A. Ahlbergh

SIMPLE RULES
AND
PROBLEMS IN NAVIGATION

BY

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Licensed Master Mariner

Corrected and Revised by

BRADLEY JONES

THIRD AND REVISED EDITION

NEW YORK

E. P. DUTTON & COMPANY

681 FIFTH AVENUE

Printed in the United States of America

TO

Mr. Henry Howard

DIRECTOR OF RECRUITING SERVICE
UNITED STATES SHIPPING BOARD

As a mark of appreciation of the Service rendered by him in replacing the American Flag to its proper place upon the Seven Seas, this work is respectfully dedicated.

The Author also wishes to extend his thanks to

Captain ROBERT J. McBRIDE
UNITED STATES LOCAL INSPECTOR OF HULLS
New Orleans, La.

Captain ERNEST E. B. DRAKE
ATLANTIC COAST SUPERVISOR OF RECRUITING SERVICE
UNITED STATES SHIPPING BOARD

MR. BRADLEY JONES
INSTRUCTOR OF NAVIGATION
UNITED STATES SHIPPING BOARD SCHOOL
Boston, Mass.

MR. WALTON B. SMITH
INSTRUCTOR OF NAVIGATION
UNITED STATES SHIPPING BOARD SCHOOL
New Orleans, La.

For their kind co-operation in compiling the information contained herein.

PREFACE TO THIRD EDITION

In this edition the problems have been worked to a finer degree of accuracy than before. The interpolations used are sufficient to satisfy the strictest local inspector or the most rigid sea practice.

While it is true that all positions obtained at sea, are subject to slight error; to the necessary observational errors there should not be added errors due to not using the tables to the limit of their accuracy.

Bradley Jones.

PREFACE TO THIRD AND REVISED EDITION

The purpose of this book is to lay before the student all the rules and problems of navigation used in everyday work at sea, with short definitions of the theory of navigation, and other useful information that the young officer should know.

In making up the rules for working the problems, the author may have repeated himself several times, but it has been his experience in teaching navigation that this is necessary to make the student understand.

All of the various problems are worked out in full, with no attempt to save figures or cut down the working in any way. It is recommended to the beginner that he names everything as he goes along in his problems, as it will help to memorize.

In addition to all the problems of the First Edition, there are examples for practice with their answers, and the abstract from the American Nautical Almanac for the year 1919 for working the different problems.

Several additional features have been embodied in this edition including " The International Rule of the Road at Sea "; " A Method of Preparing a Station Bill for Boat and Fire Drill "; and " New Methods of finding latitude and longitude."

This places the entire subject of navigation under one cover, and the author believes it to be the most easily understood one published.

There are many excellent books on the theory of navigation, but very few that the ordinary man can understand, and this book has been published with theory eliminated entirely.

One of the greatest faults with navigators of to-day is their tendency to try and cut down figures in their problems. There is no excuse for this, as a man at sea has plenty of time to work his problems, and it has been this tendency for rule of thumb methods that has been the loss of many a ship. It is time enough to learn the short methods after you know the proper way, and have had several years of practical experience.

The books used in working the different problems are Bowditch's American Practical Navigator, American Line of Position Tables, American Azimuth Table and 1919 American Nautical Almanac.

The books of the First and Second Edition have been gone over carefully by several competent navigators, and all the examples are worked to the closest figure.

It is hoped that this book will be a help to the reader, as the author has tried to make it in as plain language as possible.

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INTERNATIONAL RULES

I.—ENACTING CLAUSE, SCOPE, AND PENALTY

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following regulations for preventing collisions at sea shall be followed by all public and private vessels of the United States upon the high seas and in all waters connected therewith, navigable by seagoing vessels.

Art. 30. Nothing in these rules shall interfere with the operation of a special rule, duly made by local authority, relative to the navigation of any harbor, river, or inland waters.

PRELIMINARY DEFINITIONS

In the following rules every steam vessel which is under sail and not under steam is to be considered a sailing vessel, and every vessel under steam, whether under sail or not, is to be considered a steam vessel.

The words "steam vessel" shall include any vessel propelled by machinery.

A vessel is "under way," within the meaning of these rules, when she is not at anchor, or made fast to the shore, or aground.

II.—LIGHTS, AND SO FORTH

The word "visible" in these rules when applied to lights shall mean visible on a dark night with a clear atmosphere.

INLAND RULES

I.—ENACTING CLAUSE, SCOPE, AND PENALTY

Whereas the provisions of chapter eight hundred and two of the laws of eighteen hundred and ninety, and the amendments thereto, adopting regulations for preventing collisions at sea [i.e., international rules of left-hand column], apply to all waters of the United States connected with the high seas navigable by sea-going vessels, except so far as the navigation of any harbor, river, or inland waters is regulated by special rules duly made by local authority; and

Whereas it is desirable that the regulations relating to the navigation of all harbors, rivers, and inland waters of the United States, except the Great Lakes and their connecting and tributary waters as far east as Montreal and the Red River of the North and rivers emptying into the Gulf of Mexico and their tributaries, shall be stated in one act: Therefore,

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled. That the following regulations for preventing collisions shall be followed by all vessels navigating all harbors, rivers, and inland waters of the United States, except the Great Lakes and their connecting and tributary waters as far east as Montreal and the Red River of the North and rivers emptying into the Gulf of Mexico and their tributaries, and are hereby declared special rules duly made by local authority:

Sec. 3. That every pilot, engineer, mate, or master of any steam vessel, and every master or mate of any barge or canal boat, who neglects or refuses to observe the provisions of this act, or the regulations established in pursuance of the preceding section [see section 2, page 4], shall be liable to a penalty of fifty dollars, and for all damages sustained by any passenger in his person or baggage by such neglect or refusal: Provided, That nothing herein shall relieve any vessel, owner, or corporation from any liability incurred by reason of such neglect or refusal.

Sec. 4. That every vessel that shall be navigated without complying with the provisions of this act shall be liable to a penalty of two hundred dollars, one-half to go to the informer, for which sum the vessel so navigated shall be liable and may be seized and proceeded against by action in any district court of the United States having jurisdiction of the offense.

PRELIMINARY DEFINITIONS

In the following rules every steam vessel which is under sail and not under steam is to be considered a sailing vessel, and every vessel under steam whether under sail or not, is to be considered a steam vessel.

The words " steam vessel " shall include any vessel propelled by machinery.

A vessel is " under way," within the meaning of these rules, when she is not at anchor, or made fast to the shore, or aground.

II.—LIGHTS, AND SO FORTH

The word " visible " in these rules, when applied to lights, shall mean visible on a dark night with a clear atmosphere.

INTERNATIONAL RULES

Article 1. The rules concerning lights shall be complied with in all weathers from sunset to sunrise, and during such time no other lights which may be mistaken for the prescribed lights shall be exhibited.

STEAM VESSELS—MASTHEAD LIGHT

Art. 2. A steam vessel when under way shall carry—(a) On or in front of the foremast, or if a vessel without a foremast, then in the fore part of the vessel, at a height above the hull of not less than twenty feet, and if the breadth of the vessel exceeds twenty feet, then at a height above the hull not less than such breadth, so, however, that the light need not be carried at a greater height above the hull than forty feet, a bright white light, so constructed as to show an unbroken light over an arc of the horizon of twenty points of the compass, so fixed as to throw the light ten points on each side of the vessel, namely, from right ahead to two points abaft the beam on either side, and of such a character as to be visible at a distance of at least five miles.

STEAM VESSELS—SIDE LIGHTS

(b) On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the starboard side, and of such a character as to be visible at a distance of at least two miles.

(c) On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the port side, and of such a character as to be visible at a distance of at least two miles.

(d) The said green and red side lights shall be fitted with inboard screens projecting at least three feet forward from the light, so as to prevent these lights from being seen across the bow.

STEAM VESSELS—RANGE LIGHTS

(e) A steam vessel when under way may carry an additional white light similar in construction to the light mentioned in subdivision (a). These two lights shall be so placed in line with the keel that one shall be at least fifteen feet higher than the other, and in such a position with reference to each other that the lower light shall be forward of the upper one. The vertical distance between these lights shall be less than the horizontal distance.

INLAND RULES

ARTICLE 1. The rules concerning lights shall be complied with in all weathers from sunset to sunrise, and during such time no other lights which may be mistaken for the prescribed lights shall be exhibited.

STEAM VESSELS—MASTHEAD LIGHT

ART. 2. A steam vessel when under way shall carry—(a) On or in the front of the foremast, or if a vessel without a foremast, then in the fore part of the vessel, a bright white light so constructed as to show an unbroken light over an arc of the horizon of twenty points of the compass, so fixed as to throw the light ten points on each side of the vessel, namely, from right ahead to two points abaft the beam on either side, and of such a character as to be visible at a distance of at least five miles.

STEAM VESSELS—SIDE LIGHTS

(b) On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the starboard side, and of such a character as to be visible at a distance of at least two miles.

(c) On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the port side, and of such a character as to be visible at a distance of at least two miles.

(d) The said green and red side lights shall be fitted with inboard screens projecting at least three feet forward from the light, so as to prevent these lights from being seen across the bow.

STEAM VESSELS—RANGE LIGHTS

(e) A seagoing steam vessel when under way may carry an additional white light similar in construction to the light mentioned in subdivision (a). These two lights shall be so placed in line with the keel that one shall be at least fifteen feet higher than the other, and in such a position with reference to each other that the lower light shall be forward of the upper one. The vertical distance between these lights shall be less than the horizontal distance.

(f) All steam vessels (except seagoing vessels and ferryboats), shall carry in addition to green and red lights required by article two (b), (c), and screens as required by article two (d), a central range of two white lights; the after light being carried at an elevation at least fifteen feet above the light at the head of the vessel. The headlight shall be so constructed as to show an unbroken light through twenty points of the compass, namely, from right ahead to two points abaft the beam on either side of the vessel, and the after light so as to show all around the horizon.

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STEAM VESSELS WHEN TOWING

ART 3. A steam vessel when towing another vessel shall, in addition to her side lights, carry two bright white lights in a vertical line one over the other, not less than six feet apart, and when towing more than one vessel shall carry an additional bright white light six feet above or below such lights, if the length of the tow measuring from the stern of the towing vessel to the stern of the last vessel towed exceeds six hundred feet. Each of these lights shall be of the same construction and character, and shall be carried in the same position as the white light mentioned in article two (a), excepting the additional light, which may be carried at a height of not less than fourteen feet above the hull.

Such steam vessel may carry a small white light abaft the funnel or aftermast for the vessel towed to steer by, but such light shall not be visible forward of the beam.

SPECIAL LIGHTS

ART. 4. (a) A vessel which from any accident is not under command shall carry at the same height as a white light mentioned in article two (a), where they can best be seen, and if a steam vessel in lieu of that light two red lights, in a vertical line one over the other, not less than six feet apart, and of such a character as to be visible all around the horizon at a distance of at least two miles; and shall by day carry in a vertical line one over the other, not less than six feet apart, where they can best be seen, two black balls or shapes, each two feet in diameter.

(b) A vessel employed in laying or in picking up a telegraph cable shall carry in the same position as the white light mentioned in article two (a), and if a steam vessel in lieu of that light three lights in a vertical line one over the other not less than six feet apart. The highest and lowest of these lights shall be red, and the middle light shall be white, and they shall be of such a character as to be visible all around the horizon, at a distance of at least two miles. By day she shall carry in a vertical line, one over the other, not less than six feet apart, where they can best be seen, three shapes not less than two feet in diameter, of which the highest and lowest shall be globular in shape and red in color, and the middle one diamond in shape and white.

(c) The vessels referred to in this article, when not making way through the water, shall not carry the side lights, but when making way shall carry them.

(d) The lights and shapes required to be shown by this article are to be taken by other vessels as signals that the vessel showing them is not under command and can not therefore get out of the way.

These signals are not signals of vessels in distress and requiring assistance. Such signals are contained in article thirty-one.

LIGHTS FOR SAILING VESSELS AND VESSELS IN TOW

ART. 5. A sailing vessel under way and any vessel being towed shall carry the same lights as are prescribed by article two for a steam vessel under way, with the exception of the white lights mentioned therein, which they shall never carry.

INLAND RULES

STEAM VESSELS WHEN TOWING

Art. 3. A steam vessel when towing another vessel shall, in addition to her side lights, carry two bright white lights in a vertical line one over the other, not less than three feet apart, and when towing more than one vessel shall carry an additional bright white light three feet above or below such lights, if the length of the tow measuring from the stern of the towing vessel to the stern of the last vessel towed exceeds six hundred feet. Each of these lights shall be of the same construction and character, and shall be carried in the same position as the white light mentioned in article two (a) or the after range light mentioned in article two (f).

Such steam vessel may carry a small white light abaft the funnel or aftermast for the vessel towed to steer by, but such light shall not be visible forward of the beam.

LIGHTS FOR SAILING VESSELS AND VESSELS IN TOW

Art. 5. A sailing vessel under way or being towed shall carry the same lights as are prescribed by article two for a steam vessel under way, with the exception of the white lights mentioned therein, which they shall never carry.

INTERNATIONAL RULES

LIGHTS FOR SMALL VESSELS

Art. 6. Whenever, as in the case of small vessels under way during bad weather, the green and red side lights can not be fixed, these lights shall be kept at hand, lighted and ready for use; and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient time to prevent collision, in such manner as to make them most visible, and so that the green light shall not be seen on the port side nor the red light on the starboard side, nor, if practicable, more than two points abaft the beam on their respective sides. To make the use of these portable lights more certain and easy the lanterns containing them shall each be painted outside with the color of the light they respectively contain, and shall be provided with proper screens.

LIGHTS FOR SMALL STEAM AND SAIL VESSELS AND OPEN BOATS

Art. 7. Steam vessels of less than forty, and vessels under oars or sails of less than twenty tons gross tonnage, respectively, and rowing boats, when under way, shall not be required to carry the lights mentioned in article two (a), (b), and (c), but if they do not carry them they shall be provided with the following lights:

First. Steam vessels of less than forty tons shall carry—

(a) In the fore part of the vessel, or on or in front of the funnel, where it can best be seen, and at a height above the gunwale of not less than nine feet, a bright white light constructed and fixed as prescribed in article two (a), and of such a character as to be visible at a distance of at least two miles.

(b) Green and red side lights constructed and fixed as prescribed in article two (b) and (c), and of such a character as to be visible at a distance of at least one mile, or a combined lantern showing a green light and a red light from right ahead to two points abaft the beam on their respective sides. Such lanterns shall be carried not less than three feet below the white light.

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LIGHTS FOR FERRYBOATS, BARGES, AND CANAL BOATS IN TOW

Sec. 2. That the supervising inspectors of steam vessels and the Supervising Inspector-General shall establish such rules to be observed by steam vessels in passing each other and as to the lights to be carried by ferryboats and by barges and canal boats when in tow of steam vessels (and as to the lights and day signals to be carried by vessels, dredges of all types, and vessels working on wrecks by [or] other obstruction to navigation or moored for submarine operations, or made fast to a sunken object which may drift with the tide or be towed) not inconsistent with the provisions of this act, as they from time to time may deem necessary for safety, which rules when approved by the Secretary of Commerce are hereby declared special rules duly made by local authority, as provided for in article thirty of chapter eight hundred and two of the laws of eighteen hundred and ninety. Two printed copies of such rules shall be furnished to such ferryboats (barges, dredges, canal boats, vessels working on wrecks) and steam vessels, which rules shall be kept posted up in conspicuous places in such vessels (barges, dredges, and boats).

LIGHTS FOR SMALL VESSELS

Art. 6. Whenever, as in the case of vessels of less than ten gross tons under way during bad weather, the green and red side lights can not be fixed, these lights shall be kept at hand, lighted and ready for use; and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient time to prevent collision, in such manner as to make them most visible, and so that the green light shall not be seen on the port side nor the red light on the starboard side, nor, if practicable, more than two points abaft the beam on their respective sides. To make the use of these portable lights more certain and easy the lanterns containing them shall each be painted outside with the color of the light they respectively contain, and shall be provided with proper screens.

Art. 7. Rowing boats whether under oars or sail, shall have ready at hand a lantern showing a white light which shall be temporarily exhibited in sufficient time to prevent collision.

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Second. Small steamboats, such as are carried by seagoing vessels, may carry the white light at a less height than nine feet above the gunwale, but it shall be carried above the combined lantern mentioned in subdivision one (b).

Third. Vessels under oars or sails of less than twenty tons shall have ready at hand a lantern with a green glass on one side and a red glass on the other, which, on the approach of or to other vessels, shall be exhibited in sufficient time to prevent collision so that the green light shall not be seen on the port side nor the red light on the starboard side.

Fourth. Rowing boats, whether under oars or sail, shall have ready at hand a lantern showing a white light which shall be temporarily exhibited in sufficient time to prevent collision.

The vessels referred to in this article shall not be obliged to carry the lights prescribed by article four (a) and article eleven, last paragraph.

LIGHTS FOR PILOT VESSELS

Art. 8. Pilot vessels when engaged on their station on pilotage duty shall not show the lights required for other vessels, but shall carry a white light at the masthead, visible all around the horizon, and shall also exhibit a flare-up light or flare-up lights at short intervals, which shall never exceed fifteen minutes.

On the near approach of or to other vessels they shall have their side lights lighted, ready for use, and shall flash or show them at short intervals, to indicate the direction in which they are heading, but the green light shall not be shown on the port side, nor the red light on the starboard side.

A pilot vessel of such a class as to be obliged to go alongside of a vessel to put a pilot on board may show the white light instead of carrying it at the masthead, and may, instead of the colored lights above mentioned, have at hand, ready for use, a lantern with green glass on the one side and red glass on the other, to be used as prescribed above.

Pilot vessels when not engaged on their station on pilotage duty shall carry lights similar to those of other vessels of their tonnage.

A steam pilot vessel, when engaged on her station on pilotage duty and in waters of the United States, and not at anchor, shall, in addition to the lights required for all pilot boats, carry at a distance of eight feet below her white masthead light a red light, visible all around the horizon and of such a character as to be visible on a dark night with a clear atmosphere at a distance of at least two miles, and also the colored side lights required to be carried by vessels when under way.

When engaged on her station on pilotage duty and in waters of the United States, and at anchor, she shall carry in addition to the lights required for all pilot boats the red light above mentioned, but not the colored side lights. When not engaged on her station on pilotage duty, she shall carry the same lights as other steam vessels.

LIGHTS, ETC., OF FISHING VESSELS

Art. 9. Fishing vessels and fishing boats, when under way and when not required by this article to carry or show the lights hereinafter specified, shall carry or show the lights prescribed for vessels of their tonnage under way.

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LIGHTS FOR PILOT VESSELS

Art. 8. Pilot vessels when engaged on their stations on pilotage duty shall not show the lights required for other vessels, but shall carry a white light at the masthead, visible all around the horizon, and shall also exhibit a flare-up light or flare-up lights at short intervals, which shall never exceed fifteen minutes.

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When engaged on her station on pilotage duty and in waters of the United States, and at anchor, she shall carry in addition to the lights required for all pilot boats the red light above mentioned, but not the colored side lights. When not engaged on her station on pilotage duty, she shall carry the same lights as other steam vessels.

LIGHTS, ETC., OF FISHING VESSELS

Art. 9. (a) Fishing vessels of less than ten gross tons, when under way and when not having their nets, trawls, dredges, or lines in the water, shall not be obliged to carry the colored side lights; but every such vessel shall, in lieu thereof, have ready at hand a lantern with a green glass on

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(a) Open boats, by which is to be understood boats not protected from the entry of sea water by means of a continuous deck, when engaged in any fishing at night, with outlying tackle extending not more than one hundred and fifty feet horizontally from the boat into the seaway, shall carry one all-round white light.

Open boats, when fishing at night, with outlying tackle extending more than one hundred and fifty feet horizontally from the boat into the seaway, shall carry one all-round white light, and in addition, on approaching or being approached by other vessels, shall show a second white light at least three feet below the first light and at a horizontal distance of at least five feet away from it in the direction in which the outlying tackle is attached.

(b) Vessels and boats, except open boats as defined in subdivision (a), when fishing with drift nets, shall, so long as the nets are wholly or partly in the water, carry two white lights where they can best be seen. Such lights shall be placed so that the vertical distance between them shall be not less than six feet and not more than fifteen feet, and so that the horizontal distance between them, measured in a line with the keel, shall be not less than five feet and not more than ten feet. The lower of these two lights shall be in the direction of the nets, and both of them shall be of such a character as to show all around the horizon, and to be visible at a distance of not less than three miles.

Within the Mediterranean Sea and in the seas bordering the coasts of Japan and Korea sailing fishing vessels of less than twenty tons gross tonnage shall not be obliged to carry the lower of these two lights. Should they, however, not carry it, they shall show in the same position (in the direction of the net or gear) a white light, visible at a distance of not less than one sea mile, on the approach of or to other vessels.

(c) Vessels and boats, except open boats as defined in subdivision (a), when line fishing with their lines out and attached to or hauling their lines, and when not at anchor or stationary within the meaning of subdivision (h), shall carry the same lights as vessels fishing with drift nets. When shooting lines, or fishing with towing lines, they shall carry the lights prescribed for a steam or sailing vessel under way, respectively.

Within the Mediterranean Sea and in the seas bordering the coasts of Japan and Korea sailing fishing vessels of less than twenty tons gross tonnage shall not be obliged to carry the lower of these two lights. Should they, however, not carry it, they shall show in the same position (in the direction of the lines) a white light, visible at a distance of not less than one sea mile on the approach of or to other vessels.

(d) Vessels when engaged in trawling, by which is meant the dragging of an apparatus along the bottom of the sea—

First, if steam vessels, shall carry in the same position as the white light mentioned in article two (a) a tri-colored lantern so constructed and fixed as to show a white light from right ahead to two points on each bow, and a green light and a red light over an arc of the horizon from two points on each bow to two points abaft the beam on the starboard and port sides, respectively; and not less than six nor more than twelve feet below the tri-colored lantern a white light in a lantern, so constructed as to show a clear, uniform and unbroken light all around the horizon.

Second, if sailing vessels, shall carry a white light in a lantern, so constructed as to show a clear, uniform, and unbroken light all around

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one side and a red glass on the other side, and on approaching to or being approached by another vessel such lantern shall be exhibited in sufficient time to prevent collision, so that the green light shall not be seen on the port side nor the red light on the starboard side.

(b) All fishing vessels and fishing boats of ten gross tons or upward, when under way and when not having their nets, trawls, dredges, or lines in the water, shall carry and show the same lights as other vessels under way.

(c) All vessels, when trawling, dredging, or fishing with any kind of drag nets or lines, shall exhibit from some part of the vessel where they can be best seen, two lights. One of these lights shall be red and the other shall be white. The red light shall be above the white light, and shall be at a vertical distance from it of not less than six feet and not more than twelve feet; and the horizontal distance between them, if any, shall not be more than ten feet. These two lights shall be of such a character and contained in lanterns of such construction as to be visible all round the horizon, the white light a distance of not less than three miles and the red light of not less than two miles.

LIGHTS FOR RAFTS OR OTHER CRAFT NOT PROVIDED FOR

(d) Rafts, or other water craft not herein provided for, navigating by hand power, horse power, or by the current of the river, shall carry one or more good white lights, which shall be placed in such manner as shall be prescribed by the Board of Supervising Inspectors of Steam Vessels.

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the horizon, and shall also, on the approach of or to other vessels, show where it can best be seen a white flare-up light or torch in sufficient time to prevent collision.

All lights mentioned in subdivision (d) first and second shall be visible at a distance of at least two miles.

(e) Oyster dredgers and other vessels fishing with dredge nets shall carry and show the same lights as trawlers.

(f) Fishing vessels and fishing boats may at any time use a flare-up light in addition to the lights which they are by this article required to carry and show, and they may also use working lights.

(g) Every fishing vessel and every fishing boat under one hundred and fifty feet in length, when at anchor, shall exhibit a white light visible all around the horizon at a distance of at least one mile.

Every fishing vessel of one hundred and fifty feet in length or upward, when at anchor, shall exhibit a white light visible all around the horizon at a distance of at least one mile, and shall exhibit a second light as provided for vessels of such length by article eleven.

Should any such vessel, whether under one hundred and fifty feet in length or of one hundred and fifty feet in length or upward, be attached to a net or other fishing gear, she shall on the approach of other vessels show an additional white light at least three feet below the anchor light, and at a horizontal distance of at least five feet away from it in the direction of the net or gear.

(h) If a vessel or boat when fishing becomes stationary in consequence of her gear getting fast to a rock or other obstruction, she shall in daytime haul down the day signal required by subdivision (k); at night show the light or lights prescribed for a vessel at anchor; and during fog, mist, falling snow, or heavy rain storms make the signal prescribed for a vessel at anchor. (See subdivision (d) and the last paragraph of article fifteen.)

(i) In fog, mist, falling snow, or heavy rain storms drift-net vessels attached to their nets, and vessels when trawling, dredging, or fishing with any kind of drag net, and vessels line fishing with their lines out, shall, if of twenty tons gross tonnage or upward, respectively, at intervals of not more than one minute make a blast; if steam vessels, with the whistle or siren, and if sailing vessels, with the fog-horn, each blast to be followed by ringing the bell. Fishing vessels and boats of less than twenty tons gross tonnage shall not be obliged to give the above-mentioned signals; but if they do not, they shall make some other efficient sound signal at intervals of not more than one minute.

(k) All vessels or boats fishing with nets or lines or trawls, when under way, shall in daytime indicate their occupation to an approaching vessel by displaying a basket or other efficient signal where it can best be seen. If vessels or boats at anchor have their gear out, they shall, on the approach of other vessels, show the same signal on the side on which those vessels can pass.

The vessels required by this article to carry or show the lights hereinbefore specified shall not be obliged to carry the lights prescribed by article four (a) and the last paragraph of article eleven.

INLAND RULES

INTERNATIONAL RULES

LIGHTS FOR AN OVERTAKEN VESSEL

ART. 10. A vessel which is being overtaken by another shall show from her stern to such last-mentioned vessel a white light or a flare-up light.

The white light required to be shown by this article may be fixed and carried in a lantern, but in such case the lantern shall be so constructed, fitted, and screened that it shall throw an unbroken light over an arc of the horizon of twelve points of the compass, namely, for six points from right aft on each side of the vessel, so as to be visible at a distance of at least one mile. Such light shall be carried as nearly as practicable on the same level as the side lights.

ANCHOR LIGHTS

ART. 11. A vessel under one hundred and fifty feet in length when at anchor shall carry forward, where it can best be seen, but at a height not exceeding twenty feet above the hull, a white light, in a lantern so constructed as to show a clear, uniform, and unbroken light visible all around the horizon at a distance of at least one mile.

A vessel of one hundred and fifty feet or upwards in length when at anchor shall carry in the forward part of the vessel, at a height of not less than twenty and not exceeding forty feet above the hull, one such light, and at or near the stern of the vessel, and at such a height that it shall be not less then fifteen feet lower than the forward light, another such light.

The length of a vessel shall be deemed to be the length appearing in her certificate of registry.

A vessel aground in or near a fairway shall carry the above light or lights and the two red lights prescribed by article four (a).

SPECIAL SIGNALS

ART. 12. Every vessel may, if necessary, in order to attract attention, in addition to the lights which she is by these rules required to carry, show a flare-up light or use any detonating signal that can not be mistaken for a distress signal.

NAVAL LIGHTS AND RECOGNITION SIGNALS

ART. 13. Nothing in these rules shall interfere with the operation of any special rules made by the Government of any nation with respect to additional station and signal lights for two or more ships of war or for vessels sailing under convoy, or with the exhibition of recognition signals adopted by shipowners, which have been authorized by their respective Governments and duly registered and published.

STEAM VESSEL UNDER SAIL BY DAY

ART. 14. A steam vessel proceeding under sail only, but having her funnel up, shall carry in daytime, forward, where it can best be seen, one black ball or shape two feet in diameter.

INLAND RULES

LIGHTS FOR AN OVERTAKEN VESSEL

ART. 10. A vessel which is being overtaken by another, except a steam vessel with an after range light showing all around the horizon, shall show from her stern to such last-mentioned vessel a white light or a flare-up light.

ANCHOR LIGHTS

ART. 11. A vessel under one hundred and fifty feet in length when at anchor shall carry forward, where it can best be seen, but at a height not exceeding twenty feet above the hull, a white light, in a lantern so constructed as to show a clear, uniform, and unbroken light visible all around the horizon at a distance of at least one mile.

A vessel of one hundred and fifty feet or upwards in length when at anchor shall carry in the forward part of the vessel, at a height of not less than twenty and not exceeding forty feet above the hull, one such light, and at or near the stern of the vessel, and at such a height that it shall be not less than fifteen feet lower than the forward light, another such light.

The length of a vessel shall be deemed to be the length appearing in her certificate of registry.

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STEAM VESSEL UNDER SAIL BY DAY.

ART. 14. A steam vessel proceeding under sail only, but having her funnel up, may carry in daytime, forward, where it can best be seen, one black ball or shape two feet in diameter.

INTERNATIONAL RULES

III. SOUND SIGNALS FOR FOG, AND SO FORTH

PRELIMINARY

Art. 15.—All signals prescribed by this article for vessels under way shall be given:

First. By " steam vessels " on the whistle or siren.

Second. By " sailing vessels " and " vessels towed " on the fog horn.

The words " prolonged blast " used in this article shall mean a blast of from four to six seconds duration.

A steam vessel shall be provided with an efficient whistle or siren, sounded by steam or by some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog horn, to be sounded by mechanical means, and also with an efficient bell. In all cases where the rules require a bell to be used a drum may be substituted on board Turkish vessels, or a gong where such articles are used on board small seagoing vessels. A sailing vessel of twenty tons gross tonnage or upward shall be provided with a similar fog horn and bell.

In a fog, mist, falling snow, or heavy rain storms, whether by day or night, the signals described in this article shall be used as follows, namely:

STEAM VESSEL UNDER WAY

(a) A steam vessel having way upon her shall sound, at intervals of not more than two minutes, a prolonged blast.

(b) A steam vessel under way, but stopped, and having no way upon her, shall sound, at intervals of not more than two minutes, two prolonged blasts, with an interval of about one second between.

SAIL VESSEL UNDER WAY

(c) A sailing vessel under way shall sound, at intervals of not more than one minute, when on the starboard tack, one blast; when on the port tack, two blasts in succession, and when with the wind abaft the beam, three blasts in succession.

VESSELS AT ANCHOR OR NOT UNDER WAY

(d) A vessel when at anchor shall, at intervals of not more than one minute, ring the bell rapidly for about five seconds.

VESSELS TOWING OR TOWED

(e) A vessel when towing, a vessel employed in laying or in picking up a telegraph cable, and a vessel under way, which is unable to get out of the way of an approaching vessel through being not under command, or unable to maneuver as required by the rules, shall, instead of the signals prescribed in subdivisions (a) and (c) of this article, at intervals of not more than two minutes, sound three blasts in succession, namely: One prolonged blast followed by two short blasts. A vessel towed may give this signal and she shall not give any other.

INLAND RULES

III. SOUND SIGNALS FOR FOG, AND SO FORTH

PRELIMINARY

ART. 15. All signals prescribed by this article for vessels under way shall be given:

1. By " steam vessels " on the whistle or siren.
2. By " sailing vessels " and " vessel towed " on the fog horn.

The words " prolonged blast " used in this article shall mean a blast of from four to six seconds duration.

A steam vessel shall be provided with an efficient whistle or siren, sounded by steam or by some substitute for steam, so placed that the sound may not be intercepted by any obstruction, and with an efficient fog horn; also with an efficient bell. A sailing vessel of twenty tons gross tonnage or upward shall be provided with a similar fog horn and bell.

In fog, mist, falling snow, or heavy rain storms, whether by day or night, the signals described in this article shall be used as follows, namely:

STEAM VESSEL UNDER WAY

(a) A steam vessel under way shall sound, at intervals of not more than one minute, a prolonged blast.

SAIL VESSELS UNDER WAY

(c) A sailing vessel under way shall sound, at intervals of not more than one minute, when on the starboard tack, one blast; when on the port tack, two blasts in succession, and when with the wind abaft the beam, three blasts in succession.

VESSELS AT ANCHOR OR NOT UNDER WAY

(d) A vessel when at anchor shall, at intervals of not more than one minute, ring the bell rapidly for about five seconds.

VESSELS TOWING OR TOWED

(e) A steam vessel when towing, shall, instead of the signals prescribed in subdivision (a) of this article, at intervals of not more than one minute, sound three blasts in succession, namely, one prolonged blast followed by two short blasts. A vessel towed may give this signal and she shall not give any other.

INTERNATIONAL RULES

SMALL SAILING VESSELS AND BOATS

Sailing vessels and boats of less than twenty tons gross tonnage shall not be obliged to give the above-mentioned signals, but, if they do not, they shall make some other efficient sound signal at intervals of not more than one minute.

SPEED IN FOG

Art. 16. Every vessel shall, in a fog, mist, falling snow, or heavy rain storms, go at a moderate speed, having careful regard to the existing circumstances and conditions.

A steam vessel hearing, apparently forward of her beam, the fog signal of a vessel the position of which is not ascertained shall, so far as the circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

IV. STEERING AND SAILING RULES

PRELIMINARY

Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.

SAILING VESSELS

Art. 17. When two sailing vessels are approaching one another, so as to involve risk of collision, one of them shall keep out of the way of the other, as follows, namely:

(a) A vessel which is running free shall keep out of the way of a vessel which is closehauled.

(b) A vessel which is closehauled on the port tack shall keep out of the way of a vessel which is closehauled on the starboard tack.

(c) When both are running free, with the wind on different sides, the vessel which has the wind on the port side shall keep out of the way of the other.

(d) When both are running free, with the wind on the same side, the vessel which is to the windward shall keep out of the way of the vessel which is to the leeward.

(e) A vessel which has the wind aft shall keep out of the way of the other vessel.

STEAM VESSELS

Art. 18. When two steam vessels are meeting end on, or nearly end on, so as to involve risk of collision, each shall alter her course to starboard, so that each may pass on the port side of the other.

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RAFTS, OR OTHER CRAFT NOT PROVIDED FOR

(f) All rafts or other water craft, not herein provided for, navigating by hand power, horse power, or by the current of the river, shall sound a blast of the fog horn, or equivalent signal, at intervals of not more than one minute.

SPEED IN FOG

Art. 16. Every vessel shall, in a fog, mist, falling snow, or heavy rain storms, go at a moderate speed, having careful regard to the existing circumstances and conditions.

A steam vessel hearing, apparently forward of her beam, the fog signal of a vessel the position of which is not ascertained shall, so far as the circumstances of the case admit, stop her engines, and then navigate with caution until danger of collision is over.

IV.—STEERING AND SAILING RULES

PRELIMINARY

Risk of collision can, when circumstances permit, be ascertained by carefully watching the compass bearing of an approaching vessel. If the bearing does not appreciably change, such risk should be deemed to exist.

SAILING VESSELS

Art. 17. When two sailing vessels are approaching one another, so as to involve risk of collision, one of them shall keep out of the way of the other as follows, namely:

(a) A vessel which is running free shall keep out of the way of a vessel which is closehauled.

(b) A vessel which is closehauled on the port tack shall keep out of the way of a vessel which is closehauled on the starboard tack.

(c) When both are running free, with the wind on different sides, the vessel which has the wind on the port side shall keep out of the way of the other.

(d) When both are running free, with the wind on the same side, the vessel which is to the windward shall keep out of the way of the vessel which is to the leeward.

(e) A vessel which has the wind aft shall keep out of the way of the other vessel.

STEAM VESSELS

Art. 18. Rule I. When steam vessels are approaching each other head and head, that is, end on, or nearly so, it shall be the duty of each to pass on the port side of the other; and either vessel shall give, as a signal of her intention, one short and distinct blast of her whistle, which the other vessel shall answer promptly by a similar blast of her whistle, and thereupon such vessels shall pass on the port side of each other. But if the courses of such vessels are so far on the starboard of each other as not to be considered as meeting head and head, either vessel shall immedi-

INTERNATIONAL RULES

This article only applies to cases where vessels are meeting end on, or nearly end on, in such a manner as to involve risk of collision, and does not apply to two vessels which must, if both keep on their respective courses, pass clear of each other.

The only cases to which it does apply are when each of the two vessels is end on, or nearly end on to the other; in other words, to cases in which, by day, each vessel sees the masts of the other in a line, or nearly in a line, with her own; and by night, to cases in which each vessel is in such a position as to see both the side-lights of the other.

It does not apply by day to cases in which a vessel sees another ahead crossing her own course; or by night, to cases where the red light of one vessel is opposed to the red light of the other, or where the green light of one vessel is opposed to the green light of the other, or where a red light without a green light, or a green light without a red light, is seen ahead, or where both green and red lights are seen anywhere but ahead.

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ately give two short and distinct blasts of her whistle, which the other vessel shall answer promptly by two similar blasts of her whistle, and they shall pass on the starboard side of each other.

The foregoing only applies to cases where vessels are meeting end on, or nearly end on, in such a manner as to involve risk of collision; in other words, to cases in which, by day, each vessel sees the masts of the other in a line, or nearly in a line, with her own, and by night to cases in which each vessel is in such a position as to see both the sidelights of the other.

It does not apply by day to cases in which a vessel sees another ahead crossing her own course, or by night to cases where the red light of one vessel is opposed to the red light of the other, or where the green light of one vessel is opposed to the green light of the other, or where a red light without a green light or a green light without a red light, is seen ahead, or where both green and red lights are seen anywhere but ahead.

Rule III. If, when steam vessels are approaching each other, either vessel fails to understand the course or intention of the other, from any cause, the vessel so in doubt shall immediately signify the same by giving several short and rapid blasts, not less than four, of the steam whistle.

Rule V. Whenever a steam vessel is nearing a short bend or curve in the channel, where, from the height of the banks or other cause, a steam vessel approaching from the opposite direction can not be seen for a distance of half a mile, such steam vessel, when she shall have arrived within half a mile of such curve or bend, shall give a signal by one long blast of the steam whistle, which signal shall be answered by a similar blast given by any approaching steam vessel that may be within hearing. Should such signal be so answered by a steam vessel upon the farther side of such bend, then the usual signals for meeting and passing shall immediately be given and answered; but, if the first alarm signal of such vessel be not answered, she is to consider the channel clear and govern herself accordingly.

When steam vessels are moved from their docks or berths, and other boats are liable to pass from any direction toward them, they shall give the same signal as in the case of vessels meeting at a bend, but immediately after clearing the berths so as to be fully in sight they shall be governed by the steering and sailing rules.

Rule VIII. When steam vessels are running in the same direction, and the vessel which is astern shall desire to pass on the right or starboard hand of the vessel ahead, she shall give one short blast of the steam whistle, as a signal of such desire, and if the vessel ahead answers with one blast, she shall put her helm to port; or if she shall desire to pass on the left or port side of the vessel ahead, she shall give two short blasts of the steam whistle as a signal of such desire, and if the vessel ahead answers with two blasts, shall put her helm to starboard; or if the vessel ahead does not think it safe for the vessel astern to attempt to pass at that point, she shall immediately signify the same by giving several short and rapid blasts of the steam whistle, not less than four, and under no circumstances shall the vessel astern attempt to pass the vessel ahead until such time as they have reached a point where it can be safely done, when said vessel

INTERNATIONAL RULES

TWO STEAM VESSELS CROSSING

Art. 19. When two steam vessels are crossing, so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way of the other.

STEAM VESSEL SHALL KEEP OUT OF THE WAY OF SAILING VESSEL

Art. 20. When a steam vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, the steam vessel shall keep out of the way of the sailing vessel.

COURSE AND SPEED

Art. 21. Where, by any of these rules, one of two vessels is to keep out of the way the other shall keep her course and speed.

Note—When, in consequence of thick weather or other causes, such vessel finds herself so close that collision can not be avoided by the action of the giving-way vessel alone, she also shall take such action as will best aid to avert collision. [See articles twenty-seven and twenty-nine.]

CROSSING AHEAD

Art. 22. Every vessel which is directed by these rules to keep out of the way of another vessel shall, if the circumstances of the case admit, avoid crossing ahead of the other.

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ahead shall signify her willingness by blowing the proper signals. The vessel ahead shall in no case attempt to cross the bow or crowd upon the course of the passing vessel.

Rule IX. The whistle signals provided in the rules under this article, for steam vessels meeting, passing, or overtaking, are never to be used except when steamers are in sight of each other, and the course and position of each can be determined in the daytime by a sight of the vessel itself, or by night by seeing its signal lights. In fog, mist, falling snow or heavy rain storms, when vessels can not see each other, fog signals only must be given.

SUPPLEMENTARY REGULATIONS

Sec. 2. That the supervising inspectors of steam vessels and the Supervising Inspector-General shall establish such rules to be observed by steam vessels in passing each other and as to the lights to be carried by ferryboats and by barges and canal boats when in tow of steam vessels, not inconsistent with the provisions of this act, as they from time to time may deem necessary for safety, which rules when approved by the Secretary of Commerce are hereby declared special rules duly made by local authority, as provided for in article thirty of chapter eight hundred and two of the laws of eighteen hundred and ninety. Two printed copies of such rules shall be furnished to such ferryboats, and steam vessels which rules shall be kept posted up in conspicuous places in such vessels.

TWO STEAM VESSELS CROSSING

Art. 19. When two steam vessels are crossing, so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way of the other.

STEAM VESSEL SHALL KEEP OUT OF THE WAY OF SAILING VESSEL

Art. 20. When a steam vessel and a sailing vessel are proceeding in such directions as to involve risk of collision, the steam vessel shall keep out of the way of the sailing vessel.

COURSE AND SPEED

Art. 21. Where, by any of these rules, one of the two vessels is to keep out of the way, the other shall keep her course and speed.

[See articles twenty-seven and twenty-nine.]

CROSSING AHEAD

Art. 22. Every vessel which is directed by these rules to keep out of the way of another vessel shall, if the circumstances of the case admit, avoid crossing ahead of the other.

INTERNATIONAL RULES

STEAM VESSEL SHALL SLACKEN SPEED OR STOP

Art. 23. Every steam vessel which is directed by these rules to keep out of the way of another vessel shall, on approaching her, if necessary, slacken her speed or stop or reverse.

OVERTAKING VESSELS

Art. 24. Notwithstanding anything contained in these rules every vessel, overtaking any other, shall keep out of the way of the overtaken vessel.

Every vessel coming up with another vessel from any direction more than two points abaft her beam, that is, in such a position, with reference to the vessel which she is overtaking that at night she would be unable to see either of that vessel's side lights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of these rules, or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

As by day the overtaking vessel can not always know with certainty whether she is forward of or abaft this direction from the other vessel she should, if in doubt, assume that she is an overtaking vessel and keep out of the way.

NARROW CHANNELS

Art. 25. In narrow channels every steam vessel shall, when it is safe and practicable, keep to that side of the fairway or mid-channel which lies on the starboard side of such vessel.

RIGHT OF WAY OF FISHING VESSELS

Art. 26. Sailing vessels under way shall keep out of the way of sailing vessels or boats fishing with nets, or lines, or trawls. This rule shall not give to any vessel or boat engaged in fishing the right of obstructing a fairway used by vessels other than fishing vessels or boats.

GENERAL PRUDENTIAL RULE

Art. 27. In obeying and construing these rules due regard shall be had to all dangers of navigation and collision, and to any special circumstances which may render a departure from the above rules necessary in order to avoid immediate danger.

SOUND SIGNALS FOR PASSING STEAMERS

Art. 28. The words "short blast" used in this article shall mean a blast of about one second's duration.

When vessels are in sight of one another, a steam vessel under way, in taking any course authorized or required by these rules, shall indicate that course by the following signals on her whistle or siren, namely:

One short blast to mean, "I am directing my course to starboard."

INLAND RULES

STEAM VESSEL SHALL SLACKEN SPEED OR STOP

ART. 23. Every steam vessel which is directed by these rules to keep out of the way of another vessel shall, on approaching her, if necessary, slacken her speed or stop or reverse.

OVERTAKING VESSELS

ART. 24. Notwithstanding anything contained in these rules every vessel, overtaking any other, shall keep out of the way of the overtaken vessel.

Every vessel coming up with another vessel from any direction more than two points abaft her beam, that is, in such a position, with reference to the vessel which she is overtaking that at night she would be unable to see either of that vessel's side lights, shall be deemed to be an overtaking vessel; and no subsequent alteration of the bearing between the two vessels shall make the overtaking vessel a crossing vessel within the meaning of these rules, or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

As by day the overtaking vessel can not always know with certainty whether she is forward of or abaft this direction from the other vessel she should, if in doubt, assume that she is an overtaking vessel and keep out of the way.

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ART. 27. In obeying and construing these rules due regard shall be had to all dangers of navigation and collision, and to any special circumstances which may render a departure from the above rules necessary in order to avoid immediate danger.

SOUND SIGNALS FOR PASSING STEAMERS

[See article eighteen.]

INTERNATIONAL RULES

Two short blasts to mean, "I am directing my course to port."

Three short blasts to mean, "My engines are going at full speed astern."

PRECAUTION

ART. 29. Nothing in these rules shall exonerate any vessel, or the owner or master or crew thereof, from the consequences of any neglect to carry lights or signals, or of any neglect to keep a proper lookout, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

ART. 30. [See page 2.]

DISTRESS SIGNALS

ART. 31. When a vessel is in distress and requires assistance from other vessels or from the shore the following shall be the signals to be used or displayed by her, either together or separately, namely:

In the daytime—

First. A gun or other explosive signal fired at intervals of about a minute.

Second. The international code signal of distress indicated by N. C.

Third. The distance signal, consisting of a square flag, having either above or below it a ball or anything resembling a ball.

Fourth. A continuous sounding with any fog-signal apparatus.

At night—

First. A gun or other explosive signal fired at intervals of about a minute.

Second. Flames on the vessel (as from a burning tar barrel, oil barrel, and so forth).

Third. Rockets or shells throwing stars of any color or description, fired one at a time, at short intervals.

Fourth. A continuous sounding with any fog-signal apparatus.

INLAND RULES

Art. 28. When vessels are in sight of one another a steam vessel under way whose engines are going at full speed astern shall indicate that fact by three short blasts on the whistle.

PRECAUTION

Art. 29. Nothing in these rules shall exonerate any vessel, or the owner or master or crew thereof, from the consequences of any neglect to carry lights or signals, or of any neglect to keep a proper lookout, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

LIGHTS ON UNITED STATES NAVAL VESSELS AND REVENUE CUTTERS

Art. 30. The exhibition of any light on board of a vessel of war of the United States or a Coast Guard cutter may be suspended whenever, in the opinion of the Secretary of the Navy, the commander in chief of a squadron, or the commander of a vessel acting singly, the special character of the service may require it.

DISTRESS SIGNALS

Art. 31. When a vessel is in distress and requires assistance from other vessels or from the shore the following shall be the signals to be used or displayed by her, either together or separately, namely:

In the daytime—

A continuous sounding with any fog-signal apparatus, or firing a gun.

At night—

First. Flames on the vessel as from a burning tar barrel, oil barrel, and so forth.

Second. A continuous sounding with any fog-signal apparatus, or firing a gun.

CHAPTER II

USEFUL DEFINITIONS AND INFORMATION

Altitude.—The angular height of a heavenly body above the horizon.

Amplitude.—The bearing (never exceeding 90°) of a heavenly body at rising or setting, measured from East or West.

Apparent Time.—Time calculated by the sun. When the sun crosses the meridian of the observer it is apparent noon where he is, as well as at all places on his meridian from pole to pole.

Astronomical Time.—This commences at noon of the civil day, the hours being counted numerically from 1 to 24, so that the day begins and ends at noon. To convert civil time into astronomical time proceed as follows: If the civil time is A. M. take 1 from the date and add 12 to the hours. If P. M. take away the sign P. M. and the answer will be Astronomical Time.

Azimuth.—The bearing (never exceeding 180°) of a heavenly body calculated from the north and south points of the heavens.

Chronometer.—A marine timepiece constructed with the idea of great accuracy, and set to the time of some first meridian. The Americans and English use the time of the meridian of Greenwich.

Civil Time.—The civil time consists of 24 hours; it commences at midnight and the first 12 hours are called A. M. and the second 12 hours P. M.

Compass.—The mariner's compass consists of a magnetized steel bar secured parallel to the north and south line of a circular card, which latter is balanced on a pivot so as to turn freely in the horizontal plane, and to indicate the magnetic meridian. The surface of the card is divided into 32 courses with their intermediate quarters, and, in addition to this, all steamships have the circumference of the compass card graduated into degrees.

Variation of the Compass.—The compass needle when uninfluenced by deviation points to the magnetic poles of the earth, and as these do not coincide with the true or geographical poles, the magnetic meridians form an angle with the true meridians, and this is called the variation of the compass, which varies in extent in different parts of the world. The magnetic North Pole is situated in Latitude 70° North, Longitude 97° West. The magnetic South Pole is situated in Latitude 70° South, Longitude 145° East. The variation of the compass is not constant, but undergoes an annual change, and the amount of this yearly increase or decrease will be found plainly marked on charts.

Declination.—The angular distance of a heavenly body North or South of the celestial equator.

Departure.—The amount of easting or westing made by a vessel in miles.

Deviation of the Compass.—What is known as the deviation of the compass is the deflection of the compass needle from the magnetic meridian caused by the attraction of the hull, machinery, smokestacks, masts, or by certain elements of magnetism in the cargo. The manner of ascertaining the existence and amount of compass deviation is found by taking bearings of the sun or some fixed object. Deviation is named East or West according as to the North point of the compass is drawn to the eastward or westward of the magnetic meridian.

Equation of Time.—The difference between mean and apparent time.

Latitude.—The distance of a place on the earth's surface north or south of the equator, expressed in degrees, minutes and seconds.

Longitude.—The distance of a place on the earth's surface east or west of some given prime meridian, expressed in degrees, minutes and seconds.

Longitude in Time.—The position or distance of a vessel east or west of a given prime meridian, expressed in hours, minutes and seconds.

Magnetic Bearing.—The direction pointed out by the magnetic meridian.

Compass Bearing.—The direction pointed out by the compass.

Mean Noon.—The time that the mean sun is supposed to cross the meridian of the observer.

Mean Sun.—An imaginary sun which is supposed to move uniformly, and to cross the same meridian at the same time every day, thus giving a value of exactly 24 hours to the day. This mean or fictitious sun sometimes crosses the observers meridian a little in advance of the true sun, and other times a little after it, and this difference or interval between the real and imaginary suns is known as the equation of time.

Mean Time.—Time calculated by the motion of the mean sun. All watches and clocks represent mean time.

Mercators Sailing.—A method of finding the true course and distance between two places by employing meridional parts instead of the middle latitude.

Meridian.—The highest point reached by a heavenly body from its rising to its setting.

Meridian Altitude.—The angular height of a heavenly body from the horizon line at the time the body is crossing the meridian.

Middle Latitude Sailing.—The method of finding the true course and distance between two places by employing the middle latitude between them.

Parallax.—Is the correction applied to observed altitude of sun, caused by observing the sun from earth's surface instead of center.

Parallel Sailing.—Sailing on a parallel; sailing true east or west.

Pelorus.—An instrument much used for observing bearings and for finding the deviation of the compass. It is a dummy compass with sight vanes attached.

Polar Distance.—The angular distance of a heavenly body from the pole nearest the observer.

Refraction.—The change of direction of a ray of light in passing through atmospheric mediums of varying density.

Semi-diameter.—Half a diameter, or the distance from top or bottom of the sun to the center.

Sextant.—An instrument of reflection used by navigators for measuring the altitudes of heavenly bodies.

The Sextant.—The sextant derives its name from the extent of its limb, which is the sixth part of a circle, or 60°, but being an instrument of double reflection it is divided into 120°.

The Quadrant.—The quadrant is properly an Octant, as the limb is only the eighth part of a circle, or 45°, but, like the sextant, being an instrument of double reflection, it is divided into 90°.

Both instruments are constructed on the same principle, and can be made equally accurate and perfect.

Siderial Time.—Time measured by the stars. Siderial time commences when the First Point of Aries is on the meridian, and is counted from 1 to 24 hours, when the same point returns to the meridian again.

Solar Time.—Time measured by the sun.

Variation.—The divergence of the compass needle from the true North due to pointing to the North magnetic instead of North geographic pole.

Zenith Distance.—The angular distance of a heavenly body from the zenith of the observer.

Zenith.—That point in the heavens directly overhead of the observer, and 90° distance from every point of the horizon.

Prime Vertical.—A heavenly body is on the prime vertical when it bears true East or West, and is the best time to observe a sight for longitude, as an error of latitude will have no effect on the longitude.

Right Ascension.—The distance in time of a heavenly body reckoned eastward on the equinoctial from the First Point of Aries.

First Point of Aries.—That point in the heavens which the sun's center occupies when its declination changes from North to South, or when the sun crosses the line bound North.

Mercator Chart.—The Mercator chart has a compass printed on it, with an arrow to represent the North point which is the top, the bottom South; East right, West left. Meridians are the lines running North and South, on the chart—those on the sides, are divided into degrees and minutes, and are called Graduated Meridians. Parallels of latitude are the lines running east and west—those at top and bottom are divided into degrees and minutes, and are called Graduated Parallels. Latitude is measured at the sides on the Graduated Meridians. Longitude is measured at the top and bottom on the Graduated Parallels. A Mercator chart is a distortion of the earth's surface, the meridians being equal, and the parallels increased from the equator to the poles. The outer compass is a true compass, and the inner compass is a magnetic compass. The variation is found printed on the compass, and also lines of variation will be found on chart. Soundings are given in fathoms in clear parts, and in feet in shaded parts, and the nature of bottom is given by letters abbreviated. The chart gives all information as to lightships, light houses, visibility of lights, and nature of lights.

Clinometer.—An instrument used for registering amount of list or heel, generally to be found on the binnacle. As one degree of list will frequently alter the deviation to a like amount, this will require careful watching. It also comes in handy when putting ship in dry dock to ascertain if ship is upright.

Hydrometer.—An instrument used for measuring the density or the specific gravity of liquids, used by seamen for finding the different drafts that a ship will float at, in fresh and salt water. The specific gravity of fresh water is 1000. The specific gravity of salt water is 1026. To find the draft a ship can be loaded to in fresh water, in order to ascertain the amount of water she will draw at sea, proceed as follows: Take the density of water at wharf, from below the surface if possible, by hydrometer. Multiply mean draft of ship by this reading, and divide by 1026. The result will be mean sea draft. (By mean sea draft is meant adding forward and after draft together, and dividing sum by 2.) For example: Dock water reading of hydrometer 1006. Mean draft of vessel 21 ft.

$$\frac{1006 \times 21}{1026} = 20.6 \text{ ft. mean sea draft.}$$

Mercurial Barometer.—The barometer is an instrument used for determining at any moment the weight or pressure of the atmosphere in its immediate vicinity. It is made by taking a glass tube sealed at one end, and placing the other end in a receptacle containing mercury. The mercury will then descend the tube until the weight of the column of mercury in the tube is balanced by the atmospheric pressure or weight on the mercury in the cup. The glass tube is graduated in proper ratio, so that the increase or decrease of pressure can be read on the scale at the side of the glass.

Aneroid Barometer.—Is another type of barometer, which, owing to its compact form, and the fact that no liquid is used, is coming into use more and more for sea service. The varying pressure of the atmosphere is registered on the dial by a hand, which is controlled by the expansion or contraction of a metal box, generally of a circular form with corrugated surface, from which almost all air has been withdrawn leaving a partial vacuum.

The instruments should not be removed from the ship, but frequent comparisons should be made to ascertain error of instrument by reading barometer at 12-hour intervals

3 times (8 A. M. or Noon preferable) and forwarding same to Local Weather Bureau.

To Find the Storm Center of Tropical Cyclonic Storms.—In the Northern Hemisphere look into wind and 8 points to the right will be the center. In the Southern Hemisphere 8 points to the left will be center approximately.

Notices to be Posted on Steamers Carrying Passengers.—Certificate of Inspection, 2 Copies of Pilot Rules, 2 Copies of Safety First, 3 Copies Excluding Certain Persons from Pilot House, 3 Copies of Station Bills required, 5 Copies of Line Carrying Gun Drill, Station Bills for Fire and Boat Drills for Deck and Engineer's Department, Life Preserver Notices to be posted in each stateroom and in conspicuous places around vessel. Also to have on board 2 Copies of Law Governing the Steamboat Inspection Service, and 1 Copy of General Rules and Regulations of the Board of Supervising Inspectors.

Dangerous Articles Forbidden on Passenger Steamers.—No loose hay, loose cotton, or loose hemp, camphene, nitroglycerine, naphtha, benzine, coal oil, crude or refined petroleum, benzole, or other like explosive burning fluids, or like dangerous articles, shall be carried as freight or used as stores on any steamer carrying passengers. Gunpowder may be carried if the vessel is provided with a chest or safe composed of metal, or entirely lined or sheathed therewith, at a secure distance from any fire, after an examination has been made by the Local Inspectors of such chest or safe, and a license to carry gunpowder has been issued, such license to be kept conspicuously posted on board vessel.

Watchmen Required on Passenger Steamers.—Every steamer carrying passengers during the night time shall keep a suitable number of watchmen in the cabins, and on each deck to guard against fire or other dangers, and to give alarm in case of accident or disaster. All steamers while navigating at night shall keep a man on the lookout forward if weather permits, or at some other suitable place.

Reports to be Made to Local Inspectors.—The Master of every steamer shall make a report in writing to the Local Inspectors of any accident to vessel or loss of life. Notice shall be made in writing to Local Inspectors of number of passengers carried, and fire and boat drill practiced, each month.

Drills to be Entered in Log Book.—Fire and boat drill shall be practiced once each week on passenger steamers.

The line carrying gun shall be fired once every three months and such drills shall be entered in ship's log book.

How Fire Hose Shall be Carried.—Fire hose shall be carried connected to fire plugs, and ready for immediate use, with suitable spanners at each plug.

Lamp and Paint Locker Requirements.—All steamers carrying passengers shall have a metal-lined paint and lamp locker. This locker to have a $\frac{3}{4}$-in. steam pipe run into it for smothering fires, and the valve of such steam pipe shall be plainly marked.

How Lifeboats shall be Carried and Marked.—All lifeboats on steamers carrying passengers shall be carried under davits of approved mechanical design, capable of sustaining the weight of boat and equipment and number of persons allowed to be carried. They shall be marked in numerical order, odd numbers on starboard side, even numbers on port side, cubical contents and number of persons allowed shall be painted on each bow in letters not less than $\frac{3}{4}$ in. high. Vessel's name and home port shall be painted on stern in letters 3 in. high. Number of persons allowed shall be painted on two thwarts in letters 3 in. high. All boats shall be in condition for immediate launching at all times and the falls shall not be painted or covered,and shall be stowed in covered tubs or reels on outside of boat.

Equipment of Lifeboats.—A properly secured life line the entire length on each side, such line to be festooned in bights not longer than 3 ft., with a seine float in each bight; at least 2 life preservers; 1 painter of not less than $2\frac{3}{4}$ in. manila rope; a full complement of oars and 2 spare oars; a set and a half of rowlocks, each rowlock to be attached to boat with a separate chain; 1 steering oar with rowlock or becket, or 1 rudder with yoke and suitable yoke ropes; 1 boat hook attached to staff of a suitable length; 2 axes; 1 bucket with lanyard attached; 1 bailer; 1 liquid compass with not less than 2-in. card; 1 lantern with attached lamp containing sufficient oil to burn at least 9 hours and ready for immediate use; 1 gallon of illuminating oil in a substantial can; at least 1 box of friction matches wrapped in a waterproof package and carried in a box attached to the underside of the stern thwart; at least 2 quarts of water for each person carried, in a strong wooden breaker or suitable tank fitted with a siphon, pump, or spigot for drawing water; 2 drinking cups of enameled metal; 1 substantial metal can containing 2 lbs. of hard bread for each person carried, the metal bread can to be fitted with an opening in the top not less than 5-in. in diameter, properly protected with a screw cap of heavy cast brass with machine thread and an attached double toggle seating to a pliable rubber gasket which shall insure a tight joint in order to properly protect the contents of the can; 1 canvas bag containing sailmaker's palm and needles, sail twine, marline spike, and hatchet; 12 pyrotechnic red lights carried in a metal case; 1 drag sail; 1 gallon of storm oil; and 1 mast and sail with necessary rigging.

Equipment of Life Rafts.—A properly secured life line entirely around the sides and ends of raft festooned to the gunwales in bights not longer than 3 ft. with a seine float in each bight; 1 painter of $2\frac{3}{4}$ in. manila rope of a suitable length; 4 oars; 5 rowlocks properly attached; 1 boat hook attached to staff of suitable length; 1 self-igniting life-buoy light; 1 sea anchor; 1 vessel containing 1 gallon of vegetable or animal oil, so constructed that the oil can be easily distributed on the water, and so arranged that it can be attached to the sea anchor; 2 lb. of hard bread for each person carried, carried in a receptacle same as in lifeboats; 1 water breaker containing 1 quart of water for each person carried; 2 enameled drinking cups; 1 metal case containing 6 pyrotechnic red lights; 1 water-tight box of matches. All loose equipment must be securely attached to the raft to which it belongs.

How to Mark a Lead Line.—Two fathoms, 2 strips of leather; 3 fathoms 3 strips of leather; 5 fathoms white rag; 7 fathoms red rag; 10 fathoms leather with 1 hole; 13 fathoms blue rag; 15 fathoms white rag; 17 fathoms red rag; 20 fathoms leather with 2 holes; 25 fathoms cord with 1 knot; 30 fathoms cord with 3 knots.

Explain the Use of the Deep Sea Sounding Machine.—The deep sea sounding machine has a reel of fine wire to which the lead is attached by a line having made fast to it the lead and a brass tube. Into the brass tube is placed the depth recorder which is a long glass tube, which is placed sealed end up. When the lead is armed and everything is ready the brake is released, and the wire is allowed to run out until the bottom is struck. The amount of wire run out is shown by an indicator on the side of the machine. The amount of wire is not the depth of water obtained, as the amount run out varies with the speed of the ship. The wire is then reeled back, and the glass tube is taken out. The pressure of the water causes the tube to become discolored a certain length up for a certain depth, and the amount of such depth is found by measuring the discoloration on a scale provided for that purpose.

How to Find Course and Distance by Mercator Chart and Parallel Rules.—Lay the parallel rules on the two places that the course and distance is wanted for. After obtaining proper angle, move the rules to the nearest compass rose on the chart and read off the course obtained. Measure the distance between the places on the side of the chart in the latitude column always, using the middle latitude between the places.

How to Find Ship's Position by Cross Bearings.—Take a bearing of two fixed objects by ship's compass, and correct for the deviation for ship's head and the variation at the place, making the bearings true. Lay off the bearings on the chart from the objects used, and where the two lines cross one another will be the ship's position at time of taking the bearings.

How to Find the Distance Off a Fixed Point by Four Point Bearings.—Take a bearing of the object when it bears four points on the bow and also when abeam. If the ship has held the same course while taking the two bearings the distance run between the two bearings will be the distance off the object when abeam.

What is the Duty of a Mate on Watch? Keep a good lookout, watch the steering, see that man on lookout keeps a good lookout. If it comes on thick or foggy, stop or slow the vessel, blow the whistle, and send someone to call the Master.

What Would You Do Should a Man Fall Overboard?—Stop the ship, throw the stern of the ship from the man, send a man aloft to watch out and direct the boat, throw over a life buoy, and lower the lee boat.

What Would You Look After When Lowering a Boat, and How Would You Place Your Men in the Boat?—See if the plug was in the boat, and the davit falls all clear. Place one man in bow and another in stern to unhook davit tackles, rest of crew sitting down ready with oars.

How Would You Handle a Boat in a Heavy Surf?—I would head my boat to the sea and pull towards it when it breaks. If about to beach a boat in the surf pull in close to the breakers, then back the boat in, pulling toward the sea as it breaks. Do not let her fall broadside too, or the boat will swamp.

