

UNIT

3

Compass Surveying**Learning Objectives**

After studying this unit, the student will be able to

- Understand what is meridian and types of meridian
- Bearing and types of bearings
- Representation of bearing
- Conversion of whole circle bearing into quadrantal bearing.
- Calculating included angles of a closed traverse from observed bearings.
- Local attraction, correcting the bearings for local attraction.

3.0 Introduction

According to the method employed, surveying is classified into Triangulation surveying and Traverse surveying. A series of connected survey lines of known lengths and directions is called a traverse. When triangulation is not possible, traversing method is used. In traversing, when compass is used for making angular measurements, it is known as compass traversing or compass surveying.

3.1 PURPOSE AND PRINCIPLES OF COMPASS SURVEYING:

Compass surveying is suitable in the following situations:

1. When the survey work is to be completed quickly.

2. When the area is hilly and chaining is difficult.
3. When the area to be surveyed is relatively large.
4. When the details are too many.
5. When the area is can not be divided into network of triangles.
6. When the area to be surveyed is long and narrow e.g. road, stream etc.
7. When the survey is to be done through dense forest.

Principle of Compass Surveying

In compass traversing the directions of survey lines are fixed by angular measurements and not by forming a network of triangles. A compass survey is one in which the traverse work consists of series of lines the lengths and directions of which are measured with a chain or a tape, and with an angular instrument respectively.

A traverse may be classified as:

- a) Closed traverse
- b) Open traverse

A) Closed traverse: A closed traverse is a traverse in which the sides of a traverse form a closed polygon.

B) Open traverse: An open traverse is a traverse in which the sides of traverse do not form a closed polygon.

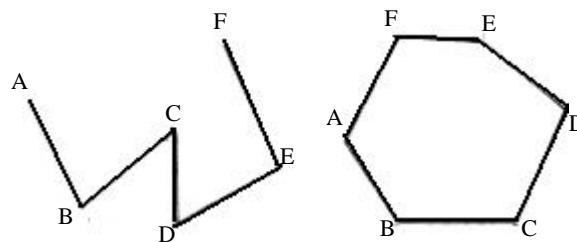


Fig. 3.1

Description of Prismatic Compass

The prismatic compass consists of a circular box about 85 to 110 mm diameter. At the center of metal box a needle and pivot is provided. The pivot balances the magnetic needle which is attached to graduated aluminum

ring. The graduations are in degrees to 30 minutes and from 0° to 360° in the clock wise direction. The 0° is marked at south end of magnetic needle because the readings are read at the opposite end of the object. At west it is marked 90° , north 180° and east 270° respectively. The graduations are marked inverted because they are viewed through a prism which is cut to 45° on one face and 90° for other two faces. The readings get reflected through prism resulting in erected image. A sighting slit is provided in the box carrying the prism. This box can be moved up and down for focusing by means of stud. The prism box is hinged so that it can be folded to the rim of the compass box. Two sun glasses are provided to observe bright objects. An object vane is provided in line of sighting slit. It is an open frame with a central vertical horse hair for sighting the object. The object vane is hinged to compass. When it is not in use, it is folded flat on the glass cover. The base of object vane presses the lifting pin bringing the magnetic needle to rest with the help of lifting lever. A brake pin is provided to stop the oscillations of the graduated ring to facilitate the reading of the graduated ring. A glass cover is fitted over the box to protect the needle from dust. The compass is fitted to a tripod stand. A tripod stand consists of a ball and socket joint which helps in leveling the compass quickly.

