fathom line is crossed with a Loran reading of 3H5.1800 and a course of 005° C is steered at 10 knots for 30 minutes. At the end of this time Southeast Pt. Lt. is bearing 291° C at 6¾ miles. Find the set and rate of the current experienced if the wind effect is negligible.

3. A 1½-hour set is now made allowing 5° leeway for a southeasterly wind. What compass course should be steered in order to make good a course of 354° T, assuming the set and rate of current as found? What distance would be covered in this set?

4. A hurricane warning is now received and the course is set for New Bedford, steering 058° C in heavy rainfall. At 1400 Buzzards Bn. is bearing 099° C and at 1430 it bears 167° C. Give the vessel's position at 1430 if the tide is estimated to be setting 210° T at 2 knots between bearings. Give the two compass courses from here to the Hurricane Barrier at New Bedford, altering course at the fl. gn. buoy to the southward of Negro Ledge. What time should the vessel pass the Hurricane Barrier if, because of adverse weather conditions, the speed is reduced to 8½ knots after 1430?

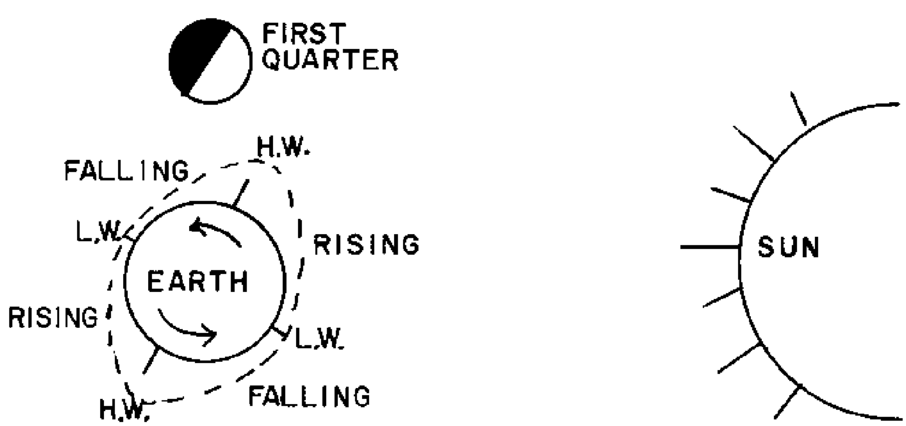
Tides

The combined gravitational effects of the moon and sun, in the power ratio of 7 to 3 respectively, attract the water envelope around 73 percent of the earth's surface into an elliptical shape. At spring tides their combined effects act together to give a very high, high water and a very low, low water, whereas at neap tides their effects are opposed which results in lower high waters and higher low waters. This simply means that the spring range of tide is far greater than the neap range.



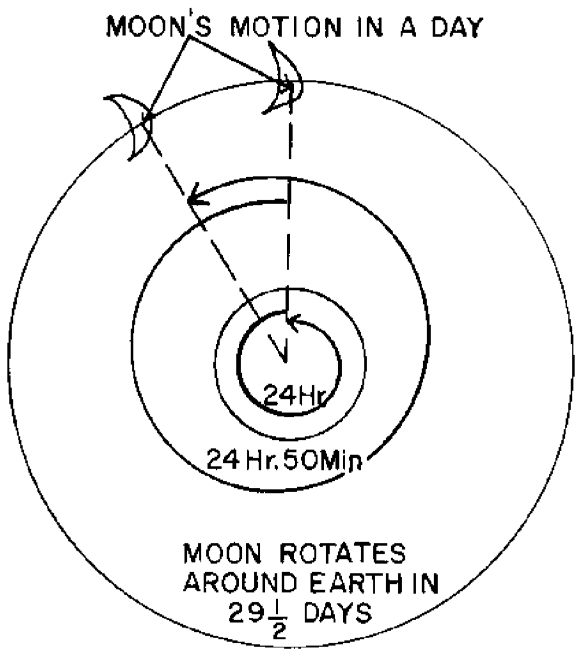
SPRING TIDES

Spring tides occur in reciprocal longitudes at the time of new moon and full moon. As the earth rotates on its axis once each day, a given location will have two high and two low tides in about a day.



NEAP TIDES

The moon orbits the earth once every 29½ days and the earth rotates on its axis each 23 hours 56 minutes 04 seconds. These two factors result in the moon crossing the observer's meridian every 24 hours 50 minutes. Because a high water also occurs when the moon is on the farther side of the earth, successive high waters will be about 12 hours 25 minutes apart and the *duration of high water to low water* will be about 6 hours 12 minutes.



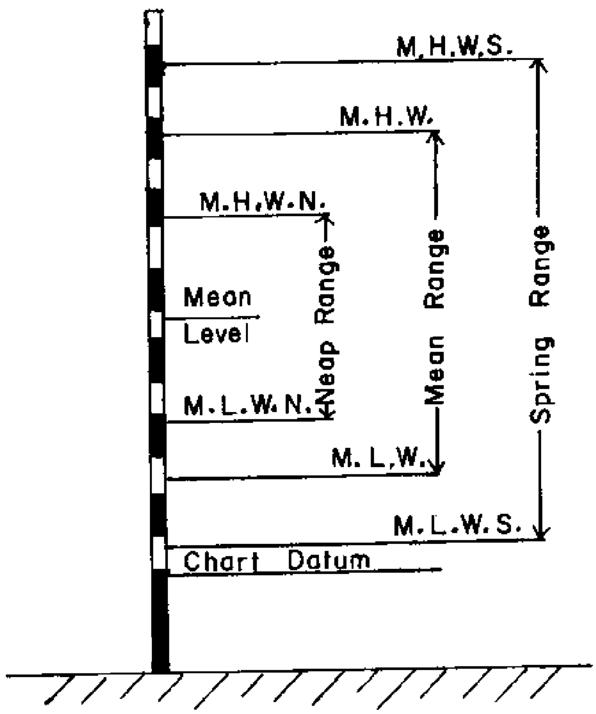
The tides for a certain port can be predicted by formulating the various tidal affecting forces into equations of tidal constants. These harmonic constants include the effects of the relative positions of the earth, moon and sun and such modifying factors as the geographical layout of the port, shallow water effects, etc. The predictions of the time and height of low water and high water for one complete year for certain selected standard ports are contained in *tide tables*. Four volumes of these include tidal predictions for most of the major ports of the world. It is impractical to include every minor inlet and bay; such secondary places are referred, by a time and height difference, to the nearest standard port. A standard port may have ten-to-twenty secondary ports linked to it as indicated in a tidal difference table found toward the end of the tide tables.

The tide tables state the expected time and height of high water and low water, but often it is necessary to know the height of the tide at an intermediate time or the time that the tide will attain a certain height. These problems are solved by the use of a table called the Height of Tide at Any Time. This table is designed under the assumption that vertical tidal motion is directly related to a cosine curve. However, this assumption is in most cases not strictly true and, therefore, data computed in this manner should be regarded as approximate only. A full explanation of the use of this table is contained in the tide table itself. Note that interpolation is not needed when using this table.

Remember always that the times and heights of tides contained in the tide tables are computed from the past tidal history of the place and geographical, celestial, and average meteorological conditions. Unusual meteorological conditions, such as very low atmospheric pressure, a strong steady wind for a number of days, or a hurricane over a thousand miles away, can greatly distort the calculated tidal predictions. However, the tide tables are in normal conditions exceedingly accurate.

The times of H.W. and L.W. stated in the tables are for the time zone indicated by the standard meridian given. Thus, 75° W will be + 5 hrs. zone time because 15° = 1 hr. and 5 hrs. are to be added to obtain Greenwich mean time.

Daylight saving time, or summer time, should be applied afterwards.



THE TIDE POLE

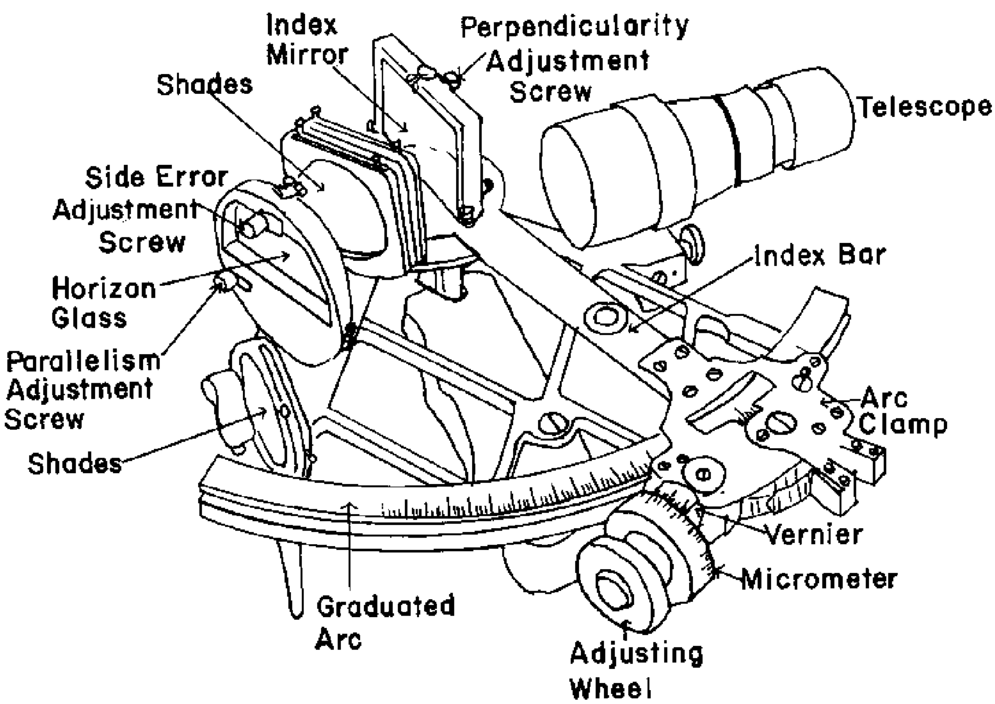
Exercise 12. TIDES (*1968 East Coast America Tide Tables*)

1. Give the duration and range of ebb tide at Boston, Mass., on April 18 p.m.
2. State the duration and range of the a.m. flood tide at Newport, R.I., on Sept. 9.
3. Give the times and heights of H.W. and L.W. on the morning of July 15 at Wickford, R.I.
4. State the duration and range of flood tide at Block Island Harbor, R.I., on the evening of Feb. 18.
5. Give the times and heights of H.W. and L.W. for the morning of Aug. 22 at Catskill, N.Y.
6. Calculate the height of tide at New London, Conn., at 1800 on May 27.
7. Find the height of tide at Newport, R.I., at 0430 S.T. on June 10.
8. Calculate the time that the tide reaches a height of 7 ft. on the morning of Dec. 29 at Boston, Mass.
9. Find the height of tide at Narragansett Pier, R.I., at 1530 on Jan. 17.
10. Between what times will there be less than 1 ft. of tide at Point Judith, R.I., on Christmas morning?

