Surveying-I

Introduction to Surveying

***Definition*:** Surveying is the technique of determining the relative position of different features on, above or beneath the surface of the earth by means of direct or indirect measurements and finally representing them on a sheet of paper known as plan or map.

Object of Surveying/Purpose of Surveying: The primary object of survey is the preparation of plan of estate or buildings roads, railways, pipelines, canals, etc. or to measure area of field, state, nation.

- **The successful completion of any engineering project mainly depends upon accurate surveying.**

The primary aims of field surveying are:

- to measure the horizontal distance between points
- to measure the vertical elevation between points
- to find out relative direction of lines by measuring horizontal angles with reference to any artbitrary direction
- to find out absolute direction by measuring horizontal angles with reference to a fixed direction

Importance of Surveying to Civil Engineers

- The planning and design of all Civil Engineering projects such as construction of highways, bridges, tunnels, dams etc. are based upon surveying measurements.
- Moreover, during execution, project of any magnitude is constructed along the lines and points established by surveying.
- Thus, surveying is the basic requirement for all Civil Engineering projects.
- Other principal works in which surveying is primarily utilized are:
  - to fix the national and state boundaries
  - to chart coastlines, navigable streams and lakes.
  - to establish control point. (Control point → Stations having known position)
  - to execute hydrographic and oceanographic charting and mapping; and
  - to prepare topographic map of land surface of the earth.

Primary Division of Surveying

- Primary division is based on whether the curvature of earth is considered or not.
- The approximate shape of the earth can best be defined as an oblate or spheroid.

- Based upon the consideration of the shape of the earth, surveying is broadly divided into two types:
  (i) Geodetic surveying
  (ii) Plane surveying

Geodetic Surveying

- In this branch of surveying, true shape of the earth, i.e., curvature of earth is taken into account.
- This type of surveying is being carried out for highly precise work and is adopted for surveying of large area.
- All lines lying on the surface are curved lines and triangles are spherical triangles.
- The directions of plumb lines at various points are converging towards centre of earth.
- Geodetic survey is needed to fix the widely spaced control points that are later on used as necessary control points for fixing the minor control points.
- Geodetic survey is carried out by Department of National Survey of India.

Plane Surveying

- In this branch of surveying curvature of earth is neglected and is assumed to be a flat surface.
- In plane surveying, relatively small areas are under consideration (lees then 200 square kilometer).
- The vertical line is indicated by the direction of a freely suspended plumb bob. A single horizontal plane of reference is selected. There the plumb bob lines at all points of the area are assumed to be parallel. The curved line on the earth's surface is considered as straight.
- In plane survey difference in length between the arc and its substended chord on the earth surface for a distance of 18.2 km, in only 10 mm.
- Also, the difference between the sum of angles in a plane triangle and spherical triangle is only one second (1″) for a triangle at the earth's surface having an area of 195 square kilometer.

Uses of Surveying

- ► To prepare a topographical map this shows the hills, valley, rivers, villages, town, etc., of a country.
- ► To prepare a cadastral map showing the boundaries of fields houses, and other properties.
- ► To prepare an engineering map to show details like roads, railways, canals, etc.
- ► To prepare military map showing roads and railways, communication with different parts of country.
- ► To prepare contour map and to determine capacity of a reservoirs and to find the best possible route for roads, railways etc.
- ► To prepare archeological map including places where ancient relics exist.
- ► To prepare a geological map showing areas including underground resources.

Principles of Surveying

Location of a point by measurement of two control points

- Let P and Q be two given control points. Any other point say, R can be located with reference to these points, by any one of the following methods:

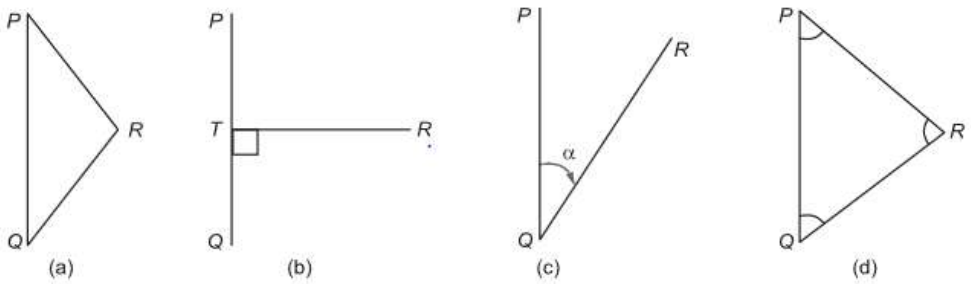


Fig. *Shows location of points*

- principles (a) and (b) are generally used in the method of chain survey.
- principle (c) are used in the method of 'Theodolite traversing'.
- principle (d) is used in the method of 'Triangulation'.

Working from the whole to the pert

- The main principle of surveying whether plane or geodetic is to work from the whole to the part.
- To achieve this in actual practice, a sufficient number of primary control points are established with higher precision in and around the area to the detail surveyed.
- Minor control points in between the primary control points, are then established with less precise method.
- The main idea of working from whole to part is to prevent accumulation of errors and to localize minor errors within the framework of control points.

The following terms are generally used in surveying:

(i) **Plan:** A plan is the graphical representation of the features on the earth surface or below the earth surface as projected on a horizontal plane.

(ii) **Map**

- The representation of earth surface on small scale, is called map.
- The map shows its geographical position on the globe.
- On a map, topography of the terrain, is depicted generally by contours, hachures, and spot levels.

Measurements in Surveying

- In surveying, the direction of gravity can always be taken as reference for all measurements.
- The direction of gravity is established by suspending a plumb bob freely. This direction of gravity is taken as the vertical direction. Thus horizontal direction is at right angles to the vertical direction.
- Any plane which contains the horizontal line and perpendicular to the vertical direction is called as **horizontal plane**. The plane containing the vertical line is called as **vertical plane**.

In surveying, the following basic measurements are made :

(a) **Horizontal distance:** The horizontal distance is measured in horizontal plane. On slopping ground, the distance between two points is reduced to horizontal equivalent.

(b) **Horizontal angle:** The horizontal angle is measured between two lines in horizontal plane. Theoretically the angle between two lines can vary from 0° to 360°.

(c) **Vertical distance:** As stated above, the direction of gravity is taken as vertical direction and thus vertical distances are measured in the direction of gravity. The vertical distances are measured to determine the difference of elevations between the various points.

(d) **Vertical angle:** Vertical angle is measured between two lines in vertical plane.

Units of Measurements

- There are many units of measurement that are prevalent worldwide like the CGS System, FPS System, MKS System but the standard one is the **SI System**.
- Past records of all survey works are usually in FPS System. Thus to use those records and any other records that are in different units, those have to be converted into SI unit or other unit that is in use.