Your Ship is Ashore, Your Boats and Life Rafts are all Stove in, What Would You Do to Save the People on Board Your Vessel?—Send up distress rockets and make distress signals to attract the attention of the life-saving crew on shore. If not answered, build a raft out of anything that will float, bend a line to it, and throw the raft overboard and see if it will drift ashore. If so, haul it back again and put two good swimmers and a long line coiled on the raft, and then let it drift as near the shore as it will go, then let the men jump over and swim ashore with the line. Then haul the raft backward and forward until every one is off the vessel.

How Would You Find the Approximate Position of a Vessel by Taking One Bearing of a Point or Light?—Take a bearing of the point, and drop the lead. Then go to the chart and draw a line representing the bearing of the particular point, and hunt along this line until the depth of water and nature of bottom is found. The result will be the approximate position of the vessel.

In Case of Collision While in Command or in Charge of a Watch What are your Duties?—Stop the ship and ascertain the damage to my own vessel. Call all hands to attention, serve out life belts, man boats and get ready for lowering. Next ascertain if the other vessel needs assistance; if so, render it, if not, and both vessels are able to proceed, exchange names of vessels and port of registry, and immediately upon arrival in port send in a written report to the steamboat inspectors, and make out wreck report and file it at the custom house. If the report is not made the Master is liable to a fine.

What are the Duties of a Mate Towards the Master, Passengers and Crew?—The duty of an officer of a vessel is to obey all orders emanating from his superior officer; assist in the navigation of the vessel to the best of his ability; report to the Master whenever the officer is of the opinion that a danger exists if the orders of his superiors are carried out, show an example to the crew by obeying all orders promptly; keep the passengers out of dangerous places; see that the crew know their stations in case of fire or collision; do not molest passengers; see that all life saving and fire fighting equipment is kept ready for use and in good condition; and keep a good lookout while on watch.

What do the Figures and Letters You See on a Chart Represent?—The figures represent the depth of the water in fathoms or feet, at a mean low water, and the letters represent the nature of the bottom.

If You Think You Hear a Fog Whistle on Your Bow, What Would You Do?—Stop my vessel, ascertain the position of the other vessel if possible, and then proceed with caution.

How Would You Approach a Sinking Vessel With a Boat in a Heavy Sea and Take the People Off, if it Was Too Rough to go Alongside?—Run dead to windward of the sinking vessel as close as safety will permit; stop my ship and make one side of my ship a lee side, lower away the lee boat, and at the same time throw overboard a can of oil to smooth the sea. Let the boat drift down toward the wreck, and when the boat is near the wreck, look out for wreckage and fall in on the lee side of the wreck as near as possible. If dangerous to go alongside, throw the boat head up and let a man stand in the bow of the boat and throw a heaving line with a bowline in the end of it on board the wreck, which one of the people on board will place around him, and then jump overboard, and who will be hauled into the boat. The vessel in the meantime will run to the leeward and wait for the boat, when she leaves the wreck with a boat load of people. This will be repeated until everybody is off the wreck.

How Would You Heave To in a Gale Under Steam, or With Engines Disabled?—Slow the engines, head her up to the sea, and get on some after canvas. If she will not lay to, use a drag over the weather bow. If disabled try to make her lay her head to the sea with a drag over her bow, and some after canvas, but if she would not lay to keep her helm amidship, take in the after canvas and pass the drag aft to the weather quarter and let her lay stern to.

How Would You Approach the Land in a Fog, and What Precaution Would You Take?—Go slow and use the lead frequently. If in doubt stop and wait for weather to clear.

When Taking Soundings, What do You Use Besides the Depth of Water to Confirm Your Position?—The nature of the bottom which is brought up on the arming of the lead.

Buoyage System of U. S.—On entering channels nun-shaped or peaked buoys, red with even numbers, starboard side. Can-shaped or flat-top buoys, black with odd numbers, port side. Black and white perpendicular striped buoys are fairway buoys. Black and red horizontal striped buoys are obstruction buoys, give berth on both sides. White buoys are anchorage ground, anchor inside of buoys. Gas, Bell and Whistling Buoys are colored and placed according to the needs of surrounding and locality and are described in local buoy books. Buoys and beacons with cages are generally placed at turns in narrow channels, and may be colored with reference to background.

Danger Bearing.—If crossing a vessel or approaching the land observe a bearing. If this bearing does not change, risk of collision or grounding should be assumed.

U. S. WEATHER BUREAU SIGNALS

The Small Craft Warning.—A red pennant displayed alone indicates that, while the wind may not reach a velocity sufficiently high to justify the display of a regular storm warning, they will interfere with the safe operation of small craft, such as those engaged in fishing, towing, motor-boating, and yachting.

The Storm Warning.—A red flag (8 ft. square) with black center (3 ft. square) indicates that a storm of marked violence is expected.

Pennants.—The pennants displayed with the flag indicates the direction from which the wind is expected to blow.

The Red Pennant.—(Eight ft. hoist and 15 ft. fly) displayed with the flag indicates easterly winds.

The White Pennant.—(Eight ft. hoist and 15 ft. fly) displayed with the flag indicates westerly winds.

When the **red pennant** is hoisted above the storm flag, winds are expected from the **Northeast quadrant**; when below, from the **Southeast quadrant.**

When the **white pennant** is hoisted above the storm flag, winds are expected from the **Northwest quadrant**; when below, from the **Southwest quadrant.**

Night Warnings.—By night, two red lights one above the other, indicate winds from the Northeast **quadrant**; a single red light indicates **Southeast quadrant**; a white light above a red light indicates **Northwest quadrant**; and a red light above a white light indicates **Southwest quadrant.**

The Hurricane Warning.—Two storm flags (red with black center), displayed one above the other, are used to announce the expected approach of tropical hurricanes, and also those extremely severe and dangerous storms which occasionally move across the Lakes and northern Atlantic Coast.

The Night Hurricane Warning.—Two red lights with a white light between in a vertical line.

INSTRUCTIONS FOR THE USE OF THE GUN AND ROCKET APPARATUS, AS PRACTICED BY U. S. LIFE SAVING SERVICE

If your vessel is stranded and a shot with a small line is fired over it, get hold of the line, haul it on board until you get a tail block with an endless line rove through it, make the tail block fast to the lower mast well up, or in the event the masts have gone, to the best place to be found. Cast off small shot line, see that rope in block runs free, and make signal to shore.

A hawser will be bent to the endless line on shore, and hauled off to your ship by the life-saving crew. Make hawser fast about 2 ft. above the tail block, and unbend hawser from endless line. See that rope in block runs free, and make signals to shore.

Life savers on shore will then set hawser taut, and by means of the endless line haul off to your ship a breeches buoy.

Let one man get clear into the breeches buoy, thrusting his legs through the breeches, make signal to shore as before, and he will be hauled ashore by the life savers, and the empty buoy returned to the ship.

The following signals have been adopted by the Coast Guard of the United States:

No. 1. Upon the discovery of a wreck by night the station crew will burn a red pyrotechnic light or a red rocket to signify, " You are seen; assistance will be given as soon as possible."

No. 2. A red flag waved on shore by day, or a red light, red rocket, or red Roman candle displayed by night, will signify, " Haul away."

No. 3. A white flag waved on shore by day, or a white light swung slowly back and forth, or a white rocket or white Roman candle fired by night, will signify, " Slack away."

No. 4. Two flags, a white and a red, waved at the same time on shore by day, or two lights, a white and a red, slowly swung at the same time, or a blue pyrotechnic light burned by night, will signify, " Do not attempt to land in your own boats; it is impossible."

No. 5. A man on shore beckoning by day, or two torches burning near together by night, will signify. " This is the best place to land."

INTERNATIONAL CODE OF SIGNALS

The International Code of Signals consists of 26 Flags—one for each letter of the alphabet—and a Code Flag.

Letters " A " and " B " are Burgees.

Letters " C," " D," " E," " F " and " G " and " Answering Pennant " are pennants.

The balance of the alphabet are in square flags.

Two Flag Signals.—Are urgent and important signals. Such as " NC " which means " I am in distress."

Three Flag Signals.—Are general signals. Such as " CXL " which means " Do not abandon me."

Four Flag Signals.—Are Geographical, Alphabetical Spelling Tables, and Vessels' Numbers. Such as " AZOT " is the Geographical Signal for New York City. Alphabetical signals are the words spelled out by the flags, and answered by the Answering Pennant. Vessels' Numbers are given in the List of Merchant Vessels. Each vessel having a certain number.

Meanings of Flags and Pennants Hoisted Singly

" B " I am taking in (or, discharging) explosives.

" C " Yes, or, Affirmative.

" D " No, or, Negative.

" L " I have (or, have had) some dangerous infectious disease on board.

" P " I am about to sail; all persons to report on board.

"Q " I have a clean bill of health, but am liable to quarantine.

" S " I want a pilot.

How to Make a Signal

1. Ship A, wishing to make a signal, hoists her Ensign code flag under it.

2. When Ship A has been answered by the vessel she is addressing she proceeds with the signal which she desires

to make, first hauling down her code flag if it is required for making the signal.

3. Each hoist should be kept flying until Ship B hoists her Answering Pennant.

4. When Ship A has finished signalling she hauls down her Ensign.

How to Answer a Signal

1. Ship B (the ship signalled to) on seeing the signal made by Ship A, hoists her Answering Pennant at the "Dip."

2. When A's hoist has been taken in, looked out in the signal book, and is understood, B hoists her Answering Pennant "Close Up" and keeps it there until A hauls her hoist down.

3. B then lowers her Answering Pennant to the "Dip" and waits for next hoist.

4. If the flags in A's hoist cannot be made out, B keeps her Answering Pennant at the "Dip" and hoists the signal OWL or WCX, or such other signal as may meet the case; and when A has repeated or rectified her signal, and B thoroughly understands it, B hoists her Answering Pennant "Close Up."

DOT AND DASH CODE

This method is used to converse with vessels at sea by means of flashlights, flags, or whistle.

With a little practice the reader will have no trouble in being proficient.

Alphabet

A	. —	N	— .
B	— . . .	O	— — —
C	— . — .	P	. — — .
D	— . .	Q	— — . —
E	.	R	. — .
F	. . — .	S	. . .
G	— — .	T	—
H	. . . .	U	. . —
I	. .	V	. . . —
J	. — — —	W	. — —
K	— . —	X	— . . —
L	. — . .	Y	— . — —
M	— —	Z	— — . .

Numerals

1	. — — — —	6	— . . . .
2	. . — — —	7	— — . . .
3	. . . — —	8	— — — . .
4	. . . . —	9	— — — — .
5	. . . . .	0	— — — — —

Additional Symbols

Cornet — — — —
Letters (follow) — — — .
Signals (follow) . . — —
Code Interval or Designator . — . —

Conventional Signals

End of word.................Interval
End of sentence.............Double Interval
End of message.............Triple Interval
Signal separating preamble from address; address from text; text from signature — . . . —
Acknowledgment........... . — . (R)
Error..................... . . . .
Interrogatory.............. . . — — . .
Repeat after (word).........Interrogatory, A (word)
Repeat last word............Interrogatory twice
Repeat message.............Interrogatory three times
Send faster.. ....QRQ
Send slower... ....QRS
Cease sending..............QRT
Wait a moment............. . — . . .
Execute....................IX, IX
Move to your right..........MR
Move to your left...........ML
Move up ....MU
Move down.................MD
Finished (end of work)....... . . . — . —

SIMPLE RULES FOR STOWAGE OF CARGO

When the cargo is discharged from the ship all the holds and 'tween decks, should be well cleaned and dunnage stacked up on the side ready for next cargo.

Dunnage is loose wood, laid on the bottom and 'tween deck of a vessel to prevent damage by vessel leaking, leaking water pipes, liquid cargo leaking, etc.

Dunnage should be laid in the holds fore and aft about 9 in. high, and in the 'tween deck athwartship about 3 in. high. The reasons for laying dunnage in this way is to allow any water that may get under the cargo to have free access to bilge suctions, and scupper pipes.

Casks are stowed fore and aft, bung up, and bilge free, with dunnage under the quarters, and well chocked off. Begin amidship for first tier, and work towards the wings.

To determine the location of the bung of a cask, if it is not visible, look for the rivets in the hoops, which will always be in line with the bung.

Bale goods should be stowed on their flat, with marks and numbers up.

Acids should be stowed on deck, so that it can readily be thrown overboard in case of leakage, and should be securely lashed.

When carrying a cargo of cotton special attention should be given that dunnage is well laid, and all iron work in holds properly protected, so that no friction may occur between the bands of the bales and the iron work.

A cargo of coal should be taken on board dry, and plenty of surface ventilation given to holds to avoid against the coals getting heated and taking fire. In fine weather at sea the hatches should be left open, and the temperature of the holds taken each watch. In case of fire batten down all hatches, ventilators, etc., and turn steam in holds, it is possible in some instances to hold the fire in this way.

On taking on board a cargo of steel rails operations should begin in the main hold, and the iron stowed fore and aft until level with keelson, then stowed grating fashion. To protect the sides of the vessel, place rails fore and aft and also have locking tiers of rails; when high enough lash all together with chains, and place battens across and tom all down securely from beams; also tom from the sides of the vessel.

A cargo of iron should be stowed in the body of the vessel, trimmed towards the wings, and raised up in the holds to a good height; by doing so the vessel will be in better trim for rough weather, and will not roll so heavily.

For general cargo have all the holds cleaned and dunnage laid down. Consider the nature of cargo, and stow it in the various holds so that the vessel will be kept in good trim.

The quantity of coal in the bunkers will have to be taken into consideration. If the vessel is to call at a number of ports, the cargo should be stowed so that at the first port of call the cargo for that place will be handy for discharging.

Deadweight should be stowed in the lower holds, and used for trimming the ship; bale goods, etc., on top; tallow and butter should be kept in a cool place away from fireroom bulkhead; liquors should be kept in a locker in the 'tween deck for that purpose.

A cargo of iron ore takes up little space in a vessel, as the ship is down to her draught before the holds are full. This cargo of dead weight should be placed in the body of the vessel, raised up in the main hold, and trimmed out towards the wings, also fore and aft to keep vessel in trim. By stowing cargo high up the vessel will behave better in a seaway.

To carry a cargo of grain in bulk, have all holds cleaned out, and bilges clear. The holds must be divided into compartments by means of fore and aft shifting boards 3 in. thick and athwartship bulkheads, the various compartments being grain-tight and strongly constructed from the bottom of the hold right up to the deck. The 'tween deck must be fitted with feeders to feed the lower hold.

When the grain is coming on board it ought to be well trimmed into all the corners and tramped down, otherwise if the vessel encounters bad weather, she will probably take a heavy list by the cargo settling over to the lee side. All grain cargoes must be properly trimmed, stowed and secured.

If the vessel is not fitted up with properly constructed feeders, she must have not less than one-fourth of the grain carried in each hold or compartment made up in bags, and before shipping the bags, matting and platforms must be laid upon the grain in bulk.

Weights should be distributed when loading, about two-thirds in lower holds and one-third in 'tween deck approximately.

Deck cargo should be well secured, and particular attention given to cargo stowed on after deck to keep it clear from steering chains or rods.

A practical rule for ascertaining strength of rope is given below:

Square the circumference and divide by 3 for breaking strain in tons, by 6 for working strain.

To find the weight rope will lift, when rove as a tackle:

Multiply the weight the rope is capable of lifting, by the number of parts at the moving block, and less one-quarter for resistance.

To find the number of parts of small rope required to equal a larger rope:

Divide the square of the circumference of the larger rope by the square of the circumference of the smaller, result will be number of parts the smaller rope requires.

SIMPLE RULES IN COMPASS ADJUSTMENT

Strip compass of all magnets. Suppose the ship to be at sea and intended to use the sun, proceed as follows:

Set your watch to A. T. S., take from the azimuth tables the sun's true bearing for every four minutes of the time during which you will be occupied in adjusting. Correct it into the correct magnetic bearing, and write it down plainly in a small pass book.

Ship's Head North.—Set the lubber's point of the pelorus at North, and the sight vanes clamped to the sun's magnetic bearing. Then starboard or port the helm until the sun's bearing is reflected and bisected by the thread of the pelorus vane. The vessel's head will now be North correct magnetic. If the compass agrees with the pelorus the compass is correct. If the compass shows easterly deviation, place either before or abaft a steel magnet with its red end to starboard above or below in the most convenient place, but on the fore and aft centerline of the compass. Reverse magnets for opposite deviation.

Ship's Head East.—Noting the A. T. S. and magnetic bearing of the sun, screw lubber's line of the pelorus East, and keep vanes set to the sun's correct magnetic bearing. Port the helm until the sun is bisected in the sight vanes of the pelorus, steady her carefully on this fresh course. If the compass agrees with the pelorus it should show East, should it fail to do so, the difference is the deviation. If westerly deviation is shown, place a steel magnet fore and aftways on either side of the compass with its red end aft, and center on the athwartship line of the compass. Move it slowly towards the compass until half of the westerly deviation is corrected. Next place the Flinder's bar forward of the binnacle at such a distance as will cause the ship's head to appear due East, whence it may be securely bolted down to the deck. The semi-circular deviation of the compass is now corrected.

Quadrantal Deviation.—Put ship's head by the pelorus N E (Corr Mgc), noting apparent time as before. In nearly every case the deviation is Easterly. Cast iron cylinders or globes are placed on each side of the compass bowl and moved near to or further from it until the ship's head points N E by the compass also, this adjustment properly made does not require touching ever after, unless some alterations are made in the ironwork near the compass or if the ship were to load a cargo of iron. **Rule:** The ends of the correctors must not be nearer to the center of the card than $1\frac{1}{4}$ times the length of the longest needle. The compass is now fully adjusted, swing the ship for final deviation card.

Semi-circular deviation is so termed because it has contrary names, thus if it is Easterly on North, it is Westerly on South.

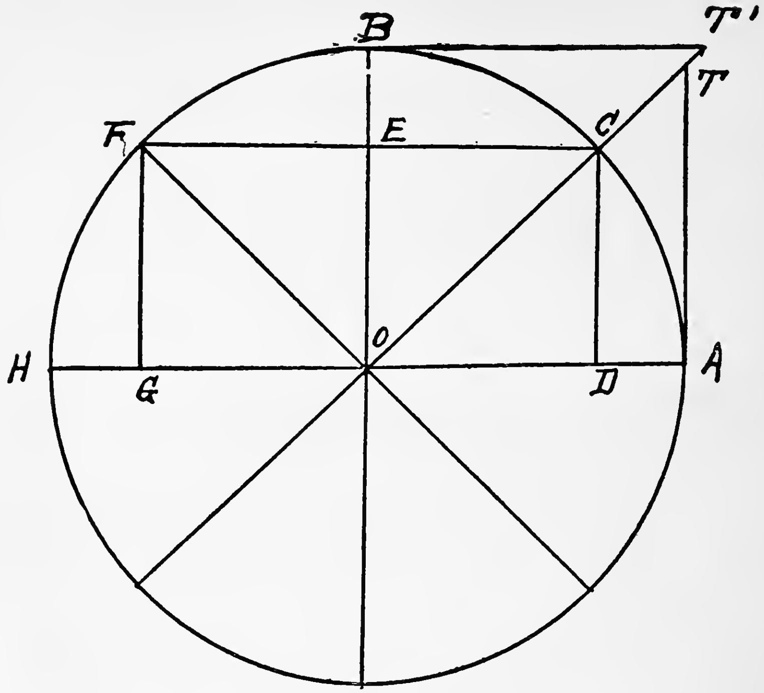
Quadrantal deviation is so termed because it is greatest on the four inter-cardinal points. It has the same name in opposite quadrants, thus, if it is easterly on N E, it will be easterly on S W also, but westerly on S E and N W. Thus the two kinds of deviation are vastly different.

Steel fore and aft magnets produce their greatest effect on East and West, diminishing to nothing on North and South when they become parallel to the compass needle.

Steel athwartship magnets produce their greatest effect on North and South, diminishing to nothing on East and West, when they become parallel to the compass needle.

Quadrantal correctors produce their greatest effect on N E; S E; S W; and N W; tapering to nothing on N; S; E or West.

A flinder's bar placed on the center line of the compass before or abaft acts in the same way as the fore and aft steel magnets.



EXPLANATION BELOW WILL EXPLAIN DIAGRAM

No. 1. The complement of an arc is 90° minus the arc. Thus B C is the complement of the arc A C.

No. 2. The supplement of an arc is 180° minus the arc. Thus F H is the supplement of the arc A B F.

No. 3. The sine of an arc is the perpendicular let fall from one extremity of the arc on the diameter which passes through the other extremity. Thus C D is the sine of the arc A C.

No. 4. The cosine of an arc is the sine of its complement, or it is the distance between the foot of the sine and center of the circle. Thus C E or O D is the cosine of the arc A C.

No. 5. The tangent of an arc is a line which is perpendicular to the radius at one extremity of the arc and limited by a line passing through the center of the circle and the other extremity. Thus A T is the tangent of the arc A C.

No. 6. The cotangent of an arc is equal to the tangent of the complement of arc. Thus B T′ is the cotangent of the arc A C.

No. 7. The secant of an arc is a line drawn from the center of the circle through one extremity of the arc, and limited by a tangent at the other extremity. Thus O T is the secant of the arc A C.

No. 8. The cosecant of an arc is the secant of the complement of the arc. Thus O T′ is the cosecant of the arc A C.

SHIP'S BUSINESS

Invoice.—Is a bill of goods for stores or supplies or a claim against a vessel for unpaid bills, also a claim to hold cargo for freight unpaid.

Bill of Lading.—A description of cargo, and an agreement to deliver same at a certain place for a certain condition. It is made out in 3 copies, 1 for consignor, 1 for consignee, and 1 for master, all signed by master.

Manifest.—A manifest is a description of cargo, also of passengers if any, and their baggage, also a description of the vessel and its voyage. It should be signed by master and should be handed to boarding officer upon arrival at port.

Bottomry Bond.—A bottomry bond is where a master pledges his vessel as security for money loaned to complete voyage.

Charter Party.—A charter party is where the master, owner or agent makes an agreement for the vessel to perform certain services for a certain consideration.

A Protest.—A protest should be sworn to by Master and members of crew before a notary, or consul if abroad. It is a description of some accident happening during the voyage, and protests against blame being placed on ship or crew for accident caused by the elements.

Average.—When it is found necessary to jettison cargo, and some shippers cargo is sacrificed to save the rest of the cargo and ship, a general average is made out so that each should pay their proportionate part.

METHOD OF PREPARING A STATION BILL FOR FIRE AND BOAT DRILL ON AN OCEAN PASSENGER STEAMER

Steamer's crew consists of the following members:

One master, 4 mates, 1 boatswain, 2 carpenters, 3 quartermasters, 12 seamen, 1 chief engineer, 3 assistant engineers, 3 junior engineers, 6 oilers, 3 water tenders, 18 firemen, 9 coal passers, 1 deck engineer, 1 steward, 1 assistant steward, 4 cooks, 1 baker, 3 messmen, 2 pantrymen, 12 waiters, 2 wireless operators and 1 purser.

Vessel has 12 lifeboats allowed 36 persons each. Twelve fire plugs and 2 hand pumps.

FIRE DRILL

RAPID RINGING OF SHIP'S BELL

All crew to report at their proper fire stations, connect hose and have same ready to be run in direction as ordered.

Master in general charge on bridge, with 1 quartermaster as aid. Quartermaster on watch at the wheel.

First officer in charge of deck, and to see that orders of master are obeyed.

Chief engineer in charge of his department.

Third assistant engineer to take charge of engine room and fire pumps with his watch consisting of 1 junior engineer, 2 oilers, 1 water tender, 6 firemen and 3 coal passers. Fire pumps to be started and stopped when directed from bridge.

Hydrant No. 1

Third Officer (in charge)
Water Tender No. 1
Fireman No. 1
Coal Passer No. 1

Hydrant No. 2

Fourth Officer (in charge)
Seaman No. 1
Fireman No. 2
Coal Passer No. 2

Hydrant No. 3

Boatswain (in charge)
Seaman No. 2
Fireman No. 3
Coal passer No. 3

Hydrant No. 4

First Engineer (in charge)
Seaman No. 3
Fireman No. 4
Coal Passer No. 4

Hydrant No. 5

Second Engineer (in charge)
Seaman No. 4
Fireman No. 5
Officers' Messman

Hydrant No. 6

Junior Engineer (in charge)
Seaman No. 5
Fireman No. 6
Firemen's Messman

HYDRANT No. 7

Junior Engineer (in charge)
Seaman No. 6
Fireman No. 7
Sailors' Messman

HYDRANT No. 8

Oiler No. 1 (in charge)
Seaman No. 7
Fireman No. 8
First Pantryman

HYDRANT No. 9

Oiler No. 2 (in charge)
Seaman No. 8
Fireman No. 9
Second Pantryman

HYDRANT No. 10

Oiler No. 3 (in charge)
Seaman No. 9
Fireman No. 10
Chief Cook

HYDRANT No. 11

Oiler No. 4 (in charge)
Seaman No. 10
Fireman No. 11
Second Cook

HYDRANT No. 12

Second Officer (in charge)
Water Tender No. 2
Fireman No. 12
Third Cook

FORWARD HAND PUMP

Quartermaster (in charge)
Seaman No. 11
Coal Passer No. 5
Fourth Cook

AFTER HAND PUMP

Deck Engineer (in charge)
Seaman No. 12
Coal Passer No. 6
Baker

Chief carpenter in charge of fire axes forward with 1 waiter as assistant.

Second carpenter in charge of fire axes aft with waiter No. 2 as assistant. Purser, steward, assistant steward and 10 waiters to take charge of fire buckets and fire extinguishers, and to take charge of and assure passengers.

Two wireless operators on watch in radio room.

BOAT DRILL AND ABANDON SHIP

SEVERAL SHORT BLASTS OF STEAM WHISTLE

All boat crews to report at their stations, uncover and swing out boats.

Officer in charge of each boat to see that his proper complement of crew and passengers report, and that plug is in and boat falls clear, ready for lowering.

Boats shall be loaded quietly without unnecessary excitement and overcrowding.

Lifeboats of this class are required to have at least 2 certificated lifeboat men, and officer in charge shall see that the proper men are put in charge of handling the falls for lowering the boat.

Notices shall be posted in every passenger stateroom of the number of the boat the passenger is to report to, in case of boat drill or to abandon ship.

Every passenger shall be required immediately after leaving port to participate in a boat drill, and also instructed in the proper way to adjust a cork life preserver.

No boat shall be lowered until ordered by master or a proper representative of him.

STATION BILL FOR BOAT DRILL

No. 1 Boat (Starboard Side)

Master (in charge)
Seaman No. 1 (Cert. Lifeboat Man)
Fireman No. 1 (Cer. Lifeboat Man)
Chief Steward
Oiler No. 1
Coal Passer No. 1
Chief Cook
Wireless Operator

No. 2 Boat (Port Side)

Chief Officer (in charge)
Seaman No. 2 (Cer. Lifeboat Man)
Fireman No. 3 (Cer. Lifeboat Man)
First Asst. Engineer
Water Tender No. 1
Fireman No. 3
Baker
Wireless Operator

No. 3 Boat (Starboard Side)

Second Officer (in charge)
Seaman No. 3 (Cer. Lifeboat Man)
Fireman No. 4 (Cer. Lifeboat Man)
Second Asst. Engineer
Water Tender No. 2
Fireman No. 6
Officers' Messman
Waiter No. 1

No. 4 Boat (Port Side)

Third Officer (in charge)
Seaman No. 4 (Cer. Lifeboat Man)
Fireman No. 5 (Cer. Lifeboat Man)
Third Asst. Engineer
Water Tender No. 3
Fireman No. 7
Fireman's Messman
Waiter No. 2

No. 5 Boat (Starboard Side)

Fourth Officer (in charge)
Seaman No. 5 (Cer. Lifeboat Man)
Fireman No. 8 (Cer. Lifeboat Man)
Junior Engineer
Coal Passer No. 2
Fireman No. 10
Sailor's Messman
Waiter No. 3

No. 6 Boat (Port Side)

Chief Carpenter (in charge)
Seaman No. 6 (Cer. Lifeboat Man)
Fireman No. 9 (Cer. Lifeboat Man)
Junior Engineer
Coal Passer No. 3
Fireman No. 11
Chief Pantryman
Waiter No. 4

No. 7 Boat (Starboard Side)
Second Carpenter (in charge)
Seaman No. 7 (Cer. Lifeboat Man)
Fireman No.12 (Cer. Lifeboat Man)
Junior Engineer
Coal Passer No. 4
Fireman No. 14
Second Pantryman
Waiter No. 6

No. 8 Boat (Port Side)
Boatswain (in charge)
Seaman No. 8 (Cer. Lifeboat Man)
Fireman No. 13 (Cer. Lifeboat Man)
Oiler No. 2
Coal Passer No. 5
Deck Engineer
Waiter No. 5
Waiter No. 7

No. 9 Boat (Starboard Side)
Chief Engineer (in charge)
Seaman No. 9 (Cer. Lifeboat Man)
Fireman No.15 (Cer. Lifeboat Man)
Oiler No. 3
Coal Passer No. 6
Assistant Steward
Waiter No. 8
Waiter No. 9

No. 10 Boat (Port Side)
No. 1 Quartermaster (in charge)
Seaman No. 10 (Cer. Lifeboat Man)
Fireman No. 16 (Cer. Lifeboat Man)
Oiler No. 4
Coal Passer No. 7
Purser
Second Cook
Waiter No. 10

No. 11 Boat (Starboard Side)
Quartermaster No. 2 (in charge)
Seaman No. 11 (Cer. Lifeboat Man)
Fireman No.17 (Cer. Lifeboat Man)
Oiler No. 5
Coal Passer No. 8
Third Cook
Waiter No. 11

No. 12 Boat (Port Side)
Quartermaster No. 3 (in charge)
Seaman No. 12 (Cer. Lifeboat Man)
Fireman No.18 (Cer. Lifeboat Man)
Oiler No. 6
Coal Passer No. 9
Fourth Cook
Waiter No. 12

Sextant Adjustments.—*No.* 1. *To Adjust the Index Glass.*—This glass must be perpendicular to the plane of the instrument. To prove this, set the vernier to about the center of the arc and clamp it. Hold the instrument face up with the arc away from you, then look obliquely into the index glass and observe if the arc seen direct and its reflection form one continuous line; if so, the glass is perpendicular to the plane of the instrument, but if the reflected image appears to be lower than the other it proves the glass leans backward; if, however, the reflected image appears to be higher, the glass leans forward.

No. 2. *Adjustment of the Horizon Glass.*—This glass must also be perpendicular to the plane of the instrument. To test this, let the two zeros cut, and holding the instrument almost horizontal look at the horizon line, and note if the direct and the reflected images of the horizon line coincide—that is, if they show as an unbroken line both in the silvered and clear parts of the glass. If they do, the horizon glass is perpendicular, but if they do not, then adjust the glass to the required angle by the adjusting screw on back.

No. 3.—*The Two Glasses to be Parallel.*—With the two zeros cutting, hold the instrument vertically, and if the direct and reflected images of the horizon line show as an unbroken line the horizon glass is parallel to the index glass, but if they do not show in an unbroken line, adjust the horizon glass by the adjusting screw on back.

No. 4. *To Find the Index Error.*—Should it prove impossible to obtain a perfect adjustment, find the error of the instrument as follows: Let the two zeros cut, then holding the instrument vertically look at the horizon, and gently finger the tangent screw so as to move the vernier either forward or backward along the arc until the image of, and the horizon line itself show in an unbroken line across the glass, then the difference between zero on the vernier and zero on the arc will be the index error.

CHAPTER III

ARITHMETIC OF NAVIGATION

The arithmetic used in navigation consists of the plain rules of arithmetic (addition, subtraction, multiplication and division). The addition, subtraction, multiplication and division of decimal fractions, and the addition, subtraction and division of degrees, minutes and seconds and hours, minutes and seconds.

The plain rules of arithmetic it is taken for granted the student knows.

ADDITION OF DECIMALS

In addition of decimals place the numbers that are to be added so that the decimal points will be over each other, and add as a whole number. Place the decimal point in answer under the decimal points in the line.

For example: Add 2894.965; 238.6; and 28.65.

$$\begin{array}{r} 2894.965 \\ 238.6 \\ 28.65 \\ \hline \text{(Ans.)}\quad 3162.215 \end{array}$$

SUBTRACTION OF DECIMALS

In the subtraction of decimals place the decimal point in the numbers so that they will be under each other, and the decimal point in the remainder will be under the decimal point.

For example: Subtract 2846.65 from 3897.286.

$$\begin{array}{r} 3897.286 \\ -2846.65 \\ \hline \text{(Ans.)}\quad 1050.636 \end{array}$$

MULTIPLICATION OF DECIMALS

In the multiplication of decimals multiply as in whole numbers, and count the number of decimal places there are in both numbers, which will be the number of figures counting from the right, where the decimal point goes in the product.

For example: Multiply 24.48 by 2.6.

```
          24.48
        × 2.6
        -------
          14688
          4896
        -------
(Ans.)    63.648
```

DIVISION OF DECIMALS

In the division of decimals divide as whole number. If the divisor has more decimals than the dividend, add that many decimal zeros to the dividend before making the division. To place the decimal point, subtract the number of decimals in the divisor from the number of decimal places in the dividend, and point off as many decimal places in the quotient as there are in the remainder.

Example: Divide 322 by .26.

```
.26)322.000(1238.4 nearly   (Ans.)
    26
    ---
     62
     52
     ---
     100
      78
     ---
      220
      208
      ---
       120
       104
       ---
        16
```

ADDITION OF DEGREES, MINUTES AND SECONDS OR HOURS, MINUTES AND SECONDS

The degrees, minutes and seconds must be directly under their like numbers.

For example: Add together 26° 47′ 36″ and 51° 27′ 42″.

$$\begin{array}{rrr} 26^\circ & 47' & 36'' \\ 51^\circ & 27' & 42'' \\ \hline 78^\circ & 15' & 18'' \end{array} \quad \text{(Ans.)}$$

Adding the seconds gives 78 − 60 = 18″ left, with 1′ to carry. Adding the minutes gives 75′ − 60 = 15′ left, with 1° to carry. Adding degrees gives 78°.

SUBTRACTION

The numbers must be directly under their like numbers. For example: Subtract 40° 52′ 48″ from 76° 29′ 36″.

$$\begin{array}{rrr} 76^\circ & 29' & 36'' \\ -40^\circ & 52' & 48'' \\ \hline 35^\circ & 36' & 48'' \end{array} \quad \text{(Ans.)}$$

In subtracting degrees, minutes and seconds or hours, minutes and seconds, if the number of seconds in the minuend is less than the number in the subtrahend. You take 1′ or 60″ from the minutes and apply it to the minuend. In this example 36″ is less than 48″, so borrow 1′ and make it 96″, we then subtract 48″ from this, which leaves 48″. The minutes will then be 28′. It is now necessary to borrow 1°, and add 60′ to the minutes for the next subtraction which will make 88′ − 52′ which leaves 36′. The degrees will be 75° left, from which subtracting 40° leaves 35°.

SUBTRACTION OF TIME

The problem of finding longitude resolves itself into finding the difference in time at the ship (L. A. T.) and at Greenwich (G. A. T.). In finding differences of time always put down astronomical time, i.e., a day starts at noon and runs through 24 hours till the next noon. Put down the day as well as the hours, minutes and seconds. In case it is necessary to borrow, remember that a day has 24 hours.

For example: See Chap. IX., Prob. 1.

G. A. T. 31st day	1h	58′	13″
L. A. T. 30th day	19h	43′	01″
	6h	15′	12″ (Ans.)

The 1″ may be subtracted from the 13″ and the 43′ from 58′ without difficulty. In subtracting the 19h a day (24h) is borrowed in the minuend making 25h; the days left in the minuend being 30d.

Example: See Chap. IX., Prob. 9.

G. A. T. 15d	4h	36′	00″
L. A. T. 14d	19h	25′	27″
	9h	10′	33″ (Ans.)

Borrow 1′ or 60″ and subtract 27″ leaves 33″. The minutes left will be 35. Borrow a day or 24h, making 28h, subtracting 19h leaves 9h.

DIVISION

In dividing, if there is any remainder it should be changed into the next smaller unit.

Example: Divide 38° 57′ 12″ by 2.

2)38° 57′ 12″

19° 28′ 36″ (Ans.)

Two into 57′ goes 28 times and 1′ remainder. This is changed to 60″ and added to the 12″ making 72″. Two into 72 goes 36 times.

To change longitude in time to longitude in degrees, minutes, etc., and vice versa, it should be noted that

$$360° = 24h;$$
$$15° = 1h$$
$$1° = 4'$$
$$15' = 1'$$
$$1' = 4'';$$

To change time to arc:

Multiply the hours by 15, gives degrees.

Divide minutes of time by 4, gives degrees.

Remaining minutes of time multiplied by 15 gives minutes of arc.

Divide seconds of time by 4, gives minutes of arc.

Remaining seconds of time multiplied by 15 gives seconds of arc.

Example: Change 9h 37′ 14″ to arc.

	$9\times15=$	135°			
37 divided by 4	$=$	9°			and 1′ remaining
	$1\times15=$		15′		
14 divided by 4	$=$		3′		and 2″ remaining
	$2\times15=$			30″	
		144°	18′	30″	(Ans.)

Example: Change 11h 15′ 26″ to arc.

$$\begin{array}{r} 11 \\ \times\ 15 \\ \hline 165 \end{array} \qquad \begin{array}{l} 4\overline{)15} \text{ and 3 remaining} \\ \quad 3° \quad 15 \\ \quad 165 \quad 45' \\ \hline \quad 168° \end{array} \qquad \begin{array}{l} 4\overline{)26} \text{ and 2 remaining} \\ \quad 6' \quad 15 \\ \quad 45 \quad 30'' \\ \hline \quad 51' \end{array}$$

Ans. 168° 51′ 30″

To change arc to time:

Divide degrees by 15, gives hours.

Remaining degrees multiplied by 4, gives minutes.

Divide minutes of arc by 15, gives minutes of time.

Remaining minutes of arc multiplied by 4, gives seconds of time.

Divide seconds of arc by 15, gives seconds of time.

Example: Change 81° 48′ 30″ to time.

$$\begin{array}{l} 15)81(5h \\ \underline{\ 75} \\ \ \ 6 \text{ remaining} \end{array} \qquad \begin{array}{l} 6\times4=24' \\ 15)48(\underline{\ 3'} \\ \underline{\ \ 45}\ \ 27' \\ \ \ 3 \text{ remaining} \end{array} \qquad \begin{array}{l} 3\times4=12'' \\ 15)30(\underline{\ 2''} \\ \qquad 14'' \end{array}$$

Ans. 5h 27′ 14″

EXPLANATION OF THE AMERICAN NAUTICAL ALMANAC FOR THE YEAR 1919

Pages 2 to 3 is the Right Ascension of Mean Sun at Greenwich Mean Noon, and the table below is the correction to be added for Greenwich Mean Time.

For example: G. M. T. Feb. 18th, 6h 28′. Required Sun's Right Ascension.

Sun's Right Ascension Feb. 18th	21h	49′	36″
Corr. for G. M. T. 6h 28′ +		1′	04″
S. R. A.	21h	50′	40″

Pages 6 to 29 is the Sun's Declination, Equation of Time, and Semi-diameter for Greenwich Mean Noon.

The declination and equation of time are given for every day of the year, and on the even hour.

The declination is read in degrees and minutes and tenths of minutes, the sign + means North declination, the sign − means South declination.

The equation of time is read in minutes and seconds and tenths of seconds, the sign + means to add to mean time, the sign − means to subtract from mean time.

To find the sun's declination and equation of time use always the Greenwich Mean Time; using the nearest 0.1 hour. The hourly difference will be found for each date at the bottom of each date. Take out the declination for the nearest even hour that has passed. Add to this a correction which the hourly difference multiplied by the difference in time since the last even hour, expressed in tenths of an hour. if the declination is increasing. If the declination is decreasing, the correction should be subtracted.

For example: Feb. 18, 1919. G. M. T. 9h 14′. Required declination and equation of time.

Decl. for the 18th day, 8th hour	11°	46′.9 S
Hourly difference 0′.9		
Corr. for 1.2 hours = 0′.9 × 1.2 =		1′.1 decreasing
Decl. for 18th day 9.2 hours	11°	45′.8 S
Eq. of time 18th day 8th hour	−14′	6″.8
Hourly diff. 0″.2		
Corr. for 1.2 hours = 0.2 × 1.2 =		0″.2 decreasing
Eq. of time for 18th day 9.2 hours	−14′	6″.6
or	−14′	07″

The semi-diameter is given for every 10 days and is in minutes and tenths and hundredths of minutes. Read semi-diameter to nearest date, and multiply the nearest tenth by 6 to give seconds.

For example: Required S. D. for Feb. 18th.

In N. A. nearest date given is Feb 21st = 16′.20
Therefore S. D. = 16′ 12″

Pages 30 to 75 is the Moon's Right Ascension, Declination, Semi-diameter and Horizontal Parallax given for each day, and on the even hour of that day.

The declination and right ascension are accompanied by the difference or change in every 2 hours; by means of these differences interpolation may be made to any Greenwich Mean Time by Table IV (Almanac) pages 112–114, using the difference in 2 hours at top of page, and the interval in minutes from nearest even hour on the left-hand side of page.

For example: Feb. 18th, G. M. T., 8h 15′. Required Moon's Declination.

Moon's Dec. 18d for 8h.	9°	0′.4 S	Change 208
Corr. Table IV	+	2′.6	Decl. increasing
True Decl.	9°	3′.0 S or 9° 03′ 00″ S	

For same Horizontal Parallax is 54.5
Semi-diameter 14.9

Pages 76 to 77 is the time of Moon's Transit for Meridian of Greenwich.

To find time of transit in any other Meridian, enter Table IV (Almanac). Take the change of transit in small figures between the dates at top of page, and the longitude in time at right-hand side and read the correction.

For example: Required time of Moon's Transit on Feb. 18th in Longitude 90° West.

Long. 90° = Long. in time 6h.

Moon's Trans. 18d at Greenwich	=	15h	03′
Corr. from Table IV	= +		11′
Time of Trans. Long. 90°	=	15h	14′

Correction is always to be added in West Longitude, subtracted in East Longitude.

Pages 78 to 98 is the Right Ascension, Declination, and time of transit given for Greenwich Noon, of the planets " Venus," " Mars," " Jupiter," and " Saturn."

The interpolations for finding at any other meridian are made by using Table IV (N. A.) with G. M. T. at right-hand side, and the difference at top of page.

For example: Required Right Ascension and Declination of planet " Venus " G. M. T. Feb. 18th, 8h 15′.

R. A. 18d	=	23h	23′	00″	Change 273
Corr. Table IV	= +		1′	33″	R. A. increasing
Corr. R. A.	=	23h	24′	33″	
Decl. 18d	=	5°	26.4 S		Change 304
Corr. Table IV	= −		10′.4		Decl. decreasing
True Decl.	=	5°	16′.0 S		

Pages 94 to 95 is the Right Ascension and Declination for fixed stars given for each month.

As the Declination and Right Ascension of a fixed star has a very small annual change, it will be close enough for practical purposes to take it for the month.

Example: Required Declination and Right Ascension * " Spica " on Feb. 18th.

Declination 10° 44′ 30″ S. Right Ascension 13h 20′ 58″.

The balance of the tables explain themselves.

EXPLANATION OF TABLES IN BOWDITCH NAVIGATOR OR EPITOME

TABLE 2

Is to find the difference of latitude and departure in miles for any course in degrees.

The degrees of the course are found at top of page from 0° to 45°.

The degrees of the course are found at bottom of page from 45° to 90°.

When the course is less than 45° read the table as follows: Distance in first column. Difference of latitude in second column. Departure in third column.

When the course is more than 45° read the table as follows: Distance in first column. Departure in second column. Difference of latitude in third column.

For example: Course N 38° E. Distance 48 miles. Diff. lat. will be 37.8 N. Departure 29.6 E.

Course N 52° E. Distance 48 miles. Diff. lat. will be 29.6 N. Departure 37.8 E.

To find the difference of longitude ship has made, look for middle latitude as the course, and the departure in miles in the latitude column, in the distance column opposite will be the difference of longitude in minutes.

For example: Middle Lat. 38°. Departure 105.6 miles. At 38° look for 105.6 in latitude column, which will equal 134′, which is the difference of longitude in minutes. By dividing this by 60, we obtain Diff. Long. 2° 14′.

Middle Lat. 52°. Departure 105.6 miles. By same rule we find distance 171′, or difference of longitude 2° 51′.

To find course and distance ship has run, compare difference of latitude in miles and departure in miles as close as possible, course will be found from top of page if latitude is greatest, from bottom if departure is greatest, and distance will be found on side in distance column.

For example: Diff. Lat. 151.3. Departure 118.2. Comparing these we find course 38° distance 192 miles.

Diff. Lat. 118.2. Departure 151.3. We find course 52° distance 192 miles.

TABLE 3

Used in Mercators sailing for finding the Meridional difference of latitude.

The degrees of latitude are read from top of page, minutes from side.

For example:

Lat. A. 28° 46 Mer. Parts Table 3 = 1792.2

Lat. B. 72° 13 Mer. Parts Table 3 = 6354.8

The meridional parts are to be added together when degrees and minutes of latitude are added, subtracted when degrees and minutes of latitude are subtracted.

TABLE 7

Is to convert arc into time and the reverse.

There are 4′ of time to 1° of arc, and 4″ of time to 1′ of arc, and this table is based on this principle.

For example: To turn Long. 94° 32′ into time. By figures we multiply 94 by 4 and divide by 60, or $94 \times 4 = 376$ divided by 60 = 6h 16′. The same rule applies for the minutes, so $32 \times 4 = 128$ divided by 60 = 2′ 8″. By adding these two together we get 6h 18′ 8″ longitude in time.

By using Table 7 we find that 94° = 6h 16′ and that 32′ = 2′ 8″. By adding these together we get the same result as above.

The use of this table reduces the amount of figures in computing considerably, but the student should understand the principle it is based on.

To turn longitude in time into degrees and minutes proceed in figures as follows:

Multiply hours by 60 and add the minutes or 6h × 60 = 360′ + 18′ = 378′. Divide result by 4, or 378′ divided by 4 = 94° with 2′ left over. Reduce minutes to seconds by same rule and add seconds. Or 2′ × 60 = 120″ + 8″ = 128″, divided by 4 = 32′ or Long. 94° 32′.

To use Table 7 proceed as follows:

Take the hour and nearest minute that can be found, which will be 6h 16′ will = 94°. We then have 2′ 8″ left over. Looking for 2′ 8″ we find 32′ or Long. 94° 32′.

When using this table remember that degrees of arc are read as hours and minutes of time, minutes of arc as minutes and seconds of time, and seconds of arc as seconds and $\frac{1}{60}''$ of time.

TABLE 11

Is used to find the time of Moon's Meridian Passage over any Meridian.

The difference between Moon's Transit is found from top of page, and longitude of place at side.

The numbers taken from this table are to be added to the time of Greenwich transit in West longitude, subtracted in East longitude.

TABLE 20A

Is the Mean Refraction. This table is used for the stars only.

The apparent altitude is read in first column, and the refraction will be found opposite to it.

The refraction is always to be subtracted from apparent altitude.

By apparent altitude is meant, the observed altitude corrected for Index Error if any, and Dip.

For example: Appar. Alt. 19° 12′ = Refr. 2′ 46″ to be subtracted.

TABLE 20B

Is the correction for the Sun's apparent altitude for Refraction and Parallax, always to be subtracted.

The apparent altitude is the observed altitude corrected for Index Error if any, Semi-diameter and Dip.

For example: Appar. Alt. 28° 49′ = Refr. and Par. −1′ 38″.

TABLE 24

Is the correction for the Moon's Apparent Altitude for Parallax and Refraction.

With the Horizontal Parallax as found in Almanac at top of page and apparent altitude at side, read the correction.

This correction is always to be added to Appar. Alt.

Example: H. P. 54.9 Moon's Appar. Alt. 22° 12′ = Par. and Refr. +48′ 30″.

TABLE 26

Is the variation of altitude in 1′ from Meridian Passage.

It is used for finding the latitude by Ex-Meridian observations of a heavenly body.

With declination to nearest degree at top of page, and latitude to nearest degree at side, the variation of altitude in 1′ will be read.

(Note) Notice whether latitude and declination are same or contrary names.

Example:

Lat. 28° N. Decl. 18° S = Variation 2″.3.

By squaring the number of minutes from noon, and multiplying same by this number, will give correction for sun's altitude always to be added.

For example: Time 12′ from noon = 12 × 12 = 144 × 2″.3 = 331″ or 5′ 31″ altitude correction to be added.

TABLE 27

Is the reduction to be applied to altitudes near the meridian.

This table is based on the principle of the number of minutes from noon squared, multiplied by number from Table 26 = Alt. Corr.

Taking the number found in Table 26 in previous example 2″.3 and time from noon 12′, enter Table 27 with 12′ at top of page and 2.0 on side, we find 4′ 48″ alt. corr. By interpolating between this and number below would give 5′ 31″ alt. corr., if 2.3 was used.

By squaring minutes and multiplying by number from Table 26 eliminates this table.

TABLE 42

Is the logarithms of numbers from 1 to 9999.

For finding the logarithm of a number proceed as follows: 1, 2, or 3 figures in the number the logarithm will be read alongside of the number in the 0 column.

Four figures in the number, the first 3 numbers will be read on the side and the last number from top of page. Five figures in the number, the first 4 numbers as above; the fifth is obtained by interpolation.

In interpolation, the difference "D" between the logs of the nearest four-figure numbers, smaller and larger respectively, is found and divided by 10. This is multiplied by the last figure to give difference *d*. *d* is then added to the smaller four-figure log.

For example: To find log of 4.8883.

$$\begin{aligned} \text{Log. } 4.888 &= 0.68913 \\ \text{Log. } 4.889 &= 0.68922 \\ \hline D &= \quad\quad 9 \\ d &= 3 \times .9 = 2.7 \text{ or } 3 \\ \text{Log. } 4.8880 &= 0.68913 \\ d &= \quad\quad 3 \\ \hline \text{Log. } 4.8883 &= 0.68916 \end{aligned}$$

Every logarithm has an index number i.e., the number in front of the decimal point; which is found by following rule:

Number between 0 and 1	Index number is 0
Number between 1 and 10	Index number is 1
Number between 10 and 100	Index number is 2
Number between 100 and 1000	Index number is 3

For example:

Log. of 8 = 0.90309
Log. of 28 = 1.44716
Log. of 365 = 2.56229
Log. of 4888 = 3.68913

At the side of the main table are small tables of proportional parts which give the corrections to be added to a log. of a four-figure number to give the log. of a five-figure number. The difference D is at the top of little table in heavy type, in the vertical columns are given the difference d.

For example: To find the log of 4.8883.
Log. of 4.888 is 0.68913 and D is **9**.

Looking at side of main table and find small table with 9 in heavy type at top. d for 3 is 3.

To find log. of 1.2934.
Log. of 1.293 is 0.11160 and D is 33.

Looking at side of main table and find small table with 33 in heavy type at top. d for 4 is 13.

$$\begin{aligned} \text{Log. } 1.2930 &= \quad 0.11160 \\ d &= + \quad\quad 13 \\ \hline \text{Log. } 1.2934 &= \quad 0.11173 \end{aligned}$$

TABLE 44

Is the logarithms of the sines, cosecants, tangents, cotangents, secants and cosines.

From 0° to 45° will be found from top of page and minutes in left-hand column reading down.

From 45° to 90° will be found on bottom, minutes on right-hand side reading up.

For example: Log. Sine of 18° 48′ = 9.50821
Log. Sine of 71° 12′ = 9.97619

To find log. sin, etc.; to nearest second of angle.

If angle is larger than 4°; between each two columns of logs there is a column of differences, the seconds corresponding being the left-hand column of minutes. Find the log. to the nearest minute, then look down the left-hand column to where the number of seconds is found; then look straight across to the vertical column of differences next to that in which the log. was found for the correction. The correction is to be added if the log. is increasing and vice versa.

If angle is smaller than 4° the difference for 1′ is given. This must be divided by 60 to give the difference for 1″. It must then be multiplied by the number of seconds to give the correction.

For example: (See Chap. IX, Prob. 1.)

Find log. cos. of 73° 39′ 24″

Log. cos. 73° 39′ =	9.44948
Opp. 24 in left-hand col. find in col. of diff.	17
Since cos. is decreasing sub.	9.44931

Find log. sin of 59° 38′ 42″

Log. sin 59° 38′;	= 9.93591
Opp. 42 in left-hand col. find in col. of diff.	5
Since sin is increasing add	9.93596

TABLE 45

Is the Table for Log. Haversines and Nat. Haversines.

The Log. Haversine is in light type. The Nat. Haversine in heavy type.

When looking for Log. Haversine of L. A. T. if the sight is A. M., the hours and minutes of time are read from bottom of page, and the seconds from right-hand column reading up the page.

When the hours and minutes are taken from the bottom of page, the astronomical date will be the date before the civil date which is given in example.

For example: Feb. 9th A. M. at ship. Log. Hav. as found from sum of logs. = 9.38624. Log. Hav. 9.38624 = L. A. T. Feb. 8th, 20h 3′ 32″.

If the sight is P. M. the hours and minutes will be found on top in light type, and the astronomical date will be the same as civil date, and the seconds will be found on left-hand side reading down the page.

For example: Feb. 9th P. M. at ship. Log. Hav. 9.38624 = L. A. T. Feb. 9th, 3h 56′ 28″.

For turning longitude in time into degrees, minutes and seconds proceed as follows: Read hours and minutes of longitude in time at top, seconds in left-hand column.

For example: Turn long. in time 3h 56′ 28″ into arc.

For 3h 56′ we find 59° 0′. For 28″ we find +7′ or Long. 59° 7′.

To find the Nat. Hav. look for Log. Hav. and alongside of it will be Nat. Hav.

For example: Log. Hav. 9.38624 = Nat. Hav. .24335 and

Nat. Hav. .24335 = 59° 07′
Nat. Hav. .24339 = 59° 07′ 15″
Nat. Hav. .24342 = 59° 07′ 30″
Nat. Hav. .24345 = 59° 07′ 45″

TABLE 46

is the correction to be applied to an observed altitude of sun or star to find true altitude.

This table does away with the necessity for applying the Semi-diameter, Dip, Refraction and Parallax to sun's altitude, and dip and refraction to star's altitude.

The height of eye will be found at top of page, and obs. alt. at side, and the correction for sun in first column to be added, and to the star in second column to be subtracted.

For example: Sun's Obs. Alt. 28° 50′ Dip 28′ = Corr. + 9′ 13″ or True Alt. 28° 59′ 13″.

Star's Obs. Alt. 28° 50′. Dip 28′ = Corr. −6′ 57″ or True Alt. 28° 43′ 03″.

This shortens the work of correcting the altitude considerably, but the student should understand the other method before using this table.

CHAPTER IV

DAY'S WORK OR SHIP'S POSITION BY DEAD RECKONING

This problem is to find the ship's position when no observations are obtainable. It is accurate as long as the proper distance on each course is allowed, and leeway, deviation, and variation is correct.

The leeway is the amount the ship is drifting to leeward from the compass course, and is by the judgment of the navigator set to so many degrees or points of the compass.

The deviation is the difference between the compass course and the magnetic course, and is explained under Deviation of the Compass.

The variation is the difference between the magnetic course and true course, and is explained under Variation of the Compass.

To convert a compass course into a true course allow easterly deviation and variation to the right of the compass course; westerly to the left, always imagining yourself standing in the center of the compass and looking toward the course you are steering.

To convert a true course into a compass course, allow east to left; west to right.

The departure course is the bearing of the point of departure by a compass. This course must be reversed (imagining the ship to have sailed from the point to the place you are at time of taking the bearing), and corrected for the deviation and variation for the ship's head, making the bearing true, and entered in the traverse table as a regular course.

The courses are then corrected for Leeway, deviation and variation, and entered in traverse taole.

The current course is the amount and direction the current has set the ship for the day, and is corrected for Variation only, and entered in traverse table as a regular course.

The traverse table is drawn and the true courses and distance of each entered.

The difference of latitude and departure is found for each course and distance, from Table 2 (Bowditch) and entered in traverse table.

The difference of latitude is the amount of latitude north or south in miles the ship has run on the course.

The departure is the amount of easting or westing in miles the ship has made on the course.

The latitude and departure columns are then added up separately, and the less subtracted from the greater.

The amount of each left will be the difference of latitude north or south, and departure east or west.

The latitude left is now put down and the difference of latitude converted into degrees, minutes and seconds, allowing 60 miles to 1° of latitude from the equator to the poles.

Applying this difference of latitude to latitude left will give the latitude arrived at.

A degree of longitude is worth 60 miles on the equator or Lat. 0° but on account of the curvature of the earth there is no longitude at the poles or Lat. 90°. It is then necessary to find the value of a degree of longitude halfway between the latitude left and latitude arrived at, we then proceed as follows:

To find Middle Latitude: Add together, Lat. left and Lat. in, and divide sum by 2. Answer will be Middle Latitude.

The longitude left is now put down and the difference of longitude is found as follows:

Enter Table 2 (Bowditch) with Middle Latitude to nearest degree as a regular course, look in the latitude column for the difference of departure, and in the distance column will be the difference of longitude in minutes.

Convert this difference of longitude in minutes into degrees, minutes and seconds by dividing by 60, and apply to longitude left. Answer will be longitude arrived at.

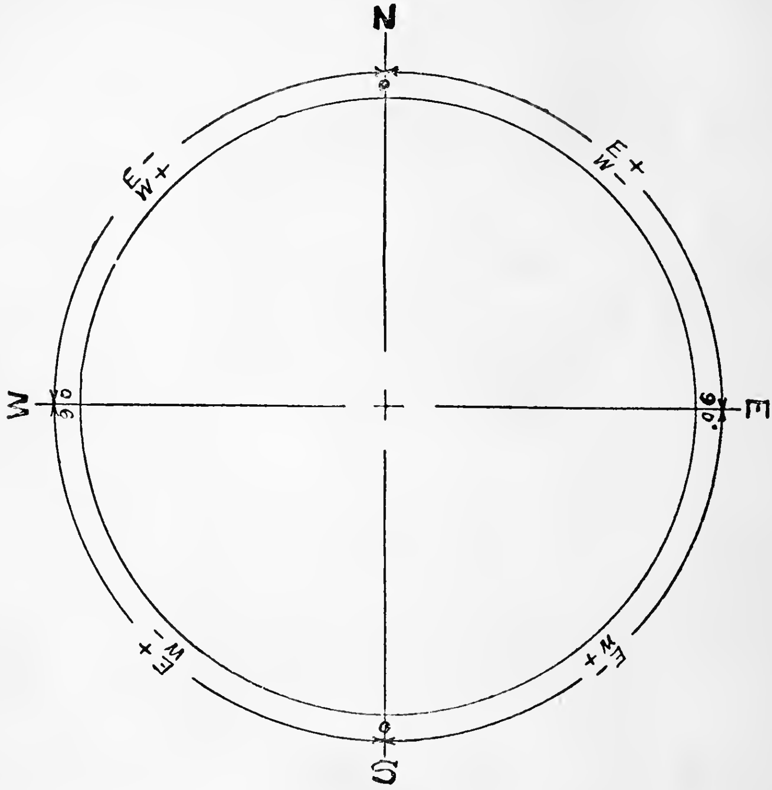
The latitude and longitude arrived at will be the position of the vessel by dead reckoning.

To find the true course and distance made in a straight line between the places, enter Table 2 (Bowditch) and compare the difference of latitude in miles with the departure in miles as close as possible.

Where these two compare will be the course and distance.

The course will be found from top of page if difference of latitude is greatest number.

From bottom of page if Departure is greatest number.
In the distance column opposite to where these agree will be the distance ship has run.



DIAGRAM

For Converting Compass Courses into True Courses

Allow easterly deviation and variation to the right.
Allow westerly deviation and variation to the left.

To Convert a True Course into a Compass Course

Allow easterly deviation and variation to the left.
Allow westerly deviation and variation to the right.

To Convert a True Course into a Magnetic Course

Allow for variation only, to the left for easterly, to the right for westerly.

To Convert a Compass Course into a Magnetic Course

Allow for deviation only, to the right for easterly, to the left for westerly.

PROBLEM NO. 1

A ship takes her departure from Lat. 28° 14′ 00″ N, Long. 79° 30 W and sails the following courses:

Courses	Distance	Deviation	Variation
N 20° W	26	4° E	8° W
S 16° E	31	4° W	8° W
S 80° W	35	6° E	8° W
S 70° E	40	12° W	8° W
N 40° E	45	6° E	8° W
North	50	3° E	8° W

Required Lat. and Long. arrived at. True course and distance made?

1st Course	2d Course
N 20° W	S 16° E
Dev. 4° E to right	Dev. 4° W to left
N 16° W	S 20° E
Var. 8° W to left	Var. 8° W to left
N 24° W (true)	S 28° E (true)

3d Course	4th Course
S 80° W	S 70° E
Dev. 6° E to right	Dev. 12° W to left
S 86° W	S 82° E
Var. 8° W to left	Var. 8° W to left
S 78° W (true)	East (true)

5th Course	6th Course
N 40° E	North
Dev. 6° E to right	Dev. 3° E to right
N 46° E	N 3° E
Var. 8° W to left	Var. 8° W to left
N 38° E (true)	N 5° W (true)

Corrected Courses	Distance	Difference Lat. North	South	Departure East	West
N 24° W	26	23.8			10.6
S 28° E	31		27.4	14.6	
S 78° W	35		7.3		34.2
East	40			40.0	
N 38° E	45	35.5		27.7	
N 5° W	50	49.8			4.4
		109.1	34.7	82.3	49.2
		34.7		49.2	

Diff. Lat. 74.4 N Dep. 33.1 E

Latitude left	28° 14′ 00″ N
Diff. Lat.	1° 14′ 24″ N
Latitude in	29° 28′ 24″ N
	2)57° 42′ 24″
Middle Lat.	28° 51′ 12″ or 29°

Longitude left	79° 30′ W
Diff. Long.	38′ E
Longitude in	78° 52′ W

True course N 24° E. Distance 81 miles.

PROBLEM NO. 2

Ship takes her departure from a point in Lat. 37° 03′ N Long. 9° 00 W bearing by compass N 48° E distance 15 miles. Ship's head S 67° W.

Courses	Distance	Wind	Leeway	Deviation	Variation
S 67° W	45	N W	6°	11° W	22° W
N 39° W	49	S W	3°	17° W	22° W
N 22° W	38	West	9°	11° W	22° W
N 56° W	31	S W	14°	20° W	22° W
S 39° W	36	S E	11°	6° W	22° W
S 84° W	41	South	6°	14° W	22° W

Current set S 65° W (Corr. Mgc.) 8 miles for day.

Required Lat. and Long. arrived at. True course and distance made?

PROBLEM NO. 2

Method of Converting Compass Courses into True Courses Before Entering in Traverse Table

No. 1

Bearing course N 48° E to be reversed and read
S. 48° W
Dev. 11° W to left
————
S 37° W
Var. 22° W to left
————
S 15° W (true)

No. 2

S 67° W
6° Leeway to left
————
S 61° W
Dev. 11° W to left
————
S 50° W
Var. 22° W to left
————
S 28° W (true)

No. 3

N 39° W
3° Leeway to right
————
N 36° W
17° W Dev. to left
————
N 53° W
22° W Var. to left
————
N 75° W (true)

No. 4

N 22° W
9° Leeway to right
————
N 13° W
11° W Dev. to left
————
N 24° W
22° W Var. to left
————
N 46° W (true)

No. 5

N 56° W
14° Leeway to right
————
N 42° W
20° W Dev. to left
————
N 62° W
22° W Var. to left
————
N 84° W (true)

No. 6

S 39° W
11° Leeway to right
————
S 50° W
6° W Dev. to left
————
S 44° W
22° W Dev. to left
————
S 22° W (true)

No. 7

S 84° W
6° Leeway to right

W 90°
14° W Dev. to left

S 76° W
22° W Var. to left

S 54° W (true)

No. 8 Current

S 65° W set of current magnetic
22° W Variation

S 43° W set of cur. true

The true courses are now entered in traverse table with their distance in the distance column, and the difference of latitude and departure found for each in Table 2.

