Title: Lectures in Navigation

Author: Ernest Gallaudet Draper

Release date: December 28, 2008 [eBook #27642]

Language: English

Credits: Produced by Viv, Ted Garvin and the Online Distributed
Proofreading Team at http://www.pgdp.net

LECTURES IN NAVIGATION

Prepared for Use as a Text Book

at the

OFFICERS' MATERIAL SCHOOL NAVAL AUXILIARY RESERVE

by

Lieutenant ERNEST G. DRAPER, U.S.N.R.F.

Head of the Department of Navigation

Officers' Material School, Naval Auxiliary Reserve

FOREWORD

These Lectures have been compiled as speedily as possible to meet the demand for some quick but fairly comprehensive method whereby large bodies of men, divided into small classes, might learn the elements of Navigation and thus assume, without delay, their responsibilities as Junior Officers of the deck, Navigators and Assistant Navigators in the United States Naval Auxiliary Reserve.

I realize that the haste with which the book has been written is apparent in many places, and it is hoped that many evidences of this haste will disappear in case further editions are printed. Besides acknowledging the help and information which was secured from the list of navigational works, mentioned on another page, I wish to mention particularly Prof. Charles Lane Poor's book, entitled "Nautical Science," from which was secured practically all of the information in the Lecture on Planets and Stars (Tuesday - Week V); Commander W. C. P. Muir's book, "Navigation and Compass Deviations," and Lieutenant W. J. Henderson's book, "Elements of Navigation," the text of which was followed closely in discussing Variation and Deviation and Traverse Sailing.

I desire to express my gratitude to Lieutenant Commander R. T. Merrill, 2nd, U. S. N., for suggesting a detailed outline of the whole course; to Lieutenant Commander B. O. Wills, U. S. N., for his valuable criticisms and almost daily help during the preparation of these Lectures; to Lieutenant (j. g.) C. D. Draper, U. S. N. R. F.; Lieutenant (j. g.) R. Brush, U. S. N. R. F., and Lieutenant (j. g.) P. C. McPherson, U. S. N. R. F., for many criticisms and suggestions; and to Captain Huntington, Seamen's Church Institute, for suggesting helpful diagrams, particularly the one on page 44. This opportunity is also taken for thanking the many Instructors in the School for their opinions on various questions that have come up in connection with the course and for assistance in eliminating errors from the text.

E. G. D.

LIST OF BOOKS CONSULTED

American Practical Navigator, Bowditch
Navigation and Compass Deviations, Muir
Nautical Science, Poor
Elements of Navigation, Henderson
Wrinkles in Practical Navigation, Lecky
Whys and Wherefores of Navigation, Bradford
Epitome of Navigation, Norie
Navigation, Hosmer
Finding a Ship's Position at Sea, Sumner
General Astronomy, Young

PREFACE

To those taking this course in Navigation:

These lectures have been written with the idea of explaining, in as simple language as possible, the fundamental elements of Navigation as set forth in Bowditch's American Practical Navigator. They will be given you during the time at the Training School devoted to this subject. At present this time includes two morning periods of one and a half hours each, separated by a recess of fifteen minutes. In general the plan is to devote the first period to the lecture and the second period to practical work.

Not many examples for practical work have been included in this book, but one example, illustrating each new method, has been worked out. If you understand these examples you should be able to understand others similar to them.

Toward the end of the course a portion of each second period will be devoted to handling the sextant, work with charts, taking sights, etc. In short, every effort will be made to duplicate, as nearly as possible, navigating conditions on board a modern merchant ship.

Department of Navigation,

Officers' Material School,

Naval Auxiliary Reserve

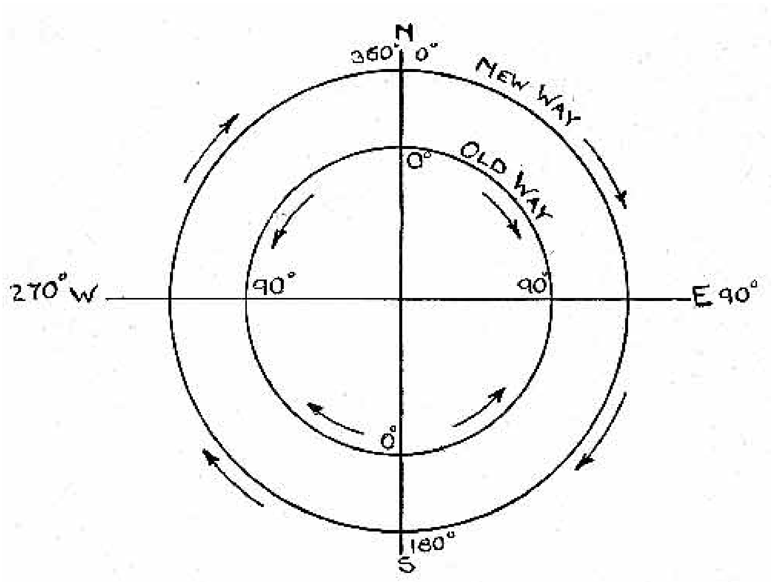
CONTENTS

WEEK I—PILOTING

TUESDAY LECTURE

THE COMPASS

Everyone is supposed to know what a compass looks like. It is marked in two ways—the old way and the new way. Put in your Note-Book this diagram:



The new way marked on the outside of the diagram, starts at North with 0°, increases toward the right through East at 90°, South at 180°, West at 270° and back to North again at 360° or 0°.

The old way, marked on the inside of the diagram, starts at North with 0°, goes to the right to 90° at East and to the left to 90° at West. It also starts at South with 0°, goes to the right to East at 90° and to the left to West at 90°.

A Compass Course can be named in degrees, according to either the new or old way. For instance, the new way is just 45°. The old way for the same course is N 45° E. New way - 100°. Old way for same course - S 80° E.

There is another way to name a compass course. It is by using the name of the point toward which the ship is heading. On every ship the compass is placed with the lubber line (a vertical black line on the compass bowl) vertical and in the keel line of the ship. The lubber line, therefore, will always represent the bow of the ship, and the point on the compass card nearest the lubber line will be the point toward which the ship is heading.

The compass card of 360° is divided into 32 points. Each point, therefore, represents 11¼°. The four principal points are called *cardinal* points. They are - North, East, South, West. Each cardinal point is 90° from the one immediately adjacent to it. It is also 8 points from the one adjacent to it, as 90° is 8 points, i.e., 11¼° (one point) times 8. Midway between the cardinal points are the inter-cardinal points. They are - N E, S E, S W, N W, and are 45° or 4 points from the nearest cardinal point. Midway between each cardinal and inter-cardinal point - at an angular distance of 22½° or 2 points, is a point named by combining a cardinal point with an inter-cardinal point. For instance, NNE, ENE, ESE, SSE, SSW, WSW, WNW, NNW. Midway between the last points named and a cardinal or inter-cardinal point, at an angular distance of 11¼°, is a point which bears the name of that cardinal or inter-cardinal point joined by the word *by* to that of the cardinal point nearest to it. As, for instance, N by E, E by N, E by S, S by E, S by W, W by S, W by N, N by W. Also NE x N, NE x E, SE x E, SE x S, SW x S, SW x W, NW x W, NW x N. The angular distance between each and every whole point is divided into 4 parts called half and quarter points and each representing an angular measure of approximately 2° 49'. In mentioning fractional points, the U. S. Navy regulations are to name each point from North and South toward East and West except that divisions adjacent to a cardinal or inter-cardinal point are always referred to that point: For instance, N ½ E, N x E ½ E, NE ½ N, NW ½ N, NW ¼ W, NW ¾ W, NW ¼ N.

Boxing the compass is naming each point and quarter-point in rotation, i.e., starting at North and going around to the right back to North again. Every man should be able to identify and name any point or quarter-point on the compass card.

In changing a point course into a degree course, for either new or old compass, a guide is herewith furnished you. This should be pasted into the front of your Bowditch Epitome. It shows, from left to right, the name of the point course, its angular measure in the new compass and its angular measure in the old compass. It also shows at the bottom, the angular measure of each division of one point. In understanding this guide, remember that each course is expressed in degrees or degrees and minutes.

Put in your Note-Book:

In Navigation, each degree is written thus °. Each fraction of a degree is expressed in minutes and written thus '. There are 60' in each degree. Each fraction of a minute is expressed in seconds and is written ". There are 60" in each minute. Four degrees, ten minutes and thirty seconds would be written thus: 4° 10' 30".

Although this guide just given you is given as an aid to quickly transfer a point course into a new or old compass course - or vice versa - you should learn to do this yourself, after awhile, without the guide.

Put in your Note-Book:

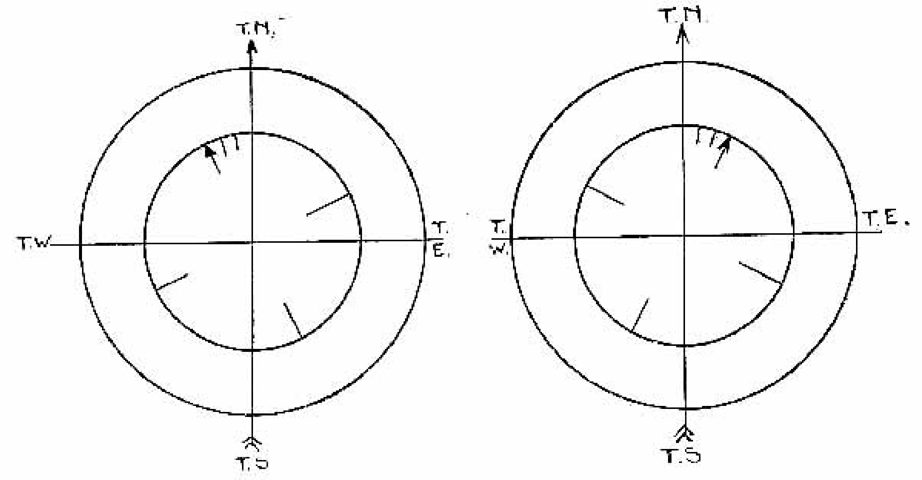
Ship's Head	**New**	**Old**	**By Point**
NE	45°	N 45° E	NE
90°	90°	N 90° E	EAST
SE × E	123° 45'	S 56° E	SE × E
S 20° E	160°	S 20° E	S x E ¾ E
S 2 pts. E	157° 30'	S 22° 30' E	SSE
NW ¾ W	306° 34'	N 53° W	NW ¾ W
289° 41'	289° 41'	N 70° W	WNW ¼ W

I will show you just how each one of these courses is secured from the guide just given you.

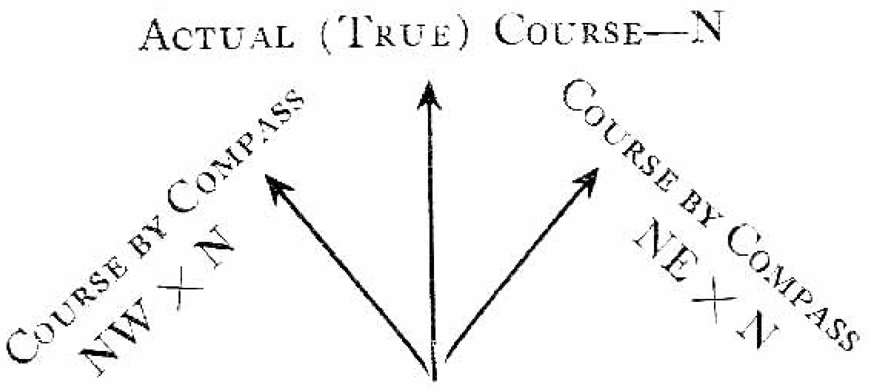
Note to Instructor: After explaining these courses in detail, assign for reading *in the class room* the following articles in Bowditch: Arts. 25-26-27-28-29-30-31-32, 74-75-76-77-78-79-80-81-82.

Every compass, if correct, would have its needle point directly to the real or *true* North. But practically no compass with which you will become familiar will be correct. It will have an error in it due to the magnetism of the earth. This is called Variation. It will also have an error in it due to the magnetism of the iron in the ship. This is called Deviation. You are undoubtedly familiar with the fact that the earth is a huge magnet and that the magnets in a compass are affected thereby. In other words, the North and South magnetic poles, running through the center of the earth, do not point true North and South. They point at an angle either East or West of the North and South. The amount of this angle in any one spot on the earth is the amount of Variation at that spot. In navigating a ship you must take into account the amount of this Variation. The amount of allowance to be made and the direction (i.e. either East or West) in which it is to be applied are usually indicated on the chart. On large charts, such as those of the North Atlantic, will be found irregular lines running over the chart, and having beside them such notations as 10° W, 15° W, etc. Some lines are marked "No Variation." In such cases no allowance need be made. On harbor charts or other small charts, the Variation is shown by the compass-card printed on the chart. The North point of this card will be found slewed around from the point marking True North and in the compass card will be some such inscription as this: "Variation 9° West in 1914. Increasing 6' per year."

Now let us see how we apply this Variation so that although our compass needle does not point to true North, we can make a correction which will give us our true course in spite of the compass reading. Note these diagrams:



The outer circle represents the sea horizon with the long arrow pointing to true North. The inner circle represents the compass card. In the diagram to the left, the compass needle is pointing three whole points to the left or West of True North. In other words, if your compass said you were heading NE x N, you would not actually be heading NE x N. You would be heading true North.



In other words, standing in the center of the compass and looking toward the circumference, you would find that every true course you sailed would be three points to the *left* of the compass course. That is called Westerly Variation.

Now look at the diagram to the right. The compass needle is pointing three whole points to the right or East of True North. In other words, standing in the center of the compass and looking toward the circumference, you would find that every true course you sailed would be three points to the *right* of the compass course. That is called Easterly Variation.

Hence we have these rules, which put in your Note-Book:

To convert a compass course into a true course

When the Variation is westerly, the true course will be as many points to the left of the compass course as there are points or degrees of Variation. When the Variation is easterly, the true course will be as many points or degrees to the right of the compass course.

To convert a true course into a compass course

The converse of the above rule is true. In other words, Variation westerly, compass to the right of true course; variation easterly, compass course to the left.

DEVIATION

As stated before, Deviation causes an error in the Compass due to the magnetism of the iron in the ship. When a ship turns, the compass card does not turn, but the relation of the iron's magnetism to the magnets in the compass is altered. Hence, every change in course causes a new amount of Deviation which must be allowed for in correcting the compass reading. It is customary in merchant vessels to have the compasses adjusted while the ship is in port. The adjuster tries to counteract the Deviation all he can by magnets, and then gives the master of the ship a table of the Deviation errors remaining. These tables are not to be depended upon, as they are only accurate for a short time. Ways will be taught you to find the Deviation yourself, and those ways are the only ones you can depend upon.

Put in your Note-Book:

Westerly Deviation is applied exactly as westerly Variation. Easterly Deviation is applied exactly as easterly Variation.

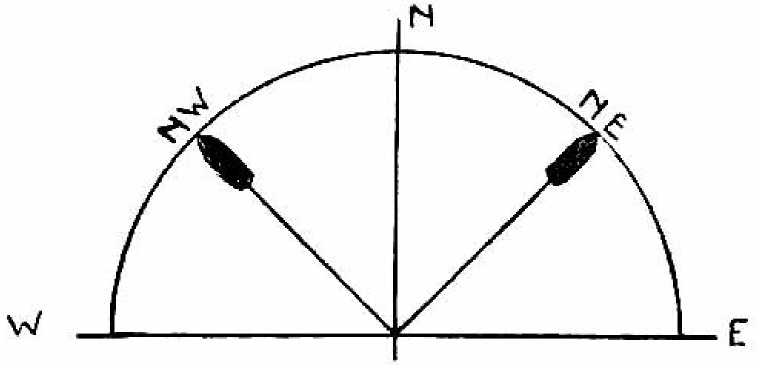
The amount of Variation plus the amount of Deviation is called the Compass Error. For instance, a Variation of 10° W plus a Deviation of 5° W equals a compass error of 15° W, or a Variation of 10° W plus a Deviation of 5° E leaves a net compass error of 5° W.

LEEWAY

Leeway is not an error of the compass, but it has to be compensated for in steaming any distance. Hence it is mentioned here. A ship steaming with a strong wind or current abeam, will slide off to the leeward more or less. Hence, her course will have to be corrected for Leeway as well as for Variation and Deviation.

Put in your Note-Book:

Leeway on the starboard tack is the same as westerly Variation. Leeway on the port tack is the same as easterly Variation. This is apparent from the following diagram:



As the wind, blowing from the North, hits the left hand ship, for instance, on her starboard side, it shoves the ship to the left of her true course by the number of points or degrees of leeway.

Leave a space and put the following heading in your Note-Book:

I. Complete rule for converting a compass course into a true course:
  1. Change the compass course into a new compass reading.
  2. Apply Easterly Variation and Deviation +.
  3. Apply Westerly Variation and Deviation -.
  4. Apply port tack Leeway +.
  5. Apply starboard tack Leeway -.

II. Complete rule for converting a true course into a compass course:
  1. Reverse the above signs in applying each correction.

I will now correct a few courses, and these are to be put into your Note-Book:

C Cos	Wind	Leeway	Dev.	Var.	New	Old
N x E	NW	½ pt.	5° E	10° W	12°	N 12° E
S 67° E	S	1 pt.	3° W	5° E	104°	S 76° E
E x N	SE	½ pt.	5° W	10° E	78°	N 78° E
W x N	NW	1½ pts.	1° E	15° E	280°	N 80° W

Assign for Night Work the following arts. in Bowditch: 36-8-10-13-14-15-16-17-18-19-20-21-22-23-24.

WEDNESDAY LECTURE

PELORUS, PARALLEL RULERS, THE LEAD, SOUNDING MACHINE, DIVIDERS AND LOG

I. The Pelorus

This is an instrument for taking bearings of distant objects, and for taking bearings of celestial bodies such as the sun, stars, etc. It consists of a circular, flat metallic ring, mounted on gimbals, upon a vertical standard. The best point to mount it is in the bow or on the bridge of the ship, where a clear view for taking bearings can be had. The center line of the pelorus should also be directly over the keel line of the ship. The inner edge of the metallic ring is engraved in degrees - the 0° or 360° and the 180° marks indicating a fore-and-aft line parallel to the keel of the ship. Within this ring a ground glass dial is pivoted. This ground glass dial has painted upon it a compass card divided into points and sub-divisions and into 360°. This dial is capable of being moved around, but can also be clamped to the outside ring. Pivoted with the glass dial and flat ring is a horizontal bar carrying at both of its extremes a sight vane. This sight vane can be clamped in any position independently of the ground glass dial, which can be moved freely beneath it. An indicator showing the direction the sight vane points can be read upon the compass card on the glass dial. If the glass dial be revolved until the degree of demarcation, which is coincident with the right ahead marking on the flat ring, is the same as that which points to the lubber's line of the ship's compass, then all directions indicated by the glass dial will be parallel to the corresponding directions of the ship's compass, and all bearings taken will be compass bearings, i.e., as though taken from the compass itself. In other words, it is just as though you took the compass out of its place in the pilot house, or wherever it is regularly situated, put it down where the pelorus is, and took a bearing from it of any object desired.

In taking a bearing by pelorus, two facts must be kept in mind. First, that when the bearing is taken, the exact heading, as shown by the ship's compass, is the heading shown by the pelorus. In other words, if the ship is heading NW, the pelorus must be set with the NW point on the lubber line when the bearing is taken of any object. Second, it must be remembered that the bearing of any object obtained from the pelorus is the bearing *by compass*. To get the true bearing of the same object you must make the proper corrections for Variation and Deviation. This can be compensated for by setting the glass dial at a point to the right or left of the compass heading to correspond with the compass error; then the bearing of any object will be the true bearing. But naturally, you will not be able to make compensation for these errors unless you have immediately before found the correct amount of the compass error.

Parallel Rulers

The parallel rulers need no explanation except for the way in which they are used on a chart. Supposing, for instance, you wish to steam from Pelham Bay to the red buoy off the westerly end of Great Captain's Island. Take your chart, mark by a pencil point the place left and the place to go to and draw a straight line intersecting these two points. Now place the parallel rulers along that line and slide them over until the nearest edge intersects the center of the compass rose at the bottom or side of the chart. Look along the ruler's edge to find where it cuts the circumference of the compass rose. That point on the compass rose will be the *true* compass course, and can be expressed in either the new or old compass, as, for instance, 60° or N 60° E. Remember, however, that this is the *true* course. In order to change it into the compass course of your ship, you must make the proper corrections for the compass error, i.e., Variation and Deviation and for Leeway, if any.

The Lead and Sounding Machine

The lead, as you know, is used to ascertain the depth of the water and, when necessary, the character of the bottom. There are two kinds of leads: the hand lead and deep-sea lead. The first weighs from 7 to 14 pounds and has markings to 25 fathoms. The second weighs from 30 to 100 pounds and is used in depths up to and over 100 fathoms. Put in your Note-Book:

Fathoms which correspond with the depths marked are called *marks*. All other depths are called *deeps*. The hand lead is marked as follows:

2 fathoms - 2 strips of leather.
3 fathoms - 3 strips of leather or blue rag.
5 fathoms - A white rag.
7 fathoms - A red rag.
10 fathoms - A piece of leather with one hole in it.
13 fathoms - Same as at 3.
15 fathoms - Same as at 5.
17 fathoms - Same as at 7.
20 fathoms - 2 knots or piece of leather with 2 holes.
25 fathoms - 1 knot.
30 fathoms - 3 knots.
35 fathoms - 1 knot.
40 fathoms - 4 knots.
And so on up to 100 fathoms.

The large hand leads are hollowed out on the lower end so that an "arming" of tallow can be put in. This will bring up a specimen of the bottom, which should be compared with the description found on the chart.

All up-to-date sea-going ships should be fitted with Sir William Thompson's Sounding Machine (see picture in B. J. Manual). This machine consists of a cylinder around which are wound about 300 fathoms of piano wire. To the end of this is attached a heavy lead. An index on the side of the instrument records the number of fathoms of wire paid out. Above the lead is a copper cylindrical case in which is placed a glass tube open only at the bottom and chemically colored inside. The pressure of the sea forces water up into this tube, as it goes down, a distance proportionate to the depth, and the color is removed. When hoisted, the tube is laid upon a prepared scale, and the height to which the water has been forced inside shows the depth in fathoms on the scale.

DIVIDERS

The dividers are nothing but an instrument for measuring distances, etc., on the chart.

THE LOG

There are two kinds of logs - the chip log, used for measuring the speed of the ship, and the patent log, used for measuring distance run.

The chip log consists of a reel, line, toggle and chip. Usually a second glass is used for measuring time. The chip is the triangular piece of wood ballasted with lead to ride point up. The toggle is a little wooden case into which a peg, joining the ends of the two lower lines of the bridle, is set in such a way that a jerk on the line will free it, causing the log to lie flat so that it can be hauled in. The first 10 or 15 fathoms of line from the log-chip are called "stray line," and the end of this is distinguished by a mark of red bunting. Its purpose is to let the chip get clear of the vessel's wake. The marks on the line (called knots) are pieces of fish line running through the strands of the reel line to the number of two, three, four, etc. A piece of white bunting marks every two-tenths of a knot. This is because the run of the ship is recorded in knots and tenths. The knots of fish line are 47 feet 4 inches from each other.

The log glass measures 28 seconds in time. For high rates of speed, a 14 second glass is used. Then the number of knots shown by the log line must be doubled. The principle of the chip log is that each division of the log line bears the same ratio to a nautical mile that the log glass does to the hour. In other words, if 10 knots or divisions of the log line run out while the 28 second glass empties itself, the ship's speed is 10 knots per hour. If ten knots or divisions run out while the 14 second glass empties itself, the ship's speed is 20 knots per hour.

The patent or towing log consists of a dial, line and rotator. The large circle of the dial records the knots and the small circle tenths of knots. When changing course, read the log and enter it in the log book. When changing course again, read the log again. The difference between the two readings will be the distance run.

Both logs are liable to error. A following sea makes them under-rate, a head sea over-rate. With both logs you must allow for currents. If a current is against you - and you know its rate - you must deduct its rate from that recorded in the log and vice versa. The reason for this is that your log measures your speed through the water. What you must find is your actual distance made good over the earth's surface.

Put in your Note-Book:

Between Sandy Hook and Fort Hamilton, bound due North, speed by chip-log was 10 knots, tidal current setting North 2 knots per hour; what did the ship make per hour? Answer: 12 knots.

At sea in North Sea ship heading S x W, patent log bet. 8 A.M. and 12 M. registered 32 miles, current running N x E 2 knots per hour; what was the actual distance made good? Answer: 24 miles.

Directions for allowing for a current setting diagonally across a ship's course will be given in the proper place.

Assign for Night Work the following articles in Bowditch: Arts. 161-162-163-164-165.

THURSDAY LECTURE

THE CHART

Aids to Navigation

A chart is a map of an ocean, bay, sound or other navigable water. It shows the character of the coast, heights of mountains, depths at low water, direction and velocity of tidal currents, location, character, height and radius of visibility of all beacon lights, location of rocks, shoals, buoys, and nature of the bottom wherever soundings can be obtained.

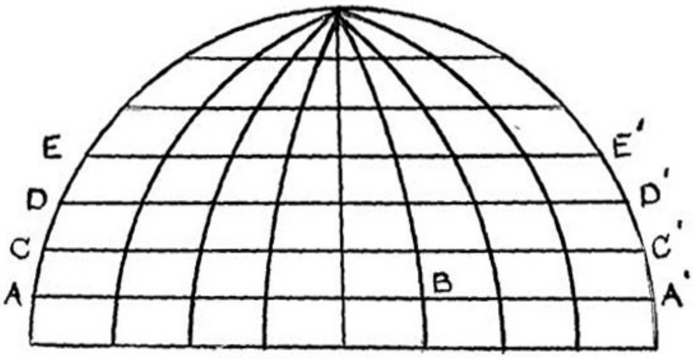
The top of the chart is North unless otherwise noted. When in doubt as to where North is, consult the compass card printed somewhere on the chart. On sea charts, such as those of the North Atlantic, only the true compass is printed, with the amount and direction of Variation indicated by lines on the chart.

Parallels of latitude are shown by straight lines running parallel to each other across the chart. The degrees and minutes of these parallels are given on the perpendicular border of the chart. Meridians of longitude are shown by straight lines running up and down, perpendicular to the parallels of latitude, and the degrees and minutes of these meridians are given on the horizontal border of the chart.

Put in your Note-Book:

A minute of latitude is always a mile, because parallels of latitude are equidistant at all places. A minute of longitude is a mile only on the equator, for the meridians are coming closer to each other as they converge toward either pole. They come together at the North and South poles, and here there is no longitude.

I can explain this very easily by reference to the following illustration:



As every parallel of latitude is a circle of 360° the distance from A to B will be the same number of degrees, minutes and seconds whether measured upon parallel AA' or EE', but it will not be the same number of miles as the meridians of longitude are gradually converging toward the poles. On the other hand, the distances from A to C, C to D, D to E, etc., must be the same because the lines AA', CC', DD', EE' are all parallel. That is why the distance is always measured on the latitude scale (i.e. on the vertical border of the chart), and a minute of latitude is always a mile on the chart, no matter in what locality your ship happens to be.

You should be able to understand any kind of information given you on a chart. For instance, what are the various kinds of buoys and how are they marked?

Put in your Note-Book:

1. In coming from seaward, red buoys mark the starboard side of the channel, and black buoys the port side.

2. Dangers and obstructions which may be passed on either hand are marked by buoys with red and black horizontal stripes.

3. Buoys indicating the fairway are marked with black and white vertical stripes and should be passed close to.

4. Sunken wrecks are marked by red and black striped buoys described in No. 2. In foreign countries green buoys are frequently used to mark sunken wrecks.

5. Quarantine buoys are yellow.

6. As white buoys have no especial significance, they are frequently used for special purposes not connected with Navigation.

7. Starboard and port buoys are numbered from the seaward end of the channel, the black bearing the odd and red bearing the even numbers.

8. Perches with balls, cages, etc., will, when placed on buoys, be at turning points, the color and number indicating on which side they shall be passed.

9. Soundings in plain white are in fathoms; those on shaded parts are in feet. On large ocean charts fathom curves, showing the range of soundings of 10, 20, 30, 40, etc., fathoms are shown.

10. A light is indicated by a red and yellow spot. F. means fixed, Fl., flashing; Int., intermittent; Rev., revolving, etc.

11. An arrow indicates a current and its direction. The speed is always given.

12. Rocks just under water are shown by a cross surrounded by a dotted circle; rocks above water, by a dotted circle with dots inside it.

Practically all charts you will use will be called Mercator charts. Just how they are constructed is a difficult mathematical affair but, roughly, the idea of their construction is based upon the earth being a cylinder, instead of a sphere. Hence, the meridians of longitude, instead of converging at the poles, are parallel lines. This compels the parallels of latitude to be adjusted correspondingly. Although such a chart in any one locality is out of proportion compared with some distant part of the earth's surface, it is nevertheless in proportion for the distance you can travel in a day or possibly a week - and that is all you desire. The Hydrographic Office publishes blank Mercator charts for all latitudes in which they can be used for plotting your position. It makes no difference what longitude you are in for, on a Mercator chart, meridians of longitude are all marked parallel. It makes a great difference, however, what latitude you are in, as in each a mile is of different length on the chart. Hence, it will be impossible for you to correctly plot your course and distance sailed unless you have a chart which shows on it the degrees of latitude in which you are. For instance, if your Mercator chart shows parallels of latitude from 30° to 40° that chart must be used when you are in one of those latitudes. When you move into 41° or 29°, you must be sure to change your plotting chart accordingly. In very high latitudes and near the North pole, the Mercator chart is worthless. How can you steer for the North pole when the meridians of your chart never come together at any pole? For the same reason, bearings of distant objects may be slightly off when laid down on this chart in a straight line. On the whole, however, the Mercator chart answers the mariner's needs so far as all practical purposes are concerned.

The instruments used in consulting a chart, i.e., parallel rulers, dividers, etc. have already been described. The only way to lay down a course and read it is by practice.

The one important thing to remember in laying down a course, is that what you lay down is a true course. To steam this course yourself, you must make the proper correction for your compass error.

Assign for Night Work in Bowditch, Arts. 9-239-240-241-243-244-245-246-247-248-249-251-252-253-254-255-256-257-258.

If any time in class room is left, spend it in laying down courses on the chart and reading them; also in answering such questions as these:

1. I desire to sail a true course of NE. My compass error is 2 points Westerly Variation and 1 point Easterly Deviation. What compass course shall I sail?

2. I desire to sail a true course of SW x W. My Variation is 11° W, Deviation 2 pts. W and Leeway 1 pt. starboard. What compass course shall I sail?

3. I desire to sail a true course of 235°. My compass error is 4 pts. E Variation, 27° W Deviation, Leeway 1 pt. port. What compass course shall I sail?

4. I desire to sail a true course of S 65° W. My compass error is 10° E Variation, 3° E Deviation, Leeway ¼ point starboard. What compass course shall I sail?

FRIDAY LECTURE

The Protractor And Sextant

The protractor is an instrument used to shape long courses. There are many kinds. The simplest and the one most in use is merely a piece of transparent celluloid with a compass card printed on it and a string attached to the center of the compass card. To find your course by protractor, put the protractor down on the chart so that the North and South line on the compass card of the protractor will be immediately over a meridian of longitude on the chart, or be exactly parallel to one, and will intersect the point from which you intend to depart. Then stretch your string along the course you desire to steam. Where this string cuts the compass card, will be the direction of your course. Remember, however, that this will be the *true* course to sail. In order to convert this true course into your compass course, allow for Variation and Deviation according to the rules already given you.

In case you know the exact amount of Variation and Deviation at the time you lay down the course - and your course is not far - you can get your compass course in one operation by setting the North point of your protractor as far East or West of the meridian as the amount of your compass error is. By then proceeding as before, the course indicated on the compass card will be the compass course to sail. This method should not be used where your course in one direction is long or where your course is short but in two or more directions. The reason for this is that in both cases, either your Variation or Deviation may change and throw you off.

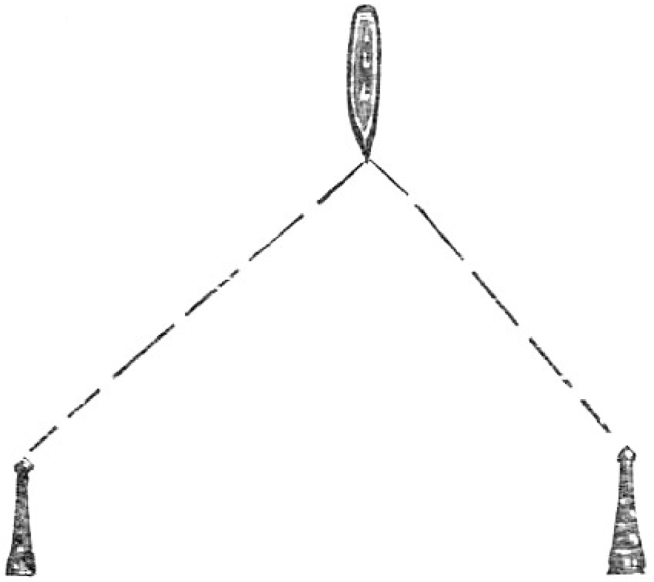
Practically all navigation in strange waters in sight of land and in all waters out of sight of land depends upon the determination of angles. The angle at which a lighthouse is seen from your ship will give you much information that may be absolutely necessary for your safety. The angular altitude of the sun, star or planet does the same. The very heart of Navigation is based upon dealing with angles of all kinds. The instrument, therefore, that measures these angles is the most important of any used in Navigation and you must become thoroughly familiar with it. It is the sextant or some member of the sextant family - such as the quadrant, octant, etc. The sextant is the one most in use and so will be described first.

