

Chapter _4

Angles and Directions

4.1. Introduction

Measurements of angles is basic to any surveying operation. When an angle is measured in a horizontal plane it is *horizontal angle*; when measured in a vertical plane it is *vertical angle*. Angle measurement needs the following:

1. Reference of starting line
2. Direction of turning
3. Angular value (Value of the angle)

These are clearly illustrated in the fig 5.1.1

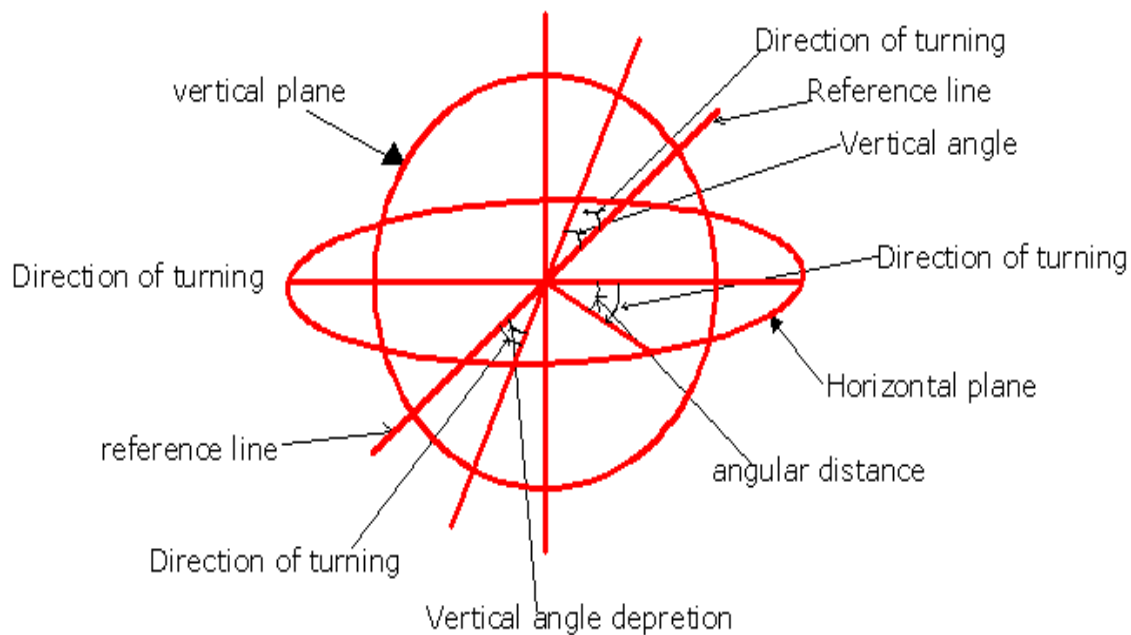


