Chapter 2

Compass and Plane Table Surveying

CHAPTER HIGHLIGHTS

- *Compass Surveying*
- *Plane Table Surveying*

Compass Surveying

Introduction

Chain surveying can be used for relatively small and flat areas. But when large areas are involved, any instrument which enables angles or directions of the survey lines are to be used. Compass survey is one such instrument in which directions of survey lines are measured with compass and lengths of lines are measured with a tape or chain. Used to run a traverse (open or close).

Types of Meridians

Meridian is any specified direction where bearings (angles) are taken relative to that direction.

1. **True meridian:** Line joining true north and true south. It always converges from North Pole to South Pole. Established by astronomical observations.
2. **Magnetic meridian:** It is the direction shown by a freely floating and balanced magnetic needle, free from all other attractive forces. Established with magnetic compass.
3. **Arbitrary meridian:** Any convenient direction towards a permanent and prominent mark or signal (example like top of a chimney). Used to determine the relative positions of lines in a small area.

Types of Bearings

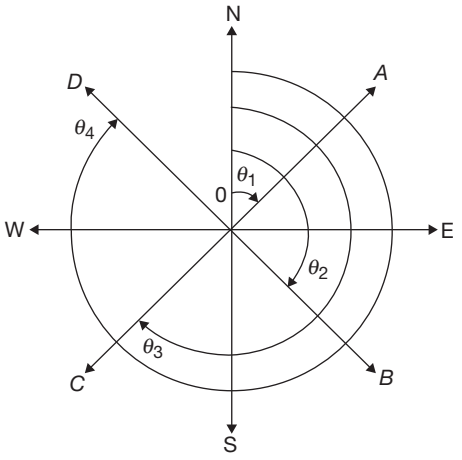
Bearing is an angle between a meridian and survey line.

1. **True bearing:** True bearing of a line is horizontal angle between true meridian and the line. Since true meridian is fixed through a point, true bearing is constant irrespective of time. (Also known as Azimuth).
2. **Magnetic bearing:** Magnetic bearing of a line is the horizontal angle made with the magnetic meridian. Used for small areas and changes with time. Measured with magnetic compass.
3. **Arbitrary bearing:** Arbitrary bearing of a line is the horizontal angle made with any arbitrary meridian. Theodolite is used to measure it.

System of Bearings

Whole Circle Bearing System (WCB) or Azimuthal System

- Bearing of a line is measured with magnetic north in clockwise direction.
- Bearings vary from 0°–360°.
- **Prismatic compass** is graduated in this system.



WCB system

Bearing of lines:

$OA = \theta_1$;

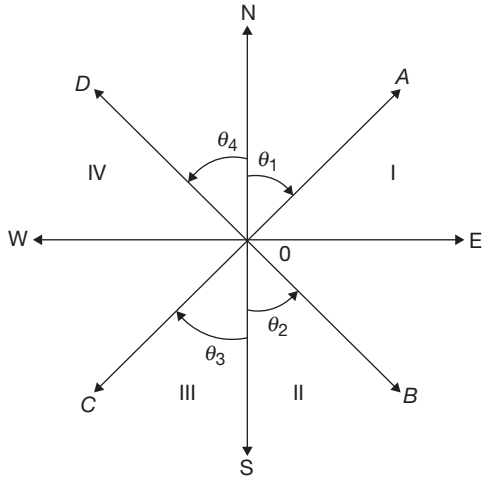
$OB = \theta_2$;

$OC = \theta_3$;

$OD = \theta_4$;

Quadrantal Bearing System (QB)

- Bearing of a line is measured eastward or westward from north or south whichever is nearer.
- Bearings vary from 0°–90°.
- Observed by **surveyors compass**.
- Bearings are called **reduced bearings**.