Put in your Note-Book:

The sextant has the following parts: (Instructor points to each.)

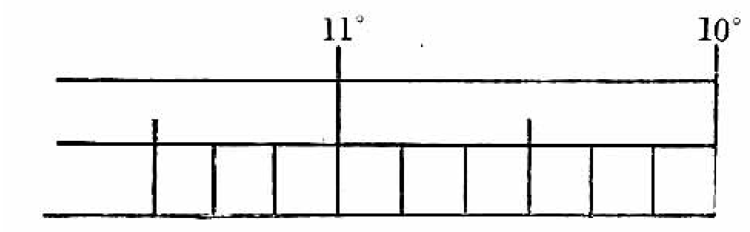
1. Mirror
2. Telescope
3. Horizon Glass
4. Shade Glasses
5. Back Shade Glasses
6. Handle
7. Sliding Limb
8. Reading Glass
9. Tangent Screw
10. Arc

In getting angles of land-marks or buoys, the sextant is held by the handle No. 6 in a horizontal position. The vernier arrow in the sliding limb is set on zero. Now, suppose you wish to get the angular distance between two lighthouses as seen from the bridge of your ship. (Draw diagram.)



Look at one lighthouse through the line of sight and true horizon part of the horizon glass. Now, move the sliding limb along the arc gradually until you see the other lighthouse in the reflected horizon of the horizon glass. When one lighthouse in the true horizon is directly on top of the other lighthouse in the reflected horizon, clamp the sliding limb. If any additional adjustment must be made, make it with the tangent screw No. 9.

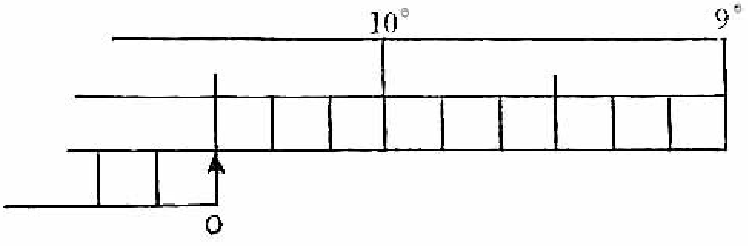
Now look through the reading glass No. 8. You should see that the arc is divided into degrees and sixths of degrees in the following manner:



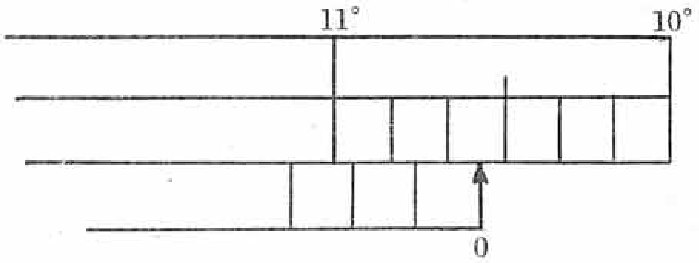
Now, as every degree is divided into sixty minutes, one-sixth of a degree is 10 minutes. In other words, each of the divisions of a degree on this arc represents 10 minutes.

Now on the vernier in the sliding limb, directly under the arc, is the same kind of a division. But these divisions on the vernier represent minutes and sixths of a minute, or 10 seconds.

To read the angle, the zero point on the vernier is used as a starting point. If it exactly coincides with one of the lines on the scale of the arc, that line gives the measurement of the angle. In the following illustration the angle is 10½ degrees or 10° 30':



If however, you find the zero on the vernier has passed a line of the arc, your angle is more than 10° 30' as in this:



You must then look along the vernier to the left until you find the point where the lines do coincide. Then add the number of minutes and sixths of a minute shown on the vernier between zero and the point where the lines coincide to the number of degrees and minutes shown on the arc at the line which the vernier zero has passed, and the sum will be the angle measured by the instrument.

Now in measuring the altitude of the sun or other celestial body, exactly the same process is gone through except that the sextant is held vertically instead of horizontally. You look through the telescope toward that part of the sea directly beneath the celestial body to be observed. You then move the sliding limb until the image of the celestial body appears in the horizon glass, and is made to "kiss" the horizon, i.e., its lowest point just touching the horizon. The sliding limb is then screwed down and the angle read. More about this will be mentioned when we come to Celestial Navigation.

Every sextant is liable to be in error. To detect this error there are four adjustments to be made. These adjustments do not need to be learned by heart, but I will mention them:

1. The mirror must be perpendicular to the plane of the arc. To prove whether it is or not, set the vernier on about 60°, and look slantingly through the mirror. If the true and reflected images of the arc coincide, no adjustment is necessary. If not, the glass must be straightened by turning the screws at the back.

2. The horizon glass must be perpendicular to the plane of the arc. Set the vernier on zero and look slantingly through the horizon glass. If the true and reflected horizons show one unbroken line, no adjustment is necessary. If not, turn the screw at the back until they do.

3. Horizon glass and mirror must be parallel. Set the vernier on zero. Hold the instrument vertically and look through the line of sight and horizon glass. If the true and reflected horizons coincide, no adjustment is necessary. If they do not, adjust the horizon glass.

4. The line of sight (telescope) must be parallel to the plane of the arc. This adjustment is verified by observing two stars in a certain way and then performing other operations that are described in Bowditch, Art. 247.

Do not try to adjust your sextant yourself. Have it adjusted by an expert on shore. Then, if there is any error, allow for it. An error after adjustment is called the Index Error.

Put in your Note-Book:

How to find and apply the IE (Index Error):

Set the sliding limb at zero on the arc, hold the instrument perpendicularly and look at the horizon. Move the sliding limb forward or backward slowly until the true horizon and reflected horizon form one unbroken line. Clamp the limb and read the angle. This is the IE. If the vernier zero is to the left of the zero on the arc, the IE is minus and it is to be subtracted from any angle you read, to get the correct angle. If the vernier zero is to the right of the zero on the arc, the IE is plus and is to be added to any angle you read to get the correct angle. Index error is expressed thus: IE + 2' 30" or IE - 2' 30".

Quadrants, octants and quintants work on exactly the same principles as the sextant, except that the divisions on the arc and the vernier differ in number from the sixth divisions on the arc and vernier of the sextant.

If any time is left, spend it in marking courses with the protractor and handling the sextant.

Assign for Night Work the following Arts. in Bowditch: 134-135-136-138-142-144-145-151-152-157-158-159-160-161-162-163.

SATURDAY LECTURE

Fixes, Angles By Bearings And Sextant

There are five good ways of fixing your position (obtaining a "fix," as it is called) providing you are within sight of landmarks which you can identify or in comparatively shoal water.

Put in your Note-Book:

1. Cross bearings of two known objects.

2. Bearing and distance of a known object, the height of which is known.

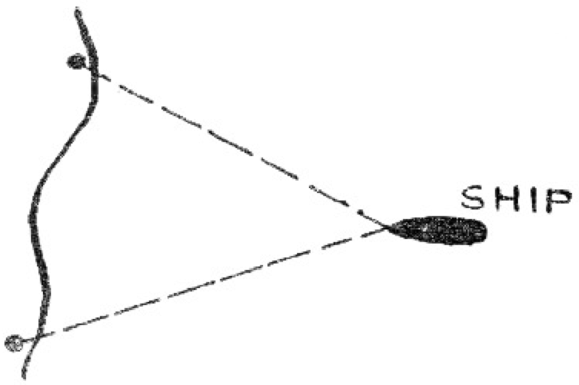
3. Two bearings of a known object separated by an interval of time, with a run during that interval.

4. Sextant angles between three known objects.

5. Using the compass, log and lead in a fog or in unfamiliar waters.

1. Cross bearings of two known objects.

Select two objects marked on the chart, so far apart that each will bear about 45° off your bow but in opposite directions. These bearings will be secured in the best way by the use of your pelorus. Correct each bearing for Variation and Deviation so that it will be a true bearing. Then with the parallel rulers carry the bearing of one object from the chart compass card until you can intersect the object itself and draw a line through it. Do exactly the same with the other object. Where the two lines intersect, will be the position of the ship at the time the bearings were taken.

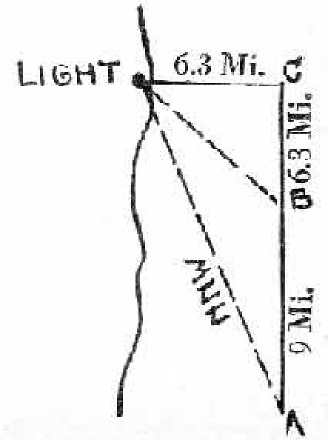


Now supposing you wish to find the latitude and longitude of that position of the ship. For the latitude, measure the distance of the place from the nearest parallel with the dividers. Take the dividers to the latitude scale at the side of the chart and put one point of them on the same parallel. Where the other point touches on the latitude scale, will be the latitude desired. For the longitude, do exactly the same thing, but use a meridian of longitude instead of a parallel of latitude and read from the longitude scale at the top or bottom of the chart instead of from the side.

2. Bearing and distance of a known object, the height of which is known.

Take a bearing of, say, a lighthouse the height of which is known. The height of all lighthouses on the Atlantic Coast can be found in a book published by the U.S. Dept. of Commerce. Correct the bearing, as mentioned in case No. 1. Now read the angle of the height of that light by using your sextant. Do this by putting the vernier 0 on the arc 0, sliding the limb slowly forward until the top of the lighthouse in the reflected horizon just touches the bottom of the lighthouse in the true horizon. With this angle and the known height of the light, enter Table 33 in Bowditch. At the left of the Table will be found the distance off in knots. This method can be used with any fairly perpendicular object, the height of which is known and which is not more than 5 knots away, as Table 33 is not made out for greater distances.

3. Two bearings of the same object, separated by an interval of time and with a run during that interval.



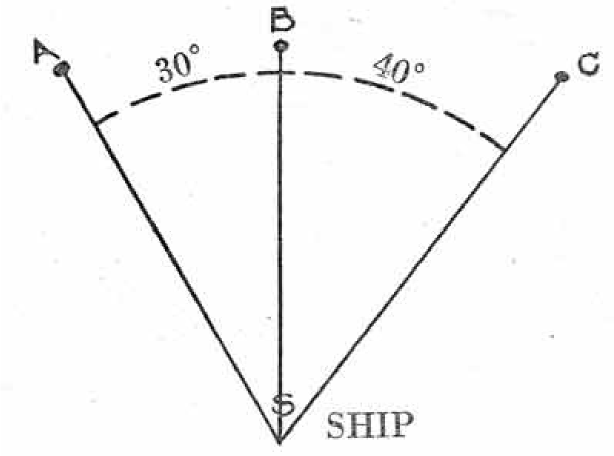
Take a compass bearing of some prominent object when it is either 2, 3 or 4 points off the bow. Take another bearing of the same object when it is either 4, 6 or 8 points off the bow. The distance run by the ship between the two bearings will be her distance from the observed object at the second bearing. "The distance run is the distance off."

A diagram will show clearly just why this is so:

The ship at A finds the light bearing NNW 2 points off her bow. At B, when the light bears NW and 4 points off, the log registers the distance from A to B 9 miles. 9 miles, then, will be the distance from the light itself when the ship is at B. The mathematical reason for this is that the distance run is one side of an isosceles triangle. Such triangles have their two sides of equal length. For that reason, the distance run is the distance off. Now the same fact holds true in running from B, which is 4 points off the bow, to C, which is 8 points off the bow, or directly abeam. The log shows the distance run between B and C is 6.3 miles. Hence, the ship is 6.3 miles from the light when directly abeam of it. This last 4 and 8 point bearing is what is known as the "bow and beam" bearing, and is the standard method used in coastwise navigation. Any one of these methods is of great value in fixing your position with relation to the land, when you are about to go to sea.

4. Sextant angles between three known objects.

This method is the most accurate of all. Because of its precision it is the one used by the Government in placing buoys, etc. Take three known objects such as A, B and C which are from 30° to 60° from each other.



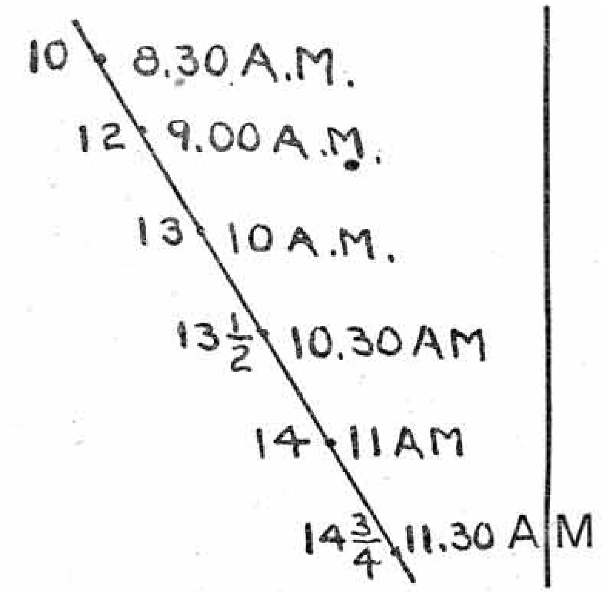
With a sextant, read the angle from A to B and from B to C. Place a piece of transparent paper over the compass card and draw three lines from the center of the compass card to the circumference in such a way that the angles secured by the sextant will be formed by the three lines drawn. Now take this paper with the angles on it and fit it on the chart so that the three objects of which angles were taken will be intersected by the three lines on the paper. Where the point S is (in my diagram) will be the point of the ship's position at the time of sight. To secure greater accuracy the two angles should be taken at the same time by two observers.

5. Using a compass, log and lead when you are in a fog or unfamiliar waters.

Supposing that you are near land and want to fix your position but have no landmarks which you can recognize. Here is a method to help you out:

Take a piece of tracing paper and rule a vertical line on it. This will represent a meridian of longitude. Take casts of the lead at regular intervals, noting the time at which each is taken, and the distance logged between each two. The compass corrected for Variation and Deviation will show your course. Rule a line on the tracing paper in the direction of your course, using the vertical line as a N and S meridian. Measure off on the course line by the scale of miles in your chart, the distance run between casts and opposite each one note the time, depth ascertained and, if possible, nature of the bottom. Now lay this paper down on the chart which can be seen under it, in about the position you believe yourself in when you made the first cast. If your chain of soundings agrees with those on the chart, you are all right. If not, move the paper about, keeping the vertical line due N and S, till you find the place on the chart that does agree with you. That is your line of position. You will never find in that locality any other place where the chain of soundings are the same on the same course you are steaming. This is the only method by soundings that you can use in thick weather and it is an invaluable one.

Put in your Note-Book this diagram:



Assign for Night Work, Review for Weekly Examination to be held on Monday.

Add an explanation of the Deviation Card in Bowditch, page 41.

Put in your Note-Book:

Entering New York Harbor, ship heading W ¾ N, Variation 9° W. Observed by pelorus the following objects:

Buoy No. 1 - ENE ¼ E
" " 2 - E ½ N
" " 3 - NE ¼ E
" " 4 - NW ¼ N

Required true bearings of objects observed.

Answer:

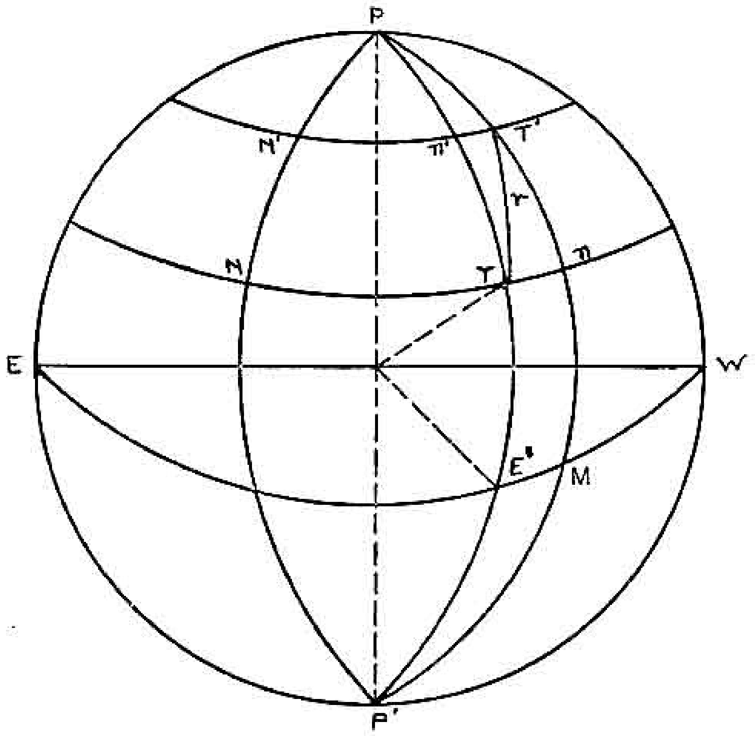
From Deviation Card in Bowditch, p. 41, Deviation on W ¾ N course is 5° E. Hence, Compass Error is 5° E (Dev.) + 9° W (Var.) = 4° W.

	C. B.	C. E.	T. B.
ENE ¼ E	70°	4° W	66°
E ½ N	84°	4° W	80°
NE ¼ E	48°	4° W	44°
NW ¼ N	318°	4° W	314°

WEEK II—DEAD RECKONING

TUESDAY LECTURE

Latitude And Longitude



We have been using the words Latitude and Longitude a good deal since this course began. Let us see just what the words mean. Before doing that, there are a few facts to keep in mind about the earth itself. The earth is a spheroid slightly flattened at the poles. The axis of the earth is a line running through the center of the earth and intersecting the surface of the earth at the poles. The equator is the great circle, formed by the intersection of the earth's surface with a plane perpendicular to the earth's axis and equidistant from the poles. Every point on the equator is, therefore, 90° from each pole.

Meridians are great circles formed by the intersection with the earth´s surface of planes perpendicular to the equator.

Parallels of latitude are small circles parallel to the equator.

The Latitude of a place on the surface of the earth is the arc of the meridian intercepted between the equator and that place. It is measured by the angle running from the equator to the center of the earth and back through the place in question. Latitude is reckoned from the equator (0°) to the North Pole (90°) and from the equator (0°) to the South Pole (90°). The difference of Latitude between any two places is the arc of the meridian intercepted between the parallels of Latitude of the places and is marked N or S according to the direction in which you steam (T n´).

The Longitude of a place on the surface of the earth is the arc of the equator intercepted between the meridian of the place and the meridian at Greenwich, England, called the Prime Meridian. Longitude is reckoned East or West through 180° from the Meridian at Greenwich. Difference of Longitude between any two places is the arc of the equator intercepted between their meridians, and is called East or West according to direction. Example: Diff. Lo. T and T´ = E´ M, and E or W according as to which way you go.

Departure is the actual linear distance measured on a parallel of Latitude between two meridians. Difference of Latitude is reckoned in minutes because miles and minutes of Latitude are always the same. Departure, however, is only reckoned in *miles*, because while a mile is equal to 1´ of longitude on the equator, it is equal to more than 1´ as the latitude increases; the reason being, of course, that the meridians of Lo. converge toward the pole, and the distance between the same two meridians grows less and less as you leave the equator and go toward either pole. Example: TN, N´n´. 10 mi. departure on the equator = 10´ difference in Lo. 10 mi. departure in Lat. 55° equals something like 18´ difference in Lo.

The curved line which joins any two places on the earth´s surface, cutting all the meridians at the same angle, is called the Rhumb Line. The angle which this line makes with the meridian of Lo. intersecting any point in question is the Course, and the length of the line between any two places is called the distance between them. Example: T or T´.

Chart Projections

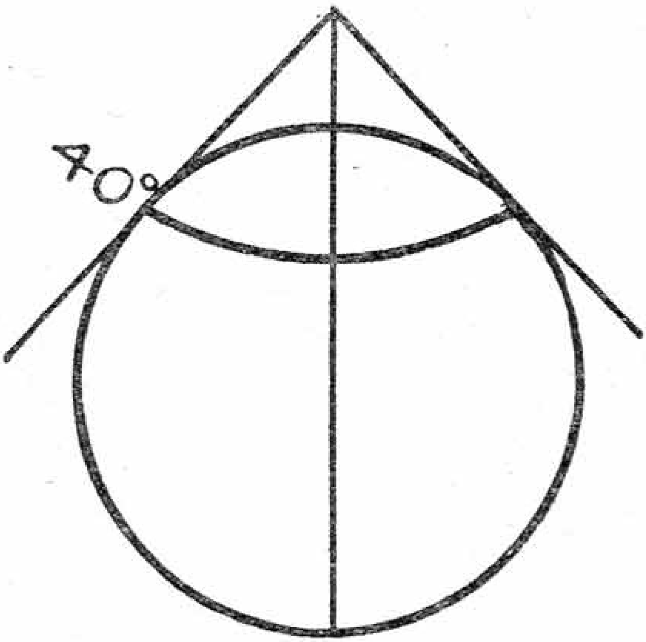
The earth is projected, so to speak, upon a chart in three different ways - the Mercator Projection, the Polyconic Projection and the Gnomonic Projection.

The Mercator Projection

You already know something about the Mercator Projection and a Mercator chart. As explained before, it is constructed on the theory that the earth is a cylinder instead of a sphere. The meridians of longitude, therefore, run parallel instead of converging, and the parallels of latitude are lengthened out to correspond to the widening out of the Lo. meridians. Just how this Mercator chart is constructed is explained in detail in the Arts. in Bowditch you were given to read last night. You do not have to actually construct such a chart, as the Government has for sale blank Mercator charts for every parallel of latitude in which they can be used. It is well to remember, however, that since a mile or minute of latitude has a different value in every latitude, there is an appearance of distortion in every Mercator chart which covers any large extent of surface. For instance, an island near the pole, will be represented as being much larger than one of the same size near the equator, due to the different scale used to preserve the accurate character of the projection.

The Polyconic Projection

The theory of the Polyconic Projection is based upon conceiving the earth´s surface as a series of cones, each one having the parallel as its base and its vertex in the point where a tangent to the earth at that latitude intersects the earth´s axis. The degrees of latitude and longitude on this chart are projected in their true length and the general distortion of the earth´s surface is less than in any other method of projection.



A straight line on the polyconic chart represents a near approach to a great circle, making a slightly different angle with each meridian of longitude as they converge toward the poles. The parallels of latitude are also shown as curved lines, this being apparent on all but large scale charts. The Polyconic Projection is especially adapted to surveying, but is also employed to some extent in charts of the U. S. Coast & Geodetic Survey.

Gnomonic Projection

The theory of this projection is to make a curved line appear and be a straight line on the chart, i.e., as though you were at the center of the earth and looking out toward the circumference. The Gnomonic Projection is of particular value in sailing long distance courses where following a curved line over the earth´s surface is the shortest distance between two points that are widely separated. This is called Great Circle Sailing and will be talked about in more detail later on. The point to remember here is that the Hydrographic Office prints Great Circle Sailing Charts covering all the navigable waters of the globe. Since all these charts are constructed on the Gnomonic Projection, it is only necessary to join any two points by a straight line to get the *curved* line or great circle track which your ship is to follow. The courses to sail and the distance between each course are easily ascertained from the information on the chart. This is the way it is done:

(Note to Instructor: Provide yourself with a chart and explain from the chart explanation just how these courses are laid down.)

Spend the rest of the time in having pupils lay down courses on the different kinds of charts. If these charts are not available assign for night work the following articles in Bowditch, part of which reading can be done immediately in the class room - so that as much time as possible can be given to the reading on Dead Reckoning: 167-168-169-172-173-174-175-176 - first two sentences 178-202-203-204-205-206-207-208.

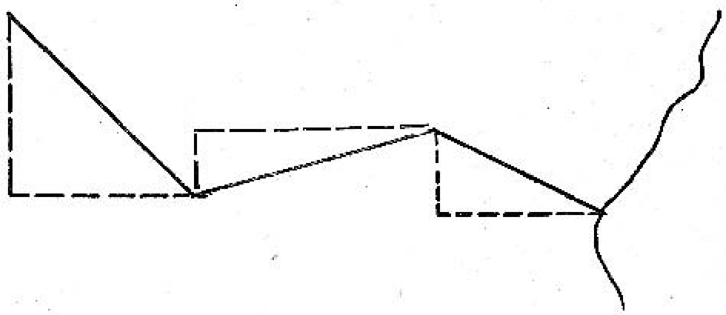
Note to pupils: In reading articles 167-178, disregard the formulæ and the examples worked out by logarithms. Just try to get a clear idea of the different sailings mentioned and the theory of Dead Reckoning in Arts. 202-209.

WEDNESDAY LECTURE

USEFUL TABLES—PLANE AND TRAVERSE SAILING

The whole subject of Navigation is divided into two parts, i.e., finding your position by what is called Dead Reckoning and finding your position by observation of celestial bodies such as the sun, stars, planets, etc.

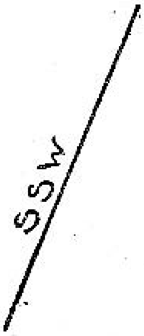
To find your position by dead reckoning, you go on the theory that small sections of the earth are flat. The whole affair then simply resolves itself into solving the length of right-angled triangles except, of course, when you are going due East and West or due North and South. For instance, any courses you sail like these will be the hypotenuses of a series of right-angled triangles. The problem you have to solve is, having left a point on land, the latitude and longitude of which you know, and sailed so many miles in a certain direction, in what latitude and longitude have you arrived?

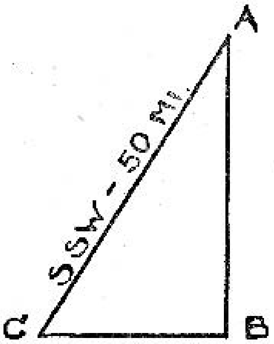


If you sail due North or South, the problem is merely one of arithmetic. Suppose your position at noon today is Latitude 39° 15' N, Longitude 40° W, and up to noon tomorrow you steam due North 300 miles. Now you have already learned that a minute of latitude is always equal to a nautical mile. Hence, you have sailed 300 minutes of latitude or 5°. This 5° is called difference of latitude, and as you are in North latitude and going North, the difference of latitude, 5°, should be added to the latitude left, making your new position 44° 15' N and your Longitude the same 40° W, since you have not changed your longitude at all.

In sailing East or West, however, your problem is more difficult. Only on the equator is a minute of longitude and a nautical mile of the same length. As the meridians of longitude converge toward the poles, the lengths between each lessen. We now have to rely on tables to tell us the number of miles in a degree of longitude at every distance North or South of the equator, i.e., in every latitude. Longitude, then, is reckoned in *miles*. The number of miles a ship makes East or West is called Departure, and it must be converted into degrees, minutes and seconds to find the difference of longitude.

A ship, however, seldom goes due North or South or due East or West. She usually steams a diagonal course. Suppose, for instance, a vessel in Latitude 40° 30' N, Longitude 70° 25' W, sails SSW 50 miles. What is the new latitude and longitude she arrives in? She sails a course like this:





Now suppose we draw a perpendicular line to represent a meridian of longitude and a horizontal one to represent a parallel of latitude. Then we have a right-angled triangle in which the line AC represents the course and distance sailed, and the angle at A is the angle of the course with a meridian of longitude. If we can ascertain the length of AB, or the distance South the ship has sailed, we shall have the difference of latitude, and if we can get the length of the line BC, we shall have the Departure and from it the difference of longitude. This is a simple problem in trigonometry, i.e., knowing the angle and the length of one side of a right triangle, what is the length of the other two sides? But you do not have to use trigonometry. The whole problem is worked out for you in Table 2 of Bowditch. Find the angle of the course SSW, i.e., S 22° W in the old or 202° in the new compass reading. Look down the distance column to the left for the distance sailed, i.e., 50 miles. Opposite this you find the difference of latitude 46-4/10 (46.4) and the departure 18-7/10 (18.7). Now the position we were in at the start was Lat. 40° 30' N, Longitude 70° 25' W. In sailing SSW 50 miles, we made a difference of latitude of 46' 24" (46.4), and as we went South - toward the equator - we should subtract this 46' 24" from our latitude left to give us our latitude in.

Now we must find our difference of longitude and from it the new or Longitude in. The first thing to do is to find the *average* or middle latitude in which you have been sailing. Do this by adding the latitude left and the latitude in and dividing by 2.

40° 30' 00"
39 43 36
——————
2) 80 13 36
——————
40° 06' 48" Mid. Lat.

Take the nearest degree, i.e., 40°, as your answer. With this 40° enter the same Table 2 and look for your departure, i.e., 18.7 in the *difference of latitude* column. 18.4 is the nearest to it. Now look to the left in the distance column opposite 18.4 and you will find 24, which means that in Lat. 40° a departure of 18.7 miles is equivalent to 24' of difference of Longitude. We were in 70° 25' West Longitude and we sailed South and West, so this difference of Longitude should be added to the Longitude left to get the Longitude in:

Lo. left	70° 25' W
Diff. Lo.	24
	————
Lo. in	70° 49' W

The whole problem therefore would look like this:

Lat. left N	40° 30'	Lo. left	70° 25' W
Diff. Lat.	46 24	Diff. Lo.	24
	————		————
Lat. in N	39° 43' 36"	Lo. in	70° 49' W

There is one more fact to explain. When the course is 45° or less (old compass reading) you read from the top of the page of Table 2 down. When the course is more than 45° (old compass reading) you read from the bottom of the page up. The distance is taken out in exactly the same way in both cases, but the difference of Latitude and the Departure, you will notice, are reversed. (Instructor: Read a few courses to thoroughly explain this.) From all this explanation we get the following rules, which put in your Note-Book:

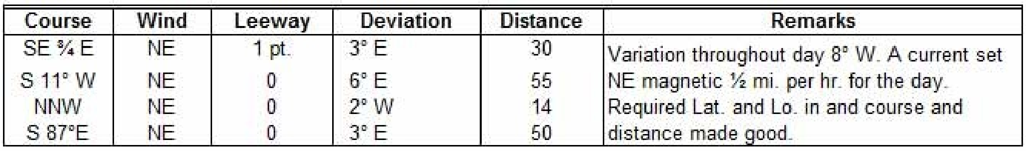
To find the new or Lat. in: Enter Table 2 with the true course at the top or bottom of the page according as to whether it is less or greater than 45° (old compass reading). Take out the difference of Latitude and Departure and mark the difference of Latitude minutes ('). When the Latitude left and the difference of Latitude are both North or both South, add them. When one is North and the other South, subtract the less from the greater and the remainder, named North or South after the greater, will be the new Latitude, known as the Latitude in.

To find the new or Lo. in: Find the middle latitude by adding the latitude left to the latitude in and dividing by 2. With this middle latitude, enter Table 2. Seek for the departure in the difference of latitude column. Opposite to it in the distance column will be the figures indicating the number of minutes in the difference of longitude. With this difference of Longitude, apply it in the same way to the Longitude left as you applied the difference of Latitude to the Latitude left. The result will be the new or Longitude in.

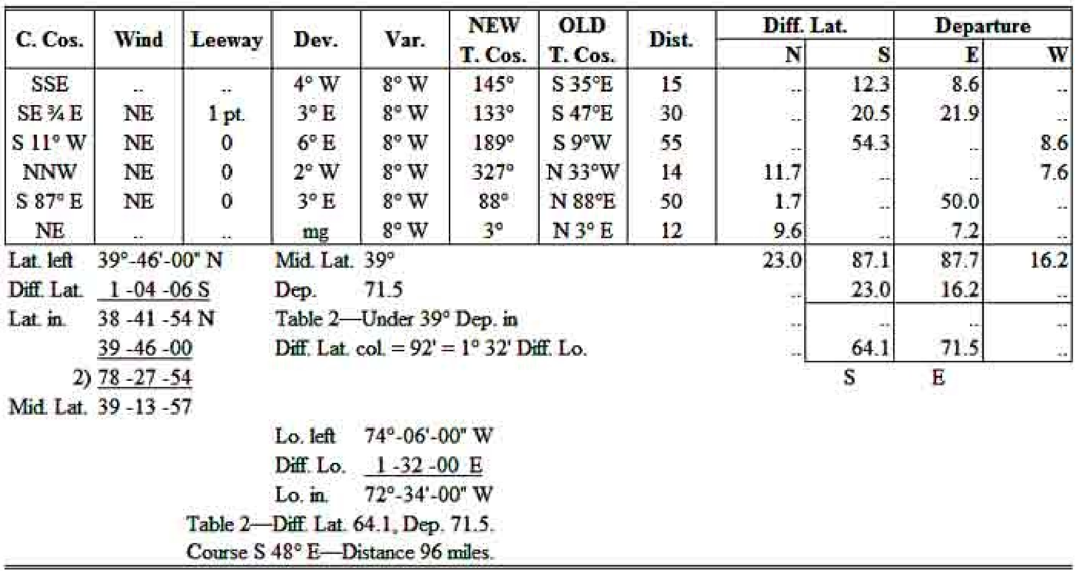
Now if a ship steamed a whole day on the same course, you would be able to get her Dead Reckoning position without any further work, but a ship does not usually sail the same course 24 hours straight. She usually changes her course several times, and as a ship's position by D.R. is only computed once a day - at noon - it becomes necessary to have a method of obtaining the result after several courses have been sailed. This is called working a traverse and sailing on various courses in this fashion is called Traverse Sailing.

