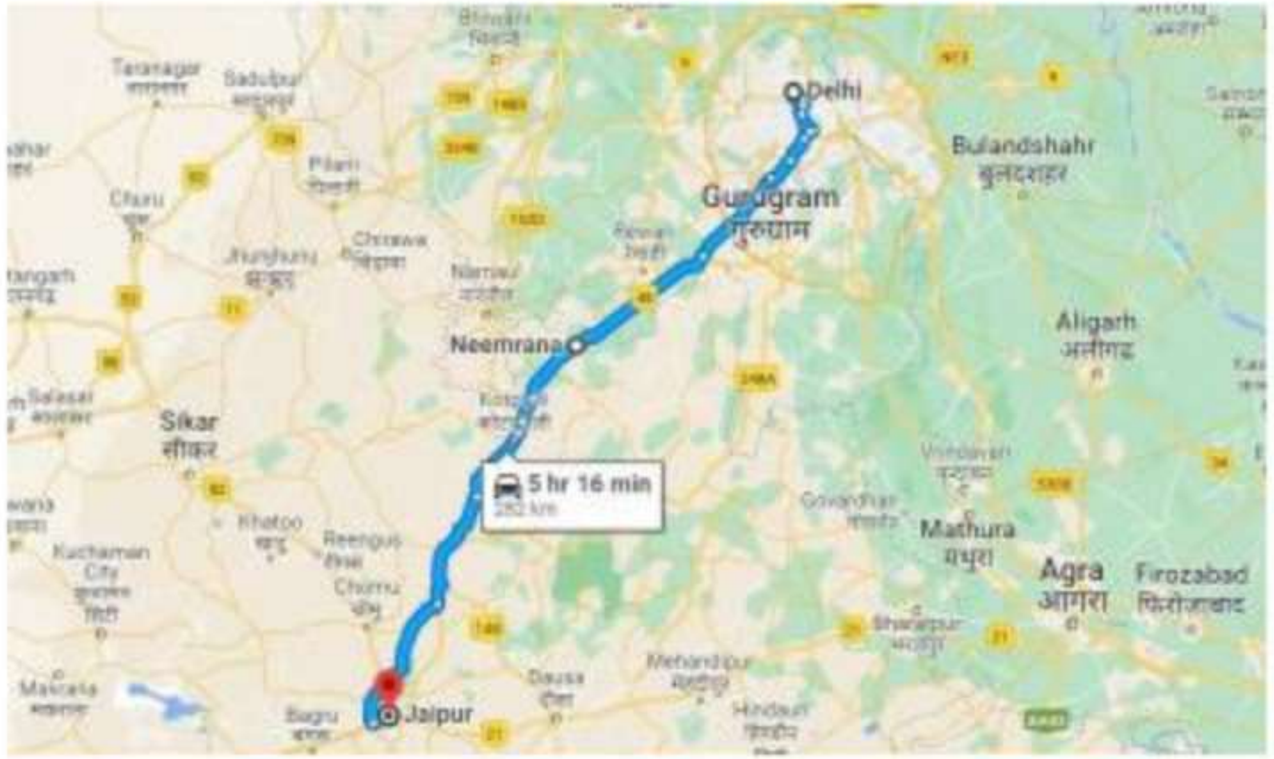
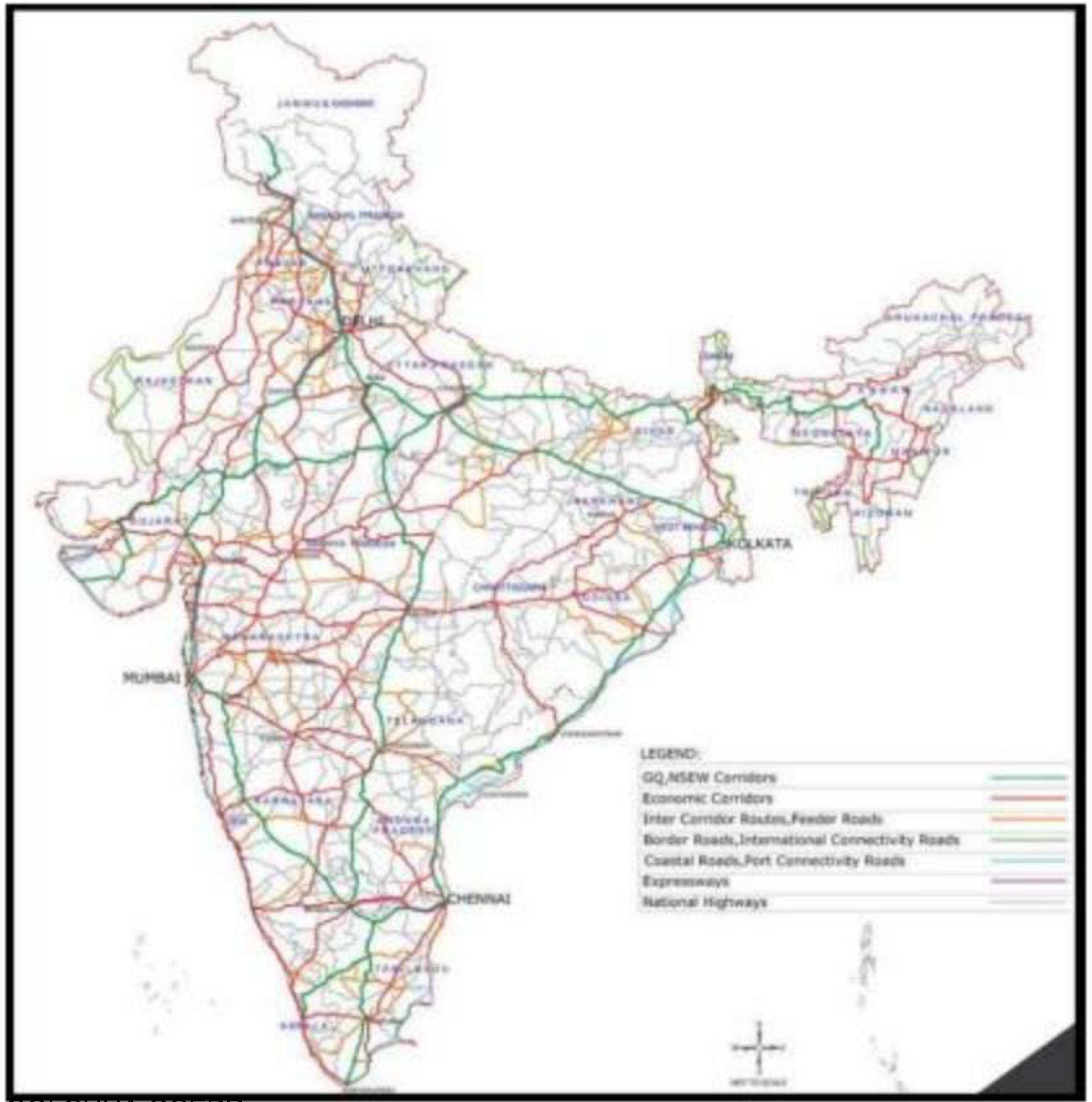
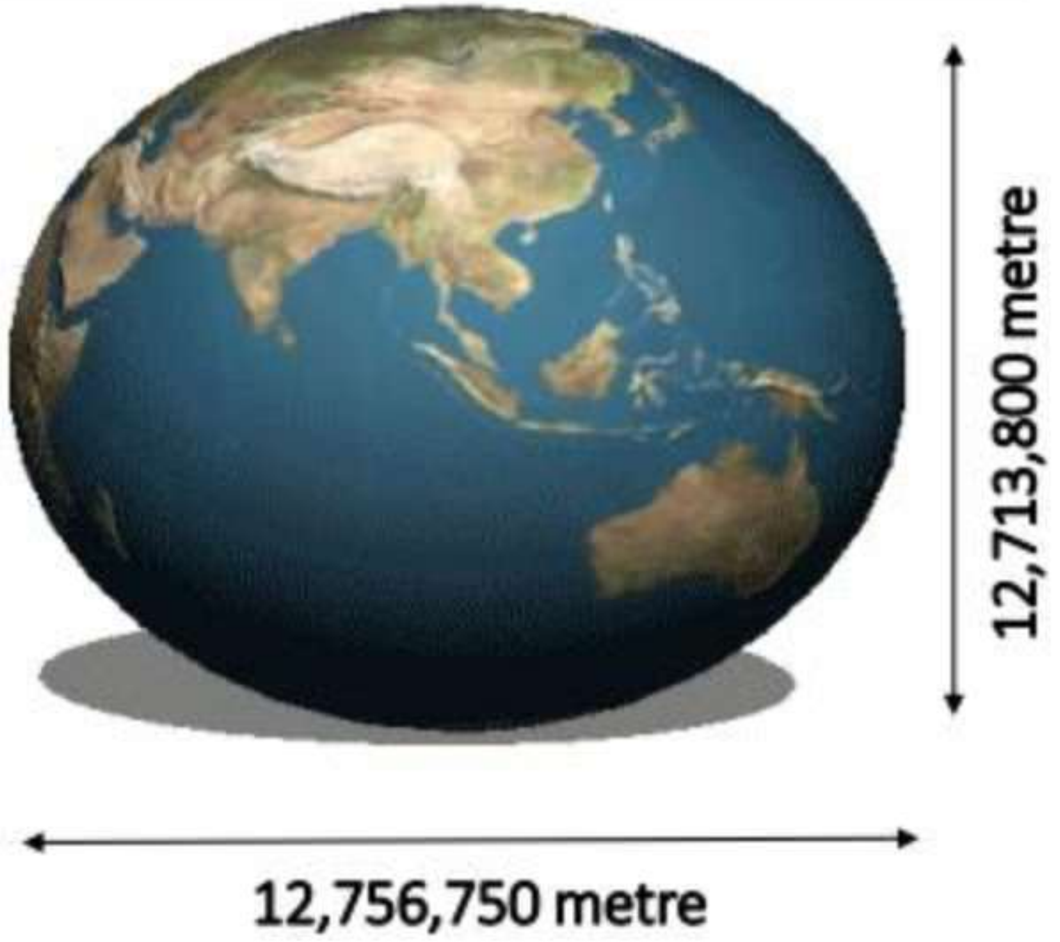
Chapter 1: Fundamentals of Surveying





Basic Definitions

1. <u>Shape of Earth</u>
   a) <u>Oblate spheroid</u> → slightly flattened at poles, polar axis is 43.5 km smaller than Equatorial axis
   b) <u>Ellipsoid</u> → Equatorial section is slightly elliptical in nature
   c) <u>Ovalloid</u> → Southern Hemisphere is slightly larger than Northern hemisphere

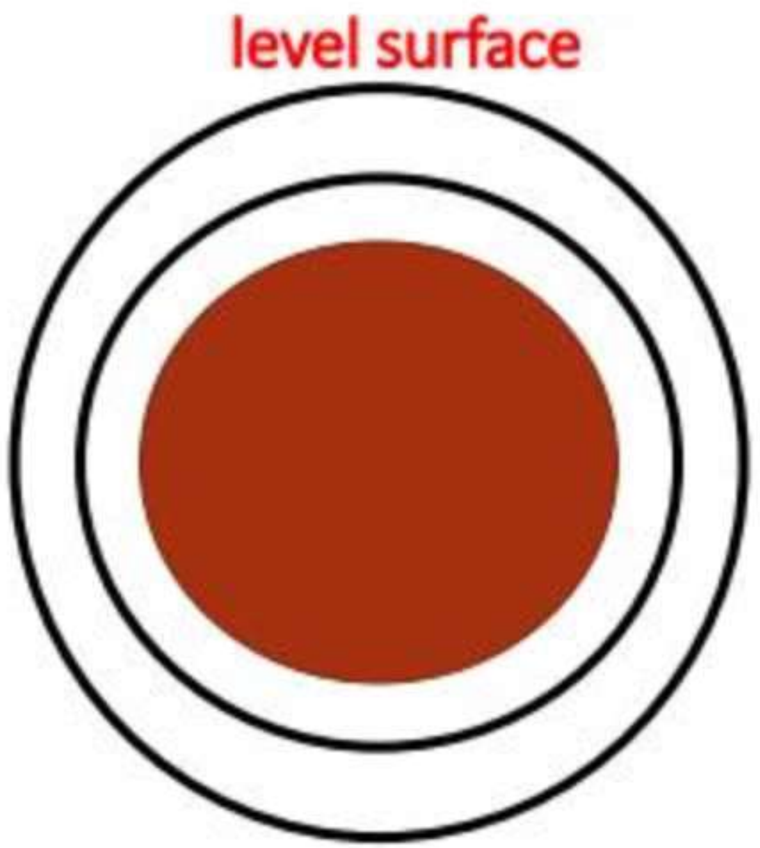


- **We can observe that no geometrical shape perfectly defines shape of earth.**
- **Therefore a new name has been given, i.e, "*GEOID*":-**
- **Or the ease in calculation the shape of earth is assumed to be "Spherical"**

Basic Definitions

2. Level Surface

- Level surface is a curved surface parallel to earth surface and every point, it is equidistant from the centre of the Earth, every element on the level surface is perpendicular to plumb line

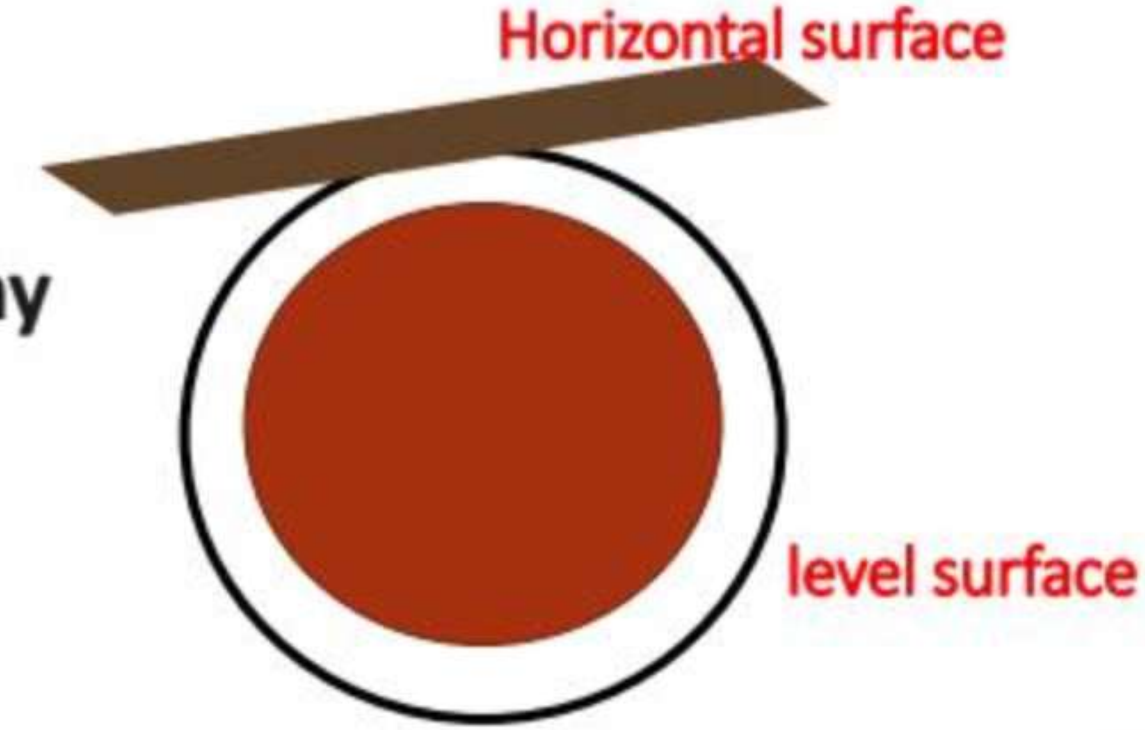


3. Level line

- It is a line in the level surface

4. Horizontal plane:

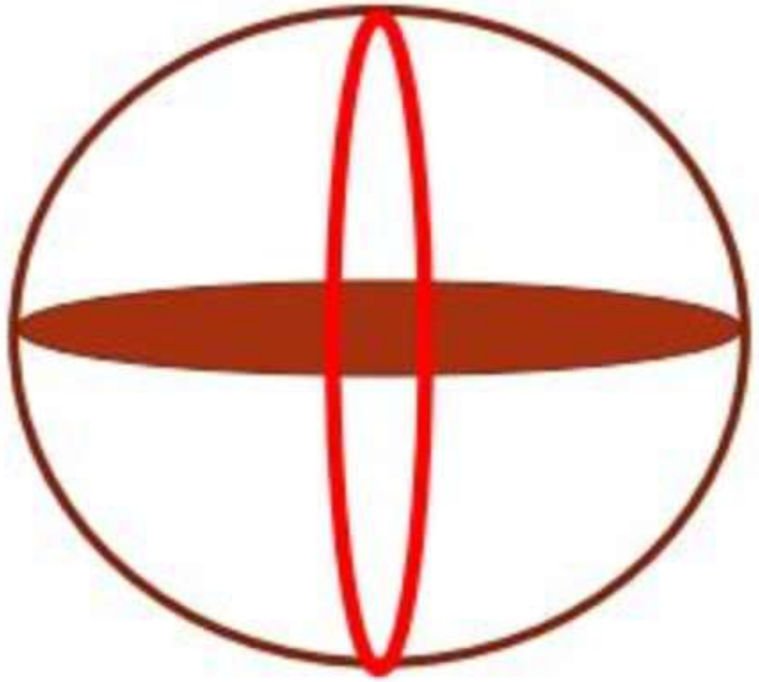
- It is a plane tangential to Earth surface at any point.
- It is also normal to plumb line



Basic Definitions

5. <u>Great Circle:</u>

- It is an imaginary circle passing through centre of the Earth
- A great circle divides earth into two equal parts
- Example : Equator and longitude



6. <u>Spherical triangle</u>:

- A spherical triangle is that triangle which is formed on the surface of a sphere by intersection of three arcs of great circle
- The Arcs enclosing the spherical triangle are called as its sides, and the angles in which these Arcs intersect are called as “Spherical Angle”.

Basic Definitions

6. <u>Spherical triangle</u>:
   - A spherical triangle is that triangle which is formed on the surface of a sphere by intersection of three arcs of great circle
   - The Arcs enclosing the spherical triangle are called as its sides, and the angles in which these Arcs intersect are called as "Spherical Angle".
   - Spherical Angle is defined as the angle between tangents to the great circle drawn at the point of intersection.
   - Length of a side of a spherical triangle is defined as angle subtended by that side at the centre of the earth

Basic Definitions

6. Properties of Spherical triangle:

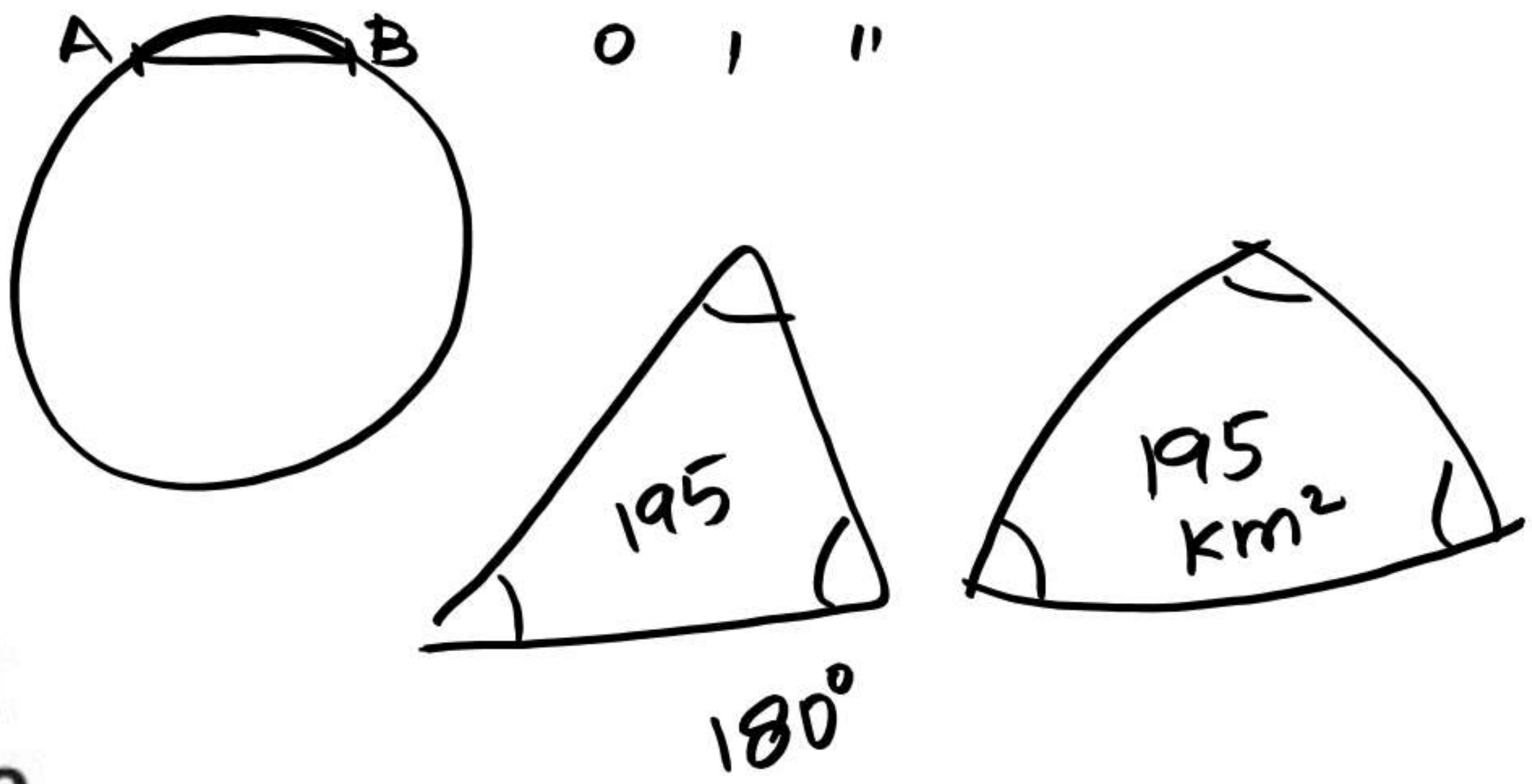
- Length of a side of a spherical triangle should be less than equal to 180°
- Each angle of a spherical triangle should be less than 180°
- Sum of three spherical sides should be in between 0° to 360°
- Sum of spherical angles should be in the range of 180° to 540°

Note:-

- Amount by which sum of the angles of a spherical triangle exceed by 180° is called as "spherical excess"
- Surface Area of a spherical triangle should be less than $2\pi r^2$ where r → radius of the Earth

Note

- Length of an arc of 12 kilometres long lying on Earths surface is only 1 cm greater than the subtended chord
- Difference between sum of angles in a plain triangle and a those in a spherical triangle is ONE SECOND for a triangle at Earth's surface having area of 195 km^2.



Classification of Surveying

Surveying can be classified into many types on the basis of instrument used, place of survey, purpose of survey etc.

But mainly surveying is classified as, Plane Surveying, Geodetic Surveying.

Plane Surveying	Geodetic Surveying
In the Plane Surveying we neglect the effect of Curvature and plotted Measurements are projected on Horizontal plane	Geodetic survey is done for large Area in which effect of Curvature of the Earth surface is considered
Area $< 195.5\ km^2$	Area $\geq 195.5\ km^2$
It is done for local surveys	It is done by Survey of India to establish control points which serves the purpose of reference point for local surveys
Plane trigonometry	Spherical Trigonometry

NOTE

- **Length of an arc of 12 kilometres long lying on Earths surface is only 1 cm greater than the subtended chord**
- **Difference between sum of angles in a plain triangle and a those in a spherical triangle is ONE SECOND for a triangle at Earth's surface having area of 195 km^2.**

Classification based on Purpose

1. **Topographical survey:**
   - These surveys are used to obtain Maps which show details of maps and man made features on the Earth surface including elevation
   - Ex: Mountains – water bodies woods valley, rivers etc.
2. **Engineering Survey:**
   - These are surveys used for Engineering works like Railway, Highway, Bridge etc.
   - Building:- 1:50 to 1:200
   - Bridge & other civil engineering works :- 1:500 to 1:2500

Classification based on Purpose

3. **Cadastral Survey:-**
   - It is done to establish property boundaries
4. **Hydrographic Survey:**
   - These are the surveys done on (or) near the water body
   - Ex:- River, lake etc.
5. **Astronomical Survey**
   - With the help of this survey we can determine Latitude, longitude. Local mean time at any place on the Earth surface

Classification based on Purpose

6. Geological Survey

- It is done to determine information about various strata of earth surface

Classification based on Instrument

1. **Chain Surveying:-**
   - It is simplest type of surveying in which only linear measurements are done with the help of chain and tape and no angular measurements are done

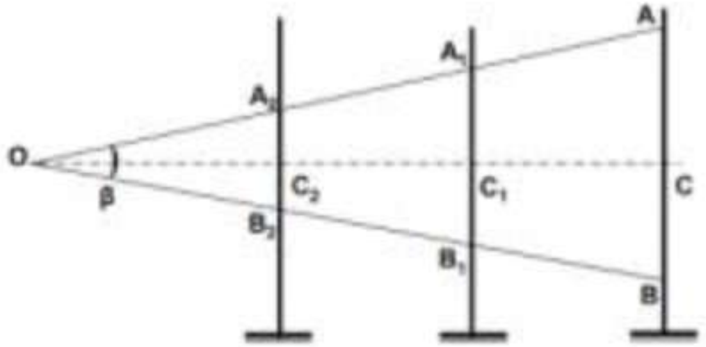
2. **Compass Surveying:-**
   - It is the branch of Surveying in which horizontal angles and directions of lines are measured with compass and length of line are measured with chain and tape.
3. **Theodolite Survey**
   - In this Surveying Horizontal and vertical angles are measured with theodolite and distances are measured with chain on tape

Classification based on Instrument

4. **Levelling**
   - In this type of Survey, elevations of various points are measured with the leveling instrument and a vertical staff

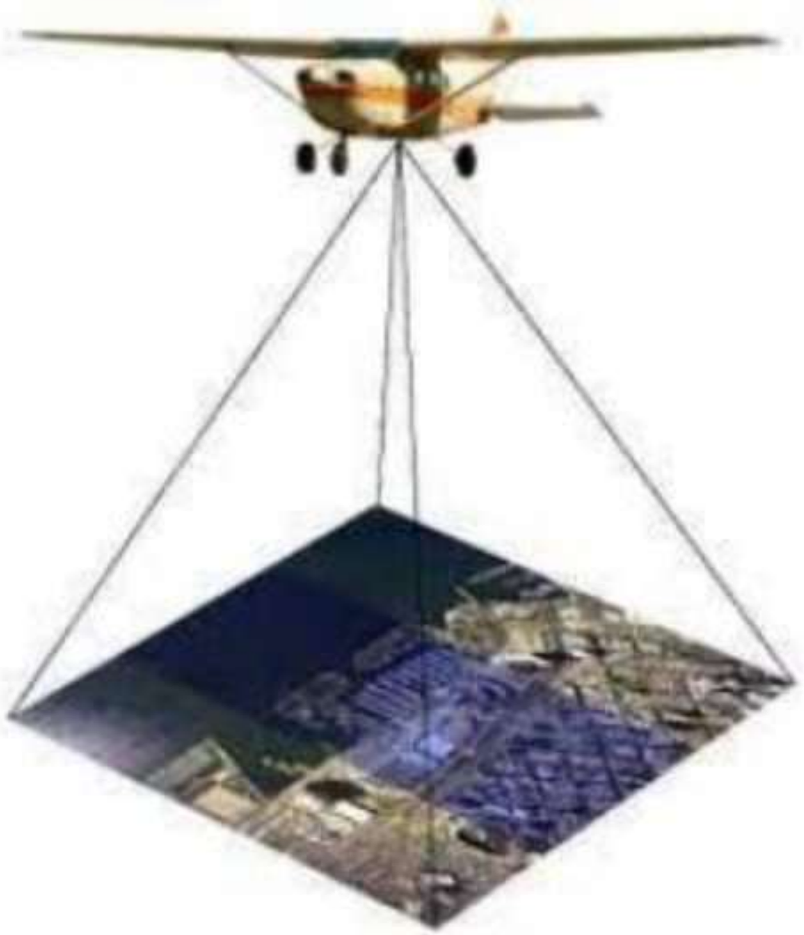
5. **Plane table Surveying**
   - In plane table Surveying, plan or Map is produced by determining directions of various points and taking linear measurements with chain on Tape.

6. **Tachometric Surveying**
   - In this Surveying horizontal & Vertical distances are measured with an instrument called "Tachometer".



Classification based on Instrument

7. Photogrammetric Survey
    - In this survey photographs are taken for an area which are inaccessible (or) line available is less and area to be Surveyed is large.



Principles of Surveying

- Working from whole to Part.
  - Main objective of working from whole to part is to localize the error where as if we works from part to whole error gets maximize
- Locating a point at least by 2 points of reference.

Units of Measurement

- **There are four kinds of measurements in Plane Surveying**

Horizontal Distance

Vertical Distance

Horizontal Angle

Vertical Angle

Units of Length

- 12 inches =1 foot
- 3 FEET=1 Yard
- 100 links= 66 feet=1 chain
- 10 chains = 1 furlong
- 8 furlongs=1 mile
- 1 mile = 1.6 km
- 1852 metres=1 nautical mile

Units of Area

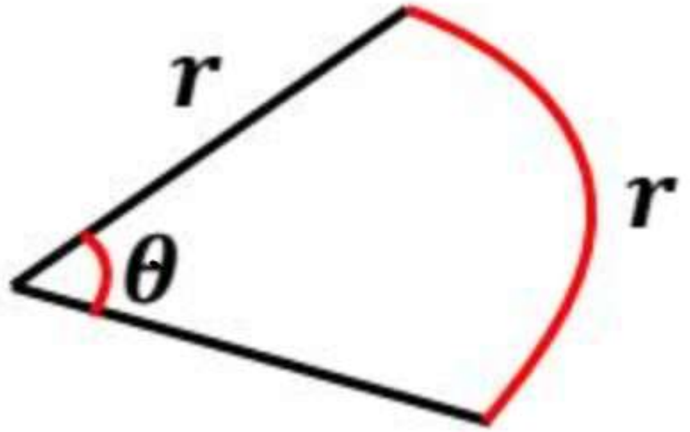
- 1 sq foot=144 sq inch
- 100 sq m= 1 are
- 100 are=1 hectare
- 1 are=0.0247 acres
- 1 acre= 10 sq chains
- 1 sq mile=640 acres

Units of Volume

- 1 Gallon=4.55 L (British)
- 1 Gallon = 3.78 Litres (US)
- 1 cub yard= $0.7645 m^3$

Units of Angle

- Angle is difference in directions of two intersecting lines
- The radian is the angle between two radii of a circle which cutsoff on the circumference of an arc equal in length to the radius.



- There are three popular systems of angular measurements:
  - *(a) Sexagesimal System*
    - 1 circumference = 360° (degrees of arc)
    - 1 degree = 60' (minutes of arc)
    - 1 minute = 60" (seconds of arc)
  - *(b) Centesimal System*
    - 1 circumference = 400. (grads)
    - 1 grad = 100' (centigrades)
    - 1 centigrade = 100" (centi-centigrads)
  - *(c) Hours System*
    - 1 circumference = 24^h (hours).
    - 1 hour = 60^m (minutes of time)
    - 1 minute = 60^s (seconds of time)

1 radian = 206265" (angle)

1 day = 86400 sec (time)

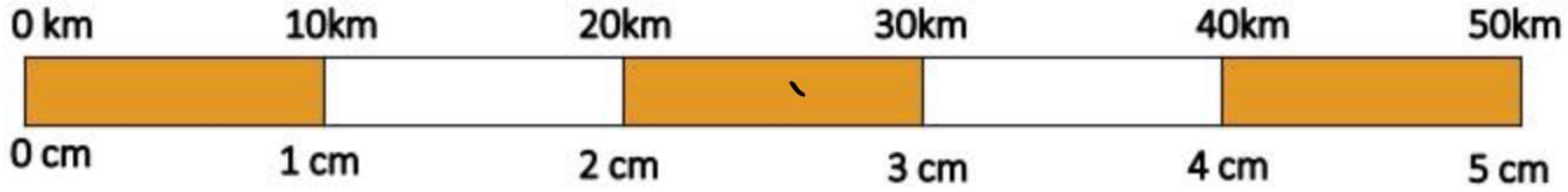
SCALE

- The area to be surveyed is very vast so suitable plan are made to after using some scale
- Scales can be represented by following methods:
  1. Numerical Method
  2. Graphical Method

SCALE

$$Scale = \frac{length\ of\ a\ line\ on\ Plan\ or\ Map}{length\ of\ same\ line\ on\ the\ ground}$$

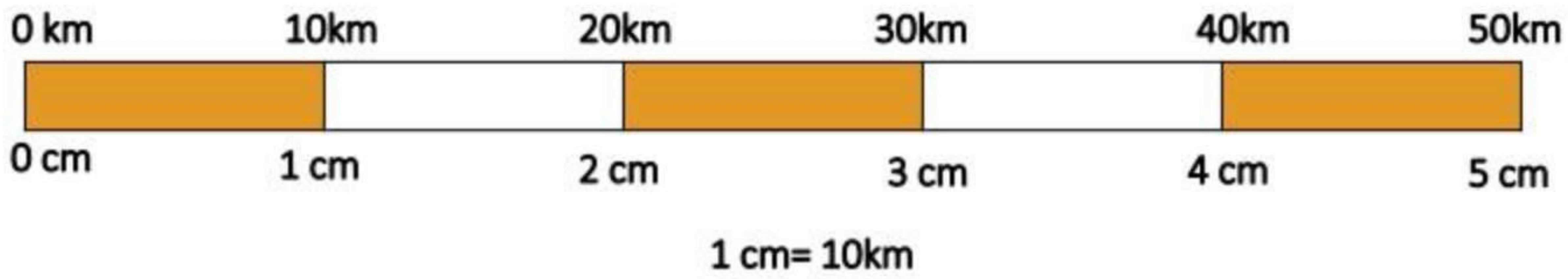
1. Numerical Scale
   a) Representative Fraction (RF) : (1: 10^6)
   b) Engineer Scale 1 cm= 10 km
2. Graphical Scale



1 cm= 10km

SCALE

- Graphical scale has advantage over Numerical scale such that distance on the Plan (or) map can be determined by actual Scaling, Even though plane (or) Map is shrunk.
- In case of shrinkage of Map, Graphical scale also changes with the Map and therefore ratio is unaffected.



Types of Scales

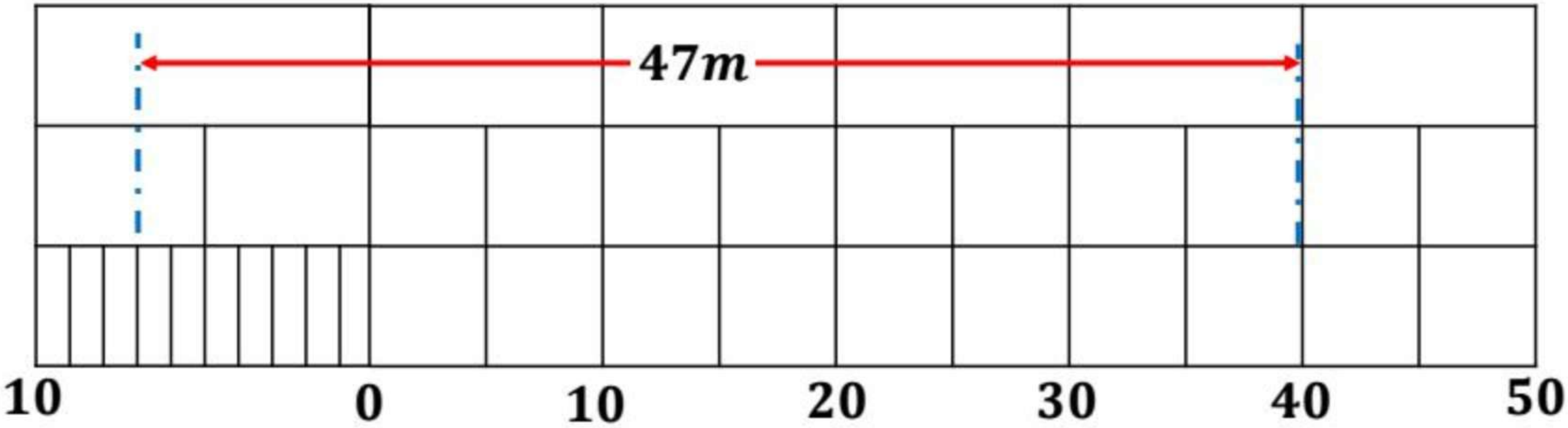
- Plain Scale
- Diagonal Scale
- Vernier Scale
- Scale of Chords

Types of Scales

1. PLAIN SCALE

- In plane scale, we can measure TWO dimensions such as Metres and Decimeters

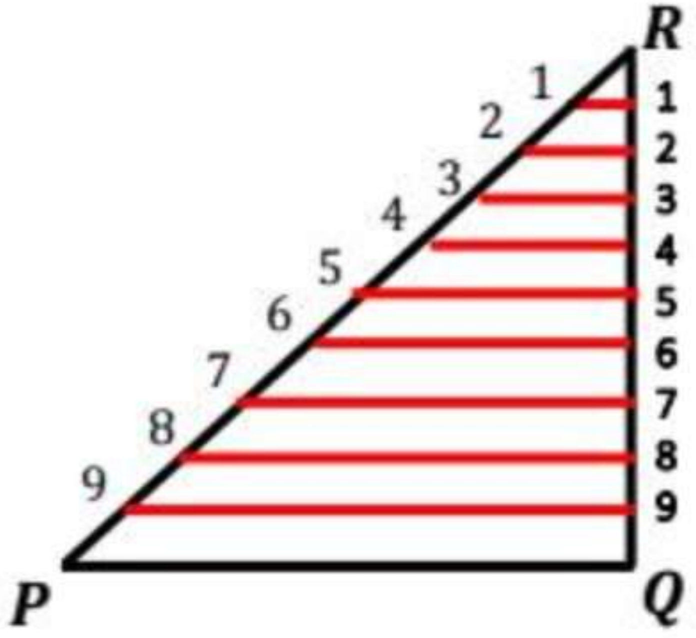
Let us take the scale as 1cm = 3m and plot a distance of 47m on it



Types of Scales

2. DIAGONAL SCALE

- On a Diagonal Scale it is possible to measure THREE DIMENSIONS such as unit, tengths and hundredths or metres, decimetres and centimetres
- Principle of similar triangles is used to divide a short length into number of parts



Let us take a line PQ which has to be divided into 10 equal parts

Draw perpendicular QR at Q for some suitable length

Join PR, also Divide QR into 10 equal parts and draw lines parallel to PQ

Now section 1 – 1 will represnt $\frac{1}{10}$ *of PQ*

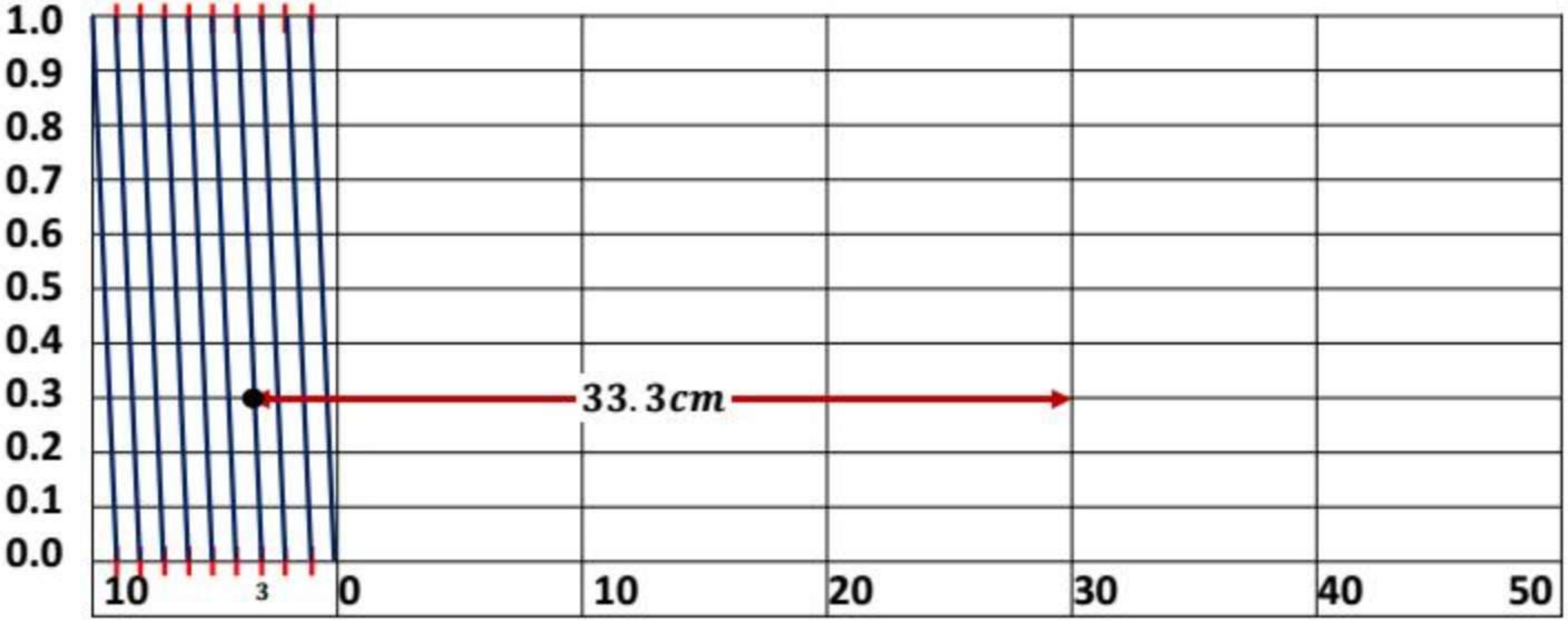
Now section 2 – 2 will represnt $\frac{2}{10}$ *of PQ*

Now section 9 – 9 will represnt $\frac{9}{10}$ *of PQ*

2. DIAGONAL SCALE

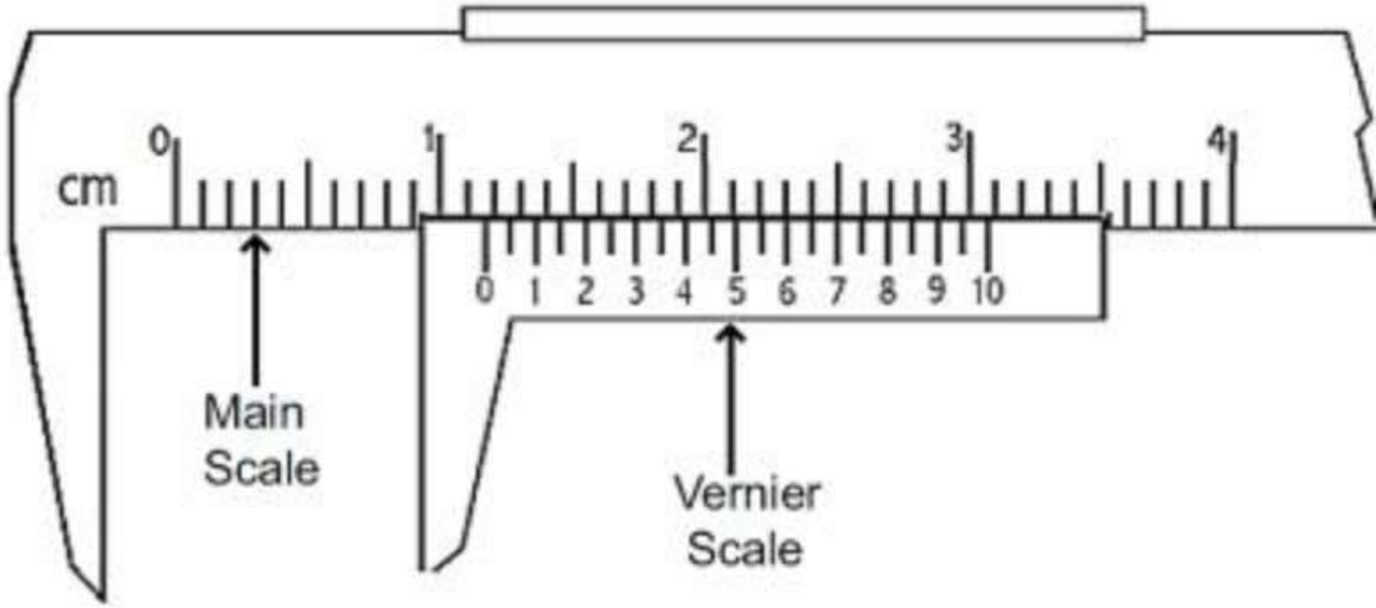
<u>Que.</u> Construct a diagonal scale 1cm=3m to read decimetres and show 33.3 m on it

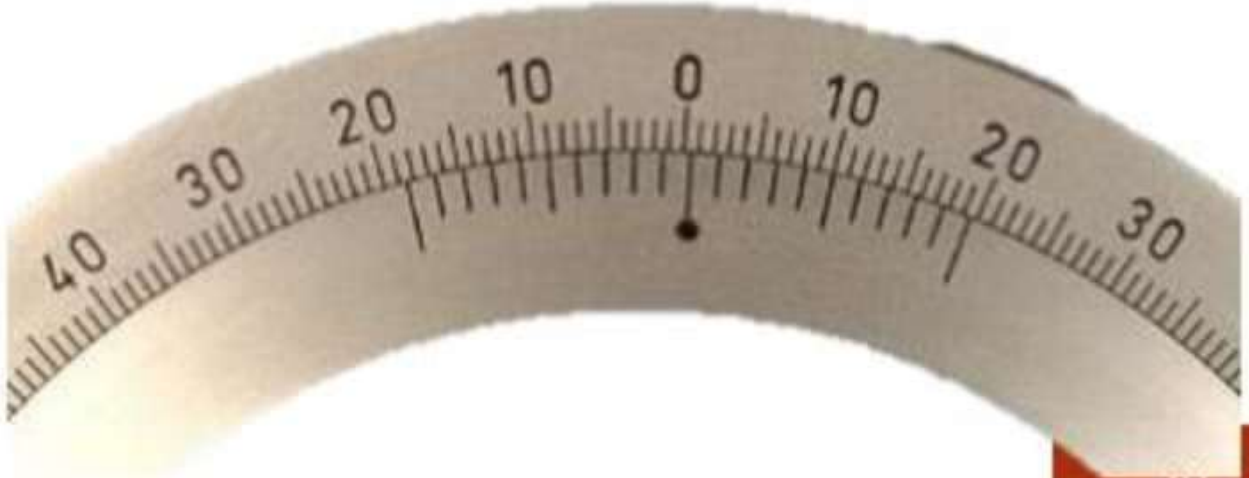
- Take a length of 20cm and divide it into 6 equal parts, each part representing 10m
- Subdivide the first left columns, left side into 10 divisions, and also from top and bottom.
- Join the top and bottom divisions diagonally
- Now read 33.3m



3.Vernier Scale

- Vernier is a device used to measure fractional part of one of the smallest divisions of a graduated scale.
- It consists of a small auxiliary scale which slides along the side of main scale
- Generally verniers are used for finest reading upto 20” and then micrometer microscopes are used to read to 1”
- ***Principle of Vernier:***
  - It works on the principle that Eye can perceive without strain and with considerable precision when two graduations coincide to form one continuous straight line.





