1

Fundamentals of Surveying

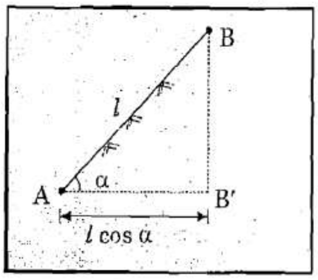
Introduction

- Surveying may be defined as the method of making measurements of the relative positions of, natural & man-made features on earth's surface and the presentation of this information either graphically or numerically.
- The commonest methods of presentation are by means of a **Plan** or **Map**.
- Both **Plans** and **Maps** are the graphical representations of the features on a horizontal plane.
- **Plan** is a *large scale* representation whereas **Map** is a *small scale* representation.
- Height information can be added either as **spot heights,** which are individual heights of points, or as contours which give a less detailed but better visual representation of the area.

Plane & Geodetic Surveying

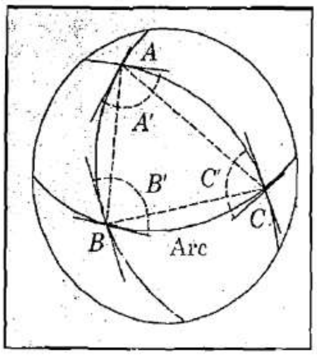
- Surveying is divided primarily into **Geodetic surveying & Plane surveying**.
- In **Geodetic surveying,** large areas of earth's surface are involved and the **curvature of earth is taken into account.**
- In **Plane surveying,** relatively small areas are under consideration, and it is assumed that the earth's surface is flat.
- In Plane surveying, measurements plotted will represent the projection on the horizontal plane of the actual field measurements.

  For example, AB is plotted as AB′



- A horizontal plane is normal to the direction of gravity (as defined by a **Plumb bob** at that point).
- However, such a plane will infact be **tangential to the earth's surface** at that point.

  Thus, if a large area is considered, the descripency will become apparent between the area of the horizontal plane and the actual curved area of the earth's surface.



- In the above figure if actual area is ABC, the projected area will become A'B'C'.

Note:

That Arc AC will be projected as Chord A′C′ represented by dotted line. If Arc AB = 18.5 km then Chord A'B' will be 1.52 cm shorter than Arc AB.

- Length AB, BC & CA in Geodetic surveying are determined using spherical trigonometry, whereas lengths A'B', B'C' & C'A' are determined in plane surveying using plane trigonometry.
- For Survey upto 195.5 km^2 in area, this descrepency is not serious and therefore plane surveying will be adequate. However precautions are required when connecting such survey to control points established and co-ordinated by geodetic surveys.
- Plane surveys are done for engineering projects such as factories, bridges, dams, location & construction of canals, highways, railways etc.
- Geodetic surveying is done for fixing widely spaced **control point**, which may afterwards be used as necessary control points for fixing minor control points for plane survey.
- Geodetic survey is carried out by Department of National Survey of India.

Note:

Control points are points of known co-ordinates. It is used as a reference for taking other measurements during surveying.

Classification of Surveying based on Purpose

Based on the purpose the surveys can be classified as under.

1. Topographical Survey

It is a survey conducted to obtain data and to make a map indicating inequalities of land surface by measuring elevations and locating the natural and artificial features of the earth, e.g. rivers, woods, hills, etc. There scales ranges from 1 : 25 000 to 1 : 1000000.

2. Engineering Survey

- These are survey work required before, during and after any engineering works.
- Before any work is started, large-scale topographical maps or plans are required as a basis for design.
- It is especially used for the design and construction of new routes, e.g. roads and railways.
- It is also used to calculate the areas and volumes of land and data for setting out curves for route alignment.

Typical scales are as follows:

• Building work	1 : 50,	1 : 100,	1 : 200		
• Site plans, Civil engineering works:	1 : 500,	1 : 1000,	1 : 1250,	1 : 2000,	1 : 2500
• Town surveys, Highway surveys:	1 : 1250,	1 : 2000,	1 : 2500,	1 : 5000,	1 : 10000,
	1 : 20000,	1 : 50000			

3. Cadastral Survey

- These are undertaken to produce plans of property boundaries for legal purposes. These are also known as public land survey. Scales are 1 : 1000 to 1 : 5000

4. Hydrographic Survey

- These surveys are conducted on or near the water body, such as lakes, rivers, bays, harbours. Marine surveys are special type of hydrographic surveys, covers a broader area near sea for offshore structures, navigations, tides, etc.

- The hydrographic survey consists of locating shore lines, water flow estimation, and determination of the shape of area under the water surface, determination of channel depth, location of locks, sand bars, buoys, etc.

5. Astronomic Survey

- These surveys are conducted for determination of latitudes, longitudes, azimuths, local time, etc. at various places on the earth by observing heavenly bodies (the sun or stars).

Note:

The absolute locations of a point on the earth surface is obtained by astronomic surveys.

6. Geological Survey

- These surveys are conducted to obtain information about different strata of the earth's surface for the purpose geological studies. Geological maps are prepared depicting the details of the strata.

Classification of Survey based on Instruments used

Based on the instruments used, the surveys can be classified as under:

1. Chain Surveying

It is the simplest type of surveying in which only linear measurements are taken either with a chain or a tape.

Note:

Angular measurements are not taken in chain surveying.

2. Compass Surveying

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

- Although a magnetic compass is not a precise angle-measuring instrument, hence the compass survey is not very accurate. However, it is more accurate than a chain survey.

3. levelling

In this type of survey a levelling instrument is used for determination of relative elevations (levels) of various points in the vertical plane.

4. Plane Table Surveys

In this type of survey, a map (or plan) is prepared in the field while viewing the terrain after determining the directions of various lines and measuring the linear distances with a chain or a tape.

- The accuracy of the plane table survey is low. Its main advantage is that the measuremtns and plottings are done simultaneously in the field.

5. Theodolite Surveys

In this type of survey horizontal and vertical angles are measured with the help of theodolite. A theodolite is a very precise instrument used for measuring horizontal and vertical angles.

The theodolite surveys can be broadly classified into two types:

(i) Traverse survey

(ii) Triangulation survey

- In traverse survey, the various stations form a polygon. The horizontal angles are measured with the help of a theodolite, whereas the linear measurements are made with a tape.
- In triangulation survey, the lines form a system of triangles. The base line is measured accurately and the lengths of all other lines are computed from the measured angles.
- Triangulation is used for establishing control points over extensive areas.

Note:

Theodolite surveys are quite accurate.

6. Tacheometric Surveys

- In this type of survey a special type of theodolite called as Tacheometer is used, which is fitted with a stadia diaphragm having two horizontal cross hairs in addition to the central horizontal hair.
- In tachcometric surveying, horizontal angles, horizontal distances and vertical distances (elevation) are measured with tacheometer.
- Although tacheometric surveys are not very accurate in plane areas, but these are extremely convenient and gives better result then the theodolite surveys in rough terrain.

7. Photogrammetric Surveys

- Photogrammetry is the science of taking measurements with the help of photographs.
- Photogrammetric surveys are generally used for Topographic mapping of large areas.
- These are extremely useful for obtaining Topographical details of areas which are difficult to access.
- Photographs are generally taken from an aeroplane. However, for certain areas where suitable sites exist, photographs can be taken from ground-based cameras.

8. EDM Surveys

- Trilateration is a type of triangulation in which all the three sides of each triangle are measured accurately with the help EDM instruments.
- Then angles are computed indirectly form the known sides of the triangles.
- Hence all the sides and angles are determined.

Note:

Trilateration is also used for fixing the position of control points like triangulation. With the help of modern EDM instruments, the trilateration is more convenient in comparision to triangulation and is a major means of control surveys.

Principles of Surveying

There are two basic principles of surveying.

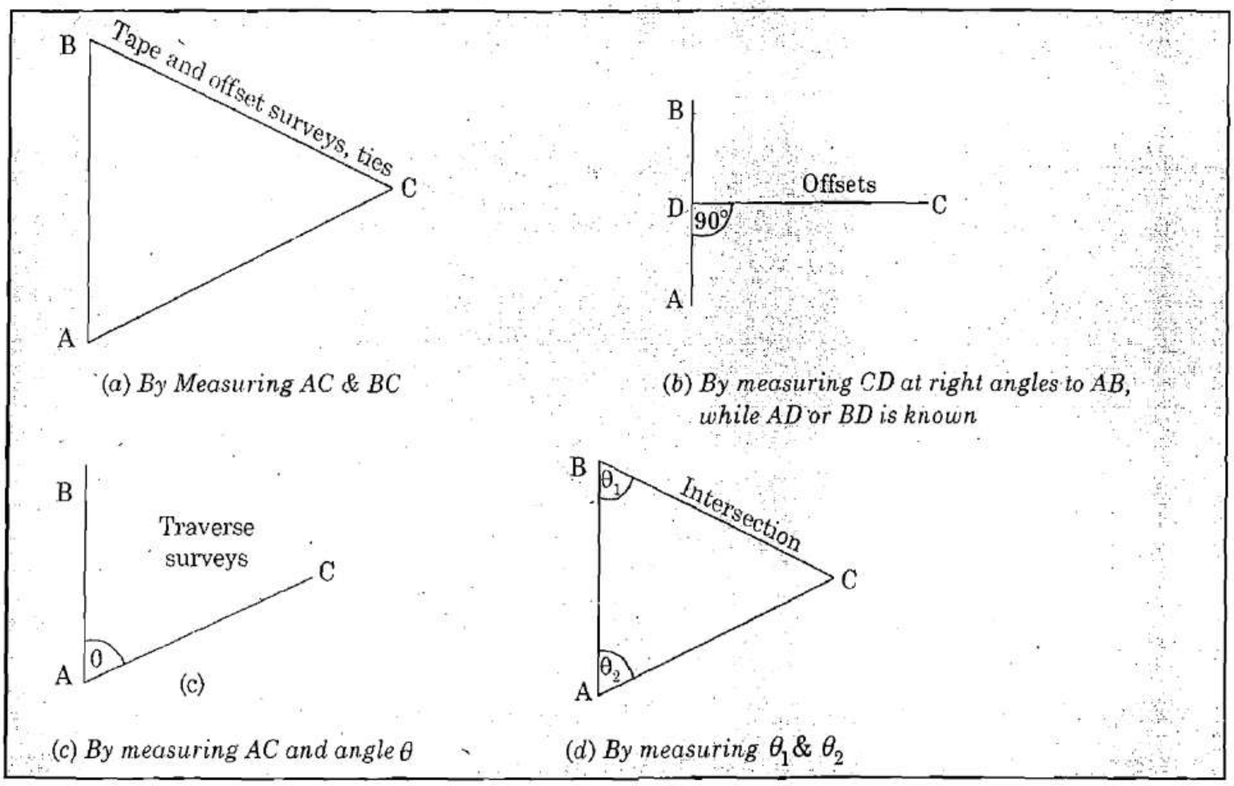
1. Work from whole to part.
2. Locate a point by at least two measurements.

1. Work from Whole to Part

- The main idea of working from whole to part is to localize the errors and prevent their accumulation.
- The survey area is covered with the simplest possible frame-work of high-quality measurements. If the rest of the survey work is carried out within this area, the possible accumulation of error can be contained.
- If we work from part to whole, the errors accumulate and expand to a greater magnitude in the process of expansion of survey.

2. Locate a Point by at Least Two Measurements

- Two control points A & B (any two important features) are selected in the area and the distance between them is measured accurately. Line AB is called baseline.
- If A and B be the two control points, whose positions are already known on the plan, the position of C can be plotted by any of the following methods.



(a) By Measuring AC & BC

(b) By measuring CD at right angles to AB, while AD or BD is known

(c) By measuring AC and angle θ

(d) By measuring θ_1 & θ_2

Scale of a map

- Scale of a map or plane represents the ratio of a line on the map (or plan) to the length of the same line on ground.
- A scale may be represented numerically by Engineer's scale or Representative Fraction.
- The Engineer's scale is represented by a statement, eg 1 cm = 40 m
- When a scale is represented as a fraction, it is called as **Represantative Fraction**

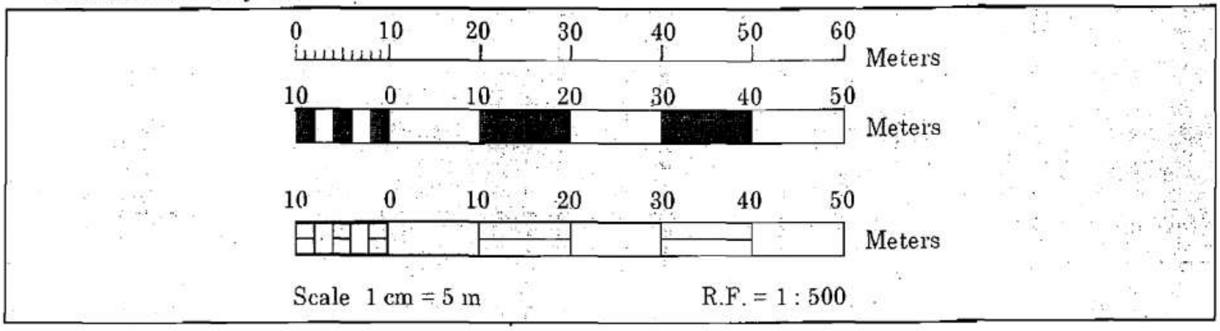
Engineer's scale   1 cm = 40 m

Representative Fraction (R.F) = $\frac{1}{4000}$

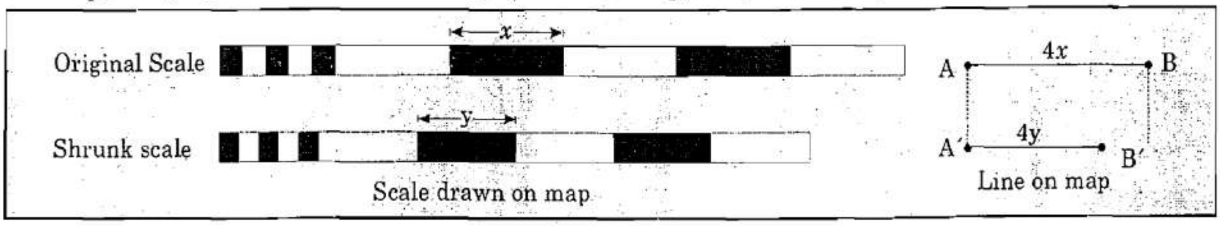
Note:

$\frac{1}{1000}$ *scale is larger scale than* $\frac{1}{10000}$ *scale*

- Scale can also be **graphically** represented by drawing a line on map and marking the ground distance directly on it.



- The graphical scales have the advantage over the numerical scales that the distances on the maps can be determined by actual scaling even when the map has shrunk. In the case of shrinking of map, the graphical scale also changes with the map, and, therefore, the ratio is unaffected.



- If x mm on map = 100m on ground, then length of line AB will be 400m.
- If now the map shrinks such that 100m is represented by y mm on map, then again the distance A′B′ measured on map, with the help of scale on map, will be 400 m.

  This is the advantage of graphical scale.

- Shrunk scale = $\frac{y}{100 \times 1000}$
- Original scale = $\frac{x}{100 \times 1000}$
- $\boxed{\frac{\text{Shrunk length}}{\text{Original length}} = \frac{y}{x} = \frac{\text{Shrunk Scale}}{\text{Original scale}}}$
- The ratio of shrunk length to the actual length is known as Shrinkage Ratio (SR), or Shrinkage Factor (SF)

  Thus,

- $\boxed{\text{Shrinkage ratio (SR) or (SF)} = \frac{\text{Shrunk length}}{\text{Original length}} = \frac{\text{Shrunk Scale}}{\text{Original scale}} = \frac{\text{Shrunk RF}}{\text{Original RF}}}$

$$\boxed{\text{Correct distance on map in terms of original scale} = \frac{\text{measured distance on map}}{\text{SF}}}$$

$$\boxed{\text{Correct area on map in terms of original scale} = \frac{\text{measured area on map using planimeter}}{(\text{SF})^2}}$$

CHAPTER

2

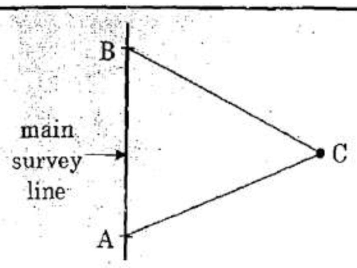
Linear Measurements

Introduction

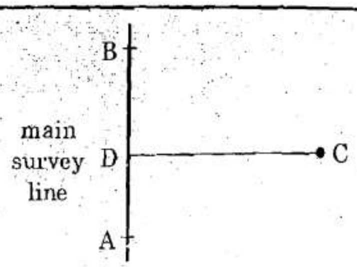
- Surveying is often referred to as chain surveying (or tape and offset surveying), if the principal item of equipment traditionally used is a measuring chain tape.
- Now a days, as a result of improvements in manufacturing techniques and a consequential reduction in purchase price, the chain has been replaced by the more accurate steel band.
- Chain surveying is used for areas of small extent on open ground having few simple details. It is not suitable for large areas having many details.
- In surveying, the term detail means a natural or man-made feature at or near the ground surface. It consists of
  1. Hard details such as buildings, roads, walls;
  2. Soft details; such as a vegetations, trees, river;
  3. Overhead details, such as power and telephone lines
  4. Underground details, such as water mains, sewers.

Procedure in Chain Surveying

- Chain surveying consists of measuring the lengths of a series of straight lines with tape/chain and then locating the details on the ground relative to these lines.
- The details are located by measuring two other lines, known as **ties** or by measuring **offsets** at right angles to the main survey line.



C is located measuring AC & BC, where AC & BC are called Ties.