Note that answers are given for 1968 tidal information. If the 1968 *Tide Tables* are not available, work the problems for any year and disregard answers in the back of this book.

The Marine Sextant

The principal tool of trade of the "deep sea" navigator is the marine sextant. The sextant's main purpose is to measure the altitude of heavenly bodies above the visible horizon at sea in order to compute the vessel's position.



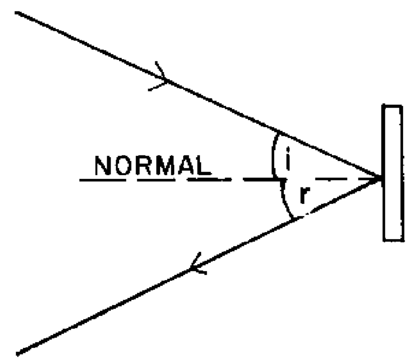
The sextant consists of a framework bearing a radial index bar. One end of the bar moves along a graduated arc and the other end pivots about the center of curvature of the arc. The telescope is in line with the horizon glass, which is in two halves. The half nearest the plane of the instrument is a plane mirror which shows the double reflection of an object from the index mirror. The other half is clear to allow the observer to look directly at an object. Thus, the reflected image of one object can be brought into line with another object by moving the index bar along the arc.

The sextant arc is about one-sixth of a circle but because the process of double reflection will result in a measured angle of only half the size of the true angle, the arc is graduated to about 120 degrees. This second principle of the sextant is explained in the labelled diagram.

A mircrometer allows readings to an accuracy of 1 minute of arc, and a small vernier attached to the micrometer facilitates readings down to 10 seconds of arc.

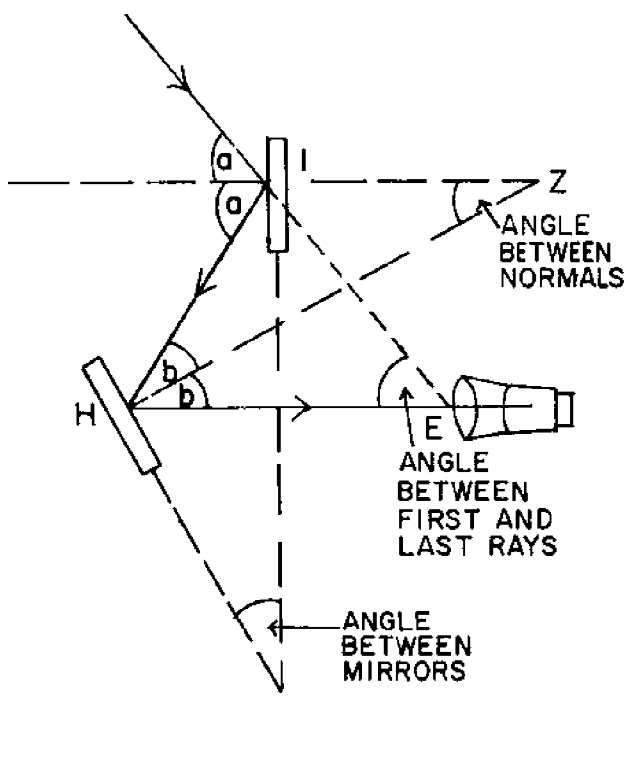
FIRST PRINCIPLE OF THE SEXTANT

When a ray of light strikes a plane mirror, the angle of incidence is always equal to the angle of reflection.



SECOND PRINCIPLE OF THE SEXTANT

When a ray of light suffers two successive reflections in the same plane by two plane mirrors, the angle between the first and last rays is equal to twice the angle between the two mirrors.



Note that the angle between the mirrors equals the angle between the normals to those mirrors $(\angle Z)$.

Proof

In Δ HIZ, Exterior $\angle$ a = 2 interior opposite $\angle$ s, b + Z .... ①

In Δ HIE, Exterior $\angle$ 2a = 2b + E .... ②

Multiply eq ① by 2. Then 2a = 2b + 2Z

therefore, $\cancel{2b} + E = \cancel{2b} + 2Z$

i.e., the angle between first and last rays (E) equals twice the angle between the mirrors (Z).

ERRORS AND ADJUSTMENTS OF THE SEXTANT

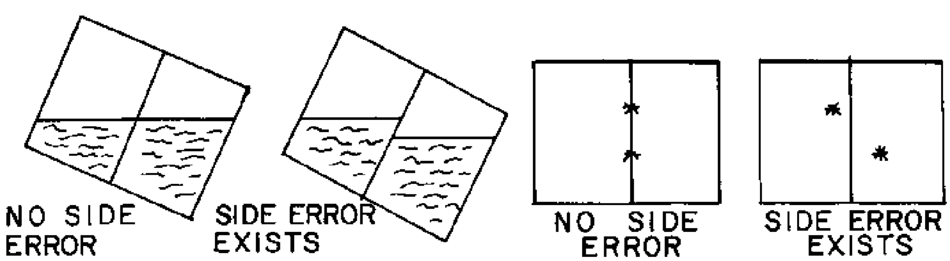
There are three main errors which are liable to exist in a sextant.These can be corrected by turning the appropriate adjustment screw.

1. Perpendicularity

The first error of the sextant is caused by the index glass not being truly perpendicular to the plane of the instrument. This error can be recognized by holding the sextant horizontally at arm's length. With the arc away from the observer and set at about 35°, the observer looks down into the index glass at a fine angle. If the reflection of the arc does not coincide with the arc itself, the error of perpendicularity exists. This error is corrected by turning the first adjustment screw on the back of the index mirror until the arc and its reflection do coincide.

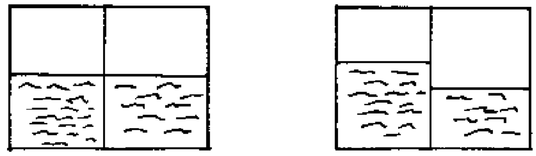
2. Side Error

The second error of the sextant, which is known as side error, is due to the horizon glass not being truly perpendicular to the plane of the sextant. This error is found by holding the sextant obliquely with the arc at zero and observing the true and reflected images of a clear horizon. If the object and its image are not in a continuous line, side error exists. This error can also be found by rotating the micrometer screw back and forth each side of zero while looking at a star. If the reflected star does not pass directly over the true star, then side error exists. This error is corrected by turning the second adjustment screw on the back of the horizon glass until coincidence is effected.



3. Error of Parallelism

The third adjustable error of the sextant, the error of parallelism, is caused by the index mirror and horizon glass not being truly parallel when the arc is set at zero. This error is discovered by setting the arc at zero and observing a clear horizon or a star which is not too bright with the sextant held vertically. If the true object and its reflected image do not coincide, then the error of parallelism exists. This error can be corrected by turning the third adjustment screw, which is situated on the back of the horizon glass nearest to the plane of the instrument.



NO ERROR OF PARALLELISM   ERROR OF PARALLELISM

Index Error

Side error and the error of parallelism are interrelated in that the correction of one error may induce the other. Adjustment for these two errors should be made alternately a number of times. Any error of parallelism remaining which cannot be removed without inducing side error is called index error. The index error must then be applied to every angle that is taken. When a larger arc reading than the true angle results, the index error is subtracted and termed "on the arc." When the sextant gives a smaller angle than the true angle, then obviously the index error is to be added and is termed so many minutes "off the arc." Index error is often zero and usually no more than 2 minutes or 3 minutes plus or minus.

Four Unadjustable Errors

There are four errors to the sextant which are not adjustable and which can only be corrected by the sextant manufacturer.

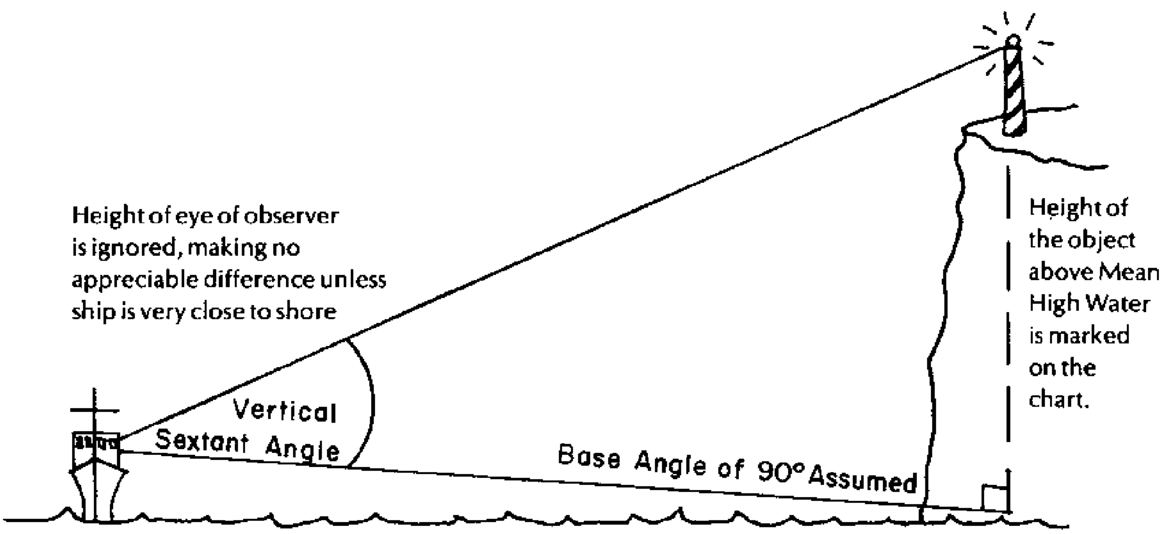
Collimation error exists when the axis of the telescope is not exactly parallel to the plane of the sextant. This error causes the measured altitude to be greater than the real altitude.

Graduation error exists when the arc, micrometer or vernier are incorrectly calibrated.

Shade error is caused by the faces of shade glasses not being ground parallel. This error is found by comparing the angle between two objects one time with shade up and the other with shade down.

Centering error is present when the index arm is not pivoted at the true center of curvature of the arc.

Vertical Sextant Angles



From the diagram it can be seen that:

Distance off Lighthouse = Cotan of Vertical Angle × Height of Object

It is not usually necessary to make an allowance for the tidal difference from mean high water.

