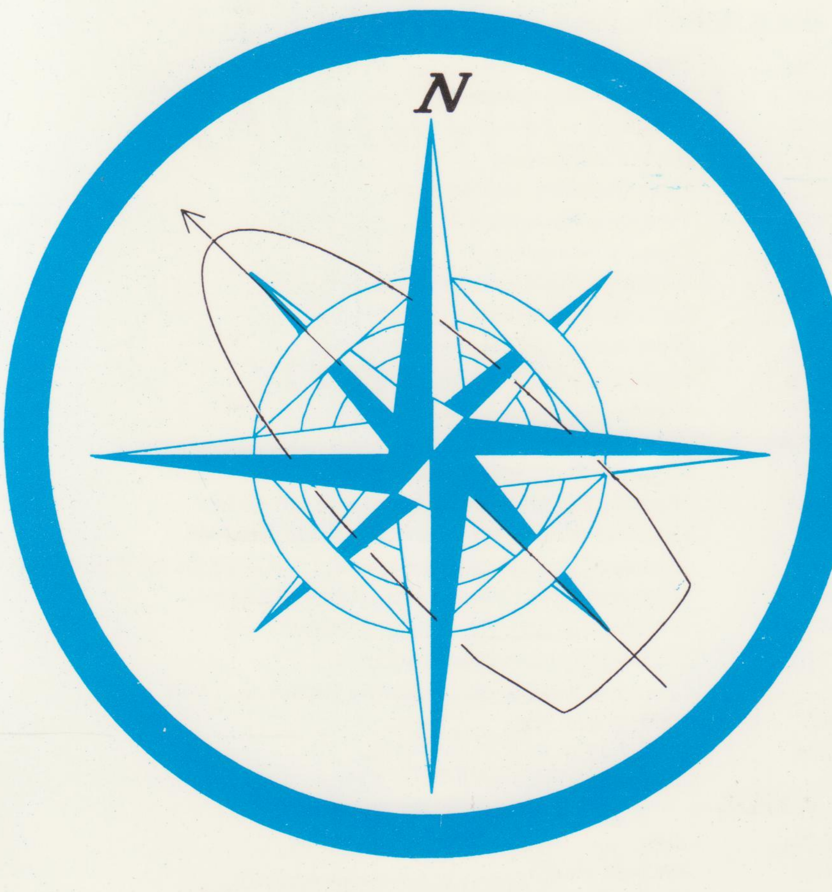
TERRESTRIAL NAVIGATION 1



EUGENIO J. YNION

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EUGENIO J. YNION

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Foreword

In June 1998, the *Commission on Higher Education (CHED)* implemented a new structure as well as new curricula for education towards Bachelor of Science in Marine Transportation and Bachelor of Science in Marine Engineering. These changes were made to comply with the amendments made to the *International Convention on Standards of Training and Watchkeeping for Seafarers of 1978 (STCW 78)* and adopted by the *International Maritime Organization (IMO)* in July 1995.

The goal of this book is to at least provide the knowledge needed to meet the requirements stated in CHED's syllabus for the subject. Every reasonable effort has been made to ensure that the information provided is relevant and presented in a logic and pedagogical correct way.

It must be born in mind, however, that the technical and socio-economical development entail that new equipment and systems will constantly be introduced and implemented in the shipping industry. This development and its consequences must also be reflected in the applicable teaching aids.

Any comments for improving and updating this book will therefore be highly appreciated.

Manila, March 8, 2001
Philippine Foundation for Maritime Teaching Aids, Inc.
Erik Raeng, Director

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Preface

In the preparation of this book, the author took into consideration the Course Module on NAV 1 (Terrestrial Navigation 1) which was prepared for the BSMT curriculum by the curriculum developers of the Commission on Higher Education (CHED) in cooperation with the specialists on Enhancing Maritime Education and Training (EMET) program.

Consideration was also given to both the estimated entry level of knowledge of the students enrolling in this course and to the time allotted to the study of the course. The author realizes that a good book on this subject should contain the basic ideas and theories of terrestrial navigation and the practical application of such theories on specific and realistic problems and situations as a more desirable objective from the mariners point of view.

It is for these reasons that the author decided to give more emphasis on the applications rather than on the intricacies of mathematical theories although some simple derivations of basic concepts are presented whenever they are thought to enhance the student's interest on the particular topic.

To meet the curricular requirements of the course, the book presents the following salient features:

1. Simple presentation of the basic concepts in terrestrial navigation.
2. Clear explanation of procedures, with illustrations.
3. Close adherence to the sequencing of recommended topics.
4. Practical exercises are attuned to contemporary practice of marine navigation.

This book begins with the basic concepts in terrestrial navigation on the assumption that the student is familiar with elementary geometry and arithmetic. The student is then led from a review of these basic concepts learned from high school to the discussion of relevant topics in navigation which find varied applications in the subsequent practical exercises.

The undersigned believes that a textbook should be a little more than a suggestive outline, not a complete treatise to take the place of the living teacher or to obviate the need of study and research on the part of the student. A textbook should be a stimulus and a guide to work, not a substitute for work. Having said this, the undersigned has intentionally left some undefined terms and theorems that the student has to do a little research in order to fully understand such theorems and theories.

The author is grateful to the challenge posed and the inspiration provided by Capt. Erik Raeng and to the staff of MARTA for their incessant reminders on deadlines and overdue manuscripts and to all those who in one way or the other have encouraged and helped me produce this book.

CAPT. EUGENIO J. YNION

Chapter One
BASIC CONCEPTS IN TERRESTRIAL NAVIGATION

At the end of this chapter, the student should be able to:

- identify the circles, points and angles on the Earth that are used in navigation;
- locate the position of the observer on the surface of the Earth;
- compute the basic latitude and longitude problems usually encountered in navigation; and
- calculate speed-time-distance relationship problems that are involved in the process of navigation.

Navigation has been defined as a process of directing the movement of a ship from one point of the earth to the other via a shortest, convenient route that is consistent with safety. Simply stated, the shortest route may not always be convenient and safe or the most convenient and safest route may not always be the shortest. This means that a ship has to be navigated across a body of water that is safe for the vessel to pass through.

Terrestrial navigation is a kind of navigation which makes use of landmarks such as lighthouses, buoys, headlands, or any objects on the surface of the Earth as a means of determining the position of the ship.

There are several ways and methods of determining a ship's position by means of terrestrial objects. This part of the book will introduce the beginner to the world of terrestrial navigation.

1.1 THE EARTH

The Earth, the planet in which we live in, is roughly spherical in shape. That means it is not actually a perfect sphere. Its true shape is that of an "oblate spheroid". It is a little bit flattened at the poles. Its polar diameter is shorter than its equatorial diameter by about 11.5 miles but in most problems of navigation, the earth is treated as if it is a true sphere. For navigational purposes, therefore, the earth is considered a perfect sphere.

In the old days, professors and theorists in the subject of Navigation had to submit general proofs that the Earth is round.

However, when the U.S. and Russia launched rocket ships to space that brought man to the moon and beyond photographs were taken of the Earth from space and since that time there were no more debates as to the real shape of the Earth.

Figure 1.1 – A photograph of the illuminated part of the Earth taken from a weather satellite.

(Source: National Environmental Satellite Service (NESS), USA)

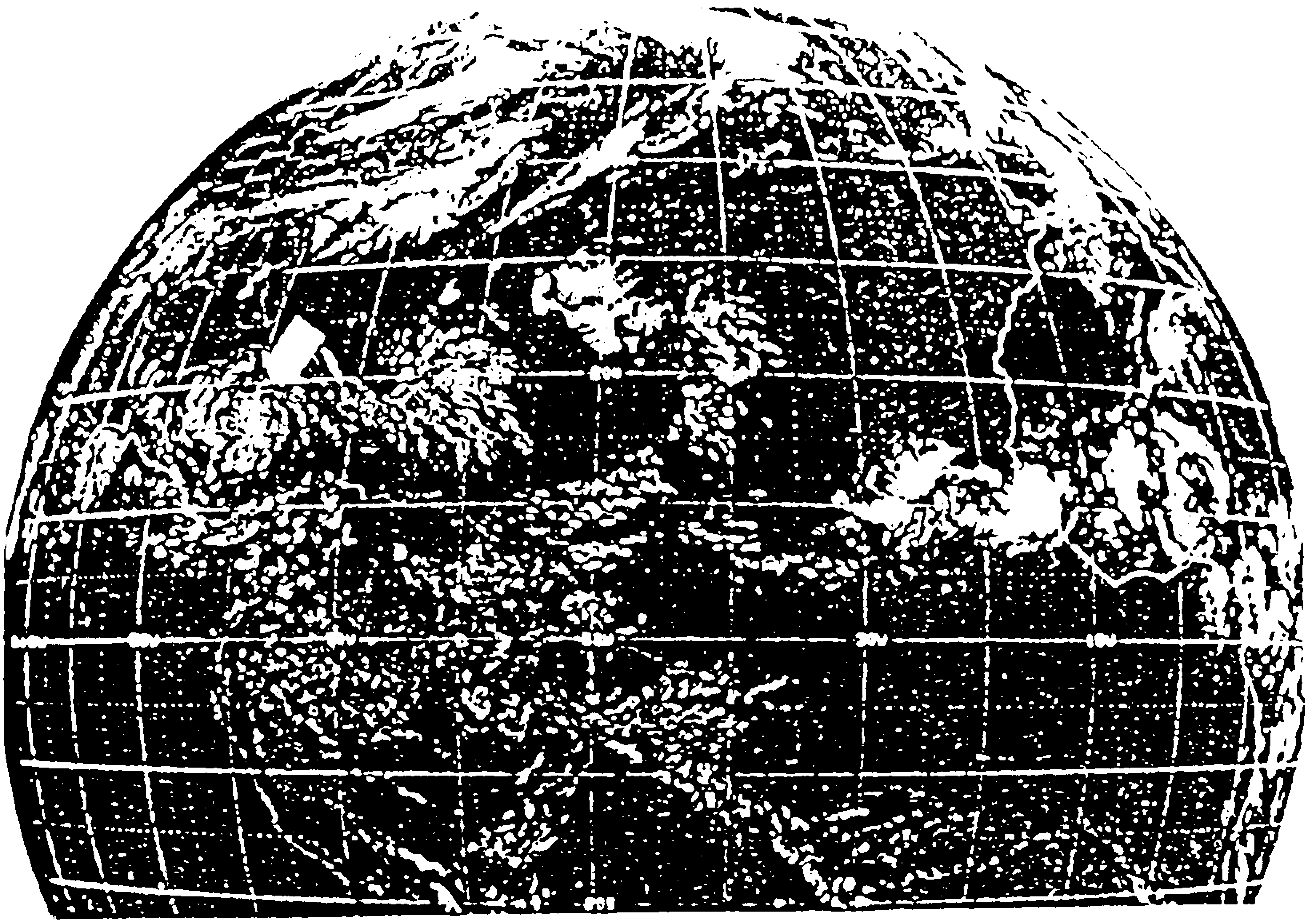


Figure 1.2 – Another photograph of the Earth taken from a weather satellite showing about ¾ of the Earth from South America to the North Pole
(Source: NESS, USA)

Figure 1.3 – A photograph of the whole Earth as seen from a weather satellite orbiting the Earth above the equator from a height of about 22,300 miles.
(Source: NESS, USA)

All these photographs offer proofs that the shape of the Earth is almost a perfect sphere.

The globe in the library is the Earth in miniature. The two points where the globe spins are the poles. Our planet Earth rotates about a fixed diameter called the Earth's "axis". The extremities of the Earth's axis are known as the Earth's "poles". The direction towards which the Earth's surface is carried around the Earth's axis is known as "East". The opposite direction is known as "West". To get a clearer view of this explanation, picture a basketball rotating at the fingertip of a basketball player. If the direction of rotation is from left to right that direction is called *east*. The opposite direction is *west*. The point at which the fingertip is located is one of the poles. Diametrically opposite this point is another pole *(see Figure 1.4).*

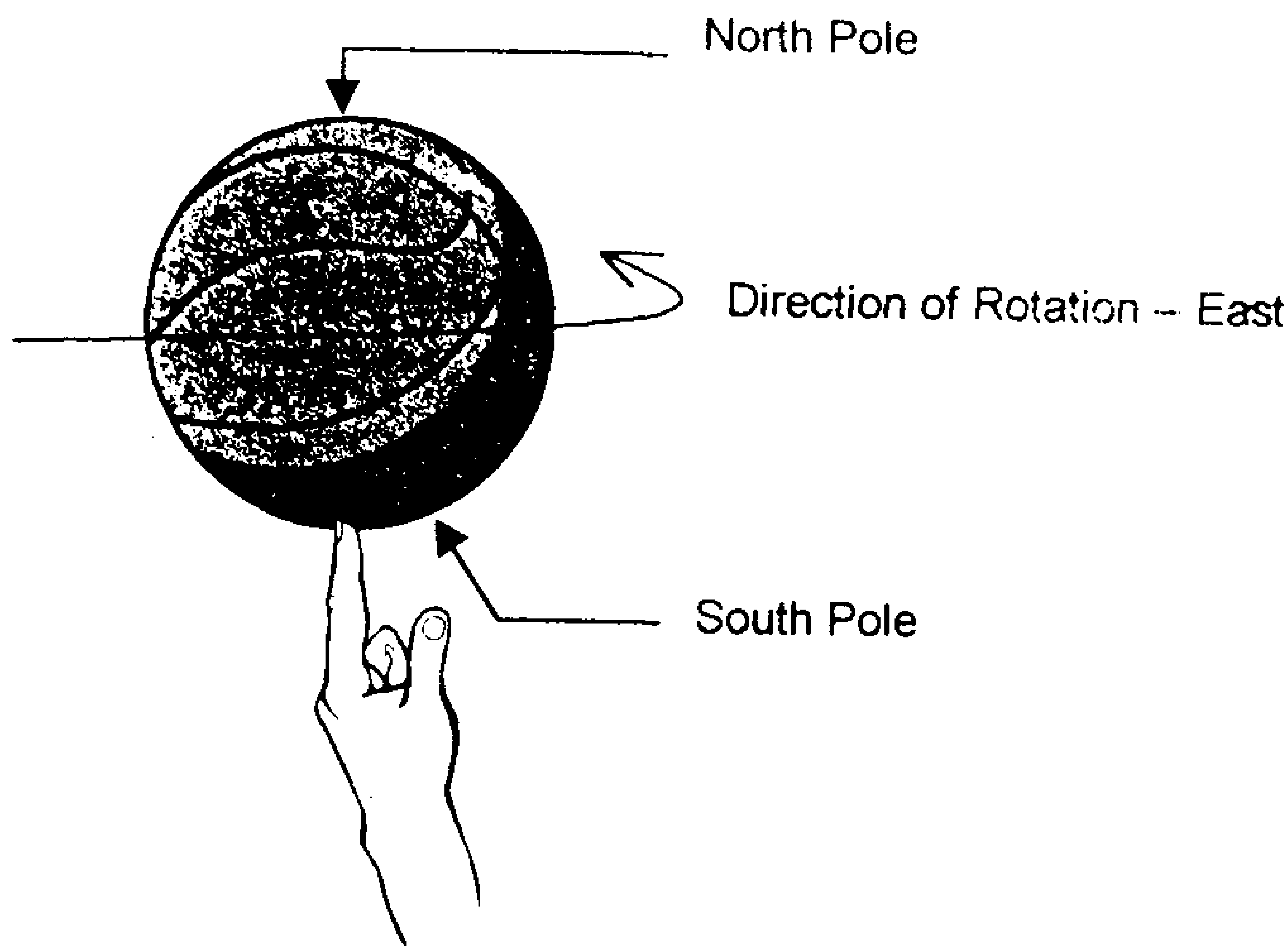


Figure 1.4 – The Earth's poles

The Earth's pole, from which the Earth's rotation would be observed to be anti-clockwise, is known as the "North Pole". The other pole from which the Earth's rotation would be observed to be clockwise is known as the "South Pole".

Questions

1. Research on the origin of the word "navigate".
2. Research on the definition of a sphere and its properties.

1.2 CIRCLES OF THE EARTH

Before discussing the circles of the Earth, it is necessary for the student to know what are small and great circles. A piece of orange can be used. Have a knife cut through it such that the blade of the knife passes through the center of the orange. There will be two circles as shown in Figure 1.5.

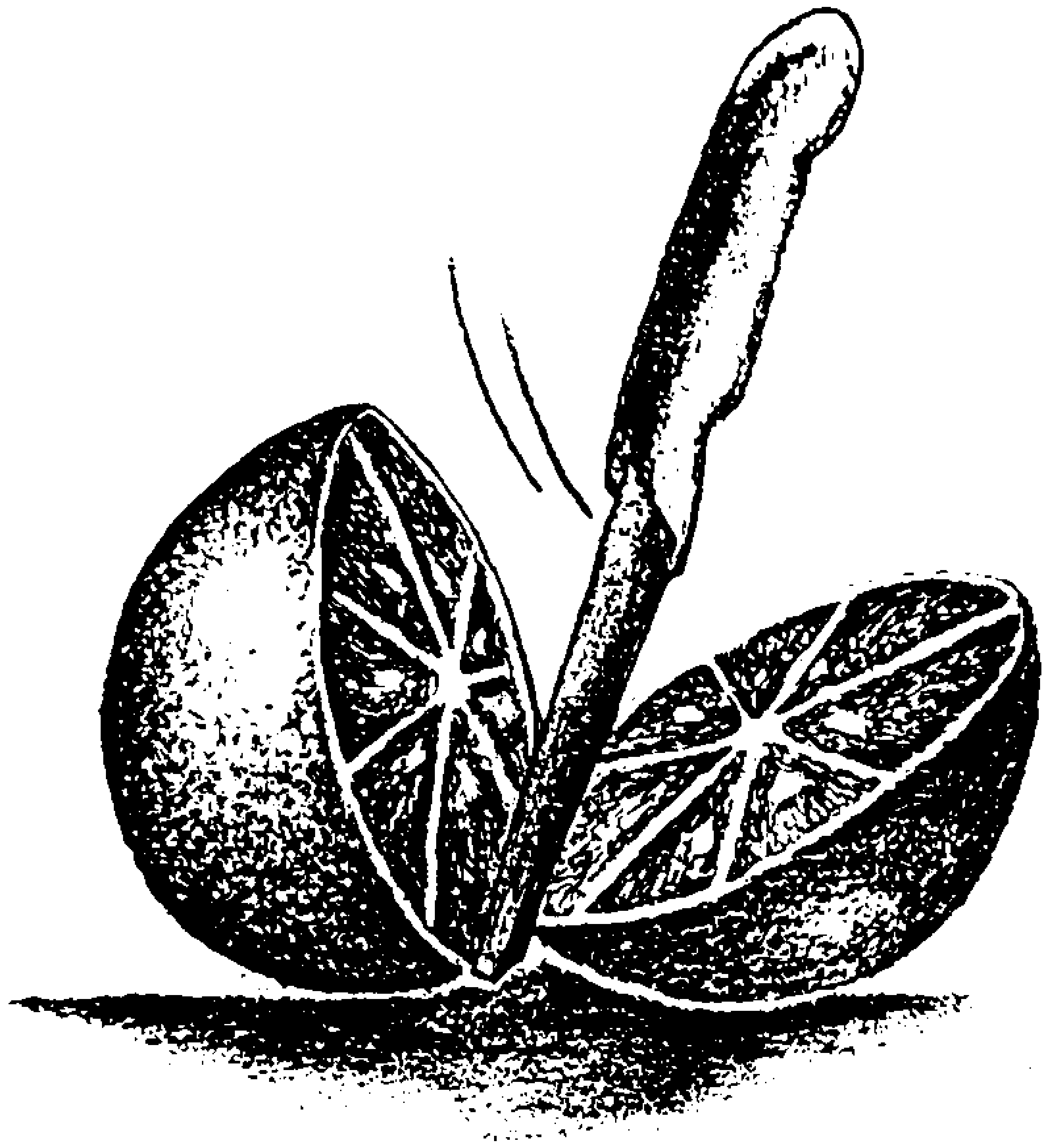
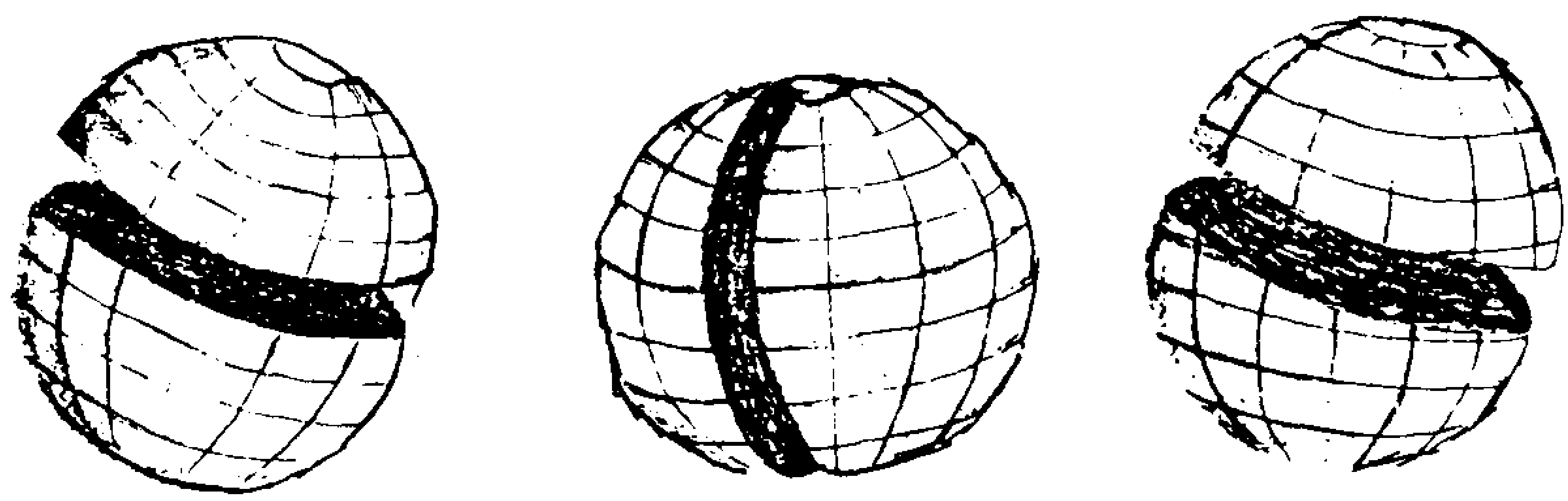


Figure 1.5 – Great circles

For as long as the blade (plane) of the knife passes through the center of the orange the circles that are produced will always be great circles.

A *great circle* therefore is formed by the intersection of a spherical surface with any plane passing through its center. It is that line on the surface of a sphere which divides the sphere into two equal parts.

Another piece of orange is taken and to be cut into two parts again but this time the blade of the knife does not pass through the center of the orange such as the one shown in Figure 1.6.



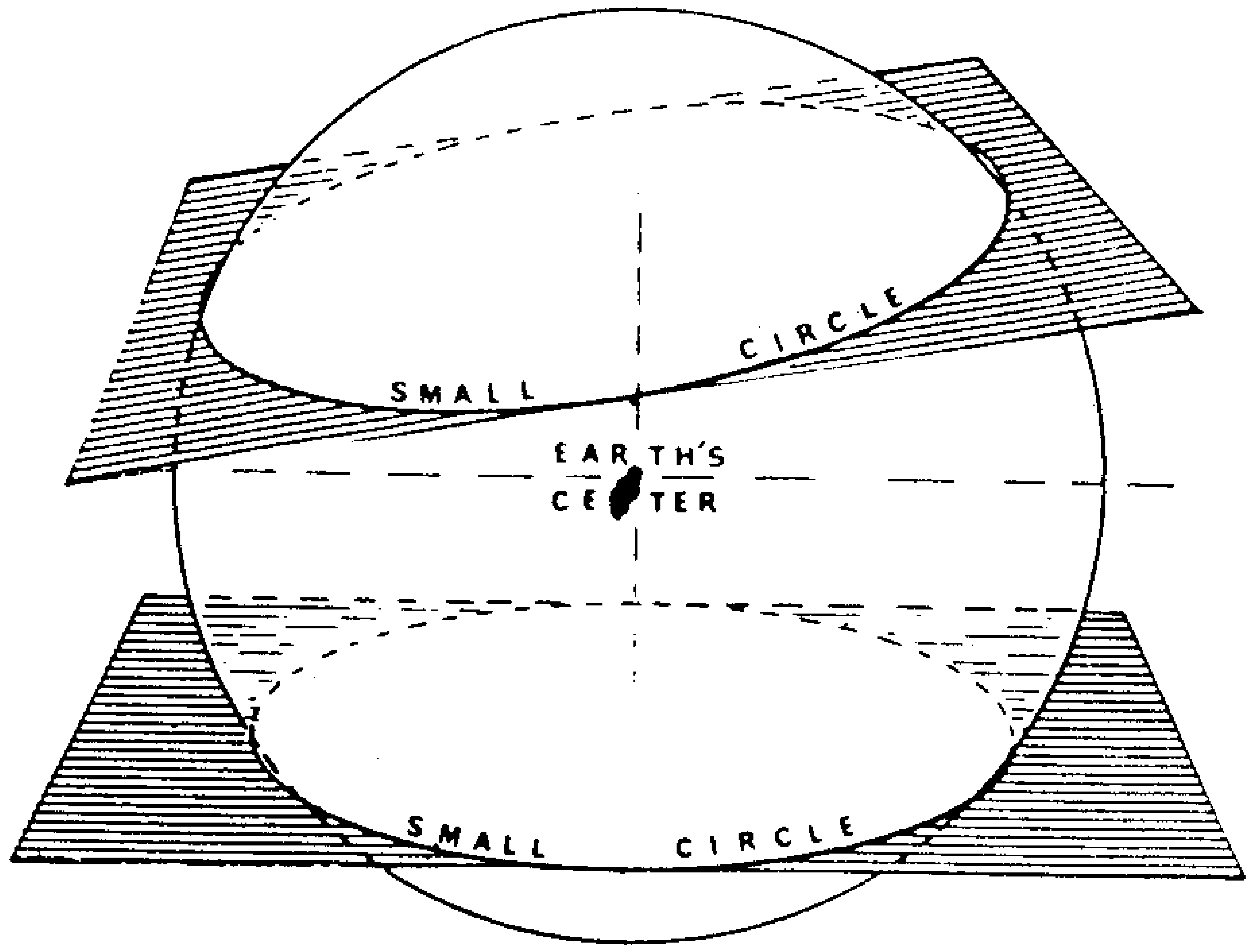


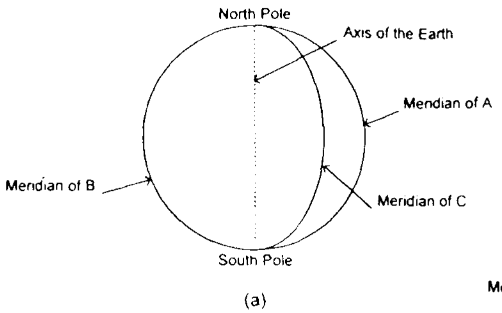
Figure 1.6 – Small circles

It can be seen from the figure that regardless of how large or small the "sliced off" portion of the orange maybe as long as the cutting edge does not pass through the center of the orange, it does not divide the orange into two equal halves. The circles that can be produced through this process are called *small circles*.

The Meridians

A great circle whose plane passes through the North and South poles of the Earth would describe two semi-great circles which are diametrically opposite each other. These semi-great circles are called *meridians*. There are many meridians that can be drawn on the surface of the earth. In fact, there are 360 meridians that can be drawn around the earth which are spaced at one degree from each other. And, there are 21,600 meridians that can be drawn around the earth which are one minute (1') of arc apart. Actually, these semi-great circles are imaginary "strings" that connect the North and South poles of the Earth *(see Figure 1.7)*. If you take a closer look at the globe, you will see many places on the Earth that are situated along the same meridian.

One particular meridian that passes through the original position of the Royal Observatory at Greenwich, England is called the *Greenwich Meridian* or the *Prime Meridian*. This meridian will become very important to you later in this chapter.



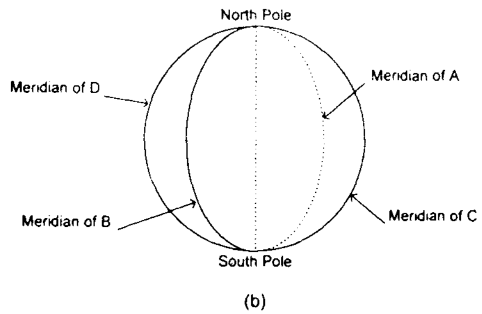


Figure 1.7 – Meridian

Referring to Figure 1.7(a), the right semi-circle is the meridian of A while the left semi-circle is the meridian of B. Another meridian, C, is also shown.

Let the earth be rotated a little bit to the right and let it stop at its position in Figure 1.7(b). You will see that the Meridian of A has now moved at the back of the figure *(shown by a dotted semi-circle to emphasize that it is at the back of the figure).* Meridian C has now taken the place of Meridian A. Meridian B has moved towards the front of the figure and another Meridian D has emerged from behind.

What is emphasized in this illustration is that every time a circle is drawn to represent the earth, the circumference will always represent two meridians, one meridian diametrically opposite each other. Because they are imaginary semi-circles that are fixed on the surface of the earth, they are considered permanent and they go with the rotation of the Earth.

The Equator

A great circle whose plane is perpendicular to the plane of all meridians is called the ***equator***. Since there is only one great circle that can satisfy this definition it follows that there is only one equator on the surface of the Earth.

Earlier it was said that the Earth is spherical in shape, though not a perfect sphere. If it is a sphere then one half of it is called a *hemisphere*.

The equator therefore divides the Earth into two hemispheres. The hemisphere which covers the area of the Earth from the equator to the North Pole is called the ***northern hemisphere***. The other hemisphere that covers the area of the Earth from the equator to the South Pole is called the ***southern hemisphere***.

Places on the surface of the Earth like the Philippines that are located north of the equator are said to be in the northern hemisphere. Australia is in the southern hemisphere.

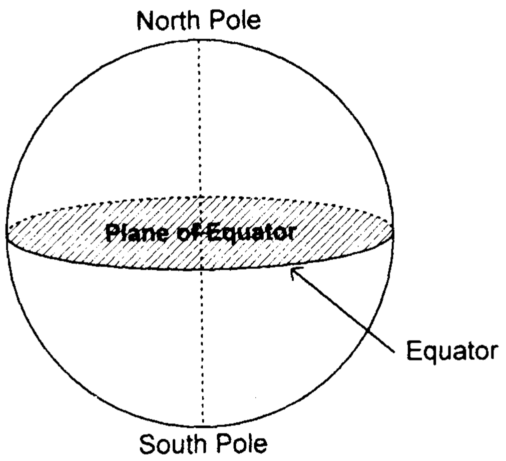


Figure 1.8 - The Equator

The Parallels of Latitude

Small circles whose planes are parallel to the plane of the equator are called ***parallels of latitude***. Sometimes they are also referred to as ***latitude parallels*** or simply ***parallels***. Like meridians, there are also many parallels of latitude that can be drawn on the surface of the Earth. In fact there are 88 parallels of latitude that can be drawn from the equator to the North Pole at a distance of one degree from each other; Likewise, there are also 88 parallels of latitude from the Equator to the South Pole that are spaced at one degree from each other *(see Figure 1.9)*.

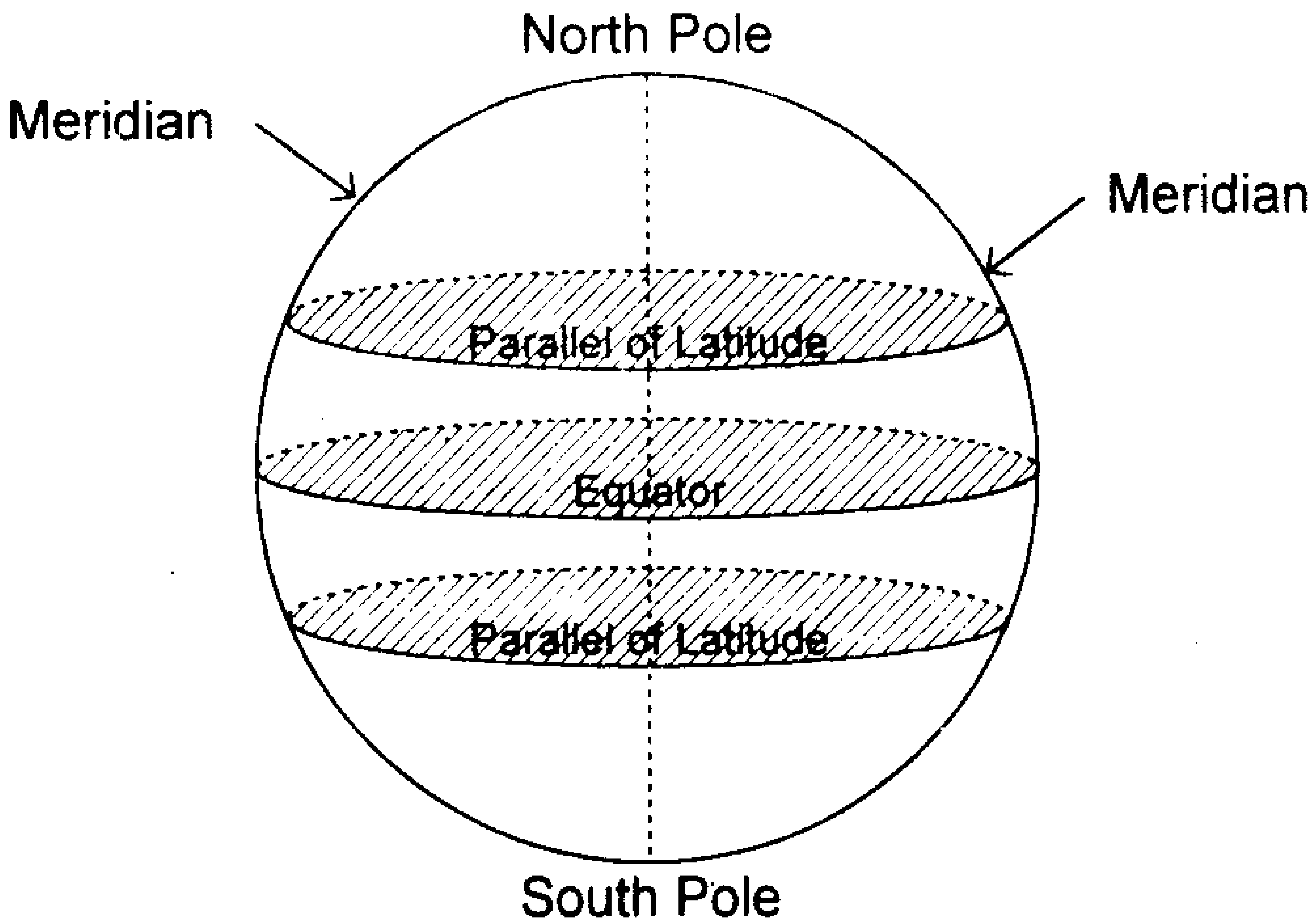


Figure 1.9 – The Parallels of Latitude

If one takes a closer look at the globe he will see many places on the Earth that are situated along the same parallel of latitude. The city of Manila, for instance, lies almost on the same parallel with Dakar, Senegal and San Salvador, Guatemala.