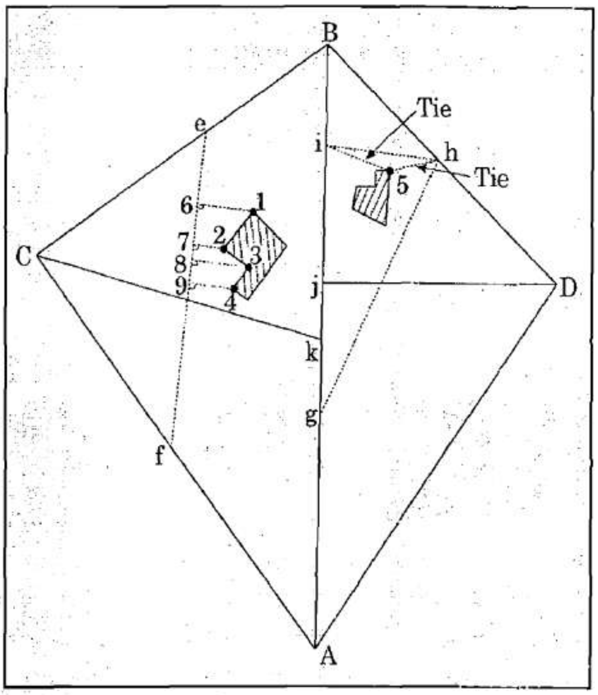


C is located by measing offset CD and length AD

- When larger area is to be surveyed using ties & offset method, a network of triangle covering the complete area is made and then details are noted with respect to the sides of these triangles using ties & offset method.

Basic Definitions

In larger area Survey, the following terms need to be under stood.



Main Station

Main station is a point in chain survey where the two sides of a triangle meet. These stations command the boundaries of the survey. Here A, B, C, D are the main stations.

Tie Station or Subsidiary Station

Tie station is a station on a survey line joining two main stations. These are helpful in locating the interior details of the area to be surveyed, e, f, g, h, i are the tie stations.

Main Survey Line

The chain line joining two main survey stations is called main survey line. AD, DB, BC, CA, BA are main survey lines.

Tie Line or Subsidiary Line

A chain line joining two tie stations is called *tie line* such as *ef* or *gh*. These are also called *auxiliary line*. Tie lines are provided to locate the interior details which are far away from the main survey lines.

Base Line

- It is the longest main survey line on a fairly level ground and passing through the centre of the area.
- It is the most important line, as the direction of all other survey lines are fixed with respect to this line. AB is the base line.

Check Line

Check line or *proof line* is a line provided to check the accuracy of the field work. The measured length of the check line and the computed one (from the scale of the plan) must be the same. Ck & Dj are check lines. Check line is not required for plotting the point.

Offset

It is the distance of the object from the survey line. It may be perpendicular or oblique. 1-6, 2-7, 3-8, are offsets.

Chainage

- Chainage is the distance measured along the main survey line in the direction of progress of work.
- In other words, Chainage is a cumulative increase of distance measured from a starting point, normally at one end of the project i.e., the point of zero chainage. Thus a point with chainage 2000 m would be 2 km along the project from the starting point.

- The term chainage is used in linear construction projects such as roads, railways and sewers to distinguish a unique point on the works.

Well conditioned triangle

- In chain surveying attemps should be made to select main survey stations such that they form well conditioned triangle.
- A triangle is said to be well-conditioned if all intersections of lines are clear for plotting purposes.

No clear intersection at A *Clear intersection at A*

If the angle between lines are between 30° to 120°, clear intersections are achieved.

Note:

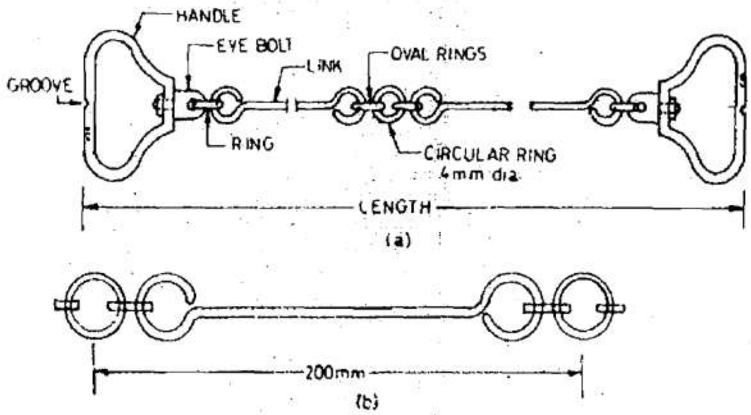
An equilateral triangle will be the most appropriate well conditioned triangle.

Equipments used in Chain Surveying

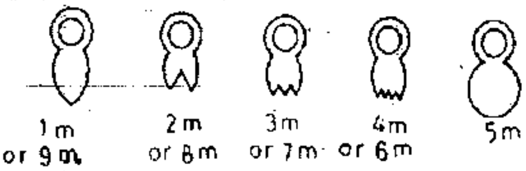
(a) Equipments for measuring lines

Surveying Chain

- A Surveying Chain, or simply a chain, is commonly used for measurement of distances where a very high accuracy is not required. A chain consists of a number of large links made of galvanised mild steel wire of 4mm diameter.



To enable the reading of fraction of a chain length without difficulty, brass tallies (or tags) and rings are attached to the chain at some fixed interval. For 10 m long chain, brass tallies are fixed at every metre of the chain. The shape of tallies at 1m, 2m, 3m, 4m, and 5m is shown in fig. below. The shape of tallies at 6m, 7m, 8m & 9 m are identical to those at 4m, 3m, 2m & 1m respectively.



(b)

Types of Chain

The various types of chains are as mentioned under below:

Revenue chain — 33 ft long (16 links)

Gunter's chain — 66 ft long (100 links),

Engineer's chain — 100 ft long (100 links)

Metric chains — 30 m (150 links) or 20 m (100 links)

Note:

1 mile = 80 Gunter's chain
1 acre = (10 Gunter's chain)^2
The surveying chain is not as accurate as a steel tape or steel band.

Suitability of Chain

1. It can be read easily.
2. It is suitable for rough use only.
3. It can be easily repaired in field.

Unsuitability of Chain

1. As being heavier, it sags considerably when suspended in air.
2. It is suitable for ordinary work only because the length of links gets altered by shortening/lengthening.

- As per IS specifications, every metre length of the chain should individually be accurate to within ± 2 mm when measured under a tension of 80 N (8 kgf).
- The overall length of the chain should be within the limits given below

(a) 20 m ± 5 mm for 20 m chain

(b) 30 m ± 8 mm for 30 m chain.

Tapes

Tapes are available in a variety of materials, lengths and weights. The different types of tapes used in general are discussed as below.

1. Cloth or Linen Tape

This is closely woven linen or synthetic material and is varnished to resist the moisture, and are available in lengths of 10-30 m and widths of 12-15 mm.

Disadvantages of Cloth or Linen Tape are:

1. It is affected by moisture and gets shrunk.
2. Its length gets changed by stretching.
3. It is likely to twist and does not remain straight in strong winds.

2. Metallic Tape

- This is a linen tape with brass or copper wires woven into it longitudinally to reduce stretching. The wires are not visible because it is varnished. These are available in lengths of 20-30 m.
- It is an accurate measurement device and is commonly used for measuring offsets.
- As it is reinforced with brass or copper wires, all the defects of linen tapes are overcome.

3. Steel Tape

- It is more accurate than metallic tapes. They are made up of steel or stainless steel strips. These are available in lengths of 1-50 m and width of 6-10 mm.
- At the end of the tape a brass ring is attached, the outer end of which is zero point of the tape.
- Steel tapes cannot be used in ground with vegetation and weeds.

4. Invar Tape

These are made up of an alloy of nickle (36%) and steel (64%). These tapes have very low coefficient of thermal expansion (0.122×10^{-6}/°C). These are available in lengths of 30, 50 and 100 m and width of 6 mm.

Advantages of Invar Tape

1. Highly precise.
2. It is less affected by temperature changes in comparission to the other tapes.

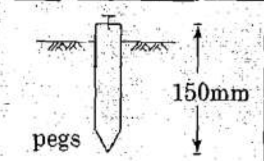
Disadvantages of Invar Tape

1. It is soft hence deforms easily.
2. It requires much attention in handling, hence not used for ordinary works.

Accessories for Chaining

Pegs

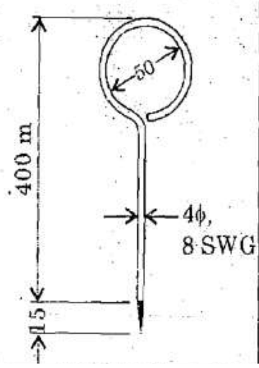
These are used to mark definite points on the ground either temporarily or semipermanently. The exact point from or to, which the measurements are to be taken, or over which an instrument is to be set, are often marked on the peg using nails.



Arrow

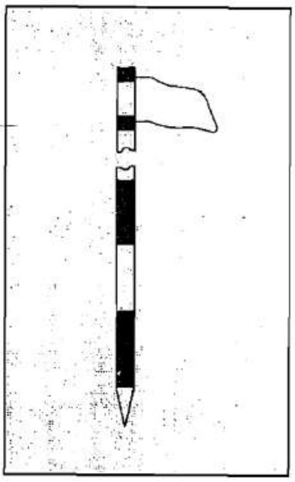
When measuring the length of a long line, the tape has to be laid down a number of times and the positions of the ends are marked with arrows.

As the arrows are placed in the ground after every chain length, the number of arrows held by the follower indicates the number of chains that have been measured. It provideds a check over the length of line as entered in the field notes.



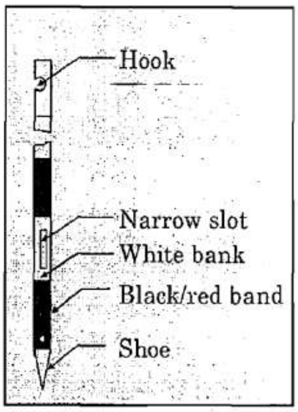
Arrows

Ranging Rods



- The process of locating a number of points on a long survey line is called Ranging or Ranging out.
- Ranging rods are used to locate intermediate points such that these points lie on the straight line joining the end stations. Ranging is must before starting the measurement of a line whose length is more than a chain length such that the measurement is made along a straight line.
- Ranging Rods are 30 mm in diameter and 2 or 3 m long. These are painted with alternate bands of either red and white or black and white of 200 mm length such that at sometimes the rod can also used for the rough measurement of short lengths.

Offset Rods

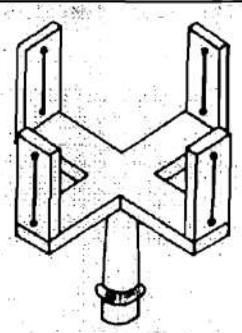


- These are similar to ranging rods except at the top, a stout open ring recessed hook is provided, as shown in figure below.
- It is also provided with two short narrow vertical slots at right angles to each other, passing through the centre of the section, at about eye level.
- It is mainly used to align the offset line and measure the short offsets. With the help of hook provided at the top of rod, the chain can be pulled or pushed through the hedges or other obstructions, if required.

Equipment for measuring Right Angles

Cross staff

- The cross staff or an open cross staff is a simple instrument used for setting out offsets to the chain line from a given point. It is also used for setting out a right angle at a given point on the chain line.



Open cross staff

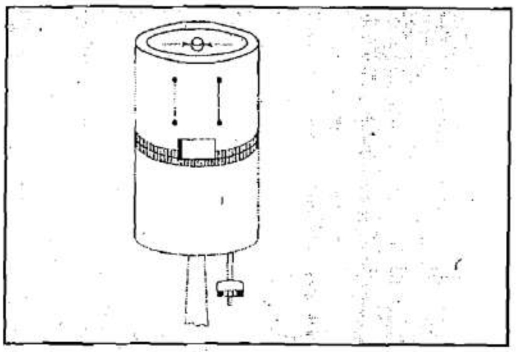
French Cross staff

- The accuracy of the French cross staff is less than that of an open cross staff. However, the French cross staff has the advantage that the lines can also be set out at angles of 45° and 135°. In that respect, a French cross staff is superior to an open cross staff.

Adjustable cross staff

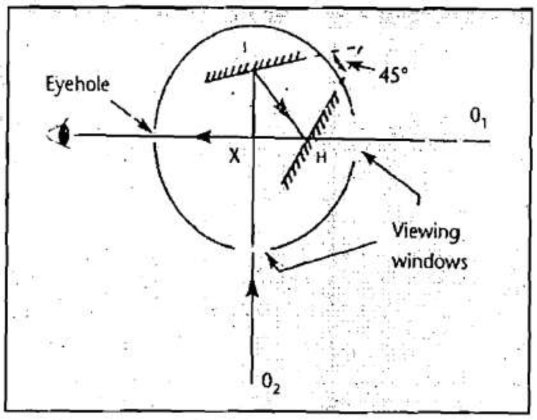
- It consists of two cylinders of equal diameter placed one above the other.

- The upper cylinder can be rotated over the lower one. The lower cylinder is graduated in degrees and its subdivisions.
- The upper cylinder carries the vernier and the slits to provide a line of sight. Thus, it can be used to take offsets and to set out any desired angle from the chain line.



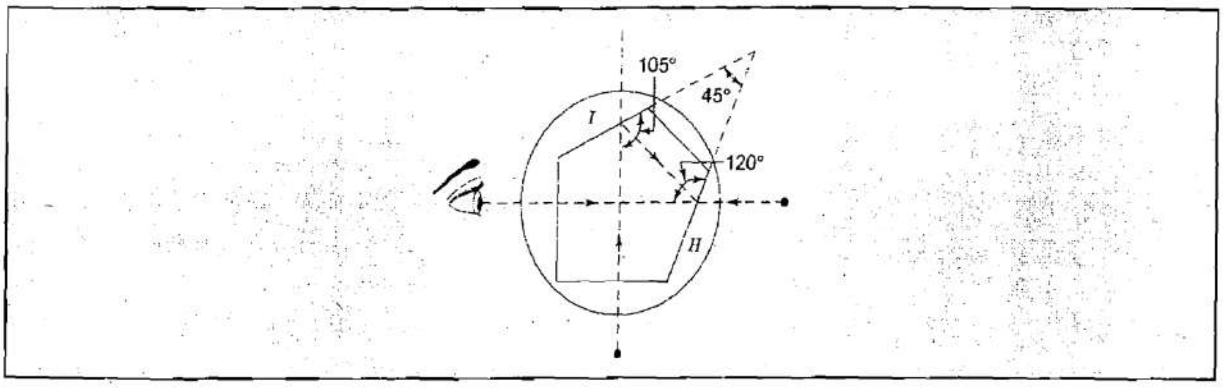
Optical Square

- An optical square is a small pocket instrument, slightly larger than a watch. It is used for setting out right angles.
- The optical square is more convenient and more accurate than a cross staff.
- There are two mirrors, H and I, placed vertically above the base and inclined at 45° to each other. The mirror H, is called Horizon glass, is unsilvered at the bottom and silvered on the top,
- The mirror I, called as Index glass, is fully painted silvered and is opposite to the opening O_2.
- The optical square is based on the optical principle that, if a ray of light undergoes two successive reflections in a plane at right angles to each of the two plane mirrors, the angle between the incident ray and the reflected ray is twice the angle between the mirrors. In the optical square, as the angle between the mirrors is 45°, the reflected ray is perpendicular to the incident ray.



Prism Square

The prism square is based on the same optical principle as that of an optical square. In a prism square, a prism is used which has two reflecting surfaces *I* and *H* fixed at 45°.

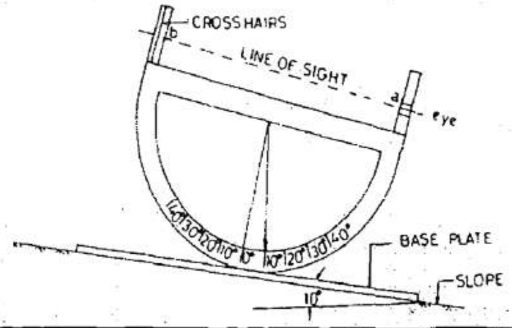


Equipment for measuring ground slope

Simple Clinometer

- A simple Clinometer is used for measuring the angle of slope of the ground. A light plumb bob is suspended from the centre of the semi-circle. A flat base is attached to the semi-circle to lay the clinometer on the surface whose slope is required.

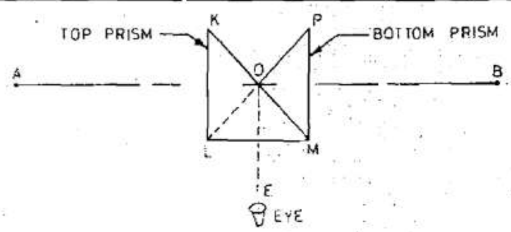
- As the surface is leveled, the plumb bob shows the zero mark. When the ground surface is sloping, the angle of slope is read at the graduation where the plumb bob touches the graduated semi circle.



Equipment for Estabilishing Intermediate Points

Direct Ranging with a Line Ranger

- A line ranger consists of two right-angled isosceles triangular prisms placed one above the other. The diagonals of the two prisms are painted silvered so as to form the reflecting surfaces. There is a handle at the bottom of the instrument to hold the instrument in one hand. A hook is also provided below the handle for attaching the plumb bob to transfer the point on the ground.



Plan of line ranger

Following procedure is used to establish an intermediate point C on the line AB with the help of a line ranger.

1. Hold the line ranger in hand at the eye level and stand at C very near the line AB, as judged by eye.
2. Observe the ranging rod at A through the upper prism KLM. The ray of light from station A enters the upper prism, gets reflected from the silvered diagonal KO and enters the eye at right angles to the line AB.

   Also observe the ranging rod at station B through the lower prism PLM. The ray of light from B enters the lower prism, gets reflected from the silvered diagonal PO and enters the eye at right angles to the line AB.
3. Check whether the images of the ranging rods at A and B are seen in one vertical line or not. If the point at which the line ranger is held is not exactly on the line AB, the images of station A & B appear out of line. However if A & B are one in line with C, the two images appear in one vertical line.
4. This point is now transfered to the ground by hanging a plum bob from the hook on the handle.