ANSWER TO PROBLEM NO. 2

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
S 15° W	15		14.5		3.9
S 28° W	45		39.7		21.1
N 75° W	49	12.7			47.3
N 46° W	38	26.4			27.3
N 84° W	31	3.2			30.8
S 22° W	36		33.4		13.5
S 54° W	41		24.1		33.2
S 43° W	8		5.9		5.5
		42.3	117.6	Dep.	182.6W
			42.3		
		Diff. Lat.	75.3 S		

Lat. left	37°	03′	00″	N
Diff. Lat.	1°	15′	18″	S
Lat. in	35°	47′	42″	N
Lat. left	37°	03′		
	2)72°	50′	42″	
Mid. Lat.	36°	25′	21″	or 36°

Long. left	9°	00′ W
Diff. Long.	3°	46′ W
Long. in	12°	46′ W

True course S 68°W. Distance 197 miles.

PROBLEM NO. 3

A ship takes her departure from a point in Lat. 28° 16′ 15″ N Long. 93° 26′ W and sails the following courses:

Courses	Distance	Wind	Leeway	Deviation	Variation
North	50	West	4°	6° E	18° W
N 20° W	52	West	5°	8° W	18° W
West	53	North	6°	7° E	18° W
S 49° W	54	North	7°	8° W	18° W
S 79° W	55	North	7°	9° E	18° W
South	56	West	20°	7° E	18° W
S 10° E	57	West	8°	6° W	18° W

Current set east (Corr. Mgc.) 8 miles for day.

Required latitude and longitude arrived at. True course and distance made.

ANSWER TO PROBLEM NO. 3

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 8° W	50	49.5			7.0
N 41° W	52	39.2			34.1
S 73° W	53		15.5		50.7
S 16° W	54		51.9		14.9
S 63° W	55		25.0		49.0
S 31° E	56		48.0	28.8	
S 42° E	57		42.4	38.1	
N 72° E	8	2.5		7.6	
		91.2	182.8	74.5	155.7
			91.2		74.5
		Diff. Lat	91.6 S	Dep.	81.2W

Lat left	28°	16′	15″	N
Diff. Lat.	1°	31′	36″	S
Lat. in	26°	44′	39″	N
Lat. left	28°	16′	15″	
	2)55°	00′	54″	
Mid. Lat.	27°	30′	27″	or 27°

Long. left	93°	26′	W
Diff. Lon.	1°	31′	W
Long. in	94°	57′	W

True course S 42° W. Distance 123 miles.

PROBLEM NO. 4

A ship takes her departure from a point in Lat. 21° 12′ N Long. 8° 15′ E bearing by Compass N 20° W. Distance 12 miles. Ship's head S 45° W.

Courses	Distance	Wind	Leeway	Deviation	Variation
S 45° W	40	South	3°	8° E	7° W
S 80° W	41	South	8°	4° E	7° W
N 75° W	42	S W	4°	5° E	7° W
N 45° W	43	West	3°	3° W	7° W
North	44	East	2°	4° W	7° W
N 10° E	45	East	3°	5° E	7° W

Current set east (Corr. Mgc.) 12 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 4

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
S 19° E	12		11.3	3.9	
S 49° W	40		26.2		30.2
S 85° W	41		3.6		40.8
N 73° W	42	12.3			40.2
N 52° W	43	26.5			33.9
N 13° W	44	42.9			9.9
N 5° E	45	44.8		3.9	
N 83° E	12	1.5		11.9	
		128.0	41.1	19.7	155.0
		41.1			19.7
	Diff. Lat.	86.9 N		Dep.	135.3W

Lat. left	21°	12′	00″	N
Diff. Lat.	1°	26′	54″	N
Lat. in	22°	38′	54″	N
Lat. left	21°	12′		
	2)43°	50′	54″	
Mid. Lat.	21°	55′	27″	or 22°

Long. left	8°	15′	E
Diff. Long.	2°	26′	W
Long. in	5°	49′	E

True course N 57° W. Distance 161 miles.

PROBLEM NO. 5

A ship takes her departure from a point in Lat. 18° 14′ 12″ S Long. 156° 12′ E bearing by compass N 89° E distance 12 miles. Ship's head North.

Courses	Distance	Wind	Leeway	Deviation	Variation
North	60	East	2°	12° W	6° E
N 20° W	61	N E	4°	8° W	6° E
N 50° W	62	North	3°	4° E	6° E
N 80° W	63	North	4°	5° E	6° E
S 80° W	64	N W	5°	6° W	6° E
S 15° W	65	West	4°	14° W	6° E

Current set S 15° E (Corr. Mgc.) 18 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 5

Corrected Courses	Distance	Difference Lat. North	South	Departure East	West
S 83° W	12		1.5		11.9
N 8° W	60	59.4			8.4
N 26° W	61	54.8			26.7
N 43° W	62	45.3			42.3
N 73° W	63	18.4			60.2
S 75° W	64		16.6		61.8
S 3° W	65		64.9		3.4
S 9° E	18		17.8	2.8	
		177.9	100.8	2.8	214.7
		100.8			2.8
Diff. Lat.		77.1 N		Dep.	211.9W

Lat. left	18°	14′	12″	S
Diff. Lat.	1°	17′	06″	N
Lat. in	16°	57′	06″	S
Lat. left	18°	14′	12″	
	2)35°	11′	18″	
Mid. Lat.	17°	35′	39″	or 18°
Long. left	156°		12′	E
Diff. Long.	3°		43′	W
Long. in	152°		29′	E

True course N 70° W. Distance 225 miles.

PROBLEM NO. 6

A ship takes her departure from a point in Lat. 62° 12′ S Long. 171° 12′ E bearing by compass East distance 12 miles. Ship's head S 15° W.

Courses	Distance	Wind	Leeway	Deviation	Variation
S 15° W	62	West	4°	8° W	18° E
South	64	S W	5°	9° W	18° E
West	66	North	6°	7° E	18° E
N 45° W	68	West	3°	19° W	18° E
S 59° W	70	South	6°	8° W	18° E
N 50° W	72	S W	7°	10° W	18° E

Current set S 15° E (Corr. Mgc.) 18 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 6

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 80° W	12	2.1			11.8
S 21° W	62		57.9		22.2
S 4° W	64		63.8		4.5
N 71° W	66	21.5			62.4
N 43° W	68	49.7			46.4
S 75° W	70		18.1		67.6
N 35° W	72	59.0			41.3
S 3° W	18		18.0		0.9
		132.3	157.8	Dep.	257.1W
			132.3		
		Diff. Lat.	25.5 S		

Lat. left	62°	12′	00″	S
Diff. Lat.		25′	30″	S
Lat. in	62°	37′	30″	S
Lat left	62°	12′		
	2)124°	49′	30″	
Mid. Lat	62°	24′	45″	or 62°

Long. left	171°	12′	E
Diff. Long.	9°	08′	W
Long. in	162°	04′	E

True course S 84° W. Distance 258 miles.

PROBLEM NO. 7

A ship takes her departure from a point in Lat. 36° 56′ N Long. 75° 51′ W bearing by compass N 67° W distance 7 miles. Ship's head S 56° E.

Courses	Distance	Wind	Leeway	Deviation	Variation
S 56° E	50	East	3°	4° W	8° E
S 23° E	40	East	2°	2° W	8° E
South	20	East	4°	12° W	8° E
East	60	North	8°	3° E	8° E
N 73° E	30	North	4°	4° W	8° E
N 51° E	40	North	3°	3° E	8° E

Current set S 46° W (Corr. Mgc.) 14 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 7

Corrected Courses	Distance	Difference Lat.		Departure	
		North	South	East	West
S 63° E	7		3.2	6.2	
S 49° E	50		32.8	37.7	
S 15° E	40		38.6	10.4	
South	20		20.0		
S 71° E	60		19.5	56.7	
N 81° E	30	4.7		29.6	
N 65° E	40	16.9		36.3	
S 54° W	14		8.2		11.3
		21.6	122.3	176.9	11.3
			21.6	11.3	

Diff. Lat. 100.7 S 165.6 Dep. E

Lat. left	36°	56′	00″	N
Diff. Lat.	1°	40′	42″	S
Lat. in	35°	15′	18″	N
	2)72°	11′	18″	
Mid. Lat.	36°	05′	39″	or 36°

Long. left	75°	51′	W
Diff. Long.	3°	25′	E
Long. in	72°	26′	W

True course S 59° E. Distance 193 miles.

PROBLEM NO. 8

A ship takes her departure from a point in Lat. 0° 21′ N Long. 178° 21′ E bearing by compass S 21° E distance 13 miles. Ship's head N 18° E.

Courses	Distance	Wind	Leeway	Deviation	Variation
N 18° E	60	East	4°	7° E	9° W
N 3° W	61	N E	5°	4° E	9° W
N 45° W	62	N E	3°	1° W	9° W
West	63	North	2°	6° E	9° W
S 50° W	64	N W	1°	2° E	9° W
South	65	West	2°	6° E	9° W

Current set S 15° E (Corr. Mgc.) 24 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 8

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 23° W	13	12.0			5.1
N 12° E	60	58.7		12.5	
N 13° W	61	59.4			13.7
N 58° W	62	32.9			52.6
S 85° W	63		5.5		62.8
S 42° W	64		47.6		42.8
S 5° E	65		64.8	5.7	
S 24° E	24		21.9	9.8	
		163.0	139.8	28.0	177.0
		139.8			28.0
	Diff. Lat.	23.2 N		Dep.	149.0W

Lat. left	0°	21′	00″	N
Diff. Lat.		23′	12″	N
Lat. in	0°	44′	12″	N
	2)1°	05′	12″	
Mid. Lat.		32′	36″	or 1°
Long. left	178°	21′	E	
Diff. Long.	2°	29′	W	
Long. in	175°	52′	E	

True course N 81° W. Distance 151 miles.

PROBLEM NO. 9

A ship takes her departure from a point in Lat. 3° 10′ 12″ S Long. 0° 15′ W bearing by compass N 10° W distance 14 miles. Ship's head S 15° W.

Courses	Distance	Wind	Leeway	Deviation	Variation
S 15° W	40	S E	4°	3° W	40° E
S 15° E	41	East	5°	8° W	40° E
East	42	South	6°	1° E	40° E
N 70° E	43	South	4°	4° W	40° E
N 45° E	44	North	2°	1° E	40° E
N 15° E	45	East	1°	2° E	40° E

Current set N 16° W (Corr. Mgc.) 18 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 9

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
S 27° W	14		12.5		6.4
S 56° W	40		22.4		33.2
S 22° W	41		38.0		15.4
S 55° E	42		24.1	34.4	
S 78° E	43		8.9	42.1	
N 88° E	44	1.5		44.0	
N 56° E	45	25.2		37.3	
N 24° E	18	16.4		7.3	
		43.1	105.9	165.1	55.0
			43.1	55.0	
		Diff. Lat.	62.8 S	110.1	Dep. E

Lat. left	3° 10′ 12″ S
Diff. Lat.	1° 02′ 48″ S
Lat in	4° 13′ 00″ S
	2)7° 23′ 12″
Mid. Lat.	3° 41′ 36″ or 4°
Long. left	0° 15′ W
Diff. Long.	1° 50′ E
Long. in	1° 35′ E

True course S 60° E. Distance 127 miles.

PROBLEM NO. 10

A ship takes her departure from a point in Lat. 67° 15′ 08″ N Long. 112° 12′ W bearing by compass S 80° W distance 20 miles. Ship's head North.

Courses	Distance	Wind	Leeway	Deviation	Variation
North	50	East	3°	4° E	21° W
N 40° W	51	N E	2°	9° E	21° W
N 15° W	52	N E	3°	3° E	21° W
West	53	North	2°	26° E	21° W
N 70° W	54	North	1°	2° E	21° W
S 89° W	55	South	3°	4° E	21° W

Current set S 22° E (Corr. Mgc.) 14 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 10

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 63° E	20	9.1		17.8	
N 20° W	50	47.0			17.1
N 54° W	51	30.0			41.3
N 36° W	52	42.1			30.6
N 87° W	53	2.8			52.9
West	54				54.0
S 75° W	55		14.2		53.1
S 43° E	14		10.2	9.5	
		131.0	24.4	27.3	249.0
		24.4			27.3
	Diff. Lat.	106.6 N		Dep.	221.7W

Lat. left	67°	15′	08″	N
Diff. Lat.	1°	46′	36″	N
Lat. in	69°	01′	44″	N
	2)136°	16′	52″	
Mid. Lat.	68°	08′	26″	or 68°

Long. left	112°	12′	W
Diff. Long.	9°	52′	W
Long. in	122°	04′	W

True course N 64° W. Distance 246 miles.

PROBLEM NO. 11

A ship takes her departure from a point in Lat. 0° 00 Long. 0° 00′ bearing by compass South distance 18 miles Ship's head East.

Courses	Distance	Wind	Leeway	Deviation	Variation
East	70	S E	2°	12° E	18° W
S 45° E	71	South	8°	5° E	18° W
S 15° E	72	East	3°	25° E	18° W
South	73	East	4°	8° E	18° W
S 10° W	74	East	2°	4° E	18° W
S 45° W	75	S E	1°	6° E	18° W

Current set N 8° W (Corr. Mgc.) 19 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 11

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 6° W	18	17.9			1.9
N 82° E	70	9.7		69.3	
S 66° E	71		28.9	64.9	
S 5° E	72		71.7	6.3	
S 6° E	73		72.6	7.6	
S 2° E	74		74.0	2.6	
S 34° W	75		62.2		41.9
N 26° W	19	17.1			8.3
		44.7	309.4	150.7	52.1
			44.7	52.1	
		Diff. Lat.	264.7 S	98.6 Dep. E	

Lat. left	0° 00′ 00″
Diff. Lat.	4° 24′ 42″ S
Lat. in	2)4° 24′ 42″ S
Mid. Lat.	2° 12′ 21″ or 2°

Long. left	0° 00′ 00″
Diff. Long.	1° 38′ 45″ E
Long. in	1° 38′ 45″ E

True course S 20° E. Distance 281 miles.

PROBLEM NO. 12

A ship takes her departure from a point in Lat. 51° 37′ N Long. 8° 32′ W bearing by compass N 45° W distance 12 miles. Ship's head S 17° W.

Courses	Distance	Wind	Leeway	Deviation	Variation
S 17° W	26	West	3°	5° E	24° W
S 53° W	30	N W	3°	9° W	24° W
S 67° W	50	N W	6°	12° W	24° W
N 3° W	38	N W	9°	4° W	24° W
S 51° E	32	S W	0°	11° E	24° W

Current set N 79° W (Corr. Mgc.) 14 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 12

Corrected Courses	Distance	Difference Lat. North	South	Departure East	West
S 64° E	12		5.3	10.8	
S 5° E	26		25.9	2.3	
S 17° W	30		28.7		8.8
S 25° W	50		45.3		21.1
N 22° W	38	35.2			14.2
S 64° E	32		14.0	28.8	
S 77° W	14		3.1		13.6
		35.2	122.3	41.9	57.7
			35.2		41.9
		Diff. Lat.	87.1 S	Dep.	15.8W

Lat. left	51° 37′ 00″ N
Diff. Lat.	1° 27′ 06″ S
Lat. in	50° 09′ 54″ N
	2)101° 46′ 54″
Mid. Lat.	50° 53′ 27″ or 51°
Long. left	8° 32′ W
Diff. Long.	25′ W
Long. in	8° 57′ W

True course S 10° W. Distance 89 miles.

PROBLEM NO. 13

A ship takes her departure from a point in Lat. 62° 11′ N Long 5° 08′ E bearing by compass S 28° W distance 10 miles. Ship's head N 22° W.

Courses	Distance	Wind	Leeway	Deviation	Variation
N 22° W	39	N E	6°	7° W	20° W
N 68° W	36	North	8°	18° W	20° W
S 28° W	39	S E	3°	9° W	20° W
S 11° E	40	East	0°	3° E	20° W
S 6° E	35	S W	11°	2° E	20° W
N 23° E	31	N W	14°	6° E	20° W

Current set S 56° W (Corr. Mgc.) 36 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 13

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 1° E	10	10.0		0.2	
N 55° W	39	22.4			31.9
S 66° W	36		14.6		32.9
S 2° W	39		39.0		1.4
S 28° E	40		35.3	18.8	
S 35° E	35		28.7	20.1	
N 23° E	31	28.5		12.1	
S 36° W	36		29.1		21.2
		60.9	146.7	51.2	87.4
			60.9		51.2
		Diff. Lat.	85.8 S	Dep.	36.2W

Lat. left	62°	11′	00″	N
Diff. Lat.	1°	25′	48″	S
Lat. in	60°	45′	12″	N
	2)122°	56′	12″	
Mid. Lat.	61°	28′	06″	or 61°

Long. left	5°	08′	E
Diff. Long.	1°	15′	W
Long. in	3°	53′	E

True course S 23° W. Distance 93 miles.

PROBLEM NO. 14

A ship takes her departure from a point in Lat. 47° 34′ N Long. 52° 40′ W bearing by compass N 70° W distance 17 miles. Ship's head N 84° E.

Course	Distance	Wind	Leeway	Deviation	Variation
N 84° E	20	S E	14°	9° E	31° W
N 20° E	33	East	6°	11° E	31° W
S 42° E	35	N E	3°	4° E	31° W
N 70° W	35	S W	5°	6° W	31° W
N 53° E	·37	N W	3°	4° E	31° W
S 64° E	28	N E	5°	3° W	31° W

Current set N 73° E (Corr. Mgc.) 17 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 14

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 88° E	17	0.6		17.0	
N 48° E	20	13.4		14.9	
N 6° W	33	32.8			3.4
S 66° E	35		14.2	32.0	
S 78° W	35		7.3		34.2
N 29° E	37	32.4		17.9	
N 87° E	28	1.5		28.0	
N 42° E	17	12.6		11.4	
		93.3	21.5	121.2	37.6
		21.5		37.6	

Diff. Lat. 71.8 N Dep. 83.6 E

Lat. left	47° 34′ 00″ N
Diff. Lat.	1° 11′ 48″ N
Lat. in	48° 45′ 48″ N
	2)96° 19′ 48″
Mid. Lat.	48° 09′ 54″ or 48°

Long. left	52° 40′ W
Diff. Long.	2° 05′ E
Long. in	50° 35′ W

True course N 49° E. Distance 111 miles.

PROBLEM NO. 15

A ship takes her departure from a point in Lat. 38° 43′ S Long. 77° 35′ E bearing by compass S 28° E distance 16 miles. Ship's head N 56° W.

Course	Distance	Wind	Leeway	Deviation	Variation
N 56° W	35	North	11°	16° W	25° W
S 34° E	40	S W	3°	11° E	25° W
S 6° W	41	S E	0°	2° W	25° W
N 87° W	37	North	6°	26° W	25° W
N 28° E	34	N W	20°	8° E	25° W
S 11° E	37	East	8°	3° E	25° W

Current set S 56° E (Corr. Mgc.) 39 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 15

Corrected Courses	Distance	Difference Lat.		Departure	
		North	South	East	West
N 69° W	16	5.7			14.9
S 72° W	35		10.8		33.3
S 51° E	40		25.2	31.1	
S 21° E	41		38.3	14.7	
S 36° W	37		29.9		21.7
N 31° E	34	29.1		17.5	
S 25° E	37		33.5	15.6	
S 81° E	39		6.1	38.5	
		34.8	143.8	117.4	69.9
			34.8	69.9	
		Diff. Lat.	109.0 S	47.5	Dep. E

Lat. left	38°	43′	00″	S
Diff. Lat.	1°	49′	00″	S
Lat. in	40°	32′	00″	S
	2)79°	15′	00″	
Mid. Lat.	39°	37′	30″	or 40°

Long. left	77°	35′ E
Diff. Long	1°	02′ E
Long. in	78°	37′ E

True course S 23° E. Distance 119 miles.

PROBLEM NO. 16

A ship takes her departure from a point in Lat. 61° 19′ N Long. 179° 19′ E bearing by compass N 56° W distance 18 miles. Ship's head N 23° E.

Courses	Distance	Wind	Leeway	Deviation	Variation
N 23° E	34	N W	11°	6° E	20° E
N 56° E	40	North	3°	16° E	20° E
N 86° E	30	South	14°	21° E	20° E
S 23° W	26	S E	28°	7° W	20° E
N 73° W	30	North	20°	19° W	20° E
S 23° E	36	S W	8°	7° E	20° E

Current set S 56° E (Corr. Mgc.) 38 miles for day.

Required latitude and longitude arrived at. True course and distance?

ANSWER TO PROBLEM NO. 16

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
S 30° E	18		15.6	9.0	
N 60° E	34	17.0		29.4	
S 85° E	40		3.5	39.8	
S 67° E	30		11.7	27.6	
S 64° W	26		11.4		23.4
S 88° W	30		1.0		30.0
S 4° E	36		35.9	2.5	
S 36° E	38		30.7	22.3	
		17.0	109.8	130.6	53.4
			17.0	53.4	
		Diff. Lat.	92.8 S	77.2	Dep. E

Lat. left	61°	19′	00″	N
Diff. Lat.	1°	32′	48″	S
Lat. in	59°	46′	12″	N
	2)121°	05′	12″	
Mid. Lat.	60°	32′	36″	or 61

Long. left	179°	19′	E
Diff. Long.	2°	39′	E
Long. in	178°	02′	W

True course S 40° E. Distance 121 miles.

PROBLEM NO. 17

A ship takes her departure from a point in Lat. 40° 19′ S Long. 9° 44′ W bearing by compass East distance 20 miles. Ship's head N 39° W.

Courses	Distance	Wind	Leeway	Deviation	Variation
N 39° W	22	S W	3°	3° E	20° W
N 23° W	23	West	3°	8° E	20° W
N 23° E	18	N W	6°	20° E	20° W
S 48° E	19	N W	0°	6° W	20° W
S 34° E	10	S W	0°	9° W	20° W
N 3° W	42	West	3°	14° E	20° W

Current set N 73° W (Corr. Mgc.) 36 miles for day.

Required latitude and longitude arrived at. True course and distance

ANSWER TO PROBLEM NO. 17

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
S 73° W	20		5.8		19.1
N 53° W	22	13.2			17.6
N 32° W	23	19.5			12.2
N 29° E	18	15.7		8.7	
S 74° E	19		5.2	18.3	
S 63° E	10		4.5	8.9	
N 6° W	42	41.8			4.4
S 87° W	36		1.9		36.0
		90.2	17.4	35.9	89.3
		17.4			35.9
	Diff. Lat.	72.8 N		Dep.	53.4W

Lat. left	40° 19′ 00″ S
Diff. Lat.	1° 12′ 48″ N
Lat. in	39° 06′ 12″ S
	2)79° 25′ 12″
Mid. Lat.	39° 42′ 36″ or 40°
Long. left	9° 44′ W
Diff. Long.	1° 10′ W
Long. in	10° 54′ W

True course N 36° W. Distance 90 miles.

PROBLEM NO. 18

A ship takes her departure from a point in Lat. 49° 42′ S Long. 178° 42′ E and sails the following courses:

Courses	Distance	Wind	Leeway	Deviation	Variation
N 42° E	35	S E	5°	21° E	14° E
N 73° E	36	North	3°	15° E	14° E
S 48° W	37	S E	3°	15° W	14° E
S 17° E	26	East	9°	13° W	14° E
N 8° E	33	East	8°	18° E	14° E
N 14° W	38	N E	3°	12° E	14° E

Current set N 56° E (Corr. Mgc.) 28 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 18

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 72° E	35	10.8		33.3	
S 75° E	36		9.3	34.8	
S 50° W	37		23.8		28.3
S 7° E	26		25.8	3.2	
N 32° E	33	28.0		17.5	
N 9° E	38	37.5		5.9	
N 70° E	28	9.6		26.3	
		85.9	58.9	121.0	28.3
		58.9		28.3	

Diff. Lat. 27.0 N   Dep. 92.7 E

Lat. left	49°	42′	00″	S
Diff. Lat.		27′	00″	N
Lat. in	49°	15′	00″	S
	2)98°	57′	00″	
Mid. Lat.	49°	28′	30″	or 49°

Long. left	178°	42′	E
Diff. Long.	2°	21′	E
Long. in	178°	57′	W

True course N 73° E. Distance 96 miles.

PROBLEM NO. 19

A ship takes her departure from a point in Lat. 28° 14′ S Long. 102° 16′ E bearing by compass S 68° E distance 14 miles. Ship's head North.

Courses	Distance	Wind	Leeway	Deviation	Variation
North	60	West	4°	7° W	9° E
N 28° W	61	S W	5°	3° E	9° E
N 28° E	62	East	3°	12° E	9° E
S 87° E	63	North	2°	4° W	9° E
S 15° E	64	S W	4°	14° W	9° E
East	65	North	3°	8° W	9° E

Current set S 23° W (Corr. Mgc.) 19 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 19

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 66° W	14	5.7			12.8
N 6° E	60	59.7		6.3	
N 11° W	61	59.9			11.6
N 46° E	62	43.1		44.6	
S 80° E	63		10.9	62.0	
S 24° E	64		58.5	26.0	
S 86° E	65		4.5	64.8	
S 32° W	19		16.1		10.1
		168.4	90.0	203.7	34.5
		90.0		34.5	

Diff. Lat. 78.4 N Dep. 169.2 E

Lat. left	28°	14′	00″	S
Diff. Lat.	1°	18′	24″	N
Lat. in	26°	55′	36″	S
	2/55°	09′	36″	
Mid. Lat.	27°	34′	48″	or 28°

Long. left	102°	16′	E
Diff. Long.	3°	12′	E
Long. in	105°	28′	E

True course N 65° E. Distance 187 miles.

PROBLEM NO. 20

A ship takes her departure from a point in Lat. 24° 16′ N Long. 37° 18′ W bearing by compass East distance 9 miles. Ship's head South.

Courses	Distance	Wind	Leeway	Deviation	Variation
South	70	East	4°	5° W	10° E
S 45° W	71	N W	5°	3° W	10° E
West	72	North	4°	9° E	10° E
N 80° W	73	South	4°	4° W	10° E
S 15° W	74	West	2°	3° W	10° E
N 45° W	75	N E	3°	8° W	10° E

Current set East (Corr. Mgc.) 17 miles for day.

Required latitude and longitude arrived at. True course and distance made?

ANSWER TO PROBLEM NO. 20

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
N 85° W	9	0.8			9.0
S 9° W	70		69.1		11.0
S 47° W	71		48.4		51.9
N 75° W	72	18.6			69.5
N 70° W	73	25.0			68.6
S 20° W	74		69.5		25.3
N 46° W	75	52.1			54.0
S 80° E	17		3.0	16.7	
		96.5	190.0	16.7	289.3
			96.5		16.7
		Diff. Lat.	93.5 S	Dep.	272.6W

Lat. left	24°	16′	00″	N
Diff. Lat.	1°	33′	30″	S
Lat. in	22°	42′	30″	N
	2)46°	58′	30″	
Mid. Lat.	23°	29′	15″	or 23°

Long. left	37°	18′	W
Diff. Long.	4°	56′	W
Long. in	42°	14′	W

True course S 71° W. Distance 288 miles.

PROBLEM NO. 21

I steered S 18° W by Compass, Error 18° E, Var. 7° E, 16 miles, N 18° W Magnetic, Error 18° E, Var. 7° E, 16 miles.

How would I have to steer to get back to where I started from, and if Cape Flyaway (Lat. 43° 17′ N Long. 73° 18′ E) bore North (True) 21 miles, what would be my position?

Corrected Courses	Dist.	N	S	E	W
S 36° W	16		12.9		9.4
N 11° W	16	15.7			3.1
		15.7	12.9		Dep. 12.5W
		12.9			
	D. Lat.	2.8 N			

Course to steer to get back to point of Departure S 78° E 13 miles.

Cape Flyaway Lat.	43°	17′ N	Long.	73°	18′ E
Difference Lat.		21′ S			
Ship's Position Lat.	42°	56′ N	Long.	73°	18′ E

PROBLEM NO. 22

At sea in Lat. 26° 12′ N Long. 88° 13′ W. Received wireless that South Pass Light-Vessel had been adrift 47 hours. Current setting E. S. E. (Mgc.) 3 miles per hour. Now at anchor. Please find Light-Vessel and tow her back to her position Lat. 28° 59′ N Long. 89° 07′ W, Var. 5° E.

Find true course and distance to Light-Vessel and course and distance back to her position.

Corrected Courses	Dist.	N	S	E	W
S 62° E	141		66.2	124.5	

Position of Light-Vessel Lat.	28°	59′ N
Diff. Lat.	1°	06′ S
Present Position Light-Vessel	27°	53′ N
Ship's Position Lat.	26°	12′ N
Diff. Lat.	1°	41′ N

Long. of Light-Vessel	89° 07′ W
Diff. Long.	2° 21′ E
Present Long. of Light-Vessel	86° 46′ W
Ship's Position Long.	88° 13′ W
Diff. Long.	1° 27′ E
Diff. Lat. 101 N	Dep. 77.5 E

Course and distance to Light-Vessel N 38° E 127 miles.

Course and distance back to Light-Vessel's Station N 62° W 141 miles.

PROBLEM NO. 23

A ship sailed from Point Neverbudge, Lat. 41° 00′ S Long. 86° 15′ E, the following courses:

South true 14 miles.
South by Compass, Error 6° E, Var. 6° W, 14 miles.
East by Compass, Dev. 4° E, Var. 6° W, 24 miles.
West by Compass, Dev. 6° E, Var. 6° W, 24 miles.
North by Compass, Dev. 16° E, Var. 6° W, 28 miles.

Find course and distance made good and latitude and longitude arrived at.

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Difference Departure East	Difference Departure West
South	14		14.0		
S 6° W	14		13.9		1.5
N 88° E	24	0.8		24.0	
West	24				24.0
N 10° E	28	27.6		4.9	
		28.4	27.9	28.9	25.5
		27.9		25.5	
	Diff. Lat.	.5 N		Dep. 3.4 E	

Lat. left	41° 00′ 00″ S	Long. left	86° 15′ 00″ E
Diff. Lat.	30″ N	Diff. Long.	4′ 30″ E
Lat. Ar. at	40° 59′ 30″ S	Long. Ar. at	86° 19′ 30″ E

Mid. Lat. (41°)

Course N 81° E. Distance 3 miles.

PROBLEM NO. 24

From Nantucket Shoals Light Ship (Lat. 40° 37′ N Long. 69° 36′ W) bearing North (True) 10 miles. Error 7° W. I steered N 75° W by Compass Var. 12° 30′ W Dev. 7° 30′ E for 95 miles. How would Block Island S E Light (Lat. 41° 09′ N Long. 71° 33′ W) bear True?

Corrected Courses	Dist.	N	S	E	W
South	10		10		
N 80° W	95	16.5			93.6
		16.5	10	Dep.	93.6W
		10			
	Diff. Lat. 6.5 N				

Nantucket Shoals Light Ship Lat.	40° 37′ 00″ N
Difference Latitude	6′ 30″ N
Position of Ship Lat.	40° 43′ 30″ N
Block Island Light Lat.	41° 09′ 00″ N
Diff. Lat.	25′ 30″ N
Mid. Lat. 41° Diff. Lat. 25.5 N.	
Nantucket Shoal Lightship Long.	69° 36′ W
Diff. Long.	2° 04′ W
Position of Ship Long.	71° 40′ W
Block Island Light Long.	71° 33′ W
Diff. Long.	7′ E

Dep. 5.3 E.

True bearing N 12 E 26 miles.

PROBLEM NO. 25

Steer East (Mgc.).
North (True).
West (True).
South (Mgc.).
Steamed 12 knots for one hour on each course.
Variation for the 4 hours 7° W.

Find position of ship if you left Lat. 43° 17′ N Long. 73° 14′ E.

Corrected Courses	Dist.	N	S	E	W
N 83 E	12	1.5		11.9	
North	12	12.0			
West	12				12.0
S 7° E	12		11.9	1.5	
		13.5	11.9	13.4	12.0
		11.9		12.0	

Diff. Lat. 1.6 N Dep. 1.4 E

Lat. left	43°	17′	00″ N	Long. left	73°	14′ E
Diff. Lat.		1′	36″ N	Diff. Long.		2′ E
Lat. Ar. at	43°	18′	36″ N	Long. Ar. at	73°	16′ E

Course N 41° E. Distance 2 miles.

PROBLEM NO. 26

A ship from Point Neverbudge (Lat. 42° 25′ N Long. 86° 15′ E), steered the following courses:

South (True) 14 miles.
East by Compass, Error 6° E, Var. 6° W, 14 miles.
N 15° E by Compass, Dev. 9° W, Var. 6° W, 15 miles.
S 4° W (Mgc.), Dev. 7° E, Var. 6° W, 19 miles.
S 17° E by Compass, Dev. 9° E, Var. 6° W, 25 miles.

Find course and distance made good and latitude and longitude arrived at.

Corrected Courses	Dist.	N	S	E	W
South	14		14.0		
S 84° E	14		1.5	13.9	
North	15	15			
S 2° E	19		19.0	0.7	
S 14° E	25		24.3	6.0	
		15	58.8	20.6 E Dep.	
			15.0		

Diff. Lat. 43.8 S

Lat. left.	42°	25′	00″	N	Long. left	86°	15′	E
Diff. Lat.		43′	48″	S	Diff. Long.		28′	E
Lat. Ar. at	41°	41′	12″	N	Long. Ar. at	86°	43′	E

Mid. Lat. 42°.

Course S 25° E. Distance 48 miles.

U. S. NAVY METHOD

A ship takes her departure at Noon heading 210° (p. s. c.) with Point Pinos Lighthouse, Cal., abeam distance 7 miles. Pat. Log. read 81.

At 5 P. M. changed course to 280°. Patent Log 50.
At 8 P. M. changed course to 350°. Patent Log 1.
At 2 A. M. changed course to 270°. Patent Log 90.
At 6 A. M. changed course to 180°. Patent Log 47.
At 9 A. M. changed course to 110°. Patent Log 86.
At Noon Patent Log read 28.

Current set for day 60° (Mgc.) at rate of $1\frac{1}{4}'$.

Variation on all courses 22° E. Use deviation table from Page 41 (Bowditch).

Required Noon position, and course and distance made.

Point Pinos on California coast.

First course is bearing. If ship was heading 210° when bearing was taken, and lighthouse was abeam, the lighthouse must have been 90° from 210° or to the eastward of the ship, being on the California coast. So we find

	210°	
	− 90°	
	120°	bearing of Lighthouse
	+180°	
	300°	bearing reversed.
Dev.	27°	E as per ship's head.
	327°	
Var.	22°	E
True	349°	7 miles.

No. 2

Course	210°	Log 5 P. M.	50
Dev.	27° +	Log Noon	−81
	237°	Dist.	69
Var.	22° +		
True	259° = 69 miles.		

No. 3

	280°	Log	50
Dev.	4° +	Log	1
	284°		51
Var.	22° +		
True	306°	Dist.	51

No. 4

	350°	
Dev.	16° −	
	334°	
Var.	22° +	
True	356°	Dist. 89.

No. 5

	270°	
Dev.	10° +	
	280°	
Var.	22° +	
True	302°	Dist. 57′

No. 6

	180°	
Dev.	18° +	
	198°	
Var.	22° +	
True	220°	Dist. 39′.

No. 7

	110°	
Dev.	9° −	
	101°	
Var.	22° +	
True	123°	Dist. 42′

No. 8

24 hours at $1\frac{1}{4}$ miles per hour.

Current	60°	
Var.	22° +	
True	82°	Dist. 30′

Corrected Courses	Distance	Difference Lat. North	South	Departure East	West
349°	7	6.9			1.3
259°	69		13.2		67.7
306°	51	30.0			41.3
356°	89	88.8			6.2
302°	57	30.2			48.3
220°	39		29.9		25.1
123°	42		22.9	35.2	
82°	30	4.2		29.7	
		160.1	66.0	64.9	189.9
		66.			64.9
	Diff. Lat.	94.1 N		Dep.	125.0W

Latitude left	36°	37′	55″	N
Diff. Lat.	1°	34′	06″	N
Lat. in	38°	12′	01″	N
	2)74°	49′	56″	
Mid. Lat.	37°	24′	58″	
Long. left	121°	56′	02″	W
Diff. Long.	2°	37′	00″	W
Long. in	124°	33′	02″	W

True course 307°. Distance 157 miles.

U. S. NAVY METHOD

A ship takes her departure at 4 P. M. heading 93° Dev. 4° W (p. s. c.) with Nantucket South Shoal Lightship, Mass., abeam, distance 9 miles. Patent log read 77.

At 7 P. M. changed course to 170° P. L. 16 Dev. 9° W.
At 11 P. M. changed course to 189° P. L..67 Dev. 10° W.
At 1 A. M. changed course to 115° P. L. 94 Dev. 6° W.
At 4 A. M. changed course to 70° P. L. 32 Dev. 1° W.
At 8 A. M. changed course to 90° P. L. 84 Dev. 4° W.

Variation on all courses 11° W.

At noon log read 36.
Current set 286° (Mgc.) at rate of $1\frac{2}{3}$ miles per hour.
Required noon position. True course and distance.

Corrected Courses	Distance	Difference Lat. North	Difference Lat. South	Departure East	Departure West
168°	9		8.8	1.9	
78°	39	8.1		38.1	
150°	51		44.2	25.5	
168°	27		26.4	5.6	
98°	38		5.3	37.6	
58°	52	27.6		44.1	
75°	52	13.5		50.2	
275°	33	2.9			32.9
		52.1	84.7	203.0	32.9
			52.1	32.9	
		Diff. Lat.	32.6 S	170.1	Dep. East

Lat. left	40°	37′	05″	N
Diff. Lat.		32′	36″	S
Lat. in	40°	04′	29″	N
	2)80°	41′	34″	
Mid. Lat.	40°	20′	47″	
Long. left	69°	36′	33″	W
Diff. Long.	3°	42′		E
Long. in	65°	54′	33″	W

True course 101°. Distance 173 miles.

CHAPTER V

MERCATORS SAILING

This problem is to find the course and distance in a straight line between two places.

The latitude and longitude A is the point of starting, and the latitude and longitude B is the place bound for.

The latitude A and latitude B and longitude A and longitude B are put down under each other, and the difference between the places is found in degrees, minutes and seconds by the following rule:

Both of the same name, subtract. Different name, add the two.

If the degrees of longitude exceed 180°; subtract total from 360°.

The degrees and minutes are turned into minutes by multiplying the degrees by 60, and adding to the result the minutes.

A Mercator chart is constructed on the principle that the earth is a flat plane, and the degrees of longitude are equal, and the degrees of latitude are increased from the equator to the poles to allow for the decrease in the degrees of longitude.

From Table 3 (Bowditch) take out the Meridional Parts for the degrees and minutes of each latitude.

Add or subtract these meridional parts, same as was done with the degrees and minutes of latitude in the problem.

In Table 42 (Bowditch) will be found Logarithms of numbers. All logarithms of numbers have an index number which is found by table below:

2 figures in the distance, the index number is 1.
3 figures in the distance, the index number is 2.
4 figures in the distance, the index number is 3.

When the number is of 2 or 3 figures the logarithm is read in the 0 column alongside of the number given.

When the number has 4 figures the first 3 numbers of the figures are read on the side, and the last number at top of page.

Take out from Table 42 logarithm of difference of longitude in minutes, adding 10 to the index number, and logarithm of meridional parts, index number by rule above.

Subtract logarithm of meridional parts from logarithm of difference of longitude.

The Logarithm Tangent in Table 44 (Bowditch) that agrees with answer will be the course in degrees and minutes.

If the index number for Tangent is 8 or 9 the course will be from top of page.

If the index number for Tangent is 10 or 11 the course will be from bottom of page.

Take out the Logarithm Secant from Table 44 for the degrees and minutes of the course, rejecting the 10 from the index number.

Take out the logarithm of difference of latitude (Table 42) applying its index number by rule above.

Add together Logarithm Secant of course, and logarithm of difference of latitude.

The logarithm that agrees with this sum in the body of the logarithms, Table 42, will be the distance in the left-hand column for the first 3 numbers, and the number of the column logarithm was found in on top will be the last number.

If the index number is 1 the distance will be in 2 figures.
If the index number is 2 the distance will be in 3 figures.
If the index number is 3 the distance will be in 4 figures.

PROBLEM NO. 1

Lat. A 43° 08′ N	Mer Parts 2858.0	Long. A 5° 56′ E
Lat. B 39° 29′ N	Mer Parts 2567.5	Long. B 0° 24′ W
3° 39′	290.5	6° 20′
60		60
180		360
+ 39		+ 20
D. L. 219		Diff. Lon. 380

Log. of Diff. Long. 380 = 12.57978
Log. of Mer. Parts 290.5 = 2.46315

Tangent 10.11663 = Course S 52°36′ W

Secant of Course 52° 36′ = 0.21654
Log of Diff. Lat. 219 = 2.34044

Log. 2.55698 = Dist. 360.6 miles

PROBLEM NO. 2

Lat. A 15° 55′ S	Mer. Parts 961.1	Long. A 5° 44′ W
Lat. B 55° 59′ S	Mer. Parts 4052.7	Long. B 67° 16′ W
Diff. Lat. 2404′	Mer. Parts 3091.6	Diff. Long. 3692′

Log. of Diff. Long. 3692 = 13.56726
Log. of Mer. Parts 3092 = 3.49024

Tangent 10.07702 = Course S 50° 03′ W

Secant of Course 50° 03′ = 0.19238
Log of Diff. Lat. 2404 = 3.38093

Log. 3.57331 = Dist. 3744 miles

PROBLEM NO. 3

Lat. A 15° 12′ S	Mer. Parts 916.8	Long. A 2° 12′ E
Lat. B 28° 49′ S	Mer. Parts 1795.6	Long. B 17° 11′ E
Diff. Lat. 817′ S	Mer. Parts 878.8	Diff. Long. 899′

Log. of Diff. Long. 899 = 12.95376
Log. of Mer. Parts 878.8 = 2.94389

Tangent 10.00987 = Course S 45° 39′ E

Secant of Course 45° 39′ = 0.15550
Log. of Diff. Lat. 817′ = 2.91222

Log. 3.06772 = Dist. 1169 miles

PROBLEM NO. 4

Lat. A 17° 15′ S	Mer. Parts 1044.1	Long. A 92° 21′ W
Lat. B 31° 42′ S	Mer. Parts 1994.9	Long. B 110° 10′ W
Diff. Lat. 867′	Mer. Parts 950.8	Diff. Long. 1069′

Log. of Diff. Long. 1069 = 13.02898
Log. of Mer Parts 950.8 = 2.97809

Tangent 10.05089 = Course S 48° 21′ W

Secant of Course 48° 21′ = 0.17745
Log. of Diff. Lat. 867 = 2.93802

Log. 3.11547 = Dist. 1305 miles

PROBLEM NO. 5

Lat. A 18° 12′ S	Mer. Parts 1103.5	Long. A 18° 10′ E
Lat. B 46° 11′ S	Mer. Parts 3114.5	Long. B 32° 21′ W
Diff. Lat. 1679′	Mer. Parts 2011	Diff. Long. 3031′

Log. of Diff. Long. 3031 = 13.48159
Log. of Mer. Parts 2011 = 3.30341

Tangent 10.17818 = Course S 56′ 26′ W

Secant of Course 56° 26′ = 0.25735
Log. of Diff. Lat. 1679 = 3.22505

Log. 3.48240 = Dist. 3037 miles

PROBLEM NO. 6

Lat. A 30° 29′ N	Mer. Parts 1910.1	Long. A 179° 47′ E
Lat. B 15° 12′ N	Mer. Parts 916.8	Long. B 126° 44′ E
Diff. Lat. 917′	Mer. Parts 993.3	Diff. Long. 3183′

Log. of Diff. Long. 3183 = 13.50284
Log. of Mer .Parts 993.3 = 2.99708

Tangent 10.50576 = Course S 72° 40′ W

Secant of Course	72° 40′ =	0.52589	
Log. of Diff. Lat	917 =	2.96237	
	Log.	3.48826	= Dist. 3078 miles

PROBLEM NO. 7

Lat. A 8° 05′ S	Mer. Parts 483.3	Long. A 18° 02′ W
Lat. B 62° 04′ S	Mer. Parts 4762.8	Long. B 103° 03′ W
Diff. Lat. 3239′	Mer. Parts 4279.5	Diff. Long. 5101′

Log. of Diff. Long.	5101 =	13.70766	
Log. of Mer. Parts	4279 =	3.63134	
	Tangent	10.07632	= Course S 50° 01′ W
Secant of Course	50° 01′ =	0.19208	
Log. of Diff. Lat	3239 =	3.51041	
	Log.	3.70249	= Dist. 5041 miles

PROBLEM NO. 8

Lat. A 0° 00′	Mer. Parts 0000.0	Long. A 0° 02′ W
Lat. B 51° 12′ N	Mer. Parts 3569.7	Long. B 16° 14′ E
Diff. Lat. 3072′	Mer. Parts 3569.7	Diff. Long. 976′

Log. of Diff. Long.	976 =	12.98945	
Log. of Mer. Parts	3570 =	3.55267	
	Tangent	9.43678	= Course N 15° 17′ E
Secant of Course	15° 17′ =	0.01564	
Log. of Diff. Lat.	3072 =	3.48742	
	Log.	3.50306	= Dist. 3185 miles

PROBLEM NO. 9

Lat. A 71° 02′ S	Mer. Parts 6129.7	Long. A 16° 12′ E
Lat. B 22° 05′ S	Mer. Parts 1350.3	Long. B 102° 15′ E
Diff. Lat. 2937′	Mer. Parts 4779	Diff. Long. 5163′

Log. of Diff. Long.	5163 =	13.71290	
Log. of Mer. Parts	4779 =	3.67934	
	Tangent	10.03356	= Course N 47° 13′ E
Secant of Course	47° 13′ =	0.16798	
Log. of Diff. Lat.	2937 =	3.46790	
	Log.	3.63588	= Dist. 4324 miles

PROBLEM NO. 10

Lat. A 14° 12′ S	Mer. Parts 855.1	Long. A 178° 02′ E
Lat. B 79° 02′ S	Mer. Parts 8033.2	Long. B 115° 16′ W
Diff. Lat. 3890′	Mer. Parts 7178.1	Diff. Long. 4002′

Log. of Diff. Long.	4002 =	13.60228	
Log. of Mer. Parts	7178 =	3.85600	
	Tangent	9.74628	= Course S 29° 08′ E
Secant of Course	29° 08′ =	0.05877	
Log. of Diff. Lat.	3890 =	3.58995	
	Log.	3.64872	= Dist. 4454 miles

PROBLEM NO. 11

Lat. A 3° 12′ N	Mer. Parts 190.8	Long. A 118° 00′ W
Lat. B 79° 15′ N	Mer. Parts 8102.2	Long. B 142° 12′ W
Diff. Lat. 4563′	Mer. Parts 7911	Diff. Long. 1452′

Log. of Diff. Long	1452 =	13.16197	
Log. of Mer. Parts	7911 =	3.89823	
	Tangent =	9.26374	= Course N 10° 24′ W
Secant of Course	10° 24′ =	0.00719	
Log. of Diff. Lat	4563 =	3.65925	
	Log.	3.66644	= Dist. 4639 miles

PROBLEM NO. 12

Lat. A 19° 36′ N	Mer. Parts 1191.8	Long. A 18° 12′ E
Lat. B 21° 42′ S	Mer. Parts 1325.6	Long. B 2° 06′ W
Diff. Lat. 2478′	Mer. Parts 2517	Diff. Long. 1218′

Log. of Diff. Long.	1218 =	13.08565	
Log. of Mer. Parts	2517 =	3.40088	
	Tangent	9.68477	= Course S 25° 49′ W
Secant of Course	25° 49′ =	0.04566	
Log. of Diff. Lat.	2478 =	3.39410	
	Log.	3.43976	= Dist. 2753 miles

PROBLEM NO. 13

Lat. A 36° 08′ N	Mer. Parts 2314.1	Long. A 159° 00′ E
Lat. B 17° 17′ S	Mer. Parts 1046.1	Long. B 159° 00′W
Diff. Lat. 3205′	Mer. Parts 3360	Diff. Long. 2520′

Log. of Diff. Long.	2520 =	13.40140	
Log. of Mer. Parts	3360 =	3.52634	
	Tangent	9.87506	= Course S 36° 52′ E
Secant of Course	36° 52′ =	0.09689	
Log. of Diff. Lat.	3205 =	3.50583	
	Log.	3.60272	= Dist. 4006 miles

PROBLEM NO. 14

Lat. A 9° 18′ S	Mer. Parts 556.7	Long. A 74° 13′ E
Lat. B 42° 17′ S	Mer. Parts 2788.9	Long. B 47° 17′ E
Diff. Lat. 1979′	Mer. Parts 2232.2	Diff. Long. 1616′

Log. of Diff. Long.	1616 =	13.20844	
Log. of Mer. Parts	2232 =	3.34869	
	Tangent	9.85975	= Course S 35° 54′ W

Secant of Course	35° 54′ =	0.09149	
Log. of Diff. Lat.	1979 =	3.29645	
	Log.	3.38794	= Dist. 2443 miles

PROBLEM NO. 15

Lat. A 14° 06′ N	Mer. Parts 849.0	Long. A 81° 59′ W
Lat. B 32° 55′ N	Mer. Parts 2080.8	Long. N 59° 17′ W
Diff. Lat. 1129′	Mer. Parts 1232	Diff. Long. 1362′

Log. of Diff. Long.	1362 =	13.13418	
Log. of Mer. Parts	1232 =	3.09061	
	Tangent	10.04357	= Course N 47° 52′ E
Secant of Course	47° 52′ =	0.17337	
Log. of Diff. Lat.	1129 =	3.05269	
	Log.	3.22606	= Dist. 1683 miles

PROBLEM NO. 16

Lat. A 0° 06′ N	Mer. Parts 6.0	Long. A 0° 00′ W
Lat. B 60° 10′ N	Mer. Parts 4527.1	Long. B 41° 02′ W
Diff. Lat. 3604′	Mer. Parts 4521	Diff. Long. 2462′

Log. of Diff. Long.	2462 =	13.39129	
Log. of Mer. Parts	4521 =	3.65523	
	Tangent	9.73606	= Course N 28° 34′ W
Secant of Course	28° 34′ =	0.05638	
Log. of Diff. Lat.	3604 =	3.55678	
	Log.	3.61316	= Dist. 4103 miles

PROBLEM NO. 17

Lat. A 34° 22′ S	Mer. Parts 2184.9	Long. A 18° 24′ E
Lat. B 15° 55′ S	Mer. Parts 961.1	Long. B 5° 45′ W
Diff. Lat. 1107′	Mer. Parts 1224	Diff. Long. 1449′

Log. of Diff. Long.	1449 =	13.16107	
Log. of Mer. Parts	1224 =	3.08778	
	Tangent	10.07329	= Course N 49° 49′ W
Secant of Course	49° 49′ =	0.19028	
Log. of Diff. Lat.	1107 =	3.04415	
	Log.	3.23443	= Dist. 1716 miles

PROBLEM NO. 18

Lat. A 8° 04′ S	Mer. Parts 482.3	Long. A 34° 53′ W
Lat. B 14° 45′ N	Mer. Parts 889.0	Long. B 17° 32′ W
Diff. Lat. 1369′	Mer. Parts 1371	Diff. Long. 1041′

Log. of Diff. Long.	1041 =	13.01745	
Log. of Mer. Parts	1371 =	3.13704	
	Tangent	9.88041	= Course N 37° 12′ E
Secant of Course	37° 12′ =	0.09880	
Log. of Diff. Lat.	1369 =	3.13640	
	Log.	3.23520	= Dist. 1719 miles

CHAPTER VI

MIDDLE LATITUDE SAILING

This method is to find the course and distance between two places, when the distance is small.

Proceed as in Mercators sailing to find the difference of latitude and longitude in minutes.

Find the Middle Latitude between the places as in Day's Work.

Take the Middle Latitude to the nearest degree as a course, and in Table 2 (Bowditch) look in the Distance column for the difference of longitude in minutes, and in the latitude column corresponding to this distance will be the Departure in miles.

Compare the difference of latitude in miles and departure in miles in Table 2, and the course and distance will be found as in Day's Work.

Never cross the equator with this method.

PROBLEM NO. 1

Lat. A 28° 17′ N	28° 17′	Long. A	14° 16′ W
Lat. B 30° 02′ N	30° 02′	Long. B	23° 10′ W
1° 45′	58° 19′		8° 54′
Diff. Lat. 105′	29° 09′ Mid. Lat.		
or 105 miles		Diff. Long. 534′	
		Departure 467 miles	

Course N 77° W. Distance 479 miles.

PROBLEM NO. 2

Lat. A 38° 16′ S	38° 16′	Long. A	102° 12′ E
Lat. B 40° 12′ S	40° 12′	Long. B	108° 11′ E
1° 56′	78° 28′		5° 59′
Diff. Lat. 116′	39° 14′ Mid. Lat.		
or 116 miles		Diff. Long. 359′	
		Departure 279.0 miles	

Course S 67° E. Distance 302 miles.

PROBLEM NO. 3

Lat. A 76° 08′ S	76° 08′	Long. A 179° 53′ E
Lat. B 74° 16′ S	74° 16′	Long. B 178° 10′ W
1° 52′	150° 24′	1° 57′
Diff. Lat. 112′	75° 12′ Mid Lat	
or 112 miles		Diff. Long. 117′
		Departure 30.3 miles

Course N 15° E. Distance 116 miles.

PROBLEM NO. 4

Lat. A 42° 08′ N	42° 08′	Long. A 18° 23′ E
Lat. B 47° 05′ N	47° 05′	Long. B 21° 06′ E
4° 57′	89° 13′	2° 43′
Diff. Lat. 297′	44° 36′ Mid Lat.	
or 297 miles		Diff. Long. 163′
		Departure 115.3 miles

Course N 21° E. Distance 318 miles.

PROBLEM NO. 5

Lat. A 51° 53′ N	51° 53′	Long. A 37° 18′ W
Lat. B 56° 18′ N	56° 18′	Long. B 40° 17′ W
4° 25′	108° 11′	2° 59′
Diff. Lat. 265′	54° 05′ Mid. Lat.	
or 265 miles		Diff. Long. 179′
		Departure 105.2 miles

Course N 22° W. Distance 285 miles.

PROBLEM NO. 6

Lat. A 43° 10′ S	43° 10′	Long. A 108° 00′ W
Lat. B 40° 08′ S	40° 08′	Long. B 109° 40′ W
3° 02′	83° 18′	1° 40′
Diff. Lat. 182′	41° 39′ Mid. Lat.	
or 182 miles		Diff. Long. 100′
		Departure 74.3 miles

Course N 22° W. Distance 197 miles.

PROBLEM NO. 7

Lat. A 12° 13′ S	12° 13′	Long. A 14° 18′ E
Lat. B 9° 16′ S	9° 16′	Long. B 17° 03′ E
2° 57′	21° 29′	2° 45′
Diff. Lat. 177′	10° 44′ Mid. Lat.	
		Diff. Long. 165′
		Departure 162.0 miles

True course N 42° E. Distance 240 miles.

PROBLEM NO. 8

Lat. A 49° 06′ N	49° 06′	Long. A 179° 15′ E
Lat. B 51° 10′ N	51° 10′	Long. B 179° 32′ W
2° 04′	100° 16′	1° 13′
Diff. Lat. 124′	50° 08′ Mid. Lat.	
		Diff. Long. 73′
		Departure 46.9 miles

Course N 21° E. Distance 133 miles.

PROBLEM NO. 9

Lat. A 38° 07′ N	38° 07′	Long. A 13° 12′ E
Lat. B 36° 51′ N	36° 51′	Long. B 19° 06′ E
1° 16′	74° 58′	5° 54′
Diff. Lat. 76′	37° 29′ Mid. Lat.	
		Diff. Long. 354′
		Departure 282.7 miles

Course S 75° E. Distance 292 miles.

PROBLEM NO. 10

Lat. A 14° 28′ S	14° 28′	Long. A 0° 06′ W
Lat. B 10° 19′ S	10° 19′	Long. B 7° 18′ E
4° 09′	24° 47′	7° 24′
Diff. Lat. 249′	12° 23′ Mid. Lat.	
		Diff. Long. 444′
		Departure 434.3 miles

Course N 60° E. Distance 500 miles.

PROBLEM NO. 11

Lat. A	6° 14′ N	6° 14′	Long. A	28° 13′ E
Lat. B	14° 16′ N	14° 16′	Long. B	26° 09′ E
	8° 02′	20° 30′		2° 04′
Diff. Lat.	482′	10° 15′ Mid. Lat.		
			Diff. Long.	124′
			Departure	122.1 miles

Course N 14° W. Distance 497 miles.

PROBLEM NO. 12

Lat. A	60° 10′ N	60° 10′	Long. A	4° 16′ W
Lat. B	58° 11′ N	58° 11′	Long. B	6° 18′ W
	1° 59′	118° 21′		2° 2′
Diff. Lat.	119′	59° 10′ Mid. Lat.		
			Diff. Long.	122′
			Departure	62.8 miles

Course S 28° W. Distance 135 miles.

CHAPTER VII

LATITUDE BY MERIDIAN ALTITUDE OF SUN

The latitude by the sun is found most easily by a noon sight, when the sun is on the meridian, or the highest point reached by the sun on that day.

When the sun crosses the meridian it is either directly overhead or due north or south. It is then exactly 0h 00′ 00″ local apparent time.

A chronometer always shows Greenwich time, and if we could read the chronometer when the sun was exactly at its highest point and was about to descend, we could use that time to look up the declination in the Nautical Almanac.

As at this time the sun's motion is nearly horizontal, i.e., its rise is very slow, it is very difficult to tell when it has ceased to ascend and is starting to descend.

If the longitude is known, the Greenwich apparent time may be found; for longitude expressed in hours, minutes and seconds is the difference between local and Greenwich time.

If in west longitude the apparent time at Greenwich will be past noon: therefore, add the longitude in time to 0 hours, and the answer will be the G. A. T. on the same day as the ship.

If in east longitude the apparent time at Greenwich will be before noon; therefore, subtract the longitude in time from 24 hours and the answer will be the G. A. T. of the day before.

In the Nautical Almanac, the equation of time is given with + or − signs to show whether it is to be added to or subtracted from the G. M. T. to get the G. A. T.

Since the G. A. T. is known and the G. M. T. is desired, the equation of time is applied the opposite way to that shown by the signs in the Nautical Almanac.

It is necessary to know the G. M. T. when the sight was taken for the declination at that instant must be known and the declination is given in the Nautical Almanac for G. M. T. and not for G. A. T. or L. A. T.

The declination of the sun is the distance north or south of the equator. The sign + in the almanac means north, the sign – south. The declination is given for each day and on the even hour of that day.

To find the declination for any given time, look up in the almanac the declination for the even hour preceding. This is corrected by adding or subtracting the change in the intervening minutes. The hourly difference (H. D.) is found printed in the almanac at the end of each day. This is multiplied by the fractional part of an hour to get the correction. If the declination is decreasing this is subtracted, if increasing it is added.

The altitude is measured by the sextant.

When the sun is on the meridian, it is either due north, directly overhead, or due south of the observer.

The index error (I. E.) is the error of the sextant used for the observation. When it is " off the scale " it is added; when " on scale " it is subtracted.

The semi-diameter (S. D.) is half the diameter of the sun, or the distance from the bottom or top of the sun to the center. In lower limb (L. L.) sights, or sights taken on the lower edge, the S. D. is added. In upper limb (U. L.) sights it is subtracted. It is given in the Nautical Almanac. The nearest date is used and the nearest .1 of a minute.

The dip correction is the correction for the height of the eye of the observer above sea level. It is always subtracted and is found in Table 14 (Bowditch).

Refraction is the change of direction of a ray of light in passing through the atmosphere.

Parallax is the error caused by taking altitude from the surface of the earth while the calculations are made on the assumption that the observer is at the center of the earth.

The corrections for refraction and parallax (R. & P.) are combined in Table 20*B* and are always subtracted.

After making these corrections to the observed meridian altitude, the answer is the true altitude.

The point in the sky directly over the observer's head is the zenith. It is 90° from the horizon in all directions.

Subtracting the altitude from 90° gives the zenith distance (Z. D.) or distance from the sun to the zenith. It always has the opposite name to the sun's bearing.

Under zenith distance put down the declination.

If both are the same name add: the sum is the latitude, named the same.

If different names, subtract the lesser from the greater; the difference is the latitude, named the same as the greater.

PROBLEM NO. 1

Jan. 30, 1919. Obs. Mer. Alt. Sun's L. L. 44° 18′ S. Dip 36 ft. Long. 91° W.

Longitude in time 6h 04′.		L. A. T., 30d	0h 00′ 00″
Obs. Alt	44° 18′ 00″	Long.	+ 6h 04′ 00″
S. D.	+ 16′ 18″	G. A. T.	6h 04′ 00″
	44° 34′ 18″	Eq. Time	+ 13′ 22″
Dip	− 5′ 53″	G. M. T., 30d	6h 17′ 22″ or
	44° 28′ 25″	30d	6.3h
R. & P.	− 53″		
True Alt.	44° 27′ 32″		
	90° 00′ 00″	Dec. for 30 d 6h	17° 47′.9 S
True Alt.	44° 27′ 32″	Corr. for .3h	− .2
Z. D.	45° 32′ 28″ N	Dec. for 30d 6.3h	17° 47′.7 S
Dec.	17° 47′ 42″ S	H. D.	=.7′ decrease
Lat.	27° 44′ 46″ N	D. for .3h = .3×.7′ = .2′	

PROBLEM NO. 2

Feb. 1, 1919. Obs. Mer. Alt. Sun's L. L. 78° 05′ 05″ S. Dip 12 ft. Long. 78° 14′ E.

Longitude in time 5 h 12′ 56″		L. A. T., Feb., 1d	0h 00′ 00″
Obs. Alt.	78° 05′ 05″	Long.	5h 12′ 56″
S. D.	+ 16′ 18″	G. A. T., Jan. 31	18h 47′ 04″
	78° 21′ 23″	Eq. Time	+ 13′ 36″
Dip	− 3′ 24″	G. M. T., Jan. 31	19h 00′ 40″
	78° 17′ 59″		
R. & P.	− 10″		
True Alt.	78° 17′ 49″		
	90° 00′ 00″		
True Alt.	78° 17′ 49″		
Z. D.	11° 42′ 11″ N	Dec. for 31d 18h	17° 23′.1 S
Dec.	17° 22′ 24″ S	H. D.	− .7 dec.
Lat.	5° 40′ 13″ S	Dec. for 31d 19h	17° 22′.4 S

PROBLEM NO. 3

Mar. 20, 1919. Obs. Mer. Alt. Sun's L. L. 89° 37′ N. Index Error +4′ 27″. Dip 18 ft. Long. 111° E.

Longitude in time 7h 24′.

Obs. Alt.		89° 37′ 00″
I. E.	+	4′ 27″
		89° 41′ 27″
S. D.	+	16′ 06″
		89° 57′ 33″
Dip	−	4′ 09″
		89° 53′ 24″
R. & P.	−	00″
		89° 53′ 24″
Z. D.		0° 06′ 36″ S
Dec.		0° 35′ 12″ S
Lat.		0° 41′ 48″ S

L. A. T., 20d		0h 00′ 00″
Long.		7h 24′ 00″
G. A. T., 19d		16h 36′ 00″
Eq. Time	+	7′ 55″
G. M. T. 19d		16h 43′ 55″ or 16.7h

Dec. for 19d 16h		0° 35′.9 S
Corr. for .7h	−	0′.7
Dec. for 19d 16.7h		0° 35′.2 S

PROBLEM NO. 4

Mar. 10, 1919. Obs. Mer. Alt. Sun's L. L. 59° 59′ 50″ S. Index Error +50″. Dip 15 ft. Long. 102° 41′ W.