Questions

1. What are small circles? What are great circles?
2. Give examples of great circles on the Earth.
3. What is the difference between a meridian and the equator?
4. What is one thing in common between a meridian and the equator?
5. If it is possible to bring the observer directly over the equator and facing the North Pole at such a distance that he can see the whole Earth, how would the meridians appear?
6. At what point of the Earth will you position yourself so that you can see the Earth rotate in a clockwise direction?

1.3 ANGLES ON THE EARTH

The Latitude (Lat or L)

The angle that a parallel of latitude makes with the plane of the equator is called *latitude.* This angle is measured at the center of the Earth from the plane of the equator to the plane of the parallel of latitude. Latitude should not be confused with parallel of latitude as there is a difference between the two. Latitude is an angle while parallel of latitude is a circle. Latitude is also defined as an arc of a meridian located between the equator and the parallel of latitude.

Latitude is named either ***north*** or ***south***. If the latitude of a point on the Earth's surface is, for example, 30°, this means that the angle subtended by the parallel of latitude in which this particular point is located is 30° from the equator. Since the same angle can be describe from both sides of the Equator, a distinction must be made whether this angle is measured northward or southward from the equator.

When the latitude of a point on the Earth's surface is measured northward from the equator, the same place is said to have a north latitude. If the latitude is 30°, then the latitude of a place is said to be latitude 30° North. The same is true in south latitude. Sydney, in Australia, is situated about Lat 34° S. Manila is situated about latitude 14° N.

Bear in mind that latitude is measured in degrees from 0° to 90° North or South from the equator to the poles.

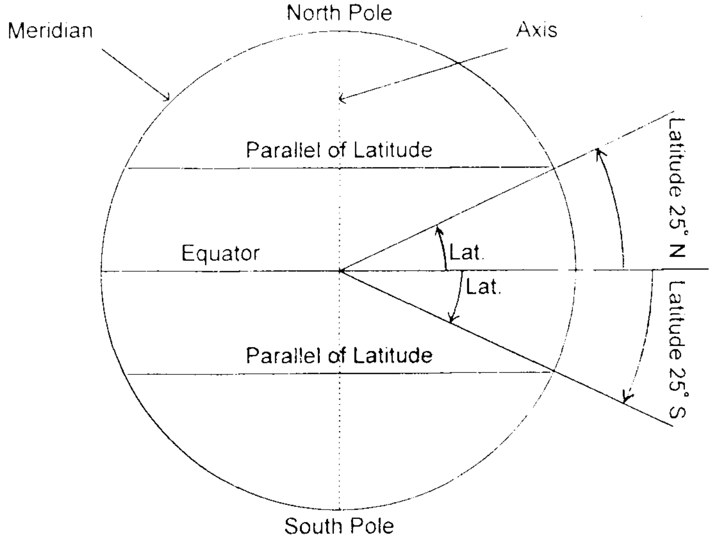


Figure 1.10 – The Measurement of Latitude

Finding the Difference of Latitude

The difference of latitude (d. lat. or l) between two places is the arc of a meridian, contained between the parallels of latitude of the two places *(see Figure 1.11).*

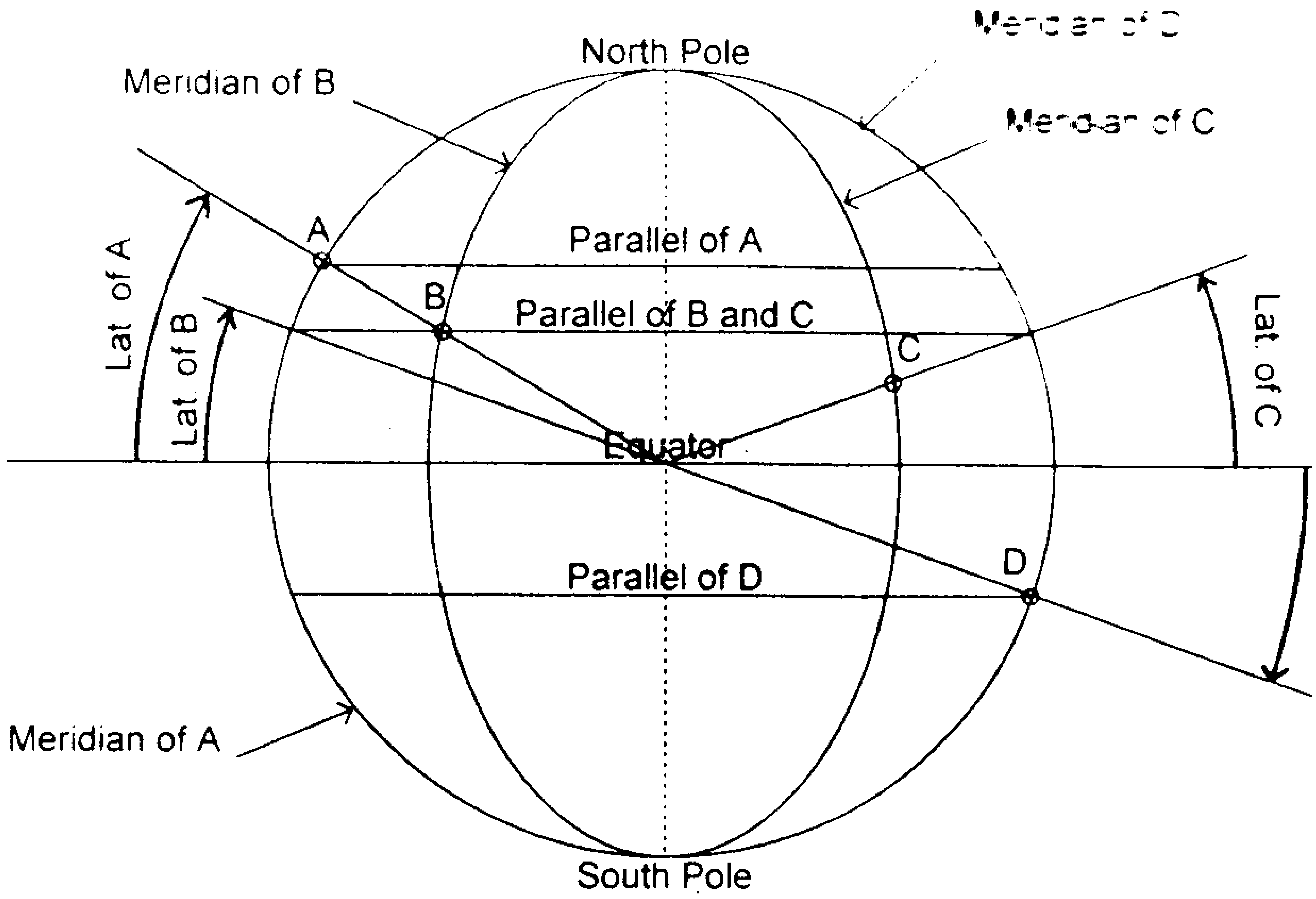


Figure 1.11 – Difference of latitude

From what can be seen in Figure 1.11, one can derive rules to find the difference of latitude. For instance, the difference of latitude between points A and B which are located on the same side of the Equator can be found by finding the difference between the latitude of B and the latitude of A. On the other hand, the difference of latitude between points C and D can be found by adding the latitude of C and the latitude of D.

The rules, therefore, are as follows:

1. Latitude the same name (both North or both South) - subtract the lesser latitude from the greater latitude.
2. Latitude different names (one North, one South) - add their latitudes.

Example

Find the d. lat. between the following places:

(a)	Lat. of A	=	20° 38' N
	Lat. of B	=	15° 22' N
(b)	Lat. of A	=	15° 10' S
	Lat. of B	=	06° 08' N
(c)	Lat. of A	=	20° 33' S
	Lat. of B	=	15° 36' S
(d)	Lat. of A	=	54° 45' N
	Lat. of B	=	00° 55' S

(e) A ship sailed from L 14° 06.7' N and arrived at L 35° 00.7' N. Find the difference of latitude that she made.

Solutions:

(a)	Lat. of A	=	20° 38' N
	Lat. of B	=	15° 22' N
	d. lat.	=	5° 16'
(b)	Lat. of A	=	15° 10' S
	Lat. of B	=	06° 08' N
	d. lat.	=	21° 18'
(c)	Lat. of A	=	20° 33' S
	Lat. of B	=	15° 36' S
	d. lat.	=	04° 57'
(d)	Lat. of A	=	54° 45' N
	Lat. of B	=	00° 55' S
	d. lat.	=	55° 40'
(e)	Lat. of departure (A)	=	14° 06.7' N
	Lat. of arrival (B)	=	35° 00.7' N
	d. lat.	=	20° 54.0' N

Note: **The best method to solve this kind of a problem is to make a plot of the parallel of the two places. It will be easy for you to determine the direction of travel of the ship rather than resort to rules which you are apt to forget. Note further, that d. lat is named N or S whenever the direction of movement is North or South respectively. When the direction of travel is not specified, d. lat has no name.**

Situation (e) can now be plotted as follows:

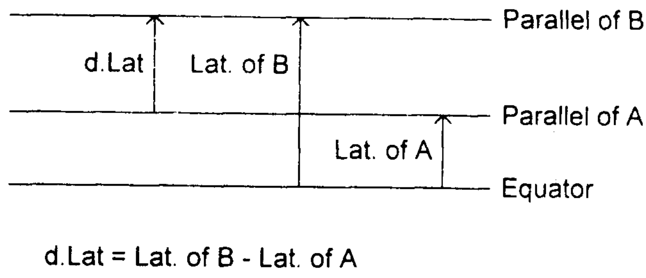


Figure 1.12 – Plotting difference of latitude

The Longitude (λ or Long)
In the topic of "meridians", a particular meridian was introduced which is called the ***Greenwich Meridian*** or the ***Prime Meridian.*** This particular meridian has been selected as the starting point for the measurement of ***longitude.***

Short History of Prime Meridian
Unlike latitude where there is only one Equator to serve as a reference great circle for measuring latitude, longitude has many meridians that could serve as reference meridian from where to start measuring the longitude. Deciding which particular meridian to use as the reference meridian for measuring longitude requires international agreement. In fact, up to the beginning of the 19th Century, there was little uniformity among chart makers of the world as to the meridian from which to measure longitude. Before the 19th century, reference meridians transferred from one prominent meridian to another. The meridian passing through the city of London, England was used as early as 1676 but this was not used extensively throughout the world. In 1810, there was an attempt to make the meridian passing through Washington, D.C., U.S.A. as the prime meridian for American navigators and chart makers but that attempt proved unsuccessful. It was only towards the end of the 18th Century (1884) when the meridian passing through the Royal Observatory in Greenwich, England, became very popular internationally that chart makers began using the meridian of that observatory as the prime meridian.

Today, all maritime nations have designated the Greenwich Meridian as the *Prime Meridian.*

Figure 1.13 – The South Building of the Royal Observatory in Greenwich, England. Originally built in the 1890's to house two telescopes and offices for the Royal Observatory, the South Building today accommodates the museum's planetarium.

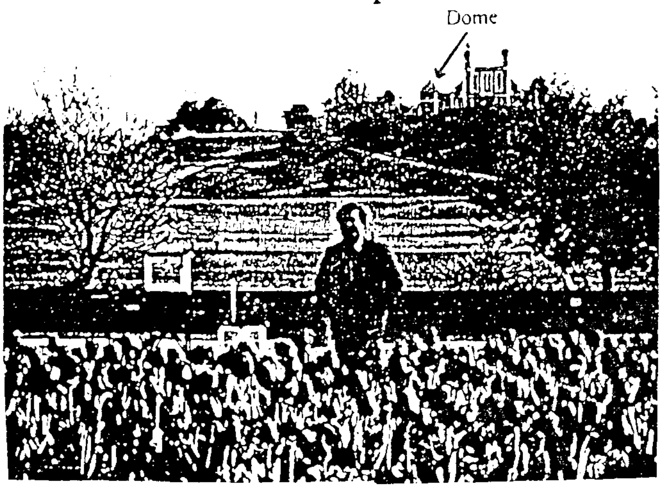


Figure 1.14 – The author during one of his calls to the Port of London, England, stands at the lawn of the National Maritime Museum at Greenwich, England. At the background is the new North Building of the Royal Astronomical Observatory. Note the dome of the Old Observatory. Imagine a semi-great circle running north-south passing through the dome of the old Royal Observatory building. That imaginary semi-great circle is the Prime Meridian.

Definition of Longitude

The *longitude* of a point on the Earth's surface is defined as the angular distance between the meridian of Greenwich and the meridian passing through the point. It is measured in degrees from 0° to 180° east or west from the Prime Meridian.

Longitude can also be described as an arc of a parallel of latitude subtended form the meridian of Greenwich to the meridian of a place or an arc of the equator measured from the meridian of Greenwich. It can also be the angle at the pole between the plane of the meridian of Greenwich and the plane of the meridian of a point on the Earth's surface. Figure 1.15 shows longitude as (A) an arc of the equator; (B) as an arc of a parallel of latitude; (C) as an angle at the pole and (θ) as an angle at the center of the Earth.

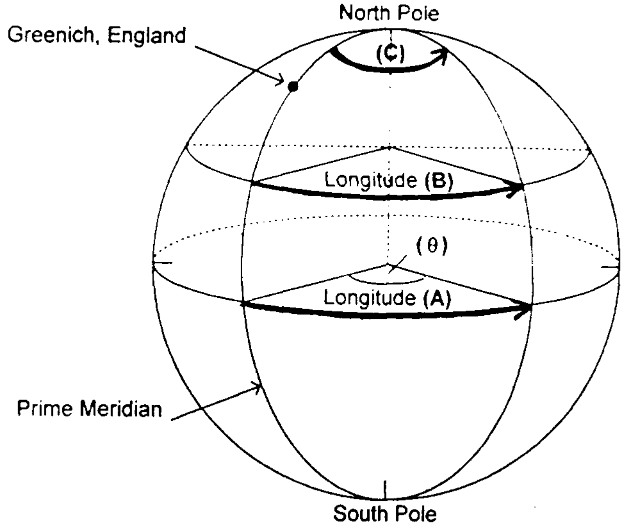


Figure 1.15 – Longitude

The center of the cross on the dome of the Manila Cathedral in Intramuros, Manila is a reference point of longitude 120° E which is the central meridian of the Philippine Archipelago. When one visits the cathedral, he will see from the side of the main door the tablet on which this fact is inscripted.

It is important to remember the following points when one deals with longitude:

1. The maximum value of longitude (in degrees) is 180°.
2. The "180th Meridian" is diametrically opposite the meridian of Greenwich.
3. The Greenwich meridian and the 180th meridian divides the Earth into two hemispheres, the eastern hemisphere and the western hemisphere.
4. Longitude is an angle not a circle.

Finding the Difference of Longitude (DLO) Between Two Points on the Earth's Surface

The difference of longitude (DLO) between two places is the smaller angle at the pole or the minor arc of the equator that is contained between the meridian of the two places *(see Figures 1.16 (a) and 1.16 (b)).*

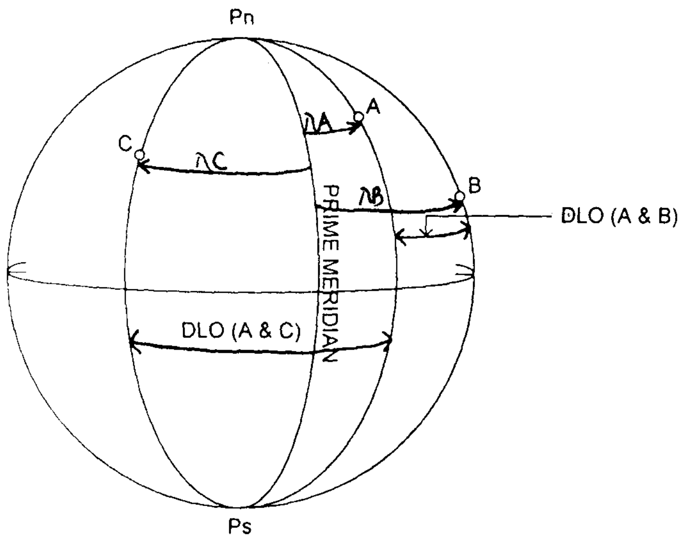


Figure 1.16 (a)

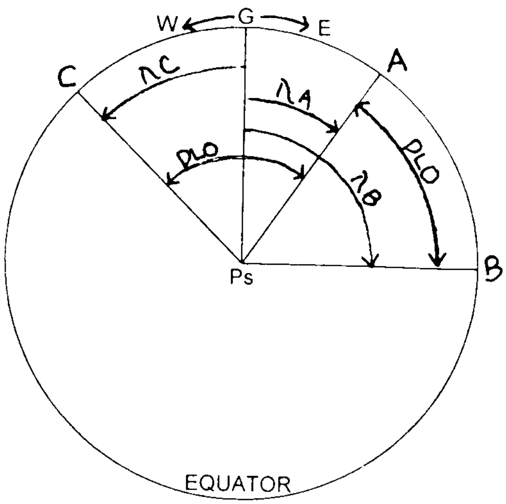


Figure 1.16 (b)

Figure 1.16(a) illustrates the DLO between places A and B and A and C. λA represents the longitude (east) of place A. λB represents the longitude (east) of place B. λC represents the longitude (west) of place C. The DLO between A and B and the DLO between A and C is indicated in the figure.

To get a better view of the DLO, turn the Earth so that the eye of the observer is now directly over the South Pole in such a location that the outermost circle that he can see is the equator. This diagram is commonly known as the ***diagram on the plane of the equator.*** The reason why the South Pole is chosen as a reference point instead of the North Pole is to establish a uniform system of indicating direction because the new form of compass reading is read from 0° to 360° clockwise. Therefore, in order not to confuse the student, the diagram on the plane of the equator should also be oriented to a clockwise direction where East is moving towards the right.

Figure 1.16(b) represents the diagram on the plane of the equator. G represents the meridian of Greenwich. Ps represents the South Pole. The longitude of meridians A, B and C are shown. The DLO between these places is also indicated. Notice that the DLO in both figures, 1.16(a) and 1.16(b), show the DLO as the smaller angle at the pole or the minor arc at the equator.

Sometimes it is necessary to give a name to DLO. In such a case, the DLO is named East if the direction of movement is towards the East. It is named West if the direction of movement is towards the West. So, in figure 1.16(b) if the ship is sailing from A to B the DLO is named East. If it is sailing from B to A, the DLO is named West. Note that the value of DLO did not change. Only the direction of movement has changed. The same explanation can be made for the DLO between A and C. *(Interconversions of DLO and departure will be discussed later in the topic of parallel sailing)*

A better understanding can be made on how to find the DLO by making a diagram on the plane of the equator. For instance, if both places have the same name which means that they are both located on the same hemisphere or on the same side of Greenwich, the DLO is the difference of their longitudes. If they are on opposite side of Greenwich, one East and the other West, the DLO is equal to the sum of their longitudes, provided that the sum is not more than 180°, in which case the DLO is equal to 360° minus the sum of the longitudes. *(The DLO is the minor arc at the equator or the smaller angle at the pole).*

Example

Find the DLO between the following places:

(a) Long. of A = 96° 54' W
Long. of B = 35° 34' W

(b) Long. of A = 36° 09' E
Long. of B = 06° 55' E

(c) Long. of A = 04° 00' W
Long. of B = 05° 36' E

(d) Long. of A = 176° 25' E
Long. of B = 164° 52' W

(e) A ship sailed from Longitude 136° 24' E and arrived in Longitude 153° 10' E. Find the DLO that she made.

Solutions:

(a) Long of A = 96° 54' W
Long of B = 35° 34' W
DLO = 61° 20'

(b) Long of A = 36° 09' E
Long of B = 06° 55' E
DLO = 29° 14'

(c)	Long of A	=	04° 00' W
	Long of B	=	05° 36' E
	DLO	=	09° 36'

(d)	Long of A	=	176° 25' E
	Long of B	=	164° 52' W
			341° 17'
			- 360° 00
	DLO	=	18° 43'

(e)	Long of departure (A)	=	136° 24' E
	Long of arrival (B)	=	153° 10' E
	DLO	=	16° 46' E
			Direction of travel is Eastward

(f) If a ship sailed from longitude 176° 25' E and arrived in longitude 164° 52' W, what is the DLO that she made?

> ***Note:*** **To get a clear picture of problems (e) and (f) it is better to make a plot of the meridians of departure and arrival in the diagram on the plane of the equator. The following figures will show how these two problems can be presented in the diagram and how the DLO is named.**

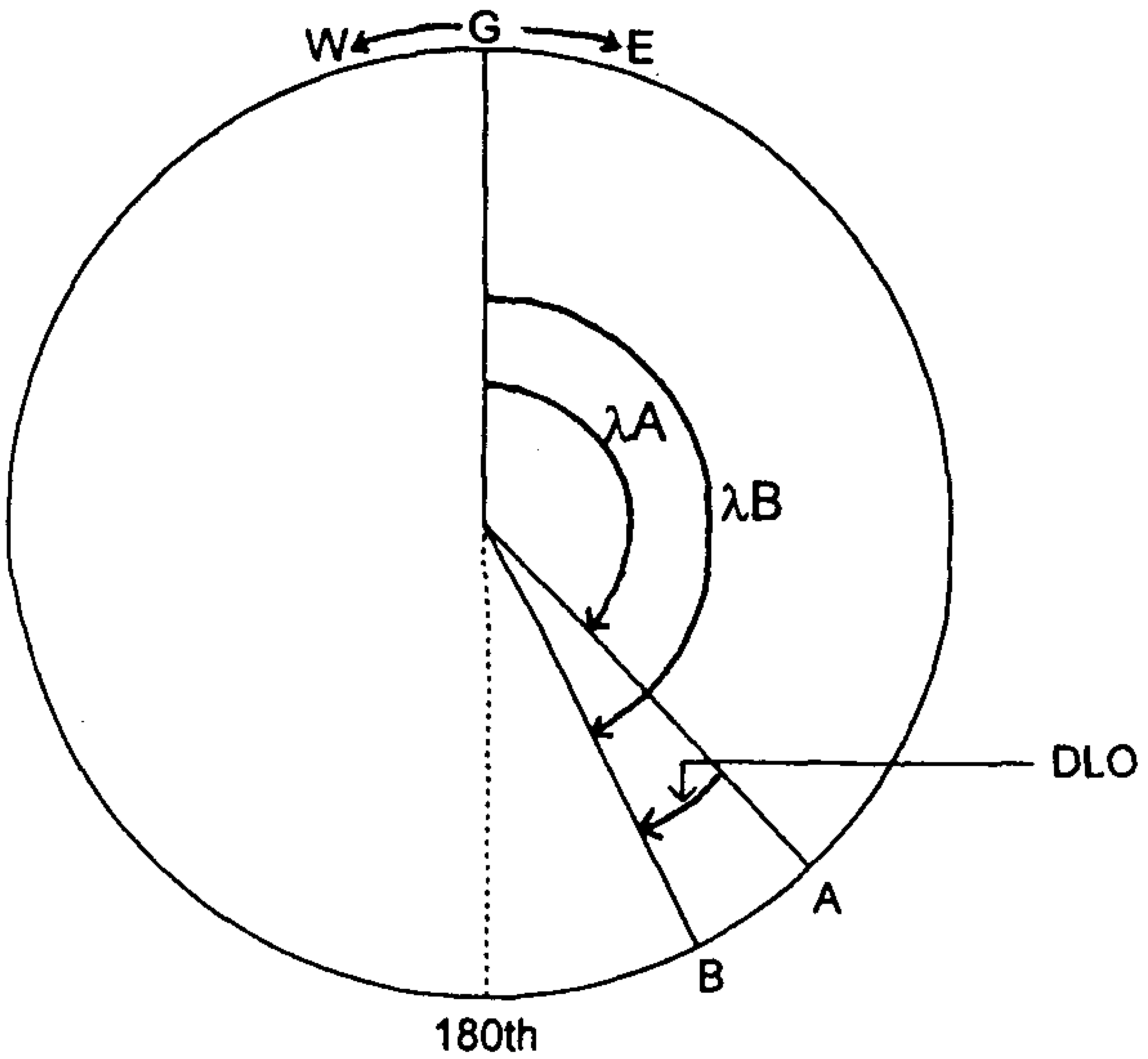


Figure 1.17 – Diagram of example (e)

DLO = $\lambda A - \lambda B$

= 16° 46' E

DLO is named East because the direction of travel is towards the East

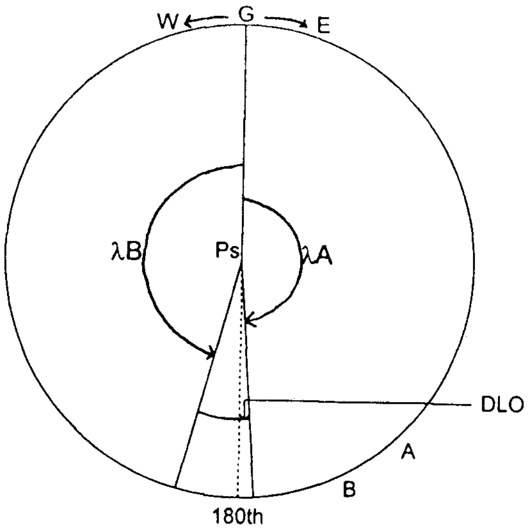


Figure 1.18 – Diagram of example (f)

DLO = 360° - ($\lambda a + \lambda B$)

= 360° - (176° 25' + 164° 52')

= 18° 43' E

1.4 DEPARTURE

It is important to remember at this point, what the students learned in geometry, about arcs and central angles. We recall that the length of an arc of a circle is expressed in linear units of measurement such as miles, meters and so on. Degrees are used to represent the measure of an arc.

A theorem in geometry states that, "A central angle equals numerically its intercepted arc". That means that if the central angle is 30° its intercepted arc on the circumference is also equal to 30°. So regardless of how big or small the circle is the intercepted arc subtended by the two radii of the same circle will numerically be equal to the central angle. See Figure 1.19(a) where angle AOB is called a *central angle.* Although the sides of a central angle determine a minor and major arc, we will refer to the minor arc as the *intercepted arc.*

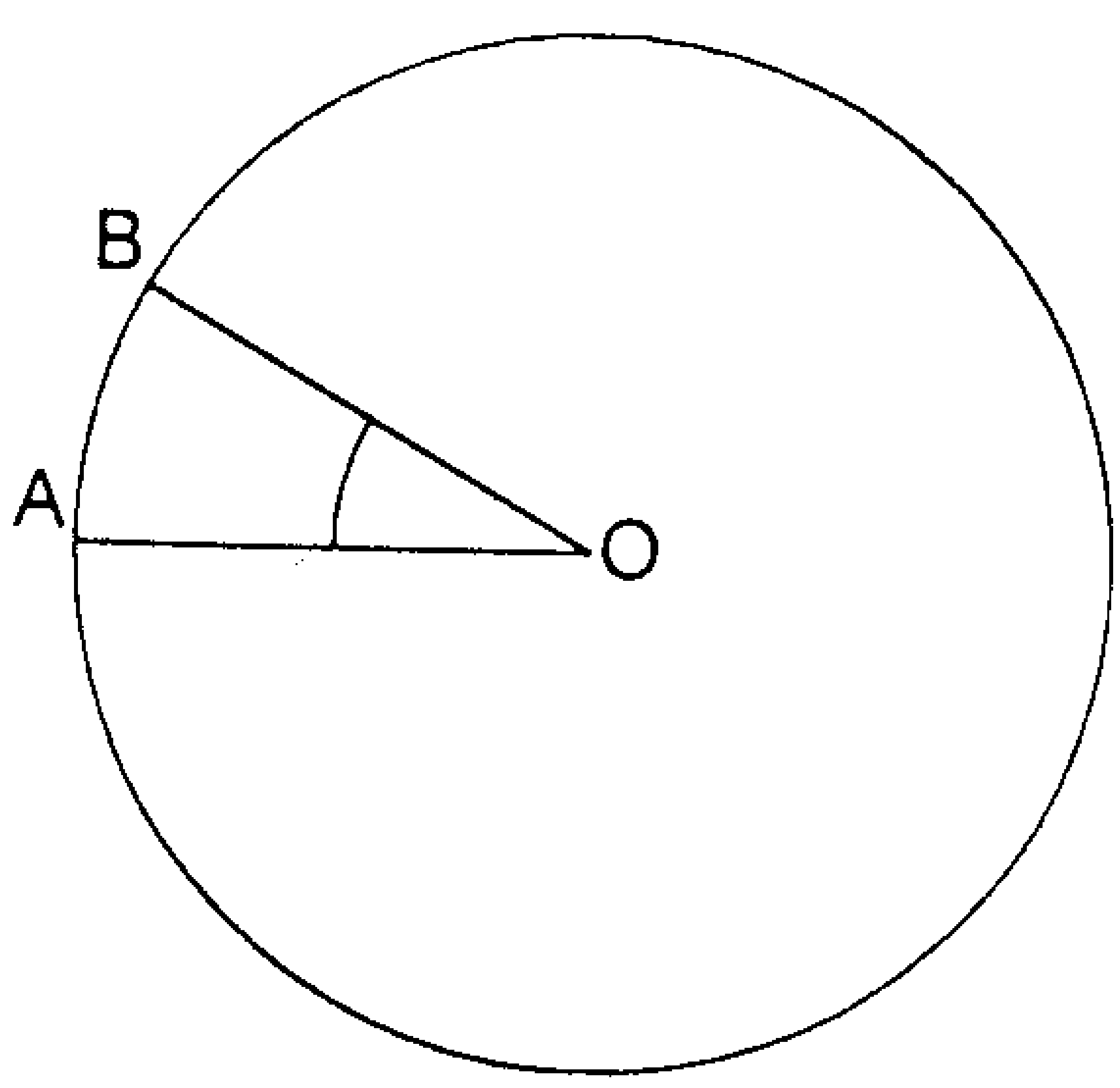


Figure 1.19(a) – Central angles equals numerically its intercepted arc.

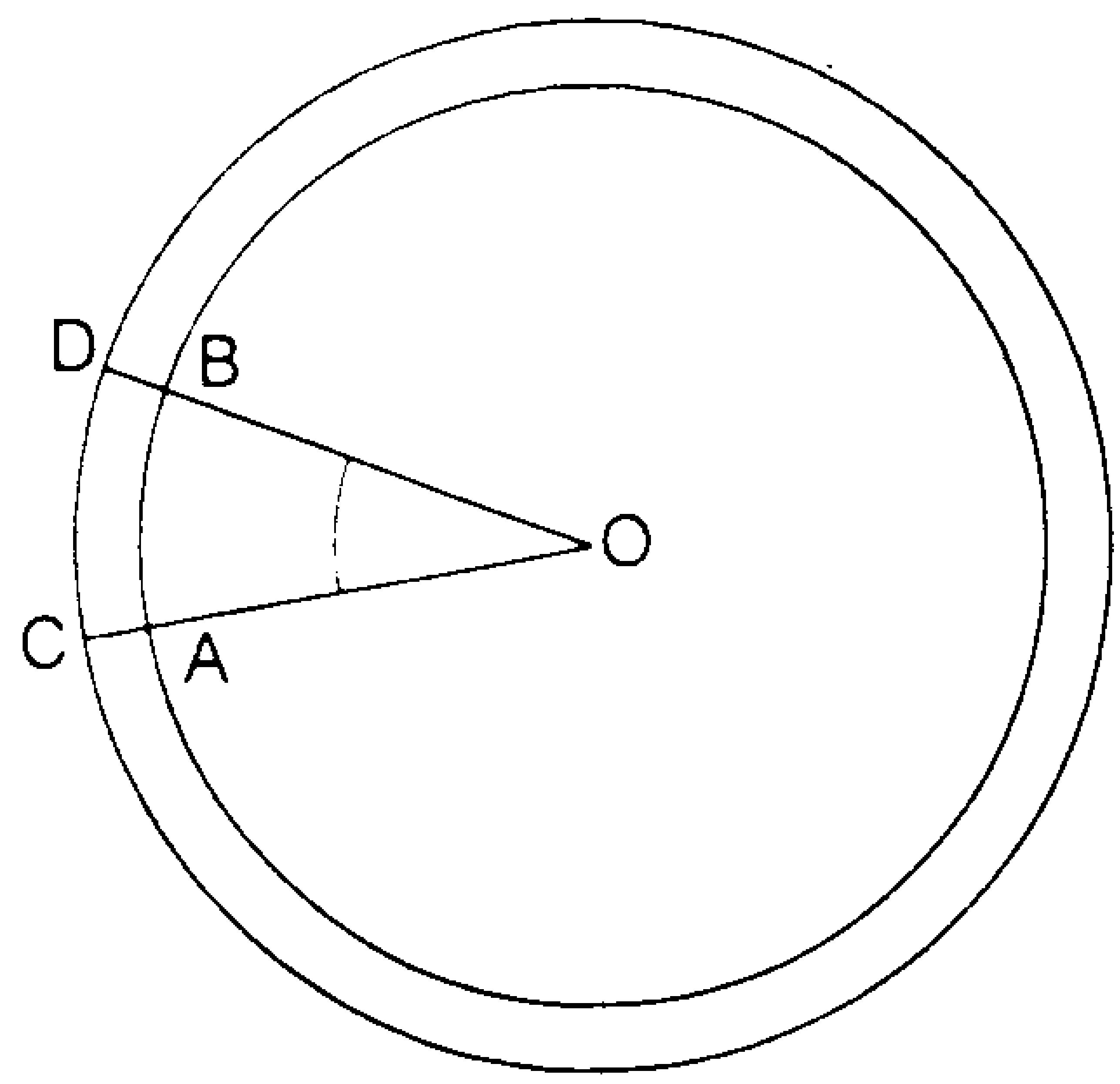


Figure 1.19(b)

In Figure 1.19(b), there are two concentric circles. The central angle (O) is contained between the radii OA and OB of the smaller circle and radii OC and OD of the bigger circle. According to the theorem the intercepted arc AB and CD as shown are both numerically equal to the central angle, O.