QB system

Bearings of lines:

$OA = N\theta_1E$

$OB = S\theta_2E$

$OC = S\theta_3W$

$OD = N\theta_4W$

Conversions of Bearings from One System to Other

Conversion of WCB into RB

Line	WCB Between (q)	Rule for RB or QB	Quadrant
OA	0° and 90°	WCB (θ)	NE(I)
OB	90° and 180°	180° – WCB (θ)	SE (II)
OC	180° and 270°	WCB (θ) – 180°	SW (III)
OD	270° and 360°	360° – WCB (θ)	NW (IV)

Conversion of RB into WCB

Line	RB	Rule for WCB	WCB Between
OA	$N\theta_1E$	RB	0° and 90°
OB	$S\theta_2E$	180° – RB	90° and 180°
OC	$S\theta_3W$	180° + RB	180° and 270°
OD	$N\theta_4W$	360° – RB	270° and 360°

Fore and Back Bearing

- The bearing of a line measured in the direction of progress of survey is called fore bearing (FB).
- The bearing measured in the opposite direction of survey or in opposite direction to FB is called back bearing (BB).

Calculating BB from FB

1. **If FB is given in WCB:**

   BB = FB + 180° if FB < 180°

   BB = FB – 180° if FB > 180°

2. **If FB is given in QB:**

   To convert to BB, the value of the bearing remains same, except that 'N' substituted by 'S', 'E' substituted by 'W' and vice-versa.

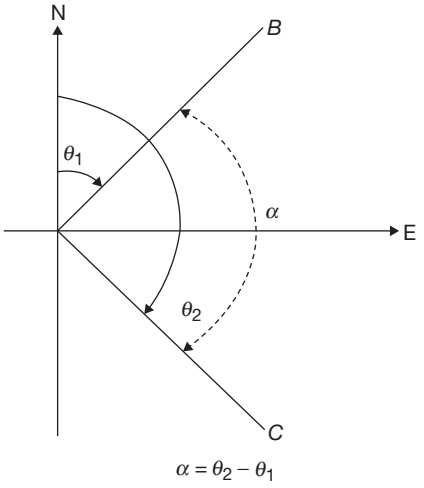
Calculation of Included Angles from Bearings

Can be calculated by using diagrams.

1. **If WCB are given:**

   (a) Bearing of two lines measured from common point

Included angle = FB of one line – FB of other line

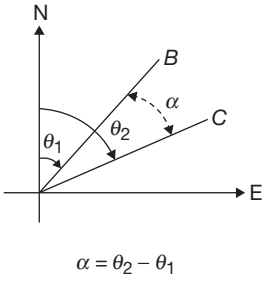


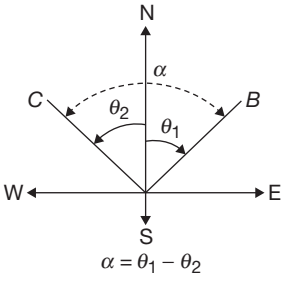
(b) Bearings of two lines not measured from common point.

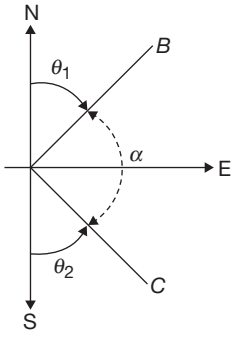
Included angle = BB of previous line − FB of next line.

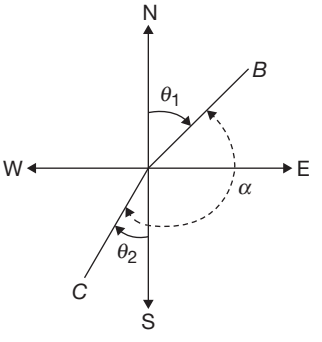
2. If QB or RB are given:

In case of QB, it is easy to find included angle by drawing diagram.









Calculation of Bearings from Angles

- Traverse in which included angles between successive lines are measured and the bearings of the lines can be calculated provided the bearing of any one line is also measured.
- In a closed traverse, clockwise angles will be the interior angles if traverse is run in anti-clockwise direction.

Bearing of a line = Bearing of previous line + Included angle

- If the sum is more than 180°, deduct 180°.
- If the sum is less than 180°, add 180°.

NOTE

Sum of included angles = $(2n - 4)90°$

Where, n is number of included angles.

Magnetic Compass

- It gives directly the magnetic bearings of lines.
- Lines of force of earth's magnetic field run generally from south to north.