3. Vernier Scale

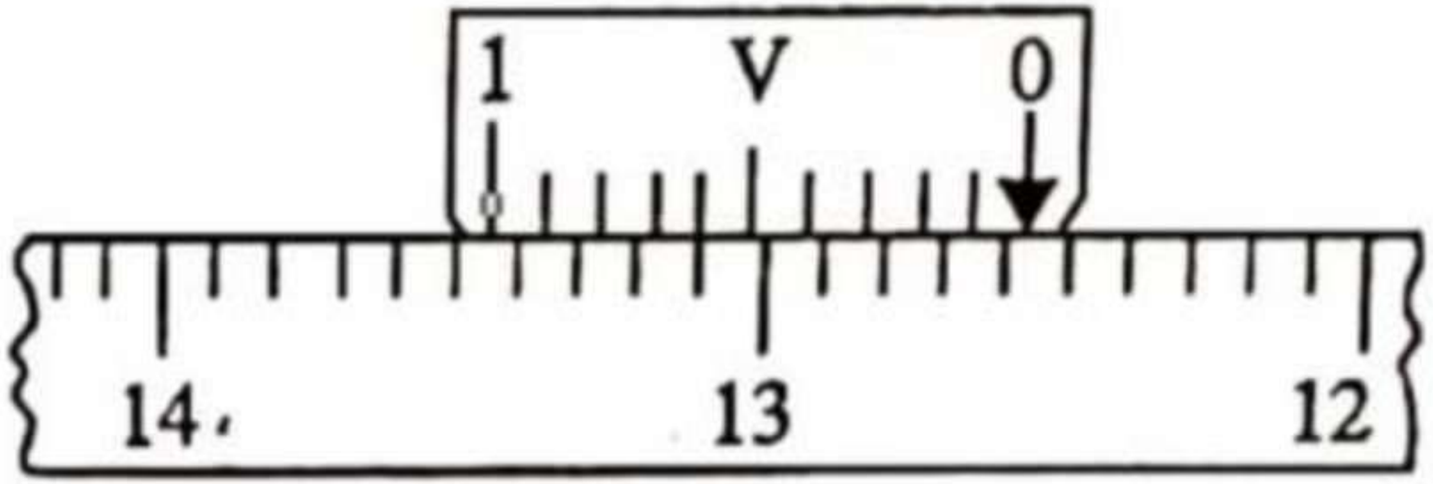
- **If graduations on main scale is on one side only, then the Vernier used is called as *Single Vernier***
- **If graduations on main scale are numbered in both sides it is called as *Double Vernier***
- ***Fineness* of Reading or *Least Count* is defined as Difference between smallest Division on main scale and smallest division on Vernier.**
- **Divisions on the Vernier can be a little smaller than the main scale or a little larger than the main scale**

3. Vernier Scale

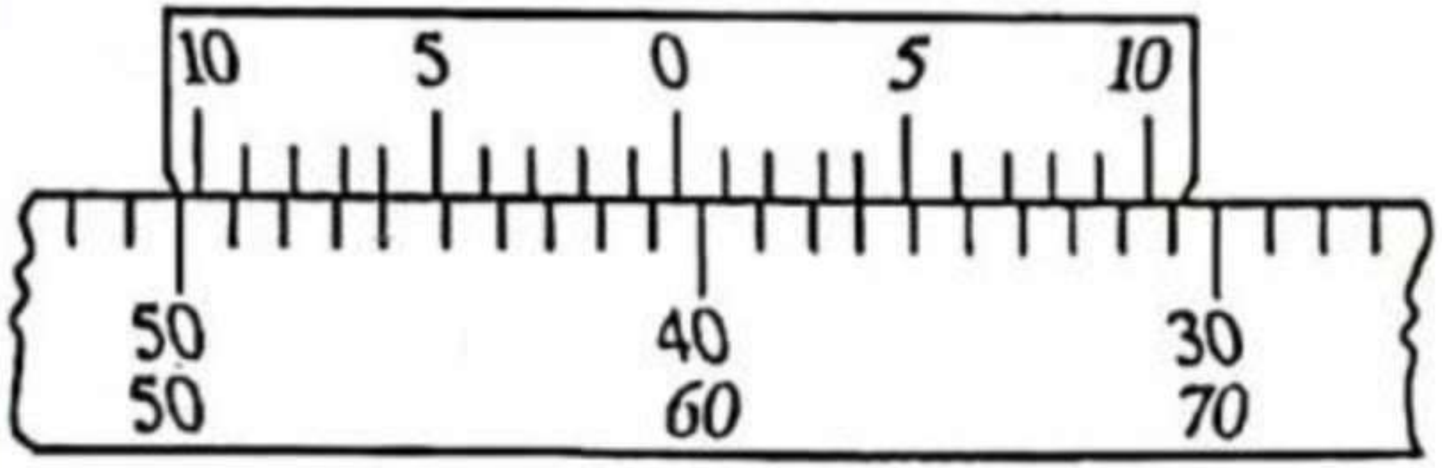
Vernier is of two types

1. *Direct Vernier*

- In direct Vernier smallest division (v) on Vernier is **shorter** than the smallest division (s) on Main Scale
- It extends in the **same** direction as that of main scale
- It is constructed such that $(n-1)$ divisions on main scale are equal in length of n division of the Vernier



Direct Vernier of Single Type



Direct Vernier of Double Type

Vernier Scale

1. Direct Vernier

- $s = value\ of\ one\ smallest\ division\ on\ main\ scale$
- $v = value\ of\ one\ smallest\ division\ on\ Vernier$
- $n = Number\ of\ Division\ on\ Vernier$
- $Length\ of\ (n-1)\ divisions\ of\ main\ scale\ is\ equal\ to\ n\ divisions\ of\ vernier$

$$i.e.\qquad nv = (n-1)s$$

$$\Rightarrow v = \left(\frac{n-1}{n}\right)s$$

$$\text{Least Count} = s - v$$

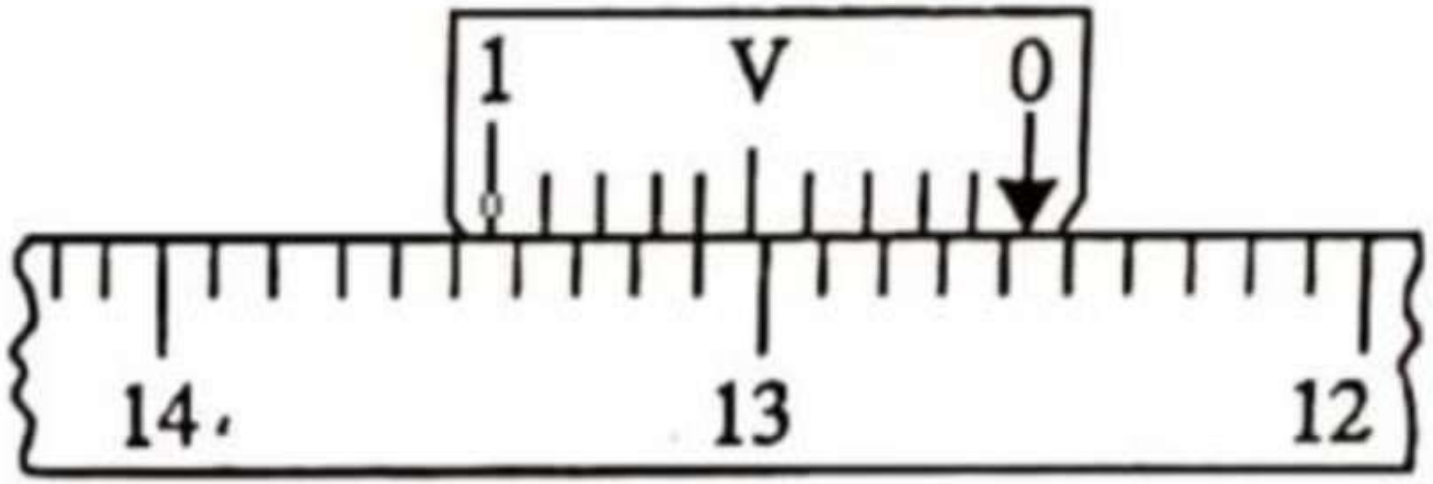
$$= s - \left(\frac{n-1}{n}\right)s$$

$$\text{Least Count} = \frac{s}{n}$$

Least Count is 'one main scale division' divided by total number of division on the Vernier

$$Reading = 12.56$$

$$LC = \frac{0.1}{10} = 0.01$$

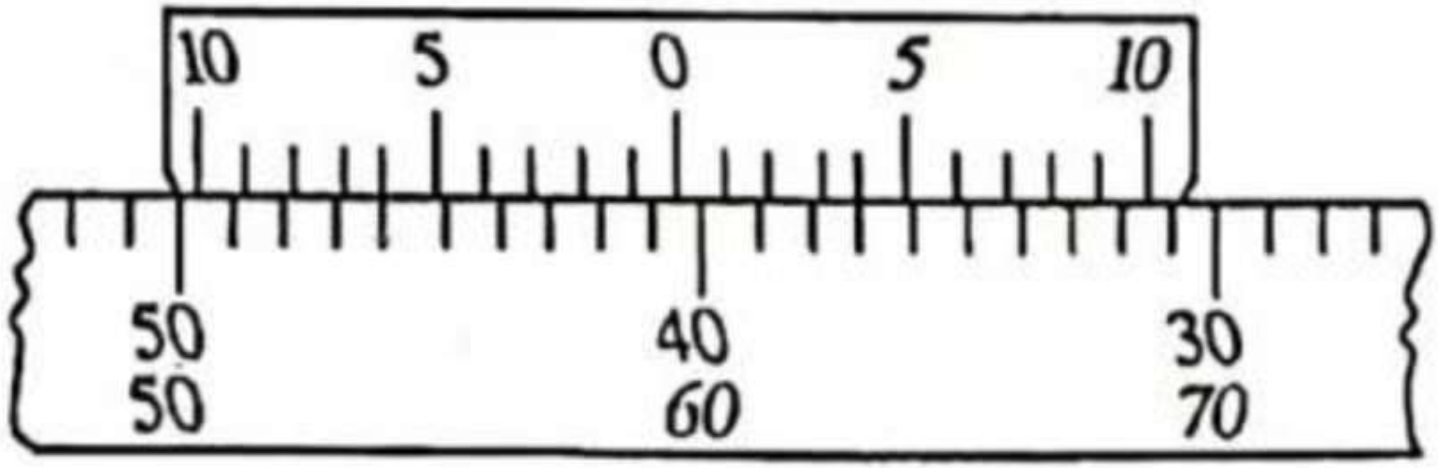


Direct Vernier of Single Type

$$Reading = 40.6$$

$$Reading = 59.4$$

$$LC = \frac{1}{10} = 0.1$$



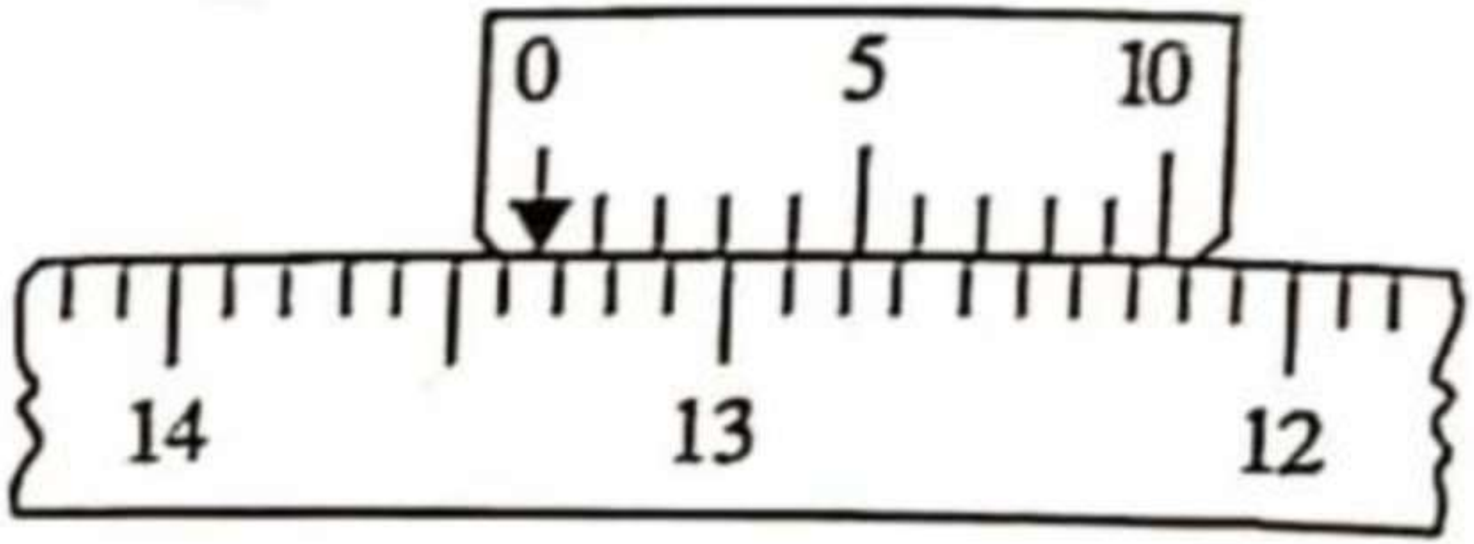
Direct Vernier of Double Type

Vernier Scale

Vernier is of two types

2. *Retrograde Vernier*

- In Retrograde Vernier smallest division on Vernier (v) is longer than the smallest division (s) on Main Scale
- It extends in the opposite direction as that of main scale
- It is constructed such that $(n+1)$ divisions on main scale are equal in length of n divisions of the Vernier



Vernier Scale

2. Retrograde Vernier

- $s = value\ of\ one\ smallest\ division\ on\ main\ scale$
- $v = value\ of\ one\ smallest\ division\ on\ Vernier$
- $n = Number\ of\ Division\ on\ Vernier$
- $Length\ of\ (n + 1)\ divisions\ of\ main\ scale\ is\ equal\ to\ n\ divisions\ of\ vernier$

$$i.e.\qquad nv = (n+1)s$$

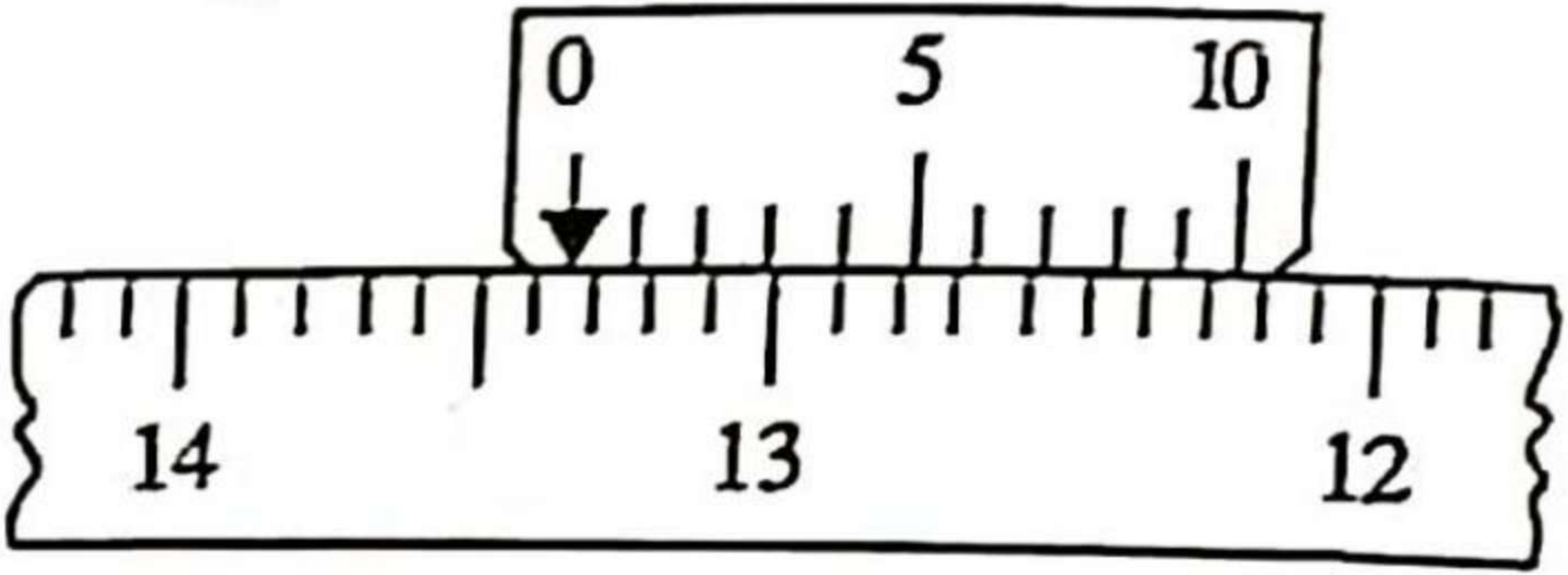
$$\Rightarrow v = \left(\frac{n+1}{n}\right)s$$

$$\text{Least Count} = v - s$$

$$= \left(\frac{n+1}{n}\right)s - s$$

$$\text{Least Count} = \frac{s}{n}$$

Least Count is 'one main scale division' divided by total number of division on the Vernier

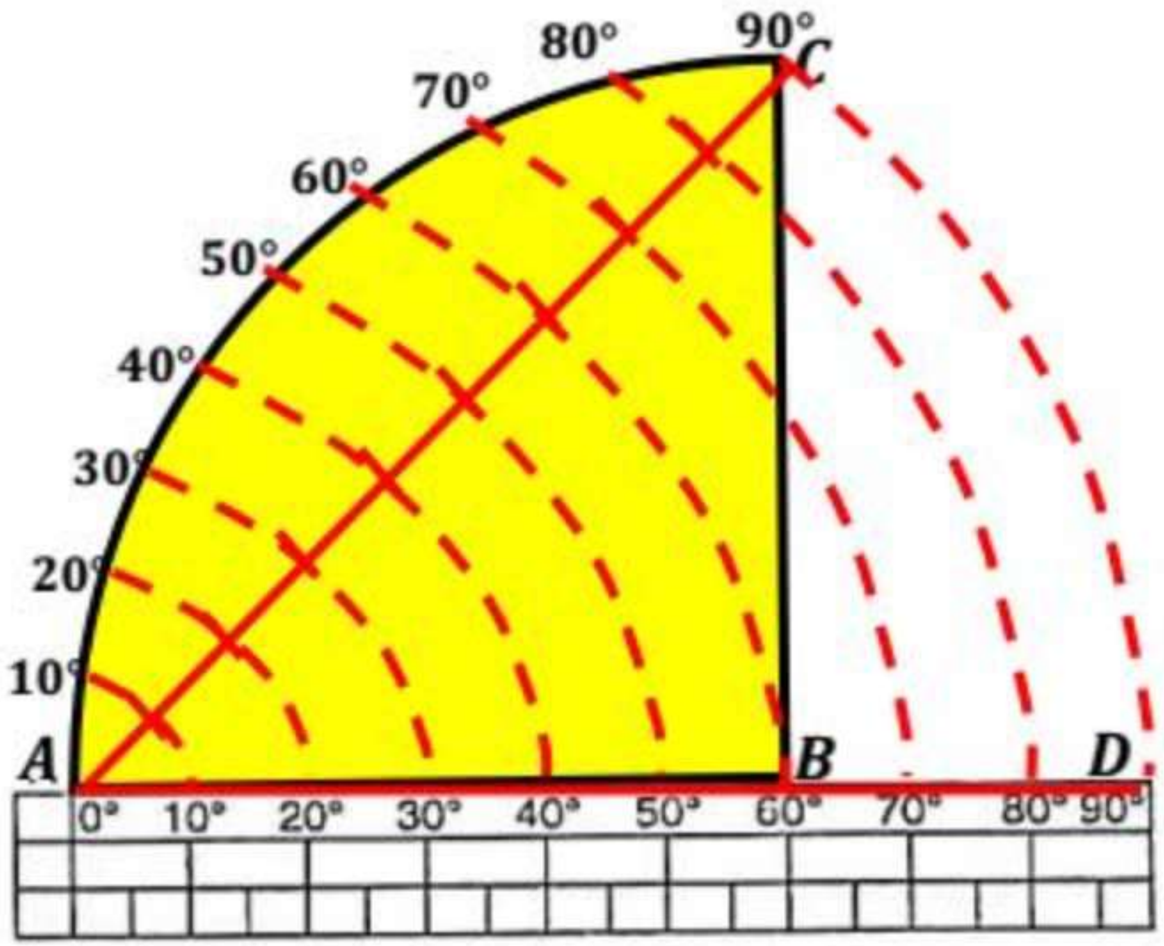


$$Reading = 13.34$$

$$LC = \frac{0.1}{10} = 0.01$$

4. Scale of Chords

- **Scale of Chord is used to measure an angle or to set off an angle and is marked either on a rectangular protractor or on an ordinary box wood scale**
  - Draw a quadrant ABC, making AB=BC
  - Prolong AB to D, making AD=AC
  - Divide AC in 9 equal parts, each part representing 10°
  - With A as centre draw arcs at each division
  - NOTE: *Arc through the 60° division must pass through the point B or 'The chord of 60° is equal to the radius AB*
  - *Distance from A to any mark on the scale is equal to chord of the angle of that mark*



Error due to use of wrong scale

- $$Correct\ length = \frac{RF\ of\ wrong\ scale}{RF\ of\ correct\ scale} \times measured\ length$$
- $$Correct\ Area = \left(\frac{RF\ of\ wrong\ scale}{RF\ of\ correct\ scale}\right)^2 \times calculated\ area$$

Kabil dost $\left(\frac{1}{50}\right)$

×

Measured length = 1500m.

True length = ?

✓

$\left(\frac{1}{100}\right)$

$$TL = \frac{\text{wrong RF}}{\text{correct RF}}$$

$$= \frac{\frac{1}{50}}{\frac{1}{100}} \times 1500$$

$$= 3000m$$

Shrunk Scale

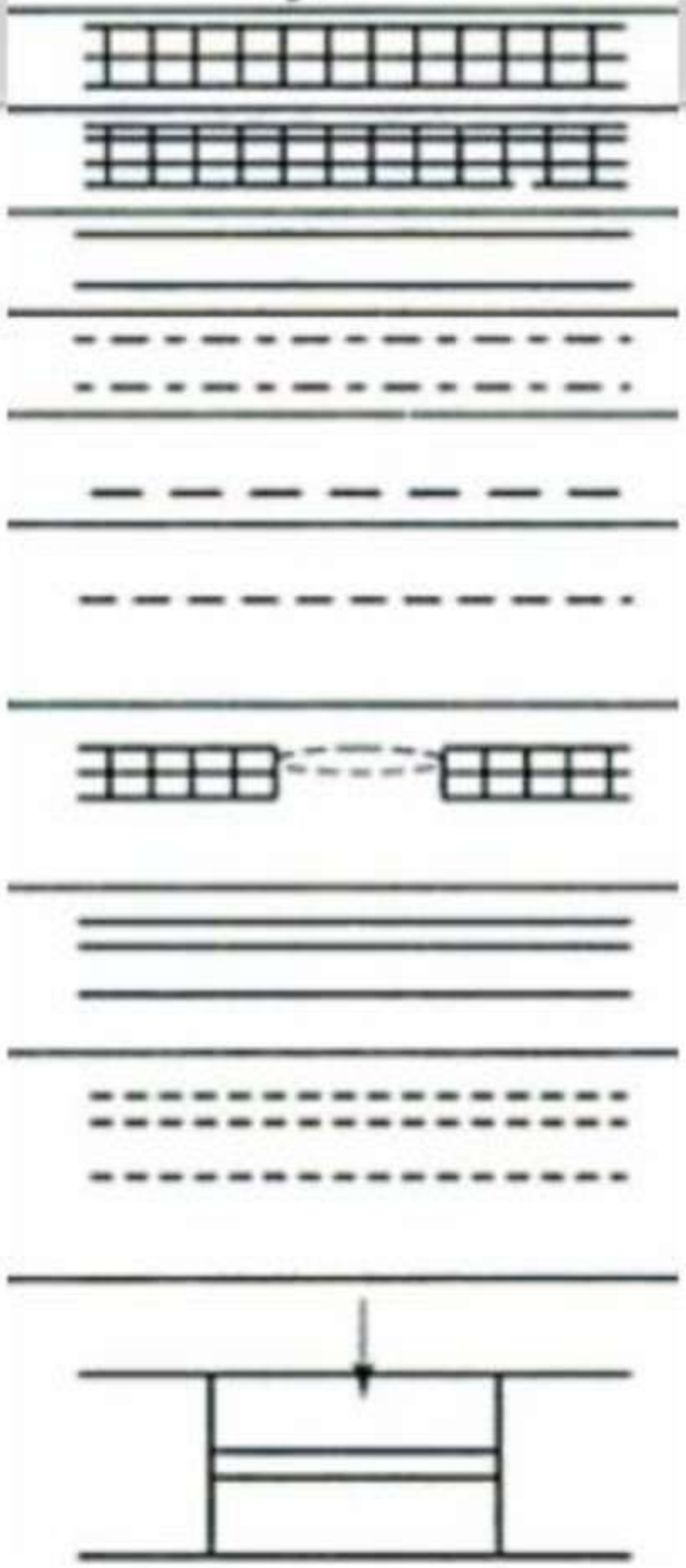
- **If graphical scale is not drawn on the plan and the sheet on which the plan is drawn shrinks due to variations in the atmospheric conditions, it becomes essential to find the shrunk scale of the plan.**

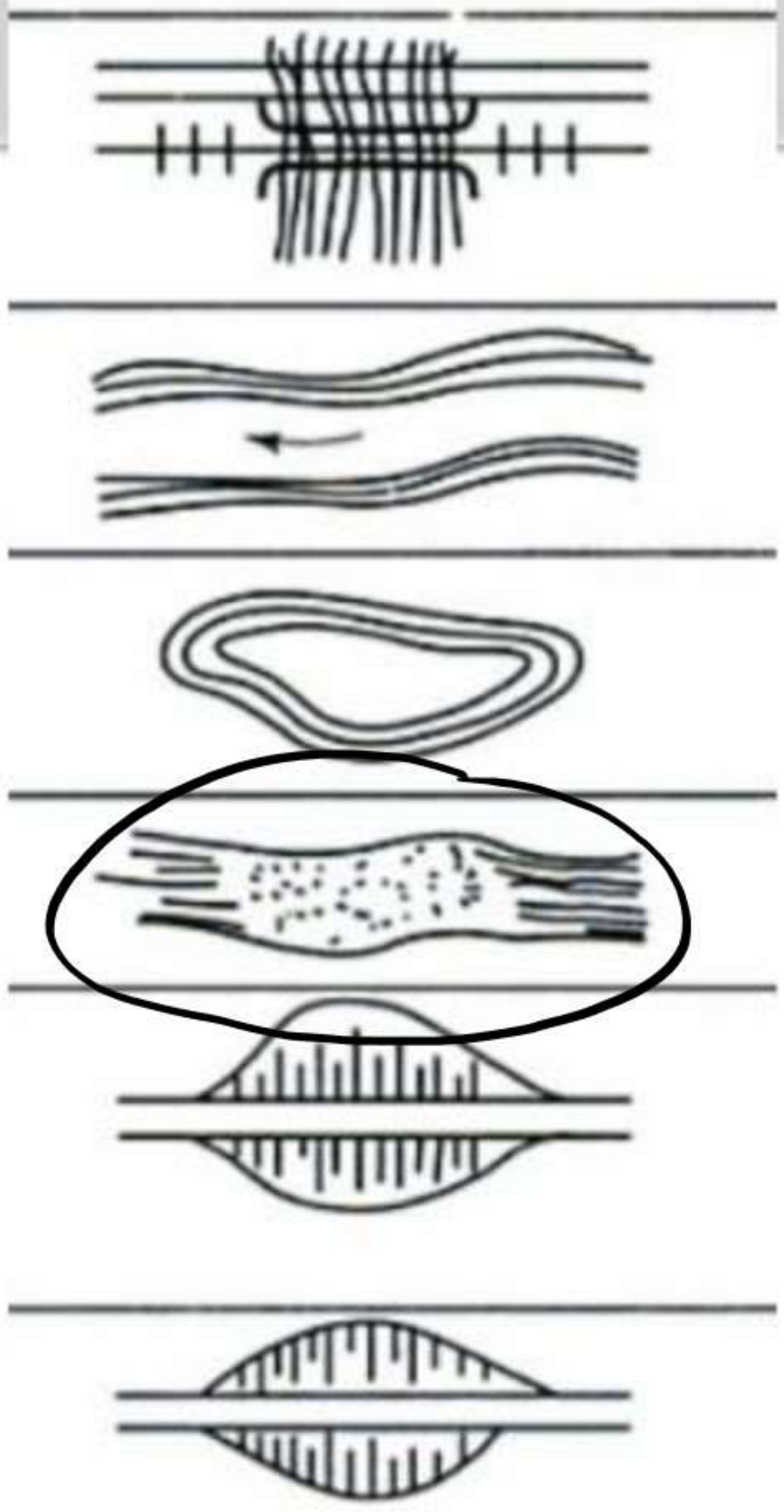
$$Shrunk\ Scale = Shrinkage\ Factor \times Original\ Scale$$

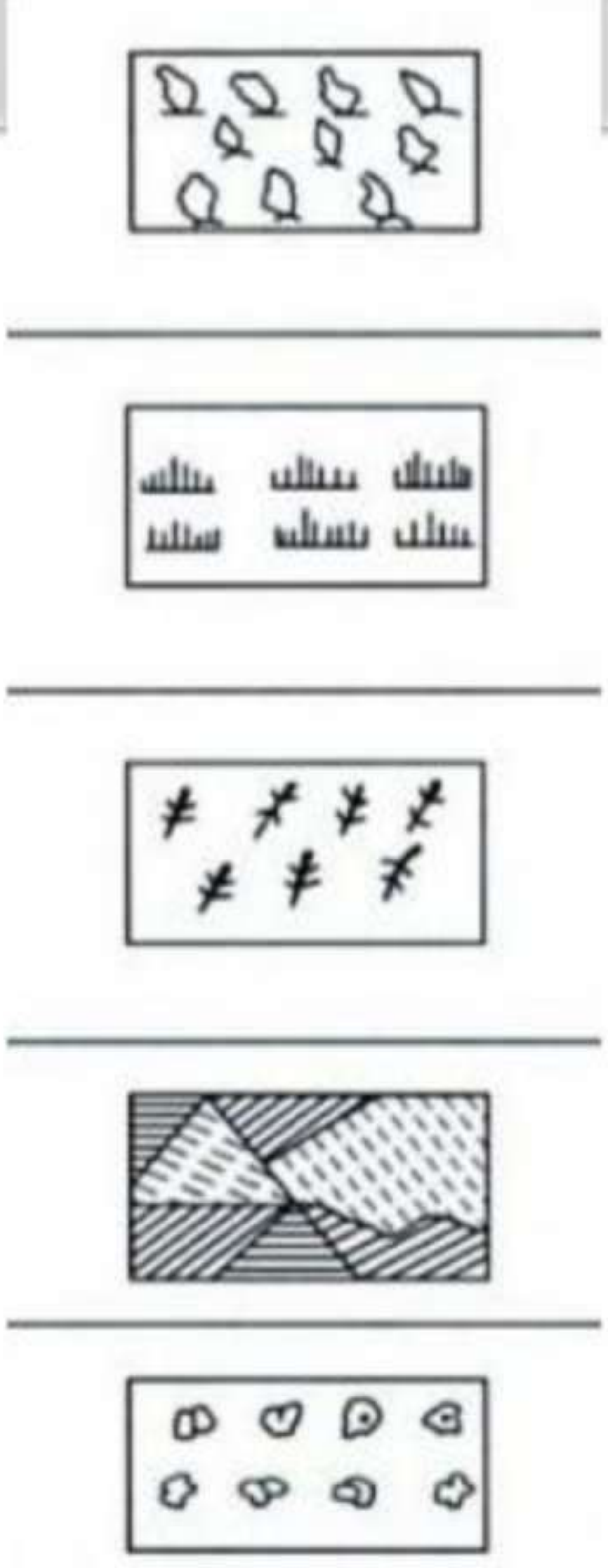
$$Shrinkage\ Factor\ or\ Shrinkage\ Ratio = \frac{Shrunk\ Length}{Actual\ Length}$$

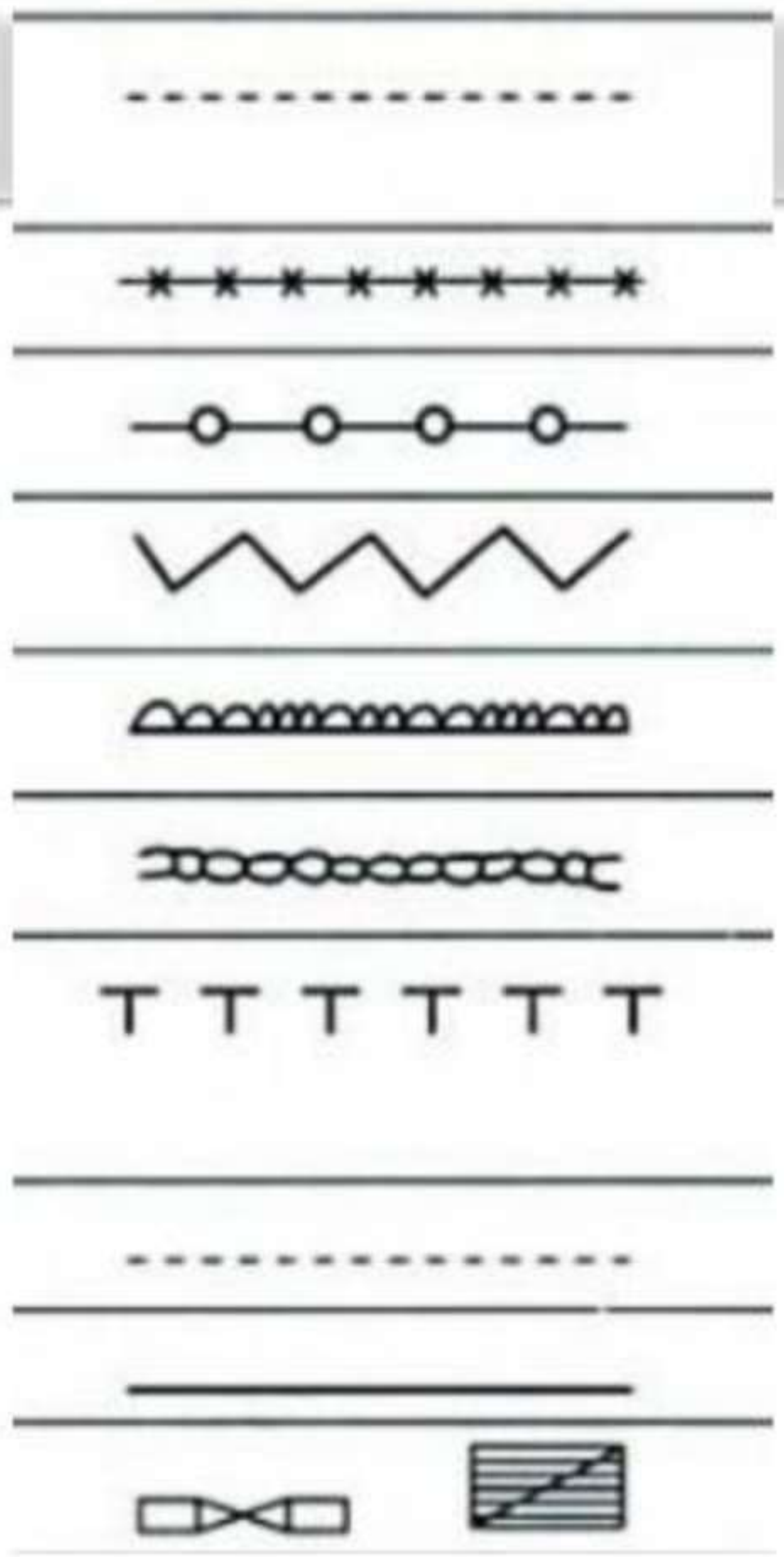
$$\Rightarrow \frac{Shrunk\ Scale}{Original\ Scale} = \frac{Shrunk\ Length}{Original\ Length}$$

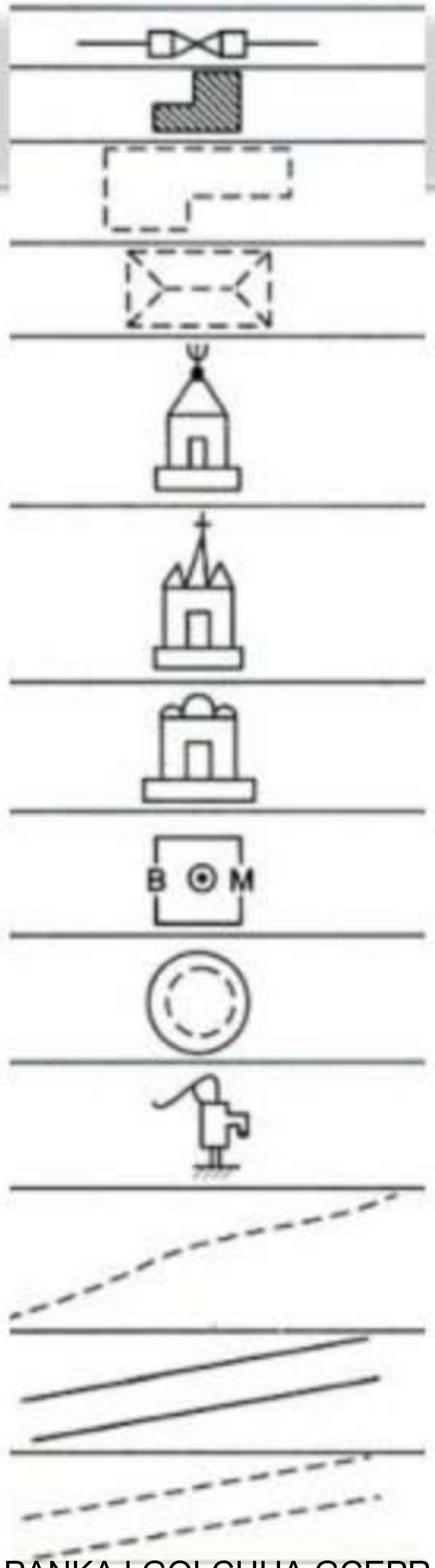
Symbol











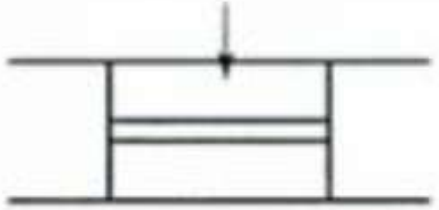
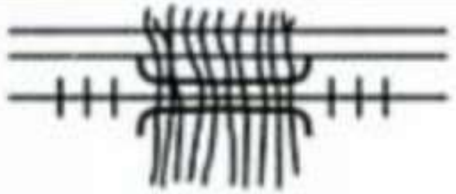
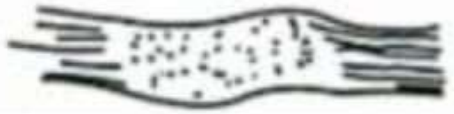
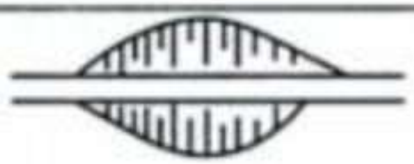
Furnishing Drawings in Surveying

- **Meridian arrow is used for direction indication**
- **Various symbols used in surveying are:**

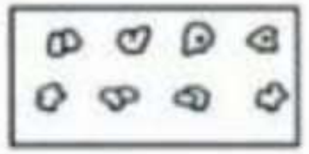
Object	Symbol	Colour
Single Track		Black
Double Track		Black
Pucca Road		Vermilion Red
Kutcha Road		Vermilion Red
Footpath		Vermilion Red
Fencing Post and Rail Fence		Vermilion Red
Tunnel (Road or Rail Road)		Black
Canals and Ditches		Black
Aqueducts and Water		Black
Pipes		

Meridian arrow

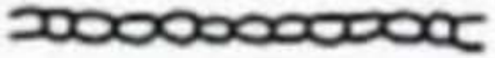
Furnishing Drawings in Surveying

Dam		Black
Bridge		Black
Stream		Prussian Blue
Pond		Prussian Blue
Falls and Rapids		Black
Road in Embankment		Indian Blue Ink and Road in Vermilion Red
Road in Cutting		Indian Blue Ink and Road in Vermilion Red

Furnishing Drawings in Surveying

Garden		Indian Black Ink Boundary Chain Dotted and Hopper's Green Wash
Marshy Ground		Indian Black Ink Boundary Chain Dotted and Hooper's Green Wash
Jungle		Indian Black Ink Boundary Chain Dotted and Hooper's Green Wash
Cultivated Land		Green
Orchard		Green

Furnishing Drawings in Surveying

Fence of any kind (or Board Fence)		Black
Barbed Wire Fence		Black
Smooth Wire Fence		Black
Rail Fence		Black
Hedge Fence		Green
Stone Fence		Black
Telegraph or Telephone Line		Black
Power Line		BlacK
Wall		Vermilion Red
Gate		Vermilion Red

Furnishing Drawings in Surveying

Wall and Gate		Vermilion Red
Building (Large Scale)		Black
Building (*Kutcha*)		Umber
Huts		Yellow
Temple		Crimson lake
Church		Crimson lake
Mosque		Crimson lake
Benchmark	B ⊙ M	Black
Open well		Purssina blue
Tube well		Black
Footpath		Black
Metalled road		Burnt sienna
Unmetalled road		Burnt sienna

ACCURACY AND ERRORS

PRECISION	Degree of perfection **USED** in instrument, methods and observations
ACCURACY	Degree of perfection OBTAINED

Mistake and Error

- **Mistake:**
  - These are discrepancies caused due to carelessness, misunderstanding. Poor judgment
  - Ex:- miscounting of Tape length (or) 5 m reading recorded as 8m
- **Error:**
  - These are discrepancies other than mistakes
  - $\boxed{E = M.V - T.V}$
  - $C = T.V - M.V$
    - M.V → Measured value
    - T.V → True value
    - C → Correction

SOURCES OF ERROR

1. Instrumental
2. Personal
3. Natural

Types of Errors

1. Mistakes

- Errors that arise due to inattention, inexperience, carelessness and poor judgement

2. Systematic Errors/Cumulative Errors

- Under same conditions, the error will be of same type, sign and size

3. Compensating Errors/Accidental Errors

- Compensating Errors are those which remain after mistakes and systematic errors have been eliminated and are caused beyond the limitations of surveyor

THEORY OF PROBABILITY

- **ACCIDENTAL ERRORS follow the LAW OF PROBABILITY.**
- **Some features of ACCIDENTAL OR COMPENSATING ERRORS are:**
  1. ***Small Errors*** **tend to be more frequent than large ones, so they are** ***more probable***
  2. ***Positive and Negative Errors*** **happen of the same size happen with equal frequency i.e. they are** ***equally probable***
  3. ***Large errors*** **occurs infrequently and are** ***improbable***

Most Probable Value

- **It is that value which has more chance of being correct than any other**

Most Probable Error

- It is that quantity which when added to and subtracted from, the most probable value fixes the limits within which it is an even chance that the TRUE VALUE of the measured quantity must lie.
- Probable error of single observation is calculated as

$$\boldsymbol{E_s = \pm 0.6745\sqrt{\frac{\sum v^2}{(n-1)}}}$$

The probable error of mean of a number of observations

Most Probable Error

- It is that quantity which when added to and subtracted from, the most probable value fixes the limits within which it is an even chance that the TRUE VALUE of the measured quantity must lie.
- Probable error of single observation is calculated as

$$E_s = \pm 0.6745 \sqrt{\frac{\sum v^2}{(n-1)}}$$

- The probable error of mean of a number of observations of the same quantity is given by

$$E_m = \pm 0.6745 \sqrt{\frac{\sum v^2}{n(n-1)}} = \frac{E_s}{\sqrt{n}}$$

- $E_m = probable\ error\ of\ the\ mean$
- $E_s = probable\ error\ of\ single\ observation$
- $n = number\ of\ observations\ in\ the\ series$
- $v = difference\ between\ any\ single\ observation\ and\ mean\ of\ the\ series$

Principle of Least Square

- If we have a number of observations, the most probable value of an observed quantity is the one which has sum of squares of errors as minimum.