Put in your Note-Book the following example and the way in which it is worked:

Departure taken from Barnegat Light in Lat. 39° 46' N, Lo. 74° 06' W, bearing by compass NNW, 15 knots away. Ship heading South with a Deviation of 4° W. She sailed on the following courses:



Course	Wind	Leeway	Deviation	Distance	Remarks
SE ¾ E	NE	1 pt.	3° E	30	Variation throughout day 8° W. A current set NE magnetic ½ mi. per hr. for the day. Required Lat. and Lo. in and course and distance made good.
S 11° W	NE	0	6° E	55	
NNW	NE	0	2° W	14	
S 87°E	NE	0	3° E	50	



C. Cos.	Wind	Leeway	Dev.	Var.	NEW T. Cos.	OLD T. Cos.	Dist.	Diff. Lat.		Departure	
								N	S	E	W
SSE	..	..	4° W	8° W	145°	S 35°E	15	..	12.3	8.6	..
SE ¾ E	NE	1 pt.	3° E	8° W	133°	S 47°E	30	..	20.5	21.9	..
S 11° W	NE	0	6° E	8° W	189°	S 9°W	55	..	54.3	..	8.6
NNW	NE	0	2° W	8° W	327°	N 33°W	14	11.7	..	..	7.6
S 87° E	NE	0	3° E	8° W	88°	N 88°E	50	1.7	..	50.0	..
NE	..	..	mg	8° W	3°	N 3° E	12	9.6	..	7.2	..
								23.0	87.1	87.7	16.2
								..	23.0	16.2	..
								..	..	..	..
								..	64.1	71.5	..
									S	E	

Lat. left 39°-46'-00" N
Diff. Lat. 1 -04 -06 S
Lat. in. 38 -41 -54 N
39 -46 -00
2) 78 -27 -54
Mid. Lat. 39 -13 -57

Mid. Lat. 39°
Dep. 71.5
Table 2—Under 39° Dep. in
Diff. Lat. col. = 92' = 1° 32' Diff. Lo.

Lo. left 74°-06'-00" W
Diff. Lo. 1 -32 -00 E
Lo. in. 72°-34'-00" W

Table 2—Diff. Lat. 64.1, Dep. 71.5.
Course S 48° E—Distance 96 miles.

The rule covering all these operations is as follows:

1. Write out the various courses with their corrections for Leeway, Deviation, Variation and the distance run on each.

2. In four adjoining columns headed N, S, E, W respectively, put down the Difference of Latitude and Departure for each course.

3. Add together all the northings, all the southings, all the eastings and all the westings. Subtract to find the difference between northings and southings and you will get the whole difference of Latitude. The difference between the eastings and westings will be the whole departure.

4. Find the latitude in, as already explained.

5. Find the Lo. in, as already explained.

6. With the whole difference of Latitude and whole Departure, seek in Table 2 for the page where the nearest agreement of Difference of Latitude and Departure can be found. The number of degrees at the top or bottom of the page (according as to whether the Diff. of Lat. or Dep. is greater) will give you the true course made good, and the number in the distance column opposite the proper Difference of Latitude and Departure will give you the distance made.

It is often convenient to use the reverse of the above method, i.e., being given the latitude and longitude of the position left and the latitude and longitude of the position arrived in, to find the course and distance between them by Middle Latitude Sailing. The full rule is as follows:

1. Find the algebraic difference between the latitudes and longitudes respectively.

2. Using the middle (or average) latitude as a course, find in Table 2 of Bowditch the Diff. of Lo. in the distance column. Opposite, in the Diff. of Lat. column, will be the correct Departure.

3. With the Diff. of Lat. between the position left and the position arrived in, and the Departure, just secured, seek in Table 2 for the page where the nearest agreement to these values can be found. On this page will be secured the true course and distance made, as explained in the preceding method.

4. Use this method only when steaming approximately an East and West course.

For an example of this method, see Bowditch, p. 77, example 3.

THURSDAY LECTURE

EXAMPLES ON PLANE AND TRAVERSE SAILING (*Continued*)

1. Departure taken from Cape Horn. Lat. 55° 58' 41" S, Lo. 67° 16' 15" W, bearing by compass SSW 20 knots. Ship heading SW x S, Deviation 4° E, steamed the following courses:

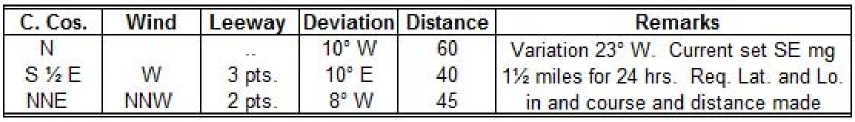
C. Cos	Wind	Leeway	Deviation	Distance
SW x S	SE	1 pt.	4° E	40
WNW	N	2 pts.	5° E	25
S 40° E	NE	2 pts.	4° W	20

Remarks

Variation 18° E throughout. Current set NW magnetic 30 mi. for the day. Required Latitude and

Longitude in and course and distance made good.

2. Departure taken from St. Agnes Lighthouse, Scilly Islands, Lat. 49° 53' S, Lo. 6° 20' W, bearing by compass E x S, distance 18 knots, Deviation 10° W, Variation 23° W. Ship headed N steamed on the following courses:



C. Cos.	Wind	Leeway	Deviation	Distance	Remarks
N		..	10° W	60	Variation 23° W. Current set SE mg 1½ miles for 24 hrs. Req. Lat. and Lo. in and course and distance made
S ½ E	W	3 pts.	10° E	40	
NNE	NNW	2 pts.	8° W	45	

Assign for Night Work the following articles in Bowditch: 179-180-181-182. Also additional problems in Dead Reckoning.

FRIDAY LECTURE

MERCATOR SAILING

This is a method to find the true course and distance between two points. The method can be used in two ways, i.e., by the use of Tables 2 and 3 (called the inspection method) and by the use of logarithms. The first method is the quicker and will do for short distances. The second method, however, is more accurate in all cases, and particularly where the distances are great. The inspection method is as follows (Put in your Note-Book):

Find the algebraic difference between the meridional parts corresponding to the Lat. in and Lat. sought by Table 3. Call this Meridional difference of Latitude. Find the algebraic difference between Longitude in and Longitude sought and call this difference of Longitude. With the Meridional difference of Latitude and the difference of Longitude, find the course by searching in Table 2 for the page where they stand opposite each other in the latitude and departure columns. Now find the real difference of latitude. Under the course just found and opposite the *real* difference of Latitude, will be found the distance sailed in the distance column. Example:

What is the course and distance from Lat. 40° 28' N, Lo. 73° 50' W, to Lat. 39° 51' N, Lo. 72° 45' W?

Lat. in	40° 28' N	Meridional pts.	2644.2
Lat. sought	39 51 N	Meridional pts.	2596.0
	0° 37'	Mer. diff. Lat.	48.2
Lo. in	73° 50' W		
Lo. sought	72 45 W		
	1° 05' = 65'		

On page 604 Bowditch you will find 48.7 and 64.7 opposite each other, and as 48.7 is in the Lat. column only when you read from the bottom, the course is S 53° E. The real difference of Lat. under this course is opposite 62 in the distance column. Hence the distance to be sailed is 62 miles.

If distances are too great, divide meridional difference of Lat., real difference of Latitude and difference of Longitude by 10 or any other number to bring them within the scope of the distances in Table 2. When distance to be sailed is found, it must be multiplied by the same number. For instance, if the difference of Lat., difference of Lo., etc., are divided by 10 to bring them in the scope of Table 2, and with these figures 219 is the distance found, the real distance would be 10 times 219 or 2190.

Now let us work out the same problem by logarithms. This will acquaint us with two new Tables, i.e., Tables 42 and 44. Put this in your Note-Book:

Lat. in	40° 28' N	Mer. pts.	2644.2	Lo. in	73° 50'
Lat. sought	39 51	Mer. pts.	2596.0	Lo. sought	72 45
Real diff.	0° 37'		48.2		1° 05'
					60
					60
					5
			(Table 42) log (+ 10)		65 = 11.81291
			Log 48.2		= 1.68305
			Log tan TC (Table 44)		10.12986

TC = S 53° 26' E
Log sec TC (53° 26') = 10.22493
Log real diff. Lat. = 1.56820 +
11.79313
- 10
1.79313
Distance (Table 42) = 62.11 miles

Find algebraically the real difference of latitude, meridional difference of latitude and the difference of longitude. Reduce real difference of latitude and difference of longitude to minutes. Take log of the difference of longitude (Table 42) and add 10. From this log subtract the log of difference of meridional parts. The result will be the log tan of the True Course, which find in Table 44. On the same page find the log sec of true course. Add to this the log of the real difference of latitude, and if the result is more than 10, subtract 10. This result will be the log of the distance sailed. This method should be used only when steaming approximately a North and South course.

Note. - For detailed explanation of Tables 42 and 44 see Bowditch, pp. 271-276.

Assign for Night Reading Arts, in Bowditch: 183-184-185-186-187-188-189-194-259-260-261-262-263-264-265-266-267-268.

Also, one of the examples of Mercator sailing to be done by both the Inspection and Logarithmic method.

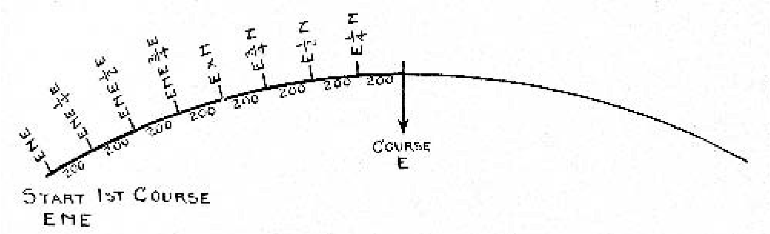
SATURDAY LECTURE

GREAT CIRCLE SAILING—THE CHRONOMETER

In Tuesday's Lecture of this week, I explained how a Great Circle track was laid down on one of the Great Circle Sailing Charts which are prepared by the Hydrographic Office.

Supposing, however, you do not have these charts on hand. There is an easy way to construct a great circle track yourself. Turn to Art. 194, page 82, in Bowditch. Here is a table with an explanation as to how to use it. Take, for instance, the same two points between which you just drew a line on the great circle track. Find the center of this line and the latitude of that point. At this point draw a line perpendicular to the course to be sailed, the other end of which must intersect the corresponding parallel of latitude given in the table. With this point as the center of a circle, sweep an arc which will intersect the point left and the point sought. This arc will be the great circle track to follow.

To find the courses to be sailed, get the difference between the course at starting and that at the middle of the circle, and find how many quarter points are contained in it. Now divide the distance from the starting point to the middle of the circle by the number of quarter points. That will give the number of miles to sail on each quarter point course. See this illustration:



Difference between ENE and E = 2 pts. = 8 quarter points. Say distance is 1600 miles measured by dividers or secured by Mercator Sailing Method. Divide 1600 by 8 = 200. Every 200 miles you should change your course ¼ point East.

The Chronometer

The chronometer is nothing more than a very finely regulated clock. With it we ascertain Greenwich Mean Time, i.e., the mean time at Greenwich Observatory, England. Just what the words "Greenwich Mean Time" signify, will be explained in more detail later on. What you should remember here is that practically every method of finding your exact position at sea is dependent upon knowing Greenwich Mean Time, and the only way to find it is by means of the chronometer.

It is essential to keep the chronometer as quiet as possible. For that reason, when you take an observation you will probably note the time by your watch. Just before taking the observation, you will compare your watch with the chronometer to notice the exact difference between the two. When you take your observation, note the watch time, apply the difference between the chronometer and watch, and the result will be the CT.

For instance, suppose the chronometer read 3h 25m 10s, and your watch, at the same instant, read 1h 10m 5s. C-W would be:

	3h	25m	10s
-	1	10	05
	2h	15m	05s

Now suppose you took an observation which, according to your watch, was at 2h 10m 05s. What would be the corresponding C T? It would be

WT	2h	10m	05s
C-W	2	15	05
CT	4h	25m	10s

If the chronometer time is less than the W T add 12 hours to the C T, so that it will always be the larger and so that the amount to be added to W T will always be +. For instance, CT 1h 25m 45s, WT 4h 13m 25s, what is the C-W?

CT	13h	25m	45s
WT	4	13	25
C-W	9h	12m	20s

Now, suppose an observation was taken at 6h 13m 25s according to watch time. What would be the corresponding CT?

WT	6h	13m	25s
C-W	9	12	20
	15h	25m	45s
	- 12		
CT	3h	25m	45s

Put in your Note-Book: CT = WT + C-W.

If, in finding C-W, C is less than W, add 12 hours to C, subtracting same after CT is secured.

Example No. 1:

CT	3h	25m	10s
WT	1	10	05
C-W	2h	15m	05s
WT	2h	10m	05s
+ C-W	2	15	05
CT	4h	25m	10s

Example No. 2:

	CT	1h	25m	45s
	WT	4h	13m	25s
(+12 hrs.)	CT	13h	25m	45s
	WT	4	13	25
	C-W	9h	12m	20s
	WT	6h	13m	25s
	+ C-W	9	12	20
		15h	25m	45s
(-12 hrs.)		12		
	CT	3h	25m	45s

There is one more very important fact to know about the chronometer. It is physically impossible to keep it absolutely accurate over a long period of time. Instead of continually fussing with its adjustment and hands, the daily rate of error is ascertained, and from this the exact time for any given day. It is an invariable practice among good mariners to *leave the chronometer alone*. When you are in port, you can find out from a time ball or from some chronometer maker what your error is. With this in mind, you can apply the new correction from day to day. Here is an example (Put in your Note-Book):

On June 1st, CT 7h 20m 15s, CC 2m 40s fast. On June 16th, (same CT) CC 1m 30s fast. What was the corresponding G.M.T. on June 10th?

June 1st 2m 40s fast
16th 1m 30s fast
——————————
1m 10s
60
—
60
10
—
15) 70s (4.6 sec. Daily Rate of error losing

June 1st-10th, 9 days times 4.6 sec. = 41 sec. losing

June 1st 2m 40s fast
June 10th 41s losing
————
June 10th 1m 59s fast
CT 7h 20m 15s
CC - 1 59
——————
G.M.T. 7h 18m 16s on June 10th

If CC is fast, subtract from CT
If CC is slow, add to CT

WEEK III—CELESTIAL NAVIGATION

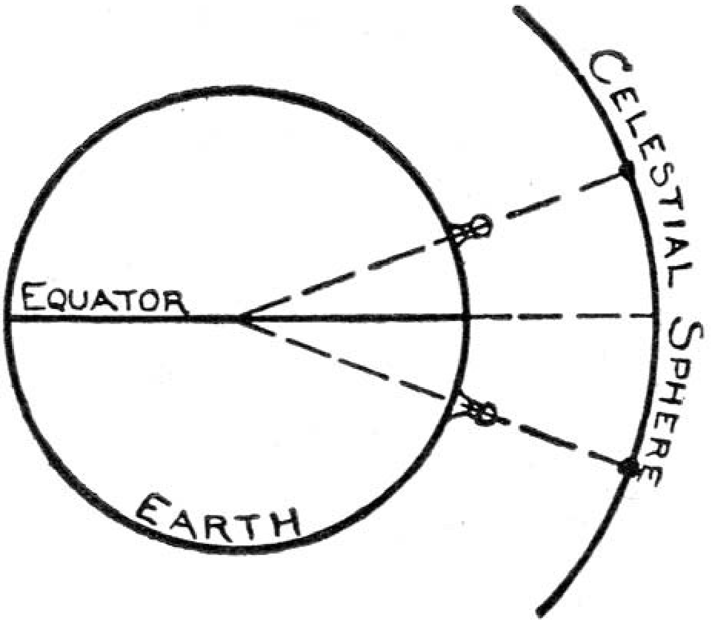
TUESDAY LECTURE

Celestial Co-ordinates, Equinoctial System, Etc.

We have already discussed the way in which the earth is divided so as to aid us in finding our position at sea, i.e., with an equator, parallels of latitude, meridians of longitude starting at the Greenwich meridian, etc. We now take up the way in which the celestial sphere is correspondingly divided and also simple explanations of some of the more important terms used in Celestial Navigation.

As you stand on any point of the earth and look up, the heavenly bodies appear as though they were situated upon the surface of a vast hollow sphere, of which your eye is the center. Of course this apparent concave vault has no existence and we cannot accurately measure the distance of the heavenly bodies from us or from each other. We can, however, measure the direction of some of these bodies and that information is of tremendous value to us in helping us to fix our position.

Now we could use our eye as the center of the celestial sphere but more accurate than that is to use the center of the earth. Suppose we do use the center of the earth as the place from which to observe these celestial bodies and, in imagination, transfer our eye there. Then we will find projected on the celestial sphere not only the heavenly bodies but the imaginary points and circles of the earth's surface. Parallels of latitude, meridians of longitude, the equator, etc., will have the same imaginary position on the celestial sphere that they have on the earth. Your actual position on the earth will be projected in a point called your zenith, i.e., the point directly overhead.



From this we get the definition that the Zenith of an observer on the earth's surface is the point in the celestial sphere directly overhead.

It would be a simple matter to fix your position if your position never changed. But it is always changing with relation to these celestial bodies. First, the earth is revolving on its own axis. Second, the earth is moving in an elliptic track around the sun, and third, certain celestial bodies themselves are moving in a track of their own. The changes produced by the daily rotation of the earth on its axis are different for observers at different points on the earth and, therefore, depend upon the latitude and longitude of the observer. But the changes arising from the earth's motion in its orbit and the motion of various celestial bodies in their orbits, are true no matter on what point of the earth you happen to be. These changes, therefore, in their relation to the center of the earth, may be accurately gauged at any instant. To this end the facts necessary for any calculation have been collected and are available in the Nautical Almanac, which we will take up in more detail later.

Now with these facts in mind, let us explain in simple words the meaning of some of the terms you will have to become acquainted with in Celestial Navigation.

In the illustration (Bowditch p. 88) the earth is supposed to be projected upon the celestial sphere N E S W. The Zenith of the observer is projected at Z and the pole of the earth which is above the horizon is projected at P. The other pole is not given.

The Celestial Equator is marked here E Q W and like all other points and lines previously mentioned, it is the projection of the Equator until it intersects the celestial sphere. Another name for the Celestial Equator is the Equinoctial.

All celestial meridians of longitude corresponding to longitude meridians on the earth are perpendicular to the equinoctial and likewise P S, the meridian of the observer, since it passes through the observer's zenith at Z, is formed by the extension of the earth's meridian of the observer and hence intersects the horizon at its N and S points. This makes clear again just what is the meridian of the observer. It is the meridian of longitude which passes through the N and S poles and the observer's zenith. In other words, when the sun or any other heavenly body is on your meridian, a line stretched due N and S, intersecting the N and S poles, will pass through your zenith and the center of the sun or other celestial body. To understand this is important, for no sight with the sextant is of value except with relation to your meridian.

The Declination of any point in the celestial sphere is its distance in arc, North or South of the celestial equator, i.e., N or S of the Equinoctial.

North declinations, i.e., declinations north of the equinoctial are always marked, +; those south of the equinoctial, -. For instance, in the Nautical Almanac, you will never see a declination of the sun or other celestial body marked, N 18° 28' 30". It will always be marked +18° 28' 30" and a south declination will be marked -18° 28' 30". Another fact to remember is that Declination on the celestial sphere corresponds to latitude on the earth. If, for instance, the Sun's declination is +18° 28' 30" at noon, Greenwich, then at that instant, i.e., noon at Greenwich, the sun will be directly overhead a point on earth which is in latitude N 18° 28' 30".

The Polar Distance of any point is its distance in arc from either pole. It must, therefore, equal 90° minus the declination, if measured from the pole of the same name as the declination or 90° plus the declination if measured from the pole of the opposite name.

P M is the polar distance of M from P, or P B the polar distance of B from P.

The true altitude of a celestial body is its angular height from the true horizon.

The zenith distance of any point or celestial body is its angular distance from the zenith of the observer.

The Ecliptic is the great circle representing the path in which the sun appears to move in the celestial sphere. As a matter of fact, you know that the earth moves around the sun, but as you observe the sun from some spot on the earth, it appears to move around the earth. This apparent track is called the Ecliptic as stated before, and in the illustration the Ecliptic is represented by the curved line, C V T. The plane of the Ecliptic is inclined to that of the Equinoctial at an angle of 23° 27½', and this inclination is called the obliquity of the Ecliptic.

The Equinoxes are those points at which the Ecliptic and Equinoctial intersect, and when the sun occupies either of these two positions, the days and nights are of equal length. The Vernal Equinox is that one which the sun passes through or intersects in going from S to N declination, and the Autumnal Equinox that which it passes through or intersects in going from N to S declination. The Vernal Equinox (V in the illustration) is also designated as the First Point of Aries which is of use in reckoning star time and will be mentioned in more detail later.

The Solstitial Points, or Solstices, are points of the Ecliptic at a distance of 90° from the Equinoxes, at which the sun attains its highest declination in each hemisphere. They are called the Summer and Winter Solstice according to the season in which the sun appears to pass these points in its path.

To sum up: The way to find any point on the earth is to find the distance of this point N or S of the equator (i.e., its Latitude) and its distance E or W of the meridian at Greenwich (i.e., its longitude). In the celestial sphere, the way to find the location of a point or celestial body such as the sun is to find its declination (i.e., distance in arc N or S of the equator) and its hour angle. By hour angle, I mean the distance in time from your meridian to the meridian of the point or celestial body in question.

Assign for Night reading, Arts, in Bowditch: 270-271-272-273-274-275-277-278-279-280-282-283-284.

WEDNESDAY LECTURE

TIME BY THE SUN—MEAN TIME, SOLAR TIME, CONVERSION, ETC.

There is nothing more important in all Navigation than the subject of Time. Every calculation for determining the position of your ship at sea must take into consideration some kind of time. Put in your Note-Book:

There are three kinds of time:

1. Apparent or solar time, i.e., time by the sun.

2. Mean Time, i.e., clock time.

3. Sidereal Time, or time by the stars.

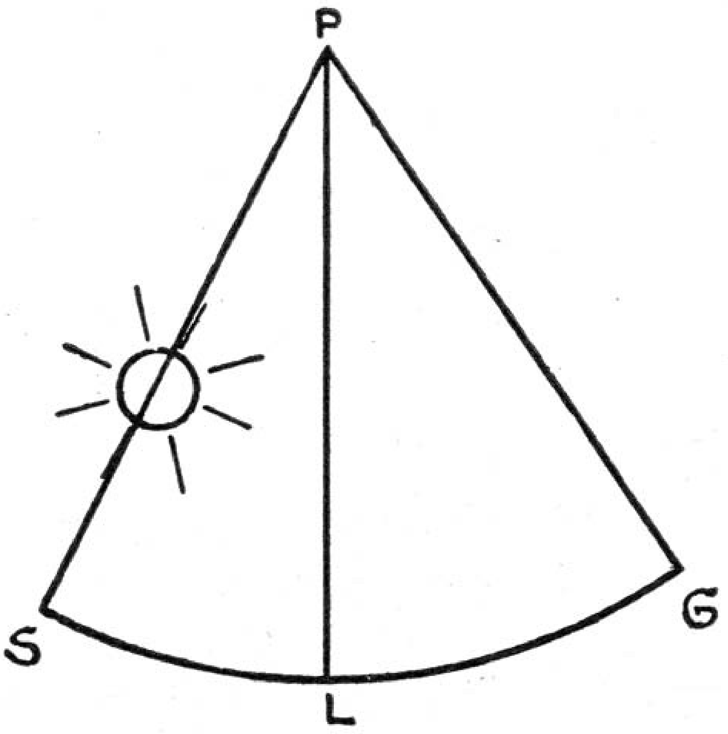
So far as this lecture is concerned, we will omit any mention of sidereal time, i.e., time by the stars. We will devote this morning to sun time, i.e., apparent time, and mean time.

Apparent or Solar Time is, as stated before, nothing more than sun time or time by the sun. The hour angle of the center of the sun is the measure of apparent or solar time. An apparent or solar day is the interval of time it takes for the earth to revolve completely around on its axis every 24 hours. It is apparent noon at the place where you are when the center of the sun is directly on your meridian, i.e., on the meridian of longitude which runs through the North and South poles and also intersects your zenith. This is the most natural and the most accurate measure of time for the navigator at sea and the unit of time adopted by the mariner is the apparent solar day. Apparent noon is the time when the latitude of your position can be most easily and most exactly determined and on the latitude by observation just secured we can get data which will be of great value to us for longitude sights taken later in the day.

Now it would be very easy for the mariner if he could measure apparent time directly so that his clock or other instrument would always tell him just what the sun time was. It is impossible, however, to do this because the earth does not revolve at a uniform rate of speed. Consequently the sun is sometimes a little ahead and sometimes a little behind any average time. You cannot manufacture a clock which will run that way because the hours of a clock must be all of exactly the same length and it must make noon at precisely 12 o'clock every day. Hence we distinguish clock time from sun time by calling clock time, mean (or average) time and sun time, apparent or solar time. From this explanation you are ready to understand such expressions as Local Mean Time, which, in untechnical language, signifies clock time at the place where you are; Greenwich Mean Time which signifies clock time at Greenwich; Local Apparent Time, which signifies sun time at the place where you are; Greenwich Apparent Time, which signifies sun time at Greenwich.

Now the difference between apparent time and mean time can be found for any minute of the day by reference to the Nautical Almanac which we will take up later in more detail. This difference is called the Equation of Time.

There is one more fact to remember in regard to apparent and mean time. It is the relation of the sun's hour angle to apparent time. In the first place, what is a definition of the sun's HA? It is the angle at the celestial pole between the meridian intersecting any given point and the meridian intersecting the center of the sun. It is measured by the arc of the celestial equator intersected between the meridian of any point and the meridian intersecting the center of the sun.



For instance, in the above diagram, suppose PG is the meridian at Greenwich, and PS the meridian intersecting the sun. Then the angle at the pole GPS, measured by the arc GS would be the Hour Angle of Greenwich, or the Greenwich Hour Angle. And now you notice that this angular measure is exactly the same as apparent time at Greenwich or Greenwich Apparent Time, for Greenwich Apparent Time is nothing more than the distance in time Greenwich, England, or the meridian at Greenwich is from the sun, i.e., the time it takes the earth to revolve from Greenwich to the sun; and that distance is exactly measured by the Greenwich Hour Angle or the arc on the celestial equator, GS.

The same is correspondingly true of Local Apparent Time and the ship's Hour Angle. Suppose, for instance, PL is the meridian intersecting the place where your ship is. Then your ship's hour angle would be the angle at the pole intersecting the meridian of your ship and the meridian of the sun or LPS and measured by the arc LS. And you will note that this distance is exactly the same as apparent time at the ship, for Apparent Time at ship is nothing more than the distance in time which the ship is from the sun. We can sum up all this information in a few simple rules, which put in your Note-Book:

Mean Time = Clock Time.

G.M.T. = Greenwich Mean Time.

L.M.T. = Local Mean Time.

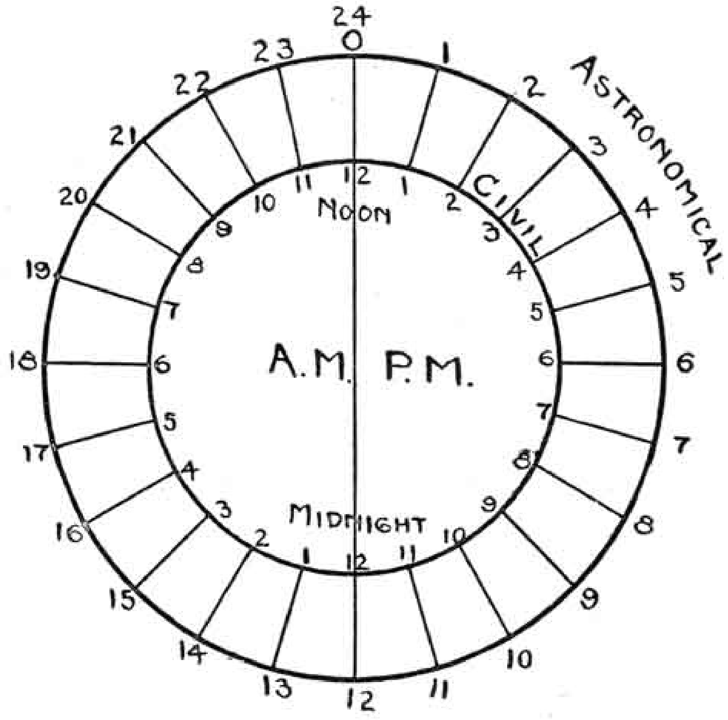
Apparent Time = Actual or Sun Time.

G.A.T. (G.H.A.) = Greenwich Apparent Time or Greenwich Hour Angle.

L.A.T. (S.H.A.) = Local Apparent Time or Ship's Hour Angle.

Difference between apparent and mean time or mean and apparent time - Equation of Time.

Right under this in your Note-Book put the following diagram, which I will explain:



You will see from this diagram that civil time commences at midnight and runs through 12 hours to noon. It then commences again and runs through 12 hours to midnight. The Civil Day, then, is from midnight to midnight, divided into two periods of 12 hours each.

The astronomical day commences at noon of the civil day of the same date. It comprises 24 hours, reckoned from O to 24, from noon of one day to noon of the next. Astronomical time, either apparent or mean, is the hour angle of the true or mean sun respectively, measured to the westward throughout its entire daily circuit.

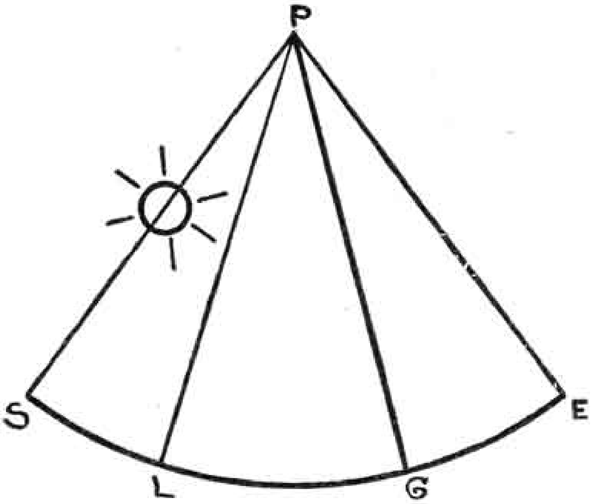
Since the civil day begins 12 hours before the astronomical day and ends 12 hours before it, A.M. of a new civil day is P.M. of the astronomical day preceding. For instance, 6 hours A.M., April 15th civil time is equivalent to 18 hours April 14th, astronomical time.

Now, all astronomical calculations in which time is a necessary fact to be known, must be expressed in astronomical time. As chronometers have their face marked only from 0 to 12 as in the case of an ordinary watch, it is necessary to transpose this watch or chronometer time into astronomical time. No transposing is necessary if the time is P.M., as you can see from the diagram that both civil and astronomical times up to 12 P.M. are the same. But in A.M. time, such transposing is necessary. Put in your Note-Book:

Whenever local or chronometer time is A.M., deduct 12 hours from such time to get the correct astronomical time:

CT 15d 9h 10m 30s A.M.
- 12
———————————————
CT 14d 21h 10m 30s
———
L.M.T. 10d 4h 40m 16s A.M.
- 12
———————————————
L.M.T. 9d 16h 40m 16s

Now we come to a very important application of time. You will remember that in one of the former lectures we stated that to find our latitude, we had to find how far North or South of the equator we were, and to find our longitude, we had to find how far East or West of the meridian at Greenwich we were. Never mind about latitude for the present. We can find our longitude exactly if we know our Greenwich time and our time at ship. For instance, in the accompanying diagram:



Suppose PG is the meridian at Greenwich, then anything to the west of PG is West longitude and anything to the East of PG is East longitude. Now suppose GPS is the H.A. of G. or G.A.T. - i.e., the distance in time G. is from the sun. And L P S is the H.A. of the ship or L.A.T. - i.e., the distance in time the ship is from the sun. Then the difference between G P S and L P S is G P L, measured by the arc L G, and that is the difference that the ship, represented by its meridian PL, is from the Greenwich meridian PG. In other words, that is the ship's longitude for, as mentioned before, longitude is the distance East or West of Greenwich that any point is, measured on the arc of the celestial equator. The longitude is West, for you can see LPG or the arc LG is west of the meridian PG.

Likewise if P E is the meridian of your ship, the Longitude in time is the S.H.A. or L.A.T., E P S (the distance your ship is from the sun) less the G.H.A. or G.A.T., G P S (the distance Greenwich is from the sun) which is the angle G P E measured by the arc G E. And this Longitude is East for you can see G P E, measured by G E, is east of the Greenwich meridian, P G.

In both these cases, however, the longitude is expressed in time, i.e., so many hours, minutes and seconds from the Greenwich meridian and we wish to express this distance in degrees, minutes and seconds of arc. The earth describes a circle of 360° every 24 hours. Then if you are 1 hour from Greenwich, you are 1/24 of 360° or 15° from Greenwich and if you are 12 hours from Greenwich, you are ½ of 360° or 180° from Greenwich. By keeping this in mind, you should be able to transpose time into degrees, minutes and seconds of arc for any fraction of time. It is, however, all worked out in Table 7 of Bowditch which turn to. (Note to Instructor: Explain this table carefully). Put in your Note-Book:

89° 24' 26" = (89°) 5h 56m
(24') 1m 36s
(26") 1 44/60s
——————————
5h 57m 37s 44/60s = 38s

4h 42m 26s
4h 40m = 70°
2m 24s = 36'
2s = 30"
—————
70° 36' 30"

Also put in your Note-Book this diagram and these formulas: (For diagram use illustration on p. 40.)

L.M.T. + West Lo. = G.M.T.	L.A.T. + West Lo. = G.A.T.
L.M.T. - East Lo. = G.M.T.	L.A.T. - East Lo. = G.A.T.
G.M.T. - West Lo. = L.M.T.	G.A.T. - West Lo. = L.A.T.
G.M.T. + East Lo. = L.M.T.	G.A.T. + East Lo. = L.A.T.

If G.M.T. or G.A.T. is greater than L.M.T. or L.A.T. respectively, Lo. is West.