Figure 1.20 is analogous to Figures 1.19(a) and 1.19(b). This time, the circles of the Earth are projected.

In Figure 1.20, let Ps be the South Pole of the Earth. The outermost circle represents the Earth's equator. The radius PsG represents the meridian of Greenwich.

The radius PsE is the meridian of a point at the equator. Note that points A and B lie along the same meridian as G and points C and D along the same meridian as E. The two other concentric circles are parallels of latitude.

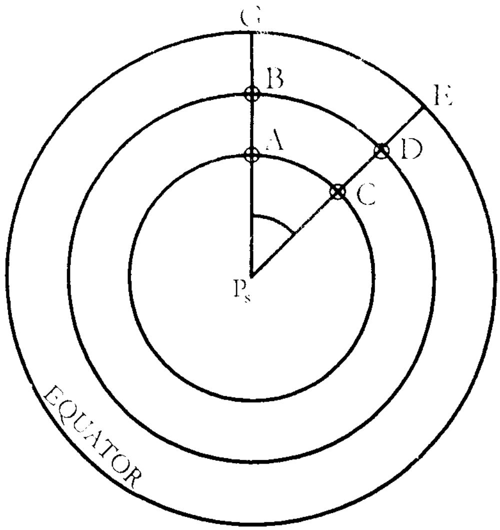


Figure 1.20

A and B are situated on different parallels. C and D are also situated on different parallels, B is north of A and D is north of C. Let us suppose that the latitude of A is 50° S and the latitude of B is 25° S. Therefore, point C, which is situated along the same parallel as A, is also in Lat 50° S. The same situation can be said of point D. Its latitude is also the same as point B, Lat 25° S. Following the theorem, arcs AC, BD and GE are the intercepted arcs of the central angle Ps, and therefore are numerically equal to the value of the central angle. Meaning that if the central angle (Ps) is 50°, the intercepted arcs AC, BD and GE are also equal to 50°. Notice however that the length of arcs AC, BD and GE are not the same, GE being longer than BD and longer than AC. The length of the arcs measured along their respective parallels of latitude is called *departure*.

1.5 THE GEOGRAPHICAL COORDINATES

In plane trigonometry, the students were introduced to rectangular "Cartesian" coordinates. Cartesian coordinates define a point relative to two intersecting lines, called *axes*. If the axes are perpendicular, the coordinates are rectangular. Consider this familiar diagram in trigonometry.

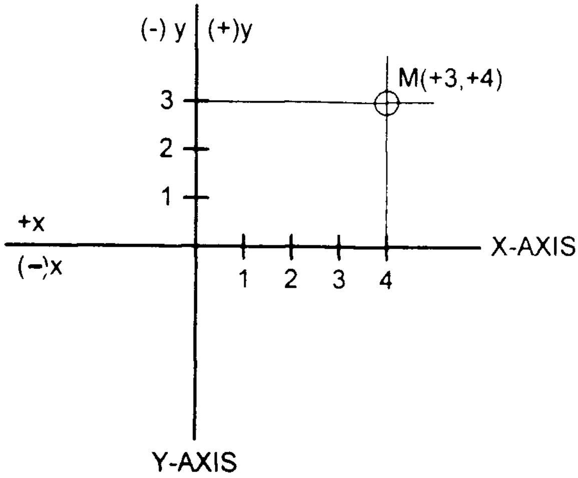


Figure 1.21

There are two axes in Figure 1.21, the x-axis and the y-axis. By convention all points to the right of the y-axis is positive or (+) and all points to the left of the y-axis is negative or (-). Likewise, all points above the x-axis is positive or (+) and all points below the x-axis is negative or (-).

Suppose we would like to define a point M in Figure 1.21. One will see that point M is at the point of intersection of +x and +y. Therefore, it can be said that point M is located at coordinates (+x, +y). If a specific distance from the x and y axes are known at 3 units above the x-axis and 4 units to the right of the y-axis then we can say that Point M is at coordinates (+3, +4) as illustrated in Figure 1.21.

Describing a Position on the Surface of the Earth

Geographical or terrestrial coordinates, known as "latitude" and "longitude" define a position on the Earth *(see Figure 1.22)*.

In the figure, the equator can be treated as the x-axis and the Greenwich meridian as the y-axis: Points to the right of Greenwich are designated as East (E) and point to the left of G is designated as West (W). Likewise all points above the equator are designated as North (N) and points below the Equator are designated as South (S). For example, in Figure 1.23, Point O is defined by the intersection of two perpendicular lines which represents an arc of a meridian and an arc of the parallel of latitude. If the scale is 1 division is equal to 5° then latitude of O is 15° and the longitude is 20°, then point O is located at coordinates, Lat 15° N, Longitude 20° E. This is the most common method of defining a position on the surface of the Earth.

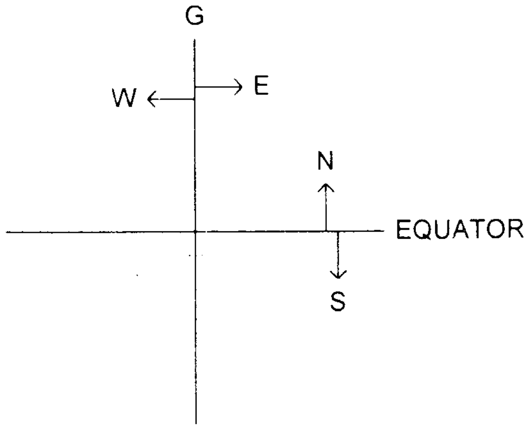


Figure 1.22

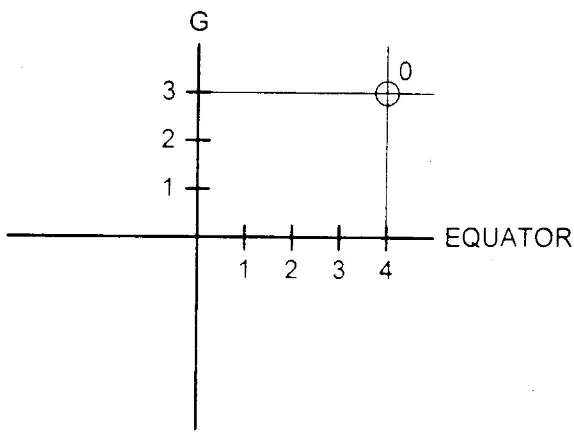


Figure 1.23

Another method of describing a terrestrial position is to state the direction and distance from a known position. The direction of a point is known as its ***bearing****. Thus, it may be stated that the ship is in a position having El Fraile Island (located at the mouth of Manila Bay) bearing 135° (True) at a distance of 3 miles. This means that the ship lies 315° (the reciprocal of 135°), 3 miles from El Fraile.

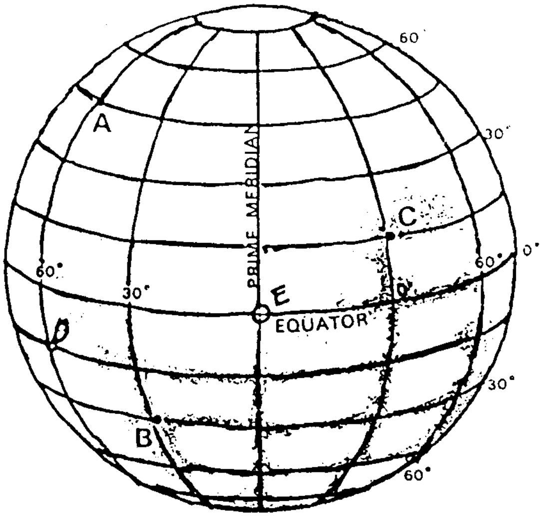


Figure 1.24 – Positions on the Earth

The position of points A, B, C, D, E, and F in Figure 1.24 are defined by the points of intersection of the parallel of latitude and the meridian passing through these points.

Questions

1. Research and find the meaning of "reciprocal" as applied to mathematics.
2. How many great circles can be drawn around the Earth at a distance of 1° from each other?
3. aHow is latitude measured?
4. How is longitude measured?
5. What is the difference between a parallel of latitude and latitude?
6. If a ship is sailing along a meridian what direction is she heading?

*The topic on bearing is discussed lengthily in the subject of **Directions on the Earth.**

7. How will you describe a position on the Earth's surface?
8. If you are standing at the Earth's North Pole, what is the direction of any point from your position? What is the direction of Earth's rotation?

The Navigational Units of Distance

The length of the equator, in angular units is 360°, which is equal to 21,600 minutes of arc (360° x 60'). These minutes are known as *geographical miles.* Distances in navigational work are given in *nautical miles.* A nautical mile is a distance which is equal to the length of an arc of a meridian between two places whose geographical latitude differs by 1'. For practical purposes, the length of a nautical mile is taken as 6,080 feet or 1,852 meters.

Sometimes the term *cable* will be encountered which is also used as a measure of distance. In practice, it is usual to reckon a cable as 600 ft. One nautical mile is roughly equal to 10 cables.

The navigational unit of speed is known as a ***knot.*** One knot is one nautical mile per hour. The term ***"knots per hour"*** refers to acceleration not speed. It may also be stated that speed is rate of motion, or distance per unit of time. If S is the rate of motion, and D is the distance traveled in T units of time, then: $D = S \times T$.

Examples

1. A ship covers a distance of 12 miles in 2 hours. Find her speed.

$$S = D/T = 12/2 = 6 \text{ knots}$$

2. At 12 knots, a ship can travel from place A to place B in 18 hours. Find the distance between A and B.

$$D = ST = 12 \times 18 = 216 \text{ miles}$$

3. How long will it take a ship to sail from place A to place B, a distance of 120 miles if her speed is 10 knots?

$$T = D/S = 120/10 = 12 \text{ hours}$$

Useful Reminders

1. The length of a degree of latitude (measured along a meridian) is everywhere the same on a sphere, from the equator to the poles. One minute of latitude equals one nautical mile.
2. The length of a degree of longitude (measured along a parallel of latitude) decreases from 60 nautical miles at the equator to 30 nautical miles at Lat. 60° and to zero at the poles.

   This is the very reason why the longitude scales are never used to measure distances in the Mercator chart. Only the Latitude scale is used.

CHAPTER TEST

A. **Essay**

1. Explain why longitude scales cannot be used to measure distances in a Mercator chart.
2. If you are situated directly over the North Pole at such a distance that you can see the whole Earth what circle would appear as the outermost circle?
3. In Question No. 2, what would be the direction of the Earth's rotation?
4. If you were to draw a figure of what you see in Question No. 2, how would the parallels of latitude appear?
5. In Question No. 2, how would the North Pole of the Earth appear?
6. In Question No. 2, where is the South Pole of the Earth located?
7. From what reference plane is longitude measured?
8. If the departure is zero, where is the observer located?
9. Plot the meridian of a place whose longitude is 30° west of a place situated in longitude 45° E.
10. If the ship is sailing along a parallel of latitude, what direction is she heading?

B. **Find the d.lat. between the following places:**

1.	Lat. of A	=	10° 43' S
	Lat. of B	=	11° 43' N
2.	Lat. of A	=	34° 18' N
	Lat. of B	=	01° 43' N

C. Find the DLO between the following places:

1.	Long. of A	=	96° 01' W
	Long. of B	=	54° 14' E
2.	Long. of A	=	176° W
	Long. of B	=	176° E

D. Find the latitude of arrival:

1.	Lat. of departure	=	35° 10' S
	d. lat.	=	10° 40' N
2.	Lat. of departure	=	10° 40' N
	d. lat.	=	35° 10' S
3.	Lat. of departure	=	16° 36' S
	d. lat.	=	16° 36' S
4.	Lat. of departure	=	05° 10' N
	d. lat.	=	05° 10' N

E. Find the latitude of departure:

1.	Lat. of arrival	=	00° 00'
	d. lat.	=	05° 10' N
2.	Lat. of arrival	=	16° 54.3' N
	d. lat.	=	16° 54.3' N
3.	Lat. of arrival	=	16° 54.3' N
	d. lat.	=	24° 00.8' N
4.	Lat. of arrival	=	41° 33' N
	d. lat.	=	0° 47.6' S

F. Find the longitude of arrival:

1.	Long. of departure	=	10° 40' E
	DLO	=	10° 40' W
2.	Long. of departure	=	47° 30' W
	DLO	=	10° 40' W
3.	Long. of departure	=	165° 10' E
	DLO	=	96° 40' E
4.	Long. of departure	=	43° 43' W
	DLO	=	102° 01' E

G. Find the longitude of departure:

1.	Long. of arrival	=	11° 50' E
	DLO	=	34° 00' E
2.	Long. of arrival	=	74° 15' W
	DLO	=	15° 15' W
3.	Long. of arrival	=	10° 00' E
	DLO	=	10° 00' E
4.	Long. of arrival	=	179° 10' E
	DLO	=	34° 35' W

H. Related problems:

1. What is the longitude of a place that is 15° 10' west of a place in longitude 97° 45' E?
2. Find the DLO between the 180th meridian and longitude 135° 45' W, if the ship sailed from 180th meridian.
3. Arriving at a place whose longitude is unknown, a ship made a DLO equal, numerically and by name, to the longitude of this place. If the ship made a DLO of 120° E, in what longitude did she came from?
4. A lighthouse situated 15 miles east of longitude 120° 10' E is 30 miles west of a ship. Find the longitude of the ship.
5. A ship sailed and arrived in longitude 179° 15' E. If she made a DLO of 35° 16' W, from what longitude did she came from?
6. Ship A is situated 420' north of ship B. If the latitude of ship A is 30° 10' N, find the latitude of ship B.
7. A lighthouse situated 30 miles south of latitude 10° 05' N is 60 miles north of a certain ship. Find the latitude of the ship.
8. Arriving at the place whose latitude is unknown, a ship made a difference of latitude equal, numerically and by name, to the latitude of this place. If the ship made a difference of latitude of 12° 10' S, find the latitude where she came from.
9. A ship passed 5 miles directly south of a lighthouse which is situated in Lat. 5° N. Find the latitude of the ship at the instant of passage.
10. If you are at the South Pole, what is your latitude?

EXERCISES ON DISTANCE, SPEED, AND TIME

1. A ship sailed due North along the meridian of Long. 120° E for 3 days at a speed of 14 knots. What would be her final position if she departed from Lat. 23° 40'N?
2. A ship sailed due West along the equator for 4 days at a speed of 10 knots. What would be her final position if she departed from Long.135° E?
3. How far can a ship sail in 15 minutes if her speed is 18 knots?
4. The distance by sea between Bacolod and Manila is approximately 320 miles. How long will it take a ship to sail from Bacolod to Manila if her speed is 12 knots?
5. At 24 knots, a passenger liner can cover a distance of 240 miles in 10 hours. How long will it take the same ship to sail a distance of 3 miles if she maintains the same speed?
6. Two ships, A and B are 60 miles apart. A is north of B. A sailed directly north at 12 knots while B sailed directly south at 8 knots. Find the difference of latitude between them after 45 m.
7. A ship left L 10° 16' N, Long. 120° 16' E and sailed directly south for 6h 15m. If she maintained a speed of 14 knots, find her position of arrival.
8. Ships A and B are both sailing east, and along the equator. A is 15 miles west of B. If A sailed at 11 knots and B at 18 knots, what would be the difference of longitude between them in 1h 12 m?
9. A vessel covers 70 miles in 4 hours against a current which flows at the rate of 6 miles per hour. How fast can the vessel sail if there is no current?
10. A ship left Banago, Bacolod wharf at 0930H and arrived Iloilo at 1200H. If the distance between Banago and Iloilo is 27 miles, find her speed.
11. A ship left port A at 0815 H bound for port B which is 66 miles away. If her speed is 8 knots, what time will she arrive in port B?
12. It takes a ship, sailing directly north, exactly 14 hours to sail from L 1° 15.6' S to L 0° 45.2' N. Find her speed.

Chapter Two
NAUTICAL CHARTS

At the end of this chapter, the student should be able to:

- specify the main requirements of a navigational chart;
- identify the advantages and disadvantages of using the mercator chart;
- specify the physical as well as distinguishing features of a mercator chart; and
- classify the various nautical publications and their uses.

2.1 INTRODUCTION

Many reference books in navigation have covered quite extensively this subject on Nautical Charts. These books have covered the type of projections used in the construction of charts and the mathematical calculations involved in the process of its construction.

For the first year students of the BSMT program it is not necessary that the mathematical principles used in the construction of the various types of chart projections be introduced this early in their study of navigation. The mathematical calculations employed in the construction of charts are the work of the cartographers (chart makers). It is sufficient that the student is made aware that there are various types of chart projections and that there are several kinds of charts used. In actual navigation work, the navigator does not concern himself on how his chart is constructed but rather he is more concerned how to use the chart, and interpret correctly the signs and symbols printed on it. An average navigator can quite safely navigate his ship without a deep knowledge of the techniques of chart construction and projection.

One of the main functions of a nautical chart is to find from it or lay off thereon, the ship's position and course. Many methods of position fixing are based on geometrical principles, so in order that these principles and methods may be understood it is desirable that a navigator should have a good working knowledge of the fundamentals of geometry.

This chapter will cover only the basic information that are to be taken from a chart.

2.2 WHAT ARE CHARTS?

Charts are representation of portions of the Earth's surface. They are printed specifically for the use of the navigator in order that it may present to him in a comprehensive form the trend of the coastline, position of lights, important headlands, rocks, shoals, depth of water, direction of tidal streams, channels and all other information essential for the safe navigation of a vessel in navigable waters.

2.3 WHAT IS THE DIFFERENCE BETWEEN A CHART AND A MAP?

A ***map*** is a representation of some part of the earth's surface that shows political boundaries, physical features, cities and towns, and other geographic information. A *chart* is also a representation of a portion of the earth's surface, but has been specially designed for use in navigation.

A ***nautical chart*** is primarily concerned with navigable water areas. It includes information such as coastline and harbors, channels and obstructions, currents, depths of water, aids to navigation and other information that may be useful to the navigator.

An ***aeronautical chart*** shows elevations, obstructions, prominent landmarks, airports, aids to navigation and other information that are important to air navigation.

2.4 CLASSIFICATION OF CHARTS

Charts may be classified into groups according to the purpose they serve and according to the specifications of the chart makers. Two major chart manufacturers in the world, the British Admiralty (BA) Charts of Britain and the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) of the U.S., have classified the charts into the following:

1. **Ocean Charts (BA) or Sailing Charts (DMAHTC).** These charts are small-scale charts. That means a long distance of the Earth's surface is represented by a comparatively short distance on the chart. These charts are used mainly for deep-sea navigation and for this reason, its coastal details such as rocks, shoals that are lining the shores are not depicted.

2. **General Charts (DMAHTC)** are intended for use in coastwise navigation outside of outlying reefs and shoals when the vessel is generally within sight of land or aids to navigation and his course can be directed by piloting.

3. **Coastal Charts (BA and DMAHTC).** Coastal charts are large-scale charts used when navigating in close proximity to the coast. Many details of the coast is depicted such as nature of the coastline, position and characteristics of lights, radio telegraph stations, towers and beacons, and other prominent features which are observable from the bridge of the ship and which may aid the navigator. Depths of water, current and tidal information, positions of rocks, shoals and buoys and other floating aids to navigation, are also depicted.

4. **Plan Charts (BA), Harbor Charts (DMAHTC).** These are very large-scale charts on which are depicted detailed information of small areas such as harbors, river estuaries, etc.

5. **Miscellaneous Charts.** In this group are included all charts which are not involved in the other three classes. These include gnomonic charts for facilitating great-circle sailings, variation charts, route charts, weather charts, etc.

2.5 CHART PROJECTIONS

Basically, the construction of charts presents a problem to chart makers on how to represent a portion of the earth's surface (which is a curved surface) into a plane surface. Actually, it is impossible to accomplish this exactly without a certain amount of distortion. For small areas of the earth, perhaps this can be safely neglected.

To provide practical and sufficiently accurate results, various methods known as *projections* have been developed.

The transfer of information from the sphere to the flat surface of the chart should be accomplished with as little distortion as possible in the shape and size of land and water areas, the angular relation of position, the distance between points, and other more technical properties. Each of the different projections is superior to others in one or more of these qualities but none is superior in all characteristics. In all projections, as the area covered by the chart is decreased, the distortion diminishes and the difference between various types of projection lessens.

A sufficient knowledge of the "how" and "why" of chart construction will help the student in understanding and using nautical charts.

Types of Chart Projections

Generally, the types of projection used in chart construction are the following:

1. Mercator Projection
2. Polyconic Projection
3. Lambert Confromal Projection
4. Gnomonic Projection

1. ***Mercator Projection*** is often illustrated as a projection onto a cylinder. A chart developed out of this projection is called a ***Mercator Chart.*** A Mercator projection starts with the placement of a cylinder around the earth *(as in Figure 2.1)* parallel to the polar axis and touching the earth at the equator. The meridians are projected out onto the cylinder and appear as a series of parallel straight lines when the cylinder is unrolled into a flat plane.

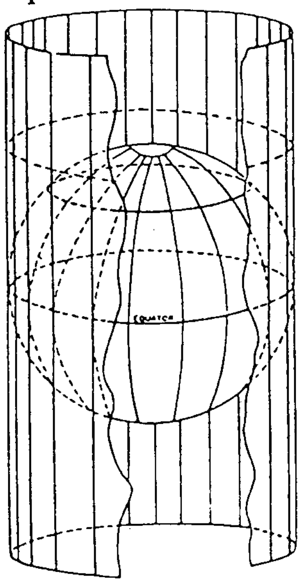


Figure 2.1 – The development of the Mercator Projection
(Courtesy of Chapman)

Actually, the chart is developed mathematically to allow for the known shape of the earth, which is not quite a true sphere. The meridians appear as straight, vertical lines. Here we have our first example of distortion: the meridians no longer converge, but are now shown as being parallel to each other. This changes the representation of the shape of island or continents by stretching out their dimensions in an East-West direction.

To minimize the distortion of shape which is one of the qualities that must be preserved as much as possible, there must be a "stretching-out" of dimensions in a North-South direction. This North-South stretching results in the increase in the spacing of the parallels of latitude.

Their spacing increases northward from the equator in accordance with a mathematical formula of the earth. This increase in spacing is not readily seen in the case of charts of relatively small areas, such as in the harbor and coastal charts, but it is very apparent in Mercator projections of the world *(see Figure 2.2)*.

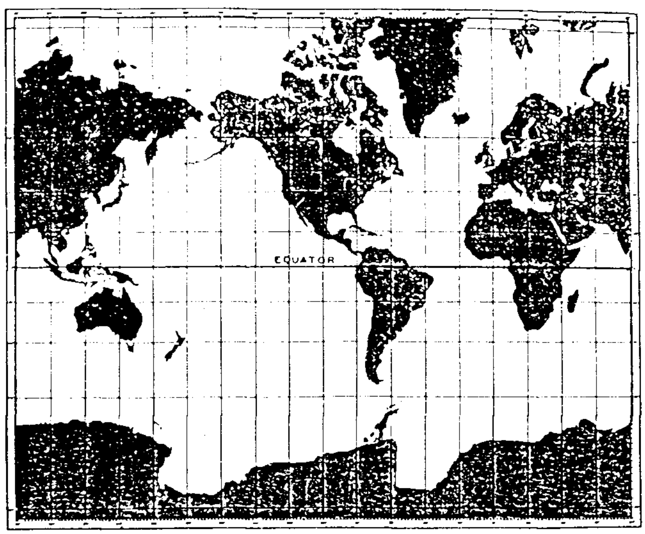


Figure 2.2 – The Mercator Projection of the world
Note: the maximum latitude is about 80°
(Source: Chapman)

The Mercator projection is said to be "conformal", which means that angles are correctly represented and the scale is the same in all directions from any point.

Because of the mathematical calculations and principles used in the construction of a Mercator chart, the shape of areas in high latitudes is correctly shown, but their size appears greater than that of similar areas in lower latitudes. An island, for example, such as Iceland in about Lat. 65° N would appear to have the same area as the Island of Borneo which is situated at the equator when in actual fact the land area of Borneo is about seven times the land area of Iceland. Similarly, Greenland appears to be larger than South America, although it is actually only one-ninth (1/9) as large as the continent.

Advantages and Disadvantages of a Mercator Chart

The great value of the Mercator chart is that the meridians of longitude appear as straight lines all intersecting the parallels of latitude, which are also straight lines, at right angles. Directions can be measured with reference to any meridian or any compass rose. The geographic coordinates of a position can easily be measured from the scales along the four borders of the chart. We can draw a straight line between two points and actually sail that course by determining the true direction between them. This straight line is known as the ***rhumb line***. The heading is the same along this line and the direction of a rhumb line may be measured at any convenient meridian.

However, a great circle, the shortest distance between two points on the earth's surface, is a curved line in a Mercator chart. Great-circle distances and directions cannot be readily determined without first plotting the great circle on a gnomonic chart and transferring points along the line to the Mercator chart.

The scale of a Mercator chart will vary with the distance away from the equator as a result of the North-South (N-S) expansion. The change in scale with latitude becomes bigger and bigger as the N-S expansion approaches the poles. The meridians cannot be extended all the way to the pole because the pole has been already stretched all the way to infinity. As a result, most Mercator projections extend no farther from the equator than about 70°, and very rarely beyond 80°.

2. ***Polyconic Projections*** are developed onto a series of cones tangent to the earth. It is termed ***polyconic*** because it uses separate cones for each parallel of latitude *(see Figure 2.3)*. The vertex of the cone is at the point where a tangent to the earth at the specified latitude intersects the earth's axis as extended.

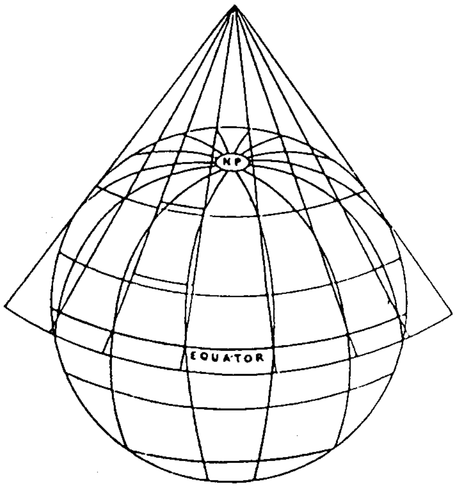


Figure 2.3 – Development of a Polyconic Projection
(Source: Chapman)

The polyconic projection introduces little distortion in shape, and relative sizes are more correctly preserved than in the Mercator projection. The scale is correct along any parallel and along the central meridian of the projection. Along other meridians, the scale increases with increased difference in longitude from the central meridian.

The parallels of latitude appear as nonconcentric arcs of circles and meridians as curved lines converging toward the pole, concaved towards the central meridian *(see Figure 2.4)*. This type of projection is not so widely used in marine navigation.

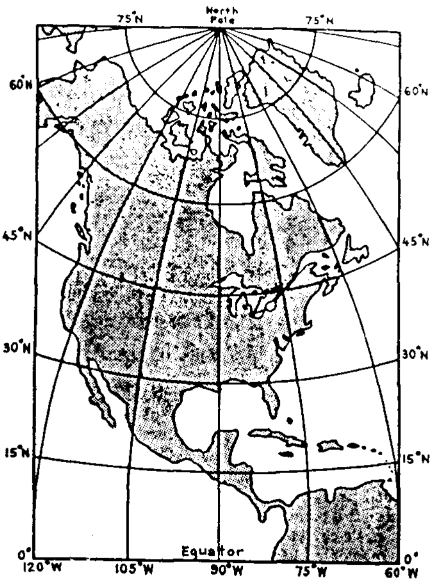


Figure 2.4 – Polyconic Projection of a large area of the Earth
(Source: Chapman)

3. **Lambert Conformal Projection.** A single cone tangent to the earth at a single specified parallel of latitude is termed a *single conic projection.* It is generally a poor projection as the scale is not correct except along the standard parallel. Areas are not projected equally and correct angular relationships are not preserved.

   The polyconic projection avoids some of these distortions but only because it uses a series of cones.

   If the spacing of the parallels is altered so that the distortion is the same along them as along the meridians, the projection becomes conformal, that is, the angular relationships are correctly represented. This is known as the *Lambert Conformal Projection.* It is the most widely used conic projection, although its use is more common among aviators than marine navigators.

   Radio bearings, from signals which are considered to travel great circle paths, can be plotted on a *Lambert Conformal Chart* without the correction needed when using a Mercator chart. This feature has made this projection popular for aeronautical charts since airplanes make much use of radio aids to navigation.

In a slightly modified form, the Lambert Conformal Projection is sometimes used for polar charts.

4. Gnomonic Projection. A ***gnomonic chart,*** which is commonly referred to as a ***great-circle sailing chart,*** results when the meridians and parallels of latitude are projected onto a plane surface tangent to the earth at one point.

   A Gnomonic Projection is made by placing a plane surface tangent to the earth such as the one illustrated in Figure 2.5. Points on the earth's surface are then projected onto this plane. The point of tangency may be at any location.

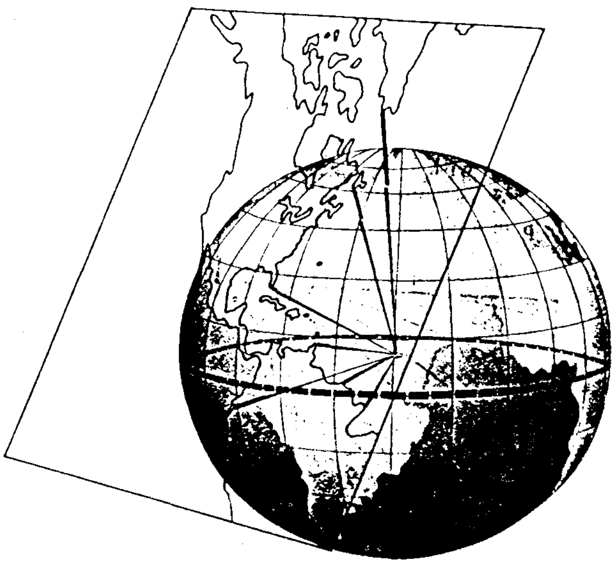


Figure 2.5 – Development of a Gnomonic Projection
(Source: Chapman)

   Distortion is great, but this projection is used in special cases because of its unique advantage–great circles appear as straight lines, which of course is not so with the other projections.

   A special case of gnomonic chart projection occurs when the geographic pole is selected as the point of tangency. In this case, all meridians will appear as straight lines and the parallels as concentric circles. The result is a chart that is used in the polar regions where ordinary Mercator charts cannot be used.

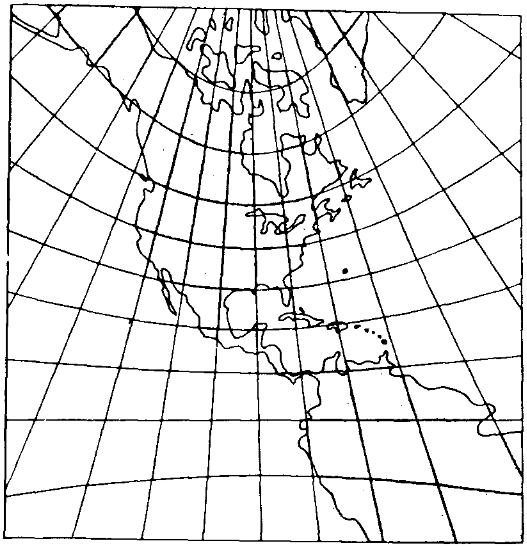


Figure 2.6 – A chart made on the Gnomonic projection shows meridians as straight lines converging towards the nearer pole. The parallels, other than the equator, appear as curves.
(Source: Chapman)

Gnomonic charts are most often used for planning a great-circle track between two points. Points along the determined track known as ***waypoints*** are then transferred to a Mercator Chart like the one you can see in Figure 2.7. The great circle is then followed by following the rhumb line from one waypoint to the next.

The advent of computers have made the use of Gnomonic charts obsolete because computer programs which automatically calculate great circle routes between points can provide the latitude and longitude of corresponding rhumb line without the necessity of using the Gnomonic chart.

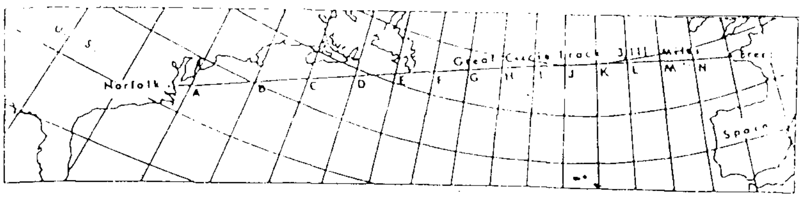


Figure 2.7(a) – A great circle track plotted on a Gnomonic Chart
(Source: Chapman)

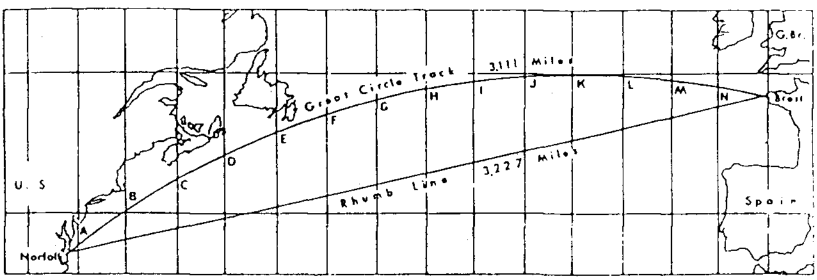


Figure 2.7(b) – A great circle track plotted on a Mercator Chart
(Source: Chapman)

2.6 MERCATOR CHART

Most of the charts of the world that are displayed in the school's library as well as in public and private offices are in the Mercator projection. The Mercator chart fulfills the two main requirements of a navigational chart which are:

1. Rhumb lines (lines that cut all meridians at equal angles) should be represented as straight lines, so that courses may be drawn easily.
2. Angles, such as course angles, should not be distorted.

Navigators often use this kind of chart as it is suited to their special requirements, because it shows all rhumb lines, including the equator, parallels of latitude and meridians as straight lines.

As stated before, the Mercator chart, in spite of its many advantages, has also some defects, some of which are:

1. It cannot be used in the polar regions.
2. Every latitude has a different scale of distance.
3. Great circle arcs, except arcs of the equator or meridians, are drawn as curved lines.