Length Unit Conversion

Unit	Conversion factor for m
1 astronomical unit	149597870691
1 angstrom	1×10^{-10}
1 chain	20.1168
1 fathom	1.8288
1 foot	0.3048
1 furlong	201.168
1 inch	0.0254
1 light year	9460730472581000
1 mile	1609.344
1 nautical mile	1852
1 yard	0.9144

Area Unit Conversion

Unit	Conversion factor for m^2
1 acre	4046.85
1 are	100
1 hectare	10^4
1 ft^2	0.0929
1 $inch^2$	6.4516×10^4
1 $mile^2$	2589988.11
1 $yard^2$	0.8361

Volume Unit Conversion

Unit	Conversion factor for m^3
1 barrel	0.1589873
1 $yard^3$	0.765
1 US gallon	3.785×10^{-3}
1 UK gallon	4.546×10^{-3}
1 liter	0.001

Pressure Unit Conversion

Unit	Conversion factor for N/m^2
1 atm	101325
1 bar	1×10^5
1 mm Hg	133.3
1 pound per sq. feet (psf)	47.88
1 pound per sq. inch (psi)	6894.75
1 torr	133.32

Instruments used for taking measurements

(a) **For horizontal distance measurement :** Tape, chain, tacheometer, EDM etc.
(b) **For horizontal angle measurement :** Magnetic compass, theodolites, total station, sextant etc.
(c) **For vertical distance measurement :** Tacheometer, levelling instruments like dumpy level etc.
(d) **For vertical angle measurement :** Sextant, clinometer, theodolite etc.

Classification of Surveying

A. Primary Classification or Primary Division:

1. Plane surveying: Plane surveying is carried out over a small area, so the surface of the earth is considered as a plane. Plane surveying is done on an area of less than 250 sq.km.

2. Geodetic surveying: In geodetic surveying the curvature of the earth is taken into consideration. It is extended over a large area greater than 250 sq.km.

B. Secondary Classification:

1. Based on instrument: Chain Survey, Compass Survey, Plane Table Survey, Theodolite Survey, Tacheometric Survey, Photographic Survey

2. Based on method: Triangulation Survey, Traverse Survey

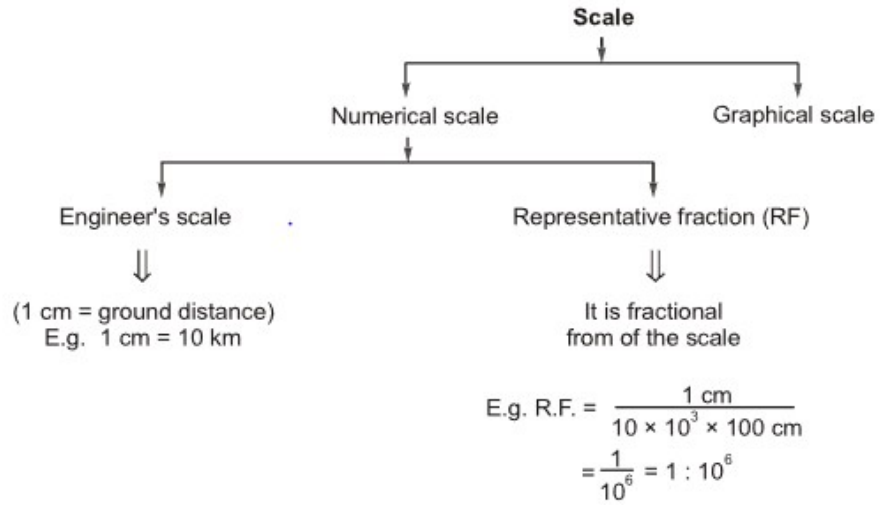
3. Based on object of survey: Geological Survey, Mine survey, Archeological Survey, Military Survey

4. Based on instrument: Land Survey, Marine Survey, Astronomical Survey

Scales

Technique through which we represent the ground distance on map.

$$\text{Scale} = \frac{\text{Map distance}}{\text{Ground distance}}$$



Scales may be represented in following ways:

1. Increasing Scale: Actual dimensions of objects are increased
2. Full Scale: Actual dimensions of objects are taken
3. Reducing Scale: Actual dimensions of objects are decreased

Representative Fraction: The ratio of the distance on drawing to the corresponding actual distance of the object is known as representative fraction.

Note:

Larger is the denominator of RF smaller is the scale.

Plain Scale: A scale representating either two units or a unit and its sub-division is called a plain scale.

Diagonal Scale: A scale representating either three units or a unit and its fraction upto two decimal places is called a diagonal scale.

Well Conditioned Triangles: A triangle is said to be well- conditioned or well proportioned when it contains no angle smaller than 30^0 and no angle greater than 120^0.

Chain Surveying

- Chain surveying is the type of surveying in which only linear measurements are made in the field and no angular measurements are taken.
- The main principle of chain surveying or chain triangulation is to provide a framework consist of number of well-conditioned triangles or nearly equilateral triangles. It is used to find the area of the field.

Purpose of Chain Surveying:

Chain surveying is suitable when:

1. A small area is to be surveyed
2. The formation of well-conditioned triangles is easy
3. The ground surface is more or less level
4. A small-scale map is to be prepared

Chain surveying is unsuitable when:

1. The area is very large
2. The formation of well-conditioned triangles becomes difficult due to obstacles
3. The area consists of too many undulations
4. The area is crowded with many details

Operations in Chain Surveying

1. Ranging: The process of locating intermediate points on a straight line between two end points in a straight line.

There are two methods of ranging:

I. Direct Ranging: It is done when both end stations of the survey lines are intervisible.

Two methods: Ranging by eye-judgement, Ranging by line-ranger

II. Indirect Ranging or Reciprocal Ranging: It is done when end stations are not intervisible

2. Chaining: The process of measuring the distance with a chain or tape.
3. Offsetting: The process of measuring the lateral distance of the object from the survey line to the left or right according to their positions.

There are two types of offsets:

1. Perpendicular Offsets: When the lateral measurements are taken perpendicular to the chain line, they are known as perpendicular offsets.
2. Oblique Offsets: Any offset not perpendicular to the Chain line is said to be oblique.

Basic Terms Used in Chain Surveying

When the area to be surveyed is large, it is recommended to subdivide the whole area into different fragments.

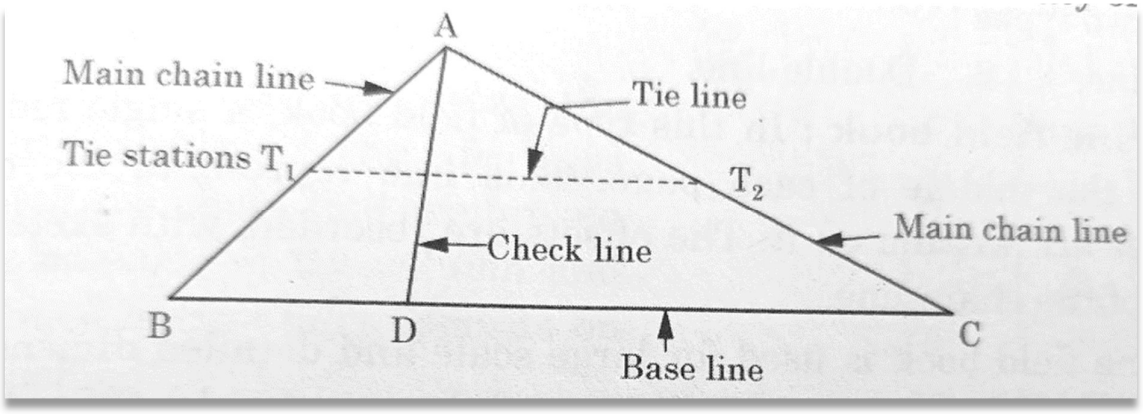


Fig.: Basic terms in Chain Surveying

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

Tie Station/Subsidiary Stations: It is a station on the main survey line joining two main stations. Tie stations are helpful in the inner detailings of the survey area. Tie station is also known as a subsidiary station. Here, T_1 and T_2 are the tie stations.