If G.M.T. or G.A.T. is less than L.M.T. or L.A.T. respectively, Lo. is East.

Example:

In longitude 81° 15' W, L.M.T. is April 15d 10h 17m 30s A.M. What is G.M.T.?

L.M.T. 15d 10h 17m 30s A.M.
- 12
——————————

L.M.T. 14d 22h 17m 30s
5 25 W +
——————————
G.M.T. 15d 3h 42m 30s
————

G.M.T. April 15d 3h 42m 30s

L.M.T. April 15d 10h 17m 30s A.M.

In what Lo. is ship?

G.M.T. 15d 3h 42m 30s

L.M.T. 14d 22h 17m 30s
——————————

Lo. in T 5h 25m 00s W

Lo. = 81° 15'W

Assign also for Night Work reading the following articles in Bowditch: 276-278-279-226-228-286-287-288-290-291-294 (omitting everything on page 114.)

THURSDAY LECTURE

Sidereal Time—Right Ascension

Our last lecture was devoted to a discussion of sun time. Today we are going to talk about star time, or, using the more common words, sidereal time.

Now, just one word of review. You remember that we have learned that astronomical time is reckoned from noon of one day to noon of the next and hence the astronomical day corresponds to the 24 hours of a ship's run. The hours are counted from 0 to 24, so that 10 o'clock in the morning of October 25th is astronomically October 24th, 22 hours or 22 o'clock of October 24th.

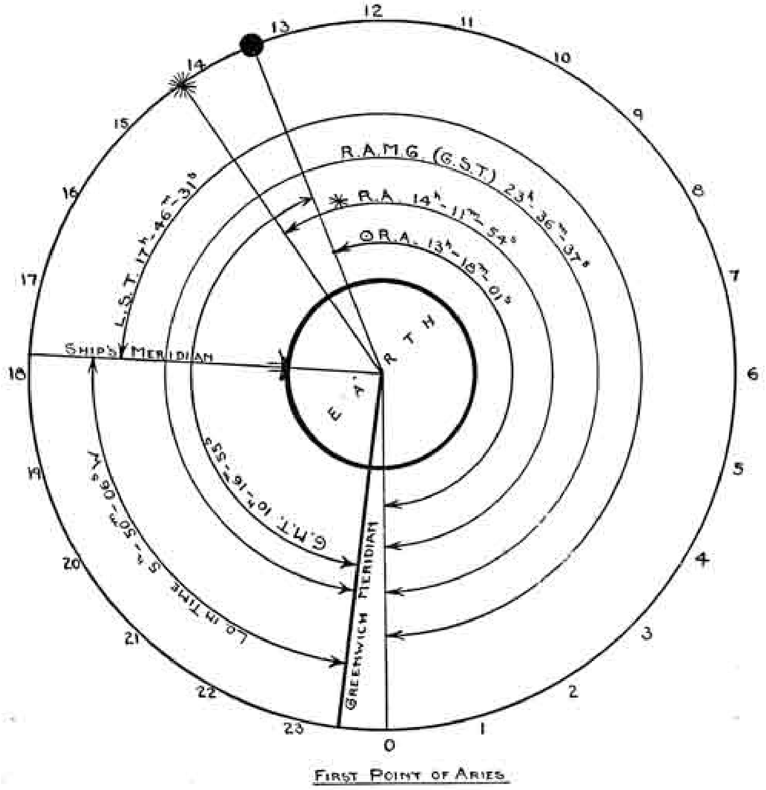
Now Right Ascension is different from both astronomical and civil time. Right Ascension is practically celestial longitude. For instance, the position of a place on the earth is fixed by its latitude and longitude; the position of a heavenly body is fixed by its declination and right ascension. But Right Ascension is not measured in degrees and minutes nor is it measured East and West. It is reckoned in hours and minutes all the way around the sky, eastward from a certain point, through the approximate 24 hours. The point from which this celestial longitude begins is not at Greenwich, but the point where the celestial equator intersects the ecliptic in the spring of the year, i.e., the point where the sun, coming North in the Spring, crosses the celestial equator. This point is called the First Point of Aries. You will frequently hear me speak of a star having, for instance, a Right Ascension of 5h 16m 32s. I mean by that, that starting at the celestial meridian, i.e., the meridian passing through the First Point of Aries, it will take a spot on the earth 5h 16m 32s to travel until it reaches the meridian of the star in question.

Roughly speaking then, just as Greenwich Apparent Time means the distance East or West the Greenwich meridian is from the sun and Local Apparent Time means the distance East or West your ship is from the sun, so R.A.M.G. means the distance in time the Meridian of Greenwich is from the First Point of Aries, measured eastward in a circle. And this distance is the same as Greenwich Sidereal Time, i.e., Sidereal Time at Greenwich or the distance in time the meridian of Greenwich is from the First Point of Aries.

Now, what is the star time that corresponds to local time? It is called the Right Ascension of the Meridian, which means the R. A. of the meridian which intersects your zenith. Just as L.A.T. is the distance in time your meridian is from the sun, so Local Sidereal Time is the R. A. of your meridian, i.e., the distance in time your meridian is from the First Point of Aries. Put in your Note-Book:

G.S.T. and R.A.M.G. are one and the same thing.
L.S.T. and R.A.M. are one and the same thing.
G.M.T. + ☉.R.A. + ⊕.C.P. = G.S.T. (R.A.M.G.) If the result is more than 24 hours, subtract 24 hours.
G.S.T. - ☉.R.A. - ⊕.C.P. = G.M.T.
G.S.T. - W.Lo. = L.S.T.
+ E.Lo.
L.S.T. + W.Lo. = G.S.T.
- E.Lo.

I can explain all these formulas very easily by the following illustration which put in your Note-Book: (Note to Instructor: If possible have copies of this illustration mimeographed and distributed to each student.)



There is one term I have used which does not appear in the illustration. It is the Earth's Central Progress (⊕.C.P.). The astronomical day based on the sun, is 24 hours long, as said before. The sidereal day, however, is only 23h 56m 04s long. This is due to the fact that whereas the earth is moving in its ecliptic track around the sun while revolving on its own axis, the First Point of Aries is a fixed point and hence never moves. The correction, then, for the difference in the length of time between a sidereal day and a mean solar day is called the Earth's Central Progress and, of course, has to be figured for all amounts of time after mean noon at Greenwich, since the Sun's Right Ascension tables in the Nautical Almanac are based on time at mean noon at Greenwich.

Now you have a formula for practically all kinds of conversion except for converting L.M.T. into L.S.T. You could do it by the formula

L.M.T. + W.Lo. = G.M.T. + ☉.R.A. + ⊕.C.P. = G.S.T. - W.Lo. = L.S.T.
- E.Lo. + E.Lo.

But that involves too many operations.

A shorter way, though not so simple perhaps, is as follows: L.M.T. + Reduction page 2 N.A. for time after local mean noon + ☉.R.A. of Greenwich mean noon ± Reduction page 2 N.A. for Lo. in T. (W+, E-) = L.S.T.

Note to Instructor:

Explain this formula by turning to page 107 N.A. and work it out by the formula L.M.T. + Lo. in T (W) = G.M.T. + ☉.R.A. + ⊕.C.P. = G.S.T. - Lo. in T (W) = L.S.T. Example:

L.M.T.	10h	40m	30s	
Lo. in T	4 +	56		W
	———	———	———	
G.M.T.	15	36	30	
☉.R.A.	5	11	10	
⊕.C.P.		2	34	
	———	———	———	
G.S.T.	20	50	14	
Lo. W	- 4	56		
	———	———	———	
L.S.T.	15h	54m	14s	

Now Bowditch gets this L.S.T. in still another way. Turn to page 110, Article 290. There the formula used is L.M.T. + ☉.R.A. + ⊕.C.P. = L.S.T, and in order to get the correct ☉.R.A. and ⊕.C.P. the G.M.T. has to be secured by the formula L.M.T. + W.Lo. = G.M.T.
- E.Lo.

Let us work this same example in Bowditch by the other two methods. First by the formula

L.M.T. + W.Lo. = G.M.T. + ☉.R.A. + ⊕.C.P.= G.S.T. - W.Lo. = L.S.T.
- E.Lo. + E.Lo.

L.M.T. 22d 2h 00m 00s
+ W. Lo. 5 25
————————
G.M.T. 22d 7h 25m 00s
☉.R.A. 1 57 59
⊕.C.P. 1 13
————————
G.S.T. 22d 9h 24m 12s
- W. Lo. 5 25
————————
L.S.T. 22d 3h 59m 12s

The small difference between this answer and that of Bowditch's is that the ☉.R.A. for 1916 is slightly different from that of 1919. Bowditch used the 1916 Almanac, whereas we are working from the 1919 Almanac. Now turn to page 107 of the N.A. and let us work the same example in Bowditch by the method used here:

L.M.T.	2h - 00m - 00s
Red. for 2h	0 - 20
☉.R.A. 0h	1 - 57 - 59
Red. Lo. 5h - 25m	0 - 53
	————————
L.S.T.	3h - 59m - 12s

The reason I am going so much into detail in explaining methods of finding L.S.T. is because, by a very simple calculation which will be explained later, we can get our latitude at night if we know the altitude of Polaris (The North Star) and if we know the L.S.T. at the time of observation. Some of you may think that the N.A. way is the simplest. It is given in the N.A., and in an examination it would be permissible for you to use the N.A. as a guide because, in an examination, I propose to let you have at hand the same books you would have in the chart house of a ship. On the other hand, the method given in the N.A. is not as clear to my mind as the method which starts with L.M.T., then finds with the Longitude the G.M.T. That gives you, roughly speaking, the distance in time Greenwich is from the sun. Add to that the sun's R.A. or the distance in time the sun is from the First Point of Aries at Greenwich Mean Noon. Add to that the correction for the time past noon. The result is G.S.T. Now all you have to do is to apply the longitude correctly to find the L.S.T., just as when you have G.M.T. and apply the longitude correctly you get L.M.T. That is a method which does not seem easy to forget, for it depends more upon simple reasoning where the others, for a beginner, depend more upon memory. However, any of the three methods is correct and can be used by you. Perhaps the best way is to work a problem by two of the three that seem easiest. In this way you can check your figures. When I give you a problem that involves finding the L.S.T. I do not care how you get the L.S.T. providing it is correct when you get it.

Assign for Night Reading in Bowditch the following Arts.: 282-283-284-285. Also the following questions:

1. Given the G.M.T. and the longitude in T which is W, what is the formula for L.S.T.?

2. Given the L.A.T. and longitude in T which is E, what is the formula for G.S.T.?

3. Given the L.S.T. and longitude in T which is W. Required G.M.T.

Etc.

FRIDAY LECTURE

THE NAUTICAL ALMANAC

For the last two days we have been discussing Time - sun time or solar time and star time or sidereal time. Now let us examine the Nautical Almanac to see how that time is registered and how we read the various kinds of time for any instant of the day or night. Before starting in, put a large cross on pages 4 and 5. For any calculations you are going to make, these pages are unnecessary and they are liable to lead to confusion.

Sun time of the mean sun at Greenwich is given for every minute of the day in the year 1919 in the pages from 6 to 30. This is indicated by the column to the left headed G.M.T. Turn to page 6 under Wednesday, Jan. 1st. You can see that the even hours are given from 0 to 24. Remember that these are expressed in astronomical time, so that if you had Jan. 2nd - 10 hours A.M., you would not look in the column under Jan. 2nd but under the column for Jan. 1st, 22 hours, since 10 A.M. Jan. 2nd is 22 o'clock Jan. 1st, and no reading is used in this Almanac except a reading expressed in astronomical time. Now at the bottom of the column under Jan. 1st you see the letters H.D. That stands for "hourly difference" and represents the amount to be added or subtracted for an odd hour from the nearest even hour. In this instance it is .2. You note that even hours 2, 4, 6, etc., are given. To find an odd hour during this astronomical day, subtract .2 from the preceding even hour. For any fraction of an hour you simply take the corresponding fraction of the H.D. and subtract it from the preceding even hour. For instance, the declination for Jan. 1st - 12 hours would be 23° 1.8' or 23° 1' 48", 13 hours would be 23° 1.6' or 23° 1' 36", 12½ hours would be 23° 1.7' or 23° 1' 42", and 13½ hours would be 23° 1.5' or 23° 1' 30".

Now to the right of the hours you note there is given the corresponding amount of Declination and the Equation of Time. Before going further, let us review a few facts about Declination. The declination of a celestial body is its angular distance N or S of the celestial equator or equinoctial. Now get clearly in your mind how we measure the angular distance from the celestial equator of any heavenly body. It is measured by the angle one of whose sides is an imaginary line drawn to the center of the earth and the other of whose sides is an imaginary line passing from the center of the earth into the celestial sphere through the center of the heavenly body whose declination you desire. Now as you stand on any part of the earth, you are standing at right angles to the earth itself. Hence if this imaginary line passed through you it would intersect the celestial sphere at your zenith, i.e., the point in the celestial sphere which is directly above you. Now suppose you happen to be standing at a certain point on the earth and suppose that point was in 15° N latitude. And suppose at noon the center of the sun was directly over you, i.e., the center of the sun and your zenith were one and the same point. Then the declination of the sun at that moment would be 15° N. In other words, your angular distance from the earth's equator (which is another way of expressing your latitude) would be precisely the same as the angular distance of the center of the sun from the celestial equator. Suppose you were standing directly on the equator and the center of the sun was directly over you, then the declination of the sun would be 0°. Now if the axis of the earth were always perpendicular to the plane of the sun's orbit, then the sun would always be immediately over the equator and the sun's declination would always be 0°. But you know that the axis of the earth is inclined to the plane of the sun's orbit. As the earth, then, revolves around the sun, the amount of the declination increases and then decreases according to the location of the earth at any one time with relation to the sun. On March 21st and Sept. 23rd, 1919, the sun is directly over the equator and the declination is 0°. From March 21st to June 21st the sun is coming North and the declination is increasing until on June 21st - 12 hours - it reaches its highest declination. From then on the sun starts to travel South, crosses the equator on Sept. 23d and reaches its highest declination in South latitude on Dec. 22nd, when it starts to come North again. This explains easily the length of days. When the sun is in North latitude, it is nearer our zenith, i.e., higher in the heavens. It can, therefore, be seen for a longer time during the 24 hours that it takes the earth to revolve on its axis. Hence, when the sun reaches its highest declination in North latitude - June 21st - i.e., when it is farthest North from the equator and nearest our zenith (which is in 40° N latitude) it can be seen for the longest length of time. In other words, that day is the longest of the year. For the same reason, Dec. 22nd, when the sun reaches its highest declination in South latitude, i.e., when it is farthest away to the South, is the shortest day in the year for us; for on that day, the sun being farthest away from our zenith and hence lowest down toward the horizon, can be seen for the shortest length of time.

Put in your Note-Book:

North Declination is expressed +.
South Declination is expressed - .

Now turn to page 6 of the Nautical Almanac. You will see opposite Jan. 1st 0h, a declination of - 23° 4.2'. Every calculation in this Almanac is based on time at Greenwich, i.e., G.M.T. So at 0h Jan. 1st at Greenwich - that is at noon - the Sun's declination is S 23° 4.2'.

You learned in the lecture the other day on solar time, that the difference between mean time and apparent time was called the equation of time. This equation of time, with the sign showing in which way it is to be applied, is given for any minute of any day in the column marked "Equation of Time." You will also notice that there is an H.D. for equations of time just as there is for each declination, and this H.D. should be used when finding the equation of time for an odd hour.

Put in your Note-Book:

1. The equation of time is to be applied as given in the Nautical Almanac when changing Mean Time into Apparent Time.

2. When changing Apparent Time into Mean Time, reverse the sign as given in the Nautical Almanac.

That is all there is to finding sun time, either mean or apparent, for any instant of any day in the year 1919. Do not forget, however, that all this data is based upon Greenwich Mean Time. To find Local Mean Time you must apply the Longitude you are in. To find Local Apparent Time you must first secure G.A.T. from G.M.T. and then apply the Longitude.

(Note to Instructor: Make the class work out conversions here if you have time to do so and can finish the rest of the lecture by the end of the period.)

So much for time by the sun. Now let us examine time by the stars - sidereal time. Turn to pages

2-3. There you find the Right Ascension of the Mean Sun at Greenwich Mean Noon for every day in the year. You remember that, roughly speaking, the Sun's Right Ascension was the distance in time the sun was from the First Point of Aries. So these tables give that distance (expressed in time) for noon at Greenwich of every day. For the correction to be applied for all time after noon at Greenwich (i.e., ⊕.C.P.), use the table at the bottom of the page. For instance, the ☉.R.A. at Greenwich 9h 24m on Jan. 1st would be

☉.R.A.	18h	40m	21s
⊕.C.P.		1	33
	———————		
	18h	41m	54s

Now we must go back to some of the formulas we learned when discussing star time and apply them with the information we now have from the Nautical Almanac. If the G.M.T. on April 20th is 4h 16m 30s, what is the G.S.T. for the same moment? That is, when Greenwich is 4h 16m 30s from the sun, how far is Greenwich from the First Point of Aries? You remember the formula was G.S.T. = G.M.T. + ☉.R.A. + ⊕.C.P.

G.M.T.	4h	16m	30s
☉.R.A.	1	50	6
⊕.C.P.		0	42
	———————		
G.S.T.	6h	07m	18s

Suppose you were in Lo. 74° W. What would be the R.A.M. (L.S.T.)? You remember the formula for L.S.T. from G.S.T. was the same relatively as L.M.T. from G.M.T., i.e., L.S.T. = G.S.T. - W. Lo.
+ E. Lo,

Here it would be

G.S.T.	6h	07m	18s
(74° W)	- 4	56	00
	—————————		
L.S.T.	1h	11m	18s

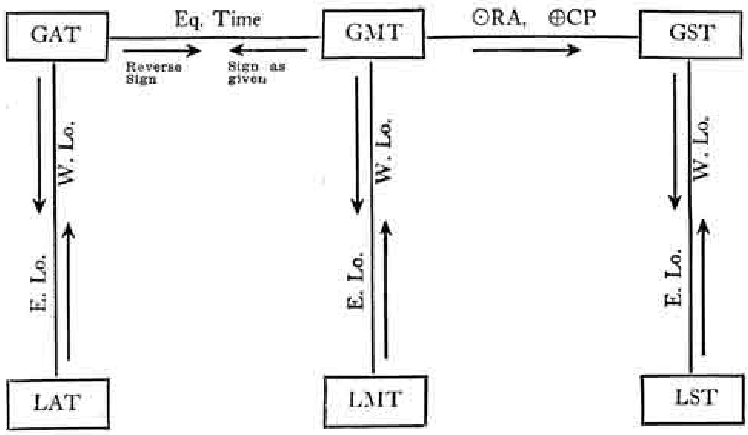
Now these are not a collection of abstruse formulas that you are learning just for the sake of practice. They are used every clear night on board ship, or should be, and are just as vital to know as time by the sun.

Suppose you are at sea in Lo. 70° W and your CT is October 20th 6h 4m 30s A.M., CC 2m 30s fast. You wish to get the R.A. of your M, i.e., the L.S.T. How would you go about it? The first thing to do would be to get your G.M.T. It is CT—CC.

	20d	06h	04m	30s A.M.
		- 12		
	———————————			
CT	19d	18h	04m	30s
CC			- 02	30
	———————————			
G.M.T.	19d	18h	02m	00s
Then get your G.S.T.				
Oct.	19d	18h	02m	00s
☉.R.A.		13	47	38.5
⊕.C.P.			2	57.7
	———————————			
	19d	31h	52m	36.2s
		- 24		
	———————————			
G.S.T.	19d	7h	52m	36.2s
Then get your L.S.T.				
G.S.T.		7h	52m	36.2s
W.Lo (-)		4	40	
	———————————			
L.S.T.		3h	12m	36.2s

The last fact to know at this time about the Almanac is found on pages 94-95. Here is given a list of the brighter stars with their positions respectively in the heavens, i.e., their celestial longitude or R.A. on page 94 and their celestial latitude or declination on page 95. These stars have very little apparent motion. They are practically fixed. Hence, their position in the heavens is almost the same from January to December though, of course, their position with relation to you is constantly changing, since you on the earth are constantly moving.

The relationship between these various kinds of time is clearly expressed by the following diagram, which put in your Note Book:



Going with arrow, add.
Going against arrow, subtract.

Assign for reading in Bowditch, Articles 294-295-296-297-299-300-301-302-303-304-305-306-307.

If any time is left, have the class work out such examples as these:

1. G.M.T. June 20th, 1919, 5h 14m 39s. In Lo. 68° 49' W. Required L.S.T., G.S.T., L.M.T., L.A.T.

2. L.M.T. Oct. 15th, 1919, 6h 30m 20s A.M. In Lo. 49° 35' 16" E. Required L.S.T.

3. L.M.T. May 14th, 1919, 10h 15m. 20s A.M. Lo. 56° 21' 39" W. Required L.A.T.

4. W.T. April 20th, 1919, 11h 30m 14s C-W 2h 14m 59s CC 4m 30s slow. In Lo. 89° 48' 30" W. Required G.M.T., G.A.T., L.M.T., L.A.T., G.S.T., L.S.T.

5. What is Declination and R.A. on May 15th, 1919, of Polaris, Arcturus, Capella, Regulus, Altair, Deneb, Vega, Aldebaran?

6. What is the sun's declination and R.A., Time at Greenwich, July 30th:

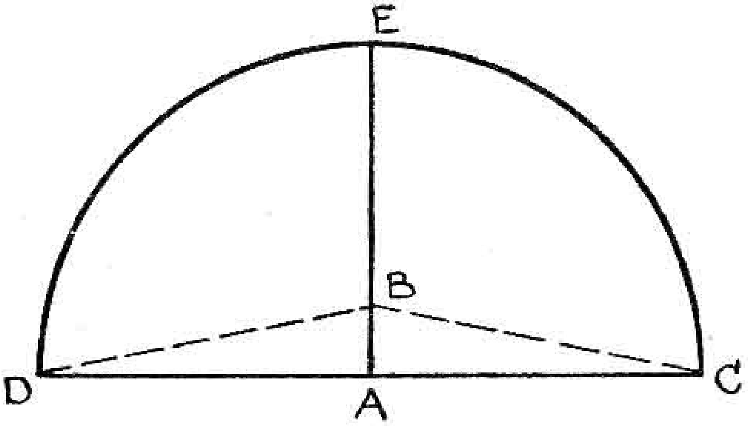
7h 14m 39s A.M.
4h 29m 14s A.M.
3h 04m 06s
11h 49m 59s
2h 14m 30s A.M.?

SATURDAY LECTURE

Correction Of Observed Altitudes

The true altitude of a heavenly body is the angular distance of its center as measured from the center of the earth. The observed altitude of a heavenly body as seen at sea by the sextant may be converted to the true altitude by the application of the following four corrections: Dip, Refraction, Parallax and Semi-diameter.

Dip of the horizon means an increase in the altitude caused by the elevation of the eye above the level of the sea. The following diagram illustrates this clearly:

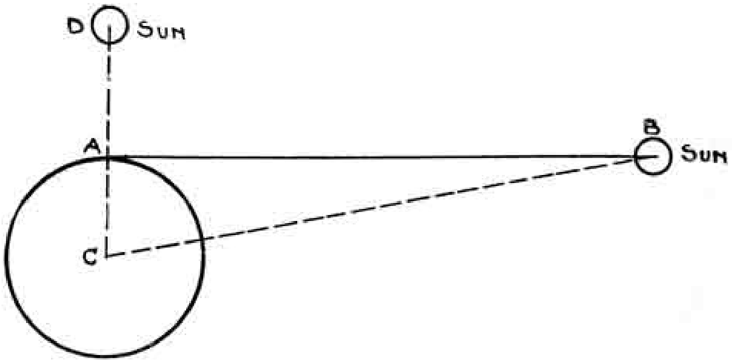


If the eye is on the level of the sea at A, it is in the plane of the horizon CD, and the angles EAC and EAD are right angles or 90° each. If the eye is elevated above A, say to B, it is plain that the angles EBC and EBD are greater than right angles, or in other words, that the observer sees more than a semi-circle of sky. Hence all measurements made by the sextant are too large. In other words, the elevation of the eye makes the angle too great and therefore the correction for dip is always subtracted.

Refraction is a curving of the rays of light caused by their entering the earth's atmosphere, which is a denser medium than the very light ether of the outer sky. The effect of refraction is seen when an oar is thrust into the water and looks as if it were bent. Refraction always causes a celestial object to appear higher than it really is. This refraction is greatest at the horizon and diminishes toward the zenith, where it disappears. Table 20A in Bowditch gives the correction for mean refraction. It is always subtracted from the altitude. In the higher altitudes, select the correction for the nearest degree.

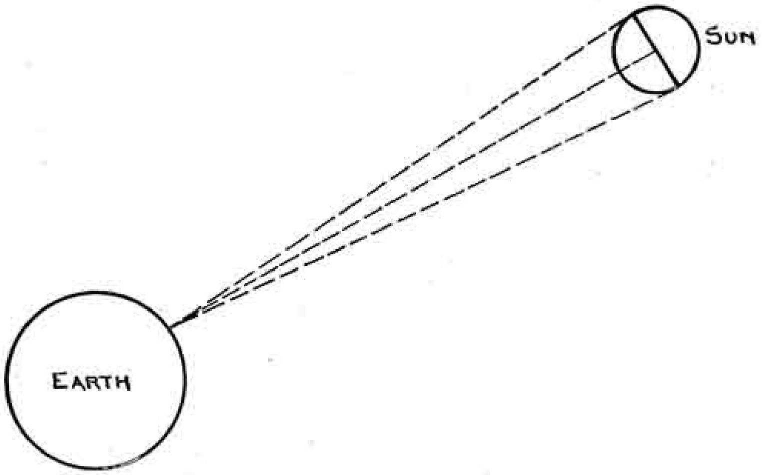
You should avoid taking low altitudes (15° or less) when the atmosphere is not perfectly clear. Haziness increases refraction.

Parallax is simply the difference in angular altitude of a heavenly body as measured from the center of the earth and as measured from the corresponding point on the surface of the earth. Parallax is greatest when the body is in the horizon, and disappears when it is at the zenith.



When the angular altitude of the sun in this diagram is 0, the parallax ABC is greatest. When the altitude is highest there is no parallax. The sun is so far away that its parallax never exceeds 9". The stars have practically none at all from the earth's surface. Parallax is always to be added in the case of the sun.

The semi-diameter of a heavenly body is half the angle subtended by the diameter of the visible disk at the eye of the observer. For the same body, the SD varies with the distance. Thus, the difference of the sun's SD at different times of the year is due to the change of the earth's distance from the sun.



The SD is to be added to the observed altitude in case the lower limb is brought in contact with the horizon, and subtracted if the upper limb is used. Probably most of the sights you take will be of the sun's lower limb, i.e., when the lower limb is brought in contact with the horizon, so all you need to remember is that in that event the SD is additive.

Now at first we will correct altitudes by applying each correction separately, but as soon as you get the idea, there is a short way to apply all four corrections at once. This is done in Table 46. However, disregard that for the moment. Put this in your Note-Book:

Dip is -.	Table 14 Bowditch
Refraction is -.	Table 20 Bowditch
Parallax is +.	Table 16 Bowditch
S.D. is +.	Nautical Almanac

Observed altitude of Sun's lower limb is expressed $\underline{\odot}$.

True altitude is expressed $-\!\ominus\!-$.

Remember that before an observation is at all accurate, it must be corrected to make it a true altitude. Remember also that the IE must be applied, in addition to these other corrections, in order to make the observed altitude a $-\!\ominus\!-$ altitude. So there are really five corrections to make instead of four, providing, of course, your sextant has an IE.

Examples:

1. June 20th, 1919, observed altitude of $\underline{\odot}$ 69° 25' 30". IE + 2' 30". HE 16 ft. Required $-\!\ominus\!-$.

2. April 15th, 1919, observed altitude of $\underline{\odot}$ 58° 29' 40". IE - 2' 30". HE 18 ft. Required $-\!\ominus\!-$.

3. March 4th, 1919, observed altitude of $\underline{\odot}$ 44° 44' 10". IE - 4' 20". HE 20 ft. Required $-\!\ominus\!-$.

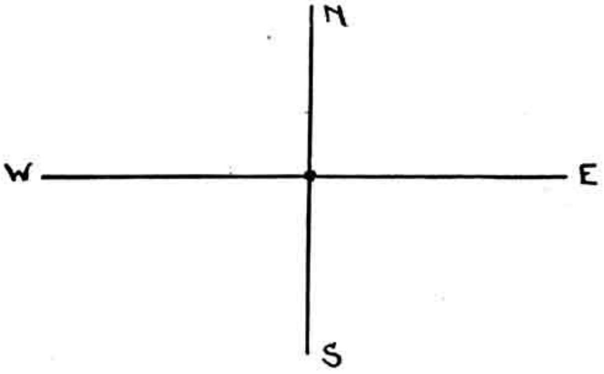
Etc.

WEEK IV—NAVIGATION

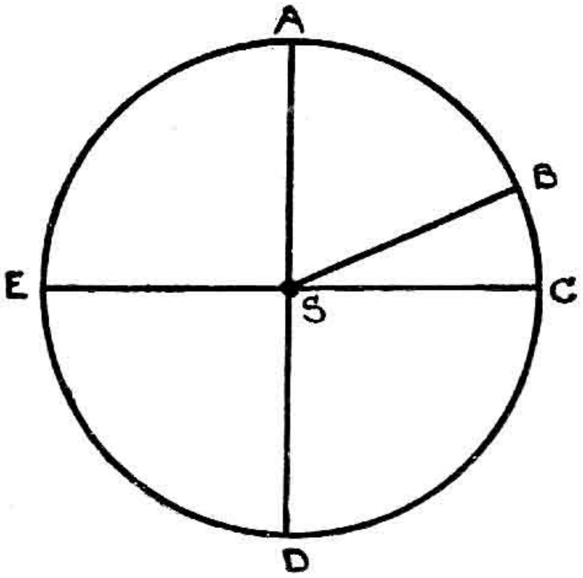
TUESDAY LECTURE

The Line Of Position

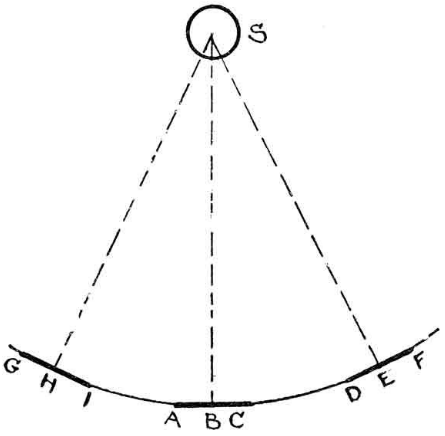
It is practically impossible to fix your position exactly by one observation of any celestial body. The most you can expect from one sight is to fix your line of position, i.e., the line somewhere along which you are. If, for instance, you can get a sight by sextant of the sun, you may be able to work out from this sight a very accurate calculation of what your latitude is. Say it is 50° N. You are practically certain, then, that you are somewhere in latitude 50° N, but just where you are you cannot tell until you get another sight for your longitude. Similarly, you may be able to fix your longitude, but not be able to fix your latitude until another sight is made. Celestial Navigation, then, reduces itself to securing lines of position and by manipulating these lines of position in a way to be described later, so that they intersect. If, for instance, you know you are on one line running North and South and on another line running East and West, the only spot where you *can* be on *both* lines is where they intersect. This diagram will make that clear:



Just what a line of position is will now be explained. Wherever the sun is, it must be perpendicularly above the same spot on the surface of the earth marked in the accompanying diagram by S



and suppose a circle be drawn around this spot as ABCDE. Then if a man at A takes an altitude, he will get precisely the same one as men at B, C, D, and E, because they are all at equal distances from the sun, and hence on the circumference of a circle whose center is S. Conversely, if several observers situated at different parts of the earth's surface take simultaneous altitudes, and these altitudes are all the same, then the observers must all be on the circumference of a circle and *only one* circle. If they are not on that circle, the altitude they take will be greater or less than the one in question.



Now such a circle on the surface of the earth would be very large - so large that a small arc of its circumference, say 25 or 30 miles, would be practically a straight line.

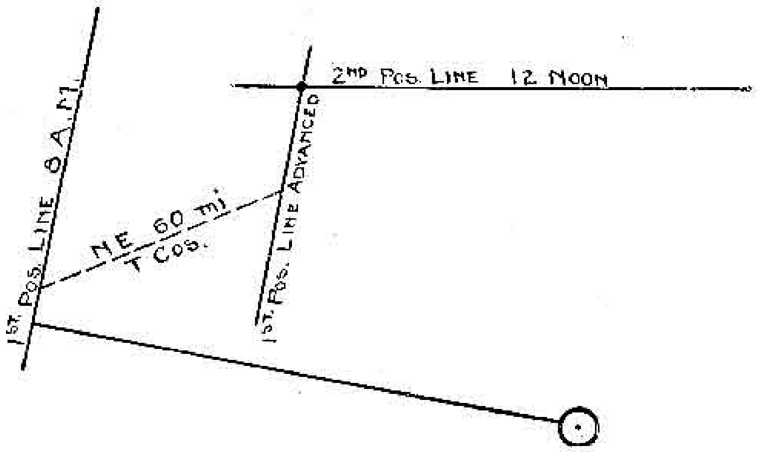
Suppose S to be the point over which the sun is vertical and GF part of the circumference of a circle drawn around the point. Suppose you were at B and from an altitude of the sun, taken by sextant, you worked out your position. You would find yourself on a little arc ABC which, for all purposes in Navigation, is a straight line at right angles to the true bearing of the sun from the point S. You can readily see this from the above diagram. Suppose your observer is at H. His line is GHI, which is again a straight line at right angles to the true bearing of the sun. He is not certain he is at H. He may be at G or I. He knows, however, he is somewhere on the line GHI, though where he is on that line he cannot tell exactly. That line GHI or ABC or DEF is the line of position and such a line is called a Sumner Line, after Capt. Thomas Sumner, who explained the theory some 45 years ago. Put in your Note-Book:

Any person taking an altitude of a celestial body must be, for all practical purposes, on a straight line which is at right angles to the true bearing of the body observed.