Longitude in time 6h 50′ 44″.

Obs. Alt.		59° 59′ 50″
I. E.	+	50″
		60° 00′ 40″
S. D.	+	16′ 06″
		60° 16′ 46″
Dip	−	3′ 48″
		60° 12′ 58″
R. & P.	−	30″
		60° 12′ 28″
Z. D.		29° 47′ 32″ N
Dec.		4° 17′ 24″ S
Lat.		25° 30′ 08″ N

L. A. T., 10d		0h 00′ 00″
Long.		6h 50′ 44″
G. A. T.		6h 50′ 44″
Eq. Time	+	10′ 35″
G. M. T. 10d		7h 01′ 19″ or 7h

Dec. for 10d 6h		4° 18′.4 S
Corr. for 1 h	−	1′.0
Dec. for 10d 7h		4° 17′.4 S

PROBLEM NO. 5

Jan. 31, 1919. Obs. Mer. Alt. Sun's L. L. 46° 56′ S. Dip 36 ft. Long. 94° W.

Longitude in time 6h 16′.			L. A. T., 31d		0h 00′ 00″
Obs. Alt.		46° 56′ 00″	Long.	+	6h 16′ 00″
S. D.	+	16′ 18″	G. A. T.		6h 16′ 00″
		47° 12′ 18″	Eq. Time	+	13′ 31″
Dip	−	5′ 53″	G. M. T.		6h 29′ 31″ or
		47° 06′ 25″	31d		6.5h
R. & P.	−	48″			
True Alt.		47° 05′ 37″			
Z. D.		42° 54′ 23″ N	Dec. for 31d 6h		17° 31′.4 S
Dec.		17° 31′ 06″ S	Corr. for .5h	−	0′.3 dec.
Lat.		25° 23′ 17″ N	Dec. for 31d 6.5h		17° 31′.1 S

PROBLEM NO. 6

Mar. 21, 1919. Obs. Mer. Alt. Sun's L. L. 57° 21′ S. Dip 38 ft. Long. 77° 26′ W.

Longitude in time 5h 09′ 44″			L. A. T., 21d		0h 00′ 00″
Obs. Alt.		57° 21′ 00″	Long.	+	5h 09′ 44″
S. D.	+	16′ 06″	G. A. T.		5h 09′ 44″
		57° 37′ 06″	Eq. Time	+	7′ 28″
Dip	−	6′ 02″	G. M. T.		5h 17′ 12″ or
		57° 31′ 04″	21d		5.3h
R. & P.	−	0′ 32″			
True Alt.		57° 30′ 32″			
Z. D.		32° 29′ 28″ N	Dec. for 21d 4h		0° 00′.3 S
Dec.		01′ 00″ N	Corr. for 1.3h	+	01′.3
Lat.		32° 30′ 28″ N	Dec. for 21d 5.3h.		0° 01′.0 N

PROBLEM NO. 7

Sept. 3, 1919. Obs. Mer. Alt. Sun's L. L. 49° 02′ 15″ S. Dip 28 ft. Long. 118° 15′ E.

Longitude in time 7h 53′			L. A. T., 3d	0h 00′ 00″
			Long.	− 7h 53′ 00″
Obs. Alt.		49° 02′ 15″ S	G. A. T., 2d	16h 07′ 00″
S. D.	+	15′ 54″ S	Eq. Time	− 0′ 18″
		49° 18′ 09″	G. M. T., 2d	16h 06′ 42″ or
Dip.	−	5′ 11″	2d	16.1h
		49° 12′ 58″		
R. & P.	−	45″		
True Alt.		49° 12′ 13″		
		90° 00′ 00″		
Z. D.		40° 47′ 47″ N	Dec. for 2d 16h	7° 58′.2 N
Dec.		7° 58′ 06″ N	Corr. for .1h	− 0′.1
Lat.		48° 45′ 53″ N	Dec. 2d 16.1h	7° 58′.1 N

PROBLEM NO. 8

Aug. 8, 1919. Obs. Mer. Alt. Sun's L. L. 38° 16′ N. Dip 27 ft. Long. 3° 15′ W.

Longitude in time 0h 13′			G. A. T., 8d	0h 13′ 00″
			Eq. Time	+ 5′ 37″
Obs. Alt.		38° 16′ 00″ N	G. M. T., 8d	0h 18′ 37″ or
S. D.	+	15′ 48″	8d	0.3h
		38° 31′ 48″		
Dip	−	5′ 06″		
		38° 26′ 42″		
R. & P.	−	1′ 07″		
True Alt.		38° 25′ 35″		
		90° 00′ 00″		
Z. D.		51° 34′ 25″ S	Dec., 8d 0h.	16° 22.′6 N
Dec.		16° 22′ 24″ N	Corr., for .3h	− 0′.2
Lat.		35° 12′ 01″ S	Dec. 8d 0.3h	16° 22′.4 N

PROBLEM NO. 9

July 4, 1919. Obs. Mer. Alt. Sun's L. L. 70° 15′ S. Dip 24 ft. Long. 97° 12′ W.

Longitude in time 6h 28′ 48″.

Obs. Alt.		70° 15′ 00″
S. D.	+	15′ 48″
		70° 30′ 48″
Dip	−	4′ 48″
		70° 26′ 00″
R. & P.	−	18″
		70° 25′ 42″
Z. D.		19° 34′ 18″ N
Dec.		22° 55′ 54″ N
Lat.		42° 30′ 12″ N

L. A. T., 4d		0h 00′ 00″
Long.	+	6h 28′ 48″
G. A. T.		6h 28′ 48″
Eq. Time	+	4′ 04″
G. M. T., 4d		6h 32′ 52″ or 6.5h
Dec. for 4d 6h		22° 56′.0 N
Corr. for .5h	−	0′.1
Dec. for 4d 6.5h		22° 55′.9 N

PROBLEM NO. 10

Apr. 18, 1919. Obs. Mer. Alt. Sun's L. L. 41° 02′ S. Dip 22 ft. Long. 97° 15′ E.

Longitude in time 6h 29′ 00″.

Obs. Alt.		41° 02′ 00″
S. D.	+	16′ 00″
		41° 18′ 00″
Dip	−	4′ 36″
		41° 13′ 24″
R. & P.	−	59″
		41° 12′ 25″
Z. D.		48° 47′ 35″ N
Dec.		10° 27′ 18″ N
Lat.		59° 14′ 53″ N

L. A. T., 18d		0h 00′ 00″
Long.		6h 29′ 00″
G. A. T., 17d		17h 31′ 00″
Eq. Time	−	0′ 25″
G. M. T., 17d 17d		17h 30′ 35″ or 17.5h
Dec. for 17d, 16h	+	10° 26′.0 N
Corr. for 1.5h	+	1′.3
Dec. for 17d 17.5h		10° 27′.3 N

PROBLEM NO. 11

Mar. 11, 1919. Obs. Mer. Alt. Sun's L. L. 81° 16′ N. Index Error −3′ 20″. Dip 28 ft. Long. 19° 16′ E.

Longitude in time 1h 17′ 04″		
Obs. Alt.		81° 16′ 00″
I. E.	−	3′ 20″
		81° 12′ 40″
S. D.	+	16′ 06″
		81° 28′ 46″
Dip	−	5′ 11″
		81° 23′ 35″
R. & P.	−	07″
True Alt.		81° 23′ 28″
Z. D.		8° 36′ 32″ S
Dec.		4° 02′ 18″ S
Lat.		12° 38′ 50″ S

L. A. T., 11d		0h 00′ 00″
Long.		1h 17′ 04″
G. A. T., 10d		22h 42′ 56″
Eq. Time	−	10′ 23″
G. M. T. 10d		22h 32′ 33″ or 22.5h
Dec. for 10d 22h		4° 02′.8 S
Corr. for .5h	−	0′.5
Dec. for 10d 22.5h		4° 02′.3 S

PROBLEM NO. 12

Oct. 23, 1919. Obs. Mer. Alt. Sun's L. L. 37° 21′ S. Index Error +9′ 10″. Dip 16 ft. Long. 86° 15′ W.

Longitude in time 5h 45′		
Obs. Alt.		37° 21′ 00″
I. E.	+	9′ 10″
		37° 30′ 10″
S. D.	+	16′ 06″
		37° 46′ 16″
Dip	−	3′ 55″
		37° 42′ 21″
R. & P.	−	1′ 08″
True Alt.		37° 41′ 13″
Z. D.		52° 18′ 47″ N
Dec.		11° 12′ 54″ S
Lat.		41° 05′ 53″ N

L. A. T., 23d		0h 00′ 00″
Long.		5h 45′ 00″
G. A. T.		5h 45′ 00″
Eq. Time	−	15′ 31″
G. M. T. 23d		5h 29′ 29″ or 5.5h
Dec. for 23d 4h		11° 11′ .6 S
Corr. for 1.5h	+	1′ .3
Dec. for 23d 5.5h		11° 12′ .9 S

PROBLEM NO. 13

Oct. 11, 1919. Obs. Mer. Alt. Sun's L. L. 26° 53′ 10″ S. Index Error −2′ 40″. Dip 17 ft. Long. 18° 02′ W.

Longitude in time 1h 12′ 08″		G. A. T., 11d	1h 12′ 08″
Obs. Alt.	26° 53′ 10″ S	Eq. Time	− 13′ 00″
I. E.	− 2′ 40″	G. M. T., 11d	0h 59′ 08″ or
		11d	1h
	26° 50′ 30″		
S. D.	+ 16′ 03″		
	27° 06′ 33″		
Dip	− 4′ 02″		
	27° 02′ 31″		
R. & P.	− 1′ 46″		
True Alt.	27° 00′ 45″		
	90° 00′ 00″		
Z. D.	62° 59′ 15″ N	Dec. for 11d 0h	6° 43′.6 S
Dec.	6° 44′ 30″ S	Corr. for 1h	+ 0.9
Lat.	56° 14′ 45″ N	Dec. 11d 1h	6° 44′.5 S

PROBLEM NO. 14

Apr. 3, 1919. Obs. Mer. Alt. Sun's L. L. 60° 22′ S. Dip 21 ft. Long. 20° 59′ E.

Longitude in time 1h 23′ 56″		L. A. T., 3d	00h 00′ 00″
Obs. Alt.	60° 22′ 00″ S	Long.	− 1h 23′ 56″
S. D.	+ 16′ 00″	G. A. T., 2d	22h 36′ 04″
	60′ 38″ 00″	Eq. T.	+ 3′ 36″
Dip	− 4′ 29″	G. M. T., 2d	22h 39′ 40″ or
		2d	22.7h
	60° 33′ 31″		
R. & P	− 0′ 28″		
True Alt.	60° 33′ 03″ S		
Z. D.	29° 26′ 57″ N	Dec. for 2d 22h	4° 58.′8 N
Dec.	4° 59′ 30″ N	Corr. .7h	+ 0′.7
Lat.	34° 26′ 27″ N	Dec. 2d 22.7h	4° 59′.5 N

PROBLM NO. 15

Aug. 30, 1919. Obs. Mer. Alt. Sun's L. L. 57° 18′ 30″ N. Index Error +45″. Dip 18 ft. Long. 129° 15′ W.

Longitude in time 8h 37′		G. A. T., 30d		8h 37′ 00″
		Eq. Time	+	44″
Obs. Alt.	57° 18′ 30″ N			
I. E.	+ 45″	G. M. T., 30d		8 37′ 44″ or
		30d		8.6h
	57° 19′ 15″			
S. D.	+ 15′ 54″			
	57° 35′ 09″			
Dip	− 4′ 09″			
	57° 31′ 00″			
R. & P.	− 32″			
True Alt.	57° 30′ 28″ N			
Z. D.	32° 29′ 32″ S	Dec. for 30d 8h		9° 10′.4 N
Dec.	9° 09′ 54″ N	Corr. .6h	−	0′.5
Lat.	23° 19′ 38″ S	Dec.	30d 8.6h	9° 09′.9 N

PROBLEM NO. 16

Dec. 3, 1919. Obs. Mer. Alt. Sun's L. L. 64° 45′ 15″ N. Index Error −1′ 10″. Dip 20 ft. Long. 63° 18′ E.

Longitude in time 4h 13′ 12″.		L. A. T., 3d		00h 00′ 00″
		Long.	−	4h 13′ 12″
Obs. Alt.	64° 45′ 15″ N			
I. E.	− 1′ 10″	G. A. T., 2d		19h 46′ 48″
		Eq. Time	−	10′ 30″
	64° 44′ 05″			
S. D.	+ 16′ 18″	G. M. T., 2d		19h 36′ 18″ or
		2d		19.6h
	65° 00′ 23″			
Dip	− 4′ 23″			
	64° 56′ 00″			
R. & P.	− 23″			
True Alt.	64° 55′ 37″ N			
Z. D.	25° 04′ 23″ S	Dec. for 2d 18h		21° 57′.7 S
Dec.	21° 58′ 18″ S	Corr. 1.6h	+	0′.6
Lat.	47° 02′ 41″ S	Dec.		21° 58′.3 S

PROBLEM NO. 17

Mar. 20, 1919. Obs. Mer. Alt. Sun's L. L. 89° 42′ 40″ N. Index Error +2′ 20″. Dip 20 ft. Long. 101° 30′ W.

Long. in time 6h 46′		L. A. T., 20d	0h 00′ 00″
Obs. Alt.	89° 42′ 40″	Long.	+ 6h 46′ 00″
I. C.	+ 2′ 20″	G. A. T.	6h 46′ 00″
	89° 45′ 00″	Eq. Time	+ 7′ 45″
S. D.	− 16′ 06″	G. M. T.	6h 53′ 45″ or
	90° 01′ 06″	20d	6.9h
Dip	− 4′ 23″		
True Alt.	89° 56′ 43″		
Z. D.	3′ 17″ S	Dec. for 20 d 6h	0° 22′.0 S
Dec.	21′ 06″ S	Corr. for .9h	− 0′.9
Lat.	0° 24′ 23″ S	Dec. for 20d 6.9h	0° 21′.1 S

LATITUDE CONSTANT

In practice, probable position at noon is figured in advance (dead reckoning). The officer can then know at what time by the chronometer noon will occur.

Very commonly, sights are worked up in detail before noon and an expression obtained which only requires the introduction of the observed altitude to obtain the latitude at once.

Using D. R. longitude the G. M. time is known and the declination found. I. E.; S. D.; and dip are likewise known in advance. From D. R. latitude, working backwards an approximate altitude is found and R. & P. for this altitude used to find an expression, composed of declination and corrections to altitude, which applied to observed altitude give latitude instantly. Performing this work in advance enables the officer to have his position immediately after noon. Knowing approximate altitude before taking the sight is also of great value on a cloudy day.

Declination is found in the usual way.

If declination and D. R. latitude are same name the difference is Z. D., if different name the sum is Z. D.

Subtract Z. D. from 90° to get an approximate altitude. The R. & P. for this altitude is used as correct.

If declination and latitude are opposite names or if same names with declination greater apply correction to declination and subtract from 90° to get the constant.

If same names but latitude greater than declination apply correction with opposite sign to declination, i.e., add if −, subtract if +. The declination with correction is then added to 90° to get the constant.

The observed altitude is in all cases subtracted from the constant.

PROBLEM NO. 18

July 5, 1919. Probable noon position: Lat. 41° 07′ N. Long. 143° 17′ E. Index Error+1′ 30″. Dip 36 ft.

Longitude in time 9h 33′ 08″.			L. A. T., 5d		0h 00′ 00″
			Long.		9h 33′ 08″
Prob. Lat.		41° 07′ 00″ N			
Dec.		22° 54′ 12″ N	G. A. T., 4d		14h 26′ 52″
			Eq. Time	+	4′ 08″
Approx. Z. D.		18° 12′ 48″ N			
Approx. Alt.		71° 47′ 12″ S	G. M. T. 4d		14h 31′ 00″ or 14.5h
R. & P.	−	16″	Dec. for 4d 14h		22° 54′.3 N
Dip	−	5′ 53″	Corr. for .5h	−	0′.1
	−	6′ 09″	Dec. for 4d 14.5h		22° 54′.2 N
S. D.	+	15′ 48″			
	+	9′ 39″			
I. E.	+	1′ 30″			
Total Alt. Corr.		11′ 09″ +			
(Dec. and latitude same name, latitude greater).			Dec.		22° 54′ 12″ N
			Subtract Corr.		11′ 09″
					22° 43′ 03″
					90° 00′ 00″
			Const.		112° 43′ 03″ N

Officer will prepare to take his sight when chronometer reads 2:31 A. M.

The Mer. Alt. of Sun's L. L. is now measured and found to be 71° 41′ 10″, bearing S. It is subtracted from the expression worked out and gives latitude at once.

Const.	112° 43′ 03″ N
Obs. Alt.	71° 41′ 10″ S
Lat.	41° 01′ 53″ N

PROBLEM NO. 19

Jan. 30, 1919. Probable noon position: Lat. 43° 17′ N. Long. 61° 11′ W. Index Error − 1′ 20″. Dip 36 ft.

Longitude in time 4h 04′ 44″			L. A. T., 30d	0h 00′ 00″
Prob. Lat.		43° 17′ 00″ N	Long.	4h 04′ 44″
Dec.		17° 49′ 06″ S	G. A. T.	4h 04′ 44″
Approx. Z. D.		61° 06′ 06″ N	Eq. Time	+ 13′ 21″
Approx. Alt.		28° 53′ 54″ S	G. M. T. 30d	4h 18′ 05″ or 4.3h
R. & P.	−	1′ 42″	Dec. for 30d 4h	17° 49′.3 S
Dip	−	5′ 53″	Corr. for .3h	0′.2
I. E.	−	1′ 20″	Dec. for 30d 4.3h	17° 49′.1 S
	−	8′ 55″		
S. D.	+	16′ 18″		
Total Alt. Corr.	+	7′ 23″		
(Declination and latitude opposite names).			Dec.	17° 49′ 06″ S
			Corr.	+ 7′ 23″
				17° 56′ 29″
				90° 00′ 00″
			Const.	72° 03′ 31″ N

Officer takes sight at 4:18 P. M. by chronometer and finds sun at its highest point has an altitude of 29° 00′, bearing S.

Const.	72° 03′ 31″ N
Obs. Alt.	29° 00′ 00″ S
Lat.	43° 03′ 31″ N

PROBLEM NO. 20

Aug. 8, 1919. Probable noon position: Lat. 31° 16′ 10″ S. Long. 22° 10′ E. Index Error+30″. Dip 36 ft.

Longitude in time 1h 28′ 40″.

Prob. Lat.		31° 16′ 10″ S
Dec.		16° 22′ 54″ N
Approx. Z. D.		47° 39′ 04″ S
Approx. Alt.		42° 20′ 56″ N
R. & P.	−	57″
Dip	−	5′ 53″
	−	6′ 50″
S. D.	+	15′ 48″
		8′ 58″
I. E.	+	30″
Total Alt. Corr.	+	9′ 28″

(Declination and latitude opposite names).

L. A. T., 8d		0h 00′ 00″
Long.		1h 28′ 40″
G. A. T., 7d		23h 31′ 20″
Eq. Time	+	5′ 37″
G. M. T. 7d		23h 36′ 57″ or 23.6h
Dec. for 7d 22h		16° 24′.0 N
Corr. for 1.6h		1′.1
Dec. for 7d 23.6h		16° 22.′9 N

Dec.		16° 22′ 54″ N
Corr.	−+	9′ 28″
		16° 32′ 22″
		90° 00′ 00″
Const.		73° 27′ 38″ S

Sun will cross meridian when chronometer reads 11h 36′ 57″ A. M. Altitude observed 42° 50′, bearing N.

Const.	73° 27′ 38″ S
Alt.	42° 50′ 00″ N
Lat.	30° 37′ 38″ S

PROBLEM NO. 21

Dec. 15, 1919. Probable noon position: Lat. 10° 12′ S. Long. 60° 00′ W. Dip 36 ft.

Longitude in time 4h			L. A. T., 15d	0h 00′ 00″
Prob. Lat.		10° 12′ 00″ S	Long.	4h 00′ 00″
Dec.		23° 14′ 36″	G. A. T.	4h 00′ 00″
Approx. Z. D.		13° 02′ 36″ N	Eq. Time	− 5′ 05″
Approx. Alt.		76° 57′ 24″ S	G. M. T. 15d	3h 54′ 55″ or 3.9h
R. & P.	−	12″	Dec. for 15d 4h	23° 14.′6 S
Dip	−	5′ 53″	Corr. for .1h	0′.0
	−	6′ 05″	Dec. for 15d 3.9h	23° 14′.6 S
S. D.	+	16′ 18″		
Total Alt. Corr.	+	10′ 13″		
(Declination and latitude same names, declination greater).			Dec.	23° 14′ 36″ S
			Corr.	+ 10′ 13″
				23° 24′ 49″
				90° 00′ 00″
			Const.	66° 35′ 11″ N

Officer takes sight at 3:55 P. M. by chronometer. Observed altitude 76° 10′, bearing S.

Const.	66° 35′ 11″ N
Obs. Alt.	76° 10′ 00″ S
Lat.	9° 34′ 49″ S

CHAPTER VIII

LATITUDE BY MERIDIAN ALTITUDE OF STAR

This example is worked the same as the previous one.

The declination of a star having a very small annual cnange, it is only necessary to take out the minutes for the month, and the number of degrees on the side opposite the star used.

Declination is found on page 95, Nautical Almanac.

There is no Semi-diameter or Parallax for a star, so the meridian altitude is corrected as follows:

Index Error as per sign if any.

Dip (Table 14) subtract.

Refraction (Table 20A) subtract.

Answer will be true altitude.

Subtract true altitude from 90°. Answer will be Zenith Distance, to be named opposite name to star's bearing.

Under Zenith Distance put down declination and apply as follows:

Same names, add.

Different names, subtract less from greater.

Answer will be latitude.

Name the latitude as follows:

If added, will be named the same as the two of them.

If subtracted, will be named the same as greater of two.

FINDING TIME OF STARS' MERIDIAN PASSAGE

From page 96 (Nautical Almanac) take out G. M. T. of transit of the star for the first day of the month. Then subtract from this time the correction given on page 97 (N. A.) for the day of the month to reduce the time to the date of the observation. This will be local mean time of transit, very closely. A further correction of 10^s for every 15° longitude added if E longitude. subtracted if W longitude, may be applied.

PROBLEM NO. 1

Jan. 10, 1919. Find time of Meridian Passage of Star "Spica."

Time of Transit Jan. 1		18h 38′
Correction for 10d	–	35′
Time of Transit Jan. 10		18h 03′

PROBLEM NO. 2

Feb. 16, 1919. Find time of Meridian Passage of Star "Arcturus."

Time of Transit Feb. 1		17h 27′
Correction for 16d	–	59′
Time of Transit Feb. 16		16h 28′

PROBLEM NO. 3

June 3, 1919. Find time of Meridian Passage of Star "Canopus."

Time of Transit June 1		1h 46′
Correction for 3d	–	8′
Time of Transit June 3		1h 38′

PROBLEM NO. 4

May 12, 1919. Find time of Meridian Passage of Star "Sirius."

Time of Transit May 1		4h 07′
Correction for 12d	–	43′
Time of Transit May 12		3h 24′

LATITUDE BY STAR

PROBLEM NO. 1

Nov. 12, 1919. Obs. Mer. Alt. *Rigel 26° 47′ 10″ S. Index Error –1′ 20″. Dip 18 ft.

Dec. 8° 17′.5 S

Alt.		26° 47′ 10″		90° 00′ 00″
I. E.	–	1′ 20″	True Alt.	26° 39′ 46″
		26° 45′ 50″	Z. D.	63° 20′ 14″ N
Dip	–	4′ 09″	Dec.	8° 17′ 30″ S
		26° 41′ 41″	Lat.	55° 02′ 44″ N
Ref.	–	1′ 55″		
True Alt.		26° 39′ 46″		

PROBLEM NO. 2

Feb. 12, 1919. Obs. Mer. Alt. *Procyon 77° 18′ 10″ S. Index Error +20″. Dip 16 ft.

Dec. 5° 25′.8 N

Alt.	77° 18′ 10″		90° 00′ 00″
I. E.	+ 20″	True Alt.	77° 14′ 22″
	77° 18′ 30″	Z. D.	12° 45′ 38″ N
Corr. (46)	− 4′ 08″	Dec.	5° 25′ 48″ N
True Alt.	77° 14′ 22″	Lat.	18° 11′ 26″ N

PROBLEM NO. 3

Mar. 19, 1919. Obs. Mer. Alt. *Arcturus 36° 10′ 20″ N. Index Error +2′ 40″. Dip 20 ft.

Dec. 19° 35′.9 N

Alt.	36° 10′ 20″		90° 00′ 00″
I. E.	+ 2′ 30″	True Alt.	36° 07′ 17″
	36° 13′ 00″	Z. D.	53° 52′ 43″ S
Corr. (46)	− 5′ 43″	Dec.	19° 35′ 54″ N
True Alt.	36° 07′ 17″	Lat.	34° 16′ 49″ S

PROBLEM NO. 4

July 9, 1919. Obs. Mer. Alt. *Spica 49° 16′ 25″ S. Dip. 18 ft.

Dec. 10° 44′.6 S

Obs. Alt.	49° 16′ 25″		90° 00′ 00″
Corr. (46)	− 4′ 59″	True Alt.	49° 11′ 26″ S
	49° 11′ 26″	Z. D.	40° 48′ 34″ N
		Dec.	10° 44′ 36″ S
		Lat.	30° 03′ 58″ N

PROBLEM NO. 5

Mar. 11, 1919. Obs. Mer. Alt. *Betelgeux 80° 10′ 20″ N. Dip 30 ft.

Dec. 7° 23′.5 N

Obs. Alt	80° 10′ 20″		90° 00′ 00″
Corr. (46)	− 5′ 32″	True Alt.	80° 04′ 48″ N
True Alt.	80° 04′ 48″	Z. D.	9° 55′ 12″ S
		Dec.	7° 23′ 30″ N
		Lat.	2° 31′ 42″ S

PROBLEM NO. 6

Feb. 16, 1919. Obs. Mer. Alt. *Aldebaran 38° 15′ S. Dip 28 ft.

Dec. 16° 20′.8 N

Obs. Alt.	38° 15′ 00″		90° 00′ 00″
Corr. (46)	– 6′ 25″	True Alt.	38° 08′ 35″ S
True Alt.	38° 08′ 35″	Z. D.	51° 51′ 25″ N
		Dec.	16° 20′ 48″ N
		Lat.	68° 12′ 13″ N

PROBLEM NO. 7

Nov. 21, 1919. Obs. Mer. Alt. *Sirius 41° 16′ 00″ S. Dip 40 ft.

Dec. 16° 36′.4 S

Obs. Alt.	41° 16′ 00″		90° 00′ 00″
Corr. (46)	– 7′ 20″	True Alt.	41° 08′ 40″ S
True Alt.	41° 08′ 40″	Z. D.	48° 51′ 20″ N
		Dec.	16° 36′ 24″ S
		Lat.	32° 14′ 56″ N

PROBLEM NO. 8

Apr. 6, 1919. Obs. Mer. Alt. *Fomalhaut 18° 17′ 00″ S. Dip 28 ft.

Dec. 30° 03′.0 S

Obs. Alt.	18° 17′ 00″		90° 00′ 00″
Corr. (46)	– 8′ 06″	True Alt.	18° 08′ 54″ S
True Alt.	18° 08′ 54″	Z. D.	71° 51′ 06″ N
		Dec.	30° 03′ 00″ S
		Lat.	41° 48′ 06″ N

PROBLEM NO. 9

May 12, 1919. Obs. Mer. Alt. *Antares 80° 16′ 00″ N. Dip 20 ft.

Dec. 26° 15′.3 S

Obs. Alt.	80° 16′ 00″		90° 00′ 00″
Corr. (46)	– 4′ 33″	True Alt.	80° 11′ 27″ N
True Alt.	80° 11′ 27″	Z. D.	9° 48′ 33″ S
		Dec.	26° 15′ 18″ S
		Lat.	36′ 03′ 51″ S

PROBLEM NO. 10

July 16, 1919. Obs. Mer. Alt. *Fomalhaut 73° 36′ 00″ S. Index Error+1′ 40″. Dip 24 ft.

Dec. 30° 02′.6 S

Obs. Alt.		73° 36′ 00″		90° 00′ 00″
I. E.	+	1′ 40″	True Alt.	73° 32′ 35″ S
		73° 37′ 40″	Z. D.	16° 27′ 25″ N
Corr. (46)	−	5′ 05″	Dec.	30° 02′ 36″ S
		73° 32′ 35″	Lat.	13° 35′ 11″ S

PROBLEM NO. 11

Apr. 6, 1919. Obs. Mer. Alt. *Regulus 50° 14′ 20″ S. Index Error +1′ 15″. Dip 18 ft.

Dec. 12° 21′.5 N

Obs. Alt.		50° 14′ 20″		90° 00′ 00″
I. E.	+	1′ 15″	True Alt.	50° 10′ 37″ S
		50° 15′ 35″	Z. D.	39° 49′ 23″ N
Corr. (46)	−	4′ 58″	Dec.	12° 21′ 30″ N
True Alt.		50° 10′ 37″	Lat.	52° 10′ 53″ N

PROBLEM NO. 12

Dec. 26, 1919. Obs. Mer. Alt. *Sirius 36° 28′ 30″ S. Index Error −45″. Dip 16 ft.

Dec. 16° 36′.5 S

Obs. Alt		36° 28′ 30″		90° 00′ 00″
I. E.	−	45″	True Alt.	36° 22′ 31″ S
		36° 27′ 45″	Z. D.	53° 37′ 29″ N
Corr. (46)	−	5′ 14″	Dec.	16° 36′ 30″ S
		36° 22′ 31″	Lat.	37° 00′ 59″ N

CHAPTER IX

LONGITUDE BY SUN

The longitude of a place is the number of hours, minutes and seconds east or west of the meridian of Greenwich, which is Long. 0°, expressed in degrees, minutes and seconds.

A chronometer is an ordinary clock of the finest make, with a 12-hour face, and keeps the time of Greenwich.

The astronomical day is explained under Definitions, and begins at noon and ends at noon.

In all instances in this example if chronometer time is A. M. add 12 to the hours and date one day back.

P. M. chronometer time keeps same date as example.

Put down chronometer time and correct fast or slow as given. Answer will be Greenwich Mean Time expressed G. M. T.

Take out Sun's declination for Greenwich mean time.

The polar distance is the angular distance of a heavenly body from the pole nearest the observer. To find polar distance follow rule:

If latitude and declination are different names, add 90° to declination.

If latitude and declination are same names, subtract declination from 90°.

A chronometer always keeps the time of a day of exactly 24 hours, which is called a Mean day, but the sun's time which is known as Apparent Time, changes a little every day. The difference between mean time and apparent time is called the equation of time.

Take from the almanac equation of time for Greenwich date and time, and apply it to G. M. T. as by sign given in almanac.

Answer will be Greenwich Apparent Time expressed G. A. T.

Correct observed altitude of sun as follows:

Index error as per sign, if any.

Semi-Diameter from almanac. Add for Lower Limb. Subtract for Upper.

Dip (Table 14) subtract.

Refraction and parallax (Table 20*B*) subtract.

Answer will be true altitude.

Add together true altitude, latitude and polar distance, and divide sum by 2. Answer will be half sum.

Subtract true altitude from half sum. Answer will be remainder.

From Table 44 (Bowditch) take out the following logarithms to the nearest second of arc:

Secant of latitude. Rejecting 10 from index number.

Cosecant of polar distance. Rejecting 10 from index number. (See note.)

Cosine of half sum.

Sine of remainder.

Add these four logarithms together, and subtract 10 from index number.

Note.—If polar distance exceeds 90° take Secant of declination instead.

Logarithm Haversine (Table 45) that agrees with sum of logarithms will be the Local Apparent Time, expressed L. A. T.

If sight was taken in A. M. read hours and minutes from bottom, and seconds in right-hand column, and date one day back.

If sight was taken in P. M. read hours and minutes from top, and seconds in left-hand column, and date same as example.

Under L. A. T. put down G. A. T. If both are same date subtract less from greater, if different dates add 24 hours to greatest date, and then subtract less from greater. Answer will be longitude in time.

Multiply hours of longitude in time by 60, and add the minutes. Divide the minutes by 4, and the result will be degrees of longitude. If any minutes are left multiply by 60 and add the seconds, divide by 4, and the result will be minutes of longitude. If any seconds are left multiply by 60 and divide by 4, and the result will be seconds of longitude.

If the Greenwich time is best, the longitude is west.

If the Greenwich time is least, the longitude is east.

FINDING GREENWICH DATE AND TIME

The Greenwich time and date is absolutely necessary to be found correctly in this example.

In some of the problems given in this book the reading of the chronometer is given A. M. or P. M., others longitude by dead reckoning is given; in others the Greenwich date and time is given.

Below will be found the different methods that an example may be given, and the explanation of how the Greenwich date may be found.

If the chronometer reads A. M. and no longitude by D. R. is given, add 12 hours to the time, and date one day back.

For example: Jan. 25th P. M. at ship. Chronometer read 10h 16′ 28″ A. M.

Greenwich date and time will be Jan. 24th 22h 16′ 28″.

If chronometer reads P. M. and no longitude by D. R. is given, the Greenwich date and time will be the same as the example.

For example: Jan. 25th A. M. at ship. Chronometer read 1h 16′ 28″ P. M.

Greenwich date and time will be Jan. 25th 1h 16′ 28″.

If the Greenwich date is given, the chronometer is put down in the following manner:

Jan. 25th A. M. at ship. Chronometer read Jan. 24th 11h 16′ 28″.

Greenwich date and time will be Jan. 24th 11h 16′ 28″.

If the approximate ship's time and longitude by D. R. are given in an example, and the chronometer reading without stating whether it is A. M. or P. M. the student must be able to determine whether the chronometer is A. M. or P. M. in order to convert it into astronomical time.

For example, if problem was given in following manner:

Jan. 26th about 7 A. M. at ship. Longitude by D. R. 90° W. Chronometer read 1h 10″.

Now as the difference between ship's time and Greenwich time is the longitude in time, we have for the above example a longitude in time of 6 hours.

In west longitude the Greenwich time is the largest. So if it is about 7 A. M. at ship, it must be 1h 10′ P. M. at Greenwhich. Or, Greenwich date Jan. 26th 1h 10′.

Now presuming this example was in longitude by D. R. 90° E.

In east longitude the ship's time is the largest. So if it is about 7 A. M. at ship, it must be 1h 10′ A. M. at Greenwich. Or, Greenwich date Jan. 25th 13h 10′.

This will explain practically all the methods of finding Greenwich date, and if the student will read his problem carefully he should have no trouble.

It must always be remembered that the astronomical day begins at noon of the civil day, and ends at noon, and a 24-hour face clock must be imagined.

PROBLEM NO. 1

Jan. 31, 1919, A. M. Obs. Alt. Sun's L. L. 13° 54′ 00″. Dip 36 ft. Chronometer read 2h 46′ 17″ P. M., fast 34′ 34″. Lat. 25° 44′ N.

Chron.	2h 46′ 17″	Dec., 31d, 2h	17° 34′.2 S
Fast	− 34′ 34″	Corr. .2h	− 0′.1
G. M. T., 31d	2h 11′ 43″	Dec. 31d 2.2h	17° 34′.1 S
Eq. Time	− 13′ 30″		
			90° 00′ 00″
G. A. T., 31d	1h 58′ 13″	Dec.	17° 34′ 06″
		P. D.	107° 34′ 06″
Altitude	13° 54′ 00″		
S. D.	+ 16′ 15″		
	14° 10′ 15″		
Dip	− 5′ 53″		
	14° 04′ 22″		
R. & P.	− 3′ 40″		
True Alt. (h)	14° 00′ 42″		
Lat.	25° 44′ 00″	Sec.	.04536
P. D.	107° 34′ 06″	Csc	.02074
	2)147° 18′ 48″		
Half Sum (s)	73° 39′ 24″	Cos	9.44931
h	14° 00′ 42″		
s − h	59° 38′ 42″	Sin	9.93596
		Log. Hav.	9.45137

L. A. T., 30d	19h 43′ 01″
G. A. T., 31d	1h 58′ 13″
Long.	6h 15′ 12″ or
	93° 48′ W

PROBLEM NO. 2

Jan. 30, 1919, P. M. Obs. Alt. Sun's L. L. 18° 32′. Dip 36 ft. Chron. read 10h 42′ 46″ P. M., fast 34′ 28″. Lat. 27° 12′ N.

Chron.	10h 42′ 46″	Dec. 30d 10h	17° 45′.2 S
Fast	34′ 28″	Corr. .1h	− 0′.1
G. M. T., 30d	10h 08′ 18″	Dec. 30d 10.1h	17° 45′.1 S
Eq. Time	− 13′ 23″		90° 00′ 00″
G. A. T.	9h 54′ 55″	P. D.	107° 45′.1

Altitude	18° 32′ 00″		
S. D.	+ 16′ 15″		
	18° 48′ 15″		
Dip	− 5′ 53″		
	18° 42′ 22″		
R. & P.	− 2′ 43″		
True Alt	18° 39′ 39″		
Lat.	27° 12′ 00″	Sec	.05089
P. D.	107° 45′ 06″	Csc	.02118
	2)153° 36′ 45″		
s	76° 48′ 22″	Cos	9.35841
	18° 39′ 39″		
s−h	58° 08′ 43″	Sin	9.92911
		Log. Hav.	9.35959

L A. T, 30d	3h 48′ 39″
G. A. T., 30d	9h 54′ 55″
Long.	6h 06′ 16″ or

91° 34′ W

PROBLEM NO. 3

Mar. 11, 1919, A. M. Obs. Alt. Sun's L. L. 28° 13′ 00″. Dip 38 ft. Chronometer read 3h 12′ 15″ A. M. Lat. 31° 46′ S.

G. M. T., 10d	15h 12′ 15″	Dec. 10d 14h	4° 10′.6 S
Eq. Time	− 10′ 28″	Corr. for 1.2h	− 1′.2 S
G. A. T., 10d	15h 01′ 47″	Dec. 10d 15.2h	4° 09′.4 S
			90° 00′
		P. D.	85° 50′.6

Alt.	28° 13′ 00″		
S. D.	+ 16′ 06″		
	28° 29′ 06″		
Dip	− 6′ 02″		
	28° 23′ 04″		
R. & P.	− 1′ 40″		
True Alt.	28° 21′ 24″		
Lat.	31° 46′ 00″	Sec	.07048
P. D.	85° 50′ 36″	Csc	.00114
	2)145° 58′ 00″		
s	72° 59′ 00″	Cos	9.46635
s − h	44° 37′ 36″	Sin	9.84664
		Log. Hav.	9.38461

L. A. T., 10d	20h 04′ 01″
G. A. T., 10d	15h 01′ 47″
Long.	5h 02′ 14″ or

75° 33′ 30″ E

PROBLEM NO. 4

Jan. 31, 1919, P. M. Obs. Alt. Sun's L. L. 18° 32′. Dip 36 ft. Chronometer read 10h 42′ 46″ A. M., fast 34′ 28″. Lat. 27° 12′ N.

Chron.	22h 42′ 46″	Dec. 30d 22h	17° 37′.0 S
Fast	– 34′ 28″	Corr. for .1h	– 0′.1
G. M. T., 30d	22h 08′ 18″	Dec. 30d 22.1h	17° 36′.9
Eq. Time	· 13′ 28″		90° 00′.0
G. A. T., 30d	21h 54′ 50″	P. D.	107° 36′.9

Alt.	18° 32′ 00″		
S. D.	+ 16′ 18″		
	18° 48′ 18″		
Dip	– 5′ 53″		
	18° 42′ 25″		
R. & P.	– 2′ 43″		
h	18° 39′ 42″		
Lat.	27° 12′ 00″	Sec	.05089
P. D.	107° 36′ 54″	Csc	.02086
	2)153° 28′ 36″		
s	76° 44′ 18″	Cos	9.36059
s – h	58° 04′ 36″	Sin	9.92879
		Log. Hav.	9.36113

L. A. T., 31d	3h 49′ 06″
G A. T, 30d	21h 54′ 50″
Long.	5h 54′ 16″ or
88° 34′ E	

PROBLEM NO. 5

Mar. 10, 1919, A. M. Obs. Alt. Sun's L. L. 21° 00′ 00″. Dip 38 ft Chronometer read 1h 07′ 56″ P. M. Lat. 31° 19′ N.

G. M. T., 10d	1h 07′ 56″	Dec. 10d 0h	4° 24′.3 S
Eq. Time	− 10′ 37″	Corr. 1.0h	− 1′.0
G. A. T. 10d	0h 57′ 19″	Dec. 10 d. 1h	4° 23′.3 S
			90° 00′.0
		P. D.	94° 23′.3

Alt.	21° 00′ 00″		
S. D.	+ 16′ 06″		
	21° 16′ 06″		
Dip	− 6′ 02″		
	21° 10′ 04″		
R. & P.	− 2′ 21″		
h	21° 07′ 43″		
Lat.	31° 19′ 00″	Sec	.06839
P. D.	94° 23′ 18″	Csc	.00127
	2)146° 50′ 01″		
s	73° 25′ 00″	Cos	9.45547
s − h	52° 17′ 17″	Sin	9.89823
		Log. Hav.	9.42336

L. A. T., 9d	19h 52′ 06″
G. A. T., 10d	0h 57′ 19″
Long.	5h 05′ 13″ W or

76° 18′ 15″ W

PROBLEM NO. 6

July 5, 1919, A. M. Obs. Alt. Sun's L. L. 18° 15′. Dip 38 ft. Chronometer read 10h 15′ 25″ A. M., slow 12′ 10″. Lat. 37° 15′ N.

Chron.	22h 15′ 25″	Dec. 4d 22h	22° 52′.6 N
Slow	+ 12′ 10″	Corr. .4h	− 0′.1
G. M. T.	22h 27′ 35″	Dec.	22° 52′.5
Eq. Time	− 4′ 11″		90° 00′.0
G. A. T. 4d	22h 23′ 24″	P. D.	67° 07′.5

Alt.	18° 15′ 00″		
S. D.	+ 15′ 45″		
	18° 30′ 45″		
Dip	− 6′ 02″		
	18° 24′ 43″		
R. & P.	− 2′ 45″		
h	18° 21′ 58″		
Lat.	37° 15′ 00″	Sec	.09909
P. D.	67° 07′ 30″	Csc	.03557
	2)122° 44′ 28″		
s	61° 22′ 14″	Cos	9.68047
s − h	43° 00′ 16″	Sin	9.83382
		Log. Hav.	9.64895

L. A. T., 4d	18h 24′ 59″
G. A. T., 4d	22h 23′ 24″
Long.	3h 58′ 25″ or

59° 36′ 15″ W

PROBLEM NO. 7

July 5, 1919, A. M. Obs. Alt. Sun's L. L. 14° 28′ 30″. Dip 21 ft. Chronometer read 4h 16′ 28″ A. M., slow 14′ 28″. Lat. 26° 33′ N.

Chron	16h 16′ 28″	Dec. 4d 16h	22° 53′.9 N
Slow	+ 14′ 28″	Corr. .5h	− 0′.1
G. M. T.	16h 30′ 56″	Dec. 4d 16.5h	22° 53′.8
Eq. Time	− 4′ 09″		90° 00′
G. A. T. 4d	16h 26′ 47″	P. D.	67° 06′.2

Alt.	14° 28′ 30″		
S. D.	+ 15′ 45″		
	14° 44′ 15″		
Dip	− 4′ 29″		
	14° 39′ 46″		
R. & P.	− 3′ 30″		
h	14° 36′ 16″		
Lat.	26° 33′ 00″	Sec	.04840
P. D.	67° 06′ 12″	Csc	.03564
	2)108° 15′ 28″		
s	54° 07′ 44″	Cos	9.76787
s−h	39° 31′ 28″	Sin	9.80373
		Log. Hav.	9.65564

L. A. T., 4d	18h 21′ 48″
G. A. T., 4d	16h 26′ 47″
Long.	1h 55′ 01″ E or 28° 45′ 15″ E

PROBLEM NO. 8

Jan. 31, 1919, P. M. Obs. Alt. Sun's L. L. 23° 16′. Dip 36 ft. Chronometer read 10h 38′ 38″ P. M., fast 34′ 37″. Lat. 24° 55′ N.

Chron.	10h 38′ 38″	Dec. 31d 10h	17° 28′.7 S
Fast.	− 34′ 37″	Corr. .1h	− 0′.1
G. M. T. 31d	10h 04′ 01″	Dec. 31d 10.1h	17° 28′.6 S
Eq. Time	− 13′ 33″		90° 00′.0
G. A. T.	9h 50′ 28″	P. D.	107° 28′.6

Alt.	23° 16′ 00″		
S. D.	+ 16′ 16″		
	23° 32′ 16″		
Dip	− 5′ 53″		
	23° 26′ 23″		
R. & P.	− 2′ 05″		
h	23° 24′ 18″		
Lat.	24° 55′ 00″	Sec	.04243
P. D.	107° 28′ 36″	Csc	.02052
	2)155° 47′ 54″		
s	77° 53′ 57″	Cos	9.32146
s−h	54° 29′ 39″	Sin	9.91066
		Log. Hav.	9.29507

L. A. T., 31d	3h 30′ 57″
G. A. T. 31d	9h 50′ 28″
Long.	6h 19′ 31″ W or

94° 52′ 45″ W

PROBLEM NO. 9

Dec. 15, 1919, A. M. Obs. Alt. Sun's L. L. 28° 16′ 15″. Dip 40 ft. Chronometer read 4h 16′ 28″ P. M., slow 14′ 28″. Lat. 26° 33′ S.

Chron.	4h 16′ 28″	Dec. 15d 4h	23° 14′.6 S
Slow	+ 14′ 28″	Corr. for .5h	+ 0′.1
G. M. T. 15d	4h 30′ 56″	Dec. 15d 4.5h	23° 14′.7 S
Eq. Time	+ 5′ 04″		90° 00′
G. A. T.	4h 36′ 00″	P. D.	66° 45′.3

Alt.	28° 16′ 15″		
S. D.	+ 16′ 18″		
	28° 32′ 33″		
Dip	− 6′ 12″		
	28° 26′ 21″		
R. & P.	− 1′ 39″		
h	28° 24′ 42″		
Lat.	26° 33′ 00″	Sec	.04840
P. D.	66° 45′ 18″	Csc	.03676
	2)121° 43′ 00″		
s	60° 51′ 30″	Cos	9.68750
s−h	32° 26′ 48″	Sin	9.72958
		Log. Hav.	9.50224

L. A. T., 14d	19h 15′ 27″
G. A. T., 15d	4h 36′ 00″
Long.	9h 10′ 33″ W or

137° 38′ 15″ W

PROBLEM NO. 10

Oct. 24, 1919, A. M. Obs. Alt. Sun's L. L. 18° 26′ 15″. Dip 40 ft. Chronometer read 2h 08′ 03″ A. M., fast 58′ 13″. Lat. 3° 21′ S.

Chron.	14h 08′ 03″	Dec. 23d 12h	11° 18′.6 S
Fast	− 58′ 13″	Corr. for 1.2h	+ 1′.1
G. M. T. 23d	13h 09′ 50″	Dec. 23d 13.2h	11° 19′.7 S
Eq. Time	+ 15′ 33″		90° 00′
G. A. T. 23d	13h 25′ 23″	P. D.	78° 40′.3

Alt.	18° 26′ 15″		
S. D.	+ 16′ 06″		
	18° 42′ 21″		
Dip	− 6′ 12″		
	18° 36′ 09″		
R. & P.	− 2′ 43″		
h	18° 33′ 26″		
Lat.	3° 21′ 00″	Sec	.00074
P. D.	78° 40′ 18″	Csc	.00855
	2)100° 34′ 44″		
s	50° 17′ 22″	Cos	9.80544
s−h	31° 43′ 56″	Sin	9.72094
		Log. Hav.	9.53567

L. A. T., 23d	19h 13′ 04″
G. A. T., 23d	13h 25′ 23″
Long.	5h 47′ 41″ E or

86° 55′ 15″ E

CHAPTER X

NOON POSITION SIGHTS

The following problems are worked the same as the foregoing longitude sights as far as obtaining the longitude at sight.

In working a sight for longitude the correct latitude of the place at time of sight must be used.

In this problem the latitude at noon is given, and the latitude at sight must be found by taking from Table 2 (Bowditch) the difference of latitude and departure for the course and distance sailed between sight and noon.

If the sight is taken in A. M. the name of the latitude difference north or south must be reversed to work the latitude back to sight.

If taken in P. M. the name of the latitude difference stays the same.

By applying the difference of latitude to latitude at noon, will be found the latitude at sight, which is the latitude to be used in working the problem.

The middle latitude is then found by adding together latitude at noon and latitude at sight, and dividing sum by 2.

Enter Table 2 with middle latitude as a course and look for departure in latitude column. In the distance column opposite will be difference of longitude in miles.

If sight is taken in P. M. the name of the difference of longitude east or west must be reversed to work the problem back to noon.

If sight is A. M. the name of the difference of longitude stays the same.

The chronometer is corrected for the original error slow or fast, and the number of days and tenths of a day from date of original error to Greenwich date are figured out, and multiplied by daily rate; this will give the accumulated rate.

This accumulated rate is then applied to chronometer, and the result will be G. M. T.

The example is then worked as in previous problem, and the longitude at sight is obtained.

By applying the difference of longitude to the longitude at sight, will give the longitude at noon.

This will give ship's noon position.

PROBLEM NO. 1

Feb. 10, 1919, A. M. Obs. Alt. Sun's L. L. 9° 09′ 50″. Index Error −3′ 20″. Dip 18 ft. Chronometer read Feb 9, 9h 59′ 25″ which was fast on Jan. 10, 34′ 12″ and losing 10″.8, daily. Lat. at noon 50° 16′ 24″ N. Ship's run from sight to noon S 56° W (true) 38 miles.

Chron.	9h 59′ 25″		30.4 days
Fast	34′ 12″		10″.8
	9h 25′ 13″		328″ Acc. rate or 5′ 28″.
Acc. Rate	− 5′ 28″	Dec. 9d 8h	14° 48′.5
		Corr. 1.3h	− 1′.0
G. M. T. 9d	9h 30′ 41″		
Eq. Time	− 14′ 22″	Dec. 9d 9.3h	14° 47′.5 S
			90° 00′
G. A. T. 9d	9h 16′ 19″		
		P. D.	104° 47′.5
		Lat. Noon	50° 16′ 24″ N
		Diff. Lat.	21′ 12″
		Lat. at Sight	50° 37′ 36″ N

At. Mid. Lat 50°; Dep. 31.5 miles; Diff. Long 49′ W

Alt.	9° 09′ 50″		
I. E.	− 3′ 20″		
	9° 06′ 30″		
S. D.	+ 16′ 12″		
	9° 22′ 42″		
Dip	− 4′ 09″		
	9° 18′ 33″		
R. & P.	− 5′ 33″		
True Alt.	9° 13′ 00″		
Lat.	50° 37′ 36″	Sec	.19765
P. D.	104° 47′ 30″	Csc	.01464
	2)164° 38′ 06″		
s	82° 19′ 03″	Cos	9.12607
s−h	73° 06′ 03″	Sin	9.98083
		Log. Hav.	9.31919

L. A. T. 9d	20h 22′ 37″
G. A. T. 9d	9h 16′ 19″
Long. Sight	11h 06′ 18″ or 166° 34′ 30″ E
Diff. Long.	49′ 00″ W
Long. Noon	165° 45′ 30″ E

PROBLEM NO. 2

Jan. 31, 1919, A. M. Obs. Alt. Sun's L. L. 15°08′. Dip 36 ft. Chronometer read 2h 45′ 49″ P. M. which was fast on Jan. 11th, 31′ 34″ and gaining 9″ daily. Lat. at noon 25° 31′ 17″ N. Ship's run from sight to noon S 26° W (true) 57 miles.

Chron.		2h 45′ 49″
Fast	−	31′ 34″
		2h 14′ 15″
Acc. Rate	−	3′ 01″
G. M. T. 31d		2h 11′ 14″
Eq. Time	−	13′ 30″
G. A. T. 31d		1h 57′ 44″

	20.1 days
	9″
	180″.9 Acc. Rate

Lat. Noon		25° 31′ 17″ N
Diff. Lat.		51′ 12″ N
Lat. Sight		26° 22′ 29″ N

At Mid. Lat. 26°; Dep. 25.0 miles, Diff. Long. 28′ W.

Dec. 31d 2h		17° 34′.2 S
Corr. .2h	−	.1′ S
Dec. 31d 2.2h		17° 34′.1 S
		90° 00′
P. D.		107° 34′.1

Obs. Alt.		15° 08′ 00″		
S. D.	+	16′ 15″		
		15° 24′ 15″		
Dip	−	5′ 53″		
		15° 18′ 22″		
R. & P.	−	3′ 22″		
h		15° 15′ 00″		
Lat.		26° 22′ 29″	Sec	.04774
P. D.		107° 34′ 06″	Csc	.02074
		2)149° 11′ 35″		
s		74° 35′ 48″	Cos	9.42425
s−h		59° 20′ 48″	Sin	9.93463
			Log. Hav.	9.42736

L. A. T. 30d	19h 50′ 50″
G. A. T. 31d	1h 57′ 44″
Long. at Sight	6h 06′ 54″ W or
	91° 43′ 30″ W
Diff. Long.	28′ 00″ W
Long. at Noon	92° 11′ 30″ W

PROBLEM NO. 3

Jan. 2, 1919, A. M. Obs. Alt. Sun's L. L. 49° 10′. Index Error −2′ 40″. Dip 14 ft. Chronometer read 7h 08′ 50″ A. M., which was slow on Dec. 7, 19′ 10″.6 and losing 9″.8 daily. Lat. at noon 37° 21′ 36″ S. Ship's run from sight to noon S 45° W (true) 32 miles.

Chron.	19h 08′ 50″		25.8 days
Slow	+ 19′ 10″		9″.8
	19h 28′ 00″		253″ Acc. Rate
Acc. Rate	+ 4′ 13″		
		Dec. 1d 18h	23° 00′.6 S
G. M. T. 1d	19h 32′ 13″	Corr. 1.5h	0′.3
Eq. Time	− 3′ 42″		
		Dec. 1d 19.5h	23° 00′.3
G. A. T. 1d	19h 28′ 31″		90° 00′.0
		P. D.	66° 59′.7
		Lat. at Noon	37° 21′ 36″ S
		Diff. Lat.	22′ 36″ S
		Lat. at Sight	36° 59′ 00″ S

Obs. Alt.	49° 10′ 00″		
I. E.	− 2′ 40″		
	49° 07′ 20″		
S. D.	+ 16′ 18″		
	49° 23′ 38″		
Dip	− 3′ 40″		
	49° 19′ 58″		
R. & P.	− 45″		
h	49° 19′ 13″		
Lat.	36° 59′ 00″	Sec	.09756
P. D.	66° 59′ 42″	Csc	.03599
	2)153° 17′ 55″		
s	76° 38′ 58″	Cos	9.36344
s−h	27° 19′ 45″	Sin	9.66191
		Log. Hav.	9.15890

L. A. T. 1d	21h 01′ 28″
G. A. T. 1d	19h 28′ 31″
Long. at Sight	1h 32′ 57″ or
	23° 14′ 15″ E
Diff. Long.	28′ W
Long. at Noon	22° 46′ 15″ E

PROBLEM NO. 4

Oct. 17, 1919, P. M. Obs. Alt. Sun's L. L. 16° 19′ 15″. Dip 28 ft. Chronometer read 11h 55′ 03″ P. M., which was fast on Sept. 23, 8′ 23″ and gaining 8.″2 daily. Latitude at noon 22° 55′ 48″ S. Ship's run from noon to sight N 18° W (true) 42 miles.

Chron.	11h 55′ 03″	24.5 days	
Fast	− 8′ 23″	8″.2	
	11h 46′ 40″	201″ Acc. Rate	
Acc. Rate	− 3′ 21″		
		Dec. 17d 10h	9° 07′.3 S
G. M. T. 17d	11h 43′ 19″	Corr. 1.7h	+ 1′.5
Eq. Time	+ 14′ 31″		
		Dec. 17d 11.′7h	9° 08′.8
G. A. T. 17d	11h 57′ 50″		90° 00′
		P. D.	80° 51′.2
		Lat. Noon	22° 35′ 48″ S
		Diff. Lat.	39′ 54″ N
		Lat. Sight	21° 55′ 34″ S

At Mid. Lat. 22°; Dep. 13.0 miles; Diff. Long. 14′ E.

Alt.	16° 19′ 50″		
S. D.	+ 16′ 06″		
	16° 35′ 21″		
Dip.	− 5′ 11″		
	16° 30′ 10″		
R. & P.	− 3′ 06″		
h	16° 27′ 04″		
Lat.	21° 55′ 34″	Sec	.03261
P. D.	80° 51′ 12″	Csc	.00556
	2)119° 13′ 50″		
s	59° 36′ 55″	Cos	9.70398
s−h	43° 09′ 51″	Sin	9.83511
		Log. Hav.	9.57726

L. A. T. 17d	5h 03′ 25″
G. A. T. 17d	11h 57′ 50″
Long. at Sight	6h 54′ 25″ or
	103° 36′ 15″ W
Diff. Long.	14′ E
Long. at Noon	103° 22′ 15″ W

PROBLEM NO. 5

Dec. 1, 1919, A. M. Obs. Alt. Sun's L. L. 15° 18′ 12″. Dip 26 ft. Chronometer read Nov. 30th, 9h 02′ 05″, which was slow on Nov. 10th 3′ 55″, and gains 7″.8 daily. Latitude at noon 18° 16′ N. Ship's run from sight to noon N 28° E (true) 58 miles.

Chron.		9h 02′ 05″
Slow	+	3′ 55″
		9h 06′ 00″
Acc. Rate	−	2′ 39″
G. M. T. 30d		9h 03′ 21″
Eq. Time	+	11′ 24″
G. A. T. 30d		9h 14′ 45″

20.4 days
7″.8

159″ Acc. Rate

Lat. at Noon		18° 16′ 00″ N
Diff. Lat.		51′ 12″ S
Lat. at Sight		17° 24′ 48″ S

At Mid. Lat. 18°; Dep. 27.2 miles; Diff. Long. 28′.5 E.

Dec. 30d 8h		21° 34′.9 S
Corr. 1.2h	+	0′.5
Dec. 30d 9.2h		21° 35′.4 S
		90° 00′
P. D.		111° 35′.4

Obs. Alt.		15° 18′ 12″		
S. D.	+	16′ 15″		
		15° 34′ 27″		
Dip	−	5′ 00″		
		15° 29′ 27″		
R. & P.	−	3′ 19″		
True h		15° 26′ 08″		
Lat.		17° 24′ 48″	Sec	.02037
P. D.		111° 35′ 24″	Csc	.03159
	2)	144° 26′ 20″		
s		72° 13′ 10″	Cos	9.48483
s−h		56° 47′ 02″	Sin	9.92252
			Log. Hav.	9.45931

L. A. T. 30d	19h 40′ 23″
G. A. T. 30d	9h 14′ 45″
Long. at Sight	10h 25′ 38″ or
	156° 24′ 30″ E
Diff. Long.	28′ 30″ E
Long. at Noon	156° 53′ 00″ E

PROBLEM NO. 6

May 3, 1919, A. M. Obs. Alt. Sun's L. L. 28° 49′. Dip 30 ft. Chronometer read 8h 03′ 02″ A. M., which was slow on Apr. 7, 3′ 28″, and gaining 2″.8 daily. Latitude at noon 28° 16′ 28″ N. Ship's run from sight to noon S 69° W (true) 73 miles.

Chron.	20h 03′ 02″		25.8 days
Slow	+ 03′ 28″		2″.8
	20h 06′ 30″		72″ Acc. Rate
Acc. Rate	− 1′ 12″	Dec. 2d 20h	15° 23′.5 N
G. M. T. 2d	20h 05′ 18″	Corr. .1h	0′.1
Eq. Time	+ 03′ 06″	Dec. 2d 20.1h	15° 23′.6 N
G. A. T. 2d	20h 08′ 24″		90° 00′.0
		P. D.	74° 36′.4
		Lat. at Noon	28° 16′ 28″ N
		Diff. Lat.	26′ 12″ N
		Lat. at Sight	28° 42′ 40″ N

At Mid. Lat. 29°; Dep. 68.2 miles; Diff. Long. 77′ W.

Obs. Alt.	28° 49′ 00″		
S. D.	+ 15′ 54″		
	29° 04′ 54″		
Dip	− 5′ 22″		
	28° 59′ 32″		
R. & P.	− 1′ 37″		
True Alt.	28° 57′ 55″		
Lat.	28° 42′ 40″	Sec	.05698
P. D.	74° 36′ 24″	Csc	.01589
	2)132° 16′ 59″		
s	66° 08′ 30″	Cos	9.60690
s−h	37° 10′ 35″	Sin	9.78123
		Log. Hav.	9.46100

L. A. T. 2d	19h 39′ 49″
G. A. T. 2d	20h 08′ 24″
Long. at Sight	28′ 35″ or
	7° 08′ 45″ W
Diff. Long.	1° 17′ 00″ W
Long. at Noon	8° 25′ 45″ W

PROBLEM NO. 7

Apr. 23, 1919, A. M. Obs. Alt. Sun's L. L. 23° 15′. Dip 26 ft. Chronometer read 0h 03′ 12″ A. M., which was slow on Mar. 16th, 4′ 28″, and gaining 11″.7 daily. Latitude at noon 27° 23′ S. Ship's run from sight to noon N 28° E (true) 62 miles.

Chron.	12h 03′ 12″
Slow	+ 04′ 28″
	12h 07′ 40″
Acc. Rate	− 07′ 19″
G. M. T. 22d	12h 00′ 21″
Eq. Time	+ 01′ 28″
G. A. T. 22d	12h 01′ 49″

37.5 days
11″.7

439″ Acc. Rate

Dec. 22d 12h	12° 06′ N
	90° 00′
P. D.	102° 06′
Lat. at Noon	27° 23′ 00″ S
Diff. Lat.	54′ 42″ S
Lat. at Sight	28° 17′ 42″ S

At Mid. Lat. 28°; Dep. 29.1 miles; Diff. Long. 33′ E.

Obs. Alt.	23° 15′ 00″		
S. D.	+ 15′ 54″		
	23° 30′ 54″		
Dip	− 5′ 00″		
	23° 25′ 54″		
R. & P.	− 2′ 05″		
True Alt. (h)	23° 23′ 49″		
Lat.	28° 17′ 42″	Sec	.05526
P. D.	102° 06′ 00″	Csc	.00976
	2)153° 47′ 31″		
s	76° 53′ 46″	Cos	9.35550
s−h	53° 29′ 57″	Sin	9.90518
		Log. Hav.	9.32570

L. A. T. 22d	20h 20′ 51″
G. A. T. 22d	12h 01′ 49″
Long. at Sight	8h 19′ 02″ or
	124° 45′ 30″ E
Diff. Long.	33′ E
Long. at Noon	125° 18′ 30″ E

PROBLEM NO. 8

Nov. 28, 1919, A. M. Obs. Alt. Sun's L. L. 50° 25′. Dip 30 ft. Chronometer read 9h 33′ 10″ A. M., which was fast on Oct. 22d, 3′ 28″ and losing 4.″7 daily. Latitude at noon 0° 10′ 30″ N. Ship's run from sight to noon N 79° E (true) 31 miles.

Chron. 27d	21h 33′ 10″		36.8 days
Fast	− 03′ 28″		4″.7
	21h 29′ 42″		173″ Acc. Rate
Acc. Rate	+ 02′ 53″	Dec. 27d 20h	21° 08′.8 S
G. M. T.	21h 32′ 35″	Corr. 1.5h	+ 0′.7
Eq. Time	+ 12′ 16″	Dec. 27d 21.5h	21° 09.′5 S
G. A. T. 27d	21h 44′ 51″		90° 00′
		P. D.	111° 09′.5
		Lat. at Noon	00° 10′ 30″ N
		Diff. Lat.	5′ 54″ S
		Lat. at Sight	00° 04′ 56″ N

Dep. 30.4 miles; Diff. Long. 30′.4.