Main Survey Line: The chain line joining two main stations is called the main survey line. Here, AB, BC and AC are the main survey lines.

Tie Line: A chain line joining two tie stations is called a tie line. T_1T_2 in the picture is the tie line.

Base Line: It is the longest main survey line on fairly level ground and passes through the centre of the area. Baseline in surveying is the most important line of the survey area, as all the other lines are drawn with reference to this line. Here BC is the baseline.

Check Line: Check line is drawn to check the accuracy of the survey. It is also called a proof line. It should be noted that the check line is not used to locate points in Chain Surveying. *AD* is the Check line.

Instruments used in Chain Surveying

1. Chain
2. Ranging Rods
3. Arrows
4. Offset Rods
5. Cross-staff or Optical Square
6. Tapes
7. Pegs
8. Plumb Bob
9. Wooden Mallet

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

Types of Chain in Surveying

The various types of chain in Surveying are as follows :

S.No.	Type of chain	Length of chain	Number of links
1.	Revenue chain	33 ft	16 links
2.	Gunter's chain	66 ft	100 links
3.	Engineer's chain	100 ft	100 links
4.	Metric chain	20 m	100 links
		30 m	150 links

2. Ranging Rods: The process of locating a number of points on a long survey line is called Ranging. Ranging rods are used to locate intermediate points such that these points lie on the straight line joining the end stations. Ranging is required 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 25mm or 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 in length.
3. Arrows: 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 provides a check over the length of line as entered in the field notes.
4. Offset Rods: These are similar to ranging rods, except a stout open ring recessed hook is provided at the top. 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 hooks provided at the top of the rod, the chain can be pulled or pushed through the hedges or other obstructions if required.

5. Cross Staff: It is the simplest instrument used for setting out perpendicular i.e., taking offsets from a chain line.

   Common Forms of Cross-staff: Metal open cross-staff, French cross- staff

6. Tapes: Based on the materials, weights and lengths, various types of tapes are used in Chain Surveying:

   i. Cloth or Linen Tape: This is closely woven linen or synthetic material and is varnished to resist moisture. It is available in a length of 10 to 15 m and width of 10 to 15 mm. Cloth tape tends to change its length when stretched. It is likely to twist and not remain straight when subjected to strong winds.
   ii. 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 15, 20 and 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.
   iii. 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, 2, 10, 20 and 50 m and widths of 6 to 16 mm. A brass ring is attached at the end of the tape, the outer end of which is the zero point of the tape. Steel tapes cannot be used in the ground with vegetation and weeds.
   iv. Invar Tape: These are made up of an alloy of nickel (36%) and steel (64%). These tapes have a very low coefficient of thermal expansion. These are available in lengths of 30, 50 and 100 m and a width of 6 mm. Invar tape is seldom used in chain surveying.

Advantages of Invar Tape

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

Disadvantages of Invar Tape

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

7. Pegs: In chain surveying, these are used to mark definite points on the ground either temporarily or semi-permanently. 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.
8. Plumb Bob: Plumb bob is made of conical weight of metal (preferably brass) and is suspended from strong thread for testing the verticality of the objects. It is used to transfer the points to the ground while chaining on sloping ground as in method of stepping. It is also used for accurate centering of the theodolite over the station point.
9. Wooden Mallet: Wooden mallet (or hammer) is made of hard wood. It is 7 to 10 cm in diameter at ends, about 20 to 25 cm in length and is provided with a wooden handle about 45 cm long. It is used for driving in the pegs into the ground.

Chain Corrections

1. Correction for Chain Length

$$True\ or\ correct\ distance = \frac{Incorrect\ length\ of\ chain \times Measured\ distance}{Correct\ length\ of\ chain}$$

2. Correction to Area

$$True\ area = Measured\ area \times \left(\frac{Incorrect\ length\ of\ chain}{Correct\ length\ of\ chain}\right)^2$$

3. Correction to Volume

$$True\ volume = Measured\ volume \times \left(\frac{Incorrect\ length\ of\ chain}{Correct\ length\ of\ chain}\right)^3$$

4. Pull Correction

   $Cp=\{(P-P_o)L\}/AE$

   P = pull applied during measurement.
   P_o= Standard pull applied during calibration
   L = Measured length
   A = Cross-sectional area of the tape
   E = Young's modulus of material of tape

5. Temperature Correction
   $C_t=\alpha(T_m-T_o)L$
   Where, C_t= correction due to temperature
   α = linear coefficient of thermal expansion
   T_m = Mean temperature
   T_o= Standard temperature
6. Sag Correction
   $C_s=LW^2/24P^2$
   Where, W = Weight of tape per unit length.
   P = applied pull.
   L= length of the tape suspended between the supports

Errors in Chaining

Errors and mistakes in chaining may arise from any one or more of the following sources such as erroneous length of chain, bad ranging of intermediate points, poor straightening of tape, carelessness in holding and marking of points, variation of temperature, variation of pull, displacement of arrows, miscounting of chain lengths, misreading of tape, erroneous booking and many more. The two most common errors that occur in Chain Surveying are compensating and cumulative errors.

There are three sources of errors:

1. Instrumental errors

2. Natural errors
3. Personal errors

Classification of errors

1. Cumulative errors: The other name for cumulative error is systematic error. This error follows the law of mathematics and is hence called systematic error. They are liable to occur in one direction only and tend to accumulate. Cumulative error is directly proportional to the length of the line.
2. Compensating errors: This is also known as random error. This type of error is likely to occur in both directions and tends to compensate.
3. Mistakes in Chaining: These are errors occurring due to carelessness or inexperience of chainman.

Advantages and Disadvantages of Chain Survey

Advantages:

1. No angular instrument is required.

2. The length of lines are required only.

3. There is complete check on measurements due to check lines and tie lines in the frame work.

4. It is easy to performance and plotting as the number of the lines can be run between the frame work so as to reduce the length of off sets.

5. It requires less and easy calculation to obtain area.

6. It requires less time.

7. It a cheap.

Disadvantages

1. This method cannot be adopted when the boundary is broken.

2. It is unsuitable for narrow strip or road as it is difficult to run triangles.

Compass Surveying

Compass surveying is a significant part of surveying that is frequently used to locate an item using both angular and linear measurements. In this case, a compass is used to measure angles, while a chain or tape is used to measure lengths.

Some priorities for compass surveying are as follows-

- If a huge area needs to be surveyed, such as the river's course line or the coastal regions.
- Chain surveying becomes impractical when there are too many details and impediments in the area to allow for triangulation.
- If the surveyor is working within a strict time frame to complete the extensive area.