Most sets of nautical tables contain a table on distance by vertical sextant angle. An extract from such a table is shown below.

	Height of Object in Feet		
Distance Off in Miles	200′	220′	240′
2.4	0°47′	0°52′	0°57′
2.6	0°44′	0°48′	0°52′
2.8	0°40′	0°44′	0°48′
3.0	0°38′	0°41′	0°45′

<u>Find the distance off a 210-ft. point for a vertical sextant angle of 0° 48′.</u>

Interpolation is necessary halfway between 200′ and 220′. That is, 0° 49′.5 gives 2.4 miles and 0° 46′ gives 2.6 miles for a 210 foot object. The given angle is 0° 48′ which is about midway between the two.

Therefore, Distance Off the Point = 2.5 Miles.

After some practice with interpolation these problems can be quickly done mentally by using simple proportion.

If vertical sextant angle tables are not available the following approximate formula can be used.

$$\text{Distance Off (in Miles)} = \frac{\text{Half Object's Height (in Feet)}}{\text{Vertical Sextant Angle (in Minutes)}}$$

It may be necessary to round a point or a beacon while keeping a certain distance from it to avoid rocks or shoals. The sextant angle necessary for such a distance off can be set on the sextant as a *danger angle*. If the angle increases beyond the set danger angle the vessel is setting too close inshore and the helm is applied out until the danger angle is again reached. Thus, the point is rounded with safety if the danger angle is maintained.

The distance off computed from a vertical sextant angle will be the radius of a position circle with its center on the object concerned. Further information such as that obtained from a single bearing is necessary to fix the vessel's position.

Exercise 13. VERTICAL SEXTANT ANGLES

1. Find the distance off a lighthouse 230 feet high if it subtends a vertical sextant angle of 0°45′.

2. What distance off the land would a vertical sextant angle of 0° 47′ indicate if the height at that point is charted as 207 feet?

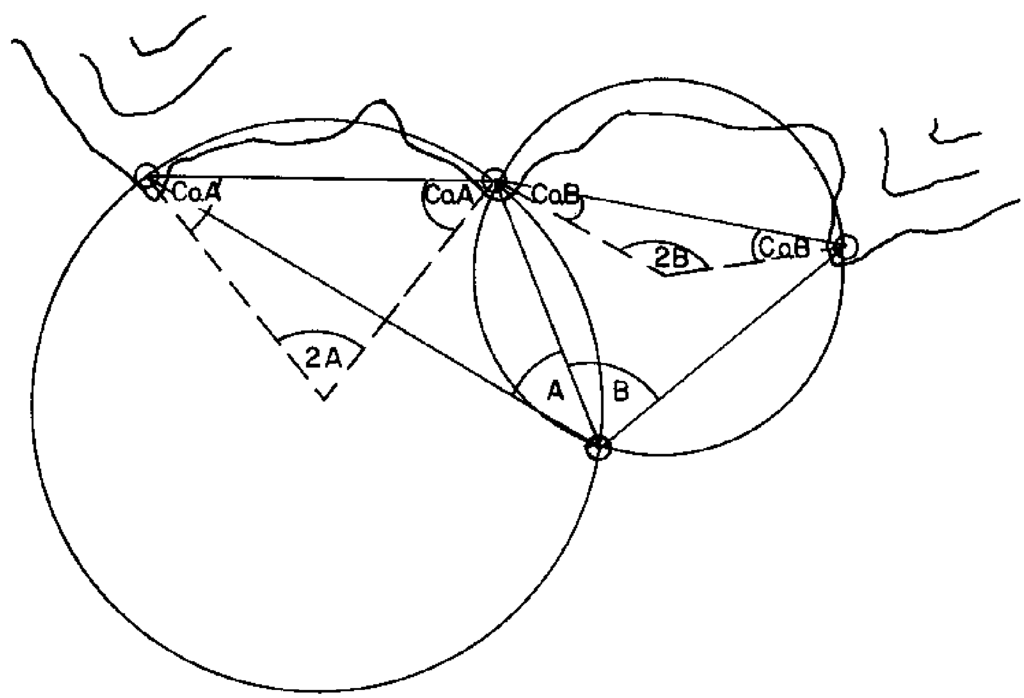
3. Find the distance off Southeast Pt. Lt. Hs., Block Island, if it is subtending a vertical sextant angle of 0°39′.

4. What danger angle should be used to round a 235-foot lighthouse at a distance of 3 miles?

5. What danger angle would be necessary to round Southeast Pt. Lt. Hs., keeping 1½ cables outside the wreck marking the buoy off the point?

Horizontal Sextant Angles

A single horizontal sextant angle gives only a position circle. The two objects concerned will subtend that same horizontal angle anywhere along the position circle. To find an observed position by using horizontal sextant angles it is necessary to use two such position circles. The vessel will be at the intersection of these two circles.



To construct the circles, a base line is drawn between the points concerned and the complement of the horizontal angle is laid off from each end of the base line on the seaward side. (If the horizontal angle exceeds 90 degrees lay off the excess of the 90 degrees on the landward side of the base line.) The intersection of the lines from the base line will be the center of the position circle.

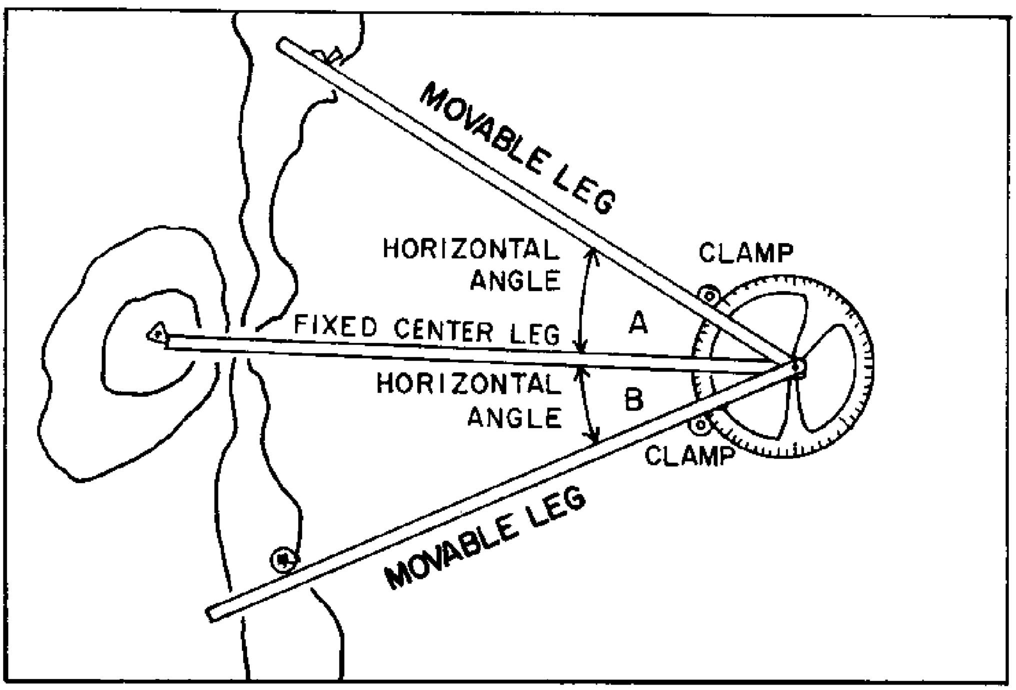
This method of position finding is based on the well-known geometric theorem that the angle that a chord subtends at the center of a circle will be twice the angle it subtends at the circumference. If the complement of the horizontal angle is laid off each end of the base line, then these two construction lines must cross at an angle of twice the size of the horizontal angle. A circle drawn with this point as its center and the base line as a chord must, therefore, pass through all points where the chord would subtend this particular horizontal angle.

THE STATION POINTER OR THREE ARM PROTRACTOR

The station pointer consists of a 360-degree protractor with a fixed center leg and two adjustable side legs. The horizontal angles are set on the instrument and the legs are clamped in position. The instrument is then maneuvered on the chart until each leg lies on its appropriate land mark. The vessel's position can then be marked through the small hole in the center of the station pointer.

Horizontal sextant angles are not used a great deal for chartwork but are useful in checking a vessel's anchorage position. The two angles can be set up on separate sextants; any deviation from these horizontal sextant angles indicates movement of the vessel.

The compass error can also be checked by noting any differences between true bearings on the chart (from the position established by plotting horizontal sextant angles) and observed compass bearings of the same objects.



Exercise 14. HORIZONTAL SEXTANT ANGLES (Chart 1210)

1. Give the latitude and longitude of a vessel anchored with Warren Pt. 56° Quicksand Pt. 78° Gooseberry Neck Tr.

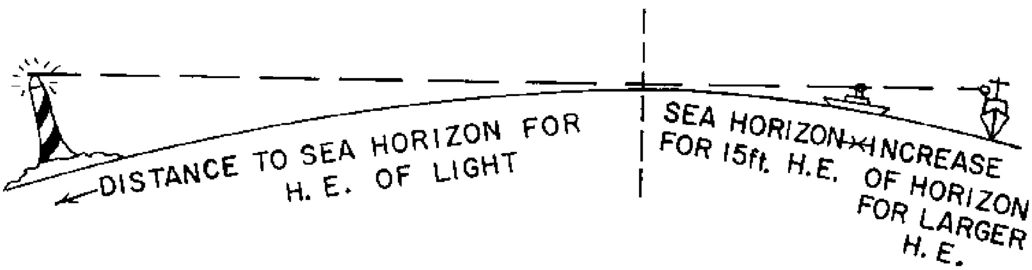
2. What distance from the River Ledge Buoy is a vessel anchored with Bonnet Pt. 51° Beavertail Pt. 55° Brenton Reef Bn.?

3. How far off the breakwater is a vessel with Southeast Pt. Lt. 48° Aero Lt. 110° Conspicuous House?

4. Give the latitude and longitude of a vessel anchored with Gay Head Lt. 63° Menemsha Bight Lt. 115° Cape Higgon.

5. Give the position of a vessel anchored with Weepecket Main I. 78° Woods Hole Dome 54° Standpipe.

Rising and Dipping of Lights



The visibility of a lighted beacon, buoy or lighthouse varies as to its height, the intensity of the light and the height of eye (H. E.) of the observer.

The range of visibility of a "weak light" will be limited by its luminous intensity. However, the range of visibility of the rays emitted from a "strong light" will depend upon the height of that light and also the height of eye of the observer due to the curvature of the earth. (See diagram.)

All sets of nautical tables contain tables for the distance of the sea horizon for a given height of eye and also a table for the distance a strong light will be seen for a given height of eye and height of light. In computing the visibility of a strong light, it is always assumed that the light is sufficiently powerful to be seen at the computed range.