Comparison between the Mercator Chart and Gnomonic Chart:

	Mercator Chart	Gnomonic Chart
Meridians	Appear as vertical, straight lines	Appear as straight lines converging toward the nearer pole
Parallels of Latitude	Appears as horizontal, straight lines intersecting the meridians at right angles	Appear as curves, except the equator
Great Circles of Tracks	Appear as curved lines, except meridians and equator	Appear as straight lines
Distance Scale	Varies with distance from the equator	Changes too rapidly, no constant scale
Rhumb Lines	Appears as straight line	Appear as curved line

Salient features of the Mercator Chart:

1. Both meridians and parallels are expanded at the same ratio with increased latitude. The expansion is the same in all directions.
2. If the latitude is small, distances can be measured directly on the chart.
3. Small areas appear in their true size and shape near the equator. However, areas located in higher latitudes appear large because of the expansion of the parallels and meridians but still conform to their original shape.
4. The scale of longitude is constant.
5. The scale of latitude varies, increasing towards the poles.

2.7 SCALES USED ON CHARTS

The scale of a chart is defined as the ratio of a distance unit on the chart to the actual distance on the surface of the earth. Because it is a ratio, it does not matter what size the unit is, or in what system it is measured. For example, a scale of 1:50,000 means that one unit (inch, foot, meter, etc.) on the chart represents 50,000 of such units on the earth.

Scales on charts may be expressed in various ways, such as:

1. *Natural or fractional scale.* This is a simple ratio or fraction. For example, 1:200,000 or 1/200,000 *(see Figure 2.8).*

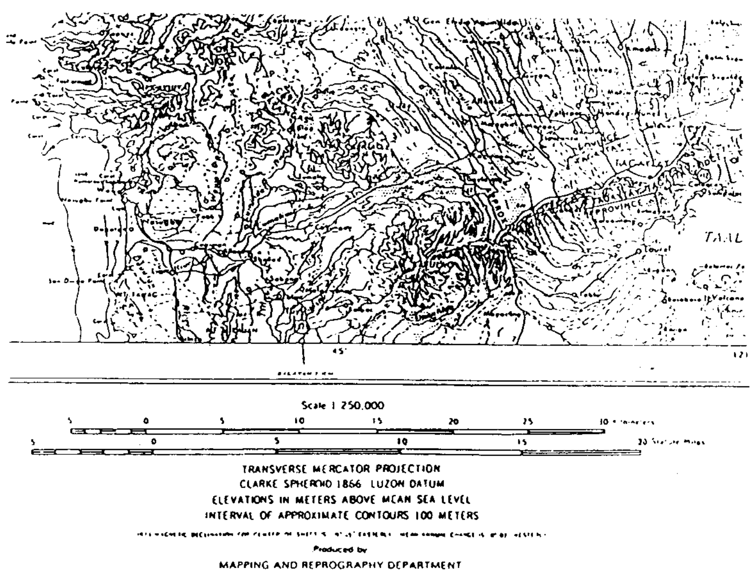


Figure 2.8 – Sample of natural scale
Note: Scale 1:250,000
(Source: NAMRIA)

2. *Numerical or equivalent scales.* This is a scale that is stated in descriptive terms or a statement that a given distance on the earth equals a given measure on the chart or vice versa. For example, "20 miles to the inch" means that 1 inch on the chart represents 20 miles of the earth's surface. Similarly, "2 inches to a mile" indicates that 2 inches on the chart represent 1 mile on the earth's surface. On a Mercator chart, sometimes it is stated that "1° of longitude equals 1.25 inches." The scale

is stated in this form because the spacing between meridians is the one constant on a Mercator projection.

3. *Graphic Scale.* This is a line or bar that may be drawn at a convenient place on the chart and subdivided into nautical miles, kilometers, yards, meters, etc. *(see Figure 2.9).*

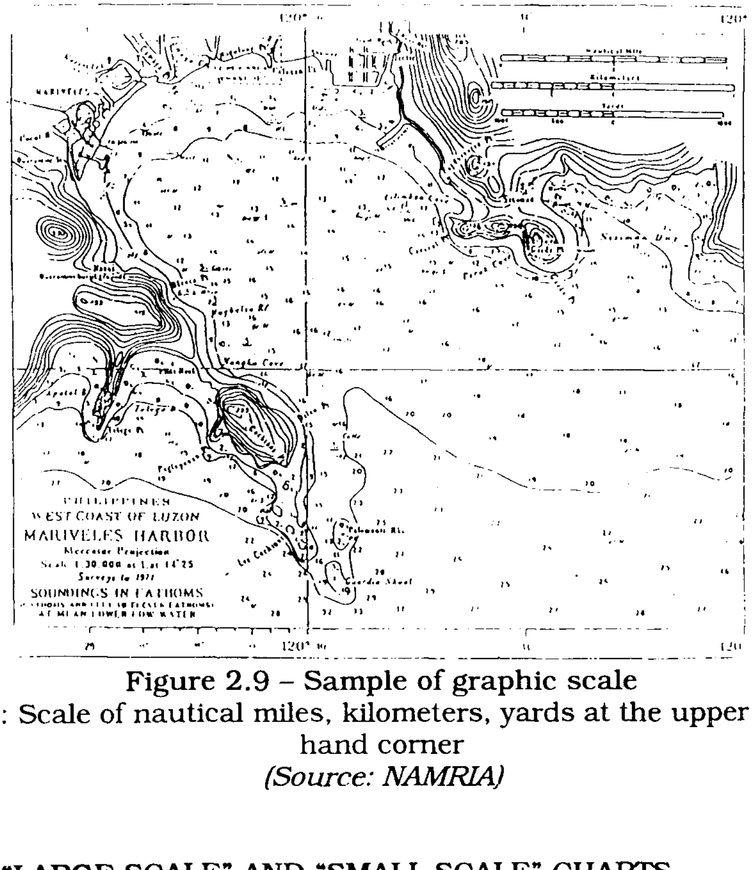


Figure 2.9 – Sample of graphic scale
Note: Scale of nautical miles, kilometers, yards at the upper right hand corner
(Source: NAMRIA)

2.8 "LARGE SCALE" AND "SMALL SCALE" CHARTS

The terms "large scale" and "small scale" are often confusing. For example, if a chart has a scale of 1:100,000 it would seem that it has a larger scale than one with a scale of 1:50,000. But remember that these scales can also be written in a fractional form 1/100,000 or 1/50,000 and the larger the denominator of a fraction, the smaller is the quantity.

At a scale of 1:100,000, one nautical mile is only 0.73 inch in length on the chart; at 1:50,000, it is 1.46 inches - which is twice as long.

There is no fix definition for the terms "large-scale charts" and "small-scale charts." These two terms are only relative, meaning a chart at a scale of 1:50,000 is a large-scale chart compared to a chart at a scale of 1:100,000. Similarly, a chart at 1:100,000 is a large-scale chart compared to a chart at 1:500,000.

To summarize, remember that small scale charts cover large areas; large-scale charts cover small areas.

2.9 LATITUDE SCALE AND LONGITUDE SCALE

The latitude scale and the longitude scale refer to the graduated meridians and the graduated parallels that are found in the four borders of a chart. The scale of latitude is found at the left and right borders of the chart and the scale of longitude is found at the top and bottom borders. This may seem a little bit confusing to a person who are not accustomed to using charts.

Just remember that the scale of latitude is graduated along a meridian and the scale of longitude is graduated along a parallel of latitude.

The graduated meridians and parallels are divided into degrees and minutes of arc and in large-scale charts, even the minutes are further subdivided.

2.10 CLASSIFICATION OF CHARTS BY SCALE

As mentioned in 2.4, charts are issued by many various agencies, such as the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) of the USA, the National Ocean Service (NOS) also of the United States, British Admiralty (BA), or Canadian Hydrographic Service of Canada and others.

The Charts issued by each of these many various agencies have their own distinct systems of classifying their charts. So it is the obligation of every marine officer to study thoroughly the chart that he is using - who issued the chart (BA or DMAHTC, etc.), what system is used (English or metric) and other details.

The charts published by the National Ocean Service of the United States are classified according to their scale. The scales of nautical charts range from about 1:2,500 to about 1:5,000,000. These charts are classified into the following "series":

Sailing Charts	-	Scales 1:600,000 and smaller
General Charts	-	Scales 1:150,000 and 1:600,000
Coast Charts	-	Scales 1:50,000 to 1:150,000
Harbor Charts	-	Scales larger than 1:50,000

2.11 MEASURING DISTANCES ON THE MERCATOR CHART

Measuring distances on a Mercator chart must be performed with great care, particularly so if the chart covers a considerable change of latitude. Distance is always measured on the latitude scale, that is, on the graduated meridian.

To measure distance, place the points of the dividers on the two positions whose distance apart is required to be measured.

Without changing the spread of the divider, transfer the divider to the graduated meridian directly abreast of the two places and read off the degrees and minutes between the points. Read the scale and reduce it to nautical miles.

Note: It is very important when measuring distances to place the dividers on the graduated meridian directly abreast of the positions between which it is required to measure the distance. If the measurement is taken to the northward or southward of the given positions, the distance maybe too small or too large as the case may be. When both are in or about the same latitude, place the points of the dividers on the graduated meridian equally above and below the latitude of the places and read off the distance.

The parallel of latitude are divided into degrees, but since the meridians on the Earth's surface converge as they approach the poles, the length of these degrees varies according to the latitude in which they are measured. Hence, longitude cannot be used for measuring distances. And one more thing: since mathematically, latitude scale increases proportionally to the secant of the latitude and since the natural secant of 90° (the latitude of the poles) is infinity, the maximum latitude that is depicted on the Mercator chart is only up to 85° N and S or lower, because beyond these limits the latitude scale can no longer be stretched.

Reminder! Do not get confused about the use of the latitude and longitude scales on a Mercator chart. Distances and latitudes are measured actually on the graduated meridian which is referred to as the ***scale of latitude*** while longitude is measured on the graduated parallel which is referred to as the ***scale of longitude.***

In Figure 2.10, suppose it is desired to measure the distance between points A and B. Using the latitude scale which is midway between A and B, place your divider at any convenient unit along the scale then "walk" your dividers as shown.

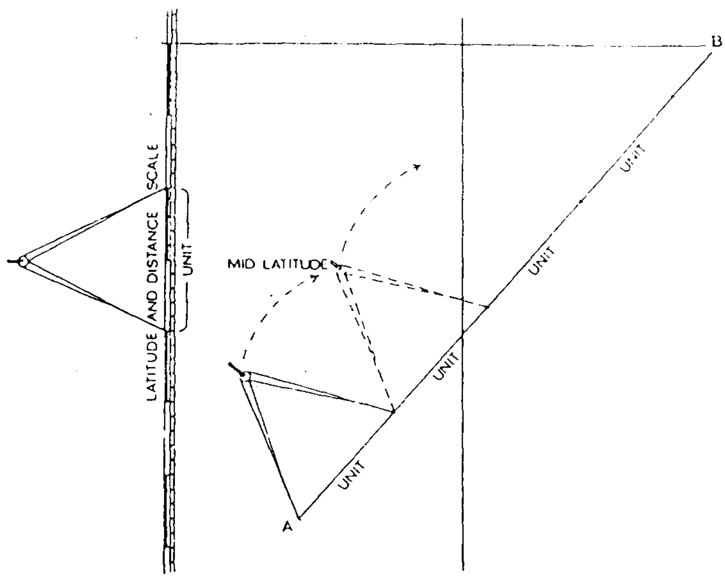


Figure 2.10 – Measuring Distance

2.12 PLOTTING POSITIONS ON THE MERCATOR CHART

In the preceding chapter, we have learned that the position of a ship is actually a point with no magnitude and is determined by the intersection of two coordinates, a parallel and a meridian which intersects at right angles.

To plot latitude: Place the edge of the parallel ruler aligned with a printed parallel and carefully maneuver the ruler preserving the original East-West direction until the edge of the ruler coincides with the given latitude. Now draw in the latitude.

Note: **There is no hard and fast rule on how to "maneuver" the parallel. This will depend entirely on common sense.**

To plot longitude: Use the divider to measure from the nearest meridian to the required longitude at the top or bottom of the chart. Then without changing the spread of the divider transfer the divider along the edge of the parallel ruler as shown in the figure. Then draw the meridian.

The point of intersection of the parallel and the meridian is the required position *(see Figure 2.11).*

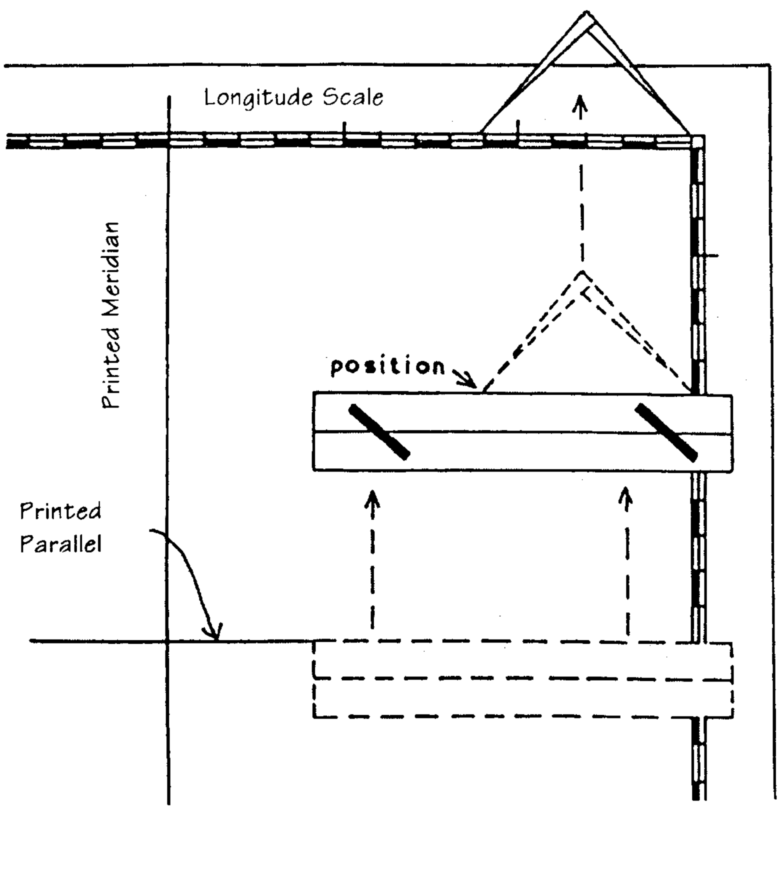


Figure 2.11 – Plotting a position on the chart by parallel ruler and divider.

If the parallel ruler is graduated, you can lay the ruler as shown in Figure 2.12 and maneuver the ruler as follows:

To plot the latitude: Place the 90 and ↓ graduation of the parallel ruler in line with the printed meridian as shown, then maneuver the ruler preserving the East-West direction until the edge of the ruler coincides with the given latitude. Draw in the latitude parallel.

To plot the longitude: Place the 90 and ↓ graduation of the parallel ruler in line with the printed parallel and maneuver the ruler preserving the North-South orientation until the edge of the ruler coincides with the given longitude. Now draw in the meridian.

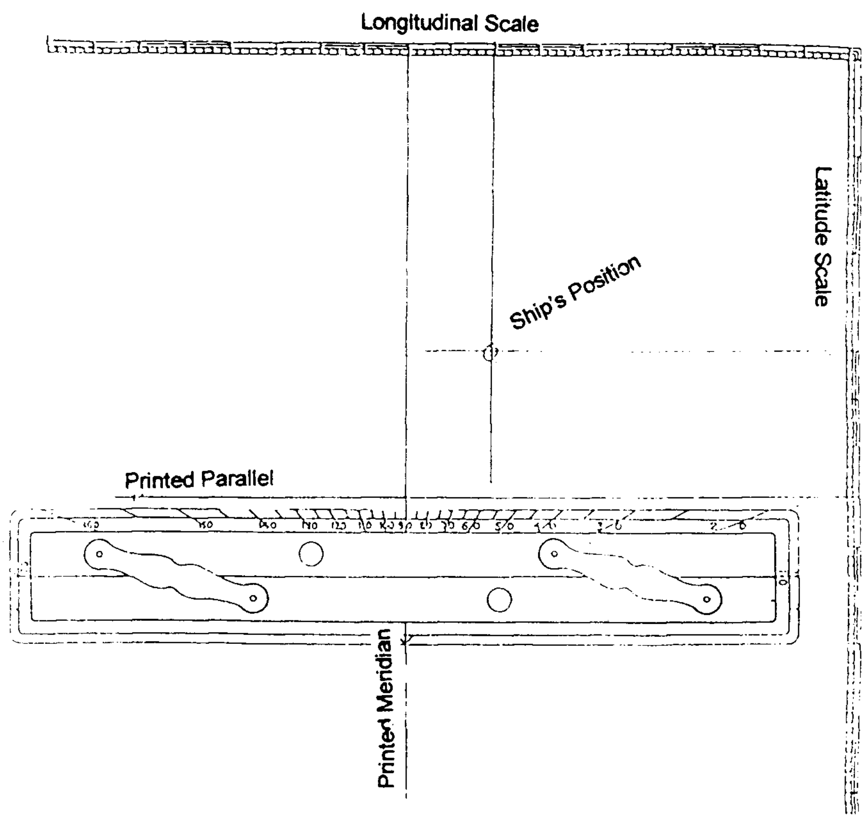


Figure 2.12 - Laying down latitude with a graduated parallel ruler

Another method of plotting a position on the Mercator chart is by the use of a good pair of dividers:

To plot latitude: Place one leg of the divider on a printed parallel of latitude nearest the required latitude and place the other leg at the desired latitude on the latitude scale. Then without changing the spread of the divider, transfer the divider to the nearest meridian of the required position and mark the point with your pencil as shown in Figure 2.13.

To plot the longitude: Place one leg of the divider on the printed meridian nearest the required position to be plotted and the other leg on the desired longitude at the longitude scale.

Without changing the spread of the divider, transfer the divider to where the latitude was marked. The ship's position is where the divider intersects the parallel as shown in Figure 2.13.

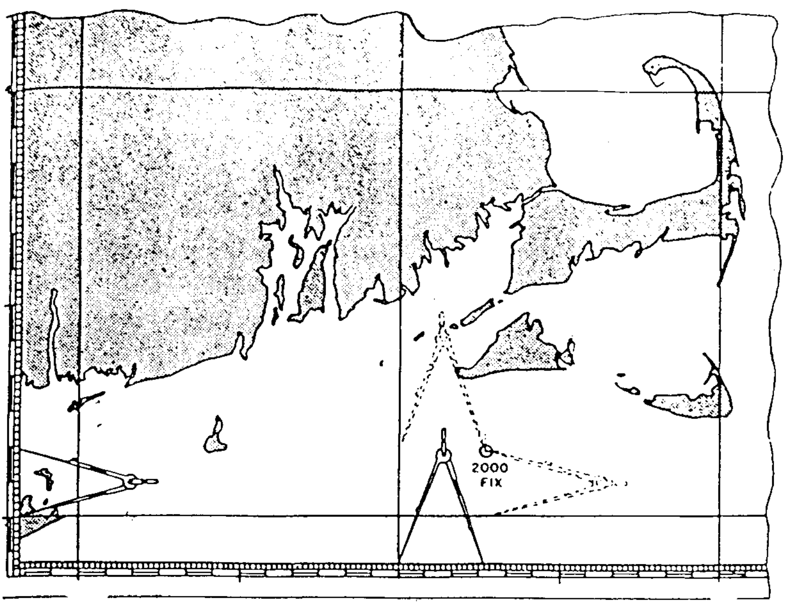


Figure 2.13 – Use of dividers in plotting a ship's position

Another method is to use a pair of triangles. Having understood the measurement required to plot a position, plotting a position by means of a pair of triangle can be quickly and conveniently performed. Common sense will just do the trick *(see Figure 2.14)*.

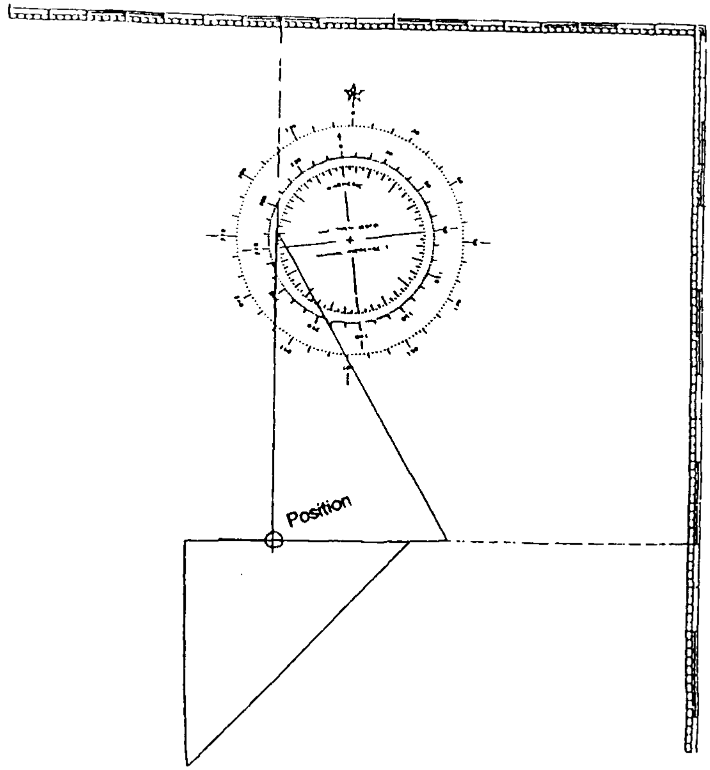


Figure 2.14 – Using a pair of triangles in plotting a position

2.13 TAKING OFF POSITIONS ON THE CHART

Taking off a position from the chart employs a procedure which is opposite to plotting a position *(see Figure 2.15).*

To take off latitude: Referring to Figure 2.15, suppose it is required to take off the position of Tabones Island (encircled on the chart). The edge of the parallel ruler is placed to coincide with the printed parallel. It is now carefully moved until the edge passes through the position of Tabones Island and the parallel through the island is drawn. The latitude of Tabones as read off the scale is found to be Latitude 14° 49.5' N.

To take off longitude: Referring to Figure 2.15, by using the same procedure as what we have done when we took off the latitude, the longitude can be measured, thus the longitude of Tabones as read off the scale is longitude 120° 03.7' E.

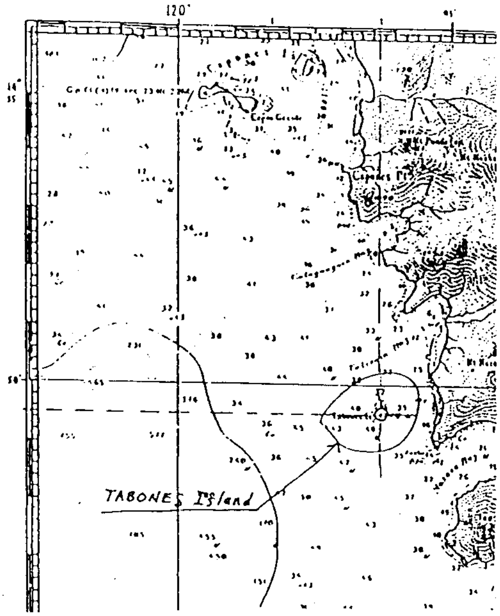


Figure 2.15 – Taking off position on the chart

Note: It can be ascertained whether the chart is in the Northern or Southern Hemisphere by observing how the latitude increases. If it increases to the northward, the chart is for the Northern Hemisphere, and if to the southward, the chart is for the Southern Hemisphere. Likewise, if the longitude increases to the right or eastward, that chart is of East longitude, and if to the left or westward, it is of West longitude.

2.14 PLOTTING SHEETS

Position plotting sheets are "dummy charts" which show only the latitude and longitude scales and a compass rose. The meridians are usually not labeled so that the plotting sheet can be used for any longitude. For the purpose of this book, only a small-area plotting sheet shall be used for plotting lessons. In the small-area plotting sheet, the meridians and parallels are not labeled so that the student will learn to label meridians and parallels for any latitude and longitude.

Small-area plotting sheets can be constructed when emergency situations demand. Directions on how to construct a small-area plotting sheet may be learned in the later topics.

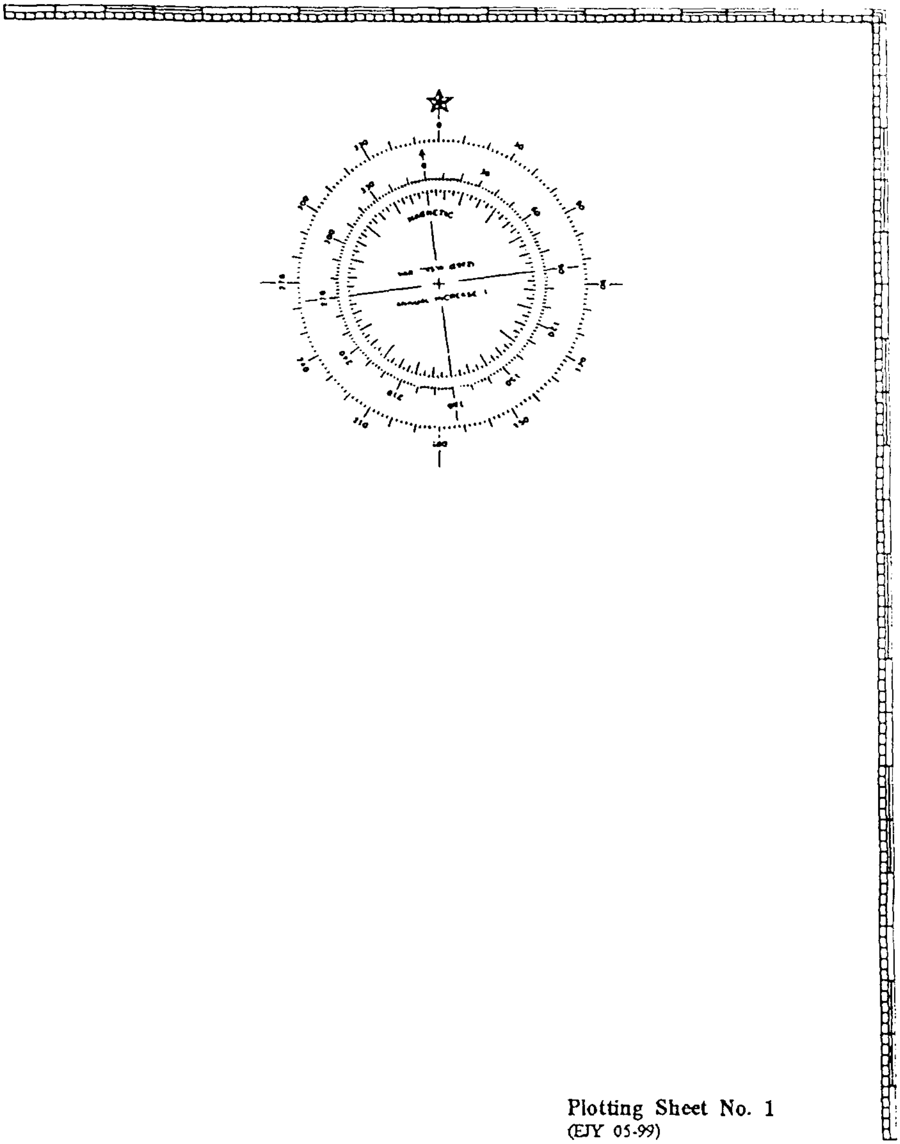


Figure 2.16 – Small-area plotting sheet

2.15 CONVENTIONAL SIGNS, SYMBOLS AND ABBREVIATIONS ON THE MERCATOR CHART

All maritime schools are required to have copies of Chart No. 1 which contains symbols and abbreviations that have been approved for use on nautical charts published by the United States of America. This publication comes in two forms, a booklet and a chart. United Kingdom also publishes the British Admiralty Chart of "Symbols and Abbreviations" which every maritime school should also have. The student is required to examine these charts in detail in order to be able to see and know the various signs, symbols and abbreviations and the other features used in a chart.

2.16 NAUTICAL PUBLICATIONS

Closely allied with chartwork are many sources of information which the navigator uses when planning and conducting a voyage. These sources include ***notice to mariners, sailing directions, coast pilots, light lists, tide tables, sight reduction tables,*** *and* ***almanacs.*** Other British publications also include ***The Admiralty Sailing Directions, Ocean Passages of the World, The Admiralty List of Lights. Radio Aids and Fog Signals, The Admiralty List of Radio Signals, Tidal Publications,*** and ***Admiralty Notice to Mariners.***

Miscellaneous Nautical Publications

1. *Radio Navigational Aids (Pub. 117)* – Published by DMAHTC, this publication contains a selected list of worldwide radio stations which perform services to the mariner. Topics covered include radio direction finder and radar station, radio time signals, radio navigation warnings, distance and safety communications, medical advice by radio, LORAN, and the AMVER systems.

2. *Chart No. 1* – This publication is not actually a chart but a book containing a key to chart symbols. It contains a listing of chart symbols in four categories:
    a. Chart symbols used by the National Ocean Service
    b. Chart symbols used by the Defense Mapping Agency
    c. Chart symbols recommended by the International Hydrographic Organization
    d. Chart symbols used on foreign charts reproduced by DMAHTC

The subjects covered include general features of charts, topography, hydrography, and aids to navigation.

3. *World Port Index (Pub. 150)* - This publication contains a tabular listing of thousands of ports throughout the world, describing their locations, characteristics, facilities and services available.

4. *Distances Between Ports (Pub. 151)* - This publication lists the distance between major ports. Reciprocal distances between two ports may differ due to different routes that are chosen because of currents and climatic conditions. This book is most helpful for voyage planning in conjunction with the proper volumes of the Sailing Directions (Planning Guide).

5. *International Code of Signals (Pub. 102)* - This book lists the signals to be employed by vessels at sea to communicate a variety of information relating to safety, distress, medical, and operational information.

6. *Catalogs* - A chart catalog is a valuable reference to the navigator for voyage planning, inventory control, and for ordering. This catalog contains comprehensive ordering instructions and information about the product listed. These are produced by the National Ocean Service of the U.S.

7. *Notice to Mariners (Maritime Safety Information)* - Every nation publishes its own Notice to Mariners, the frequency of publication depending on the policy of each nation.

   In the U.S., this publication is published weekly by the DMAHTC, prepared jointly by the National Ocean Service (NOS) and the U.S. Coast Guard. It advises mariners of important matters affecting navigational safety, including new hydrographic information, changes in channels and aids to navigation, and other important data.

   About 60 countries which produce nautical charts also produce their own notices to mariners.

   Mariners are requested to cooperate in the correction of charts and publications by reporting all discrepancies between published information and conditions actually observed and by recommending appropriate improvements.

2.17 NAUTICAL TEXTS

1. *Sailing Directions* - This publication is published by the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC). It consists of thirty-seven *Enroutes* and ten *Planning Guides.*

   The *Planning Guides* assist the navigator in planning an extensive oceanic voyage. It consists of five chapters. The first chapter covers pratique, pilotage, signals, and shipping regulations. Also search and rescue topics include the location of all lifesaving stations.

   The second chapter gives the mariner meteorological and oceanographic information to be considered in planning a route.

   The third chapter lists foreign firing danger area not shown in other DMAHTC publications. It also identifies publications listing danger areas and gives pertinent navigation cautions.

   The fourth chapter describes recommended steamship routes. It also includes all applicable Traffic Separation Schemes.

   The fifth chapter describes available radio navigation systems and the areas' systems of lights, beacons, and buoys.

   Sailing Directions (Enroute) contains numbered sections along a coast or through a strait. Each sector is discussed. It may also contain special information on local winds and weather, anchorages, significant coastal features and navigation dangers.

2. Coast Pilots - This publication usually comes in volumes depending on what country publishes it. Each volume normally contains comprehensive sections on local operational conditions and navigation regulations and other detailed discussions of coastal navigation, additional weather information, communications services and other data.

   The Philippines also publishes the Philippine Coast Pilots in two volumes, Notice to Mariners to be used in Philippine Waters, Tide Tables and other publications. It also produces charts and maps for the Philippines. These publications and charts used to be published by the Philippine Coast and

Geodetic Survey but this work has been transferred to the National Mapping and Resource Information Authority (NAMRIA) which is under the Department of Environment and Natural Resources (DENR). Ships engaged in coastwise navigation in Philippine waters use the NAMRIA publications.

The navigator must know what information he needs to navigate his ship safely and how to obtain it.

3. *Light Lists* - also published by the DMAHTC, it furnishes complete information about navigation lights and other navigation aids. They supplement, but do not replace, charts and sailing directions. The navigator must consult the chart for the location and characteristic of lights and all navigation aids but must consult the light lists to determine their detailed description.

2.18 GENERAL INFORMATION PROVIDED BY NAUTICAL CHARTS

1. *Title Block* - Each chart has a title block. This block includes the title of the chart and a statement of the projection used. If the chart is based on foreign sources, as many BA or DMAHTC charts are, the original authority and date of surveys will appear on this block.

   Also in the title block are statements regarding the planes of reference used for heights and depths. The datum for soundings (measurement of depth of water) is generally some form of average low water so that at any stage of tide the mariner has at least the charted depth. Among the various levels used are ***mean low water (MLW), mean lower low water (MLLW), and mean low water springs (MLWS).***

   The unit of measurement - feet, meter, or fathom - is also stated as part of the block *(see Figure 2.17).*

2. *Chart Notes* - Many valuable information are printed on charts in the form of notes and as boxes of data. These notes will relate to such topics as regulatory restriction, cautions and warnings, unusual magnetic conditions, etc. The boxes may show depths of channels, ocean and extremes of tidal stages, etc. Notes and boxes are printed in the margins or on the face of the chart at locations where they will not obscure navigational information.

2800

PHILIPPINES

Mercator Projection

3256 Scale 1:1,575,000 at Lat., 13°12'

SOUNDINGS IN FATHOMS
(FATHOMS AND FEET TO ELEVEN FATHOMS)
AT MEAN LOWER LOW WATER

2941 TIDAL INFORMATIONS

Place	Height referred to datum of soundings (MLLW)				
	Mean High Water interval		Mean Higher High Water	Mean Tide Level	Extreme Low Water
	hr.	min.	Meters	Meters	Meter
Manila, Luzon	10	23	1.00	0.48	-1.06
Aparri, Luzon	6	31	1.07	0.52	-0.50
Hilaban I, Samar	6	10	1.43	0.76	-0.67
Zamboanga, Mindanao	6	31	1.01	0.43	-0.50
Cebu, Cebu	11	36	1.53	0.72	-0.64
Pagasa I, Kalayaan Grp.	10	05	1.06	0.55	-1.06

(189)

ABBREVIATIONS:

Lights (Lights are white unless otherwise indicated)

F. fixed	S-L short - long	OBSC obscured	Rot. rotating
Fl. flashing	Occ. occulting	WHIS. whistle	Sec. sector
Qk. quick	Alt. alternating	DIA. diaphone	m. minutes
Gp. group	I Qk. interrupted quick	N. M. nautical miles	sec. seconds

Buoys

TB temporary buoy	N. Nun.	B. black	Or. orange	W. white
C. can	S. spar	R. red	G. green	Y. yellow

Bottom characteristics.