But there are also some limitations to compass surveying. It is not recommended for the areas that avoid public attention and have the presence of iron ore deposits, magnetic substances like metallic or steel structures, electric cables conveying current, etc.

Principle of Compass Surveying

- Compass surveying relies on a technique called **Traversing**, which uses a network of interconnected lines.
- The distances between the lines are measured using a chain or tape, and the magnetic bearings of the lines are measured using a surveyor compass. The creation of a network of triangles is not necessary for this survey.
- By deriving offsets from the primary survey lines, interior details are identified. Subsidiary lines may occasionally be used to locate these facts.
- Traversing can be done by various methods like compass traverse, plane table traverse, stadia traverse, theodolite traverse, etc.

Important Parts of Compass

1. A box with graduated circle
2. A magnetic needle
3. A line of sight

Types of Compass in Surveying

There are mainly two kinds of Compass used in Surveying, namely Prismatic Compass, Level Compass and Surveyor Compass.

A. Prismatic Compass

The prismatic compass is a magnetic compass in which there is a prism for taking observations. It consists of a circular box about 100 mm in diameter. The magnetic needle used in a prismatic compass is broad in shape. The prismatic compass is used in the calculation of whole circle bearings of the lines. Sighting of the object and reading the bearing are done simultaneously in the case of a prismatic compass.

Some main points:

1. Graduation circle is fixed to broad type needle. Hence, it will not rotate with the line of sight.
2. There is a prism at viewing end.
3. Sighting and reading can be done simultaneously.
4. The magnetic needle do not act as an index.
5. The graduations are in whole circle bearing.
6. Graduations are marked inverted since its reflection is read through prism.
7. The reading is taken through a prism.
8. Tripod may or may not be used. It can be held on a stretched hand also.

B. Surveyor's Compass

A surveyor compass is an instrument used for the measurement of horizontal angles and the bearing of a line of sight. The Surveyor compass is commonly referred to as the **Circumferentor**. It essentially consists of a graduated horizontal circle, a pivoted magnetic needle, and a sighting device. The size of the surveyor compass is defined by the diameter of the reading edge of the graduated ring. It generally ranges from 50 mm to 200 mm. The surveyor compass is used to determine the reduced bearings or quadrantal bearings of lines.

Some main points:

1. Graduation circle is fixed to the box. Hence, it rotates with the line of sight.
2. At viewing end there is no prism. There is only a slit.
3. Sighting and viewing cannot be done simultaneously.
4. Magnetic needle acts as index while reading.
5. The graduations are in quadrantal system.
6. Graduations are marked directly. They are not inverted.
7. The reading is taken by directly viewing from top glass.
8. Tripod is essential for using it.

Prismatic compass	**Surveyor compass**
In this compass the reading are taken with the help of prism.	There is no prism on it. Reading are taken with naked eyes
With the help of prismatic compass whole circle bearing (W.C.B) can be measured	With the help of surveyor compass reduced bearing can be measured.
Graduation in prismatic compass are marked from 0^{o} to 360^{o}	Surveyor compass is divided into four quadrant and graduation are marked from 0^{o} to 90^{o} in each quadrant.
In a prismatic compass a mirror is provided with the sight vane.	In a surveyor compass no mirror is attached to the objective vane.
Sighting the object as well as reading the graduated circle can simultaneously be done without changing the position of the eye.	Sighting the object as well as reading the graduated circle cannot be done simultaneously without changing the position of eye.

Purpose of Compass Surveying

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

2. When the area is hilly and chaining is difficult.

3. When the area to be surveyed is relatively large.

4. When the details are too many.

5. When the area is can not be divided into network of triangles.

6. When the area to be surveyed is long and narrow e.g. road, stream etc.

7. When the survey is to be done through dense forest.

Use and Working of Prismatic Compass

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

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

(i) Centering

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

(ii) Levelling

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

(iii) Observing the bearing.

To observe the bearing of a line AB

1) Centre the compass over the station A and level it.

2) Having turned up vertical prism and the sighting vane, raise or lower the prism until the graduations are clearly visible.

3) Turn the compass box until the ranging rod at the station B is bisected by the hair when looked through the slit above the prism.

4) When the needle comes to rest, look through the prism and note the reading at which the hair line produced appears to cut the image of the graduated ring which gives the required bearing of the line AB.

Readings are usually estimated to the nearest 15'.

Meridian

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

1) True meridian

2) Magnetic meridian

3) Arbitrary meridian.

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

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

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

Bearing

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

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

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

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

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

Representation of Bearing

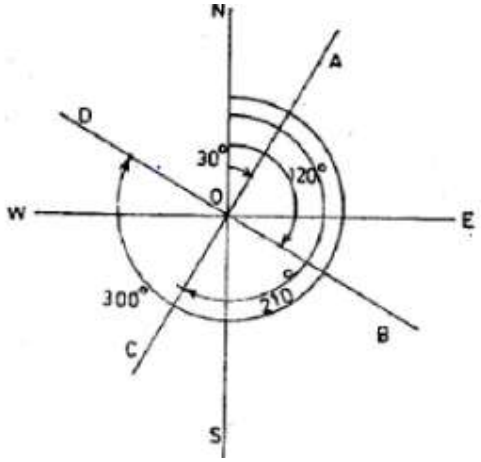
Bearings are expressed in the following two systems.

1) Whole circle bearings system.

2) Quadrantal bearings system or Reduced bearing system.

1) Whole Circle Bearing

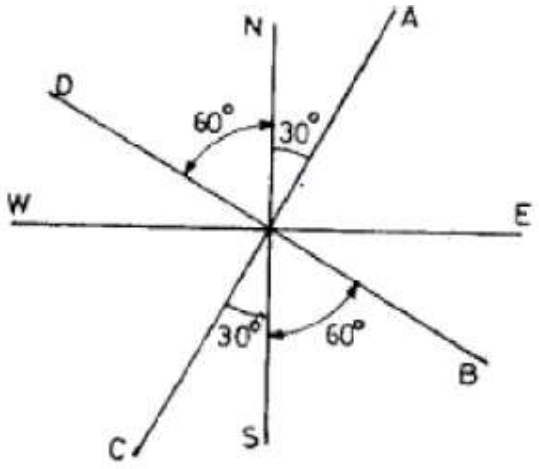
In this system, the bearing of a line is always measured clock wise from the direction of the north of the meridian towards the line around the circle. Whole circle bearings of lines have been shown in fig. below.



2) Quadrantal Bearings or Reduced Bearings

In this system the bearings of a line is measured from either the north or the south, clock wise or counter clockwise which ever is nearer to the line towards the east or west. The angle at any station in a plane is divided into four quadrants by two lines at right angles to each other. These

are the north south and east- west lines. The bearing is reckoned from 0^0 to 90^0 in each quadrant. Quadrantel bearings are also called Reduced Bearings.



Conversion of Whole Circle bearings into Quadrantal Bearings

The whole circle bearing of a line can be converted to quadrantal bearing by reducing it to an angle less than 90^0 which has the same numerical value of the trigonometric functions. Rule of conversion of whole circle bearings into quadrantel bearing.