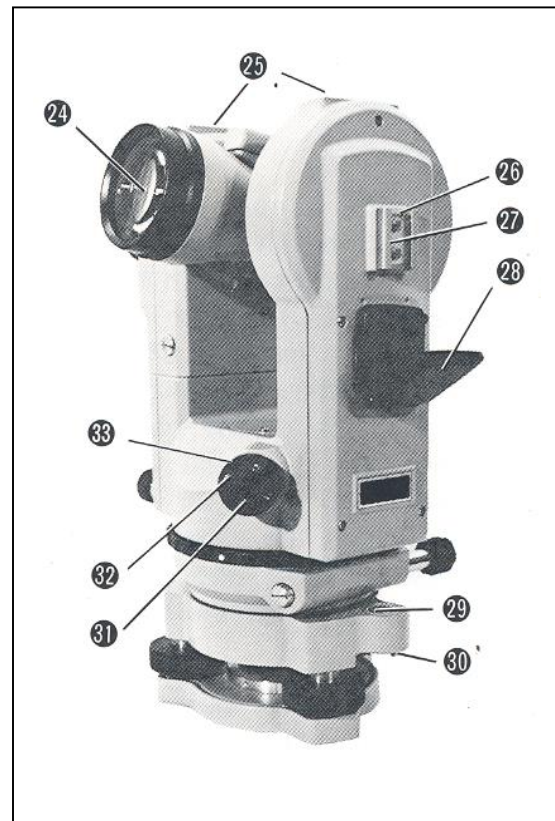
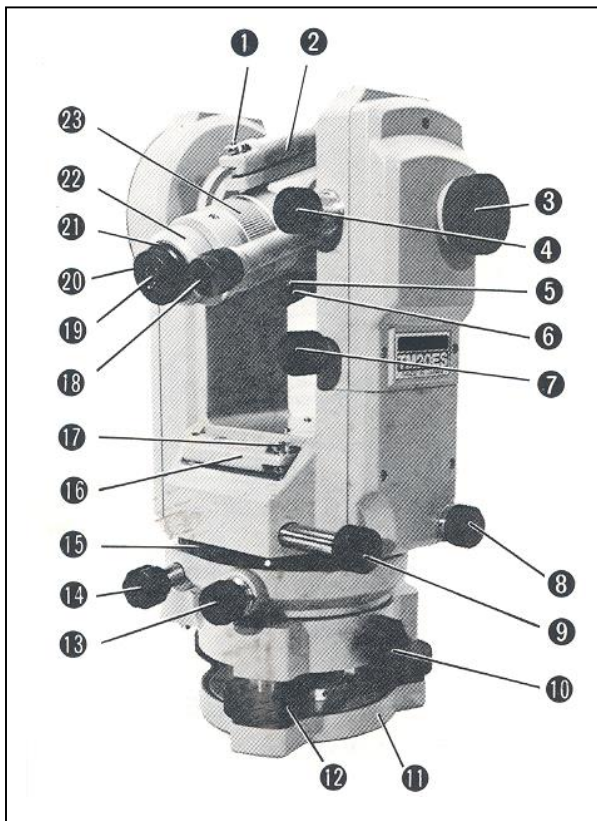
Fig 5.1.1

4.2. Angle measuring instruments

A **theodolite** is an instrument used to measure horizontal and vertical angle. Depending on the facilities provided for reading of observations, theodolite may be classified as:

1. Optical theodolite
2. Digital theodolite

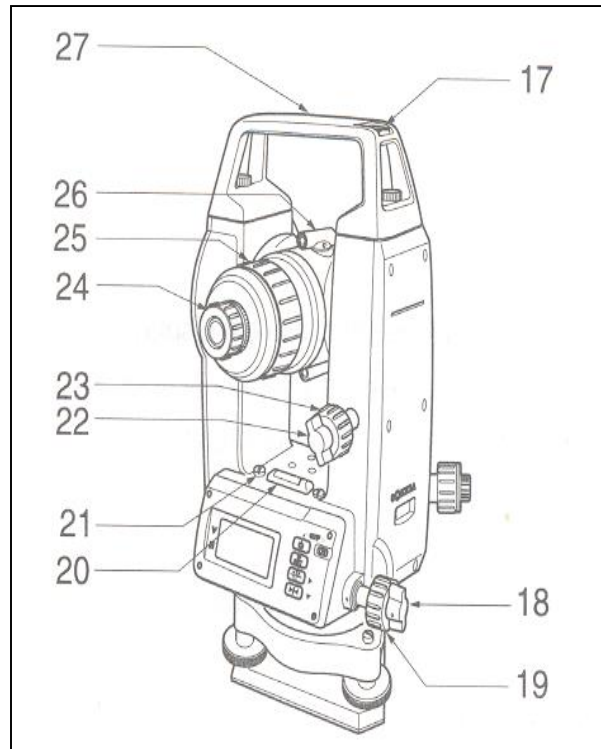
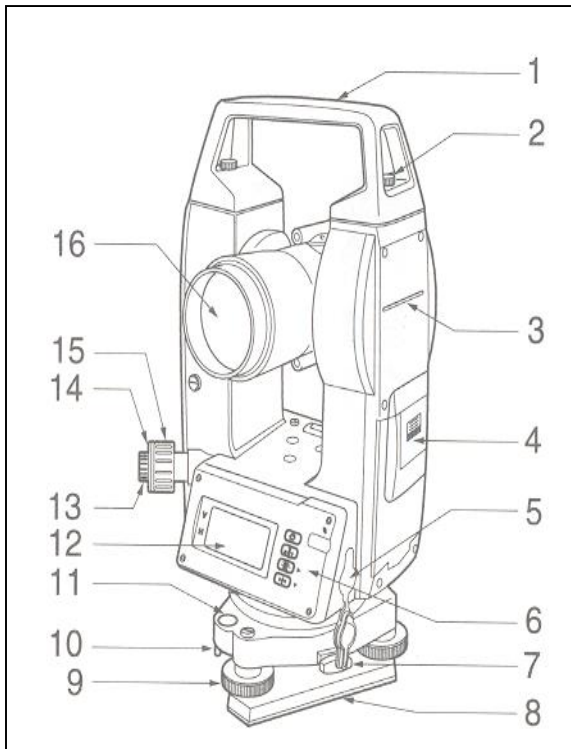
1. Optical Theodolite