Probable error of mean of a number of observations

- The probable error of mean of a number of observations of the same quantity is given by

$$E_m = \frac{E_s}{\sqrt{n}}$$

- $E_m = probable\ error\ of\ the\ mean$
- $E_s = probable\ error\ of\ single\ observation$
- $n = number\ of\ observations\ in\ the\ series$

PERMISSIBLE ERROR

- It is maximum allowable limit from which the a measurement may vary from TRUE VALUE
- NOTE:
  - In surveying, indication of accuracy is shown by significant figures.
    - The last digit is considered to be least accurate (for example if 123.45 has 5 significant figures and error might lie of a value of 0.005)
  - The accuracy of ANGULAR and LINEAR measurements should be compatible
    - Angular values measured to *1 second* requires distances to be measured upto *1mm*
    - Angular values measured to *1 minute* requires distances to be measured upto *1cm*

Accumulation of Errors

- When errors are known for their sign, we add them algebraically
- If we have random errors, then error is represented by root mean square value

$$e_t = \sqrt{\pm e_1^2 \pm e_2^2 \pm e_3^2 \dots \pm e_n^2}$$

Chapter 3 : Linear Measurements

DIRECT MEASUREMENTS

MEASUREMENTS BY OPTICAL MEANS

ELECTROMAGNETIC METHODS

Methods of Linear / Horizontal distance measurement

1. Direct method → chain (or) Tape
2. Tachometric method → optical method
3. Electronic distance measuring instrument (EDMI)

Note:-

→ EDMIs can be classified into 3 types based on carrier wave

1. Light wave → Geodimeter & Mekometer
2. Radio wave / Microwave → Distomat & Tellurometer (most precise instrument for measuring horizontal distances)
3. Infrared → Total station

DIRECT MEASUREMENTS

- Direct measurement can be done by

PACING

PASSOMETER (counts steps)

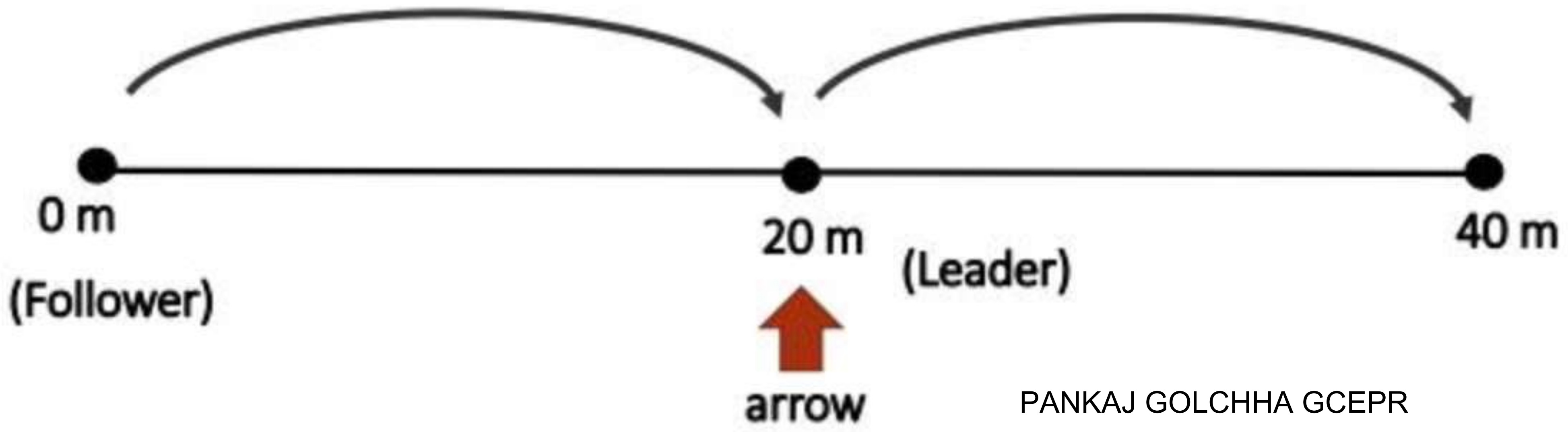
PEDOMETER (counts distance)

ODOMETER AND SPEEDOMETER

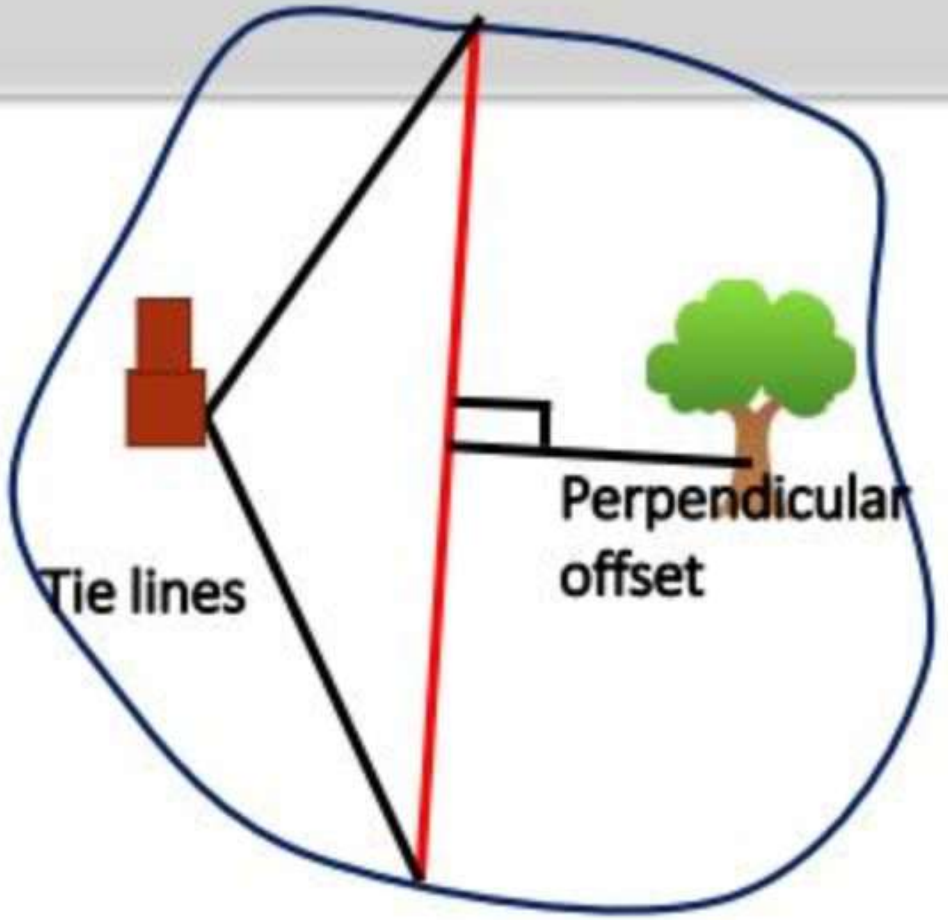
CHAINING

Chain Surveying

- It is the branch of surveying in which distances are measured with chain (or) Tape and this process is called as “chaining”.
- Chain surveying is done for smaller Area.
- In the process of chaining the survey the team consist of Follower (0 m)and leader. (20 m (or) 30 m)
- Leader drives the Arrow and follower collects it
- No. of arrows with the follower signifies chain length measured



Chain Surveying

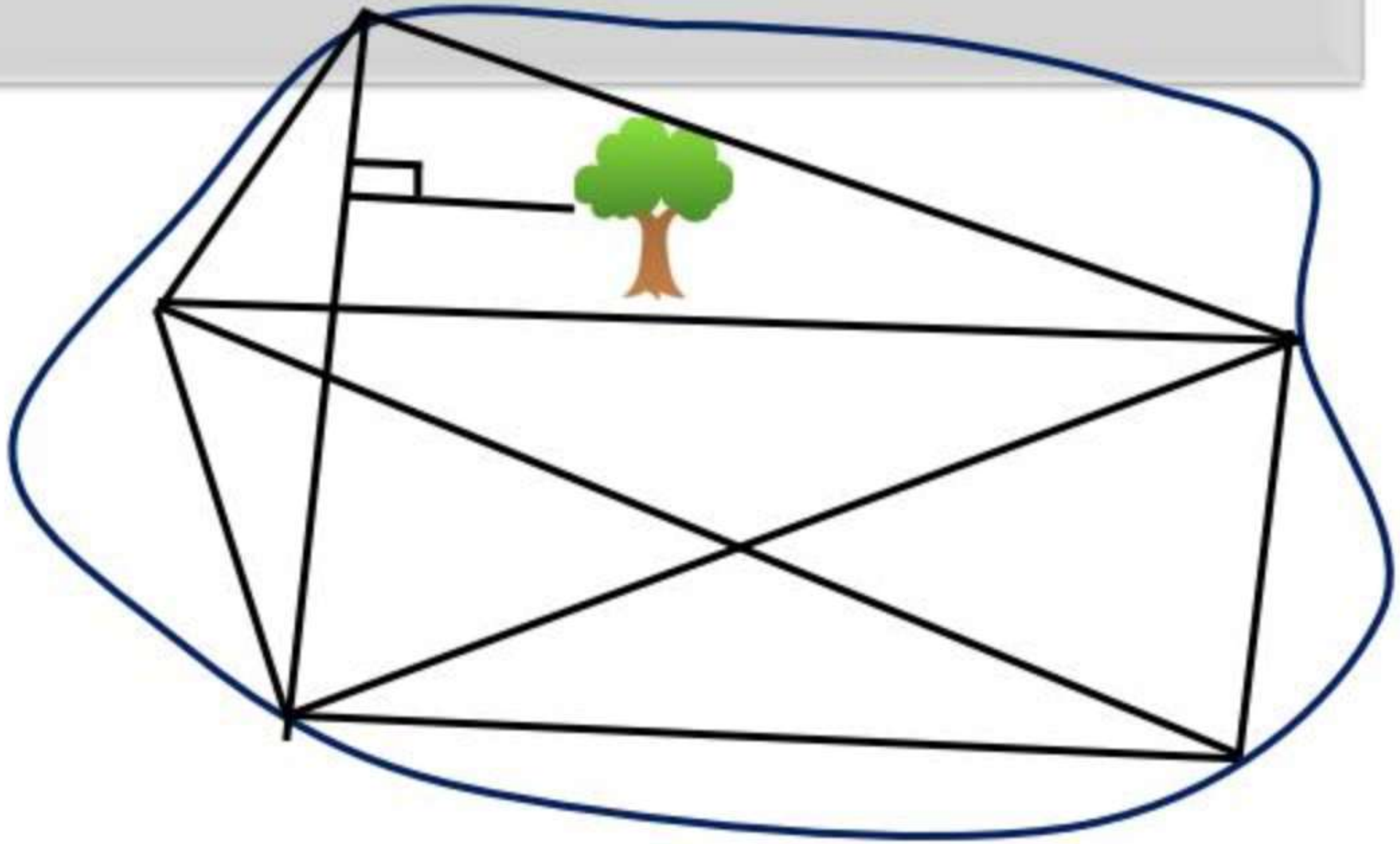


Procedure in chain surveying:-

- In chain surveying various points are located by measuring distance is the help of chain (or) Tape
- For smaller Area, details of various points can be collected using ties and offset.
- Note: → Offsets are lateral distances measured from a survey line to the point to information is to be collected.

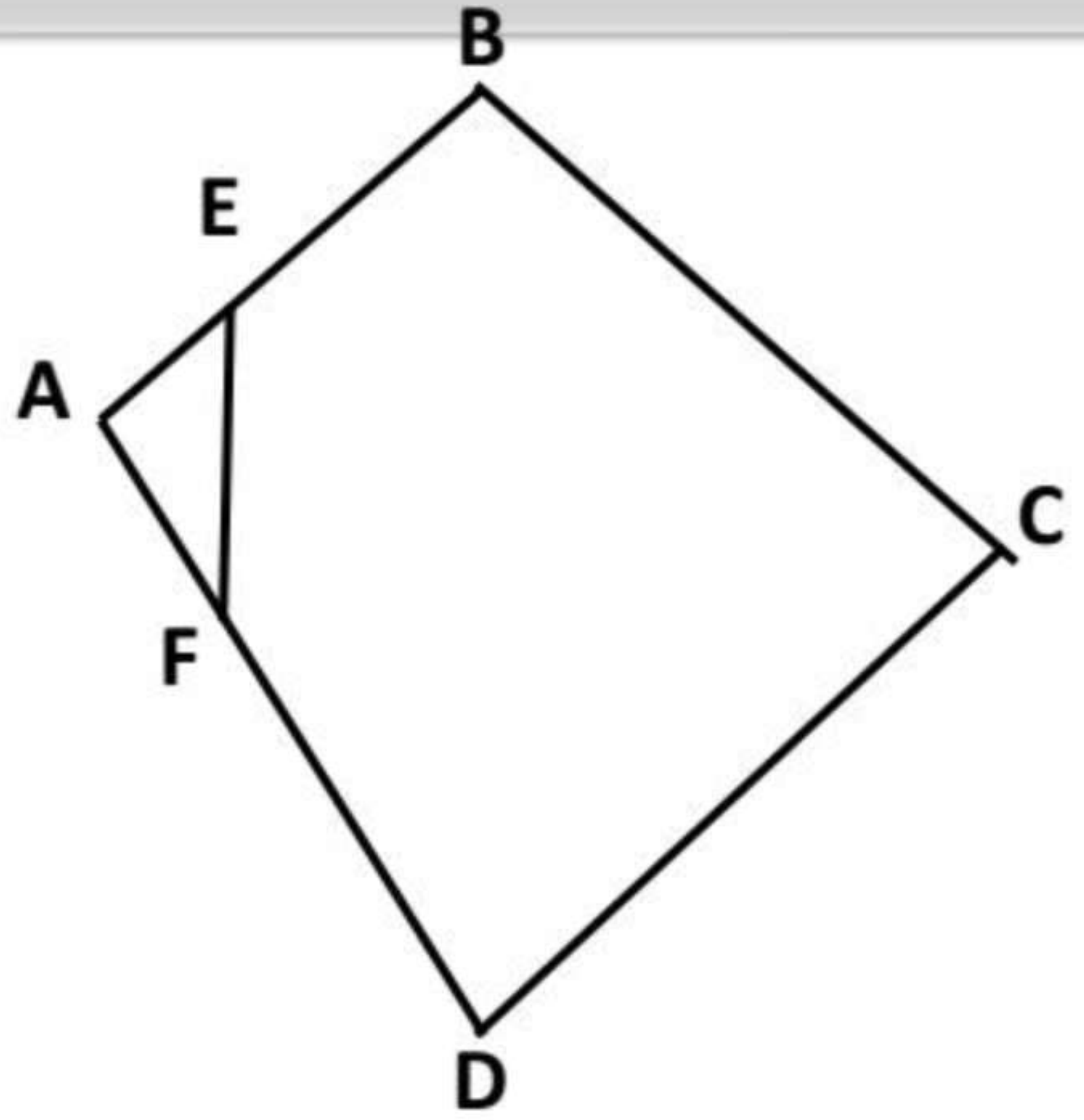
Chain Surveying

- But when Area is large, error introduced due to large offset will be more, therefore to overcome this difficulty large area is first of all converted into Network of small triangles and then these details are collected using ties and offset.



Some Basic Definitions

1. ***Main station:***
   - main station is a point where two sides of a triangle meet and these stations decides boundary of the survey
   - Exp: A, B, C, D
2. ***Main survey line***
   - These are the lines joining main survey stations
   - AB, BC, CD, DA, BD
3. ***Tie station / subsidiary station / Auxiliary station:***
   - Tie station are station on the line joining main stations
   - Exp: E, F



Some Basic Definitions

4. *Tie line / Auxiliary line / Subsidiary line:*

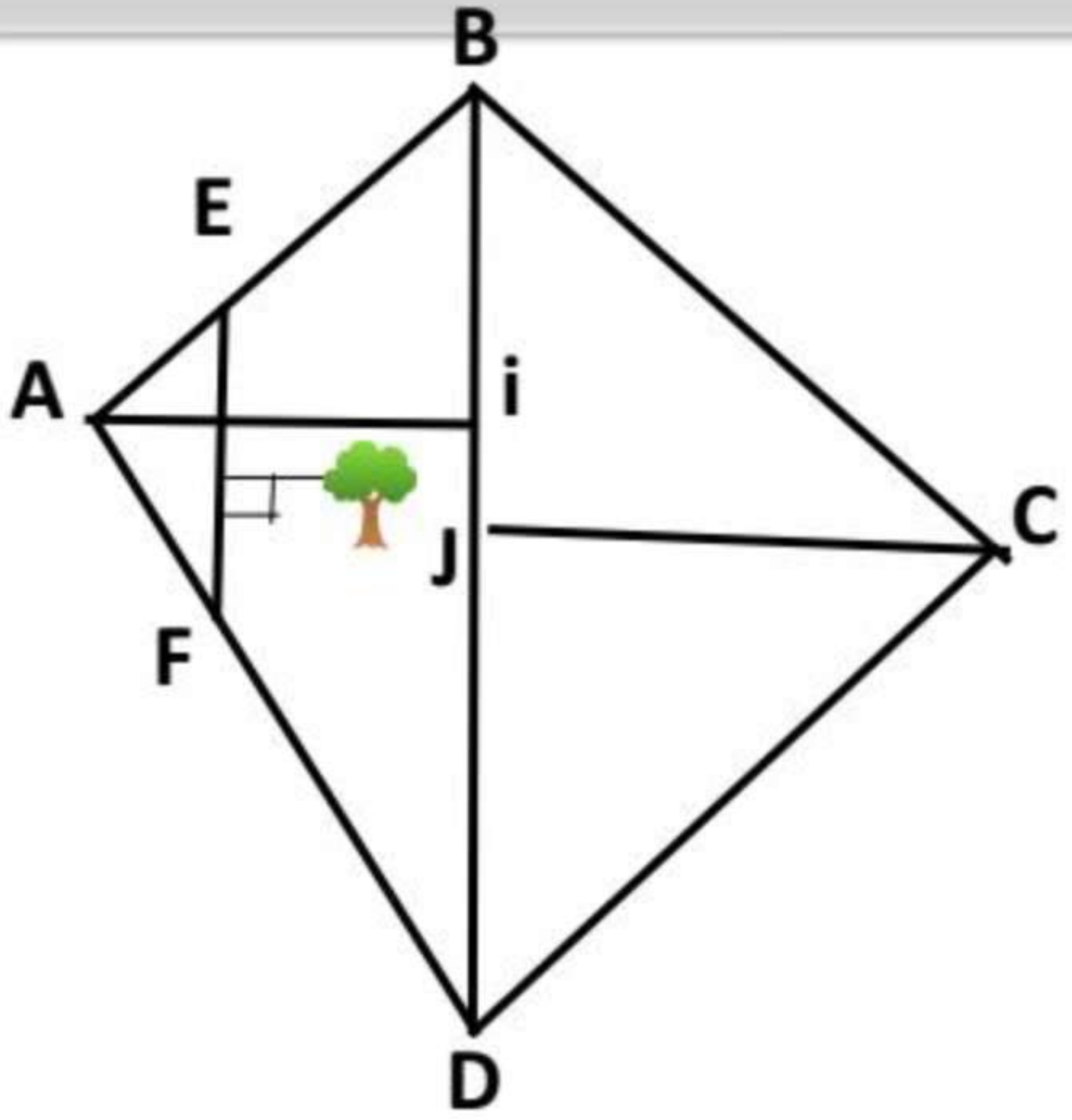
- These are the lines joining tie stations
- These are helpful in locating inner details of the Area.
- Exp: EF

5. *Base line*

- It is longest main Survey line which generally passes through the central port of the Area.
- Ex:- BD

6. *Check line / Proof line*

- Check line is provided to check the Accuracy of the field work and plan work
- It is not used for plotting of any point
- Measured length of the check line should be equal to length scaled from the plan.
- Ex:- Ai & Cj



Some Basic Definitions

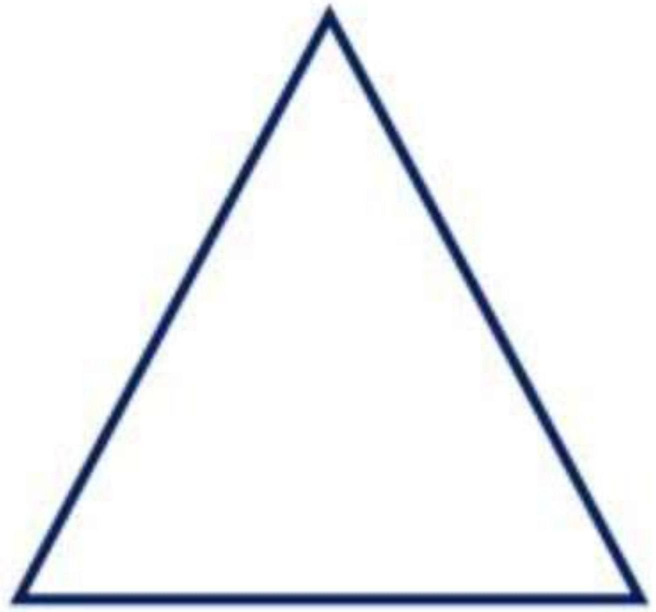
7. Chainage:

- Chainage is the distance measured along the direction of progress of survey
- It is the distance of a well defined point from the starting point.
- Word Chainage is generally used in linear projects.
- Ex:- Railway, Highway, Canal etc.
- They are used to represent important features in the work

Some Basic Definitions

8. *Well-conditioned Triangle*

- In chain surveying attempt should be made to form a triangle such that intersection of lines is clear and distinct, for the purpose of plotting
- Hence for obtaining distinct intersection, the angle should be in the range of 30° to 120°
- Best possible well conditioned triangle is “Equilateral triangle



Equipments used in Chain Surveying

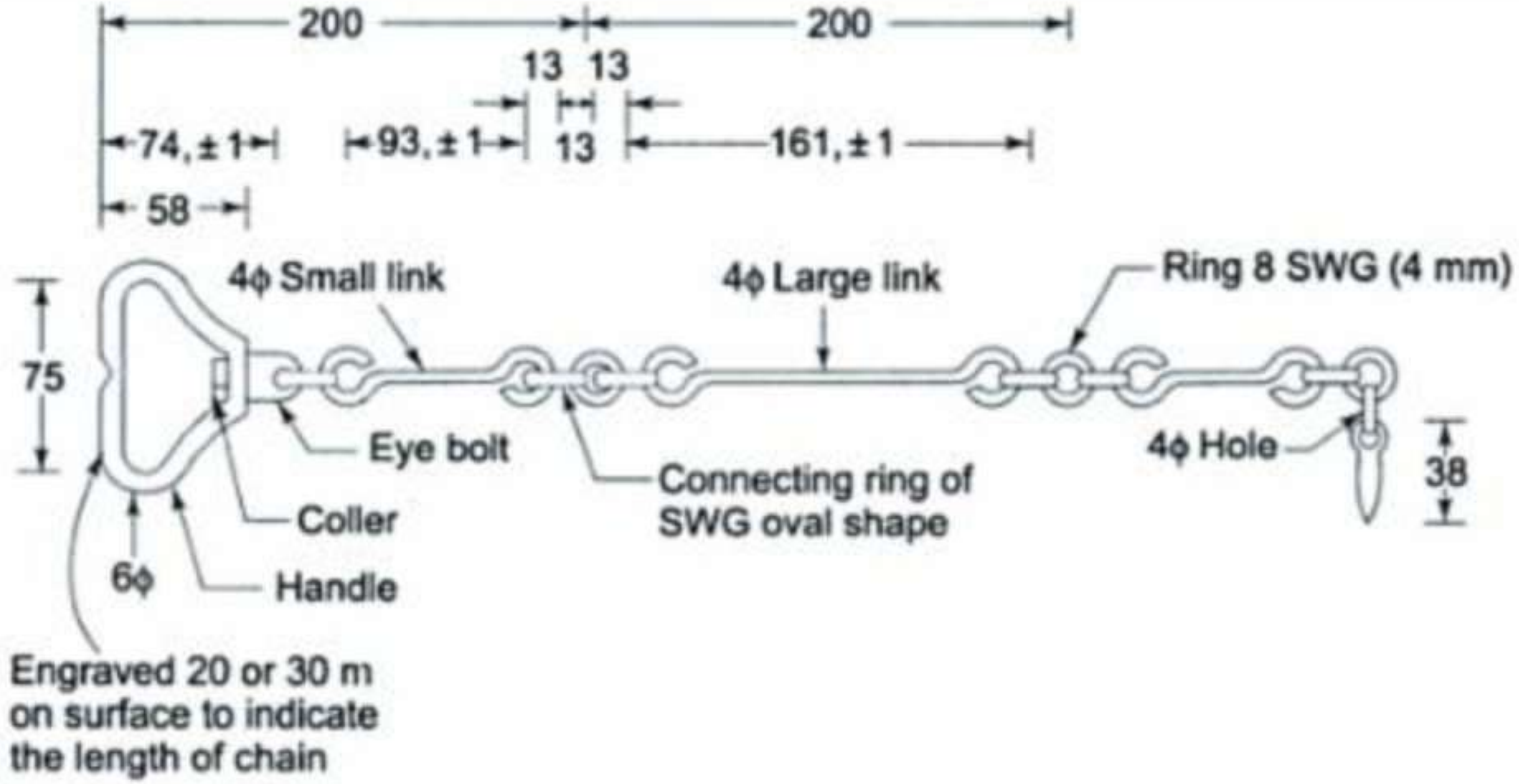
1. Surveying chain:-
   A. Revenue chain → 33 feet, 16 link
   B. Gunter's chain or Surveyor's chain → 66 feet, 100 link
   C. Engineer's chain → 100 feet, 100 link
   D. Metric chain →
      a) 5 m, 25 link
      b) 10 m, 50 link
      c) 20 m, 100 link
      d) 30 m, 150 link

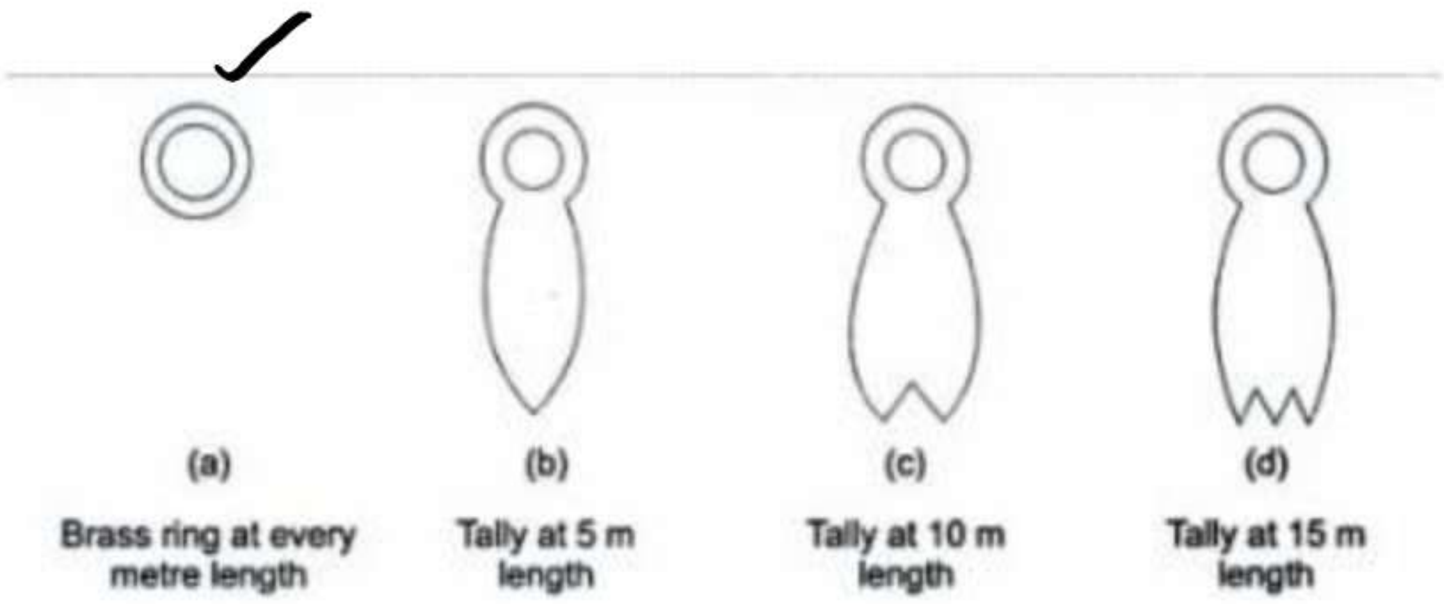
Note:

- 1 mile = 1.6093 km = 80 Gunter's chain
- 1 Acre = 4046.856 m^2 = 10x (Gunter's chain)^2 = 40 guntas = 43560 ft^2
- 1 yard = 3 feet = 0.9144 m

Note: Metric Chain

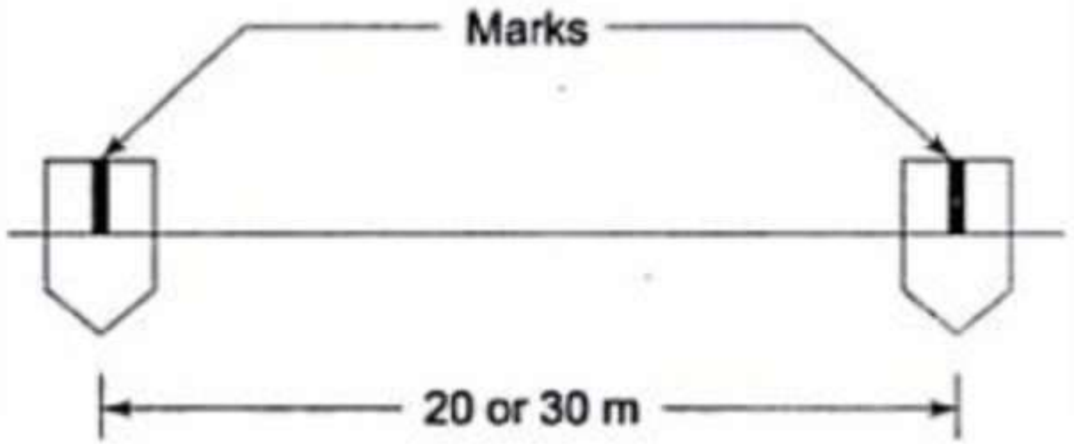
- Every metre has 5 links
- 4 mm dia wire is used
- Brass handles are provided with swivel joint so that chain can be turned around without twisting
- Metallic Tags or TALLIES are used at 5m, 10m, 15m, 20m, 25 m
- Small brass links are provided at every metre length





Note: Metric Chain

- Two pegs at a required distance of 20 or 30 m are inserted on a flat ground
- The overall length of the chain is compared with the marks and the difference is noted
- *If the chain is found to be too long*, it may be adjusted by closing the opened joints of rings; reshaping the elongated links; removing one or more circular rings; and replacing the worn out rings.
- *If chain is found too short*, it may be adjusted by straightening the bent links; flattening the circular rings; replacing circular rings by bigger rings; and inserting additional rings.



Two peg Test

IMPORTANT POINTS

1. When a tension of 80 N is applied at the ends of chain, every metre length should be accurate within ±2mm.
2. Maximum tolerance in a 20 m & 30 m chain are ± 5 mm and ± 8 mm.
3. While measuring horizontal distance with chain on hills, it is better to measure the distance by "Stepping down slope".
4. Chainage in chain survey means "the distance of the object along the chain line from the zero end of the chain".
5. The allowable Length of an offset depends upon:
   - Degree of accuracy required
   - Method of setting out the perpendicular and nature of ground.
   - Scale of potting

IMPORTANT POINTS

5. In chain Surveying, field work is limited to "Linear measurements only"
6. The accuracy of Measurement in chain surveying, does not depend upon "general layout of the chain lines"
7. The double-line field book is most commonly used for recording "Ordinary chain Survey work".
8. Offset are lateral measurements made w.r.t. main survey lines in which line may be oblique (or) ⊥ lar.
9. Correct methods of ranging employed to solve the problem of vision obstructed are:

   i) Reciprocal ranging

   ii) Random line method.

TAPES

1. <u>Cloth (or) Linen Tape:-</u>
   - It is made up of closely woven linen & synthetic material which is varnished to resist moisture.
   - This tape does not remains straight during strong winds.
2. <u>Metallic Tape:-</u>
   - It is made up of linen with brass and copper wire woven into it & varnished
   - This Tape gives better results than in comparison to cloth Tape because stretching is reduced.
3. <u>Steel Tape:</u>
   - It is made up of stainless steel

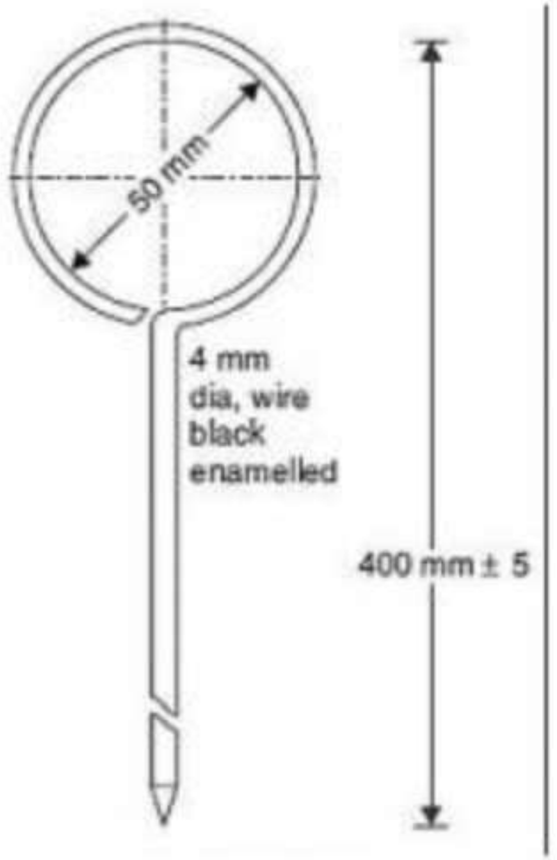
TAPES

4. Invar Tape

- Nickel : 36 %
- Steel : 64 %
- This Tape is highly accurate and have very small thermal coefficient of linear expansion
- But these tapes require much attention in the field because it is soft and deforms easily.

Accessories used in chaining

1. **Pegs**
   - There are used to mark a definite point temporarily (or) Semi- permanently
2. **Arrow:**
   - These are used to mark end point of a chain length
   - No. of arrows with the follower signifies number of chain length measured
3. **Ranging Rod:**
   - Ranging rods are used to establish intermediate points along a straight line and this process is called as “Ranging”.
   - These are 30 mm & Available in length of 2m (commonly used) and 3 m
   - If distance is more than 200m, a red, white or yellow flag should be used



Accessories used in chaining

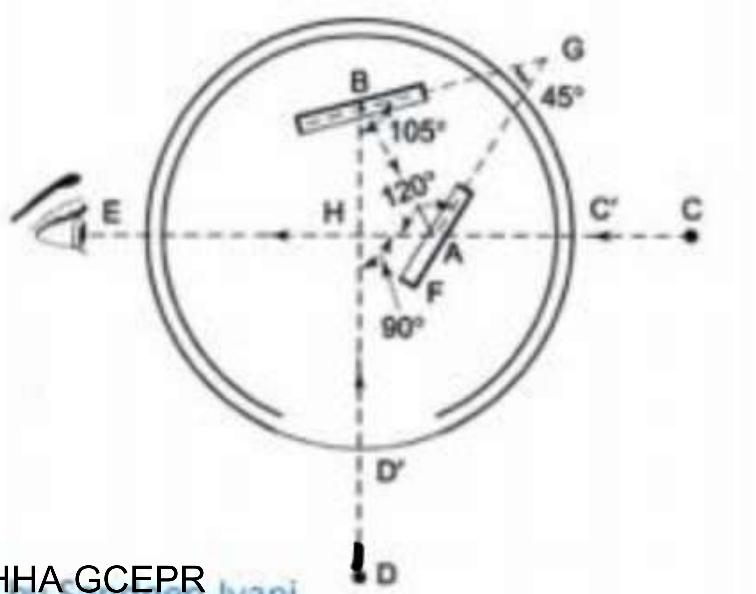
4. Offset rod:

- It is a Ranging rod with slots made at right angle and it helps to take perpendicular offset.
- Maximum length of an offset depends on
  - Scale of plotting
  - Nature of ground
  - Accuracy defined

Accessories used in chaining

5. **Cross staff / open cross staff:**
   - It is used for taking perpendicular offset along a survey line

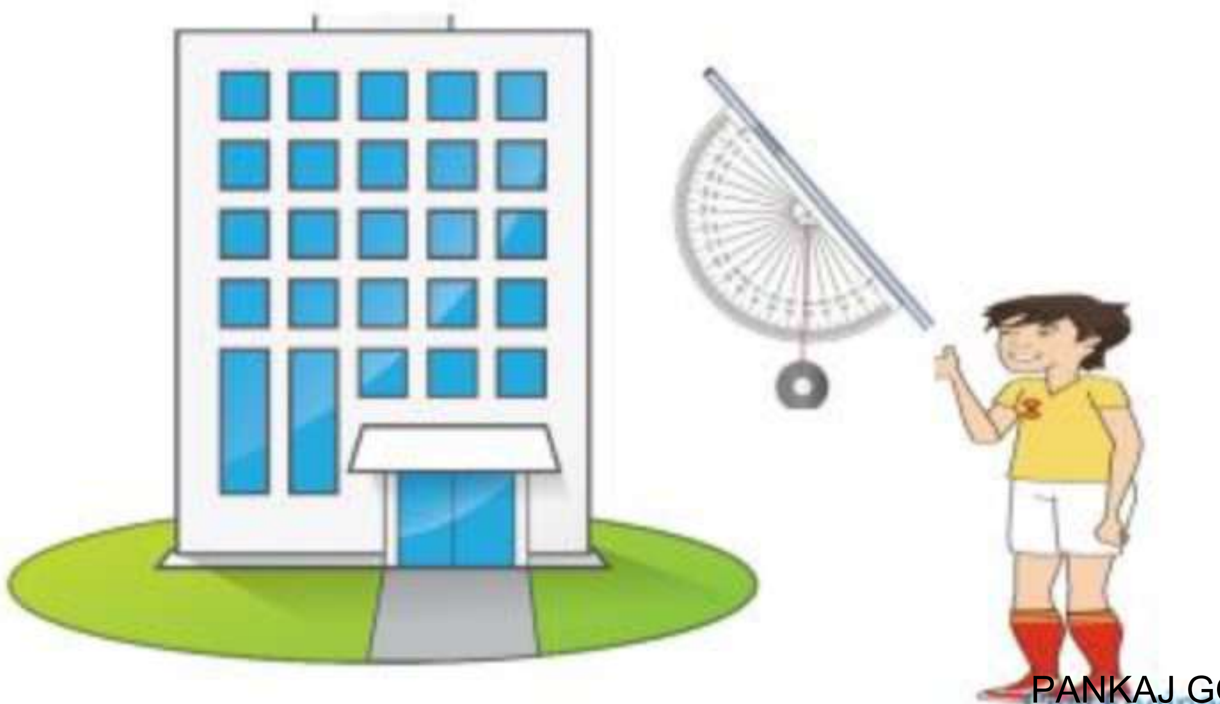
6. **French cross staff:-**
   - It is used to take offsets at 45°, 90°, 135° from the survey line
7. **Optical square:**
   - It is used to setout right angles
   - It uses the principle of Double reflection.
   - Index mirror fully silvered , Horizon Mirror bottom half silvered and Top half

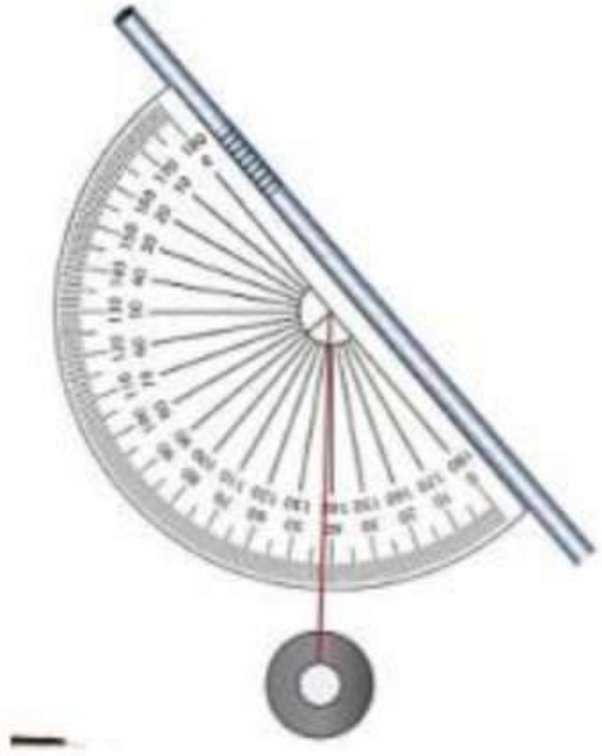


Accessories used in chaining

8. **Prism square:-**
   - It has similar arrangement as compare to optical square with mirror replaced by prism

9. **Simple clinometer**
   - It is used to measure slope of the ground and vertical angles





Ranging

- It is the process of establishing intermediate points along a straight line
- While we are measuring distances from one terminal to another terminal Station, if length is less than length of chain or tape, there is no difficulty
- But if we want to measure distance that is more than a chain/tape length, then we establish some intermediate points in the line joining terminal station before we start chaining

Types of Ranging

Direct Ranging

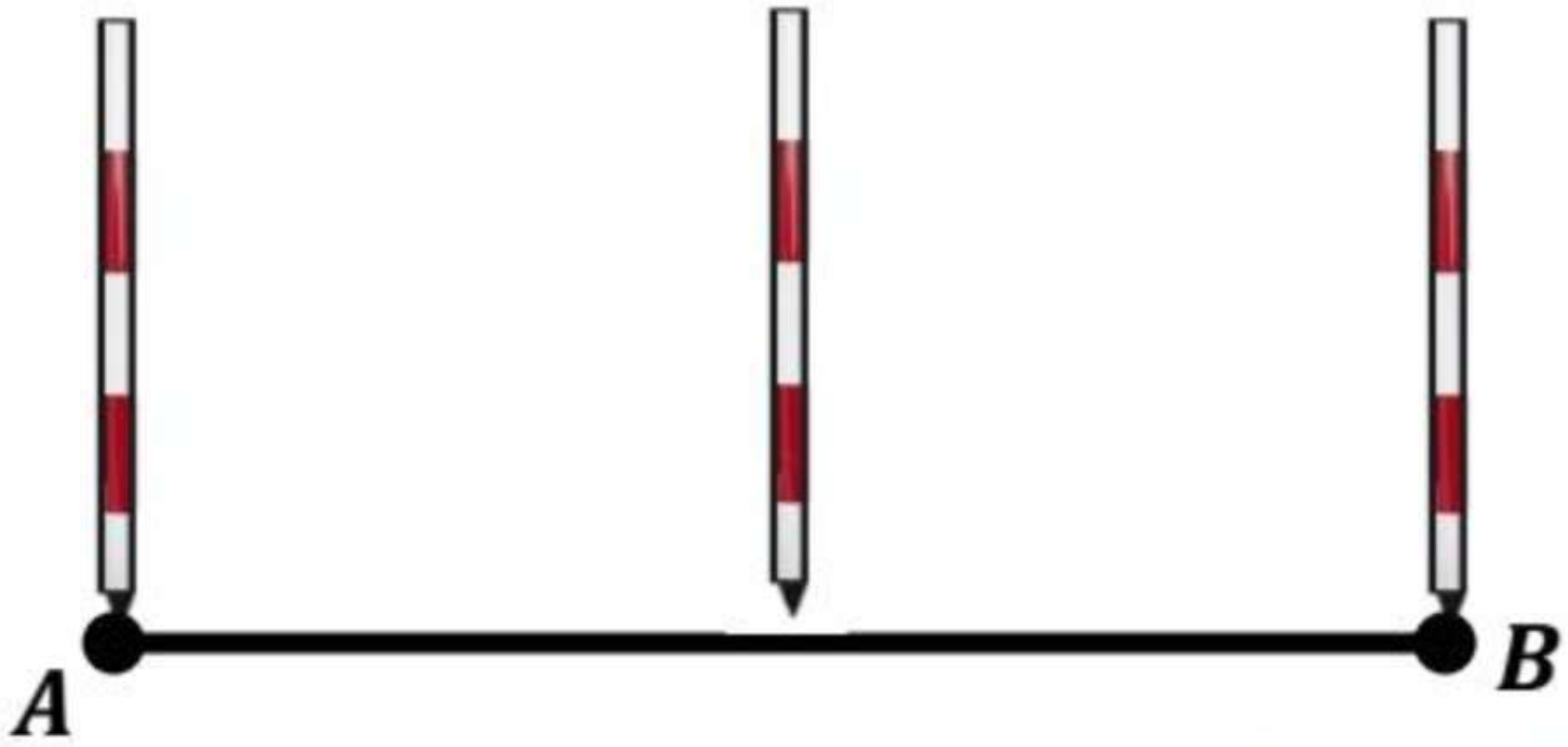
Indirect Ranging

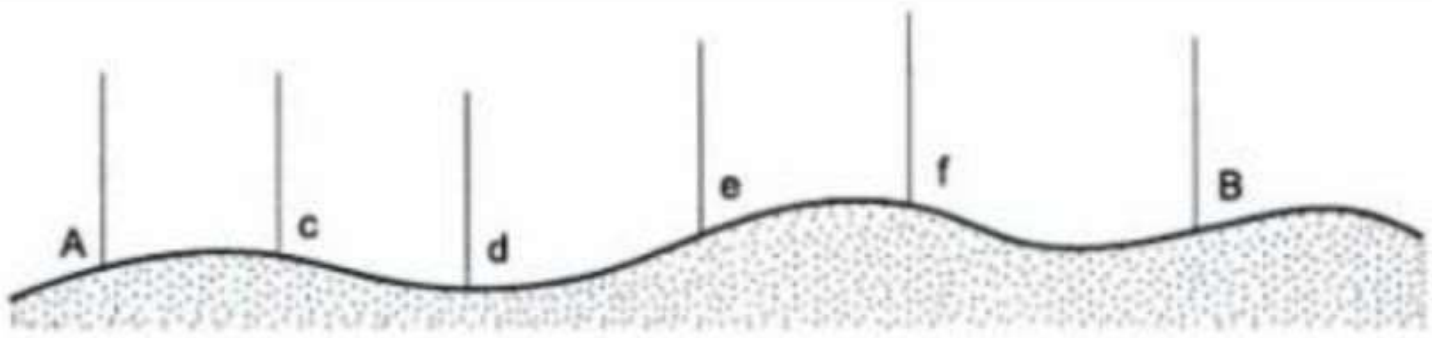
Ranging

Types of Ranging;

1. Direct Ranging:

- It is the process of establishing intermediate points along a chain line when end stations are intervisible

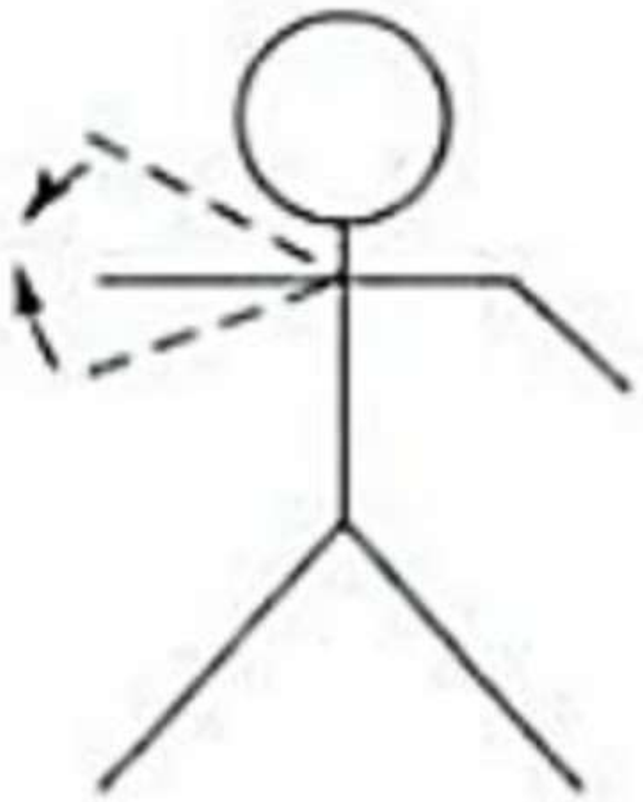




Ranging

1. Rapid sweep with right hand (Fig. a).
2. Slow sweep with right hand.

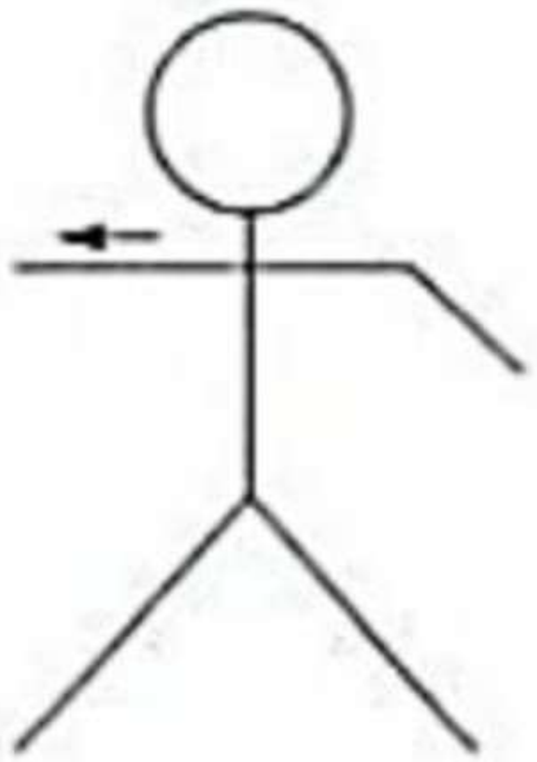
1. Move considerably in that direction (to your left).
2. Move slowly to your left.