If no tables are available the following formula can be used:

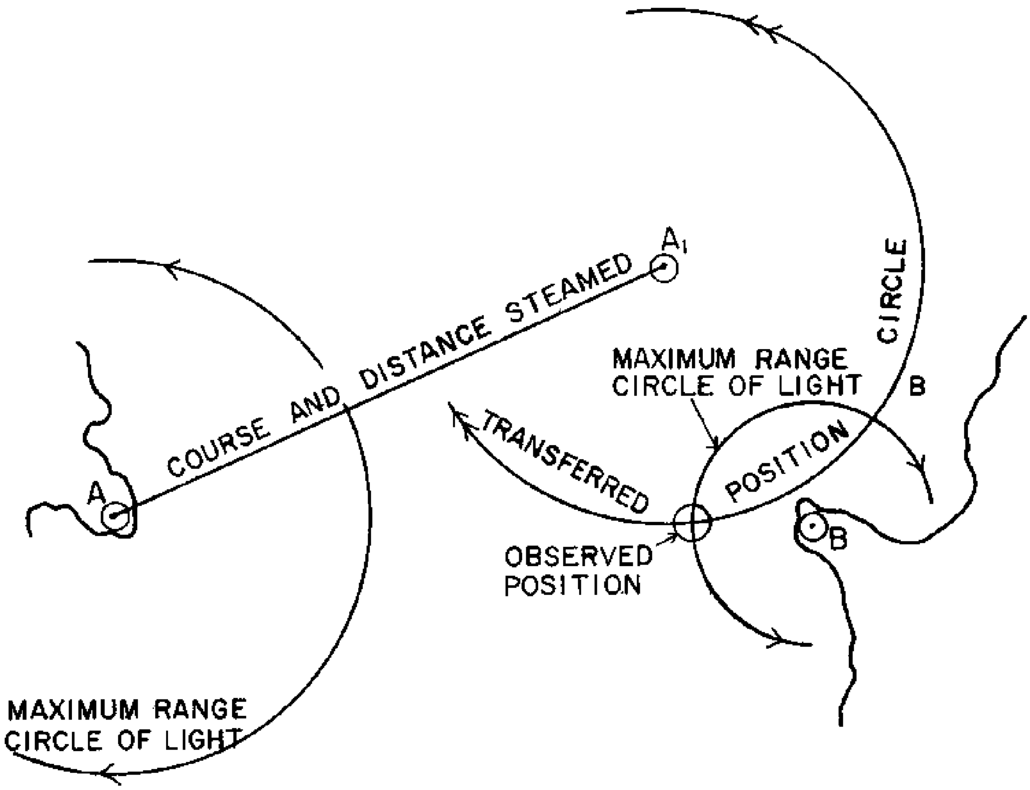
$$\text{Range of Visibility in Nautical Miles (approx.)} = 1.15\left(\sqrt{\text{Height of Eye in Feet}} + \sqrt{\text{Height of Light in Feet}}\right)$$

Most lights have their range of visibility to the nearest mile indicated in their abbreviated characteristics listed on the chart itself. This range is computed for a standard height of eye of 15 feet.

A vessel steaming toward the light from seaward may see the glow or the loom of the light pulsating from below the horizon. As the light is approached the light will suddenly appear. To check maximum range the light may be "bobbed" by alternately lowering and raising the height of eye to make the light disappear and then appear again.

The table for rising and dipping distance is computed for atmospheric conditions of normal refraction. Conditions of abnormal refraction, such as those created by warm air over cooler sea, can result in the normal rising distance being exceeded. Occasionally lights may be seen to rise at two or three times their predicted range under extreme conditions of abnormal refraction.

The computed range of visibility of a given light for a given height of eye gives a position circle somewhere along which the vessel will lie. Additional information, such as a bearing, is required for a fix. The position circle can be used in a method similar to that for the transferred position line, as shown in the following diagram. It is usually obvious which of the two intersections in the diagram is the observed position.

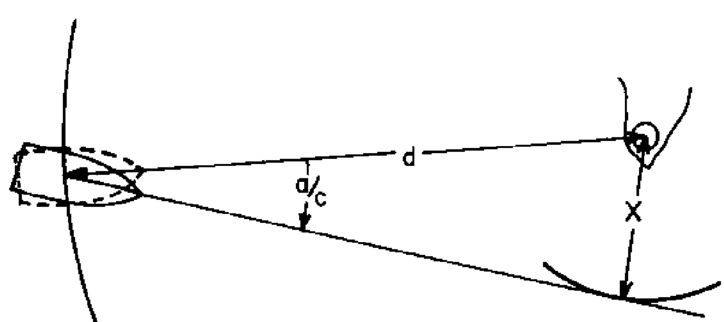


TRANSFERRED POSITION CIRCLE

THE RULE OF SIXTY

Head directly to the light at rising distance, d.n.m. Alteration of course necessary in order to pass X n.m. abeam the light is approximately (60/d) × X degrees.

For example, Rising distance d = 15 n.m. required to pass 5 n.m. off the light; alteration of course necessary from light directly ahead = (60/15) × 5 = 20°.



Exercise 15. RISING AND DIPPING DISTANCES (Chart 71)

1. Give the latitude and longitude of a vessel with a height of eye of 25 feet if Cape Sable Lt. rises bearing 045° C, and the vessel is steering due east by compass using Deviation Card I.
2. Nantucket Lt. V/L Lt. rose bearing 225° C to a vessel steering 306° C. Give the vessel's position if her height of eye is 32 feet and she is using Deviation Card I.
3. Give the position of a vessel steering due west by compass if Cape Cod Lt. rose bearing 250° C. Use Deviation Card II and a height of eye of 28 feet.
4. If Cape Ann Gp. which is Occ. Lt. dips bearing 328° C to a vessel with height of eye 30 feet, steering 165° C, how many miles should this vessel steam before Cape Cod Lt. rises? Use Deviation Card I.
5. At 0400 Seal I. Lt. dipped and the vessel steered 310° T at 10 knots. At 0600 Lurcher Shoal Lt. V/L Lt. rose. Find the vessel's position if the height of eye is 20 feet.
6. Matinicus Rock Lt. dipped to a vessel steering 056° T at 8 knots. One hour 15 minutes later Mt. Desert Rock Lt. rose. Find the vessel's position if the height of eye is 32 feet.
7. Nantucket Shoal Lt. V/L Lt. dipped astern of a vessel which had a height of eye 32 feet and which was steaming at 10 knots. Three hours later Sankaty Hd. Lt. rose. Give the vessel's position if she was steaming 316° C, using Deviation Card II.
8. Cape Cod Lt. dipped at 0330 to a vessel steaming 342° C at 12 knots. near Wildcat Knoll. One hour later the occulting light off Cape Ann rose. Give the vessel's position at 0430 if the height of eye was 20 feet. Use Deviation Card I.
9. A vessel is approaching Cape Cod Lt. steering due west when the light rises directly ahead. What alteration of course is necessary to leave the light 5 nautical miles to port when abeam? Height of eye of observer is 15 feet.

Lines of Soundings

If after fishing for some time you are unsure of your vessel's position, a good estimation can be made from soundings.

These should be taken at regular intervals, approximately the steaming distance apart that the chart soundings are spaced.

Mark these soundings on a straight edge graduated to the distance scale of the chart. The straight edge can then be angled on the chart to roughly correspond with the course steered, and can be moved around until the soundings appear to correspond with the depths marked on the chart.

This method of position finding should not be relied upon entirely; as soon as land is neared and other means become available the position should be checked.

On Chart 71 the soundings are spaced about 3 miles apart. A 12-knot vessel would take soundings every 15 minutes. A stiff paper straight edge could then be marked with graduations from the latitude scale at 3-mile intervals and with the corresponding soundings. With the first sounding as a point of departure, the straight edge is angled on the chart at approximately the course steered. The final position is estimated when the soundings match up.

Exercise 16. LINES OF SOUNDINGS (Chart No. 71)

1. A vessel in the vicinity of Lindenkohl Knoll proceeded on a westerly course recording soundings at half-hour intervals as follows: 99F, 117F, 103F, 97F, 104F, 106F, 110F, 93F. State the compass course made good and the position at the time of the last sounding if her steaming speed is estimated at 12 knots. Use Deviation Card I.

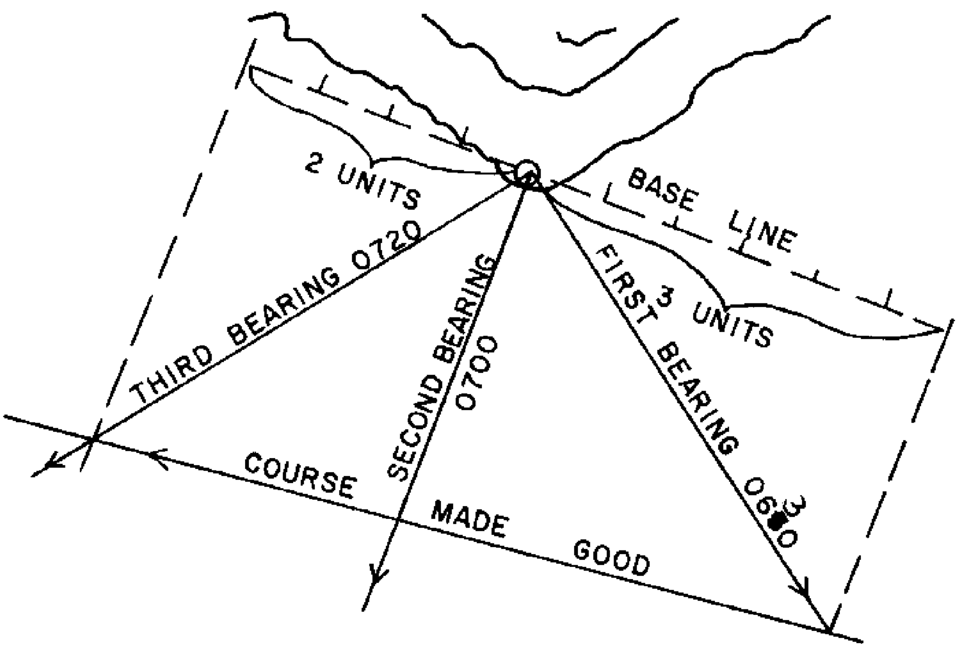
2. A vessel, with height of eye 20 feet, steering 247° C at about 10 knots records the following soundings at 2-hour intervals, starting at 0100: 6F, 20F, 33F, 36F. At what time should Nantucket Shoal Lt. V/L Lt. be seen and, at what angle on the bow, if the vessel had been fishing near Little Georges? Use Deviation Card I.