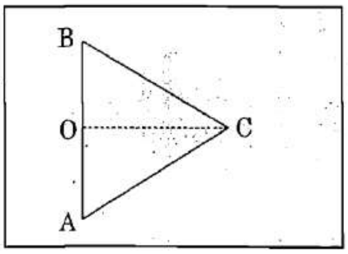
CHAPTER

3

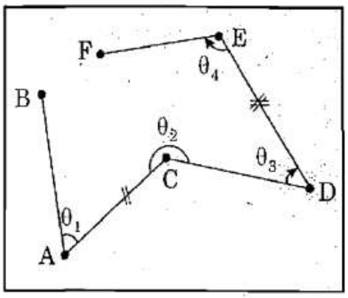
Compass Surveying

Introduction

From the fundamental principle of surveying we know that on any area of land to be surveyed, it is always possible to chose two points and to measure distance between them. Other points can be located relative to the 1st line by taking two other measurements.



- The line AB is called **base line** and all measurements are taken from this line.
- In chain surveying point 'C' was located by taking only distance measurements.
- However in compass surveying point 'C' is located by taking measurement of angle between BA & AC & measurement of length AC or angle between AB & BC, BA & AC.
- When the whole area to be surveyed cannot be seen from this one line, additional lines have to be defined relative to the 1st, using again two measurements. The points of the junctions of these lines are called **Control Points,** and together with the lines they constitute a framework or control. This method of establishing the control points is called control surveying.

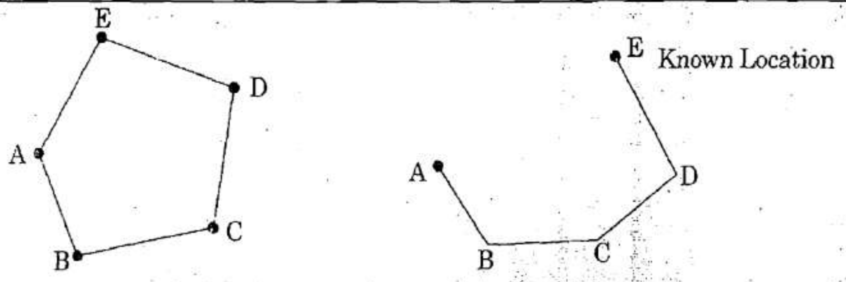


- In chain surveying the control network consisted of series of triangles of survey lines.
- In compass surveying points C, D, E, F are established by measuring lengths AC, CD, DE, EF etc & angles $\theta_1, \theta_2, \theta_3, \theta_4$ etc.
- This method of establishing points C, D, E, F etc successively by taking linear & angular measurments is called traversing.
- Where lines AB, BC, CD, DE, EF etc are called traverse lines.
- In traverse surveying the frame work consists of a series of connected lines forming an open or closed polygon. Accordingly, the traverse is called open traverse or closed traverse.

1. Closed traverse

- A closed traverse starts from a station and closes either on the same station or another station whose location is already known.
- As shown below in figure (a), the traverse starts from the station A and closes on the same station. It forms a closed polygon. This type of closed traverse is called as a loop traverse.

- In fig. (b), the traverse starts from the station A and closes at the station E whose location is also known or established. This type of closed traverse is called a link traverse or connecting traverse.



(a) Loop Traverse *(b) Link Traverse*

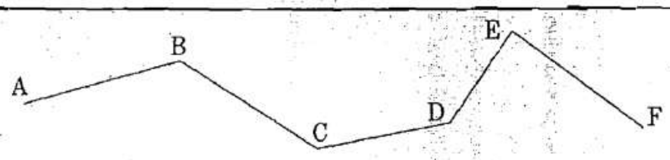
Closed Traverse

Note:

An error in a closed traverse can be easily detected and the traverse can be adjusted and balanced.

2. Open traverse

- An open traverse starts from a station A and closes at another station F whose location is neither known nor established.
- It consists of a series of connected lines.
- An open traverse is generally used in surveying of the area for a road, railway line, canal, etc.



Open Traverse

Note:

An open traverse cannot be properly checked and adjusted. As far as possible, it should be avoided.

Difference between Traverse surveying & Chain surveying

	Chain Surveying	Traverse Surveying
1.	Requires only linear measurements hence relatively easier	Requires both linear and angular measurements. Hence requires trained personnel.
2.	The frame work consists of triangles	Frame work consists of a series of connected lines froming an open or closed polygon. As the directions of lines are measured, the polygon can be plotted without constructing triangles.
3.	Check lines are required in chain Surveying	Check lines are not required because accuracy of the framework can be checked by the methods of adjustments.
4.	Used when area to be surveyed is small, ground is flat and accuracy required is low	Used when area involved is large, and better accuracy is required.

Note:

Traversing can be done by various methods like compass traverse, plane table traverse, stadia traverse, theodolite traverse.

Compass Traverse

In compass traverse, a magnetic compass is used to determine the angles of the traverse. The sides of the traverse (called traverse lines) are measured with a chain or a tape.

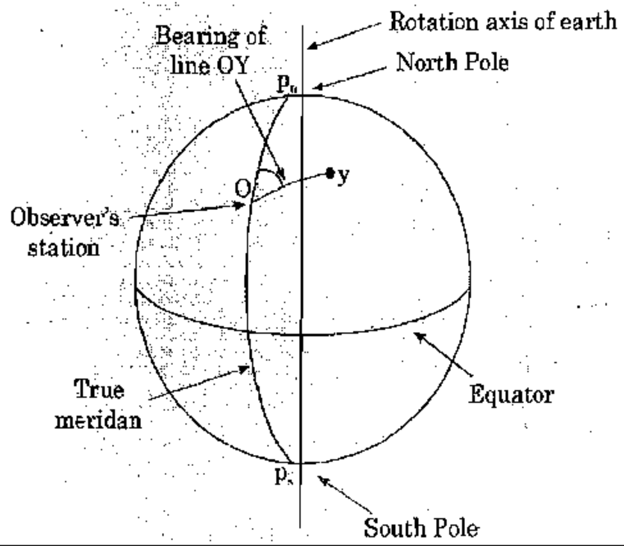
Measurement of Angles

The direction of a line is defined by the horizontal angle which the line makes with a reference line. The fixed line of reference is called a meridian. There are 4 types of meridians used in surveying.

1. True meridian
2. Magnetic meridian
3. Grid meridian
4. Arbitrary meridian.

1. True Meridian

- The true meridian passing through a point on the earth surface is the line in which a plane passing through a given point and the geographical north and south poles, intersects the surface of the earth.
- It represents the true north-south direction at the place.
- True meridian at a point can be determined by astronomical observations to the sun or stars.
- The true meridians through various stations are not parallel, but converge at the poles. However for small surveys, they are assumed to be parallel to each other.
- True meridian at a point is fixed.



2. Magnetic Meridian

- Magnetic meridian at a point is the direction indicated by a freely suspended, balanced magnetic needle (or a magnetic bar) at that point. This magnetic needle should not be affected by magnetic forces other than that of the earth for determining the correct direction of the magnetic meridian.

- The freely suspended magnetic needle comes to rest in a position parallel to the line passing through the magnetic north and south poles, and therefore it indicates the direction of the magnetic meridian at that place.
- The magnetic poles are not fixed in position on the earth. They change their positions continually due to some unknown reasons.
- Hence, magnetic meridian at a point is not fixed it varies with time.

3. Grid Meridian

- For survey of a country, the true meridian passing through the central place is sometimes taken as a reference meridian for the whole country. Such a reference meridian is known as grid meridian. The meridians of all other places in that state are assumed to be parallel to the grid meridian.
- A line parallel to the grid meridian and passing through the point indicates the directions of the grid north and south. Like this rectangular grids are plotted on the map.

4. Arbitrary Meridian

- Arbitrary meridian is the meridian which is taken in any convenient, arbitrary direction. Any reference line may be taken as arbitrary meridian. But usually it is taken in the direction from a traverse station to a well-defined, permanent point such as a church spire, the chimney, etc. Sometimes, even the first traverse line is also taken as an arbitrary meridian.
- The arbitrary meridian is used for determine the relative directions of various lines in a small traverse.

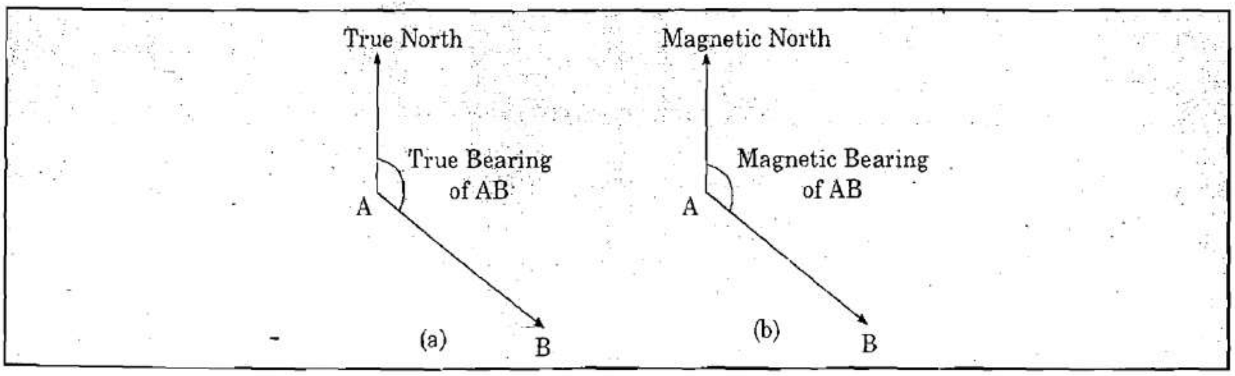
Types of Bearings

Bearing of a line is the horizontal angle which it makes with a reference line (meridian).

Depending upon the meridian, there are 4 types of bearings.

1. True Bearing

- The true bearing of a line is the horizontal angle between the true meridian and the line. As the true bearing of a line does not change with time and can be re-established even after hundreds of years, hence it is a general practice to use the true bearings for all important surveys.



- The true bearing of a line is also called as Azimuth.
- In plane surveying, the true bearing is measured from the true north in the clockwise direction.
- The true bearing of a line can be determined by astronomical observations.

2. Magnetic Bearing

- Magnetic bearing of a line is the horizontal angle which the line makes with the magnetic north as shown in the fig(b).
- As the magnetic meridian changes slowly with time, the magnetic bearing of a line also changes with time. Hence the magnetic bearings are used for small, less important surveys.
- The magnetic bearings are determined with the help of a prismatic compass as a whole circle bearing and with a surveyor's compass as a quadrantal bearing.

3. Grid Bearing

The grid bearing of a line is the horizontal angle which the line makes with the grid meridian, of the state.

4. Arbitrary Bearing

The arbitrary bearing of a line is the horizontal angle which the line makes with the arbitrary meridian.

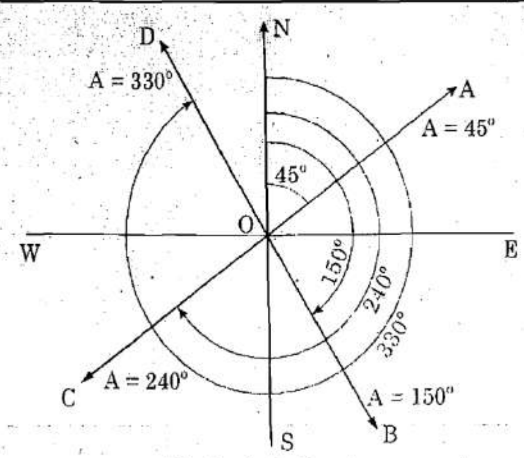
Designation of Bearings

The bearing of a line is designated in the following systems.

1. Whole Circle Bearing System
2. Quadrantal Bearing System

1. Whole circle bearing (W.C.B) System

- The whole circle bearing (W.C.B.) of a line is the horizontal angle between the line and the north end of the reference meridian in the clockwise direction. The direction of the line is indicated by an arrow. The reference meridian is generally represented as a vertical line with its north end towards the top of the paper.
- The whole circle bearing of a line may vary from 0° to 360°.
- In fig, the whole circle bearings of the line OA, OB, OC and OD are 45°, 150°, 240° and 330° respectively.
- The whole circle bearing is also called azimuth, and is represented by A.
- The whole circle bearing is measured with a prismatic compass.



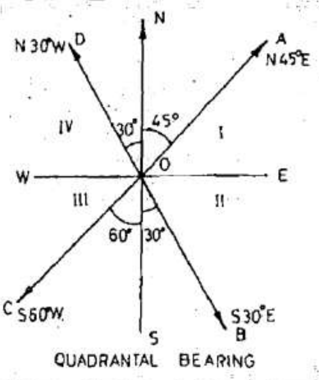
Whole-circle Bearing

2. Quadrantal Bearing (Q.B.) System

- The quadrantal bearing (Q.B.) of a line is the acute angle which the line makes with the meridian.
- Thus the quadrantal bearing is measured from the north point or the south point, whichever is closer therefore the quadrantal bearing of a line cannot be greater than 90°.
- The letters N, E, S and W are used to represent north, east, south and west, respectively. While writing the quadrantal bearing of a line following rules are used.
  (i) First the letter N or S.
  (ii) Then the angle of the bearing.
  (iii) Lastly the letter E or W. For example, the quadrantal bearings of the lines OA, OB, OC and OD as shown in the above figure will be.

line OA,	N 45° E
line OB,	S 30° E
line OC,	S 60° W
line OD,	N 30° W

- The quadrantal bearing of a line is measured with a surveyor's compass.



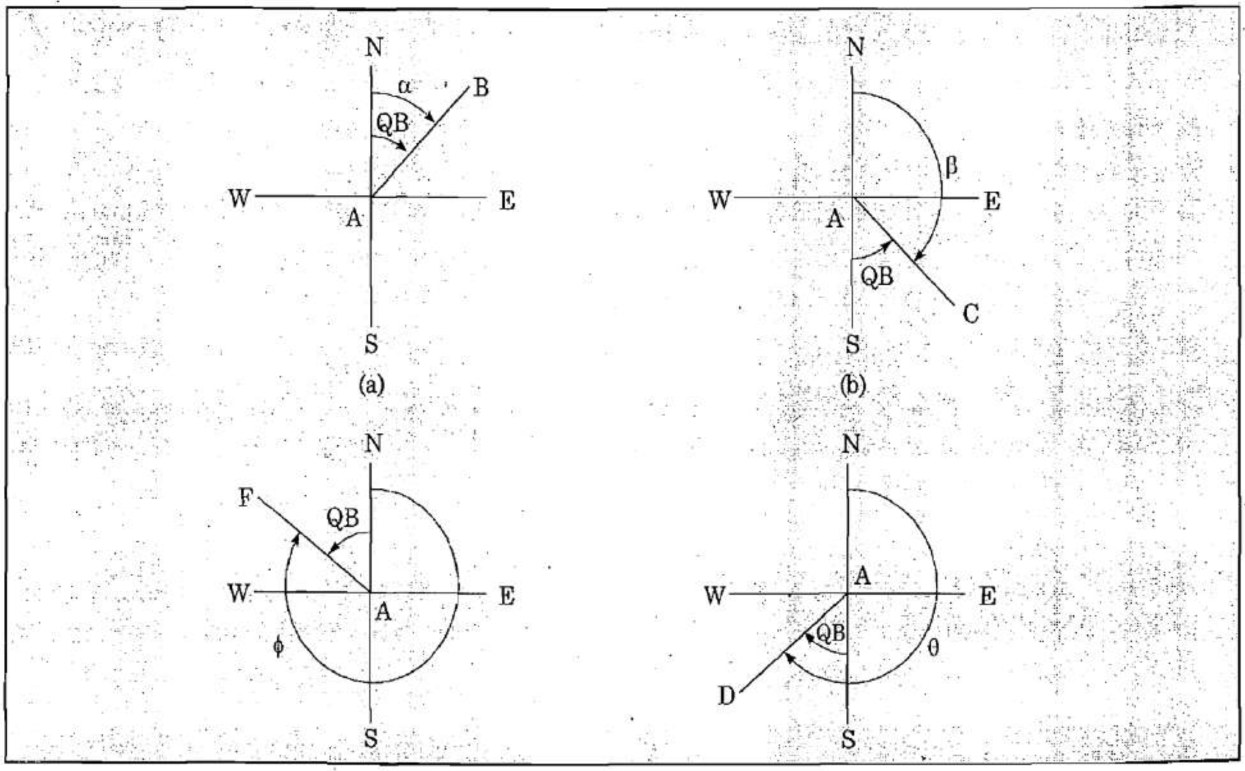
Note:

In the quadarant bearing system the angles measured can be either clock wise or anticlockwise.

Reduced Bearing

- When the whole circle bearing of a line exceeds 90°, it must be reduced to the corresponding angle less than 90°. This angle is called as Reduced Bearing.
- Conversion of whole circle bearing to Quadarant Bearing

Case	W.C.B. between	R.B.	Quadrant
1.	0° – 90°	W.C.B.	NE
2.	90° – 180°	180° – W.C.B.	SE
3.	180° – 270°	W.C.B. – 180°	SW
4.	270° – 360°	360° – W.C.B.	NW



- When a line points towards north, east, south or west, it is written as 'due north', 'due east', 'due south' or 'due west'. Thus

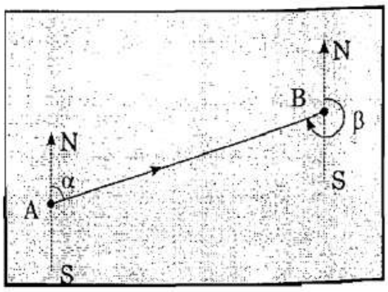
  N 0° = Due North

  N 90° E = S 90° E = S 90° E = Due East

  N 90° W = S 90° W = Due West

  S 0° = Due South

Fore Bearing and Back Bearing



The bearing of the line in the direction of the progress of survey is called the fore bearing (F.B). The bearing of line in the opposite direction of the progress of survey is called Back Bearing (B.B.). To avoid confusion, the arrows are marked to indicate the direction of the progress of survey.

Line	Fore Bearing	Back Bearing
AB	α	β
BA	β	α

Note:

That force bearing & back bearing of a line have a difference of 180°.