(a)

Ranging

3. Right arm extended (Fig. b)
4. Right arm op and moved to the right.

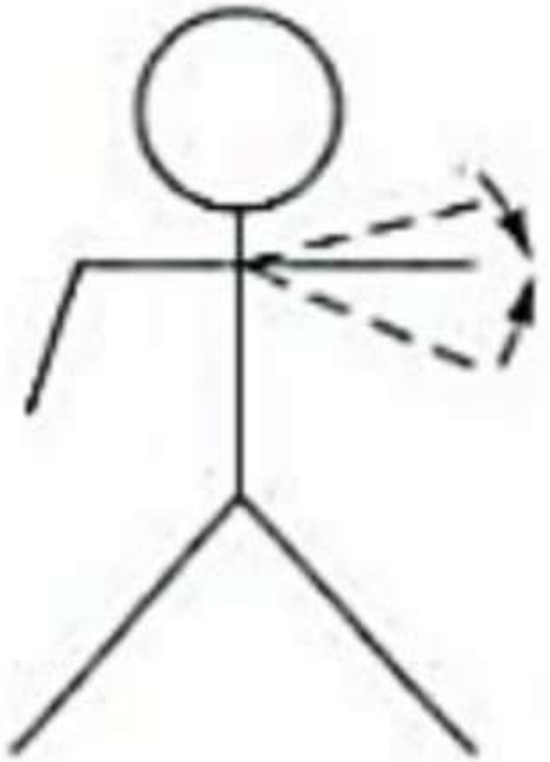


(b)

3. Continue to move to your left
4. Plumb the rod to your left

Ranging

5. Rapid sweep with left hand (Fig. c).
6. Slow sweep with left had.



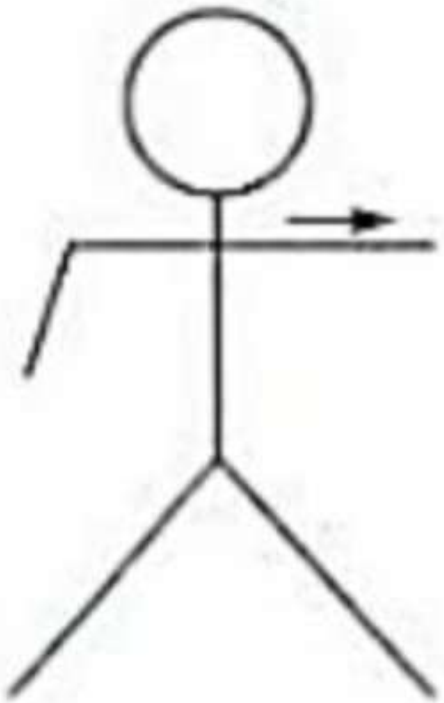
(c)

5. Move considerably in that direction (to your right).
6. Move slowly to your right.

Ranging

7. Left arm extended (Fig. d)
8. Left arm up and moved to the left.
9. Both hands above head and then brought down (Fig. e)
10. arms extended forward horizontally and the hands brought down quickly.

7. Continue to move your right.
8. Plumb the rod to your right.
9. Ranging is correct
10. Fix the ranging rod.

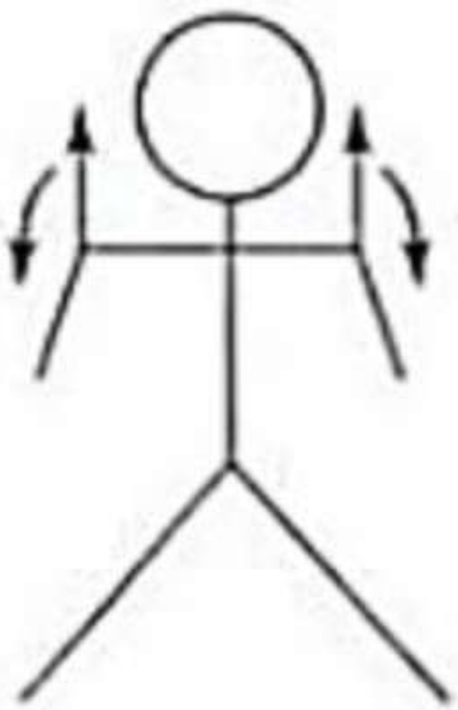


(d)

Ranging

9. Both hands above head and then brought down (Fig. e)
10. arms extended forward horizontally and the hands brought down quickly.

9. Ranging is correct
10. Fix the ranging rod.

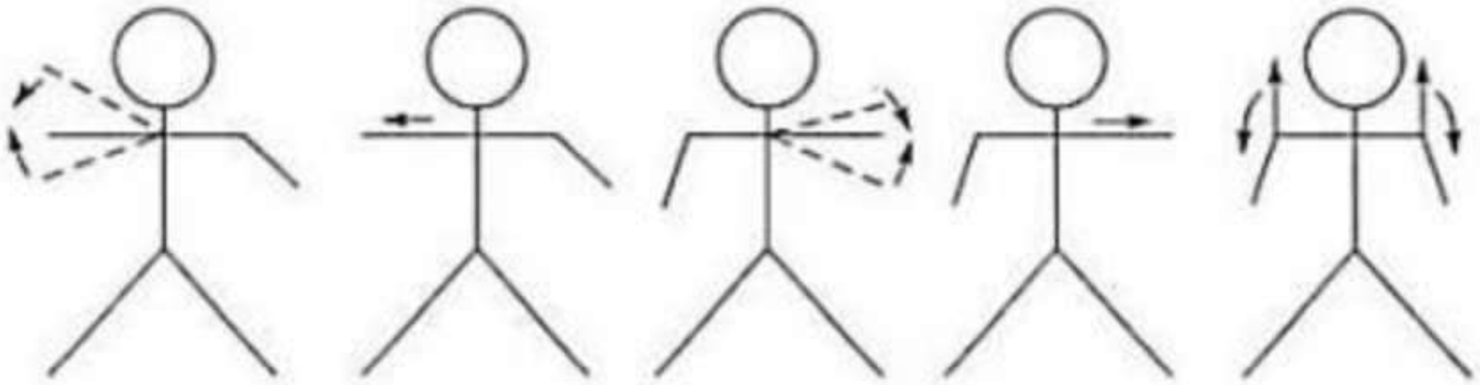


(e)

Ranging

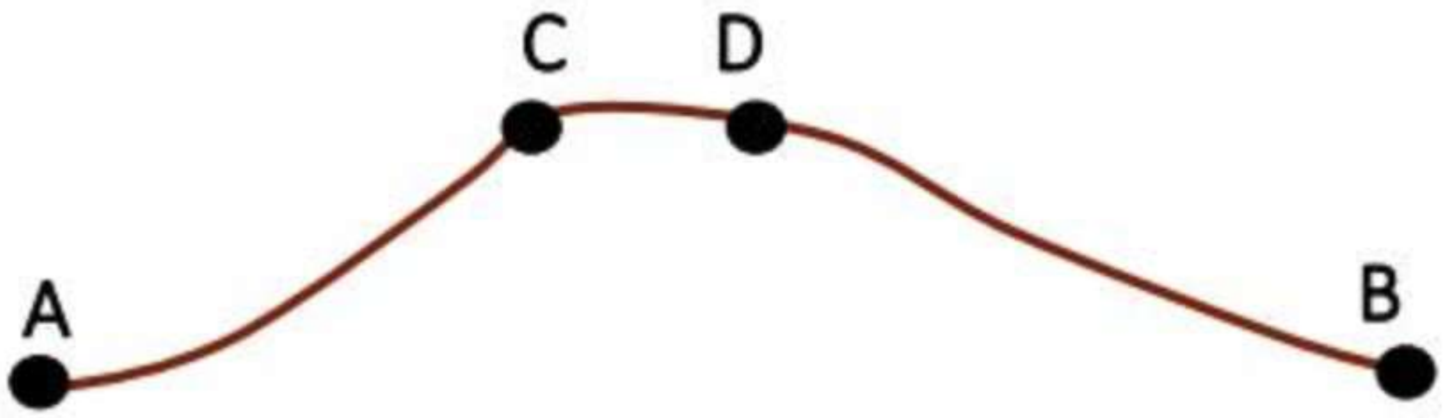
1. Rapid sweep with tight hand (Fig. a).
2. Slow sweep with right hand.
3. Right arm extended (Fig. b)
4. Right arm op and moved to the right.
5. Rapid sweep with left hand (Fig. c).
6. Slow sweep with left had.
7. Left arm extended (Fig. d)
8. Left arm up and moved to the left.
9. Both hands above head and then brought down (Fig. e)
10. arms extended forward horizontally and the hands brought down quickly.

1. Move considerably in that direction (to your left).
2. Move slowly to your left.
3. Continue to move to your left
4. Plumb the rod to your left
5. Move considerably in that direction (to your right).
6. Move slowly to your right.
7. Continue to move your right.
8. Plumb the rod to your right.
9. Ranging is correct
10. Fix the ranging rod.



(a) (b) (c) (d) (e)

Ranging



2. **Indirect / Reciprocal / Repeated alignment Ranging:**
   - This method is used when end stations are not intervisible due to rising ground between them (or) due to long distance between them.
   - During this process we select two intermediate stations (say C and D) Such that,
   - From station C → station B & D are visible,
   - From station D → station A & C are visible.

Corrections

Chain

- **Correction for standardization**
- **Correction for slope**

Tape

- Correction for standardization
- Correction for slope
- Correction for Pull
- Correction for Sag
- Correction for Temperature
- Correction for MSL
- Correction for misalignment.

Corrections

1. **Correction for standardization: (C_a)**
   - It is also called as correction for Absolute length.
   - If Actual length of the tape or not equal to Nominal length of the tape, then correction for standardization is required.
   - If tape is actually ***shorter*** than Nominal length then ***error will be positive*** because measured distance will be greater than correct distance
   - Therefore correction will be negative
   - Nominal Designated length → l' (20 m or 30 m)
   - Actual / Absolute length of tape → l (19 m)

Measured distance = L'
Correct distance = L
<u>Note</u>: if Tape is shorter then correction is subtractive

Corrections

1. Correction for standardization: (C_a)
   - Nominal Designated length → l' (20 m or 30 m)
   - Actual / Absolute length of tape → l (19 m)
   - Measured distance = L'
   - Correct distance = L

$$\boxed{Correct\ distance\ or\ True Length\ of\ line = Measured\ length\ of\ line \times \frac{incorrect\ or\ actual\ length\ of\ tape\ used}{designated\ or\ Nominal\ Length\ of\ tape}}$$

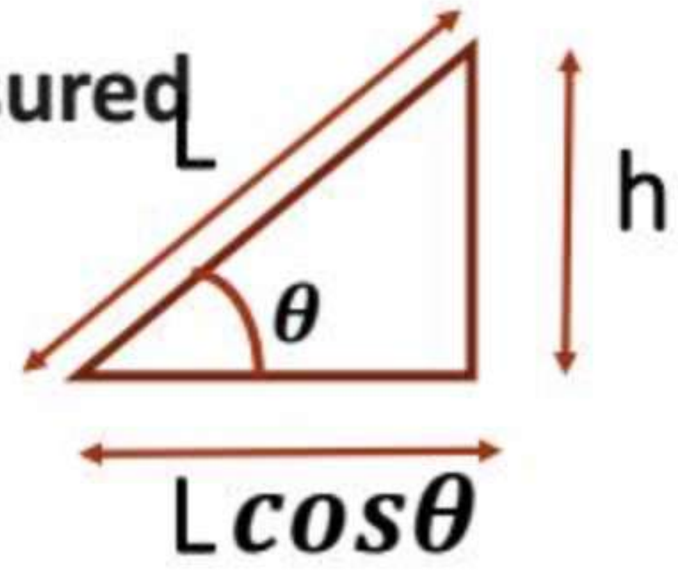
$$\boxed{TL\ or\ CD = AL \times \frac{MD}{NL}}$$

$$Correct\ area\ or\ True\ area = (Measured\ area) \times \left[\frac{incorrect\ or\ actual\ length\ of\ tape\ used}{designated\ or\ Nominal\ Length\ of\ tape}\right]^2$$

Corrections

2. Correction for slope (C_g)

- **We know that slope distance will always be greater than corresponding horizontal distance, therefore correction for slope will always be negative**
- **Case : 1 When slope of the ground θ is measured**



$$C_g = T.V - M.V$$

$$= L\cos\theta - L$$

$$C_g = -L(1 - \cos\theta)$$

Corrections

2. Correction for slope (C_g)

Case II:- When height difference 'h' is measured.

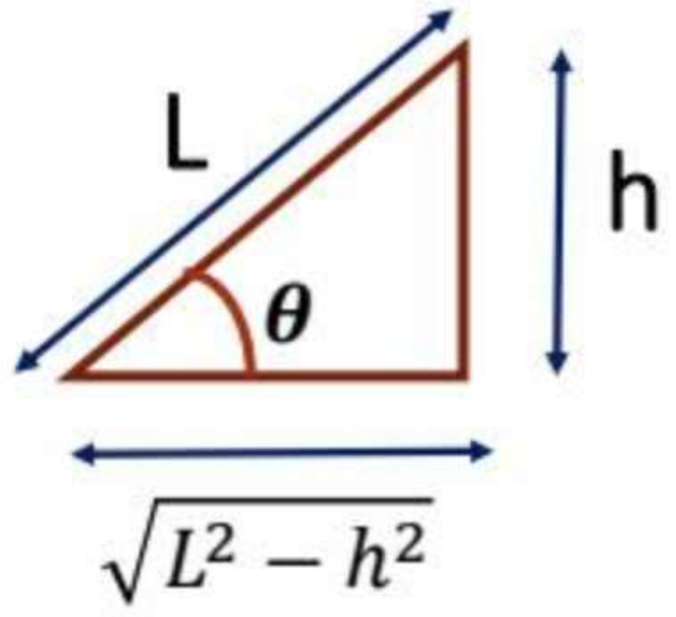
$$C_g = \sqrt{L^2 - h^2} - L$$

$$C_g = L\left[\left(1 - \frac{h^2}{L^2}\right)^{\frac{1}{2}} - 1\right]$$

$$C_g = L\left[\left(1 - \frac{h^2}{2L^2} - \frac{h^4}{8L^4} + \cdots\right) - 1\right]$$

$$C_g = \frac{-h^2}{2L} - \frac{h^4}{8L^3}$$

$$C_g = \frac{-h^2}{2L}$$



Corrections

3. Correction for pull

$$C_P = \frac{(P-P_0)L}{AE}$$

where

P_o → standard pull

P → Pull applied in the field

A → Cross-sectional Area of the Tape

E → Young's modulus of Elasticity

L → Nominal length of the tape/measured length of the line

If P > P_o → then correction for pull will be positive and vice-versa.

Corrections

4. <u>Correction for temperature</u> C_t

$$C_t = \alpha(t - t_o)L$$

α → thermal coefficient of linear expansion

t_o → standard temperature

t → field temperature

L → Nominal length of the Tape/measured length of the line

If $t > t_o$ → then C_t will be positive

Corrections

5. Correction for sag C_s

- When the Tape is supported between two ends, it takes the shape of catenary.
- If the Tape is standardized on Flat and used in catenary then correction for sag will be $negative$, because chord length will always be less than Arc length.
- For determination of correction for sag, the shape is assumed to be parabolic, instead of catenary.

$$C_s = \frac{-(wl)^2 l}{24\,p^2} = \frac{-W^2 l}{24\,p^2}$$

Where, w → wt. per unit length of the Tape

l → length of the Tape suspended between two supports

W → Total wt. of the Tape

P → Pull applied at the ends.

Corrections

5. Correction for sag C_s

- To reduce sag correction we can increase no of supports.
- If Total length of the Tape suspended is 'l' which is supported between 'n' no of bays

- $C_s = -\frac{W^2\, l}{24\, n^2 p^2} = \frac{-(wl)^2 l}{24 n^2 p^2}$

Note:-

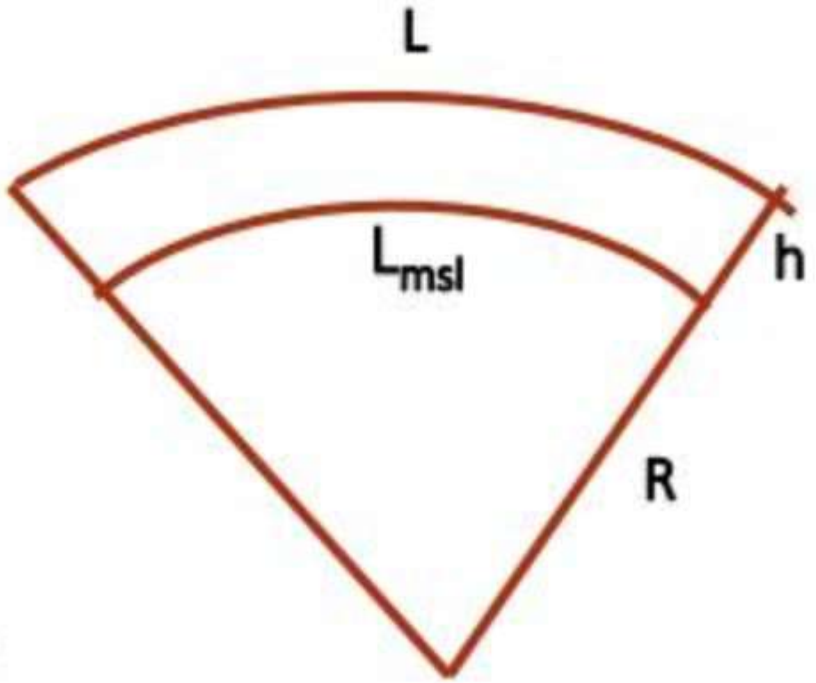
- If Tape is standardized in catenary and used on flat then correction for Sag will be positive
- Normal Tension (P_n) is that theoretical pull at which sag correction and pull correction cancel outs each other–

$$\frac{(P_n - P_o)l}{AE} = \frac{W^2 l}{24\, P_n^2}$$

Corrections

5. Correction for MSL C_{MSL}

$$C_{MSL} = L_{MSL} - L$$
$$C_{MSL} = R\theta - (R+h)\theta$$
$$C_{MSL} = -h\theta$$
$$C_{MSL} = \frac{-hL}{R+h}$$



Since, h is very small in comparison to R, therefore we can neglect it,

$$C_{MSL} = \frac{-hL}{R}$$

Que.40 Determine correction for MSL if measured length of the line is 1000 m and Average elevation of the line from MSL is 300 m. if R = 6370 km.

Sol:

Que. 40 Determine correction for MSL if measured length of the line is 1000 m and Average elevation of the line from MSL is 300 m. if R = 6370 km.

Sol:

$$C_{MSL} = \frac{-hL}{R}$$

$$= \frac{-300 \times 1000}{6370 \times 10^3}$$

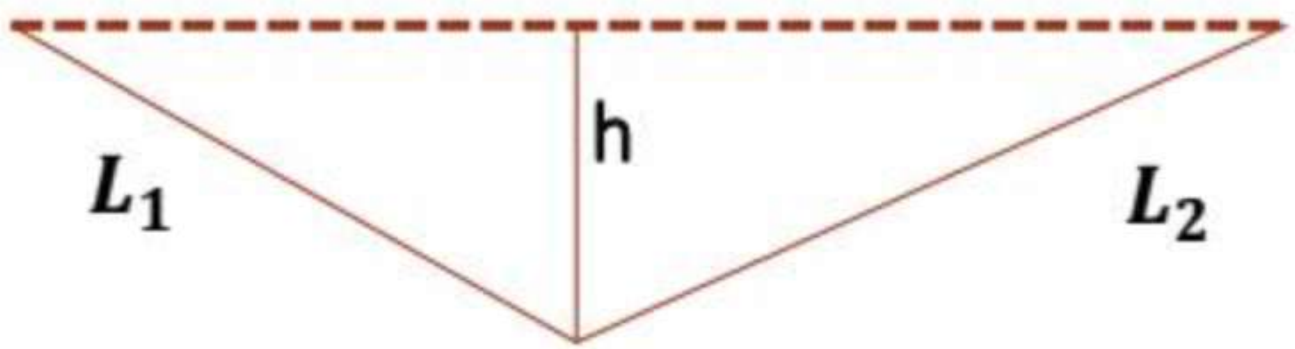
$$= -0.047m$$

Corrections

6. Correction for Misalignment C_m

$$C_m = \left(\sqrt{L_1^2 - h^2} + \sqrt{L_2^2 - h^2}\right) - (L_1 + L_2)$$

Error due to misalignment is always positive.



FIELD WORK IN CHAIN SURVEY

1. Reconnaissance survey

It is preliminary inspection of the area to be surveyed to get some idea of the terrain and to identify principle features of the area

It helps the surveyor to decide upon best possible arrangement of triangles.

FIELD WORK IN CHAIN SURVEY

2. Marking of station

After completion of Reconnaissance Survey best suitable positions of Main stations are marked on the ground such that they can be easily identified afterwards if required.

3. Running of survey lines

Survey lines are run to measure the distance between main stations and to locate adjacent detail by taking offsets.

FIELD WORK IN CHAIN SURVEY

4. Taking offsets

Maximum length of offset depends on;

- **Scale of plan (or) Map**
- **Accuracy desired**
- **Nature of ground**

Degree of Accuracy of the offset depends on

- **Length of offset**
- **Scale of plan (or) Map**
- **Importance of detail towards which offset is taken**

OBSTACLES IN CHAINING

CASE I : Chaining round the obstacle is possible. (LAKE)

OBSTACLES IN CHAINING

CASE II : Chaining round the obstacle is not possible(RIVER)

Chapter 4: Compass Surveying

- It is branch of surveying in which direction of Survey lines are measured with a compass and length is determined with chain or tape
- Generally, compass is used to set traverse in the field

Compass Surveying

- There are two types of instruments that we use in compass surveying:

Instruments for direct measurement of DIRECTIONS

1. Surveyor's Compass
2. Prismatic Compass

Instrument for measuring of ANGLES

1. Sextant
2. Theodolite

Instruments for direct measurement of DIRECTIONS

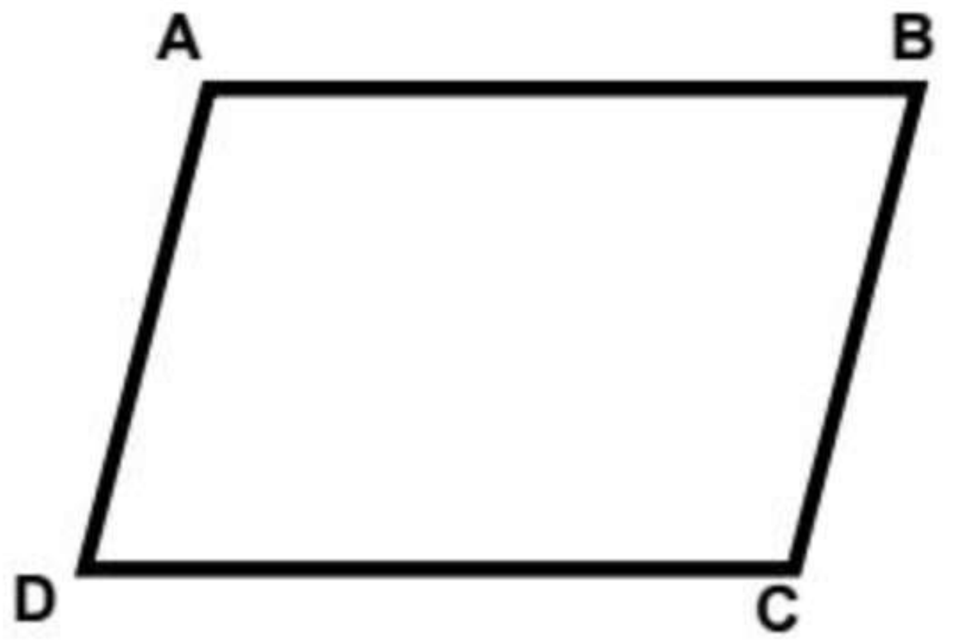
1. Surveyor's Compass
2. Prismatic Compass

Instrument for measuring of ANGLES

1. Sextant
2. Theodolite

Traverse

- Traverse is a framework consisting of series of straight lines connected together forming a closed or open polygon



- Points such as A, B, C,D are called traverse points and the line joining there points are called "Traverse line."

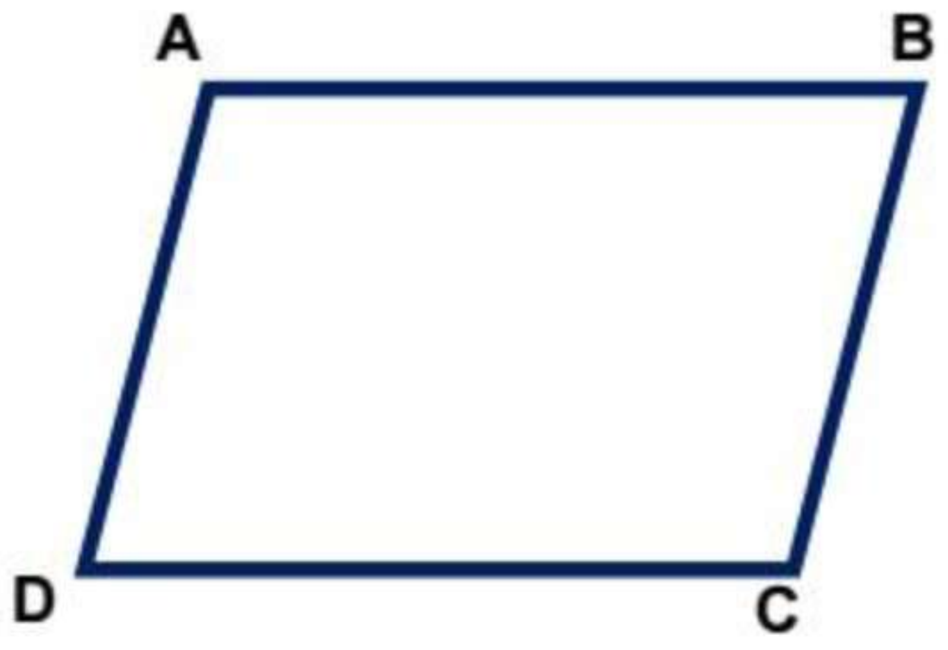
Traverse

Depending upon instrument used, traverse can be classified as:

(i)Compass Traverse

(ii)Plane Table Traverse

(iii)Theodolite Traverse



Difference between Chain Survey and Traverse Survey

Chain Survey

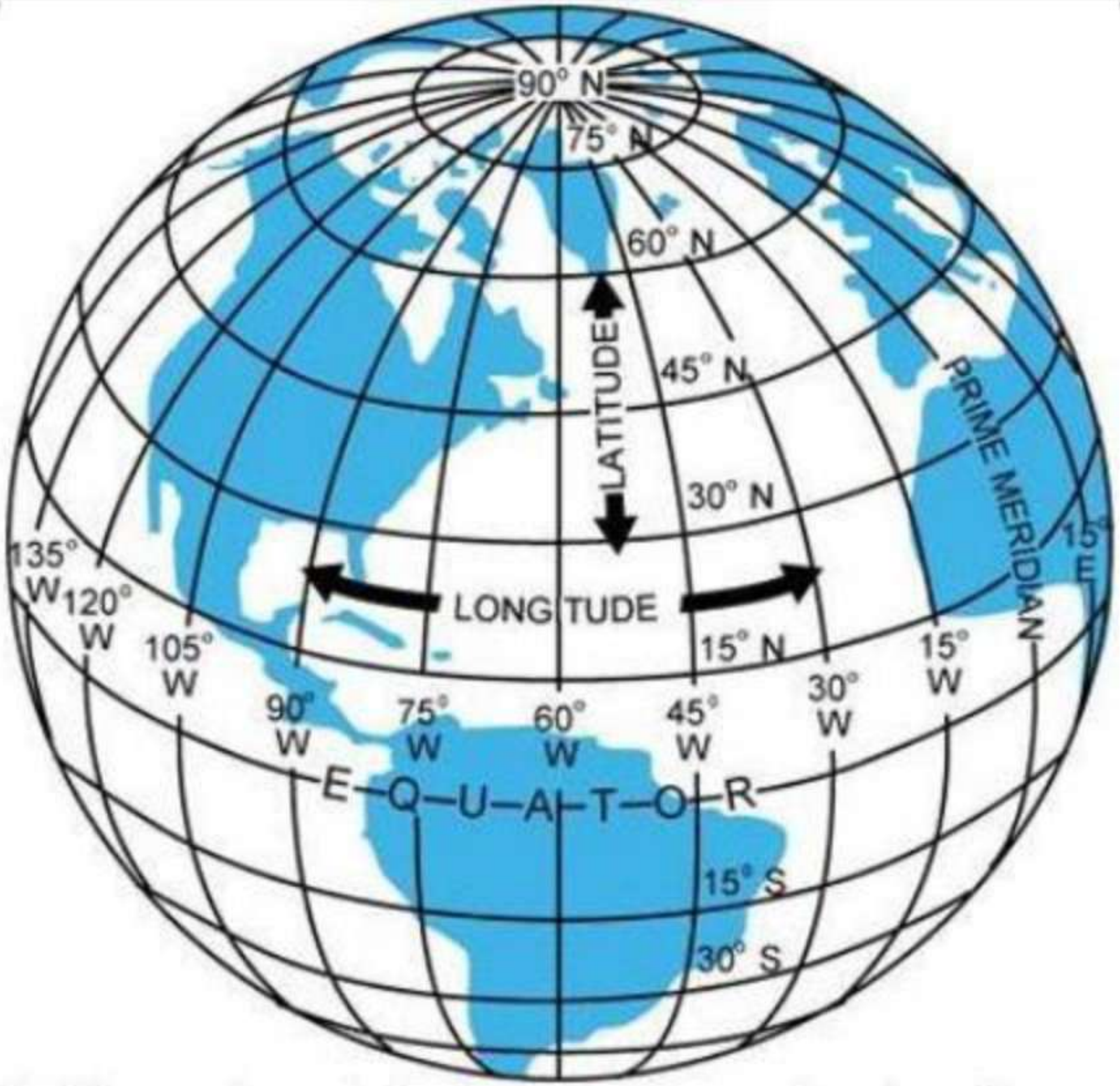
- Only linear measurements are done
- framework consists of network of triangles
- Check line or prop line are required to check accuracy of plot
- Accuracy desired is low as it is used for small area

Traverse survey

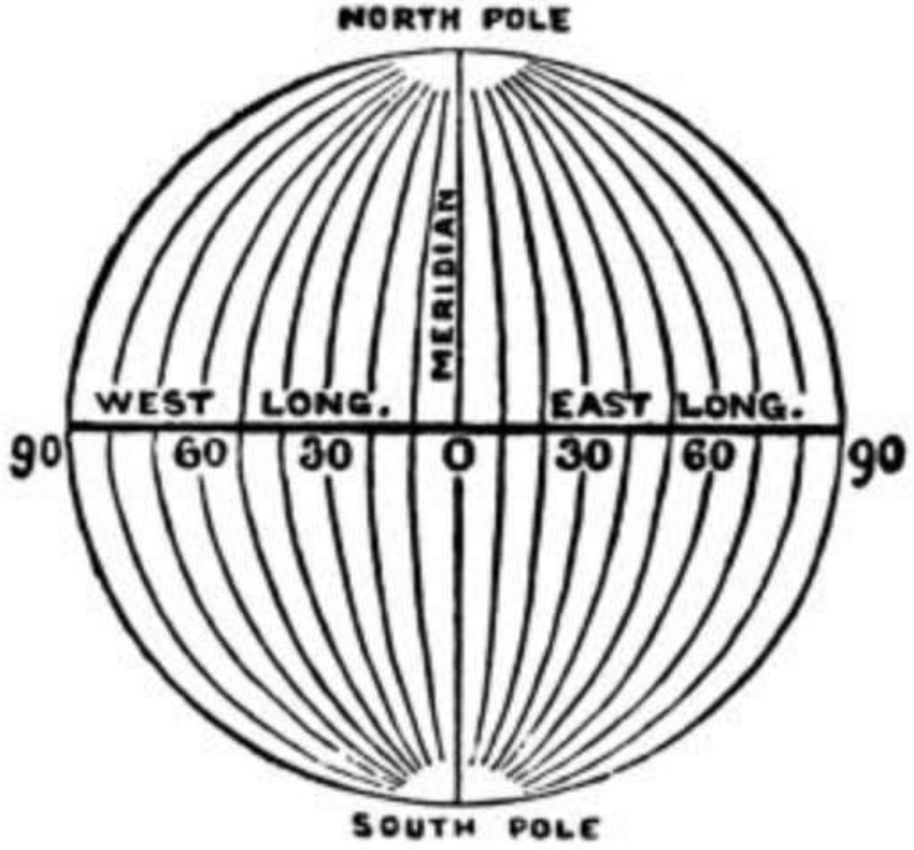
- Linear and angular measurements are done
- Frame work consists of open or closed traverse of polygons
- Check lines & proof lines are not required as accuracy is checked by method of Adjustment
- Used for large area when accuracy desired is high.

MEASUREMENT OF ANGLES

- Direction of survey lines can be defined in two ways :
  - Relative to each other
  - Relative to some fixed reference direction
- In surveying, this fixed reference direction is called as "Meridian"


90° N
75° N
60° N
45° N
30° N
15° N
15° S
30° S
LATITUDE
LONG TUDE
PRIME MERIDIAN
135° W
120° W
105° W
90° W
75° W
60° W
45° W
30° W
15° W
15° E
E-Q-U-A-T-O-R

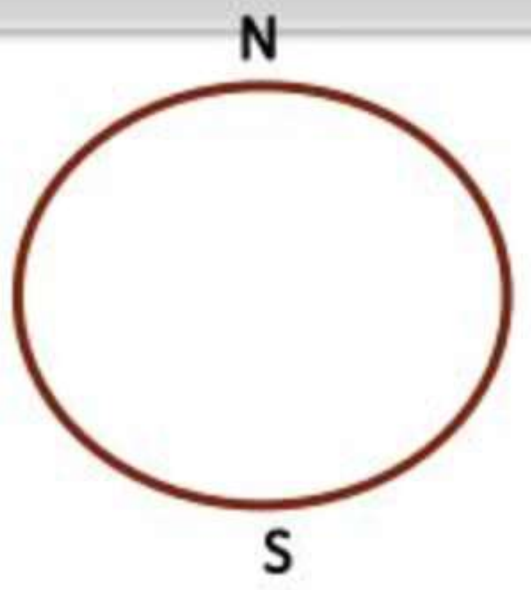

Prime Meridian
0° Longitude
Equator
0° Latitude


NORTH POLE
MERIDIAN
WEST LONG.
EAST LONG.
90 60 30 0 30 60 90
SOUTH POLE

TYPES OF MERIDIAN

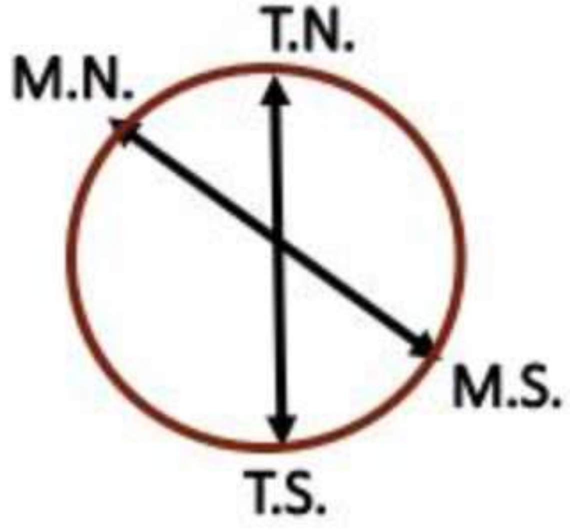
1. ***True meridian:***

- True meridian at a point on the Earth surface is the line joining geographic North and geographic south at that point.
- True meridian at a place is determined with the help of astronomical observation of sum and stars.
- True meridian at a place does not change with passage of time.



2. ***Magnetic Meridian:***

- Magnetic meridian at a point is the direction indicated by a freely suspended magnetic bar or needle provided that it should not be affected by magnetic forces other than that of Earth.
- Magnetic meridian at a point changes with passage of time.



TYPES OF MERIDIAN

3. Grid Meridian:

- For survey of a country, they meridian passing through central place is taken as reference meridian for whole country and such a reference meridian is called as Grid meridian.
- Example: 82.5° E (Prayagraj)
- It passes through
  - Uttar Pradesh
  - Madhya Pradesh
  - Chhattisgarh
  - Odisha
  - Andhra Pradesh

TYPES OF MERIDIAN

4. ***Arbitrary Meridian :***
   - **It is meridian which is taken in any arbitrary direction**
   - **Generally it is taken in the direction from a traverse station to a well define point such as top of four, chimney, etc.**
   - **Sometimes direction of first traverse line is also taken as reference meridian.**

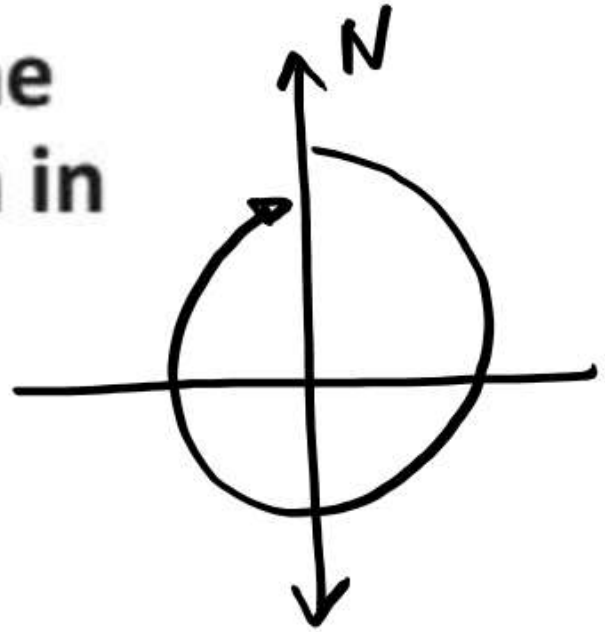
TYPES OF BEARINGS

- Bearing is the horizontal angle between fixed reference direction and survey line.
- Types of Bearing:
  - True Bearing
  - Magnetic Bearing
  - Grid Bearing
  - Arbitrary bearing

NOTE : For all important surveys true bearing is preferred over magnetic bearing

DESIGNATIONS OF BEARING

1. **Whole circle Bearing : (WCB) / Azimuthal system**
    - WCB of a line is the horizontal angle between the survey line and North End of reference meridian in clockwise direction
    - Prismatic compass is used.
    - It ranges from 0° to 360°



DESIGNATIONS OF BEARING

2. Quadrantal Bearing system (Reduced Bearing)
   - Quadrantal Bearing is the acute Horizontal angle between reference meridian (N or S) and survey line.
   - Surveyors compass is used.

FORE BEARING AND BACK BEARING

- **Fore Bearing :**
  - Fore Bearing of a line is Horizontal angle in the direction of progress of survey.
- **Back Bearing:**
  - Back Bearing of a line is the horizontal angle in the direction opposite of the progress of survey.

$$\boldsymbol{BB = FB \pm 180^\circ}$$

Positive → FB → less than 180°

Negative → FB →greater than 180°

FORE BEARING AND BACK BEARING

Note : If Fore Bearing of line is given in quadrantal bearing system, then Back Bearing can be obtained by replacing

- N → S
- S → N
- E → W
- W → E

INCLUDED/INTERIOR ANGLES

- **Included Angles :**
  - Included angle is the angle measured in clockwise direction from previous line to the next line .
  - Included angle = FB of Next line – BB of previous line
  - If negative value is obtained, then add 360°.

  - Interior Angle= BB of previous line –FB of Next line

INCLUDED/Interior ANGLES

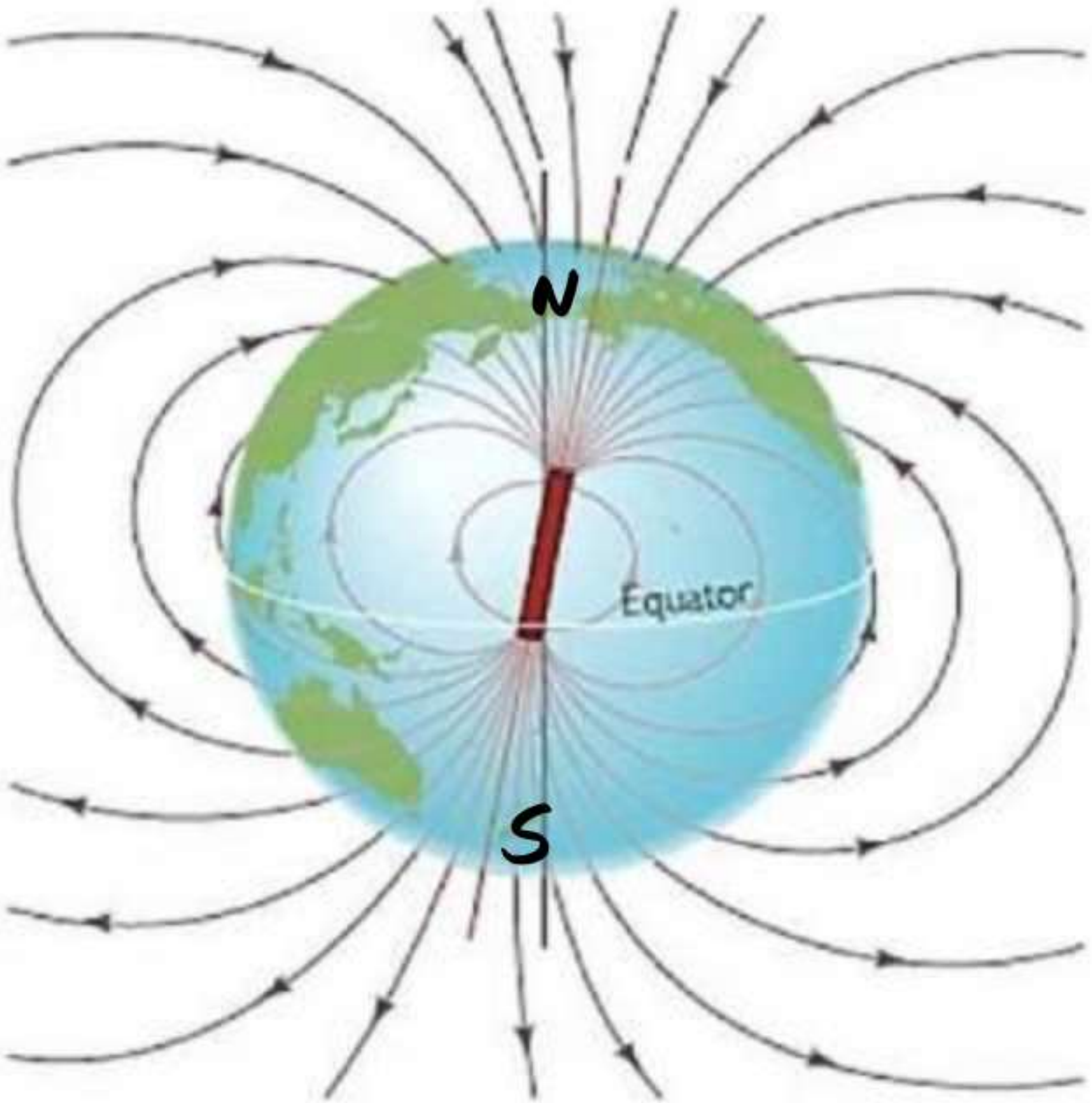
- Interior Angles :
  - Interior Angle= BB of previous line – FB of Next line

To measure bearing from Angle

- To calculate Bearing of next line,
  - Add the measured clockwise angles to the bearing of previous line, if the sum is more than 180, deduct 180. If the sum is less than 180, add 180

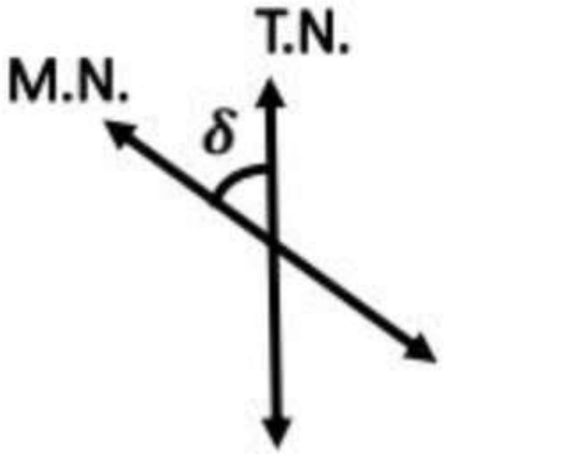
MAGNETIC FIELD OF EARTH

- Earth acts as a powerful magnet with its magnetic lines of forces running from *South end to North end.*
- Magnetic lines of forces are *perpendicular at poles* and *parallel at equator*
- Magnetic needle when freely suspended about its CG, it is influenced by Earth's magnetic field and aligns itself parallel to magnetic force of Earth at that point.
- The vertical angle between magnetic needle and Earth surface is called as Angle of dip–
  - At poles dip = 90°
  - At Equator dip = 0°

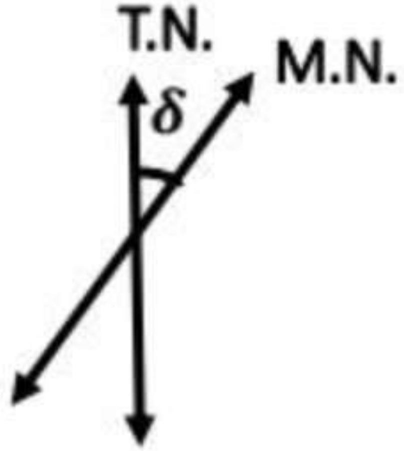


MAGNETIC DECLINATION

- Generally, magnetic meridian and true meridian do not coincide with each other.
- Horizontal angle between the true Meridian and Magnetic Meridian at the time of observation is called as "magnetic declination" or simply declination.



$WESTWARD\ \delta$
-ve



$EASTWARD\ \delta$
+ve

$$TRUE\ BEARING = MAGNETIC\ BEARING \pm DECLINATION$$

MAGNETIC DECLINATION

Note: Magnetic Declination in the field can be measured by determining magnetic Bearing and True Bearing of the same line

- Declination of a time changes from time to time.
- Declination at a time changes from point to point.
- Variation of declination is shown by isogonic lines.