1. Telescope level adjustment
2. Telescope level
3. Micrometer knob
4. Telescope motion clamp screw mounting ring
5. Field of view illumination level
6. Collimator sight
7. Vertical slow motion screw
8. Horizontal motion clam screw
9. Horizontal slow motion screw
10. Shifting clamp
11. Base plate
12. Leveling screw
13. Lower motion clamp screw
14. Lower slow motion screw
15. Circle positioning ring adjustment screw
16. Plate level
17. Plate level adjustment screw Circle Positioning ring

18. Micrometer eyepiece
19. Telescope eyepiece
20. Telescope eyepiece
21. Telescope eyepiece
22. Reticule adjustment cover
23. Focusing ring
24. Objective lens
25. Standards
26. Instrument height mark
27. clamping slot
28. light reflector
29. Circular level
30. Circular level adjustment screw
31. Optical plummet
32. Optical plummet
33. Optical plummet focusing ring.

2. Digital Theodolite



1. Handle
2. Handle screwing screw
3. Instrument height mark
4. Battery cover
5. Data output connector
6. Operation panel
7. Tribrach clamp
8. Base plate
9. Leveling foot screw
10. Circular level adjusting screw
11. Circular level
12. Display
13. Optical plummet eyepiece

14. Optical plummet reticule cover
15. Optical plummet focusing ring
16. Objective lens
17. Tubular compass slot
18. Horizontal clamp
19. Horizontal slow motion screw
20. plate level
21. plate level adjusting screw
22. Vertical clamp
23. Vertical slow motion screw
24. Telescope eyepiece
25. Telescope focusing ring
26. peep sight
27. Instrument center mark.

4.3. Preparing theodolite for measurement (Temporary adjustment)

There are different ways to prepare a theodolite for measurements. Among these we noted the below procedure.

This procedure contains four steps.

1. *Stetting up*

Initially the tripod is set up at a convenient height and the instrument is approximately leveled.

2. *Centering*

It is place up the vertical axis exactly over the station

It is done by means of a foot screw

3. *Leveling up*

- The circular bubble is then accurately leveled with the help of tripod and
- The cylindrical bubble of the instrument fairly leveled by using foot screws to level the cylindrical bubble.

4. *Focusing*

This done in two steps. The first step is focusing the eye piece. This is done by turning either in or out until the crosshairs are sharp and distinct. This will vary from person to person as it depends on the vision of the observer. The next step is focusing the object. This is done by means of the focusing screw where by the image of the staff is brought to the plane of the crosshairs.

4.4 Types of horizontal angle

Horizontal angle can be

1-Interior horizontal angle (included)

2 Deflection horizontal angles

Interior angles:-can be clockwise or anticlockwise depending on the direction of turning the upper part of the theodolite. (Fig 5.3.1a and b)