Cl. clay	M. mud	hrd. hard	bk. black	gy. gray
Co. coral	R. rock	rky. rocky	br. brown	rd. red
G. gravel	S. sand	sft. soft	bu. blue	wh. white
Grs. grass	Sh. shells	Stk. sticky	gn. green	yl. yellow
Oz. ooze	crs. coarse	fne. fine	brk broken	spk. speckled

2900 21 Wreck, rock, obstruction or shoal swept clear to the depth indicated

(2) Rocks, that cover and uncover with height in feet above datum of soundings

AERO aeronautical R. Bn. radio beacon Flood

Bn. daybeacon R. TR radio tower Ebb

AUTH. authorized Obstr. obstruction P.A. position approximate

E.D. existence doubtful P.D. position doubtfu

HEIGHTS

Heights in meters above Mean Sea Level

1794 AUTHORITIES

Hydrography and topography by the Coast and Geodetic Survey
with additions from other Sources

Figure 2.17 – Chart of the Philippines showing title, projection, scale, datum used for height and depths, and other information.

3. *Use of Color on Charts* – Almost all charts, BA, DMAHTC or Canadian charts, employ color to distinguish various kinds of information such as deep water, shoal water, and land areas.

Basic color variations of black, blue, green, gray, magenta, gold and white are used.

4. *Lettering Styles* – The style of lettering on a chart also provide information. In almost all sources of charts, vertical lettering identifies features that are dry at high water; submerged and floating hydrographic features (except depths of water) are identified by leaning or slanting letters.

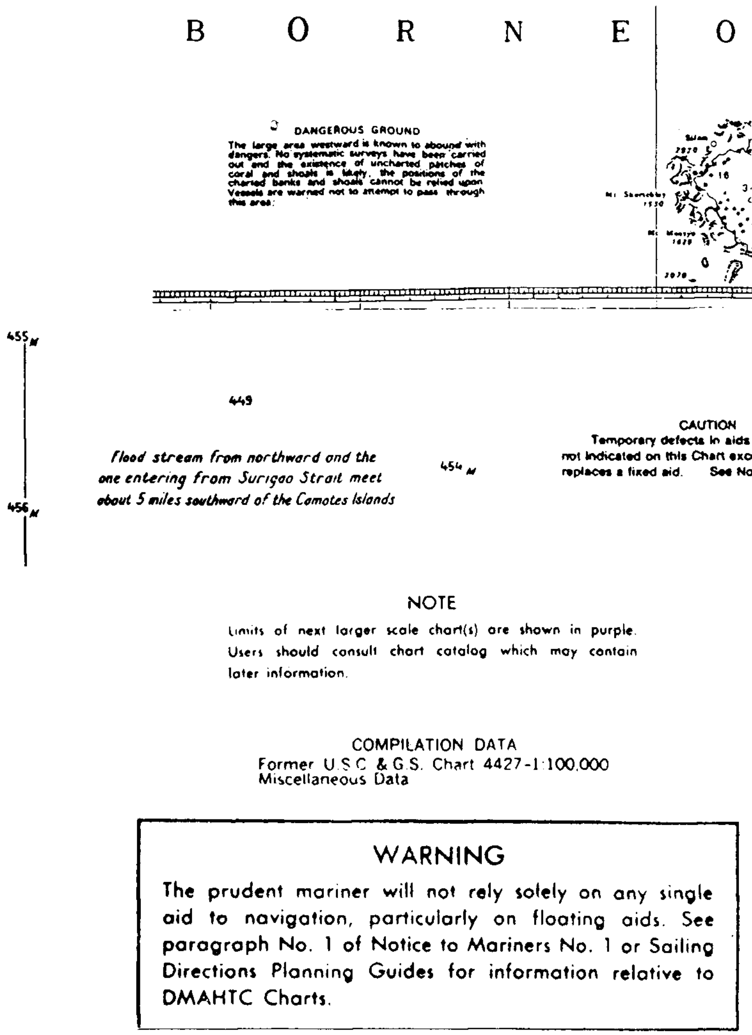


Figure 2.18 – Chart Notes
(Source: NAMRIA)

5. *Water Features* – The greatest concern to a navigator is the depth of water where his ship is navigating. These are shown as many small numbers in roman type. The unit of measurement and the datum from which it is measured are in the title block. In most charts, water areas having equal depths are connected by lines, known as ***contour lines*** and are generally termed as ***depth curves.***

6. ***Character of the Sea Bottom*** – Information on the composition of the sea bottom such as mud, sand, rocks, coral, clay, etc., is of interest to the mariners especially when anchoring. This is shown on Chart No. 1.

7. ***Features of the Shoreline*** – A steep coast or a rocky coast and other natures of coastlines such as cliffs or marshy areas or vegetation extending out into the water are noted by symbols and abbreviations. This is also shown in Chart No. 1. Various forms of vegetation may be also shown on a chart by symbols and/or abbreviations.

8. ***Land Features*** – Information shown on nautical charts that relates to land features is generally limited only to features that is useful to the navigator to assist him in establishing his position and directing his vessel's movements safely. These features will also relate to the shoreline that can be observed from the sea.

   Land forms are generally shown by the use of contour lines connecting points of equal heights.

9. *Man-made features* – These features are shown for both water and land areas. For areas above water, these include bridges, piers, oil platforms and overhead power cables. Below the water surface, these are submarine cables and pipelines.

   On land, man-made features include landmarks such as tower, stacks, tanks, etc. buildings, breakwaters and jetties, wharves and drydocks. In some scale of charts, even streets and railroads are also indicated by symbols and identified by lettering.

2.19 CHART CORRECTIONS

All charts in regular use on board ships should be kept corrected and up-to-date according to the latest information from all sources such as the Notice to Mariners and other information disseminated by radio. Always remember that an uncorrected chart is not safe to use.

2.20 COMPUTER-BASED CHARTS

The National Ocean Service has established an automated information system with a database that can store all chart information in digital form. Every point, line, symbol, letters and numbers - everything - is being stored in digital form or discs *(Maloney, 1985).*

In STCW Code Table A-II/1 - Specification of minimum standard of competence for officers in charge of a navigational watch on ships of 500 gross tonnage or more, one area of knowledge, understanding and proficiency is a "thorough knowledge of and ability to use navigational charts and publications." A note in the table indicates that the Electronic Chart Display and Information Systems (ECDIS) are considered to be included in the term charts.

Although not required as a navigational equipment on ships' bridges, the technology associated with electronic charting is rapidly becoming a standard part of bridge construction, particularly as ships are built or modified to have integrated bridge systems and integrated navigation systems. This being the case it is important to those aspiring as officers in charge of a navigational watch to know that at the time they graduate from the BSMT course this ECDIS Systems will already be a part of the ship's bridge systems.

Therefore, by the time the present BSMT student steps into the bridge of the ship in the future corrections to the chart as previously mentioned will be done in computer-based charts. These are the effects of a fast changing shipboard technology.

However, because of its huge financial cost not all shipowners may not be able to afford to equip their ships with this electronic charts and the "old reliable" printed charts will still be there.

2.21 NOTES ON THE USE AND CARE OF CHARTS

Charts must be used intelligently, not blindly. The degree of reliance to be placed on a particular chart or portion of a chart is paramount. As the navigator gains experience in dealing with charts he develops the skill to make the chart a much more useful and dependable aid. Remember that a chart is a basic tool in the art of navigation. Learn to use it skillfully.

The following tips on the use and care of charts are helpful:

1. Read carefully all notes appearing on the chart. Do not merely look at it as though it is a picture.
2. Check the scale, note the date of survey on which it is based, if given, and see whether or not the chart is corrected and updated from "Notice to Mariners."
3. Investigate any "Cautionary Notices" which are sometimes not in a conspicuous location on the chart.

   These cautionary notices may include:
   a. Prohibited and dangerous areas
   b. Areas of abnormal magnetic variation
   c. Exceptional tides and currents
   d. Ice warnings, etc.

4. Check that the sounding coverage is complete and if not, note the areas where lack of information may indicate danger.
5. Note the systems of projection used, so that you can be sure how to measure direction and distance.
6. Check the tidal reference plane.
7. Whenever possible, always use the largest scale chart because:
   a. more details are shown
   b. any errors are reduced to a minimum
   c. it is more up-to-date
   d. errors of distortion are less
8. Store charts properly in their proper folios.
9. Always keep the chartroom door closed during damp weather.

2.22 THE COMPASS ROSE

Compass Roses *(see Figure 2.19)* are printed on most charts to make the process of laying down and taking off courses and bearings easy for the navigator. It usually consists of two compasses with a common center, the outer being true and inner magnetic.

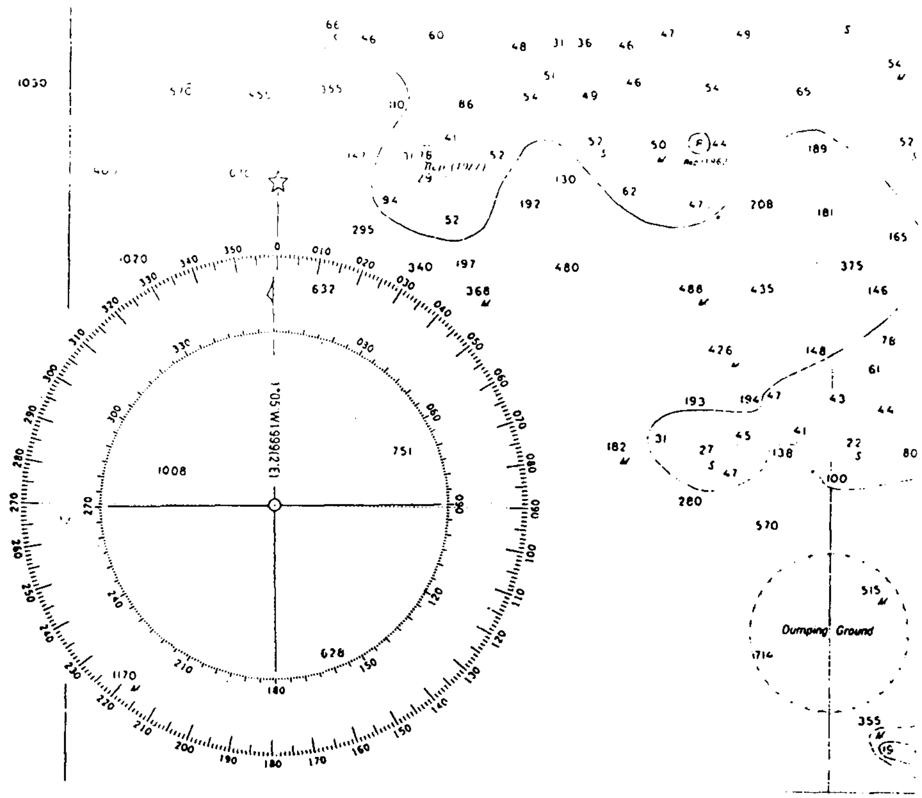


Figure 2.19 – Compass rose

The outer circle represents the true compass and is graduated in degrees clockwise from 0° to 360°, the North-South direction being the direction of the true or geographic meridian.

The inner circle represents the magnetic compass card and is also graduated from 0° to 360°. The North-South line is aligned with the magnetic meridian and the angle it makes with the true North-South line is the variation of the locality which the chart represents.

Since the value of variation undergoes a yearly change, the year for which the magnetic rose applies, together with the annual change (decrease or increase), is printed at the center of the rose. It is therefore necessary that when the chart is used for a year different from which the magnetic rose is drawn a correction will have to be made to compensate for the change.

The value of variation printed in the compass rose in Figure 2.19 is 1° 05' W in the year 1999. It is predicted to have an annual change of 2' E (which means decreasing since the variation is west). The area from which the compass rose is placed is located near the southeastern shores of Bataan Peninsula in Luzon, Philippines.

CHAPTER TEST

1. What are the main requirements of a navigational chart?
2. Describe the Mercator chart and state the advantages and disadvantages from the navigator's point of view.
3. How is distance measured in a Mercator chart? What instrument is used to measure distance?
4. What are large-scale charts? What are small-scale charts?
5. Whenever possible why is it advisable to use the largest scale chart available?
6. Why are Mercator charts not used in the polar regions?
7. What is a rhumb line?
8. Explain why islands near the equator appear in their true size and shape in a Mercator chart. Why does Iceland appear to be the same size as the island of Borneo in a Mercator chart when in fact Borneo is about seven times bigger than Iceland?
9. On what part of the Mercator chart is the scale of latitude graduated?
10. What are the different scales used on charts?
11. What information can you derive from Chart No. 1?
12. In the Plan Chart of Mariveles Harbor in the Workbook,
    a. What is the datum used for soundings?
    b. What is the unit of measurement used to measure the depth of water?

c. What are the various bottom characteristics of the sea bottom inside the harbor?
d. What are the underwater hazards in the harbor?
e. What is the length of the breakwater in yards? In feet? In meters?
f. Connect the quarantine jetty (near Lat. 14° 26' N, Long. 120° 29' E) and the mouth of the slipway near Palasan Point with a straight line. Measure and determine the distance in yards and in kilometers.
g. How wide (in nautical miles) is the entrance to the harbor? What is the deepest depth of water at the entrance?

Chapter Three
COMPASS, COURSES AND BEARINGS

At the end of this chapter, the student should be able to:

- identify the three Norths and the three courses that are used in navigation;
- correct the errors of the compass;
- convert compass courses to true courses and vice versa; and
- differentiate bearings from courses and how to apply them.

3.1 DIRECTION ON THE EARTH

Direction is the position of one point relative to another without reference to the distance between them. In the classroom, for instance, the teacher can point to the position of Cadet A as being seated to the right of Cadet B or the position of Cadet C as being seated at the rear of Cadet B. So, if you follow the direction stated by the teacher all that you have to do in order to locate Cadet A is look towards the right of Cadet B. Likewise, Cadet C can be found if you look at the direction towards the rear of Cadet B. To be able to locate Cadets A and C however the exact location of Cadet B has to be known. The position of Cadet B is the reference point. Note that the positions of Cadets A and C were located without stating their respective distances from Cadet B.

Out in the open sea where the navigator is surrounded by a seemingly boundless horizon, the navigator has no way of knowing his exact direction of travel except perhaps knowing that the point where the sun rises is East and the point where the sun sets is West. However, these are vague indications that cannot serve the specific purpose of the navigator. In order to know exactly the direction he is heading, the navigator needs an instrument that indicates direction. This instrument is the *ship's compass.*

3.2 THE MAGNETIC COMPASS

One of the oldest - if not the oldest of the navigator's instrument is the magnetic compass. Its origins are not recorded by history but it has been used by several different seagoing cultures from the time that man discovered navigation.

Despite the invention of the gyrocompass, the magnetic compass still retains its importance and reliability. While the former is an extremely accurate instrument, it is highly complex, dependent on an electrical power supply and subject to mechanical damage. The magnetic compass on the other hand, is entirely self-contained, simple, and not easily damaged.

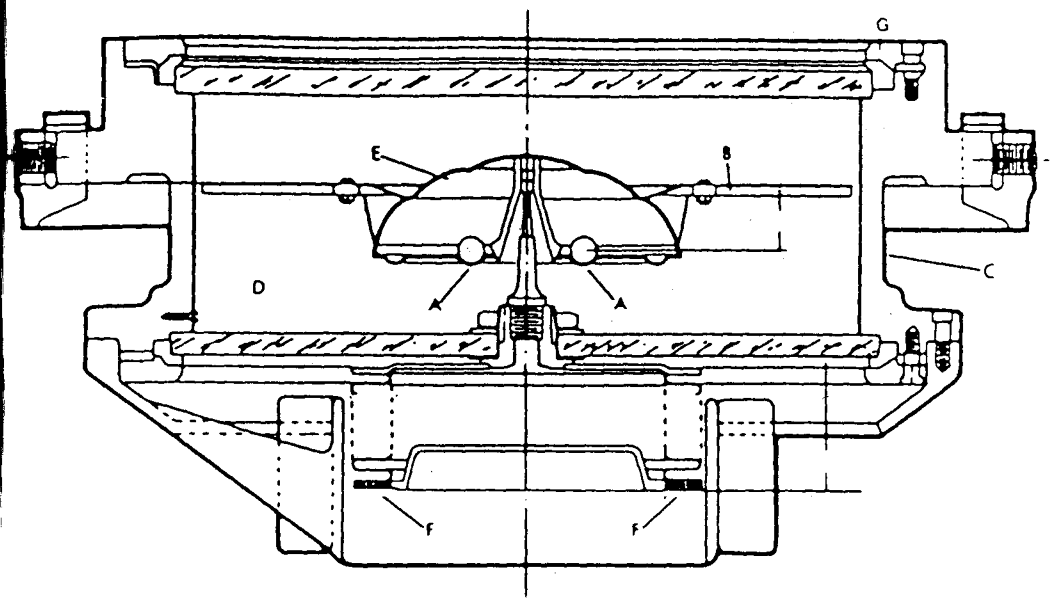
The magnetic compass operates solely under the principle of magnetism. This book shall not deal with this theory anymore as the author assumes that this has been studied extensively in high school physics. So, suffice it to state that the study of magnetism has been made.

Modern Magnetic Compass Construction

The basic mechanism of modern magnetic compasses is exactly the same as that of the earliest ones - a small bar magnet freely suspended in the magnetic field of the earth. Some refinements have been added during the past hundreds of years for greater accuracy, steadiness of indication, and ease of reading, but the fundamental meridian remains unchanged.

Components of a Modern Magnetic Compass

Figure 3.1 shows a cutaway view of a magnetic compass. The letter C indicates the bowl with its cover secured by a grooved ring, G. At the forward side of the bowl is the ***lubber's line***, which indicates the direction of the vessel's head. The bowl is fitted with expansion bellows (letter F), which permits the bowl to remain filled as the liquid expands and contracts with temperature changes. The bowl is supported in ***gimbals*** or double rings hinged on both the fore and aft and athwartships axes. These gimbals permit the compass bowl to remain horizontal, or nearly so, regardless of the vessel's rolling or pitching. A gimbal is illustrated in Figure 3.2.



A – magnets
B – compass card
C – bowl
D – fluid
E – float or air chamber
F – expansion bellows
G – grooved ring

Figure 3.1 – Cutaway view of a magnetic compass
(Source: Dutton's Navigation and Piloting, 14th ed.)

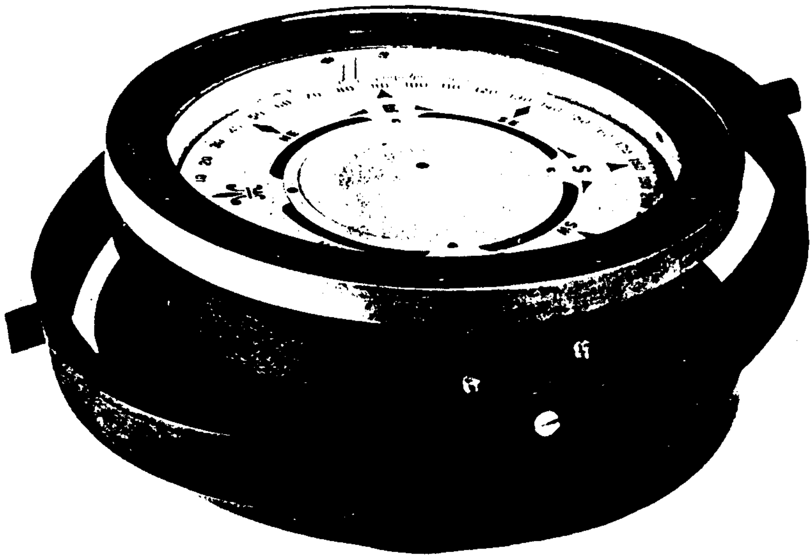


Figure 3.2 – Standard magnetic compass
(Source: Dutton's Navigation and Piloting, 14th ed.)

The gimbald compass is mounted in a ***binnacle*** or stand, made of non-magnetic material. A typical binnacle is shown in Figure 3.3 (The balls on either side are called ***quadrantal spheres***).

Letter B indicates the compass card which floats on top of a vertical pin situated at the center of the bottom of the bowl and acts as a pivot. To the bottom of this card are attached two or more magnets, (letters A) which are aligned with the north-south axis of the compass card.

In order to reduce friction on the pivot and to dampen vibration, the compass bowl is filled with a clear fluid (letter D) that is not subject to freezing at normal temperatures. Usually these fluids are either varsol or alcohol. The card has a ***float*** or air chamber (letter E) designed so that it will support the weight of the card with its attached magnets.

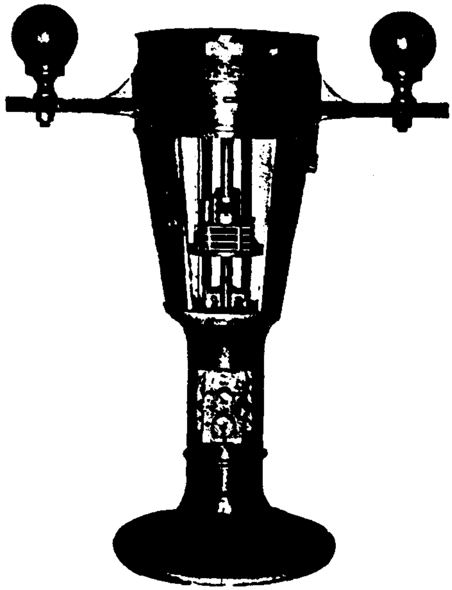


Figure 3.3 – Binnacle for standard magnetic compass
(Source: Dutton's Navigation and Piloting, 14th ed.)

3.3 OLD AND NEW FORM OF COMPASS CARD READING

The old form of compass reading uses points where the compass card is sub-divided into 32 points, with one point equal to 11.25°. There are four cardinal directions which are known as the ***cardinal points*** and another four inter-cardinal directions known as ***inter-cardinal points***. The cardinal points are N, S, E and W. While the inter-cardinal points are NE, SE, SW and NW. Reciting the points in correct order, and starting at any named point is called ***"boxing the compass"***. The old form of compass reading is described in Table 3.1.

Table 3.1

POINTS				ANGULAR MEASURE
North	East	South	West	0°
N by E	E by S	S by W	W by N	11°15'
NNE	ESE	SSW	WNW	22°30'
NE by N	SE by E	SW by S	NW by W	33°45'
NE	SE	SW	NW	45°00'
NE by E	SE by S	SW by W	NW by N	56°15'
ENE	SSE	WSW	NNW	67°30'
E by N	S by E	W by S	N by W	78°45'
East	South	West	North	90°00'

With the advent of modern direction-finding instruments in navigation the use of the old-form of compass reading has been confined only to indicate wind direction and sometimes in weather reports, but even this is fast becoming obsolete as weather facsimile charts now use other forms of compass reading. But, it still remains a solemn duty and obligation of the navigator to know how to "box" his compass and he must possess a commanding knowledge of correcting courses and bearings from "true" to "compass" and vice-versa. Failure on the part of the navigator to show his proficiency in the area of compass reading and correction is an omission of duty he can never forgive himself.

The new and modern method of compass reading is the use of the three-figure notation. In this method, directions are reckoned from 000° to 360° clockwise from North.

Example

OLD FORM	NEW FORM
N	000°
E	090°
S	180°
W	270°
N	360°

Sometimes, the Quadrantal notation is also used in expressing directions.

Example

NEW FORM	QUADRANTAL FORM
060°	N 60° E
120°	S 60° E
235°	S 55° W
320°	N 40° W

It will be easy to visualize these forms if you plot it in the compass card.

The above examples can be plotted as follows:

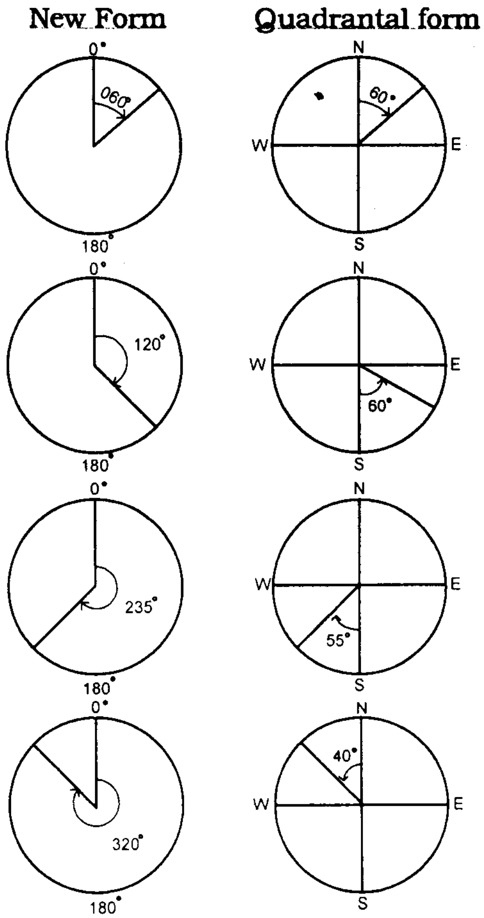
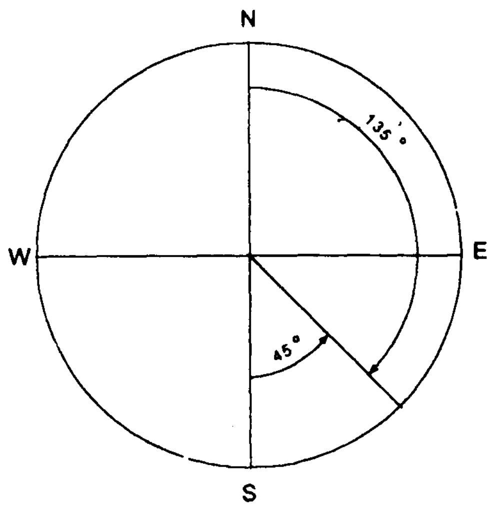


Figure 3.4 – New and Quadrantal Form of compass reading

It can be seen from the figures that the prefix indicates the starting point of measuring the angle while the suffix tells the student towards what direction he is going to measure such angle.

Let's take another Example: New Form = 135°, Quadrantal Form = S 45° E. Since the prefix is S or South and the suffix is E or East, the angle of 45° is described from South towards the East. It is also correct to say in this case if the form had been expressed as N 135° E. So it can be seen in the figures that as long as you follow the direction of movement from the prefix to the suffix and as long as you know how to describe and estimate the size of the angle it would be very easy to convert one form of compass reading to the other.



135° = S 45° E

Figure 3.5 – New Form and Quadrantal Form of compass reading

Table 3.2 shows the tabulation of the compass card divisions in the old form with their corresponding points and reading on the new form and on the quadrantal form.

Old Form	Points	New Form	Quadrantal Form
North	0	000°	North
N by E	1	011°15'	N 11°15'00" E
NNE	2	022°30'	N 22°30'00" E
NE by N	3	033°45'	N 33°45'00" E
NE	4	045°	N 45°00'00" E
NE by E	5	056°15'	N 56°15'00" E
ENE	6	067°30'	N 67°30'00" E
E by N	7	078°45'	N 78°45'00" E
East	8	090°	East
E by S	9	101°15'	S 78°45'00" E
ESE	10	112°30'	S 67°30'00" E
SE by E	11	123°45'	S 56°15'00" E
SE	12	135°	S 45°00'00" E
SE by S	13	146°15'	S 33°45'00" E
SSE	14	157°30'	S 22°30'00" E
S by E	15	168°45'	S 11°15'00" E
South	16	180°	South
S by W	17	191°15'	S 11°15'00"W
SSW	18	202°30'	S 22°30'00" W
SW by S	19	213°45'	S 33°45'00" W
SW	20	225°	S 45°00'00" W
SW by W	21	236°15'	S 56°15'00" W
WSW	22	247°30'	S 67°30'00" W
W by S	23	258°45'	S 78°45'00" W
West	24	270°	West
W by N	25	281°15'	N 78°45'00" W
WNW	26	292°30'	N 67°30'00" W
NW by W	27	303°45'	N 56°15'00" W
NW	28	315°	N 45°00'00" W
NW by N	29	326°15'	N 33°45'00" W
NNW	30	337°30'	N 22°30'00" W
N by W	31	348°45'	N 11°15'00" W
North	32	360°	North

Table 3.2

Note: The Student must bear in mind that interconversions of one form to the other of the above forms of compass reading always arises in the practice of navigation. The old form of compass reading, although obsolete in modern day navigation, is occasionally used in weather reports.

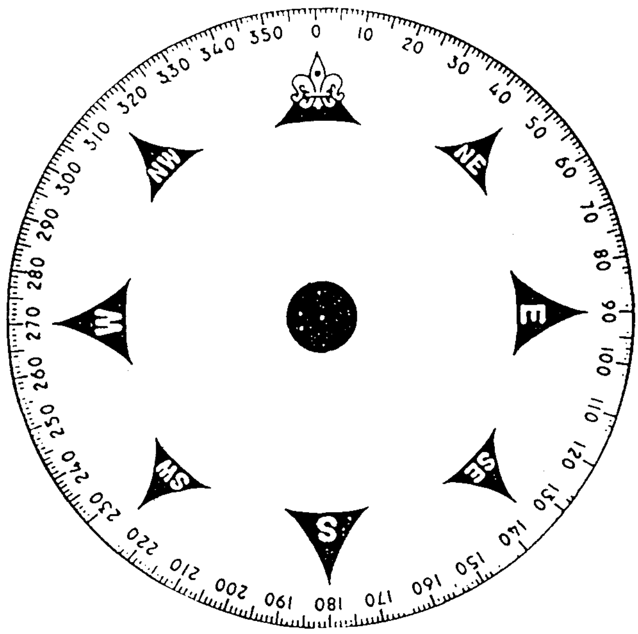


Figure 3.6 – Compass Card: degrees, cardinals and intercardinals
(Source: Chapman, 1972)

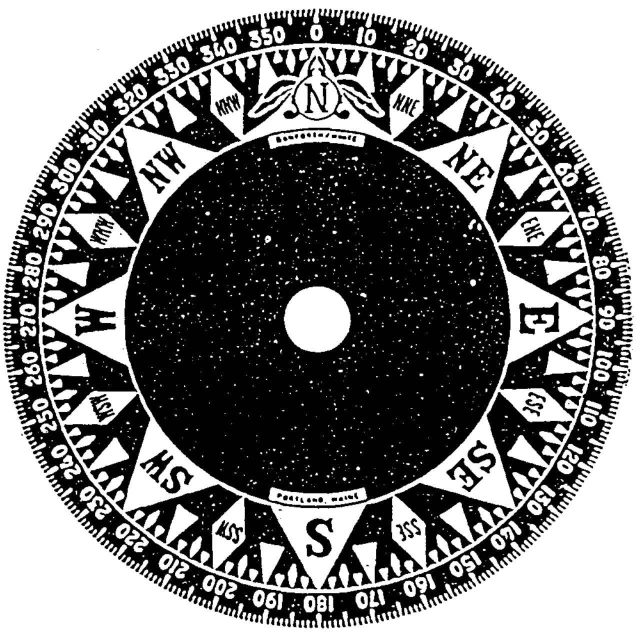


Figure 3.7 – Compass Card: degrees, points and quarter points
(Source: Chapman, 1972)

3.4 BEARING

Bearing is a horizontal direction generally expressed as an angle between a reference line extending from a reference point and a line extending from a reference point to a given direction. Imagine yourself with a telescope standing on the ground facing North. At this position, your line of sight is aligned with a meridian. Turn a little to your right and direct your telescope to a nearby tower or a tree. The horizontal angle contained between your first line of sight (a meridian) and the imaginary line of sight directed to a tower or a tree is the bearing of the tower or the tree. Since your first line of sight is the true geographic meridian, you call this kind of bearing as the ***true bearing*** of the given point.

Figure 3.8 – The photograph shows a silhouette of a deck officer sighting through the azimuth circle of the compass bearing of a charted object.

There are a number of reference points and directions that are used in navigation, such as the magnetic north, geographic north or true north, the ship's head or the heading of another ship.

True Bearing of an object is the horizontal angle between the direction of true north and the direction in which the object lies or bears.

Magnetic Bearing of an object is the horizontal angle between the direction of magnetic north and the direction of the object.

Compass Bearing of an object is the horizontal angle between the direction of compass north and the direction of the object.

Bearings are obtained by compass, pelorus, gyro repeater, and radar. One type of bearing which can be obtained by eye without measurement is a ***range bearing.*** When two objects are directly in line, one behind the other irrespective of distance between them, they are said to be "in range", and together they give a ***range line.***

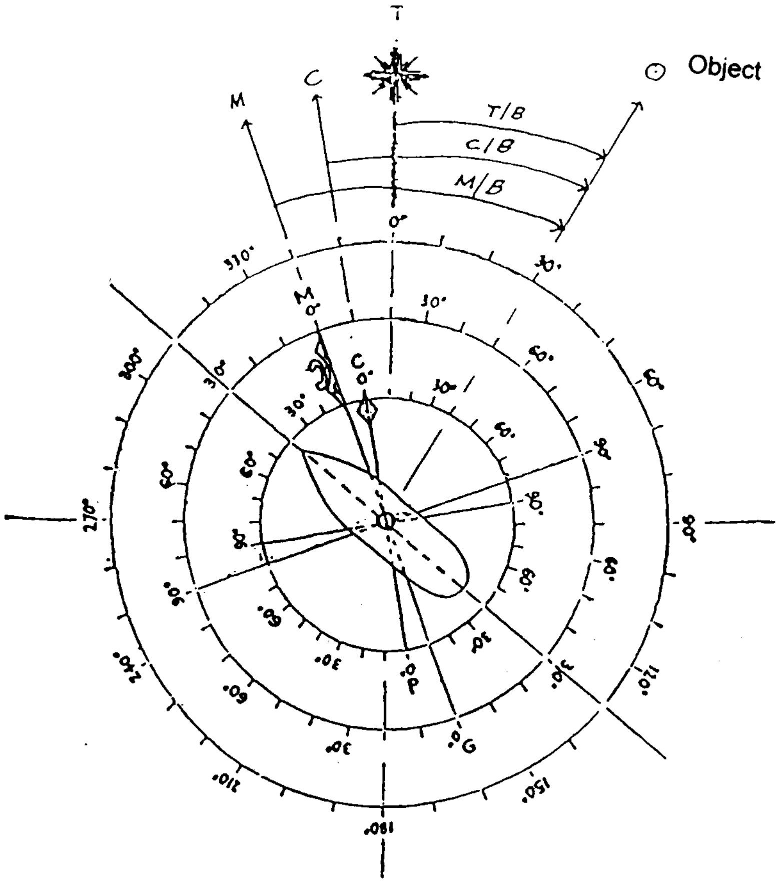
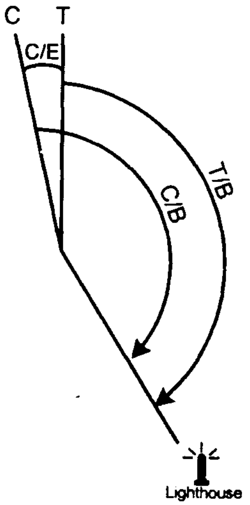


Figure 3.9 – The three bearings

Essentially, bearing is an angle, although the term is often used to denote direction.