It should be perfectly clear now that if the sun bears due North or South of the observer, i.e., if the sun is on the observer's meridian, the resulting line of position *must* run due East and West. In other words it is a parallel of latitude. And that explains why a noon observation is the best of the day for getting your latitude accurately. Again, if the sun bears due East or West the line of position must bear due North and South. And that explains why a morning or afternoon sight - about 8-9 A.M. or 3-4 P.M., if the sun bears either East or West respectively, is the best time for determining your North and South line, or longitude.

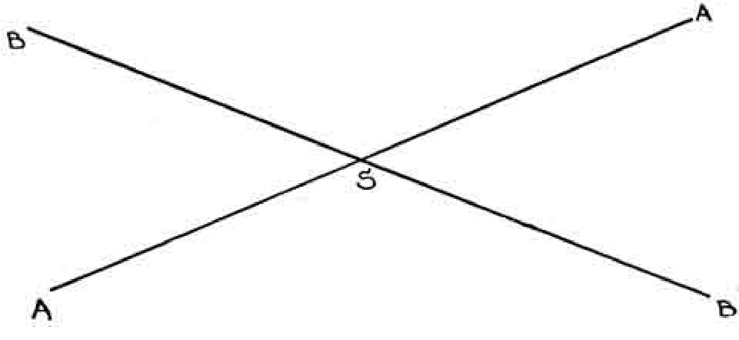
Now suppose you take an observation at 8 A.M. and you are not sure of your D.R. latitude. Your 8 A.M. position when the sun was nearly due East, will give, you an almost accurate North and South line and longitude. Suppose that from 8 A.M. to noon you sailed NE 60 miles. Suppose at noon you get another observation. That will give you an East and West line, for then the sun bears true North and South. An East and West line is your correct latitude. Now you have an 8 A.M. observation which is nearly correct for longitude and a noon position which is correct for latitude. How can you combine the two so as to get accurately both your latitude and longitude? Put in your Note-Book:

Through the 8 A.M. position, draw a line on the chart at right angles to the sun's true bearing. Suppose the sun bore true E ½ S. Then your line of position would run N ½ E. Mark it 1st Position Line.



Now draw a line running due East and West at right angles to the N-S noon bearing of the sun and mark this line Second Position Line. Advance your First Position Line the true course and distance sailed from 8 A.M. to noon, and through the extremity draw a third line exactly parallel to the first line of position. Where a third line (the First Position Line advanced) intersects the Second Position Line, will be your position at noon. It cannot be any other if your calculations are correct. You knew you were somewhere on your 8 A.M. line, you know you are somewhere on your noon line, and the only spot where you can be on both at once is the point where they intersect. You don't necessarily have to wait until noon to work two lines. You can do it at any time if a sufficient interval of time between sights is allowed. The whole matter simply resolves itself into getting your two lines of position, having them intersect and taking the point of intersection as the position of your ship.

There is one other way to get two lines to intersect and it is one of the best of all for fixing your position accurately. It is by getting lines of position by observation of two stars. If, for instance, you can get two stars, one East and the other West of you, you can take observations of both so closely together as to be practically simultaneous. Then your Easterly star would give you a line like AA' and the westerly star the line BB' and you would be at the intersection S.



Assign for reading: Articles in Bowditch 321-322-323-324. Spend the rest of the period in getting times from the N. A., getting true altitudes from observed altitudes, working examples in Mercator sailing, etc.

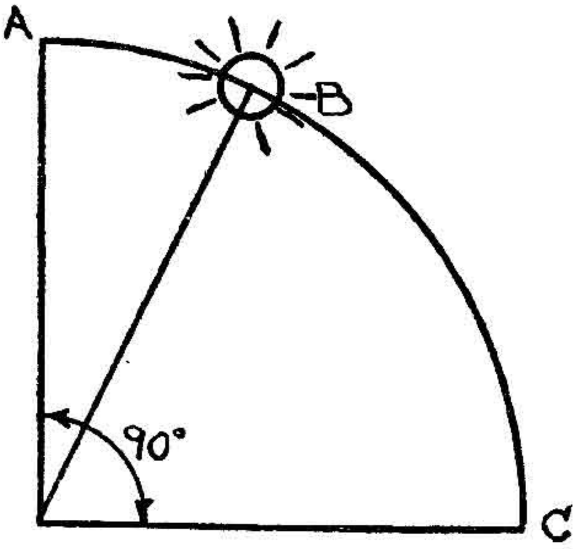
WEDNESDAY LECTURE

LATITUDE BY MERIDIAN ALTITUDE

A meridian altitude is an altitude taken when the sun or other celestial body observed bears true South or North of the observer or directly overhead. In other words, when the celestial body is on your meridian and you take an altitude of the body by sextant at that instant, the altitude you get is called a meridian altitude. In the case of the sun, such a meridian altitude is at apparent noon. Now latitude is always secured most accurately at noon by means of your meridian altitude. The reason for this was explained in yesterday's lecture. The general formula for latitude by meridian altitude is (Put in your Note-Book):

Latitude by meridian altitude = Zenith Distance (ZD) ± Declination (Dec).

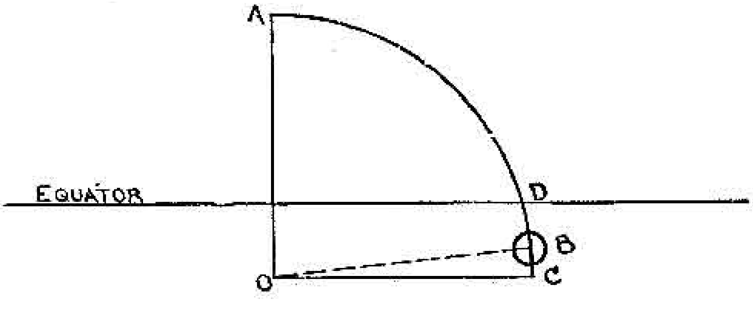
Zenith distance is the distance in degrees, minutes and seconds from your zenith to the center of the observed body. For simplicity's sake, we will consider the sun only as the observed body. Then the zenith distance is the distance from your zenith to the center of the sun. Now suppose that you and the sun are both North of the equator and you are North of the sun. If you can determine exactly how far North you are of the sun and how far North the sun is of the equator, you will, by adding these two measurements together, know how far North of the equator you are, i.e., your latitude. As already explained, the declination of the sun is its distance in degrees, minutes and seconds from the equator and the exact amount of declination is, of course, corrected to the proper G.M.T. Your zenith distance is the distance in the celestial sphere you are from the sun. You know that it is 90° from your zenith to the horizon. Your zenith distance, therefore, is the difference between the true meridian altitude of the sun, obtained by your sextant, and 90°. Hence, having secured the true meridian altitude of the sun, you have only to subtract it from 90° to find your zenith distance, i.e., how far you are from the sun. This diagram will make the whole matter clear:



A = Zenith, B = Sun, C = Horizon.

The arc ABC measures 90°. That is the distance from your zenith to the horizon. Now if BC is the true meridian altitude of the sun at noon, 90°-BC or AB is your zenith distance. If BC measures by sextant 60°, AB measures 90°-60° or 30°. This 30° is your Zenith Distance. Now suppose that from the Nautical Almanac we find that the G.M.T. corresponding to the time at which we measured the meridian altitude of the sun shows the sun's declination to be 10° N. Well, if you are 30° North of the sun, and the sun is 10° North of the equator, you must be 40° North of the equator or in latitude 40° N. For that is all latitude is, namely, the distance in degrees, minutes and seconds you are due North or South of the equator. That is the first and simplest case.

Another case is when you are somewhere in North latitude and the sun's declination is South. Then the situation would, roughly, look like this:



BC = Altitude of the sun, AB = Zenith Distance and DB = Sun's Declination.

In this case, your distance North of the equator AD would be your zenith distance AB minus the sun's declination DB. This diagram is not strictly correct, for the observer's position on the earth 0 appears to be South of the equator instead of North of the equator. That is because the diagram is on a flat piece of paper instead of on a globe. So far as illustrating the Zenith Distance minus the Declination, however, the diagram is correct. The last case is where you are, say, 10° N of the sun (your zenith Distance is 10°) and the sun is in 20° S declination. In that case you would have to subtract your zenith distance from the sun's declination to get your latitude, for the sun's latitude (its declination) is greater than yours.

Now from these three cases we deduce the following directions, which put in your Note-Book:

Begin to measure the altitude of the sun shortly before noon. By bringing its image down to the horizon, you can detect when its altitude stops increasing and starts to decrease. At that instant the sun is on your meridian, it is noon at the ship, and the angle you read from your sextant is the meridian altitude of the sun. To work out your latitude, name the meridian altitude S if the sun is south of you and N if north of you.

Correct the observed altitude to a true altitude by Table 46. If the altitude is S, the Zenith Distance is N or vice versa. (Note to Instructor: If the sun is South of you, you are North of the sun and vice versa.)

Correct the declination for the proper G.M.T. as shown by chronometer (corrected). If zenith distance and declination are both North or both South, add them and the sum will be the latitude, N or S as indicated. If one is N, and the other S, subtract the less from the greater and the result will be the latitude in, named N or S after the greater. Example:

At sea June 15th, observed altitude of ☉ 71° 15´ S, IE - 47´, HE 25 ft. CT 3h 34m 15s P.M. Required latitude of ship.

☉ S	71° 15' 00	IE - 47'
Corr.	- 36 24	HE + 10 36
	———————	———
⦵ S	70° 38' 36"	Corr. - 36' 24"
	- 90 00 00	
	———————	
ZD N	19° 21' 24"	
Dec. N	23 17 15	(G.M.T. June 15 3h 34m 15s)
	———————	
Lat. N	42° 38' 39"	
	———————	

Assign for Night Work or to be worked in class room such examples as the following:

1. June 1st, 1919. ☉ 33° 50' 00" S. G.M.T. 8h 55m 44s. HE 20 ft. IE + 4' 3". Required latitude in at noon.

2. April 2nd, 1919. ☉ 12° 44' 30" N. CT was 2d 5h 14m 39s A.M., which was 1m 40s slow on March 1st (same CT) and 4m 29s fast on March 15th (same CT). IE - 2' 20". HE 22 ft. Required latitude in at noon.

Assign for Night Work reading also, the following Articles in Bowditch: 344 and 223.

THURSDAY LECTURE

Azimuths Of The Sun

This is a peculiar word to spell and pronounce but its definition is really very simple. Put in your Note-Book:

The azimuth of a heavenly body is the angle at the zenith of the observer formed by the observer's meridian and a line drawn to the center of the body observed. Azimuths are named from the latitude in and toward the E in the A.M. and from the latitude in and toward the W in the P.M.

All this definition means is that, no matter where you are in N latitude, for instance, if you face N, the azimuth of the sun will be the true bearing of the sun from you. The same holds true for moon, star or planet, but in this lecture we will say nothing of the star azimuths for, in some other respects, they are found somewhat differently from the sun azimuths. Put this in your Note-

Book:

To find an azimuth of the sun: Note the time of taking the azimuth by chronometer. Apply chronometer correction, if any, to get the G.M.T. Convert G.M.T. into G.A.T. by applying the equation of time. Convert G.A.T. into L.A.T. by applying the longitude in time. The result is L.A.T. or S.H.A. With the correct L.A.T., latitude and declination, enter the azimuth tables to get the sun's true bearing, i.e., its azimuth. Example:

March 15th, 1919. CT 10h 4m 32s. D.R. latitude 40° 10' N, longitude 74° W. Find the TZ.

G.M.T.	10h	04m	32s	
Eq. T.	-	09	10	
G.A.T.	9h	55m	22s	
G.A.T.	9h	55m	22s	
Lo. in T.	4	56	00	(W -)
L.A.T.	4h	59m	22s	

Latitude and Declination opp. name.

TZ = N 101° 30'W

We will take up later a further use of azimuths to find the error of your compass. Right now all you have to keep in mind is what an azimuth is and how you apply the formulas already given you to get the information necessary to enter the Azimuth Tables for the sun's true bearing at any time of the astronomical day when the sun can be seen. In consulting these tables it must be remembered that if your L.A.T. or S.H.A. is, astronomically, 20h (A.M.), you must subtract 12 hours in order to bring the time within the scope of these tables which are arranged from apparent six o'clock A.M. to noon and from apparent noon to 6 P.M. respectively.

We are taking up sun azimuths today in order to get a thorough understanding of them before beginning a discussion of the Marc St. Hilaire Method which we will have tomorrow. You must get clearly in your minds just what a line of position is and how it is found. Yesterday I tried to explain what a line of position was, i.e., a line at right angles to the sun's or other celestial body's true bearing - in other words, a line at right angles to the sun's or other celestial body's azimuth. Today I tried to show you how to find your azimuth from the azimuth tables for any hour of the day. Tomorrow we will start to use azimuths in working out sights for lines of position by the Marc St. Hilaire Method.

Note to Instructor: Spend the rest of the time in finding sun azimuths in the tables by working out such examples as these:

1. April 29th, 1919. D.R. latitude 40° 40' N, Longitude 74° 55' 14" W. CT 10h 14m 24s. CC 4m 30s slow. Find TZ.

2. May 15th, 1919. D.R. latitude 19° 20' S, Longitude 40° 15' 44" E. CT 10h 44m 55s A.M. CC 3m 10s fast. Find TZ.

Note to Instructor:

If possible, give more examples to find TZ and also some examples on latitude by meridian altitude.

Assign for Night Work reading the following Articles in Bowditch: 371-372-373-374-375. Also, examples to find TZ.

FRIDAY LECTURE

MARC ST. HILAIRE METHOD BY A SUN SIGHT

You have learned how to get your latitude by an observation at noon. By the Marc St. Hilaire Method, which we are to take up today, you will learn how to get a line of position, at any hour of the day. By having this line of position intersect your parallel of latitude, you will be able to establish the position of your ship, both as to its latitude and longitude.

Now you have already learned that in order to get your latitude accurately, you must wait until the sun is on your meridian, i.e., bears due North or South of you, and then you apply a certain formula to get your latitude. When the sun is on or near the prime vertical (i.e., due East or West) you might apply another set of rules, which you have not yet learned, to get your longitude. By the Marc St. Hilaire method, the same set of rules apply for getting a line of position at any time of the day, no matter what the position of the observed body in the heavens may be. Just one condition is necessary, and this condition is necessary in all calculations of this character, i.e., an accurate measurement of the observed body's altitude is essential.

What we do in working out the Marc St. Hilaire method, is to assume our Dead Reckoning position to be correct. With this D. R. position as a basis, we compute an altitude of the body observed. Now this altitude would be correct if our D. R. position were correct and vice versa. At the same time we measure by sextant the altitude of the celestial body observed, say, the sun. If the computed altitude and the actual observed altitude coincide, the D. R. position is correct. If they do not, the computed altitude must be corrected and the D. R. position corrected to coincide with the observed altitude. Just how this is done will be explained in a moment. Put in your Note-Book:

Formula for obtaining Line of Position by M. St. H. Method.

I. Three quantities must be known either from observation or from Dead Reckoning.

1. The S. H. A., marked "t."

Note: The method for finding S. H. A. (t) differs when the sun or star is used as follows:

(a) For the Sun:

Get G.M.T. from the corrected chronometer time. Apply the equation of time to find the G.A.T. Apply the D.R. Lo.

$\genfrac{}{}{0pt}{}{(-W)}{(+E)}$ and the result is L.A.T. or S.H.A. as required.

(b) For a Star:

(Note to pupils: Leave this blank to be filled in when we take up stars in more detail.)

2. The Latitude, marked "L."

3. The Declination of the observed body, marked "D."

II. Add together the log haversine of the S.H.A. (Table 45), the log cosine of the Lat. (Table 44), and the log cosine of the Dec. (Table 44) and call the sum S. S is a log haversine and must always be less than 10. If greater than 10, subtract 10 or 20 to bring it less than 10.

III. With the log haversine S enter table 45 in the adjacent parallel column, take out the corresponding Natural Haversine, which mark N_S.

IV. Find the algebraic difference of the Latitude and Declination, and from Table 45 take out the Natural Haversine of this algebraic difference angle. Mark it $N_{D\pm L}$

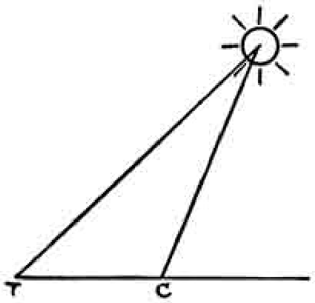
V. Add the N_S to the $N_{D\pm L}$, and the result will be the Natural Haversine of the calculated zenith distance. Formula $N_{ZD} = N_S + N_{D\pm L}$

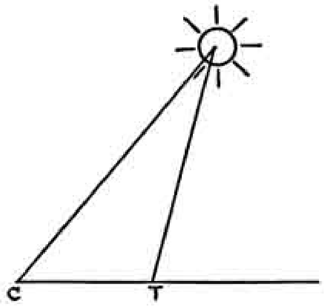
VI. Subtract this calculated zenith distance from 90° to get the calculated altitude.

VII. Find the difference between the calculated altitude and the true altitude and call it the altitude difference.

VIII. In your Azimuth Table, find the azimuth for the proper "t," L and D.

IX. Lay off the altitude difference along the azimuth either away from or toward the body observed, according as to whether the true altitude, observed by sextant, is less or greater than the calculated altitude.





X. Through the point thus reached, draw a line at right angles to the azimuth. This line will be your Line of Position, and the point thus reached, which may be read from the chart or obtained by use of Table 2 from the D. R. Position, is the nearest to the actual position of the observer which you can obtain by the use of any method from one sight only.

Example:

At sea, May 18th, 1919, A.M. $\underline{\odot}$ 29° 41' 00". D.R. Latitude 41° 30' N, Longitude 33° 38' 45" W. WT 7h 20m 45s A.M. C-W 2h 17m 06s CC + 4m 59s. IE - 30". HE 23 ft. Required Line of Position and most probable position of ship.

WT	18d	7h	20m	45s A.M.

WT	17d	19h	20m	45s		
C-W		2	17	06	Corr.	+ 9' 34"
					IE	- 30
CT	17d	21h	37m	51s		
CC +			4	59		+ 9' 04"
G.M.T.	17d	21h	42m	50s	⊙	29° 41' 00"
Eq. T. +			3	47		+ 9 04
G.A.T.	17d	21h	46m	37s	⊖	29° 50' 04"
Lo. in T	)	2	14	35 (W -		
					log hav	9.48368
L.A.T.(t)	17d	19h	32m	02s	log cos	9.87446
Lat.	41° 30' N				log cos	9.97473
Dec.	19° 21' 25" N					
					log hav S	9.33287
					N_S	.21521
L ~ D	22° 08' 35"				$N_{D \pm L}$	.03687
Calc. ZD	60° 16' 30"				N_{ZD}	.25208
	- 90° 00 00					
					TZ found from table to be N 90° E.	
Cal. Alt.	29° 43' 30"					
⊖	29° 50' 04"					
Alt. Diff	6' 34" Toward.					

Course.	*Dist.*	*Diff. Lat.*	*Dep.*	*Diff. Lo.*
90°	6' 34"	0	6.5	8.6

D.R. Lat.	41° 30' N	D.R. Lo.	33° 38' 45" W
Diff. Lat.	-	Diff. Lo.	8 36 E
Most probable fix Lat.	41° 30' N	Lo.	33° 30' 09" W

As azimuth is N 90° E, Line of Position runs due N & S (360°) through Lat. 41° 30' N. Lo. 33° 30' 09" W.

Assign for work in class and for Night Work examples such as the following:

1. July 11th, 1919. ⊙ 45° 35' 30", Lat. by D. R. 50° 00' N, Lo. 40° 04' W. HE 15 ft. IE - 4'. CT (corrected) 5h. 38m 00s P.M. Required Line of Position by Marc St. Hilaire Method and most probable fix of ship.

2. May 16th, 1919, A.M. ⊙ 64° 01' 15", D. R. Lat. 39° 45' N, Lo. 60° 29' W. HE 36 ft. IE + 2' 30". CT 2h 44m 19s. Required Line of Position by Marc St. Hilaire Method and most probable fix of ship.

Etc.

SATURDAY LECTURE

EXAMPLES ON MARC ST. HILAIRE METHOD BY A SUN SIGHT

1. Nov. 1st, 1919. A.M. at ship. WT 9h 40m 15s. C-W 4h 54m 00s. D. R. Lat. 40° 50' N, Lo. 73° 50' W. ⊙ 27° 59'. HE 14 ft. Required Line of Position by Marc St. Hilaire Method and most probable position of ship.

2. May 30th, 1919. P.M. at ship. D. R. Lat. 38º 14' 33" N, Lo. 15° 38' 49' W. The mean of a series of observations of ⊙ was 39° 05' 40°. IE - 01' 00". HE 27 ft. WT 3h 4m 49s. C-W 1h 39m 55s. C.C. fast, 01m 52s. Required Line of Position by Marc St. Hilaire Method, and most probable position of ship.

3. Oct. 21st, 1919, A.M. D. R. Lat. 40° 12' 38" N, Lo. 69° 48' 54" W. The mean of a series of

observations of ☉ was 19° 21' 20". IE + 02' 10". HE 26 ft. WT 7h 58m 49s. C-W 4h 51m 45s. C. slow, 03m 03s. Required Line of Position by Marc St. Hilaire Method and most probable position of ship.

4. June 1st, 1919, P.M. at ship. Lat. D. R. 35° 26' 15" S, Lo. 10° 19' 50" W. W.T. 3h 30m 00s. C-W 0h 20m 38s. CC 1m 16s slow. ☉ 16° 15' 40". IE + 2' 10". HE 26 ft. Required Line of Position and most probable fix of ship.

5. Jan. 5th, 1919. A.M. D. R. Lat. 36° 29' 38" N, Lo. 51° 07' 44" W. The mean of a series of observations of ☉ was 23° 17' 20". IE + 01' 50". HE 19 ft. WT 7h 11m 37s. C-W 5h 59m 49s. C. slow 58s. Required Line of Position and most probable fix of ship.

WEEK V—NAVIGATION

TUESDAY LECTURE

A Short Talk On The Planets And Stars

Identification Of Stars

1. The Planets

You should acquaint yourself with the names of the planets and their symbols. These can be found opposite Page 1 in the Nautical Almanac. All the planets differ greatly in size and in physical condition. Three of them - Mercury, Venus and Mars - are somewhat like the earth in size and in general characteristics. So far as we know, they are solid, cool bodies similar to the earth and like the earth, surrounded by atmospheres of cool vapors. The outer planets on the other hand, i.e., Jupiter, Saturn, Uranus, and Neptune, are tremendously large - many times the size of the earth, and resemble the sun more than the earth in their physical appearance and condition. They are globes of gases and vapors so hot as to be practically self luminous. They probably contain a small solid nucleus, but the greater part of them is nothing but an immense gaseous atmosphere filled with minute liquid particles and heated to an almost unbelievably high temperature.

Of the actual surface conditions on Venus and Mercury, little is definitely known. Mercury is a very difficult object to observe on account of its proximity to the sun. It is never visible at night; it must be examined in the twilight just before sunrise or just after sunset, or in the full daylight. In either case the glare of the sun renders the planet indistinct, and the heat of the sun disturbs our atmosphere so as to make accurate visibility almost impossible. The surface of Mercury is probably rough and irregular and much like the moon. Like the moon, too, it has practically no atmosphere. Mercury rotates on its axis once in 88 days. Its day and year are of the same length. Thus the planet always presents the same face toward the sun and on that side there is perpetual day while on the other side is night - unbroken and cold beyond all imagination.

Venus resembles the earth more nearly than any other heavenly body. Its diameter is within 120 miles of the earth's diameter. The exasperating fact about Venus, however, is that it is shrouded in deep banks of clouds and vapors which make it impossible for us to secure any definite facts about it. The atmosphere about Venus is so dense that sunlight is reflected from the upper surface of the clouds around the planet and so reaches our telescopes without having penetrated to the surface at all. From time to time markings have been discovered that at first seemed real but whether they are just clouds or tops of mountains has never really been established.

Of all the planets, we know more about Mars than any other. And yet practically nothing is actually known in regard to conditions on the surface of this planet. We do know, however, that Mars more nearly resembles a miniature of our earth than any other celestial body. The diameter of Mars is 4,210 miles - almost exactly half the earth's diameter. The surface area of Mars is just about equal to the total area of dry land on the earth. Like the earth, Mars rotates about an axis inclined to the plane of its orbit, and the length of a Martian day is very nearly equal to our own. The latest determinations give the length of a Martian solar day as 24h 39m 35s. Fortunately for us, Mars is surrounded by a very light and transparent atmosphere through which we are able to discover with our telescopes, many permanent facts.

The most noticeable of these are the dazzling white "polar caps" first identified by Sir William Herschel in 1784. During the long winter in the northern hemisphere, the cap at the North pole steadily increases in size, only to diminish during the next summer under the hot rays of the sun. These discoveries establish without doubt the presence of vapors in the Martian atmosphere which precipitate with cold and evaporate with heat. The polar caps, then, are some form of snow and ice or possible hoar frost. Outside the polar caps the surface of Mars is rough, uneven and of different colors. Some of the darker markings appear to be long, straight hollows. They are the so-called "canals" discovered by Schiaparelli in 1877. The term "canal" is an unfortunate one. The word implies the existence of water and the presence of beings of sufficient intelligence and mechanical ability to construct elaborate works. Flammarion in France and Lowell in the United States claim the word is correctly used, i.e., that these markings are really canals and that Mars is actually inhabited. The consensus of opinion among the most celebrated astronomers is contrary to this view. Most astronomers agree that these canals may not exist as drawn - that they are to great extent due to defective vision. There is no conclusive proof of man-made work on Mars, nor of the existence of conscious life of any kind. It may be there but conclusive proof of it is still lacking.

2. The Stars

The planets are often called wanderers in the sky because of their ever changing position. Sharply distinguished from them, therefore, are the "fixed" stars. These appear as mere points of light and always maintain the same relative positions in the heavens. Thousands of years ago the "Great Dipper" hung in the northern sky just as it will hang tonight and as it will hang for thousands of years to come. Yet these bodies are not actually fixed in space. In reality they are all in rapid motion, some moving one way and some another. It is their tremendous distance from us that makes this motion inappreciable. The sun seems far away from us, but the nearest star is 200,000 times as far away from us as is the sun. Expressed in miles, the figure is so huge as to be incomprehensible. A special unit has, therefore, been invented - a unit represented by the distance traversed by light in one year. In one second, light travels over 186,000 miles. In 8-1/3 minutes, light reaches us from the sun and, in doing so, covers the distance that would take the Vaterland over four centuries to travel. Yet the nearest star is over four "light years" distant - it is so far away that it requires over four years for its light to reach us. When you look at the stars tonight you see them, not as they are, but as they were, even centuries ago. Polaris, for instance, is distant some sixty "light years." Had it disappeared from the heavens at the time Lee surrendered to Grant, we should still be seeing it and entirely unaware of its disappearance.

Now each star in the heavens is in reality a sun, i.e., a vast globe of gas and vapor, intensely hot and in a continuous state of violent agitation, radiating forth heat and light, every pulsation of which is felt throughout the universe. So closely indeed do many of the stars resemble the sun, that the light which they emit cannot be distinguished from sunlight. Some of them are larger and hotter than the sun - some smaller and cooler. Yet the sun we see can be regarded as a typical star and from our knowledge of it we can form a fairly correct idea of the nature and characteristics of these other stars.

Anyone knows that the stars vary in brightness. Some of this variation is due partly to actual differences among the stars themselves and partly to varying distances. If all the stars were alike, then those which were farthest away would be faintest and we could judge a star's distance by its brilliancy. This is not the case, however. Some of the more brilliant stars are far more distant than some of the fainter ones. There are stars near and remote and an apparently faint star may in reality be larger and more brilliant than a star of the first magnitude. Vega, for instance, is infinitely farther away from us than the sun, yet its brightness is more than 50 times that of the sun. Polaris, still farther away, has 100 times the light and heat of the sun. In fact the sun, considered as a star, is relatively small and feeble.

3. Identification of Stars

Only the brighter stars can be used in navigation. So much light is lost in the double reflection in the mirrors of the sextant, that stars fainter than the third magnitude can seldom be observed. This reduces the number of stars available for navigation to within very narrow limits, for there are only 142 stars all told which are of the third magnitude or brighter. The Nautical Almanac gives a list of some 150 stars which may be used, but as a matter of fact, the list might be reduced to some 50 or 60 without serious detriment to the practical navigator. About 30 of these are of the second magnitude or greater and hence easily found. It is not difficult to learn to know 30 or 40 of the brighter stars, so that they can be recognized at any time. To aid in locating the stars, many different star charts and atlases have been published, but most of them are so elaborate that they confuse as much as they help. The simpler the chart, the fewer stars it pretends to locate, the better for practical purposes. Also, all charts are of necessity printed on a flat surface and such a surface can never represent in their true values, all parts of a sphere. A chart, therefore, which covers a large part of the heavens, is bound to give a distorted idea of distances or directions in some part of the sky and must be used with caution.

There are a few stars which form striking figures of one kind or another. These can always be easily located and form a starting point, so to speak, from which to begin a search for other stars. Of these groups the Great Dipper is the most prominent in the northern sky and beginning with this the other constellations can be located one by one.

When the groups or constellations are not known, then any individual star can be readily found by means of its Right Ascension, and Declination. As you have already learned, Declination is equivalent to latitude on the earth and Right Ascension practically equivalent to longitude on the earth, except that whereas longitude on the earth is measured E. and W. from Greenwich, Right Ascension is measured to the east all the way around the sky, from the First Point of Aries. With this in mind, you can easily see that if a star's R.A. is less than yours, i.e., less than L.S.T. or the R.A. of your Meridian, the star is not as far eastward in the heavens, as is your zenith. In other words it is to the west of you. And vice versa, if the Star's R.A. is greater than yours, the Star is more to the eastward than you and hence to the east of you. Moreover, as R.A. is reckoned all around a circle and in hours, each hour's difference between the Star's R.A. and yours is 1/24 of 360° or 15°. Hence if a star's R.A. is, for instance, 2 hours greater than yours, the star will be found to the east of your meridian and approximately 30° from your meridian, providing the star is in approximately the same vertical east and west plane as is your zenith.

When the general east or west direction of any star has been determined, its north or south position can at once be found from its declination. If you are in Latitude 40° N. your celestial horizon to the South will be 90° from 40° N. or 50° S. and to the North it will be 90° + 40° N. = 130° or 40° N. (below the N. pole). The general position of the equator in the sky is always readily found according to the latitude you are in. If you are in 40° N. latitude, the celestial equator would intersect the celestial sphere at a point 40° South of you. Knowing this, the angular distance of a star North or South of the equator (which is its declination) should be easily found. Remember, however, that the equator in the sky is a curved line and hence a star in the East or West which looks to be slightly North of you may actually be South of you.

Put in your Note-Book:

If the star is west of you its R.A. is less than yours. If east of you, its R.A. is greater than yours. Star will be found approximately 15° to east or west of you for each hourly difference between the star's R.A. and your R.A. (L.S.T.).

Having established the star's general east and west direction, its north and south position can be found from its declination.

4. Time of Meridian Passage of a Star

It is often invaluable to know first, when a certain star will be on your meridian or second, what star will be on your meridian at a certain specified time. Here is the formula for each case, which put in your Note Book:

1. To find when a certain star will cross your meridian, take from the Nautical Almanac, the R.A. of the Mean Sun for Greenwich Mean Noon of the proper astronomical day. Apply to it the correction for longitude in time (West +, East -) as per Table at bottom of page 2, Nautical Almanac, and the result will be the R.A. of the Mean Sun at local mean noon, i.e., the distance in sidereal time the mean sun is from the First Point of Aries when it is on your meridian. Subtract this from the star's R.A., i.e., the distance in sidereal time the star is from the First Point of Aries (adding 24 hours to the star's R.A., if necessary to make the subtraction possible). The result will be the distance in sidereal time the star is from your meridian i.e., the time interval from local mean noon expressed in units of sidereal time. Convert this sidereal time interval into a mean time interval by always subtracting the reduction for the proper number of hours, minutes and seconds as given in Table 8, Bowditch. The result will be the local mean time of the star's meridian passage.

Example:

April 22nd, 1919, A.M. at ship. In Lo. 75° E. What is the local mean time of the Star Etamin's meridian passage?

R.A.M.S. Gr. 21d 0h	1h 54m 02s
Red. for 75° E (- 5h)	- 49.3
	—————————
R.A.M.S. local mean noon	1h 53m 12.7s
Star's R.A.	17h 54m 44s
	- 1 53 12.7
	—————————
Sidereal interval from L.M. Noon	16h 01m 31.3s
Red. for Sid. Int. (Table 8)	- 2 37.3
	—————————
L.M.T. 21 d	15h 58m 54s

Hence, star will cross meridian at 3h 58m 54s A.M. April 22nd.

2. To find at any hour desired what star will cross your meridian, take the R.A. of the Mean Sun for Greenwich Mean Noon of the proper astronomical day. Apply to it the correction for longitude in time (West +, East -) as per table at bottom of page 2, Nautical Almanac, and the result will be the R.A. of the Mean Sun at local mean noon; i.e., the distance in sidereal time the mean sun is from the First Point of Aries when it is on your meridian. Suppose you wish to find the star at 10 P.M. Add 10 sidereal hours to the sun's R.A. just found. The result will be the R.A. of your meridian at approximately 10 P.M.