Relationship between Fore Bearing and Back bearing

The Back Bearing of a line can be determined if its Fore Bearing is given and vice versa.

1. If the Fore Bearing of a line is given as the whole circle bearing,
   Back Bearing = Fore bearing + 180°, if F.B. < 180°
   and, Back Bearing = Force bearing − 180°, if F.B. > 180°
   B.B. = F.B $\pm 180°$
2. If the Fore Bearing of a line is given as the Quadrantal Bearing,
   Back Bearing = Numerically equal to Fore Bearing
   Just change N for S, and vice versa and E for W, and vice versa.

Example: N30°E $\rightarrow$ S30°W

- While converting the Whole Circle Bearing to the Quadrantal Bearing or vice-versa and also while determining the Back Bearing from the Fore Bearing, there is no need of memorising any rule. It is suggested that always draw a rough sketch and determine the required Bearing directly by calculations.

Example 1.

Convert the following whole circle bearings into Quadrantal Bearings:

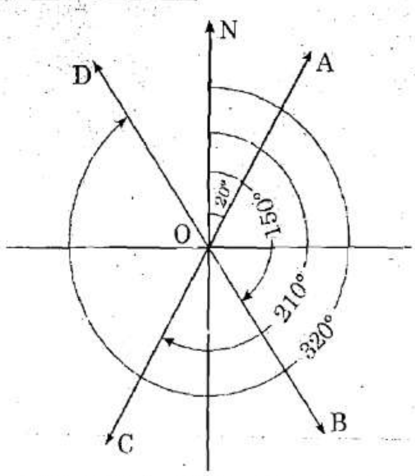
(i) 20° (ii) 150°

(iii) 210° (iv) 320°

Sol.

The lines OA, OB, OC and OD show the given directions. The required quadrantal bearings will be.

Line OA	N 20° E
Line OB	S 30° E
Line OC	S 30° W
Line OD	N 40° W



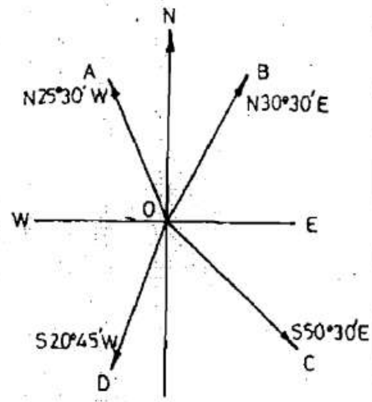
Example 2.

Convert the following Quadrantal Bearings into Whole Circle Bearings:

(i) N 25° 30'W (ii) N 30° 30' E

(iii) S 20°45'W (iv) S 50°30' E

Sol.



The lines OA, OB, OD and OC show the given lines.

The whole circle bearings can be written directly as below.

Line OA, 360° – 25°30' = 334°30'

Line OB, 30°30'

Line OD, 180° + 20°45' = 200°45'

Line OC, 180° – 50°30' = 129°30'

Example 3.

The fore bearings of the four lines AB, CD, EF and GH are, respectively, as under

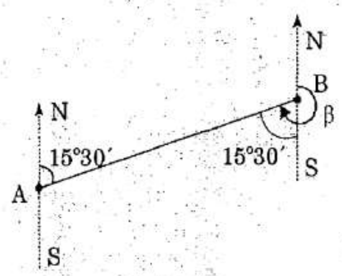
(i) 15°30' (ii) 115°45'

(iii) 250°30' (iv) 340°0'

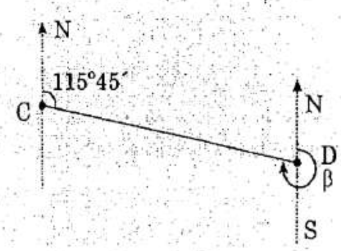
Find out the back bearings.

Sol.

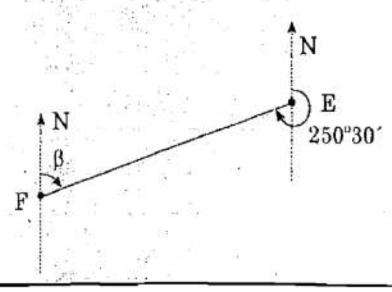
(i) Back Bearing of AB = β = 180° + 15°30' = 195°30'



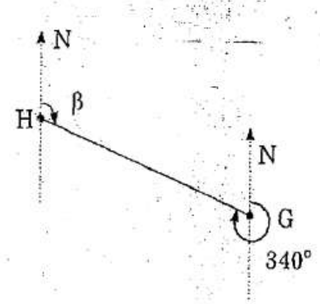
(ii) Back Bearing of CD = β = 180° + 115°45' = 295°45'



(iii) Back Bearing of EF = β = 250°30' – 180° = 70°30'



(iv) Back Bearing of AB = $\beta = 340^\circ - 180^\circ = 160^\circ$



Example 4.

The Fore Bearings of the four lines AB, CD, EF and GH are, respectively, as under

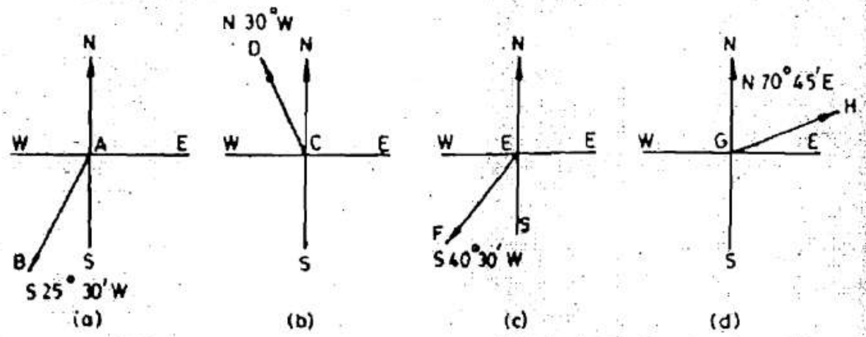
(i) S 25°30' W; (ii) N 30° W;

(iii) S 40°30' W; (iv) N 70°45' E

Find out the Back Bearings.

Sol.

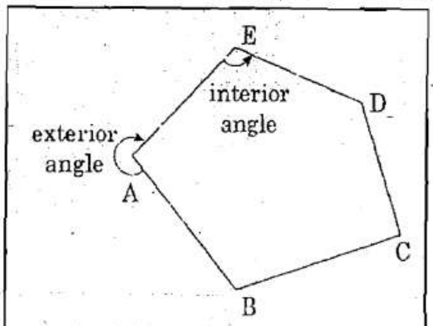
Fig. shows the four lines.



The Back Bearings are obtained by simply interchanging the letters S and N and also by interchanging E and W.

Line AB,	N 25°30' E
Line CD,	S 30° 0' E
Line DF,	N 40° 30' E
Line GH,	S 70° 45' W

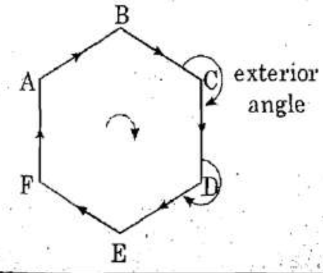
Include angles



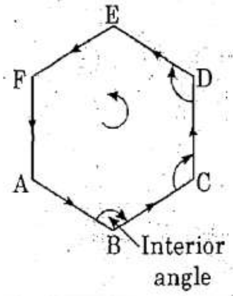
- Where two lines meet at a point, the angle between them is called as included angle. The included angle can be either interior angle or exterior angle.
- Included angles can be computed if bearing of lines are known.

- But in field of surveying included angles are defined as "Angle measured in the clockwise direction from the preceding line of a tranverse to the forward line."

Case I When the traverse run in clockwise direction the included angle will be exterior angle.



Case II When the traverse run in the anticlockwise direction the included angle will be the interior one.



For calculation of included angle from bearing or for calculation of bearing from included angle no rules need to be remembered. Simply, draw a rough sketch and perform the calculations.

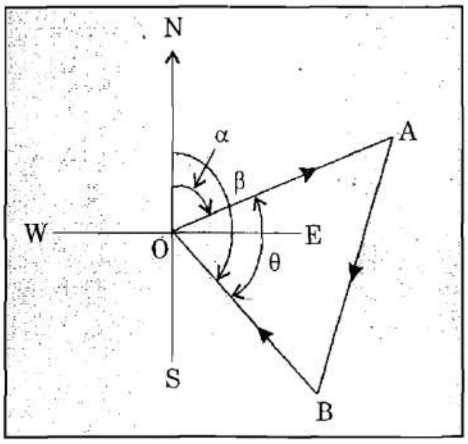
But few emperical relationship are being developed which are disscussed in the following sections.

Calculation of Included Angles from Bearings

If the bearing of adjacent lines are known, then the included angles may be calculated as below:

Case I Given Whole Circle Bearing of lines.

In a clockwise close traverse OAB, OA is the forward line (next line) and BO is the previous line at station O. Let Whole Circle Bearing of the line OA = α and W.C.B. of the line OB = β The included angle $\angle AOB = \theta$



= F.B. of the forward line − B.B. of the previous line

$= \alpha - \beta$

= a negative value

Note :

If the value is a negative one (as above) add 360° to get the actual included angle which will be the exterior included angle.

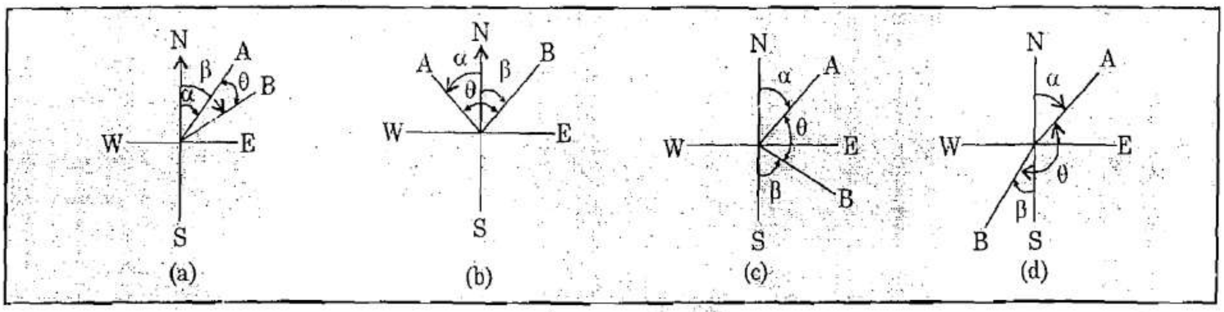
Case II Given Q.B. of lines:

(a) When bearings are measured in the same side of the common meridian, $\theta = \beta - \alpha$

(b) When bearings are measured in the opposite side of the common meridian, $\theta = \beta + \alpha$

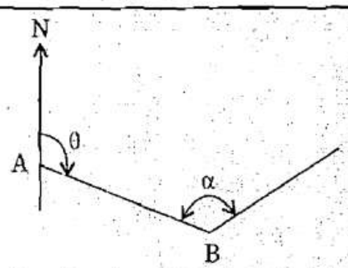
(c) When bearings are measured in the same side of the different meridians, $\theta = 180° - (\alpha + \beta)$

(d) When bearings are measured in the opposite side of the different meridians, $\theta = 180° - (\alpha - \beta)$



Calculation of Bearings from Included Angles

- By knowing the included angles of a traverse, and bearing of a line, the bearings of other lines may be calculated as below:
- Let the Fore Bearing AB = θ
- Included angle with the next adjacent line = α
- The Fore Bearing of next line = F.B of previous line + Included angle.
- For the bearing of the next line, "Add the included angle measured clockwise to the bearing of the previous line".



Bearing from included angles.

If the sum is:

- more than 180°, deduct 180°
- more than 540°, deduct 540°
- less than 180°, add 180°.

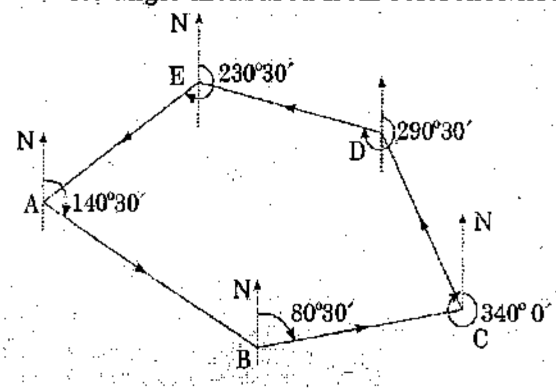
Example 5.

The following bearings were observed for a closed traverse ABCDEA

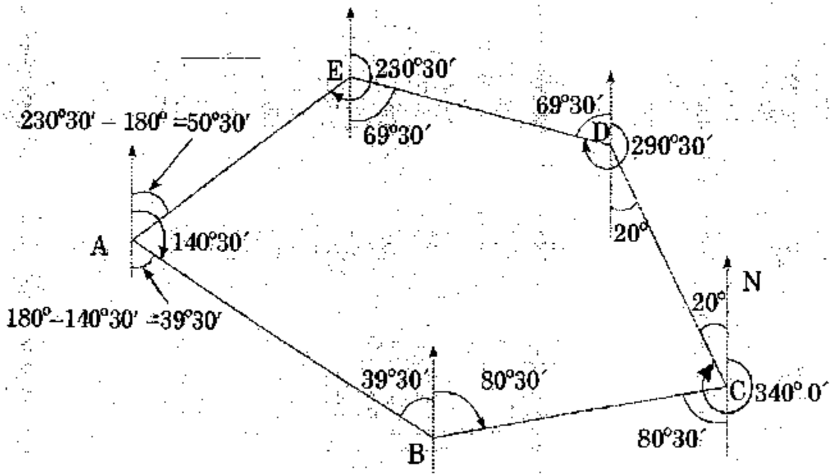
Line	AB	BC	CD	DE	EA
F.B.	140°30'	80°30'	340°0'	290°30'	230°30'

Compute the included angles.

Sol. Bearing is actually a clockwise angle measured from reference noth direction. Hence



Calculation can be performed as shown below



$\angle A = 140°30' - 50°30' = 90°$

$\angle B = 39°30' + 80°30' = 120°$

$\angle C = 340° - 180° - 80°30' = 79°\ 30'$

$\angle D = 290°30' - 180° + 20° = 130°30'$

$\angle E = 230°30' - 180° + 69°30' = 120°$

Example 6.

Determine the value of included angles in a closed compass traverse ABCD (fig.) conducted in clockwise direction, given the following fore bearings of the respective lines.

Line	AB	BC	CD	DA
F.B.	40°	70°	210°	280°

Sol.

We know that traversing is done in clockwise direction, hence the included angles will be the exterior angles.

Included angle = F.B. of next line – B.B. of the previous line.

$\angle A$ =F.B. of AB – B.B. of DA

$= 40° - (280° - 180°) + 360°$

$= 300°$

$\angle B =$ F.B. of BC − B.B. of AB

$= 70° - (40° + 180°) + 360°$

$= 210°$

$\angle C =$ F.B. of CD − B.B. of BC

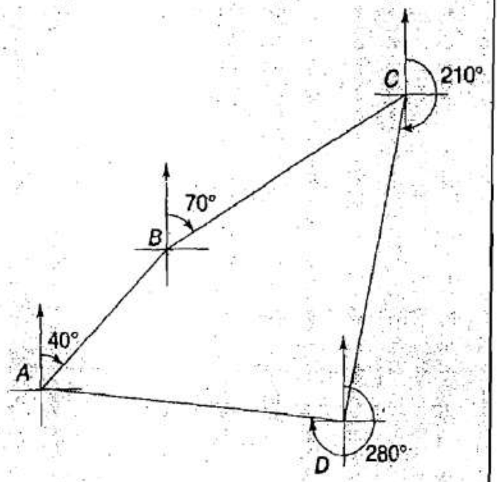
$= 210° - (180° + 70°) + 360°$

$= 320°$

$\angle D =$ F.B. of DA − B.B. of CD

$= 280° - (210° - 180°)$

$= 250°$



We know that,

Theoretical sum of exterior included angles $= (2n + 4)\ 90° = 1080°$

Also, sum of calculated included angles $= \angle A + \angle B + \angle C + \angle D$

$= 300° + 210° + 320° + 250°$

$= 1080°$ **(O.K.)**

Note:

If the included angle is negative, then 360° is added to it, has been done in the case of angle A, B and C.

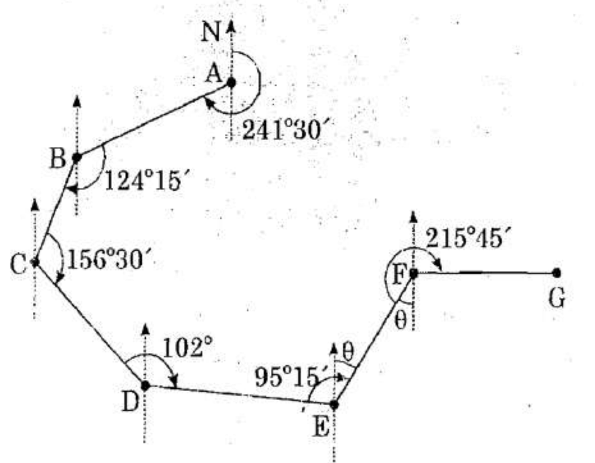
Example 7.

The following angles were observed in clockwise direction in an open traverse

$\angle ABC = 124°15'$, $\angle BCD = 156°30'$, $\angle CDE = 102°\ 0'$, $\angle DEF = 95°15'$, $\angle EFG = 215°45'$

The magnetic bearing of line AB was 241°30′. What would be the bearing of line FG.

Sol.



To find out the bearing of line FG we need angle θ as shown in the fig. above.

Bearing of FG = 215°45′ + θ − 180°

Or We can go on calculating the bearing of each line and ultimately find out the bearing of the line FG

Line	Fore bearing
AB	241°30
BC	124°15′ + (241°45′ − 180°) = 185°45′
CD	156°30′ + (185°45′ − 180°) = 162°15′
DE	102° − (180° − 162°15′) = 84°15′
EF	95°15′ − (180° − 84°15′) = −0°30′ = 359°30′ *
FG	215°45′ − (180° − θ) = 215°45′ −[180 −(−0°30′)] = 215°45′ − 180°30′ = 35°15′ **

⇒ **Bearing of FG = 35°15′**

* Note that when any angle comes out to be negative, add 360° to get the final bearing of the angle.