Example

Find the true bearing of a lighthouse if the compass bearing is 140° and the compass error is 10° W.



$$
\begin{aligned}
T/B &= C/B - CE \\
&= 140^\circ - 10^\circ \\
&= 130^\circ
\end{aligned}
$$

The fourth kind of bearing that uses the fore-and-aft line of the ship as the reference point is a ***relative bearing***. It is usually measured from 000° from the ship's head or bow, clockwise through 360°. Sometimes, however, it is also expressed as points just like the points of the compass *(see Figure 3.10)*.

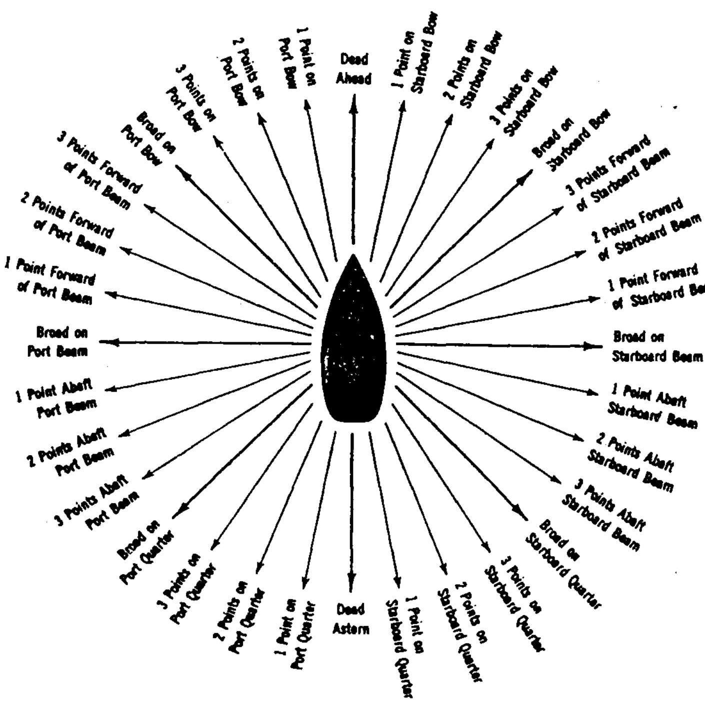


Figure 3.10 – One method of expressing relative bearing

3.5 COURSES

Course is a direction in which a ship is heading. Since both bearings and courses are directions, they are, therefore lines - imaginary lines that may be directed to any direction.

Most if not all modern ships engaged in international voyages are fitted with a gyrocompass which take its reference from true North or true geographic meridian. Hence, the course steered by the ship is the angle made by the ship's head with the true geographic north. This course is known as the ***true course***.

Another kind of compass which is still compulsory but often a neglected piece of equipment on board merchant ships today is the ***magnetic compass***. This compass uses the magnetic meridian as its reference. Unfortunately, the magnetic poles of the Earth did not coincide with the Earth's geographic poles. The North magnetic pole is approximately located in the vicinity of ***Lat. 78° N, Long. 105° W**** and the South magnetic pole is approximately located near ***Lat. 65° S, Long. 140° E****. Because of this non-coincidence, there will always be some angle between the true and magnetic meridians (except when the true and magnetic poles are in the same line wherein the true and magnetic meridians coincide).

This angle between the two meridians is known as ***variation*** and is named ***East*** when the magnetic North is to the right of true north, and ***West*** when magnetic North is to the left of true North. The angle that the ship's head makes with the magnetic meridian is known as the ***magnetic course***.

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*These coordinates are taken from a Mercator chart of the World which can be found in the school's library.

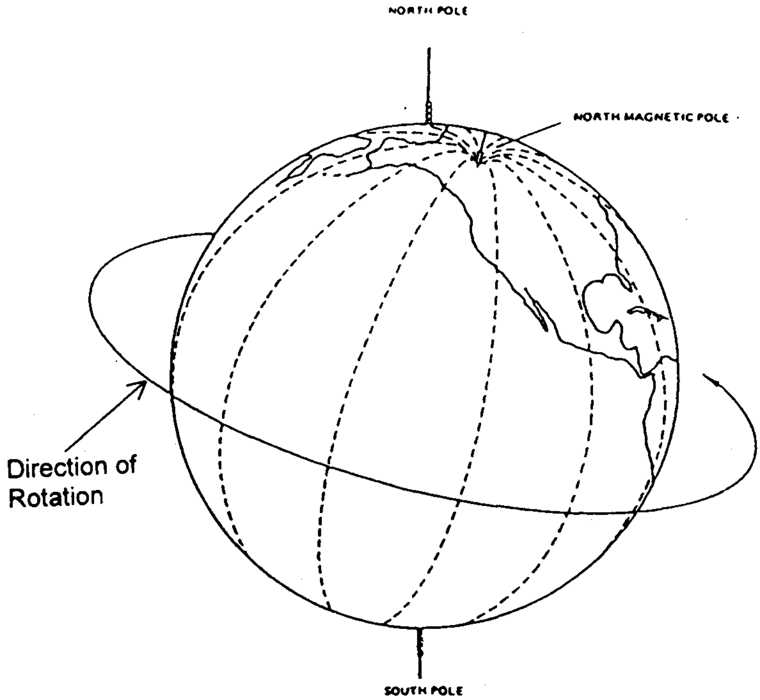


Figure 3.11 – The North Magnetic Pole

The magnetic poles are not permanent in their locations. Therefore, variation also undergoes constant changes in value due to changes in the location of the magnetic poles.

3.6 VARIATION

Variation is the horizontal angle which the magnetic needle makes with the true meridian. The magnetic needle aligns itself parallel to the Earth's magnetic lines of force, which force originates from the magnetic poles of the Earth.

The positions of the magnetic poles do not coincide with the geographic poles, the North magnetic pole, to which the north point of the needle is attracted, is situated in the islands of Northern Canada, and the South magnetic pole in Antarctica, below Tasmania.

The positions of magnetic poles are not fixed, but are constantly moving in unknown paths, apparently completing a revolution around the geographic poles in a period of hundreds of years.

The earth's magnetism is irregular and the magnetic poles are not 180° apart, unlike the geographical poles. Because of this, the lines of force do not flow directly from the South magnetic pole to the North magnetic pole but their direction is locally variable. These physical circumstances cause a magnetic needle in the Atlantic to be deflected in a varying degree to the left of the true meridian and thus produce westerly variations, while in the Pacific, the needle is deflected to the right of the true meridian and the variation is easterly.

Inasmuch as the magnetic poles are not diametrically opposed, the magnetic meridians are not perfect semi-great circles. Thus, it is not true to say that a compass needle will point to the magnetic north pole when under the influence of the earth's field alone *(Squair, 1971)*. That is when the compass needle is lying along the magnetic meridian it will not necessarily point to the magnetic north pole.

The ***magnetic meridian*** is thus defined as the direction a compass needle will take up when under the influence of the earth's magnetic field alone.

Therefore, the correct definition of ***variation*** should be "the angle between the magnetic meridian and the true meridian at any place".

The movement of the magnetic poles causes the variation to increase or decrease a few minutes yearly. This amount by which the variation changes yearly is called the ***secular change.***

In Figure 3.12, N and S represent the North and South geographic poles. Mn and Ms represent the North and South magnetic poles respectively. Angle Mn O N is the angle between the true and magnetic meridians at point O. This angle is called ***variation***. Notice that if the observer is situated at the meridian N Mn E S, the North geographic pole is in line with the North Magnetic Pole and therefore, there is zero variation. The same thing can be said of the value of variation on meridian N W Ms S.

Since the magnetic poles of the Earth do not coincide with the geographic poles, a compass needle which is aligned with the magnetic meridian will not indicate true direction. This is the reason why variation has different values at different location on the earth.

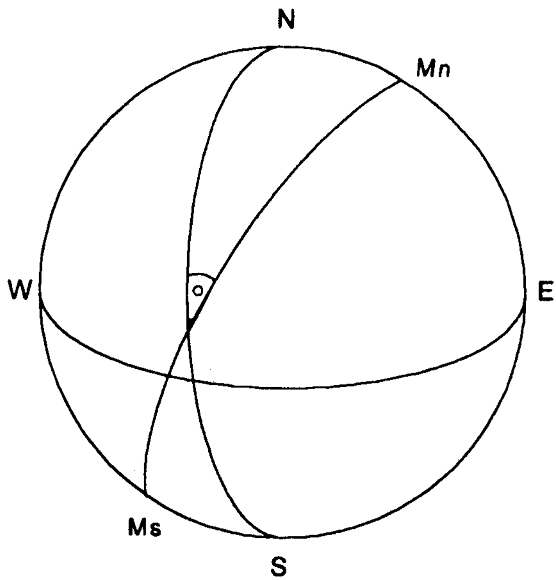


Figure 3.12 – Variation

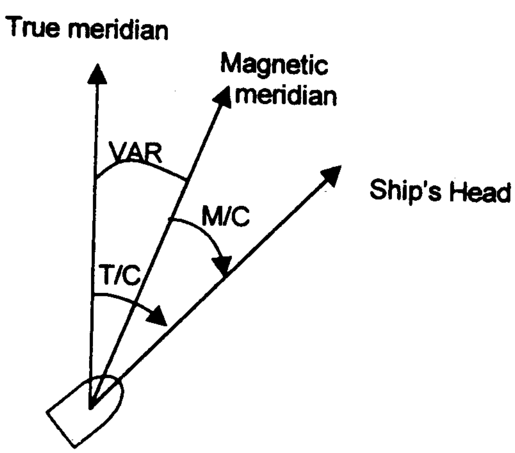
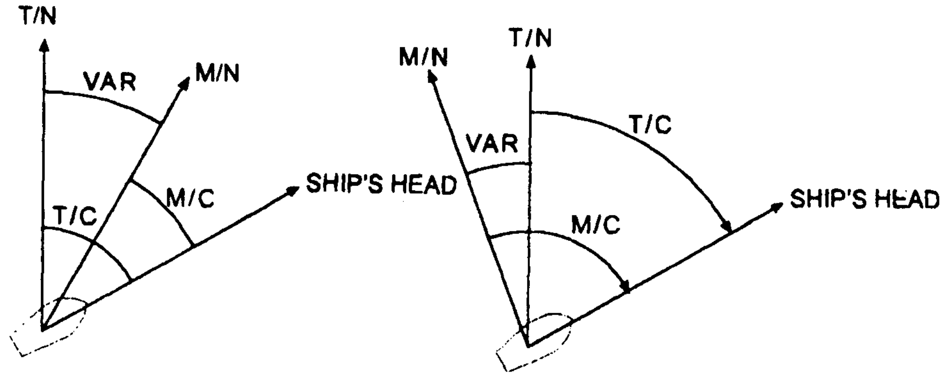


Figure 3.13 – True and Magnetic Courses



(a) VAR is named EAST (b) VAR is named WEST

Figure 3.14 – Naming the variation

From Figure 3.14(a), it can be seen that the name of variation is East, while variation on Fig. 3.14(b) is West. It can be seen further that to convert magnetic course to true, the variation is added when East and subtracted when West.

3.7 DEVIATION

When a magnetic compass is installed on board a ship, its compass needle is forced to turn horizontally and tends to align itself with the earth's magnetic field. In a steel ship, however, it is not free to do so because the steel structure which has magnetic properties of their own which tend to deflect or deviate the compass needle away from the magnetic meridian. This deflection between the north-south axis of the compass card and the magnetic meridian is called *deviation.*

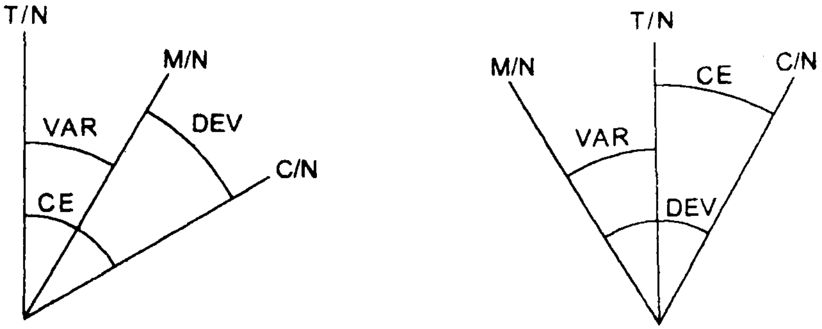
Deviation is caused not only by the magnetic properties of the steel ship but also from magnetic materials on board ship such as the ship's rigging, electrical wirings installed in the vicinity of the compass, and other magnetic materials around the immediate vicinity of the compass.

Deviation is named East when the compass needle is deflected to the right of the magnetic meridian and West if the deflection is to the left of the magnetic meridian. The course indicated by a magnetic compass which is influenced by both variation and deviation is known as the *compass course.*

Unlike variation which can be easily found by referring to the chart of the area where the ship is located, deviation is not so simple to ascertain. Deviation varies not only on different ships, but also on any particular ship it varies with changes in the ships heading. Also, it changes in value with large changes in the vessel's latitude as a result of change in the relative strengths of local disturbing influence.

The combined error (algebraic sum) of variation and deviation is known as the *compass error.*

To obtain the amount and name of the compass error refer to Figure 3.15.



CE = VAR + DEV

CE = DEV – VAR

(a)

(b)

Figure 3.15

It can be seen from the above diagram that the compass error is equal to the sum of variation and deviation when both have the same name and equal to their difference if variation and deviation have different names.

3.8 NAMING THE COMPASS ERROR

A rule can be established from Figures 3.15 (a) and (b):

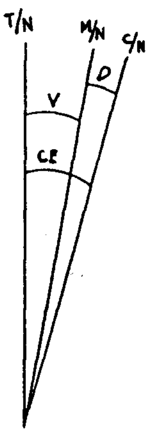
1. If variation and deviation is of the same name, add their values and affix to the result (CE) their common name.
2. If variation and deviation have different names, subtract the lesser from the greater value and affix to the result (CE) the name of the greater.

Thus, for example:

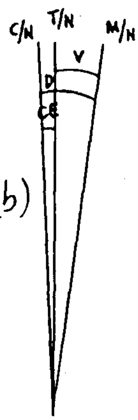
(a)	Deviation	= 5° E	(b)	Deviation	= 10° W
	Variation	= 10° E		Variation	= 7.5° E
	Compass Error	= 15° E		Compass Error	= 2.5° W

A plot of these two conditions can be made, thus:

(a)



(b)



CE = V + D

Compass Error is named East because the Compass North lies to the right of True North.

CE = D - V

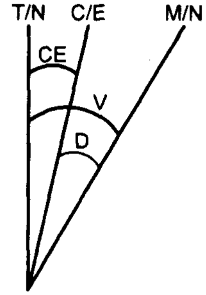
Compass Error is named West because the Compass North lies to the left of True North.

A case will arise when the deviation of the ship's compass is required. In this case, the compass error and variation must be known.

Examples

Given:

Compass error = 4° E; Variation = 15° E



D = V - CE

Find:

Deviation

Solution:

V = 15° E

CE = 4° E

D = 11° W

A simple reasoning may be employed in plotting the compass meridian and the magnetic meridian in relation to the true geographic meridian.

First, plot the true meridian (T). Next, plot the compass meridian (C) to the right of T because the compass error is East. Finally, plot the magnetic meridian to the right of T but farther to the right of the compass north because the variation is East and greater in value than the compass error.

Then, make your own equation based on the plot that you made, observing the rules for naming the errors.

> ***Note:*** **Problems similar to the above problem can be solved conveniently by this procedure.**

Given:

CE = 20° W; V = 15° W

Find:

D

Solution:

CE = 20° W

V = 15° W

D = 5° W

The student should be able to explain how the diagram was made and how the answer was arrived at.

There are instances where naming the compass error will arise. In this case, just compare the values of True and Compass bearing and use this popular "rule of the thumb":

"Compass Least, error East"
"Compass Best, error West"

This is a very good aid to memory as the word least rhymes with East and the word Best rhymes with West. Simply interpreted, this means that if the compass bearing of the object is lesser or (least) than the true bearing, the CE is East. On the other hand, if the compass bearing is greater (Best) than the true bearing, the CE is West. Then you might ask: Where are you going to get the true bearing of the object? Answer: From the chart.

The navigator must bear in mind that when using a compass on board ship, the direction that his ship his heading is called a ***compass course*** and must be corrected for compass error to obtain the true course.

So when compass courses are considered the following definitions must apply:

True Course (T/C) - the direction of the ship's head relative to the direction of the true north. It is the horizontal angle between the direction of true north and the ship's head.

Magnetic Course (M/C) - the horizontal angle between the direction of magnetic north and the direction of the ship's head.

Compass Course (C/C) - is the horizontal angle between the direction of compass north and the direction of the ship's head.

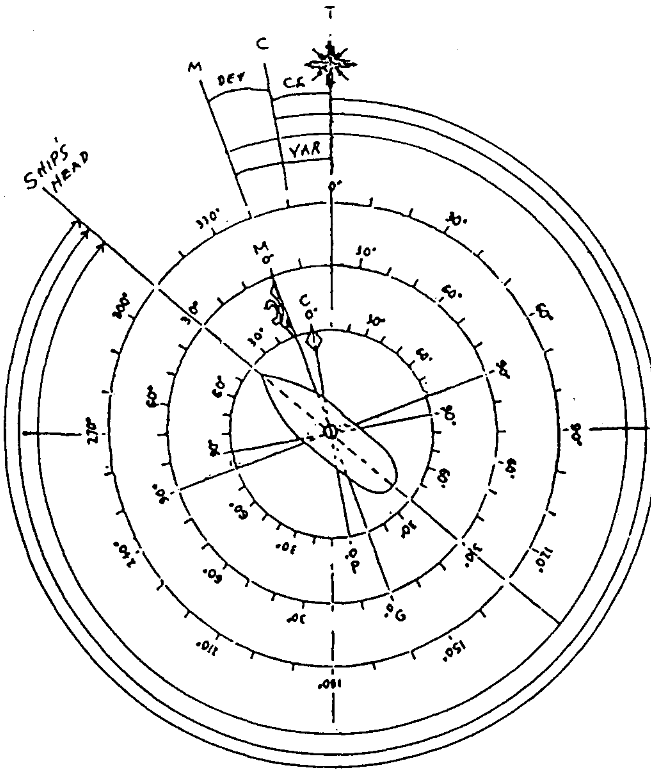


Figure 3.16 – The Three Courses

Examples

1. A vessel is on course 215° true in the area where the variation is 7° W. The deviation is 1.5° W. A lighthouse bears 306.5° by magnetic compass.

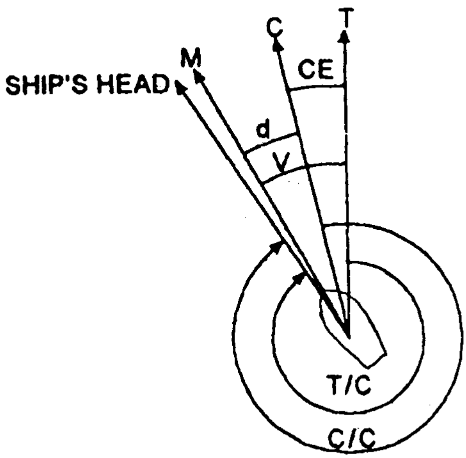
   Required:
   a. Magnetic course
   b. Compass course
   c. Compass error
   d. Magnetic bearing of the lighthouse
   e. True bearing of the lighthouse
   f. Relative bearing of the lighthouse

Solution:

	T/C = 215°		C/B = 306.5°
	V = 7°		D = 1.5°
a.	MC = 222°	d.	M/B = 305.0°
	D = 1.5°		V = 7.0°W
b.	C/C = 223.5°	e.	T/B = 298.0°
			T/C = 215°
	D = 1.5°W	f.	R/B = 083°
	V = 7.0°W		
c.	CE = 8.5°W		

From the diagram, it can be seen that the true course can be obtained by applying the errors variation, deviation and compass error to the ship's course.

2. The ship's heading by compass is 327°. The deviation of the compass is 4° E and the variation of the locality is 20° W. Find the ship's true course.



T/C = Ship's Course - CE
= 327° - (V - D)
= 327° - (20° - 4°)
= 327° - 16°
= 311°

3.9 VARIATION, DEVIATION AND COMPASS ERROR

Variation, ***deviation*** and ***compass error*** are always used in relation to the ship's direction of movement or the ship's course. Although these terms and their corresponding values are confined these days to ships which are not equipped with modern navigation equipment such as Gyro compass, Global Positioning Systems (GPS), Electronic Chart Display and Information System (ECDIS) and other convenient methods of navigating ships, the basic knowledge on how to obtain their values and how to apply them when needed cannot be disregarded. Even on board the most modern ships, the magnetic compass is still a requirement of the SOLAS Convention and therefore reference to its use is still required.

Furthermore, the magnetic compass still retains its title as the "old reliable" despite the invention of the gyrocompass. While the gyrocompass is an extremely efficient and reliable direction-finding instrument, it is dependent on electrical power supply and subject to failure or mechanical damage. The magnetic compass on the other hand is simple, entirely self-contained, not easily damaged and not subject to electrical failure. When electrical power fails, the gyrocompass fails but the magnetic compass prevails.

As a last reminder to the student, there is a tendency not only among young officers but also among the senior officers in the management level on board ships equipped with gyro systems and on board ships with GPS to forget or neglect their study of the magnetic compass. This may spell disaster during an emergency when the gyro fails or in a steel lifeboat where any compass is erratic. Every student must realize that a working knowledge of the magnetic compass has been and will always be the most important single element of the art of navigation.

CHAPTER TEST

A. **Finding true, magnetic and compass courses:**

1. Given:

a. M/C = 141°
V = 13° E

b. M/C = 203°
V = 5° W

c. M/C = 354°
V = 19° E

Find: T/C

2. Given:

a.	T/C	=	013°
	V	=	19° E
b.	T/C	=	074°
	V	=	12° E
c.	T/C	=	349°
	V	=	25° W

Find: M/C

3. Given:

a.	C/C	=	139°
	D	=	6° W
b.	C/C	=	244°
	D	=	3° E
c.	C/C	=	358°
	V	=	5° E

Find: M/C

4. Given:

a.	M/C	=	007°
	D	=	12° E
b.	M/C	=	049°
	D	=	4° W
c.	M/C	=	354°
	D	=	9° W

Find: C/C

5. A vessel steers a compass course of 147°. Variation is 3° E and deviation is 5° W. Find the corresponding magnetic and true courses.

6. A vessel is to steer a true course of 254°. Variation is 5° W and deviation is 3° E. Find the corresponding magnetic and compass courses.

7. The compass north is deflected 4° to the left of the true north. Variation is 4° E. Sketch the pertinent meridians and show the value of deviation and the corresponding true and magnetic courses of the vessel whose compass course is 002°.

8. Find the corresponding compass and magnetic bearings of an object whose true bearing is 208°. The compass course is 002°. The corresponding magnetic course is 358°. The total error is 5° W. Find the variation and the corresponding true course.

B. **Finding true, magnetic, compass and relative bearings:**

1. The compass bearing of an object is 018°. Variation = 5° E and deviation 7° E. Find the magnetic and true bearings of the object.

2. The compass bearing of an object is 037°. Variation = 5° W and deviation = 7° W. Find the magnetic and true bearings of the object.

3. The compass bearing of an object is 325°. Variation = 6° W and deviation = 10° E. Find the magnetic and true bearings of the object.

4. The true bearing of an object is 030°. Variation = 5° E and deviation = 7° E. Find the magnetic and compass bearings of the object.

5. The true bearing of an object is 25°. Variation = 5° W and deviation = 7° W. Find the magnetic and compass bearings of the object.

6. The true bearing of an object is 329°. Variation = 6° W and deviation = 10° E. Find the magnetic and compass bearings of the object.

7. An object bore SE x S per standard compass (psc). Variation = 2° E and deviation = 5° W. Find the corresponding magnetic and true bearings of the object.

8. The true bearing of an object is E x N. Variation = 3¼° E, Deviation = 2-1/2° E. Find the corresponding magnetic and compass bearings of the object.

9. The compass bearing of an object is N 89° W. Variation equals 3 ½° E. Sketch the pertinent meridian and show the values of the true bearing of the object, the deviation and the total error.

10. A ship steers a compass course of 049°. Variation = 3° E and deviation = 6° W. A lighthouse is sighted 2 points forward of starboard beam. Find the true bearing of the lighthouse.

11. A ship steered a course of 279° by steering compass with a beacon dead ahead. Variation = 2.6° E, deviation of the steering compass = 1° W. Find the true bearing of the beacon.

12. Steaming on course 270° per standard compass, the navigator of a ship observed another ship bearing dead astern. Find the relative bearing of the other ship.

13. A ship is on course 046° T. With this course, the navigator sighted a banca broad on his port quarter. If the variation of the locality is 5° E, find the magnetic bearing of the banca.

14. From a magnetic course of 146°, a ship turned 106° to starboard and found the tower at her starboard beam. If the variation of the locality is 0.2° W, find the true bearing of the tower.

15. Convert a relative bearing of 126° to true bearing if the true course is 100°.

16. The compass bearing of an object is 348°. Variation is 3 ½° E and deviation is 1 ½° W. Find the magnetic and true bearings of the object.

17. The compass bearing of an object is 213°. Variation is 4 ½° W and deviation is 2 ½° W. Find the magnetic and true bearings of the object.

18. The compass bearing of an object is 171°. Variation is 2 ½° W and deviation is 3 ½° W. Find the magnetic and true bearings of the object.

19. The true bearing of an object is 325°. Variation is 4° E and deviation is 5° E. Find the magnetic and compass bearings of the object.

20. The true bearing of an object is S 29° E. Variation is 3 ½° E and deviation is 4 ½° E. Find the magnetic and compass bearings of the object.

21. The compass bearing of an object is S 88° W. The corresponding magnetic bearing is N 88° W. Variation is 3° W. Find the deviation, the total error and the corresponding true bearing.

22. The magnetic bearing of an object is S 5° E. The corresponding true bearing is S 9° E. Deviation is 5° W. Find the variation, the total error and the corresponding compass bearing.

Chapter Four
POSITION AND POSITION LINES

At the end of this chapter, the student should be able to:

- define and plot terrestrial lines of position;
- identify the different methods of establishing position on the earth;
- calculate and plot dead reckoning and estimated positions; and
- plot positions on the chart.

4.1 A LINE OF POSITION (LOP)

A *line of position (LOP)* is simply a line drawn on a chart at any point of which the ship is situated. If a true bearing of the lighthouse is observed by a navigator on the ship and this bearing line is plotted on the chart passing through the lighthouse as in Figure 4.1 then the navigator can say, with certainty, that on that particular time his ship's position is somewhere along this line.

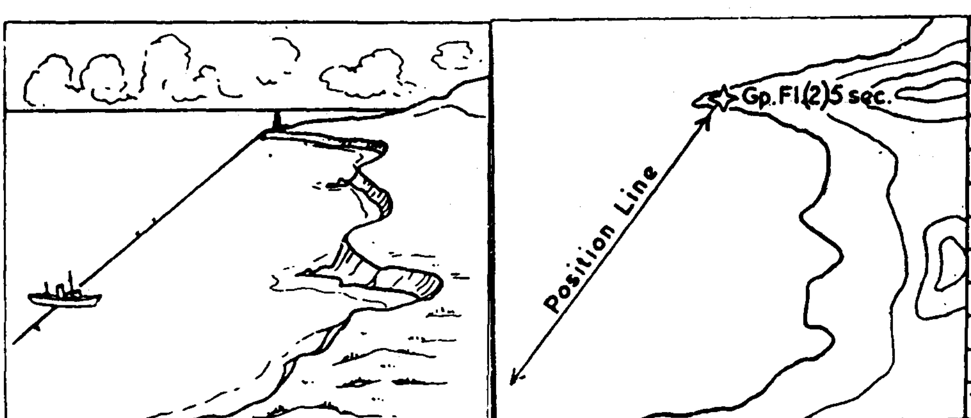


Figure 4.1 – LOP from a Bearing Line

Not all position lines from terrestrial objects are straight lines. If the distance of the ship from a charted shore object is known and a circle is drawn with the object as the center and the radius equal to the distance of the ship from the object, the ship is assumed to be situated somewhere along the circumference of this circle. Such a circle is known as the *circle of position (see Figure 4.2).*

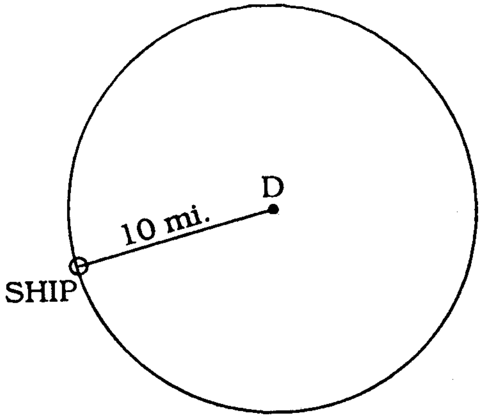


Figure 4.2 – Circle of Position

In Figure 4.2, the navigator found the distance of the lighthouse (D) to be ten miles. The ship must be somewhere on a circle of ten mile-radius, centered on the light. In most cases only a segment of the circle is drawn on the chart, the segment that cuts the second LOP.

Note: **Distance to the object may be obtained by radar, by range finder, and if the height of the object is known, by stadimeter or sextant.**

When two points such as a lighthouse and a charted buoy in Figure 4.3 are in line, these two points are said to be "in range". If a line is drawn to connect these two points and extending seaward to the ship, such a line is called a *range line* and provided that these two objects are charted then this line is also a line of position *(see* 4.9 *for details on labeling LOPs).*

Lines of position can be obtained from any of the following :

1. Bearing line (such as the one in Figure 4.1)
2. Range line
3. LOPs taken from celestial observations

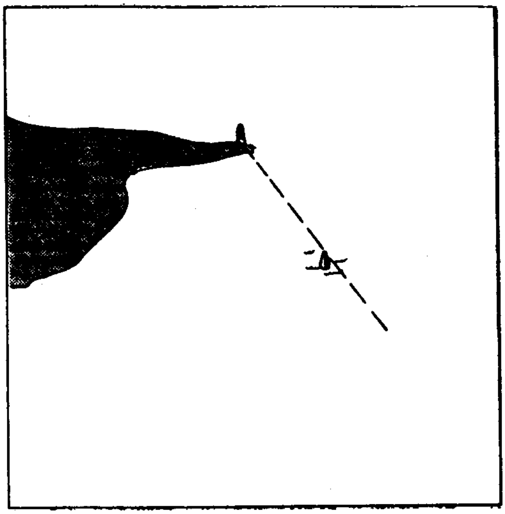


Figure 4.3 – Range line

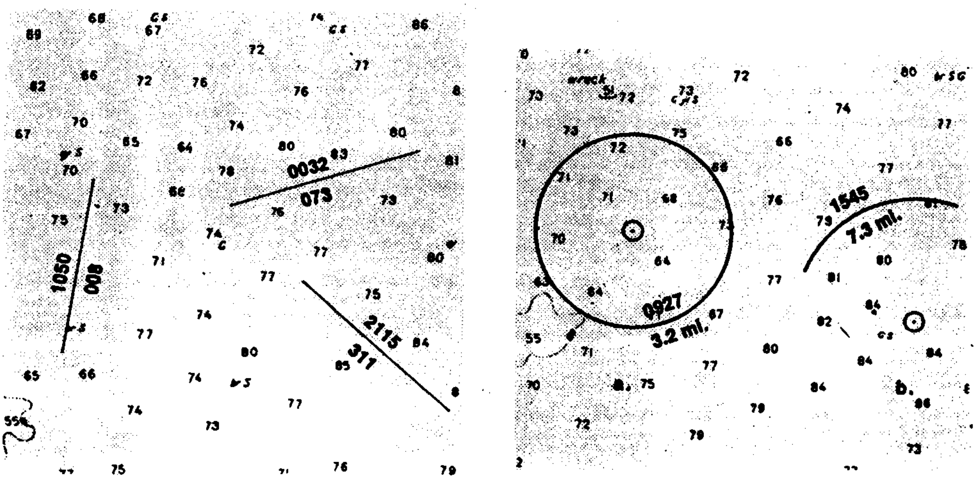


Figure 4.4 – Labeling a line of position

Circles of position are labeled in the same general manner as straight lines of position. The time is placed above the line and the distance below. The time may be "inside" or "outside" the circle as determined by the curvature of the arc.

Reminder on LOPs: LOPs are very valuable to a navigator, but it should be born in mind that they can be in error because of imperfections in plotting, human limitations, and errors to bearings not correctly applied.

4.2 A FIX

When two lines of positions intersect, the position of the ship is at the point of intersection.

In selecting objects to be observed for a line of position, fixed shore objects are to be preferred to floating objects, near objects to be preferred to distant ones and as far as possible the angle of cut is as near to 90° as possible.

Methods of Obtaining a Fix:

1. *By Cross Bearing.* This is the most common or perhaps the most reliable method of fixing a ship's position. Two simultaneous bearings of two suitably placed shore objects and obtaining two LOPs from them. This method is illustrated in Figure 4.5. The fix is at the point of intersection of the two LOPs.