Select in the table on p. 94 the R.A. of the star nearest in time to your R.A. just secured. Subtract the R.A. of the Mean Sun at local mean noon from the star's R.A. just found on p. 94 of the N.A. and the result will be the exact distance in sidereal time the star you have just identified is from your meridian, i.e., the time interval from local mean noon expressed in units of sidereal time. Convert this sidereal time interval into a mean time interval by always subtracting for the proper number of hours, minutes and seconds as per Table 8, Bowditch. You will then have secured the name of the star desired and the exact local mean time of the star's meridian passage.

Example No. 2: At sea Dec. 14, 1919. Desired to get a star on my meridian at 11 P.M. Lo. by D.R. 74° W.

☉.R.A.G.M.N.	17h 28m 26s
Corr. 74° W. (4th - 56m W +)	+ 0 48.6
	——————————
☉.R.A. your M.	17h 29m 14.6s
	+ 11
	——————————
R.A.M.	28h 29m 14.6s
	- 24
	——————————
	4h 29m 14.6s

R.A. of Star Aldebaran	4h 31m 18.5s
Star R.A.	28h 31m 18.5
☉.R.A.your M.	17 29 14.6
	——————————
Sid. Int. from L.M. Noon	11h 02m 03.9s
Red for Sid. Int. (Table 8)	- 1 48
	——————————
L.M.T.	11h 00m 15.9s

Aldebaran, then, is the star and the exact L.M.T. of its meridian passage will be 11h 00m 15.9s

Note: If the R.A.M. is more than 24 hours, deduct 24 hours. You will know whether the star is North or South of you by its declination. If you are in North latitude, the star will be south of you if its declination is South or if its declination is North and less than your latitude. If its declination and your latitude are both North and its declination is greater, the star will be north of you. The same principle applies if you are in South latitude.

Assign any of the following to be worked in the class room or at night:

1. At sea, November 1st, 1919. In Latitude 40° N., Longitude 74° W. WT 8h 30m P.M. Observed unknown star about 80° east of my meridian and 25° south of me. What was the star?

2. At sea, December 1st, 1919. CT 10h 45m 01s. CC 20m 16s slow. In D.R. Latitude 30° N., Longitude 60° 30' W. Observed unknown star about 60° west of meridian and about 22° S. What was the star?

3. March 15th, 1919. In D.R. Latitude 10° 42' N, Longitude 150° 14' 28" W. CT 5h 14m 28s. CC - 2m 10s. Observed unknown star almost on my meridian and about 28° north of me. What was the star?

4. Aug. 3, 1919, P.M. at ship. In D.R. Latitude 37° 37' N. Longitude 38° 37' W. At what local mean time will the Star Antares be on the meridian?

5. What star will transit at about 4:10 A.M. on Aug. 3rd, 1919? In D.R. position Latitude 38° 10' N, Longitude 34° 38' W.

6. At what local mean time will the Star Arcturus transit on July 17th, 1919, in Latitude 45° 35' N., Longitude 28° 06' W.?

WEDNESDAY LECTURE

LATITUDE BY MERIDIAN ALTITUDE OF A STAR—LATITUDE BY POLARIS

(POLE OR NORTH STAR)

To find your latitude by taking an altitude of a star when it is on your meridian, is one of the quickest and easiest of calculations in all Navigation. The formula is exactly the same as for latitude by meridian altitude of the sun. In using a star, however, you do not have to consult your Nautical Almanac to get the G.M.T. and from that the declination. All you have to do is to turn to page 95 of the Nautical Almanac, on which is given the declination for every month of the year, of any star you desire. The rest of the computation is, as said before, the same as for latitude by the sun and follows the formula Lat. = Dec. ± Z.D. (90° - true altitude). As when working latitude by the sun, you subtract the Z.D. and Dec. when of opposite name and add them when of the same name. Put in your Note-Book:

Formula: Lat. = Dec. ± Z.D. (90° - true altitude).

At sea, Dec. 24th, 1919. Meridian altitude Star Aldebaran 52° 36' S. HE 20 ft. Required latitude of ship.

Obs. Alt.	52° 36' S
Corr.	- 5 08
	——————
True Alt.	52° 30' 52" S
	- 90 00 00
	——————
Z.D.	37° 29' 08" N
Dec.	16 21 00 N
	——————
Lat.	53° 50' 08" N

Note to Instructor:

Have class work examples such as the following before taking up Latitude by Pole Star:

1. At sea, May 5th, 1919. Meridian altitude Star Capella, 70° 29' S. HE 32 ft. Required latitude of ship.

2. At sea, August 14th, 1919. Meridian altitude Star Vega, 60° 15' 45" N. HE 28 ft. Required latitude of ship.

Etc.

Latitude by Polaris (*Pole or North Star*)

You remember we examined the formula in the N.A. for Lat. by the pole star when we were discussing sidereal time some weeks ago. We will now take up a practical case of securing your latitude by this method. Before doing so, however, it may be of benefit to understand how we can get our latitude by the pole star. In the first place, imagine that the Pole Star is directly over the N pole of the earth and is fixed. If that were so, and imagine for a minute that it is so, then it would be exactly 90° from the Pole Star to the celestial equator. Now, no matter where you stand, it is 90° from your zenith to your true horizon. Hence if you stood at the equator, your zenith would be in the celestial equator and your true horizon would exactly cut the Pole Star. Now, supposing you went 10° N of the equator. Then your northerly horizon would drop by 10° and the Pole Star would have an altitude of 10°. In other words, when you were in 10° N latitude, the pole star would measure 10° high by sextant. And so on up to 90°, where the Pole Star would be directly over you and you would be at the North Pole. Now all this is based upon the Pole Star being in the celestial sphere exactly over the North Pole of the earth. It is not, however. Owing to the revolution of the earth, the star appears to move in an orbit of a maximum of 1° 08'. Just what part of that 1° 08' is to be applied to the true altitude of the star for any time of the sidereal day, has been figured out in the table on page 107 of the Nautical Almanac. What you have to get first is the L.S.T. Find from the table the correction corresponding to the L.S.T. and apply this correction with the proper sign to the true altitude of Polaris. The result is the latitude in. Put in your Note-Book:

To get latitude by pole star, first get L.S.T. This can be secured by using any one of the three formulas given you in Week III - Thursday's Lecture on Sidereal Time and Right Ascension. Then proceed as per formula in N.A.

Note to Instructor:

Spend rest of time in solving examples similar to the following:

1. At sea, Feb. 14th, 1919. CT 13d 21h 52m 33s. CC 1m 14s fast. In Lo. 72° 49' 00" W. IE + 1' 10". HE 15 ft. Observed altitude Polaris 42° 21' 30" N. Required latitude in.

2. At sea, March 31st, 1919. In Lo. 160° 15' E. CT 7h 15m 19s. Observed altitude Polaris 38° 18' N. IE + 3' 00". HE 17 ft. Required latitude in.

Etc.

THURSDAY LECTURE

MARC ST. HILAIRE METHOD BY A STAR SIGHT

You have already been given instructions for finding a Line of Position by the Marc St. Hilaire

Method, using a sight of the sun. Today we will work out the same method by using a sight of a star. Put this in your Note-Book here and also under I(b) of the formula given you in Week IV - Friday's Lecture:

Get G.M.T. from corrected chronometer time. With your G.M.T. find the corresponding G.S.T. according to the formula already given you. With your G.S.T. apply the D.R. longitude

(- W. Lo.)
(+ L. Lo.)

to get the L.S.T. With the L.S.T. and the star's R.A. subtract the less from the greater and the result is the star's H.A. at the ship or "t." In using Sun Azimuth tables always take "t" from the P.M. column. Mark Azimuth N or S according to the lat. in and E or W, according as to whether the Star is East or West of your meridian. Then proceed as in the case of a sun sight. Formula:

G.M.T. + ⊙.R.A. + ⊕CP = G.S.T. (-W. Lo.) = L.S.T. - Star's R.A.
(+E. Lo.)

(or vice versa if Star's R.A. is greater) = Star's H.A. at ship (t). Then proceed as in case of sun sight.

Example:

On May 31st, 1919, in D.R. Lat. 50° N, Lo. 45° W, G.M.T. 31d 14h 33m 30s. What was Star's H.A. at ship?

G.M.T.	14h	33m	30s
.R.A.	4	31	44.2
.C.P.		2	23
G.S.T.	19h	07m	37.2s
W Lo. -	3	00	00
L.S.T.	16h	07m	37.2s
Star's R.A. (Spica)	13	20	59
Star's H.A. (t)	2h	46m	38.2s

Now let us work out some examples by this method:

1. Nov. 29th, 1919. CT 30d 2h 14m 39s A.M. CC 3m 14s fast. D.R. position Lat. 41° 14' N, Lo. 68° 46' W. Observed altitude Star Aldebaran East of meridian 50° 29' 40". HE 29 ft. Required Line of Position by Marc St. Hilaire Method and most probable position of ship.

2. Jan. 23rd, 1919. P.M. at ship. CT 3h 45m 40s. Lat. by D.R. 38° 44' 19" N. Lo. 121° 16' 14" E. Observed altitude Star Rigel 28° 59' 20" West of meridian. IE + 4' 30". HE 42 ft. Required Line of Position by Marc St. Hilaire Method and most probable position of ship.

Assign for Night Work one or two examples similar to the above.

FRIDAY LECTURE

EXAMPLES: LATITUDE BY MERIDIAN ALTITUDE OF A STAR, LATITUDE BY POLARIS, MARC ST. HILAIRE METHOD BY A STAR SIGHT

1. At sea, Dec. 5th, 1919. Observed meridian altitude Star Aldebaran 69° 28' 40" S. No IE. HE 26 ft. Required latitude in.

2. At sea, Jan. 20th, 1919. CT 21d 2h 16m 48s A.M. In longitude 56° 29' 46" W. Observed altitude of Star Polaris 48° 44' 30" N. IE + 10' 20". HE 37 ft. Required latitude in.

3. At sea, June 4th, 1919. A.M. at ship. CT 10h 16m 32s. CC 5m 45s fast. Lat. by D.R. 42° 44' N, Longitude 53° 13' 44" E. Observed altitude of Star Altair East of meridian, 52° 19' 30". IE - 14' 00". HE 56 ft. Required line of position by Marc St. Hilaire Method and most probable position of ship.

Etc.

Assign for Night Work the following Articles in Bowditch: 336 through 341, disregarding the formulas.

SATURDAY LECTURE

LONGITUDE BY CHRONOMETER SIGHT OF THE SUN (TIME SIGHT)

You have now learned, first, how to get your latitude by a meridian altitude of the sun or a star and second, how to get your Line of Position and most probable fix, including both latitude and longitude, by the Marc St. Hilaire Method, using for your calculations either the sun or a star. We are now going to take up a method of getting your longitude only. This method requires as much, if not more, calculation than the Marc St. Hilaire Method. Its results, on the other hand, are far less complete, for while the Marc St. Hilaire Method will give you a fairly accurate idea of both your latitude and longitude, this method will, at best, only give you your longitude. Moreover, you can use it for accurate results only when the sun bears almost due East or West of you, for that is the best time, as you have already learned, to get a line of position running due North and South, which is nothing more than a meridian of longitude. The only reason we explain this method at all is because it is in common practice among merchantmen and may, therefore, be of assistance to you, if you go on a merchant ship. Remember, however, that it belongs to Old Navigation as distinguished from New Navigation, exemplified by the Marc St. Hilaire Method. It is undoubtedly being used less and less among progressive, up-to-date navigators, and will continue to be used less as time goes on. The fact remains, however, that at present many merchantmen practice it, and so it will do you no harm to become familiar with the method, too.

This method is based on securing your longitude by a time sight or longitude by chronometer sight, meaning that at the time the sun bears as near due East or West as possible, you take a sight of it by sextant and at the same instant note the time by chronometer. With this information you proceed to work out your problem and secure your longitude according to the following formula. Put in your Note-Book:

To find your longitude by chronometer (or time) sight.

1. Take sight by sextant only when the sun bears as near as possible due East or West. At exact time of taking sight, note chronometer time.

2. Get G.M.T. from corrected chronometer time. Apply Equation of Time to get the corresponding G.A.T.

3. Correct observed altitude to get T.C.A. Also have at hand Lat. by D. R. and Polar Distance. (Note: Secure P. D. by subtracting Dec. from 90°, if Lat. and Dec. are of same name. If Lat. and Dec. are of opposite name, secure P. D. by adding Dec. to 90°.)

4. Add together the T.C.A. the Lat. by D.R. and the P.D. Divide the sum by 2 and call the quotient Half Sum. From the Half Sum subtract the T.C.A. and call the answer the Difference.

5. Add together the secant of the Latitude, the cosecant of the P.D., the cosine of the Half Sum and the sine of the Difference (Table 44). The result will be the log haversine of the S.H.A. or L.A.T. It must always be less than 10. If greater than 10, subtract 10 or 20 to bring it less than 10.

6. From Table 45, take out the corresponding S.H.A. (L.A.T.), reading from the top of the page if P.M. at ship, or from bottom of page if A.M. at the ship.

7. Find the difference between L.A.T. and G.A.T. This difference is Lo. in Time which turns into degrees, minutes and seconds by Table 7. If G.A.T. is greater than L.A.T. longitude is West; if G.A.T. is less than L.A.T. longitude is East. Example:

August 26th, 1919, A.M. CT 26d 2h 29m 03s A.M. CC 16m 08s slow. ☉ 44° 57' 00". IE - 1' 30". HE 32 ft. D.R. Lat. 4° 55' 32" N. Required longitude in at time of observation.

	26d	2h	29m	03s A.M.		
		- 12				
	————	————	————			
CT	25d	14h	29m	03s		- 90° 00' 00"
CC+			+16	08	Dec.	10 49 48
	————	————	————			————————
G. M. T.	25d	14h	45m	11s	P. D.	79° 10' 12"
Eq. T.			-2	05		
	————	————	————			
G. A. T.	25d	14h	43m	06s		- 1' 30"
						+ 9 27
☉				44° 57' 00"		————
Corr.				7 57	Corr.	+ 7' 57"

⊖	45° 04' 57"			
Lat.	4 55 32 N	sec.	.00160	
P. D.	79 10 12	cosec.	.00781	
2)	129° 10' 41"			
½ S	64° 35' 20"	cos.	9.63266	-9
⊖	45 04 57			
Diff.	19° 30' 23"	sin.	9.52350	-14
			9.16557	+5
log. hav. S.H.A. (L.A.T.)			9.16562	

S.H.A. (L.A.T.)	25d	21h	00m	01s
G.A.T.	25	14	43	06
Lo. in T.		6h	16m	55s E
Lo. (Table 7) 94° 13' 45" E				

I wish to caution you about confusing this method with the one Bowditch uses, and still another which Henderson uses in his book "Elements of Navigation." It is not exactly like either one. It requires one operation less than either, however, and it also requires the use of fewer parts of the various tables involved. For that reason it is given you.

Assign for work in class room and also for work at night examples similar to the following:

1. Oct. 1st, 1919. A.M. ☉ 17° 15' 00". G.M.T. 1d 11h 30m 00s A.M. D.R. Lat. 40° 30' N. IE - 2' 20". HE 25 ft. Required longitude in.

2. Oct. 10th, 1919. P.M. ☉ 25° 14' 30". CT 1h 15m 20s. CC 4m 39s slow. IE - 3' 10". HE 26 ft. D.R. Lat. 41° 29' 00" S. Required longitude in.

3. May 27, 1919. P.M. Lat. by D.R. 40° 55' N. ☉ 34° 4' 00". IE + 1' 10". HE 10 ft. CT 8h 55m 42s. CC 2m 02s fast. Required longitude in.

4. May 18th, 1919. A.M. ☉ 29° 41' 15". WT 7h 20m 45s. C-W 2h 17m 06s. CC 4m 59s slow. Latitude by D.R. 41° 33' N. IE - 1' 30". HE 23 ft. Required longitude in.

5. August 24th, 1919. A.M. ☉ 23° 32' 10". IE - 2'00". HE 16 ft. In latitude 39° 04' N. CT 24d 2h 47m 28s A.M. CC + 4m 28s. Required longitude in.

6. June 26th, 1919. P.M. ☉ 44° 08' 20". IE - 2' 20". HE 37 ft. CT 8h 18m 45s. CC 3m 20s fast. Latitude by D.R. 6° 43' S. Required longitude in.

7. July 29th, 1919. A.M. CT 29d 11h 14m 39s A.M. CC 2m 18s slow. ☉ 28° 08' 30". IE + 0' 30". HE 38 ft. Latitude by D.R. 39° 48' N. Required longitude in.

8. May 22nd, 1919. P.M. CT 9h 14m 38s. CC 5m 28s slow. ☉ 21° 07' 40". In latitude 41° 26' N. IE + 3' 10". HE 40 ft. Required longitude in.

WEEK VI—NAVIGATION

TUESDAY LECTURE

Longitude by Chronometer Sight of a Star

In getting your longitude by a time sight of a star, you proceed somewhat differently from the method used when observing the sun. What you wish to get first is G.S.T., i.e., the distance in time Greenwich is from the First Point of Aries. If you can then get the distance the ship is from the First Point of Aries, the difference between the two will be the longitude in, marked East or West according as to which is greater. By looking at the diagram furnished you when we were talking of Sidereal Time, all this becomes perfectly clear. The full rule for finding longitude by a star is as follows, which put in your Note-Book:

Correct your CT to get your G.M.T. From the G.M.T. get the G.S.T. From the observed altitude of the star, obtain the star's H.A. at the ship in the same way L.A.T. is secured in case of the sun. To or from the R.A. of the star add, if West of your meridian, subtract if East of your meridian, the star's H.A. at the ship, just obtained. The result is the R.A. of the ship's meridian or L.S.T.

Find the difference between G.S.T. and L.S.T. and the result is the longitude, marked East or West according as to whether G.S.T. is less or greater than L.S.T. Note: Always take the star's H.A. from the top of the page of Table 45.

Dec. 2, 1919. A.M. Observed altitude Star Sirius 2O° 05' 20", West of meridian. CT 11h 45m 29s P.M. CC 1m 28s slow. IE - 1' 20". HE 21 ft. Latitude by D. R. 38° 57' N. Required longitude in.

CT	11h	45m	29s		
CC		+ 1	28		
G.M.T.	11h	46m	57s		
☉RA	16	37	10.3		
⊕CP		1	56.1		
G.S.T.	28h	26m	03.4s	IE	-1' 20"
	- 24			HE	-7 08
G.S.T.	4h	26m	03.4s	Corr.	-8' 28"
Obs. Alt.	20° 05' 20				
Corr.	-8 28				
T.C.A.	19° 56' 52"				
Lat.	38 57			sec.	.10919
P.D.	106 36 24			cosec.	.01849 + 1

2)	165° 30' 16"		
½ S	82° 45' 08"	cos.	9.10106 - 13
T.C.A.	19 56 52		
Diff.	62° 48' 16"	sin.	9.94911 + 2
			9.17785
			- 11
	log. hav. Star's H.A. at ship		9.17774

Star's H.A.	3h	02m	40s
Star's R.A.	6	41	39
L.S.T.	9h	44m	19s
G.S.T.	4	27	01
Lo. in T.	5h	17m	18s E
Longitude in	79° 19' 30" E		

Assign for Night Work or work in the class room examples similar to the following:

1. April 16, 1919, in Latitude 11° 47' S. Observed altitude of the Star Aldebaran, West of the meridian 23° 13' 20". CT 6h 58m 29s. CC 2m 27s fast. IE - 2' 00". HE 26 ft. Required longitude in.

2. Dec. 10th, 1919. Observed altitude of Star Sirius 20° 05' 40" West of meridian. CT 11h 45m 29s. CC 1m 28s slow. IE - 1' 20". HE 21 ft. D.R. latitude 38° 57' N. Required longitude in.

Note to Instructor: If any time in the period is left or for Night Work assign examples to be worked by Marc St. Hilaire Method, changing slightly the D.R. Lat. and Longitude just obtained by the Time Sight Method.

WEDNESDAY LECTURE

Examples on Longitude by Chronometer Sight of a Star

1. Dec. 9th, 1919. In latitude 36° 48' N. Observed altitude Star Capella, East of meridian 46° 18' 30". IE 2' 50" off arc. HE 33 ft. CT 10d 3h 05m 05s A.M. CC 1m 18s slow. Declination of star is 45" 55' N. Required longitude in.

2. October 26th, 1919. In latitude 39° 54' S. Observed altitude Star Rigel, West of meridian 42° 18' 40". CT 27d 10h 32m 55s A.M. CC 2m 18s fast. IE 4' 20" off arc. HE 42 ft. Required longitude in.

3. April 11th, 1919. P.M. at ship. In latitude 43° 16' 48" S. Observed altitude Star Spica 33° 18' 20", East of meridian. CT 11h 08m 44s P.M. IE 3' 20" on arc. CC 4m 18s slow. HE 39 ft. Required longitude in.

4. September 15th, 1919. P.M. at ship. In latitude 49° 38'N. Observed altitude Star Deneb, East of meridian, 36° 16' 50". IE 3' 40" off arc. HE 40 ft. CC 6m 18s slow. CT 10h 00m 13s P.M. Declination of star is 44° 59' 36" N. Required longitude in.

If any time is left, work same examples by Marc St. Hilaire Method assuming a position near the one found by Time Sight.

Assign for Night Work any of the above examples, to be worked either as Time Sights or by the Marc St. Hilaire Method, and also the following Arts. in Bowditch: 326-327-328-329.

THURSDAY LECTURE

Latitude by ex-meridian Altitude of the Sun

You have learned that when you calculate your latitude from a meridian altitude of the sun, one of the necessary requisites is to have the sun exactly on your meridian. In fact, that is just another way of expressing meridian altitude, i.e., an altitude taken when the sun is on your meridian. Now suppose that 10 or 15 minutes *before* noon you fear that the sun will be clouded over at noon so that a meridian altitude cannot be secured. There is a way to calculate your latitude, even though the altitude you secure is taken by sextant some minutes before or after noon. This is called latitude by an ex-meridian altitude. It must be kept in mind that this method can be used accurately only within 26 minutes of noon, either before or after, and only then when you know your longitude accurately. Put in your Note-Book:

1. Get your L.A.T. (S.H.A.).

2. Subtract it from 24h 00m 00s, or vice versa, according as to whether L.A.T. is just before or just after local apparent noon. Call the result "Time Interval from Meridian Passage."

3. With your D.R. latitude, declination and Time Interval from Meridian Passage, enter Table 26 to get the proper amount of Variation of Altitude in one minute from meridian passage.

4. With the Time Interval from Meridian Passage and the Variation, enter Table 27 to get the total amount of Variation of Altitude.

5. Add this total amount of Variation to the true observed altitude taken before or after noon, and the result is the corrected altitude.

6. Then proceed to get your latitude according to the rules already given you for latitude by meridian altitude.

Example: At sea, Jan. 23rd, 1919. CT 4h 22m 14s. CC 1m 10s fast. Longitude 66° 04' W. Latitude by D.R. 19° 16' 00" N. ☉ 50° 51' 00" S. HE 49 ft. IE - 1' 30". Required latitude in.

CT		4h - 22m - 14s
CC		- 1 - 10
	————————————	
G.M.T.		4h - 21m - 04s
Eq. T.		- 11 - 50
	————————————	
G.A.T.		4h - 09m - 14s
Lo. in T	(W-)	4 - 24 - 16
	————————————	
L.A.T.	22d - 23h - 44m - 58s	

24h - 00m - 00s
- 23 - 44 - 58
————————
15m - 02s = Time Interval from Meridian Passage.

Dec. 19° 34' 48" S   Table 26 = 2.8 Variation
Lat. 19° 16' 00" N   For 1 min. 0 altitude.

Time Interval from Meridian Passage 15m 02s - 2.8" Variation for 1 minute

(Table 27)	2" = 7' 30"		
	.8 = 3 00		
	————		
	10' 30" +		
IE	- 1' 30"	☉	50° 51' 00"
HE	+ 8 42		+ 7 12
	———		————
Corr.	+ 7' 12"	⊖	50° 58' 12"
			+ 10 30
			————
			51° 08' 42"
			- 90 00 00
			————
		ZD	38° 51' 18" N
		Dec.	19 34 48 S
			————
		Lat. in	19° 16' 30" N

Assign for work in class room and Night Work, examples similar to the following:

1. At sea, July 11th, 1919. Latitude by D.R. 50° 01' 00" N. Longitude 40° 05' 16" W. Observed ex-meridian altitude ☉ 61° 45' 30" S. HE 15 ft. IE - 4' 10". CT (corrected) 2h 38m 00s. Required latitude in.

2. At sea, June 6th, 1919. Latitude by D. R. 49° 21' N, Longitude 18° 18' W. Observed ex-meridian altitude ☉ 61° 30' 22" S. HE 42 ft. CT 1h 06m 18s. CC - 1m 14s. IE 0' 30" off the arc. Required latitude in of ship.

If any time is left, work similar examples by Marc St. Hilaire Method.

FRIDAY LECTURE

EXAMPLES: LATITUDE BY EX-MERIDIAN ALTITUDE OF THE SUN

1. Jan. 1st, 1919. WT 11h 53m 18s A.M. C-W 5h 56m 16s. Latitude by D. R. 58° 05' S. Longitude 89° 00' 48" W. ☉ ex-meridian 55° 16' 30" N. IE 2' 00" off the arc. CC 1m 28s fast. HE 36 ft. Required latitude in.

2. March 11th, 1919. CT 11d 9h 14m 39s A.M. Latitude by D. R. 39° 20' N, Longitude 39° 48' 16" E. ☉ ex-meridian 46° 17' 30" S. IE 2' 00" on the arc. CC 1m 16s slow. HE 29 ft. Required latitude in.

3. April 26th, 1919. CT 26d 4h 46m 38s A.M. Latitude by D. R. 24° 25' S, Longitude 107° 16' 56" E. ☉ ex-meridian 52° 18' 50" N. IE - 2' 40". CC 3m 56s slow. HE 33 ft. Required latitude in.

4. May 10, 1919. CT 2h 18m 46s A.M. Latitude by D. R. 23° 54' S, Longitude 143° 20' 18" E. ☉ ex-meridian 48° 26' 20" N. IE 3' 20" on the arc. CC 4m 18s fast. HE 41 ft. Required latitude in.

5. June 21st, 1919. CT 4h. 56m 18s. Latitude by D. R. 42° 01' N, Longitude 75° 00' 18" W. ☉ ex-meridian 71° 29' 40" S, IE - 2' 30". CC 3m 04s slow. HE 28 ft. Required latitude in.

6. Dec. 18th, 1919. WT 11h 50m 18s A.M. C-W 3h 14m 18s. Latitude by D. R. 11° 55' S. Longitude 48° 02' 29" W. ☉ ex-meridian 78° 32' 30" S. IE 3' 30" on the arc. CC 2m 44s slow. HE 35 ft. Required latitude in.

If there is any time left, give examples of latitude by meridian altitude, Marc St. Hilaire Method by sun or star sight, etc.

SATURDAY LECTURE

FINDING THE WATCH TIME OF LOCAL APPARENT NOON

Noon at the ship is the pivotal point of the day's work at sea. It is then that the navigator must report to the commanding officer the latitude and longitude by dead reckoning, the latitude and longitude by observation, the course and distance made good, the deviation of the compass and the course and distance to destination. Apparent noon, then, is a most important time to calculate accurately, and to do so when the ship is under way, is not so easy at it first appears.

If the ship is stationary, and you know the longitude you are in, the problem is simple. Then it is merely a question of starting with L.A.T. of 00h-00m-00s, adding or subtracting the longitude, according as to whether it is West or East, to get G.A.T.; applying the equation of time with sign reversed to get G.M.T.; applying the C. Cor. with sign reversed to get the C.T.; and applying the C-W to get the WT. If, for instance, this WT happens to be 11h-42m-31s, when the watch reads that number of hours, minutes and seconds, the sun will be on the meridian and it will be apparent noon.

When the ship is moving, the problem is more difficult. At first thought you might imagine that all you would have to do would be to take the difference between the L.A.T. of the morning sight and 24 hours, calculate the distance the ship would run in this time and from that determine the longitude you would be in at noon. Then proceed as in the case of the ship being stationary. But such a calculation does not take into consideration the easting or westing of the ship itself. Suppose that at the morning sight the L.A.T. is found to be 20h-10m-30s. If the ship does not move, it will be 3h-49m-30s to noon. But suppose the ship is moving eastward. Then, in addition to the speed at which the sun is approaching the ship, there must be added the speed at which the ship is moving toward the sun - i.e. the change in longitude per hour which the ship is making, expressed in minutes and seconds of time. Likewise, if the ship is moving westward, an allowance must be made for the westing of the ship. And this change of longitude in minutes and seconds of time must be subtracted from the speed of the sun's approach since the ship, in going west, is traveling away from the sun.

There are various ways to calculate this allowance for the ship's speed, among the best of which is given in Bowditch, Art. 403, p. 179. Another, and even easier way, is the following, which was explained to the writer by Lieutenant Commander R.P. Strough, formerly head of the Seamanship Department of this School:-

1. Take the morning sight for longitude when the sun is on or as near as possible to the prime vertical.

2. Subtract the L.A.T. of the morning sight from 24 hours. This will give the total time from the morning sight to noon if the ship were stationary.

3. From the course to noon and speed of the ship, figure the change in longitude per hour in terms of seconds of time. For instance, suppose a ship were steaming a course of 275° at the rate of 11 knots per hour in approximately 38° North latitude. The change of longitude per hour for this speed would be 14' of arc or 56s of time.

4. Now the sun travels at the rate of 60 minutes or 3600 seconds per hour. To this hourly speed of the sun must be added or subtracted the hourly speed of the ship according as to whether the ship is going in an easterly or westerly direction. If, as mentioned above, the ship is steaming a course of 275° (W ½ N) and hence changing its longitude at the rate of 56s per hour, then the net rate of approach of the sun per hour would be 3600s - 56s, or 3544s per hour.

5. Divide the total time to noon from the L.A.T. of the morning sight (expressed in seconds of time) by the net rate of approach of the sun per hour. The result will be the corrected time to noon - i.e. the time at which the sun will be on the ship's meridian when the ship is changing its longitude to the westward at the rate of 56s per hour.

6. One more step is necessary. To the watch time of the morning sight, add the corrected time to noon. The result will be the watch time of Local Apparent Noon. Thirty minutes before will be the watch time of 11:30 A.M. and at 11:30 A.M. all deck clocks should be set to the local apparent time of the place the ship will be at local apparent noon.

The following example illustrates the explanation just given and should be put in your Note Book:-

Example:- At sea, August 7th, 1919. About 7:30 A.M. by ship's time, position by observation just found to be Latitude 30° 05' N, Longitude 58° 08' W. WT of morning sight 6h-53m-13s A.M. C-W 4h-37m-21s. CC + 3m-38s. Course 275°. Speed 11 knots. TZ N 90° E. What will be the Watch Time of Local Apparent Noon?

	6h	53m	13s

WT	A.M.		
+	12		
	18	53	13
C-W	4	37	21
CT	23	30	34
CC		+ 3	38
G.M.T.	23	34	12
Eq. T.		- 5	42
G.A.T.	23	28	30
Lo. in T.	3	52	32
L.A.T.	19	35	58
	24	00	00
Total time to Noon	4h	24m	02s

Course - 275°

Change in Lo. per hr. - 14', 56s.

3600s
-56
———
3544s, Net rate of approach of sun

4h
60
———
240m
+ 24
———
264m x 60 = 15840s

15840s
+ 02
———
15842s, Total time to noon.
3544) 15842 (4.47 hours
14176
———
16660
14176
———
24840
24808
———

Corrected time to Noon	4h	28m	12s
WT of A.M. sight	6h	53m	13s
WT of L.A.N.	11h	21m	25s
WT of 11:30 A.M.	10h	51m	25s

When, therefore, the watch reads 10h 51m 25s, the deck clocks should be set to 11.30 A.M. and thirty minutes later it will be apparent noon at the ship.

In all these calculations it is taken for granted that the speed of the ship and hence the change in longitude can be gauged accurately. A check on this can be made by comparing the longitude of the A.M. sight with the D.R. longitude of the same time. Any appreciable difference between the two can be ascribed to current. Now, if a proportionate amount of current is allowed for in reckoning the speed of the ship from the time of the A.M. sight to noon, then a proper correction can be made in the net rate of approach of the sun and the corrected time to noon will be very close to the exact time of noon. Of course there will be an error in this calculation but it will be small and the result gained will be accurate enough for ordinary work.

So much for finding the watch time of Local Apparent Noon. Careful navigators carry the process further and get the watch times of 15, 10 and 5 minutes before noon, so that by the use of constants for each one of these times, an accurate check on the noon latitude can be quickly and easily secured. We have not time in this course to explain how these constants are worked out but it is well worth knowing. The information regarding it is in Bowditch Art. 325, p. 128, and Art. 405, p. 181.

A word about the watch used by the navigator should be included here. This watch should be a good one and receive as much care, in its way, as the chronometer. It should be wound at the same time every day, carefully handled and, in other respects, treated like the fine time-piece that it is.

While authorities differ on this point, the best practice seems to be not to change the navigator's watch to correspond with the apparent time of each day's noon position. The reason for this is two-fold. First, because constant moving of the hands will have an injurious effect on the works of the watch, and second, because, by not changing the watch, the C-W remains approximately the same, and thus a good check can be kept on both the watch and the chronometer as well as on the navigator's figures in reckoning the times of his various sights.