3. A vessel proceeding to the westward near Corsair Canyon crossed the 100-fathom line at 1100 and again at 1120 and 1130. The 50-fathom line was crossed at 1225 and the 40-fathom line at 1318. What time should the 30-fathom line be crossed and what compass course will be made good? The vessel is steaming at about 14 knots, using Deviation Card II.

4. A vessel leaves the Winter Fishing Ground on Georges Bank steaming at about 11 knots in rough weather and steering 296° C, using Deviation Card I. The following soundings were recorded at half-hour intervals: 30F, 25F, 6F, 31F. Estimate the amount that the vessel is being set to port of her course. Should she continue on this course?

The Three-Bearing Problem

The three-bearing problem is a means of determining the course made good by a vessel sailing under the influence of an unknown current.



Three bearings are taken of a single object and the time between each is noted. A base line is drawn through the object perpendicular to the center bearing. The base line is then marked on each side of the object in the same ratio as the time or log distance between the bearings. For example, if the run between the first and second bearings was 30 minutes and the run between the second and third bearings was 20 minutes the base line would be marked in a ratio of 3:2, as indicated in the diagram. Construction lines are then drawn parallel to the center bearing from the marks on the base line. The course made good will be a line joining the points where these construction lines intersect the first and last bearings.

It should be noted that this method determines the course made good only and is not necessarily the vessel's actual track through the water. The track will be parallel to the course made good but may be to port or starboard of the course made good as found. Further information, such as a sounding or radar distance from land, is required to fix the vessel's position at the time of one of the bearings and then the course made good may be drawn through this point to give the vessel's track.

Exercise 17. THE THREE-BEARING PROBLEM

1. Brenton Reef Bn. was bearing 002° T at 0500, 335° T at 0520, and 291° T at 0600. Estimate the true course that the vessel is making good.

2. Gay Head Lt. bore 088° T at 0700, 062° T at 0724, and 025° T at 0806. Estimate the compass course that the vessel is making good. Use Deviation Card I.

3. A vessel in latitude 41°20′ N observed Buzzards Horn Bn. at 1100 bearing 327° T. At 1120 the beacon was bearing 358° T and at 1150 it bore 038° T. Estimate the set and rate of the current if the vessel was steering 255° T at 7.2 knots.

4. The southeast point of Nomans Land bore 063° C at 0600, 039° C at 0618, and 005° C at 0654. If the vessel was steering 136° C, find the compass course she is making good. Use Deviation Card I.

THIRD GENERAL CHARTWORK EXERCISE (Chart 71)

Use Deviation Card I.

1. Leaving Gloucester, give the compass course to steer from Eastern Pt. to pass 10 miles off Cape Cod. Also state the distance on this course to the 100-fathom line.

2. At 0600 the vessel was steaming at 12 knots. Cape Cod was observed 4 points on the st'b'd bow and at 0645 it was abeam. What distance off the land should a radar check indicate at 0645?

3. A short time later the vessel altered course due south magnetic and began fishing at a speed of about 3 knots. At this time Nauset Beach Lt. Hs. was bearing 230° C; one hour later it bore 256° C, and two hours after this it bore 289° C. State the true course made good.

4. Fishing was bad, and at 1030 the vessel stopped fishing and proceeded on a southerly course at 12 knots. The following soundings were taken at intervals commencing at 1100: 100F, 66F, 50F, 27F, 19F, 7½F. Estimate the position at 1330.

5. The course was altered at 1330 to 144° C for 1 hour and at 1430, with a sounding of 29 fathoms, the course was again altered to 223° C and fishing was resumed. Two 3-hour sets were made on this course, while trawling at about 3 knots. At 2030, crossing the 20-fathom line to the south of Fishing Rip, the course was altered 90° to port and the gear hauled in. The vessel steamed at full speed until a 29-fathom sounding was obtained. At this time the gear was set again and the original course of 223° C resumed. At what time should Nantucket Lt. V/L Lt. rise if the height of eye is 25 feet?

6. At midnight the course was altered to 295° C and another four 2-hour sets were made in this direction. At 0830, while steaming at full speed on the same course, a 4-second flashing light was seen 4 points on the port bow, and 20 minutes later it was abeam. Give the compass course to steer, to counteract a current estimated to be setting 010° T at 2 knots and a southerly wind giving 5° leeway, in order to pass 2 miles off the Nomans Land Whistle Buoy abeam. What time will the buoy be abeam?

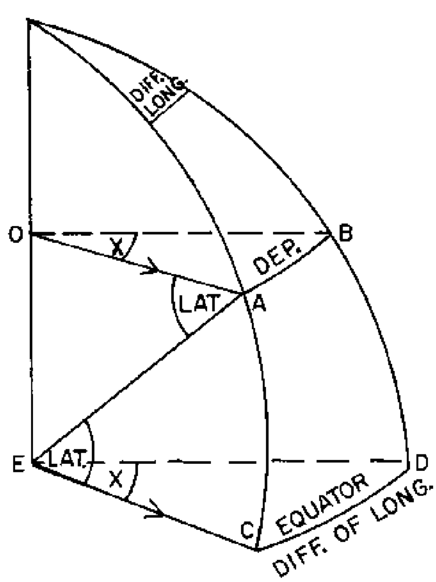
The Sailings

So far in this text, most of the more practical aspects of chartwork have been discussed and it is now intended to introduce some of the basic theories of navigation. "Deep sea" navigation, which utilizes observations of celestial bodies and information from electronic navigational aids, will be discussed in a second text. However, the three navigational sailings—parallel, plane and Mercator sailing—are included in this and the following chapters to introduce the second volume and to serve as a connecting link between the two distinct fields of chartwork and navigation.

PARALLEL SAILING

Parallel sailing establishes the relationship between difference of longitude (d. long.) and departure (dep.). i.e., *Departure = Difference of Longitude × Cosine of Latitude*

As stated before in this book, the values of difference of longitude and departure between two given positions in the same latitude are equal at the equator, but as the poles are approached departure decreases to nil while difference of longitude remains the same. That is, departure varies from maximum at the equator to nil at the poles. Therefore, departure varies as to the cosine of the latitude. The proof follows.



PARALLEL SAILING PROOF

To determine departure, or number of miles steamed along a given parallel of latitude for a given difference of longitude, first remember that the difference of longitude, or angle between the planes of two meridians, is the same in any latitude.

Thus, in the diagram, Angle x = D. Long.

Then, the circular measure of $x = \frac{AB}{OA}$ or $\frac{CD}{EC}$

$$\frac{\text{Dep.}}{OA} = \frac{\text{D. Long.}}{EC.}$$

$$\frac{\text{Dep.}}{\text{D. Long.}} = \frac{OA}{E.C.}$$

but, EC = EA (both radii of the sphere)

$$\frac{\text{Dep.}}{\text{D. Long.}} = \frac{OA}{EA}$$

In Δ OAE

$\angle OAE = \angle AEC$ (Alt. $\angle$s $OA \parallel EC$)

$$\text{Cosine of } \angle OAE = \frac{OA}{EA}$$

$$\text{Cosine of Lat.} = \frac{\text{Dep.}}{\text{D. Long.}}$$

$$\text{It follows that Secant of Lat.} = \frac{\text{D. Long.}}{\text{Dep.}}$$

Dep. = D. Long × Cos. Lat.

and D. Long = Dep. × Sec. Lat.

It should be noted that parallel sailing gives a rhumb line tracked out by a vessel steering due east or west. This track is not the shortest distance between the two points concerned. The shortest distance would be the arc of a great circle between these points.

Two examples of parallel sailing problems follow.

Example 1

What distance in nautical miles is contained between the meridians of 169°47′ E and 173°00′ W in latitude 53°12′ N?

Note that the 180° meridian comes between these two longitudes. Therefore, each longitude should be subtracted from 180° and the two differences added to give the total difference of longitude.

D. Long = (180-169° 47′) + (180°-173° 00′)

D. Long = 10° 13′ + 7° = 17° 13′

Dep. = D. Long × Cos. of Lat.

Dep. = 17° 13′ × Cos. 53° 12′ (1° = 60′)

Dep. = 1033′ × Cos. 53° 12′.

No.	Log.
Log. Cos. 53°12′	$\bar{1}.77744$
Log. 1033	3.01410
Log. Dep.	2.79154

Departure = 618.8 miles

Example 2

At what speed would an observer in lat. 1°12′ rotate in space?

The earth rotates through 360° of longitude in 1 day and, therefore, through 15° of longitude in 1 hour. The departure covered for 1 hour's rotation is required.

Dep. = D. Long. × Cos. of Lat.
Dep. = 15° × Cos. 1°12′ (1° = 60′)
Dep. = 900′ × Cos. 1°12′.
Dep. = 899.8

No.	Log.
Log. Cos. 1°12′	$\bar{1}.99990$
Log. 900	2.95424
Log. Dep.	2.95414

Speed of Rotation is 899.8 knots

Exercise 18. PARALLEL SAILING

1. Calculate the departure corresponding to a difference of longitude of 3°42′ in lat. 37° 56′ N.

2. A vessel goes from 7°46′ W to 13°12′ W along the parallel of 49°16′ N. What distance does she travel?

3. A vessel steers due east for 820 miles in lat. 13°7′ S. What difference of longitude will she cover?

4. A ship in lat. 57°18′ N makes good 714 miles due west from 6°12′ E. Calculate her new longitude.

5. Find the number of miles a vessel makes good from 3°6′ E to 5°17′ W in lat. 62°12′ N.

6. A vessel makes good a distance of 420 miles while steaming due west through 8°40′ difference of longitude. What latitude is she in?

7. At what rate is Greenwich Observatory in lat. 51°28′.5 N being carried around the earth's axis?

8. What is the distance between the meridians of 8° and 15° W in lat. 56°22.′5 N?

9. A vessel makes good 372 miles due west in lat. 13°27′ S. What difference of longitude does she cover?

10. In what latitude does 526 miles of departure give a difference of longitude of 11°?

11. A vessel steams from 5°12′ E to 8°04′ W in lat. 18°27′ S. How many miles is this?

12. A vessel steams 512 miles due east from 8°12′ W in lat. 56° N. What is her new longitude?

13. In what latitude is departure half the value of difference of longitude?

14. A vessel goes from 126° E to 153°27′ E in lat. 43°12′ N. How many miles is this?

15. A ship steams 357 miles due east in lat. 3°08′ N. What difference of longitude does she cover?

The Traverse Tables

The traverse tables establish the three sides of a plane right-angle triangle for all even angles from 1 to 89 degrees and all hypotenuses from 1 to 600 units. An example of the general layout of the table is shown below.