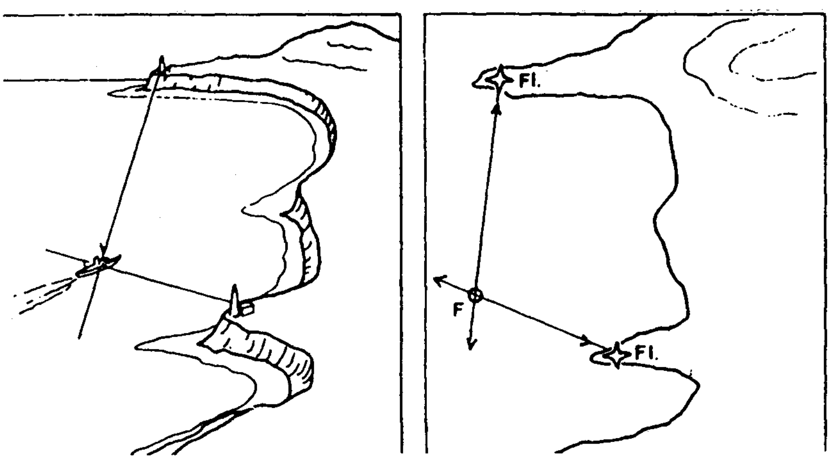


Figure 4.5 – Fix by cross bearing

Sometimes the navigator would wish to have another bearing of another shore object to serve as a check bearing. When three LOPs are drawn on a chart, they do not usually intersect at a common point (except perhaps for very experienced or very inexperienced navigator). The three LOPs usually form a small triangle which is known as a ***cocked hat***. In this case, the point of intersection of two LOPs that is nearest to danger should be considered to allow for a "margin of safety" *(see Figure 4.6)*.

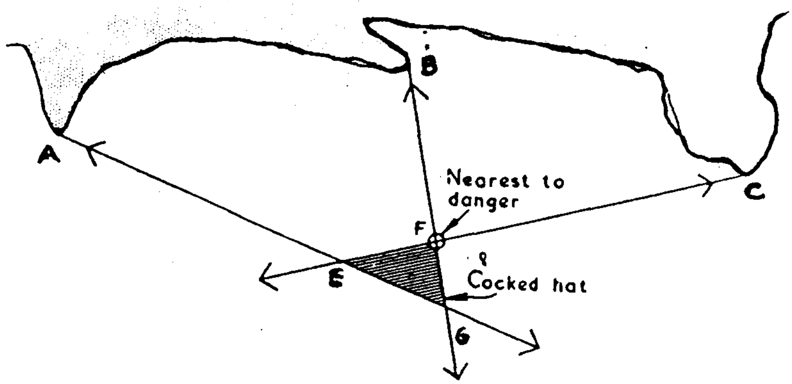


Figure 4.6 – The Cocked Hat
Note: Points E, F, G are possible positions of the ship.

If the three LOPs which are obtained from a bearing of the points A, B, and C are drawn on the chart, as shown in Figure 4.6, the ship's position would be reckoned as being at position F.

2. *By a bearing and a range*. A single range bearing crossed with any other bearing line establishes a fix.

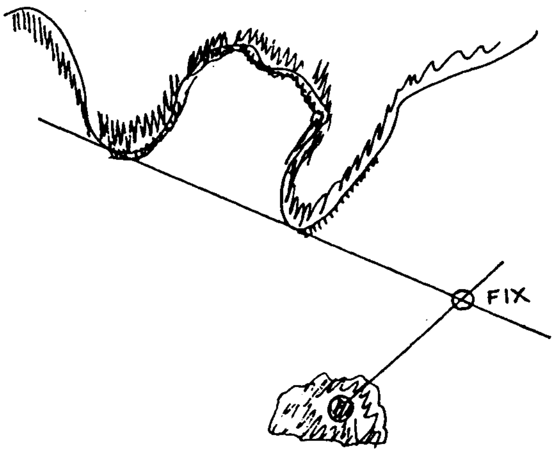


Figure 4.7 - Fix by a bearing and a range

3. *By two ranges.* Two ranges are seldom available even when navigating along the coast but if they do occur, they become an absolute means of obtaining a fix.

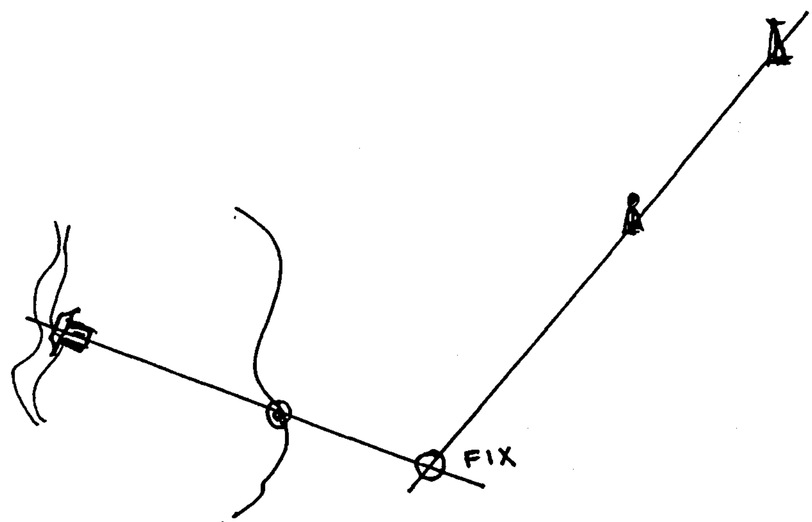


Figure 4.8 - Fix by two ranges

4. **By bearing and distance of the same object.** This method can be best explained by referring to Figure 4.9 and solving this problem:

   A ship is on Course 090° T, speed 10 knots. At 1227, a radar bearing of lighthouse A was taken to be 350° T, dist 7.5 miles. Plot and label the 1227 fix.

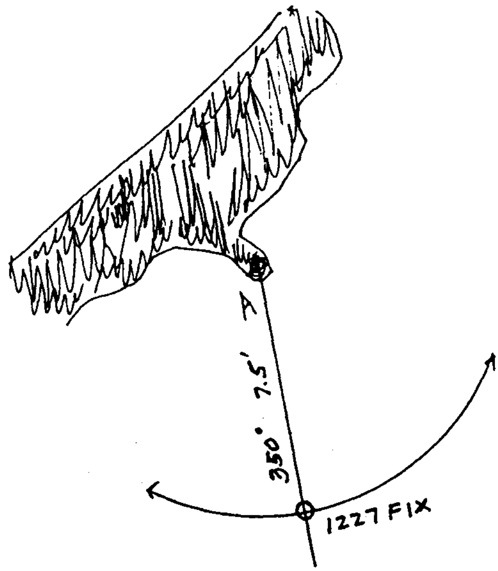


Figure 4.9 – A plot of bearing and distance of the same object

5. **By bearing and distance of different objects.** This method can be best explained by solving this problem.

   At 1425, a ship on Course 135° T, speed 10 knots sights a bearing of Tower A to bear 350° T. At the same time, the distance from a headland marked by another Tower B was taken by radar to be 5 miles. Plot and label the 1425 fix.

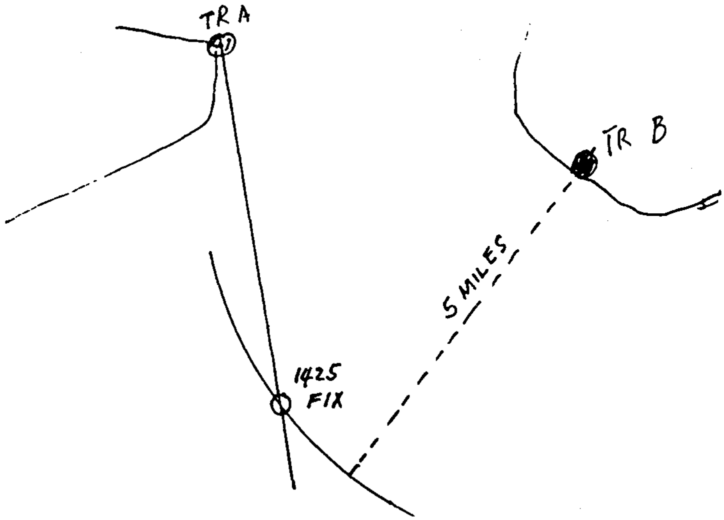


Figure 4.10 – A fix by bearing and distance of different objects

Solution: Plot the bearing of Tower A. With a compass-divider, describe a circle of position from Tower B with radius equal to distance from it. The 1425 Fix is the point of intersection of the LOP and the circle of position.

6. By a relative bearing and one angle. Figure 4.11 illustrates this case. Suppose a ship is heading 090° T with the lighthouse L abeam to starboard, at the same time the angle between the lighthouse and a church spire is 40°.

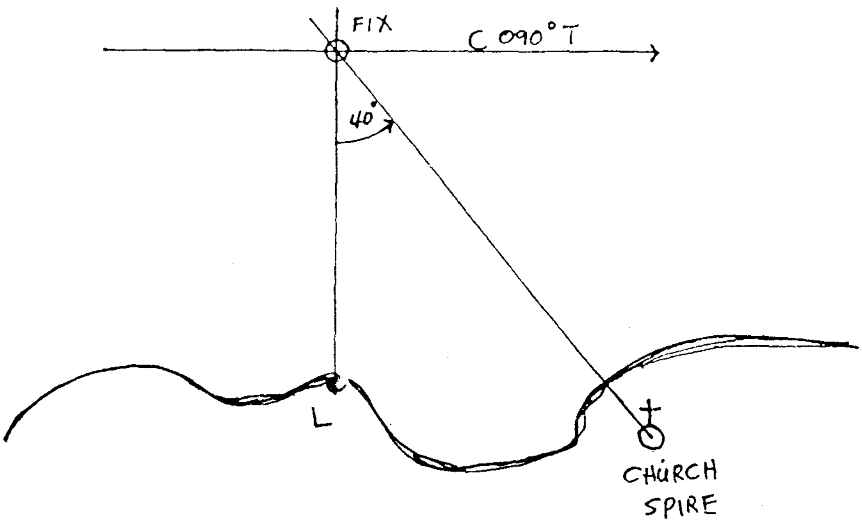


Figure 4.11 – Fix by relative bearing and one angle

Solution: First plot the relative bearing of the lighthouse. Then draw a line that cuts the first LOP at an angle of 40°. The fix is at the point of intersection of the two LOPs.

Other practical, common sense method of fixing a ship's position can be employed by the navigator as he gains experience in coastal navigation. For instance a sounding may assist in fixing a ship or the change in the color of a sector light from green to red may fix the ship's position at the dotted line on the chart which indicates the bearing of the lighthouse at the change of the color.

When taking bearings for the purpose of fixing a ships position, it is better, when choice is available, to start with objects whose bearing changes very little such as objects dead ahead or very fine on the bow. Then move on to another object near the stern or at the port or starboard quarter. And, if you desire to take a check bearing, take bearings of objects abeam or near abeam. In this method you avoid increasing the size of the "cocked hat" or avoid errors in laying off the LOPs which are caused by the movement of the ship due to the time that has elapsed between the first LOP and the subsequent LOPs.

Moreover it should be remembered that most reliable fixes are obtained from bearings of two near, widely spaced charted objects.

For good fixes the angle between two LOPs (which is known as the angle of cut) should be as near as possible to a right angle (90°) and should never be less than about 30°.

4.3 DEAD RECKONING

The process by which the ship is carried forward by courses and distances from the last fix is called ***dead reckoning***. When the navigator has no means of fixing his ship's position he resorts to calculating the distance run. Given the speed of his ship and the elapsed time from the last fix he then measures the distance run along the course line drawn from the last fix. The calculated position so found is called the ***dead reckoning position*** or the ***D.R.***

Plotting the D.R. starts from a known or well-determined position and is carried forward by plotting the courses steered and distances run through the water.

The point of departure is the point from which the course line is first drawn. The course to plot is the true course. The distance to plot is the distance run through the water.

The time to plot the D.R depends on the judgement of the navigator but it must be plotted –

1. whenever the course is changed; and
2. when a fix is obtained.

The difference between the old D.R. and the new fix is the error of the D.R. at the time of the fix.

A D.R. position may be in error because of:

1. Error in point of departure
2. Deviation errors
3. Bad steering
4. Errors in distance
5. Leeway
6. Current

Note: Leeway and current will be discussed extensively in Navigation 2.

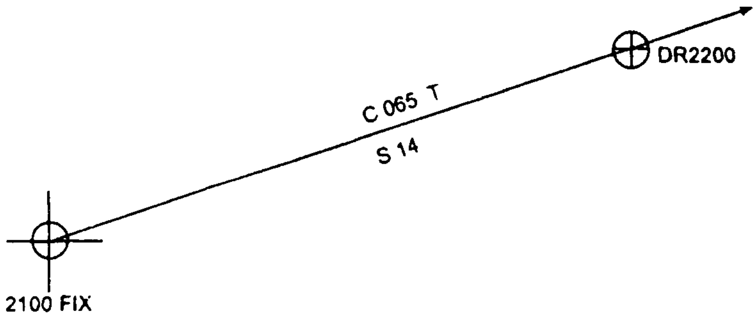


Figure 4.12 - Plotting a D. R.

In modern navigation, a D.R. position is one that has been worked up from the last position which was obtained from celestial or terrestrial objects and makes no allowance for current or leeway.

4.4 ESTIMATED POSITION (EP)

Estimated position is the best estimate of the ship's position after consideration is made of the effects of wind, current, leeway, bad steering, etc. In effect, it is the D.R. position modified by the best information available. Consider the illustration in Figure 4.13.

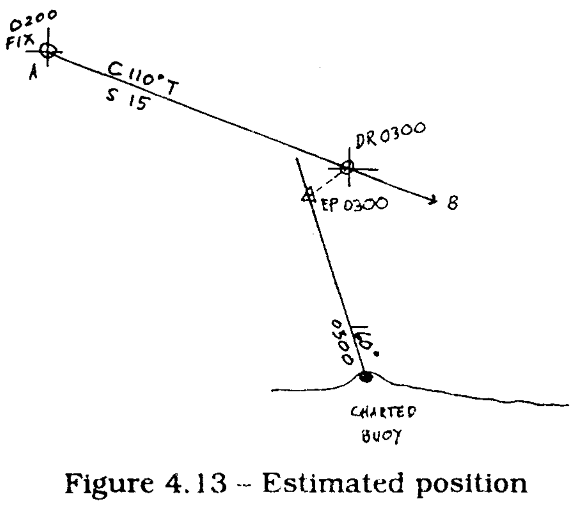


Figure 4.13 - Estimated position

In the figure, let A be the point of departure, direction of AB be the course steered. The DR position is calculated using DR speed and distance run from 0200 to 0300.

If at 0300 the navigator was able to obtain a single LOP from a charted buoy and he estimated the set and drift of current, tidal streams, weather condition, etc. to have drifted the ship towards the southwest, then the estimated position (EP) is plotted as per judgement of the navigator.

4.5 THE TRANSFERRED LOP

A ship cannot be fixed from a single LOP alone. The only information which can be derived from a single LOP, as we have explained earlier. is that the ship is situated somewhere along this line. So if only one terrestrial object is available in the area where the ship is navigating. a bearing of that object will give a single LOP. This LOP will be of little use to the navigator at the time of observation but because it can be transferred it can be of great value to the navigator.

How is a line of position transferred? Refer to the illustration in Figure 4.14.

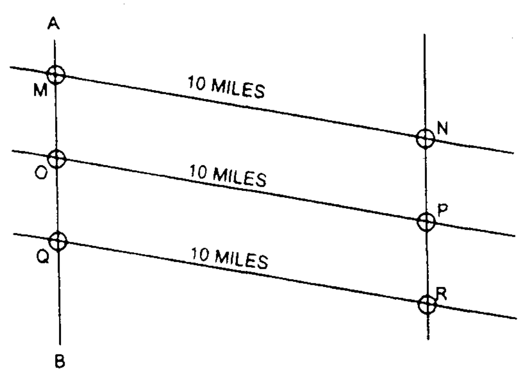


Figure 4.14 – Transferring a line of position

In the figure, suppose A is a charted object on shore and a bearing was taken of it. The LOP (AB) was plotted at the time of this observation. The ship may be assumed to lie at any point along this LOP. Now, suppose the ship sailed a distance of, let us say 10 miles, on a course of 135° T. If the ship is at position M when the bearing of the point A was taken, then after making this run, she would be at N. If, however, the ship was at O when the bearing was taken, she would be at P after making 10 miles. If the ship is at Q when the observation was made, she would be at R after making the run. It will be noticed that a straight line may be drawn through points N, P, and R, and the line is parallel to the first position line AB.

From the figure, it can also be said that regardless of where the ship may be assumed to be situated on the position line AB, a line drawn from this point in a direction 135° T for a distance representing 10 miles would terminate somewhere on the straight line on which N, R, and P are situated. This line is known as the ***transferred position line*** and the ship's position must lie on this line at the end of her run.

The transferred position line is labeled as shown in Figure 4.15. To plot the transferred LOP mark off from any point on the first LOP, a line representing the course and distance made from the time of observation to the time at which the transferred LOP is required. Through the end of this line draw a line parallel to the first LOP. This is the transferred LOP *(see Figure 4.15)*.

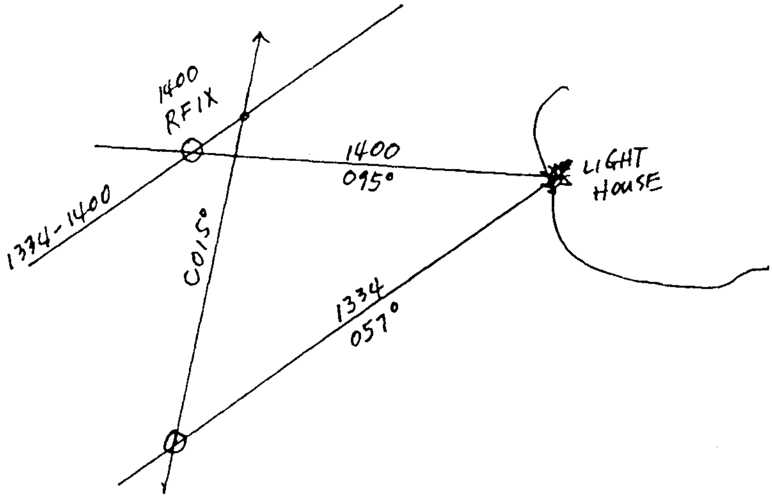


Figure 4.15 – The transferred LOP

It should be born in mind that the reliability of the transferred LOP depends upon two factors, the course and distance. If the actual distance sailed is shorter or longer than the plotted distance then the transferred LOP will be displaced by that amount.

A ship may make more than one course in the interval but so long as the courses are known with accuracy, and are laid off carefully, a transferred position line may be of great value. The following example will illustrate the use of a transferred position line.

Example
A navigator on a ship proceeding up a channel observed lighthouse E to bear 020° T at 0800. The ship was steaming at 10 knots on a course of 040° T. At 0830, the course was changed to 080° T. Plot the transferred position line at 0900.

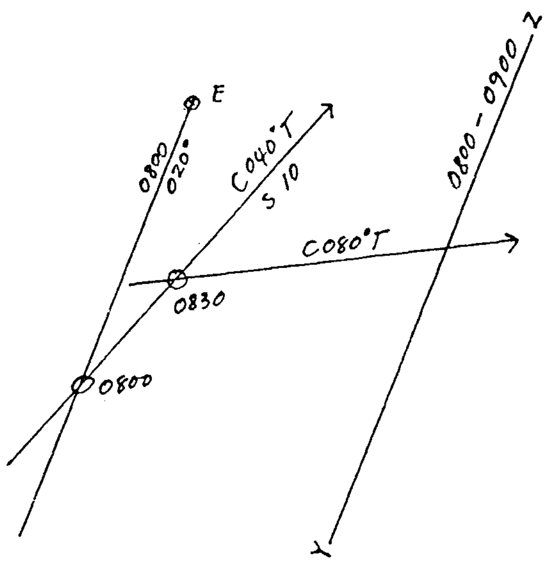


Figure 4.16 – The ship's position is somewhere on the line YZ at 0900
Note how the transferred position line was labeled.

4.6 TRANSFERRING A CIRCLE OF POSITION

Sometimes it is necessary to transfer a circle of position in order to obtain a running fix. Since it is impossible to transfer a curve, in the same manner that a straight line is transferred, the only solution to this kind of problem is to transfer the center of the circle, thereby transferring the whole circle.

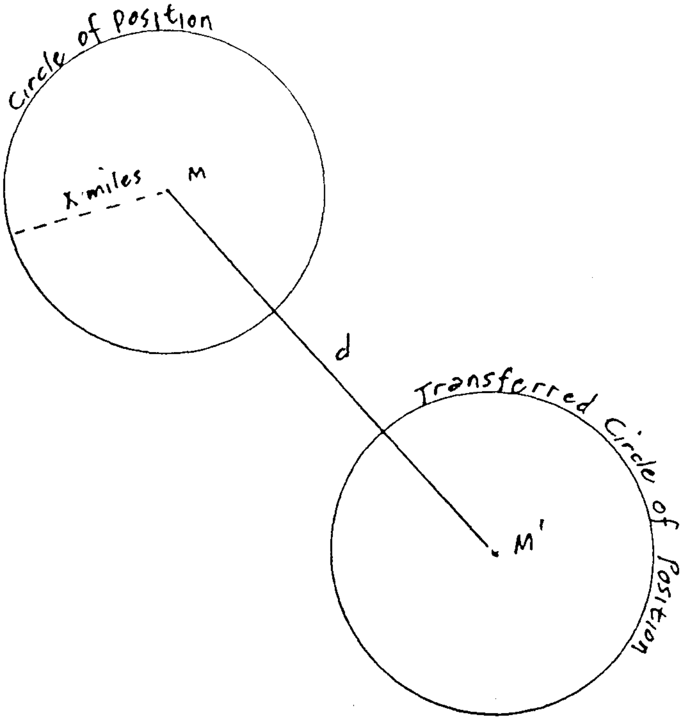


Figure 4.17 – Transferring a circle of position

In the figure above, suppose the navigator obtained the distance of x miles from point M. This would place the ship somewhere on the circumference of a circle of center M and radius X miles. If she then sails along her course for a distance of d miles, her position will then be on the circumference of the transferred circle, with the same radius and with center M'. The position of M' can be found by laying off the course and distance traveled from M.

Example
At 1345, the distance of a headland marked by a lighthouse M was taken at 6 miles. The ship's course is 100° T, speed 12 knots. At 1445, the light P bore 030° T.

Plot the running fix at the time of the second bearing.

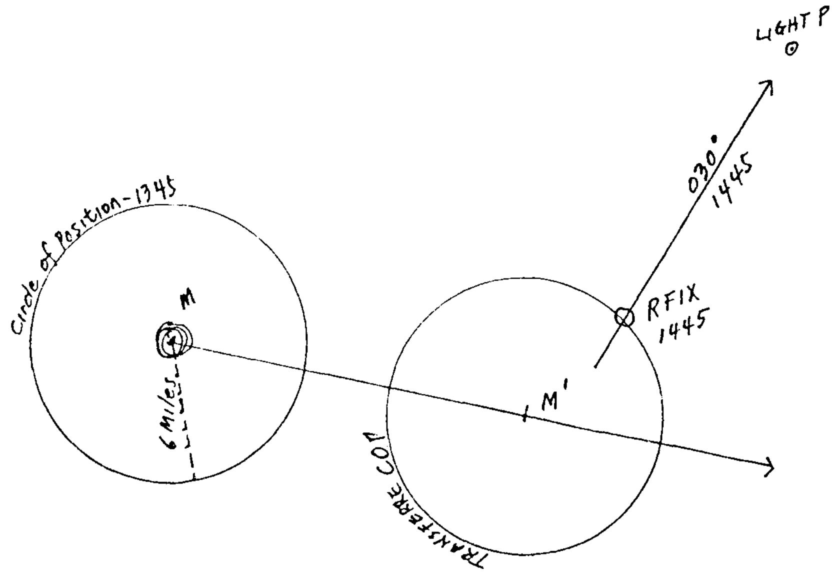


Figure 4.18 – Transferring a circle of position

4.7 THE RUNNING FIX

This method of fixing the ship's position can be used to advantage when it is impossible to obtain simultaneous position lines.

How To Do A Running Fix

The two LOPs are obtained at different times and the fix is made by transferring the first LOP to the time of taking the second LOP. The point of intersection of transferred LOP and the second LOP is the ship's RFix at the time of the second observation.

Example

At 0900, the lighthouse S bore 320° T and at 1000, it bore 015° T. Course 247° T and speed 12 knots. Plot the running fix at 1000.

Solution: Refer to Figure 4.19.

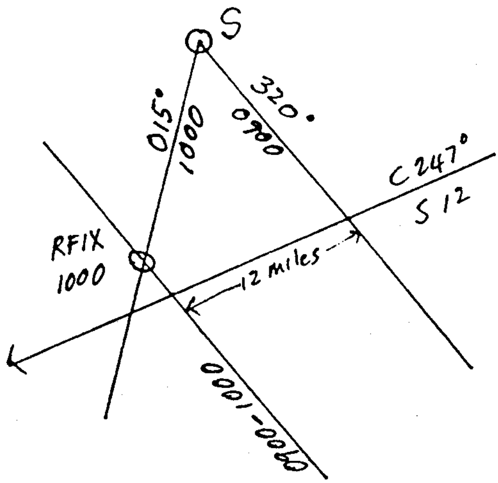


Figure 4.19 – A plot of a running fix

Procedure: Plot the first LOP at 0900. From any point along the first LOP, plot the ship's course and distance sailed (247° x 12 miles). Transfer the first LOP at the extremity of the distance measured.

Plot the second LOP at 1000. The intersection of the second LOP and the transferred LOP is the Running Fix.

To Find the Position of the Ship on the First Bearing

In the preceding example, it was shown how to find the ship's position at the time of taking the second bearing.

If it is desired to find the position of the ship at the time of taking the first bearing simply lay off the course made good in the reverse direction. Where this course line cuts the first LOP is the estimated ship's position at the first observation.

Experience has suggested that for a running fix to be reliable the maximum interval of time between fixes should be about 30 minutes.

Types of Running Fixes

There are several types of running fixes which are often referred to as *special cases.* The most extensively used methods are:

1. Doubling the angle on the bow
2. Four-point bearing
3. Distance run equals distance ship will pass off the object when abeam.

Let us illustrate the above methods and explain them.

1. *Doubling the angle on the bow.* This is simply a particular case of a running fix wherein relative bearings are used instead of compass bearings. If the relative bearing of a particular object is observed, the distance run between the time of observation and the time when the relative bearing is doubled is equal to the distance off the object at the time of the second observation, provided, of course, the vessel is not subjected to the effect of current and leeway.

   In Figure 4.20, let AB = distance run between 1st and 2nd observation. BC = distance off the object at the time of the 2nd observation. 2a = double the 1st bearing.

   $a + b + c = 180°$ **Equation (1)**

   but $b + 2a = 180°$

   $\therefore b = 180° - 2a$ **Equation (2)**

   Substituting value of b in Equation (2) in Equation (1), we have:

   $a + 180° - 2a + c = 180°$

   $a - 2a + c = 180° - 180°$

   $-a = -c$

   $\therefore a = c$

   $\therefore \Delta$ ABC is isosceles and AB = BC

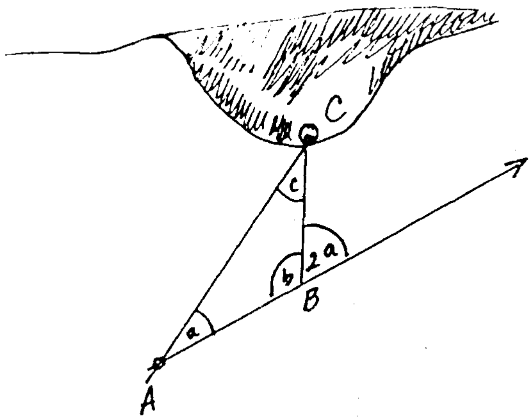


Figure 4.20 – Diagram illustrating doubling the angle on the bow

2. The Four point bearing. More popularly known as the *Bow and Beam Bearing*, this is a refinement of the running fix whereby the initial angle is four points from the bow or 45° and the second bearing is 90° on the bow or abeam. The distance run is equal to the distance off the object when abeam.

Example

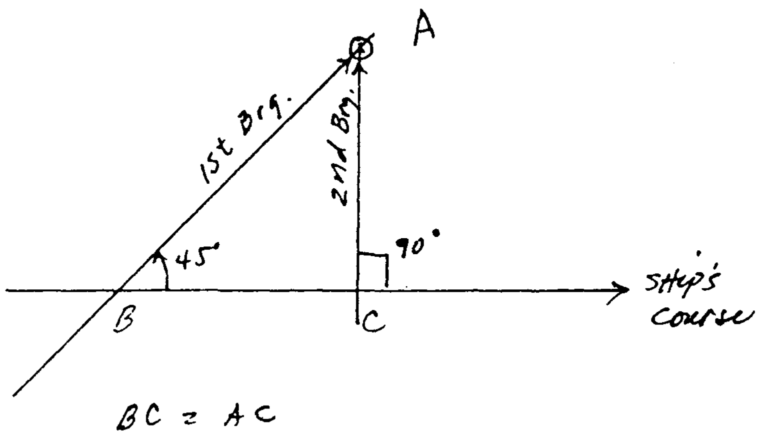


Figure 4.21 – The four-point bearing

3. **Distance Run is the distance ship will pass off the object when abeam.** This type is more of a refinement of the case of doubling the angle on the bow, which was explained on page 114. In this particular case it involves the distance run equals the distance of the object when abeam.

There are three cases in this type of a running fix:

1. ***First Case (The 22.5° - 45° Case).*** This case is more commonly known as the *7/10* or *.7 Rule*, whereby 0.7 of the distance run between 1st and 2nd bearing equals the distance of the object when abeam.
2. ***Second Case (The 30° - 60° Case).*** This case is commonly known as the *7/8 Rule*, in which the relative bearings are 30° and 60° on the bow. This is another case of doubling the angle on the bow wherein the distance run by the ship between the first and second bearing equals the distance of the ship from the object on second bearing. In this particular rule, 7/8 of the distance run between the 1st and 2nd bearing equals the distance the object will be passed abeam.
3. ***Third Case (The 26.5° - 45° Case.*** If the first bearing is 26.5° on the bow and the second is 45°, then you go back to the case of the Bow and Beam Bearing. This is also true in other combination of angles whose natural cotangents differ by unity, that is, the difference between their natural cotangents equals 1 or nearly 1.

   For example, take the natural cotangent of 26.5° = 2.00. Then, take the natural cotangent of 45° = 1.00. The difference in their natural cotangent equals 1 or unity. How do we prove this relationship? Refer to Figure 4.22 for the answer.

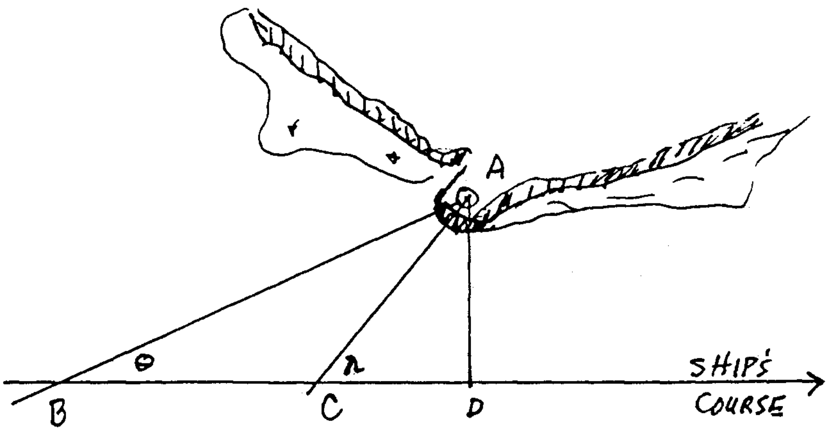


Figure 4.22 – The Third Case

In the figure, let A be the charted object on shore and the direction of line BA and CA are the first and second bearings, respectively. BD is the ship's course and DA is the beam bearing.

It is given that BC = DA, distance run between 1st and 2nd bearing equals distance off the object when abeam. Let first angle on the bow equals θ and the second angle equals λ.

So, BC = DA (given)

In Δ BDA, $\frac{BC + CD}{DA} = \cot \theta$

In Δ CDA, $\frac{CD}{DA} = \cot \lambda$

$\therefore \frac{BC + CD}{DA} - \frac{CD}{DA} = \cot \theta - \cot \lambda$

Simplifying the left side of the equation, we have:

$\frac{BC}{DA} = \cot \theta - \cot \lambda$

But BC = DA

Therefore, $1 = \cot \theta - \cot \lambda$

Hence, in order that the distance run between the first and second bearings will be equal to the distance off the object when abeam, the difference between the natural cotangents of the first and second angles on the bow must be 1 or very nearly 1.

If you consult the table of natural trigonometric functions in the navigation tables, you will run into many pairs of angles whose natural cotangents will differ by 1. For example, the angles 37° and 71° 53' (or nearly 72°) whose cotangents are 1.327 and 0.327 respectively, comply with this requirement. Your scientific pocket calculator can also help you find these pair of angles very conveniently. For example, you want to find the pair of 22° (first bearing). Your calculator will tell you that the natural cotangent of 22° is 2.475. And since this value must differ with the natural cotangent of its pair angle, you must look for this angle whose natural cotangent approximates 1.475 (2.475 - 1 = 1.475). Turning to your calculator, you will find that this natural cotangent belongs to 34.1° or 34° 08'. Therefore, your pair angles are 22° and 34°. That is, your first bearing is 22° and your second bearing is 34°.

The procedure in this case is to decide, what angle on the bow will be most convenient for the first bearing and make adjustments for the second bearing.

CHAPTER TEST

The following multiple-choice questions were given in the licensure examination for Third Mates during the past years.