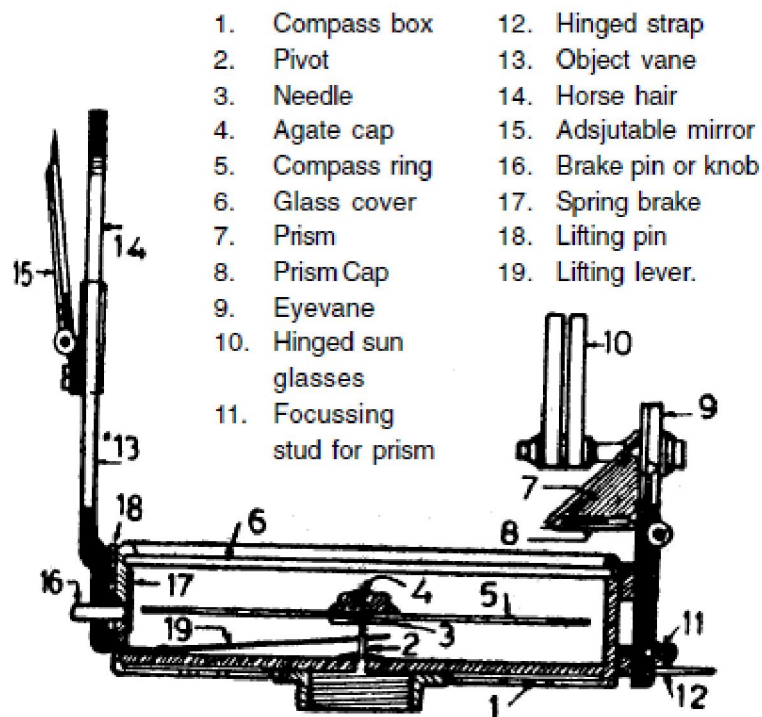


Fig. 3.2

Method of using Prismatic Compass: The compass may be held in the hand, but for better results, it is usually mounted on a tripod which carries a vertical spindle in a ball and socket joint to which the box is screwed. By means of this arrangement the instrument can be quickly leveled and also rotated in a horizontal plane and clamped in any position.

Working of Prismatic Compass

This can be used while holding it in hand, but for better accuracy, it is usually mounted on a light tripod which carries a vertical spindle in the ball and socket arrangement to which compass is screwed. By means of this arrangement the compass can be placed in position easily. Its working involves the following steps.

(i) Centering (ii) Levelling, and (iii) observing the bearing

(i) Centering

The compass should be centered over the station where the bearing is to be taken by dropping a small piece of stone so that it falls on the top of the peg marking the station.

(ii) Levelling

The compass should then be leveled by eye, by means of a ball and socket joint so that the ring may swing quite freely. It should be clamped when leveled.

(iii) Observing the bearing.

To observe the bearing of a line AB

- 1) Centre the compass over the station A and level it.
- 2) Having turned up vertical prism and the sighting vane, raise or lower the prism until the graduations are clearly visible.
- 3) Turn the compass box until the ranging rod at the station B is bisected by the hair when looked through the slit above the prism.
- 4) When the needle comes to rest, look through the prism and note the reading at which the hair line produced appears to cut the image of the graduated ring which gives the required bearing of the line AB. Readings are usually estimated to the nearest 15'.

3.2. Concept of Meridian, True Median, Magnetic Meridian and Arbitrary Meridian

Meridian: Meridian is a standard direction from which, the bearings of survey lines are measured. There are three types of meridians.

- 1) True meridian
- 2) Magnetic meridian
- 3) Arbitrary meridian.

True meridian: It is a line of intersection of earth's surface formed by a plane passing through north and south poles and the given place.

Magnetic meridian: It is the direction indicated by a freely suspended magnetic needle.

Arbitrary meridian: It is any convenient direction assumed as meridian for measuring bearings of survey lines.

3.3. Bearing

It is a horizontal angle made by the survey line with reference to the meridian, based on the meridian the bearings are three types.

- 1) True bearing
- 2) Magnetic bearing
- 3) Arbitrary bearing

True bearing: The angle made by a survey line with reference to true meridian is called true bearing. It always remains constant.

Magnetic bearing: The angle made by a survey line with reference to magnetic meridian is called magnetic bearing. It changes from place to place and time.

Arbitrary bearing: The angle made by a survey line with reference to arbitrary meridian is called arbitrary bearing.