27°

D. Long.	**Dep.**	
Dist.	**D. Lat.**	**Dep.**
Hyp.	**Adj.**	**Opp.**
301	268.2	136.7
302	269.1	137.1
303	270.0	137.6
304	270.9	138.0
305	271.8	138.5
306	272.6	138.9
307	273.5	139.4
308	274.4	139.8
309	275.3	140.3
310	276.2	140.7
Hyp.	**Opp.**	**Adj.**
Dist.	**Dep.**	**D. Lat.**
D. Long		**Dep.**

63°

Thus a plane right-angle triangle, with an angle of 27 degrees and a hypotenuse of 305 units, will have the side opposite the 27 degree angle equal to 138.5 units and the remaining adjacent side equal to 271.8 units.

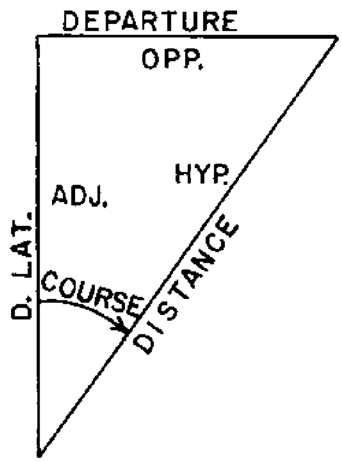
Similarly, due to the relationship between difference of longitude and departure found in parallel sailing, the angle may be used as a latitude and the values of departure and difference of longitude read off.

For example in latitude 27° N or S a difference of longitude of 305 minutes would give a departure value of 271.8 miles. This is because the cosine of the latitude equals departure divided by difference of longitude as proven. Therefore, the cosine relationship is provided by substituting difference of longitude for the hypotenuse side and departue for the adjacent side.

Therefore, parallel sailing problems can be solved by using the traverse tables, but take care to use the outer columns headed D. Long and Dep. *not* the center column.

For angles or latitudes over 45 degrees, the table is inverted and used in the same manner.

General sailing problems can easily be solved by substituting difference of latitude (d. lat.) for the adjacent side, departure for the opposite side and distance steamed for the hypotenuse side. The true course made good is substituted for the angle.



Note that difference of longitude cannot be used together with difference of latitude in a trigonometric relationship because their basic unit values differ.

If the angle, course steered or latitude, whichever the case may be, is not a whole degree, then the values of the sides of the triangle for the nearest degree below and above that angle are extracted and the required intermediate value is determined by interpolation. Or, in simpler words, the intermediate value is found by proportion.

For example, a departure of 276.2 corresponds to a difference of longitude of 310 in lat. 27°. For lat. 28° a difference of longitude of 310 gives a departure of 273.7.

If the departure for a difference of longitude of 310 in lat. 27° 12′ is required then 12/60 of the difference between the departure values of 27 and 28 degrees must be applied to the 27 degree value.

That is, $\frac{12}{60}$ or $\frac{1}{5}$ of (276.2-273.7) is to be subtracted from 276.2.

Therefore, as $276.2 - \left(\frac{1}{5} \times 2.5\right) = 275.7$, the required departure is 275.7 miles.

A detailed explanation of the traverse table is usually contained in the preamble to the tables.

With a good deal of practice, reasonably accurate interpolation can be carried out mentally and, thus, considerably reduce the calculating time.

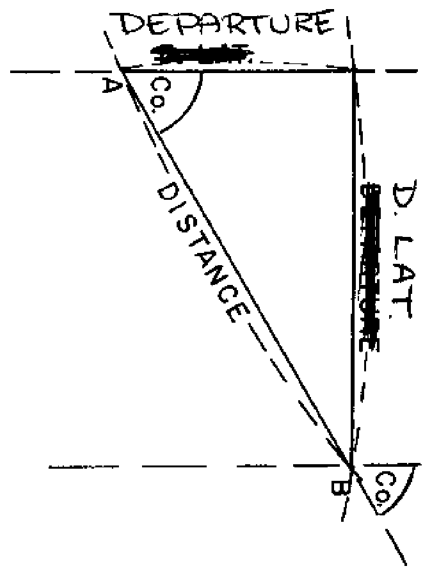
Exercise 19. PARALLEL SAILING BY TRAVERSE TABLE

Check calculation with the traverse table.

1. In what latitude will a departure of 273 miles correspond to a difference of longitude of 8°12′?
2. How many miles separate the 9° and 15° meridians in lat. 82°30′ N?
3. A vessel steams at 23 knots due west for 4 hours in lat. 32°15′ S. What difference of longitude does she cover?
4. In what latitude does 312 miles of departure give a difference of longitude of 17°08′?
5. A vessel leaves 73°6′ E and goes west along the 49°08′ parallel for 807 miles. What will be her arrival longitude?
6. What is the departure of a vessel covering 8°12′ difference of longitude along the 21° parallel of latitude?
7. A vessel steams 436 miles due west in latitude 61°12′ S. What difference of longitude does she cover?
8. In what latitude does 264 miles departure correspond to a difference of longitude of 7°12′?
9. A vessel goes from 173° E to 179°12′ W in lat. 15°12′ N. How many miles does she travel?
10. What difference of longitude would a vessel pass through if she covered 562 miles along the 56° parallel?
11. In what latitude does the difference-of-longitude value equal 3 times the departure?
12. A vessel covers 11°17′ difference of longitude in lat. 32°12′ S. How many miles has she steamed?
13. A vessel steams 485 miles in lat. 46°08′ N. What difference of longitude has she covered?
14. In what latitude does 412 miles departure correspond to 16°30′ difference of longitude?
15. At what speed will an observer in 48°12′ N rotate around the earth's axis?

Plane Sailing

Plane sailing is used to compute the change in latitude and longitude of a vessel steering a rhumb-line course, or, conversely, to find the rhumb-line course and distance between two known positions.



The spherical triangle formed by the sides of difference of latitude, departure, and distance can be treated as a plane triangle, without undue distortion, providing the distance involved is not too great.

Parallel sailing the latitude of A in the diagram will result in a departure larger than the mean value while sailing the latitude of B will give a departure smaller than the mean value. For this reason a mean of the latitudes is used when computing the departure:

$$\text{Mean Lat.} = \frac{\text{Lat. A} + \text{Lat. B}}{2}$$

$$\underline{\text{Then, Cosine of the Mean Lat.} \times \text{D. Long.} = \text{Dep.}}$$

If the latitudes of the two positions are widely spaced, the arithmetical mean latitude will not give a sufficiently accurate departure. In such a case it is necessary to use a geographical mean latitude, called the middle latitude, which will give the true departure value, taking the convergency of the meridians into consideration. This correction is contained in some sets of nautical tables. However, in most cases, Mercator sailing is used for distances exceeding about 600 miles.

Plane sailing problems involve four quantities: course, distance, difference of latitude and departure. If two of these quantities are known, then the other two are easily found by using plane trigonometry or the traverse tables.

For example, if the difference of latitude is known and the departure has been calculated by the parallel sailing method, utilizing the mean latitude, then the course and distance are calculated by:

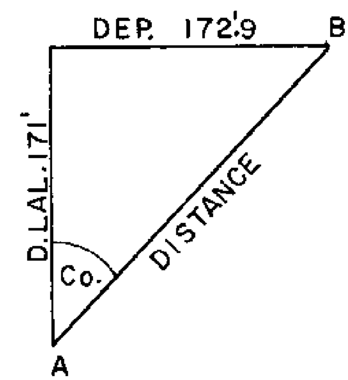
$$\text{Tan. Course} = \frac{\text{Dep.}}{\text{D. Lat.}} \text{ and Distance} = \text{Secant Course} \times \text{D. Lat.}$$

Two worked plane sailing examples follow.

Example 1

Calculate the course and distance from 43°27′ N 22°12′ W to 46°18′ N 18°08′ W.

43°27′ N	22°12′ W
46°18′ N	18°08′ W
2°51′ N	4° 4′ E
×60	×60
D. Lat. 171′ N	D. Long. 244′ E



$$\text{Mean Lat.} = 43°27' + \frac{2°51'}{2} = 44°52'.5\text{ N}$$

Dep. = Cos. Mean Lat. × D. Long.
Dep. = Cos. 44°52′.5 × 244
Dep. = 172.9

$$\text{Tan. Course} = \frac{\text{Dep.}}{\text{D. Lat.}} = \frac{172.9}{171}$$

Course = N 45°19′.1 E
Distance = Sec. Co. × D. Lat.
Distance = Sec. 45°19′.1 × 171
Distance = 243.2 Miles

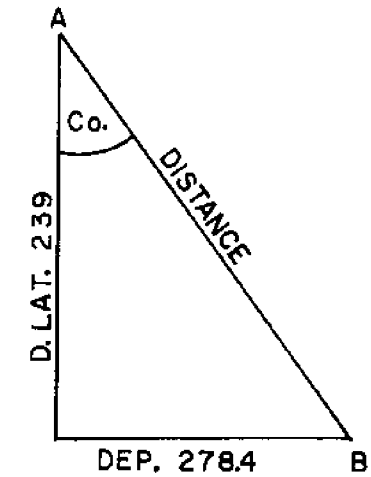
	No.	Log.
Log. Cos.	44°52′.5	T.85043
	244	2.38739
Log. Dep.		2.23782
	172.9	2.23782
	171	2.23300
Log. Tan. Co.		0.00482
Log. Sec.	45°19.1	0.15294
	171	2.23300
Log. Dist.		2.38594

Traverse table check: Dep. 172.8, Course 45°20′, Distance 243.5 miles

Example 2

Calculate the course and distance from 48°12′ S 178°18′ E to 52°11′ S 174°27′ W.

48°12′ S	178°18′ E	through 180°
52°11′ S	174°27′ W	
3°59′ S +	5°33′ E	
	1°42′	
×60	×60	
D. Lat. 239′ S	D. Long. 435′ E	



Mean Lat. = $48°12' S + \frac{3°59'}{2} = 50°11''5$ N

Dep. = Cos. M. Lat. × D. Long.

Dep. = Cos. 50°11′.5 × 435

Dep. = 278.5

$\text{Tan. Course} = \frac{\text{Dep.}}{\text{D. Lat.}} = \frac{278.5}{239}$

Course = S 49°21′.8 E

Distance = Sec. Co. × D. Lat.