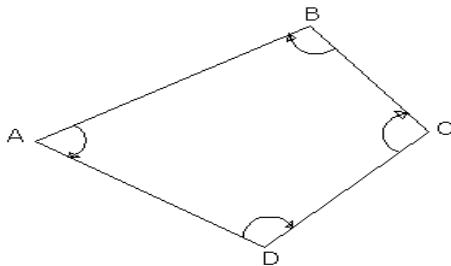


Fig5.3.1a

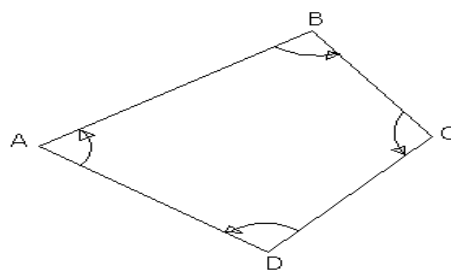
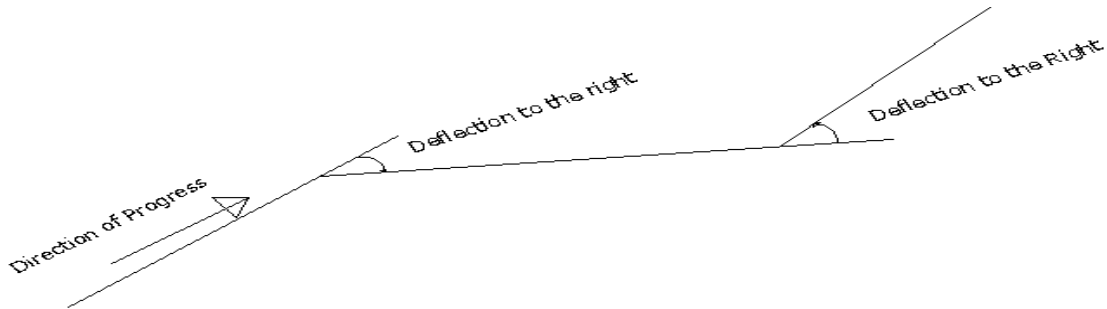


Fig5.3.1b

Deflection angles: - similarly deflection angle can be deflection to the right (clockwise) and deflection to the left (anticlockwise).fig5.3b



4.5 Direction

Direction of a line is the horizontal angle measured from a reference line called (Reference north).

There are four basic types of North.

- 1. Astronomic north**

It is an imaginary line on the earth's surface passing through the north–South geographical north.

- 2. Magnetic north**

- It is the direction of a vertical plane shown by a freely suspended magnetic needle.
- It will be measured by surveyor compass.

- 3. Grid North-**

- A line through a point parallel to the Y–axis of a rectangular coordinate system on the map.

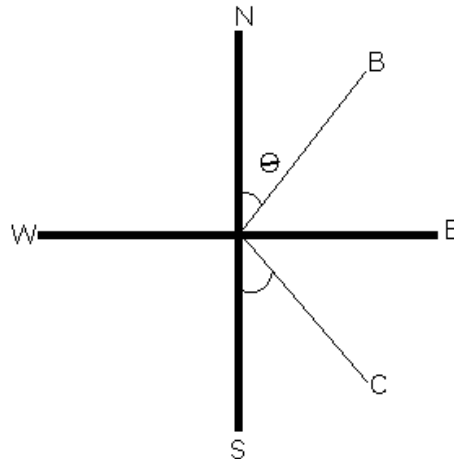
- 4. Arbitrary North**

- An arbitrary chosen line with a directional value assigned by the observer.

4.6. Bearing and Azimuth

4.6.1. Bearing

- **Bearing** of a line is an angle with reference to north or south direction.
- Bearing can be measured clockwise or anticlockwise.
- It is measured with reference to North or south.
- The range of bearing is ($0^0 - 90^0$)