Dip

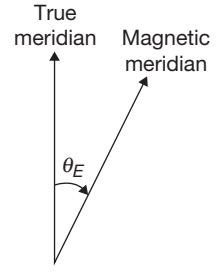
The angle which the lines of force make with the surface of earth is called the angle of dip or simply dip of the needle.

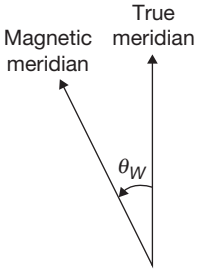
- At 70° north latitude and 96° west longitudinal, dip will be 90° and it is called north magnetic pole. Similarly near south magnetic pole dip is 90° (i.e., at Poles)
- Lines of force are parallel to the surface of the earth only at equator.
- Dip of the needle is zero at equator and needle will remain horizontal.

Magnetic Declination

Magnetic declination = True bearing − Magnetic bearing

- Mariners call declination by the name 'variation'.
- If the magnetic meridian is to the right side (eastern side) of the true meridian, declination is said to be eastern or positive.
- If the declination is to the left side (western side) of the true meridian, it is said to be western or negative.





- **Isogonics line** is the line drawn through the points of same declination.

- **Agonic line** is the line made up of points having zero declination.
- 'Magnetic declination' at a place is not constant but varies from time to time.

Variations in Declination

1. **Diurnal variation:**
   - It is the daily variation and more in day and less at night.
   - Considerably more in summer than in winter.
   - More at magnetic poles and less at equator.
   - Amount of variation changes year to year.
2. **Annual variation:** Variation which has an yearly period is known as annual variation. Varies from place to place.
3. **Secular variation:**
   - It follows the roller coaster (sine-curve) and swings like a pendulum.
   - It is variation over a very long period, i.e., approximately 250 years.
   - Most important in the works of surveyor.
4. **Irregular variation:** These variations are due to magnetic storms, earthquakes and other solar influences.

Determination of True Bearing

True bearing = Magnetic bearing ± Declination

Use '+' if the declination is to the East.
Use '–' if the declination is to the West. } (for WCB only)

SOLVED EXAMPLES

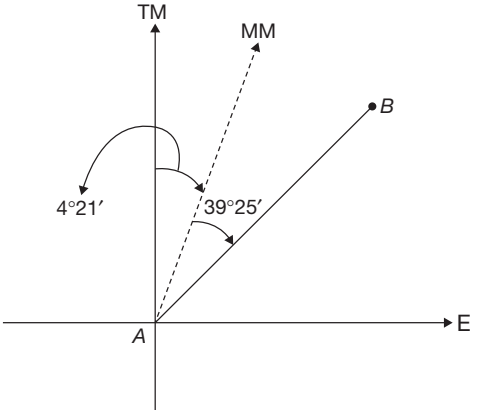
Example 1

What is the true bearing of the line *AB*. If magnetic bearing = 39°25′ and magnetic declination is 4°21′ E.

(A) 35°4′ (B) 43°46′
(C) 30°43′ (D) 48°7′

Solution

True bearing is wrt true meridian



From diagram we can say,

True bearing = Magnetic bearing + Magnetic declination

TB = 39°25′ + 4°21′

= 43°46′.

Hence, the correct answer is option (B).

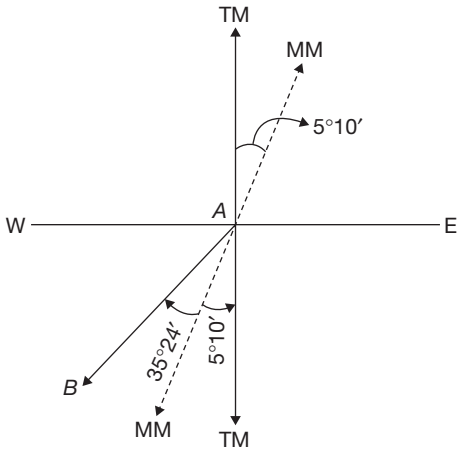
Example 2

The magnetic bearing of a line *AB* is S35°24′ W.