3.3.1. Representation of Bearing

Bearings are expressed in the following two systems.

- 1) Whole circle bearings system.
- 2) Quadrantal bearings system.

1) Whole Circle Bearing

In this system, the bearing of a line is always measured clock wise from the direction of the north of the meridian towards the line around the circle. Whole circle bearings of lines have been shown in fig 3.3

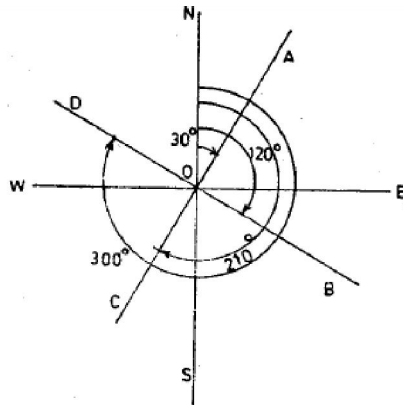


Fig. 3.3

2) Quadrantal Bearings

In this system the bearings of a line is measured from either the north or the south, clock wise or counter clockwise whichever is nearer to the line towards the east or west. The angle at any station in a plane is divided into four quadrants by two lines at right angles to each other. These are the north south and east-west lines. The bearing is reckoned from 0° to 90° in each quadrant. Quadrantal bearings of lines have been shown in fig 3.4 Quadrantal bearings are also called as reduced bearings.

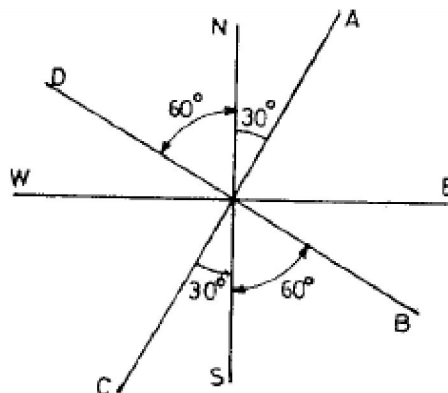


Fig. 3.4

3.32 Conversion of Whole Circle bearings into Quadrantal Bearings

The whole circle bearing of a line can be converted to quadrantal bearing by reducing it to an angle less than 90° which has the same numerical value of the trigonometric functions. Rule of conversion of whole circle bearings into quadrantal bearing.

S.No.	W.C.B	QUADRANT	RULE
1.	Between 0° to 90°	N.E	Q.B = W.C.B
2.	Between 90° to 180°	S.E	Q.B = $180^\circ - \text{W.C.B}$
3.	Between 180° to 270°	S.W	Q.B = $\text{W.C.B} - 180^\circ$
4.	Between 270° to 360°	N.W	Q.B = $180^\circ - \text{W.C.B}$

Example 3.1

1. Convert the following whole circle bearings of lines to quadrantal bearings.

a) OA 32° b) OB 109° c) OC 211° d) OD 303°

Solution:

Refer to fig 3.5

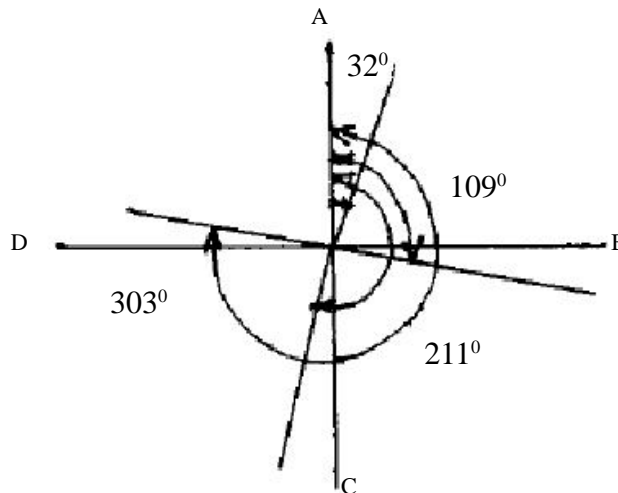


Fig. 3.5

a) W.C.B of OA = 32°

Quadrantal bearing = N 32° E

b) W.C.B of OB = 109°

Quadrantal bearing = $108^{\circ} - \text{W.C.B} = 180^{\circ} - 109^{\circ} = \text{S } 71^{\circ} \text{ E}$