S.No.	W.C.B	QUADRANT	RULE
1.	Between 0° to 90°	N.E	Q.B = W.C.B
2.	Between 90° to 180°	S.E	Q.B = 180°-W.C.B
3.	Between 180° to 270°	S.W	Q.B = W.C.B-180°
4.	Between 270° to 360°	N.W	Q.B = 180°-W.C.B

Fore And Back Bearings

Every survey line has two bearing, one observes at each and of the line. The bearing observed in the direction of progress of survey is called Fore Bearing (F.B) and the bearing observed in the opposite direction is called Back Bearing (B.B).

The bearing is always measured from North direction in clockwise direction.

In W.C. B. system.

Back bearing Fore bearing± 180°

Use (+) sign when fore bearing is less than 180° and (-) sign if it exceeds 180°.

In the quadrantal system the fore and back bearing are exactly equal but with opposite signs e.g. If the fore bearing of a line AB is Nθ_1°E as shown in Fig. its back bearing will be S θ_1°W.

Similarly, thus, it is obtained simply by substituting N for S or S for N and E for W or W for E.

Magnetic Dip and Declination

Magnetic Dip: Due to the magnetic influence of earth, the needle after magnetization will not remains in horizontal position. It will be inclined toward the pole. This deflection of needle with the horizontal is called dip of the needle. The dip is not constant but varies from place to place on the surface of earth.

Magnetic Declination: The magnetic meridian at a place does not coincide with the true meridian at that place. In some cases the magnetic meridian is deflected to the East side of the true meridian while in others it points to the west of the true meridian.

The horizontal angle made by the magnetic meridian with the true meridian is called magnetic declination. The magnetic meridian varies from place to place and also from time to time on the surface of the earth and hence, the declination is also different at different places.

Local Attraction

A compass needle is affected by the presence of masses of iron and steel such as lamp posts electric cables, steel girders etc., they deflect the needle and the effect of this disturbance is called local attraction. Due to local attraction, the difference between the fore bearing and back bearing of a survey line will not be equal to 180^0.The observed bearings of lines affected by local attraction are corrected by starting from the unaffected line and the correct bearings of the successive lines are calculated.

Detection of Local Attraction: Normally the back bearing and fore bearing of a line should differ by 180^0. If they do not, it may be due to observational error or local attraction when observational and instrumental errors are eliminated and if the difference still remains, the local attraction exists at one or at both the stations.

Sources of Local Attraction/Causes of Local Attraction:

The sources of local attraction are:

1. Magnetic rock or iron ore.

2. Electric poles carrying electric current.

3. Presence of iron rails and underground iron pipes.

4. Keys, knife, iron button with surveyor.

5. Iron made instruments such as hammer, chain, arrows, iron ranging rods near the instrument station.

6. Workshop sheds near the compass.

Errors in Compass Surveying

Errors in compass surveying may be due to the following causes:

(a) Instrument Errors

1. Compass out of level.

2. Needle not straight.

3. Movement of level sluggish.

4. Magnetism of needle weak.

5. Plane of sight not vertical

6. Line of sight not passing through centre of graduated ring.

(b) Personal Errors

1. Compass not properly levelled.

2. Compass not properly centred over the station.

3. Ranging rod or signal not accurately bisected.

4. Incorrect reading and recording of the graduated ring.

(c) Natural Errors

1. Variation in declination

2. Local attraction.

3. Magnetic changes in atmosphere due to clouds and storms. 4. Irregular variation in magnetic storms.

Levelling

Levelling in surveying is primarily used to determine the relative height of various points on, above, and below the ground's surface. It is a method of calculating the difference in elevations or levels between two points on the earth's surface.

Purpose of Levelling:

1. Levelling in done to determine the undulations of the ground on the earth surface. This is most important for engineers for the purpose of planning. designing and execution of engineering projects such as alignment of railways, highways, water supply and drainage etc.

2. Levelling also becomes necessary in the selection of site for bridges, dams, buildings and sanitary schemes etc.

3. Preparing of contour plans.

4. Setting points in the field to check the heights of objects.

5. To find the depth of cutting or filling for any work.

6. To layout gradients

7. To find difference of elevation between two points.

Important Terms in Levelling:

- **Level Surface:** A level surface is a curved surface in which all the points are at the same distance from the earth's surface. The continuous surface that is perpendicular to the earth's mean spheroid is known as a level surface.
- **Level Line:** The term "level line" refers to the line that represents a level surface. At every point, the level line forms a right angle with the vertical or plumb lines. It indicates that any point on a straight line is equally distant from the centre of the planet. For smaller area works, while being a curved surface, it is treated as a planar surface.
- **Horizontal Plane:** It is a plane tangential to the level surface at any point under consideration.
- **Horizontal Surface:** The surface through a point which is tangential to level surface at that point is called a horizontal surface.
- **Horizontal Line:** It refers to any line that lies in the horizontal plane.
- **Vertical surface:** A vertical surface through any point is a surface normal to the level surface at that point.
- **Vertical Line:** It is a line from any point of the Earth's surface to the centre of the Earth. Plumb line can be regarded as a vertical line.
- **Vertical Angle:** The angle between two connected lines in a vertical plane is called vertical angle.
- **Datum:** Datum is the reference with respect to which other stations are fixed.
- **Mean Sea Level:** It is a reference point and is obtained by averaging the elevations of high and low tides, at several points, for a long period of time, about 19 years.
- **Benchmark:** It is the fixed reference point of known elevation. Depending on the permanency and the precision with which the benchmark is located, benchmarks are classified as:
- *Great Trigonometric Survey (GTS) Benchmark*: These benchmarks are established by the Survey of India at an interval of about 100 km all over the country, with the datum being taken as the mean sea level at Bombay Port. The elevations of the benchmarks are shown in the GTS Maps.
- *Permanent Benchmark*: In between the GTS benchmarks, permanent benchmarks are established by the Government departments on a clearly defined and permanent point like the top of a parapet wall, a bridge or a culvert, kilometre stone, railway platform, etc.
- *Arbitrary Benchmark*: These are the reference points whose elevations are arbitrarily assumed generally for a small levelling purpose. It should be noted that arbitrary benchmarks do not imply any fixed datum.
- *Temporary Benchmark*: These are the reference points on which a day's work is closed and from where levelling is continued the next day. Examples of such types of benchmarks are the kilometre stones, parapets etc.
- **Reduced Level in Surveying:** Reduced level in surveying refers to equating elevations of survey points with reference to a commonly assumed datum. It is a vertical distance between the survey point and the adopted datum plane. Thus, it is considered as the base elevation, which is used as reference to reckon the heights or depths of other important places. Reduced here means equating and level means elevations. Datum may be a real or imaginary location with a nominated elevation of straight zero.
- **Line of Collimation:** Line of sight.