Calculate the true bearing if the declination is 5°10′ E.

(A) S40°34′ E (B) S30°14′ E
(C) S40°34′ W (D) S30°26′ W

Solution



From diagram,

TB = MB + Declination

= S35°24′ W + 5°10′

= S40°34′ W.

Hence, the correct answer is option (C).

Comparison of Prismatic Compass and Surveyor's Compass

Object	Prismatic Compass	Surveyor's Compass
Bearing	WCB (0° to 360°)	QB (0°–90°)
Graduations	Inverted readings, as we have to see them through prism	Erect readings
Needle	Broad type—filled to the bottom of aluminium ring.	Edge bar type—also acts as an index.
Scale	Free to float along with the broad type magnetic needle	Attached to the box
Sighting at object and taking bearing	Done simultaneously	Sighting is to be done first and then the surveyor has to read the northern end of the needle
Tripod	Not essential	Essential

Adjustments of Prismatic Compass

1. **Temporary adjustments:** Made at every setup of instrument
   - **(a) Centering (over the station):** Done by adjusting legs of tripod and using plumb bob.
   - **(b) Leveling:** With the help of ball and socket over the tripod leveling is done.
   - **(c) Focusing the prism:** Prism is moved until graduations are clearly seen.
2. **Permanent adjustments:** These are related to the instrument and its parts and done when the relations between parts are disturbed.

Local Attraction

- This is a term used to denote the influence of any magnetic materials like magnetite in ground, wire carrying electric current, steel structures, chains, steep tapes, etc.,
- If BB – FB ≠ 180°, then the station has local attraction.

Plane Table Surveying

Introduction

Plane table surveying is a graphical method of survey in which the field observations and plotting proceed simultaneously. This is most suitable in magnetic areas and for small scale maps.

Instruments Used

1. **Plane table:** Three distinct types of tables are used.
   - **(a) The traverse table:** Consists of a small drawing board mounted on a tripod. Table is levelled by adjusting tripod legs, usually by eye estimation.
   - **(b) Johnson table:** Consists of a drawing board usually 45 × 60 cm or 60 × 75 cm. The head consists of a ball and socket joint.
   - **(c) Coast survey table:** This table is superior to the above two types and is used for work of high precision.
2. **Alidade:** It is a straight edge with some form of sighting device.
   - **(a) Plain alidade:** Consists of a metal or wooden rule with two vanes at the ends. The working edge against which lines are drawn is also known as 'beveled edge or edge'.

     It is not very much suitable on hilly area since the inclination of the line of sight is limited.
   - **(b) Telescopic alidade:**
     - Used when it is required to take inclined sights.
     - Accuracy and range of sights are increased by its use.
3. **Plumbing fork:** It is used in large work and is meant for centering the table over the point or station occupied by the plane table when the plotted position of point is already known on the sheet.
4. **Spirit level:** For confirming if the table is properly levelled or not. It may be of tabular variety or circular type.
5. **Compass:** For orienting the plane table to magnetic north. Generally a trough compass is used.
6. **Drawing paper:** Of superior quality for mapping.

Working Operations

1. **Fixing:** Fixing table to the tripod.
2. **Setting:**
   - (a) Levelling the table
   - (b) Centering
   - (c) Orientation
3. **Sighting the points**

Orientation

The process of putting the plane table into some fixed direction so that the line representing a certain direction on the plan is parallel to that direction on the ground.

This is essential to be fulfilled when more than one instrument station is to be used.

1. **Orientation by trough compass:** This is used:
   - Where speed is more important than accuracy.
   - When there is no second point for orientation
   - In certain resection problems.
2. **Orientation by back sighting:** There are two cases in this orientation.

   Case 1: When it is possible to set the plane table on the point already plotted on the sheet by way of observation from previous station.

   Case 2: When it is not possible to set the plane table on the point already plotted. This method is known as **resection**.

Methods of Plane Tabling

1. Radiation.
2. Intersection.
3. Traversing.
4. Resection.

The first two methods are generally employed for locating the details while the other two methods are used for locating the plane table stations.