Obs. Alt.	50° 25′ 00″		
S. D.	+ 16′ 12″		
	50° 41′ 12″		
Dip	− 5′ 22″		
	50° 35′ 50″		
R. & P.	− 42″		
h	50° 35′ 08″		
Lat.	0° 04′ 36″	Sec	.00000
P. D.	111° 09′ 30″	Csc	.03031
	2)161° 49′ 14″		
s	80° 54′ 37″	Cos	9.19862
s−h	30° 19′ 29″	Sin	9.70300
		Log. Hav.	8.93193

L. A. T. 27d	21h 43′ 59″
G. A. T. 27d	21h 44′ 51″
Long. at Sight	52″ or 0° 13′ 00″ W
Diff. Long.	30′ 24″ E
Long. at Noon	0° 17′ 24″ E

PROBLEM NO. 9

Mar. 21, 1919, P. M. Obs. Alt. Sun's L. L. 34° 17′ 30″. Dip 36 ft. Chronometer read 9h 45′ 17″ A. M., which was fast on Feb. 27th, 1h 06′, and losing 9.″5 daily. Latitude at noon 23° 15′ S. Ship's run from noon to sight N 24° W (true) 56 miles.

Chron.		21h 45′ 17″
Fast	−	1h 06′ 00″
		20h 39′ 17″
Acc. Rate	+	3′ 27″
G. M. T. 20d		20h 42′ 44″
Eq. Time	−	7′ 34″
G. A. T. 20d		20h 35′ 10″

21.8 days
9.″5
207″ Acc. Rate

Dec. 20d 20h		0° 08′.2 S
Corr. .7h	−	.7
Dec. 20d 20.7h		0° 07′.5 S
		90° 00′
P. D.		89° 52′.5
Lat. at Noon		23° 15′ 00″ S
Diff. Lat.		51′ 12″ N
Lat. at Sight		22° 23′ 48″ S

Dep. 22.8 miles; Diff. Long. 25′ E.

Obs. Alt.		34° 17′ 30″		
S D.	+	16′ 06″		
		34° 33′ 36″		
Dip	−	5′ 53″		
		34° 27′ 43″		
R. & P.	−	1′ 17″		
h		34° 26′ 26″		
Lat.		22° 23′ 48″	Sec	.03406
P. D.		89° 52′ 30″	Csc	0.0000
	2)	146° 42′ 44″		
s		73° 21′ 22″	Cos	9.45700
s−b		38° 54′ 56″	Sin	9.79808
			Log. Hav.	9.28914

L. A. T. 21d	3h 29′ 25″
G. A. T. 20d	20h 35′ 10″
Long. at Sight	6h 54′ 15″ or
	103° 33′ 45″ E
Diff. Long.	25′ E
Long. at Noon	103° 58′ 45″ E

PROBLEM NO. 10

Sept. 30, 1919, A. M. Obs. Alt. Sun's L. L. 38° 16′ 45″. Dip 24 ft. Chronometer read 11h 17′ 25″ P. M., which was fast on Aug. 28th, 2h 15′, and gaining 4″.7 daily. Latitude at noon 41° 16′ N. Ship's run from sight to noon S 84° W (true) 63 miles.

Chron.	11h 17′ 25″		33.4 days
Fast	− 2h 15′		4″.7
	9h 02′ 25″		157″ Acc. Rate
Acc. Rate	− 2′ 37″		
		Lat. at Noon	41° 16′ 00″ N
G. M. T. 30d	8h 59′ 48″	Diff. Lat.	06′ 36″ S
Eq. Time	+ 9′ 49″		
		Lat. at Sight	41° 22′ 36″ N
G. A. T. 30d	9h 09′ 37″		

Dep. 62.7 miles; Diff. Long. 83′ W.

Dec. 30d 8h	2° 37′.3 S
Corr. 1h	1.′0
Dec. 30d 9h	2° 38′.3
	90° 00′.0
P. D.	92° 38′.3

Obs. Alt.	38° 16′ 46″		
S. D.	+ 16′ 00″		
	38° 32′ 46″		
Dip	− 4′ 48″		
	38° 27′ 57″		
R. & P.	− 1′ 07″		
h	38° 26′ 50″		
Lat.	41° 22′ 36″	Sec	.12472
P. D.	92° 38′ 18″	Csc	.00046
	2)172° 27′ 44″		
s	86° 13′ 52″	Cos	8.81780
s−h	47° 47′ 02′	Sin	9.86959
		Log. Hav.	8.81257

L. A. T. 29d	22h 01′ 53″
G. A. T. 30d	9h 09′ 37″
Long. at Sight	11h 07′ 44″ or
	166° 56′ 00″ W
Diff. Long.	1° 23′ 00″ W
Long. at Noon	168° 19′ 00″ W

CHAPTER XI

DEVIATION BY AZIMUTH OF SUN

This problem is to find error and deviation of the compass.

Azimuth is the true bearing of a heavenly body and is reckoned from the north point in north latitude and from the south point in south latitude from 0° to 180°.

For example, if in north latitude and the sun bore N 80° E the azimuth would read N 80° E, if it bore S 80° E, the azimuth would be N 100° E.

The azimuth is obtained by a shadow pin at the center of the compass or sight vanes which cast shadow lines across the compass. Due to difficulty of reading caused by rolling, pitching, etc., several readings should be taken and the average used. In practice azimuths are read to the nearest degree.

Since azimuth is changing rapidly close to noon, azimuth of the sun should be taken in the morning or the evening when azimuth is changing slowly.

TIME AZIMUTH

If azimuth is taken at least two hours before, or after noon, it is sufficient to know apparent time of the ship to nearest minute. If chronometer is read to nearest one-half minute, and equation of time and longitude in time found with some degree of accuracy it will be sufficiently close to obtain from the H. O. 71 tables, the true bearing to the nearest degree.

Place compass bearing and true bearing under each other, and the difference will be the compass error.

Name the error as follows:

If the true bearing is to right of compass bearing, error is east.

If the true bearing is to left of compass bearing, error is west.

Note.—Always imagine that you are standing in the center of the compass and looking toward the bearings.

Under the error put down the variation as given in example and apply as follows:

Variation and error same name, subtract lesser from greater.

Variation and error different name, add the two.

The result will be deviation of compass on course steered at time of taking the bearing.

Name the deviation as follows:

The deviation will always be named the same as the error, unless you subtract the error from the variation; it will then be named the opposite name to error.

PROBLEM NO. 1

July 5, 1919. Chronometer read 11h 16′ A. M. Lat. 18° S. Long. 62° 10′ W. Sun bore by compass N 70° E. Variation 6° E.

G. M. T. 5d	23h 16′.5	In July declination is N or opposite name to latitude.
Eq. Time	− 4′.0	
G. A. T.	23h 12′.5	
Long.	4h 08′.5	
L. A. T. 5d	19h 04′.0	
True Bearing	S 117° E	
Compass Bearing	S 110° E	
Error	7° W	
Variation	6° E	
Deviation	13° W	

PROBLEM NO. 2

Oct. 24, 1919. Chronometer read 3h 23′.5 A. M. Lat 40° N. Long. 91° 02′ E. Sun bore by compass N 135° E. Variation 41° E.

G. M. T. 23d	15h 23′.5	In October declination is S, or opposite name to latitude.
Eq. Time	+ 15′.5	
G. A. T. 23d	15h 39′.0	
Long.	6h 04′.0	
L. A. T.	21h 43′ or 9:43 A. M.	
True Bearing	N 133° E	
Compass Bearing	N 135° E	
Error	2° W	
Variation	41° E	
Deviation	43° W	

PROBLEM NO. 3

Jan. 30, 1919. Chronometer read 1h 50′ P. M. Lat. 28° N. Long. 91° 15′ W. Sun bore by compass N 126° E. Variation 7° E.

G. M. T. 30d	1h 50′	In January declination is S, or opposite name to latitude.
Eq. Time	− 13′	
G. A. T., 30d	1h 37′	
Long.	6h 05′	
L. A. T. 29d	19h 32′ or	
30d	7:32 A. M.	
True Bearing	N 117° E	
Compass Bearing	N 126° E	
Error	9° W	
Variation	7° E	
Deviation	16° W	

PROBLEM NO. 4

Apr. 19, 1919. Chronometer read 1h 02′ A. M. Lat. 36° N. Long. 110° 25′ E. Sun bore by compass N 103° E. Variation 6° E.

G. M. T. 18d	13h 02′	In April declination is N, or same name as latitude.
Eq. Time	+ 0′.5	
G. A. T.	13h 02′.5	
Long.	7h 21′.5	
L. A. T. 18d	20h 24′ or	
	8:24 A. M.	
True Bearing	N 103° E	
Compass Bearing	N 103° E	
Error	0°	
Variation	6° E	
Deviation	6° W	

CHAPTER XII

DEVIATION BY AMPLITUDE

An amplitude is the bearing of a heavenly body at rising or setting.

It is reckoned from the East and West points of the compass toward North and South from 0° to 90°.

East and West are reckoned as 0° and North and South as 90°.

To convert a compass bearing into an amplitude proceed as follows:

If the sun bore at rising N 82° E, the compass amplitude would be E 8° N.

If the sun bore at setting S 79° W, the compass amplitude would be W 11° S.

Put down chronometer time and correct fast or slow as given.

Answer will be Greenwich Mean Time.

Take out Sun's declination for Greenwich date and time for degree and nearest minute.

From Table 44 (Bowditch) take out the following logs:

Secant of latitude. Rejecting 10 from index number.

Sine of declination.

Add these two logs together.

Look for Sine (Table 44) that agrees with sum of logs, and the degrees and minutes from top and side of page will be true amplitude.

Name the true amplitude as follows:

If sun is rising, name it East. If declination is North, name N, if South, name S.

If sun is setting name it West. If declination is North, name N, if South, name S.

Now convert compass bearing into an amplitude, and apply it to true amplitude as follows:

If both are of same name, subtract less from greater.

If different names, add the two.

Result will be error of compass.

Name the error of compass as follows:

If true bearing is to right of compass bearing, the error is East.

If true bearing is to left of compass bearing, the error is West.

Always imagine yourself standing in the center of the compass, and looking towards the bearings.

Under the error put down the variation given in example, and apply as follows:

Variation and error same name, subtract less from greater.

Variation and error different name, add the two.

Answer will be deviation.

Name the deviation as follows:

The deviation will always be named the same as the error, unless you subtract the error from the variation, it will then be named the opposite name to error.

Table 39 (Bowditch) may also be used. Most local inspectors, however, insist that the amplitude be worked out.

PROBLEM NO. 1

Jan. 30, 1919. Sun bore at rising N 83° E. Chronometer read 2h 12′ P.M. Lat. 46° 15′ S. Variation 8° E.

G.M.T 30d 2h 12′ Dec. 30d 2h 17° 51′ S

Sec. of Lat.	.16020
Sin of Dec.	9.48647
Sin	9.64667
True Amp.	E 26° S
Compass Amp.	E 7° N
Error	33° E
Variation	8° E
Deviation	25° E

Check by Table 39 for Lat. 46° S; dec. 18° S; amp. E 26° S.

PROBLEM NO. 2

Oct. 23, 1919. Sun bore at rising S 71° E. Chronometer read 1h 50′ P. M. Lat. 43° 02′N Variation 25° W.

G. M. T 23d 1h 50 Dec. 10° 48′ S

Sec. of Lat.	.13611
Sin of Dec.	9.27273
Sin	9.40884
True Amp.	E 15° S
Compass Amp.	E 19° S
Error	4° W
Variation	25° W
Deviation	21° E

Check by Table 39 for Lat. 43° N; dec. 11° S; amp. E 15° S.

PROBLEM NO. 3

Apr. 19, 1919. Sun bore at setting S 82° W. Chronometer read 9h 15′ A. M. Lat. 40° 12′ N. Variation 6° E.

G. M. T. 18d 21h 15′ Dec. 10° 52′ N

Sec. of Lat.	.11702
Sin of Dec.	9.27537
Sin	9.39239
True Amp.	W 14° N
Compass Amp.	W 8° S
Error	22° E
Variation	6° E
Deviation	16° E

Check by Table 39 for Lat. 40° N; dec. 11° N; amp. 14°

PROBLEM NO. 4

Mar. 11, 1919. Sun bore at rising S 88° E. Chronometer read 8h 15′ A. M. Lat. 0° 10′N. Variation 15° E.

G. M. T. 10d 20h 15′ Dec. 4° 05′ S.

Dec. = True Amp. in Lat. 0°

True Amp.	E 4° S
Compass Amp.	E 2° S
Error	2° E
Variation	15° E
Deviation	13° W

PROBLEM NO. 5

Sept. 23, 1919. Sun bore at setting N 79° W. Chronometer read 2h 10′ P. M. Lat. 48° N. Variation 2° W.

G. M. T. 23d 2h 10′ Dec. 0° 12′ N

True Amp. is E or W or 0° in Dec. 0°.

True Amp.	W 0°
Compass Amp.	W 11° N
Error	11° W
Variation	2° W
Deviation	9° W

PROBLEM NO. 6

Aug. 11, 1919. Sun bore at setting S 81° W. Chronometer read 10h 28′ A. M., slow 32′. Lat. 18° 28′ S. Variation 30° E.

Chronometer	22h 28′		
Slow	+ 32′		
G. M. T. 10d	23h 00′	Dec.	15° 33′ N
	Sec. of Lat.	.02296	
	Sin of Dec.	9.42826	
	Sin	9.45122	
	True Amp.	W 16° N	
	Compass. Amp.	W 9° S	
	Error	25° E	
	Variation	30° E	
	Deviation	5° W	

Check by Table 39 for Lat. 18° S; dec. 15°.5 N; amp. W 16° N.

PROBLEM NO. 7

Jan. 31, 1919. Sun bore at rising S 84° E. Chronometeter read 4h 16′ P.M. Lat. 36° 18′ N. Variation 3° W.

G. M. T. 31d	4h 16′	Dec.	17° 33′ S.
	Sec. of Lat.	.09370	
	Sin of Dec.	9.47934	
	Sin	9.57304	
	True Amp.	E 22° S	
	Compass Amp.	E 06° S	
	Error	16° E	
	Variation	3° W	
	Deviation	19° E	

Check by Table 39 for Lat. 36° N; dec. 17°.5 S; amp. E 22° S.

PROBLEM NO. 8

July 4, 1919. Sun bore at setting S 84° W. Chronometer read 11h 18′ P. M., slow 40′. Lat. 36° 18′ N. Variation 10° W.

Chronometer	11h 18′		
Slow	+ 40′		
G. M. T. 4d	11h 58′		Dec. 22° 54′ 08″
		Sec. of Lat.	.09370
		Sin Dec.	9.59009
		Sin	9.68379
		True Amp.	W 29° N
		Compass Amp.	W 6° S
		Error	35° E
		Variation	10° W
		Deviation	45° E

PROBLEM NO. 9

Dec. 16, 1919. Sun bore at rising S 60° E. Chronometer read 2h 46′ A. M., fast 34′. Lat. 0° 18′ S. Variation 10° W.

Chronometer	14h 46′		
Fast	– 34′		
G. M. T. 15d	14h 12′		Dec. 23° 16′ S
		True Amp.	E 23° S
		Compass Amp.	E 30° S
		Error	7° W
		Variation	10° W
		Deviation	3° E

PROBLEM NO. 10

Mar. 21, 1919. Sun bore at setting N 78° W. Chronometer read 10h 36′ P. M., fast 30′. Lat. 0° 14′ N. Variation 3° E.

Chronometer	10h 36′		
Fast	− 30′		
G. M. T. 20d	10h 06′	Dec.	0° 18′ N
	True Amp.		W 0° 18′ S
	Compass Amp.		W 12° N
	Error		12° W
	Variation		3° E
	Deviation		15° W

PROBLEM NO. 11

Jan. 31, 1919. Sun bore at rising N 89° E. Chronometer read 1h 50′ A. M. Lat. 41° 21′ N.

G. M. T. 30d	13h 50′	Dec.	17° 42′ S
	Sec. of Lat.		.12454
	Sin of Dec.		9.48292
	Sin		9.60746
	True Amp.		E 24° S
	Compass Amp.		E 1° N
	Error		25° E
	Variation		35° E
	Deviation		10° W

PROBLEM NO. 12

Oct. 23, 1919. Sun bore at setting S 88° W. Chronometer read 2h 10′ P. M. Lat. 18° 24′ N. Variation 3° E.

G. M. T. 23d 2h 10′		Dec 11° 10′ S
	Sec. of Lat.	.02279
	Sin of Dec.	9.28705
	Sin	9.30984
	True Amp.	W 12° S
	Compass Amp.	W 2° S
	Error	10° W
	Variation	3° E
	Deviation	13° W

CHAPTER XIII

LATITUDE BY POLARIS

The latitude by Polaris (or North Star) can be obtained at any time the star is visible, as long as the sea horizon is clear enough to obtain a proper altitude.

If the North Star were exactly at the pole, its altitude would be the latitude. It is, however, not quite at the pole; so that it apparently describes a small circle in the sky about the pole as an axis. This makes necessary a small correction to the true altitude; these corrections are given in the Nautical Almanac, Table 1, for every ten minutes Local Siderial Time.

To find Local Siderial Time, add to the L. M. T. the Right Ascension of the Mean Sun at Greenwich Mean Noon, add correction to R. A. M. S. for time past Greenwich Mean Noon from bottom of pages 2–3, N. A.

PROBLEM NO. 1

Jan. 31, 1919, A. M. Obs. Alt. *Polaris 24° 55′. Dip. 36 ft. Chronometer read 0h 22′ 00″ P. M. Long. 93° 30′ W.

G. M. T. 31d	0h 22′ 00″	Obs. Alt.	24° 55′ 00″
Long.	6h 14′ 00″	Dip	− 5′ 53″
L. M. T. 30d	18h 08′ 00″		24° 49′ 07″
R. A. M. S. for 31d	20h 38′ 38″	Ref.	− 2′ 05″
Corr. for 22′	04″		
		True Alt.	24° 47′ 02″
L. S. T. 30d	38h 46′ 42″ or	Corr. (I. N. A.)	+ 1° 03′ 48″
	14h 46′ 42″		
		Lat.	25° 50′ 50″ N

PROBLEM NO. 2

Jan. 30, 1919, A. M. Obs. Alt. *Polaris 27° 27′. Dip 36 ft. Chronometer read 0h 17′ 00″ P. M. Long. 90° W.

G. M. T. 30d	0h 17′ 00″	Obs. Alt.	27° 27′ 00″
Long.	6h 00′ 00″	Dip	− 5′ 53″
L. M. T. 29d	18h 17′ 00″		27° 21′ 07″
R. A. M. S. for 30d	20h 34′ 41″	Ref.	− 1′ 52″
Corr. for 17′	3″		
		True Alt.	27° 19′ 15″
L. S. T.	38h 51′ 44″ or	Corr. (I. N. A.)	+ 1° 03′ 18″
	14h 52′		
		Lat.	28° 22′ 33″ N

PROBLEM NO. 3

July 15, 1919, P. M. Obs. Alt. *Polaris 26° 17′. Dip 20 ft. Chronometer read 1h 15′ 21″ P. M. Long. 82° 17′ E.

G. M. T. 15d	1h 15′ 21″	Obs. Alt.	26° 17′ 00″
Long.	5h 29′ 08″	Corr. (46)	− 6′ 21″
L. M. T.	6h 44′ 29″	True Alt.	26° 10′ 39″
R. A. M. S.	7h 29′ 09″	Corr. (I. N. A.)	+ 1° 06′ 12″
Corr. for 1h 15′	0′ 11″		
		Lat.	27° 16′ 51″ N
L. S. T.	14h 13′ 49″ or 14h 14′		

PROBLEM NO. 4

Nov. 10, 1919, A. M. Obs. Alt. *Polaris 36° 21′. Dip 17 ft. Chronometer read 11h 15′ 20″ A. M. Long. 98° 22′ W.

G. M. T. 9d	23h 15′ 20″	Obs. Alt.	36° 21′ 00″
Long.	6h 33′ 28″	Corr. (46)	− 5′ 21″
L. M. T.	16h 41′ 52″	True Alt.	36° 15′ 39″
R. A. M. S. 9d	15h 10′ 26″	Corr. (I. N. A.)	+ 7′ 42″
Corr. for 23h 15′	3′ 49″		
		Lat.	36° 23′ 21″ N
L.S.T.	31h 56′ 07″ or 7h 56′		

PROBLEM NO. 5

Aug. 6, 1919, A. M. Obs. Alt. *Polaris 28° 16′. Dip 23 ft. Chronometer read 2h 16′ 28″ A. M., slow 1′ 25″. Long. 38° 21′ E.

Chron. 5d	14h 16′ 28″	Obs. Alt.	28° 16′ 00″
Slow	+ 1′ 25″	Dip	− 4′ 42″
G. M. T.	14h 17′ 53″		28° 11′ 18″
Long.	2h 33′ 24″	Ref.	− 1′ 49″
L. M. T.	16h 51′ 17″	True Alt.	28° 09′ 29″
R. A. M. S. 5d	8h 51′ 57″	Corr. (I. N. A.)	1° 07′ 12″
Corr. 14h 16′	2′ 21″		
		Lat.	27° 02′ 17″ N
L. S. T.	25h 45′ 35″ or 1h 46′		

PROBLEM NO. 6

June 8, 1919, A. M. Obs. Alt. *Polaris 23° 12′ 15″. Dip 38 ft. Chronometer read 11h 55′ 25″ A. M. Long. 110° 15′ W.

G. M. T. 7d	23h 55′ 25″	Obs. Alt.	23° 12′ 15″
Long.	7h 21′ 00″	Dip	− 6′ 02″
L. M. T. 7d	16h 34′ 25″		23° 06′ 13″
R. A. M. S.	4h 59′ 20″	Ref.	− 2′ 16″
Corr. for 23h 55′	3′ 56″		
		True Alt.	23° 03′ 57″
L. S. T.	21h 37′ 41″	Corr. (I. N. A.)	34′ 48″
		Lat.	22° 29′ 09″ N

PROBLEM NO. 7

May 20, 1919, P. M. Obs. Alt. *Polaris 42° 16′ 30″. Dip 39 ft. Chronometer read 6h 16′ 23″, fast 3′ 18″. Long. 3° 15′ E.

Chron.	6h 16′ 23″	Obs. Alt.	42° 16′ 30″
Fast	− 3′ 18″	Dip	− 6′ 07″
G. M. T. 20d	6h 13′ 05″		42° 10′ 23″
Long.	+ 13′ 00″	Ref.	− 1′ 04″
L. M. T.	6h 26′ 05″	True Alt.	42° 09′ 19″
R. A. M. S. 20d	3h 48′ 22″	Corr. (I. N. A.)	+ .44′ 24″
Corr. 6h 13′	1′ 01″		
		Lat.	42° 53′ 43″ N
L. S. T.	10h 15′ 28″		

PROBLEM NO. 8

Oct. 6, 1919, A. M. Obs. Alt. *Polaris 50° 24′ 45″. Dip 40 ft. Chronometer read 9h 22′ 03″ A. M., slow 4′ 23″. Long. 18° 16′ W.

Chron.	9h 22′ 03″	Obs. Alt.	50° 24′ 45″
Slow	+ 4′ 23″	Dip	− 6′ 12″
G. M. T. 5d	21h 26′ 26″		50° 18′ 33″
Long.	1h 13′ 04″	Ref.	− 48″
L. M. T.	20h 13′ 22″	True Alt.	50° 17′ 45″
R. A. M. S. 5d	12h 52′ 25″	Corr. (I. N. A.)	+ 28′ 12″
Corr.	3′ 31″		
		Lat.	50° 45′ 57″ N
L. S. T.	33h 09′ 18″ or 9h 09′		

PROBLEM NO. 9

Feb. 12, 1919, A. M. Obs. Alt. *Polaris 48° 16′. Dip 21 ft. Chronometer read 2h 06′ 28″ P. M. Long. 152° W.

G. M. T. 12d	2h 06′ 08″	Obs. Alt.	48° 16′ 00″
Long.	10h 08′ 00″	Dip	− 4′ 29″
L. M. T.	15h 58′ 28″		48° 11′ 31″
R. A. M. S. 12d	21h 25′ 50″	Ref.	− 52″
Corr. 2h 06′	21″		
		True Alt.	48° 10′ 39″
L. S. T.	37h 24′ 45″ or 13h 25′	Corr. (I. N. A.)	+ 1° 07′ 12″
		Lat.	49° 17′ 51″ N

PROBLEM NO. 10

June 6, 1919, P. M Obs. Alt. *Polaris 29° 41′ Dip 20 ft. Chronometer read 8h 16′ 21″ A. M. Long. 161° 15′ E.

G. M. T. 5d	20h 16′ 21″	Obs. Alt.	29° 41′ 00″
Long.	10h 45′ 00″	Dip	− 4′ 23″
L. M. T. 6d	7h 01′ 21″		29° 36′ 37″
R A. M. S. 5d	4h 51′ 27″	Ref.	− 1′ 42″
Corr. 20h 16′	3′ 20″		
		True Alt.	29° 34′ 55″
L. S. T.	11h 56′ 08″	Corr. (I. N. A.)	+ 1° 01′ 36″
		Lat.	30° 36′ 31″ N

PROBLEM NO. 11

Oct. 25, 1919, A. M. Obs. Alt. *Polaris 47° 15′. Dip 26 ft. Chronometer read 1h 16′ 28″ P. M. Long. 100° W.

G. M. T. 25d	1h 16′ 28″	Alt.	47° 15′ 00″
Long.	6h 40′ 00″	Dip	− 5′ 00″
L. M. T.	18h 36′ 28″		47° 10′ 00″
R. A. M. S. 25d	14h 11′ 18″	Ref.	− 54″
Corr. 1h 16′	12″		
		True Alt.	47° 09′ 06″
L. S. T.	8h 47′ 58″	Corr. (I. N. A.)	+ 22′ 30″
		Lat.	47° 31′ 36″ N

PROBLEM NO. 12

July 4, 1919, A. M. Obs. Alt. *Polaris 28° 32′ 00″. Dip 27 ft. Chronometer read 10h 58′ 03″. Long. 94° 50′ W.

G. M. T. 3d	22h 58′ 03″	Alt.	28° 32′ 00″
Long.	6h 19′ 20″	Dip	− 5′ 06″
L. M. T.	16h 38′ 43″		28° 26′ 54″
R. A. M. S. 3d	6h 41′ 51″	Ref.	− 1′ 47″
Corr. 22h 58′	3′ 46″		
		Corr. Alt.	28° 25′ 07″
L. S. T.	23h 24′ 20″	Corr. (I. N. A.)	− 56′ 54″
		Lat.	27° 28′ 13″ N

PROBLEM NO. 13

Feb. 12, 1919, P. M. Obs. Alt. *Polaris 26° 12′ 00″. Dip 14 ft. Chronometer read 7h 23′ 15″ A. M. Long. 175° E.

G. M. T. 11d	19h 23′ 15″	Obs. Alt.	26° 12′ 00″
Long.	11h 40′ 00″	Dip	− 3′ 40″
L. M. T. 11d	31h 03′ 15″ or		26° 08′ 20″
12d	7h 03′ 15″	Ref.	− 1′ 58″
R. A. M. S. 11d	21h 22′ 00″		
Corr. 19h 23′	3′ 11″	True Alt.	26° 06′ 22″
		Corr. (I. N. A.)	− 48′ 06″
L. S. T.	28h 28′ 26″		
	4h 28′	Lat.	25° 18′ 16″ N

PROBLEM NO. 14

Apr. 10, 1919, A. M. Obs. Alt. *Polaris 13° 16′. Dip 18 ft. Chronometer read 0h 02′ 23″ A. M., fast 5′ 12″. Long. 81° 15′ E.

Chron. 9d	12h 02′ 23″	Obs. Alt.	13° 16′ 00″
Fast	− 5′ 12″	Dip	− 4′ 09″
G. M. T	11h 57′ 11″		13° 11′ 51″
Long.	5h 25′ 00″	Ref.	− 4′ 04″
L. M. T.	17h 22′ 11″	True Alt.	13° 07′ 47″
R. A. M. S. 9d	1h 06′ 43″	Corr. (I. N. A.)	+ 18′ 18″
Corr. 11h 57′	1′ 58″		
		Lat.	13° 26′ 05″ N
L. S. T.	18h 30′ 52″		

CHAPTER XIV

LONGITUDE BY SUN, ALTITUDE AZIMUTH, MERIDIAN ALTITUDE OF SUN AND MERCATOR SAILING COMBINED

This problem is worked the same as previous methods for obtaining latitude by sun, longitude by sun, and course and distance by Mercator's Sailing.

The difference in the chronometer sights are that two rates for the chronometer are given, and it is necessary to find the daily rate.

To find daily rate of chronometer proceed as follows:

If first and second rate are both fast or both slow, subtract less from greater.

If first and second rate are one fast and one slow, add the two.

Turn this result to seconds, by multiplying minutes by 60 and add to the result the seconds.

Divide number of seconds by number of days between the rates, and the result will be Daily Rate.

Put down chronometer time and apply to it the last rate given in example.

Find the number of days between last rate and date of example to the nearest tenth of a day, and multiply number of days and tenths by Daily Rate already obtained.

Result will be Accumulated Rate, which apply to chronometer, and the result will be G. M. T.

The latitude at noon is found if sun's meridian altitude is given, and latitude at sight found as in previous noon position sights.

Now proceed to find the longitude at sight and noon.

The altitude azimuth is worked in conjunction with a regular longitude by sun sight, and the sun's true bearing is obtained without the use of azimuth tables.

To find sun's true bearing by altitude azimuth proceed as follows:

Add together true altitude, latitude and polar distance, using the same altitude, latitude and polar distance that longitude sight was worked with.

Divide sum by 2, answer will be Half Sum.

Under Half Sum put down polar distance, and subtract less from greater, result will be Remainder.

From Table 44 (Bowditch) take out the following logs:

Secant of Altitude. Rejecting 10 from index number.

Secant of latitude. Rejecting 10 from index number.

Cosine of Half Sum.

Cosine of Remainder.

Add these four logarithms together.

Log. Haversine (Table 45) gives azimuth. Result will be sun's true bearing from depressed pole.

If in north latitude name the true bearing S. If sight is A. M. East, P. M. West.

If in south latitude name the true bearing N. If sight is A. M. East, P. M. West.

Under true bearing put down compass bearing and obtain error and deviation of compass same as in azimuths from the tables.

The position of the ship at noon is then put down as Lat. A and Long. A, and the course and distance found by Mercator's Sailing to position given in example.

PROBLEM NO. 1

Jan. 31, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 35° 28′ 18″. Dip 15 ft. I. E. +50″. Chronometer read 2h 30′ 44″, which was slow on Nov. 25, 10′ 20″, and on Dec. 11 was slow 13′ 49″. Observed Meridian Altitude of Sun's L. L. at noon was 59° 59′ S. D. R. long. 87° W. Ship ran from sight to noon S 73° W. (true) 48 miles. Sun bore by compass N 108° 15′ E. Variation 16° W.

Required position at sight and noon; error and deviation by altitude azimuth; also course and distance by Mercator's sailing from noon to 7° 15′ S., 125° 35′ W.

Obs. Mer. Alt.	59° 59′ 00″ S	G. A. T. 31d	5h 48′ 00″
I. E.	+ 50″	Eq. Time	+ 13′ 31″
	59° 59′ 50″	G. M. T. 31d	6h 01′ 31″ or
Corr. (46)	+ 11′ 59″	31d	6h
		Dec. 17° 31′.4 S	
True Alt.	60° 11′ 49″ S		
	90° 00′ 00″	Course, N 73° E; Distance 48 miles; Diff. Lat., 14′ N; Dep., 45.9 miles E; Diff. Long., 46′.5 E.	
Z. D.	29° 48′ 10″ N		
Dec.	17° 31′ 24″ S		
		Slow, Nov. 25th	10′ 20″
Lat. at Noon	12° 16′ 46″ N	Dec. 11th	13′ 49″
Diff. Lat.	14′ 00″ N		
			3′ 29″
Lat. at Sight	12° 30′ 46″ N		or losing 209″.

Chron.	2h 30′ 44″	$\frac{209}{16}$ = 13″ daily rate.	
Slow	13′ 49″	51.1 days interval.	
Acc. Rate	11′ 04″	664″ = 11′ 4″ acc. rate losing.	
G. M. T. 31d	2h 55′ 37″	Dec. 31d 2h	17° 34′.2 S
Eq. Time	− 13′ 30″	Corr. .9h	0′.6
G. A. T. 31d	2h 42′ 07″	Dec. 31d 2.9 h	17° 33′.6 S

Obs. Alt.	35° 28′ 18″				
I. E.	+ 50″				
Corr. (46)	11′ 16″				
True Alt.	35° 40′ 24″			Sec	.09026
Lat.	12° 30′ 46″	Sec	.01044	Sec	.01044
P. D.	107° 33′ 36″	Csc	.02072		
	2)155° 44′ 46″				
One-half Sum	77° 52′ 23″	Cos	9.32239	Cos	9.32239
One-half Sum Alt.	42° 11′ 59″	Sin	9.82719		
One-half Sum P. D.	29° 41′ 13″			Cos	9.93889
		Log. Hav.	9.18074	Log. Hav.	9.36198

L. A. T. 30d	20h 56′ 40″	True Bearing	S 57° 20′ E or
G. A. T. 31d	2h 42′ 07″		N 122° 40′ E
		Obs. Bearing	N 108° 15′ E
Long. at Sight	5h 45′ 27″ or		
	86° 21′ 45″ W	Error	14° 25′ E
Diff. Long.	46′ 30″ W	Variation	16° 00′ W
Long. at Noon	87° 08′ 15″ W	Deviation	30° 25′ E

Lat. A	12° 17′ N	Mer. Parts	737.7	Long. A	87° 08′ W
Lat. B	7° 15′ S	Mer. Parts	433.2	Long. B	125° 35′ W
Diff. Lat.	19° 32′ or 1172′		1170.9	Diff. Long.	38° 27′ or 2307′

Log. of Diff. Long.	2307 = 3.36305
Log. of Mer. Parts	1171 = 3.06856
Tan	.29449 = course S 63° 05′ W
Secant of Course 63° 05′	.34420
Log. Diff. Lat. 1172	3.06893
Log.	3.41313 = distance 2589 miles.

At Sight Lat. 12° 30′ 46″ N. Long. 86° 21′ 45″ W.
At Noon Lat. 12° 16′ 46″ N. Long. 87° 08′ 15″ W.
Compass Error 14° 25′ E. Compass Deviation 30° 25′ E.
True Course S 63° 05′ W, distance 2589 miles.

It is interesting to check our azimuth, since the L. A. T. is known. H. O. 71 may be used with apparent time of 8:57 A. M., Lat. 12°.5, and Dec. 17°.5. This gives to nearest degree N 122° E.

PROBLEM NO. 2

Mar. 11, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 23° 23′. Dip 38 ft. Chronometer read 3h 16′ 28″ A. M. which was fast on Jan. 1, 14′ 28″, and on Jan. 28 was slow 2′ 12″. Latitude at noon was 28° 17′ S. Ship ran from sight to noon N 56° W (true) 49 miles. Required latitude and longitude at sight and noon.

Sun bore by compass S 108° 16′ E. Variation 14° W. Required error and deviation of compass by altitude azimuth.

Required true course and distance made by Mercator's sailing from noon to Lat. 16° 12′ S., Long. 15° 10′ E.

Chronometer	15h 16′ 28″	Chron., fast Jan. 1	14′ 28″
Slow	+ 2′ 12″	Slow, Jan. 28	2′ 12″
Acc. Rate	+ 25′ 39″		
		Lost	16′ 40″
G. M. T. 10d	15h 44′ 19″		=1000″
Eq. Time	− 10′ 28″	$\frac{1000''}{27d}$ = 37″ Daily Rate	
G. A. T. 10d	15h 33′ 51″	41.6 Days Losing	
Dec. 10d 14h	4° 10′.6	1539″ Acc. Rate = 25′ 39″	
Corr. 1.7h	− 1′.7		
Dec.	4° 08′.9 S or 4° 08′ 54″		
P. D.	85° 51′ 06″		

Lat. at Noon	28° 17′ S	
Diff. Lat.	+ 27′.4 S	Course, S 56° E; Dist., 49 miles; Diff. Lat., 27.4 miles; Dep., 40.6 miles; Diff. Long., 46′.
Lat. at Sight	28° 44′.4 S	

Obs. Alt.	23° 23′ 00″				
S. D.	+ 16′ 06″				
	23° 39′ 06″				
Dip	− 6′ 02″				
	23° 33′ 04″				
R. & P.	− 2′ 05″				
True Alt.	23° 30′ 59″			Sec	.03766
Lat.	28° 44′ 24″	Sec	.05710	Sec	.05710
P. D.	85° 51′ 06″	Csc	.00114		
	2)138° 06′ 29″				
Half Sum	69° 03′ 14″	Cos	9.55326	Cos	9.55326
s − Alt.	45° 32′ 15″	Sin	9.85352		
s − P. D.	16° 47′ 52″			Cos	9.98107
		Log. Hav.	9.46502	Log. Hav.	9.62909

L. A. T. 10d	19h 38′ 27″	True Bearing	N 81° 27′ 15″ E or
G. A. T. 10d	15h 33′ 51″		S 98° 33′ E
		Obs. Bearing	S 108° 16′ E
Long. at Sight	4h 04′ 36″ or		
	61° 09′ 00″ E	Error	9° 43′ E
Diff. Long.	46′ W	Variation	14° W
Long. Noon	60° 23′ 00″ E	Deviation	23° 43′ E

Lat. A	28° 17′ S	Mer. Parts.	1759.4	Long. A	60° 23′ E
Lat. B	16° 12′ S	Mer. Parts	978.7	Long. B	15° 10′ E
Diff. Lat.	725′		780.7	Diff. Long.	2713′

Log. of Diff. Long.	2713′ = 3.43345	
Log. of Mer. Parts.	780.7 = 2.89248	
Log. Tan	0.54057	= course N 73° 56′ W.
Log. Sec Course	73° 56′ = 0.55790	
Log. of Diff. Lat.	725′ = 2.86034	
Log.	3.41824	= distance 2620 miles.

At Sight Lat. 28° 44′ 24″ S, Long. 61° 09′ 00″ E.
At Noon Lat. 28° 17′ 00″ S, Long. 60° 23′ 00″ E.
Compass Error 9° 43′ E. Compass Dev. 23° 43′ E.
True Course N 73° 56′ W, distance 2620 miles.

Entering H. O. 71 with L. A. T. 7:38 A. M., Lat. 29°, Dec. 4° the azimuth is found to be S 98°.5 E.

PROBLEM NO. 3

Aug. 7, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 18° 18′. Dip 32 ft. Chronometer read 5h 16′ 28″ P. M., which was fast on July 9, 4′ 12″, and on Aug. 4th was slow 3′ 12″. Latitude at noon 4° 16′ N. Ship's run from sight to noon S 18° W. (true) 48 miles.

Sun bore by compass N 92° E. Variation 28° W.

Required latitude and longitude at sight and noon; error and deviation of compass by altitude azimuth; and true course and distance from noon to Lat. 5° 28′ S., Long. 150° E.

Chron.		5h 16′ 28″
Slow	+	3′ 12″
Acc. Rate	+	55″
G. M. T. 7d		5h 20′ 35″
Eq. Time	−	5′ 42″
G. A. T. 7d		5h 14′ 53″
Dec. 7d 4h		16° 36′.6 N
Corr. 1.3h	−	0′.9
Dec.		16° 35′.7 N
P. D.		73° 24′.3
Lat. at Noon		4° 16′ 00″ N
Diff. Lat.		45′ 42″ N
Lat. at Sight		5° 01′ 42″ N

Chron., fast Jul. 9	4′ 12″
Aug. 4, slow	3′ 12″
Lost	7′ 24″ or 444″

$\frac{444''}{26d} = 17''.1$ Rate Times 3.2 days $= 55''$ Lost

Course, N 18° E; Distance, 48 miles; Diff. Lat., 45.7 miles; Dep. 14.8 miles; Diff. Long., 15′ W.

Obs. Alt.		18° 18′ 00″
S. D.	+	15′ 48″
		18° 33′ 48″
Dip	−	5′ 33″
		18° 28′ 15″
R. & P.	−	2′ 44″

True Alt. (h)	18° 25′ 31″			Sec.	.02285
Lat.	5° 01′ 42″	Sec.	.00167	Sec.	.00167
P. D.	73° 24′ 18″	Csc	.01848		
	2)96° 51′ 31″				
Half Sum (s)	48° 25′ 46″	Cos	9.82187	Cos	9.82187
s−h	30° 00′ 15″	Sin	9.69902		
s−p	24° 58′ 32″			Cos	9.95736
		Log. Hav.	9.54104	Log. Hav.	9.80375

L. A. T. 6d	19h 11′ 00″	True Bearing	S 105° 40′ E or
G. A. T. 7d	5h 14′ 53″		N 74° E
		Obs. Bearing	N 92° E
Long. at Sight	10h 03′ 53″ or 150° 58′ 15″ W	Error	18° W
Diff. Long.	15′ W	Variation	28° W
Long. Noon	151° 13′ 15″ W	Deviation	10° E

Lat. A.	4° 16′ N	Mer. Parts	254.5	Long. A.	151° 13′ W
Lat. B	5° 28′ S	Mer. Parts	326.3	Long. B	150° 00′ E
Diff. Lat.	584′		580.8	Diff. Long.	3527′

Log. of Diff. Long. 3527′	=3.54741
Log. of Mer. Parts 580.8′	=2.76403
Tan	0.78338=course S 80° 39′ W.
Log. Sec. Course 80° 39′	=0.78924
Log. Diff. Lat. 584′	=2.76641
Log.	3.55565=distance 3595 miles.

At Sight Lat. 5° 01′ 42″ N, Long. 150° 58′ 15″ W.
At noon Lat. 4° 16′ 00″ N, Long. 151° 13′ 15″ W.
Compass Error 18° W. Compass Dev. 10° E.
True Course S 80° 39′ W, distance 3595 miles.

CORRECTING LONGITUDE

NOTE.—In practice it is common to work a morning time sight on D. R. latitude. When a noon sight is obtained, the latitude found at noon gives a more correct latitude for the A. M. sight. This correction to the latitude will affect the longitude. Either the entire calculation may be gone through again or the longitude previously found may be corrected by any of the following methods:

(*a*) Using Table 38 (Bowditch), knowing altitude, latitude, and polar distance, the table gives the error due to 1′ or mile error in latitude.

(*b*) Using Table 47 (Bowditch), the sun's true bearing having been found for compass correction, and the approximate latitude known, the table gives the longitude factor or error in longitude produced by 1′ or mile error in latitude.

(*c*) Using Table 2 (Bowditch) using as a course 90° from the bearing find the departure corresponding to the error in the latitude column. The departure in miles is found with the middle latitude as course and the difference in longitude in minutes is found.

PROBLEM NO. 4

Oct. 24, 1919, A. M. D. R. Lat. 22° 40′ N. Obs. Alt. Sun's L. L. 24° 16′. Dip 26 ft. Chronometer read 6h 23′ 12″ A. M., fast on Sept. 25th, 8′ 12″, and on Oct. 20th, fast 6′ 20″.

Sun bore by compass N 116° E. Variation 19° E.

Ship's run from sight to noon N 43° W (true) 52 miles.

Obs. Mer. Alt. was 55° 30′ 00″ S.

Required true course and distance by Mercator Sailing from noon to Lat. 0° 23′ S, Long. 0° 23′ W.

Chron.	18h 23′ 12″	Chron., fast Sep. 25	8′ 12″
Fast	− 6′ 20″	Fast, Oct. 20	6′ 20″
	18h 16′ 52″	Chron. Lost	1′ 52″ or
Acc. Rate	+ 17″		112″
		$\frac{112''}{25d}=4''.5$ Rate	
G. M. T. 23d	18h 17′ 09″		
Eq. Time	+ 15′ 35″	3.7 Days	
G. A. T. 23d	18h 32′ 44″	17″ Losing	

Dec. 23d 18h	11° 23′.9 S
Corr. .5h	+ 0′.5
Dec. 23d 18.5h	11° 24′.4 S
P. D.	101° 24′ 24″

Obs. Alt.	24° 16′ 00″				
S. D.	+ 16′ 06″				
	24° 32′ 06″				
Dip	− 5′ 00″				
	24° 27′ 06″				
R. & P.	− 1′ 59″				
True Alt.	24° 25′ 07″			Sec	.04070
Lat.	22° 40′ 00″	Sec	.03491	Sec	.03491
P. D.	101° 24′ 24″	Csc	.00866		
	2)148° 29′ 31″				
s	74° 14′ 46″	Cos	9.43378	Cos	9.43378
s − h	49° 49′ 39″	Sin	9.88315		
s − P. D.	27° 09′ 38″			Cos	9.94926
		Log. Hav.	9.36050	Log. Hav.	9.45865

L. A. T. 23d	20h 11′ 05″	True Bearing	S 64° 51′ 00″ or	
G. A. T. 23d	18h 32′ 44″		N 115° 09′	E
		Obs. Bearing	N 116°	E
Long.	1h 38′ 21″ or			
	24° 35′ 15″ E	Error	1°	W
		Variation	19°	E
		Deviation	20°	W

Course N 43° W. Dist. 52 miles. Diff. Lat. 38.0 miles. Dep. 35.5 miles. Diff. Long. (Approx. Mid. Lat. 23° N) 38.5′.

Long. at Sight	24° 35′ 15″ E		
Diff. Long.	38′ 30″ W		
Long. at Noon	23° 56′ 45″	or	1h 35′ 47″

G. A. T. (noon) 23d	22h 24′ 13″	Dec. 23d 22h	11° 27′.4 S
Eq. Time	− 15′ 36″	Corr. .1h	+ 0′.1
G. M. T. (noon) 23d	22h 08′ 37″	Dec.	11° 27′.5 S

Obs. Alt.	55° 30′ 00″ S
S. D.	+ 16′ 06″
	55° 46′ 06″
Dip	− 5′ 00″
	55° 41′ 06″
R. & P.	− 0′ 35″
True Alt.	55° 40′ 31″ S
Z. D.	34° 19′ 29″ N
Dec.	11° 27′ 30″ S
Lat. (noon)	22° 51′ 59″ N
Diff. Lat.	38′ S
Lat. at Sight	22° 13′ 59″ N
Lat. Used	22° 40′ 00″ N
Error	26′ 01″

Working time sight with new latitude.

h	24° 25′ 07″		
Lat.	22° 13′ 59″	Sec.	.03355
P. D.	101° 24′ 24″	Csc	.00866
	2)148° 03′ 30″		
s	74° 01′ 45″	Cos	9.43954
s−h	49° 36′ 38″	Sin	9.88176
		Log. Hav.	9.36351

L. A. T. (corr.)	20h 10′ 13″		
G. A. T.	18h 32′ 44″		
Long. (corr.)	1h 37′ 29″	or	24° 22′ 15″ E
			24° 35′ 15′ E
	Error		13′ E

TABLE 38

Twenty-six miles error latitude, alt. 24°, Lat. 22°, P. D. 101°.
Error in longitude for 1 mile latitude, .5
for 26 miles, 13

Rule.—In east longitude, body east of meridian, decreased latitude, longitude is decreased.

TABLE 47

Bearing S 65° E (see calculations).
Latitude 22°.
Longitude factor F=.51.
.51×26 miles=13′.

TABLE 2

Bearing S 65° E. Find course 90° from it, or N 25° E. Opposite Lat. 26°, find departure 12 miles. At Middle Lat. 22°, 12 miles=13′.

Noon position 22° 51′ 59″ N		Long. Sight			24° 22′ 15″ E
		Diff. Long			38′ 30″ W
		Long. Noon			23° 43′ 45″ E
Lat. A	22° 52′ N	Mer. Parts	1400.9	Long. A	23° 44′ E
Lat. B	0° 23′ S	Mer. Parts	22.8	Long. B	0° 23′ W
Diff. Lat.	23° 15′ or 1395′		1424	Diff. Long.	24° 07′ or 1447′

Log. of Diff. Long. 1447′=3.16047
Log. of Mer. Parts 1424′=3.15351

Log. Tan. .00696=course S 45° 28′ W

Log. Sec. 45° 28′ =0.15408
Log. Diff. Lat. 1395′=3.14457

Log. 3.29865=distance 1989 miles.

Position at noon: Lat. 22° 52′ N., Long. 23° 44′ E.
Position at sight: (corr.) 22° 14′ N, 24° 22′ E.
Compass error 1° W, deviation 20° W.
True course S 45° W, distance 1989 miles.

PROBLEM NO. 5

Feb. 2, 1919, A. M. D. R. Lat. 36° 59′ S. Obs. Alt. Sun's L. L. 49° 10′. Dip 14 ft. Chron. read 7h 08′ 50″ A. M., slow on Dec. 30th, 18′ 02″, and on Jan. 6th, slow 19′ 10″.6.

Ship's run from sight to noon S 45° W (true) 32 miles.

Sun bore by compass S 73° E. Variation 5° W.

Obs. Mer. Alt. 70° 25′, bearing N.

Required position and sight and at noon, also compass error and deviation.

Required course and distance by Mercator Sailing from noon to Lat. 1° 10′ N, Long. 5° 16′ W.

Chron.		19h 08′ 50″
Slow	+	19′ 10″
Acc. Rate	+	4′ 22″
G. M. T. 1d		19h 32′ 22″
Eq. Time	−	13′ 45″
G. A. T. 1d		19h 18′ 37″

Chron. slow Dec. 30th	18′ 02″
Chron. slow Jan. 6th	19′ 10″.6
Losing	1′ 08″.6
	or 68″.6

$\frac{68''.6}{7d} = 9''.8$ rate

26.8 days

Losing 262″ = 4′ 22″

Dec. 1d 18h		17° 06′.1
Corr. 1.3h	−	0′.9
Dec. 1d 19.3h		17° 05′.2 S
P. D.		72° 54′.8

Obs. Alt.		49° 10′ 00″				
S. D.	+	16′ 18″				
		49° 26′ 18″				
Dip	−	3′ 40″				
		49° 22′ 38″				
R. & P.	−	44″				
True Alt.		49° 21′ 54″			Sec	.18626
Lat.		36° 59′ 00″	Sec	.09756	Sec	.09756
P. D.		72° 54′ 48″	Csc	.01961		
	2)	159° 15′ 42″				
s		79° 37′ 51″	Cos	9.25525	Cos	9.25525
s−h		30° 15′ 57″	Sin	9.70244		
s−P. D.		6° 43′ 03″			Cos	9.99701
			Log. Hav.	9.07486	Log. Hav.	9.53608

L. A. T. 1d	21h 18′ 42″	True Bearing	N 72° E
G. A. T. 1d	19h 18′ 37″	Obs. Bearing	S 73° E
Long. at Sight	2h 00′ 05″ or 30° 01′ 15″ E	Error	35° W
		Variation	5° W
		Deviation	30° W

Course S 45° W. Dist. 32 miles. Diff. Lat. 22.6 miles = 22.6 S. Dep. 22.6 miles (37° Mid. Lat.) = 28′ W. Long. at noon 29° 33′ 15″ E, or 1h 58′ 13″.

G. A. T. 1d	22h 01′ 47″	Dec. 1d 22h	17° 03′.3 S
Eq. Time	+ 13′ 46″	Corr. .3h	0′.2
G. M. T. 1d	22h 15′ 33″	Dec. 1d 22.3h	17° 03′.1 S

Obs. Alt.	70° 25′ 00″ N	
S. D.	+ 16′ 18″	
	70° 41′ 18″	
Dip	− 3′ 40″	
	70° 37′ 38″	
R. & P.	− 17″	
Corr. Alt.	70° 37′ 21″	
Z. D.		19° 22′ 39″ S
Dec.		17° 03′ 06″ S
Noon Lat.		36° 25′ 45″ S
Diff. Lat.		22′ 36″ N
Lat. at Sight		36° 03′ 09″ S
Lat. Used		36° 59′ 00″ S
Error		55′ 51″

TABLE 47

Lat. 37°. Bearing N 72° E; F = .40. Long. Corr. = .40 × 55.8 = 22′.3.

TABLE 2

Course 18°. Lat. 55.8. Dep. 18.2 (Mid. Lat. 37°) Diff. Long. = 22′.7.

Check on azimuth (H. O. 71) Lat. 37°. Dec. 17°. L. A. T. 9h 18′. Az. 108°.

Long. at Sight (computed)	30° 01′ 15″ E
Corr. (see above)	22′ 18″ dec.
Long. at Sight (corrected)	29° 39′ E
Diff. Long.	28′ W
Long. at Noon (corrected)	29° 11′ E

Lat. A	36° 26′ S	Mer. Parts	2336	Long. A	29° 11′ E
Lat. B	1° 10′ N	Mer. Parts	69	Long. B	5° 16′ W
Diff. Lat.	37° 36′ or 2256′		2405	Diff. Long	34° 27′ or 2067′

Log. of Diff. Long.	2069′ = 3.31534
Log. of Mer. Parts	2405′ = 3.38112
Log. Tan.	9.93422 = course N 40° 41′ W
Log. Sec. Course	= 0.12015
Log. of Diff. Lat.	2256′ = 3.35334
Log.]	3.47349 = distance 2975 miles.

Position at noon: Lat. 36° 26′ S, Long. 29° 11′ E.
Position at sight: Lat. 36° 03′ S, Long. 29° 39′ E.
Compass error 35° W. Dev. 30° W.
True course N 41° W. Dist. 2975 miles.

PROBLEM NO. 6

Nov. 15, 1919, A. M. D. R. Lat. 4° 15′ N. Obs. Alt. Sun's L. L. 50° 25′. Dip 30 ft. Chron. read 9h 33′ 10″ A. M., which was fast on Oct. 22d 3′ 28″ and losing 4″.7 daily. Sun's compass bearing N 82° 30′ E. Var. 25° E. Ship sailed from sight to noon N 79° E (true) 31 miles. Obs. Mer. Alt. Sun's L. L. 68° 13′ S.

Required course and distance from noon to 24° 18′ N, 56° 28′ W.

Chron.	21h 33′ 10″	4″.7 rate		
Fast	− 3′ 28″	23.9 days		
	21h 29′ 42″	112″ = 1′ 52″ acc. rate		
Acc. Rate	+ 1′ 52″			
		Dec. 14d 20h		18° 15′.0 S
G. M. T. 14d	21h 31′ 34″	Corr. 1.5h	+	1′.0
Eq. Time	+ 15′ 29″			
		Dec. 14d 21.5h		18° 16′.0 S
G. A. T. 14d	21h 47′ 03″	P. D. = 108° 16′		

Obs. Alt.	50° 25′ 00″				
S. D.	+ 16′ 12″				
	50° 41′ 12″				
Dip	− 5′ 22″				
	50° 35′ 50″				
R. & P.	− 41″				
Corr. Alt.	50° 35′ 09″			Sec	.19728
Lat.	4° 15′ 00″	Sec	.00120	Sec	.00120
P. D.	108° 16′ 00″	Csc	.02246		
	2)163° 06′ 09″				
s	81° 33′ 04″	Cos	9.16710	Cos	9.16710
s−h	30° 57′ 55″	Sin	9.71141		
s−P. D.	26° 42′ 56″			Cos	9.95097
			8.90217		9.31655

L. A. T. 14d	21h 48′ 42″	True Bearing	S 54° 10′ E or
G. A. T. 14d	21h 47′ 03″		N 125° 50′ E
		Obs. Bearing	N 82° 30′ E
Long. at Sight	1′ 39″ or		
	0° 24′ 45″ E	Error	43° 20′ E
		Variation	25° 00′ E
		Deviation	18° E

Course N 79° E, 31 miles. Diff. Lat. 5′9 miles = 5′.9. Departure 30.4 miles. (Mid. Lat. 4°) = Diff. Long. 30′. 5 E. Long. at noon 0° 55′ 15″ E or 0h 3′ 41″.

G. A. T. 14d	23h 56′ 19″	Dec. 14d 22h	18° 16′.3 S
Eq. Time	− 15′ 28″	Corr. 1.7h	1′.2
G. M. T. 14d	23h 40′ 51″	Dec. 14d 23′.7h	18° 17′.5 S

Obs. Alt	68° 13′ 00″
S. D.	+ 16′ 12″
	68° 29′ 12″
Dip	− 5′ 22″
	68° 23′ 50″
R. & P.	− 21″
Corr. Alt.	68° 23′ 29″ S
Z. D.	21° 36′ 31″ N
Dec.	18° 17′ 30″ S
Lat. at Noon	3° 19′ 01″ N
Diff. Lat.	5′ 54″ S
Lat. at Sight	3° 13′ 07″ N
Lat. Used	4° 15′ 00″ N
Error	61′.9 N

TABLE 47

Lat. 3°. Bearing 54°. F=.73. Long. Corr.=.73×61′.9=45′.1 E.

Long.	0° 24′ 45″ E
Corr.	45′ 06″ E
Corr. Long. at Sight	1° 09′ 51″ E
Diff. Long.	30′ 30″ E
Corr. Long. at Noon	1° 40′ 21″ E

Lat. A	3° 19′ N	Mer. Part	197.8	Long. A	1° 40′ E
Lat. B	24° 18′ N	Mer. Part	1494.2	Long. B	56° 28′ W
Diff. Lat.	20° 59′ or 1259′		1296.4	Diff. Long.	58° 08′ or 3488′

Log. of Diff. Long. 3488′	=3.54258
Log. of Mer. Parts 1296′	=3.11261
Log. Tan.	.42997=course 69° 37′
Log. Sec 69° 37′	= .45805
Log. of Diff. Lat. 1259′	= .10003
Log.	.55808=distance 3615 miles.

At sight Lat. 3° 13′ N, Long. 1° 10′ E.
At noon Lat. 3° 19′ N, Long. 1° 40′ E.
Error 43° E. Dev. 18° E.
Course N 69° 37′ W. Dist. 3615 miles.

CHAPTER XV

LATITUDE BY MERIDIAN ALTITUDE OF PLANET

This problem is worked the same as latitude by fixed star, with the exception that parallax must be applied to altitude, and the declination is to be corrected for Greenwich date and time.

After finding Greenwich Mean Time, take out declination of planet from almanac for Greenwich date, and the difference in small figures between it and next date.

Note.—Notice whether declination is decreasing or increasing.

Enter Table IV (Almanac) with the difference at top of page to the nearest number, and the G. M. T. on right-hand side to the nearest hour and minute, and read the number obtained from the column.

Apply this number to Planet's Declination for Greenwich date as follows:

If declination is increasing, add the correction.

If declination is decreasing, subtract the correction.

Result will be true declination.

Note.—If G. M. T. is over 12 hours, first find the number from Table IV that 12 hours will give, and then the balance of hours and minutes left, and add the two.

For example: Jan. 24th G. M. T. 14h 14′. Required true declination of Planet " Venus."

Planet's Dec. Jan. 24th	=	16° 49′.0 S	decreasing
Corr. Table IV	= −	13′.6	Diff. 230
True Dec.	=	16° 35′.4 S	or 16° 35′ 24″ S

Looking in 230 column in Table IV, we find for 12 hours	115
For 2h 14′ the balance, we find	21
Adding the two	=136 Corr.

As the declination is decreasing correction is to be subtracted.

The Obs. Mer. Alt is corrected as follows:

Index error as per sign, if any.

Dip (Table 14) subtract.

Parallax (Table 17) add.

Refraction (Table 20*A*) subtract.

Result will be true altitude.

Subtract true altitude from 90°, find zenith distance, and apply declination as in previous examples for latitude observations.

Result will be latitude.

LATITUDE BY PLANET

PROBLEM NO. 1

Oct. 5, 1919. Obs. Mer. Alt. Planet Saturn 36° 15′ 20″ S. Dip 18 ft. Chron. read 3h 08′ 04″ P. M. Required latitude.

G. M. T. 5d		3h 08′ 04″	
*Dec. 5d		10° 26′.9 N decreasing	
Corr. 3h 08′		0′.3	
Dec. 5d 3h 08′		10° 26′.6 N	H. P. 0′.01 or 1″.
Obs. Alt.		36° 15′ 20″	
Dip	−	4′ 09″	
		36° 11′ 11″	
Par. (Table 17)	+	01″	
		36° 11′ 12″	
Ref.	−	1′ 19″	
True Alt.		36° 09′ 53″	
		90° 00′ 00″	
Z. D.		53° 50′ 07″ N	
Dec.		10° 26′ 36″ N	
Lat.		64° 16′ 43″ N	

PROBLEM NO. 2

Dec. 25, 1919. Obs. Mer. Alt. Planet Jupiter 41° 12′ 00′ N. Dip 28 ft. Chron. read 6h 38′ A. M. Required latitude.

G. M. T. 24d	18h 38′	
*Dec. 24d	16° 18′.5 N increasing	
Corr. 18h 38′	1′.1 N	
Dec. 24d 18h 38′	16° 19′.6	H. P. 0′.03 or 2″
Obs. Alt.	41° 12′ 00″	
Dip	− 5′ 11″	
	41° 06′ 49″	
Par. (Table 17)	+ 02″	
	41° 06′ 51″	
Ref.	− 1′ 07″	
True Alt.	41° 05′ 44″	
	90° 00′ 00″	
Z. D.	48° 54′ 16″ S	
Dec.	16° 19′ 36″ N	
Lat.	32° 34′ 40″ S	

PROBLEM NO. 3

Jan. 2, 1919. Obs. Mer. Alt. Planet Venus 69° 07′ 00″ N. Dip 14 ft. Chron. read 1h 12′ P. M.

G. M. T. 2d	1h 12′	
Dec. 2d	22° 56′.9 S decreasing	
Corr. 1h 12′	− 0′.4	
Dec. 2d 1h 12′	22° 56′.5 S	H. P. 0′.09 or 5″
Obs. Alt	69° 07′ 00″ N	
Dip	− 3′ 40″	
	69° 03′ 20″	
Par. (Table 17)	+ 05″	
	69° 03′ 25″	
Ref.	− 22″	
True Alt.	69° 03′ 03″	
	90° 00′ 00″	
Z. D.	20° 56′ 57″ S	
Dec.	22° 56′ 30″ S	
Lat.	43° 53′ 27″ S	

PROBLEM NO. 4

Apr. 14, 1919. Obs. Mer. Alt. Planet Jupiter 68° 58′ S. Dip 14 ft. Chron. read 1h 40′ P. M.

G. M. T. 14d		1h 40′	
Dec. 14d		22° 23′.1 N decreasing	
Corr. 1h 40′		0′.0	
Dec. 14d 1h 40′		22° 23′.1 N	H. P. 0′.03 or 2″
Obs. Alt.		68° 58′ 00″	
Dip	−	3′ 40″	
		68° 54′ 20″	
Par.	+	2″	
		68° 54′ 22″	
Ref.	−	22″	
True Alt.		68° 54′ 00″	
		90° 00′ 00″	
Z. D.		21° 06′ 00″ N	
Dec.		23° 23′ 06″ N	
Lat.		44° 29′ 06″ N	

CHAPTER XVI

LATITUDE BY EX-MERIDIAN ALTITUDE OF SUN

This problem is to find the latitude of the place, when the sun is not visible at noon.

It is possible at certain seasons of the year to obtain the latitude 28 minutes before or after noon.

When sun's declination is opposite name to latitude of observer the interval is greater, when the latitude and declination are the same name the interval is less.

If further away from noon than 28 minutes, the latitude may yet be calculated, but by a different method called $\phi' \ \phi''$ method. This method will be explained in another chapter.

Find the Local Apparent Time (L. A. T.) as follows:

Correct chronometer and obtain G. M. T.

Take from the Nautical Almanac the equation of time for this G. M. T. and apply it, giving the G. A. T.

Under G. A. T. put down longitude in time. If east longitude add; if west longitude, subtract; giving L. A. T.