Distance = Sec. 49°21′.8 × 239

Distance = 367 Miles

	No.	Log.
Log. Cos.	50°11′.5	1̄.80633
	435	2.63849
Log. Dep.		2.44482
	278.5	2.44482
	239	2.37840
Log. Tan. Co.		0.06642
Log. Sec.	49°21′.8	0.18625
	239	2.37840
Log. Dist.		2.56465

Traverse table check: Dep. 278.4, Course S. 49°20′ E, Distance 367 miles

Exercise 20. PLANE SAILING

Check calculations with the traverse table.

Find the course and distance between the following positions:

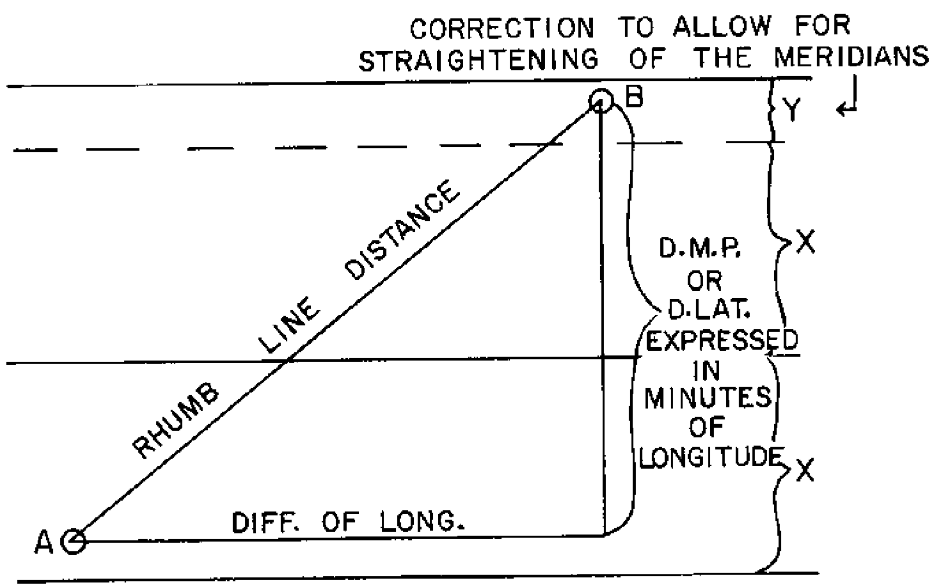
1. A. 23°18′N, 14°12′E
   B. 26°42′N, 17°07′E
2. A. 45°12′N, 18°06′W
   B. 48°03′N, 21°37′W
3. A. 17°06′S, 45°12′W
   B. 21°14′S, 47°06′W
4. A. 62°12′N; 53°12′W
   B. 61°08′N, 47°27′W
5. A. 1°08′S, 178°12′W
   B. 1°09′N, 176°47′E
6. A. 46°18′S, 123°46′E
   B. 49°00′S, 125°19′E
7. A. 13°12′N, 57°18′E
   B. 15°06′N, 52°47′E
8. A. 46°08′S, 137°14′W
   B. 49°45′S, 142°36′W
9. A. 61°12′N, 84°16′W
   B. 64°17′N, 79°14′W
10. A. 26°12′N, 178°56′E
    B. 29°15′N, 179°12′W
11. A. 32°14′S, 57°08′E
    B. 26°54′S, 55°12′E
12. A. 2°08′N, 178°14′E
    B. 1°06′S, 177°12′W
13. A. 45°18′N, 12°08′W
    B. 45°24′N, 19°47′W
14. A. 65°13′N, 145°18′E
    B. 68°11′N, 147°12′E
15. A. 2°00′N, 179°00′W
    B. 2°00′S, 177°00′E

Mercator Sailing

With plane sailing problems we found the course by means of the trigonometric ratio of the departure and difference of latitude of the plane course and distance triangle. These sides are expressed in units of nautical miles; for this reason it is necessary to convert difference of longitude into departure by the parallel sailing formula.

The Mercator sailing method uses the same two sides of the course-distance triangle but they are expressed in units of longitude. The difference of latitude side is converted into minutes of longitude by the meridianal parts table which is included in most sets of nautical tables. Thus with the difference of latitude and the difference of longitude sides both expressed in minutes of longitude, the course angle is easily calculated. The distance is then found exactly as in the plane sailing method.

As previously explained, the Mercator method is preferable when the difference of latitude is appreciable.



On a Mercator chart the latitude scale is increased by the secant of the latitude to maintain correct relative shape of masses.

Thus, Scale of 1′ Lat. = Scale of 1′ Long. × Sec Lat.

Because the latitude scale is variable, only small distances should be measured on the chart. Considerable discrepancy will occur when [redacted] MEASURING large rhumb-line distances directly from the latitude scale.

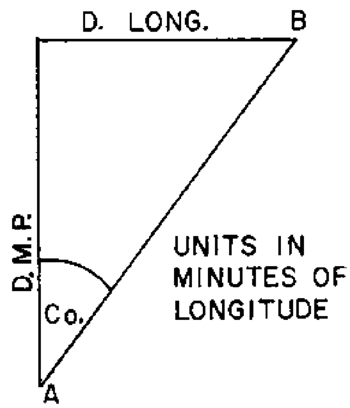
The meridianal parts for each of the two latitudes involved are extracted from the meridianal parts table and subtracted from each other if latitudes have the same name, or added if the latitudes have opposite names. The resulting figure is the difference of meridianal parts, or D.M.P., which is the difference of latitude accurately expressed in minutes of longitude.

Two worked examples of Mercator sailing problems follow. The use of a diagram is advised.

Example 1

Find the course and distance from position A in 7°42′ N 13°06′ W to position B in 24°18′ N 6°02′ W.

A.	7°	42′N		13°	06′W	M.P.* 460.3
B.	24°	18′N		6°	02′W	M.P. 1494.2
D. Lat.	16°	36′N	D. Long	7°	04′E	D.M.P. 1033.9
	60			60		
D. Lat.	996		D. Long.	424		



Tan. Co. = $\frac{\text{D. Long.}}{\text{D.M.P.}} = \frac{424}{1033.9}$

Course = N 22°18′ E

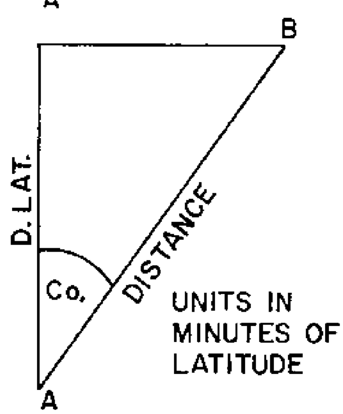
Dist. = Sec. Co. × D. Lat.

Dist. = Sec. 22°18′ × 996

Distance = 1076.5 miles

	No.	Log.
	424	2.62737
	1033.9	3.01447
		T.61290
	Sec. 22°18′	0.03376
	996	2.99826
		3.03202

Course from A to B is N 22°18′ E and Distance is 1076.5 Miles



*M.P. is the meridianal part extracted from the tables.

Example 2

A ship steers a course of S 60° W from the equator changing her longitude by 900′. What is her arrival latitude and what distance will she have steamed?

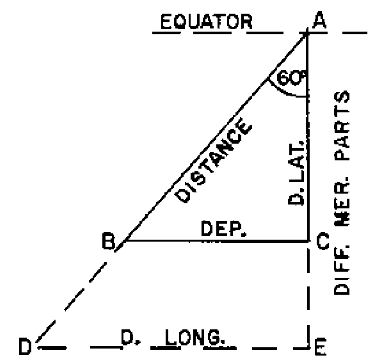
	No.	Log.
D.M.P. = Cotan Co. × D. Long	Cotan 60°	$\bar{1}$.76144
D.M.P. = 60° × 900′	900	2.95424
D.M.P. = 519.6		2.71568

Meridianal parts for equator are zero.

D.M.P. in this case will be the meridianal parts of arrival latitude.

M.P. of 519.6 gives latitude 8°41′.1 S using the meridianal parts table

D. Lat. = 521.1



△ ABC IS IN UNITS OF LATITUDE
△ ADE IS IN UNITS OF LONGITUDE

	No.	Log.
Distance = Sec. Co. × D. Lat.	Sec 60°	0.30103
Distance = Sec. 60° × 521.1	521.1	2.71692
Distance = 1042.2 miles		3.01795

Arrival Latitude is 8°41′.1 S and Distance Steamed is 1042.2 Miles

Exercise 21. MERCATOR SAILING

Find the course and distance between each of the following two positions:

1. A. 28°13′N, 6°14′E
   B. 1°04′S, 5°07′W
2. A. 3°17′S, 53°12′E
   B. 8°14′N, 72°17′E
3. A. 17°12′N, 169°14′W
   B. 34°08′N, 123°46′W
4. A. 42°08′S, 169°14′W
   B. 64°14′S, 173°08′E
5. A. 13°07′N, 54°12′E
   B. 43°08′N, 106°47′E
6. A vessel left lat. 9°00′ N and steered 060° T covering 18° difference of longitude. Find the arrival latitude and the distance steamed.
7. Find the course and distance from (a) 4°48′ S, 51°18′ W to (b) 27°06′ S, 91°14′ W.
8. A vessel left 5°12′ N, 7°18′ W and steered 321° T for 1500 miles. Find the arrival position.
9. Find the course and distance from (a) 7°04′ S, 172°48′ E to (b) 4°18′ N, 165°12′ W.
10. A vessel left lat. 12°06′ N and steered 126° T covering 22°8′ difference of longitude. Find her arrival latitude and distance steamed.
11. Find the course and distance from (a) 4°08′ N, 17°47′ W to (b) 21°07′ N, 52°12′ W.
12. A vessel left 16°08′ S, 42°17′ E and steered 171° T for 2200 miles. Find the arrival position.
13. Find the course and distance from (a) 4°17′ S, 81°04′ W to (b) 12°06′ N, 13°42′ W.
14. A vessel left lat. 5°17′ N steering 037° T over a difference of longitude of 14°40′. Find her arrival latitude and the distance steamed.
15. Find the course and distance from (a) 4°07′ N, 162°14′ E to (b) 8°16′ S, 173°06′ W.

Answers to Exercises

EXERCISE 1
Chart Scales

1. 8.22 mi.
2. 1.55 in.
3. 1:266,300
4. 3.91 mi.
5. 15.50 in.
6. 1:260,570
7. 1:508,355
8. 1:364,800
9. 3.87 mi.
10. 28.37 in.