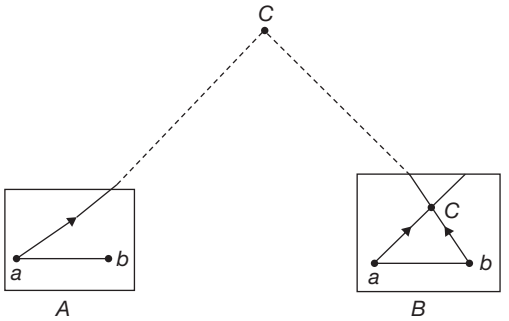
Radiation

- In this method, a ray is drawn from instrument station towards the point, distance is measured between station and point, and the point is located plotting to some scale on the drawing sheet.

- More suitable when the distances are small and one single instrument can control the points to be detailed.
- It has a wider scope if the distances are obtained tacheometrically with the help of telescopic alidade.

Intersection

- Used when the distance between the point and the instrument station is either too large or cannot be measured accurately due to some field conditions.
- Location of an object is determined by sighting at the object from two plane table stations.
- Only linear measurement is taken, and distance between the instrument stations is called base line.
- Sometimes it is also called graphic triangulation, as the intersection point forms a triangle with the instrument stations.



Intersection method

Traversing

- The method is widely used to lay down survey lines between the instrument stations of a closed or unclosed traverse.
- The working principle is same as transit traverse.
- The method is same as radiation, except that the table is placed at each station and foresight is taken from there and the procedure is repeated until last station.

Resection

This is the process of determining the plotted position of the station occupied by the plane table, by means of sight taken towards known points, locations of which have been plotted.

Resection can be done by the following methods.

1. By compass
2. By back sighting.
3. Three point problem.
4. Two point problem.

The Three Point Problem Location of the plane table on the plan, is located by means of observations to three well-defined points whose positions have been known on the ground.

1. Mechanical method (tracing paper)
2. Graphical method
3. Trial and error (Lehmann's) method.

Two Point Problem

Plan table position is plotted on the plan by means of two well-defined points on the ground.

Exercises

1. True meridians at different places converge
(A) from South to North pole.
(B) from Equator to North and South poles.
(C) from North pole to South pole.
(D) None of these

2. The quadrantal bearings of the lines *AB* and *CA* are S30° E and S70° E. The inclined angle *CAB* is _____.

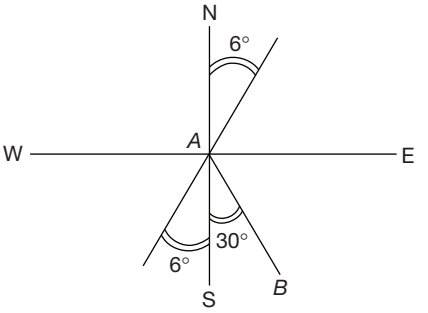
3. The observed magnetic bearing of a line *OE* was found to be 185°. It was later discovered that station *O* had a local attraction of +1.5°. The true bearing of the line *OE*, considering declination of 3.5° E will be
(A) 180° (B) 187°
(C) 190° (D) 193°

4. **Assertion (A):** In a theodolite if the lower clamp is not properly clamped or the instrument is not firmly tightened on the tripod head, the error introduced is known as 'slip'.

Reason (R): If the shifting head is loose, the error 'slip' will be introduced.

(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not a correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

5. The magnetic bearing of a line *AB* is S30° E, if the declination is 6° West, then what is the true bearing?



(A) S36° E (B) N36° W
(C) S24° E (D) N24° W

6. What is $\angle ABC$ if FB of line AB is 40° and BB of line BC is 280°?
(A) 90° (B) 120°
(C) 240° (D) 320°

7. The whole circle bearings of lines OP and OQ are 18°15′ and 335°45′ respectively. What is the value of the included angle QOP?
(A) 307°30′ (B) 42°30′
(C) 354°00′ (D) 177°00′

8. If the observed fore bearing of a line xy is 16°26′ the back bearing of this line is
(A) 103°26′ (B) 118°36′
(C) 196°26′ (D) 206°26′

9. Which of the following set of terms does not relate to operation of a theodolite?
(A) Transiting and inverting
(B) Face left and face right
(C) Right swing and left swing
(D) Gauging and sounding

10. Match List I with List II and select the correct answer:

	List I (Methods)		List II (Procedures)
a.	Traversing	1.	Rays are drawn to locate the station on which the table is set up.
b.	Resection	2.	Atleast two rays are drawn from two different stations to the details to be located.
c.	Intersection	3.	Rays are drawn in the direction of details through the station point on which the table is setup.
d.	Radiation	4.	Rays are drawn on the map by setting up the table over each of the stations towards the subsequent station.