- **Axis of Bubble Tube:** It is an imaginary line tangential to the longitudinal curve of the bubble tube at its mid point. It is horizontal when the bubble is in the centre of its run.
- **Axis of Telescope:** This axis in an imaginary line passing through the optical centre of the object glass and the optical centre of the eyepiece.
- **Height of Instrument:** When the leveling instrument is properly levelled, the reduced level of the line of collimation is known as the height of instrument. This is obtained by adding B.S. (Back sight) reading to the RL of the B.M or change point on which staff reading is taken.
- **Back Sight or Back Sight Reading:** This is the first staff reading taken in any set up of the instrument. This reading is always taken on a point of known R.L eg BM or change point. It is abbreviated as BS There will be only one B.S in each get up of instrument.
- **Fore Sight Reading:** It is the last staff reading at any set up of the instrument. It is always taken at a point of unknown elevations and indicates the shifting of instrument. It is abbreviated as F.S.
- **Inter Sight Reading or Intermediate Sight:** It is any other reading between the BS and FS in the same set up of instrument. It is always taken on the points whose elevations are to be determined. It is denoted by ES. There can be any number or no number of I.S.
- **Change Point:** This point indicates the shifting of the level. At this point two staff readings are taken. First is the FS taken form one setting and second is the B.S taken with the next setting. Well defined objects should be selected as C.P. as boundary stone. Kilometre stone, rail top, plinth of building etc. It is also called a Turning point.
- **Focussing:** The method or way of setting the eye piece and the object glass at a proper distance apart for the clear vision of object is called as focussing.

Types of Levelling in Surveying

Various types of direct levelling are discussed below :

- **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 to check 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, the day's work is sometimes checked by connecting the last station to the point of known elevation or with a B.M.
- **Fly Levelling:** It is a type of differential levelling in surveying done to determine 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 to determine the elevations of the ground surface along a fixed line. Profile levelling is also called longitudinal levelling. The levels obtained in profile levelling are used for plotting the longitudinal section, which is required for various purposes such as fixing the gradients, determining the earthwork quantities etc.
- **Cross-section Levelling:** This is also a type of differential levelling method. It is done to determine the difference of the ground surface along the line perpendicular to the center line of the proposed road.
- **Reciprocal Levelling:** It is a method of levelling in surveying used to determine the difference in 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, pond, or valley, it would not be possible to set up the instrument in between them. The difference in 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.

Application of Levelling in Surveying

Some of the main applications of levelling in surveying are discussed below.

1. Levelling is required for the estimation and design of numerous civil engineering projects, including roads, bridges, canals, etc. It is also required to survey routes and alignment of highways, bridges etc.
2. Levelling is necessary for the purpose of earthwork, including cut and fill.
3. The application of levelling includes pipeline surveys to determine their routes and also to provide optimum slope for the smooth flow inside pipelines.
4. Levelling in surveying helps in preparing contour maps and topographic maps as well.

Types of Levelling Instruments in Surveying

- A level
- A levelling staff

Auto Level

The auto level is also called as self aligning level or automatic level. In auto level the line of sight is levelled automatically. The fundamental difference between self aligning level and the directly level is that in the former the line of sight is no longer levelled manually using spirit level but is levelled automatically.

Levelling Staff

It is a graduated rod of rectangular section, to measure the vertical distance by which the staff station is above or below the horizontal line of sight.

The levelling staff is made of teak wood or aluminium alloy. Brass cap is provided to the bottom and to the top of staff. Markings of metre, decimetre are engraved from bottom to top.

Reduction of Levels

There are two methods of calculating the reduced levels or elevation of points form the staff readings observed in the field. The process of calculating the reduced level is called reductions of levels.

1. HEIGHT OF INSTRUMENT OR COLLIMATION METHOD

2. RISE AND FALL METHOD

Height of Instrument Method

In this method after setting the instrument height of instrument is calculated for each set up of instrument by adding B.S. reading to the R.L of the point where B.S reading is taken and then the R.L of other points in the same set up are obtained by deducting the staff reading i.e. I.S and F.S from this H.I.

The procedure is explained below:

1. First take a reading on B.M.

2. Find the R.L of the line of collimation or H.I. by adding this B.S. reading to the R.L of B.M.

Height of instrument = R.L of B.M + B.S

3. Calculate the R.L of point by subtracting the IS and F.S readings from the height of instrument.

4. When the instrument is shifted and levelled at new position the new plane of collimation is set up and its height is calculated by adding the B.S reading taken at a changed point to the R.L of that change point.

R.L of new line of collimation = R.L of C.P+ B.S

5. Find the R.L of the points taken in this set up by subtracting their I.S and F.S readings from this new H.I.

6. Repeat the process unstill all the reduced levels are calculated. 7.

At the end always apply the arithmetic check which's Σ B.S-Σ F.S= last R.L- First R.L

Rise and Fall Method

In this method the difference of elevation between two consecutive points is calculated by comparing each point after the first with the immediately preceding it ie.. two consecutive staff reading. If the staff reading of the following point is greater than the preceding point the difference in reading will be a fall and if the staff reading of the following point is smaller than the preceding point, the difference in reading is a rise. This fall or rise in written in their respective column in the level book against the following point The reduced level of the point is determined by adding the rise to or subtracting the fall from the reduced level of the preceding point. Height of instrument is not calculated in this method.

The following Arithmetic check is applied at the end to have a check on calculations.

Σ BS- Σ F.S= Σ Rise-Fall = Last R.L.-First R.L.

which should have the same magnitude and direction.

SI.No	Height of collimation method	Rise and fall method
1.	It is more rapid, less tedious and simpler as it involves few calculation.	It is more laborious and tedious , involving several calculations.
2.	There is no check on the RL of the intermediate points.	There is a check on the RL of the intermediate points.
3.	Errors in intermediate RL's cannot be detected.	Errors in intermediate RL's can be detected.
4.	There are two arithmetic checks on the accuracy of RL calculation. ∑BS -∑FS = Last RL –First RL.	There are three arithmetic checks on the accuracy of RL calculation. ∑BS -∑FS = ∑Rise -∑Fall =Last RL –First RL.
5.	It is suitable in the case of L.S and C.S, Contour etc.	It is suitable in fly leveling where I intermediate sights are less.

Plane Table Surveying

- Plane table surveying is a graphical method of surveying in which field work and plotting are done simultaneously.
- It is mainly used for small and medium scale mapping (1 : 10000 to 1 : 250,000)
- It is also used for plotting the topographical maps in the field.
- Before starting plane table survey at first control stations are establish to cover entire area, then after a suitable scale is decided.
- After that surveyor starts collecting detail from either of the point and traverses all the stations.
- Elevation of points of observation are determined with the help of levelling, Indian clinometer, telescope and alidade.
- The finished map so produced are known as topographic maps and this graphical method of producing topographic maps is known as cartography.
- It should be noted that all the measurements made are plotted directly on the drawing sheet instead of recording in the field book.
- The principle used in plane table surveying is that an unknown point of interest can be established by measuring it directions from known points.

Advantages of Plane Table Surveying

- The sighting and plotting are done simultaneously hence there is no chance of missing any detail.
- Irregular objects can also be plotted accurately as the lay of land is in view.
- It is most rapid and useful for filling in details.
- The error and mistakes in plotting can be checked by drawing the check lines.
- No great skill is required.
- It is less costly in comparison to theodolite survey.
- It is very advantages in areas, where compass survey is not reliable e.g. area affected by magnetic field.