c) W.C.B of OC = 211°

Quadrantal bearing = $\text{W.C.B} - 180^{\circ} = 211^{\circ} - 180^{\circ} = \text{S } 31^{\circ} \text{ W}$

d) W.C.B of OD = 303°

Quadrantal bearing = $360^{\circ} - \text{W.C.B} = 360^{\circ} - 303^{\circ} = \text{N } 57^{\circ} \text{ W}$

Example 3.2

Convert following reduced bearings to the whole circle bearings:

(i) N $52^{\circ}30'$ E (ii) S $30^{\circ}15'$ E (iii) S $85^{\circ}45'$ W (iv) N $15^{\circ}10'$ W

Solution:

(i) R.B. = N $52^{\circ}30'$ E & which is in the NE quadrant,

Therefore W.C.B = same as R.B = $52^{\circ}30'$ (Ans.)

(ii) S $30^{\circ}15'$ E which is in the SE quadrant,

Therefore W.C.B = $180^{\circ} - 30^{\circ}15' = 149^{\circ}45'$ (Ans.)

(iii) S $85^{\circ}45'$ W which is in the SW quadrant,

Therefore W.C.B = $180^{\circ} + 85^{\circ}45' = 265^{\circ}45'$ (Ans.)

(iv) N $15^{\circ}10'$ W which is in the NW quadrant,

Therefore W.C.B = $360^{\circ} - 15^{\circ}10' = 344^{\circ}50'$ (Ans.)

3.4 Compass Traversing in the Field

Compass survey requires the following instruments:

- 1) Prismatic compass
- 2) Chain and arrows
- 3) Tape
- 4) Ranging rods and

5) Pegs.

The compass traversing of an area involves the following steps:

- 1) Reconnaissance of area
- 2) Determining the direction of lines
- 3) Measuring the traverse legs and offsets.

1. Reconnaissance of area: The area is divided into triangles and of polygons. Suitable stations are selected on the rough sketch and designated as A, B, C etc.

2. Determining the directions of survey lines: The compass is set at each successive stations i.e., A, B, C, D, E of the closed traverse ABCDEA and the fore bearings and back bearings of lines are observed.

3. Measurement of traverse legs and offsets : A compass is centered over a station A and after leveling the compass the fore bearing AB and back bearing EA are taken by sighting the ranging rods at A and E. The line AB is chained and the offsets to the detailed points are noted and entered in the field notes. The operation is repeated at other stations B, C, D, and E

Forward and Backward Bearings

In compass surveying, two bearings are observed for each line, one from each end of the line. The bearing of a line in the direction of the progress of survey is called the forward bearing or fore bearing while the bearing measured in the opposite direction is called as the backward bearing or back bearing.

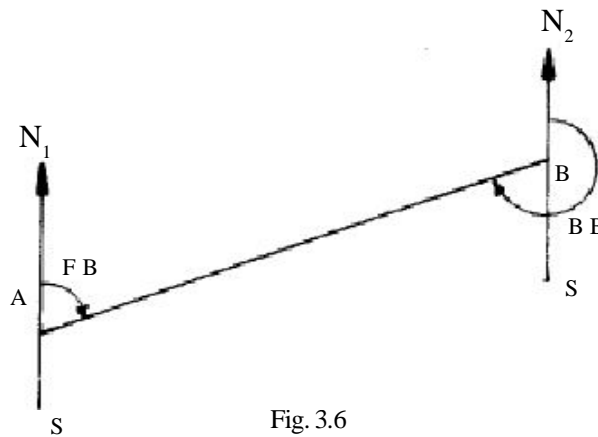


Fig. 3.6

The difference between the fore bearing and back bearing of a line is 180° .