Codes:

	a	b	c	d		a	b	c	d
(A)	4	3	2	1	(B)	2	1	4	3
(C)	4	1	2	3	(D)	2	3	4	1

11. The process of determining the location of the station (on the map) occupied by the plane is called as
(A) intersection. (B) three-point problem.
(C) traversing. (D) resection.

12. Which of the following survey employs alidade?
(A) Contour survey
(B) Defective orientation
(C) Plane table survey
(D) Reconnaissance survey

13. Which of the following errors is more severe in plane table surveying?
(A) Defective sighting
(B) Defective orientation
(C) Movement of board between sights
(D) Non-horizontality of board when points sighted are at large differences of their elevation.

14. Any convenient direction towards a permanent and prominent mark is called
(A) true meridian.
(B) magnetic meridian.
(C) arbitrary meridian.
(D) None of these

15. An offset is laid out 3° from its true direction of the field. If the scale of plotting is 10 m to 1 cm, find the maximum length of offset so that the displacement of the point on paper may not exceed 0.25 mm.
(A) 4.43 (B) 4.58
(C) 4.23 (D) 4.77

16. In a region with magnetic declination of 4° E, the magnetic fore bearing (FB) of a line AB was measured as N82°50′ E. There was a local attraction at A. To determine the correct magnetic bearing of the line, a point O was selected at which there was no local attraction. The magnetic FB of line AO and OA were observed to be S42°40′ E and N48° 20′ W respectively. What is the true FB of line AB?
(A) N81°50′ (B) N82°10′ E
(C) N79°30′ E (D) N84°10′ E

17. The incorrect statement among the following is
(A) the direction of magnetic meridian is variable.
(B) the direction of true meridian is invariable.
(C) the magnetic bearing of line varies with time.
(D) magnetic meridian through various stations are not parallel but converge at poles.

18. After surveying an area with plane table at a station it was detected that the centering of the instrument was not done accurately. The displacement of the plotted point at right angles to the ray was 20 cm. The scale used was 1 cm = 20 m. Determine the error in the plotted position of the point (in cm)
(A) 0.03 (B) 0.04
(C) 0.01 (D) 0.02

19. Pick up the incorrect pair

	Instrument	Use
(A)	Clinometers	Slope
(B)	Prism square	To set perpendiculars
(C)	Line ranger	Ranging end points of survey line.
(D)	Tellurometer	Distance

20. Magnetic bearing = 40°30′. The true bearing is _____.

21. The magnetic bearing of a line is 55°30′ and the magnetic declination is 4°30′ E. The true bearing of a line will be
(A) 60° (B) 34°30′
(C) 49°30′ (D) 51°

22. If for bearing of a line is S49°52′ E (assuming there is no local attraction), the back bearing of the line will be
(A) S52°49′ E (B) S49°52′ E
(C) N49°08′ E (D) N49°52′ W

23. Match List I (Method) with List II (Procedure) and select the correct answer using the codes given below the lists:

	List I		List II
a.	Traversing	**1.**	Rays are down to locate the station on which the table is set–up.
b.	Resection	**2.**	At last two rays are drawn from two different station to the details to be located.
c.	Intersection	**3.**	Rays are drawn in the direction of details through the station point on which the table is set-up.
d.	Radiation	**4.**	Rays are drawn on the map by setting up the table over each of the stations towards the subsequent station.