** The negative angle so obtained in the previous calculation should be used for further calculation.

Alternatively

ABCDEFG is a clockwise traverse,

F.B. of a line = F.B. of previous line + clockwise included angle

F.B. of AB = 241°30′ (Given)

F.B. of BC = F.B. of AB + ∠ABC

= 241°30′ + 124°15′

= 365°45′ − 180° = 185°45′

F.B. of CD = F.B. of BC + ∠BCD

= 185°45′ + 156°30′

= 342°15′ − 180° = 162°15′

F.B. of DE = F.B. of CD + ∠CDE

= 162°15′ + 102°00′ = 264°15′

= 264°15′ − 180° = 84°15′

F.B. of EF = F.B. of DE + ∠DEF

= 84°15′ + 95°15′ = 179°30′

= 179°30′ + 180° = 359°30′

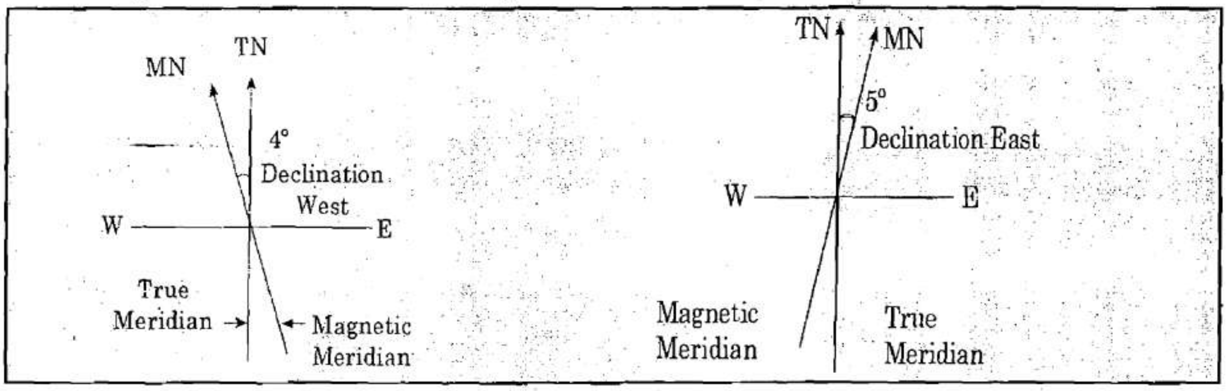
F.B. of FG = F.B. of EF + ∠EFG

= 359°30′ + 215°45′

= 575°15′ − 540° = 35°15′ **(O.K.)**

Magnetic Declination

- Generally the magnetic meridian and the true meridian at a place do not coincide with each other. The horizontal angle which the magnetic meridian makes with the true meridian is known as the magnetic declination or simply declination at that place.
- If the magnetic north (MN) is on the west side of the true north (TN), the declination is said to be west or negative. Where as on the other hand, if the magnetic north is on the east side of the true north, the declination is said to be east or positive.
- The magnetic declination at a place can be measured in the field by establishing the true meridian with the help of astronomical observations, and then determining the magnetic bearing of the line established along the true meridian.



- The declination changes from one place to the other. It also varies at the same place from time to time.
- The variation of declination at various places is represented by isogonic lines.
- The isogonic lines are the lines passing through the points on the earth surface at which the declination is the same at a given time.
- Isogonic lines radiate from the north and south pole regions and follows irregular paths.
- Agonic lines are special isogonic lines which pass through the points of zero declination.
- In other words, we can say that at all points on the agonic lines, the true meridian and the magnetic meridian coincide with each other.

Variation of Magnetic Declination

The declination at a place does not remain constant, but it varies from time to time. Basically, there can be four types of magnetic declination at a place based on the pattern of these variations.

1. Secular Variation
2. Annual Variation
3. Diurnal Variation
4. Irregular Variation

1. Secular Variation

- Secular variation of declination occurs continuously over a long period of time. For example over a period of approximately 150 years, there is a gradual shift in the earth's magnetic field in one direction. Thereafter the declination shifts in the opposite direction for 150 years. Hence cycle is completed in about 300 years. The variation follows approximately sine curve.
- Still there is no reliable method of predicting the secular variation at a place.

- We should note that the change of magnetic declination from year to year is not uniform for a given place. Moreover, the change at different places is also different. It has been observed that the time period of the cycle also varies from 100 years to 350 years.
- To estimate the secular variation, observations are made at various places throughout the world.
- The lines of equal annual change called isopars are drawn every consecutive year.
- The annual rate of change of secular variation is generally between 5 to 10 minutes.

2. Annual Variation

- It is the change in the declination at a place over a period of 1 year.
- It is caused because of the rotation of earth about sun.
- The annual rate of change of annual variation is generally between 1 – 2 min.

3. Diurnal Variation

- It is the change in the declination at a place in 24 hr.
- It is because of the rotation of earth about its own axis.
- The amount of variation is from a fraction of a minute to over 12′ and is due to the following reasons:
  (i) Geographical position of the place (lesser near equator and increases towards the poles).
  (ii) Time of the day (more in day).
  (iii) Season of the year (more in summers).
  (iv) The year of the cycle of secular variation.

4. Irregular Variation

- Magnetic disturbances or magnetic storms in the earth's magnetic field causes the irregular variation of the declination at a place.
- Such variations are uncertain, unpredictable and random in nature.
- Natural phenomena, such as earthquakes, volcanic eruptions also cause irregular variation of declination.
- The irregular variation may be quite large, depending upon the magnitude of the disturbances.
- The irregular variation upto 2° have been observed at few places on the earth.

Effect of Variation on Survey

- As the magnetic meridian changes its direction due to variation from time to time, the magnetic bearings of the survey lines also gets change.
- For complete detailed record of the survey, the following particulars should be noted on the plan of a compass traverse:
  (i) Date of survey;
  (ii) Magnetic declination and
  (iii) Annual change of the secular variation

Note:

All important surveys should be plotted with reference to the true bearings.

Determination of True Bearings from Magnetic Bearings

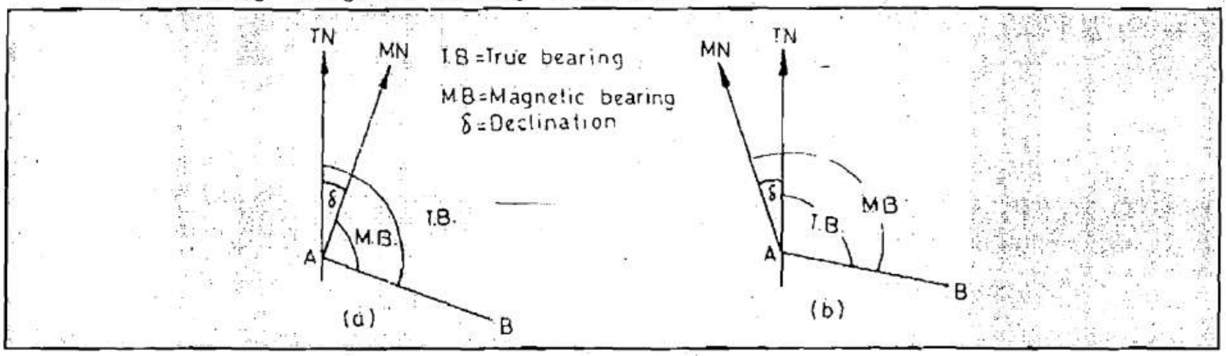
- If the magnetic declination at a place at the time of observation is known, the true bearing of a line, say AB, can be calculated from its magnetic bearing and vice-versa. The following rules are applied.

  (a) If Declination is East

  True Bearing (T.B.) = Magnetic Bearing (M.B.) + Declination

  (b) If Declination is West

  True Bearing = Magnetic Bearing – Declination

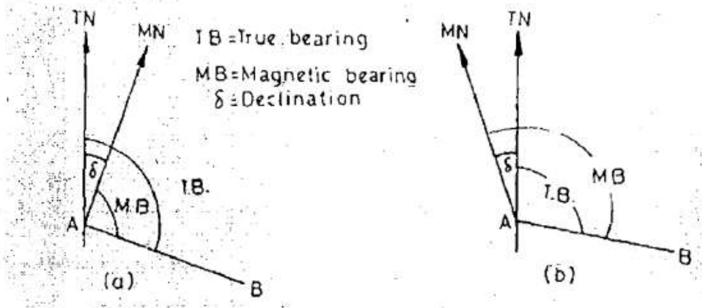


- The above relations are applicable for the conversion of the whole circle bearings. Similarly relations can be written for different quadrants if the quadrantal bearings are given. Also, the quadrantal bearing can be converted to the whole circle bearing and the above rule can be applied.

Example 8:

The magnetic bearing of a line AB is 88°45′. Determine the true bearing if (a) the magnetic declination is 5°30′ east (b) the magnetic declination is 4°45′ W.

Sol.



(a) In fig. (a)

True Bearing = Magnetic Bearing + Declination

= 88°45′ + 5°30′ = 94°15′

(b) In fig. (b)

True Bearing = Magnetic Bearing – Declination

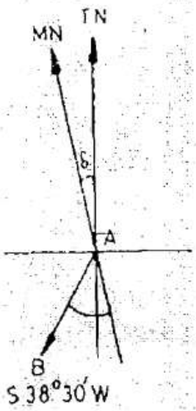
= 88°45′ – 4°45′ = 84°

Example 9.

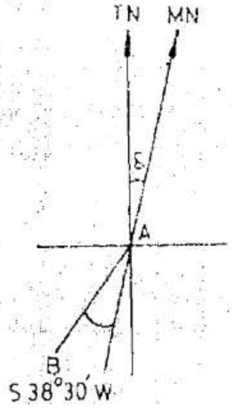
The Magnetic Bearing of a line AB is S 38°30′ W. Determine the True Bearing if the Magnetic Declination is

(a) 4°30′ W (b) 3°30′ E.

Sol.



(a)



(b)

(a) True Bearing = S 38° 30′ W – 4°30′ = **S34° W**

(b) True Bearing = S 38° 30′ W + 3°30′ = **S42° W**

Example 10.

A line AB was drawn to have a magnetic bearing of 25°30′ in an old map at that time the declination was 2° 30′ E. Determine the magnetic bearing of the line if the present declination is 5°30 W.

Sol.

True Bearing of the line = 25° 30′ + 2° 30′ = 28°

As the true bearing of the line never change, the present true bearing will also be 28°.

Present True bearing = Magnetic Bearing –5° 30′

or 28° = Magnetic Bearing –5° 30′

or Magnetic Bearing = **33° 30′**

Example 11.

A line AB had the magnetic bearing 44°30' in 1910 when the declination was 4°30' W. Determine the magnetic bearing of the same line in 1990 if the annual declination change observed as was 6' eastward.

Sol.

Total change in declination from 1910 to 1990

= 80 × 6′ = 480′ = 8°

Declination in 1990 = 4° 30′ W – 3° 30′ E

In 1910, True Bearing = Magnetic Bearing – 4° 30′

= 44° 30′ – 4° 30′ = 40° 0′

In 1990, True Bearing = Magnetic Bearing + 3° 30′

40° = Magnetic Bearing + 3° 30′

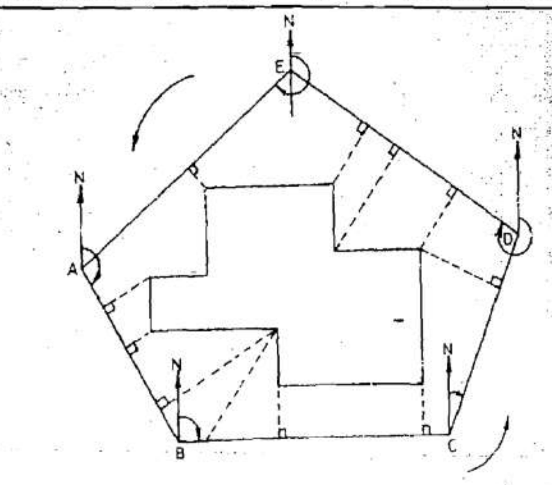
Magnetic Bearing = **36° 30′**

Compass Traverse

- In a compass traverse, a magnetic compass is used to determine the angles of the traverse.
- The sides of the traverse (traverse lines) are measured either with a chain or a tape.
- Field work consists of reconnaissance, marking and referencing of stations, running survey lines, takig offsets to the detail, similarly as in chain surveying.
- In addition to above, in a compass traverse, the bearings of all lines ~~are also~~ measured with the help of a magnetic compass.
- However, in a compass traverse, there is no need of check lines.
- The traverse may be run clockwise or anticlockwise. Generally, a anticlockwise traverse is preferred.

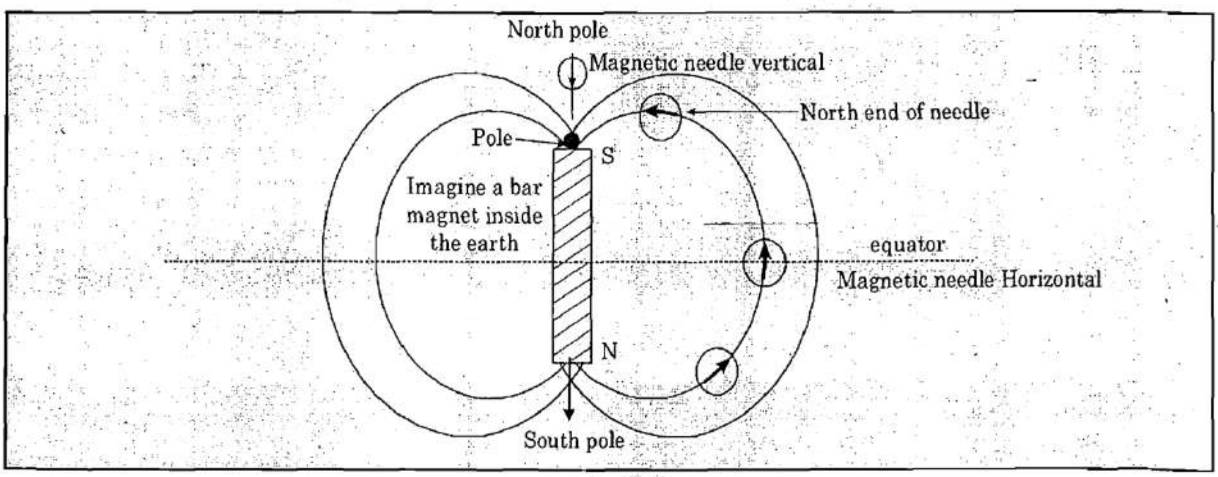
Running a Compass Traverse

- To run a compass traverse ABCDEA, the compass is set over the starting station A. The ranging rod at E is sighted and Back Bearing of the line EA is observed. Then the ranging rod at B is sighted and the fore bearing of the line AB is observed.
- The traverse line AB is ranged as done in chain surveying, and its length is measured with the help of a chain or a tape. the offsets to the objects (details) on either side of the traverse line AB are also taken similarly as in chain surveying.
- The compass is then moved to the station B. The back bearing of the line AB and the fore bearing of the line BC are observed. The traverse line BC is then ranged and chained, and offsets are taken.
- Similarly compass is then moved to the station C, D and E, respectively, and the processes of taking bearings, ranging, chaining and offsetting are repeated. Hence the traverse is complete.



Dip

- Earth is a powerful magnet. The lines of forces created by the earth's magnetic field are directed towards the north & south magnetic poles.
- A freely suspended magnetic needle aligns itself with the lines of magnetic force of the earth.
- The angle made by the lines of magnetic force with the earth's surface is called dip.
- Hence magnetic needle which aligns itself with the magnetic force is horizontal at equator but becomes vertical at magnetic poles.



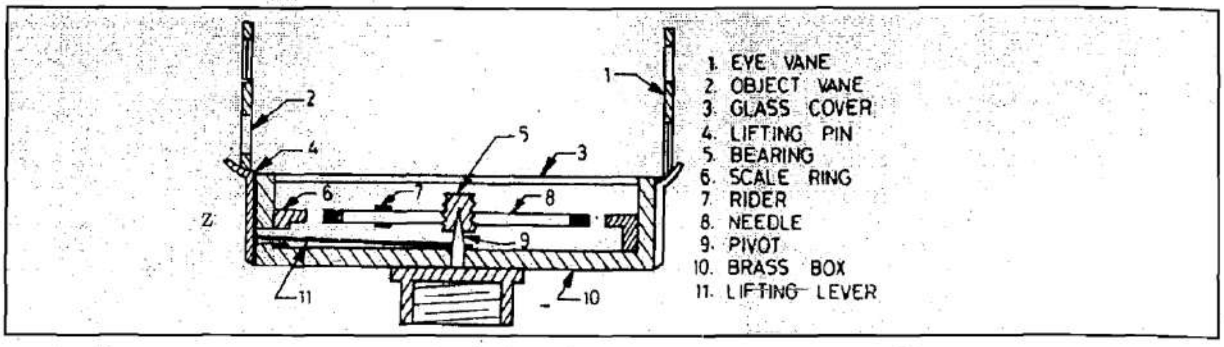
- At other places the value dip varies from 0°–90°

Note:

In Northern hemisphere the north end of the needle dips down.