Back bearing = fore bearing $\pm 180^{\circ}$.

Example 3.2: The following are the observed fore bearings of lines of a traverse.

Find their back bearings:

a) AB $42^{\circ} 45'$ b) BC $128^{\circ} 15'$

c) CD $232^{\circ} 15'$ d) DE $301^{\circ} 30'$

Solution:

a) FB of AB = $42^{\circ} 45'$

BB of AB = $42^{\circ} 45' + 180^{\circ} = 222^{\circ} 45'$

b) FB of BC = $128^{\circ} 15'$

BB of BC = $128^{\circ} 15' + 180^{\circ} = 308^{\circ} 15'$

c) FB of CD = $232^{\circ} 15'$

BB of CD = $232^{\circ} 15' - 180^{\circ} = 52^{\circ} 15'$

d) FB of DE = $301^{\circ} 30'$

BB of DE = $301^{\circ} 30' - 180^{\circ} = 121^{\circ} 30'$

3.5 Local Attraction

A compass needle is affected by the presence of masses of iron and steel such as lamp posts electric cables, steel girders etc., they deflect the needle and the effect of this disturbance is called local attraction. Due to local attraction, the difference between the fore bearing and back bearing of a survey line will not be equal to 180° . The observed bearings of lines affected by local attraction are corrected by starting from the unaffected line and the correct bearings of the successive lines are calculated.

Example 3.3

The following are the bearings of the lines of the closed traverse ABCDA taken with a compass in a place where local attraction was suspected.

Line	F.B.	B.B.
AB	35°30'	215°30'
BC	115°15'	294°15'
CD	180°45'	3°45'
DA	283°45'	101°45'

Correct the bearings of the lines for local attraction

Solution:

It is observed that the difference between the fore and back bearings of the line AB is exactly 180° , hence stations A and B are free from local attraction and the bearings observed A and B are correct. The difference of FB and BB of other lines is not 180° . Local attraction is present at those stations. The observed F.B. of BC is also correct since B is unaffected by local attraction.

$$\text{Observed F.B. of BC} = 115^{\circ}15'$$

$$\text{Add} = 180^{\circ}0'$$

$$\text{Correct BB of BC} = 295^{\circ}15'$$

$$\text{Less Observed BB of BC} = 294^{\circ}15'$$

$$\text{Error due to local attraction at C} = 1^{\circ}00'$$

Since the error is negative all bearing observed at C must be corrected by adding $1^{\circ}00'$

$$\text{Observed F.B. of CD} = 180^{\circ}45'$$

$$\text{Add correction} = 1^{\circ}00'$$

$$\text{Correct FB of CD} = 181^{\circ}45'$$

$$\text{Deduct } 180^{\circ} = 1^{\circ}00'$$

$$\text{Correct BB of CD} = 1^{\circ}45'$$

$$\text{Observed BB of CD} = 3^{\circ}45'$$

$$\text{Error due to local attraction at D} = 2^{\circ}00'$$

Hence all bearings observed at D must be corrected by $-2^{\circ}00'$ for local attraction.

Observed F.B. of DA	=	$283^{\circ}45'$
Add correction at D	=	$- 2^{\circ}00'$
Correct FB of DA	=	$281^{\circ}45'$
Less	=	$180^{\circ}00'$
Correct BB of DA	=	$101^{\circ}45'$

This is the same as the observed BB of DA which shows that there is no local attraction at A.

The corrected bearings of the lines will be as follows:

Line	F.B.	B.B.
AB	$35^{\circ}30'$	$215^{\circ}30'$
BC	$115^{\circ}15'$	$295^{\circ}15'$
CD	$181^{\circ}45'$	$1^{\circ}45'$
DA	$281^{\circ}45'$	$101^{\circ}45'$

3.6 Calculation of Included Angles of a Traverse in Compass Traverse

When two lines meet at a point two angles i.e., interior and exterior angles are formed. The sum of these two angles is equal to 360° . The following rules may be applied to find the included angle between two lines whose bearings are given.