Codes:

	a	b	c	d		a	b	c	d
(A)	4	3	2	1	(B)	2	1	4	3
(C)	4	1	2	3	(D)	2	3	4	1

24. In a plane-table survey, the process of determining the plotted position of a station occupied by the plane-table by means of sights taken towards known points, the location of which have already been plotted, is known as

(A) radiation. (B) resection.
(C) intersection. (D) traversing.

25. If whole circle bearing of a line is 290° its reduced bearing is _____.

(A) N70° W (B) S70° W
(C) W70° (D) 70° W

26. Identify the methods used for locating the 'plane table stations' in plane table surveying, from the following:

I. Radiation
II. Intersection
III. Traversing
IV. Resection

(A) I and II (B) II and III
(C) III and IV (D) I and IV

Previous Years' Questions

1. The magnetic bearings of a line *AB* is S45° E and the declination is 5° W. The true bearing of the line *AB* is **[GATE, 2007]**

(A) S45°E (B) S40°E
(C) S50°E (D) S50°W

2. In quadrantal bearing system, bearing of a line varies from **[GATE, 2009]**

(A) 0° and 360°
(B) 0° and 180°
(C) 0° to 90°
(D) 0° N to 90° S

3. The magnetic bearing of a line *AB* was N59°30′ W in the year 1967, when the declination was 4°10′ E. If the present declination is 3° W, the whole circle bearing of the line is **[GATE, 2009]**

(A) 299°20′ (B) 307°40′
(C) 293°20′ (D) 301°40′

4. The local mean time at a place located in longitude 90°40′ E when the standard time is 6 hours and 30 minutes and the standard meridian is 82°30′ E is? **[GATE, 2010]**

(A) 5 hours, 2 minutes and 40 seconds
(B) 5 hours, 57 minutes and 20 seconds
(C) 6 hours, and 30 minutes
(D) 7 hours, 02 minutes and 40 seconds

5. Following bearings are observed while traversing with a compass.

Line	Fore Bearing	Back Bearing
AB	126°45′	308° 00′
BC	45°15′	227°30′
CD	340°30′	161°45′
DE	258°30′	78°30′
EA	212°30′	31°45′

After applying the correction due to local attraction, the corrected fore bearing of line *BC* will be: **[GATE, 2013]**

(A) 48°15′ (B) 50°15′
(C) 49°45′ (D) 48°45′

6. In a region with magnetic declination of 2°E, the magnetic fore bearing (FB) of a line *AB* was measured as N79°50′E. There was local attraction at *A*. To determine the correct magnetic bearing of the line, a point *O* was selected at which there was no local attraction. The magnetic FB of line *AO* and *OA* were observed to be S52°40′ E and N50°20′ W, respectively. What is the true FB of line *AB*? **[GATE, 2015]**

(A) N81°50′ E (B) N82°10′ E
(C) N84°10′ E (D) N77°50′ E

7. In a survey work, three independent angles *X*, *Y* and *Z* were observed with weights W_X, W_Y, W_Z respectively. The weight of the sum of angles *X*, *Y* and *Z* is given by **[GATE, 2015]**

(A) $\dfrac{1}{\left(\dfrac{1}{W_X}+\dfrac{1}{W_Y}+\dfrac{1}{W_Z}\right)}$

(B) $\left(\dfrac{1}{W_X}+\dfrac{1}{W_Y}+\dfrac{1}{W_Z}\right)$

(C) $W_X + W_Y + W_Z$

(D) $W_X^2 + W_Y^2 + W_Z^2$

8. The reduced bearing of a 10 m long line is N30°E. The departure of the line is **[GATE, 2016]**

(A) 10.00 m

(B) 8.66 m

(C) 7.52 m

(D) 5.00 m

Answer Keys

Exercises

1. C	**2.** 150°	**3.** B	**4.** B	**5.** A	**6.** B	**7.** B	**8.** C	**9.** D	**10.** D
11. B	**12.** C	**13.** B	**14.** C	**15.** D	**16.** C	**17.** D	**18.** C	**19.** C	
20. 47°0′	**21.** A	**22.** D	**23.** B	**24.** B	**25.** A	**26.** C			

Previous Years' Questions

1. C	**2.** C	**3.** B	**4.** D	**5.** D	**6.** C	**7.** A	**8.** D