To find the time away from noon:

If L. A. T. is less than 24 hours, subtract it from 24 hours and the result will be the minutes and seconds before noon. If L. A. T. is over 0 hours it will be the minutes and seconds after noon.

Take out sun's declination from almanac for Greenwich date and time.

Square the number of minutes from noon. Using the nearest minute will be close enough for practical purposes.

Note.—To square a number, multiply it by itself. For example: The square of 12′ is $12 \times 12 = 144$.

Enter Table 26 (Bowditch) with latitude and declination to nearest degree, and read the number obtained from this table in its proper column. Declination will be found from top of page, latitude from side.

Note.—Notice whether latitude and declination are same or contrary names.

Multiply the square of minutes from noon by this number, and the result will be seconds of altitude correction.

Reduce the seconds to minutes and seconds, and always add it to sun's observed altitude.

Note.—Table 27 (Bowditch) is another method of finding the altitude correction. It is based on the same principle as the foregoing rule—that is, the square of the number of minutes from noon multiplied by correction from Table 26, is given in this table.

After adding to observed altitude the correction, correct altitude for index error, semi-diameter, dip, refraction and parallax, and obtain true altitude.

Find the zenith distance, and apply declination to same, as was done in meridian altitude sights.

Result will be latitude at sight.

To find the latitude at noon, it will be necessary to allow the difference of latitude made by the ship from the sight to noon on the course and distance steered in the interval.

This problem is very useful to the navigator, for if the sun is overcast at noon the latitude by observation would be lost for that day, if this example was not used.

PROBLEM NO. 1

Mar. 10, 1919. Ex. Mer. Alt. Sun's L. L. 42° 16′ 28″ S. Dip 18 ft. Chron. read 6h 45′ 15″ P. M. Long. 94° 16′ W. Lat. by D. R. 43° N.

G. M. T. 10d		6h 45′ 15″	Dec. 10d 6h		4° 18′.4 S
Eq. Time	−	10′ 34″	Corr. for .7h	−	0′.7
G. A. T.		6h 34′ 41″	Dec. 10d 6.7h		4° 17′.7 S
Long.		6h 17′ 04″			
			18		
L. A. T.		0h 17′ 37″	18		
Time past noon 18′					
			324		
Obs. Alt.		42° 16′ 28″	2″.0 from Table 26		
Alt. Corr.	+	10′ 48″			
			648″ = 10′ 48″ alt. corr.		
		42° 27′ 16″			
S. D.	+	16′ 06″			
		42° 43′ 22″			
Dip	−	4′ 09″			
		42° 39′ 13″			
R. & P.	−	56″			
True Alt.		42° 38′ 17″ S			
		90° 00′ 00″			
Z. D.		47° 21′ 43″ N			
Dec.		4° 17′ 42″ S			
Lat.		43° 04′ 01″ N			

PROBLEM NO. 2

Apr. 19, 1919. Ex. Mer. Alt. Sun's L. L. 41° 28′ 13″ N. Dip 20 ft. Chron. read 4h 45′ 08″ A. M. Long. 105° 15′ E. Lat. by D. R. 38° S.

G. M. T. 18d	16h 45′ 08″	Dec. 18d 16h	10° 47′.1 N
Eq. Time	+ 38″	Corr. .7h	+ 0′.6
G. A. T.	16h 45′ 46″	Dec. 18d 16′.7h	10° 47′.7 N
Long.	7h 01′ 00″		
		13	
L. A. T.	23h 46′ 46″	13	
Time before noon 13′			
		169	
Obs. Alt.	41° 28′ 13″ N	2″.0 from Table 26	
Alt. Corr.	+ 5′ 38″		
		338″=5′ 38″ alt. corr.	
	41° 33′ 51″		
S. D.	+ 16′ 00″		
	41° 49′ 51″		
Dip	− 4′ 23″		
	41° 45′ 28″		
R. & P.	− 58″		
True Alt.	41° 44′ 30″		
	90° 00′ 00″		
Z. D.	48° 15′ 30″ S		
Dec.	10° 47′ 42″ N		
Lat.	37° 27′ 48″ S		

PROBLEM NO. 3

Mar. 11, 1919. Ex. Mer. Alt. Sun's L. L. 45° 38′ 25″ N. Dip 22 ft. Chron. read Mar. 10, 11h 59′ 54″, slow 35′ 58″. Long. 168° 20′ E. D. R. Lat. 48° S.

Chron.		11h 59′ 54″	Dec. 10d 12h		4° 12′.6 S
Slow	+	35′ 58″	Corr. for .6h	−	0′.6
G. M. T. 10d		12h 35′ 52″	Dec. 10d 12.6h		4° 12′ S
Eq. Time	−	10′ 30″			
G. A. T. 10d		12h 25′ 22″	21		
Long.		11h 13′ 20″	21		
L. A. T.		23h 38′ 42″	441		
Time before noon 21′			1″.9 from Table 26		
			838″ = 13′ 58″ alt. corr.		
Obs. Alt.		45° 38′ 25″			
Alt. Corr.	+	13′ 58″			
		45° 52′ 23″			
S. D.	+	16′ 06″			
		46° 08′ 29″			
Dip	−	4′ 36″			
		46° 03′ 53″			
R. & P.	−	50″			
True Alt.		46° 03′ 03″			
		90° 00′ 00″			
Z. D.		43° 56′ 57″ S			
Dec.		4° 12′ 00″ S			
Lat.		48° 08′ 57″ S			

PROBLEM NO. 4

July 4, 1919. Ex. Mer. Alt. Sun's L. L. 44° 02′ N. Dip 18 ft. Chron. read 10h 17′ 10″ A. M., slow 3h 52′ 17″. Long. 35° 15′ W. D. R. Lat. 23° S.

Chron.	22h 17′ 10″	Dec. 4d 2h	22° 56′.9 N
Slow	+ 3h 52′ 17″	Corr. .1h	0′.0
G. M. T. 4d	2h 09′ 27″	Dec. 4d 2.1h	22° 56′.9 N
Eq. Time	− 4′ 02″		
		16	
G. A. T.	2h 05′ 25″	16	
Long.	2h 21′ 00″		
		256	
L. A. T.	23h 44′ 25″	2″.3 from Table 26	
Time before noon 16′.			
		589″ = 9′ 49″ alt. corr.	
Obs. Alt	44° 02′ 00″ N		
Corr.	+ 9′ 49″		
	44° 11′ 49″		
S. D.	+ 15′ 48″		
	44° 27′ 37″		
Dip	− 4′ 09″		
	44° 23′ 28″		
R. & P.	− 53″		
	44° 22′ 35″ N		
	90° 00′ 00″		
Z. D.	45° 37′ 25″ S		
Dec.	22° 56′ 54″ N		
Lat.	22° 40′ 31″ S		

PROBLEM NO. 5

Oct. 24, 1919. Ex. Mer. Alt. Sun's L. L. 37° 02′ 15″ S. Dip 18 ft. Chron. read 7h 07′ 41″ A. M., slow 16′ 19″. Long. 70° E. D. R. Lat. 41° 13′ N.

Chron.	19h 07′ 41″	Dec. 23d 18h	11° 23′.9 S
Slow	+ 16′ 19″	Corr. 1.4h	+ 1′.3
G. M. T. 23d	19h 24′ 00″	Dec. 23d 19.4h	11° 25′.2 S
Eq. Time	+ 15′ 35″		
		20	
G. A. T. 23d	19h 39′ 35″	20	
Long.	4h 40′		
		400	
L. A. T.	24h 19′ 35″	1″.8 from Table 26	
Time past noon 20′.			
		720″ or 12′ 00″ alt. corr.	
Obs. Alt	37° 02′ 15″		
Corr.	+ 12′ 00″		
	37° 14′ 15″		
S. D	+ 16′ 06″		
	37° 30′ 21″		
Dip	− 4′ 09″		
	37° 26′ 12″		
R. & P.	− 1′ 09″		
True Alt.	37° 25′ 03″		
	90° 00′ 00″		
Z. D.	52° 34′ 57″ N		
Dec.	11° 25′ 12″ S		
Lat	41° 09′ 45″ N		

PROBLEM NO. 6

Sept. 24, 1919. Ex. Mer. Alt. Sun's L. L. 50° 19′ S. Dip 16 ft. Chron. read 0h 34′ 10″ P. M. fast 19′ 20″. Long. 6° W. D. R. Lat. 38° 50′ N.

Chron.		0h 34′ 10″
Fast	−	19′ 20″
G. M. T. 24d		0h 14′ 50″
Eq. Time	+	7′ 40″
G. A. T. 24d		0h 22′ 30″
Long.	−	24′ 00″
L. A. T. 23d		23h 58′ 30″
Time before noon 1′.5.		
Obs. Alt.		50° 19′ 00″ S
Corr.	+	05″
		50° 19′ 05″
S. D.	+	16′ 00″
		50° 35′ 05″
Dip	−	3′ 55″
		50° 31′ 10″
R. & P.	−	42″
True Alt.		50° 30′ 28″ S
		90° 00′ 00″
Z. D.		39° 29′ 32″ N
Dec.		0° 09′ 24″ S
Lat.		39° 20′ 08″ N

Dec. 24d 0h		0° 9′.2 S
Corr. .2h	+	0′.2
Dec. 24d 0.2h		0° 9′.4 S

1.5
1.5
———
2.2
2″.4 from Table 26
———
5.3″ alt. corr.

PROBLEM NO. 7

Dec. 25, 1919. Ex. Mer. Alt. Sun's L. L. 64° 45′ N. Dip 15 ft. Chron. read 3h 17′ 10″ A. M., slow 13′ 05″. Long. 130° E. D. R. Lat. 48° 23′ S.

Chron.		15h 17′ 10″	Dec. 24d 14h		23° 25′.7 S
Slow	+	13′ 05″	Corr. 1.5h	–	0′.1
G. M. T. 24d		15h 30′ 15″	Dec. 24d 15.5h		23° 25′.6 S
Eq. Time	+	24″			
G. A. T. 24d		15h 30′ 39″	11		
Long.	+	8h 40′ 00″	11		
L. A. T. 24d		24h 10′ 39″	121′×2″.9 = 351″ or 5′ 51″		

Time past noon of 25th day, 10′ 39″.

Obs. Alt.		64° 45′ 00″ N
Corr.	+	5′ 51″
		64° 50′ 51″
S. D.	+	16′ 18″
		65° 07′ 09″
Dip	–	3′ 48″
		65° 03′ 21″
R. & P.	–	23″
True Alt.		65° 02′ 58″ N
		90° 00′ 00″
Z. D.		24° 57′ 02″ S
Dec.		23° 25′ 36″ S
Lat.		48° 22′ 38″ S

PROBLEM NO. 8

May 29, 1919. Ex. Mer. Alt. Sun's L. L. 64° 25′ S. Dip 10 ft. Chron. read 11h 17′ 56″ A. M., slow 3h 53′. Long. 49° 30′ W. D. R. Lat. 47° N.

Chron.	23h 17′ 56″	Dec. 29d 2h	21° 30′.6 N
Slow	3h 53′ 00″	Corr. 1.2h	+ 0′.5
G. M. T. 29d	3h 10′ 56″	Dec. 29d 3.2h	21° 31′.1 N
Eq. Time	+ 2′ 54″		
		4	
G. A. T. 29d	3h 13′ 50″	4	
Long.	3h 18′ 00″		
		16	
L. A. T. 28d	23h 55′ 50″	2″.9 from Table 26	
Time before noon 4′ 10″.			
		46″ alt. corr.	
Obs. Alt.	64° 25′ 00′ S		
Corr.	+ 46″		
	64° 25′ 46″		
S. D.	+ 15′ 48″		
	64° 41′ 34″		
Dip	− 3′ 06″		
	64° 38′ 28″		
R. & P.	− 23″		
True Alt.	64° 38′ 05″ S		
	90° 00′ 00″		
Z. D.	25° 21′ 55″ N		
Dec.	21° 31′ 06″ N		
Lat.	46° 53′ 01″ N		

PROBLEM NO. 9

Jan. 24, 1919. Ex. Mer. Alt. Sun's L. L. 22° 46′ S. Index error −1′ 25″. Dip 26 ft. Chron. read 10h 5′ 2″ P. M., which was slow 7′ 15″. Long. 155° W. D. R. Lat. 48° N.

Chron.	10h 05′ 02″	Dec. 24d 10h	19° 17′.4 S
Slow	+ 7′ 15″	Corr. .2h	− 0′.1
G. M. T. 24d	10h 12′ 17″	Dec. 24d 10.2h	19° 17′.3 S
Eq. Time	− 12′ 09″		
		20	
G. A. T. 24d	10h 00′ 08″	20	
Long.	−10h 20′ 00″		
		400	
L. A. T. 23d	23h 40′ 08″	1″.4 from Table 26	
Time before noon 19′ 52″.			
		560″ = 9′ 20″ alt. corr.	
Obs. Alt.	22° 46′ 00″ S		
Corr.	+ 9′ 20″		
	22° 55′ 20″		
I. E.	− 1′ 25″		
	22° 53′ 55″		
S. D.	+ 16′ 18″		
	23° 10′ 07″		
Dip	− 5′ 00″		
	23° 05′ 07″		
R. & P.	− 2′ 07″		
True Alt.	23° 03′ 00″ S		
	90° 00′ 00″		
Z. D.	66° 57′ 00″ N		
Dec.	19° 17′ 18″ S		
Lat.	47° 39′ 42″ N		

PROBLEM NO. 10

July 12, 1919. Ex. Mer. Alt. Sun's L. L. 78° 16′ 30″ S. Dip 26 ft. Chron. read 5h 0′ 28″ P. M. Long. 75° 18′ W. D. R. Lat. 34° N.

G. M. T. 12d	5h 00′ 28″	Dec. 12d 4h	22° 04′.1 N
Eq. Time	− 5′ 19″	Corr. 1.0h	− 0′.3
G. A. T. 12d	4h 55′ 09″	Dec. 12d 5h	22° 03′.8 N
Long.	− 5h 01′ 12″		
		6	
L. A. T. 11d	23h 53′ 57″	6	
Time before noon 6′ 03″			
		36	
Obs. Alt.	78° 16′ 30″ S	7″.3 from Table 26	
Corr.	+ 4′ 23″ S		
		263″=4′ 23″ alt. corr.	
	78° 20′ 53″		
S. D.	+ 15′ 45″		
	78° 36′ 38″		
Dip	− 5′ 00″		
	78° 31′ 38″		
R. & P.	− 9″		
True Alt.	78° 31′ 29″ S		
	90° 00′ 00″		
Z. D.	11° 28′ 31″ N		
Dec.	22° 03′ 48″ N		
Lat.	33° 32′ 19″ N		

PROBLEM NO. 11

Sept. 18, 1919. Ex. Mer. Alt. Sun's L. L. 78° 16′ 30″ S. Dip 26 ft. Chron. read 7h 03′ 00″ A. M. Long. 75° 30′ E. D. R. Lat. 13° N.

G. M. T. 17d	19h 03′ 00″	Dec. 17d 18h	2° 16′.6 N
Eq. Time	+ 5′ 29″	Corr. 1.0h	− 1′.0
G. A. T. 17d	19h 08′ 29″	Dec. 17d 19h	2° 15′.6 N
Long.	+ 5h 02′ 00″		
		10	
L. A. T. 17d	24h 10′ 29″	10	
Time after noon 10′ 29″			
		100	
Obs. Alt.	78° 16′ 30″ S	10″ from Table 26	
Corr.	+ 16′ 40″		
		1000″ = 16′ 40″ alt. corr	
	78° 33′ 10″		
S. D.	+ 16′ 00″		
	78° 49′ 10″		
Dip	− 5′ 00″		
	78° 44′ 10″		
R. & P.	− 9″		
True Alt.	78° 44′ 01″ S		
	90° 00′ 00″		
Z. D.	11° 15′ 59″ N		
Dec.	2° 15′ 36″ N		
Lat.	13° 31′ 35″ N		

PROBLEM NO. 12

Feb. 7, 1919. Ex. Mer. Alt. Sun's L. L. 42° 00′ 30″ S. Dip 18 ft. Chron. read 6h 45′ 15″ P. M. Long. 94° W. D. R. Lat. 33° N.

G. M. T. 7d		6h 45′ 15″	Dec. 7d 6h		15° 27′.9 S
Eq. Time	–	14′ 16″	Corr. .8h	–	0′.6
G. A. T. 7d		6h 30′ 59″	Dec. 7d 6.8h		15° 27′.3 S
Long.	–	6h 16′ 00″			
			15		
L. A. T. 7d		0h 14′ 59″	15		
Time after noon 14′ 59″					
			225		
Obs. Alt.		42° 00′ 30″ S	2″.1 from Table 26		
Corr.	+	7′ 52″			
			472″ 7′ 52″ alt. corr.		
		42° 08′ 22″			
S. D.	+	16′ 12″			
		42° 24′ 34″			
Dip	–	4′ 09″			
		42° 20′ 25″			
R. & P.	–	57″			
True Alt.		42° 19′ 28″ S			
		90° 00′ 00″			
Z. D.		47° 40′ 32″ N			
Dec.		15° 27′ 18″ S			
Lat.		32° 13′ 14″ N			

PROBLEM NO. 13

June 23, 1919. Ex. Mer. Alt. Sun's L. L. 41° 20′ 30″ N. Dip 20 ft. Chron. read 4h 40′ 18″ A. M. Long. 104° 50′ E. D. R. Lat. 25° S.

G. M. T. 22d	16h 40′ 18″	Dec. 22d 16h	23° 26′.8 N
Eq. Time	− 1′ 42″	Corr. .7h	0′.0
G. A. T. 22d	16h 38′ 36″	Dec.	23° 26′.8 N
Long.	6h 59′ 20″		
		22	
L. A. T. 23d	23h 37′ 56″	22	
Time before noon 22′ 04″.			
		484	
Obs. Alt.	41° 20′ 30″ N	2″.2 from Table 26	
Corr.	+ 17′ 45″		
		1065″ = 17′ 45″ alt. corr.	
	41° 38′ 15″		
S. D.	+ 15′ 48″		
	41° 54′ 03″		
Dip	− 4′ 23″		
	41° 49′ 40″		
R. & P.	− 58″		
True Alt.	41° 48′ 42″		
	90° 00′ 00″		
Z. D.	48° 11′ 18″ S		
Dec.	23° 26′ 48″ N		
Lat.	24° 44′ 40″ S		

PROBLEM NO. 14

Mar. 14, 1919. Ex. Mer. Alt. Sun's L. L. 45° 30′ 50″ N. Index error −1′ 50″. Dip 21 ft. Chron. read 0h 50′ 45″ A. M., slow 25′ 50″. Long. 167° 50′ E. D. R. Lat. 47° S.

Chron.		12h 50′ 45″
Slow	+	25′ 50″
G. M. T. 13d		13h 16′ 35″
Eq. Time	−	9′ 42″
G. A. T. 13d		13h 06′ 53″
Long.		11h 11′ 20″
L. A. T. 14d		0h 18′ 13″
Time after noon 18′ 13″		
Obs. Alt.		45° 30′ 50″ N
Corr.	+	10′ 15″
		45° 41′ 05″
I. E.	−	1′ 50″
		45° 39′ 15″
S. D.	+	16′ 06″
		45° 55′ 21″
Dip	−	4′ 29″
		45° 50′ 52″
R. & P.	−	50″
True Alt.		45° 50′ 02″ N
		90° 00′ 00″
Z. D.		44° 09′ 58″ S
Dec.		3° 00′ 36″ S
Lat.		47° 10′ 34″ S

Dec. 13d 12h		3° 01′.9 S
Corr. 1.3h	−	1′.3
Dec. 13d 13.3h		3° 00′.6 S

18
18
———
324
1″.9 from Table 26
———
615″ = 10′ 15″ alt. corr.

CHAPTER XVII

LONGITUDE BY FIXED STAR AND PLANET

This problem is to determine the longitude of a place by a fixed star and planet, and is accurate as long as the horizon is clear enough to obtain the proper altitude.

A star in the East and another in the West taken as close as possible to each other, and projected on the chart by Sumner lines, will make an excellent " fix " for the ship.

For fixed stars:

Correct chronometer same as was done in longitude by sun observations, and obtain Greenwich Mean Time.

From Page 2 (Almanac) take out Sun's Right Ascension for Greenwich date, and place it under G. M. T.

From table below on Page 2 take out correction to be added to Sun's Right Ascension, using G. M. T.

Add together G. M. T., Sun's Right Ascension and Correction. Result will be Greenwich Siderial Time, expressed G. S. T.

Take out star's declination from Page 95 (Almanac) for month of example, and star's right ascension from opposite page for month.

Find polar distance as follows:

Latitude and declination same name, subtract declination from 90°.

Latitude and declination different name, add 90° to declination.

Correct star's observed altitude as follows:

Index error as per sign, if any.

Dip (Table 14) subtract.

Refraction (Table 20*A*) subtract.

Result will be true altitude.

Add together true altitude, latitude and polar distance, and divide sum by 2. Result will be half sum.

Subtract true altitude from half sum. Result will be remainder.

From Table 44 (Bowditch) take out the following logarithms:

Secant of latitude. Rejecting 10 from index number.

Cosecant of polar distance. Rejecting 10 from index number.

Cosine of half sum.

Sine of remainder.

Note.—If polar distance exceeds 90°. Take secant of declination instead.

Add these four logarithms together, and subtract 10 from index number.

Log. Haversine (Table 45) that agrees with sum of logarithms will be star's hour angle. Always to be read from top of page or in P. M.

Under star's right ascension put down star's hour angle and apply as follows:

If star bore West when observation was taken, add the two.

If star bore East when observation was taken, subtract star's hour angle from star's right ascension. Result will be siderial time ship, expressed S. T. S.

Note.—If star bore East, and hour angle is greater than right ascension, add 24 hours to right ascension before making subtraction.

Under siderial time at ship, put down Greenwich Siderial time, and subtract less from greater. Result will be longitude in time.

Turn longitude in time into degrees, minutes and seconds as in previous methods. Result will be longitude.

If Greenwich time is best the longitude is West.

If Greenwich time is least the longitude is East.

PROBLEM NO. 1

Jan. 31, 1919, A. M. Obs. Alt. *Spica 45° 50′, bearing W. Dip 36 ft. Chron. read 1h 14′ 35″ P. M., which was fast Jan. 11, 31′ 34″ and gaining 9″ daily. Lat. 25° 53′ N. D. R. Long. 94° W.

Chron.	1h 14′ 35″	Interval	20 days
Fast	− 31′ 34″	Rate	9″
	0h 43′ 01″		180″=3′
Acc. Rate	− 3′ 00″		
		Dec.	10° 44′.5 S
G. M. T. 31d	0h 40′ 01″		90° 00′.0
R. A. M. S.	20h 38′ 38″		
Corr.	7″	P. D.	100° 44′.5
G. S. T.	21h 18′ 46″		

Obs. Alt.	45° 50′ 00″		
Dip.	− 5′ 53″		
	45° 44′ 07″		
Ref.	− 57″		
h	45° 43′ 10″		
Lat.	25° 53′ 00″	Sec	.04591
P. D.	100° 44′ 30″	Csc	.00768
	2)172° 20′ 40″		
s	86° 10′ 20″	Cos	8.82451
s−h	40° 27′ 10″	Sin	9.81212
		Log. Hav.	8.69022

*R. A.	13h 20′ 57″
*H. A.	1h 42′ 19″
L. S. T.	15h 03′ 16″
G. S. T.	21h 18′ 46″
Long.	6h 15′ 30″=93° 52′ 30″ W

PROBLEM NO. 2

Jan. 30, 1919, A. M. Obs. Alt. *Vega 43° 57′, bearing E. Dip 36 ft. Chron. read 0h 56′ 00″ P. M., fast 34′ 25″. Lat. 28° 27′ N. Long. by D. R. 90° 30′ W.

Chron.	0h 56′ 00″	Dec.	38° 42′ 18″ N
Fast	− 34′ 25″		90° 00′ 00″
G. M. T. 30d	0h 21′ 35″	P. D.	51° 17′ 42″
R. A. M. S.	20h 34′ 41″		
Corr.	03″		
G. S. T. 30d	20h 56′ 19″		

Obs. Alt.	43° 57′ 00″		
Dip	− 5′ 53″		
	43° 51′ 07″		
Ref.	− 1′ 01″		
h	43° 50′ 06″		
Lat.	28° 27′ 00″	Sec	.05590
P. D.	51° 17′ 42″	Csc	.10784
	2)123° 34′ 48″		
s	61° 47′ 24″	Cos	9.67477
s−h	17° 57′ 18″	Sin	9.48893
		Log. Hav.	9.32744

*R. A.	18h 34′ 11″	
*H. A.	3h 39′ 37″ E or−	
L. S. T.	14h 54′ 34″	
G. S. T.	20h 56′ 19″	
Long.	6h 01′ 45″	or 90° 26′ 15″ W

PROBLEM NO. 3

June 12, 1919, P. M. Obs. Alt. *Regulus 26° 18′ 32″, bearing West. Dip 17 ft. Chron. read 2h 02′ 12″ P. M., fast 14′ 8″. Lat. 37° 18′ N. Long. by D. R. 110° E.

Chron.	2h 02′ 12″	Dec.	12° 21′.6 N
Fast.	− 14′ 08″		90° 00′.0
G. M. T.	1h 48′ 04″	P. D.	77° 38′.4
R. A. M. S.	5h 19′ 03″		
Corr.	18″		
G. S. T.	7h 07′ 25″		

Obs. Alt.	26° 18′ 32″		
Dip	− 4′ 02″		
	26° 14′ 30″		
Ref.	− 1′ 58″		
h	26° 12′ 32″		
Lat.	37° 18′ 00″	Sec	.09937
P. D.	77° 38′ 24″	Csc	.01019
	2)141° 08′ 56″		
s	70° 34′ 28″	Cos	9.52190
s−h	44° 21′ 56″	Sin	9.84462
		Log. Hav.	9.47608

*R. A.	10h 04′ 05″
*H. A.	4h 25′ 20″
L. S. T.	14h 29′ 25″
G. S. T.	7h 07′ 25″
Long.	7h 22′ 00″ or 110° 30′ 00″ E.

PROBLEM NO. 4

Mar. 11, 1919, A. M. Obs. Alt. *Antares 28° 16′ 15″, bearing W. Dip 21 ft. Chron. read 8h 16′ 23″ P. M., slow 32′ 18″. Lat. 22° 18′ S. Long. by D. R. 166° 10′ W.

Chron.	8h 16′ 23″	Dec.	26° 15′.2 S
Slow	+ 32′ 18″		90° 00′.0
G. M. T.	8h 48′ 41″	P. D.	63° 44′.8
R. A. M. S.	23h 12′ 23″		
Corr.	1′ 27″		
G. S. T.	32h 02′ 31″		

Obs. Alt.	28° 16′ 15″		
Dip	− 4′ 29″		
	28° 11′ 46″		
Ref.	− 1′ 48″		
h	28° 09′ 58″		
Lat.	22° 18′ 00″	Sec	.03376
P. D.	63° 44′ 48″	Csc	.04728
	2)114° 12′ 46″		
s	57° 06′ 23″	Cos	9.73486
s−h	28° 56′ 25″	Sin	9.68476
		Log. Hav.	9.50066

*R. A.	16h 24′ 28″	
*H. A.	4h 33′ 59″	
L. S. T.	20h 58′ 27″	
G. S. T.	32h 02′ 31″	
Long.	11h 04′ 04″	or 166° 01′ 00″ W

PROBLEM NO. 5

Dec. 16, 1919, P. M. Obs. Alt. *Capella 31° 17′ 12″, bearing E. Dip 19 ft. Chron. read 10h 12′ 16″ P. M., slow 8′ 03″. Lat. 6° 48′ N. Long. by D. R. 33° 15′ W.

Chron.	10h 12′ 16″	Dec.	45° 55′
Slow	+ 8′ 03″		90° 00′
G. M. T.	10h 20′ 19″	P. D.	44° 05′
R. A. M. S.	17h 36′ 19″		
Corr.	1′ 42″		
G. S. T.	27h 58′ 20″		

Obs. Alt.	31° 17′ 12″		
Dip	− 4′ 16″		
	31° 12′ 56″		
Ref.	− 1′ 36″		
h	31° 11′ 20″		
Lat.	6° 48′ 00″	Sec	.00307
P. D.	44° 05′ 00″	Csc	.15758
	2)82° 04′ 20″		
s	41° 02′ 10″	Cos	9.87765
s−h	9° 50′ 50″	Sin	9.23307
		Log. Hav.	9.27137

*R. A.	5h 10′ 50″	
*H. A.	3h 24′ 52″	
L. S. T.	1h 45′ 58″	
G. S. T.	3h 58′ 20″	
Long.	2h 12′ 22″	or 33° 05′ 30″ W.

PROBLEM NO. 6

Apr. 16, 1919, P. M. Obs. Alt. *Aldebaran 23° 13′ 20″, bearing W. Dip 26 ft. Chron. read 7h 01′ 35″ P. M., fast 2′ 27″. Index error −2′ 00′. Lat. 11° 47′ S. Long. by D. R. 0° 05′ E.

Chron.	7h 01′ 35″	Dec.	16° 20′.8
Fast	− 2′ 27″		90° 00′.0
G. M. T.	6h 59′ 08″	P. D.	106° 20′.8
R. A. M. S.	1h 34′ 19″		
Corr.	1′ 09″		
G. S. T.	8h 34′ 36″		

Obs. Alt.	23° 13′ 20″		
I. E.	− 2′ 00″		
	23° 11′ 20″		
Dip	− 5′ 00″		
	23° 06′ 20″		
Ref.	− 2′ 15″		
h	23° 04′ 05″		
Lat.	11° 47′ 00″	Sec	.00925
P. D.	106° 20′ 48″	Csc	.01792
	2)141° 11′ 53″		
s	70° 35′ 56″	Cos	9.52138
s−h	47° 31′ 51″	Sin	9.86785
		Log. Hav.	9.41640

*R. A.	4h 31′ 17″
*H. A.	4h 05′ 42″
L. S. T.	8h 36′ 59″
G. S. T.	8h 34′ 36″
Long.	2′ 23″ or 0° 35′ 45″ E

PROBLEM NO. 7

Dec. 1, 1919, P. M. Obs. Alt. *Capella 31° 17′ 12″, bearing E. Dip 19 ft. Chron. read 9h 18′ 16″ P. M., slow 8′ 03″. Lat. 6° 48″ N. Long. by D. R. 5° W.

Chron.	9h 18′ 16″	Dec.	45° 55′
Slow	+ 8′ 03″		90° 00′
G. M. T.	9h 26′ 19″	P. D.	44° 05′
R. A. M. S.	16h 37′ 10″		
Corr	1′ 33″		
G. S. T.	26h 05′ 02″		

Obs. Alt.	31° 17′ 12″		
Dip	− 4′ 16″		
	31° 12′ 56″		
Ref.	− 1′ 36″		
h	31° 11′ 20″		
Lat.	6° 48′ 00″	Sec	.00307
P. D.	44° 05′ 00″	Csc	.15758
	2)82° 04′ 20″		
s	41° 02′ 10″	Cos	9.87754
s−h	9° 50′ 50″	Sin	9.23307
		Log. Hav.	9.27126

*R. A.	5h 10′ 49″
*H. A.	3h 24′ 50″
L. S. T.	1h 45′ 59″
G. S. T.	2h 05′ 02″
Long.	19′ 03″ or 4° 45′ 45″ E

PROBLEM NO. 8

Feb. 15, 1919, A. M. Obs. Alt. *Spica 48° 10′, bearing W. Dip 26 ft. Chron. read 1h 14′ 35″, P. M., which was fast on Jan. 11, 31′ 34″, and gaining 9″ daily. Lat. 25° 53′ N. Long. by D. R. 112° 45′ W.

Chron.	1h 14′ 35″	Interval	35 days
Fast	− 31′ 34″	Rate	9″ daily
	0h 43′ 01″		315″ = 5′ 15″
Acc. Rate	− 5′ 15″		
		Dec.	10° 44′.5 S
G. M. T.	0h 37′ 46″		90° 00′.0
R. A. M. S.	21h 37′ 46″		
Corr.	06″	P. D.	100° 44′.5
G. S. T.	22h 15′ 38″		

Obs. Alt.	48° 10′ 00″		
Dip	− 5′ 00″		
	48° 05′ 00″		
Ref.	− 0′ 47″		
h	48° 04′ 13″		
Lat.	25° 53′ 00″	Sec	.04591
P. D.	100° 44′ 30″	Csc	.00768
	2)174° 41′ 43″		
s	87° 20′ 52″	Cos	8.66535
s−h	39° 16′ 39″	Sin	9.80146
		Log. Hav.	8.52040

*R. A.	13h 20′ 58″	
*H. A.	1h 23′ 55″	
L. S. T.	14h 44′ 53″	
G. S. T.	22h 15′ 38″	
Long.	7h 30′ 45″	or 112° 41′ 15″ W

PROBLEM NO. 9

Mar. 20, 1918, P. M. Obs. Alt. *Betelgeux 32° 17′ 30″, bearing E. Dip 26 ft. Chron. read 13h 16′ 23″, fast 3′ 46″. Lat. 32° 17′ N. Long. by D. R. 164° 30′ W.

Chron	13h 16′ 23″	Dec.	7° 23′.4 N
Fast	− 3′ 46″		90° 00′.0
G. M. T.	13h 12′ 37″	P. D.	82° 36′.6
R. A. M. S.	23h 47′ 52″		
Corr.	2′ 10″		
G. S. T.	37h 02′ 39″		

Obs. Alt.	32° 17′ 30″		
Dip	− 5′ 00″		
	32° 12′ 30″		
Ref.	− 1′ 28″		
h	32° 11′ 02″		
Lat.	32° 17′ 00″	Sec	.07293
P. D.	82° 36′ 36″	Csc	.00362
	2)147° 04′ 38″		
s	73° 32′ 19″	Cos	9.45235
s−h	41° 21′ 17″	Sin	9.82002
		Log. Hav.	9.34892

*R. A.	5h 50′ 49″
*H. A.	3h 45′ 36″
L. S. T.	2h 05′ 13″
G. S. T.	13h 02′ 39″
Long.	10h 57′ 26″ or 164° 21′ 30″ W

PROBLEM NO. 10

Feb. 16, 1919, P. M. Obs. Alt. *Rigel 24° 18′, bearing W. Index error +2′ 12″. Dip 24 ft. Chron. read 11h 16′ 28″ P. M., which was fast on Jan. 10, 14′ 12″ and gaining 2″.8 daily. Lat. 16° 46′ N. Long. by D. R. 7° 45′ E.

Chron.	11h 16′ 28″	Interval	37.5 days
Fast	− 14′ 12″		2″.8 rate
	11h 02′ 16″		105″ = 1′ 45″
Acc. Rate	− 1′ 45″		
		Dec.	8° 17′.8 S
G. M. T.	11h 00′ 31″		90° 00′.0
R. A. M. S.	21h 41′ 43″		
Corr.	1′ 48″	P. D.	98° 17′.8
G. S. T.	32h 44′ 02″		

Obs. Alt.	24° 18′ 00″		
I. E.	+ 2′ 12″		
	24° 20′ 12″		
Dip	− 4′ 48″		
	24° 15′ 24″		
Ref.	− 2′ 09″		
h	24° 13′ 15″		
Lat.	16° 46′ 00″	Sec	.01887
P. D.	98° 17′ 48″	Csc	.00457
	2)139° 17′ 03″		
s	69° 38′ 31″	Cos	9.54144
s−h	45° 25′ 17″	Sin	9.85262
		Log. Hav.	9.41750

*R. A.	5h 10′ 41″	
*H. A.	4h 06′ 03″	
*L. S. T.	9h 16′ 44″	
G. S. T.	8h 44′ 02″	
Long.	32′ 42″	or 8° 10′ 30″ E

LONGITUDE BY PLANET

This problem is worked in the same manner as longitude by fixed star, with the exception that the planet's declination and right ascension must be corrected for the Greenwich date and time.

After finding G. M. T. take out planet's declination and right ascension for Greenwich date, and correct it from Table IV (Almanac) same as was done in latitude by planet.

Correct the altitude for index error, dip, parallax and refraction.

After making these corrections the balance of the problem will be worked in the same manner as longitude by fixed star.

PROBLEM NO. 1

Jan. 31, 1919, A. M. Obs. Alt. Planet Mars 18° 55′, bearing E. Dip 36 ft. Chron. read 1h 11′ 13″ P. M., fast 34′ 34″. Lat. 25° 53′ N. Required longitude?

Chron.	1h 11′ 13″	*Dec.	11° 16′ S
Fast	− 34′ 34″	Corr. Table IV—N. A. For 36′	0′
G. M. T. 31d	0h 36′ 39″		
R. A. M. S.	20h 38′ 38″	Decl.	11° 16′
Corr.	6″		90° 00′
G. S. T.	21h 15′ 23″	P. D	101° 16′

Obs. Alt.	18° 55′ 00″		
Dip	− 5′ 53″		
	18° 49′ 07″		
Parallax	+ 04″		
	18° 49′ 11″		
Ref.	− 2′ 49″		
h	18° 46′ 22″		
Lat.	25° 53′ 00	Sec	.04591
P. D.	101° 16′ 00″	Csc	.00845
	2)145° 55′ 22″		
s	72° 57′ 41″	Cos	9.46689
s−h	54° 11′ 19″	Sin	9.90899
		Log. Hav.	9.43024
*R. A.	22h 21′ 54″		
Corr. (Table IV)	0″		
Corr. R. A.	22h 21′ 54″		
H. A.	4h 10′ 05″	E or−	
L. S. T.	18h 11′ 49″		
G. S. T.	21h 15′ 23″		
Long.	3h 03′ 34″ or 45° 53′ 30″ W		

PROBLEM NO. 2

July 6, 1919, A. M. Obs. Alt. Planet Saturn 30° 16′ 28″, bearing E. Dip 16 ft. Chron. read 4h 16′ 28″, P. M., fast 3′ 28″. Lat. 27° 18′ N.

Chron.	4h 16′ 28″	*Dec. 6d	14° 16′.6 N
Fast	3′ 28″	Corr. 4.2h (Table IV)	0′.4
G. M. T.	4h 13′ 00″	Dec. 6d 4.2h	14° 16′.2 N
R. A. M. S.	6h 53′ 40″		90° 00′.0
Corr.	41″		
		P. D.	75° 43′.8
G. S. T.	11h 07′ 21″		

Obs. Alt.	30° 16′ 28″		
Dip	− 3′ 55″		
	30° 12′ 33″		
Par.	0″		
	30° 12′ 33″		
Ref.	− 1′ 40″		
h	30° 10′ 53″		
Lat.	27° 18′ 00″	Sec	0.05129
P. D.	75° 43′ 48″	Csc	0.01361
	2)133° 12′ 41″		
s	66° 36′ 20″	Cos	9.59885
s−h	36° 25′ 27″	Sin	9.77361
		Log. Hav.	9.43736
*R. A.	9h 53′ 36″		
Corr. (Table IV—N. A.) +	4″		
Corr. R. A.	9h 53′ 40″		
H. A.	4h 12′ 23″ E or−		
L. S. T.	5h 41′ 17″		
G. S. T.	11h 07′ 21″		
Long.	5h 26′ 04″ or 81° 31′ 00″ W		

CHAPTER XVIII

LATITUDE BY MERIDIAN ALTITUDE OF MOON

This problem is useful to find the latitude when the moon is on the meridian in daylight, but at night cannot be depended upon on account of the sea horizon not being clear enough for proper altitude.

The time of the Moon's Meridian Passage for Greenwich is given on Pages 76–77 (Nautical Almanac) and the difference between transit in small figures. By entering Table IV (Almanac) with difference of transit at top of page, and longitude in time at right-hand side, will give the correction to be applied to Greenwich transit, to find the time of Moon's Meridian Passage at ship.

In west longitude it is to be applied forward.

In east longitude it is to be applied backward.

Correct the chronometer and find the Greenwich date and time.

The Moon's declination changes very fast, and the Nautical Almanac gives the declination for every 2 hours of the day, and the difference in small figures between the even hours.

Take out declination for Greenwich date and closest hour, and the difference in small figures.

Enter Table IV (Almanac) with difference at top of page, and number of minutes past the hour in the left-hand column, and read the correction for declination in its proper column.

Apply this correction to declination as follows:

Declination decreasing, subtract.

Declination increasing, add.

Result will be true declination.

Take out the Moon's S. D. (Semi-Diameter) and H. P. (Horizontal Parallax) from almanac opposite the hour used.

Put down the observed meridian altitude and apply the S. D. Add for Lower, and subtract for Upper Limb.

Subtract the Dip (Table 14).

Enter Table 24 (Bowditch) with H. P. at top of page, and apparent altitude at side, and read correction in proper column.

This correction will be the Parallax and Refraction, always to be added to Altitude.

This will give the true altitude.

Subtract true altitude from 90°, find zenith distance, and apply declination as in previous examples for latitude.

Result will be latitude.

LATITUDE BY MOON

PROBLEM NO. 1

Feb. 12, 1919. Obs. Mer. Alt. Moon's L. L. 28° 14′ 00″ S. Dip 28 ft. Chronometer read 4h 16′ 28″ P. M.

G. M. T. 12d 4h 16′ 28″

Dec. 12d 4h		17° 41′.5 N decreasing
Corr for 16′.5		2′.2
Dec. 12d 4h 16′.5		17° 39′.3 N
S. D. 15′.6	Horizontal parallax	57′.3
Obs. Alt.		28° 14′ 00″
S. D.	+	15′ 36″
		28° 29′ 36″
Dip	−	5′ 11″
		28° 24′ 25″
Par. and Ref. (Table 24)	+	49′ 00″
True Alt.		29° 13′ 25″ S
		90° 00′ 00″
Z. D.		60° 46′ 35″ N
Dec.		17° 39′ 18″ N
Lat.		78° 25′ 53″ N

PROBLEM NO. 2

Mar. 18, 1919. Obs. Mer. Alt. Moon's L. L. 68° 21′ 00″ N. Dip. 26 ft. Chronometer read 6h 18′ 28″ A. M.

G. M. T. 17d 18h 18′ 28″

Dec. 17d 18h		9° 19′.7 S increasing
Corr. for 18′.5		3′.1
Dec. for 17d 18h 18′.5		9° 22′.8 S
S. D. 14′.8	H. P.	54′.4
Obs. Alt.		68° 21′ 00″
S. D.	+	14′ 48″
		68° 35′ 48″
Dip	−	5′ 00″
		68° 30′ 48″
Par. and Ref.	+	19′ 34″
True Alt.		68° 50′ 22″ N
		90° 00′ 00″
Z. D.		21° 09′ 38″ S
Dec.		9° 22′ 48″ S
Lat.		30° 32′ 26″ S

PROBLEM NO. 3

July 4, 1919. Obs. Mer. Alt. Moon's L. L. 24° 18′ 30″ S. Dip 26 ft. Chronometer read 3h 12′ 18″ P. M., slow 4′ 18″.

Chron.		3h 12′ 18″
Slow	+	4′ 18″
G. M. T. 4d		3h 16′ 36″
Dec. 4d 2h		6° 09′.7 S increasing
Corr. 1h 16′		13′.6
Dec. 4d 3h 16′		6° 23′.3 S
S. D. 15′.0	H. P.	55′
Obs. Alt.		24° 18′ 30″
S. D.	+	15′ 00″
		24° 33′ 30″
Dip	−	5′ 00″
		24° 28′ 30″
Par. and Ref.	+	47′ 58″
True Alt.		25° 16′ 28″ S
		90° 00′ 00″
Z. D.		64° 43′ 32″ N
Dec.		6° 23′ 18″ S
Lat.		58° 20′ 14″ N

PROBLEM NO. 4

May 21, 1919. Obs. Mer. Alt. Moon's L. L. 82° 10′ 13″ S. Dip 26 ft. Chronometer read 10h 18′ 26″ A. M., slow 4′ 18″.

Chron.		22h 18′ 26″
Slow	+	4′ 18″
G. M. T. 20d		22h 22′ 44″
Dec. 20d 22h		12° 47′.2 S decreasing
Corr. 23′		3′.7
Dec. 20d 22h 23′		12° 43′.5 S
S. D. 15′.4	H. P.	56′.5
Obs. Alt.		82° 10′ 13″ S
S. D.	+	15′ 24″
		82° 25′ 37″
Dip	−	5′ 00″
		82° 20′ 37″
Par and Ref.	+	7′ 24″
True Alt.		82° 28′ 01″ S
		90° 00′ 00″
Z. D.		7° 31′ 59″ N
Dec.		12° 43′ 30″ S
Lat.		5° 11′ 31″ S

PROBLEM NO. 5

Apr. 18, 1919. Obs. Mer. Alt. Moon's L. L. 46° 58′ 12″ N. Dip 28 ft. Chronometer read 6h 18′ 16″ P. M., slow 48′ 12″.

Chron.		6h 18′ 16″
Slow	+	48′ 12″
G. M. T. 18d		7h 06′ 28″
Dec. 18d 6h		21° 01′.2 S increasing
Corr. 1h 06′		2′.8
Dec. 18d 7h 06′		21° 04′.0 S
S. D. 14′.8	H. P.	54′.2
Obs. Alt.		46° 58′ 12″ N
S. D.	+	14′ 48″
		47° 13′ 00″
Dip	−	5′ 11″
		47° 07′ 49″
Par. and Ref.	+	35′ 59″
True Alt.		47° 43′ 48″
		90° 00′ 00″
Z. D.		42° 16′ 12″ S
Dec.		21° 04′ 00″ S
Lat.		63° 20′ 12″ S

PROBLEM NO. 6

Dec. 6, 1919. Obs. Mer. Alt. Moon's L. L. 82° 28′ 36″ S. Dip 18 ft. Chronometer read 2h 16′ 28″ A. M., fast 34′ 18″.

Chron.		14h 16′ 28″
Fast		− 34′ 18″
G. M. T. 5d		13h 42′ 10″
Dec 5d 12h		18° 38′.1 N increasing
Corr. 1h 42′		10′.5
Dec. 5d 13h 42′		18° 48′.6 N
S. D. 16′.7	H. P.	61′.2
Obs. Alt.		82° 28′ 36″
S. D.		+ 16′ 42″
		82° 45′ 18″
Dip		− 4′ 09″
		82° 41′ 09″
Par. and Ref.		7′ 41″
True Alt.		82° 48′ 50″ S
		90° 00′ 00″
Z. D.		7° 11′ 10″ N
Dec.		18° 48′ 36″ N
Lat.		25° 59′ 46″ N

TIME OF MOON'S MERIDIAN PASSAGE

PROBLEM NO. 1

Jan. 28, 1919. Find Meridian Passage of Moon in Long. 84° 24′ W.

Long. in time 5h 37′ 36″			
Moon's Transit (N. A.)	28d	22h 00′	Diff. 52
Corr. Table IV	W or +	12′	
Mer. Passage		22h 12′ or	
		10h 12′ A. M.	

PROBLEM NO. 2

Feb. 7, 1919. Find Meridian Passage of Moon in Long. 128° 14′ E.

Long. in Time 8h 32′ 56″			
Moon's Transit	7d	5h 50′	Diff. 57
Corr. Table IV	E or −	21′	
Mer. Passage		5h 29′ P. M.	

PROBLEM NO. 3

Mar. 10, 1919. Find Meridian Passage of Moon in Long. 178° 23′ W.

Long. in Time 11h 53′ 32″			
Moon's Transit	10d	7h 34′	Diff. 53
Corr. Table IV	W or +	27′	
Mer. Passage		8h 01′ P. M.	

PROBLEM NO. 4

Apr. 8, 1919. Find Meridian Passage of Moon in Long. 8° 16′ E.

Long. in Time 33′ 04″			
Moon's Transit	8d	7h 15′	Diff. 48
Corr. Table IV	E or −	1′	
Mer. Passage		7h 14′ P. M.	

PROBLEM NO. 5

June 16, 1919. Find Meridian Passage of Moon in Long. 110° 18′ W.

Long. in Time 7h 21′ 12″			
Moon's Transit	16d	14h 44′	Diff. 48
Corr. Table IV	W or +	14′	
Mer. Passage		14h 58′	or
		2h 58′	A. M.

PROBLEM NO. 6

July 11, 1919. Find Meridian Passage of Moon in Long. 156° E.

Long. in Time 10h 24′			
Moon's Transit	11d	11h 00′	Diff. 51
Corr. Table IV	E or –	22′	
Mer. Passage		10h 38′	P. M.

CHAPTER XIX

LONGITUDE BY SUNRISE AND SUNSET OBSERVATIONS

This problem is to find the longitude when the Sun's upper or lower limb just touches the horizon at sunrise or sunset.

It is only necessary to use a pair of marine glasses for this observation, and the chronometer must be read at instant of contact with horizon.

As it is very doubtful that a proper contact with sun and horizon has been noted, this observation is not to be relied upon, but the navigator should understand it, as it is often the case that he does not get any sights during the day and the sun sets in the clear. He can then get a fairly good idea of his longitude from this problem.

Correct chronometer and find G. M. T.

Take out declination and equation of time for Greenwich date and time.

Find G. A. T. and polar distance as before.

Add together latitude and polar distance.

Subtract 21′ from this sum if lower limb was observed.

Subtract 53′ from this sum if upper limb was observed.

Divide result by 2. Answer will be half sum.

Add 21′ to half sum if lower limb was observed.

Add 53′ to half sum if upper limb was observed.

Result will be remainder.

From Table 44 (Bowditch) take out following logs.:

Secant of latitude. Rejecting 10 from index number.

Cosecant of polar distance. Rejecting 10 from index number.

Cosine of half sum.

Sine of remainder.

Add these four logs. together, and subtract 10 from index number.

Log. haversine that agrees with sum of logs., will be L. A. T.

If the sun was rising look from bottom of page, and date one day back.

If sun was setting look from top of page, and date same as example.

Apply L. A. T. to G. A. T. as in previous methods for longitude, and obtain the longitude of the place.

These problems in this book will be given with the longitude by D. R. and the chronometer time as it reads from the chronometer. The student must ascertain for himself whether the chronometer time is A. M. or P. M.

Since at low altitude refraction is very indeterminate, this method gives only an approximate longitude.

Taking corrected altitude as −21′ and −53′ respectively, really assumes that there is no dip. If the observation were taken very much above sea level it would be better to make further correction for this by adding the correction found in Table 14.

PROBLEM NO. 1

Jan. 11, 1919, Sun's L. L. at sunset observed. Chron. read 11h 03′ 12″ which was slow on Dec. 6th, 15′ 28″ and gaining 4″.7 daily. D. R. Lat. 18° 14′ N. D. R. Long. 96° E.

Chron.	23h 03′ 12″	Interval	36 days
Slow	+ 15′ 28″	Rate	4″.7
	23h 18′ 40″		169″ = 2′ 49″ acc. rate
Acc. Rate	− 2′ 49″		
		Dec. 10d 22h	21° 56′.2 S
G. M. T. 10d	23h 15′ 51″	Corr. −	0′.5
Eq. Time	− 7′ 45″		
		Dec.	21° 55′.7 S
G. A. T. 10d	23h 08′ 06″		90° 00′.0
		P. D.	111° 55′.7

Lat.	18° 14′	Sec	.02237
P. D.	111° 55′ 42″	Csc	.03261
	130° 09′ 42″		
	− 21′		
	2)129° 48′ 42″		
s	64° 54′ 21″	Cos	9.62748
	+ 21′		
Rem.	65° 15′ 21″	Sin	9.95812
		Log. Hav.	9.64058

L. A. T. 11d	5h 31′ 06″
G. A. T. 10d	23h 08′ 06″
Long.	6h 23′ 00″ or 95° 45′ E

PROBLEM NO. 2

Feb. 23, 1919, Sun's upper limb at sunset observed. Chron. read 11h 18′ 26″ which was slow on Jan. 10th, 58′ 12″ and loses 7″.2 daily. D. R. Lat. 29° 28′ N. Long. 96° 50′ W.

Chron.	11h 18′ 26″	Interval	44.5 days
Slow	+ 58′ 12″	Rate	7″.2
	12h 16′ 38″		320″ = 5′ 20″ acc. rate
Acc. Rate	+ 5′ 20″		
		Dec. 23d 12h	9° 55′.6 S
G. M. T. 23d	12h 21′ 58″	Corr. .4h	0′.4
Eq. Time	− 13′ 33″		
		Dec.	9° 55′.2
G. A. T. 23d	12h 08′ 25″		90° 00′.0
		P. D.	99° 55′.2

Lat.	29° 28′	Sec	.06016
P. D.	99° 55′ 12″	Csc	.00654
	129° 23′ 12″		
	− 53′		
	2)128° 30′ 12″		
s	64° 15′ 06″	Cos	9.63791
	+ 53′		
Rem.	65° 08′ 06″	Sin	9.95775
		Log. Hav.	9.66236

L. A. T. 23d	5h 41′ 27″
G. A. T. 23d	12h 08′ 25″
Long.	6h 26′ 58″ or 96° 44′ 30″ W

CHAPTER XX

PHEE PRIME SIGHT FOR LATITUDE

This is only good when sun or star is within three hours of the meridian, and declination is greater than 3°.

The D. R. longitude when sight is taken as well as the chronometer time are necessary. From the chronometer time (G. M. T.) by applying the equation of time and longitude the local apparent time is found. The hour angle or time before or after local apparent noon is then known and changed into degrees.

The declination is found from the Nautical Almanac for the G. M. T. of sight.

The altitude is corrected in the usual manner.

By adding the log. sec. of the hour angle to the log. tan. of the declination; the log. tan. of an angle named ϕ'' is found.

Adding the log. csc. of the declination, the log. sin. of the corrected altitude and the sin. of the angle ϕ'', the cos. of an angle called ϕ' is found.

ϕ'' is same name N or S as declination.

ϕ' is same name as Z. D. or opposite from bearing.

If both same name latitude is the sum of the two angles and of same name.

If of different names latitude is the difference and takes name of larger.

PROBLEM NO. 1

Jan. 31, 1919. D. R. position 9° 10′ S, 46° 15′ W. Chron. time 5h 16′ 13″. Obs. Alt. Sun's L. L. 60° 10′ 20″, bearing S×W. Dip 36′.

G. M. T. 31d	5h 16′ 13″	Obs. Alt.	60° 10′ 20″
Eq. Time	− 13′ 31″	Corr.	+ 9′ 54″
G. A. T.	5h 02′ 42″	Corr. Alt.	60° 20′ 14″
Long.	3h 05′ 00″		
		Dec. 31d 4h	17° 32′.8 S
L. A. T. 31d	1h 57′ 42″	Corr. 1.3h	− 0′.9
		Dec. 31d 5.3h	17° 31′.9 S

H. A.	29° 25′ 30″	Sec	.05999		
Dec.	17° 31′ 54″	Tan	9.49956	Csc	.52110
h	60° 20′ 14″			Sin	9.93900
φ″	19° 56′ 09″ S	Tan	9.55955	Sin	9.53271
φ′	10° 24′ 00″ N			Cos	9.99281
Lat.	= 9° 32′ 09″ S				

PROBLEM NO. 2

July 5, 1919, A. M., at ship. D. R. position 27° 00′ S, 64° 50′ E. Chron. Time July 4, 18h 32′ 14″. Obs. Alt. 37° 10′, bearing N×E. Dip 36 ft.

G. M. T. 4d	18h 32′ 14″	Obs. Alt	37° 10′ 00″
Eq. Time	− 4′ 09″	Corr.	+ 8′ 43″
G. A. T. 4d	18h 28′ 05″	True Alt.	37° 18′ 43″
Long.	4h 19′ 20″		
		Dec. for 4d 18h	22° 53′.5 N
L. A. T. 4d	22h 47′ 25″	Corr. .5h	0′.1
H. A.	= 1h 12′ 35″ or		
	18° 08′ 45″	Dec. for 4d 18.5h	22° 53′.4 N

H.A.	18° 08′ 45″	Sec	.02215		
Dec.	22° 53′ 24″	Tan	9.62553	Csc	.41009
h	37° 18′ 43″			Sin	9.78256
φ″	23° 57′ 20″ N	Tan	9.64768	Sin	9.60856
φ′	50° 44′ 56″ S			Cos	9.80121
Lat.	26° 47′ 36″ S				

PROBLEM NO. 3

Aug. 8, 1919, A. M. at ship. D. R. position 49° 40′ N, 178° 12′ E. Chron. time 10h 04′ 03″. Obs. Alt. 47° 16′ 20″, bearing S×E. Dip 36 ft.

G. M. T. 7d	10h 04′ 03″	Obs. Alt.	47° 16′ 20″
Eq. Time	− 5′ 41″	Corr. (46)	+ 9′ 09″
G. A. T.	9h 58′ 22″	True Alt.	47° 25′ 29″
Long.	11h 52′ 48″		
		Dec. for 7d 10h	16° 32′.4 N
L. A. T. 7d	21h 51′ 10″	Corr. for .1h	− 0′.1
H. A.	= 2h 08′ 50″ or		
	32° 12′ 30″	Corr. for 7d 10.1h	16° 32′.3 N

H. A.	32° 12′ 30″	Sec	.07257		
Dec.	16° 32′ 18″	Tan	9.47267	Csc	.54594
h	47° 25′ 29″			Sin	9.86711
φ″	19° 20′ 18″ N	Tan	9.54524	Sin	9.52002
φ′	31° 00′ 00″ N				
				Cos	9.93307
Lat.	50° 20′ 18″ N				

CHAPTER XXI

SUMNER'S METHOD

This method of finding the ship's position by Sumner lines is most generally used when a ship has been running several days without observations, and the dead reckoning position is doubtful.

There are various methods used in plotting Sumner lines, but the most accurate of these, and one that can be easily proved to be correct, is the method of using two assumed latitudes.

Proceed as follows:

Take an observation of sun or star, and find the longitude of two places by working this observation with the 2 assumed latitudes (a separate calculation with each latitude).

After obtaining the two positions, place them on the chart and connect them together with a line. This will give the first line of bearing, and the ship must be somewhere on this line if observation was correct. This line will be at right angles to sun's true bearing, and can be proved by entering azimuth table and obtaining true bearing at time of observation.

After the sun has changed its bearing about 20° take another observation, and find the longitude of two places, using the same assumed latitudes that were used to work first observation.

Place the two positions found on chart and connect them together with a line. This will give second line of bearing, which can be proved by azimuth table as before.

From first line of bearing allow the course and distance the ship has run in the interval between the two observations and draw a line parallel to the first line through the position found after course and distance has been allowed. This will be known as the first line of bearing projected.

Where the projection of the first line crosses the second line of bearing, will be ship's position at time of second observation.

This problem is accurate if no mistake has been made in allowing the proper course and distance between observations, and the observed altitude of each is correct.

The assumed latitudes are generally reckoned 30 miles on each side of latitude by dead reckoning.

PROBLEM NO. 1 (See Illustration)

Dec. 16, 1919, A. M. at ship. When not sure of ship's position and Obs. Alt. of Sun's L. L. read 8° 16′ 40″. Dip 31 ft. Chron. read 11h 18′ 12″ A. M., which was fast on Nov. 6th, 8′ 48″ and losing 8″.2 daily. Same day later in A. M. the Obs. Alt. Sun's L. L. was 18° 16′ 40″. Chron. read 0h 43′ 15″ P. M.

Ship was assumed to be between lats. of 40° and 41° N. Ship run between observations N 56° W (true) 46 miles.

First Observation

Chron.	23h 18′ 12″	Interval	40 days	
Fast	− 8′ 48″	Rate	8.″2	
	23h 09′ 24″		328″ = 5′ 28″ acc. rate	
Acc. Rate	+ 5′ 28″		23° 17′.1 S	
		Dec.	90° 00′.0	
G. M. T. 15d	23h 14′ 52″			
Eq. Time	+ 4′ 42″	P. D	113° 17′.1	
G. A. T. 15d	23h 19′ 34″			
Obs. Alt.	8° 16′ 40″			
S. D.	+ 16′ 18″			
	8° 32′ 58″			
Dip	− 5′ 27″			
	8° 27′ 31″			
R. & P.	- 6′ 05″			
True Alt. (h)	8° 21′ 26″			
Lat.	40°	Sec		.11575
P. D.	113° 17′ 06″	Csc		.03690
	2)161° 38′ 32″			
s	80° 49′ 16″	Cos		9.20282
s−h	72° 27′ 50″	Sin		9.97933
		Log. Hav.		9.33480
L. A. T. 15d	20h 18′ 21″			
G. A. T. 15d	23h 19′ 34″			
Long.	3h 01′ 13″	or 45° 18′ 15″ W		

True Alt (h)		8° 21′ 26″		
Lat.		41°	Sec	.12222
P. D.		113° 17′ 06″	Csc	.03690
		2)162° 38′ 32″		
s		81° 19′ 16″	Cos	9.17867
s−h		72° 57′ 50″	Sin	9.98051
			Log. Hav.	9.31830
	L. A. T. 15d	20h 22′ 52″		
	G. A. T. 15d	23h 19′ 34″		
	Long.	2h 56′ 42″ or 44° 10′ 30″ W		

Position for First Line

Lat. 40° N. Long. 45° 18′ 15″ W.
Lat. 41° N. Long. 44° 10′ 30″ W.

Second Observation

Chron.	0h 43′ 15″	Dec.	23° 17′.4 S
Fast	− 8′ 48″		90° 00′.0
	0h 34′ 27″	P. D.	113° 17′.4
Acc. Rate	+ 5′ 28″		
G. M. T. 16d	0h 39′ 55″		
Eq. Time	+ 4′ 40″		
G. A. T. 16d	0h 44′ 35″		

Obs. Alt.	18° 16′ 40″
S. D.	+ 16′ 18″
	18° 32′ 58″
Dip	− 5′ 27″
	18° 27′ 31″
R. & P.	− 2′ 44″

True Alt.		18° 24′ 47″		
Lat.		40°	Sec	.11575
P. D.		113° 17′ 24″	Csc	.03691
		2)171° 42′ 11″		
s		85° 51′ 06″	Cos	8.85938
s−h		67° 26′ 19″	Sin	9.96543
			Log. Hav.	8.97747
	L. A. T. 15d	21h 36′ 26″		
	G. A. T. 16d	0h 44′ 35″		
	Long.	3h 08′ 09″ or 47° 02′ 15″ W		

True Alt. (h)	18° 24′ 47″		
Lat.	41°	Sec	.12222
P. D.	113° 17′ 24″	Csc	.03691
	2)172° 42′ 11″		
s	86° 21′ 06″	Cos	8.80368
s−h	67° 56′ 19″	Sin	9.96698
		Log. Hav.	8.92979

L. A. T. 15d	21h 44′ 20″	
G. A. T. 16d	0h 44′ 35″	
Long.	3h 00′ 15″	or 45° 03′ 45″ W

Positions for Second Line

Lat. 40° N. Long. 47° 02′ 15″ W.
Lat. 41° N. Long. 45° 03′ 45″ W.

CHAPTER XXII

MARCQ ST. HILAIRE METHOD OR COSINE—HAVERSINE FORMULA

This is a new method of plotting position lines on the chart and reduces the amount of figures used in Sumner's method considerably.

The position of the ship by dead reckoning must always be used to work from, and in the case where a course and distance is given in the interval between observations, the latitude and longitude by D. R. must be found for second observation before working problem.

Proceed as follows:

Correct chronometer and find G. M. T.

In case of the sun observed, proceed as follows:

Apply equation of time to G. M. T. and find G. A. T.

Apply longitude in time to G. A. T. as follows:

Longitude east, add.

Longitude west, subtract longitude in time from G. M. T.

Result will be local apparent time.

If L. A. T. is over 12 hours, subtract it from 24 hours and result will be Sun's hour angle.

In case of Moon, Star or Planet proceed as follows:

Apply longitude in time to G. M. T. as before, and obtain local mean time.

Add to L. M. T. the Sun's right ascension from Page 2 (Almanac) and correction from table below on same page for G. M. T.

Result will be local siderial time.

From L. S. T. subtract right ascension of body observed.

Result will be hour angle of body.

In all cases proceed as follows:

Take out declination of body observed.