Illustrative example

θ = bearing of line AB

It will be written as N <Angular value > E

If $\theta = 40^0 15'$ we can say that; Bearing AB = N $40^0 15'$ E

Bearing of line AC

- It is measured from south direction

- It will be measured as S < β > E

If $\beta = 32^0 20' 16''$, Bearing of AC is S $32^0 20' 16''$ E

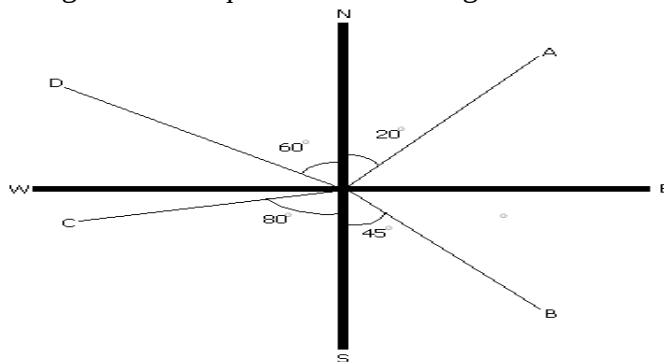
Format of bearing

Bearing in the I - quadrant is N <angular Value> E

Bearing in the II – quadrant is S < angular Value > E

Bearing in the III- quadrant is S <angular Value> W

Bearing in the IV- quadrant is N <angular Value> W



Bearing of
 OA = N 20^0 E
 OB = S 45^0 E
 OC = S 80^0 W
 OD = N 60^0 W

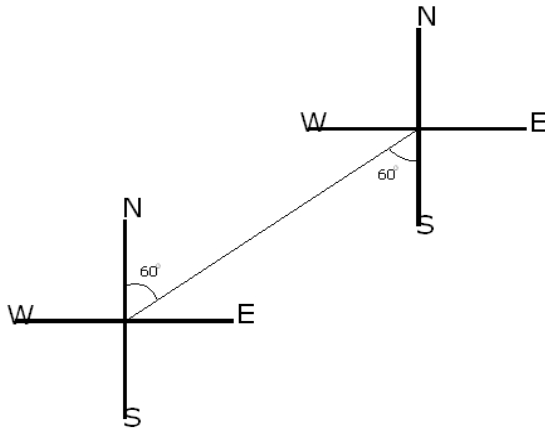
4.6.2 Back bearing

Back bearing is a reverse bearing.

For example

Forward bearing of line AB is $N 60^{\circ}E$

Backward bearing of AB is = bearing BA
= $S 60^{\circ}W$



To determine the back bearing from forward bearing,

1. Draw a line parallel to N-S direction at the end of a line.
2. Determine the quadrant in which backward line lies.
3. Mention the back bearing by using direction and angular value.

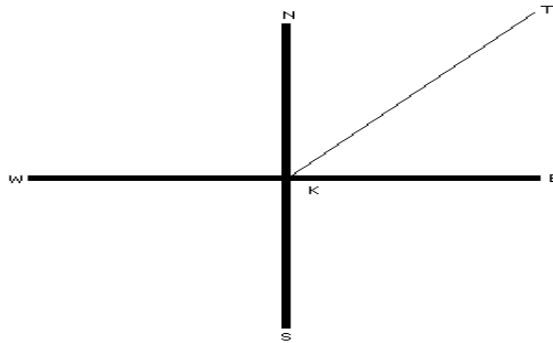
The angular value is equal to the forward bearing. Since alternative interior angles of parallel lines are equal.

Illustrative example

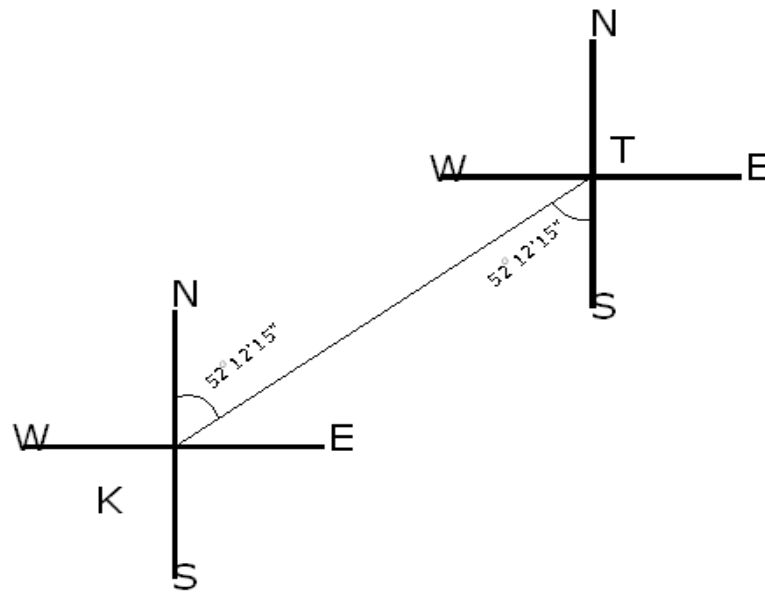
Find the back bearing of line KT if a forward bearing of KT is $N 52^{\circ}12'15'' W$.

Solution

1. Mark point K
2. Draw N-S and W-E line crossing at these points.



3. Draw line KT approximately at a given angle starting from point K
4. Draw N-S and W-E line through point T so that they are parallel to the lines through