EXERCISE 2
Position

1. 123° T × 2.4 mi.
2. 41°20′ N 71°24′ W
3. 249° T × 2.4 mi.
4. 41°14′ N 71°25′ W
5. 218° T × 5.6 mi.
6. 40°59′.5 N 71°49′.3 W
7. 299° T × 3.8 mi.
8. 41°13′.9 N 71°45′.5 W
9. 143° T × 5.9 mi.
10. 41°02′.5 N 71°29′.7 W

EXERCISE 3
Fixing Position

1. 41°00′.7 N 71°44′ W 21 fath.
2. 41°12′.2 N 71°40′.7 W 19½ fath.
3. 40°54′.3 N 72°15′ W
4. 40°54′.7 N 71°44′.5 W
5. 41°04′.5 N 72°02′.4 W 8 fath.
6. 41°14′.8 N 71°41′.9 W
7. 11 fath. and 2.7 mi.
8. 40°57′.4 N 71°43′.4 W
9. 40°52′.6 N 72°00′.3 W
10. 41°08′.6 N 72°07′.7 W

EXERCISE 5
True Course and Distance

1. 066° T, 24.7 mi.
2. 104° T, 14.5 mi., 1.3 mi.
3. 71°06′.9 W, 1 hr. 52 min.
4. 340° T, 1 hr. 57 min.
5. 057° T, 2154 hrs.
6. 3 hrs. 3 min., 149° T
7. 312° T, 3 hrs. 33 min.
8. 062° T, 34 mi.
9. 248° T, 25.6 mi.
10. 060° T, 15.6 mi.

EXERCISE 6
Running Fix

1. 41°06′.1 N 71°27′.5 W 15 fath.
2. 41°03′ N 70°48′.3 W
3. 41°22′.2 N 71°18′ W
4. 41°19′.6 N 70°59′.5 W 303° T
5. 41°23′.2 N 70°47′.3 W
6. 41°10′.4 N 70°56′ W; 70°51′.9 W
7. 41°07′.4 N 71°22′.4 W
8. 41°20′.5 N 71°32′.1 W
9. 41°25′ N 71°17′.4 W
10. 41°22′.3 N 70°50′.5 W

EXERCISE 7
Variation and Magnetic Course

1. (a) 052° M
   (b) 085° M
   (c) 296° M
   (d) 333° M
   (e) 009° M
2. (a) 055° T
   (b) 159° T
   (c) 258° T
   (d) 010° T
   (e) 354° T
3. (a) 31° E
   (b) 29° W
   (c) 33° E
   (d) 9° W
   (e) 20° W
4. 300° M
5. 181° M

EXERCISE 8
Deviation, Compass Course and Compass Error

2. 4¾° W, 2¼° W, ¾° E, 3½° E, NIL
3. 5° W, ⅝° E, 3½° E, 2½° E, NIL
4. 5° E, NIL, 5½° W, 1⅓° W, 2½° E
5. 4½° E, NIL, 7° W, 1½° W, 5° E
6. (a) 156° M, 25° W, 153° C
   (b) 18° W, 225° M, 231° C
   (c) 274° T, 15° E, 259° C
   (d) 277° T, 29° W, 299° C
   (e) 033° T, 012° M, 4° W
   (f) 314° T, 332° M, 23° W
   (g) 22° E, 7° W, 15° E
   (h) 008° T, 4° W, 012° M
   (i) 205° M, 3° E, 202° C
   (j) 136° T, 4° E, 150° C
   (k) 43° E, 309° M, 315° C
   (l) 237° T, 5° W, 14° E

(m) 151° T, 187° M, 11° E
(n) 242° T, 23° W, 265° M
(o) 21° E, 3° W, 18° E
(p) 19° W, 018° M, 017° C
(q) 319° T, 18° E, 301° C
(r) 19° E, 30° E, 336° C
(s) 350° M, NIL, 001° C
(t) 000° T, 027° M, 41° E

EXERCISE 9
Compass Courses and Bearings

1. Dev. 7° E, Var. 14° W, 40°58'.5 N 71°40'.6 W
2. Dev. 1° W, Var. 13¼° W, 40°55'.7 N 72°01' W
3. Dev. 5½° E, Var. 13¾° W, 41°09'.5 N 71°49'.9 W
4. Dev. 6° W, Distance off 1 mi.
5. 266° C
6. Dev. 1° W, Distance off 5 mi.
7. 095½° T, Dev. 3° W, Var. 13½° W, 112° C
8. C. E. 15° W, 140° C, 15.2 mi.; C. E. 21° W, 201° C
9. Dev. 6½° E, Var. 13½° W, 41°00'.4 N 71°50'.3 W
10. Dev. 3½° E, Var. 14° W, 41°13'.7 N 71°55'.3 W, 286° C

EXERCISE 10
Doubling the Angle on the Bow

1. 4 mi.
2. C.E. 9½° W, 41°20'.2 N 71°07'.1 W
3. C.E. 22° W, 3½ mi., 3.1 mi.
4. C.E. 22° W, 41°12'.1 N 71°27'.8 W
5. 2 mi.

FIRST GENERAL CHARTWORK EXERCISE

2. 233° C, 14 ft. plus tide
3. 158° C, 176° C, 41°16'.4 N 70°51'.5 W
4. 266° C, 0740
5. 132° C, NIL
6. 318° C, 310° C, 1305 Wed.

SECOND GENERAL CHARTWORK EXERCISE

1. 155° C
2. 229° T × 2½ kts.
3. 049° C, 1¼ mi.
4. 41°26.2 N 71°03.2 W
5. 067° C, 344° C, 1630 hrs.

EXERCISE 11
Allowing for Wind and Tide

1. C.E. 14° W, 101° C, 10 kts.
2. C.E. 15° W, 072° C, 8.3 kts.
3. C.E. 23° W, 235° C, 7.0 kts.
4. C.E. 14° W, 300° C, 14 kts.
5. C.E. 19° W, 152° C, 10.3 kts.
6. C.E. 14° W, 099° C, 10.8 kts.
7. C.E. 26½° W, 185° C, 7.9 kts.
8. C.E. 14° W, 343° C, 6 hrs. 54 min.
9. C.E. 10½° W, 338° C, 6 kts.
10. C.E. 20½° W, 261° C, 9.7 kts.

EXERCISE 12
Tides

1. 6 hrs. 00 min., 7.9 ft.
2. 6 hrs. 36 min., 4.4 ft.
3. 0507, 0.1 ft.; 1154, 4.0 ft.
4. 6 hrs. 23 min., 3.8 ft.
5. 0119, 4.3 ft.; 0807, -0.1 ft.
6. 1.4 ft.
7. 2.4 ft.
8. 0505
9. -0.3 ft.
10. 0326/0822

EXERCISE 13
Vertical Sextant Angles

1. 2.9 mi.
2. 2.5 mi.
3. 2.9 mi.
4. 0°44
5. 3°47

EXERCISE 14
Horizontal Sextant Angles

1. 41°27'.3 N 71°05'.2 W
2. ½ mi.
3. 6 cables
4. 41°22'.7 N 70°46'.3 W
5. 41°32'.9 N 70°41'.9 W

EXERCISE 15
Rising and Dipping Distances

1. 17M, 43°09' N 65°50' W
2. 15.9 M, 40°43'.6 N 69°17' W
3. 21.6M, 42°14' N 69°40' W
4. 21.1M, 21.8M, 2 mi. to steam
5. 16.7M, 13.8M 43°38½' N 66°44½' W
6. 17.4M, 16.5M, 43°44' N 68°19' W
7. 15.9M, 21.3M, 40°58'.5 N 70°13' W
8. 20.7M, 19.9M, 42°33.'7 N 70°08'.3 W
9. St'b'd. 15°

EXERCISE 16
Lines of Soundings

1. 272° C, 42°15' N 68°31 W
2. 0540, 2 Points on St'b'd.
3. 1450, 277° C
4. 15°, No

EXERCISE 17
Three-Bearing Problem

1. 066° T
2. 178° C
3. 000° T, 1.2 kts.
4. 142° C

THIRD GENERAL CHARTWORK EXERCISE

1. 144° C, 49 mi.
2. 9M
3. 123° T
4. 41°21′ N 69°32′ W
5. 0055
6. 299° C, 1232

EXERCISE 18
Parallel Sailing

1. 175.1 mi.
2. 212.7 mi.
3. 14°02′ E
4. 15°49′.7 W
5. 234.6 mi.
6. 36°7′.5 N or S
7. 560.6 kts.
8. 232.6 mi.
9. 6°22′.5
10. 37°9′.4 N or S
11. 755′.1 mi.
12. 7°03′.6 E
13. 60°00′ N or S
14. 1,200.6 mi.
15. 5°57′.5

EXERCISE 19
Parallel Sailing by Traverse Table

1. 56°17′.9 N or S
2. 47 mi.
3. 1°48′.8
4. 72°19′.9 N or S
5. 52°32′.6 E
6. 459.3 mi.
7. 15°5′
8. 52°19′.8 N or S
9. 451.6 mi.
10. 16°45′
11. 70°32′ N or S
12. 572.9 mi.
13. 11°39′.9
14. 65°24′.5 N or S
15. 599.9 kts.

EXERCISE 20
Plane Sailing

1. N 37°51′.8 E 258.4 mi.
2. N 40°16′.7 W, 224.1 mi.
3. S 23°28′.2 W, 270.4 mi.
4. S 68°39′.0 E, 175.8 mi.
5. N 65°31′.7 W, 330.7 mi.
6. S 21°08′.5 E, 173.7 mi.
7. N 66°32′.8 W, 286.4 mi.
8. S 44°49′.8 W, 306 mi.
9. N 36°47′ E, 231 mi.
10. N 28°26′.8 E, 208.1 mi.
11. N 17°30′ W, 335.5 mi.
12. S 54°42′ E, 335.7 mi.
13. N 88°56′.1 W, 322.7 mi.
14. N 14°12′.9 E, 183.6 mi.
15. S 45° W, 339.4 mi.

EXERCISE 21
Mercator Sailing

1. S 20°31′.9 W, 1,876.2 mi.
2. N 58°59′.5 E, 1,341.3 mi.
3. N 67°33′ E, 2,660.7 mi.
4. S 24°57′.2 W, 1,462.5 mi.
5. N 56°44′.4 E, 3,280 mi.
6. 19°07′.8 N, 1,215.6 mi.
7. S 59°49′.4 W, 2,661.9 mi.
8. 24°37′.7 N, 23°34′ W
9. N 62°47′.3 E, 1,491.4 mi.
10. 3°59.7′ S, 1,643 mi.
11. N 63°13′.7 W, 2,262.2 mi.
12. 52°20′.9 S, 49°25′.6 E
13. N 76°20′.6 E, 4,163.4 mi.
14. 24°07′.8 N, 1,415.9 mi.
15. S 63°26′.3 E, 1,661.6 mi.