Correct observed altitude of body observed, and find true altitude.

From Table 45 (Bowditch) take out log. hav. of body's hour angle.

From Table 44 (Bowditch) take out log. cos. of latitude by D. R.

From Table 44 (Bowditch) take out Log. Cosine of Declination.

Add these three logarithms together, and subtract 20 from index Number.

Opposite the Log. Haversine corresponding to sum of logarithms read the natural haversine.

If latitude and declination are same name, subtract less from greater.

If latitude and declination are different name, add the two.

Take out the Nat. Haversine of this result, and add to it the Nat. Haversine obtained already.

Nat. Haversine corresponding to the sum of the two, will be the zenith distance read from top of page (Table 45) in degrees, minutes and seconds.

Subtract zenith distance from 90°. Result will be computed altitude.

Under computed altitude, put down true altitude, and subtract less from greater. Answer will be altitude difference or intercept.

If the true altitude is greater than computed altitude, measure from the dead reckoning position on the line of azimuth toward the body a distance equal to the altitude difference or intercept, and draw the position line through this point at right angles to true bearing.

If true altitude is less than computed altitude measure away from body.

In using the signs, + means toward the body, − means away from body.

Pick out true bearing of body from azimuth table or line of position table, which will explain itself.

If the ship has made any change of position between observations, the true course and distance must be allowed from first to second sight, and a line drawn parallel to the first line on this course and distance crossing the second line, will be the ship's position at time of second observation.

A little practice with this method will convince the student that it is very convenient and simple.

The position lines will be on the same principle as Sumner lines, the only difference between the two being the saving in time and figures for making the calculations.

PROBLEM NO. 1

Dec. 16, 1919, A. M. at ship. Ship's position by D. R. Lat. 40° 27′ N. Long. 44° 40′ W. Obs. Alt. Sun's L. L. 8° 18′ 25″. Chron. read 11h 18′ 28″ A. M. Ship then ran until chron. read 0h 43′ 28″ P. M. on a course N 56° W (true) 46 miles. Obs. Alt. Sun's L. L. 18° 18′ 25″. Chron. was fast on Greenwich time 3′ 20″. Dip 31 ft. First observation, D. R. position 40° 27′ N., 44° 40′ W.

Dec. 16, 1919, A. M.

Chron. 15d		23h 18′ 28″	Dec.	23° 17′ 12″ S
Fast	−	3′ 20″		
			Obs. Alt.	8° 18′ 25″
G. M. T.		23h 15′ 08″	Corr. (46)	+ 4′ 20″
Eq. Time	+	4′ 42″		
			True Alt.	8° 22′ 45″
G. A. T.		23h 19′ 50″		
Long.		2h 58′ 40″	Lat.	40° 27′ 00″
			Dec.	23° 17′ 12″
L. A. T.		20h 21′ 10″		
			Sum	63° 44′ 12″

Log. Hav.	20h 21′ 10″	=9.32455
Log. Cos.	40° 27′	=9.88137
Log. Cos.	23° 17′ 12″	=9.96310
Log. Hav.		9.16902

9.16902=Nat. Hav.	.14758
Nat. Hav. 63° 44′ 12″	.27875
Nat. Hav.	.42633=81° 31′ 30″ Z. D.

		90° 00′ 00″	
Z. D.		81° 31′ 30″	Bearing of Sun N 130° 30′ E (from H. O. 71)
Com. Alt.		8° 28′ 30″	
True Alt.		8° 22′ 45″	
Alt. Diff.	−	5′ 45″	

First Obs. D. R. Lat.	40° 27′ 00″ N	
Course N 56° W, Dist. 46, Diff. Lat.	25′ 42″ N	
Second Obs. D. R. Lat.	40° 52′ 42″ N	
First Obs. D. R. Long.		44° 40′ 00″ W
Dep. 38.1, Mid. Lat. 41°, Diff. Long.		50′ 30″ W
Second Obs. D. R. Long.		45° 30′ 30″ W

Chron.		0h 43′ 28″	Dec. 16d 0h	23° 17′.3 S
Fast	−	3′ 20″	Corr. 0.7h	+ 0′.1 S
G. M. T. 16d		0h 40′ 08″	Dec. 16d 0.7h	23° 17′.4 S
Eq. Time	+	4′ 40″		
G. A. T. 16d		0h 44′ 48″		
Long.		3h 02′ 02″		
L. A. T.		21h 42′ 46″		

Log. Hav. 21h 42′ 46″	8.93948	Obs. Alt.	18° 18′ 25″
Log. Cos. 40° 52′ 42″	9.87858	Corr. (46)	+ 7′ 45″
Log. Cos. 23° 17′ 24″	9.96311	True Alt.	18° 26′ 10″
Log. Hav.	8.78117		
		Lat.	40° 52′ 42″
		Dec.	23° 17′ 24″
		Sum	64° 10′ 06″

Log. Hav. 8.78117 = Nat. Hav.	.06042
Nat. Hav. 64° 10′ 06″	.28213
Nat. Hav.	.34255 = 71° 38′ 30″ Z. D.

	90° 00′ 00″
Z. D.	71° 38′ 30″
Com. Alt.	18° 21′ 30″
True Alt.	18° 26′ 10″
Alt. Diff.	+ 4′ 40″

Bearing of Sun N 146° 54′ E or S 33° E (from H. O. 71).

PROBLEM NO. 2

SIMULTANEOUS OBSERVATION OF TWO FIXED STARS

Apr. 16, 1919, P. M. Position by D. R. Lat. 37° 14′ N. Long. 76° 04′ W.

Chron. read 7h 05′ 45″ P. M. Sirius in the West. Alt. 29° 29′.

Chron. read 7h 07′ 45″ P. M. Capella in the West. Alt. 50° 14′. Chron. was slow 5h 00′ 01″. Dip 41 ft.

	Sirius in the West		
Chron.	7h 05′ 45″	Dec.	16° 36′.6 S
Slow	+ 5h 00′ 01″		
G. M. T. 16d	12h 05′ 46″	Lat.	37° 14′ 00″ N
R. A. M. S.	1h 34′ 19″	Dec.	16° 36′ 36″ S
Corr.	1′ 59″		53° 50′ 36″
G. S. T. 16d	13h 42′ 04″		
Long.	5h 04′ 16″	Obs. Alt.	29° 29′ 00″
L. S. T. 16d	8h 37′ 48″	Corr. (46)	− 8′ 00″
*'s R. A.	6h 41′ 36″	True Alt.	29° 21′ 00″
*'s H. A.	1h 56′ 12″		

Log. Hav.	1h 56′ 12″	=8.79866
Log. Cos.	37° 14′	=9.90101
Log. Cos.	16° 36′ 36″	=9.98149
Log. Hav.		8.68116

Log. Hav. 8.68116 = Nat. Hav.		.04799
Nat. Hav. 53° 50′ 36″		.20499
Nat. Hav.		.25298 = 60° 23′ 30″ Z. D.
	90° 00′ 00″	
Z. D.	60° 23′ 30″	
Comp. Alt.	29° 36′ 30″	
True Alt.	29° 21′ 00″	
Alt. Diff.	− 15′ 30″	Az. S 32° W

Capella in the West

First Chron. Time	7h 05′ 45″	Dec.	45° 55′.1 N
Second Chron. Time	7h 07′ 45″		
Interval	2′	Lat.	37° 14′ 00″ N
First L. S. T.	8h 37′ 48″	Dec.	45° 55′ 06″ N
Second L. S. T.	8h 39′ 48″		8° 41′ 06″
*'s R. A.	5h 10′ 44″		
*'s H. A.	3h 29′ 04″	Obs. Alt.	50° 14′ 00″
		Corr. (46)	− 7′ 06″
Log. Hav. 3h 29′ 04″	=9.28782	True Alt.	50° 06′ 54″
Log. Cos. 37° 14′	=9.90101		
Log. Cos. 45° 55′ 06″	=9.84241		
Log. Hav.	9.03124		

Log. Hav. 9.03124 = Nat. Hav.	.10745
Nat. Hav. 8° 41′ 06″	.00573
Nat. Hav.	.11318 = 39° 19′ 00″ Z. D.

	90° 00′ 00″	
Z. D.	39° 19′ 00″	
Comp. Alt.	50° 41′ 00″	
True Alt.	50° 06′ 54″	
Alt. Diff.	− 34′ 06″	Az. N 59° W

PROBLEM NO. 3

POSITION BY OBSERVATION OF THREE FIXED STARS

Ship stationary between observations.
May 18, 1919, P. M. Position by D. R. Lat. 40° 40′ N. Long. 69° W.
Chron. read 7h 34′ 37″ P. M. Star Polaris. Alt. 39° 42′ 30″.
Chron. read 7h 36′ 58″ P. M. Star Vega in the East. Alt. 16° 23′ 30″.
Chron. read 7h 38′ 55″, P. M. Star Capella in the West. Alt. 22° 48′ 24″.
Chron. slow 4h 59′ 27″. Dip 41 ft.

Polaris

Chron.	7h 34′ 37″	Obs. Alt.	39° 42′ 30″
Slow	+ 4h 59′ 27″	Corr. (46)	− 7′ 26″
G. M. T. 18d	12h 34′ 04″	True Alt.	39° 35′ 04″
Long.	4h 36′	Corr. (I)	+ 59′ 42″
L. M. T. 18d	7h 58′ 04″	Lat.	40° 34′ 46″ N
R. A. M. S.	3h 40′ 29″		
Corr.	2′ 04″		
L. S. T.	11h 40′ 37″	Azimuth 0°	

Vega in the East

First Chron.	7h 34′ 37″	Dec.	38° 42′.4
Second Chron.	7h 36′ 58″		
		Obs. Alt	16° 23′ 30″
Interval	2′ 21″	Corr. (46)	− 9′ 30″
First L. S. T.	11h 40′ 37″		
		True Alt.	16° 14′ 00″
Second L. S. T.	11h 42′ 58″		
*'s R. A.	18h 34′ 14″	Dec.	38° 42′ 24″ N
		Lat.	40° 40′ N
*'s H. A.	6h 51′ 16″		1° 57′ 36″

Log. Hav.	6h 51′ 16″	=9.78598
Log. Cos.	40° 40′	=9.87996
Log. Cos.	38° 42′ 24″	=9.89229
Log. Hav.		9.55823

Log. Hav. 9.55823 = Nat. Hav.	.36159
Nat. Hav. 1° 57′ 36″	.00029
Nat. Hav.	.36188 = 73° 57′ 45″ Z. D.

		90° 00′ 00″
Z. D.		73° 57′ 45″
Comp. Alt.		16° 02′ 15″
True Alt.		16° 14′ 00″
Alt. Diff.	+	11′ 45″

Capella in the West

First Chron.	7h 34′ 37″	Dec.		45° 55′ N
Third Chron.	7h 38′ 55″	Lat.		40° 40′ N
Interval	4′ 18″			5° 15′
First L. S. T.	11h 40′ 37″	Obs. Alt.		22° 48′ 24″
		Corr. (46)	−	8′ 31″
Third L. S. T.	11h 44′ 55″			
*'s R. A.	5h 10′ 43″	True Alt.		22° 39′ 53″
*'s R. A.	6h 34′ 12″			

Log. Hav.	6h 34′ 12″	=9.75917
Log. Cos.	40° 40′	=9.87996
Log. Cos.	45° 55′	=9.84242
Log. Hav.		9.48155

Log. Hav. 9.48155=Nat. Hav.	.30306
Nat. Hav. 5° 15′	.00210
Nat. Hav.	.30516=67° 04′ Z. D.

		90° 00′ 00″	Position of Vessel:	
Z. D.		67° 04′ 00″	Lat.	40° 35′ 30″ N
			Long.	68° 36′ 15″ W
Comp. Alt.		22° 56′ 00″		
True Alt.		22° 39′ 53″		
Alt. Diff.	−	16′ 07″		

PROBLEM NO. 4

POSITION BY OBSERVATION OF FOUR FIXED STARS

Ship stationary during interval of observations.

May 19, 1919, P. M. Ship's position by D. R. Lat. 37° 50′ N. Long. 74° 00′ W.

Chron. read 7h 46′ 47″. Capella in the West. Alt. 22° 08′.
Chron. read 7h 47′ 59″. Vega in the East. Alt. 14° 03′.
Chron. read 7h 50′ 40″. Spica in the East. Alt. 36° 19′.
Chron. read 7h 52′ 16″. Procyon in the West. Alt. 25° 11″
Chron. slow 4h 59′ 24″. Dip 41 ft.

Capella in the West

Chron.	7h 46′ 47″	Dec.	45° 55′
Slow	+ 4h 59′ 24″	Lat.	37° 50′
G. M. T. 19d	12h 46′ 11″		8° 05′
Long.	4h 56′ 00″		
		Obs. Alt.	22° 08′ 00″
L. M. T.	7h 50′ 11″	Corr. (46)	− 8′ 40″
R. A. M. S.	3h 44′ 26″		
Corr.	2′ 06″	True Alt.	21° 59′ 20″
L. S. T.	11h 36′ 43″		
*'s R. A.	5h 10′ 43″		
*'s H. A.	6h 26′ 00″		

Log. Hav. 6h 26′	=9.74554
Log. Cos. 37° 50′	=9.89752
Log. Cos. 45° 55′	=9.84242
Log. Hav.	9.48548
Log. Hav. 9.48548=Nat. Hav.	.30584
Nat. Hav. 8° 05′	.00497
Nat. Hav.	.31081=67° 46′ Z. D.

	90° 00′ 00″	
Z. D.	67° 46′ 00″	
Comp. Alt.	22° 14′ 00″	
True Alt.	21° 59′ 20″	
Alt. Diff.	− 14′ 40″	Azimuth N 48° W

Vega in the East

First Chron.	7h 46′ 47″	Dec.	38° 42′ 24″
Second Chron.	7h 47′ 59″	Lat.	37° 50″
Interval	1′ 12″		0° 52′ 24″
First L. S. T.	11h 36′ 43″		
		Obs. Alt.	14° 03′
Second L. S. T.	11h 37′ 55″	Corr.	− 10′
*'s R. A.	18h 34′ 14″		
		True Alt.	13° 53′
*'s H. A.	6h 56′ 19″		

Log. Hav. 6h 56′ 19″	=9.79353
Log. Cos. 37° 50′	=9.89752
Log. Cos. 38° 42′ 24″	=9.89233
Log. Hav.	9.58338
Log. Hav. 9.58338=Nat. Hav.	.38317
Nat. Hav. 0° 52′ 24″	.00006
Nat. Hav.	.38323=76° 29′ 45″ Z. D.

	90° 00′ 00″		
Z. D.	76° 29′ 45″		
Comp. Alt.	13° 30′ 15″		
True Alt.	13° 53′ 00″		
Alt. Diff.	+ 22′ 45″	Azimuth N 51° E	

Spica in the East

First Chron.	7h 46′ 47″	Dec.	10° 44′ 36″ S
Third Chron.	7h 50′ 40″	Lat.	37° 50′ N
Interval	3′ 53″		48° 34′ 36″
First L. S. T.	11h 36′ 43″		
		Obs. Alt.	36° 19′ 00″
Third L. S. T.	11h 40′ 36″	Corr.	− 7′ 35″
*'s R. A.	13h 20′ 59″		
		True Alt.	36° 11′ 25″
*'s H. A.	1h 40′ 23″		

Log. Hav. 1h 40′ 23″ =8.67394
Log. Cos. 37° 50′ =9.89752
Log. Cos. 10° 44′ 36″ =9.99232

Log. Hav. 8.56378
Log. Hav. 8.56378=Nat. Hav. .03663
Nat. Hav. 48° 34′ 36″ .16913

Nat. Hav. .20576=53° 57′ Z. D.

	90° 00′ 00″		
Z. D.	53° 57′		
Comp. Alt.	36° 03′ 00″		
True Alt.	36° 11′ 25″		
Alt. Diff.	+ 8′ 25″	Azimuth S 31° E	

Procyon in the West

First Chron.	7h 46′ 47″	Dec.	5° 25′ 48″ N
Fourth Chron.	7h 52′ 16″	Lat.	37° 50′ 00″ N
Interval	5′ 29″		32° 24′ 12″
First L. S. T.	11h 36′ 43″		
		Obs. Alt.	25° 11′
Fourth L. S. T.	11h 42′ 12″	Corr.	− 8′ 20″
*'s R. A.	7h 35′ 05″		
		True Alt.	25° 02′ 40″
*'s H. A.	4h 07′ 07″		

Log. Hav. 4h 07′ 07″ =9.42089
Log. Cos. 37° 50′ =9.89752
Log. Cos. 5° 25′ 48″ =9.99804

Log. Hav. 9.31645

Log. Hav. 9.31645 = Nat. Hav.		.20723
Nat. Hav. 32° 24′ 12″		.07784
Nat. Hav.		.28507 = 64° 32′ 15″ Z. D.
	90° 00′ 00″	
Z. D.	64° 32′ 15″	
Comp. Alt.	25° 27′ 45″	
True Alt.	25° 02′ 40″	
Alt. Diff.	− 25′ 05″	Azimuth S 76° W

Position of vessel; Lat. 37° 55′ 15″ N
Long. 73° 28′ 45″ W.

PROBLEM NO. 5

TWO OBSERVED ALTITUDES OF SUN'S L. L.

Oct. 18, 1919, A. M. at ship. Position by D. R. Lat. 36° 35′ N. Long. 70° 35′ W.
Chron. read 11h 59′ 18″. Alt. 11° 51′ 30″.
Chron. read 1h 59′ 18″. Alt. 32° 18′ 45″.
Course between sights S 28° E (true) 31 miles.
Chron. slow 3′ 00″. Dip. 30 ft.

Chron.	23h 59′ 18″	Dec.	9° 20′ 06″ S
Slow	+ 3′ 00″	Lat.	36° 35′ 00″ N
G. M. T. 18d	0h 02′ 18″		45° 55′ 06″
Eq. Time	+ 14′ 37″		
		Obs. Alt.	11° 51′ 30″
G. A. T. 18d	0h 16′ 55″	Corr. (46)	+ 6′ 16″
Long.	4h 42′ 20″		
		True Alt.	11° 57′ 46″
L. A. T. 17d	19h 34′ 35″		

Log. Hav. 19h 34′ 35″	= 9.47634
Log. Cos. 36° 35′ 00″	= 9.90471
Log. Cos. 9° 20′ 06″	= 9.99421
Log. Hav.	9.37526

Log. Hav. 9.37526 = Nat. Hav.		.23727
Nat. Hav. 45° 55′ 06″		.15216
Nat. Hav.		.38943 = 77° 13′ 30″ Z. D.
	90° 00′ 00″	
Z. D	77° 13′ 30″	
Comp. Alt.	12° 46′ 30″	
True Alt.	11° 57′ 46″	
Alt. Diff.	− 48′ 44″	Azimuth S 67° E

First Obs. D. R. Lat.	36° 35′ 00″ N	D. R. Long.	70° 35′ 00″ W
Diff. Lat.	27′ 24″ S	Diff. Long.	18′ 00″ E
Sec. Obs. D. R. Lat.	36° 07′ 36″ N	D. R. Long.	70° 17′ 00″ W
Chron.	1h 59′ 18″	Dec.	9° 21′ 54″ S
Slow	+ 3′ 00″	Lat.	36° 07′ 36″ N
G. M. T. 18d	2h 02′ 18″		45° 29′ 30″
Eq. T.	+ 14′ 38″		
		Obs. Alt.	32° 18′ 45″
G. A. T. 18d	2h 16′ 56″	Corr. (46)	+ 9′ 14″
Long.	4h 41′ 08″		
		True Alt.	32° 27′ 59″
L. A. T. 17d	21h 35′ 48″		

Log. Hav.	21h 35′ 48″	=8.98113
Log. Cos.	36° 07′ 36″	=9.90726
Log. Cos.	9° 21′ 54″	=9.99417
Log. Hav.		8.88256

Log. Hav. 8.88256 = Nat. Hav.		.07630
Nat. Hav.	45° 29′ 30″	.14948
Nat. Hav.		.22578 = 56° 44′ 30″ Z. D.

	90° 00′ 00″	
Z. D.	56° 44′ 30″	
Comp. Alt.	33° 15′ 30″	
True Alt.	32° 27′ 59″	
Alt. Diff.	− 47′ 31″	Azimuth S 43° 30′ E

Position of Vessel: Lat. 36° 33′ 30″ N.
Long. 71° 08′ 30″ W.

PROBLEM NO. 6

POSITION BY SIMULTANEOUS OBSERVATION OF TWO FIXED STARS

Dec. 6, 1919. Position by D. R. Lat. 49° 30′ N. Long. 14° 00′ W.
Chron. read 7h 31′ 21″. Regulus in the West. Alt. 48° 41′ 00″.
Chron. read 7h 32′ 43″. Arcturus in the East. Alt. 46° 32′ 30″.
Chron. correct. Dip. 26 ft.

Regulus in the West

G. M. T. 5d	19h 31′ 21″	Dec.	12° 21′ 24″
Long.	0h 56′	Lat.	49° 30′ 00″
L. M. T. 5d	18h 35′ 21″		37° 08′ 36″
R. A. M. S.	16h 52′ 57″		
Corr.	3′ 12″	Obs. Alt.	48° 41′ 00″
		Corr. (46)	− 5′ 51″
L. S. T. 6d	11h 31′ 30″		
*'s R. A.	10h 04′ 08″	True Alt.	48° 35′ 09″
*'s H. A.	1h 27′ 22″		

Log. Hav. 1h 27′ 22″ =8.55500
Log. Cos. 49° 30′ =9.81254
Log. Cos. 12° 21′ 24″ =9.98982

Log. Hav. 8.35736

Log. Hav. 8.35736=Nat. Hav. .02277
Nat. Hav. 37° 08′ 36″ .10143

Nat. Hav. .12420=41° 16′ 15″ Z. D.

	90° 00′ 00″
Z. D.	41° 16′ 15″
Comp. Alt.	48° 43′ 45″
True Alt.	48° 35′ 09″
Alt. Diff.	− 8′ 36″

Azimuth S 33° 30′ W

Arcturus in the East

First Chron.	7h 31′ 21″	Lat.	49° 30′ 00″
Second Chron.	7h 32′ 43″	Dec.	19° 35′ 54″
Interval	1′ 22″		29° 54′ 06″
First L. S. T.	11h 31′ 30″		
		Obs. Alt.	46° 32′ 30″
Second L. S. T.	11h 32′ 52″	Corr. (46)	− 5′ 50″
*'s R. A.	14h 12′ 00″		
			46° 26′ 40″
*'s R. A.	21h 20′ 52″		

Log. Hav. 21h 20′ 52″ =9.06358
Log. Cos. 49° 30′ =9.81254
Log. Cos. 19° 35′ 54″ =9.97408

Log. Hav. 8.85020

Log. Hav. 8.85020=Nat. Hav. .07083
Nat. Hav. 29° 54′ 06″ .06655

Nat. Hav. .13738=43° 30′ 45″ Z. D.

	90° 00′ 00″	
Z. D.	43° 30′ 45″	
Comp. Alt.	46° 29′ 15″	
True Alt.	46° 26′ 40″	
Alt. Diff.	− 2′ 35″	Azimuth S 61° E

Position of Vessel: Lat. 49° 39′ N.
Long. 13° 57′ W.

CHAPTER XXIII

TIME OF HIGH AND LOW WATER

This problem is to find the time of high and low water at any given port.

The astronomical date must be thoroughly understood in this example, and with careful watching of dates and a little practice it is very simple.

From Appendix IV (Bowditch) take out approximate longitude of place given, and lunar interval for high and low water.

From Pages 76–77 (Almanac) take out Moon's transit for date preceding the example, and the difference between it and the transit for date of example.

From Table 11 (Bowditch) with difference of transit at top of page and approximate longitude on side, take out correction given and apply it to Moon's transit for date preceding example, by rule given in Table 11.

Result will be Moon's upper transit.

Add to Moon's upper transit the lunar interval for high water. Result will be time of high water in astronomical time.

To convert this into civil time:

If time is between 0h and 12h. The date will be the same as transit was taken for in P. M. To find time of tide in P. M. of date of example add to this the change of transit between the dates.

If time is between 12h and 24h. The date will be the same as example in A. M., after subtracting 12 hours from it.

If time is over 24 hours, subtract 24 hours from it, and the date will be the same as example in P. M.

To find time of low water:

Add to Moon's upper transit the lunar interval for low water. The same rule as before will hold good for finding time of low water.

As the difference between the morning and evening tides is half the Moon's change of transit for that date. Proceed as follows:

If time for high or low water was found for A. M., add one-half the difference of transit to it, and the result will be P. M. time of high or low water.

If time found was P. M., subtract one-half the difference of transit from it, and the result will be A. M. time of high or low water.

PROBLEM NO. 1

Jan. 18, 1919. Find time of high and low water A. M. and P. M. at Montauk Point, N. Y.

Approximate Long. 72° W. Lunar Interval H. W. 8h 20′. Lunar Interval L. W. 2h 03′.

Difference of Transit 46′

Moon's Transit 17th	13h 30′	
Corr. Table 11	+ 09′	
Moon's Upper Transit	13h 39′	
Lunar Int. H. W.	8h 20′	
High Water, Jan. 17	21h 59′	or
Jan. 18th	9h 59′	A. M.
One-half Diff. of Trans.	+ 23′	
High Water, Jan. 18th	10h 22′	P. M.
Moon's Upper Transit	13h 39′	
Lunar Int. L. W.	2h 03′	
Low Water, Jan. 17th	15h 42′	or
Jan. 18th	3h 42′	A. M.
One-half Diff. of Transit	+ 23′	
Low Water, Jan. 18th	4h 05′	P. M.

PROBLEM NO. 2

July 19, 1919. Find time of high and low water A. M. and P. M. at New York Navy Yard, N. Y.

Approximate Long. 74° W. Lunar Interval H. W. 8h 44′. Lunar Interval L. W. 2h 49′.

	Difference of Transit 51′	
Moon's Transit 18th	16h 43′	
Corr. Table 11	+ 10′	
Upper Transit	16h 53′	
Lunar Int. H.W.	8h 44′	
High Water, July 19th	1h 37′	P. M.
One-half Diff. of Trans.	− 26′	
High Water, July 19th	1h 11′	A. M.
Upper Trans.	16h 53′	
Lunar Int. L. W.	2h 49′	
Low Water, July 18th	19h 42′	or
July 19th	7h 42′	A. M.
One-half Diff. of Trans.	+ 26′	
Low Water July 19th	8h 08′	P. M.

PROBLEM NO. 3

Sept. 13, 1919. Find time of high and low water A. M. and P. M. at Aden, Arabia.

Approximate Long. 45° E. Lunar Interval H. W. 7h 49′. Lunar Interval L. W. 1h 41′.

Difference of Transit 56′.

Moon's Trans. 12th	14h 19′	
Corr. Table 11	− 07′	
Upper Trans.	14h 12′	
Lunar Int. H. W.	7h 49′	
High Water, Sept. 12th	22h 01′	or
Sept. 13th	10h 01′	A. M.
One-half Diff. of Trans.	+ 28′	
High Water, Sept. 13th	10h 29′	P. M.
Upper Trans.	14h 12′	
Lunar Int. L. W.	1h 41′	
Low Water Sept 12th	15h 53′	or
Sept. 13th	3h 53′	A. M.
One-half Diff. of Trans.	+ 28′	
Low Water Sept. 13th	4h 21′	P. M.

PROBLEM NO. 4

Feb. 17, 1919. Find time of high and low water A. M. and P. M. at Valparaiso, Chile.

Approximate Long. 72° W. Lunar Interval H. W. 9h 37′. Lunar Interval L. W. 3h 26′

Difference of Transit 43′.

Moon's Trans. 16th	13h 37′	
Corr. Table 11	+ 09′	
Upper Trans.	13h 46′	
Lunar Int. H. W.	9h 37′	
High Water, Feb. 16th	23h 23′	or
Feb. 17th	11h 23′	A. M.
One-half Diff. of Trans.	22′	
High Water, Feb. 17th	11h 45′	P. M.
Upper Trans.	13h 46′	
Lunar Int. L. W.	3h 26′	
Low Water 16th	17h 12′	or
Feb. 17th	5h 12′	A. M.
One-half Diff. of Trans.	22′	
Low Water Feb. 17th	5h 34′	P. M.

PROBLEM NO. 5

Aug. 26, 1919. Find time of high and low water A. M. and P. M. at Enderbury Island, Phoenix Islands, Islands of the Pacific.

Approximate Long. 171° W. Lunar Int. H. W. 5h 00′. Lunar Int. L. W. 11h 15′.

Change of Transit 46′.

Moon's Trans. 26th		0h 34′	
Corr. Table 11	+	22′	
Upper Trans.		0h 56′	
Lunar Int. H. W.		5h 00′	
High Water, Aug. 26th		5h 56′	P. M.
One-half Change of Trans.	–	23′	
High Water, Aug. 26th		5h 33′	A. M.
Upper Trans.		0h 56′	
Lunar Int. L. W.		11h 15′	
Low Water, Aug. 27		12h 11′	A. M.
One-half Change of Trans.	–	23′	
Low Water Aug. 26th		11h 48′	A. M.

PROBLEM NO. 6

July 8, 1919. Find time of high and low water A. M. and P. M. at New Bedford, Mass.

Approximate Long. 71° W. Lunar Interval H.W. 7h 57′. Lunar Interval L. W. 1h 18′.

Change of Transit 47′.

Moon's Trans. 7th		7h 45′	
Corr. Table 11	+	09′	
Upper Trans.		7h 54′	
Lunar Int. H. W.		7h 57′	
High Water, July 7th		15h 51′	or
July 8th		3h 51′	A. M.
One-half Change of Trans.		24′	
High Water, July 8th		4h 15′	P. M.
Upper Trans.		7h 54′	
Lunar Int. L. W.		1h 18′	
Low Water, July 7th		9h 12′	P. M.
Change of Trans.	+	47′	
Low Water, July 8th		9h 59′	P. M.
One-half Change Trans.	−	24′	
Low Water July 8th		9h 35′	A. M.

PROBLEM NO. 7

Dec. 19, 1919. Find time of high water and low water A. M. and P. M. at Vardo, Norway.

Approximate Long. 31° E. Lunar Interval H. W. 5h 40′. Lunar Interval L. W. 11h 57′.

	Change of Transit 48′	
Moon's Trans. 18th	21h 36′	
Corr. Table 11	– 04′	
Upper Trans.	21h 32′	
Lunar Int. H. W.	5h 40′	
	27h 12′	
High Water, Dec. 19th	3h 12′	P. M.
One-half Change of Trans.	– 24′	
High Water, Dec. 19th	2h 49′	A. M.
Upper Trans.	21h 32′	
Lunar Int. L. W.	11h 57′	
Low Water, Dec. 19th	9h 29′	P. M.
One-half Change of Trans.	– 24′	
Low Water Dec. 19th	9h 05′	A. M.

PROBLEM NO. 8

Feb. 4, 1919. Find time of high and low water A. M. and P. M. at Calais, Maine.

Approximate Long. 67° W. Lunar Interval H. W. 11h 36′. Lunar Interval L. W. 5h 40′.

Change of Transit 51′

Moon's Trans. Feb. 3d		2h 18′	
Corr. Table 11	+	09′	
Upper Trans.		2h 27′	
Lunar Int. H. W.		11h 36′	
High Water Feb. 3d		14h 03′	or
Feb. 4th		2h 03′	A. M.
One-half Change of Trans.	+	26′	
High Water Feb. 4th		2h 29′	P. M.
Upper Trans.		2h 27′	
Lunar Int. L. W.		5h 40′	
Low Water Feb. 3d		8h 07′	P. M.
Change of Trans.		51′	
Low Water Feb. 4		8h 58′	P. M.
One-half Change of Trans.	–	26′	
Low Water Feb. 4		8h 32′	A. M.

PROBLEM NO. 9

May 4, 1919. Find time of high and low water A. M. and P. M. at Christiania, Norway.

Approximate Long. 11° E. Lunar Interval H. W. 5h 22′. Lunar Interval L. W. 10h 37′.

Change of Transit 54′

Moon's Transit, May 4th		4h 15′	
Corr. Table 11	–	02′	
Upper Transit		4h 13′	
Lunar Int. H. W.		5° 22′	
High Water, May 4th		9h 35′	P. M.
One-half Change of Trans.	–	27′	
High Water, May 4th		9h 08′	A. M.
Upper Trans.		4h 13′	
Lunar Int. L. W.		10h 37′	
Low Water, May 4th		14h 50′	or
May 5th		2h 50′	A. M.
Change of Transit	–	54′	
Low Water, May 4th		1h 56′	A. M.
One-half Change of Trans.	+	27′	
Low Water, May 4th		2h 23′	P. M.

PROBLEM NO. 10

Jan. 10, 1919. Find time of high and low water A. M. and P. M. at Pernambuco, Picao Lighthouse, Brazil.

Approximate Long. 35° W. Lunar Interval H. W. 4h 33′. Lunar Interval L. W. 10h 50′.

Change of Transit 56′

Moon's Trans., Jan. 10th		6h 58′	
Corr. Table 11	+	05′	
Upper Transit		7h 03′	
Lunar Int. H. W.		4h 33′	
High Water, Jan. 10th		11h 36′	P. M.
One-half Change of Trans.	–	28′	
High Water, Jan. 10		11h 08′	A. M.
Upper Trans.		7h 03′	
Lunar Int. L. W.		10h 50′	
Low Water, Jan. 10		17h 53′	or
Jan 11th		5h 53′	A. M.
Change of Trans.	–	56′	
Low Water, Jan. 10th		4h 57′	A. M.
One-half Change of Trans.	+	28′	
Low Water, Jan. 10th		5h 25′	P. M.

PROBLEM NO. 11

Mar. 5, 1919. Find time of high and low water A. M. and P. M. at Hilo, Kanaha Point Light, Hawaiian Islands.

Approx. Long. 155° W. L. I. H. W. 3h 09′. L. I. L. W. 9h 06′.

Change of Transit 57′

Moon's Transit, Mar. 5th		2h 47′	
Corr. Table 11	+	24′	
Upper Transit		3h 11′	
Lunar Int. L.W.		3h 09′	
High Water, Mar. 5th		6h 20′	P. M.
One-half Change of Trans.	–	28′	
High Water, Mar. 5th		5h 52′	A. M.
Upper Trans.		3h 11′	
Lunar Int. L. W.		9h 06′	
Low Water, Mar. 6th		12h 17′	A. M.
One-half Change of Tarnsit	–	28′	
Low Water, Mar. 5th		11h 49′	A. M.

PROBLEM NO. 12

Oct. 26, 1919. Find time of high and low water A. M. and P. M. at Osaka, Fort Temposan Light, Japan.

Approx. Long. 135° E. Lunar Interval H. W. 7h 30′. Lunar Interval L. W. 1h 25′

Change of Transit 48′

Moon's Transit, Oct. 26th		1h 43′	
Corr. Table 11	–	18′	
Upper Transit		1h 25′	
Lunar Int. H. W.		7h 30′	
High Water, Oct. 26th		8h 55′	P. M.
One-half Change of Trans.	–	24′	
High Water, Oct. 26th		8h 31′	A. M.
Upper Transit		1h 25′	
Lunar Int. L. W.		1h 25′	
Low Water, Oct. 26th		2h 50′	P. M.
One-half Change of Trans.	–	24′	
Low Water, Oct. 26th		2h 26′	A. M.

CHAPTER XXIV

EXAMPLES FOR PRACTICE

DAY'S WORK

1. A ship takes her departure from a point in Lat. 32° 48′ N, Long. 116° 18′ W, bearing by compass N 48° E distance 16 miles. Ship's head N 20° W, and steers the following courses:

Courses	Distance	Wind	Leeway	Deviation	Variation
N 20° W	41	N E	5°	6° W	12° E
N 80° W	42	North	9°	8° W	12° E
S 45° W	43	N W	8°	3° W	12° E
South	44	West	6°	8° W	12° E
S 20° E	45	S W	7°	3° W	12° E
S 15° W	46	S E	4°	5° W	12° E

Current set East (Corr. Mgc.) 14 miles for day.

Required latitude and longitude arrived at? True course and distance made?

Answer. Latitude in 30° 40′ 12″ N. Long. in 118° 04′ W. True course S 35° W. Distance 156 miles.

2. A ship takes her departure from a point in Lat. 28° 32′ S, Long 28° 10′ E, bearing by compass West distance 14 miles. Ship's head N 10° E, and sails the following courses:

Courses	Distance	Wind	Leeway	Deviation	Variation
N 10° E	41	N W	6°	3° E	15° W
East	42	North	7°	4° E	15° W
S 70° E	43	N E	6°	1° E	15° W
S 30° E	44	East	7°	2° W	15° W
South	45	East	6°	4° W	15° W
S 10° W	46	S E	2°	1° W	15° W

Current set West (Corr. Mgc.) 30 miles for day.
Required latitude and longitude arrived at? True course and distance made?

Answer.—Latitude in 30° 05′ 24″ S. Longitude in 30° 19′ 30″ E. True course S 51° E. Distance 146 miles.

3. A ship takes her departure from a point in Lat. 49° 58′ N, Long. 10° 12′ W, bearing by compass N 40° E, distance 15 miles. Ship's head N 45° W, and sails the following courses:

Courses	Distance	Wind	Leeway	Deviation	Variation
N 45° W	38	North	6°	5° E	24° W
West	39	North	7°	9° E	24° W
S 78° W	40	N W	8°	10° E	24° W
S 10° W	42	West	9°	3° E	24° W
S 20° E	43	S W	8°	3° W	24° W
South	44	S W	4°	8° E	24° W

Current set S 10° E (Corr. Mgc.) 13 miles for day.
Required latitude and longitude arrived at? True course and distance made?

Answer.—Latitude in 47° 23′ 42″ N. Longitude in 11° 11′ W. True course S 14° W. Distance 159 miles.

4. A ship takes her departure from a point in Lat. 48° 10′ N, Long. 128° 46′ W, bearing by compass West, distance 10 miles. Ship's head N 28° E, and sails the following courses:

Courses	Distance	Wind	Leeway	Deviation	Variation
N 28° E	38	N W	3°	4° E	20° E
N 28° W	40	West	2°	3° W	20° E
West	42	N W	4°	5° W	20° E
S 48° W	44	N W	5°	3° W	20° E
S 10° W	46	West	3°	1° W	20° E
S 10° E	48	S W	3°	2° E	20° E

Current set East (Corr. Mgc.) 13 miles for day.
Required latitude and longitude arrived at? True course and distance made?

Answer.—Latitude in 47° 20′ 06″ N. Longitude in 130° 17′ W. True course S 51° W. Distance 79 miles.

U. S. NAVY METHOD

5. A ship is heading 340° (p. s. c.) Dev. 4° W and takes her departure at noon with Point Reyes Lighthouse, California, abeam distance 10 miles. Patent log reads 18.

At 3 P. M. Changed course to 230°. Patent log 57. Deviation 2° W.
At 7 P. M. Changed course to 180°. Patent log 9. Deviation 2° E.
At 10 P. M. Changed course to 270°. Patent log 45. Deviation 3° W.
At 12 P. M. Changed course to 310°. Patent log 71. Deviation 6° W.
At 4 A. M. Changed course to 360°. Patent log 23. Deviation 9° W.
At 8 A. M. Changed course to 330°. Patent log 72. Deviation 8° W.
At noon patent log read 24.
Current set 40° (Corr. Mgc.) at rate ½′ per hour.
Variation on all courses 22° E.
Required noon position by dead reckoning, and true course and distance?

Answer.—Latitude in 40° 22′ 33″ N. Longitude in 125° 37′ 24″ W. True course 320°. Distance 186 miles.

6. A ship is heading 65° (p. s. c.) Dev. 6° E and takes her departure at 7 A. M. with Five Fathom Bank Lightship, New Jersey, abeam. Distance 8 miles. Patent log read 0.

At noon changed course to 120°. Patent log 75. Deviation 4° E.
At 4 P. M. Changed course to 180°. Patent log 35. Deviation 2° E.
At 8 P. M. Changed course to 110°. Patent log 94. Deviation 5° E.
At 12 P. M. Changed course to 40°. Patent log 54. Deviation 8° E.
At 4 A. M. Changed course to 0°. Patent log 9. Deviation 4° E.
At 8 A. M. Changed course to 340°. Patent log 67. Deviation 2° W.

At noon patent log read 22, variation on all courses 9° W. Current set 310° (Corr. Mgc.) $\frac{3}{4}'$ per hour for run.

Required noon position by dead reckoning, and true course and distance made?

Answer.—Latitude in 40° 13′ 50″ N. Longitude in 70° 50′ 36″ W. True course 63°. Distance 192 miles.

MERCATOR'S SAILING

1. Required true course and distance from Lat. 56° 46′ N, Long. 150° 00′ W, to Lat. 73° 10′ N, Long. 168° 10′ E by Mercator's sailing?

Answer.—True course N 46° 11′ W. Distance 1421 miles.

2. Required true course and distance from Lat. 28° 14′ S, Long. 28° 30′ E, to Lat. 40° 10′ N, Long. 10° 16′ W, by Mercator's sailing?

Answer.—True course N 27° 59′ W. Distance 4647 miles.

3. Required true course and distance from Lat. 14° 16′ S, Long. 28° 00′ W, to Lat. 14° 16′ N, Long. 28° 00′ E, by Mercator's sailing?

Answer.—True course N 62° 55′ E. Distance 3760 miles.

4. Required true course and distance from Lat. 46° 18′ N, Long. 165° 20′ E, to Lat. 23° 28′ N, Long. 168° 40′ W by Mercator's sailing?

Answer.—True course S 42° 48′ E. Distance 1867 miles.

5. Required true course and distance from Lat. 13° 48′ S, Long. 113° 28′ E, to Lat. 39° 20′ N, Long. 74° 30′ E, by Mercator's sailing.

Answer.—True course N 34° 37′ W. Distance 3874 miles.

6. Required true course and distance from Lat. 46° 28′ S, Long. 18° 46′ E, to Lat. 25° 30′ S, Long. 22° 23′ W by Mercator's sailing?

Answer.—True course N 57° 37′ W. Distance 2349 miles.

MIDDLE LATITUDE SAILING

1. Required true course and distance from Lat. 28° 10′ N, Long. 76° 15′ W to Lat. 34° 12′ N, Long. 77° 40′ W by middle latitude sailing?

Answer.—True course N 11° W. Distance 369 miles.

2. Required true course and distance from Lat. 18° 46′ S long., 178° 00′ W to Lat. 16° 30′ S, Long. 175° 10′ E by middle latitude sailing?

Answer.—True course N 71° W. Distance 412 miles.

3. Required true course and distance from Lat. 48° 16′ N, Long. 2° 06′ W, to Lat. 53° 12′ N, Long. 0° 42′E, by middle latitude sailing?

Answer.—True course N 20° E. Distance 315 miles.

4. Required true course and distance from Lat. 38° 10′ N, Long. 28° 10′ W to Lat. 42° 36′ N, Long. 31° 9′ W by middle latitude sailing?

Answer.—True course N 27° W. Distance 299 miles.

5. Required true course and distance from Lat. 46° 18′ S, Long. 153° 28′ E to Lat. 49° 30′ S, Long. 159° 10′ E by middle latitude sailing?

Answer.—True course S 50° E. Distance 298 miles.

6. Required true course and distance from Lat. 38° 14′ N, Long. 25° 30′ W to Lat. 47° 18′ N, Long. 30° 40′ W by middle latitude sailing?

Answer.—True course N 23° W. Distance 591 miles.

LATITUDE BY MERIDIAN ALTITUDE OF SUN

1. Jan. 1, 1919. Obs. Mer. Alt. Sun's L. L. was 49° 48′ 10″ S. Dip 26 ft., Long. 94° 18′ W.
Required latitude?

Answer.—Latitude 16° 58′ 23″ N.

2. Feb. 9, 1919. Obs. Mer. Alt. Sun's L. L. was 81° 10′ N. Dip 40 ft. Index error +2′. Long. 57° 43′ E.
Required latitude?

Answer.—Latitude 23° 35′ 53″ S.

3. March 21, 1919. Obs. Mer. Alt. Sun's L. L. was 59° 36′ S. Index error +2′ 40″. Dip 28 ft. Long. by D. R. 41° 28′ E.
Required latitude?

Answer.—Lat. 30° 04′ 08″ N.

4. Apr. 9, 1919. Obs. Mer. Alt. Sun's L. L. was 48° 10′ N. Dip 26 ft. Long. by D. R. 168° 15′ E?
Required latitude?

Answer.—Lat. 34° 33′ 10″ S.

5. May 6, 1919. Obs. Mer. Alt. Sun's L. L. was 82° 10′ S. Dip. 36 ft. Long. by D. R. 16° 21′ W.
Required latitude?

Answer.—Lat. 23° 59′ 42″ N.

6. June 22, 1919. Obs. Mer. Alt. Sun's L. L. was 51° 28′ N. Dip 26 ft. Long. by D. R. 167° 42′ W.
Required latitude?

Answer.—Lat. 14° 55′ 00″ S.

LATITUDE BY MERIDIAN ALTITUDE OF STAR

1. Feb. 9, 1919. Obs. Mer. Alt. *Spica 41° 10′ S. Dip 39 ft.
Required latitude?

Answer.—Lat. 38° 12′ 44″ N.

2. Mar. 11, 1919. Obs. Mer. Alt. *Arcturus 28° 19′ N. Index error −1′ 50″. Dip 26 ft.
Required latitude?

Answer.—Lat. 42° 13′ 44″ S.

3. Apr. 3, 1919. Obs. Mer. Alt. *Aldebaran was 32° 46′ S. Dip 40 ft.
Required latitude?

Answer.—Lat. 73° 42′ 31″ N.

4. May 4, 1919. Obs. Mer. Alt. *Antares 81° 10′ N. Index error +3′. Dip 30 ft.
Required latitude?

Answer.—Lat. 35° 07′ 49″ S.

5. June 5, 1919. Obs. Mer. Alt. * Regulus 32° 15′ N. Dip 26 ft.
Required latitude?
Answer.—Lat. 45° 29′ 56″ S.

6. July 8, 1919. Obs. Mer. Alt. * Fomalhaut 43° 16′ S. Dip 18 ft.
Required latitude?
Answer.—Lat. 16° 46′ 29″ N.

TIME OF STAR'S MERIDIAN PASSAGE

1. Jan. 16, 1919. Find meridian passage * Spica?
Answer.—Jan. 16d 17h 39′.

2. Feb. 12, 1919. Find meridian passage * Rigel?
Answer.—Feb. 12d 7h 44′.

3. March 20, 1919. Find meridian passage * Antares?
Answer.—Mar. 20d 16h 34′.

4. May 19, 1919. Find meridian passage * Sirius?
Answer.—May 19d 2h 56′.

5. June 7, 1919. Find meridian passage * Canopus?
Answer.—June 7d 1h 22′.

6. Dec. 6, 1919. Find meridian passage * Capella?
Answer.—Dec. 6d 12h 12′.

LONGITUDE BY SUN

1. Jan. 31, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 16° 18′. Dip 26 ft. Chron. read 2h 15′ P. M., which was fast 13′ 28″. Lat. by D. R. 36° 10′ N.
Required longitude?
Answer.—Long. 80° 12′ 15″ W.

2. Feb. 9, 1919, P. M. at ship. Obs. Alt. Sun's L. L. 18° 30′. Dip 31 ft. Chron. read 10h 15′ 28″ A. M. which was fast 56′ 08″. Lat. by D. R. 28° 15′ S.
Required longitude?
Answer.—Longitude 120° 20′ 30″ E.

3. Mar. 21, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 31° 28′. Dip 26 ft. Chron. read 4h 10′ P. M. which was slow 28′ 10″. Lat. by D. R. 18° 16′ N.

Required longitude?

Answer.—Long. 124° 10′ W.

4. Apr. 3, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 14° 12′. Dip 32 ft. Chron. read 9h 15′ A. M. which was slow 46′ 10″. Lat. by D. R. 41° 08′ S.

Required longitude?

Answer.—Long. 35° 27′ 30″ W.

5. May 6, 1919, P. M. at ship. Obs. Alt. Sun's L. L. 14° 50′. Dip 29 ft. Chron. read 1h 10′ P. M. which was slow 43′ 12″. Lat. by D. R. 18° 28′ S.

Required longitude?

Answer.—Long. 38° 25′ 45″ E.

6. June 3, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 22° 16′. Dip 28 ft. Chron. read 1h 48′ 12″ P. M. which was slow 1h 18′ 08″. Lat. by D. R. 27° 30′ N.

Required longitude?

Answer.—Long. 122° 34′ W.

NOON POSITION SIGHTS

1. July 10, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 20° 15′. Dip 20 ft. Chron. read 9h 15′ 28″ A. M. which was slow on June 8th 40′ 10″ and losing 1″.9 daily. Lat. at noon was 28° 16′ N. Ship ran from sight to noon S 28° W (true) 46 miles.

Required ship's position at sight and noon?

Answer.—Lat. at sight 28° 56′ 36″ N. Long. at sight 46° 11′ 15″ W. Lat. at noon 28° 16′ 00″ N. Long. at noon 46° 36′ W.

2. Aug. 10, 1919, P. M. at ship. Obs. Alt. Sun's L. L. 19° 15′. Dip 26 ft. Chron. read 9h 16′ 18″ A. M. which was slow on July 8th, 30′ 12″ and losing 4″.7 daily. Lat. at noon was 14° 18′ S. Ship ran from noon to sight N 51° W (true) 38 miles.

Required ship's position at sight and noon?

Answer.—Sight: Lat. 13° 54′ 06″ S, Long. 98° 52′ 45″ E.
Noon Lat. 14° 18′ 00″ S, Long. 99° 23′ 15″ E.

3. Sept. 23, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 24° 10′. Dip 38 ft. Chron. read 2h 16′ 28″ P. M. which was fast on Aug. 16th 3′ 10″ and losing 3″.5 daily. Lat. at noon was 41° 10′ N. Ship ran from sight to noon S 32° E (true) 53 miles.

Required ship's position at sight and noon?

Answer.—Sight: Lat. 41° 54′ 54″ N, Long. 92° 21′ 30″ W
Noon: Lat. 41° 10′ 00″ N, Long. 91° 43′ 30″ W

4. Oct. 7, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 28° 10′. Dip 33 ft. Chron. read 6h 15′ 20″ A. M. which was slow on Sept. 22d 4′ 10″ and gaining 9″.5 daily. Lat. at noon was 36° 42′ S. Ship ran from sight to noon S 48° E (true) 39 miles.

Required ship's position at sight and noon?

Answer.—Sight: Lat. 36° 15′ 54″ S, Long. 24° 25′ 45″ E.
Noon: Lat. 36° 42′ 00″ S, Long. 25° 01′ 45″ E.

5. Nov. 14, 1919, P. M. at ship. Obs. Alt. Sun's L. L. 23° 10′. Dip 26 ft. Chron. read 9h 58′ 10″ which was slow on Oct. 8th 5′ 40″ and losing 6″.4 daily. Long. by D. R. 110° W. Lat. at noon was 31° 15′ N. Ship ran from noon to sight N 22° E (true) 43 miles. Required ship's position at sight and noon?

Answer.—Sight: Lat. 31° 54′ 54″ N, Long. 109° 51′ 15″W
Noon: Lat. 31° 15′ 00′ N, Long. 110° 10′ 15″ W

6. Dec. 3, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 20° 10′. Dip 25 ft. Chron. read Dec. 2d 18h 15′ 28″ which was slow on Nov. 7th 40′ 10″ and losing 3″.8 daily. Lat. at noon was 31° 48′ N. Ship ran from sight to noon S 40° E (true) 46 miles.

Required ship's position at sight and noon?

Answer.—Sight: Lat. 32° 23′ 12″ N, Long. 27° 25′ E.
Noon: Lat. 31° 48′ 00″ N, Long. 28° 00′ E.

DEVIATION BY AZIMUTH

1. Jan. 11, 1919, A. M. at ship. Chron. read 11h 10′ A. M. Lat. 16° 18′ N, Long. 56° 28′ W. Sun bore by compass N 123° E. Variation 8° W.

Required error and deviation of compass?

Answer.—Error of compass 6° W. Deviation 2° E.

2. Mar. 21, 1919, A. M. at ship. Chron. read 4h 10′ P. M. Lat. 28° S, Long. 140° 10′ W. Sun bore by compass S 110° E. Variation 8° E.

Required error and deviation of compass?

Answer.—Error of compass 15° E. Deviation 7° E.

3. May 3, 1919, P. M. at ship. Chron. read 8h 15′ A. M. Lat 46° N, Long. 110° 12′ E. Sun bore by compass N 110° W. Variation 6° W.

Required error and deviation of compass?

Answer.—Error of compass 5° E. Deviation 11° E.

4. July 4, 1919, P. M. at ship. Chron. read 10h 20′ P. M. Lat. 24° S, Long. 93° 10′ W. Sun bore by compass S 118° 30′ W. Variation 8° E.

Required error and deviation of compass?

Answer.—Error of compass 5° 25′ E. Deviation 2° 35′ W.

5. Sept. 3, 1919, A. M. at ship. Chron. read 4h 08′ A. M. Lat. 40° N, Long. 55° 50′ E. Sun bore by compass N 110° E. Variation 8° W.

Answer.—Error of compass 8° W. Deviation 0°.

6. Nov. 8, 1919, A. M. at ship. Chron. read 1h 12′ 16″ P. M. Lat. 28° N, Long. 100° W. Sun bore by compass N 112° E. Variation 4° E.

Required error and deviation of compass?

Answer.—Error of compass 2° W. Deviation 6° W.

DEVIATION BY AMPLITUDE

1. Feb. 7, 1919. Sun bore at setting S 80° W. Chron. read 6h 16′ P. M. Lat. 28° 10′ N. Variation 9° W.

Required error and deviation of compass?

Answer.—Error of compass 7° 36′ W. Deviation 1° 24′ E.

2. Mar. 21, 1919. Sun bore at rising N 81° E. Chron. read 10h 10′ A. M. Lat. 18° 48′ S. Variation 4° E.

Required error and deviation of compass?

Answer.—Error of compass 9° E. Deviation 5° E.

3. July 4, 1919. Sun bore at setting N 81° W. Chron. read 8h 10′ P. M. Lat. 0° 10′ S. Variation 10° E.

Required error and deviation of compass?

Answer.—Error of compass 13° 56′ E. Deviation 3° 56′ E.

4. Oct. 7, 1919. Sun bore at rising N 89° E. Chron. read 8h 10′ A. M. Lat. 46° 06′ N. Variation 10° E.

Required error and deviation of compass?

Answer.—Error of compass 8° 25′ E. Deviation 1° 35′ W.

5. November 30, 1919. Sun bore at setting S 69° W. Chron. read 10h 16′ P. M. Lat. 32° 10′ S. Variation 2° E.

Required error and deviation of compass?

Answer.—Error of compass 4° 47′ W. Deviation 6° 47′ W.

6. Dec. 3, 1919. Sun bore at rising S 60° E. Chron. read 5h 06′ P. M. Lat. 38° 16′ N. Variation 7° W.

Required error and deviation of compass?

Answer.—Error of compass 1° 27′ W. Deviation 5° 33′ E.

LATITUDE BY POLARIS

1. Sept. 18, 1919, P. M. at ship. Obs. Alt. *Polaris 16° 15′. Dip 27 ft. Chron. read 11h 57′ 18″ P. M., slow 8′ 12″ Long, 113° 26′ W.

Required latitude?

Answer.—Latitude 16° 57′ 17″ N.

2. Mar. 12, 1919, A. M. at ship. Obs. Alt. *Polaris 23° 16′. Dip 16 ft. Chron. read 1h 12′ 13″ A. M. Long. 25° 20′ E.

Required latitude?

Answer.—Latitude 24° 16′ 19″ N.

3. Feb. 8, 1919, A. M. at ship. Obs. Alt. *Polaris 28° 14′. Dip 26 ft. Chron. read 1h 16′ P. M. Long. 98° 16′ W.

Required latitude?

Answer.—Latitude 29° 02′ 23″ N.

4. July 6, 1919, P. M. at ship. Obs. Alt. * Polaris 14° 20′. Dip 30 ft. Chron. read 1h 48′ P. M. Long. 74° 10′ E.

Required latitude?

Answer.—Latitude 15° 18′ 10″ N.

5. June 6, 1919, A. M. at ship. Obs. Alt. *Polaris 38° 20′. Dip 26 ft. Chron. read 11h 16′ 20″ A. M. Long. 85° 50′ W.

Required latitude?

Answer.—Latitude 37° 27′ 17″ N.

6. Dec. 7, 1919, P. M. at ship. Obs. Alt. *Polaris 42° 06′. Dip 40 ft. Chron. read 8h 16′ A. M. Long. 160° 45′ E.

Required latitude?

Answer.—Latitude 40° 56′ 56″ N.

ALTITUDE AZIMUTH. LONGITUDE BY SUN AND MERCATOR'S SAILING COMBINED

1. June 20, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 48° 57′ 46″. Dip 10 ft. Chron. read 5h 08′ 40″ A. M. which was slow on Feb. 17th 27′ 18″ and on April 8th was slow 32′ 48″. Lat. at noon was 33° 32′ 18″ N. Ship ran from sight to noon N 23° E (true) 35 miles. Sun bore by compass S 81° 31′ E. Variation 1° E.

Required position of vessel at sight and noon?

Required error and deviation of compass by altitude azimuth, and true course and distance by Mercator's sailing from noon to Lat. 48° 10′ N, Long. 40° E?

Answer.—Sight: Lat. 33° 00′ 06″ N. Long. 47° 27′ 30″ E. Noon: Lat. 33° 32′ 18″ N, Long. 47° 44′ 00″ E. Error of compass 6° 59′ W. Deviation 7° 59′ W. True course N 21° 44′ W. Distance 945.2 miles.

2. Jan. 31, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 17° 40′. Index error +3′ 00″. Dip 16 ft. Chron. read Jan. 31st 4h 40′ 15″ which was slow on Oct. 31st 31′ 20″ and on Dec. 10th was slow 32′ 40″. Lat. at noon was 35° 59′ N. Ship ran from sight to noon S 67° W (true) 26 miles. Sun bore by compass East. Variation 22° 15′ E.

Required position of vessel at sight and noon; error and deviation of compass by altitude azimuth, and true course and distance from noon to Lat. 25° 50′ N, Long. 100° W. by Mercator's sailing?

Answer.—Sight: Lat. 36° 09′ 12″ N, Long. 126° 16′ 15″ W. Noon: Lat. 35° 59′ 00″ N, Long. 126° 45′ 45″ W. Error of compass 38° 52′ E. Deviation 16° 37′ E. True course S 66° 13′ E. Distance 1510 miles.

3. Aug. 10, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 16° 05′ 30″. Dip 11 ft. Chron. read 5h 17′ 26″ A. M. which was slow on March 17th 4′ 25″ and on June 9th was fast 6′ 53″. Lat. at noon was 47° 25′ N. Ship ran from sight to noon S 50° W (true) 40 miles. Sun bore by compass East. Variation 4° 30′ E.

Required position of vessel at sight and noon?

Required error and deviation of compass by altitude azimuth, and true course and distance by Mercator's sailing from noon to Lat. 25° 10′ N, Long. 10° 06′ E?

Answer.—Sight: Lat. 47° 50′ 42″ N, Long. 22° 37′ 45″ E. Noon: Lat. 47° 25′ 00″ N, Long. 21° 51′ 45″ E. Error of compass 5° 54′ W. Deviation 10° 24′ W. True course S 22° 54′ W. Distance 1449 miles.

4. Mar. 21, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 29° 41′. Dip 12 ft. Chron. read 4h 19′ 27″ P. M. which was fast on Jan. 18th 43′ 43″ and losing 10″.7 daily. Lat. at noon was 38° 20′ S. Ship ran from sight to noon North (true) 20 miles. Sun bore by compass S 79° E. Variation 35° W.

Required position of vessel at sight and noon; error and deviation of compass by altitude azimuth and true course and distance by Mercator's sailing from noon to Lat. 10° 08′ S, Long. 178° E.

Answer.—Sight: Lat. 38° 40′ S, Long. 105° 12′ 30″ W. Noon: Lat. 38° 20′ S, Long. 105° 12′ 30″ W. Error of compass 38° 20′ W. Deviation 3° 20′ W. True course N 67° 53′ W. Distance 4494 miles.

5. Sept. 24, 1919, P. M. at ship. Obs. Alt. Sun's L. L. 21° 10′. Dip 12 ft. Chron. read 1h 10′ 10″ P. M. which was fast on June 1st 28′ 2″ and on August 1st was fast 29′ 37″. Lat. at noon was 16° 00′ S. Ship ran from noon to sight N 36° W (true) 42 miles. Sun bore by compass S 80° W. Variation 18° 30′ E.

Required ship's position at sight and noon; error and deviation of compass by altitude azimuth and true course and distance by Mercator's sailing from noon to Lat. 8° 14′ N. Long. 3° 10′ W.

Answer.—Sight: Lat. 15° 26′ S. Long. 56° 10′ 15″ E. Noon: Lat. 16° 00′ S, Long. 56° 36′ 00″ E. Error of compass 16° E. Deviation 2° 30′ W. True course N 67° 52′ W. Distance 3859 miles.

6. Nov. 8, 1919, A. M. at ship. Obs. Alt. Sun's L. L. 42° 00′. Dip 13 ft. Chron. read 2h 40′ 22″ P. M. which was fast on Sept. 24th 1h 12′ 56″ and losing 3″.6 daily. Lat. at noon was 50° 02′ S. Ship run from sight to noon N 28° E (true) 38 miles. Sun bore by compass N 70° 30′ E. Variation 14° 18′ W.

Required position of ship at sight and noon; error and deviation of compass by altitude azimuth and true course and distance by Mercator's sailing from noon to Lat. 25° 00′ S, Long. 30° W.

Answer.—Sight: Lat. 50° 35′ 36″ S, Long. 68° 24′ 30″ W. Noon: Lat. 50° 02′ 00″ S, Long. 67° 56′ 45″ W. Error of compass 10° 46′ W. Deviation 3° 32′ E. True course N 49° 52′ E. Distance 2330 miles.

LATITUDE BY PLANET

1. June 12, 1919. Obs. Mer. Alt. Planet Mars 47° 18′ N. Dip 26 ft. Chron. read 4h 22′ P. M.

Required latitude?

Answer.—Lat. 20° 12′ 20″ S.

2. July 6, 1919. Obs. Mer. Alt. Planet Saturn 38° 28′ N. Dip 30 ft. Chron. read 5h 38′ P. M.

Required latitude?

Answer.—Lat. 37° 22′ 29″ S.

3. Feb. 8, 1919. Obs. Mer. Alt. Planet Venus 48° 41′ S. Dip 28 ft. Chron. read 3h 40′ P. M.

Required latitude?

Answer.—Lat. 31° 07′ 55″ N.

4. April 15, 1919. Obs. Mer. Alt. Planet Jupiter 58° 10′ S. Dip 26 ft. Chron. read 1h 14′ A. M.

Required latitude?

Answer.—Lat. 55° 18′ 27″ N.

LATITUDE BY EX-MERIDIAN ALTITUDE OF SUN

1. Jan. 30, 1919. Ex-Mer. Alt. Sun's L. L. 47° 48′ S. Dip 26 ft. Chron. read 7h 40′ 18″. Long. 108° 30′ W, Lat. D. R. 24° N.

Required latitude at sight?

Answer.—Lat. 24° 07′ 46″ N.

2. Mar. 21, 1919. Ex-Mer. Alt. Sun's L. L. 72° 10′ N. Dip 30 ft. Chron. read 7h 50′ 30″ A. M. Long. 61° 15′ E, Lat. by D. R. 18° S.

Required latitude at sight?

Answer.—Lat. 17° 33′ 33″ S.

3. July 12, 1919. Ex-Mer. Alt. Sun's L. L. 58° 16′ S. Dip 30 ft. Chron. read 5h 50′ 12″ P. M. Long. 90° W, Lat. by D. R. 53° 40′ N.

Required latitude at sight?