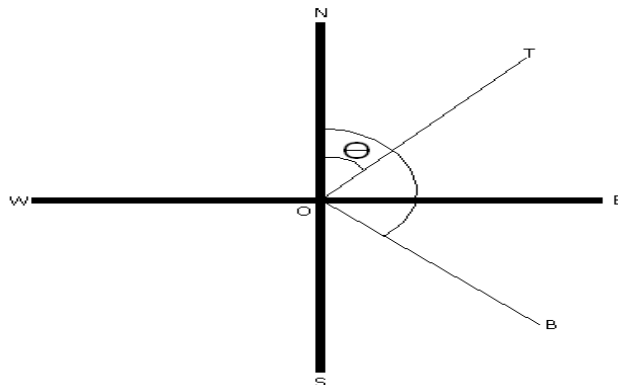


5. Back bearing of KT = bearing of TK
 = S $52^{\circ}12'15''$ E

4.6.3 Azimuths

- It is an angle measured clockwise from a reference north.
- It is always measured clock wise and north direction
- Its range is $[0,360]$
- Unlike bearing the direction will not mentioned
- Azimuth sometime called **Whole Circle Bearing**

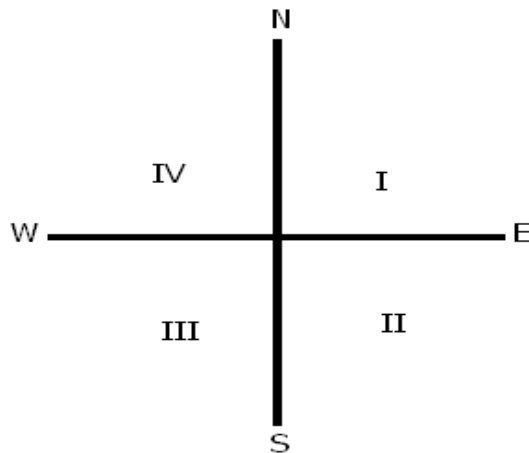
Example.1



Azimuth of line OT = θ

Azimuth of line OB = β

Range of Azimuth in different quadrants



In I Quadrant

Azimuth between 0° - 90°

In II Quadrant

Azimuth is between 90° - 180°

In III- Quadrant

Azimuth is between 180° - 270°

In IV quadrant

Azimuth is between 270° - 360°

The relationship between azimuth and bearing

The relationship b/n bearing and azimuth in different quadrants is different.

In I quadrant Angular Value of bearing = Azimuth

In II quadrant Azimuth = 180° - angular value of bearing

In III quadrant Azimuth = 180° + angular value of bearing

In IV Quadrant Azimuth = 360° - angular Value of bearing

4.6.4 Back azimuth

Similarly to bearing the back azimuth is the reverse of forward azimuth

Back azimuth of AB = Azimuth of BA

The angular difference b/n forward and backward azimuth is equal to 180°

Computing a back azimuth from forward azimuth

If a forward azimuth is less than 180° , Backward azimuth = forward Az + 180°

If a forward azimuth is greater than 180° , Backward azimuth = foreword azimuth - 180°

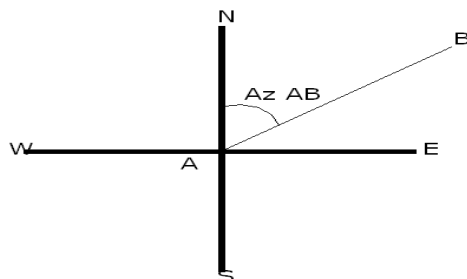
Example

Find the backward azimuth of the following lines having foreword azimuth

<u>Line</u>	<u>Forward azimuth</u>
AB	$43^{\circ}11'20''$
BC	$112^{\circ}20'15''$
CD	$197^{\circ}18'36''$
DE	$320^{\circ}17'40''$

Solution

A.

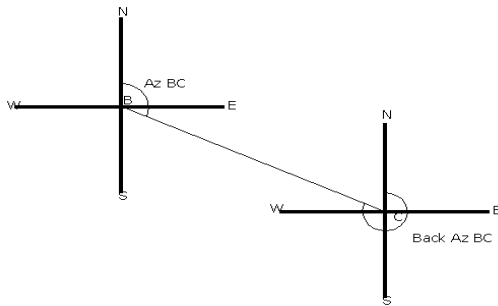


Since Az AB < 90°

$$\begin{aligned} \text{Az BA} &= \text{Azimuth of AB} + 180^{\circ} \\ &= 43^{\circ}11'20'' + 180^{\circ} \end{aligned}$$

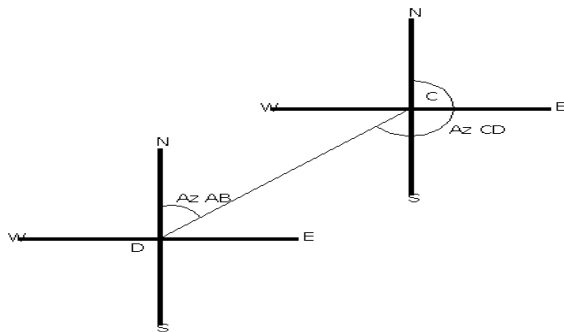
$$= \underline{223^0 11' 20''}$$

B.