Finding of included angles is divided into two cases as follows:

1. When the W.C.B of two lines measured from their point of intersection are given
2. When the W.C.B. of two lines not measured from their point of intersection are given.

Case (1) When the W.C. bearings of two lines measured from their point of intersection are given

Rule: Subtract the smaller bearing from the greater one. The difference will give the included angle. If it is less than 180^0 However if the difference exceeds 180^0 it will be the exterior angle.

The included angle is then $360^0 - \text{exterior angle}$

Example 3.4

Find the angle between the lines OA and OB given their bearings.

i) $25^045'$ and $140^000'$ ii) $35^015'$ and $315^015'$ iii) $115^015'$ and $250^015'$

Solution:

i) OA = $25^045'$ and OB = $140^000'$

$$\begin{aligned} \text{AOB} &= \text{Bearing of OB} - \text{Bearing of OA} \\ &= 140^000' - 25^045' = 114^015' \end{aligned}$$

ii) OA = $35^015'$ and OB $315^015'$

$$\begin{aligned} \text{AOB} &= \text{Bearing of OB} - \text{Bearing of OA} \\ &= 315^015' - 35^015' = 280^000' \end{aligned}$$

Since the difference is greater than 180^0 , it is the exterior angle, Interior angle

$$\text{BOA} = 360^000' - 280^000' = 80^000'$$

iii) OA = $115^015'$ and OB = $250^015'$

$$\begin{aligned} \text{AOB} &= \text{Bearing of OB} - \text{Bearing of OA} \\ &= 250^015' - 115^015' = 135^000' \end{aligned}$$

Example 3.5

The bearing of a line AB is $133^030'$ and the angle ABC is $120^032'$ what is the bearing of BC?

Solution:

Bearing of AB = $133^030'$

$$\text{bearing of BA} = 133^030' + 180^0 = 313^030'$$

$$\begin{aligned} \text{bearing of BC} &= \text{bearing of BA} + \text{Angle ABC} \\ &= 313^030' + 120^032' = 434^002' \\ &= 434^002' - 360^0 = 74^002' \end{aligned}$$

Example 3.6

The bearings of the sides of a closed traverse ABCDE are as follows:

Side	Fore Bearing	Back Bearing
AB	105°15'	285°15'
BC	20°0'	200°0'
CD	229°30'	49°30'
DE	187°15'	7°15'
EA	122°45'	302°45'

Compute the interior angles of the traverse.

$$A = \text{Bearing of AE} \sim \text{Bearing of AB}$$

$$= \text{B.B. of EA} \sim \text{FB of AB}$$

$$= 302^{\circ}45' \sim 105^{\circ}15' \sim 197^{\circ}30' = \text{exterior angle}$$

$$\text{Interior angle A} = \text{Angle EAB} = 360^{\circ} - 197^{\circ}30' = 162^{\circ}30'$$

$$B = \text{Bearing of BA} \sim \text{Fore Bearing of BC}$$

$$= \text{B.B. of AB} \sim \text{FB of BC}$$

$$= 285^{\circ}15' \sim 20^{\circ}00' = 265^{\circ}15' = \text{exterior angle}$$

$$\text{Interior angle B} = \text{Angle ABC} = 360^{\circ} - 265^{\circ}15' = 94^{\circ}45'$$

$$C = \text{Bearing of CB} \text{ difference Bearing of FB of CD}$$

$$= \text{B.B. of BC} \sim \text{FB of CD}$$

$$= 200^{\circ}0' \sim 229^{\circ}30' = 29^{\circ}30' = \text{interior angle}$$

$$D = \text{Bearing of DC} \sim \text{FB of DE}$$

$$= \text{B.B. of CD} \sim \text{FB of DE}$$

$$= 49^{\circ}30'' \sim 187^{\circ}15' = 137^{\circ}45' = \text{interior angle}$$