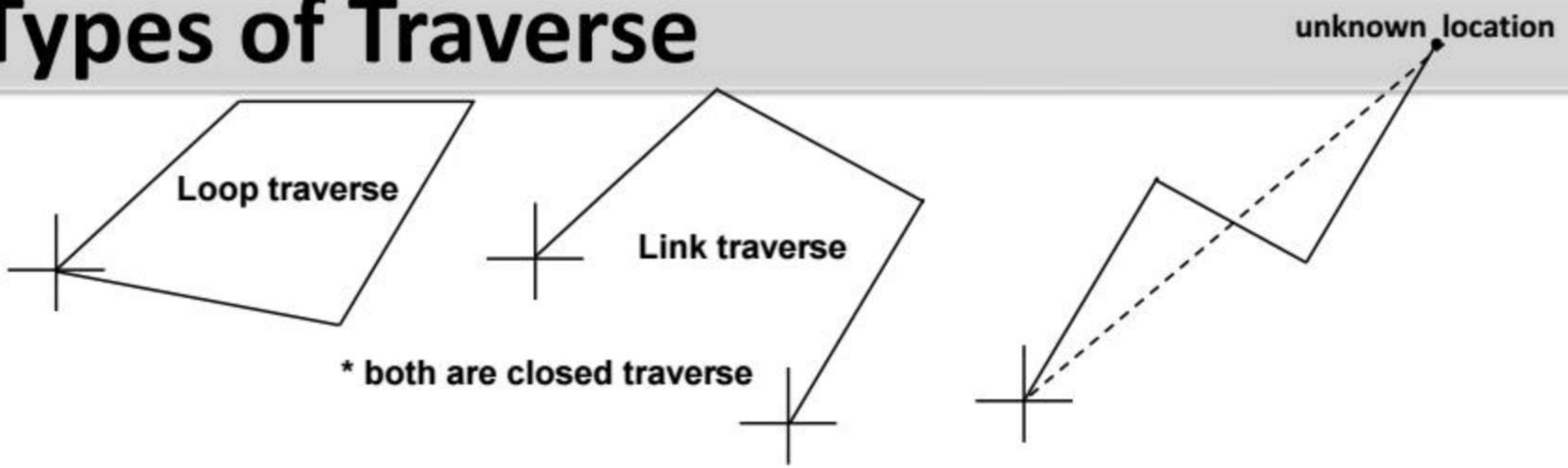
- ISOGONIC LINES – line passing through points on the surface of the earth at which declination is same at a given point of time.
- A-GONIC LINES – these are special isogonic lines, which pass through points of 0 declination, also at all points on A-Gonic line, magnetic meridian will coincide with true meridian.

Que. Find the magnetic declination at a place of magnetic bearing of the sun at noon is

a) $\mathbf{184°}$

b) $\mathbf{350°20'}$

Types of Traverse



1. Closed Traverse

- It is a traverse that starts from point of known location and closes at either same point or another point of known location.

2. Open Traverse

- It is a traverse which starts from a point of known location but closes at another point of unknown location.
- An open traverse can be checked by method of chords or astronomical observations.

Compass Traverse

- In compass traverse, compass is used to measure direction and horizontal angles
- Sides of traverse are measured with chain or tape

Compass Traverse

Prismatic compass

- The Needle is of broad needle type.
- Graduated card ring is attached with the needle. The ring does not rotate along with the line of sight
- Graduations are engraved inverted
- Reading is taken with the help of prism provided at eye slit
- Tripod may or may not be provided
- The L.C. of Prismatic Compass is 30'. It means compass can read only those observations which are multiples of 30 minutes

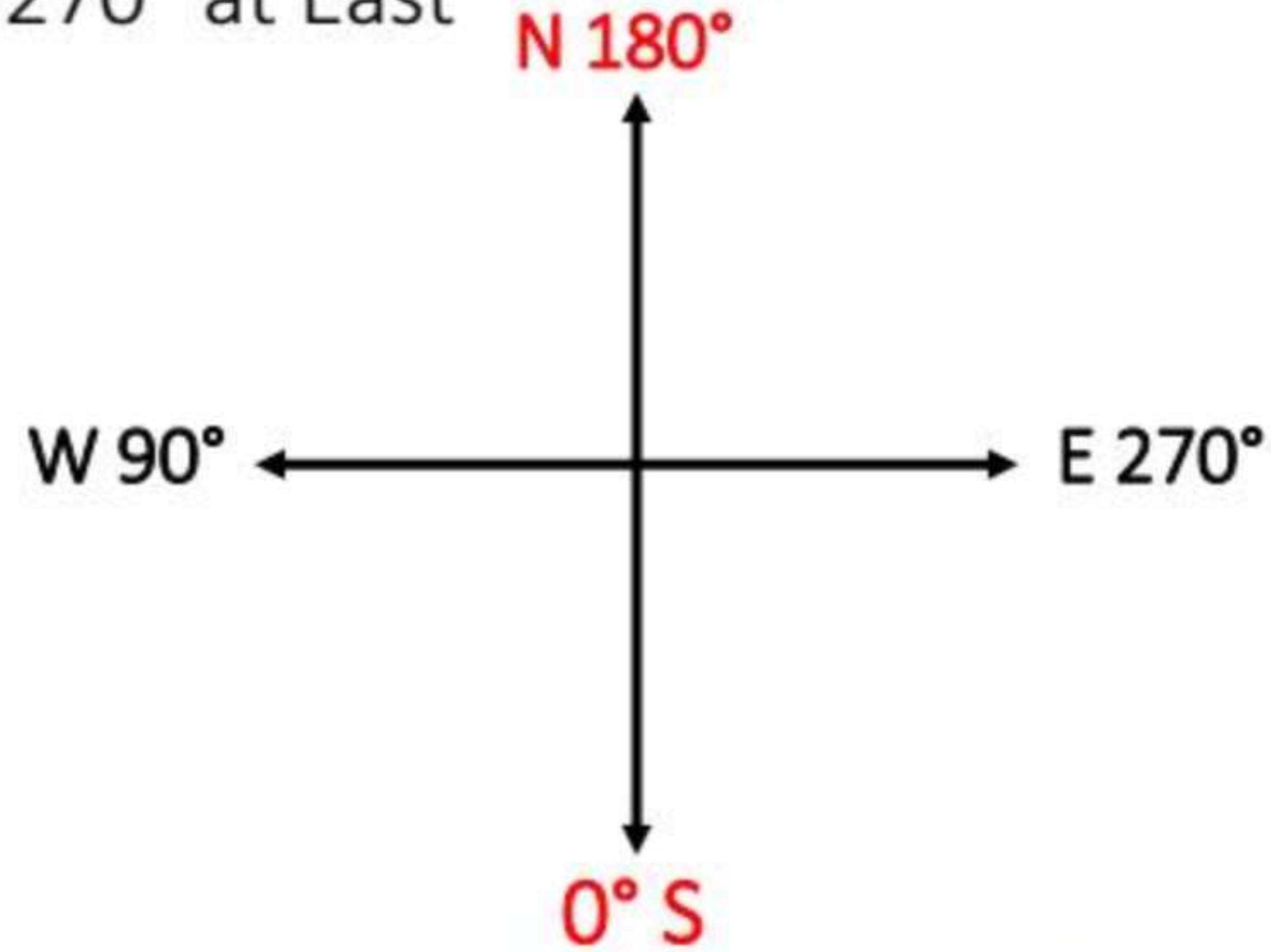
Surveyor's compass

- Needle is of edge bar type
- the graduated card is attached to the box and not to the needle. The card rotates along with the line of sight
- Graduations are engraved Erect.
- Reading is taken by directly seeing through top of glass.
- The instruments can not be used without a tripod.
- The L.C. of Surveyor Compass is 15'

Compass Traverse

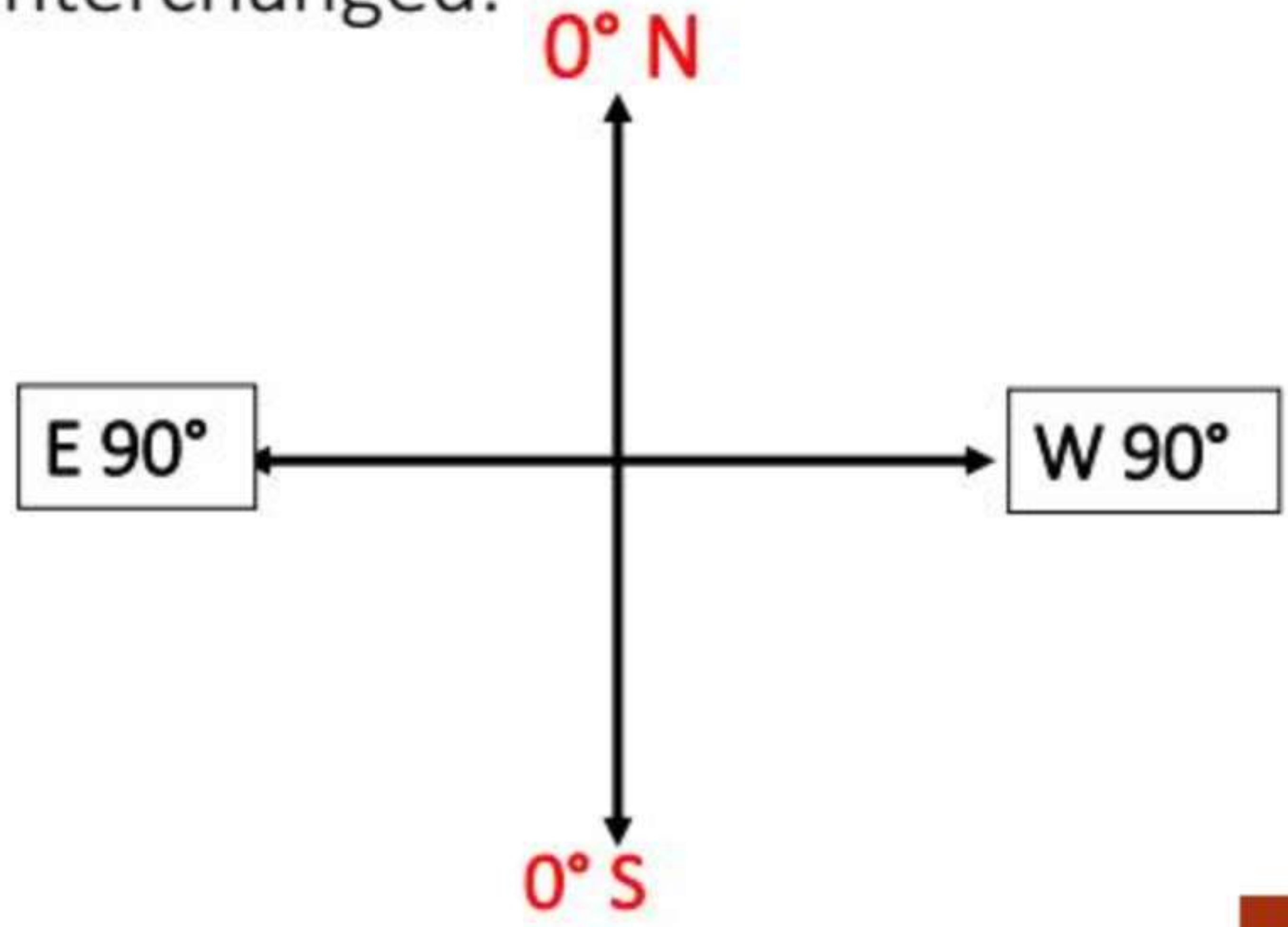
Prismatic compass

- The graduations are in W.C B system having 0° at south end, 90° at west 180° at North and 270° at East

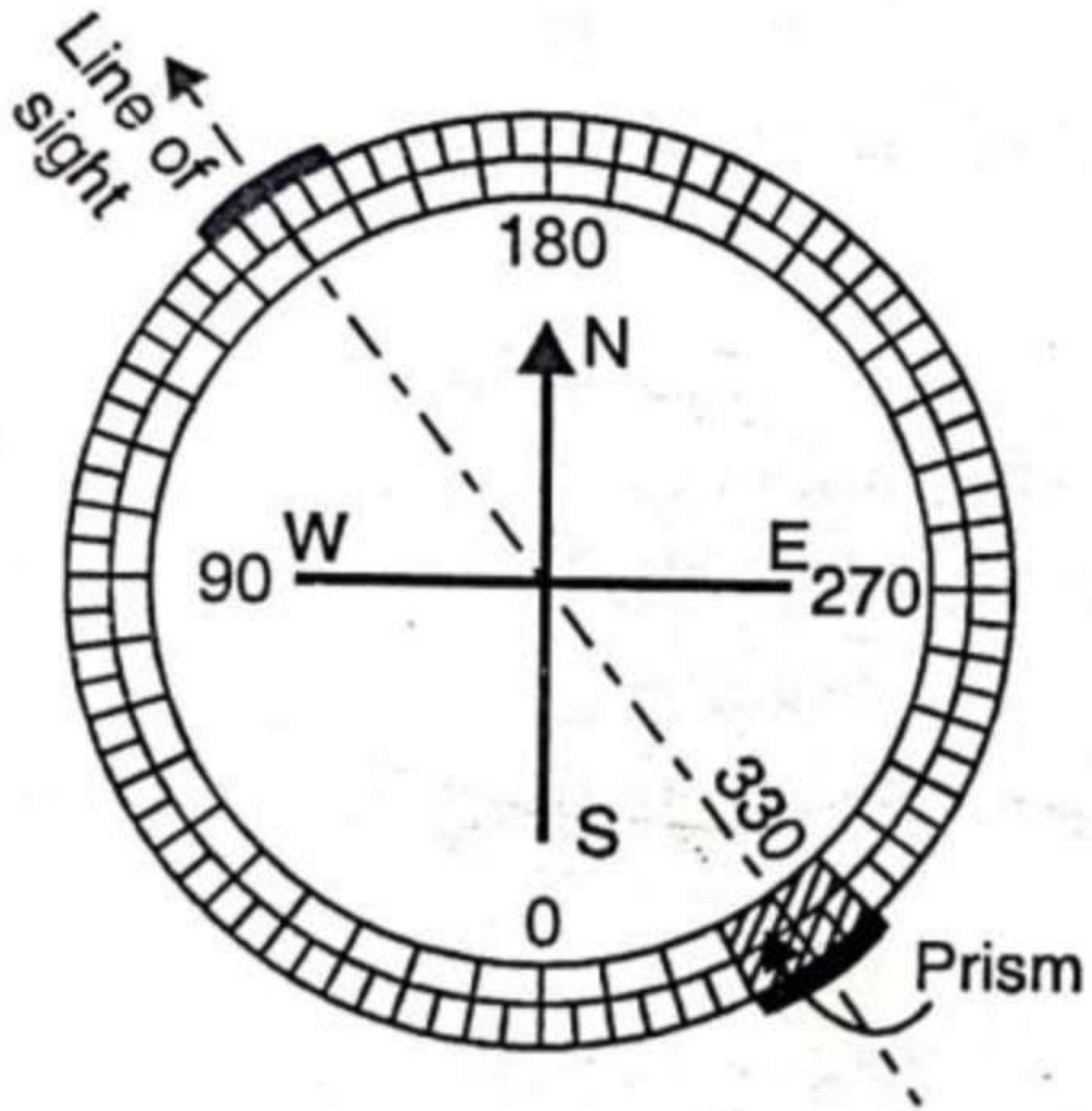


Surveyor's compass

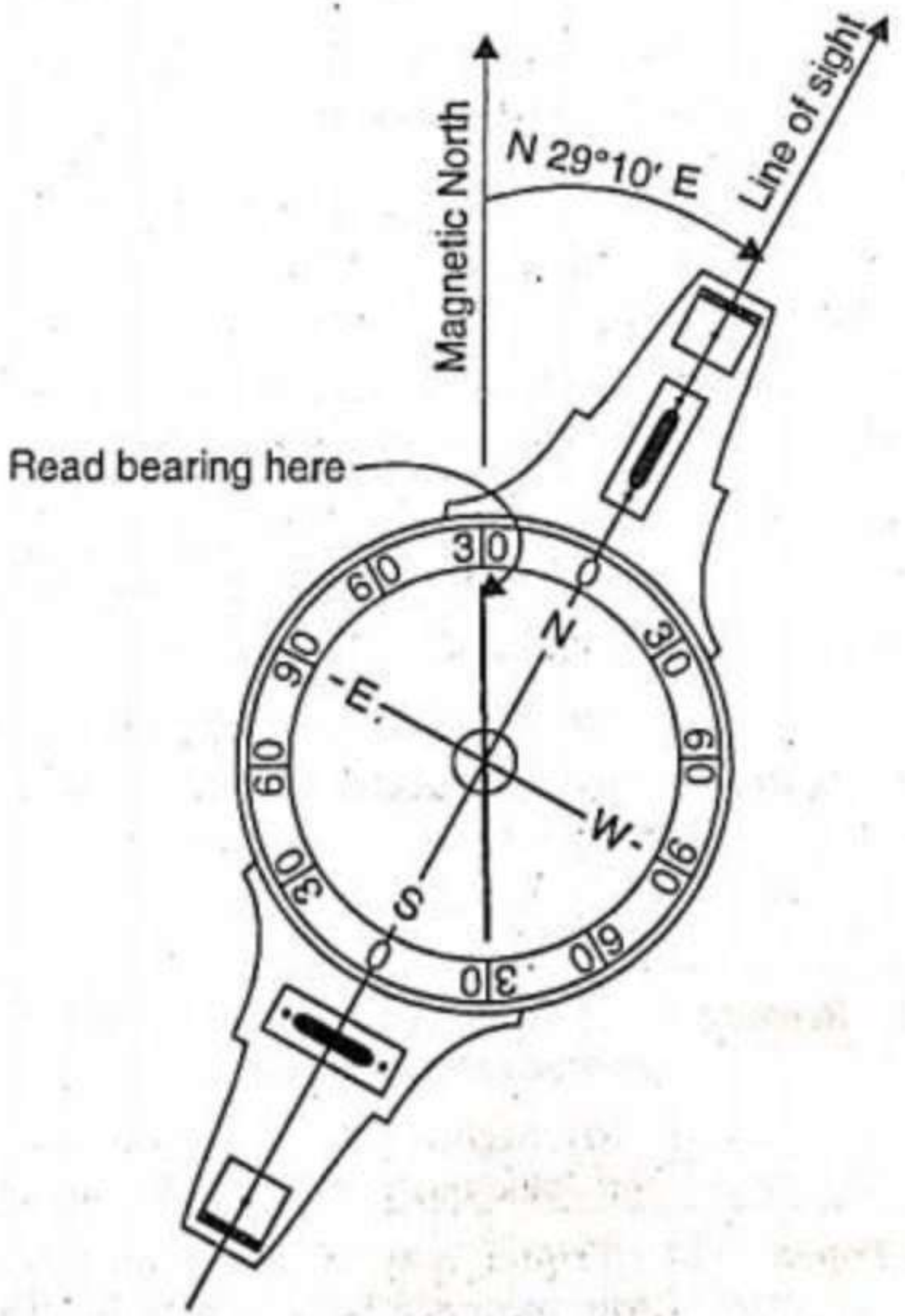
- The graduation are in QB system having 0° at North and south, 90° at East & West. East & West are interchanged.



Prismatic compass

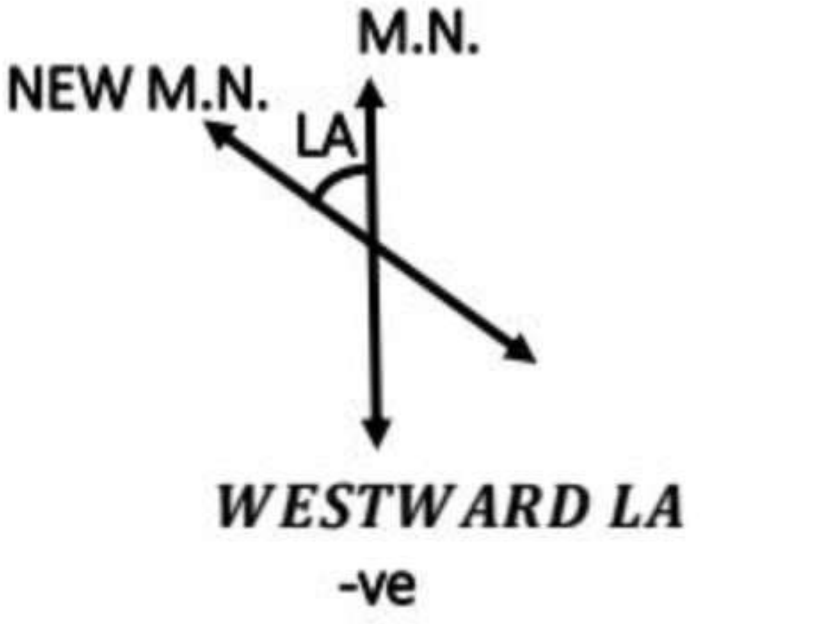


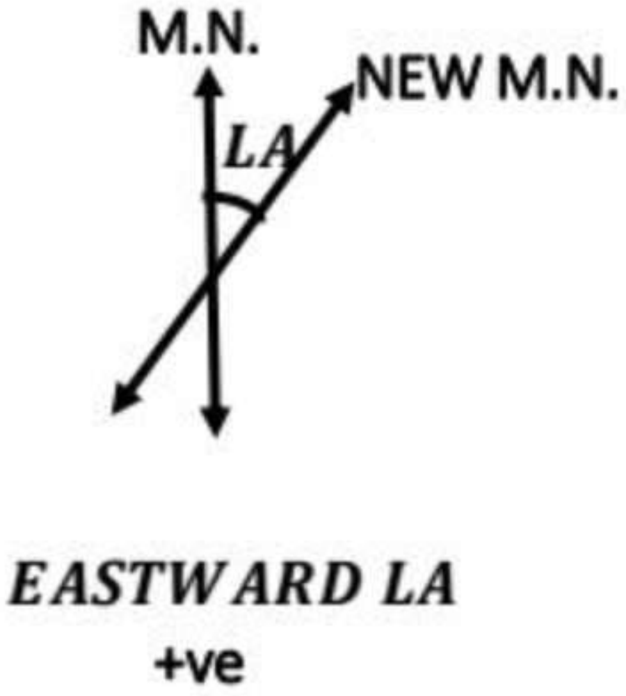
Surveyor's compass



LOCAL ATTRACTION

- Local attraction is the attraction of magnetic needle to a local magnetic field other than Earth's magnetic field.
- Under the influence of local attraction, magnetic needle will deviate from magnetic meridian which results in wrong magnetic Bearing of Traverse line.





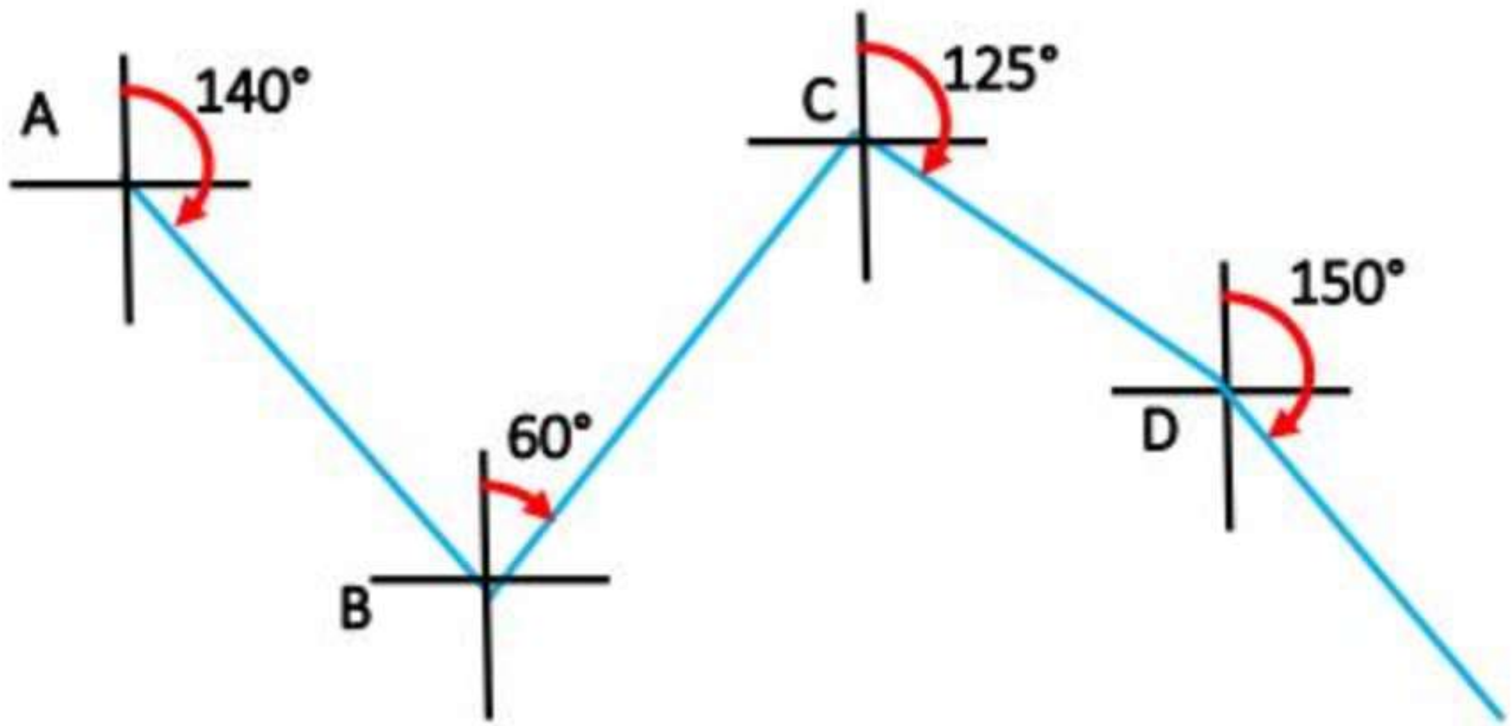
LOCAL ATTRACTION

- To determine local attraction, it is mandatory to take fore Bearing and Back bearing of Each traverse line
- It difference between FB and BB is next equal to 180°, then local attraction can be at
  - Either of the station (station A or B)
  - Both the station (station A & B)

Method 1: Correction for LA at each station

Line	FB	BB
AB	140°	318°
BC	60°	240°
CD	125°	302°
DE	150°	

- This method is suitable for open traverse
- This method will fail for closed traverse when instrumental error are present, i.e. theoretical sum of angles will not match actual sum



Step 1: Observe for a line whose FB and BB differs exactly by 180° (Here line BC)

Step 2: End station of such line are free from LA and all the bearings from this station are free from LA

- Correct BB of AB = 318°

  Therefore, correct FB of AB = 318°-180° =138°

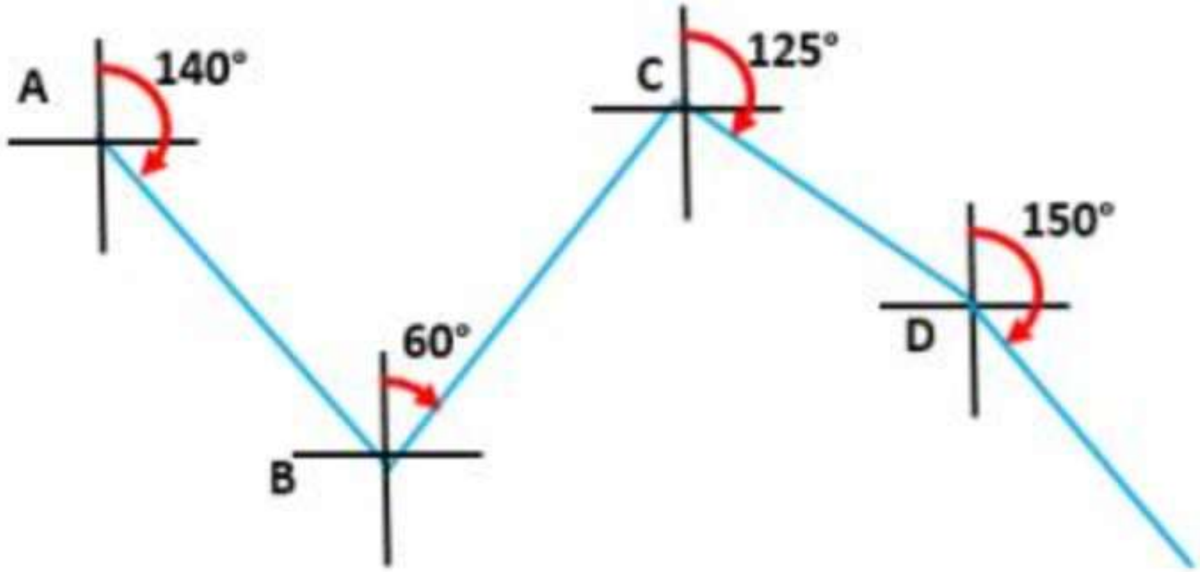
  Observed FB of AB = 140°

  Correction at station A= -2°

- Correct FB of the line CD=125°
  - Correct BB of CD=305°
  - Observed BB of CD=302°
  - Correction at station D= +3°

- **Observed FB of DE=150°**
  - So correct FB of DE=153°

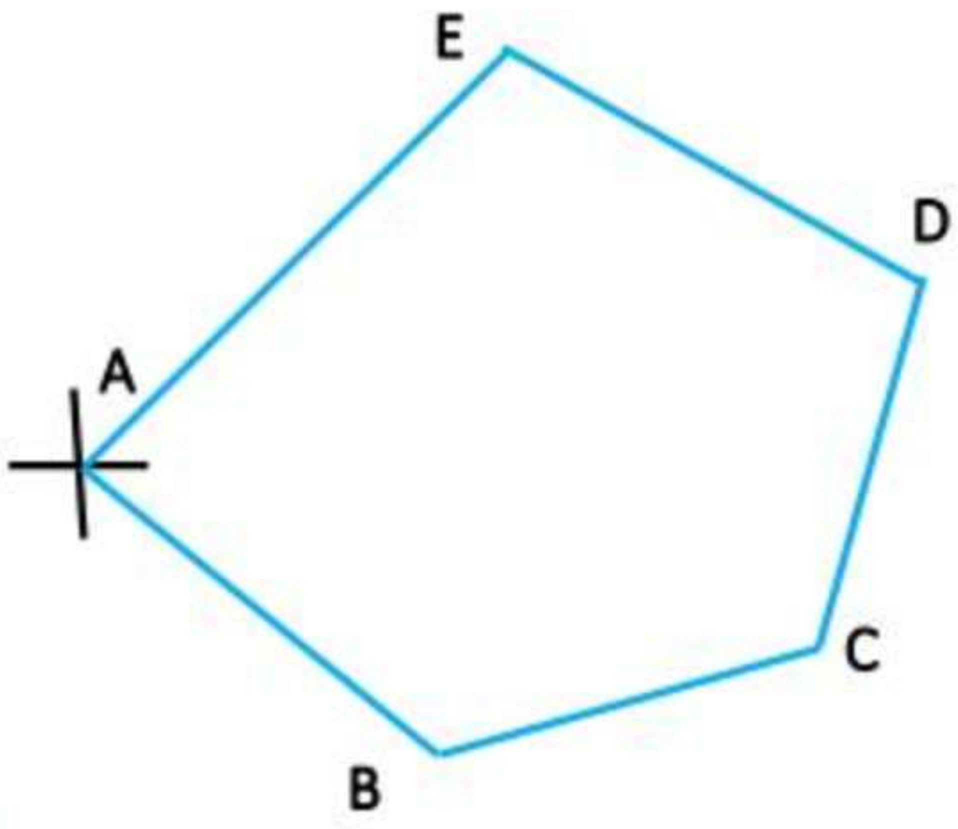
Line	FB	BB
AB	140°	$\boxed{318°}$
BC	$\boxed{60°}$	$\boxed{240°}$
CD	$\boxed{125°}$	302°
DE	150°	



Method 2: By Including angles

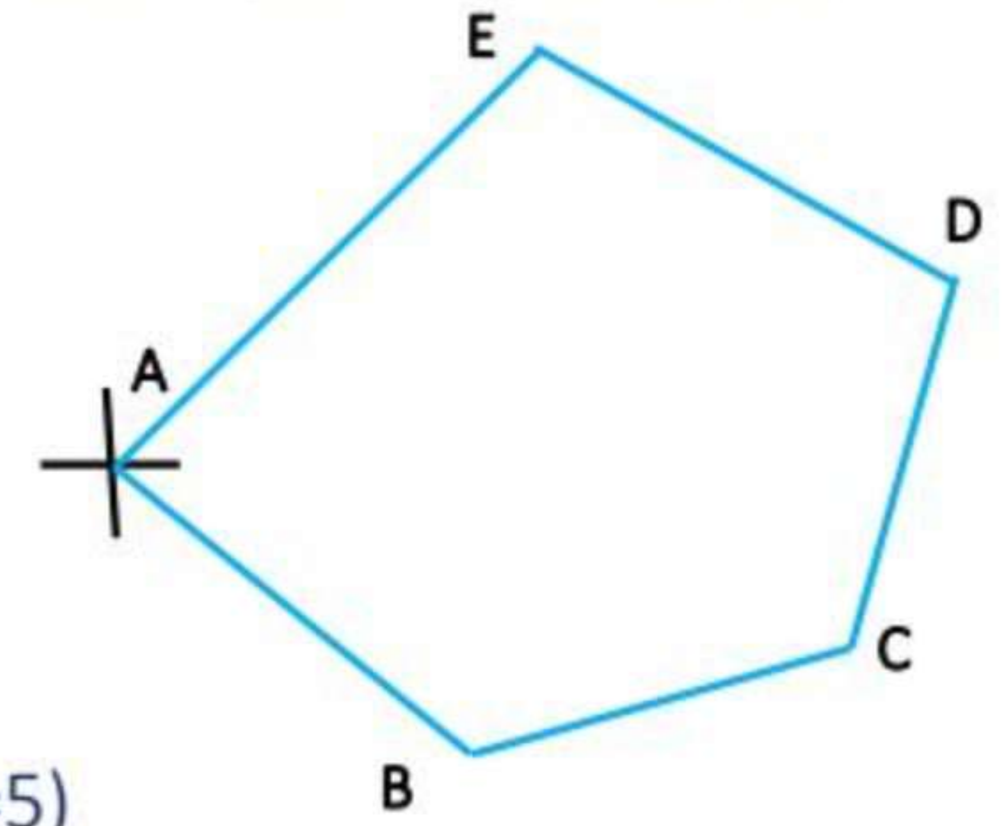
Line	FB	BB
AB	150°30′	329°45′
BC	78°	256°30′
CD	42°30′	223°45′
DE	315°45′	134°15′
EA	220°15′	40°15′

- This method is suitable for closed traverse
- As all the bearings taken at a station are affected equally and in one direction, therefore there is no effect of local attraction on included angles

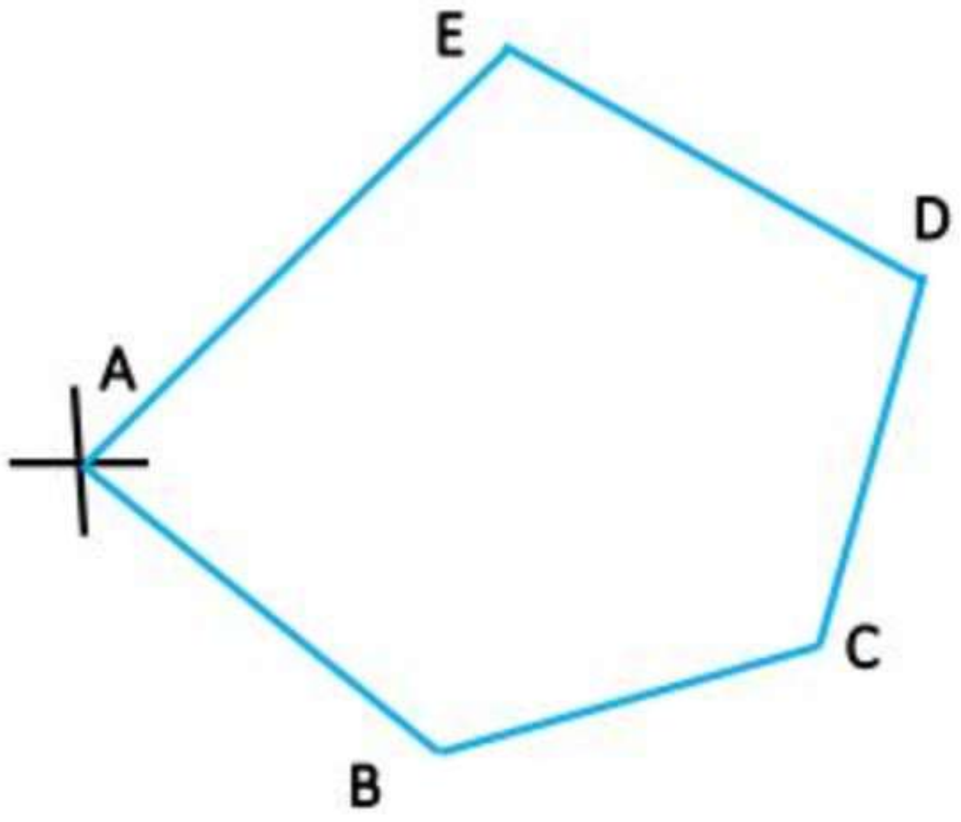


Line	FB	BB
AB	150°30′	329°45′
BC	78°	256°30′
CD	42°30′	223°45′
DE	315°45′	134°15′
EA	220°15′	40°15′

- Step 1: Locate a line whose fore bearing and back bearing differs exactly by 180°
- Step 2: Calculate Included angles
  - $\angle A$ = 150°30′ - 40°15′ = 110°15′
  - $\angle B$ = 78°0′ - 329°45′+ 360° = 108°15′
  - $\angle C$ = 42°30′ - 256°30′ + 360° = 146°
  - $\angle D$ = 315°45′ - 223°45′ = 92°
  - $\angle E$ = 220°15′ - 134°15′ = 86°
- Step 3: Actual Sum of angles = 542°30′
- Step 4: Theoretical Sum = (2n-4) x 90° = 540° (n=5)
- Step 5: Error = 542°30′ - 540° = 2°30′



- Step 1: Locate a line whose fore bearing and back bearing differs exactly by 180°
- Step 2: Calculate Included angles
  - $\angle A$ = 150°30′ - 40°15′ = 110°15′
  - $\angle B$ = 78°0′ - 329°45′+ 360° = 108°15′
  - $\angle C$ = 42°30′ - 256°30′ + 360° = 146°
  - $\angle D$ = 315°45′ - 223°45′ = 92°
  - $\angle E$ = 220°15′ - 134°15′ = 86°
- Step 3: Actual Sum of angles = 542°30′
- Step 4: Theoretical Sum = (2n-4) x 90° = 540° (n=5)
- Step 5: Error = 542°30′ - 540° = 2°30′ , correction = -2°30′
- Step 6: Correction per angle $= \frac{-2°30'}{5} = -30'$
- Step7: Corrected angles are
  - $\angle A$ =109°45′
  - $\angle B$ =107°45′
  - $\angle C$ =145°30′
  - $\angle D$ =91°30′
  - $\angle E$ =85°30′



Que2 : Following bearings were observed in a closed traverse:

Line	FB	BB
AB	75°5′	254°20′
BC	115°20′	296°35′
CD	165°35′	345°35′
DE	224°50′	44°5′
EA	304°50′	125°5′

At what stations do you suspect local attraction? Determine the correct magnetic bearings. If the declination was 5°10′ E, what are the true bearings?

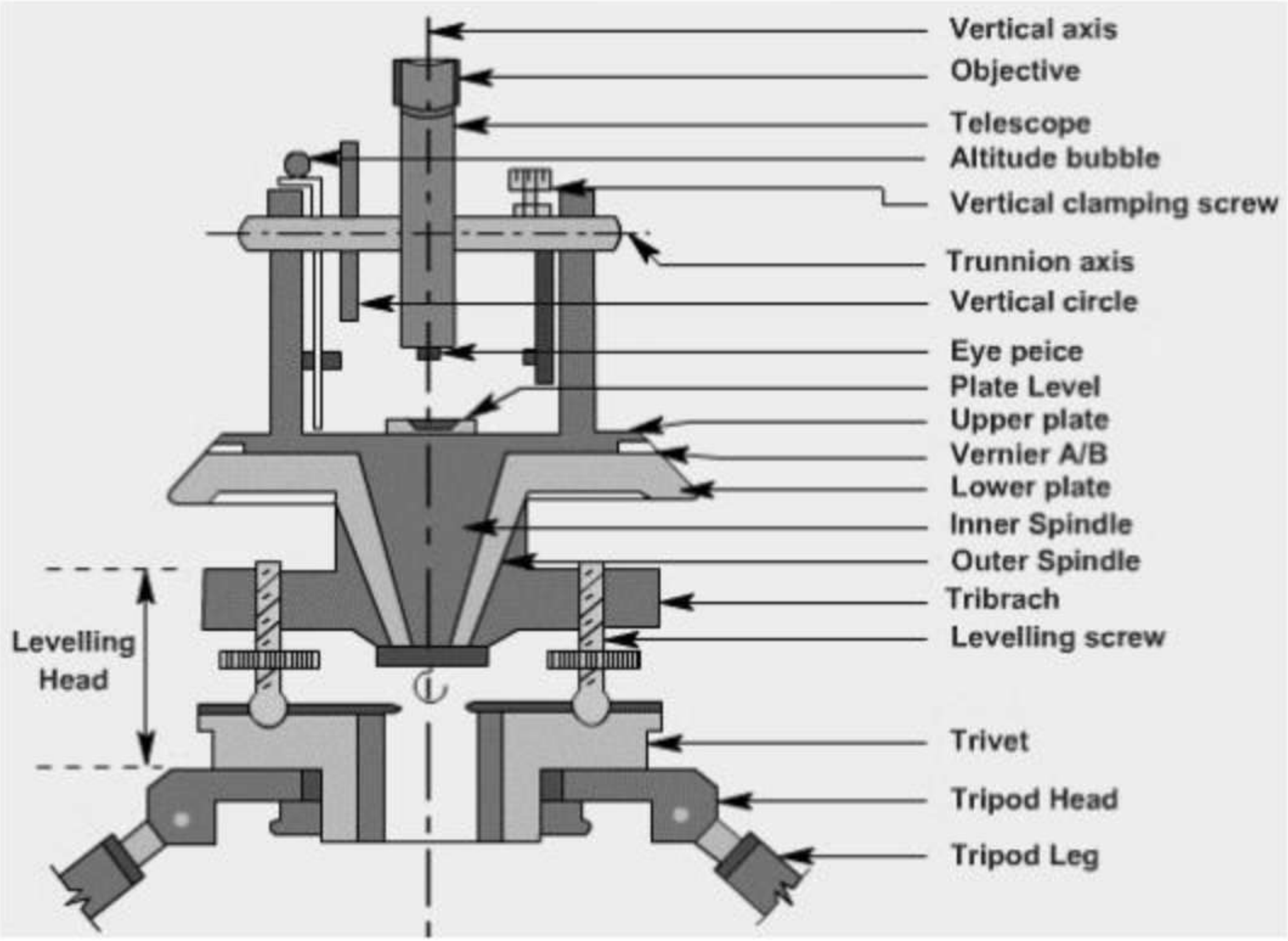
Chapter : Theodolite

- A theodolite is an instrument which is used primarily to measure angles, both horizontal and vertical.
- It is also used for many other subsidiary work during surveying such as setting up of intermediate points between inter visible points, establishment of inter visible points, prolonging a line, laying out traverse etc.
- Types:
  - Vernier
  - Digital
  - Total Station

Chapter : Theodolite

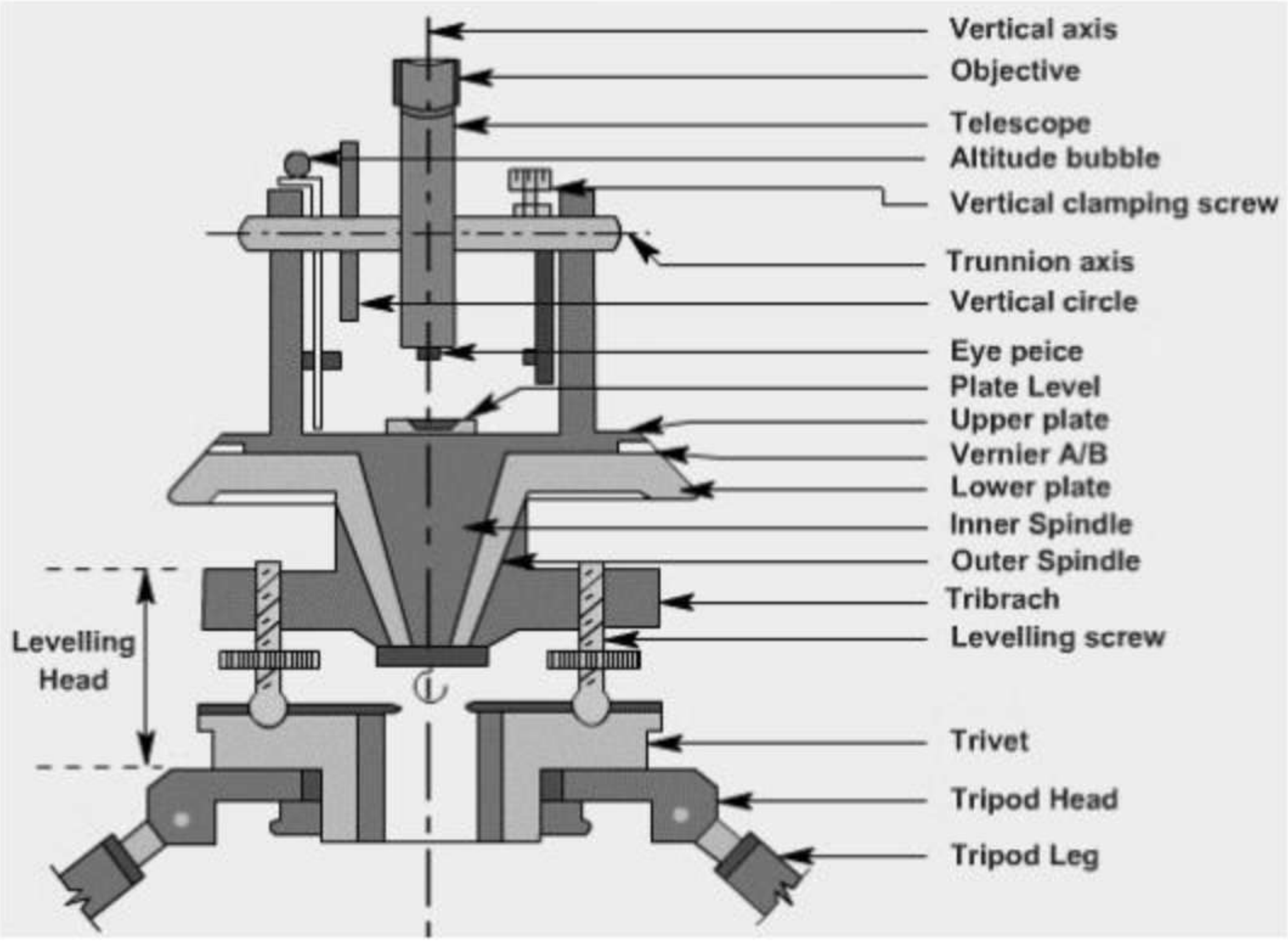
- Circles:
  - The size of a theodolite is defined by the diameter (between the reading edges of the graduations) of the horizontal circle which varies from 8 to 25 cm. It is graduated from 0° to 360° in clockwise direction.
  - The vertical circle is usually of the same diameter as the horizontal circle. The graduations on it are from 0° to 90°