Since $90^0 < \text{Az BC} < 180^0$
 Back azimuth of line BC = $112^0 29' 15'' + 180^0$
 = $\underline{290^0 29' 15''}$

C.



Since $180^0 < \text{Az CD} < 270^0$
 Back azimuth of CD = $\text{Az CD} - 180^0$
 = $197^0 18' 36'' - 180^0$
 = $\underline{17^0 18' 36''}$

D. Since $270^0 < \text{Az DE} < 360^0$

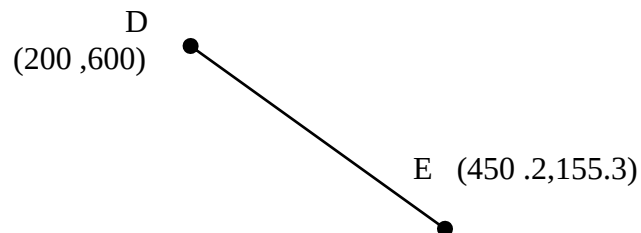
Back azimuth DE = $\text{Az DE} - 180^0$
 = $320^0 17' 40'' - 180^0$
 = $\underline{140^0 17' 40''}$

4.6.5 Computing bearing and Azimuth of a line given coordinates

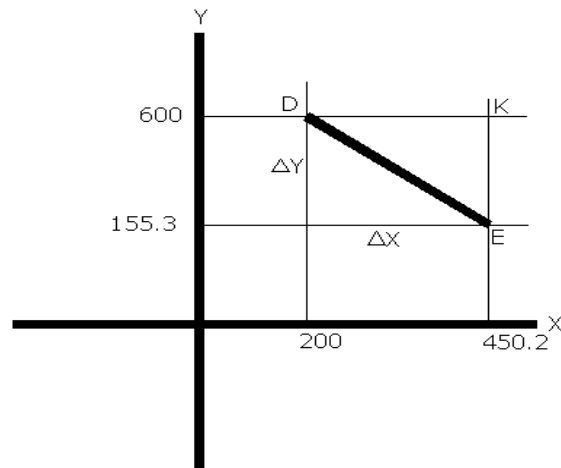
Suppose

Illustrative Example-1

Calculate bearing and azimuth of line DE,



Soln



1. Draw Parallel lines through E and D
Parallel to the X-and Y- axis
2. Since it lies in II quadrant, bearing
will be measured from south direction
3. Calculate ΔX and ΔY

$$\begin{aligned}
 \Delta X_{DE} &= X_E - X_D \\
 &= 450.2 - 200 \\
 &= 250.2 \\
 \Delta Y_{DE} &= Y_E - Y_D \\
 &= 155.3 - 600 \\
 &= -444.7 \\
 \tan \Theta &= \frac{\Delta X}{\Delta Y}
 \end{aligned}$$

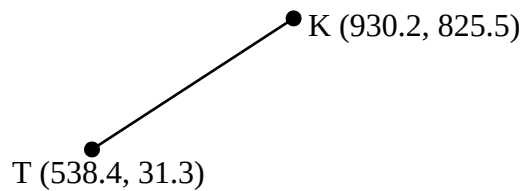
$$\begin{aligned}
 \Theta &= \tan^{-1} \left[\frac{250.2}{-444.7} \right] \\
 \Theta &= -29^{\circ}21'48''
 \end{aligned}$$

Since $\Delta Y = -ve$ and $\Delta X = +ve$ the line lies in the II quadrant

$$\begin{aligned}
 \text{Therefore} \\
 \text{Bearing of DE} &= S 29^{\circ}21'48'' E \\
 \text{Azimuth of DE} &= 180^{\circ} - \text{Bearing of DE} \\
 &= 180^{\circ} - 29^{\circ}21'48'' \\
 &= 150^{\circ}38'12''
 \end{aligned}$$

Illustrative Example-2

Suppose line KT has the following coordinates.



Calculate bearing and azimuth of line KT.