$$E = \text{Bearing of ED} \sim \text{Fore bearing of EA}$$

$$= \text{B.B. of DE} \sim \text{FB of EA}$$

$$= 7^{\circ}15'' \sim 122^{\circ}45' = 115^{\circ}30'$$

Check: The sum of the interior angles of a closed traverse must equal to $(2n-4)$ right angles, where n is the number of the sides of the traverse. In this case the sum of the angles must be equal $(10-4) \times 90^{\circ} = 540^{\circ}$.

$$\angle A + \angle B + \angle C + \angle D + \angle E = 162^{\circ}30' + 94^{\circ}45' + 29^{\circ}30' + 137^{\circ}45' + 115^{\circ}30' = 540^{\circ}00'. \text{ Hence checked.}$$

3.7 Errors in Compass Surveying

Errors in compass surveying are classified as follows:

a) Natural Errors b) Instrumental Errors

a) Natural Errors: Natural errors are of two types:

1. Errors of manipulation and sighting
2. Errors due to external influences

1. Errors of manipulation and sighting

- i) Inaccurate centering of the compass
- ii) Inaccurate leveling of the compass box
- iii) Imperfect bisection of the ranging rods at stations
- iv) Carelessness in reading the graduations
- v) Carelessness in recording the observed readings

2. Errors due to external influences

- i) Magnetic changes in atmosphere on a cloudy or stormy day
- ii) Variations in declinations
- iii) Local attraction due to proximity of steel structures

b) Instrumental Errors:

- i) The needle not being perfectly straight
- ii) The pivot being bent
- iii) The needle being sluggish
- iv) The needle not moving freely.

- v) The line of sight is not being vertical.
- vi) The graduated circle not being horizontal.
- vii) The line of sight not passing through the centre of the graduated ring and
- viii) The vertical hair being loose.

Summary

1. Closed traverse is a traverse in which the sides of a traverse form a closed polygon.
2. Open traverse is a traverse in which the sides of a traverse do not form a closed polygon.
3. Meridian is a standard direction from which, the bearings of the lines are measured.
4. Types of Meridian.
(i) True meridian. (ii) Magnetic meridian. (iii) Arbitrary meridian.
5. Bearing is a horizontal angle made by the survey line with reference to the meridian.
6. Bearings of survey lines are represented in
(i) Whole Circle Bearing System. (ii) Quadrantal Bearing System.
7. The difference between fore bearing and back bearing of a line should be 180°.
8. Local attraction: A compass needle is affected by the presence of masses of iron and steel such as lamp posts, electric cables, steel girders etc. They deflect the needle and gives the wrong value of bearing the effect of this disturbance is called local attraction.

Short Answer Type Questions

1. Define bearing
2. Define Meridian
3. Write the methods of representing bearing.
4. Convert the following WCB in to the reduced bearings.
a) 30°45' b) 215°15'

5. Define local attraction.
6. Write the types of meridian.
7. Find the angles between the lines AB and AC if their respective bearings are $145^{\circ}30'$ and $56^{\circ}45'$
8. Define fore bearing and back bearing of a line.
9. What is a closed traverse?

Long Answer Type Questions

1. Explain the construction of prismatic compass with a neat sketch
2. Write the errors in compass survey, explain the instrumental errors
3. a) How do you detect local attraction in compass survey?
b) The following bearings were observed with the compass.

Line	F.B.	B.B.
AB	$74^{\circ}15'$	$254^{\circ}15'$
BC	90°	$270^{\circ}0'$
CD	$165^{\circ}0'$	$342^{\circ}0'$
DE	$178^{\circ}0'$	$1^{\circ}0'$
EA	$187^{\circ}0'$	80°

Correct the bearings for local attraction

Activities

- Study and identify the parts of prismatic compass.
- Measuring magnetic bearing of a line using prismatic compass.