Theodolite



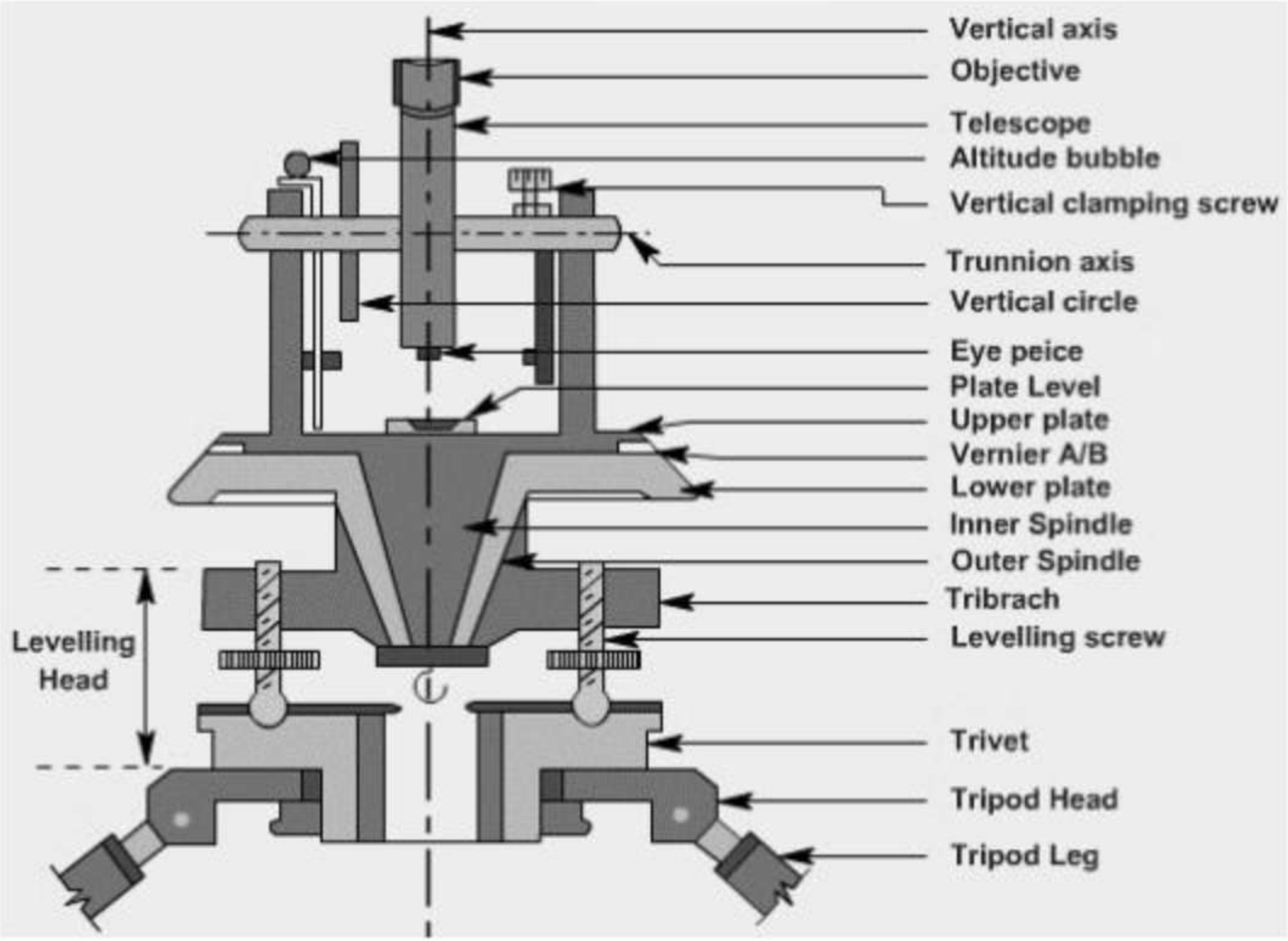
- **What are the uses of a theodolite?**
    - **Theodolite surveying is a branch of surveying, in which the theodolite is accurate instrument used for the measurement of horizontal angles, vertical angles. It can also be used for various purposes such as laying off horizontal angles, locating points on a line, prolonging survey lines, establishing grades, determining differences in elevation, etc,.**

Theodolite



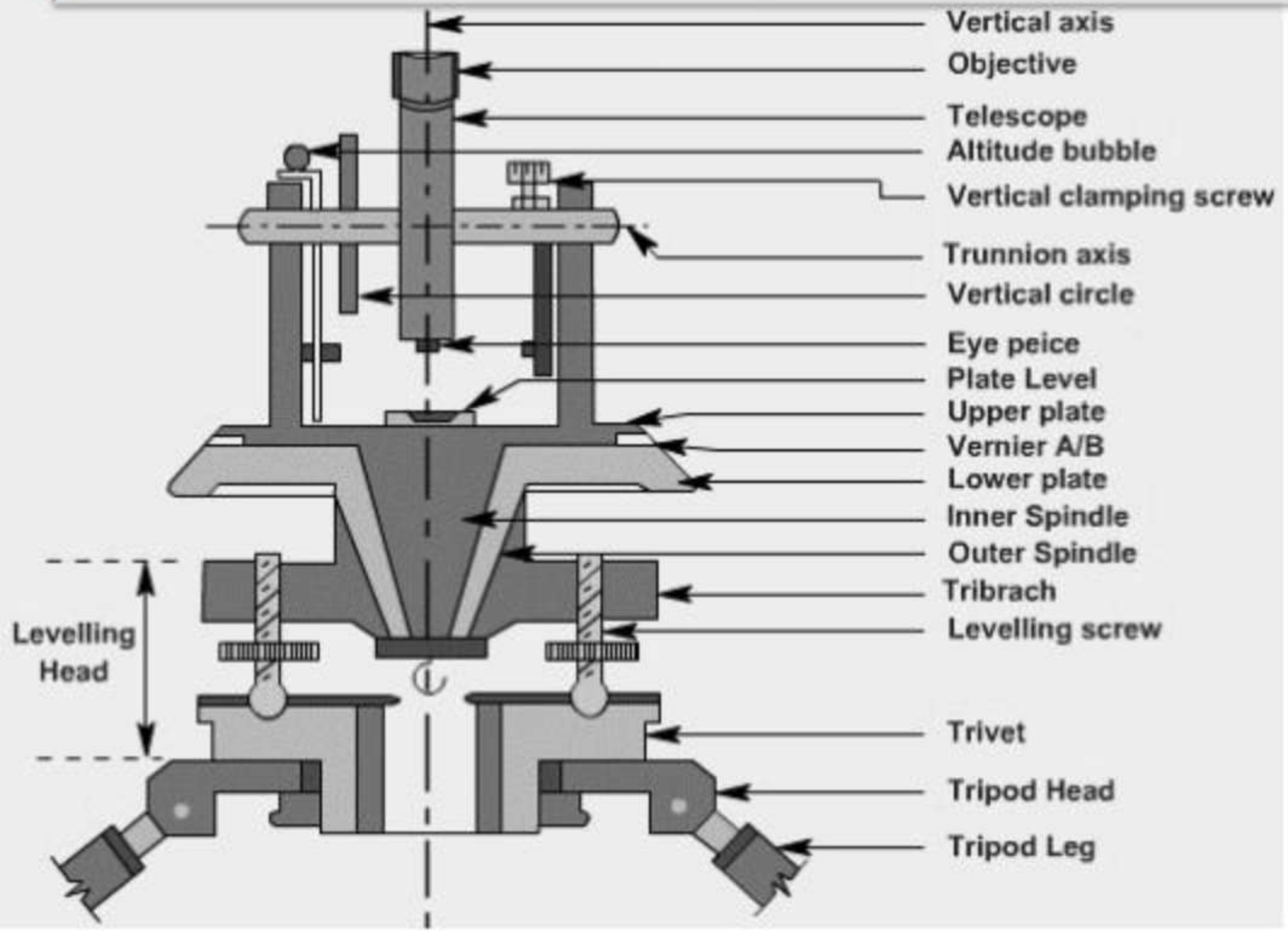
- Why a type of theodolite is called a transit theodolite?
  - A transit theodolite is one is which the line of sight can be reversed by revolving the telescope through 180^0 in the vertical plane.

Theodolite



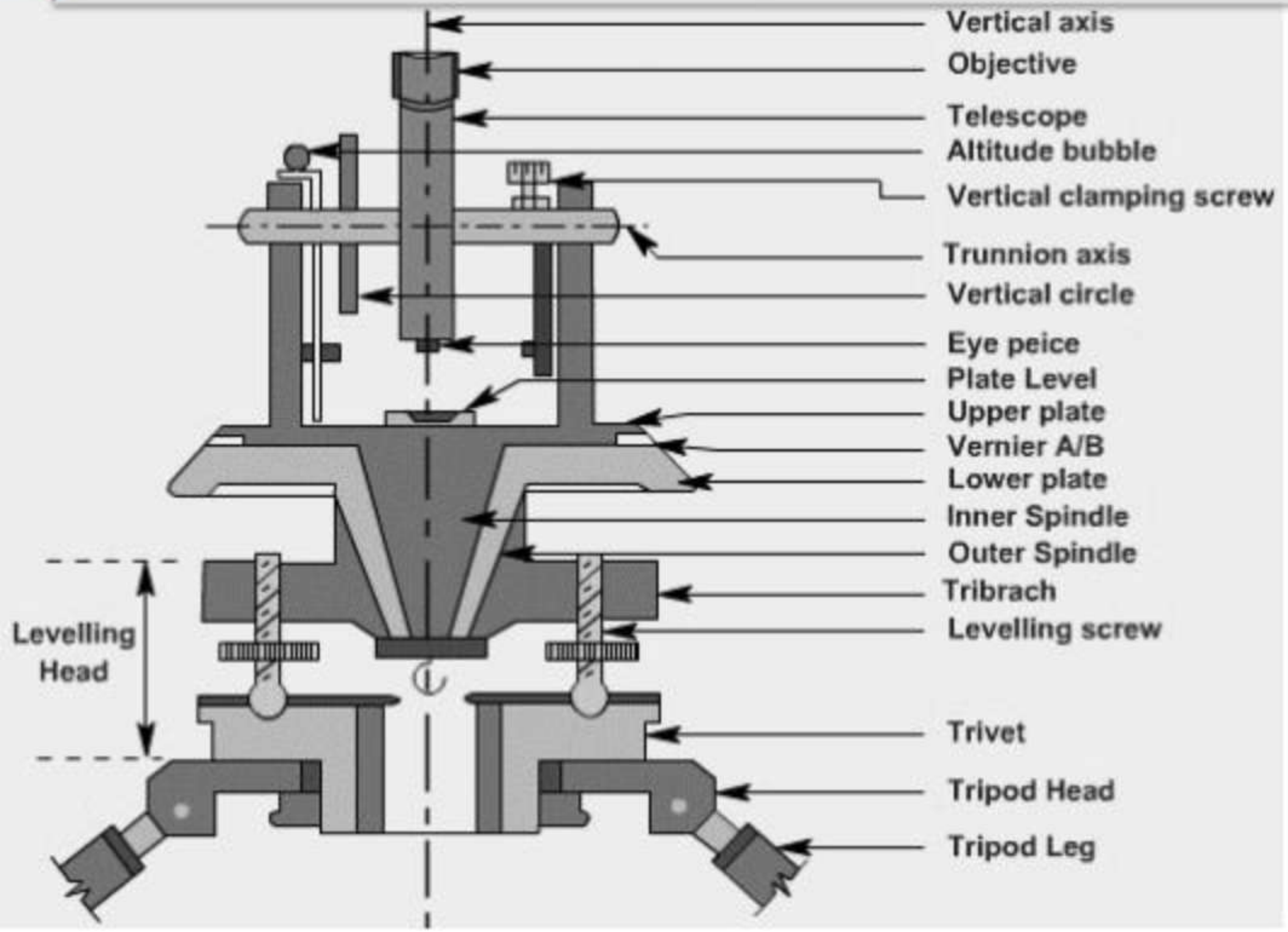
- Vernier theodolite and Micrometer theodolite
  - In Vernier theodolite the verniers are fitted to read the angles upto 20’ (minutes)
  - Micrometer theodolite micrometers are fitted to read the angles.

Theodolite



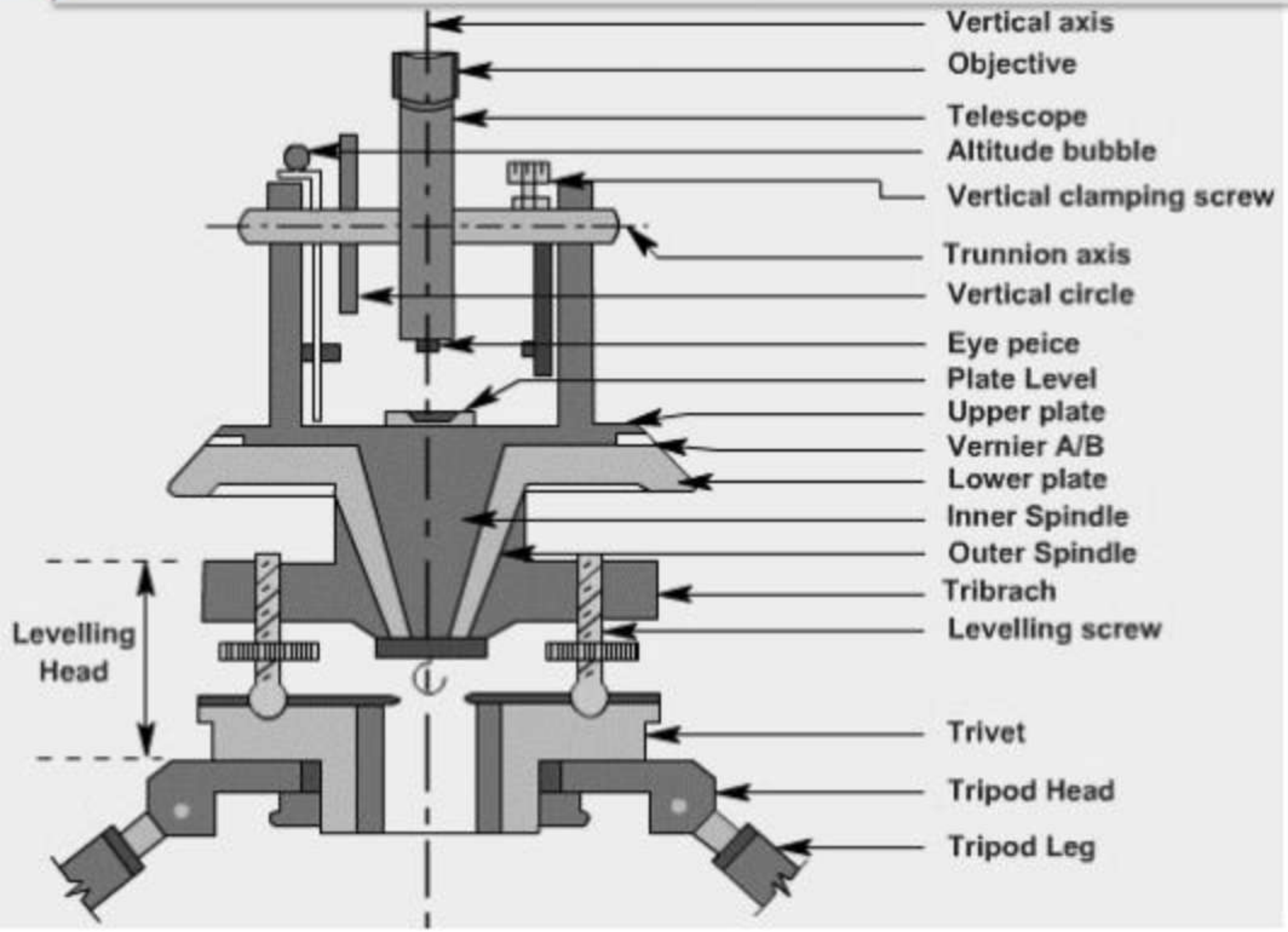
- **Features of Theodolite**
  - **The real image must be formed in front of the eye-piece.**
  - **The plane of the image must coincide with that of the cross-hairs**

Theodolite



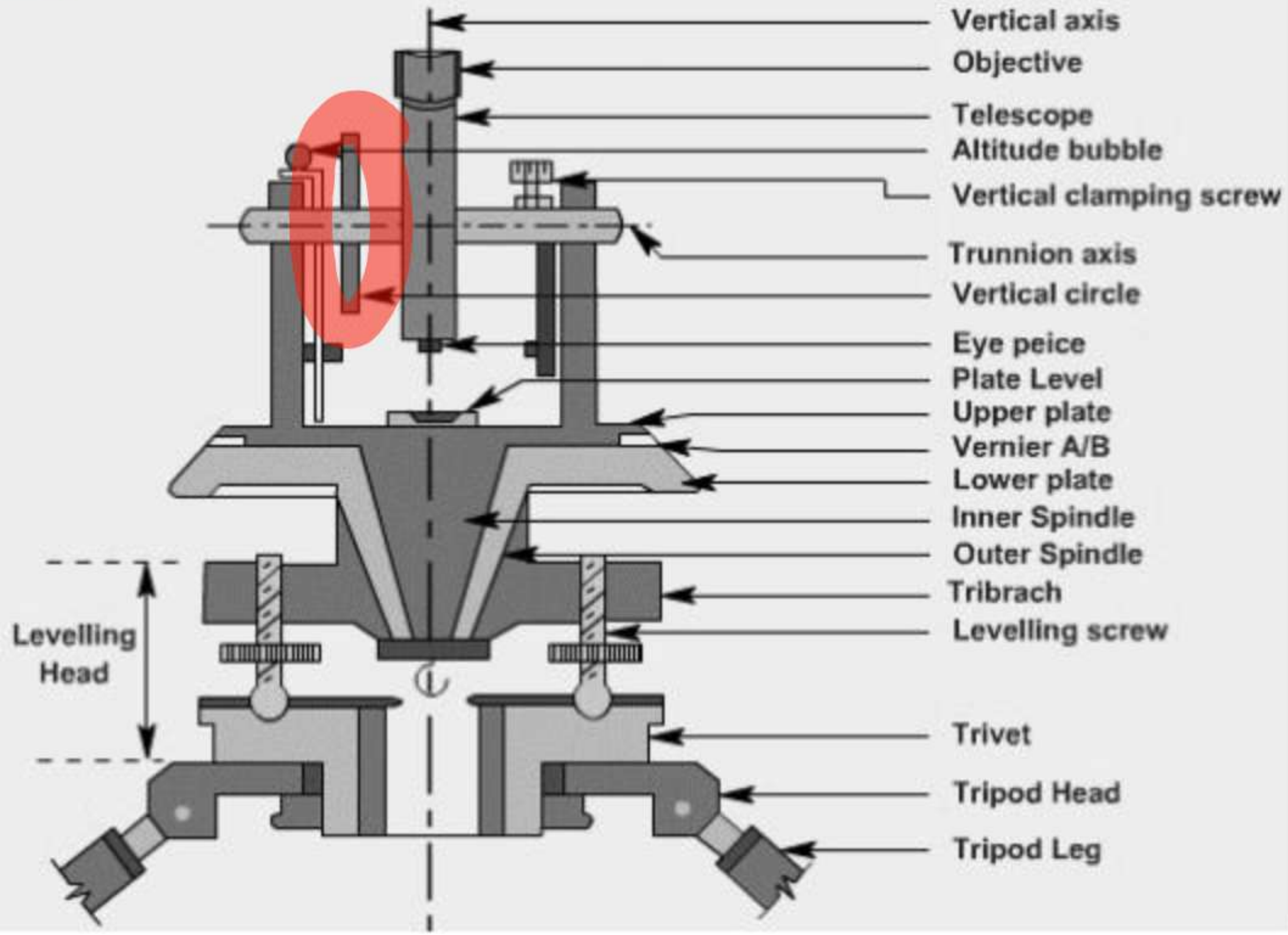
- What are the temporary adjustments of the theodolite?
  - 1. Setting up.
  - 2. Levelling up.
  - 3. Elimination of parallax.

Theodolite



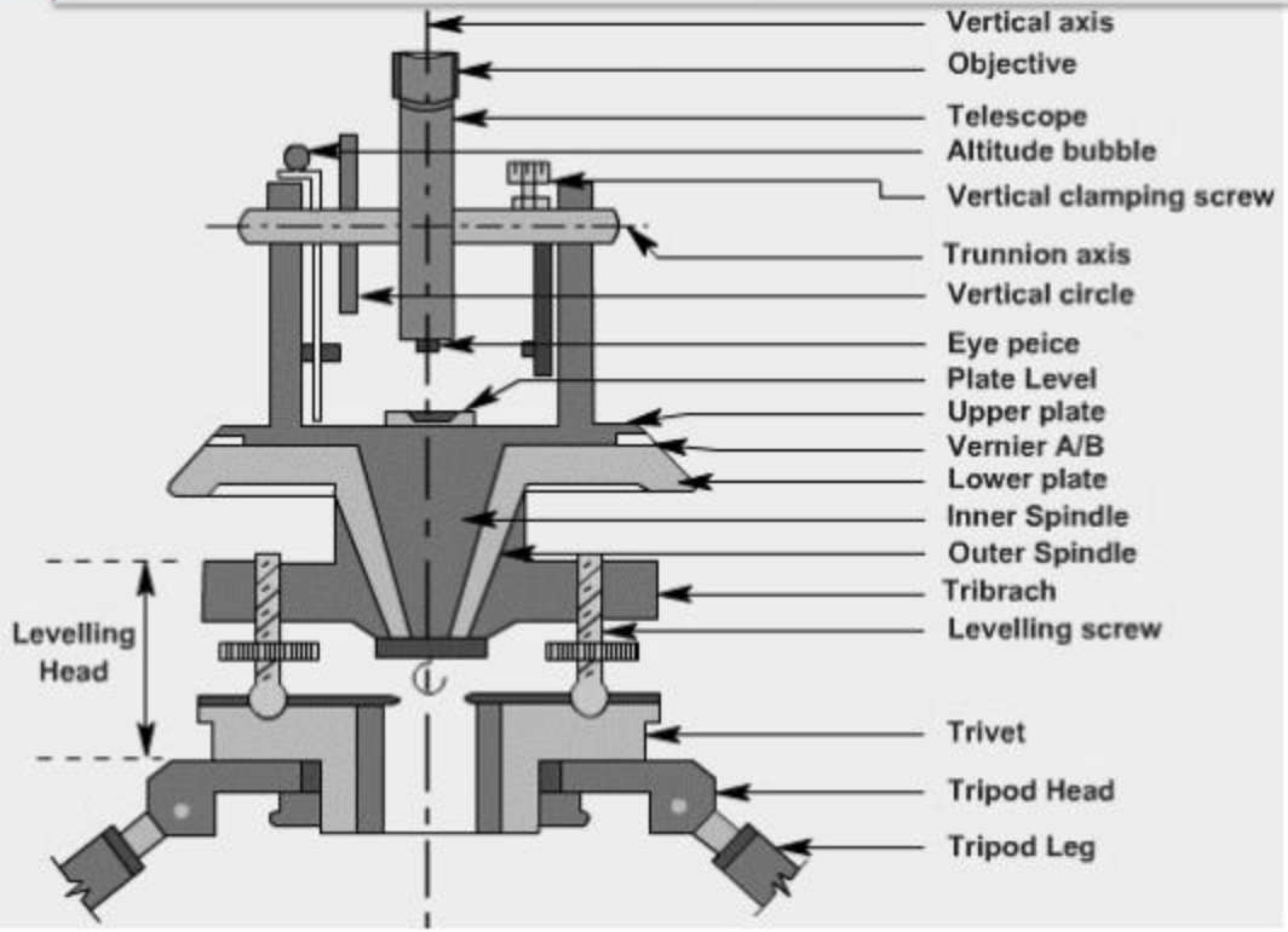
- **Centring :**
  - **It is the process of setting up the instrument exactly over the station mark.**
  - **The plumb bob suspended from a small hook attached to the underside of the inner spindle is used for centring.**

Theodolite



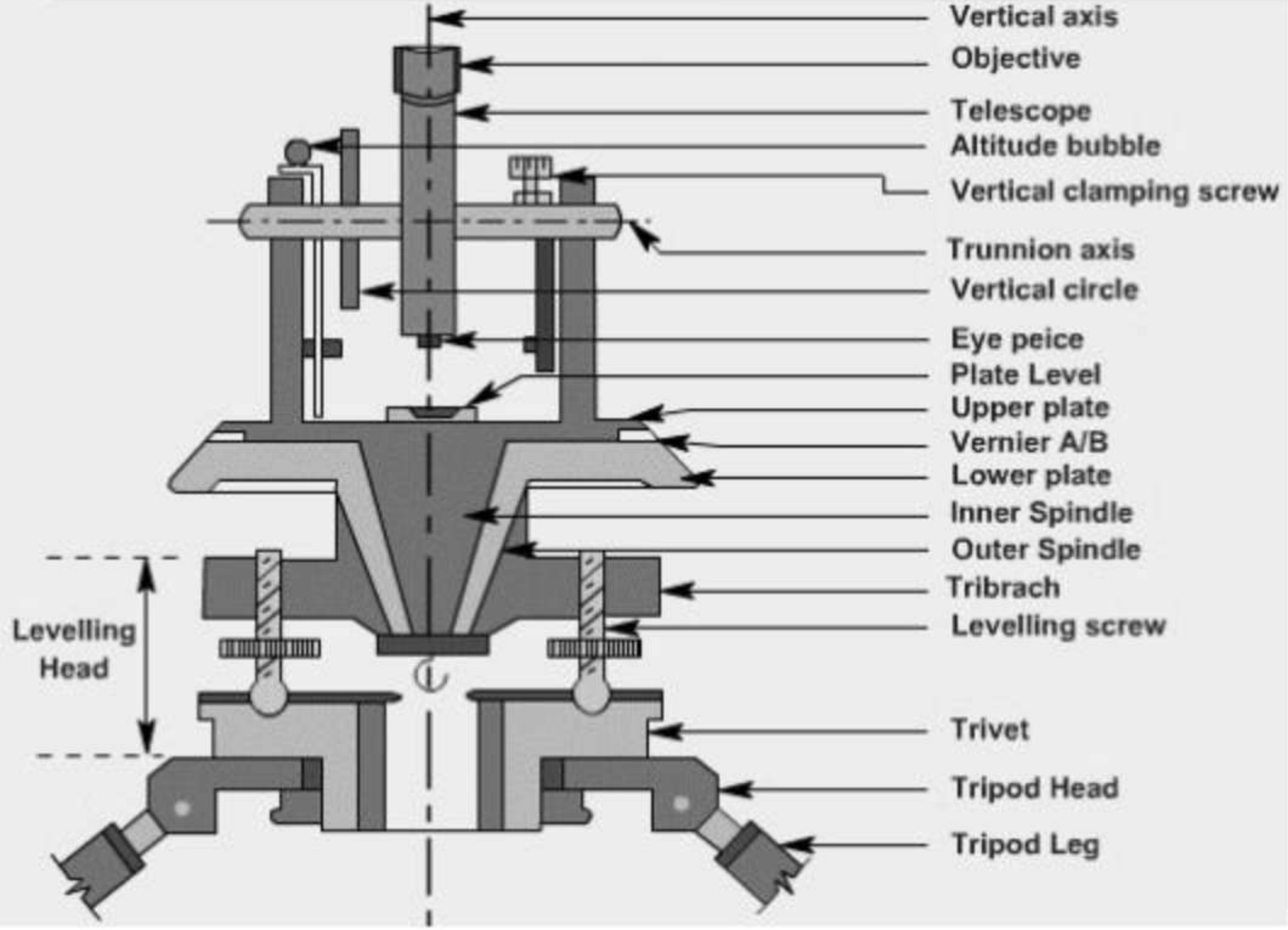
- <u>**Face Left Condition :**</u>
  - **If the vertical circle is on the left side of the observer, the theodolite is in the face left condition.**
  - **Normally, the face left condition is used in practice. The face left condition is, therefore, also known as the normal condition.**
  - **The telescope is in the normal position. It is also called the direct condition**
- <u>**Face Right Condition :**</u>
  - **If the vertical circle is on the right side of the observer, the theodolite is in the face right condition.**
  - **The telescope is in the inverted position. It is also called the reverse condition.**

Theodolite



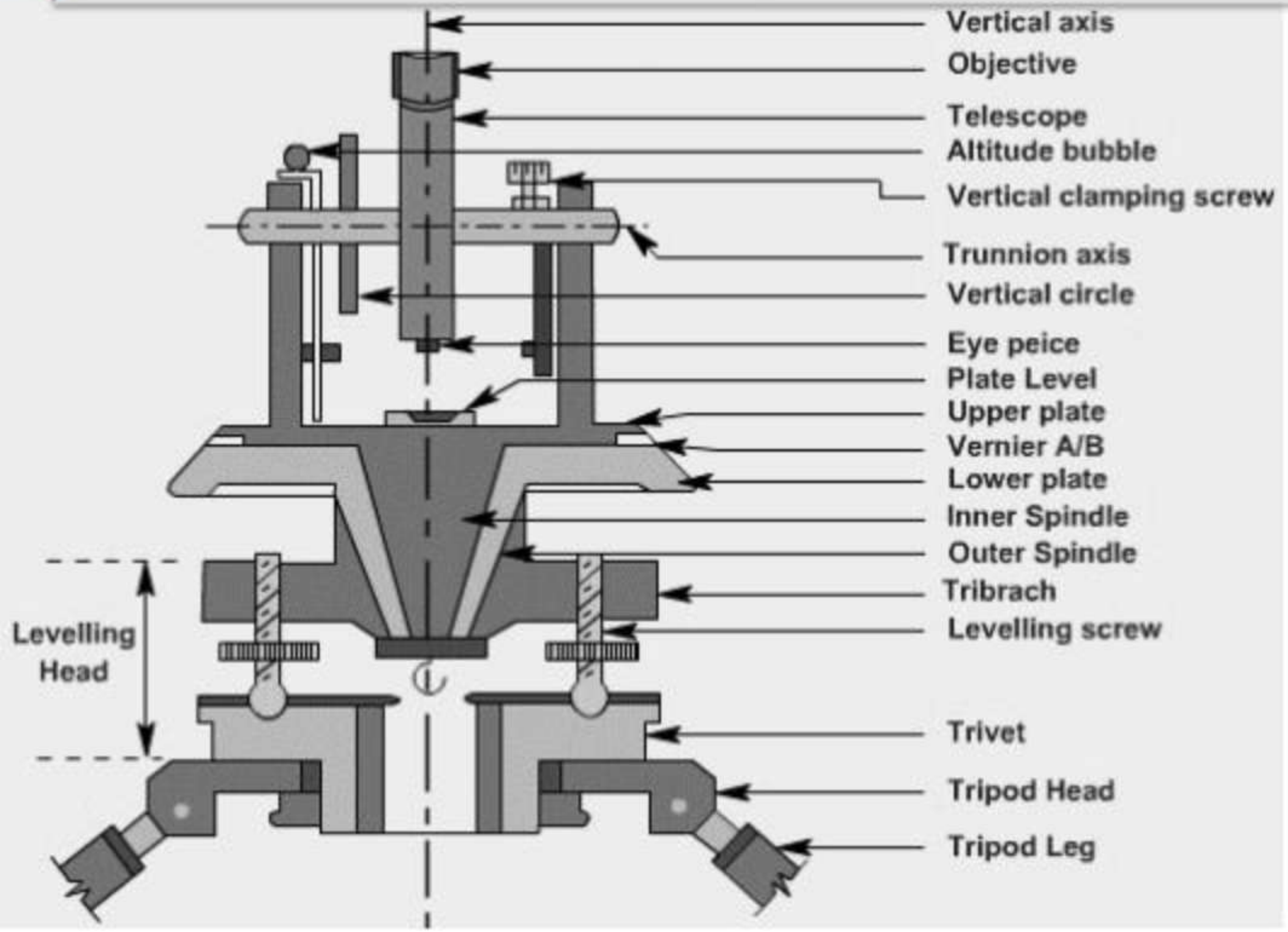
- **Centring :**
  - It is the process of setting up the instrument exactly over the station mark.
  - The plumb bob suspended from a small hook attached to the underside of the inner spindle is used for centring.
- **Changing Face :**
  - It is the operation of bringing the telescope from the face left condition to the face right condition and vice versa.
  - The face is changed by plunging the telescope and swinging it by 180°.

Theodolite



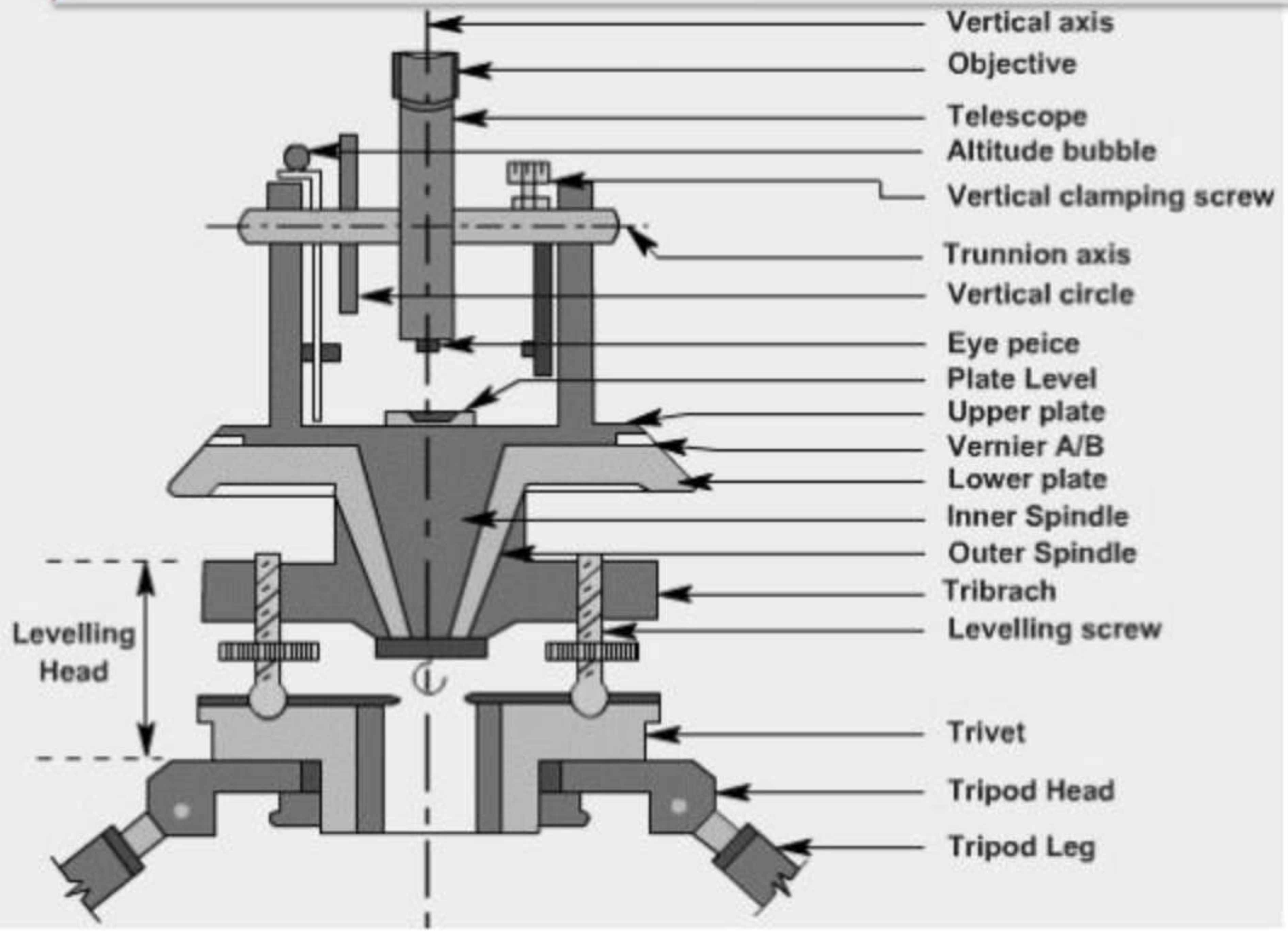
- **<u>Double Sighting :</u>**
  - **It is the process of measurement of a horizontal angle or a vertical angle twice; once with the telescope in the normal condition and once with the telescope in the inverted condition.**
  - **Double sighting is also called double centring**

Theodolite



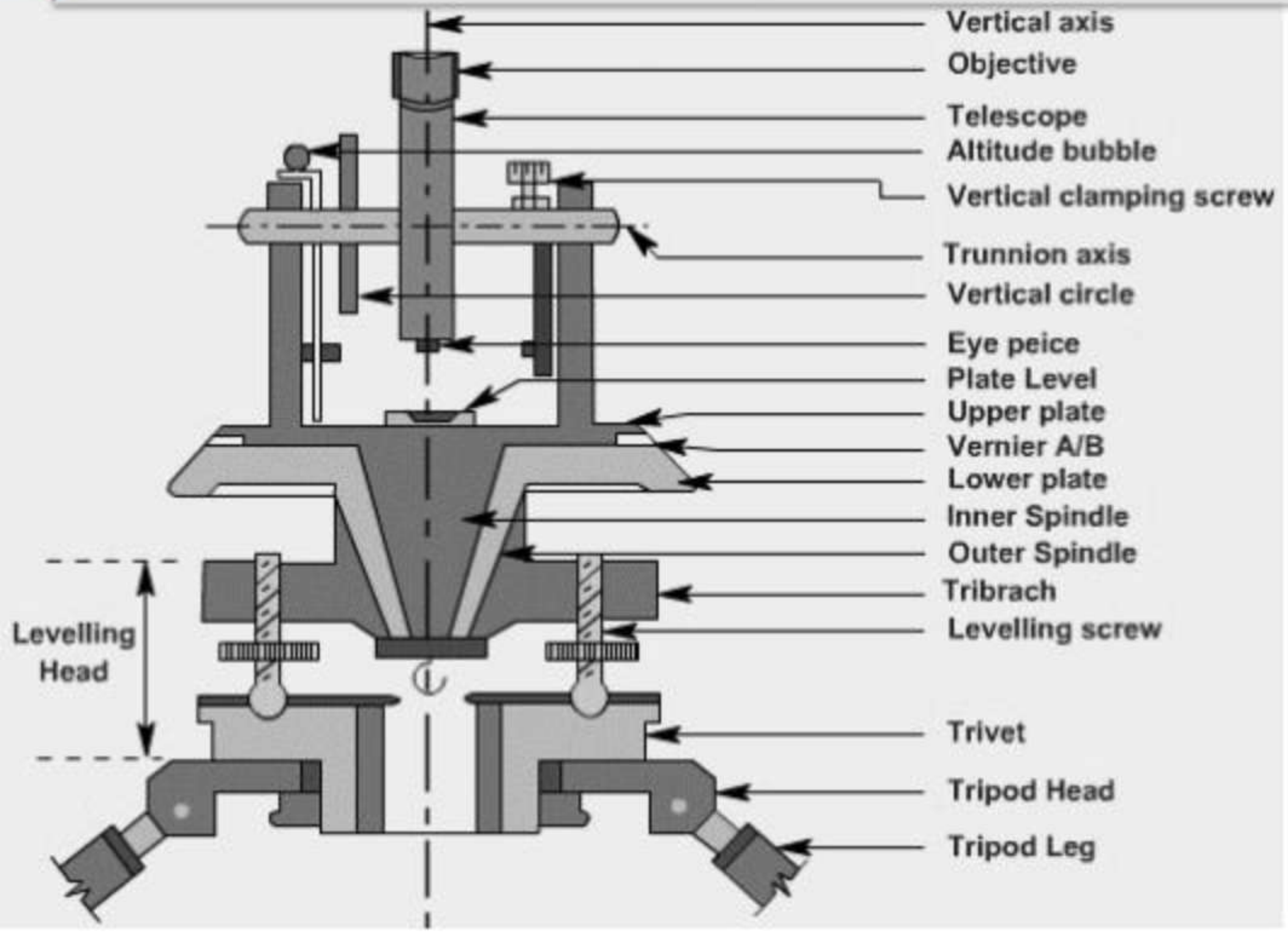
- **<u>Horizontal Axis :</u>**
  - The telescope is turned about the horizontal axis when measuring vertical angles.
  - The horizontal axis is also known as the trunnion axis, elevation axis or transverse axis.
- **<u>Line of collimation :</u>**
  - Imaginary line passing through the intersection of the cross-hairs of the diaphragm and the optical centre of the objective lens.

Theodolite



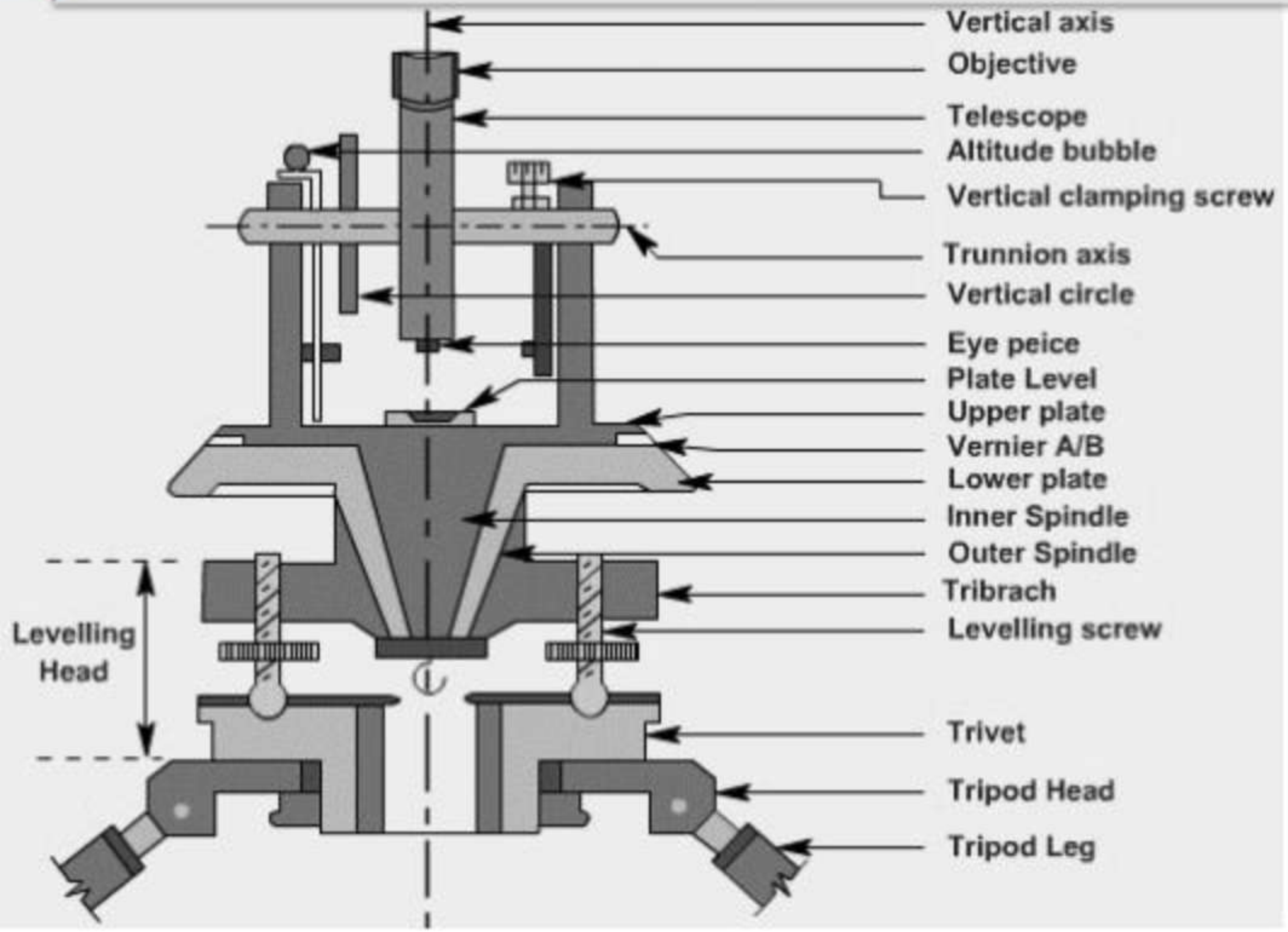
- **<u>Vertical axis :</u>**
  - **It is the direction of gravity and is indicated by a freely suspended plumb bob.**
  - **In case of perfectly adjusted theodolite, it is the line passing through the centre of the inner spindle, outer spindle and the bearing in the tribach.**

Theodolite



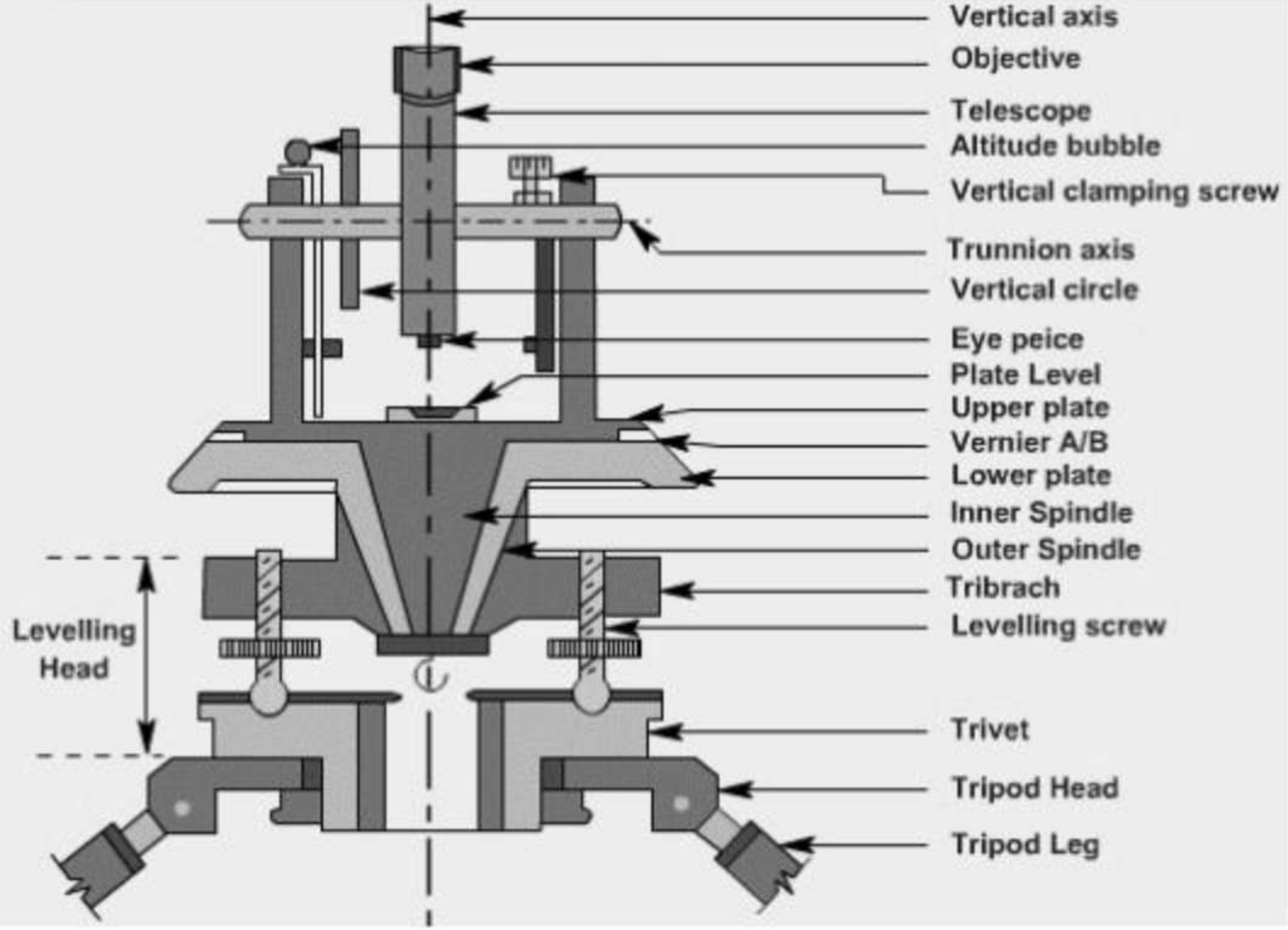
- **<u>Axis of the Altitude Level Tube :</u>**
  - **It is the straight line tangential to the longitudinal curve of the altitude level tube at its centre.**
  - **The axis of the altitude level tube is horizontal when the bubble is centred.**
- **<u>Axis of the Plate Level :</u>**
  - **It is the straight line tangential to the longitudinal curve of the plate level tube at its centre.**
  - **The axis of the plate level is horizontal when the bubble is centred.**

Theodolite



- **<u>Plunging the Telescope :</u>**
  - **It is the process of rotating the telescope over the herizontal axis through 180 in the vertical plane.**
  - **After plunging the telescope, the directions of the objective end and eyepiece end are reversed, and the telescope points exactly in the opposite direction.**
  - **Plunging is also known as transiting or reversing.**

Theodolite



- **<u>Swinging the Telescope :</u>**
  - It is the process of turning the telescope about the vertical axis in a horizontal plane.
  - The swing is called right swing when the telescope is turned clockwise from the previous position.
  - The swing is called left swing when the telescope is turned anticlockwise from previous position

Theodolite

What are the permanent adjustments of the theodolite?