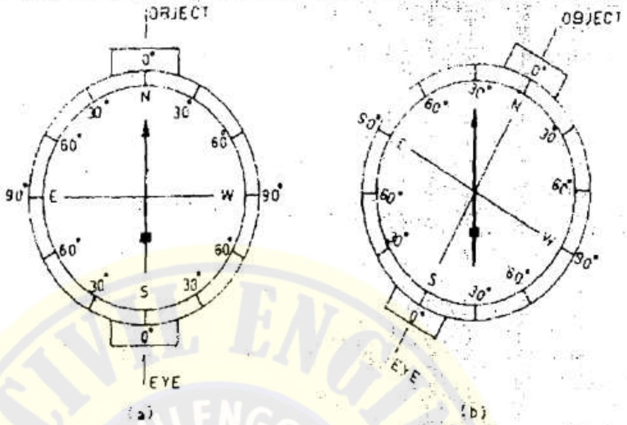
Surveyor's Compass

- Fig. shows the Cross sectional view of a surveyor's compass. It consists of a brass or aluminium circular box of about 150 mm diameter.
- The graduated card or scale ring is directly fixed to the box, which governs the size of compass.
- The graduations are in degree and half degrees.
- All parts of the compass except the magnetic needle are made of non-metallic materials.



1. Box	2. Lifting lever	3. Pivot
4. Circular graduated arc	5. Glass top	6. Sight vane
7. Jewel bearing	8. Lifting pin	9. Magnetic needle
10. Rider	11. Metal pin	12. Object vane

- When the compass is not in use, the object vane is folded over the box. it presses the lifting pin, and a lifting lever lifts the needle above the pivot. it prevents unnecessary wear of the pivot.
- The magnetic needle is made up of magnetic steel. The needle of its center has a conical Jwell bearing which rests on a hardend steel point
- A small metal rider or a sliding weight is provided on the needle to counteract the effect of dip. The rider can be slid along the needle so that the needle lies in a horizontal plane.
- The size of the compass is defined by the diameter of the reading edge of the graduated ring. It generally varies from 50 mm to 200 mm.
- The surveyor's compass is used for measurement of quadrantal bearings.



- It should be noted that since the graduated ring turns with the sight vanes and not with the compass needle, the directions E and W on the graduated ring are reversed from the actual east and west directions. This is required so that the reading of the north end of the needle gives directly the quadrantal bearing.
- The N-mark rotates as the line of sight is rotated, but the north end of the needle remains stationary. The N-mark coincides with the north end of the needle only when the line of sight is pointing towards the north.

Temporary & Permanent Adjustments

1. Temporary adjustments

Temporary adjustment are also known station adjustments. These adjustments are made at every set-up of the instrument. These adjustments consist of fixing the instrument to the tripod, centering and levelling it. Whenever the instrument is shifted to other stations, the temporary adjustments are changed and they have to be repeated.

2. Permanent Adjustments

- Permanent adjustments once made generally last for a long time, and these need not be repeated for a considerable period of time. The permanent adjustments of the instrument are generally done in laboratory or workshop by skilled persons.
- The permanent adjustments are required to ensure that, various components of the instrument are in the proper adjustments such that they perform the function properly.
- For example, in a surveyor's compass if magnetic needle is not straight and sensitive, the permanent adjustment of the needle will be required.

Note:

The temporary adjustments of an instrument can be considered as checking of brakes, air, petrol, oil, etc, before starting a vehicle, and the permanent ~~adjustments~~ can be considered as checking of the carburettor, etc. in the workshop at every servicing.

Temporary adjustments of a Surveyor's Compass

The following temporary adjustments are done after fixing the surveyor's compass on the tripod.

1. Centring

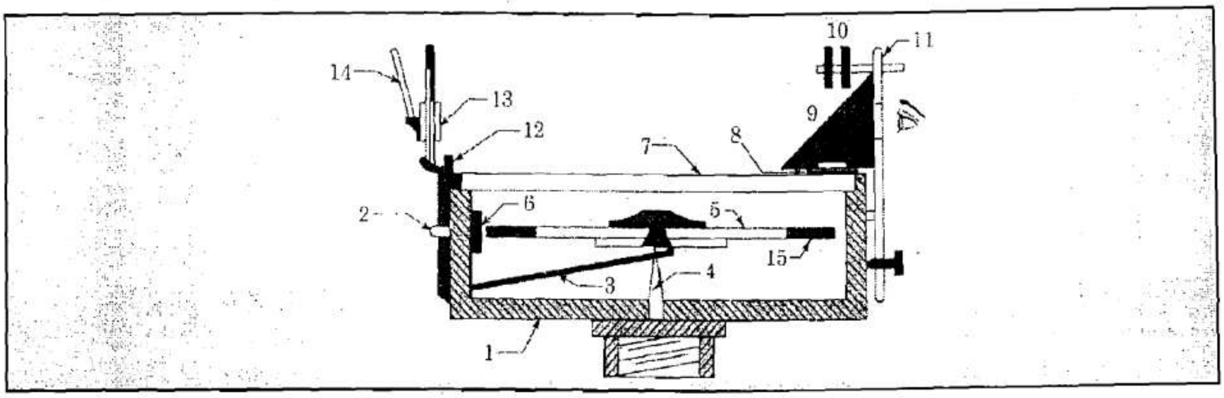
- Centring is the process of setting up the instrument exactly over the station peg. The centering is done by moving the legs of the tripod. If the compass has arrangement for attaching a plumb bob to its base, the centering is considered when the plumb bob is exactly over the peg fixed on the station.
- A compass does not need very accurate centering, unlike very precise instrume~~nts such~~ as a theodolite.

2. Levelling

- levelling is required so that the graduated ring is horizontal and it swings freely on the pivot. Both the ends of the needle should be in level with the graduated ring.
- If levelling screws and level tubes are fitted to the compass, the levelling is achived by mainpulating the levelling screws.
- If there are no levelling screws, the levelling is done by the ball-and-socket arrangement.

Prismatic Compass

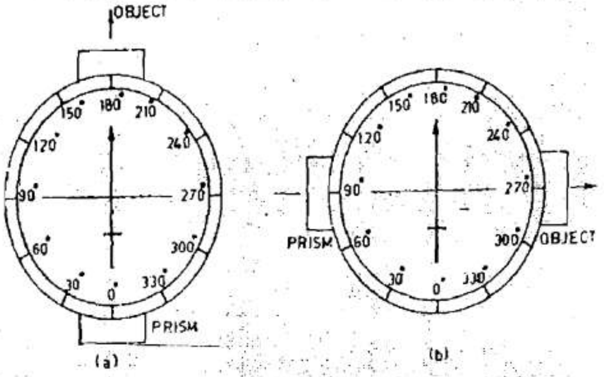
The prismatic compass is a magnetic compass in which there is a prism for taking observations.



1. Box	2. Braking pin	3. Lifting lever	4. Pivot
5. Needle	6. Spring	7. Glass cover	8. Prism cap
9. Prism	10. Sun glass	11. Eye vane	12. Lifting pin
13. Object vane	14. Mirror	15. Graduated ring	16. A gate cap

- The prismatic compass is generally smaller in size than a surveyor's compass.
- The prismatic compass consists of a circular box, about 85 to 100 mm diameter.
- The magnetic needle used in a prismatic compass is of broad in shape.
- An aluminum ring graduated in degrees and half degrees is directly attached with the needle.

- The graduations on the aluminium ring increase clockwise from 0° to 360°, with the zero of the graduations coinciding with the south end of the needle, 90° graduation is at the west, 180° graduation at the north and 270° graduation at the east as show below in the figure.
- The prismatic compass is used for the determination of the whole circle bearings (W.C.B.) of the lines.
- Readings are taken through a prism attached to the box.



- When the line of sight is exactly towards the north, the reading observed is 0°.
- When it points exactly to the east, the reading observed is 90°.
- It may be noted that in a prismatic compass, the sighting of the object and the reading of the bearing are done simultaneously, whereas in a surveyor's compass, first the object is sighted, and then reading of the bearing is taken by moving around the looking down from the glass cover.

Temporary Adjustments of a Prismatic Compass

1. Centring
2. Levelling
3. Focussing

- The prism is moved up or down in its slide till the graduations on the aluminium ring are seen to be clear, sharp and in perfect focus.

Permanent Adjustment of Surveyor's compass

1. Adjustment of levels
2. Adjustment of sight vanes
3. Adjustment for sensitivity of the needle
4. Adjustment for straightness of the needle.
5. Adjustment of pivot.

Permanent adjustment of prismatic compass

- The permanent adjustments of a prismatic compass are similar like a surveyor's compass, but they are much simpler. The following differences should be noted.
  1. Adjustments of levels: In a prismatic compass, there are no level tubes hence, there is no adjustment of levels.
  2. Adjustments for sight vanes: Sight vanes in a prismatic compass are not adjustable.
  3. Adjustments of the needle and pivot. Needle in a prismatic compass cannot be straightened.

CHAPTER

5

Traversing

Introduction

A traverse is a series of conneced lines whose length and direction are measured in field.

The field work in a theodolite traverse consists of

(i) reconnaissance,

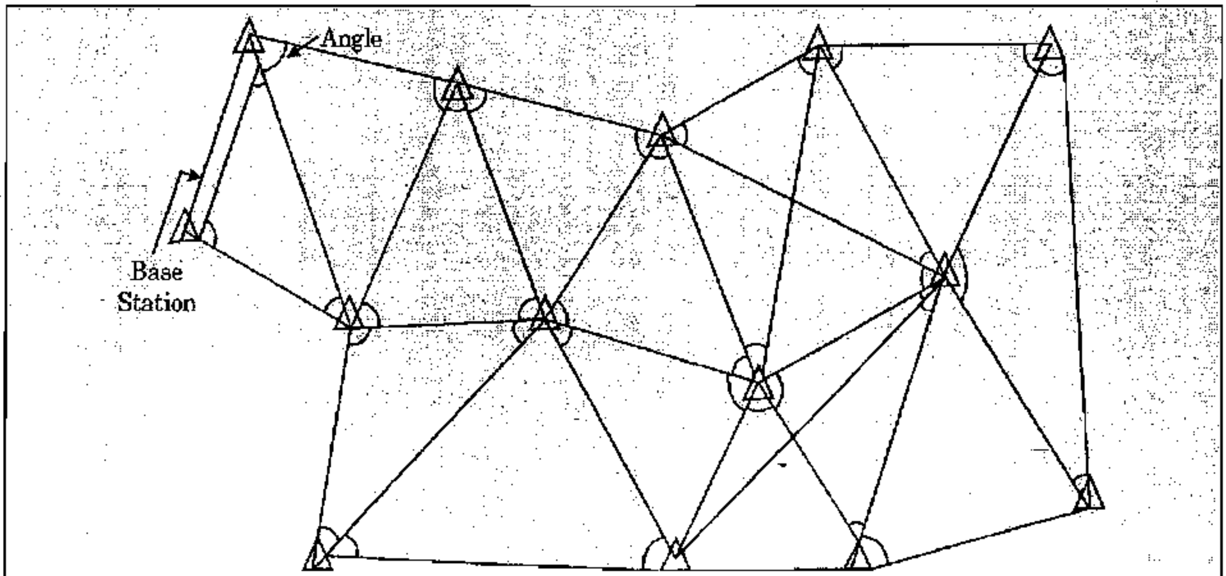
(ii) selection and marking of stations,

(iii) measurement of traverse lines,

(iv) angular measurements and

(v) picking up the details.

- A theodolite traverse is commonly used for providing a horizontal control system to determine the relative positions of the various points on the surface of the earth.
- Earlier when sophisticated distance measurement instruments were not available, we relied on triangulation. [A method where one base line was measured and all angles are measured to find out lengths of other lines]
- However with the advent of Electronic Distance Measurement Iinstruments [EDMI], traversing is fast replacing triangulation.



Triangulation

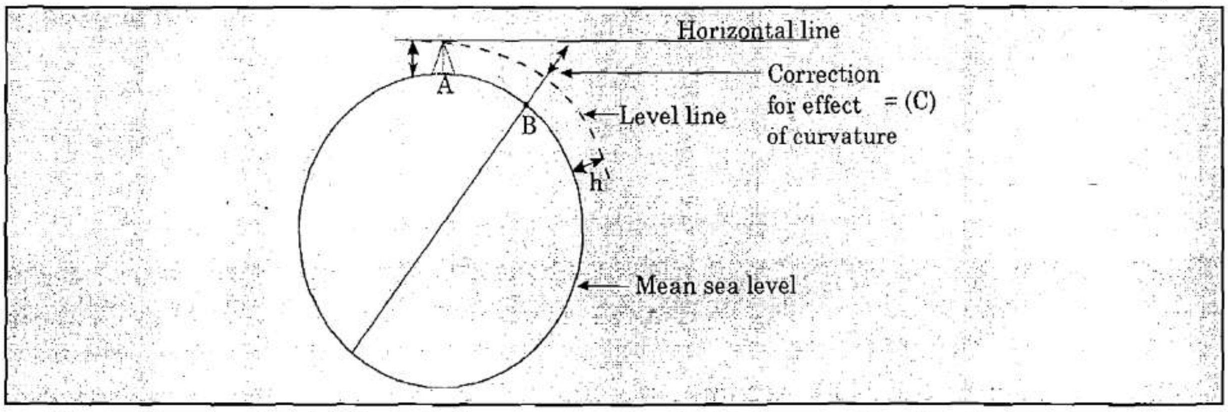
CHAPTER

6

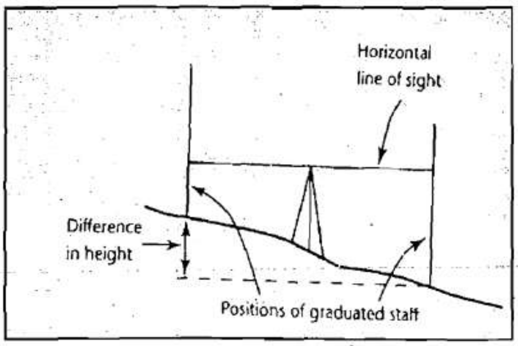
Levelling

Introduction

- Levelling is the operation required in the determination or, more strictly, the comparison of heights of points on the surface of the earth.
- If a whole series of heights is given relative to a plane, this plane is called a datum, and in topographical work the datum used is the mean level of the sea, because it makes international comparison of heights possible.
- The value for mean sea level (m.s.l.) as datum is obtained by averaging the elevations of high and low tides, at several points, for a long period of time, about 19 years.
- The vertical heights of points above or below a datum are referred to as levels.
- A level line is one that is at a constant height relative to mean sea level, and because it follows the mean surface of the earth it must be a curved line.
- A horizontal line, is tangential to the level line at any particular point, because it is perpendicular to the direction of gravity at that point. For a short distances these two lines considered to coincide with each other; but for long distances a correction for their divergence becomes necessary.



- Thus although point A & B are both at mean sea level in the previous figure due to curvature of level line (curvature of earth), it will be misconstrued that point B is below mean sea level. Thus it is clear that, why correction is required for the effect of curvature.
- The difference in the readings on the vertically held graduated staff where it is intersected by the horizontal line of sight is a direct measure of the difference in height between the two staff stations.



- **Elevation:** It is the vertical distance of the point above or below the datum surface.

  It should be noted that the vertical distances are measured along the direction of gravity.
- **Altitude:** It is the vertical distance of the point above mean sea level. Therefore, if the datum surface is the mean sea level, the elevation is the same as the altitude.

Vertical Line

- It is a line from any point on the earth's surface to the centre of the earth. It is commonly considered to be the line defined by a plumb line.

Bench Marks (B.M.)

- The bench mark is a fixed point of known elevation above the datum. Any point whose elevation is definitely known can be used as a bench mark.
- The following types of bench marks are established and used, depending upon the permanency and precision.

1. G.T.S. Bench Marks

The great trigonometrical survey (G.T.S.) bench marks are established by the Survey of India throughout the country. The levels of the G.T.S. bench marks are determined very accurately with respect to the mean sea level at Bombay port.

2. Permanent Bench Marks

The permanent bench marks are established at a closer interval between widely spaced G.T.S. bench marks. The bench marks are either established by PWD or SOI.

3. Temporary Bench Marks

These are the bench marks established temporarily whenever required. These are generally the points at which a day's work is closed and from which next day's work is started.

4. Arbitrary Bench Marks

These are the bench marks whose elevations are arbitrary assumed for levelling of a small area.

Different Methods of Levelling

The following methods are used to determine the difference in elevations of various points.

Direct Levelling

- This is the most common method of levelling.
- In this method, a spirit level fixed to the telescope of a levelling instrument is used to make the line of sight horizontal. Then all the vertical distances are measured with respect to this horizontal line of sight. These vertical distances are used to determine the difference in elevations of various points. The direct levelling is also called as Spirit levelling.

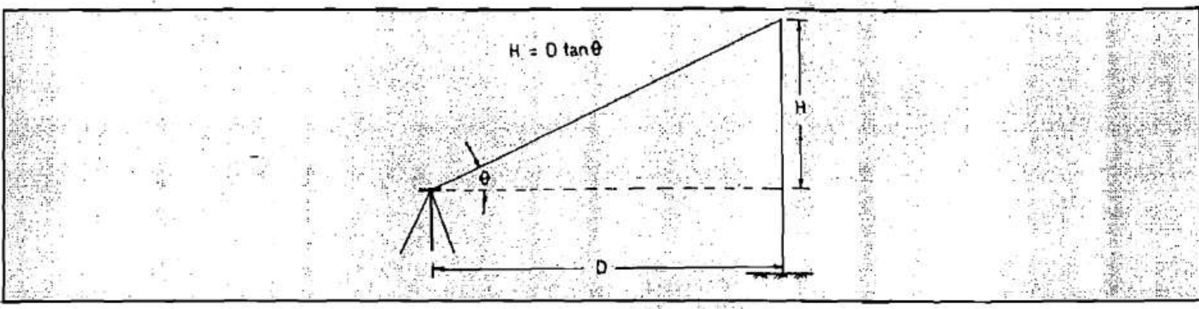
Trigonometric Levelling.

- This is the method of levelling in which the difference of elevations is determined indirectly from the horizontal distance and the vertical angle. As the trignometric relations are used to determine the elevations, the method is called as trigonometric levelling.

- Trigonometric levelling is generally used when direct levelling becomes difficult. For example, the elevations of inaccessible points, such as peak of mountain, top of towers, etc. can be determined from the trigonometric levelling.

  $$\boxed{H = D \tan\theta}$$

  Where H is the height of the top of tower above the horizontal line of sight. D is the horizontal distance and θ is the inclination of vertical line wrt to the horizontal line.