Disdvantages of Plane Table Surveying

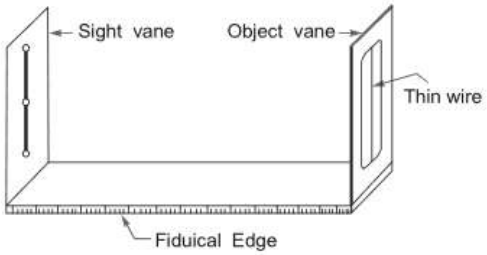
- It is not suitable for, work in a wet climate and in a densely wooded country.
- Plane table is heavy and akward to carry and the accessories are likely to be lost.
- It does not give very accurate result.
- It becomes difficult, if plan or map is to be plotted on some different scale due to absence of field notes.

Equipments used in Plane Table Surveying

(i) **Plane table board:** It consist of a drawing board mounted on a tripod which can be clamped in any position with the help of wing nut.

(ii) **Tripod:** An open frame type light tripod is usually used in the simplest form of plane tables, levelling of the board is achieved with the tripod legs and checking the horizontality of the board with the help of two spirit levels fixed at right angles to each other in a block of wood.

(iii) **Alidade:** Alidade is a straight edge ruler used for sighting the objects and drawing lines with object vane and sight vane. Line of sight will be parallel to the fiducial edge.



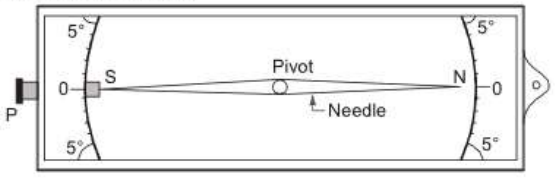
Plane alidade

(iv) **Level tube/ Spirit level**

- The essential condition in plane table surveying is that the board should be level, this level tube is either tubular or of the circular type.
- It is placed on the board in two positions mutually at right angles and the bubble is centered in each position to make the board horizontal.

(v) **Trough compass**

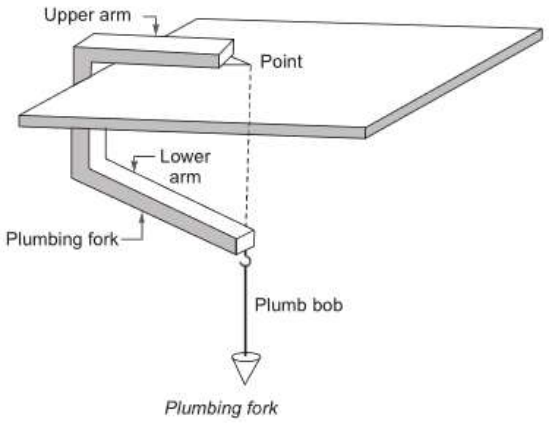
- It is used to orient the plane table w.r.t. magnetic meridian.
- Side of trough compass should be parallel and plane such that they can be used as a ruler or for placing the compass such that it coincides with the line already drawn in N-S direction.



Trough Compass

- At the extremities of the trough compass, there are graduated scales with zero at the centre and marking upto 5° on either side of the zero line.

(vi) **Plumbing form**



Plumbing fork

- Plumbing form is a U-shaped metal frame.
- Point of upper arm and plumb line are in same vertical line.
- Plumbing fork can be used for the following purpose.

(a) Centering the plane table over the station occupied by it which is already plotted on the drawing sheet.

(b) Transferring ground point on the drawing sheet.

(vi) **Drawing Sheet :** The drawing sheet used should be of the best quality to withstand rubbing scrubbing.

Setting of a plane table

Following operations are included in setting up of the plane table.

1. **Centering**
   - It is the operation of bringing the plotted station point exactly over the ground station
   - A plumbing fork is used for checking the centering.

   NOTE: Exact centering is important for large scale mapping only. For small scale mapping, an error in centering of about 30 cm is permissible.

2. **Levelling**
   - It is the operation of bringing the plane table in horizontal plane.
   - Level the board with the help of a spirit level.

3. **Orientation**

   (a) **Orientation with a Trough Compass**
   - When the plane table occupies the starting station, the trough compass is placed on the drawing sheet and rotated till the needle of the trough compass points to zero.
   - A line is drawn parallel to the long edge of the trough compass which represents the magnetic meridian.
   - In order to orient the plane table at other stations, trough compass is placed on the drawing sheet with its long edge along the line representing the magnetic meridian.
   - Plane table is then rotated till the needle ends point to zero. Plane table is then clamped at this position.
   - **Drawback:** This method of orientation is not very accurate.

   (b) **Orientation by Back-Sighting :** In this, the plane table is oriented by back sighting. Let the plane table is set up at station *Q* on the line *PQ* which has already been plotted as '*pq*' on the drawing sheet when the plane table was set up at station *P*. The alidade is placed along the plotted line '*qp*' and the plane table is rotated till the line of sight bisects the ranging rod at P. Plane table is then clamped at this position.

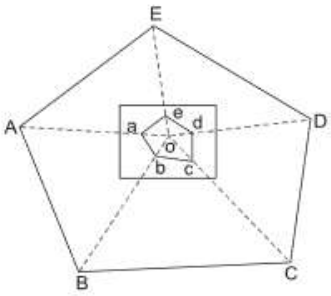
Methods of Plane Table Surveing

(i) Radiation method

(ii) Traversing method

(i) **Radiation**

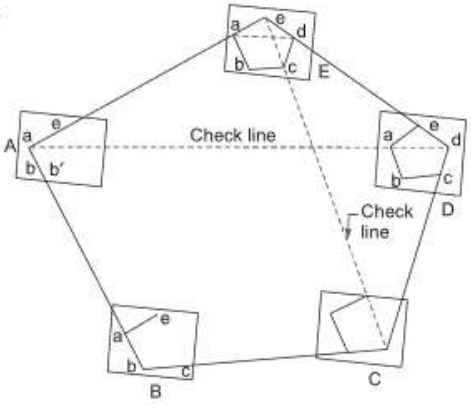
- In this method instrument is set up at a station and rays are drawn to various stations which are to be plotted, then distances are cut on a suitable scale after actual measurement.
- It is suitable for small area, and all station should be visible and accessible from the plane table station.



Radiation method

(ii) **Traversing**

- This method of traversing is same as compass traverse and theodolite traverse.
- A plane table traverse is a very rough type of traverse and is used generally for depicting the topographical details directly on the plane table.
- Traverse consists of a series of straight lines connected together.
- In plane table traversing, the angles are not measured but are in fact plotted directly.
- Plane table traversing is run between the stations whose positions have previously been fixed by some other precise methods like the theodolite traverse or the triangulation.
- The plane table is set successively on the traverse stations and back sight is taken on the preceding station followed by foresight on the following station.



Plane table traversing

- The measured traverse lines are plotted directly on the paper to some suitable scale.