Assign for night reading the following Arts. in Bowditch: 323, 324, 333. Also problems similar to the following:

1. At sea, July 28, 1919. Position by observation just found to be Latitude 44° 58' N, Longitude 22° 06' W. WT of morning sight 6h-02m-20s. CC 3m 34s slow. Course S 24° W. TZ N 90° E. Speed 9 knots. What will be the watch time of Local Apparent Noon?

2. At sea, August 9th, 1919. Position by observation just found to be Latitude 38° 48' N, Longitude 70° 46' W. WT of morning sight 8h-15m-01s A.M. C-W 3h-56m-32s. CC 3m-43s slow. Course 272°. Speed 12 knots. TZ N 90° E. What will be the watch time of Local Apparent Noon?

WEEK VII—NAVIGATION

TUESDAY LECTURE

COMPASS ERROR BY AN AZIMUTH

The easiest and most accurate way to find the error of your compass is, first, to find the bearing of the sun by your pelorus. If you set your pelorus, so that it will exactly coincide with the course you are steaming as shown by the compass in your chart house and then get a bearing of the sun by noting where the shadow from the pelorus vane cuts the circumference, this bearing will be the bearing of the sun by compass. At the same time, get your true bearing of the sun from the Azimuth Tables. The difference between the two will be the compass error, marked East or West according to the following rule which put in your Note-Book:

1. Express your Compass Bearing and your True Bearing by NEW compass reading.

2. If TZ is to the right of CZ, C.E. is East. Formula: True - Right - East.

3. If TZ is to the left of CZ, C.E. is West. Formula: True - Left - West.

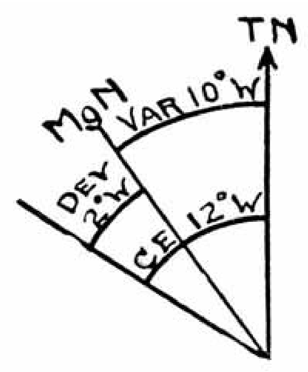
You must now remember that what you have is a Compass Error, consisting of both Variation and Deviation. To find the Deviation, the Variation and C.E. being given, is merely to apply the rules already given you under Dead Reckoning. For instance, if you had a C.E. of 10° W and a Variation of 4° E, the Deviation would be 14° W.

Put this example in your Note-Book:

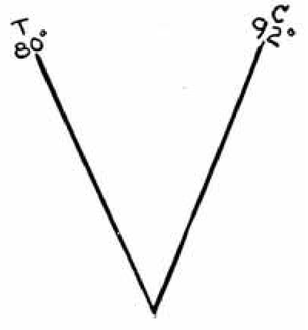
LAT 20h 59m 57s Lat. 4° 55' N Dec. 10° 39' 30" N

Ship heading N 11° W. CB of (.) S 88° E. Variation 10° W. What was the ship's true course and Deviation of Compass on direction ship was heading?

CZ 92° (New compass reading)
TZ 80° (New compass reading)
——
CE 12°
CE = 12° W



Variation 10° W
——
Deviation 2° W
True course being sailed N 23° W or 337°.



Let us now work out some of the following examples:

1. L.A.T. 22h 14m 18s
    Lat. 30° 29' S
    Dec. 17° 28' 44" N
    Ship heading S 84° W
    Compass Bearing 44°
    Variation 10° W.

Required T.C. and Deviation on ship's loading.

2. August 29th, 1919. CT 2h 29m 18s A.M. Longitude 120° 19' 46" E. Latitude 44° 14' N. Ship heading 98°.
    Compass Bearing S 42° E.
    Variation 4° E.

Required T.C. and Deviation on ship's heading.

3. June 17th, 1919. CT 4h 18m 44s A.M. Longitude 60° 14' 59" E. Latitude 38° 48' 00" S. Ship heading SW x S.
    Compass Bearing 40°
    Variation 12° W.

Required T.C. and Deviation on ship's heading.

Etc.

WEDNESDAY LECTURE

CORRECTING LONGITUDE BY A FACTOR

We are now almost ready to begin the discussion of a day's work at sea. The only method we have not taken up is the one which is the subject of today's lecture. It is a method to correct your longitude to correspond with the difference between your latitude by Dead Reckoning and your latitude by observation.

Suppose you take a sight in the morning for longitude. The only latitude you can use is a D. R. latitude, advanced from your last known position. Now suppose you run until noon and at that time take a sight for latitude. In comparing your D. R. latitude, advanced the true course and distance steamed to noon, and your latitude by observation taken at noon, suppose there is a difference of several minutes. The question is—How can we correct our longitude to correspond with this error discovered in the latitude? This is the method which put in your Note-Book:

Find the difference between the latitude by D. R. and the corresponding latitude by observation (in most cases secured from a sight at noon or from the Star Polaris). Call this the Error in Latitude. With the D. R. Latitude of the preceding sight and the azimuth or bearing of the preceding sight (always expressed as a bearing of less than 90°, old compass reading) enter Table 47 for the correct Longitude Factor. Multiply this Factor by the Error in Latitude. The result is the correction to apply to the Longitude. It is applied East or West according as to whether the Latitude by Observation is to the East or West of the D. R. Latitude on the Line of Position (the line at right angles to the Azimuth) of the preceding sight.

Example:

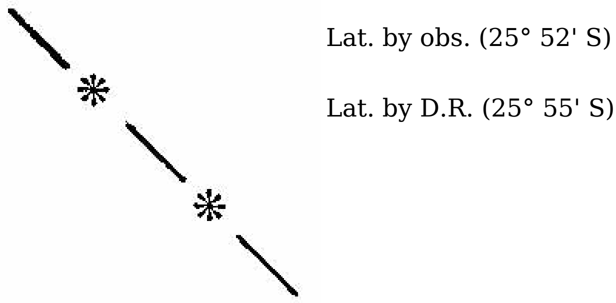
Position about 7:30 A.M. Latitude by D. R. 25° 40' S, Longitude (just secured by observation) 104° 05' 38" E. L.A.T. 7h 32m 30s A.M., Declination 4° 59' N. Thence ship ran to noon 109°, true course, 46 miles, when the latitude by meridian altitude of the sun was found to be 25° 52' S. Required corrected longitude at noon.

7:30 A.M. D.R. Lat.	25° 40' S	Lo.	104° 05' 38" E
			48 18

109°—46 k.	15 S		E
	———		————
Noon—Lat. by D.R.	25° 55' S	Lo.	104° 53' 56" E
Noon—Lat. by obs.	25° 52' S		
	———		
Error in Lat.	3'		

Enter Table 47 with azimuth (S 105° E) N 75° E as bearing and Latitude 25° 40' or 26°, Factor is found to be .3.

3' (Error in Latitude) times .3 (Factor) = .9' or 54", Correction in Longitude. Is it East or West? Since azimuth is N 74° E, Line of Position is N 16° W. The D. R. Latitude and Latitude by Observation are plotted on this line as follows:



Latitude by observation is West of Latitude by D.R. Hence correction in longitude of 54" is applied West. Position by observation, therefore, is as follows:

Lo.	104° 53' 56" E
Corr. in Lo.	54 W
	————
Lo. by obs.	104° 53' 02" E

Lat. by obs. 25° 52' S

Note to Instructor:

Assign the following examples for work in the class room:

1. April 20th, 1919 A.M. at the ship. G.M.T. 20d 10h 28m 24s A.M. ☉ 31° 55' 40". HE 30 ft. No IE, CC. Latitude by D. R. 26° 30' N. Longitude 36° 55' West.

Ship then sailed a true course of S 36° E—40 knots until noon when observed altitude ☉ 75° 40' 50" S. What was the position at noon corrected for Longitude? (Note: Work the A.M. sight by both Time Sight and Marc St. Hilaire Method.)

2. June 25th, 1919, A.M. Latitude by D. R. 36° 20' S. Longitude 96° 30' E. CT 1h 37m 16s A.M. CC 1m 30s fast. IE 2' 30" off arc. HE 36 ft. ☉ 7° 34' 20". Log registered 114.

True course to noon S 76° E. Log registered 174. Same IE, HE, CC. Observed altitude ☉ 29° 44' 40" N. Required position at noon by Longitude factor. (Note: Work A.M. Sight by Marc St. Hilaire Method.)

3. At sea, May 30th, 1919. In D. R. Latitude 38° 14' 29" N. Longitude 15° 38' 49" W. Observed altitude ☉ 39° 05' 40" and bearing by compass 259°. IE 1' 00" on arc. HE 27 ft. WT 3h 04m 49s. C-W 1h 39m 55s. CC 1m 52s fast.

Changed course to 94° p.s.c. and steamed 75 knots to about 8 o'clock. WT 8h 06m 18s. C-W 1h 39m 58s. At this time observed altitude of Star Arcturus 68° 30' 40", East of meridian. Same IE, HE, CC.

Changed course to 95° (true). Steamed 60 knots until midnight when ran into heavy fog. Slowed down to 7 knots per hour until 8 A.M. when observed altitude ☉ 48° 45' 10". CT 9h 45m 18s A.M. Same HE, IE, CC.

Required fix at 8 A.M. by Marc St. Hilaire Method, laid down on chart.

Note to Instructor:

Spend rest of period in familiarizing pupils with laying down runs and intersecting lines of position on Mercator plotting charts.

THURSDAY LECTURE

THE NAVIGATOR'S ROUTINE—A DAY'S WORK AT SEA

You are now familiar with the principal kinds of sights and the methods used in working them as explained in the foregoing pages. This information, however, relates only to each individual kind of sight. Today I will explain briefly how those sights are made use of in your daily work at sea. Such an explanation necessarily cannot include the navigator's work under all conditions and on all classes of ships. It merely gives a brief outline of and a few suggestions relating to navigating conditions on board a medium-sized transport, in time of war. I say "in time of war" because navigating then is different, to some extent, from the ordinary routine in time of peace.

Suppose you are ordered to a ship as navigator. What are your duties (a) before leaving port, (b) while at sea, and (c) on entering pilot waters?

(a) Before Leaving Port

Ascertain the height of the eye of the bridge and any other place on the ship where you would be likely to take sights.

Have posted in the chart room and on the bridge the deviation of the compass on each 15° heading, so that it can be easily referred to.

Keep in each chronometer case or in a book nearby the error and daily rate of all chronometers on board.

Test each sextant for index error and record the result where you can refer to it easily.

See that all charts of the harbor out of which you are to steam are corrected to date and are familiar to you, both as to sailing directions and buoys, and also as to lights and other aids to navigation.

Examine, in detail, the steering engine and steering apparatus. In case of its disarrangement your intimate knowledge of it may be most valuable.

See that the patent log and sounding machine are in good order. See that the lead lines are well soaked in water, stretched, and properly marked.

See that the lighting system in the chart room and the navigator's room is such that when any door is not tightly closed the lights in the room are extinguished. Likewise, when the doors are closed, see that the lights will light and without repeated slamming of the doors.

If possible, provide yourself with a flashlight set back in a metal tube so that the rays of the light are not diffused but can be focussed only on one spot at a time.

See that your charts are arranged neatly in the drawers provided for them in the chart room. If, as is usual, the charts must be folded to get them in the drawers, mark them legibly on the outside and in the same place on each chart. Put in the top drawers those charts you know you will use most frequently. This will save endless time and confusion.

Be sure you have a full complement of necessary instruments, including sextants, a stadimeter, binoculars, watches, stop watch, dividers, parallel rulers, pencils, work books; also all necessary books, such as smooth and deck log books, several volumes of Bowditch, Nautical Almanacs, Azimuth Tables, Pilot books, Light and Buoy lists, Star Identification Tables, etc. You will be repaid a thousand times for whatever effort you expend to have your navigational equipment complete to the smallest detail. The shortage, for instance, of a pair of dividers would be an unending annoyance to you. This is also true of almost any other item mentioned above. Prepare yourself, then, while you are in port and have plenty of opportunity to secure the equipment you desire.

(b) While at Sea

The least amount of work required of a navigator in time of peace would include (1) a morning sight for longitude, (2) a noon sight for latitude, (3) an afternoon sight for longitude, (4) an A.M. azimuth to check the deviation of the compass, and (5) the dead reckoning for the day's run from noon to noon.

Navigating in war time requires more work than this. If possible, the ship's position must be known accurately at any time of day or night for, in case of an emergency, the lives of all on board may be imperilled by inaccurate knowledge of your whereabouts. This means that more sights must be taken and more celestial bodies observed. While every navigator has his own idea as to the proper amount of work to do in a day, it would seem as though the following would cover the minimum amount of work necessary under present conditions:

1. An A.M. sight of the sun for longitude.

2. An azimuth of the sun for checking the deviation of the compass, taken right after the A.M. sun sight.

3. The watch time of Local Apparent Noon.

4. Ex-meridian and meridian altitudes of the sun for latitude.

5. A P.M. sight of the sun for longitude.

6. An evening twilight sight of three or four stars, preferably one in each quadrant. If these altitudes are taken correctly your position can be found to the dot.

7. A morning twilight sight for a fix or, at least, for latitude by Polaris.

8. The dead reckoning from noon to noon.

9. Distance run during the last 24 hours, from noon to noon

10. Distance to destination.

11. Set and drift of the current.

1. The A.M. Sun Sight

In order to make this a valuable sight for longitude it should be taken when the sun is on or as near as possible to the prime vertical. As the sun, in North latitudes, passes the prime vertical before sunrise in the winter, the following remarks do not hold for that season. In winter the only rule to follow is to observe the sun as soon as it is 10° or more above the horizon. In summer find out from the Azimuth Tables the local apparent time when the sun will bear 90°. Estimate, as closely as possible, the longitude you will be in the next morning when the local apparent time is as just found in the Azimuth Tables. This can be done by calculating the dead reckoning from the previous sight, or, what is even simpler, laying the distance off on the plotting chart. With this information find the W.T. corresponding to the L.A.T. mentioned above by some such formula as this: L.A.T. ± Lo. = G.A.T. ± Eq. T. (sign reversed) = G.M.T. ± C.C.(sign reversed) = C.T. - (C-W) = W.T. This will not be absolutely accurate, for the longitude you are in is only approximate, but it will be close enough for good results. This resulting W.T. will be the time to take the A.M. sight. About fifteen minutes before that time compare your watch with your chronometer to get the C-W. Also bring up the C.C. to date and make a note of it so that as much as possible of this detail work is accomplished before the sight is taken. Next, take your sextant and test it for index error. This should be done regularly before each series of sights as it is impossible to tell what may have happened when the sextant is lying idle, except by the above test. Now, with your sextant, watch and notebook, go to the place from which you have decided to take your observations and, at the proper watch time, start taking your altitudes. It is always advisable to take a number of sights, closely following each other, so that an error in one may be corrected somewhat by the others. Take at least three sights in close succession. At the same time have the log read and enter it in your notebook. An equally good method in fair weather is to secure the distance run from the revolutions of the propeller.

Having taken your sights, go to the standard compass and get a bearing of the sun, at the same time noting in your book the W.T. of the bearing and the compass heading of the ship. You are now ready to go below into the chart room and work out your position. What method shall you use? That depends upon your preference. You have missed the point of the previous lectures, however, if you forget that the New Navigation is based upon the Marc St. Hilaire Method, and this is undoubtedly the method your captain will prefer you to use if he is an Annapolis graduate. In this connection let me remind you again of the one fact, the oversight of which discourages so many beginners with the Marc St. Hilaire Method. The most probable fix, which you get by one sight only, is not actually a fix at all. Nor does any other method give you an accurate fix under like conditions. What the most probable fix is, and all it claims to be, is a point through which the required Sumner line is to be drawn. If your D.R. position happens to be only one mile away from the most probable fix, that is no assurance that the most probable fix is near the actual position of the ship. You may be 25 miles away from it. But the important information gained is that, though you may be 25 miles away, you know on what line you are, and when this line is later crossed with another line of position that fix will be accurate. "Two sights make a fix" is the whole matter in a nutshell.

2. The Compass Error

Having secured your morning sight, the next duty is to get the compass error. From your morning sight computation you know the watch time corresponding to the L.A.T. of the same sight. Find the difference between the two and apply this difference to the watch time of the compass azimuth. That will give you the L.A.T. with which to enter the Azimuth Tables to get the true bearing corresponding to the compass bearing recently observed. Apply the variation from the chart to get the magnetic bearing. The difference between this magnetic bearing and the compass bearing will be the required deviation, which you should compare with your Deviation Table. If there is a marked difference, and you are sure of your figures, use the new deviation in computing courses on this heading of the ship.

3. The Watch Time of Local Apparent Noon

You are now ready to figure the watch time of local apparent noon. Unless you have a decided preference to the contrary, do this by the method explained in the Saturday Lecture, Week VI. Do not forget that in subtracting the L.A.T. of the morning sight from 24 hours to get the total time to noon, in case the ship were stationary, you do *not* use the L.A.T. of the D.R. position, but the L.A.T. found by subtracting from G.A.T. the longitude of the most probable fix. This will give you the L.A.T., based on the longitude of the most probable fix, which will be slightly different from the L.A.T. based on the D.R. longitude. When you have secured the watch time of local apparent noon, subtract 30 minutes from it and notify the quartermaster that at that time by your watch the deck clocks are to be set to 11.30 A.M. If this change of time is very great (providing you are on an almost easterly or westerly course), it is wise to have the clocks set back in the night watches to allow for most of the time you figure you will lose. This will not work such a hardship or such an advantage to the officers and men who have the forenoon watch and will also be easier for the cooks. The clocks can then be slightly but accurately changed at 11.30 A.M., as mentioned above.

4. Ex-Meridian and Meridian Altitudes

You know the principles and methods governing sights of this character. To know your latitude exactly at noon is usually required when you are steaming in convoy, for at that time your position signals are hoisted, and it is a matter of pride with the navigator not only to have his position exact but promptly. If your A.M. sight was taken when the sun was on or near the prime vertical, a change in latitude at noon will make no change in longitude. Hence you can figure your longitude at noon just as soon as you have secured the corrected time from the A.M. sight to noon (which you have done right after working the A.M. sight). You will have your longitude, then, before you go on the bridge to observe for ex-meridian and meridian altitudes.

Sharply at noon you take your meridian altitude and tell a messenger to notify the captain that it is noon at the ship. The captain then orders eight bells struck, and you are ready to hand in your noon report, consisting of latitude and longitude by observation, latitude and longitude by dead reckoning, deviation of the compass on the ship's head at 8 A.M., distance made good since the preceding noon, distance to destination, set and drift of current (Note:—When steaming in convoy this is unnecessary and usually omitted), and any other pertinent remarks. If the sun was not taken on or near the prime vertical at the time of the A.M. sight, take out your longitude factor for the coming noon position and calculate your D.R. latitude at noon. By correcting the longitude of the A.M. sight, run to noon, with the difference of longitude, readily found at noon with the longitude factor and the error in latitude, you will have the correct noon longitude to hand in, with only a moment's delay. It will be very hard, however, to get all this information in on time without the use of latitude constants. There is no room for a discussion of these constants here, but they are easy to work and you should learn how to use them. The information is in Bowditch Art. 325, p. 128, and Art. 405, p. 181.

5. The P.M. Sun Sight

This is another longitude sight and so any previous remarks about sights of this character are applicable here. If the day is fine you need not work out this sight until after evening twilight, for a fix then by stars will give both latitude and longitude, whereas your afternoon sun sight will only give you a longitude. This P.M. sun sight is a good check sight, to be used or not, according as to whether other earlier or later sights have been obtained.

6. The Evening Twilight Sight

The beauty of using stars is that by almost simultaneous altitudes of different ones you can ascertain your position, both as to latitude and longitude. In the North Atlantic during the summer months Vega, Deneb or Altair in the East, Antares or Deneb Kaitos in the South, Arcturus in the West, and Polaris, Mizar, or Kochab in the North form an ideal combination which includes every quadrant of the compass. In the winter months, Capella, Castor or Pollux in the East, Sirius or any star in Orion's belt in the South, Deneb in the West, and Polaris in the North are equally as good.

7. The Morning Twilight Sight

In clear weather this should be primarily a sight for latitude, since the A.M. sun sight for longitude will follow it. A latitude by Polaris, and at the same time some star in one of the southern quadrants, as a check, will give admirable results.

8. The Dead Reckoning from Noon to Noon

If there is no change of course in the late forenoon, as is usually the case, the dead reckoning for the day's run can be figured any time before noon so that it will be all ready to hand in to the captain with the other noon data. It is much easier to lay this off on the chart than to go to the trouble of calculating it by Table 2, Bowditch. On the other hand, such a calculation checks the chart work and should be worked out if you wish to make "assurance doubly sure."

9. Distance Run During the Last 24 Hours

Here, again, an answer by chart and an answer by figures is a good thing to secure. As you become accustomed to your work you will find the answer by chart infinitely easier and quicker to get. It is just as accurate, too, if you lay the distances off carefully with the dividers and parallel rulers.

10. Distance to Destination

The same remarks as are made under (9) hold true here.

11. Set and Drift of Current

Find the difference between your D.R. position and your position by observation at noon, i.e., the course and distance from your D.R. position to your position by observation. The course is the set of the current, the distance the amount of drift, all of which is easily calculated by Table 2, Bowditch. This difference between the two positions is seldom due to current. It is due to all errors of steering and the like. But these are all ascribed to current, for the sake of convenience. This calculation of the current is seldom used now, particularly when steaming in convoy.

It is obvious that a schedule, such as outlined above, cannot be adhered to in all kinds of weather or under all conditions. It is merely an outline of what might properly be included in a 24 hour day, the weather conditions of which will lend themselves at any time to taking the observations mentioned. The weather of each succeeding day may force you to adopt a different routine. Nevertheless, the closer you can keep to the above schedule the more exact will your various positions be.

(c) On Entering Pilot Waters

See that all charts of the locality you intend to enter are corrected to date.

Study these charts carefully, making notes, in detail, of the aids to navigation that you intend to pick up.

In noting lights give their distinctive appearance, range of visibility, approximate time of sighting them, and any other information that you think you may need. If you have this information with you when on the bridge it will save much time and trouble that you would otherwise have to spend, at possibly a critical time, in the chart room.

See that log lines, sounding machine, etc., are in order for instant use.

Remember that in entering pilot waters the safest landmarks are permanent ones. Buoys, cans, etc., may drag from their positions or be lost altogether. This can also happen to lightships.

Become familiar with soundings, rise and fall of the tides, and the like, in the neighborhood in which you intend to anchor. If possible choose an anchorage that will enable you to get bearings from two or three fixed points on shore. As soon as possible after anchoring secure your bearings by pelorus and have them checked up by the quartermaster at regular intervals. This will determine how much, if any, dragging has taken place.

Lastly, always remember that no amount of advice can make up for your own carelessness. Hold yourself ready for any emergency, keep cool, keep patient and keep pleasant. Common sense is the best antidote in the world for strange situations. If you have that, and the knowledge you should have secured from these lectures, you cannot go far wrong.

While the day's work which follows does not include every sight in regular sequence as given in the above discussion, it will give a fair idea of the navigator's work during a day's run. Put it in your notebook. (Note to Instructor:—Spend the rest of the period in explaining carefully each step of this example.)

A Day's Work at Sea

Departure taken from noon position Jan. 25th, 1919, in Latitude 30° 01' N, Longitude 73° 47' 20" W. Course p.s.c. NE ¾ N. Deviation 2° E. Variation 4° W. Log registered 20. Ship continued on this course until about 6:30 P.M. when log registered 98 and observed altitude of Star Rigel, East of meridian, 39° 36' 20". WT 6h 33m 19s P.M. C-W 4h 55m 04s. CC 2m 16s slow. HE 37 ft. IE 0' 20" off arc.

Changed course to 40° (true) and steamed until 3 A.M. when log registered 198. At this time ship ran into heavy NE gale. Slowed down to 7 knots per hour until about 8:30 A.M. when observed $\underline{\odot}$ 18° 25' 10" and bearing by compass S 46° E. Variation 7° W. WT 8h 31m 16s A.M. C-W 4h 55m 04s. IE + 0' 10". Same HE, CC.

Ship then steamed on true course of 39° at 7 knots per hour until noon when log registered 261 and observed meridian altitude $\underline{\odot}$ 37° 59' S. Same IE (+ 0' 10"), HE, CC. Required:—

1. Position by D. R. at noon.
2. Position by observation at noon (corrected for Longitude by a factor).
3. Deviation of compass at 8:30 A.M.
4. Watch Time of Local Apparent Noon.

At Sea, Jan. 25, 1919.   Lat. in 30° 01' N   Lo. in 73° 47' 20" W   Steamed until 6:30 P.M.

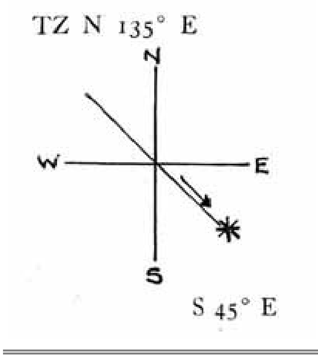
Course	Dist.	D. Lat.	Dep.	D. Lo.
N 35° E	78	63.9	44.7	51.5

Lat. Left 30° 01' N   Lo. Left 73° 47' 20" W

D. Lat.	1 03 54 N	D. Lo.	51 30 E
	———————		———————
Lat. in	31° 04' 54" N	Lo. in	72° 55' 50" W
Mid Lat.	30° 30' N		

At 6:30 P.M. Obs. * Rigel.

Obs. Alt. *	39° 36' 20"						
IE	+ 00 20	W.T.	6h 33m 19s	Log hav "t"	8.92502		
	———————	C.W.	4 55 04	Log cos Lat.	9.93269		
	39° 36' 40"	C.C.	2 16	Log cos. Dec.	9.99544		
HE	- 7 09		———————		——————		
	———————	G.M.T.	11h 30m 39s	Log hav S	8.85315	Nat hav S	.07130
T.C.A. *	39° 29' 31"	⊙.R.A.	20 14 58			Nat hav L - D	.11349
	———————	⊕.C.P.	1 53.3				
Dec. of *	8° 17' 42" S		———————			Nat hav ZD	.18479
Lat.	31 04 54 N	G.S.T.	31h 47m 30.3s	50° 55' 00"	ZD		
	———————	- W.Lo.	4 51 43	-90 00 00			
L. - D.	39° 22' 36"		———————	———————			
	———————	L.S.T.	2h 55m 47.3s	39° 05' 00"	C. Alt.		
		*R. A.	5 10 41	39 29 31	T. Alt.		
			———————	———————			
		"t"	2h 14m 54s	24' 31"	Alt. Diff. Toward.		



Course	Dist	D. Lat.	Dep.	D. Lo.
S 45° E	24.5	17.3	17.3	20

Lat. Left	31° 04' 54" N	Lo. Left	72° 55' 50" W
	17 18 S		20 E
	———————		———————
Lat. in	30° 47' 36" N	Lo. in	72° 35' 50" W

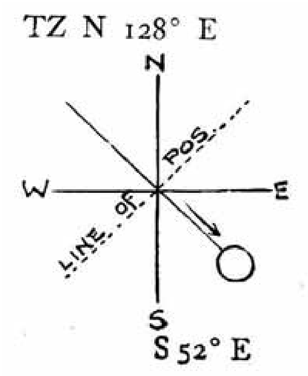
Changed course to 40° (true)

Course	Dist	D. Lat.	Dep.	D. Lo.
N 40° E	138.5	106.1	89	105

Lat. Left	30° 47' 36" N	Lo. Left	72° 35' 50" W
	1 46 06 N		1 45 E
	———————		———————
Lat. in	32° 33' 42" N	Lo. Left	70° 50' 50" W

At 8.30 A.M.

☉	18° 25' 10"	W.T	20h 31m 16s	Log hav "t"	9.28284		
IE	+ 10	C-W	4 55 04	Log cos Lat.	9.92573		
	————	C.C.	2 16	Log cos Dec.	9.97595		
	18° 25' 20"		————		————		
HE	+ 7 34	G.M.T.	1h 28m 36s	Log hav S	9.18452	Nat hav S	.15294
	————	Eq.T	- 12 32			Nat hav L-D	.18841
⊖	18° 32' 54"		————				———
		G.A.T.	1h 16m 04s	71° 30' 00"	ZD	Nat hav ZD	.34135
Dec.	18° 53' 24" S	-W.Lo.	4 43 51	-90 00 00			
Lat.	32° 33 42 N		————	————			
	————	L.A.T. (t)	20h 32m 13s	18° 30' 00"	C.Alt.		
L-D	51° 27 06"			18 32 54	T.Alt.		
				————			
				2' 54"	Toward		



Course	Dist	D. Lat.	Dep.	D. Lo.
S 52° E	3	1.8	2.4	3

Lat. Left	32° 33' 42" N	Lo.	70° 50' 50" W
	1 48 S		3 E
	————		————
Lat. in	32° 31' 54" N	Lo. Left	70° 47' 50" W

Bearing of Sun by Compass	S 46° E
True Bearing of Sun	S 52° E
	———
Total Error	6° W
Variation	7° W
	———
Deviation	1° E

Course	Dist	D. Lat.	Dep.	D. Lo.
N 39° E	24.5	19	15.4	18.4

Lat. Left	32° 31' 54" N	Lo. Left	70° 47' 50" W
	19 N		18 24 E
	————		————
Lat. in	32° 50' 54" N	Lo. in	70° 29' 26" W

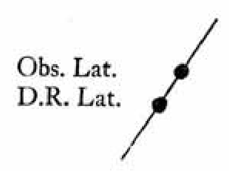
At Noon.

☉	37° 59' S	L. A. T.	00h 00m 00s
IE	+ 10	+ W. Lo.	4 41 58
	————		————
	37° 59' 10"	G.A.T.	4h 41m 58s
HE	8 55 17	E.T. (sign reversed)	+ 12 34
			————

—————— G.M.T. 4h 54m 32s

⊖ 38° 08' 22" S
51° 51' 38" N (ZD)
18 51 12 S (Dec.)
———————
33° 00' 26" N. Lat. in at Noon.

Lo. Factor =	.93	Lat. by Obs.	33° 00' 26" N
Lat. Diff.	9.5	Lat. by D.R.	32° 50' 54" N
	——		———————
Diff. Lo.	8.83	Lat. Diff.	9' 32"



Since Obs. Lat. is East of D.R. Lat. on Line of Pos.

Lo. Diff. is applied East.

Lo. by D.R.	70° 29' 26" W
Lo. Diff.	8 50 E
	———————
Lo. in at Noon	70° 20' 36" W

By Dead Reckoning from Noon to Noon

Course	**Dist.**	**D. Lat.**	**Dep.**	**D. Lo.**
N 35° E	78	63.9	44.7	176' or 2° 56'
N 40° E	138.5	106.1	89.	
N 39° E	24.5	19.	15.4	
		——	——	
		189.	149.1	

Lat. left.	30° 01' N	Lo. left	73° 47' 20" W
	3 09 N		2 56 E
	—————		———————
Lat. in	33° 10' N	Lo. in	70° 51' 20" W
Min. Lat.	31° 35'		

The Watch Time of Local Apparent Noon

Date—Jan. 26, 1919

G.A.T. of A.M. Sight	1h 16m 04s
Lo. in T. of A.M. sight	4 43 12
	——————
L.A.T.	20h 32m 52s
Total Time to Noon	3h 27m 08s

Course to Noon — 39°
Change in Lo. per hr. — 5.2', 21s
3600s + 21s = 3621s
3 x 60 = 180
27
——
207
60
———
12,420
08
—————
3621) 12,428 (3.43 hrs
10,863
———
15,650
14,484
———
11,660

10,863
———
3.43 hrs = 3h 25m 48s
W.T. of A.M. sight 8 31 16 A.M.
—————
W.T. of L.A.N. 11h 57m 04s A.M.

ANSWER.
By D.R.
Lat. 33° 10' N Lo. 70° 51' 20" W
By Observation
Lat. 33° 00' 26" N Lo. 70° 20' 36" W
Dev. at 8:30 A.M.
1° E
W.T. of L.A.N. 11h 57m 04s A.M.

FRIDAY LECTURE

Day's Work

At sea, November 28th, 1918. Departure taken at noon in Latitude 20° 50' N, Longitude 73° 15' 20" W. Log at noon registered 34. Sailed on course p.s.c. 73°, Deviation 3° E, Variation 1° W until twilight when log registered 152.

Changed course to E ¾ N p.s.c. and observed altitude of Star Aldebaran, East of meridian 37° 10' 10" and bearing by compass N 89° E, Variation 2° W. WT 8h 10m 16s. C-W 4h. 51m 30s. CC 4m 08s slow. IE 1' 10" off the arc. HE 38 ft.

Ship steamed on this course, in heavy fog and rain, until 2:30 A.M. when log registered 200. Ship changed course to E ½ N (true) and steamed at 8 knots per hour until 6:30 A.M. when weather cleared and observed altitude Star Polaris 21° 04' 20" N. WT 6h 35m 47s A.M. C-W 4h 51m 30s. Same IE, HE and CC.

Ship continued on same course and speed until about 9:30 A.M. when observed altitude of ☉ 38° 45' 20". WT 9h 39m 10s A.M. C-W 4h 51m 30s. Same IE, HE and CC.

Ship then steamed a true course of 93° at a rate of 10 knots per hour until noon when log registered 294 and observed meridian altitude ☉ 46° 49' 30". Same IE, HE and CC.

Required 1. D. R. position at noon.
2. Position by observation at noon (corrected for Longitude by a factor).
3. Deviation at 8:10 P.M.
4. Watch Time of Local Apparent Noon.

SATURDAY LECTURE

Day's Work

At sea, April 21st, 1918. Departure taken from noon position in Latitude 31° 50' N, Longitude 76° 30' 31" W. Log registered 128 at noon.