Barometric Levelling

- Barometric levelling is another type of indirect levelling in which the elevations of various points are determined indirectly from the changes in the atmospheric pressure. The atmospheric pressure decreases with an increase in elevation.
- Generally, an aneroid barometers are used for determining the changes in atmospheric pressure. These barometers are known as Altimeters. The aneroid barometer is not as accurate as the mercury barometer.
- Barometric levelling is a quick method of levelling. The Altimeter are commonly used to determine the altitude of aeroplanes.

Hypsometric Levelling

Hypsometric levelling is also a type of indirect levelling. In this method, the difference of elevations is determined by noting down the temperature at which water starts boiling. As the altitude of the place increases, the boiling point of water decreases.

Classification of Direct Levelling Methods

Simple Levelling

- This is the easiest type of direct levelling.
- In this method, only one setting of the instrument is done.
- This method is used for determining the difference of elevations of two points which are visible from a single position of the instrument.

Differential Levelling

It is a type of levelling which requires more than one setting of the instrument. This method is used when the two points whose difference of elevation is required are situated quite apart. Differential levelling is also called compound levelling.

Check levelling

- It is a type of differential levelling done for the purpose of checking of elevations which have already been obtained.

- Generally, check levelling is done at the end of each day's work from the last station to the starting station (of that day) for checking that day's work. Instead of returning to the starting station, sometimes the day's work is checked by connecting the last station to a point of known elevation or with a B.M.

Fly Levelling

- It is a type of differential levelling done for the purpose of determination of approximate elevations of different points.
- The fly levelling is done where rapidity, but low precision is required.
- Fly levelling is generally used for the reconnaissance of the area or for approximate checking of the levels.

Profile Levelling

- It is a type of differential levelling, done for the purpose of determining the elevations of the ground surface along a fixed line.
- The profile levelling is also called as longitudinal levelling.
- The levels obtained in profile levelling are used for plotting the longitudinal section which are required for various purposes such as fixing the gradients, determining the earthwork quantities etc.

Cross-section Levelling

- This type of differential levelling is done for determing the difference of the ground surface along the lines perpendicular to the centre line of the proposed road, canal, etc.

Reciprocal Levelling

- It is a method of levelling used for the determination of the difference of elevations of the two points which are situated quite apart, and it is not possible to set up the instrument midway between these points.
- For example, if the two points are located on the opposite banks of a river or pond or a valley, it would not be possible to set up the instrument in between these two points.
- Then difference of elevations between these two points is determined by reciprocal levelling, by first setting up the instrument at one bank and holding the staff at the other bank and then interchanging the positions of the staff and the instrument.

Precise Levelling

- It is a very accurate method of differential levelling used when high precision is required. The instruments and methods used are such that a very high degree of accuracy is achieved.

A levelling instrument called Level is used for determination of levels.

Major components of a level are

1. Telescope
2. Bubble tube

Telescope

- The Kepler type of telescope is commonly used in surveying instruments. It consists of two convex lenses mounted on the either side of the tube. The principal axes of the two lenses should lie on the same line. (The principal axis of a lens is the common normal to the two surfaces of a lens).

- The optical centre is the point on the principal axis, usually located near the geometrical centre of the lens. All rays passing through the optical center do not deviate, they go straight.
- A line passing through the optical centre and the centres of curvature of the lens is called the optical axis of the lens.

Optical Defects of a Lens

In the simple telescope it is assumed that the lenses are of negligible thickness and small diameter. But actually in telescopes, the thickness and diameter of the lenses are not negligible. This causes various defects in the telescope and causes curvature, distortion, unwanted colours and the image also becomes indistinct and blured. The two most common defects are

1. Chromatic Aberration and
2. Spherical Aberration

Chromatic Aberration

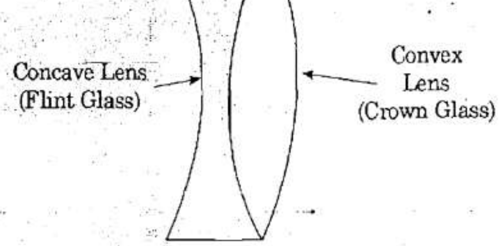
- The chromatic aberration occurs in a telescope due to of dispersion of light. The white light is split into its component colours. The image is, therefore, surrounded by a rain-bow of colours, and the focussing becomes difficult.
- Chromatic aberration is usually corrected by using two lenses cemented together to form the object glass. One of these lense is a convex lens of crown glass and the other one is a concave lens of flint glass. The convex lens is kept in the front towards the object.
- The two lenses are cemented by a material called canada balsam.

Spherical Aberration

- The spherical aberration occurs due to the spherical surfaces of the lens.
- Due to the spherical aberration, the rays incident on the edge of the lens are refracted more than rays incident on the centre of the lens.
- To correct this defect, two different lenses are combined to from a compound lens. In objectives, the convex lens and the concave lens when cemented together as discussed above corrects the spherical aberration as well.

Eye piece

- The most commonly used eye piece is the Ramsden eye piece. It is made of two identical plano-convex lenses with their curved faces towards each other.
- The Ramsden eye piece is free from spherical aberration but not free from chromatic aberration.

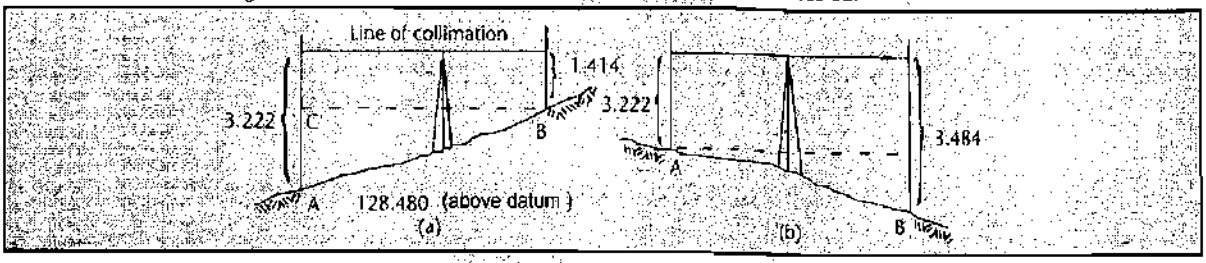


(a)

- The levelling staves of 3m and 4m lengths are commonly used in practice.
- Graduations on the staff give the distances from the bottom. Each metre is divided into 200 divisions. The thickness of each division is 5 mm.
- These divisions are painted alternatively black and white.
- However, in some staves, the graduations are marked erect, and when viewed through the instrument, they appear inverted.
- A circular level/pond bubble is sometimes provided at the back of the staff to check the verticality of the staff.

Procedure in Levelling

- The basic operation is the determination of the difference in level between two points.
- Consider two stations A and B as shown in fig. Set up the level, assumed to be in perfect adjustment, such that readings may be made on a staff held vertically on station A or B.
- If the readings on A and B are 3.222m and 1.414m respectively, then the difference in level between station A and B is equal to AC, i.e. 3.222 – 1.414 = 1.808 m, and this represents a rise in the height of the land at station B relative to station A.



- If the reading at station B is greater than that of station A(fig. b), say 3.484m, then the difference in level would be 3.222 – 3.484 = – 0.262m, and this would represent a fall in the height of the land at station B relative to station A. Hence we can conclude that
- If second reading less than first, represents a rise.
- If second reading greater than first, represents a fall.
- If the actual level of one of the two points is known to us than the level of the other points can be found by either adding the rise or subtracting the fall. For example, if the level at A is 128.480m above datum, then

  (a) Level at B= Level at A + Rise

  = 128.480 + 1.808

  = 130.288 m above datum

  (b) Level at B= Level at A – Fall

  = 128.480 – 0.262

  = 128.218m above datum.

- The levels at A and B are called as reduced levels (RL), because they give the level of the land at these points 'reduced' or referred to a datum level.
- This method of reducing the staff readings gives a system of booking known as the rise and fall method.
- Another method, known as the height of collimation method, also exists.

- The height of the line of collimation above the datum is found by adding the staff reading, obtained with the help of staff kept on a BM (point of known level), to the RL of that point.
- As shown in the figure (A) the height of collimation will be 128.480 + 3.222 = 131.702m, and this will remain same until the level is moved to another position.
- The levels of points such as b are determined by deducting the staff reading at these points from the height of collimation:

(a) Level at B = Height of collimation – Staff reading at B

= 131.702 – 1.414

= 130.288m above datum

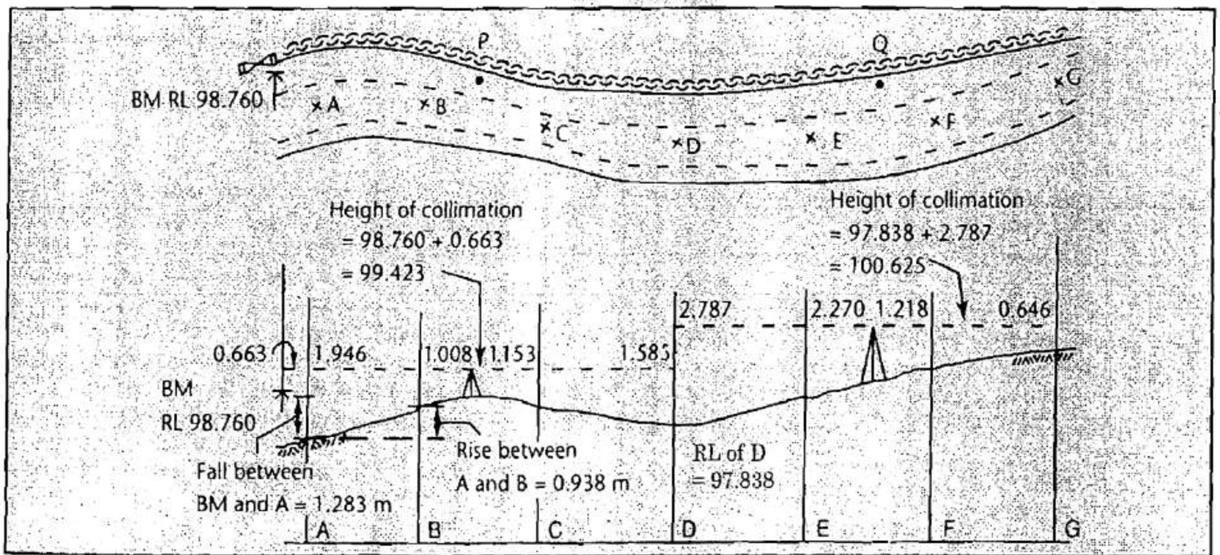
(b) Level at B = Height of collimation – Staff reading at B

= 131.702 – 3.484

= 128.218m above datum

General Procedure

This is best described by means of an example.



- The instrument is set up at a convenient position P such that a bench mark (BM) may be observed.
- This first reading, made with the staff on a point of known reduced level (BM) is known as a backsight (BS), hence we can say that back sight is the reading taken immediately after setting up the instrument, with the staff on a point of known level.
- The staff is now held at points A, B and C in turn, and readings, which are known as intermediate sights (IS), are taken. If it is observed that no readings after D are possible, owing either to change in level of the ground surface or due to some obstruction to the line of sight, it is necessary to change the position of the instrument.
- The last reading on D is then known as a foresight (FS), hence Fore Sight is the final reading taken before moving the instrument.

- The point D itself is known as a change point, because it is the staff position during which the position of the level is being changed.
- The instrument is placed at Q, set up and levelled, and the reading (a backsight) is taken on the staff at the change point D, followed by intermediate sights with the staff kept on points at which levels are required until a further change becomes necessary, resulting in a foresight on point G.
- This above procedure is repeated until all the required levels have been obtained.

Booking of level

1. Rise and Fall method

- The readings are booked in a level book which is specially printed for the purpose, as shown in table.

Note:

- *Each reading is entered on a different line in the applicable column, except at change points, where a foresight and a backsight entered the same line.*
- *The reason for this is a change point occurs at staff station D, and because the staff is not moved only one reduced level is involved requiring the one line. RL is obtained by applying the rise or fall shown by the foresight.*

Table

Backsight	Intermediate sight	Foresight	Rise	Fall	Reduced level	Distance (m)	Remarks
							BM on gate
0.663					98.760		98.76m above datum
	1.946			1.283	97.477	0	Staff station A
	1.008		0.938		98.415	20	B
	1.153			0.145	98.270	40	C
2.787		1.585		0.432	97.838	60	D (change point)
	2.270		0.517		98.355	80	E
	1.218		1.052		99.407	100	F
		0.646	0.572		99.979	120	G
Σ 3.450		2.231	3.079	1.860			

Last R.L − 1st R.L = 99.979 − 98.760 = 1.219

Justification of table

- Back sight − intermediate sight = 0.663 − 1.946 = − 1.283

  (−)ve means fall of A with respect to Bench mark.
- Intermediate sight of A − Intermediate sight of B = 1.946 − 1.008 = 0.938

Last R.L − First R.L = 99.979 − 98.760 = 1.219

Justification of table

Height of collimation of instrument at station P

= RL of Bench mark + B.S of Bench mark

= 98.76 + 0.663 = 99.423

RL of A = Height of collimation at P − Intermediate sight of A

= 99.423 − 1.946 = 97.477

RL of B = Height of collimation − Intermediatet sight of B

= 99.423 − 1.008 = 98.415

RL of D = Height of collimation at P − Foresight of D

= 99.423 − 1.585 = 97.838

Height of collimation of instrument station Q

= RL of D + Back sight of D

= 97.838 + 2.787 = 100.625

Now, RL of E

= Height of collimation at Q − Intermediate sight of E

= 100.625 − 2.270 = 98.355

The arithmetical checks to be applied to this system of booking are below

1. $\Sigma(BS) - \Sigma(FS)$ = Last RL − First RL
2. Σ(all RLs except the first) = Σ(each instrument height) × (no. of ISs and FSs deduced from it) − Σ(FS +IS)

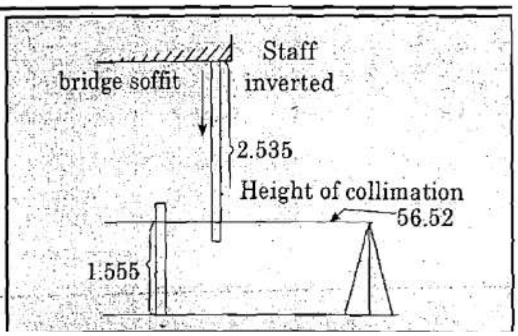
This second check is cumbersome, and is Generally ignored so that as a consequence, the intermediate RLs remains unchecked. In this case, errors could go unchecked compared with the rise and fall method where errors in all RLs are detected.

Note:

- *In Rise & Fall method the check for intermediate reading is done using $\Sigma Rise - \Sigma Fall$*
- *Reduction is easier with the height of collimation method.*
- *Collimation method is most suited for longitudinal or cross-sectional levelling and contouring where as Rise & Fall method is well suited for determining the difference of levels of two points where precision is required, e.g. estabilishing new benchmarks.*

Use of Inverted Staff

When the point, whose elevation is to be found, is much above the line of colimation (e.g. projection from the face of a building, underside of beams, girders and arches, etc.), the staff is placed inverted with its zero end touching the point.

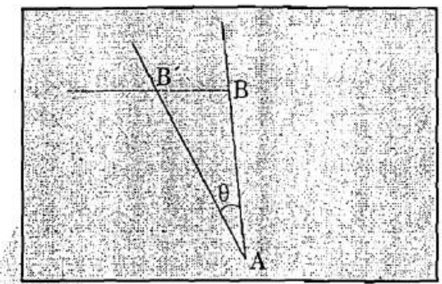


Error due to non-verticality of staff

$$\text{error} = AB' - AB$$

$$= AB\sec\theta - AB$$

$$\text{error} = AB(\sec\theta - 1)$$



Degree of Precision

When we start from a point and for cheking the precision we close the levelling work at the starting point, there is a loop formed.

If there is an error i.e. when RL of starting point doesnot match with the R.L. calculated from levelling around the loop, the error in the levels of various intermediate points is adjusted if the error is within permissible limit.

Permissible error for ordinary levelling

$$e = \pm 24\sqrt{K}$$

where e is in mm & k = perimeter is in km.

Correction in elevation at any point 1.

$$C_1 = \frac{-e \times l_1}{L}$$

e = closing error

l_1 = length upto point 1 from starting

L = total length of loop

Example 15.

The following readings were observed successively with a levelling instrument. The instrument was shifted after fifth and eleventh readings.

1. 0.585	2. 1.010	3. 1.735	4. 3.295
5. 3.775	6. 0.350	7. 1.300	8. 1.795
9. 2.575	10 3.375	11. 3.895	12. 1.735
13. 0.635	14. 1.605 m		

Draw up a page of level book and determine the R.L. of various points if the R.L. of the point on which the first reading was taken is 136.440.

Use the rise and fall method.

Sol.

As the instrument was shifted after fifth and eleventh readings, these are foresights. The sixth and twelfth readings are, therefore, backsights. The first reading is a B.S. and the last reading is a F.S. All other readings are intermediate sights.

Station	BS	IS	FS	Rise	Fall	RL	Remarks
						136.440	B.M.
A	0.585						
B		1.010			0.425	136.015	
C		1.735			0.725	135.290	
D		3.295			1.560	133.730	
E	0.350		3.775		0.480	133.250	CP
F		1.300			0.950	132.300	
G		1.795			0.495	131.805	
H		2.575			0.780	131.025	
I		3.375			0.800	130.225	
J	1.735		3.895		0.520	129.705	CP
K		0.635		1.100		130.805	
L			1.605		0.970	129.835	Last point
Σ	2.670		9.275	1.100	7.705		

Arithmetic Check

$$\Sigma BS - \Sigma FS = \Sigma Rise - \Sigma Fall = \text{Last RL} - \text{First RL}$$

or $2.670 - 9.275 = 1.100 - 7.705 = 129.835 - 136.440$

$-6.605 = -6.605 = -6.605$ **(OK)**

Example 16.