Answer.—Lat. 53° 30′ 13″ N.

4. Apr. 18, 1919. Ex-Mer. Alt. Sun's L. L. 54° 28′ N. Dip 26 ft. Chron. read 3h 48′ 32″. Long. 124° E, Lat. by D. R. 25° S.

Required latitude at sight?

Answer.—Lat. 24° 54′ 28″ S.

5. Dec. 25, 1919. Ex-Mer. Alt. Sun's L. L. 64° 20′ N. Dip 26 ft. Chron. read 2h 10′ P. M. Long. 31° W, Lat. by D. R. 49° S.

Required latitude at sight?

Answer.—Lat. 48° 52′ 40″ S.

6. Oct. 16, 1919. Ex-Mer. Alt. Sun's L. L. 79° 20′ S. Dip 28 ft. Chron. read 2h 01′ A. M. Long. 149° 10′ E, Lat. D. R. 2° N.

Required latitude at sight?

Answer.—Lat. 1° 35′ 39″ N.

LONGITUDE BY FIXED STAR AND PLANET

1. Apr. 9, 1919, P. M. at ship. Obs. Alt. *Sirius 28° 41′, bearing West. Dip 26 ft. Chron. read 5h 09′ 40″ P. M. which was fast 28′ 10″. Lat. 23° 40′ N, Long. by D. R. 60° E.

Required longitude?

Answer.—Long. 60° 39′ E.

2. Feb. 9, 1919, A. M. at ship. Obs. Alt. *Arcturus 36° 20′, bearing East. Dip 28 ft. Chron. read 10h 28′ 10″ A. M. Lat. 42° 10′ N, Long. by D. R. 141° W.

Required longitude?

Answer.—Long. 140° 55′ 15″ W.

3. Feb. 13, 1919, A. M. at ship. Obs. Alt. *Procyon 30° 00′, bearing West. Dip 36 ft. Chron. read Feb. 12th 16h 40′ 28″ which was slow of G. M. T. 3′ 26″. Lat. 28° 50′ N, Long. by D. R. 41° W.

Required longitude?

Answer.—Long. 40° 37′ 15″ W.

4. May 19, 1919, P. M. at ship. Obs. Alt. *Spica 32° 46′, bearing East. Dip 36 ft. Chron. read 1h 28′ P. M. Lat. 38° 20′ S, Long. by D. R. 65° E.

Required longitude?

Answer.—Long. 65° 26′ 15″ E.

5. Jan. 29, 1919, A. M. at ship. Obs. Alt. Planet Venus 26° 10′, bearing East. Dip 26 ft. Chron. read 1h 13′ P. M. Lat. 28° 28′ N, Long. by D. R. 47° W.

Required longitude?

Answer.—Long. 47° 23′ 15″ W.

6. Oct. 6, 1919, A. M. at ship. Obs. Alt. Planet Saturn 20° 14′ bearing East. Dip 30 ft. Chron. read 0h 36′ A. M. Lat. 38° 12′ N, Long. by D. R. 64° E.

Required longitude?

Answer.—Long. 63° 49′ E.

LATITUDE BY MOON

1. Apr. 21, 1919. Obs. Mer. Alt. Moon's L. L. 38° 16′, bearing North. Dip 26 ft. Chron. read 1h 42′ A. M.

Required latitude?

Answer.—Lat. 71° 50′ 19″ S.

2. Aug. 16, 1919. Obs. Mer. Alt. Moon's L. L. 46° 26′, bearing South. Dip 30 ft. Chron. read 1h 36′ P. M.

Required latitude?

Answer.—Lat. 55° 05′ 39″ N.

3. Sept. 15, 1919. Obs. Mer. Alt. Moon's L. L. 78° 28′, bearing North. Dip 26 ft. Chron. read 6h 28′ A. M.

Required latitude?

Answer.—Lat. 8° 44′ 32″ N.

4. June 13, 1919. Obs. Mer. Alt. Moon's L. L. 53° 14′ S. Dip 32 ft. Chron. read 4h 09′ P. M.

Required latitude?

Answer.—Lat. 14° 30′ N.

5. Nov. 25, 1919. Obs. Mer. Alt. Moon's L. L. 70° 14′, bearing North. Dip 26 ft. Chron. read 7h 08′ P. M.

Required latitude?

Answer.—Lat. 39° 03′ 28″ S.

6. Dec. 5, 1919. Obs. Mer. Alt. Moon's L. L. 68° 14′ bearing South. Dip 26 ft. Chron. read Dec. 5th 12h 43′.

Required latitude?

Answer.—Lat. 39° 54′ 44″ N.

LONGITUDE BY SUNRISE AND SUNSET OBSERVATIONS

1. Dec. 2, 1919. Sun's L. L. at Sunrise. Chron. read 7h 10′ which was slow 45′ 10″. Lat. 28° 14′ N, Long. by D. R. 19° 40′ W.

Required longitude?

Answer.—Long. 19° 31′ 45″ W.

2. Mar. 21, 1919. Sun's U. L. at Sunset. Chron. read 5h 10′ which was slow 30′ 00″. Lat. 14° 16′ S, Long. by D. R. 8° E.

Required longitude?

Answer.—Long. 7° 46′ E.

3. May 6, 1919. Sun's L. L. at Sunrise. Chron. read 0h 16′ which was slow 58′ 00″, Lat. 34° 06′ S, Long. by D. R. 98° 10′ W.

Required longitude?

Answer.—Long. 98° 21′ 45″ W.

4. Jan. 2, 1919. Sun's U. L. at Sunrise. Chron. read 1h 15′ 20″, which was slow 41′ 28″. Lat. 36° 12′ N, Long. by D. R. 78° 45′ E.

Required longitude?

Answer.—Long. 78° 34′ 15″ E.

5. October 11, 1919. Sun's U. L. at Sunset. Chron. read 1h 50′ which was slow 8′ 10″. Lat. 43° 16′ S, Long. by D. R. 65° E.

Required longitude?

Answer.—Long. 64° 50′ E.

6. July 10, 1919. Sun's L. L. at Sunset. Chron. read 10h 05′ (correct) Lat. 13° 14′ N, Long. by D. R. 126° E,

Required longitude?

Answer.—Long. 125° 57′ 15″ E.

TIME OF HIGH AND LOW WATER

1. Jan. 28, 1919. Find time of high and low water in A. M. and P. M. at Antwerp, Belgium?

Answer.—High water 12h 54′ A. M., 1h 21′ P. M.
Low water 7h 06′ A. M., 7h 33′ P. M.

2. July 4, 1919. Find time of high and low water A. M. and P. M. at Guaymas, Mexico?

Answer.—High water 4h 32′ A. M., 4h 54′ P. M.
Low water 10h 50′ A. M., 11h 12′ P. M.

3. Mar. 10, 1919. Find time of high and low water A. M. and P. M. at Copenhagen, Denmark?

Answer.—High water 4h 09′ A. M., 4h 37′ P. M.
Low water 10h 25′ A. M., 10h 53′ P. M.

4. Sept 12, 1919. Find time of high and low water A. M. and P. M. at Castillos, Uruguay?

Answer.—High water 9h 53′ A. M., 10h 20′ P. M.
Low water 3h 41′ A. M., 4h 08′ P. M.

5. June 16, 1919. Find time of high and low water A. M. and P. M. at Alligator Reef, Florida?

Answer.—High water 10h 28′ A. M., 10h 52′ P. M.
Low water 4h 06′ A. M., 4h 30′ P. M.

6. May 3, 1919. Find time of high and low water A. M. and P. M. at Cape Wilberforce, Australia?

Answer.—High water 10h 23′ A. M., 10h 54′ P. M.
Low water 4h 11′ A. M., 4h 42′ P. M.

EXPLANATION OF ILLUSTRATIONS SHOWING METHOD OF PLOTTING ONE OBSERVATION OF SUN OR STAR ON A MERCATOR CHART

This method is the most practical and simple that can be used on board of a ship, and is strongly recommended to the student of navigation.

The idea of the method is to find the longitude when an error in latitude has been made at the time of observation.

When the sun is on the prime vertical an error in latitude will have no effect on the longitude as the sun's bearing will then be true East or West, and the line of bearing at right angles to this or 90° away, will be North and South. At all other times an error in latitude used in an example for longitude, will make a difference in the longitude found.

To lay off on chart proceed as follows:

Take observation of sun or star, using the latitude by D. R. to work the observation with.

After obtaining this position, place it on the chart.

Enter azimuth table and take out true bearing of body observed, using local apparent time for sun, hour angle for star.

Draw a line through the position already placed on chart at right angles to true bearing or 90° from it.

This will give the line of bearing, and the ship will be on this line somewhere if no error in latitude has been made.

Now when we obtain the latitude at noon, knowing the course and distance the ship has sailed between sight and noon, we find the correct latitude we were in at time of observation by working the latitude back to sight, using the difference of latitude obtained from Table 2 for the course and distance.

We then take a pair of dividers and obtain the length of the correct latitude at time of observation on the side of the chart.

Where the dividers meet the line of bearing, keeping one point of dividers on parallel of latitude used, will be the ship's correct position at time of sight.

Allowing the difference of longitude found from course and distance between sight and noon, to the longitude found on line of bearing, will give the ship's noon position.

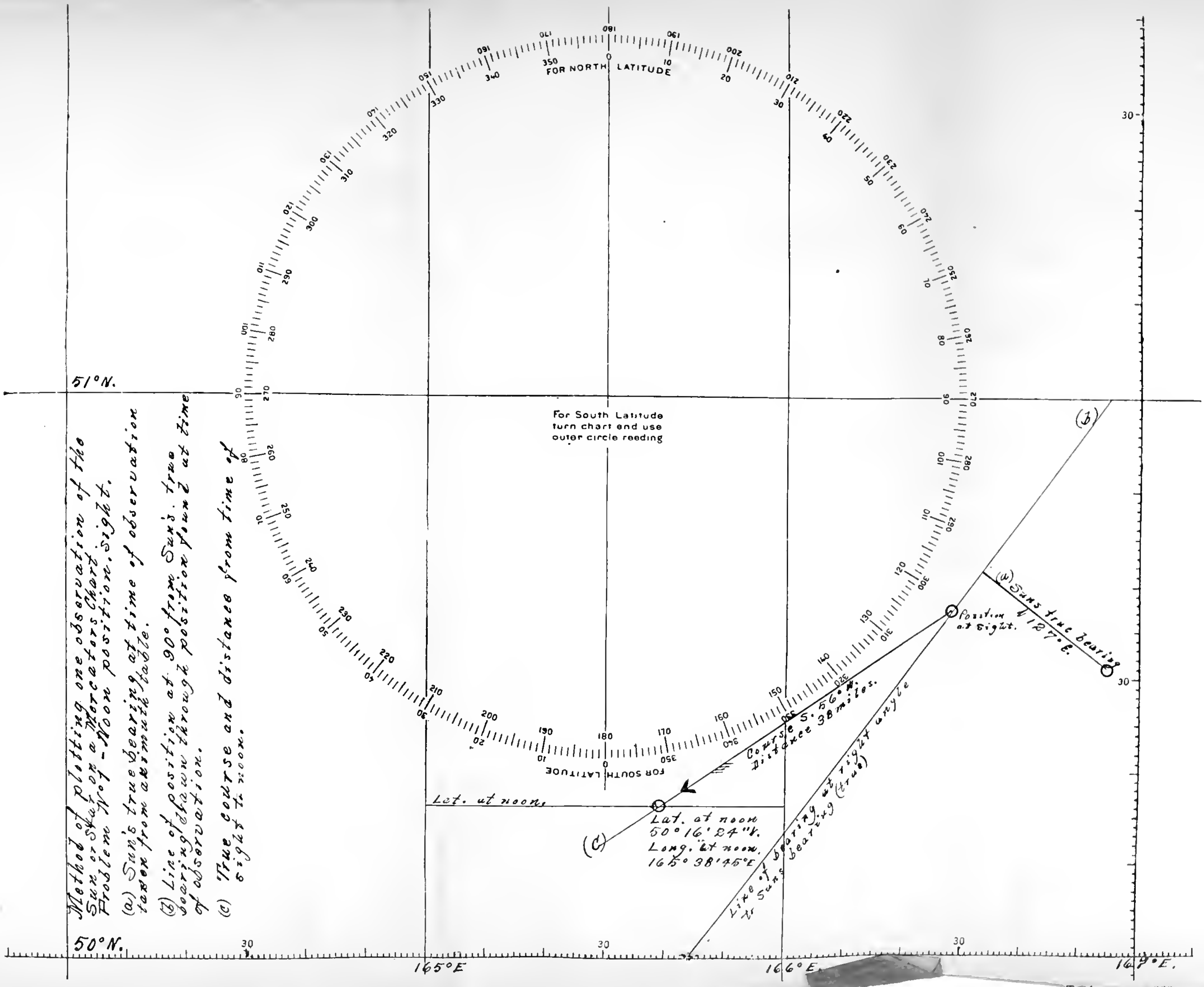
This method avoids the working of the sight over again, after the correct latitude has been found.

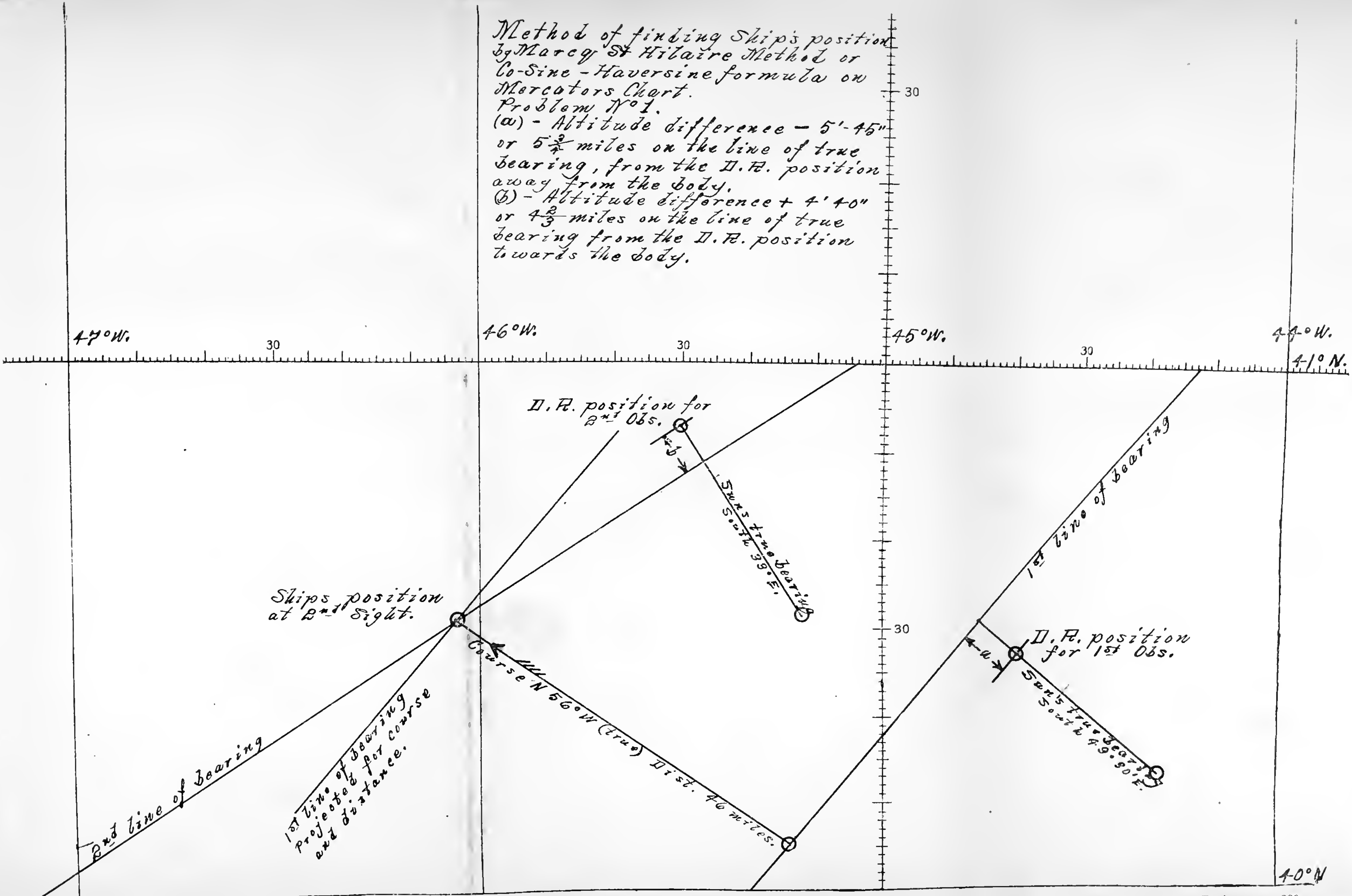
The following examples will illustrate the change in longitude for an error in latitude.

By taking a pair of dividers on the line in Lat. 50° 40′ N, the longitude will be found to be 166° 37′ E.

In Lat. 50° 20′ N, the longitude will be 166° 13′ 30″ E.

This will illustrate the amount an error in latitude will affect the longitude on this bearing, and also the method of obtaining the longitude at time of observation with correct latitude.


Method of plotting one observation of the Sun or Star on a Mercators Chart.
Problem No. 7 - Noon position, sight.
(a) Sun's true bearing at time of observation taken from azimuth table.
(b) Line of position at 90° from Sun's true bearing drawn through position found at time of observation.
(c) True course and distance from time of sight to noon.
FOR NORTH LATITUDE
FOR SOUTH LATITUDE
For South Latitude turn chart end use outer circle reading
51°N.
50°N.
165°E
166°E
Lat. at noon.
Lat. at noon 50°16'24"N.
Long. at noon 165°38'45"E
Course S.56°W.
Distance 38 miles.
Position at sight.
(a) Suns true bearing
(b)
(c)
Line of bearing at right angle to Suns bearing (true)



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EXPLANATION OF ILLUSTRATION SHOWING METHOD OF PLOTTING POSITION LINES ON MERCATOR CHART BY MARCQ ST. HILAIRE METHOD

The dead reckoning position for first observation is placed on chart.

A line representing the body's true bearing is drawn through this dead reckoning position.

The altitude difference is measured from this position towards or away from the body.

In this illustration the altitude difference is $-5' \, 45''$. Or $5\frac{3}{4}$ miles on line of bearing away from the body. As the sun was in the East in A. M., this would be allowed to the westward.

The first line of bearing is drawn at right angles or 90°, to this bearing.

The course and distance is allowed between observations same as in Sumners Method, and a line drawn parallel to first line on this course and distance.

The second dead reckoning position is then placed on chart, and a line representing the true bearing drawn through it.

In this case the altitude difference is $+ \, 4' \, 40''$, which means toward the body on the line of bearing.

The second line is then drawn at right angles to true bearing through this position, and where the second line crosses the projection of first line will be ship's position at second observation.

EXPLANATION OF ILLUSTRATION SHOWING METHOD OF PLOTTING SUMNER LINES ON MERCATOR CHART

The first line of bearing is the line drawn between the two positions found by first altitude, and is at right angles to sun's true bearing.

Example: Sun's true bearing N 130° 30′ E − 90° equals N 40° 30′ E, which is the angle of the first line.

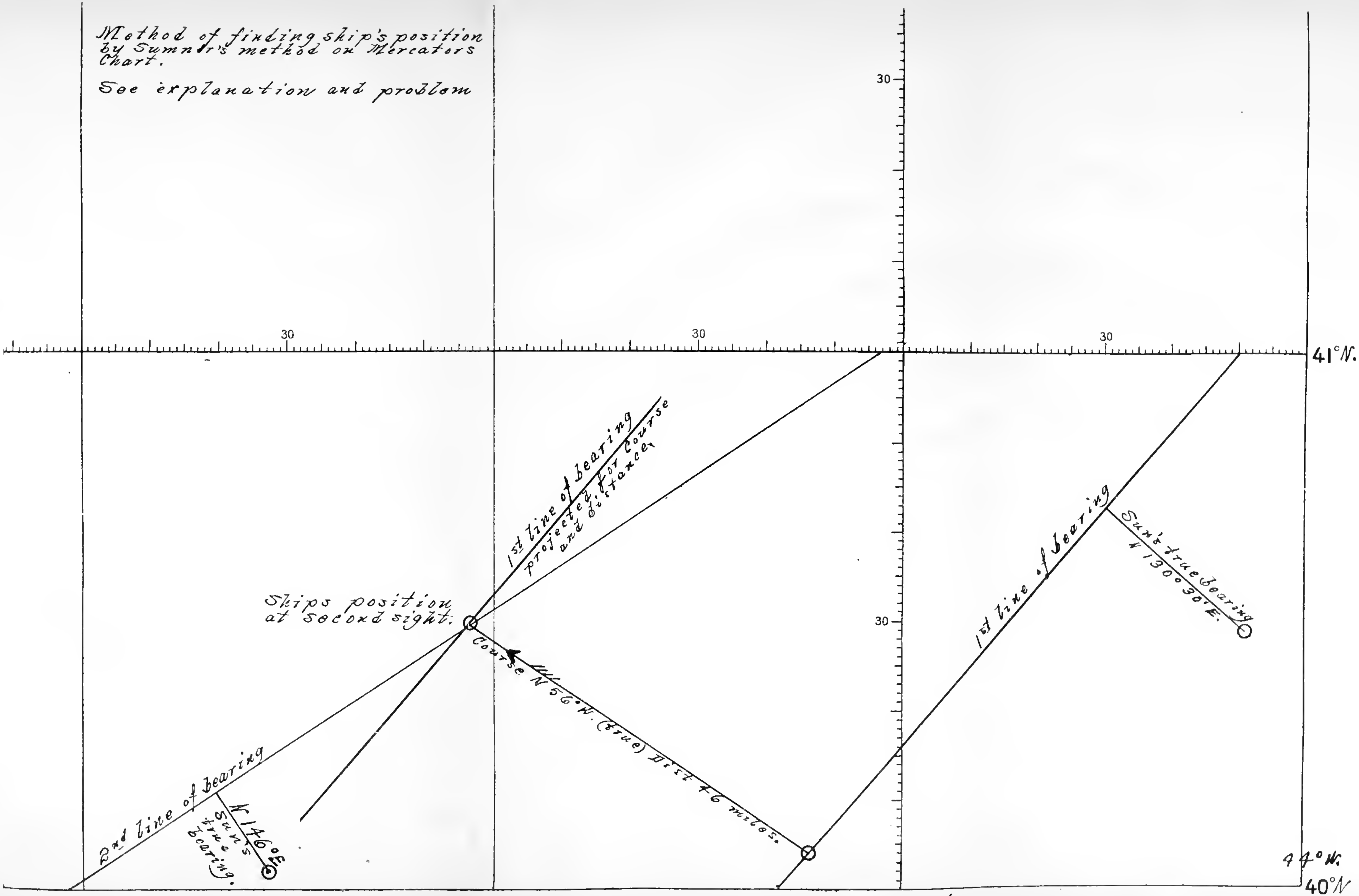
Course N 56° W (true) distance 46 miles is the line drawn allowing for the course and distance run between first and second observations.

The first line of bearing projected is the line drawn parallel to first line of bearing allowing for the course and distance.

Second line of bearing is the line drawn between the two positions found by second altitude, and is at right angles to sun's true bearing.

Example: Sun's true bearing N 146° E − 90° equals N 56° E which is the angle of second line.

Where the second line crosses the projection of first line will be ships position at second observation.



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EXTRACTS FROM THE AMERICAN NAUTICAL ALMANAC FOR THE YEAR 1919

RIGHT ASCENSION OF THE MEAN SUN AT GREENWICH MEAN NOON

JANUARY, 1919

Day	Right Ascension
28	20h 26′ 48″.1
29	20h 30′ 44″.7
30	20h 34′ 41″.2
31	20h 38′ 37″.8

FEBRUARY, 1919

Day	Right Ascension
1	20h 42′ 34″.3
7	21h 06′ 13″.7
8	21h 10′ 10″.2
9	21h 14′ 6″.8
10	21h 18′ 3″.3
11	21h 21′ 59″.9
12	21h 25′ 56″.4
13	21h 29′ 53″.0
17	21h 45′ 39″.2
18	21h 49′ 35″.8
19	21h 53′ 32″.3
20	21h 57′ 28″.9

MARCH, 1919

Day	Right Ascension
10	23h 8′ 26″.8
11	23h 12′ 23″.4
12	23h 16′ 19″.9

APRIL, 1919

Day	Right Ascension
7	0h 58′ 50″.3
8	1h 2′ 46″.8
9	1h 6′ 43″.4
10	1h 10′ 40″.0

MAY, 1919

Day	Right Ascension
18	3h 40′ 29″.0
19	3h 44′ 25″.6
20	3h 48′ 22″.1
21	3h 52′ 18″.7

JUNE, 1919

Day	Right Ascension
4	4h 47′ 30″.5
5	4h 51′ 27″.0
6	4h 55′ 23″.6
7	4h 59′ 20″.2
8	5h 3′ 16″.7

JULY, 1919

Day	Right Ascension
2	6h 37′ 54″.1
3	6h 41′ 50″.6
4	6h 45′ 47″.2
5	6h 49′ 43″.8
6	6h 53′ 40″.3
7	6h 57′ 36″.9
14	7h 25′ 12″.8
15	7h 29′ 9″.3
16	7h 33′ 5″.9

AUGUST, 1919

Day	Right Ascension
4	8h 48′ 0″.4
5	8h 51′ 57″.0
6	8h 55′ 53″.6

SEPTEMBER, 1919

Day	Right Ascension
17	11h 41′ 28″.8
18	11h 45′ 25″.4
19	11h 49′ 21″.9

OCTOBER, 1919

Day	Right Ascension
4	12h 48′ 30″.2
5	12h 52′ 26″.7
6	12h 56′ 23″.3
24	14h 7′ 21″.2
25	14h 11′ 17″.8
26	14h 15′ 14″.4

NOVEMBER, 1919

Day	Right Ascension
8	15h 6′ 29″.6
9	15h 10′ 26″.1
10	15h 14′ 22″.7

DECEMBER, 1919

Day	Right Ascension
5	16h 52′ 56″.6
6	16h 56′ 53″.1
7	17h 0′ 49″.7

THE SUN

JANUARY, 1919

G. M. T. Hrs.	Sun's Declination	Equation of Time
	WEDNESDAY, 1	
4	−23° 3′.4	−3′ 23″.9
6	23° 3′.0	3′ 26″.3
8	23° 2′.6	3′ 28″.6
10	23° 2′.2	3′ 31″.0
12	23° 1′.8	3′ 33″.4
14	23° 1′.4	3′ 35″.8
16	23° 1′.0	3′ 38″.2
18	23° 0′.6	3′ 40″.5
20	23° 0′.1	3′ 42″.9
22	22° 59′.7	3′ 45″.3
H. D.	0′.2	1″.2
	THURSDAY, 2	
0	−22° 59′.3	−3′ 47″.6
2	22° 58′.9	3′ 50″.0
H. D.	0′.2	1″.2
	FRIDAY, 10	
22	−21° 56′.2	−7′ 43″.5
H. D	0′.4	1″.0
	SATURDAY, 11	
0	−21° 55′.5	−7′ 45″.5
2	21° 54′.7	7′ 47″.5
H. D.	0′.4	1″.0
	FRIDAY, 24	
8	−19° 18′.6	−12′ 7″.5
10	19° 17′.4	12′ 8″.8
12	19° 16′.2	12′ 10″.0
H. D.	0′.6	0″.6

G. M. T. Hrs.	Sun's Declination	Equation of Time
	THURSDAY, 30	
0	−17° 52′.0	−13′ 18″.9
2	17° 50′.6	13′ 19″.8
4	17° 49′.3	13′ 20″.6
6	17° 47′.9	13′ 21″.5
8	17° 46′.5	13′ 22″.3
10	17° 45′.2	13′ 23″.2
12	17° 43′.8	13′ 24″.0
14	17° 42′.4	13′ 24″.8
16	17° 41′.1	13′ 25″.6
18	17° 39′.7	13′ 26″.4
20	17° 38′.3	13′ 27″.3
22	17° 37′.0	13′ 28″.1
H. D.	0′.7	0″.4
	FRIDAY, 31	
0	− 17° 35′.6	−13′ 28″.9
2	17° 34′.2	13′ 29″.6
4	17° 32′.8	13′ 30″.4
6	17° 31′.4	13′ 31″.2
8	17° 30′.0	13′ 32″.0
10	17° 28′.7	13′ 32″.7
12	17° 27′.3	13′ 33″.5
14	17° 25′.9	13′ 34″.3
16	17° 24′.5	13′ 35″.0
18	17° 23′.1	13′ 35″.7
20	17° 21′.7	13′ 36″.5
22	− 17° 20′.3	−13′ 37″.2
H. D.	0′.7	0″.4

SEMI-DIAMETER

Jan. 1	16′.30
11	16′.29
21	16′.28
31	16′.26

Note: The equation of time is to be applied to the G. M. T. in accordance with the sign as given.

FEBRUARY, 1919

SATURDAY, 1

G. M. T. Hrs.	Sun's Declination	Equation of Time
16	−17° 7′.6	−13′ 43″.6
18	17° 6′.1	13′ 44″.3
20	17° 4′.7	13′ 44″.9
H. D.	0′.7	0″.3

FRIDAY, 7

G. M. T. Hrs.	Sun's Declination	Equation of Time
4	15° 29′.4	−14′ 15″.8
6	15 27 .9	14 16 .1
8	15 26 .3	14 16 .4
H. D.	0.8	0 .1

SATURDAY, 8

G. M. T. Hrs.	Sun's Declination	Equation of Time
18	−14° 59′.6	−14′ 20″.5
20	14° 58′.1	14′ 20″.7
22	14° 56′.5	14′ 20″.8
H. D.	0′.8	0″.1

SUNDAY, 9

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	−14° 54′.9	−14′ 21″.0
2	14° 53′.3	14′ 21″.2
4	14° 51′.7	14′ 21″.4
6	14° 50′.1	14′ 21″.5
8	14° 48′.5	14′ 21″.7
10	14° 46′.9	14′ 21″.8
H. D.	0′.8	0″.1

TUESDAY, 18

G. M. T. Hrs.	Sun's Declination	Equation of Time
6	−11° 48′.7	−14′ 7″.2
8	11° 46′.9	14′ 6″.8
10	11° 45′.2	14′ 6″.4
H. D.	0′.9	0″.2

SUNDAY, 23

G. M. T. Hrs.	Sun's Declination	Equation of Time
10	−9° 57′.4	−13′ 33″.4
12	9 55 .6	13 32 .7
14	9 53 .7	13 32 .0
H. D.	0.9	0 .3

SEMI-DIAMETER

Feb. 1	16′.26
11	16′.23
21	16′.20
March 3	16′.16

MARCH, 1919

MONDAY, 10

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	−4° 24′.3	−10′ 37″.9
2	4° 22′.4	10′ 36″.6
4	4° 20′.4	10′ 35″.3
6	4° 18′.4	10′ 34″.0
8	4° 16′.5	10′ 32″.7
10	4° 14′.5	10′ 31″.4
12	4° 12′.6	10′ 30″.1
14	4° 10′.6	10′ 28″.8
16	4° 8′.7	10′ 27″.5
18	4° 6′.7	10′ 26″.2
20	4° 4′.7	10′ 24″.9
22	4° 2′.8	10′ 23″.6
H. D.	1′.0	0″.6

THURSDAY, 20

G. M. T. Hrs.	Sun's Declination	Equation of Time
4	−0° 24′.0	−7′ 46″.7
6	0° 22′.0	7′ 45″.2
8	0° 20′.1	7′ 43″.7
10	0° 18′.1	7′ 42″.2
12	0° 16′.1	7′ 40″.7
18	0° 10′.2	7′ 36″.3
20	0° 8′.2	7′ 34″.8
22	−0° 6′.2	−7′ 33″.3
H. D	1′.0	0″.7

THURSDAY, 13

G. M. T. Hrs.	Sun's Declination	Equation of Time
10	−3° 3′.9	−9′ 43″.4
12	3° 1′.9	9′ 42″.0
14	2° 59′.9	9′ 40″.7
H. D.	1′.0	0″.7

WEDNESDAY, 19

G. M. T. Hrs.	Sun's Declination	Equation of Time
14	− 0° 37′.8	−7′ 57″.1
16	0° 35′.9	7′ 55″.7
18	0° 33′.9	7′ 54″.2
H. D.	1′.0	0″.7

FRIDAY, 21

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	−0° 4′.3	−7′ 31″.8
2	0° 2′.3	7′ 30″.3
4	− 0° 0′.3	7′ 28″.7
6	+0° 1′.7	7′ 27″.2
8	0° 3′.6	7′ 25″.7
H. D.	1′.0	0″.8

SEMI-DIAMETER

March 1	16′.17
11	16′.13
21	16′.08
31	16′.04

APRIL, 1919

TUESDAY, 1

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+4° 14′.4	−4′ 11″.3
2	4° 16′.4	4′ 9″.8
4	4° 18′.3	4′ 8″.3
H. D.	1′.0	0″.8

WEDNESDAY, 2

G. M. T. Hrs.	Sun's Declination	Equation of Time
20	+4° 56′.9	−3′ 38″.4
22	4° 58′.8	3′ 36″.9
H. D.	1′.0	0″.7

THURSDAY, 3

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+5° 0′.7	−3′ 35″.4
2	5° 2′.6	3′ 33″.9
4	5° 4′.6	3′ 32″.4
H. D.	1′.0	0″.7

TUESDAY, 8

G. M. T. Hrs.	Sun's Declination	Equation of Time
10	+7° 4′.1	−2′ 0″.9
12	7° 5′.9	1′ 59″.5
14	7° 7′.8	1′ 58″.1
H. D.	0′.9	0″.7

THURSDAY, 17

G. M. T. Hrs.	Sun's Declination	Equation of Time
14	+10° 24′.3	+0′ 23″.1
16	10° 26′.0	0′ 24″.2
18	10° 27′.8	0′ 25″.4
20	10° 29′.6	0′ 26″.6
H. D.	0′.9	0″.6

FRIDAY, 18

G. M. T. Hrs.	Sun's Declination	Equation of Time
12	+10° 43′.6	+0′ 35″.9
14	10° 45′.3	0′ 37″.0
16	10° 47′.1	0′ 38″.2
18	10° 48′.8	0′ 39″.3
20	10° 50′.6	0′ 40″.5
22	10° 52′.3	0′ 41″.6
H. D.	0′.9	0″.6

TUESDAY, 22

G. M. T. Hrs.	Sun's Declination	Equation of Time
10	+12° 4′.3	+1′ 26″.8
12	12° 6′.0	1′ 27″.8
14	12° 7′.7	1′ 28″.8
16	12° 9′.4	1′ 29″.8
H. D.	0′.8	0″.5

SEMI-DIAMETER

April 1	16′.03
11	15′.99
21	15′.94
May 1	15′.90

MAY, 1919

THURSDAY, 1

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+14° 50′.3	+2′ 52″.7
2	14° 51′.8	2′ 53″.4
H. D.	0′.8	0″.3

FRIDAY, 2

G. M. T. Hrs.	Sun's Declination	Equation of Time
18	+15° 22′.0	+3′ 5″.6
20	15° 23′.5	3′ 6″.1
22	15° 25′.0	3′ 6″.7
H. D.	0′.7	0″.3

SATURDAY, 3

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+15° 26′.5	+3′ 7″.3
2	15° 28′.0	3′ 7″.8
4	15° 29′.5	3′ 8″.4
H. D.	0′.7	0″.3

TUESDAY, 6

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+16° 18′.9	+3′ 25″.1
2	16° 20′.3	3′ 25″.5
4	16° 21′.7	3′ 25″.9
6	16° 23′.1	3′ 26″.4
H. D.	0′.7	0″.2

THURSDAY, 29

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+21° 29′.8	+2′ 55″.5
2	21° 30′.6	2′ 54″.9
4	21° 31′.4	2′ 54″.2
H. D.	0′.4	0″.3

SEMI-DIAMETER

May 1	15′.90
11	15′.86
21	15′.83
31	15′.80

JUNE, 1919

TUESDAY, 3

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+22° 13′.1	+2′ 12″.8
2	22° 13′.7	2′ 12″.0
4	22° 14′.3	2′ 11″.2
H. D.	0′.3	0″.4

THURSDAY, 19

G. M. T. Hrs.	Sun's Declination	Equation of Time
16	+23° 25′.8	−1′ 2″.2
18	23° 25′.9	1′ 3″.2
20	23° 26′.0	1′ 4″.3
22	23° 26′.0	1′ 5″.4
H. D.	0′.0	0″.5

SUNDAY, 22

G. M. T. Hrs.	Sun's Declination	Equation of Time
10	+23° 26′.9	−1′ 38″.0
12	23° 26′.9	1′ 39″.1
14	23° 26′.8	1′ 40″.2
16	23° 26′.8	1′ 41″.3
18	23° 26′.8	1′ 42″.4
H. D.	0′.0	0″.5

SEMI-DIAMETER

June 1	15′.80
11	15′.78
21	15′.77
July 1	15′.76

JULY, 1919

FRIDAY, 4

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+22° 57′.3	−4′ 1″.0
2	22° 56′.9	4′ 1″.9
4	22° 56′.4	4′ 2″.9
6	22° 56′.0	4′ 3″.8
8	22° 55′.6	4′ 4″.7
10	22° 55′.2	4′ 5″.6
12	22° 54′.8	4′ 6″.5
14	22° 54′.3	4′ 7″.4
16	22° 53′.9	4′ 8″.3
18	22° 53′.5	4′ 9″.2
20	22° 53′.0	4′ 10″.1
22	22° 52′.6	4′ 11″.0
H. D	0′.2	0″.5

SATURDAY, 5

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+22° 52′.2	−4′ 11″.9
2	22° 51′.7	4′ 12″.8
20	22° 47′.6	4′ 20″.7
22	22° 47′.1	4′ 21″.6
H. D.	0′.2	0″.4

SUNDAY, 6

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+22° 46′.7	−4′ 22″.4
2	22° 46′.2	4′ 23″.3
H. D.	0′.2	0″.4

WEDNESDAY, 9

G. M. T. Hrs.	Sun's Declination	Equation of Time
18	+22° 22′.5	−4′ 58″.6
20	22° 21′.9	4′ 59″.3
22	22° 21′.3	5′ 0″.1
H. D.	0′.3	0″.4

THURSDAY, 10

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+22° 20′.7	−5′ 0″.8
2	22° 20′.1	5′ 1″.5
H. D.	0′.3	0″.4

SATURDAY, 12

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+22° 5′.4	−5′ 17″.5
2	22° 4′.8	5′ 18″.2
4	22° 4′.1	5′ 18″.8
6	22° 3′.4	5′ 19″.5
8	22° 2′.7	5′ 20″.1
H. D.	0′.3	0″.4

SEMI-DIAMETER

July 1	15′.76
11	15′.76
21	15′.77
31	15′.79

AUGUST, 1919

THURSDAY, 7

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+16° 39′.3	−5′ 43″.8
2	16° 37′.9	5′ 43″.3
4	16° 36′.6	5′ 42″.7
6	16° 35′.2	5′ 42″.1
8	16° 33′.8	5′ 41″.6
10	16° 32′.4	5′ 41″.0
12	16° 31′.0	5′ 40″.4
20	16° 25′.4	5′ 38″.0
22	16° 24′.0	5′ 37″.4
H. D.	0′.7	0″.3

SUNDAY, 10

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+15° 48′.5	−5′ 21″.0
2	15° 47′.0	5′ 20″.3
20	15° 33′.9	5′ 13″.8
22	15° 32′.5	5′ 13″.0
H. D.	0′.7	0″.4

MONDAY, 11

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+15° 31′.0	−5′ 12″.3
2	15° 29′.5	5′ 11″.5
H. D.	0′.7	0″.4

FRIDAY, 8

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+16° 22′.6	−5′ 36″.8
2	16° 21′.2	5′ 36″.2
4	16° 19′.8	5′ 35″.6
6	16° 18′.4	5′ 35″.0
8	16° 17′.0	5′ 34″.4
10	16° 15′.6	5′ 33″.7
H. D.	0′.7	0″.3

SATURDAY, 9

G. M. T. Hrs.	Sun's Declination	Equation of Time
14	+15° 55′.7	−5′ 24″.5
16	15° 54′.2	5′ 23″.8
18	15° 52′.8	5′ 23″.1
20	15° 51′.3	5′ 22″.4
22	15° 49′.9	5′ 21″.7
H. D.	0′.7	0″.3

SATURDAY 30

G. M. T. Hrs.	Sun's Declination	Equation of Time
6	+9° 12′.2	−0′ 45″.5
8	9° 10′.4	0′ 44″.0
10	9° 8′.7	0′ 42″.5
H. D.	0′.9	0″.8

SEMI-DIAMETER

August	1	15′.79
	11	15′.81
	21	15′.84
	31	15′.88

SEPTEMBER, 1919

TUESDAY, 2

G. M. T. Hrs.	Sun's Declination	Equation of Time
14	+8° 0′.0	+0′ 16″.4
16	7° 58′.2	0′ 17″.9
18	7° 56′.4	0′ 19″.5
H. D.	0′.9	0″.8

WEDNESDAY, 17

G. M. T. Hrs.	Sun's Declination	Equation of Time
18	+2° 16′.6	+5′ 28″.5
20	2° 14′.7	5′ 30″.3
22	2° 12′.7	5′ 32″.0
H. D.	1′.0	0″.9

TUESDAY, 23

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	+0° 14′.2	+7′ 19″.3
2	0° 12′.3	7′ 21″.0
4	0° 10′.3	7′ 22″.8
6	0° 8′.4	7′ 24″.5
H. D.	1′.0	0″.9

WEDNESDAY, 24

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	−0° 9′.2	+7′ 40″.1
2	0° 11′.1	7′ 41″.8
4	0° 13′.1	7′ 43″.6
H. D.	1′.0	0.″9

TUESDAY, 30

G. M. T. Hrs.	Sun's Declination	Equation of Time
6	−2° 35′.4	+9′ 46″.7
8	2° 37′.3	9′ 48″.3
10	2° 39′.3	9′ 50″.0
12	2° 41′.2	9′ 51″.6
20	2° 49′.0	9′ 58″.1
22	2° 50′.9	9′ 59″.7
H. D.	1′.0	0″.8

SEMI-DIAMETER

Sept.	1	15′.88
	11	15′.92
	21	15′.96
Oct.	1	16′.01

OCTOBER, 1919

WEDNESDAY, 1

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	−2° 52′.9	+10′ 1″.4
2	2° 54′.8	10′ 3″.0
H. D.	1′.0	0″.8

MONDAY, 6

16	−5° 4′.3	+11′ 46″.7
18	5° 6′.3	11′ 48″.2
20	5° 8′.2	11′ 49″.7
H. D.	1′.0	0″.7

SATURDAY, 11

0	−6° 43′.6	+12′ 59″.4
2	6° 45′.5	13′ 0″.7
4	6° 47′.3	13′ 2″.0
H. D.	0′.9	0″.6

WEDNESDAY, 15

12	−8° 24′.8	+14′ 5″.3
14	8° 26′.7	14′ 6″.4
16	8° 28′.5	14′ 7″.5
18	8° 30′.4	14′ 8″.6
H. D.	0′.9	0″.6

FRIDAY, 17

8	−9° 5′.4	+14′ 28″.9
10	9° 7′.3	14′ 29″.9
12	9° 9′.1	14′ 30″.9
14	9° 10′.9	14′ 32″.0
H. D.	0′.9	0″.5

SATURDAY, 18

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	−9° 20′.1	+14′ 37″.0
2	9° 21′.9	14′ 38″.0
4	9° 23′.7	14′ 39″.0
H. D.	0′.9	0″.5

THURSDAY, 23

0	−11° 8′.0	+15′ 28″.7
2	11° 9′.8	15′ 29″.4
4	11° 11′.6	15′ 30″.1
6	11° 13′.3	15′ 30″.8
8	11° 15′.1	15′ 31″.5
10	11° 16′.8	15′ 32″.2
12	11° 18′.6	15′ 32″.9
14	11° 20′.4	15′ 33″.6
16	11° 22′.1	15′ 34″.3
18	11° 23′.9	15′ 35″.0
20	11° 25′.6	15′ 35″.6
H. D.	0′.9	0″.3

SEMI-DIAMETER

Oct. 1	16′.01
11	16′.06
21	16′.10
31	16′.14

NOVEMBER, 1919

SATURDAY, 8

G. M. T. Hrs.	Sun's Declination	Equation of Time
0	−16° 21′.1	+16′ 13″.4
2	16° 22′.6	16′ 13″.1
4	16° 24′.1	16′ 12″.8
H. D.	0′.7	0″.2

THURSDAY, 27

18	−21° 7′.9	+12′ 18″.5
20	21° 8′.8	12′ 16″.8
22	21° 9′.7	12′ 15″.2
H. D.	0′.5	0″.8

FRIDAY, 28

0	−21° 10′.6	+12′ 13″.5
2	21° 11′.5	12′ 11″.8
H. D.	0′.4	0″.8

FRIDAY, 14

G. M. T. Hrs.	Sun's Declination	Equation of Time
8	−18° 7′.1	+15′ 33″.1
10	18° 8′.5	15′ 33″.2
12	18° 9′.8	15′ 32″.4
18	18° 13′.7	15′ 30″.1
20	18° 15′.0	15′ 29″.3
22	18° 16′.3	15′ 28″.5
H. D.	0′.7	0″.4

SUNDAY, 30

6	−21° 34′.1	+11′ 26″.9
8	21° 34′.9	11′ 25″.1
10	21° 35′.7	11′ 23″.3
H. D.	0′.4	0″.9

SEMI-DIAMETER

Nov. 1	16′.15
11	16′.19
21	16′.22
Dec. 1	16′.25

DECEMBER, 1919

G. M. T. Hrs.	Sun's Declination	Equation of Time
	MONDAY, 1	
18	−21° 48′.5	+10′ 53″.9
20	21° 49′.3	10′ 52″.1
22	21° 50′.1	10′ 50″.2
H. D	0′.4	0″.9
	TUESDAY, 2	
0	−21° 50′.9	+10′ 48″.3
2	21° 51′.6	10′ 46″.4
16	21° 56′.9	10′ 33″.1
18	21° 57′.7	10′ 31″.2
20	21° 58′.4	10′ 29″.3
22	21° 59′.2	10′ 27″.3
H. D.	0′.4	1″.0
	WEDNESDAY, 3	
0	−21° 59′.9	+10′ 25″.4
2	22° 0′.6	10′ 23″.5
4	22° 1′.4	10′ 21″.5
6	22° 2′.1	10′ 19″.6
H. D.	0′.4	1″.0

SEMI-DIAMETER

Dec. 1	16′.25
11	16′.28
21	16′.29
31	16′.30

G. M. T. Hrs.	Sun's Declination	Equation of Time
	MONDAY, 15	
0	−23° 14′.0	+5′ 9″.9
2	33° 14′.3	5′ 7″.5
4	23° 14′.6	5′ 5″.1
6	23° 14′.9	5′ 2″.7
8	23° 15′.2	5′ 0″.3
10	23° 15′.4	4′ 57″.9
12	23° 15′.7	4′ 55″.5
14	23° 16′.0	4′ 53″.1
16	23° 16′.2	4′ 50″.7
18	23° 16′.5	4′ 48″.3
20	23° 16′.8	4′ 45″.9
22	23° 17′.0	4′ 43″.4
H. D.	0′.1	1″.2
	TUESDAY, 16	
0	−23° 17′.3	+ 4′ 41″.0
2	23° 17′.5	4′ 38″.6
4	23° 17′.8	4′ 36″.2
H. D.	0′.1	1″.2
	WEDNESDAY, 24	
12	−23° 25′.8	+0′ 28″.0
14	23° 25′.7	0′ 25″.5
16	23° 25′.6	0′ 23″.0
H. D.	0′.0	1″.3
	THURSDAY, 25	
0	−23° 25′.3	+0′ 13″.0
2	23° 25′.2	0′ 10″.5
4	23° 25′.1	0′ 8″.0
H. D	0′.1	1″.2

APPARENT PLACES OF STARS, 1919—FOR THE UPPER TRANSIT OF GREENWICH

Special Name of Star.	Right Ascension.											
		Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Nov. 1	Dec. 1	Dec. 32
	h. m.	s	s	s	s	s	s	s	s	s	s	s
Spica........	13.20	56.3	57.3	58.0	58.5	58.6	58.6	58.3	58.0	57.7	58.3	59.3
Rigel.........	5.10	40.9	40.8	40.3	39.8	39.3	39.3	39.7	40.4	42.8	43.4	43.6
Procyon ...	7.35	6.1	6.4	6.2	5.7	5.2	4.9	4.9	5.3	7.6	8.4	9.1
Arcturus.....	14.11	58.3	59.3	60.1	60.7	61.0	61.0	60.8	60.3	59.6	60.0	60.8
Betelgeux....	5.50	49.6	49.6	49.2	48.7	48.3	48.2	48.5	49.1	51.6	52.3	52.7
Aldebaran....	4.31	18.6	18.4	18.0	17.5	17.2	17.3	17.9	18.7	21.2	21.8	21.9
Sirius........	6.41	36.9	37.0	36.6	36.1	35.5	35.3	35.3	35.8	38.2	39.0	39.4
Fomalhaut. ..	22.53	11.0	10.7	10.8	11.1	11.8	12.8	13.9	14.7	14.9	14.4	14.0
Antares......	16.24	26.3	27.3	28.2	29.2	29.9	30.4	30.6	30.4	29.0	29.2	29.8
Regulus......	10.04	5.5	6.2	6.5	6.4	6.0	5.6	5.3	5.2	6.6	7.6	8.5
Vega	18.34	10.7	11.2	12.0	13.0	14.0	14.7	15.2	15.1	13.1	12.7	12.7
Capella......	5.10	45.5	45.3	44.7	44.0	43.4	43.4	44.0	45.0	48.6	49.4	49.8

Special Name of Star.	Declination.											
		Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Nov. 1	Dec. 1	Dec. 32
	°	′	′	′	′	′	′	′	′	′	′	′
Spica........	−10	44.4	44.5	44.6	44.6	44.6	44.6	44.6	44.6	44.5	44.6	44.7
Rigel........	− 8	17.7	17.8	17.8	17.8	17.8	17.7	17.6	17.5	17.5	17.6	17.7
Procyon ..	+ 5	25.9	25.8	25.8	25.8	25.8	25.8	25.9	25.9	25.9	25.8	25.7
Arcturus.....	+19	36.0	35.9	35.9	35.9	36.0	36.1	36.1	36.2	36.0	35.9	35.7
Betelgeux....	+ 7	23.5	23.5	23.5	23.4	23.5	23.5	23.5	23.6	23.6	23.5	23.5
Aldebaran....	+16	20.9	20.9	20.8	20.8	20.8	20.8	20.8	20.9	21.0	21.0	20.9
Sirius........	−16	36.4	36.5	36.6	36.6	36.6	36.5	36.4	36.3	36.3	36.4	36.5
Fomalhaut. ..	−30	3.2	3.1	3.1	3.0	2.8	2.7	2.7	2.6	2.8	2.8	2.8
Antares......	−26	15.1	15.2	15.2	15.2	15.3	15.3	15.3	15.3	15.2	15.2	15.2
Regulus......	+21	21.6	21.5	21.5	21.5	21.6	21.6	21.6	21.6	21.5	21.4	21.3
Vega	+38	42.5	42.3	42.3	42.2	42.3	42.4	42.6	42.7	42.8	42.7	42.6
Capella......	+45	55.1	55.1	55.1	55.1	55.1	55.0	54.9	54.9	54.9	55.0	55.1

MERIDIAN TRANSIT OF STARS, 1919

GREENWICH MEAN TIME OF TRANSIT AT GREENWICH

Jan. 1	*Spica	18h 38′
Feb. 1	*Spica	16h 36′
1	*Arcturus	17h 27′
1	*Rigel	8h 27′
Mar. 1	*Arcturus	15h 37′
1	*Antares	17h 49′
May 1	*Sirius	4h 7′
June 1	*Sirius	2h 6′
1	*Canopus	1h 46′
July 1	*Canopus	23h 44′
Dec. 1	*Capella	12h 32′

CORRECTIONS TO BE APPLIED TO THE MEAN TIME OF TRANSIT ON THE FIRST DAY OF THE MONTH, TO FIND THE MEAN TIME OF TRANSIT ON ANY OTHER DAY OF THE MONTH.

Day of Month	Correction	Day of Month	Correction
1	0h 0′	17	−1h 3′
2	−0h 4′	18	1h 7′
3	0h 8′	19	1h 11′
4	0h 12′	20	1h 15′
5	0h 16′	21	1h 19′
6	−0h 20′	22	1h 23′
7	0h 24′	23	1h 27′
8	0h 28′	24	1h 30′
9	0h 31′	25	1h 34′
10	0h 35′	26	1h 38′
11	−0h 39′	27	1h 42′
12	0h 43′	28	1h 46′
13	0h 47′	29	1h 50′
14	0h 51′	30	1h 54′
15	0h 55′	31	−1h 58′
16	−0h 59′		

Note: If the quantity taken from this Table is greater than the mean time of transit on the first of the month, increase that time by 23h 56′ and then apply the correction taken from this Table.

MOON 1919

DECLINATION

G.M.T. Hrs.	Decl.	Diff.	S. D.	H. P.
	February 12			
2	+17° 57′.1	156	15′.7	57′.4
4	17° 41′.5	160	15′.6	57′.3
6	17° 25′.5	163	15′.6	57′.3
	February 18			
6	−8° 39′.5	209	14′.9	54′.5
8	9° 0′.4	208	14′.9	54′.5
10	9° 21′.2	206	14′.9	54′.4
	March 17			
4	−6° 52′.8	215	14′.9	54′.5
6	7° 14′.3	212	14′.9	54′.5
8	7° 35′.5	212	14′.9	54′.5
	April 18			
4	−20° 55′.4	58	14′.8	54′.1
6	21° 1′.2	53	14′.8	54′.2
8	21° 6′.5	50	14′.8	54′.2
	April 20			
10	−21° 8′.4	54	15′.0	54′.9
12	21° 3′.0	57	15′.0	54′.9
14	20° 57′.3	62	15′.0	55′.0
	May 20			
20	−13° 6′.5	193	15′.4	56′.4
22	12° 47′.2	195	15′.4	56′.5
	May 21			
0	−12° 27′.7	199	15′.4	56′.6
2	12° 7′.8	201	15′.5	56′.6
	June 13			
2	−21° 36′.2	12	14′.9	54′.6
4	21° 35′.0	16	14′.9	54′.6
6	21° 33′.4	21	14′.9	54′.7
	July 4			
0	−5° 48′.1	216	15′.0	55′.1
2	6° 9′.7	215	15′.0	55′.1
4	6° 31′.2	214	15′.0	55′.0
	August 16			
0	+12° 5′.0	214	16′.1	59′.2
2	12° 26′.4	211	16′.2	59′.2
4	12° 47′.5	208	16′.2	59′.2
	September 14			
16	+19° 42′.3	93	16′.3	59′.6
18	19° 51′.6	88	16′.3	59′.6
20	20° 0′.4	82	16′.3	59′.6
	November 25			
4	−19° 55′.7	66	14′.8	54′.2
6	19° 49′.1	70	14′.8	54′.2
8	19° 42′.1	74	14′.8	54′.3
	December 5			
10	18° 25′.4	127	16′.7	61′.2
12	18° 38′.1	123	16′.7	61′.2
14	18° 50′.4	117	16′.7	61′.3

MOON 1919

TIME OF TRANSIT, MERIDIAN OF GREENWICH

Date		Greenwich Mean Time	Diff.
Jan.	9	6h 4′	
			54
	10	6h 58′	
			56
	11	7h 54′	
	17	13h 30′	
			46
	18	14h 16′	
			44
	19	15h 0′	
	27	21h 7′	
			53
	28	22h 0′	
			52
	29	22h 52′	
Feb.	3	2h 18′	
			51
	4	3h 9′	
			52
	5	4h 1′	
			53
	6	4h 54′	
			56
	7	5h 50′	
			57
	8	6h 47′	
	16	13h 37′	
			43
	17	14h 20′	
			43
	18	15h 3′	
			43
	19	15h 46′	
Mar.	4	1h 52′	
			55
	5	2h 47′	
			57
	6	3h 44′	
	9	6h 38′	
			56
	10	7h 34′	
			53
	11	8h 27′	
Apr.	7	6h 24′	
			51
	8	7h 15′	
			48
	9	8h 3′	
May	2	2h 15′	
			62
	3	3h 17′	
			58
	4	4h 15′	
			54
	5	5h 9′	
June	15	13h 55′	
			49
	16	14h 44′	
			48
	17	15h 32′	
July	3	4h 49′	
			44
	4	5h 33′	
			43
	5	6h 16′	
	7	7h 45′	
			47
	8	8h 32′	
			48
	9	9h 20′	
			50
	10	10h 10′	
			50
	11	11h 0′	
			51
	12	11h 51′	
	18	16h 43′	
			51
	19	17h 34′	
			54
	20	18h 28′	
Aug.	24	23h 48′	
			46
	26	0h 34′	
			46
	27	1h 20′	
Sept.	11	13h 24′	
			55
	12	14h 19′	
			56
	13	15h 15′	
			58
	14	16h 13′	
Oct.	25	0h 56′	
			47
	26	1h 43′	
			48
	27	2h 31′	
Dec.	18	21h 36′	
			48
	19	22h 24′	
			48
	20	23h 12′	

RIGHT ASCENSION AND DECLINATION OF PLANETS

VENUS, 1919

Greenwich Mean Time

Date	Apparent Right Ascension	Diff.	Apparent Declination	Diff.	Transit Meridian of Greenwich
Jan. 1	19h 24′ 13″		−23° 6′.3		0h 44′
		325		94	
2	19h 29′ 38″		22° 56′.9		0h 45′
		324		101	
3	19h 35′ 2″		22° 46′.8		0h 47′
23	21h 19′ 19″		−17° 11′.6		1h 12′
		300		226	
24	21h 24′ 19″		16° 49′.0		1h 13′
		298		230	
25	21h 29′ 17″		16° 26′.0		1h 14′
28	21h 44′ 5″		−15° 14′.1		1h 17′
		293		248	
29	21h 48′ 58″		14° 49′.3		1h 18′
		292		252	
30	21h 53′ 50″		14° 24′.1		1h 19′
Feb. 7	22h 32′ 6″		−10° 49′.6		1h 26′
		282		282	
8	22h 36′ 48″		10° 21′.4		1h 27′
		281		285	
9	22h 41′ 29″		9° 52′.9		1h 27′
17	23h 18′ 27″		− 5° 56′.8		1h 33′
		273		304	
18	23h 23′ 0″		5° 26′.4		1h 34′

Hor. Parallax Jan. 1, 0′.09; Feb. 1, 0′.09.

MARS, 1919

Date	Apparent Right Ascension	Diff.	Apparent Declination	Diff.	Transit Meridian of Greenwich
Jan. 30	22h 18′ 55″		−11° 33′.5		1h 44′
		179		175	
31	22h 21′ 54″		11° 16′.0		1h 43′
		179		176	
Feb. 1	22h 24′ 53″		10° 58′.4		1h 42′
June 11	4h 38′ 56″		+22° 28′.1		23h 23′
		178		63	
12	4h 41′ 54″		22° 34′.4		23h 22′
		179		60	
13	4h 44′ 53″		22° 40′.4		23h 21′

Hor. Parallax Feb. 1, 0′.07; June 1, 0′.06

JUPITER, 1919

Greenwich Mean Time

Date	Apparent Right Ascension	Diff.	Apparent Declination	Diff.	Transit Meridian of Greenwich
Apr. 13	6h 36′ 49″		+23° 23′.5		5h 14′
		31		4	
14	6h 37′ 20″		23° 23′.1		5h 10′
		33		4	
15	6h 37′ 53″		23° 22′.7		5h 7′
Dec. 23	9h 21′ 11″		+16° 17′.2		15h 15′
		14		13	
24	9h 20′ 57″		16° 18′.5		15h 10′
		15		14	
25	9h 20′ 42″		16° 19′.9		

Hor. Parallax Apr. 1, 0′.03; Dec. 1, 0′.03; Dec. 32, 0′.03

SATURN, 1919

Date		Apparent Right Ascension	Diff.	Apparent Declination	Diff.	Transit Meridian of Greenwich
July	5	9h 53′ 12″		+14° 18′.8		3h 3′
			24		22	
	6	9h 53′ 36″		14° 16′.6		3h 0′
			25		21	
	7	9h 54′ 1″		14° 14′.5		2h 56′
Oct.	4	10h 35′ 20″		+10° 29′.3		21h 44′
			26		24	
	5	10h 35′ 46″		10° 26′.9		21h 40′
			25		23	
	6	10h 36′ 11″		10° 24′.6		21h 37′

Hor. Parallax July 1, 0′.01; Oct. 1, 0′.01

TABLE 1, P. 107, NAUTICAL ALMANAC

CORRECTION TO BE APPLIED TO TRUE ALTITUDE OF POLARIS

Local S.T.	1^h	4^h	7^h	8^h	9^h
0m	−1° 6′.7	−0° 53′.5	−0° 8′.7	+0° 8′.9	+0° 25′.8
	3	19	29	29	27
10m	1° 7′.0	0° 51′.6	0° 5′.8	0° 11′.8	0° 28′.5
	2	19	30	29	27
20m	1° 7′.2	0° 49′.7	−0° 2′.8	0° 14′.7	0° 31′.2
	1	20	29	28	25
30m	−1° 7′.3	−0° 47′.7	+0° 0′.1	+0° 17′.5	+0° 33′.7
	0	22	30	28	25
40m	1° 7′.3	0° 45′.5	0° 3′.1	0° 20′.3	0° 36′.2
	2	22	29	28	24
50m	1° 7′.1	0° 43′.3	0° 6′.0	0° 23′.1	0° 38′.6
	3	23	29	27	24
60m	−1° 6′.8	−0° 41′.0	+0° 8′.9	+0° 25′.8	+0° 41′.0

Local S.T.	10^h	11^h	13^h	14^h	15^h
0m	+0° 41′.0	+0° 53′.3	+1° 6′.7	+1° 6′.8	+1° 2′.5
	23	18	3	4	11
10m	0° 43′.3	0° 55′.1	1° 7′.0	1° 6′.4	1° 1′.4
	22	16	2	5	13
20m	0° 45′.5	0° 56′.7	1° 7′.2	1° 5′.9	1° 0′.1
	21	15	1	7	14
30m	+0° 47′.6	+0° 58′.2	+1° 7′.3	+1° 5′.2	+0° 58′.7
	20	14	0	8	15
40m	0° 49′.6	0° 59′.6	1° 7′.3	1° 4′.4	0° 57′.2
	19	13	2	9	15
50m	0° 51′.5	1° 0′.9	1° 7′.1	1° 3′.5	0° 55′.7
	18	12	3	10	17
60m	+0° 53′.3	+1° 2′.1	+1° 6′.8	+1° 2′.5	+0° 54′.0

Local S.T.	16^h	18^h	21^h	22^h	23^h
0m	+0° 54′.0	+0° 26′.8	−0° 24′.7	−0° 40′.2	−0° 52′.8
	18	27	27	23	18
10m	0° 52′.2	0° 24′.1	0° 27′.4	0° 42′.5	0° 54′.6
	19	27	27	23	17
20m	0° 50′.3	0° 21′.4	0° 30′.1	0° 44′.8	0° 56′.3
	20	28	26	21	16
30m	+0° 48′.3	+0° 18′.6	−0° 32′.7	−0° 46′.9	−0° 57′.9
	21	29	26	21	14
40m	0° 46′.2	0° 15′.7	0° 35′.3	0° 49′.0	0° 59′.3
	21	28	25	20	14
50m	0° 44′.1	0° 12′.9	0° 37′.8	0° 51′.0	1° 0′.7
	23	29	24	18	12
60m	+0° 41′.8	+0° 10′.0	−0° 40′.2	−0° 52′.8	−1° 1′.9