Solution

$$\begin{aligned}\Delta X &= X_T - X_K \\ &= 538.4 - 930.2 \\ &= -391.8 \\ \Delta Y &= Y_T - Y_K \\ &= 31.3 - 825.5 \\ &= -794.2 \\ \tan \Theta &= \frac{\Delta X}{\Delta Y} \\ &= \frac{-391.8}{-794.2} \\ \Theta &= \tan^{-1} \left[\frac{-391.8}{-794.2} \right] \\ \Theta &= 26^{\circ}15'30''\end{aligned}$$

But both ΔX and ΔY are -ve

This implies the line KT lies in III quadrant.

Therefore Bearing of line KT = S $26^{\circ}15'30''$ W

And azimuth of KT = bearing + 180° = $206^{\circ}15'30''$

4.7. Compass survey

In compass surveying, the horizontal angles are measured with the help of a magnetic compass, in addition to the linear measurements with a chain or a tape.

Magnetic Declination

The horizontal angle between true north and magnetic north is known as magnetic declination. The earth's magnetic force not only aligns a freely suspended magnetic needle along magnetic north and south but also pulls or dips one end below the horizontal position.

Declination may be towards east or west. When the magnetic north is towards the west of true north, the declination is west or negative, when towards east; it is east declination or positive.

A line on a map or chart connecting points that have the same declination is called **isogonic** line and **agonic** line consists of pointing having zero declination.

The declination at a place does not remain constant but changes with time. These changes are

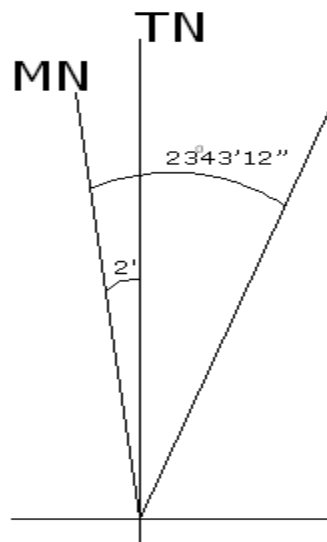
- i. Secular change
- ii. Annual change
- iii. Diurnal change
- iv. Irregular change

- i. **Secular change:** - this occurs over a long period of time approximately for 250 years. The magnitude also is very high. However, this variation does not follow any general law. It can be obtained only from detailed charts and tables derived from observations.
- ii. **Annual change:** - It is a variation over a year. It is roughly 1'-2' in amplitude. It varies from place to place.
- iii. **Diurnal change:** - means variation over a day. It depends on the following four factors :
 1. Locality: It is greater near the pole and less near equator
 2. Season : It is greater in summer than in winter
 3. Time: It is more during day and less during night. The rate of variation over 24hrs is quite irregular.
 4. Year: The daily variation changes from year to year
- iv. **Irregular variation:** is caused by unpredictable magnetic disturbances and storms. The magnitude of variation is more than a degree.

Illustrative example

1. The magnetic bearing of a line is measured and found to be $N23^{\circ}43'12''$ E. if the declination at the time of measurement was 2' east, calculate the true bearing of this line.

Solution

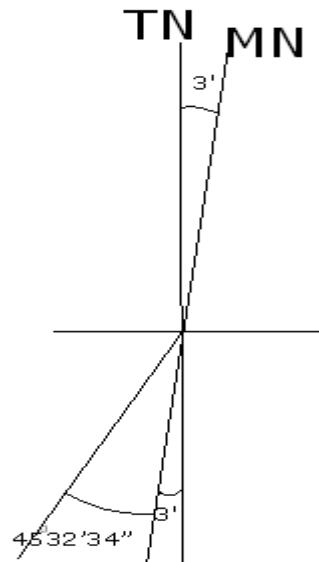


As you can see from the fig

$$\begin{aligned}
 \text{True bearing} &= \text{Magnetic bearing} - \text{magnetic declination} \\
 &= 23^{\circ}43'12'' - 2' \\
 &= 23^{\circ}41'12''
 \end{aligned}$$

2. Find true bearing of a line AB if magnetic bearing is S $45^{\circ}32'34''$ W. Use declination at a time was 3' west.

Solution



$$\begin{aligned}
 \text{True bearing} &= \text{magnetic bearing} + \text{declination} \\
 &= 45^{\circ}32'34'' + 3' \\
 &= \underline{45^{\circ}35'34''}
 \end{aligned}$$