1. Adjustment of plate level (Plate level test).

2. Adjustment of line of sight (Cross- hair test).

3. Adjustment of horizontal axis.(Spire test).

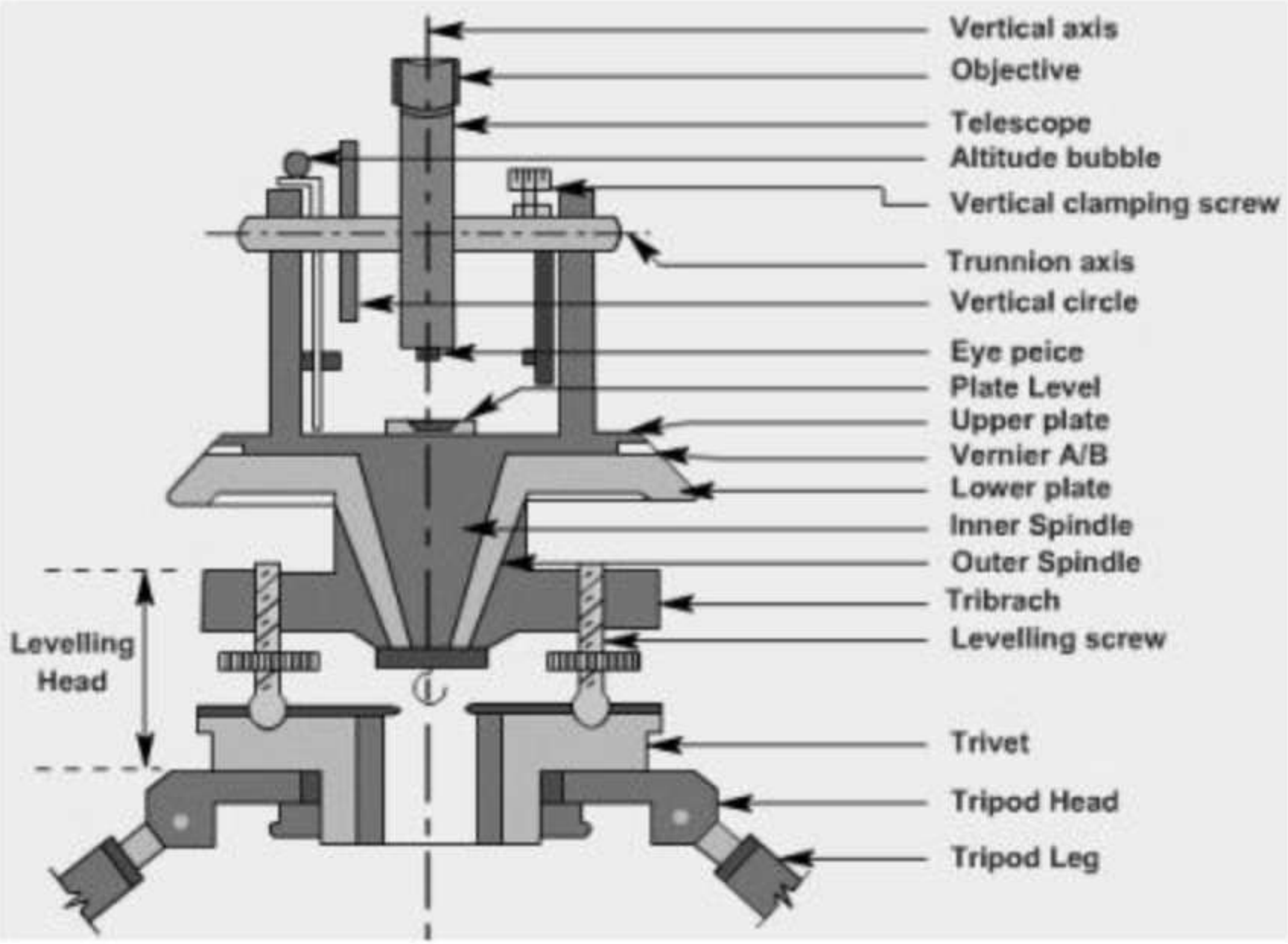
4. Adjustment of vertical index frame and altitude bubble.(Vertical arc test)

What is an anallatic lens? What is the use of an anallatic lens?

- It is a special convex lens fitted between the object glass and eye piece, at a fixed distance from the object glass, inside the telescope of a tacheometer..
- The use of an anallatic lens is to reduce the additive constant (C) to zero. Tacheometric equation, D = Ks + C. Where
  - D = horizontal distance between the staff and the instrument station. S = staff intercept
  - K = multiplying constant. C = additive constant.

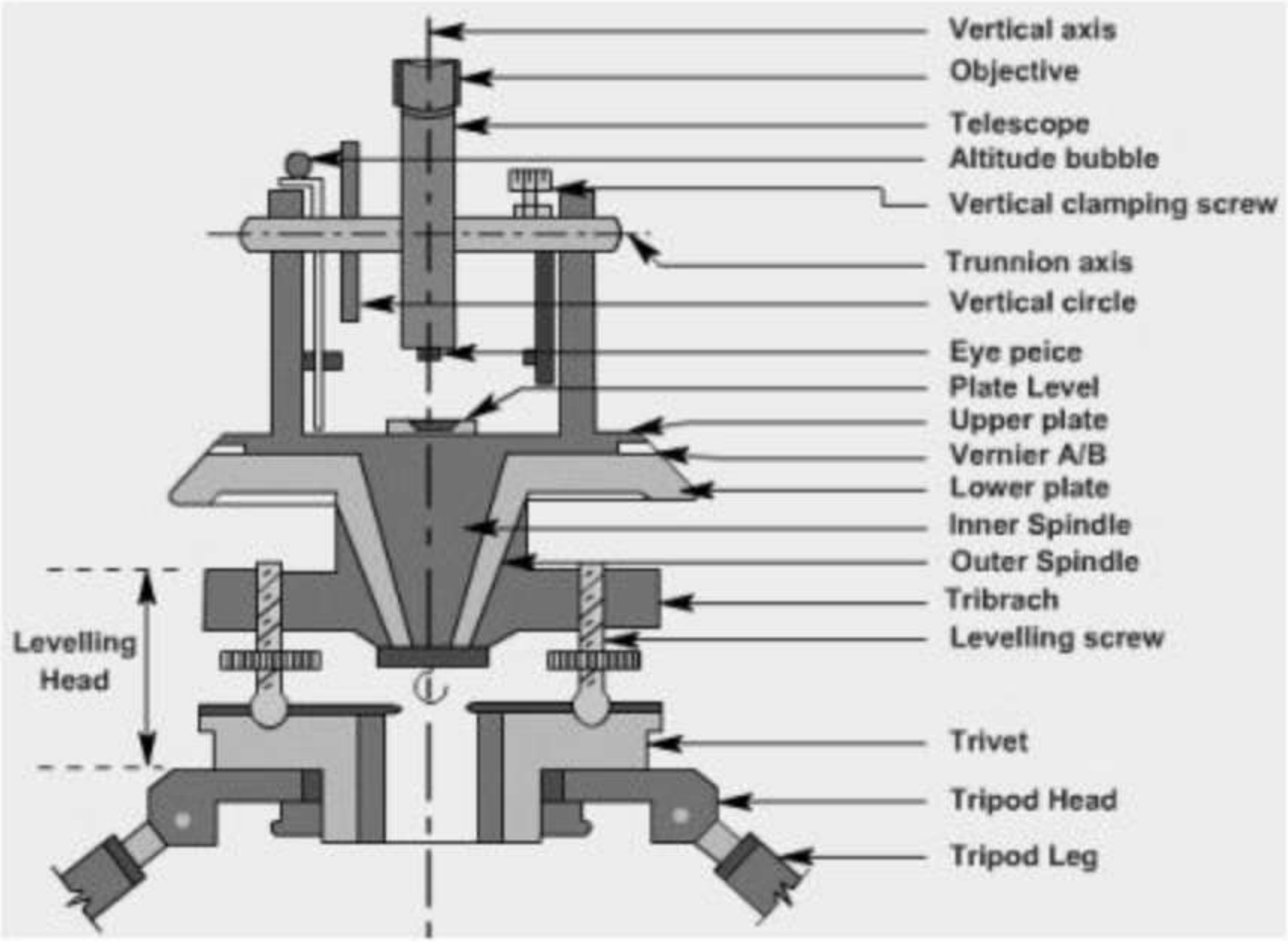
The following desired relations should exist between these lines of theodolite :

- (I) The axis of the plate level must lie in a plane perpendicular to the vertical axis. If this condition exists, the vertical axis will be truly vertical when the bubble is in the centre of its run.
- (2) The line of collimation must be perpendicular to the horizontal axis or its intersection with the vertical axis. Also, if the telescope is external focusing type, the optical axis, the axis of the objective slide and the line of collimation must coincide. If this condition exists, the line of sight will generate a vertical plane when the telescope is rotated about the horizontal axis.
- (3) The horizontal axis must be perpendicular to the vertical axis. If this condition exists, the line tit sight will generate vertical plane when the telescope is plunged.



The following desired relations should exist between these lines of theodolite :

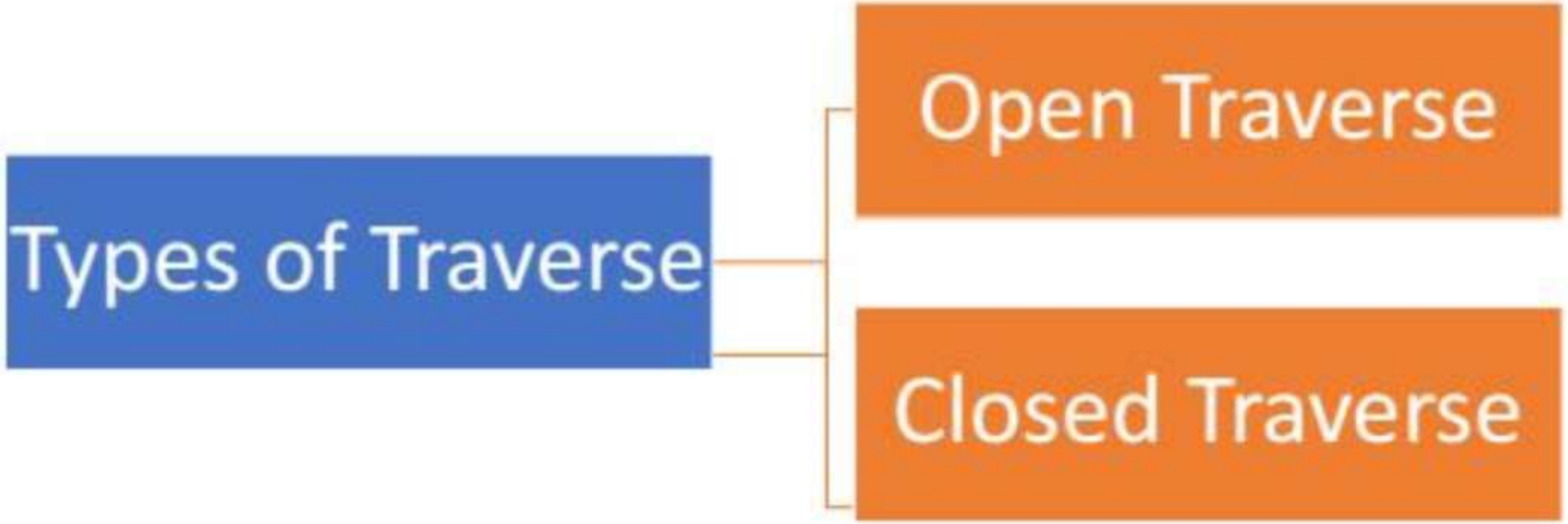
- (4) The axis of the altitude level (or telescope level) must be parallel to the line of collimation. If the condition exists, the vertical angles will be free from index error due to lack of parallelism.
- (5) The vertical circle vernier must read zero when the line of collimation is horizontal. If this condition exists. the vertical angles will he free from index error due to displacement of the vernier.



Chapter: Traversing

- Traverse is a framework consisting of series of straight lines connected together forming an open or closed traverse

Types of Traverse



Measurement in Traversing

- **Linear Measurement**
  - Chain or tape
  - Tacheometer
  - EDMI
- **Angular Measurement**
  - Loose needle method
  - Fast needle method
  - Included angle method
  - Direct angle method
  - Deflection angle method

Permissible error in Linear measurement

- **If θ is the least count of angle measuring equipment then permissible error in Linear measurement equipment should be of the order of**

$$tan\theta = \frac{\delta L}{L}$$

Que: If LC of compass is 30’, then determine order of error for linear measurement equipment in compass survey for 1m.

$$tan\theta = \frac{\delta L}{L} \quad \Rightarrow \quad \tan(30') = \frac{\delta L}{L}$$

$$\Rightarrow \quad 0.00873 = \frac{\delta L}{L}$$

If we take L=1m=1000mm, δL = 8.73 mm

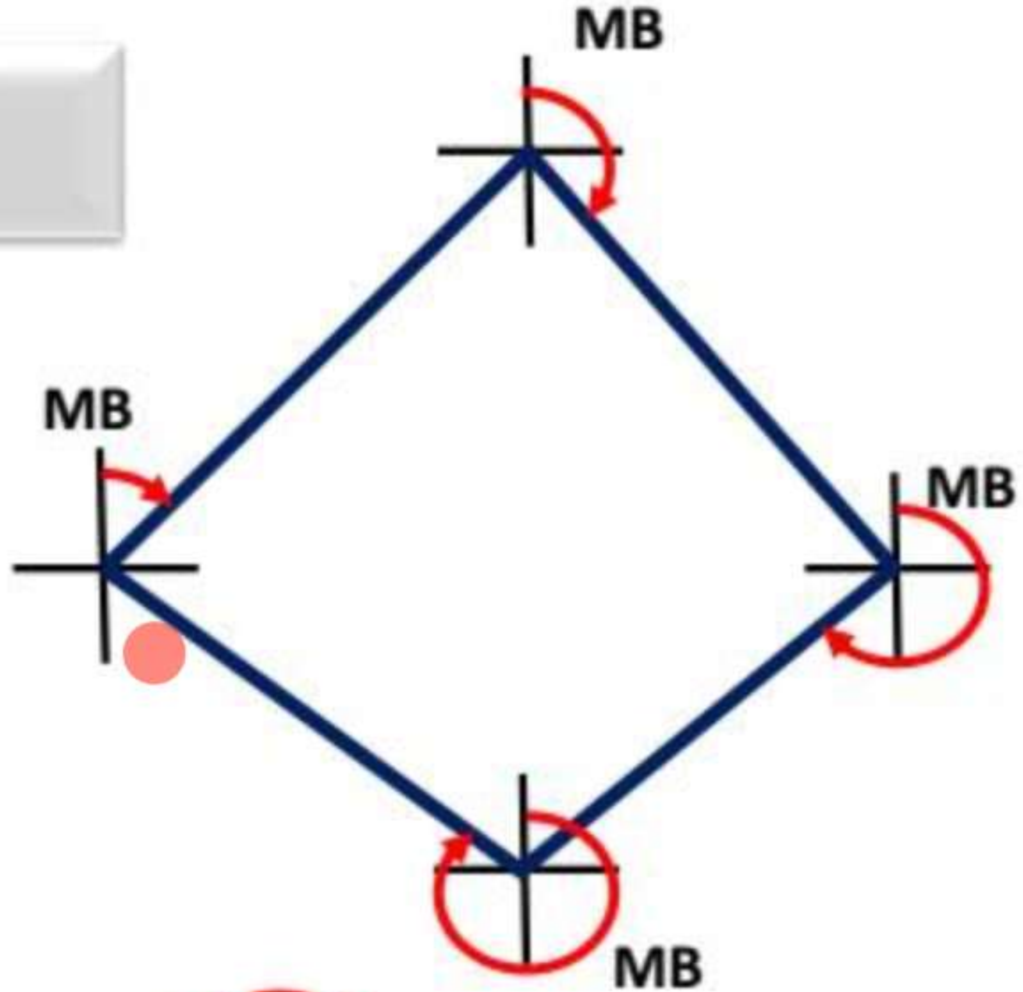
- **In traversing, Linear measurement equipment should be selected such that degree of accuracy is of some order of angle measuring equipment**
- **If very precise equipment are used for angular measurement, then equally precise equipment shall be used for distance measurement.**
- **If θ is the least count of angle measuring equipment then permissible error in Linear measurement equipment should be of the order of**

$$tan\theta = \frac{\delta L}{L}$$

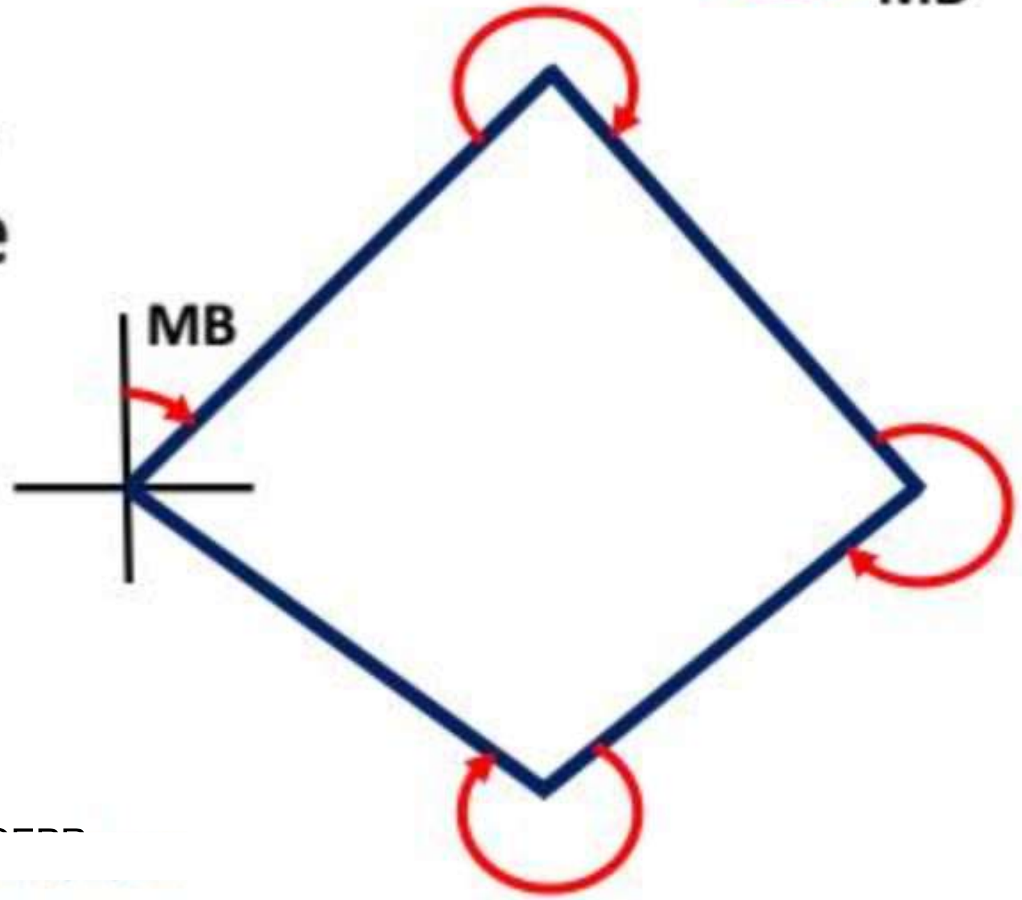
- **The accuracy of ANGULAR and LINEAR measurements should be compatible**
  - **Angular values measured to *1 second* requires distances to be measured upto *1mm***
  - **Angular values measured to *1 minute* requires distances to be measured upto *1cm***

Angular Measurements

1. ***Loose Needle Method/Free needle method***
   - In this method we try to measure magnetic bearing (MB) of each traverse line



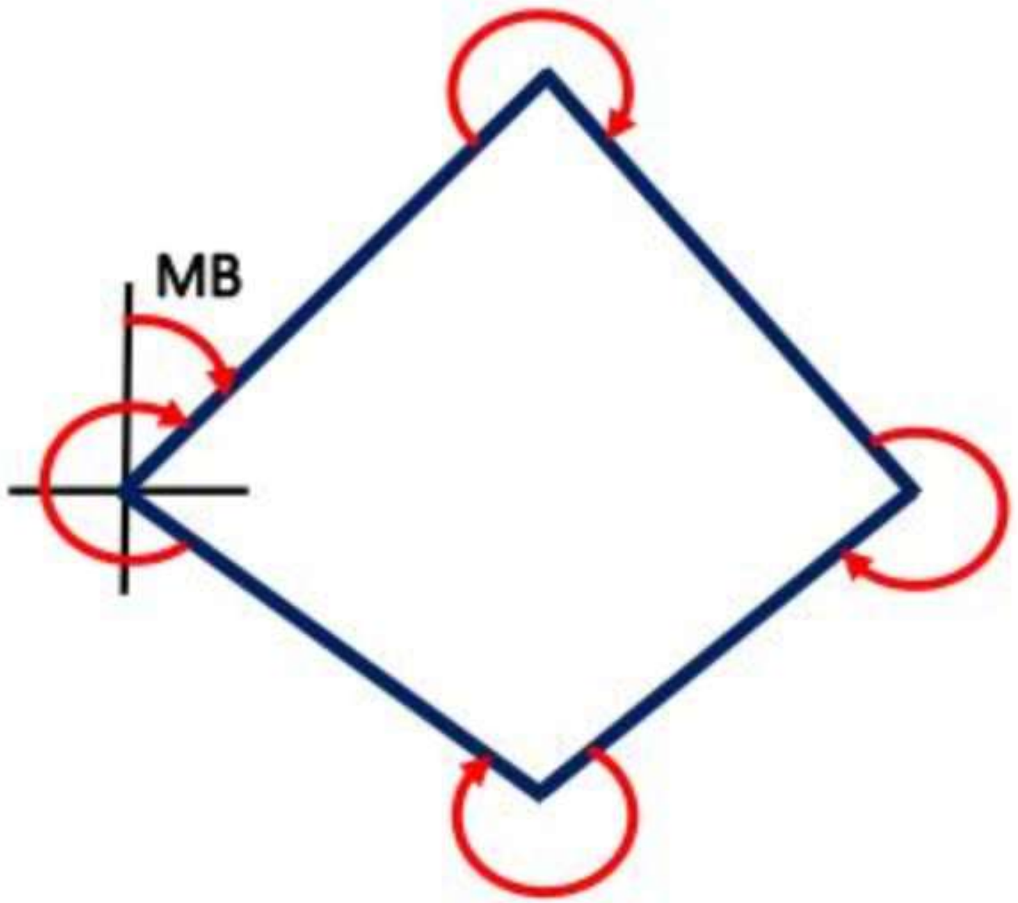
2. ***Fast Needle method***
   - In this method we measure magnetic bearing of any one line (and generally it is first traverse line and we measure included angle at all the other stations)
   - This method is more accurate than previous method



Angular Measurements

3. *Included angle Method*

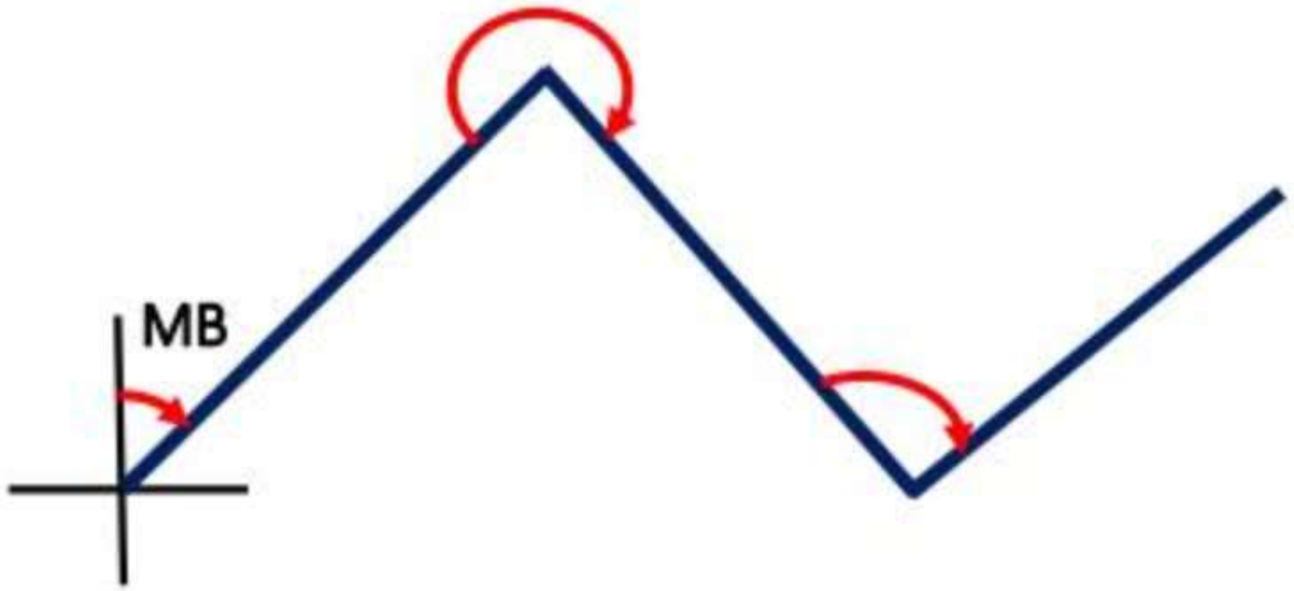
- In this method we measure MB of any one line generally
- It is the first traverse line and we measure included angles at *all* the stations.
- This method is more accurate than previous two methods



Angular Measurements

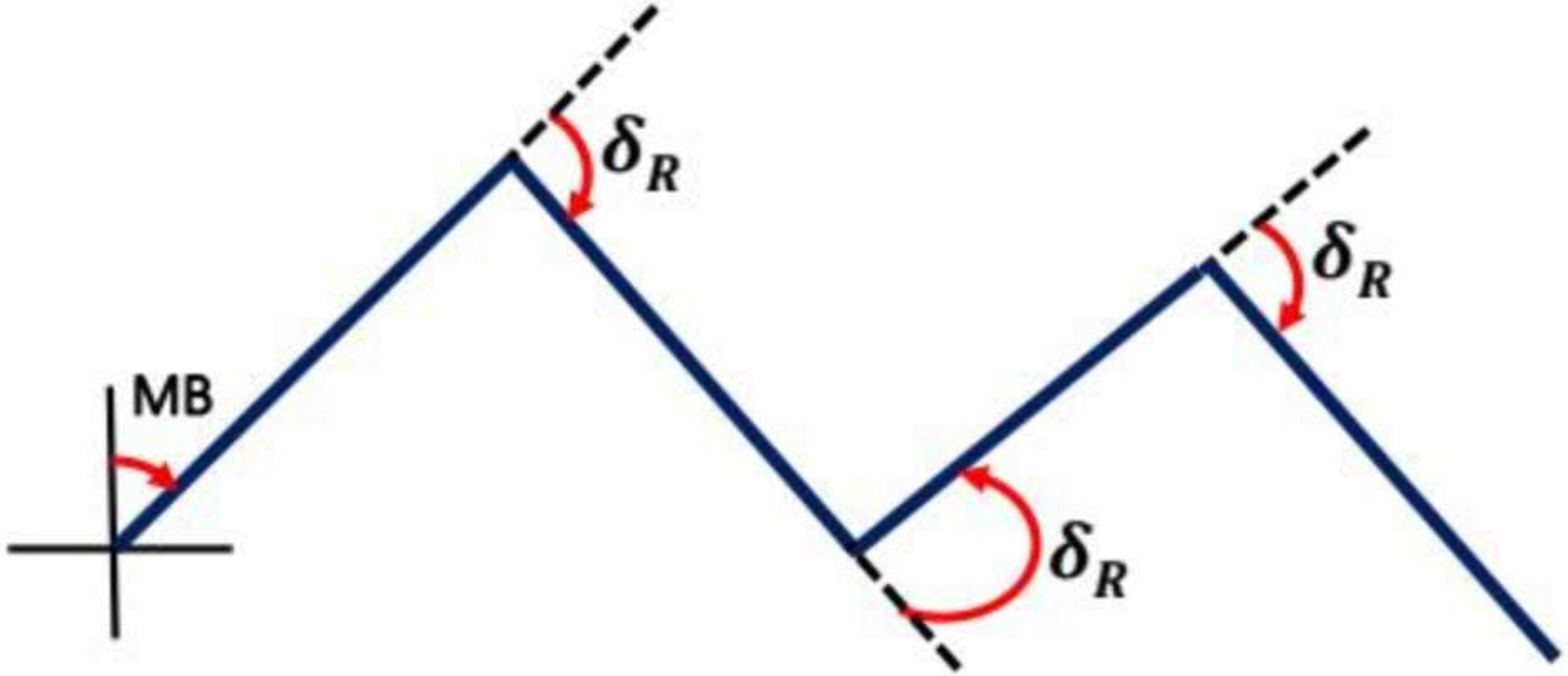
4. *Direct Angle Method*

- It is used for open traverse
- In this method direct angles, i.e. angles towards right direction are measured



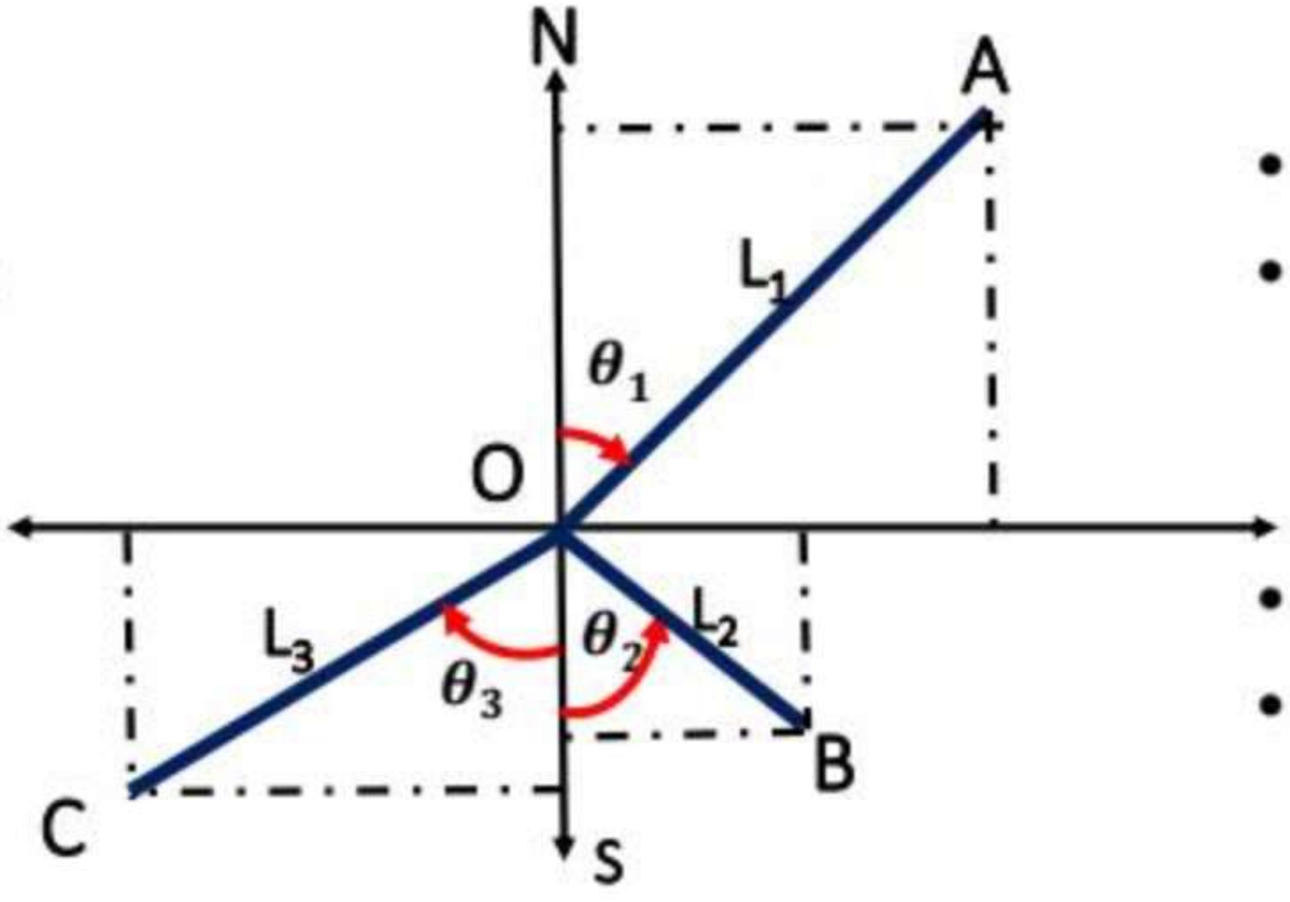
5. *Deflection Angle Method*

- Deflection angle method is used for open traverse in which traverse line makes small deflection angle like in railways, canals, sewers, etc



Latitude and Departure

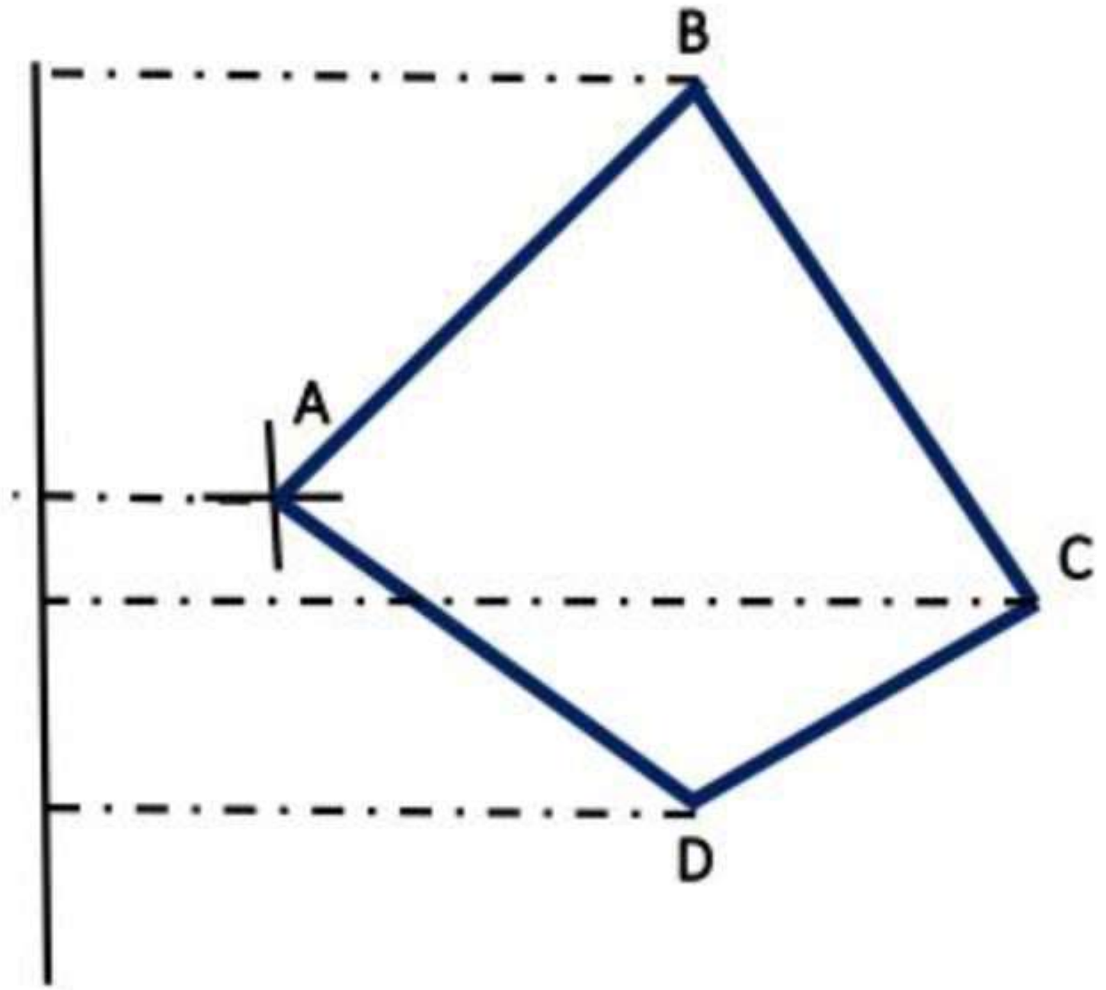
1. **Latitude**
   - Latitude of a line is orthographic projection on North-South Meridian
   - +ve → Northing
   - -ve → Southing
2. **Departure**
   - Departure is orthographic projection of a line on East West Meridian
   - +ve → Easting
   - -ve → Westing



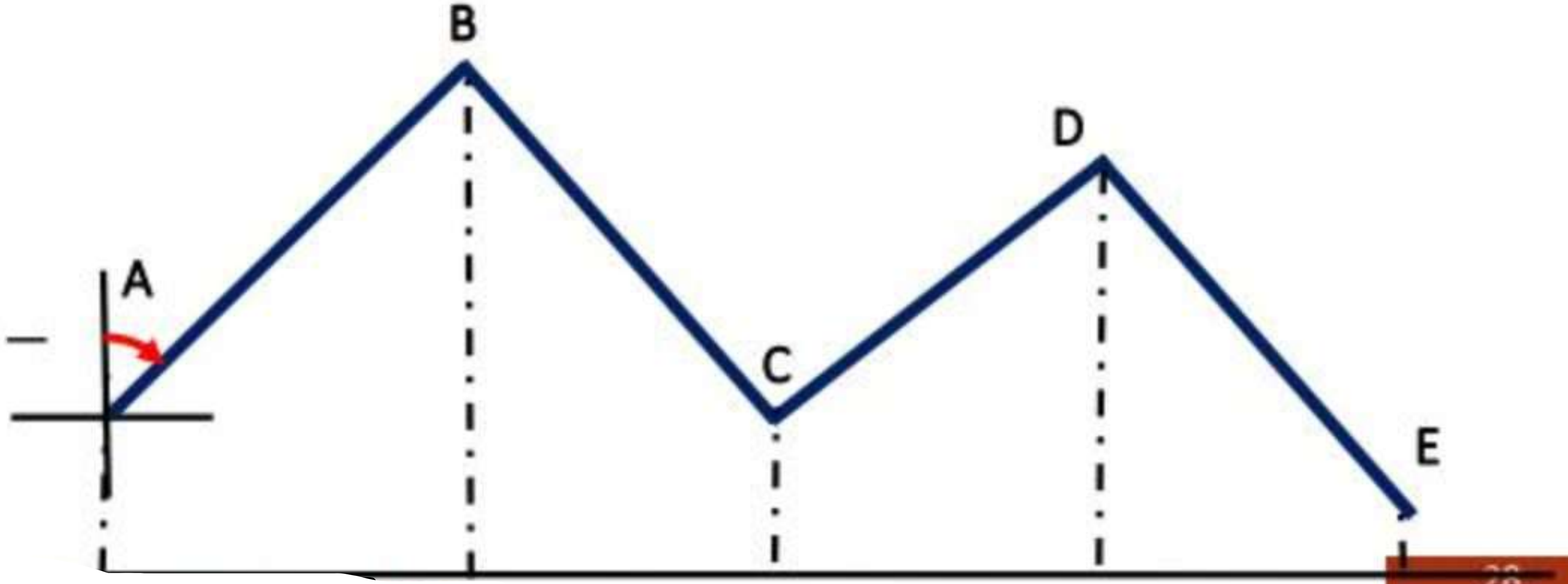
- $L_{OA} = L_1 cos\theta_1$
- $D_{OA} = L_1 sin\theta_1$
- $L_{OB} = -L_2 cos\theta_2$
- $D_{OB} = L_2 sin\theta_2$
- $L_{OC} = -L_3 cos\theta_3$
- $D_{OC} == L_3 sin\theta_3$

Check in Closed Traverse

1. **Loop Traverse**
   - **In any closed loop traverse, if a survey work is error free, then**
     - $\Sigma L = 0$
     - $\Sigma D = 0$
     - **Sum of Northings = Sum of Southings**

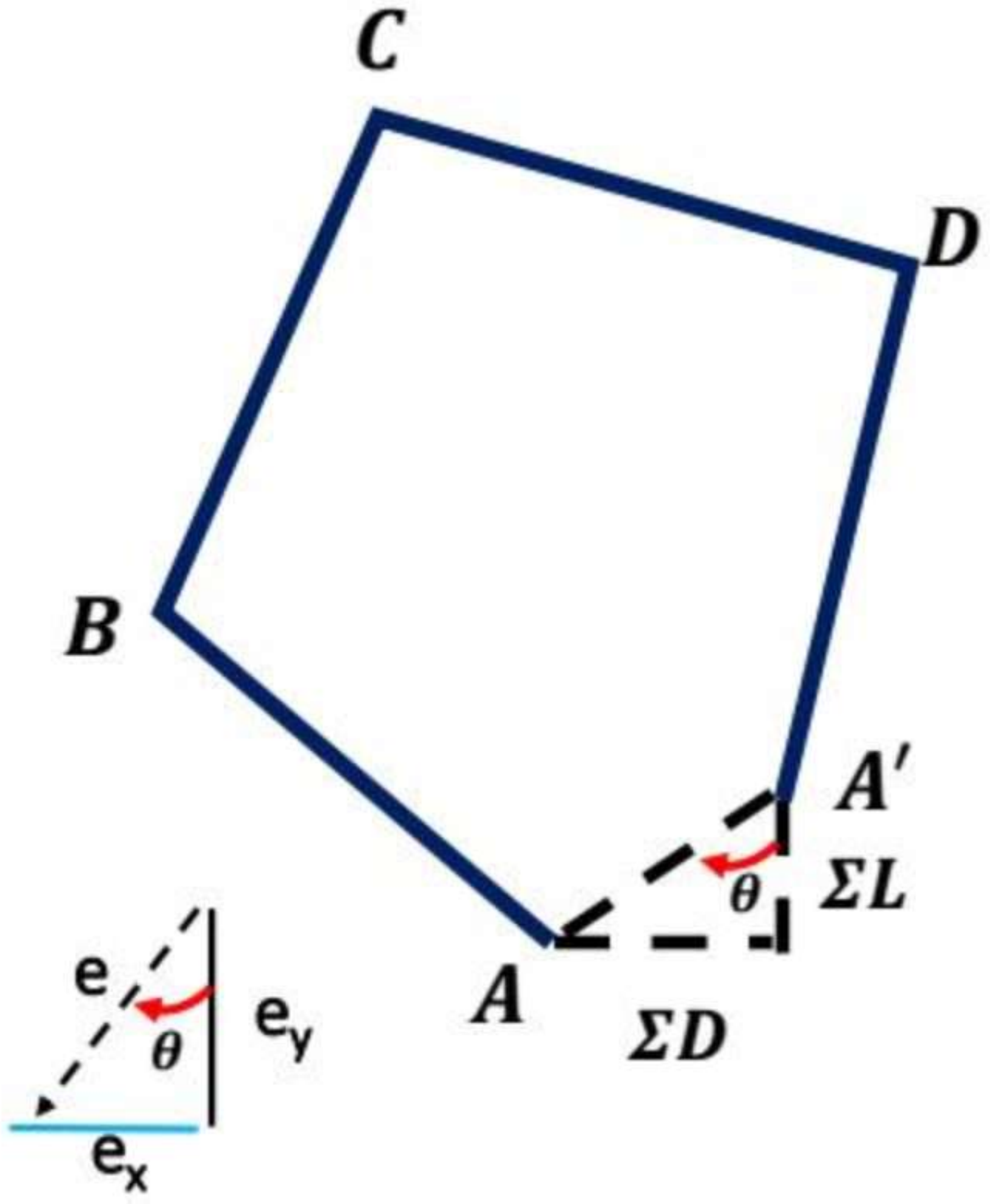


2. **Link Traverse**
   - $\Sigma L = Latitude\ of\ last\ point - Latitude\ of\ first\ point$
   - $\Sigma D = Departure\ of\ last\ point - Departure\ of\ first\ point$



Closing Error / Error of closure

- If a traverse has an error, it will not close on a piece of paper
  - Closing error = AA’
  - $e_x = \Sigma D$
  - $e_y = \Sigma L$
  - $e = \sqrt{{e_x}^2 + {e_y}^2}$
  - $\boldsymbol{\theta = tan^{-1}(\frac{\Sigma D}{\Sigma L})}$
  - $\boldsymbol{\theta = tan^{-1}(\frac{e_x}{e_y})}$



Balancing the traverse

1. **Bowditch Rule:**
   - It is also called as compass rule
   - It is generally used for adjusting traverse in which angles and distances are measured with same precision
   - Bowditch rule assumes that closing error is due to random error
   - Therefore error in traverse line will be directly proportional to root of length of the line
   - The error in linear measurements are proportional to $\sqrt{Length\ of\ Line}$
   - The error in Angular measurements are inversely proportional to $\sqrt{Length\ of\ Line}$

$$\text{Correction to latitude or departure of any side} = \frac{Length\ of\ that\ side}{Perimeter\ of\ traverse} \times Total\ error\ in\ latitude\ or\ departure$$

Balancing the traverse

2. Transit Method

- It is used where angular measurements are more precise than linear measurements
- According to this method, total error in latitude or departure is distributed in proportion to latitudes and departures of the sides

$$\text{Correction to latitude or departure of any side} = \frac{\textit{Latitude}(\textit{or departure})\textit{of that line}}{\textit{Arithmatic sum of latitude }(\textit{or departure})} \times \textit{Total error in latitude or departure}$$

Checks in Traverse

Checks on Linear Measurements

1. Every line of the traverse is measured twice. The two measurements are done with the same precision, on different days and in opposite direction.
2. Sum of northings should be equal to sum of southings. Sum of eastings should be equal to sum of westings.