A. **Multiple choice questions:**

1. A line of all possible positions of your ship at any given time is a _________:
   a. longitude line
   b. latitude line
   c. line of position
   d. fix

2. A line of position is ________:
   a) a line connecting two charted objects
   b) a line on some point of which the vessel may be presumed to be located
   c) the position of your vessel
   d) not used in a running fix

3. A line of position may be a(n) ________:
   a. irregular line
   b. straight line
   c. arc
   d. any of the above

4. A line of position formed by sighting two charted objects in line is called a(n) ________:
   a. relative bearing
   b. range line
   c. track line
   d. estimated position

5. A true bearing of a charted object, when plotted on a chart, will establish a ________:
   a. fix
   b. line of position
   c. relative bearing
   d. range

6. A position that is obtained by using two or more intersecting lines of position taken at nearly the same time is ________:
   a. a dead reckoning position
   b. an estimated position
   c. fix
   d. running fix

7. A ship's position should be plotted using bearings of ________:
   a. fixed object on shore
   b. buoys at a distance
   c. buoys nearby
   d. all of the above

8. You plot a fix using three LOPs and find that they form a cocked hat. To be on the side of safety you should plot the position of the ship ________:
   a. outside of the triangle
   b. anywhere inside the triangle
   c. on the intersection of two LOPs that is nearest to danger
   d. in the geometric center of the triangle

9. What describes an accurate position that is not based on any prior position?
   a. dead-reckoning position
   b. estimated position
   c. fix
   d. running fix

10. A position obtained by crossing lines of position taken at different times and advanced to a common time is ________:
    a. a dead reckoning position
    b. a running fix
    c. an estimated position
    d. fix

11. In calculating a running fix position, what is the minimum number of fixed objects that are needed to take your LOPs from?
    a. One
    b. Two
    c. Three
    d. None

12. You are navigating in coastal waters using running fixes. The maximum time between fixes should be about ________:
    a. 4 hours
    b. 1 hour
    c. 30 minutes
    d. 5 minutes

13. You are navigating parallel to the coast and plotting running fixes using bearing of the same object. You are making more speed than what is plotted for the running fix. In relation to the position indicated by the Running Fix, you will be ________:

a. closer to the coast
b. farther from the coast
c. on the course line ahead of the Rfix
d. on the course line behind the Rfix

14. A dead reckoning (DR) plot _________:
a. must use magnetic courses
b. must take the set and drift into account
c. should be replotted hourly
d. should be strated each time the vessel's position is fixed

15. A dead reckoning plot (DR) plot _________:
a. ignores the effect of surface currents
b. is most useful when in sight of land
c. must be plotted using magnetic courses
d. may be started at an assumed position

16. A position obtained by applying only your vessel's course and speed to a known position is a _________:
a. fix
b. running fix
c. dead reckoning position
d. probable position

17. Whenever possible, a DR plot should always be started from where?
a. Any position
b. A known position
c. An assumed position
d. None of the above

18. You should plot a dead reckoning position after every _________:
a. course change
b. speed change
c. fix or running fix
d. all of the above

19. You should plot your dead reckoning position _________:
a) from every estimated position
b) from every fix
c) every three minutes in pilotage waters
d) only in areas where the ship is close to islands and dangers

20. A position that is obtained by applying estimated current and wind to your ship's course and speed is ________:
    a. a dead reckoning position
    b. estimated position
    c. fix
    d. none of the above

21. A single LOP combined with a DR position results in ________:
    a. an assumed position
    b. estimated position
    c. fix
    d. running fix

22. Which position includes the effects of wind and current?
    a. DR position
    b. Fix position
    c. Estimated position
    d. Assumed position

23 You determine your ship's position by taking a range and bearing of a buoy. Your position will be plotted as ________:
    a. fix
    b. running fix
    c. estimated position
    d. DR position

B. Essay:

1. Describe a line of position.
2. Why is it advisable when fixing by cross bearings to take a check bearing?
3. Discuss the "cocked hat".
4. What is an "angle of cut"? What is the most preferred angle of cut if charted objects are available?
5. What is a relative bearing?
6. What is a range bearing?
7. Describe how a ship is fixed by a bearing and a range.
8. Explain how a position line is transferred.
9. What are the advantages and disadvantages of a "running fix"?
10. Explain the principle of "doubling the angle on the bow".

4.8 GUIDELINE ON PLOTTING POSITIONS ON THE CHART

Plotting is an important part of every navigator's work which he must learn to do accurately, rapidly, so that the work presents a clear picture to himself and to the master.

Also, remember that a chart is a very important part of the ship's equipment. It should be treated with the utmost care at all times.

Before you start plotting positions on the chart, it is well to observe the following guidelines on plotting:

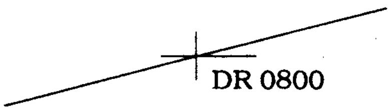
1. Neatness in plotting is a first necessity for accuracy and clear reasoning. Lack of ability to plot neatly is a serious handicap.
2. Pencils of proper grade that are kept sharp are important. Use pencils that will make a fine sharp line that will not cut the chart or plotting sheets so that lines cannot be completely erased.
3. Use erasing shield and art gums that permit erasing lines, words or figures without making damage to the chart.
4. Points may be accurately marked by drawing a small circle around it such as a fix.
5. Before drawing a line, consider where it should begin and end. Do not draw too many lines. They are confusing.
6. Make permanent corrections to paper charts in ink so that they will not be inadvertently erased.
7. Lay out and label course tracks on charts of frequently traveled ports in ink.
8. All courses should be checked and re-checked.
9. Never clutter up the path of the track ahead of your ship's position.
10. Do not obscure sounding data or other information when labeling a chart. Many groundings and strandings have occurred because rocks were erased or covered by ink in the chart.
11. Ascertain the position of the ship as soon as possible after transferring from another chart.
12. Never have more than one chart in use on the chart table at a time because you run the risk of using the scales of another chart which is not the one you are using.
13. When a voyage is completed, carefully erase the lines and labels on the chart unless there has been a grounding or collision. In this case, preserve the charts without change in the plotted fixes and lines because they will play a critical role in the investigation.
14. When not in use, stow charts flat in their proper portfolio.

4.9 LABELS ON THE CHART.

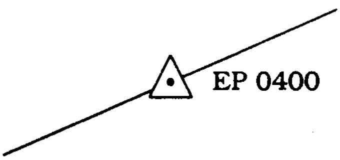
Methods of labeling courses, speeds and positions on the chart vary from one system to another and from one textbook to another textbook. Whatever method is used the most important point is that the labeling must be clearly understood by everybody participating in the navigation of the ship.

The internationally accepted system of labeling on the chart are as follows:

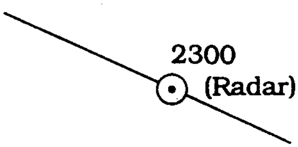
Lines and Labels — *Meaning*



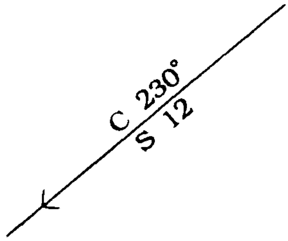
Dead Reckoning Position with time



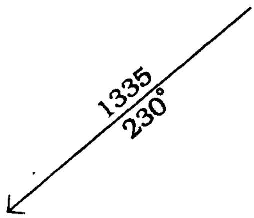
Estimated position with time



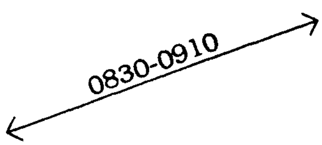
Fix and Method Used



Course line and speed in knots



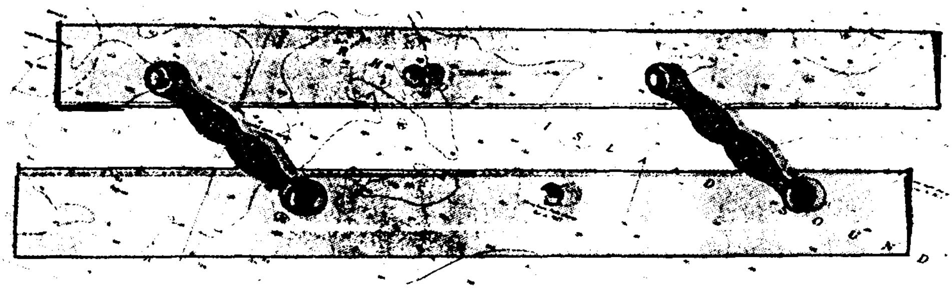
Single LOP with time and bearing



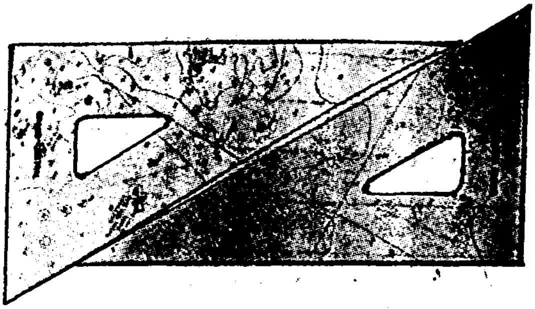
Transferred LOP

Important: It is good practice to plot only a short part of a line of position in the vicinity of the vessel to avoid unnecessary confusion and to reduce the chart work by erasure. Particularly the navigator should avoid drawing lines through the chart symbol indicating the landmark or aid to navigation.

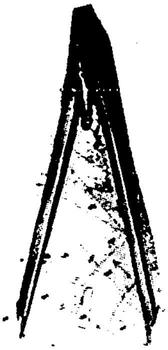
Instruments used for plotting:
1. Dividers and compasses
2. Parallel rulers
3. Drawing triangles
4. Protractors
5. Straight edge of about 18 inches

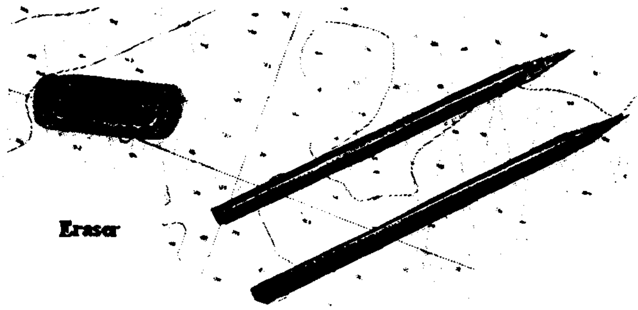


Parallel Ruler



Pair of Triangles





Compass-divider

Pencils

Figure 4.23 – Instruments in plotting

Chapter Five
THE DECK LOG BOOK

At the end of this chapter, the student should be able to:
- know the purpose and the use of the logbook;
- complete the data required in the logbook; and
- make correct entries in the logbook.

5.1 MEANING AND PURPOSE OF THE LOG BOOK

On board merchant ships the expression "to log" means "to record". This expression should not be mistaken for the other meanings of the word, such as *log* which means a whole length of a trunk of a felled tree; or *log* which is an instrument to measure speed or distance traveled by a ship, as a *patent log* or *taffrail log*; and such other expressions as "log a mile" or pieces of logs (wood).

A ***log book*** is a book in which is kept a written record of the movements of a ship with regard to courses, speeds, positions, and other information of interest to navigators and of important events that happen on board the ship. The deck log as the logbook is sometimes called, contains a description of every important occurrence concerning the ship's crew and the operation and safety of the ship.

The real purpose of a merchant ship's deck log is to serve as an official record of the ship's history during her lifetime. It presents a complete narrative of noteworthy incidents that took place in the life of the ship. Everything of significance that pertains to the ship's complement, operations or state of readiness or unreadiness of the main propulsion machinery or ability of the ship to accept cargo, is entered in the logbook. It is a detailed source of factual data.

Deck officers responsible for the maintenance of the logbook must appreciate the importance of this undertaking. They must ensure that all entries are complete, accurate, clear, concise and expressed in plain and simple merchant marine phraseology. Altogether, the entries in the logbook should constitute true and understandable historical and legal record of the ship.

A ship's logbook is a legal document. For it to assume a legal status it must be registered in the country whose flag the ship is flying. In the Philippines, a Philippine-registered ship's logbook is registered by the Maritime Industry Authority.

The deck log, the bell book, the engineer's bell book are legal records and can be used as evidence before legal authorities. Consequently, it is important that the remarks be complete and accurate. Erasures in any of these records would bring their validity as evidence into question. The officer-in-charge of the watch must initial every corrections made in the log. See a sample of log entries in the page of a logbook on pages 20 and 21 of the Workbook and note how corrections are made. Also, see a sample of a cover and a page of a ship's bell book on pages 18 and 19 of the Workbook which are filled up in consonance with the notations made in the sample of log entries. Note the various bells given to the engine room.

The logbook is often consulted in the settlement of disputes between shipowners and charterers and between charterers and shippers. A complete entry therefore must be made in the logbook concerning details of loading and unloading of cargoes including the state of weather prevailing during cargo operations. It is also consulted when a member of a ship's crew or passenger suffered injuries or even died while on board. A complete entry must also be made on every injury, accident and casualty including first aid and medical attention rendered, if any.

All entries must be handwritten and since it is handwritten, particular care must be taken in the recording of numbers, especially notation of time. The remarks must be legible and signed by the officer-in-charge of the watch with his signature over his printed name.

5.2 DESCRIPTION OF THE LOG BOOK

In almost all merchant ships, the deck log consists of two parts. The first part, the "tabular data" section, contains information concerning time of entry, courses (gyro and standard compass), weather and meteorological information, and the ship's departure and arrival drafts, contents of fresh water tanks, water ballast and bilge soundings, etc. The second part consists of the "Remarks" section which is to be filled up by the officers-on-watch regarding changes of courses and all other noteworthy events that occurred during the watch.

The format and manner of keeping the log may vary with each shipping company or with each ship but its status as an official record of the day-to-day events will not change, nor the responsibility of the deck officer for maintaining a proper and complete log.

5.3 DATA REQUIRED TO BE ENTERED IN THE LOGBOOK

When the ship is at sea, the entries in the deck log must give a complete account of the events for each day from 0000 to 2400.

In the Workbook you will find in pages 20-33 typical daily pages of a merchant ship's logbook. A quick examination of the data printed will show that the logbook is intended for a ship engaged in the overseas trade. The columns or lines are numbered so the student will know what entries to be made and where.

So, let's start filling the daily page *(see pages 22-33 of the Workbook).*

Line (1)	-	Name of ship. The abbreviations M/V usually means "motor vessel".
Line (2)	-	Name of the port where the ship is presently berthed or docked/name of the port where he is coming from.
Line (3)	-	Name of the port where the ship is going.
Line (4)	-	The number of the particular voyage the ship is making. For ships making liner services (meaning from Port A to Port B and back to Port A) a voyage is numbered every turn-around or for every "round trip." But for ships engaged in tramping, usually a voyage is numbered from the first port of loading to the first port of discharge. For example, if a ship partly loads her cargo at Antwerp, Belgium and loads the balance of her cargo at Le Have, France and discharges her cargo at Durban in the east coast of Africa, then the period of time spent from Antwerp to Durban is defined as one voyage. A ship can make as many voyages in her lifetime.
Line (5)	-	Day, month and year.
Line (6)	-	The zone description of the ship's position at the time of entry.
Column (7)	-	Hour of the day (in the 24-hour system.)
Column (8)	-	Distance sailed in nautical miles.

Column (9) - True courses steered by the ship at the time of observation. Any changes in the true course made between the hour is noted in the "Remarks" section.

Column (10) - This is the Gyro Compass Error noted at the time of observation.

Column (11) - This is the standard magnetic compass error.

Column (12) - Barometer reading in millibars.

Column (13) - Reading of the wet-bulb thermometer at the time of observation.

Column (14) - Reading of the dry-bulb thermometer at the time of observation.

Column (15) - Type of clouds prevailing at the time of observation.

Column (16) - Part of sky covered by clouds at the time of observation.

Column (17) - Relative Humidity in percent. *(Your instructor in Meteorology should teach you how to compute for relative humidity)*

Column (18) - True (not apparent) direction of the wind at the time of observation, i.e., SW, S or NE, etc.

Column (19) - Force of the Wind in the Beaufort Scale.

Column (20) - Direction of the waves, i.e., the direction from where the waves are coming.

Column (21) - Description of the sea means whether the sea is smooth, rough, etc.

Column (22) - State of weather may be fine, stormy, etc. *(Consult your notes in meteorology)*

Column (23) - Visibility may be noted as poor, good, etc.

Line (24) - Observed latitude at noon (local zone time, LZT).

Line (25) - Observed longitude at noon. (LZT)

Line (26) - Distance run from noon to noon.

Line (27) - Total time from noon to noon.

Line (28) - This is computed by dividing Distance run (line 26) with Total time (line 27).

Line (29) - Total distance run from the point of departure to noon.

Line (30) - Total time from the point of departure to noon.

Line (31) - Distance to go to the point of arrival. (When the ship is under charter, the total distance from the point of departure to the point of arrival is usually measured from pilot to pilot, i.e., from the time the pilot is disembarked at the point of departure up to the time the pilot is embarked at the pilot station at the point of arrival.)

Line (32) - Estimated time of arrival at the point of destination. The time must be local zone time of the port of destination.

Line (33) - This is the distance determined by the revolution per minute (RPM) of the main propulsion machinery.

Line (34) - This is the speed by engine RPM.

Line (35) - This is the total RPM recorded every hour divided by 24-hours.

Line (36) - Difference between the actual distance made by the ship and the distance made by engine revolution, determined from noon to noon. Slip may be positive or negative.

Line (37) - Quantity of marine diesel oil in long tons received by the engineers during last bunkering (refueling).

Line (38) - Quantity of heavy fuel oil (fuel actually used by the main engine) in long tons received by the engineer during last bunkering.

Line (39) - This is the total quantity of marine diesel oil consumed since the ship left the port of departure.

Line (40) - This is the total quantity (in long tons) of heavy fuel consumed since the ship left the port of departure.

Line (41) - This is the total quantity (in long tons) of marine diesel oil remaining on board at noon of the day reported.

Line (42) - This is the total quantity (in long tons) of heavy fuel remaining on board at noon of the day reported.

Line (43) - This is the total quantity (in long tons) of fresh water (drinking water) received in the port of departure.

Line (44) - This is the total quantity (in long tons) of feed water (water being used for steam boilers) received at the port of departure.

Line (45) - This is the quantity (in long tons) of fresh water consumed from noon to noon.

Line (46) - This is the quantity (in long tons) of feed water consumed from noon to noon.

Line (47) - This is the total quantity (in long tons) of fresh water remaining on board at the time of the report.

Line (48) - This is the total quantity (in long tons) of feed water remaining on board at the time of the report.

Line (49, 50 & 51) - These are the forward, aft and mean drafts taken at the port of departure.

Line (52) - This is the water density at the port of departure when the drafts were taken.

Line (53, 54 & 55) - These are the drafts taken when the ship arrived at the port of arrival.

Line (56) - Water density when the arrival drafts were taken.

Line (57) - When the ship is underway, the regulation lights are the running (or navigation) lights. If the ship is at anchor, the regulation lights are the anchor lights.

Line (58 & 59)- These are the local times when the lights were switched "on" and "off".

Column (60) - This space is reserved for notations that should be made when fire and boat exercises are conducted by the master. The details of the exercise are recorded in this space.

Column (61) - This is the location of the bilge wells. (Bilge wells are small tanks where the waste water accumulating in the holds drains and pumped out).

Column (62, 63 & 64) - These are quantities of bilge water that is determined through soundings of the bilge wells, in the port side of the ship, at the center and at the starboard side of the ship.

Column (65, 66, 67 & 68) - The same description as in columns 61, 62, 63 & 64 with the only exception that these are deep tanks extending from 'tween decks to bottom of ship and from shipside to shipside. Normally these tanks are used as ballast tanks or sometimes used for cargo.

Line (69 & 70)- These are self-explanatory information.

Line (71 & 72)- Signature of the Master and Chief mate of the vessel, respectively.

In the sick list are listed the names of the crew members who are in the sick bay or those who are receiving medical treatment while the ship is underway. All ships on international voyages are provided with a sick bay (hospital) where sick crew members are isolated especially when the disease afflicting the patient is highly contagious.

5.4 MAINTAINING AND KEEPING A GOOD LOG WHILE ON WATCH

When the ship is in port, the "tabular data" section is normally not filled up. Sometimes the "Remarks" are written in the "Rough Log" (usually a notebook) by the officer-in-charge of the watch and transcribed into smooth form in the official deck log after his watch. This system is resorted to by the deck officer as it would be cumbersome for him to carry the deck log all over the ship as he moves from one point of the ship to the other supervising and monitoring deck operations.

In order to maintain a good log, the officer-in-charge of the watch while in port should be aware of his duties as a duty officer in charge of the ship. It has been said that a good duty officer does not execute these responsibilities from the confines and comfort of his cabin but rather makes frequent rounds of the ship and keep himself informed of the status of every activity that is taking place on board.

The following suggestions can help the deck officer on watch perform his duty and maintain good recording of events during his watch.

The duty officer should –

1. conduct frequent and random inspections throughout the ship, keeping an eye out for hazards, cleanliness, works (especially hot works) in progress, and shipwide security. Keep a log of observations/findings made.
2. watch for sudden and unexpected changes in weather (particularly a change in barometric pressure readings). This is critical when cargo operations are underway and hatches have to be closed promptly to prevent damage to cargo and when the ship is moored in a berth that is exposed to windy conditions and strong currents. Keep a log of meteorological conditions prevailing in the area.
3. know the state of readiness of all safety and firefighting equipment. Keep a log of their status during your watch.
4. frequently spot-check hazardous storage areas to ensure proper storage of volatile materials. Keep a log of your spot-checking activity.
5. always know the status of the operational readiness of deck appliances and engineering plant. Keep a log of their status.
6. mentally prepare to respond to emergencies and should have emergency telephone numbers of shore-based fire department, ambulance, security that are within reach. Note these information in your log.

7. Inform the Master when in doubt.

5.5 LOG ENTRIES

A sample page of a deck log is shown in the Workbook. The two parts are shown. The data required in these particular deck log may not be the same as the data required in other logbooks but the format and information contained therein are generally the same.

The following are samples of log entries. It may be used as a guide for making entries in the first and second parts of the logbook. They are not "ideal entries", nor are they to be construed as the only acceptable ones. The student is instructed to transfer the following log entries properly into the pages of the logbook pages provided in the "Workbook."

Samples of Log Entries While Ship is Arriving and in Port:
Log Extracts of MV "FAR STAR" in a voyage from London to Antwerp:

Wednesday, 28 Nov 1991 (All times are local times)

0430 -	Approaching Wandelaar (Antwerp) Pilot Station from London.
0502 -	Master ordered Engine personnel to have engines ready. All deck hands on standby.
0615 -	Wandelaar (Bar) Pilot on board.
0835 -	Bar Pilot disembarked; River Pilot on board.
1202 -	First line on locks.
1220 -	Ship inside locks; River Pilot disembarked.
1225 -	Docking Pilot on board.
1300 -	Maneuvered to clear from locks.
1305 -	Last line casted off from locks. Pilot maneuvered ship to dock on berth No. 300.
1355 -	First head line on Berth No. 300.
1420 -	Ship moored alongside berth (starboard side to). Finished with Engine. Pilot disembarked.

Note: No loading operations. Cargoes not ready.

Thursday, 29 Nov 1991 *(To be entered in the Workbook on pages 22-23)*

0535 -	Deckhands opened Holds 2 & 4.
0550 -	Stevedores on board.
0615 -	Loading operations start in Hold No. 4.

0635	-	Loading operations start in Hold No. 2.
1000	-	Stopped loading in Holds 2 & 4.
1030	-	Resumed loading in Holds No. 2 & 4.
1115	-	Stopped loading in Hold No. 4; stevedores transferred to Hold No. 1.
1330	-	Stopped loading in Holds No. 1 & 2. First Gang of stevedores off, second gang on board.
1400	-	Resumed loading in Holds No. 1 & 2.
1550	-	Stopped loading in Holds No. 1 & 2, started loading in Holds No. 3 & 5.
1800	-	Stopped loading in Holds No. 3 & 5.
1830	-	Resumed loading in Holds No. 3 & 5.
2130	-	Stopped loading in Holds No. 3 & 5. Stevedores knocked off for the day. All hatches closed.

Note: From 0800 to 1600 loading operations continued under light rain in the presence of the charterer's super cargo.

From the preceding log entries extracted from the logbook of the above-named vessel, one can have a picture of the activities on board for two consecutive days.

From the time the ship approached the pilot station in Antwerp up to the time it was safely moored alongside berth on that day of 28 November 1991, all the significant movements of the vessel were recorded in detail. The changes of pilots were also recorded.

On the second day, Thursday, 29 November, the loading operations were recorded in detail as to what holds were in operation and what sequence of loading were observed. From the log entries one can also know that there were only 2 gangs* of stevedores working on two shifts that were hired to stow the cargoes in the holds. Note that the weather condition that prevailed during the entire loading operation was noted at the end of the day to preclude any claims for cargo damage due to rain. Also, delays in loading operations due to opening and closing of hatches or because there were no cargoes available were also noted. These particular notations will enter into play when charterer and shipper starts to argue about ***dispatch**** and ***demurrage****.

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* one "gang" of stevedores would normally compose of 10 to 15 men.

**These are chartering terms usually encountered in shipping.

Samples of Log Entries - Vessel Underway (Navigation)

9 Nov 1991 *(To be entered in the Workbook on pages 24-25)*

0100	-	Sighted Corregidor light, bearing 004° T, distance about 22 miles. Steady on course 000° T.
0121	-	Fuego Pt. abeam to starboard by Radar, distance 1.5 miles, altered course to 010° T.
0150	-	West point of Limbones Island abeam to starboard, distance 1.5 miles, altered course to 040° T.
0211	-	El Fraile Island abeam to starboard, distance 0.6 mile, altered course to 044° T.
0300	-	San Nicolas light abeam to starboard, distance 0.6 miles, altered course to 045° T.
0340	-	Master ordered to reduce speed to 10 knots and advise engineer on watch to place main engine on standby.
0351	-	Manila customs light bore 090° T, distance 4 miles steady on course 045° T.
0355	-	Master ordered main engine stopped. With various bells to engine room, Master maneuvered vessel towards entrance to North Harbor to pick up Harbor Pilot.

Sample Log Entries for a Vessel at Anchor

10 April 1989 *(To be entered in the Workbook on pages 26-27)*

Note: Ship coming from Gove, Australia

1005	-	Anchored off La Quinta Pier (Corpus Christi, U.S.A.) in 6 fathoms of water, mud bottom, with 36 fathoms of chain to the port anchor. Ship's anchored position fixed. Anchor detail on duty.
1030	-	Started swinging with the tide. Anchor holding good.

Note: On succeeding watches the first entry is "Anchored as before".

Sample Log Entries on Turning Over of Watch

(To be entered in the Workbook on pages 28-29)

At sea, underway from Gove, Australia to Panama Canal.
Duration of watch - From 0000-0400.

0000	Took over the bridge watch from the third officer. All bridge data were noted. Magnetic and gyro courses, engine RPM, meteorological, visibility conditions, vessel traffic noted. Underway as before on Course 070° T in company with another ship which is also eastbound on my starboard quarter, distance 5.2 miles.
0400	Relieve of watch by the chief officer on course 070° T. Ship riding well on a southeasterly swell. All bilge soundings were noted empty. RPM maintained on average of 113. Weather fine, partly cloudy skies, visibility good. Radar working well. All is well during my watch.

(SIGNED) ALTUS NAVIGADOR
Second Mate

CHAPTER TEST

1. Differentiate a rough log from an official log.
2. What information will you provide in the first part of the logbook? In the second part?
3. What is the real purpose of the ship's logbook?
4. In your opinion, how do the engine log differ from a deck log?
5. Using the blank pages of a logbook contained in the Workbook, you are required to fill in the pertinent blanks with log entries extracted from ships docking in the ports within the area where your school is located.

Chapter Six
PASSAGE PLANNING

At the end of the chapter, the student should be able to apply the lessons that have been learned in the preceding chapters, such as:

- laying out courses;
- measuring distances;
- computing the ship's speed; and
- computing estimated time of arrival (ETA).

6.1 PURPOSE OF PASSAGE PLANNING

Planning a passage is the first step in the navigation process. The planning begins well before the ship departs from a port. Usually the plan covers the planned route from the pilot station at the port of departure to the pilot station at the port of arrival. In the language of charter parties, this is commonly expressed as *"pilot to pilot"*. Simply stated, the implementation of a voyage plan begins from the time the pilot is dropped off at the point of departure (port of departure) and ends at the time when a pilot is embarked at the point of arrival (port of destination).

Strictly speaking, the execution of a voyage plan starts from the time the ship's last line is cast off from the pier of the port of departure and ends at the time when the ship is secured alongside the pier of the port of destination. Basically, a passage involves careful planning of a route, preparing the required charts, and making an inventory of the readiness of all equipment needed for the voyage. In other words, a "check-off list" of all required equipment must be made. The checklist might include the required large-scale charts covering the ports of departure and arrival and the required charts enroute. These charts must be corrected to the latest Notice to Mariners and must be stowed in the chart drawer in the order of sequence that they are to be used. This preparation should be completed well before departure.

Note: At this point of your study of terrestrial navigation, let us only consider the basic preparation that is made for charts. Other relevant preparations needed for planning a passage shall be added as the student advances to the senior years.

6.2 CHARTING A PLANNED VOYAGE

Let us now chart a voyage for a ship of about 3,000 gross tonnage with a deepest draft of 20 feet and an assumed speed of 14 knots. The voyage duration is about 24 hours.

The voyage is to be made from Manila to Cebu City. The departure point shall be taken after dropping off outbound pilot from the Manila South Harbor and the arrival point upon boarding the inbound pilot near Bagacay Island at the mouth of Mactan Strait.

Given the ship's draft and gross tonnage, the plan is to sail the ship out of Manila Bay, hug the coasts of Cavite and Batangas, pass Verde Island passage in Northern Mindoro, observing the traffic separation scheme; then, on a southeasterly course towards the northern tip of Tablas Island keeping the northern coast of Oriental Mindoro at a safe distance and keeping well clear north of Maestre de Campo and the south coast of Simara Island; then passing through the Romblon pass; then across the Sibuyan Sea on a southeasterly course towards a point about 5 miles south of Jintotolo Island; then across the Jintotolo channel passing north of North Gigantes Island then across the Visayan Sea passing between Bulalaque point north of Cebu and Malapascua Island and then finally, on a southerly course towards Bagacay point near the mouth of Mactan strait.

The planned courses are laid out in conjunction with the following Philippine Charts:

	Philippine Chart No.	Description
1.	4255	Manila Bay and Approaches
2.	4214	Verde Island Passage
3.	4714	Southwestern Luzon and Mindoro
4.	4410	Tablas Island and Vicinity
5.	4718	Panay, Negros and Cebu with parts of Bohol and Masbate
6.	4427	East Coast of Cebu

The following courses and points are plotted on the aforecited Philippine Charts:

Note: Use Chart No. 4255 in plotting the following courses and points:

1. Departure is taken from Lat. 14° 35.8' N, Long. 120° 54.4' E. From this position a course of 228° T is plotted, thence
2. to the point abeam of San Nicolas light, distance = 1.5 miles, where the course is altered to 223° T, thence
3. to the point abeam of El Fraile Island, distance = 1.0 mile, where the course is altered to 218° T, thence
4. to the point abeam of the Northwest tangent of Limbones Island, distance 1.5 miles, where the course is altered towards a point 1.4 miles due west of Fuego point, thence

Note: Use Chart No. 4214 in plotting the following courses and points:

5. to the point abeam of Fuego point where the course is altered to 180° T, thence
6. to the point where Cape Santiago Light bears 127° T, distance = 7.8 miles, where a course line running parallel to the coastline skirting the coast between Calatagan point and Cape Santiago is plotted, thence
7. to the point where Cape Santiago Light bears true East, distance 2.6 miles where the course is drawn placing the light at Port Galera dead ahead, thence
8. to the point where the North point of San Antonio Island bears 118° T, distance = 3.2 miles, where the course is altered to 090°, thence
9. to the point where Escarceo Point Light bears 180° T, distance = 2.1 miles, where the course is altered to 132°, thence
10. to the point abeam of the south point of Verde Island, distance = 2.2, where the course is altered to 093° T, thence
11. to the point due North of the East tangent of Baco Chico Island, distance = 1.0 mile, where the course is altered placing Guindauahan Islet (located at the northernmost tip of Tablas Island) dead ahead, thence

Note: Use Chart No. 4714 in plotting the following courses and points:

12. to the point where Corcuera Point (Simara Island) is abeam to port where the course is altered to 120° T, clearing Oregon Rock by 1.0 mile, thence

Note: Use Chart No. 4410 in plotting the following courses and points:

13. to the point due North of Gorda point, distance = 1.6 miles, where the course is altered to 138° T, thence
14. to the point where Gorda point bears due West, distance = 1.4 miles where the course is altered to 163° T, thence
15. to the point where San Pedro Point (Romblon Island) bears due East, distance = 2.1 miles, where the course is altered to 150° T, thence
16. to the point where Apunan Light (Romblon Island) bears 090° T, distance = 2.4 miles, where the course is altered to 135° T, thence

Note: Use Chart No. 4718 in plotting the following courses and points:

17. to the point abeam (on port side) of Cresta de Gallo Island, distance = 7.0 miles, where the course is altered to 122° T, thence
18. to the point abeam (on starboard side) of Balbagon Island, distance = 5.6 miles, where the course is altered to 090° T, thence
19. to the point where Uaydajon Islet bears 180° T, distance = 2.0 miles, where the course is altered to 123° T, thence
20. to the point where Tanguingui Island bears North, distance = 2.9 miles, where the course is altered to 109° T, thence
21. to the point due North of Chocolate Islet, distance = 1.25 miles, where the course is altered to 145° T, thence
22. to the point where Talisay point is abeam (on starboard), distance = 2.6 miles, where the course is altered to 180° T, thence
23. to a point where Tindug point is abeam (to starboard), distance = 5.25 miles, where the course is altered to 193° T, thence

Note: Use Chart No. 4427 in plotting the following courses and points:

24. to the point where Capitancillo Islet bears 090° T, distance = 1.8 miles, where the course is altered to 180° T, thence
25. to the point where Danao point bears due West, distance = 2.5 miles, where the final course is altered to 198° T, leading to the point of arrival about one mile due east of Bagacay Point in Lat. 10° 03.1' N, Longitude 124° 02.3' E.

Note: The student is directed to plot all the courses and points of the foregoing details of the planned passage on the pertinent charts and measure along the course lines the total distance from the point of departure to the point of arrival and then compute the estimated time of arrival (ETA) at the point of arrival.

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He has been a superintendent of a private maritime school, a training director of an accredited maritime training center, and port captain of a shipping agency.

From 1985 to 1992, he commanded Japanese and Norwegian-owned ships of various sizes and types engaged in worldwide trade, two of which were Panamax-type bulk carriers plying the Trans-Atlantic and Trans-Pacific routes.

Now in retirement, he devotes his time to writing maritime books and giving lectures in maritime-related seminars. His latest book, "A Guide to the Learning and Teaching the Collision Regulations," is now in circulation.

Prior to his retirement, he was member of the Professional Regulatory Board of Marine Deck Officers. When his term expired in 1998, he served as consultant of maritime affairs of the Professional Regulation Commission until January 1999.

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