Course p.s.c. until about 4:30 P.M. was N 10° E. Deviation 1° W. Variation 3° W. At about 4:30 P.M. observed altitude of sun's lower limb 25° 13' 10" and bearing by compass N 87° W. WT 4h 26m 46s. C-W 5h 04m 52s. CC 1m 03s slow. IE 0' 10" off arc. HE 29 ft. Log registered at this time 188.

Course was then changed to NE x N (true). Weather cloudy. At about twilight clouds broke away and observed altitude of Star Procyon West of meridian 40° 01' 00". CT 1h 37m 28s A.M. CC 1m 03s slow. IE 0' 10" off arc. HE 29 ft. Log registered 236. Continued on same course until midnight, at which time log registered 290. At midnight ship ran into dense fog and slowed down to 8 knots until about 6:30 A.M., when fog blew away and observed altitude of Star Polaris 35° 29' 10" N. WT 6h 32m 14s A.M. C-W 4h 59m 02s. IE 0' 10" off arc. CC 1m 03s slow. HE 29 ft.

From 6:30 A.M. ship steamed a true course of N 32° E until noon at a rate of 15 knots per hour, at which time a meridian altitude of the ☉ was observed 65° 37' 10" S. Log registered 424. HE 29 ft. IE 0' 10" off arc. CC 1m 03s slow.

Required 1. D. R. position at noon.
2. Position by observation at noon (corrected for Longitude by a factor).
3. Deviation of Compass at 4:30 P. M. sight.
4. Watch Time of Local Apparent Noon.

WEEK VIII—NAVIGATION

MONDAY LECTURE

Day's Work

At sea, Nov. 12th, 1918. Departure taken from noon position in Latitude 39° 40' N, Longitude 33° 20' 04" W. Log registered at noon 1. Course p.s.c. was 294° until about 3:30 P.M., Deviation 1° W, Variation 24° W, at which time observed altitude ☉ 13° 55' 10" and bearing by pelorus S 79° W. WT 3h 22m 18s. C-W 2h 13m 20S. CC + 1m 10s. IE 1' 10" off arc. HE 32 ft. Log registered 46.

Course was then changed to 290° p.s.c. until about 6:30 P.M. when observed altitude Star Polaris 40° 15' 40" N. WT 6h 32m 18s. C-W 2h 13m 20s. Same HE, IE, CC. Log registered 90.

Ship steamed on same course until 1:30 A.M. when log registered 196. At 1:30 A.M. sighted sub. on port bow. Ordered full speed ahead and made 17 knots per hour until 8 A.M. when observed altitude ☉ 8° 40' 00". WT 8h 01m 30s A.M. C-W 2h 13m 20s. Same HE, IE, CC.

Ship then steamed a true course of 272° at a rate of 15 knots per hour until noon, at which time observed meridian altitude ☉ 32° 35' 40" S. Same HE, IE, CC. Log registered 362.

Required 1. D. R. position at noon.
2. Position by observation at noon (corrected for Longitude by a factor).
3. Deviation of Compass at 3:30 P.M.
4. Watch Time of Local Apparent Noon.

TUESDAY LECTURE

Day's Work

At sea, Dec. 10th, 1918. Departure taken from Latitude 19° 50' N, Longitude 20° 01' 20" W. Noon position. Log registered 20. Course p.s.c. N 16° E. Deviation 2° E, Variation 18° W. Ship steamed on this course until 8 P.M. when changed course to N 18° E p.s.c. and observed altitude Star Polaris 22° 33' 14" N. WT 8h 09m 10s. C-W 1h 20m 05s. CC 2m 00s fast. IE none. HE 39 ft. Log registered 104. Ship then steamed at 14 knots per hour until midnight. At midnight changed course to N 14° E p.s.c. and steamed at 12 knots per hour until 4 A.M. At 4 A.M. slowed down to 9 knots per hour and steamed at that rate until 8:30 A.M. when course p.s.c. was changed to N 17° E and observed altitude ☉ 22° 40' 30". WT 8h 34m 16s A.M. C-W 1h 20m 05s. Same IE, HE, CC. Sun bore by compass S 65° E, Variation 18° W. Continued on this course p.s.c. for two hours, speed 12 knots. Thence steamed a true course of 4° at same speed to noon when observed meridian altitude ☉ 42° 36' 50" S. Same IE, HE, CC.

Required 1. D. R. position at noon.
2. Position by observation at noon (corrected for Longitude by a factor).
3. Deviation of Compass at 8:30 A.M.
4. Log reading at noon.

WEDNESDAY LECTURE

Day's Work

At sea, July 19th, 1918. Departure taken from Latitude 40° 30' N, Longitude 45° 00' 10" W. Noon position. Log registered at noon 68. Steamed until 2:30 P.M. on a course p.s.c. 115°. Deviation 1° W. Variation 25° W. Log registered 125. Changed course to 118° p.s.c. (Same Variation and Deviation) and steamed until about 5 P.M. At about 5 P.M. observed altitude (.) 22° 40' 20" and bearing by pelorus N 55° W. WT 5h 01m 16s. C-W 3h 00m 02s. IE 2' 20" on arc. CC 3m 32s slow. HE 32 ft. Log registered 168. Course p.s.c. was then changed to 113° until about 8 P.M. when observed meridian altitude of Star Vega 88° 15' 10" S. WT 8h 02m 26s. C-W 3h 00m 02s. Same HE, IE, CC. Log registered 210. Continued on same course p.s.c. until about 2 A.M. when observed altitude of Star Vega 47° 19' 20" West of meridian. WT 2h 04m 24s A.M. C-W 3h 00m 02s. Same IE, HE, CC. Log registered 299. TZ of Star N 86° W. Continued on same course until 4 A.M. when log registered 329.

At 4 A.M. heavy fog and rain forced ship to slow down to 5 knots per hour until about 9 A.M. when weather cleared and observed altitude ☉ 51° 52' 40". WT 9h 03m 18s A.M. C-W 3h 00m 02s. Same HE, IE, CC. Thence ship steamed a true course of 88° at a rate of 13 knots per hour to noon, when log registered 394 and observed meridian altitude ☉ 69° 52' 20" S. Same IE, HE, CC.

Required 1. D. R. position at noon.
2. Position by observation at noon (corrected for Longitude by a factor).
3. Deviation of Compass at 5 P.M.
4. Watch Time of Local Apparent Noon.

THURSDAY LECTURE

Day's Work

At sea, Nov. 25th, 1918. Departure taken at noon from Latitude 25° 05' N, Longitude 37° 10' 40" W. Log registered at noon 32. Course p.s.c. was 119°, Deviation 2° E, Variation 19° W until twilight when log registered 110 and observed altitude Star Polaris 25° 30' 40" N. IE 1' 10" off arc. HE 28 ft. WT 5h 40m 18s. C-W 2h 28m 11s. CC 4m 15s slow. Changed course to SE x E ¾ E, same Variation and Deviation, and steamed on this course until about 8:30 P.M. when observed altitude of Star Markab, West of meridian, 59° 48' 10". Log registered 157. WT 8h 34m 48s. C-W 2h 28m 11s. Same HE, IE, CC. Steamed on same course until midnight when log registered 210. Changed course to 110° p.s.c. (same Variation and Deviation), and steamed at 12 knots speed until about 8 A.M. when observed altitude ☉ 23° 05' 10" and bearing by compass S 33° E. Variation 19° W. WT 8h 04m 10s, A.M. C-W 2h 28m 11s. Same HE, IE, CC. Continued on same course p.s.c. at a speed of 15 knots per hour until noon when observed meridian altitude ☉ 44" 30' 50" S. Same IE, HE, CC. Log registered 366.

Required 1. D. R. position at noon.
2. Position by observation at noon (corrected for Longitude by a factor).
3. Deviation of Compass at 8:04 A.M.
4. Watch Time of Local Apparent Noon.

ADDITIONAL LECTURE

Compass Adjustment

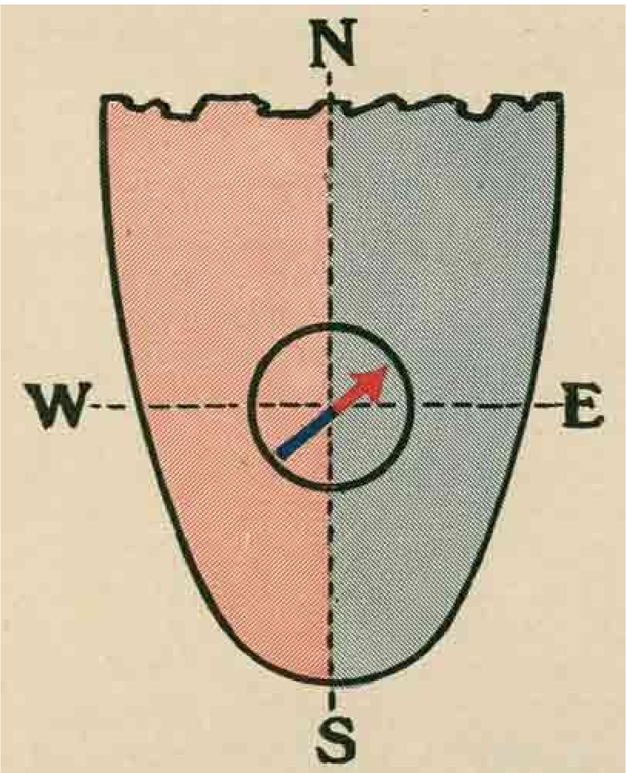
The aim of this lecture is to give you a very few facts about magnetism in general and compass adjustment in particular. The reason for including the lecture in this book is because of repeated requests on the part of graduates who have been consulted about the adjustment of the compass on their ships and who have realized that their advice might have been more helpful if they had learned more about the matter The earth is a huge magnet. It is the effect of the magnetism in the earth upon the compass needle which causes the compass error and makes it necessary to correct it. How can it be corrected? To know that we must first know the fundamental law of magnetism, namely, that opposite poles of two magnets attract each other and similar poles repel each other. From which it follows that if we decide to color red, for instance, that end of a magnetic needle which points to North, the magnetism of that part of the earth must be considered blue, i.e., of opposite magnetism to the north-seeking end of the red magnetic needle.

Now, there are various kinds of magnetism which affect a ship's compass. One is from the earth, another from the iron in the ship, etc. To discuss them and, the theoretical cause of them in detail is beyond the scope of this lecture. To correct them, four sets of magnets are necessary, two of which are usually found in the binnacle of the compass itself. One is a fore and aft magnet or set of magnets, the other an athwartship magnet or set of magnets. The third set consists of the two globes of cast iron placed on either side of the compass bowl (called Quadrantal Correctors). The fourth magnet, or set of magnets, is to correct the compass in case of severe heeling by the ship.

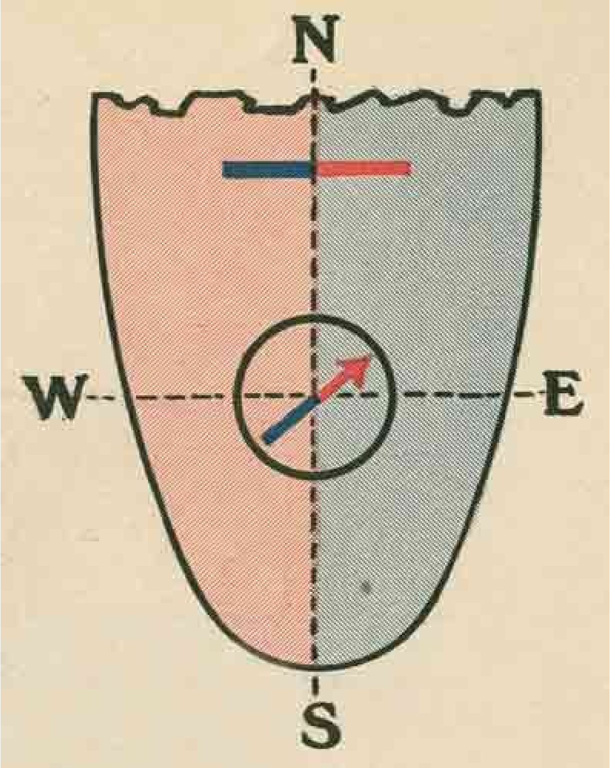
If you are ordered to adjust the compass the first thing to do is to choose a fine day with smooth water. Take your ship to a certain spot, the exact location of which you have found from the chart, and where you are certain you will have plenty of sea-way in which to swing. Set your watch to local apparent time (which you have calculated before coming out). Take from the Azimuth Tables the sun's true bearing for every four minutes of the time during which you will be occupied adjusting, and convert it into the magnetic bearing by applying the variation at the place selected (secured from the chart). Write down in a small book these times and corresponding magnetic bearings.

Now go to your compass and see that its lubber line is exactly fore and aft and in the keel line of the ship. Have another officer who is thoroughly familiar with the pelorus stand by it as the ship is swung. All being ready, secure the lubber's point of the pelorus at North and clamp the sight vane to the sun's magnetic bearing at the time you have figured to take the first heading. Starboard or port your helm until at the time calculated the reflection of the sight vane on the pelorus dial cuts on the proper magnetic bearing. The vessel's head will then be pointing to magnetic North. If, now, the compass were correct it would agree with the pelorus in showing the ship's head to be North. If it does not do so, there is Deviation in the compass and its amount is the amount of Deviation on that particular course. Suppose the Deviation were to starboard, i.e., Easterly, and were due to magnetism in the ship's starboard side. Then, if the magnetism in the North end of the needle be considered red, the magnetism in the starboard side of the vessel, in order to attract the red end of the needle, would be considered blue and the ship's magnetism, with the compass needle included, would look like this:

To counteract this blue attractive force on the starboard side, screw up the athwartship magnet in the binnacle toward the compass dial. Its magnetism, if it were laid on the deck, would look like this:

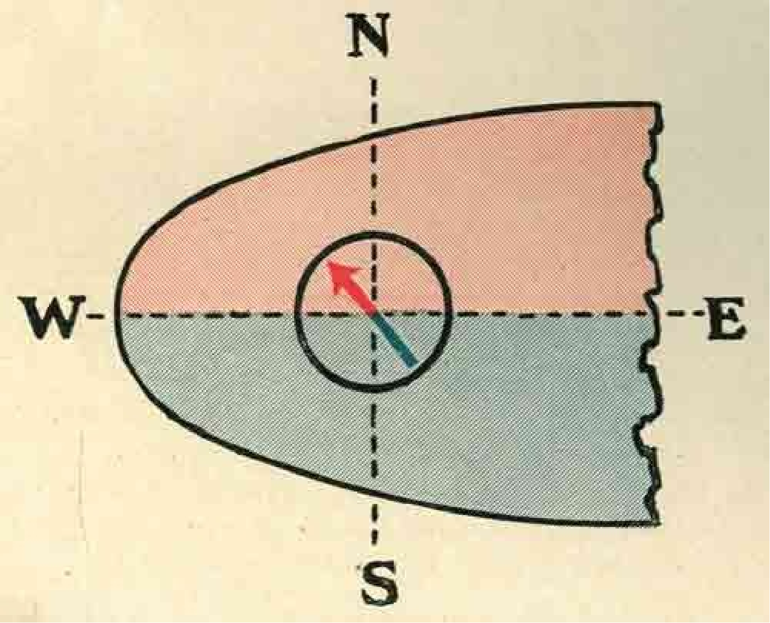


In other words, as this magnet is moved nearer the compass needle, by the law of magnetism just given, the red end of the magnet repels the red end of the compass needle from the starboard side and the blue end of the magnet attracts the red end of the compass needle toward the port side. When the compass needle points to North, as shown by the correct pelorus bearing, the Deviation on this heading (i.e., North) is corrected.



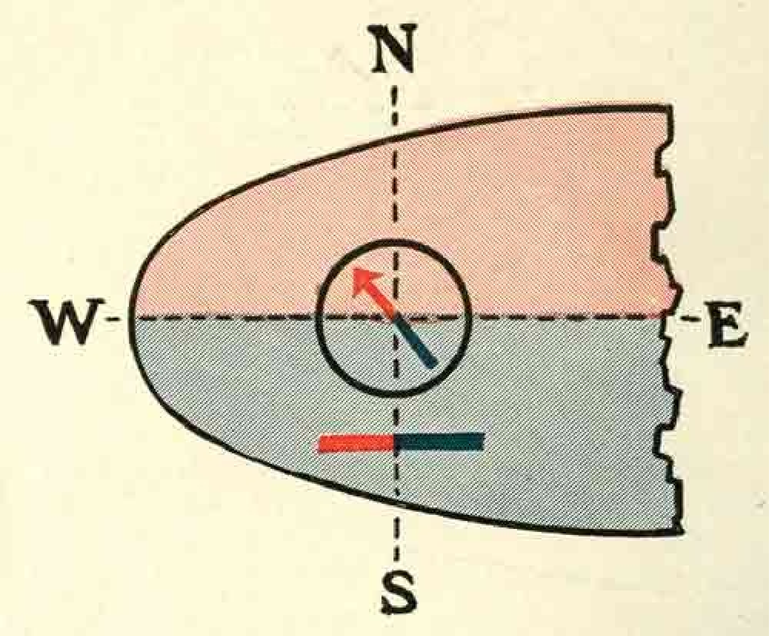
Now turn the lubber line of the pelorus to East. Steady the ship on this heading until the shadow from the pelorus vane at the proper L.A.T. cuts the circumference of the pelorus dial at the proper magnetic bearing. The ship's compass should then show the ship's head pointing to East. Suppose that it does not (as will usually be the case) but points to the right of East. Then the ship's magnetism and compass would look like this:

To bring the compass needle back to North it would be necessary to move up nearer the compass dial the fore-and-aft magnet (shown below), whose magnetism would act on the compass needle on this heading of the ship exactly as the athwartship magnet acted on the compass needle when the ship was headed North:



Now the ship's compass has been corrected for the North and East headings respectively. The next correction is for the heading half way between, i.e., North-east. If there is any Deviation on this heading, adjust the cast iron cylinders (called Quadrantal Correctors), which are on each side of the compass bowl, by moving them toward or away from the compass until the ship's head by compass is North-east at the proper time and bearing by pelorus.

The ship's compass has now been corrected for one whole quadrant, namely, from North to East, and this will suffice for all four quadrants since the relationships of the magnets themselves and the magnetism of the compass needle is the same for any of the other three quadrants as for the first. Compass adjustment, however, can never be absolutely accurate. For that reason, it is wise to steam the ship completely around, steadying on every fifteen degrees by pelorus to determine and keep a record of remaining errors.



There is one more correction to make, i.e., for the heeling error. This correction is necessary in case the ship is yawing in a sea-way so much that the relationship of the ship's magnetism to the compass needle is decidedly different from what it is when the ship is on a comparatively even keel. It is compensated by a vertical magnet directly underneath (or over) the binnacle, details in regard to which can be secured from Bowditch Art. 125, p. 53.d from Bowditch Art. 125, p. 53.

It must be borne in mind that compass adjustment is not an exact science, that an adjustment for one latitude is not correct for another, that anyone of a hundred different causes can affect the magnetism of the ship or of the compass needle, which in turn directly affects the Deviation. In this connection, it would be well to read Bowditch Art. 129, p. 55. You should also read Arts. 119-130 in which are given, more fully and in more scientific language, the contents of this lecture.

Updated editions will replace the previous one—the old editions will be renamed.

Creating the works from print editions not protected by U.S. copyright law means that no one owns a United States copyright in these works, so the Foundation (and you!) can copy and distribute it in the United States without permission and without paying copyright royalties. Special rules, set forth in the General Terms of Use part of this license, apply to copying and distributing Project Gutenberg™ electronic works to protect the PROJECT GUTENBERG™ concept and trademark. Project Gutenberg is a registered trademark, and may not be used if you charge for an eBook, except by following the terms of the trademark license, including paying royalties for use of the Project Gutenberg trademark. If you do not charge anything for copies of this eBook, complying with the trademark license is very easy. You may use this eBook for nearly any purpose such as creation of derivative works, reports, performances and research. Project Gutenberg eBooks may be modified and printed and given away—you may do practically ANYTHING in the United States with eBooks not protected by U.S. copyright law. Redistribution is subject to the trademark license, especially commercial redistribution.

START: FULL LICENSE

THE FULL PROJECT GUTENBERG LICENSE

PLEASE READ THIS BEFORE YOU DISTRIBUTE OR USE THIS WORK

To protect the Project Gutenberg™ mission of promoting the free distribution of electronic works, by using or distributing this work (or any other work associated in any way with the phrase “Project Gutenberg”), you agree to comply with all the terms of the Full Project Gutenberg™ License available with this file or online at www.gutenberg.org/license.

Section 1. General Terms of Use and Redistributing Project Gutenberg™ electronic works

1.A. By reading or using any part of this Project Gutenberg™ electronic work, you indicate that you have read, understand, agree to and accept all the terms of this license and intellectual property (trademark/copyright) agreement. If you do not agree to abide by all the terms of this agreement, you must cease using and return or destroy all copies of Project Gutenberg™ electronic works in your possession. If you paid a fee for obtaining a copy of or access to a Project Gutenberg™ electronic work and you do not agree to be bound by the terms of this agreement, you may obtain a refund from the person or entity to whom you paid the fee as set forth in paragraph 1.E.8.

1.B. “Project Gutenberg” is a registered trademark. It may only be used on or associated in any way with an electronic work by people who agree to be bound by the terms of this agreement. There are a few things that you can do with most Project Gutenberg™ electronic works even without complying with the full terms of this agreement. See paragraph 1.C below. There are a lot of things you can do with Project Gutenberg™ electronic works if you follow the terms of this agreement and help preserve free future access to Project Gutenberg™ electronic works. See paragraph 1.E below.

1.C. The Project Gutenberg Literary Archive Foundation (“the Foundation” or PGLAF), owns a compilation copyright in the collection of Project Gutenberg™ electronic works. Nearly all the individual works in the collection are in the public domain in the United States. If an individual work is unprotected by copyright law in the United States and you are located in the United States, we do not claim a right to prevent you from copying, distributing, performing, displaying or creating derivative works based on the work as long as all references to Project Gutenberg are removed. Of course, we hope that you will support the Project Gutenberg™ mission of promoting free access to electronic works by freely sharing Project Gutenberg™ works in compliance with the terms of this agreement for keeping the Project Gutenberg™ name associated with the work. You can easily comply with the terms of this agreement by keeping this work in the same format with its attached full Project Gutenberg™ License when you share it without charge with others.

1.D. The copyright laws of the place where you are located also govern what you can do with this work. Copyright laws in most countries are in a constant state of change. If you are outside the United States, check the laws of your country in addition to the terms of this agreement before downloading, copying, displaying, performing, distributing or creating derivative works based on this work or any other Project Gutenberg™ work. The Foundation makes no representations concerning the copyright status of any work in any country other than the United States.

1.E. Unless you have removed all references to Project Gutenberg:

1.E.1. The following sentence, with active links to, or other immediate access to, the full Project Gutenberg™ License must appear prominently whenever any copy of a Project Gutenberg™ work (any work on which the phrase “Project Gutenberg” appears, or with which the phrase “Project Gutenberg” is associated) is accessed, displayed, performed, viewed, copied or distributed:

> This eBook is for the use of anyone anywhere in the United States and most other parts of the world at no cost and with almost no restrictions whatsoever. You may

> copy it, give it away or re-use it under the terms of the Project Gutenberg License included with this eBook or online at www.gutenberg.org. If you are not located in the United States, you will have to check the laws of the country where you are located before using this eBook.

1.E.2. If an individual Project Gutenberg™ electronic work is derived from texts not protected by U.S. copyright law (does not contain a notice indicating that it is posted with permission of the copyright holder), the work can be copied and distributed to anyone in the United States without paying any fees or charges. If you are redistributing or providing access to a work with the phrase “Project Gutenberg” associated with or appearing on the work, you must comply either with the requirements of paragraphs 1.E.1 through 1.E.7 or obtain permission for the use of the work and the Project Gutenberg™ trademark as set forth in paragraphs 1.E.8 or 1.E.9.

1.E.3. If an individual Project Gutenberg™ electronic work is posted with the permission of the copyright holder, your use and distribution must comply with both paragraphs 1.E.1 through 1.E.7 and any additional terms imposed by the copyright holder. Additional terms will be linked to the Project Gutenberg™ License for all works posted with the permission of the copyright holder found at the beginning of this work.

1.E.4. Do not unlink or detach or remove the full Project Gutenberg™ License terms from this work, or any files containing a part of this work or any other work associated with Project Gutenberg™.

1.E.5. Do not copy, display, perform, distribute or redistribute this electronic work, or any part of this electronic work, without prominently displaying the sentence set forth in paragraph 1.E.1 with active links or immediate access to the full terms of the Project Gutenberg™ License.

1.E.6. You may convert to and distribute this work in any binary, compressed, marked up, nonproprietary or proprietary form, including any word processing or hypertext form. However, if you provide access to or distribute copies of a Project Gutenberg™ work in a format other than “Plain Vanilla ASCII” or other format used in the official version posted on the official Project Gutenberg™ website (www.gutenberg.org), you must, at no additional cost, fee or expense to the user, provide a copy, a means of exporting a copy, or a means of obtaining a copy upon request, of the work in its original “Plain Vanilla ASCII” or other form. Any alternate format must include the full Project Gutenberg™ License as specified in paragraph 1.E.1.

1.E.7. Do not charge a fee for access to, viewing, displaying, performing, copying or distributing any Project Gutenberg™ works unless you comply with paragraph 1.E.8 or 1.E.9.

1.E.8. You may charge a reasonable fee for copies of or providing access to or distributing Project Gutenberg™ electronic works provided that:

- You pay a royalty fee of 20% of the gross profits you derive from the use of Project Gutenberg™ works calculated using the method you already use to calculate your applicable taxes. The fee is owed to the owner of the Project Gutenberg™ trademark, but he has agreed to donate royalties under this paragraph to the Project Gutenberg Literary Archive Foundation. Royalty payments must be paid within 60 days following each date on which you prepare (or are legally required to prepare) your periodic tax returns. Royalty payments should be clearly marked as such and sent to the Project Gutenberg Literary Archive Foundation at the address specified in Section 4, “Information about donations to the Project Gutenberg Literary Archive Foundation.”

- You provide a full refund of any money paid by a user who notifies you in writing (or by e-mail) within 30 days of receipt that s/he does not agree to the terms of the full Project Gutenberg™ License. You must require such a user to return or destroy all copies of the works possessed in a physical medium and discontinue all use of and all access to other copies of Project Gutenberg™ works.

- You provide, in accordance with paragraph 1.F.3, a full refund of any money paid for a work or a replacement copy, if a defect in the electronic work is discovered and reported to you within 90 days of receipt of the work.

- You comply with all other terms of this agreement for free distribution of Project Gutenberg™ works.

1.E.9. If you wish to charge a fee or distribute a Project Gutenberg™ electronic work or group of works on different terms than are set forth in this agreement, you must obtain permission in writing from the Project Gutenberg Literary Archive Foundation, the manager of the Project Gutenberg™ trademark. Contact the Foundation as set forth in Section 3 below.

1.F.

1.F.1. Project Gutenberg volunteers and employees expend considerable effort to identify, do copyright research on, transcribe and proofread works not protected by U.S. copyright law in creating the Project Gutenberg™ collection. Despite these efforts, Project Gutenberg™ electronic works, and the medium on which they may be stored, may contain “Defects,” such as, but not limited to, incomplete, inaccurate or corrupt data, transcription errors, a copyright or other intellectual property infringement, a defective or damaged disk or other medium, a computer virus, or computer codes that damage or cannot be read by your equipment.

1.F.2. LIMITED WARRANTY, DISCLAIMER OF DAMAGES - Except for the “Right of Replacement or Refund” described in paragraph 1.F.3, the Project Gutenberg Literary Archive Foundation, the owner of the Project Gutenberg™ trademark, and any other party distributing a Project Gutenberg™ electronic work under this agreement, disclaim all liability to you for damages, costs and expenses, including legal fees. YOU AGREE THAT YOU HAVE NO REMEDIES FOR NEGLIGENCE, STRICT LIABILITY, BREACH OF WARRANTY OR BREACH OF CONTRACT EXCEPT THOSE PROVIDED IN PARAGRAPH 1.F.3. YOU AGREE THAT THE FOUNDATION, THE TRADEMARK OWNER, AND ANY DISTRIBUTOR UNDER THIS AGREEMENT WILL NOT BE LIABLE TO YOU FOR ACTUAL, DIRECT, INDIRECT, CONSEQUENTIAL, PUNITIVE OR INCIDENTAL DAMAGES EVEN IF YOU GIVE NOTICE OF THE POSSIBILITY OF SUCH DAMAGE.

1.F.3. LIMITED RIGHT OF REPLACEMENT OR REFUND - If you discover a defect in this electronic work within 90 days of receiving it, you can receive a refund of the money (if any) you paid for it by sending a written explanation to the person you received the work from. If you received the work on a physical medium, you must return the medium with your written explanation. The person or entity that provided you with the defective work may elect to provide a replacement copy in lieu of a refund. If you received the work electronically, the person or entity providing it to you may choose to give you a second opportunity to receive the work electronically in lieu of a refund. If the second copy is also defective, you may demand a refund in writing without further opportunities to fix the problem.

1.F.4. Except for the limited right of replacement or refund set forth in paragraph 1.F.3, this work is provided to you ‘AS-IS’, WITH NO OTHER WARRANTIES OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY OR FITNESS FOR ANY PURPOSE.

1.F.5. Some states do not allow disclaimers of certain implied warranties or the exclusion or limitation of certain types of damages. If any disclaimer or limitation set forth in this agreement violates the law of the state applicable to this agreement, the agreement shall be interpreted to make the maximum disclaimer or limitation permitted by the applicable state law. The invalidity or unenforceability of any provision of this agreement shall not void the remaining provisions.

1.F.6. INDEMNITY - You agree to indemnify and hold the Foundation, the trademark owner, any agent or employee of the Foundation, anyone providing copies of Project Gutenberg™ electronic works in accordance with this agreement, and any volunteers associated with the production, promotion and distribution of Project Gutenberg™ electronic works, harmless from all liability, costs and expenses, including legal fees, that arise directly or indirectly from any of the following which you do or cause to occur: (a) distribution of this or any Project Gutenberg™ work, (b) alteration, modification, or additions or deletions to any Project Gutenberg™ work, and (c) any Defect you cause.

Section 2. Information about the Mission of Project Gutenberg™

Project Gutenberg™ is synonymous with the free distribution of electronic works in formats readable by the widest variety of computers including obsolete, old, middle-aged and new computers. It exists because of the efforts of hundreds of volunteers and donations from people in all walks of life.

Volunteers and financial support to provide volunteers with the assistance they need are critical to reaching Project Gutenberg™’s goals and ensuring that the Project Gutenberg™ collection will remain freely available for generations to come. In 2001, the Project Gutenberg Literary Archive Foundation was created to provide a secure and permanent future for Project Gutenberg™ and future generations. To learn more about the Project Gutenberg Literary Archive Foundation and how your efforts and donations can help, see Sections 3 and 4 and the Foundation information page at www.gutenberg.org.

Section 3. Information about the Project Gutenberg Literary Archive Foundation

The Project Gutenberg Literary Archive Foundation is a non-profit 501(c)(3) educational corporation organized under the laws of the state of Mississippi and granted tax exempt status by the Internal Revenue Service. The Foundation’s EIN or federal tax identification number is 64-6221541. Contributions to the Project Gutenberg Literary Archive Foundation are tax deductible to the full extent permitted by U.S. federal laws and your state’s laws.

The Foundation’s business office is located at 809 North 1500 West, Salt Lake City, UT 84116, (801) 596-1887. Email contact links and up to date contact information can be found at the Foundation’s website and official page at www.gutenberg.org/contact

Section 4. Information about Donations to the Project Gutenberg Literary Archive Foundation

Project Gutenberg™ depends upon and cannot survive without widespread public support and donations to carry out its mission of increasing the number of public domain and licensed works that can be freely distributed in machine-readable form accessible by the widest array of equipment including outdated equipment. Many small donations ($1 to $5,000) are particularly important to maintaining tax exempt status with the IRS.

The Foundation is committed to complying with the laws regulating charities and charitable donations in all 50 states of the United States. Compliance requirements are not uniform and it takes a considerable effort, much paperwork and many fees to meet and keep up with these requirements. We do not solicit donations in locations where we have not received written confirmation of compliance. To SEND DONATIONS or determine the status of compliance for any particular state visit www.gutenberg.org/donate.

While we cannot and do not solicit contributions from states where we have not met the solicitation requirements, we know of no prohibition against accepting unsolicited donations from donors in such states who approach us with offers to donate.

International donations are gratefully accepted, but we cannot make any statements concerning tax treatment of donations received from outside the United States. U.S. laws alone swamp our small staff.

Please check the Project Gutenberg web pages for current donation methods and addresses. Donations are accepted in a number of other ways including checks, online payments and credit card donations. To donate, please visit: www.gutenberg.org/donate

Section 5. General Information About Project Gutenberg™ electronic works

Professor Michael S. Hart was the originator of the Project Gutenberg™ concept of a library of electronic works that could be freely shared with anyone. For forty years, he produced and distributed Project Gutenberg™ eBooks with only a loose network of volunteer support.

Project Gutenberg™ eBooks are often created from several printed editions, all of which are confirmed as not protected by copyright in the U.S. unless a copyright notice is included. Thus, we do not necessarily keep eBooks in compliance with any particular paper edition.

Most people start at our website which has the main PG search facility: www.gutenberg.org.

This website includes information about Project Gutenberg™, including how to make donations to the Project Gutenberg Literary Archive Foundation, how to help produce our new eBooks, and how to subscribe to our email newsletter to hear about new eBooks.