A new road across a filled-in valley has centre line pegs at 50 m interval to indicate a rising slope of 1 in 100. The first and last stations with chainages of 0.0 and 500.0 m are on bed rock. From the following data, determine the R.L. of the pegs and subsidence, if any.

Instrument station	Staff readings (chainages)		
A	0.590 (at B.M.)	2.010(0.0)	1.515 (50.0 m)
B	1.285 (50 m)	0.780 (100.0 m)	0.310 (150.0) m
C	2.005 (150 m)	1.575 (200 m)	1.005 (250 m)
D	2.610 (250 m)	2.195 (300 m)	1.585 (350 m)
E	2.855 (350 m)	2.415 (400 m)	1.785 (450 m)
F	1.480 (450 m)	1.045 (500 m)	–

Sol.

The table below shows the various entries.

Distance	BS	IS	FS	HI	Actual RL	Designed RL	Remarks
B.M.	0.590			100.590	100.00		
0.0 m		2.010			98.580	98.580	0.0
50.0 m	1.285		1.515	100.360	99.075	99.080	0.005
100.00 m		0.780			99.580	99.580	0.000
150.00 m	2.005		0.310	102.055	100.050	100.080	0.030
200.00 m		1.575			100.480	100.580	0.100
250.00 m	2.610		1.005	103.660	101.050	101.080	0.030
300.0 m		2.195			101.465	101.580	0.115
350.0 m	2.855		1.585	104.930	102.075	102.080	0.005
400.0 m		2.415			102.515	102.580	0.065
450.0 m	1.480		1.785	104.625	103.145	103.080	−0.065
500.0 m			1.045		103.580	103.580	0.0

Let us assume that the R.L. of B.M. is 100.00. The actual R.L. of different points are calculated as usual.

- As the first and last points are on bed rock, there is no subsidence at these points.
- The designed R.L. of these points are the same as the actual R.L. The designed R.L. of all other points are calculated from the given slope of 1 in 100.

The subsidence is calculated as the difference of the designed R.L. and actual R.L.

Example 17.

If the sensitivity of the bubble tube of a level is $30''$ of arc per division, determine the distance of a point at which the combined curvature and refraction correction become numerically equal to the error induced by dislevelment of one division of the level tube.

Sol.

$$\phi = \frac{s \times 206265}{L \times n}$$

or $$30'' = \frac{206265 \times s}{L \times 1}$$

or $$s = \frac{30L}{206265} \qquad \text{.............(1)}$$

Correction due to combined curvature and refraction

$$C = -0.0673\ L^2 \qquad \text{.............(2)}$$

where L is in km.

CHAPTER

15

Contouring

Introduction

The relative position of points in a plane are represented by a map. The value of the map is even more if the relief (variation in the elevation of earth's surface) is also included along with their relative positions.

There are two methods by which the conformation of the ground may be presented on a map.

(a) By delineating the surface slopes by shading, intended to given an impression of relative relief. The relative elevations of the points are not indicated in this case.

(b) By plotting the contour lines (imaginary line passing through points of equal elevations) on maps. These lines are arranged such that the form of the earth's surface can be portrayed with greater accuracy and thoroughness, and can be readily be interpreted.

Contours are used by engineers in a many ways.

Use of Contours

(a) Proper and precise location of engineering works such as roads, canals, etc.

(b) In location of water supply, water distribution and to solve the problems of steam pollution.

(c) In planning and designing of dams, reservoirs, aqueducts, transmission lines, etc.

(d) In selection of sites for new industrial plants.

(e) Determining the intervisibility of stations.

(f) Determining the profile of the country along any direction.

(g) To estimate the quantity of cutting, filling, and the capacity of reservoirs.

Definition of Contour

A contour may be defined as an imaginary line passing through points of equal elevation on the earth surface.

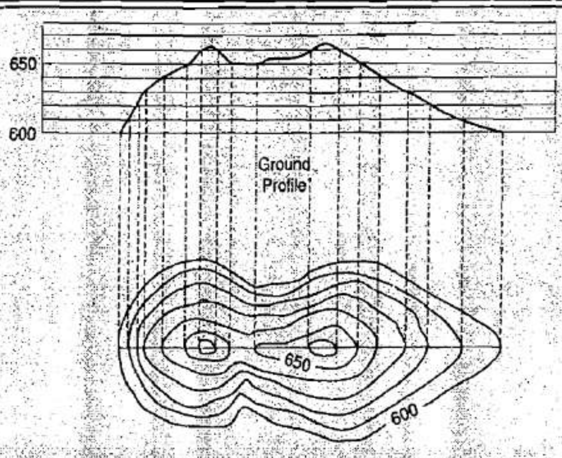
A contour line may also be defined as the intersection of a level surface with the surface of the earth.

Contour lines on a plan illustrate the topography of the ground.

When the contours are drawn underwater, they are termed as *submarine contours, fathoms or bathymetric curves.*

Note:

Generally the contours are not visible on the grounds excepts in the case of shorelines.



Contour representation

Contour Interval

- The vertical distance between consecutive contours is termed as *contour interval.*
- It is desirable to have a constant contour interval throughout the map.
- In special cases, a variable contour interval may also be provided.
- A variable contour interval is, as far as possible avoided since it gives a false impression of the relative steepness of the ground in different parts of the map.
- Generally contour intervals are taken 1 to 15 m.
- The smaller the contour interval, the more precisely the terrain relief is predicted on the plan.
- The contour interval depends upon the following factors.

  (i) Scale of the map (ii) Purpose of the map

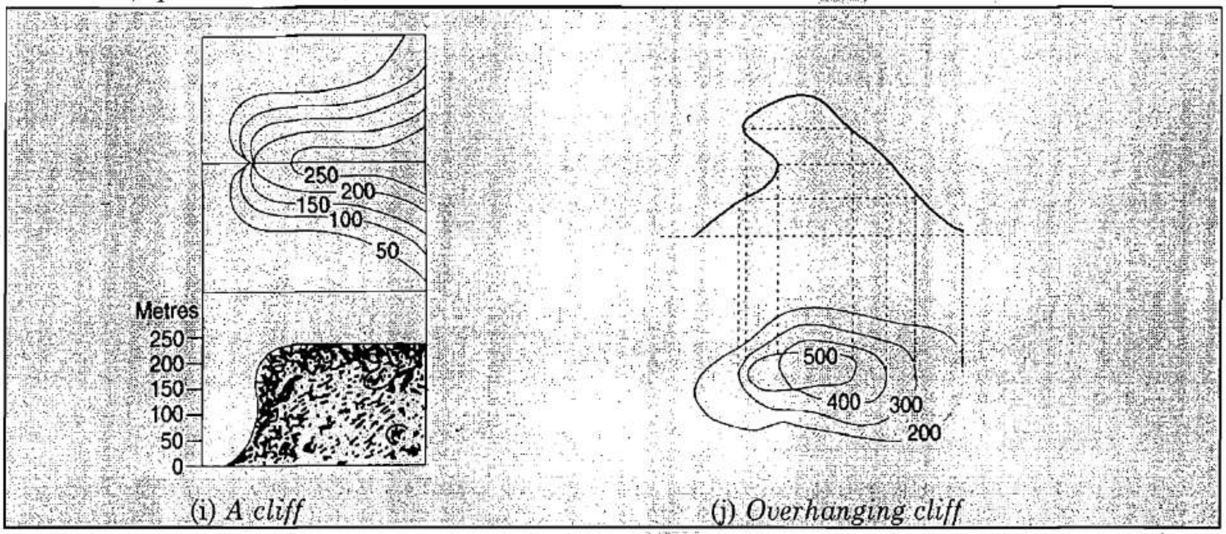
  (iii) Nature of the Country (iv) Time

  (v) Funds

1. **Scale of the Map:** If scale is small, the coutour interval is kept large so that there is no overcrowding of the contours. On the other hand, if the scale of the map is large, the contour interval can be kept small.
2. **Purpose of Map:** The contour interval selected should be small so that the map serves the intended purpose, but at the same time it should not be too small otherwise the cost of the work would be too much. The contour interval should be kept small when the plan is required for the detailed design.
3. **Nature of Ground:** For a flat ground, the contour interval is small, but for a steep slope, the contour interval is large. If the ground is broken, the contour interval is kept large so that the contours do not come too close to each other.
4. **Time:** Contour interval is kept large when time is less.
5. **Funds:** Contour interval is kept large when funds as less.

Characteristics of Contour Lines

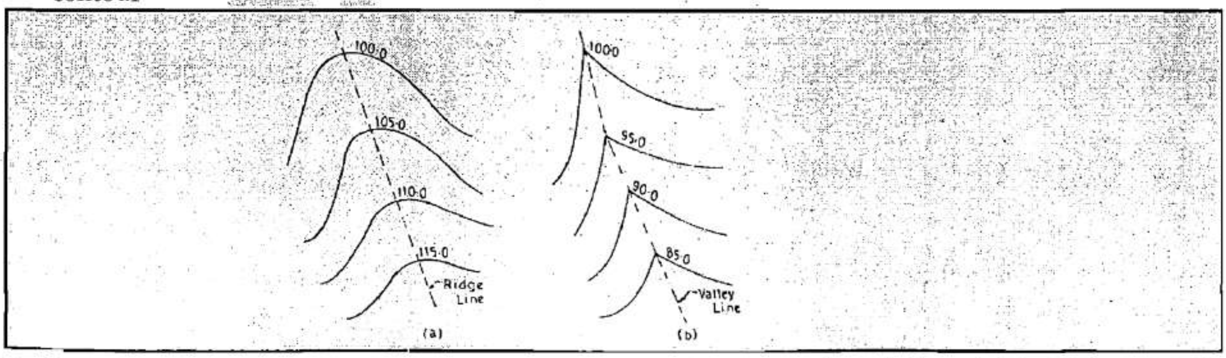
1. All the points of a contour line have the same elevation. The elevations of the contours are shown either by inserting the figure in a break in the respective contour or printed close to the contour. When no value is represented, it indicates a flat terrain. A zero meter contour line represents the coast line.



(i) *A cliff* (j) *Overhanging cliff*

2. Two contour lines do not intersect each other except in the cases of an overhanging cliff or a cave penetrating a hillside.
3. A contour line is a closed curve. They may close either on the map or outside the map, it depends on the topography.
4. Equally spaced contour represent a uniform slope and contours that are well apart represents a gentle slope.
5. A set of close contours with higher figures inside and lower figures outside indicate a hillock, whereas in case of depressions & lakes, etc., the lower figures are inside and the higher figures are outside.
6. A *watershed* or *ridge line* (line joining the highest points of a series of hills) and the *thalweg* or *valley line* (line joing the lowest points of a valley) cross the contours at right angles.
7. Irregular contours represent an uneven ground surface.
8. The direction of the steepest slope is along the shortest distance between the contours.

   At a point the direction of the steepest slope on a contour is, therefore, at righ angles to the contour



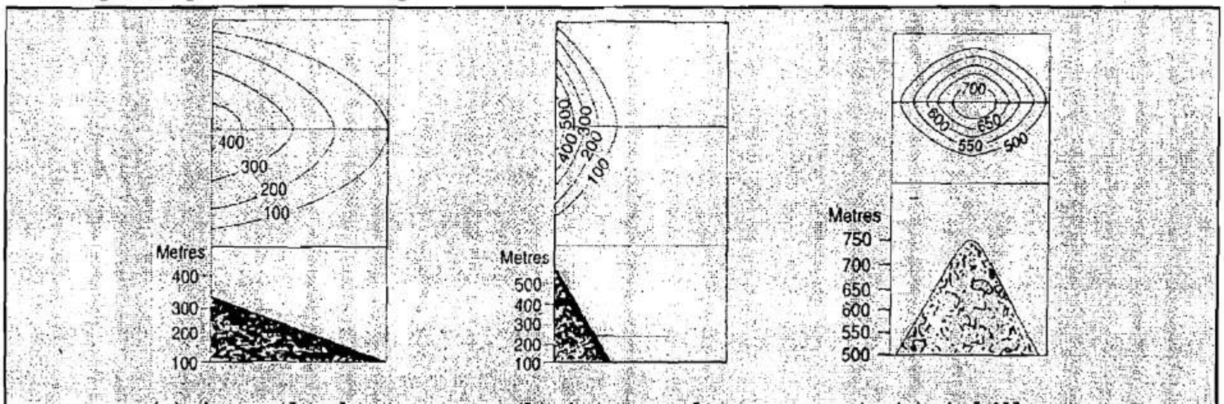
9. Two contour lines having same elevations can not unite and continue as one line. Similarly a single contour, can not put into two lines.

Typical Land Features and their Contour Forms Slopes

A slope may be gentle or steep.

A very steep slope is termed as *scarp*.

A high scrap is known as *crag*.



(a) A gentle slope (b) A steep slope (c) A hill

High-lying Forms

These are characterised by elevated grounds, for example hill, hillock and plateau.

Hills are elevated ground usually with a pointed peak. The countours of hills are bit circular in shape and increasing the contour values inwards.

Low-lying Forms

The most common among the low-lying forms are ravines, valleys, etc.

Ravine

Ravine is a through like depression of the earth's surface, elongated in one direction with the bottom inclined towards one side.

A ravine can be imagined as a depression washed out in the ground by flowing water.

Valley

A valley is a broad ravine with a gental sloping bottom.

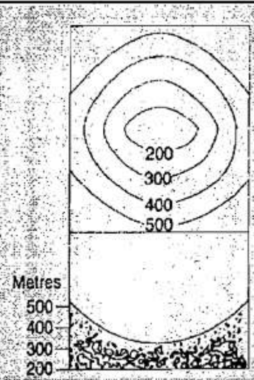
The countours of a valley are in a shape of V.

If the ground is low as compared to the surrounding land and the sides slope generally, it is called as a *depression*.

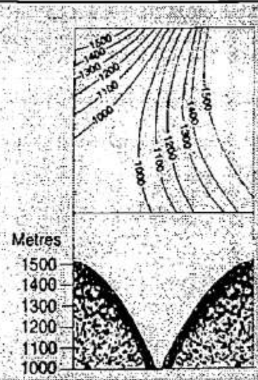
The contours are quite few and far apart.

If the valley floor is very narrow and has steep sides on a level terrain, it is called as *gorge* and in mountains as *canyons*.

Due to the steepness of sides, the contours are crowded.



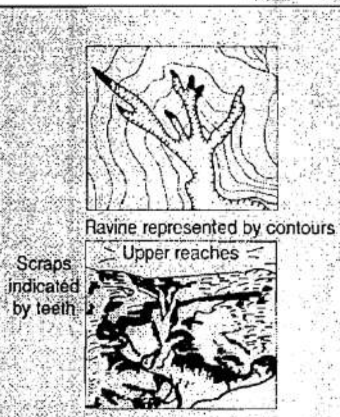
(d) A depression,



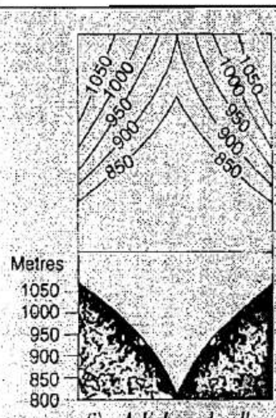
(e) A gorge or canyon

Valley Line and Ridge Line

- The slopes of ravine intersect along a line referred as the axis of the ravine, the *line of discharge*, or a *valley line* in case of a valley.
- Counter part of a ravine is a ridge—a convex form of terrain gradually declining in one direction.
- Two ravines are generally separated by a more or less pronounced ridge.
- The line along which the slopes intersect is referred as the *axis of ridge*, the *watershed* or *watershed line*. The watershed line is generally wavy.



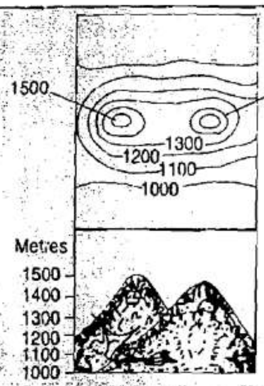
(h) Ravine

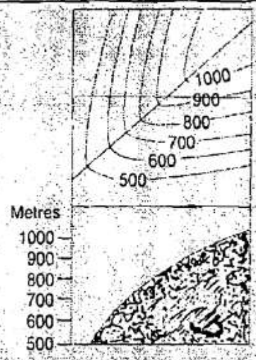


(i) A V-shaped valley

Saddle

- The lowest points on the watershed are known as *passes*.
- Pass is narrow low land passing through high mountains on either sides.
- Sometimes this narrow low land is cut back by the streams. This steep-sided depression is called as a COL. When this depression is broad and low, it is known as *saddle*.
- A part of the land in form of tongue, which cuts out from a hilly area is called as *spur*.
- The contours are similar to that of a valley, with a difference that here the counter values decrease towards the vee.

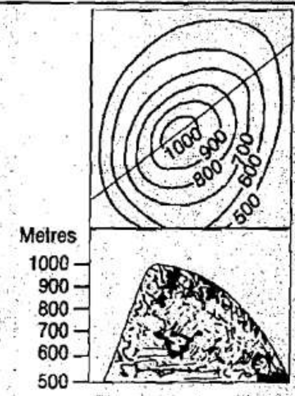




(f) A saddle, (g) A spur

- A high land, having flat narrow top with steep (scrap) slope on one side and gentle (dip) slope on the other side is called as *escrapment.*

  The contours will be closer towards the steep side and far apart towards the gentle side.



(j) Escrapment

Cliff

Cliff are the steep rock faces along the sea coast and may be vertical where the contour lines concide with each other, an *overhanging cliff* where the contour lines intersect each other.

Example 1.

From a topographic map, the areas enclosed by contour lines for a proposed dam are given below. Find the volume of impounded water using Trapezoidal formula.

Contours (m)	500	505	510	515	520
Area enclosed (hectares)	20	100	400	900	1100

Sol. We know that,

$$V = h\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + A_4\right]$$

$$= 5\left[\frac{20+1100}{2} + 100 + 400 + 900\right] \times 10^4$$

$$= 9{,}800 \times 10^4 \text{ cu.m.}$$