Errors in plane table surveying

These are three types of errors involved in plane table:

1. Instrumental errors

2. Error due to manipulation and sighting

3. Errors in plotting

Instrumental Errors

(1) The top surface of plane table not being smooth.

(ii) The working edge of the alidade may not be straight.

(iii) The vanes of alidade may not be vertical.

(iv) Horse hair may be loose or inclined.

(v) The plane table fittings may be loose.

(vi) Magnetic needle of trough compass may be defective.

(vii) The two ends of plumbing fork not in alignment.

(viii) Level tube used for levelling the table may be deflective.

The above errors can be eliminated if the instruments are checked before the start of work and adjusted if required.

Error Due to Manipulation and Sighting

(i)The plane table not being levelled.

(ii) The table may not be properly centred.

(iii) The plane table not being properly clamped.

(iv) The plane table not being correctly oriented.

(v) The objects not being properly bisected.

(vi) The alidade not being properly pivoted on the station point on paper.

(vii) The rays not being accurately drawn from the station point.

(viii) The alidade may not be placed on the same side of the station point while working.

All the above errors can be eliminated by careful observation while working.

Errors in Plotting

(i) By not using a good quality pencil with a fine pointed end.

(ii) By using wrong scale or different scales.

(iii) By not observing the correct measurement from the scale.

(iv) By not using drawing sheet of good quality which may shrink or expand with temperature.

These errors can be minimized by working carefully.

Contouring

Contouring in surveying is the determination of the elevation of various points on the land and fixing these points of the same horizontal positions in the contour map. In the land property world, a contour is an outline of a mass of land. The main objective of conducting contour surveys is to identify any noticeable difference in the elevation of the existing land. In land surveying, a contour map is a map illustrated with contour lines. For example, a topographic map shows valleys and hills and the steepness or gentleness of slopes.

Horizontal Equivalent: The horizontal distance between any two adjacent contours is termed as the horizontal equivalent. The horizontal equivalent depends upon the slope of the ground.

Contour Interval: The constant vertical distance between two consecutive contours is called the Contour Interval.

The contour interval of a contour map is the difference in elevation between successive contour lines.

Factors affecting contour interval

The contour interval depends upon the following factors:

(i) The nature of the ground:

In flat and uniformly sloping country, the contour interval is small, but in broken and mountainous region, the contour interval should be large otherwise the contours will come too close to each other.

(ii) The purpose and extent of the survey:

Contours interval is small if the area to be surveyed is small and the maps are required to be used for the design work or for determining the quantities of earth work etc., while wider interval shall have to be kept for large areas and comparatively less important works.

(iii) The scale of the map:

The contour interval should be in the inverse ratio to the scale of i.e. the smaller the scale, the greater the contour interval.

(iv) Time and expense of field and office work:

The smaller the interval, the greater is the amount of field -work and plotting-work.

Characteristics of Contours

The principal characteristics of contour lines are

(i) All points on a contour line have the same elevation.
(ii) Flat ground is represented where contour lines are widely separated.
(iii) Steep ground is represented where contour lines run close together.
(iv) Plane surface is indicated when the contour lines are straight, parallel and equally spaced.
(v) When the contour lines are uniformly spaced it indicates a uniform slope.
(vi) A series of closed contour lines on map represents a depression or pond if lower values are inside.
(vii) A series of closed contour lines on map represents a hill if higher values are inside.
(viii) Contour lines are not drawn across the water in river or stream because water level in it is not constant.
(ix) Contour lines will not end or stop in the middle of the plan or map but close themselves either with in or go out of the plan.
(x) Contour lines cross ridge or valley at right angle. A ridge line is shown when higher values are inside the loop or bend. When higher values are outside the bend it represents a valley.
(xi) Contour lines can not merge or cross one another on the map except in case of a overhanging cliff.
(xii) When several contours coincide it indicates a vertical cliff and horizontal equivalent will be zero for coinciding contours.

(xiii) Depression between summits is called a saddle. It is represented by four sets of contour. Line passing through saddles and summits gives ater shed line.

Methods of Contouring

There are mainly two methods of locating contours;
(1) Direct method, and
(2) Indirect method.

1. Direct Method:
In this method, the contours to be located are directly traced out in the field by locating and making a number of points on each contour. These points are then surveyed and plotted on plan and the contours drawn through them.
This method is the most accurate but very slow and tedious as a lot of time is wasted in searching points of the same elevation for a contour. This is suitable for small areas and where great accuracy is required.

2. Indirect Method:
In this method, the points located and surveyed are not necessarily on the contour lines but the spot levels (spot level means the R.L. of a point on the surface of the ground) are taken along the series of lines laid out over the area.
The spot levels of the several representative points representing hills, depression, ridge and valley lines, and the changes in the slope all over the area to be contoured are also observed.
Their positions are then plotted on the plan and the contours drawn by interpolation. This method of contouring is also known as contouring by spot levels. This method is commonly employed in all kinds of surveys as this is cheaper, quicker and less tedious as compared with the direct method.
There are mainly three methods contouring under this head:

(i) By Squares
(ii) By Cross-sections
(iii) By Tacheometeric method

Relative Merits and Demerits of Direct and Indirect Methods of Contouring:
Direct Method:
1. The method is most accurate but is very slow and tedious.
2. It is used for small areas where great accuracy is desired.
3. It is not very useful when the around is hilly.
4. The calculation work of reducing the levels is comparatively more since the number of points in command from one set -up of the level is very less.

Indirect Method:
1. The method is not very accurate but is cheaper, quicker and less laborious.
2. It is used for large areas where great accuracy is not the main consideration.
3. Tacheometric method of contouring is mainly used for preparing, contour plans of hilly area. The indirect method by cross -sections is used in route surveys such as a railway, a canal etc.
4. Area in command from one set -up of the tacheometer is more, therefore, the calculation work is less.

Interpolation of Contours

The process of spacing the contours proportionally between the plotted ground points is termed as interpolation of contours.

This becomes necessary in the case of indirect contouring as only the spot levels are taken in this method. The intermediate contours may also be interpolated in direct contouring if the interval is large. While interpolation of contours the ground between any two points is assumed to be uniformly sloping.

There are three methods of interpolation:

(i) By Estimation:

The positions of the contour-points between ground -points are estimated roughly, and the contours are then drawn through these points. This is a rough method and is suitable for small scale maps.

(ii) By Arithmetical Calculation:

This is very but accurate method and is used for small areas where accurate results are necessary.

(iii) By Graphical Method:

Graphical method of interpolation are simpler as compared to arithmetical methods and also the results obtained are accurate.

Uses of Contour Maps

1. The suitable site can be selected for construction activities.
2. Reservoir capacity can be determined.
3. Alignment for roads, canals, transmission lines are done efficiently with the help of contour map.
4. Nature of ground surface may be determined.
5. Estimating the quantities of earthwork.
6. The nature of ground i.e. flat, uniformly, sloping, undulating or hilly etc.
7. It is possible to select the most suitable and economical sites for work such as the location of roads, railways, canals, pipelines, dams, reservoirs etc. by using contour map.
8. Estimating of the volume of reservoir storage water, volume of earthwork in cutting and embankment can be done by using contour map.