Checks on Angular Measurements

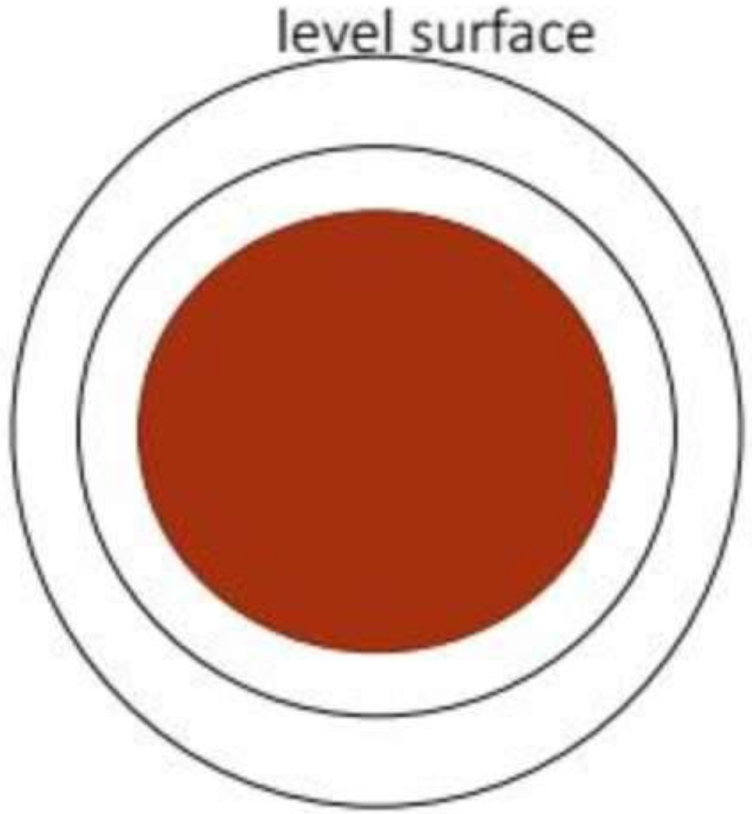
1. ***Traversing by included angles*** The sum of interior included angles should be = $(2n - 4)$ right angles, and the sum of exterior included angles should be = $(2n + 4)$ right angles, where n is the number of sides of the traverse.
2. ***Traversing by deflection angles*** The algebraic sum of the deflection angles should be = 360° (the right-hand deflection angles are taken as positive and the left-hand deflection angles are taken as negative).
3. ***Traversing by direct observation of bearings*** The fore bearing of the last line is compared with the back bearing of the line at the initial station. The two values should have a difference of 180°.

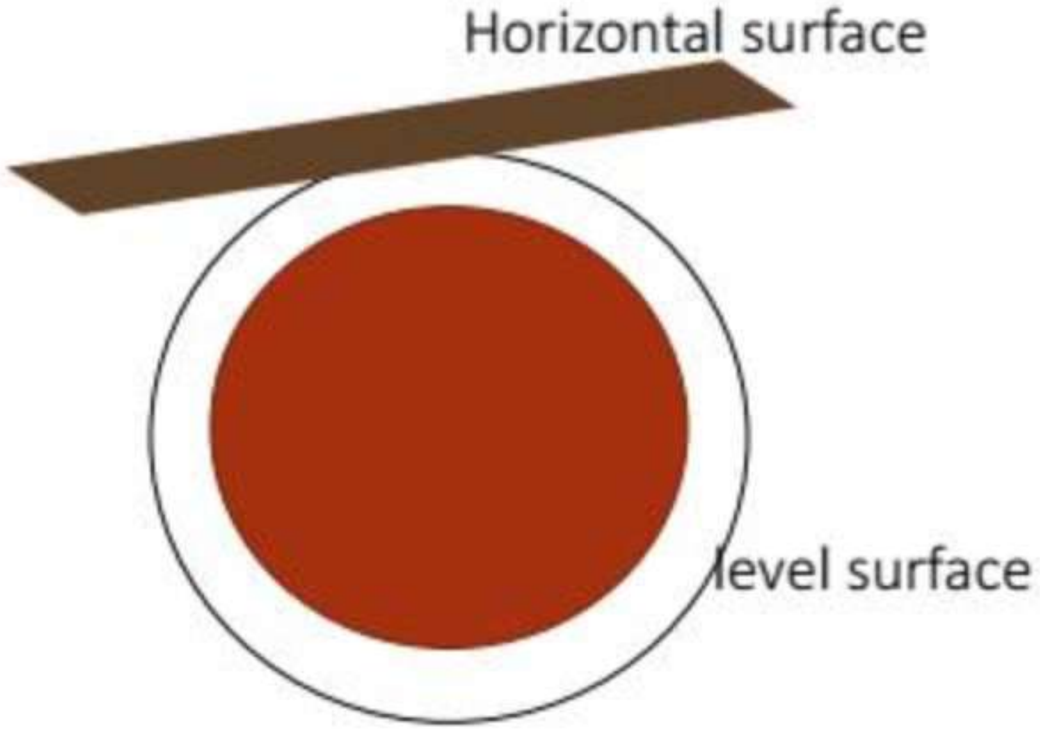
Chapter: LEVELLING

- Levelling is the operation of determining elevation of various points.
- Elevation is the height of a point above (or) below a reference level called 'Datum'.
- In topographical work most commonly used datum is Mean Level of Sea (or) Mean Sea Level (MSL).
- MSL is mean level of sea obtained by averaging elevation of high and low tides at several points for a long period of time. i.e, 19 years.

Levelling

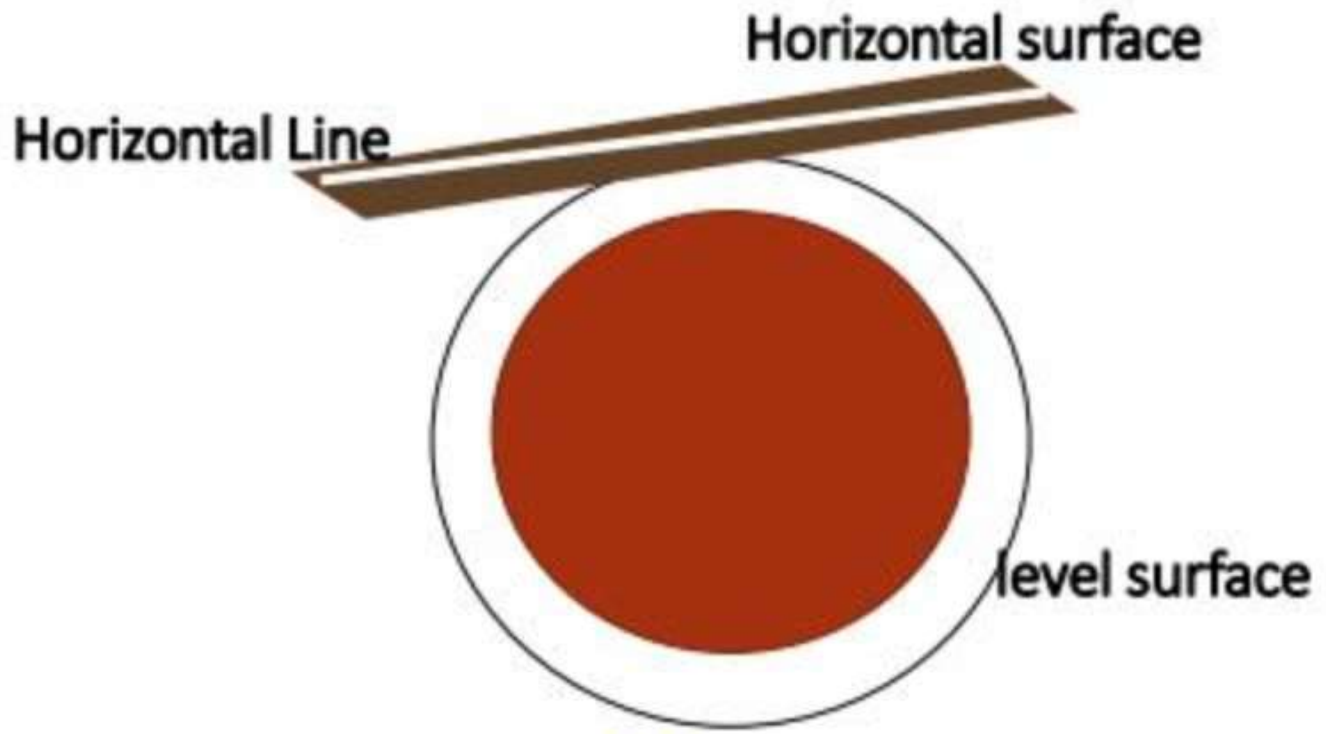
- **Level Surface:**
  - **It is curved surface which is parallel to the mean surface of the Earth (ignoring undulations)**
  - **Exp: surface of water in a still lake or pond**
- **Level Line:**
  - **It is a curved line on any level surface**
- **Horizontal Surface**
  - **Horizontal surface at any point is a plane surface tangential to the level surface at that point**
  - **It is always perpendicular to the plumb line**

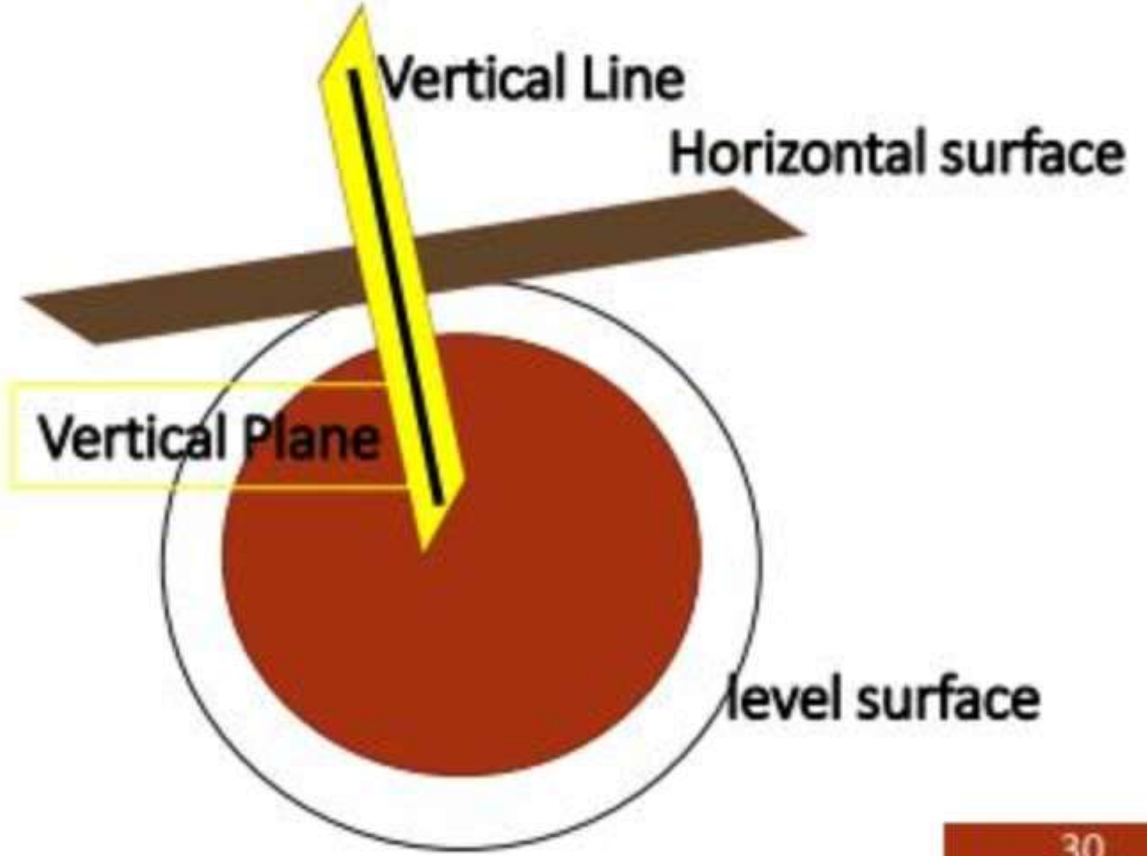




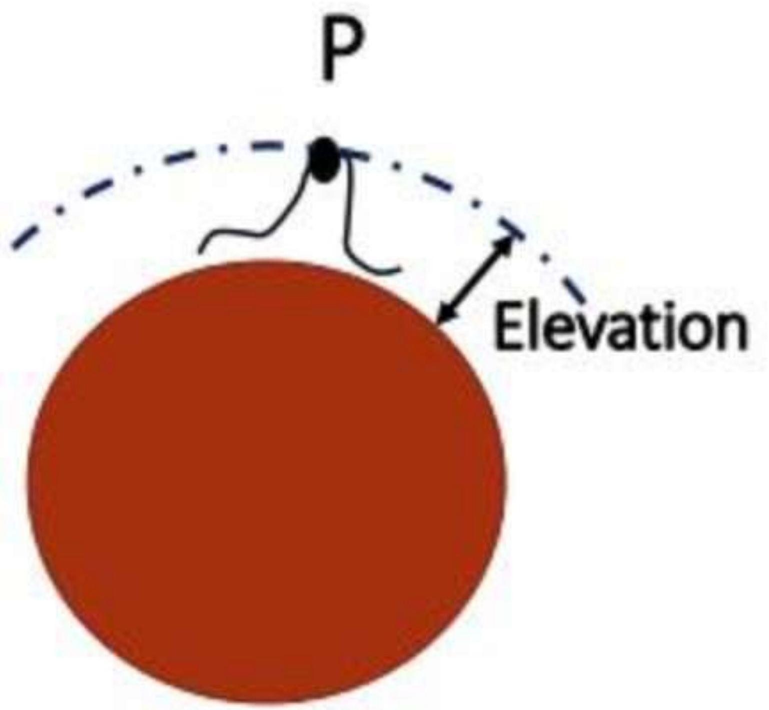
Levelling

- Horizontal Line:
  - Any line lying of on the horizontal surface
- Vertical Surface
  - At any point in a plane surface perpendicular to the horizontal surface at that point
  - Vertical surface contains the plumb line
- Datum
  - Datum is a reference level surface with reference to which elevation are measured/ referred.
  - Datum for India is Mean Sea Level at Bombay High
  - Earlier it was Karachi upto 1962.





BASIC DEFINITIONS



1) ELEVATION

- **Elevation is the vertical distance of a point above (or) below datum.**
- **Elevation are also known as 'Reduced Level Height'.**
- **Vertical distances are determined along line of Gravity.**

2) ALTITUDE

- **It is height of a point above datum.**
- **Above datum, elevation and altitude will be same thing.**

BASIC DEFINITIONS

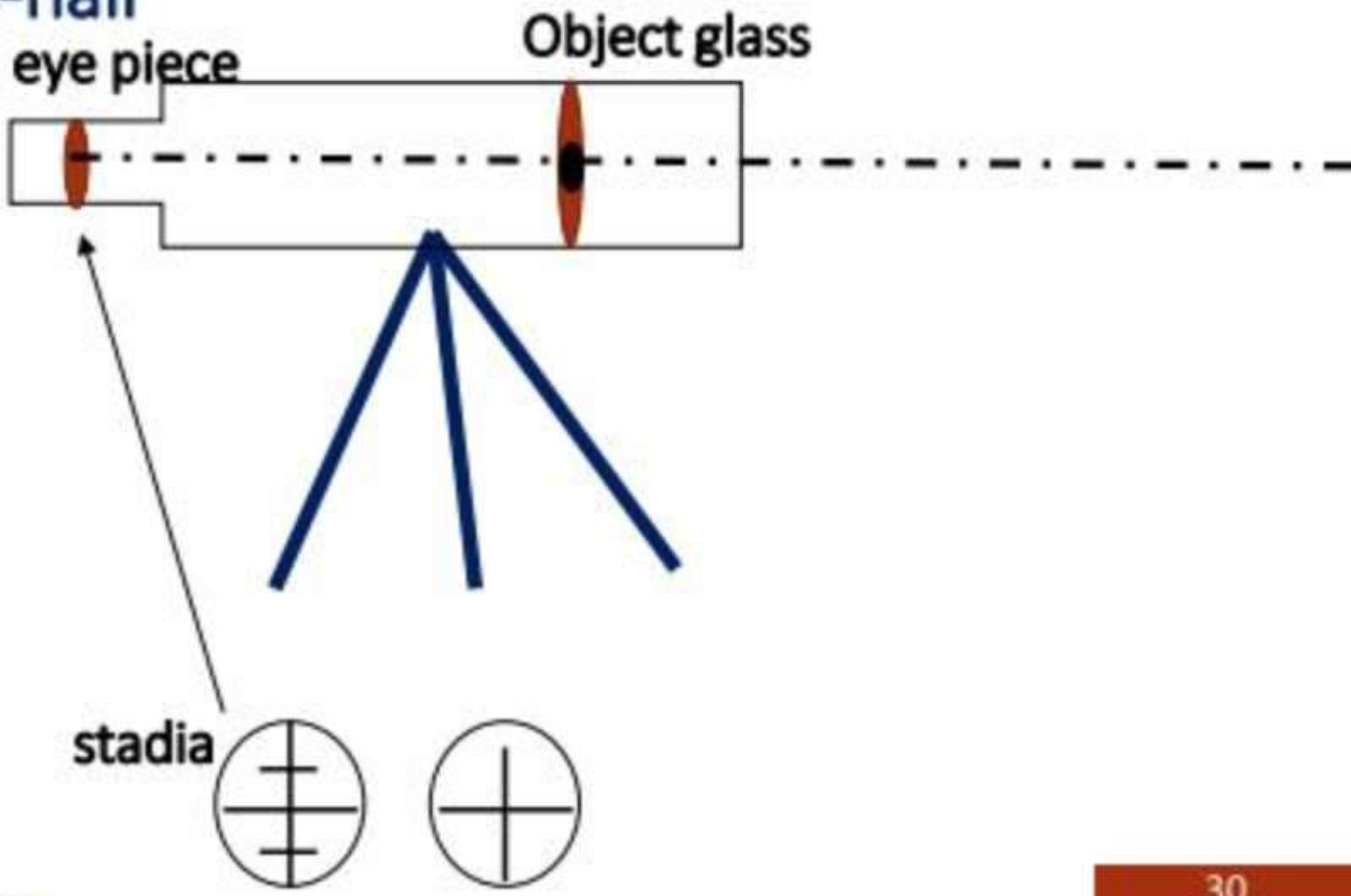
3) AXIS OF TELESCOPE

- Axis of telescope is the line joining optical centre of objective glass & centre of eye piece.

In a permanently adjusted instrument, all these lines are same

4) LINE OF SIGHT

- Line of sight is the line joining intersection of cross-hair to the optical centre of objective.



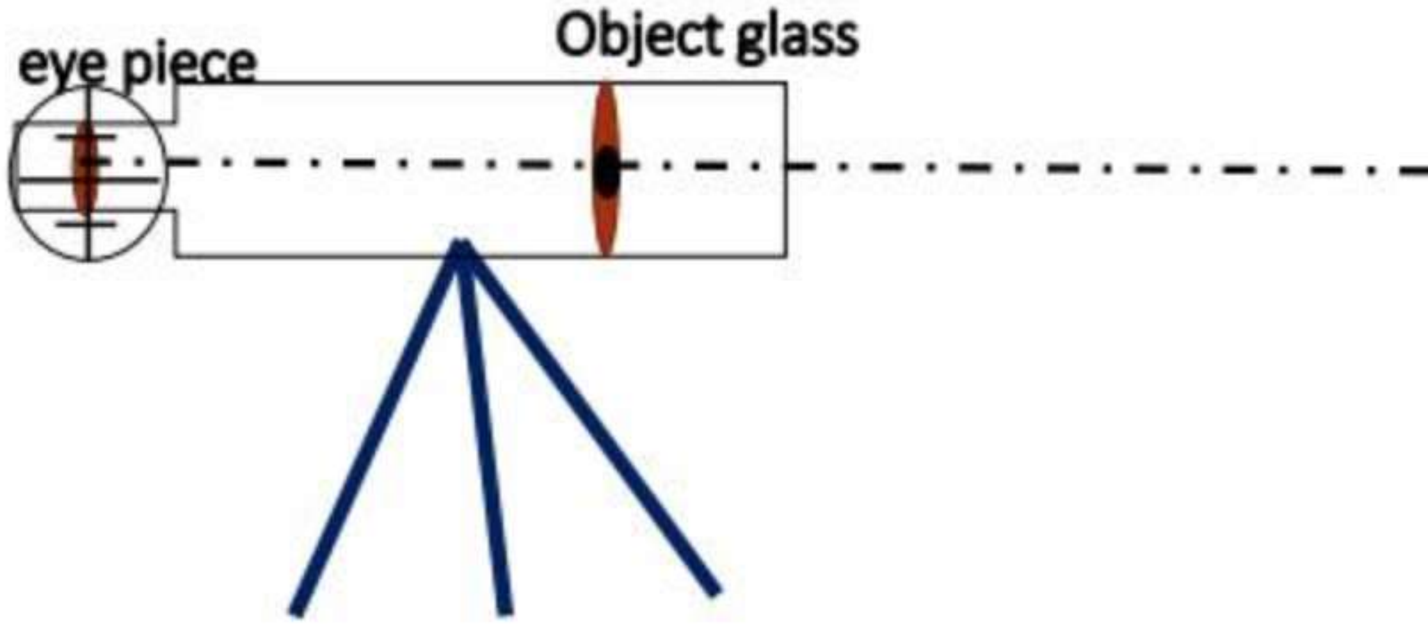
5) LINE OF COLLIMATION

- **In levelling line of sight should be horizontal while observing readings.**
- **When line of sight becomes horizontal it is called as *'line of collimation'* (or) it is line joining the intersection of cross-hair, optical centre of objective and in continuation.**

BASIC DEFINITIONS

5) LINE OF COLLIMATION

- **In levelling line of sight should be horizontal while observing readings.**
- **When line of sight becomes horizontal it is called as *'line of collimation'* (or) it is line joining the intersection of cross-hair, optical centre of objective and in continuation.**



- **Plane of Collimation: Horizontal plane formed by 360° rotation of line of collimation**

BASIC DEFINITIONS

6) HEIGHT OF INSTRUMENT

- It is RL of plane of collimation.

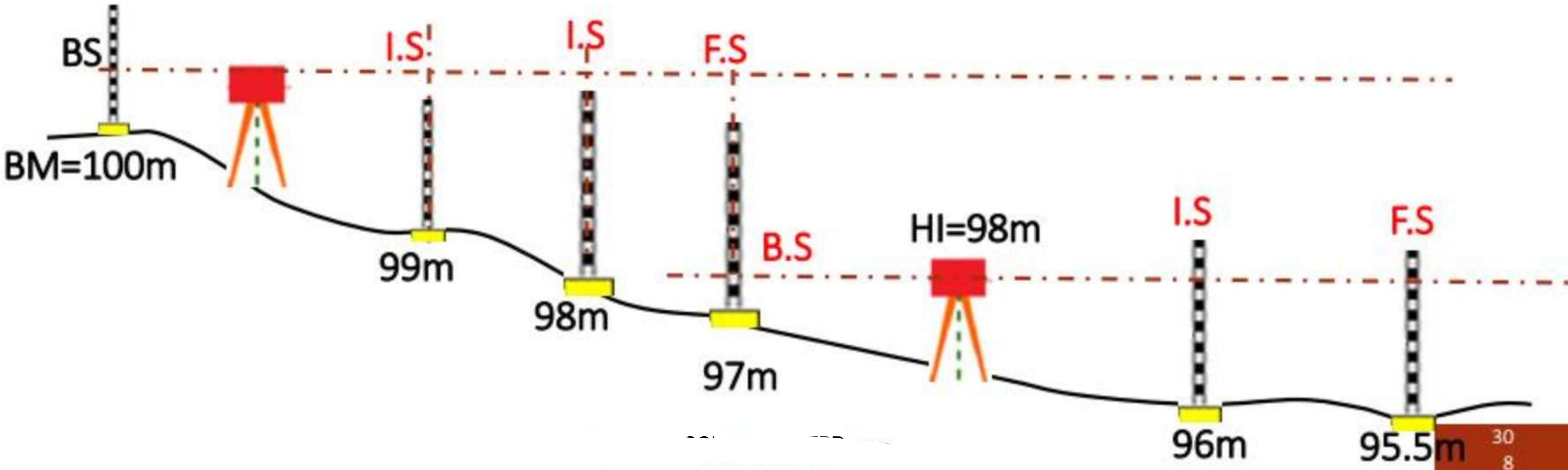
7) STATION

- Station is a point of unknown elevation where staff is held for observing readings

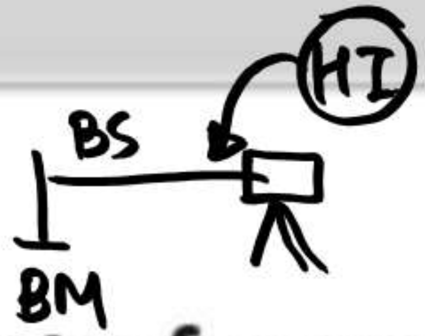
BASIC DEFINITIONS

8. Backsight (BS)

- Backsight is the staff reading taken on a point of known elevation
- It is first reading taken from after instrument is set up
- Height of instrument=RL of bench mark +Backsight



BASIC DEFINITIONS



9) FORE SIGHT

- Fore sight is the reading taken on a last point of survey or on change point i.e, just before shifting of instrument .

Elevation of staff station = H.I. – Fore Sight.

10)CHANGE POINT

- Change point is the point denoting shifting of level.
- Both B.S & F.S are taken on change point.

BASIC DEFINITIONS

11) INTERMEDIATE SIGHT

- Intermediate sight is the reading taken on a point of unknown elevation between B.S & F.S
- It should be noted that both intermediate sight and fore sight are taken at point of unknown elevation.
- But F.S. is taken either at change point (or) last point of survey, where as intermediate sight (I.S) is taken at any other point.

BASIC DEFINITIONS

12) BENCH MARK

- **Bench mark is fixed point of known R.L**
- **On the basis of degree of accuracy and permanency bench marks can be classified as below:**

a. ***GTS Bench Mark***

b. ***Temporary Bench Mark***

c. ***Permanent Bench Mark***

d. ***Arbitrary Bench Mark***

BASIC DEFINITIONS

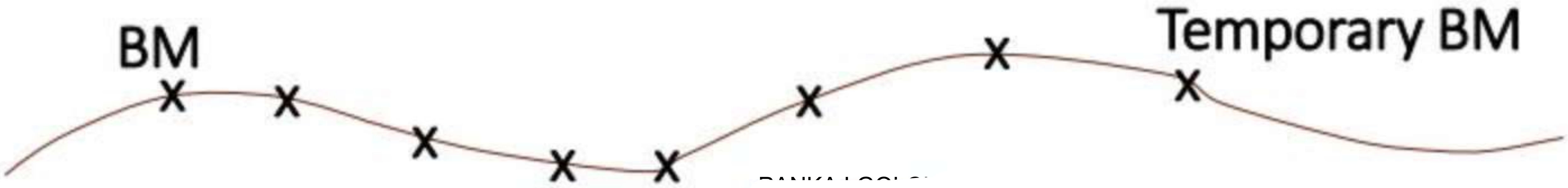
12) BENCH MARK

a. GTS Bench Mark

- **GTS (Great Trigonometrical Survey) Bench marks are established by survey of India throughout the country w.r.t. Bombay High.**

b. Temporary Bench Mark

- **These BM are temporarily established whenever required.**
- **Generally these are the points at which work is closed for a day and next day work is started.**



BASIC DEFINITIONS

12) BENCH MARK

c. Permanent Bench Mark

- Permanent Bench Marks are established at closer interval between widely spaced GTS Bench Mark.

d. Arbitrary Bench Mark

- These are bench marks whose elevation does not referred to MSL, their value is Arbitrarily assumed for small survey.

13) PARALLAX

- It is apparent movement of image.

BASIC DEFINITIONS

14) LEVEL TUBE

- With the help of level tube, vertical axis of instrument can be made to coincide with the line of gravity or line of sight can be made horizontal.
- Level tube is a glass tube sealed at both ends which is partially filled with a liquid such that an air bubble is formed in the level tube.
- The type of liquid filled should be less viscous, stable and non freezing at ordinary temperature.
- These days synthetic alcohol is used as liquid.
- Cross section of level tube is circular.

Que. 67

In reduction of levels using the Height of Instrument method, Height of instrument refers to the

(a) height of the line of sight over the instrument station

(b) height of the centre of telescope from the plane of foot screws

(c) reduced level Of the line of sight

(d) reading on the staff from the instrument

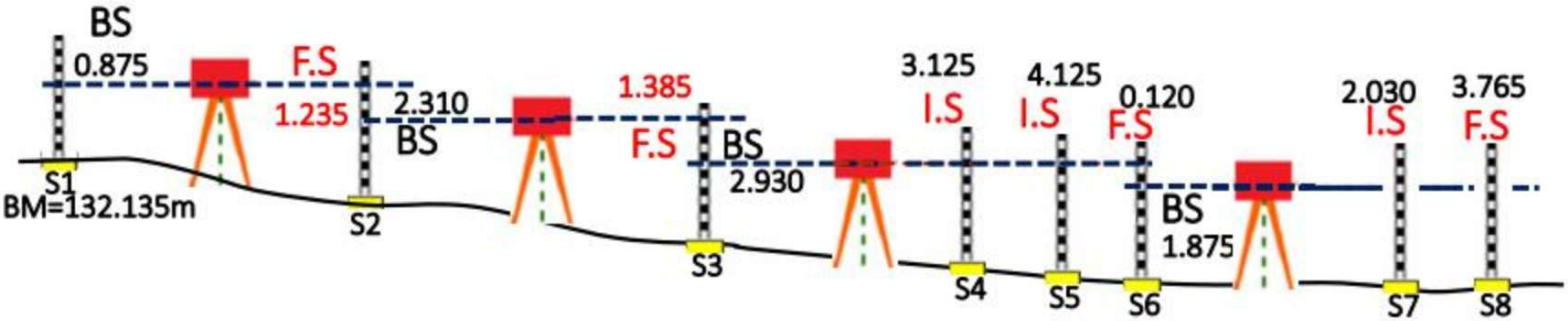
1. HEIGHT OF INSTRUMENT METHOD

- **Height of Instrument method** is more rapid, less tedious and simple. Since check on intermediate sights is not available, the mistakes in their level go unnoticed.

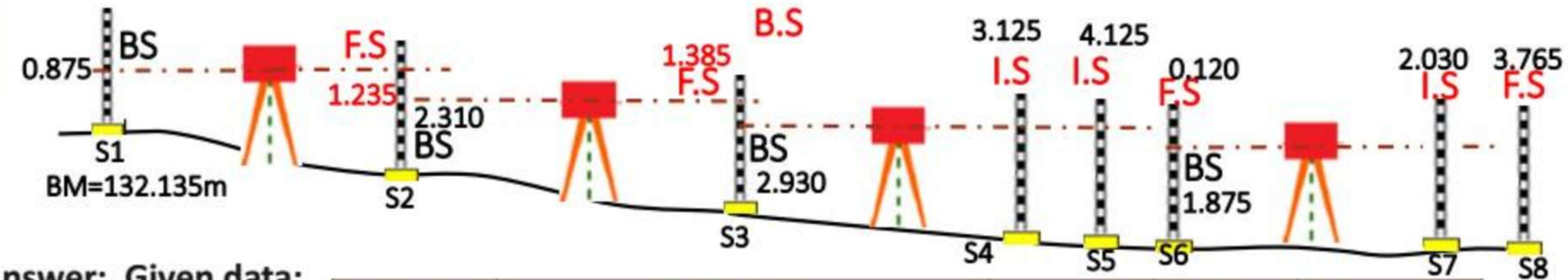
Question: The following staff readings were taken successfully with level, the instrument having been moved forward after the second, fourth and eighth reading

0.875, 1.235, 2.310, 1.385, 2.930, 3.125, 4.125, 0.120, 1.875, 2.030, 3.765

The first reading was taken on a benchmark of elevation 132.135. Enter the readings in level book form and reduce levels.



1.	0.875	BS	6.	3.125	IS
2.	1.235	FS	7.	4.125	IS
3.	2.310	BS	8.	0.120	FS
4.	1.385	FS	9.	1.875	BS
5.	2.930	BS	10.	2.030	IS
			11.	3.765	FS



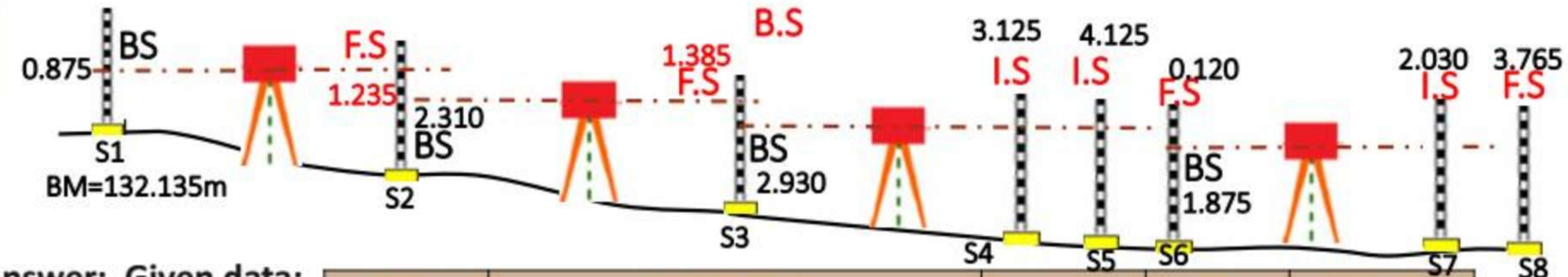
Answer: Given data:

1. 0.875 BS
2. 1.235 FS
3. 2.310 BS
4. 1.385 FS
5. 2.930 BS
6. 3.125 IS
7. 4.125 IS
8. 0.120 FS
9. 1.875 BS
10. 2.030 IS
11. 3.765 FS

Staff Station	Staff Reading			HI	RL	Remarks
	BS	IS	FS			
S1	0.875					Bench Mark
S2						
S3						
S4						
S5						
S6						
S7						
S8						

HI= RL of BM or CP + SR on BM or CP (BS)

RL of staff station= HI – IS or FS at that staff station



Answer: Given data:

1. 0.875 BS
2. 1.235 FS
3. 2.310 BS
4. 1.385 FS
5. 2.930 BS
6. 3.125 IS
7. 4.125 IS
8. 0.120 FS
9. 1.875 BS
10. 2.030 IS
11. 3.765 FS

Staff Station	Staff Reading			HI	RL	Remarks
	BS	IS	FS			
S1	0.875			133.01	132.135	Bench Mark
S2	2.310		1.235	134.085	131.775	CP1
S3	2.930		1.385	135.63	132.70	CP2
S4		3.125			132.505	
S5		4.125			131.505	
S6	1.875		0.120	137.385	135.510	CP3
S7		2.030			135.355	
S8			3.765		133.620	

HI= RL of BM or CP + SR on BM or CP (BS)

RL of staff station= HI – IS or FS at that staff station

Answer: Given data:

1. 0.875 BS
2. 1.235 FS
3. 2.310 BS
4. 1.385 FS
5. 2.930 BS
6. 3.125 IS
7. 4.125 IS
8. 0.120 FS
9. 1.875 BS
10. 2.030 IS
11. 3.765 FS

Staff Station	Staff Reading			HI	RL	Remarks
	BS	IS	FS			
S1	0.875			133.01	132.135	Bench Mark
S2	2.310		1.235	134.085	131.775	CP1
S3	2.930		1.385	135.63	132.70	CP2
S4		3.125			132.705	
S5		4.125			131.505	
S6	1.875		0.120	137.385	135.510	CP3
S7		2.030			135.355	
S8			3.765		133.620	

Sum of Backsight = 7.990

Sum of foresight = 6.505

$\Sigma BS - \Sigma FS$ =7.990-6.505=1.485m

Last RL – First RL = 133.620-132.135

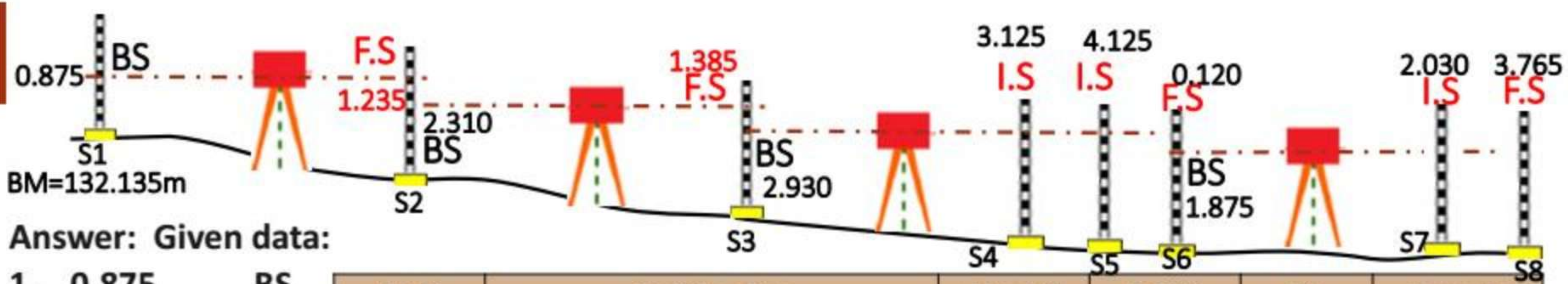
= 1.485

Check OK!

2. Rise and Fall Method

- **Rise and fall method** is more accurate as there is complete check on calculations of RLs of intermediate sites also

- **Height of Instrument method** is more rapid, less tedious and simple. Since check on intermediate sights is not available, the mistakes in their level go unnoticed.



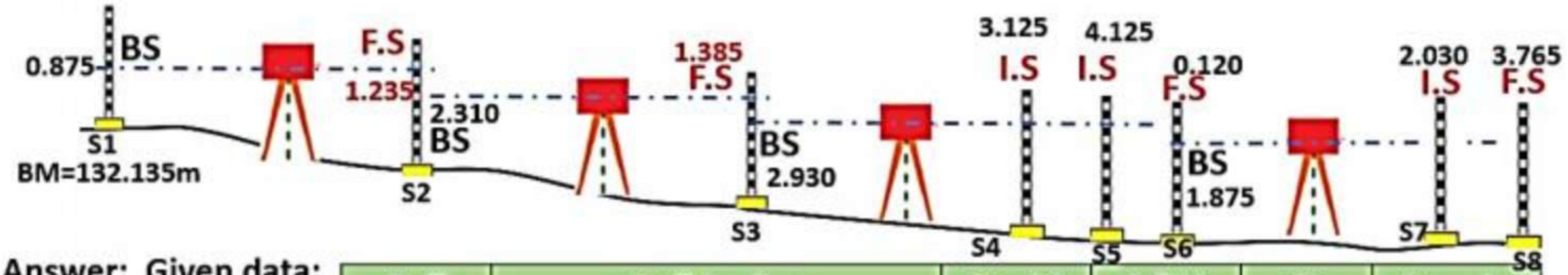
Answer: Given data:

1. 0.875 BS
2. 1.235 FS
3. 2.310 BS
4. 1.385 FS
5. 2.930 BS
6. 3.125 IS
7. 4.125 IS
8. 0.120 FS
9. 1.875 BS
10. 2.030 IS
11. 3.765 FS

Staff Station	Staff Reading			Rise (+)	Fall (-)	RL	Remarks
	BS	IS	FS				
S1	0.875					132.135	Bench Mark
S2	2.310		1.235		-0.360	131.775	CP1
S3	2.930		1.385	+0.925		132.70	CP2
S4		3.125			-0.195	132.505	
S5		4.125			-1.000	131.505	
S6	1.875		0.120	+4.005		135.510	CP3
S7		2.030			-0.155	135.355	
S8			3.765		-1.735	133.620	

RL of any staff station = RL of previous SS $\pm$ rise/fall

Rise/fall of any staff station = SR of previous SS − SR of this station



Answer: Given data:

1. 0.875 BS
2. 1.235 FS
3. 2.310 BSx
4. 1.385 FS
5. 2.930 BS
6. 3.125 IS
7. 4.125 IS
8. 0.120 FS
9. 1.875 BS
10. 2.030 IS
11. 3.765 FS

Staff Station	Staff Reading			Rise (+)	Fall (-)	RL	Remarks
	BS	IS	FS				
S1	0.875					132.135	Bench Mark
S2	2.310		1.235		-0.360	131.775	CP1
S3	2.930		1.385	+0.925		132.70	CP2
S4		3.125			-0.195	132.505	
S5		4.125			-1.000	131.505	
S6	1.875		0.120	+4.005		135.510	CP3
S7		2.030			-0.155	135.355	
S8			3.765		-1.735	133.620	

RL of any staff station = RL of previous SS ± rise/fall

Rise/fall of any staff station = SR of previous SS − SR of this station

EFFECT OF CURVATURE

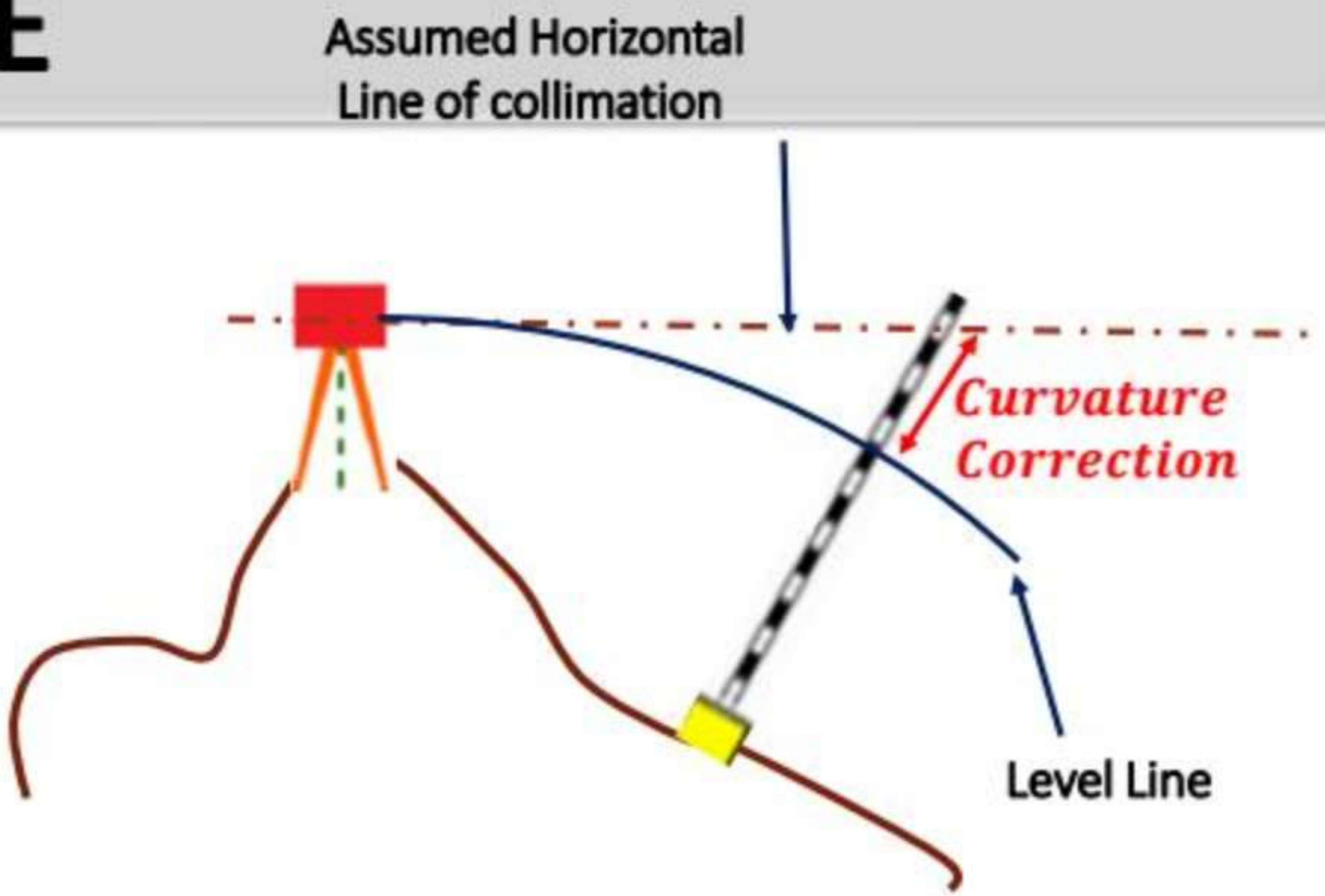
- E = M.V – T.V (M.V > T.V)
- Error due to curvature is always positive.
- So correction will be negative.
- CORRECTION DUE TO CURVATURE is given by

$$C_c = \frac{d^2}{2R}(-ve) \Rightarrow \qquad C_C = -0.0785d^2$$

R=6370 km

d = distance between instrument and staff station (in km)

C_c = in m



- Effect of curvature occurs because the difference between level line and horizontal line increases as the distance of the staff station from the instrument station is increased.
- Level line is a curved line but line of collimation is a horizontal line which is tangential to the level line.
- Due to curvature of Earth points appear to be lower than actually they are.

EFFECT OF REFRACTION

- E = M.V – T.V (M.V < T.V)
- Error due to refraction is always **negative**.
- So correction will be **positive**.
- CORRECTION DUE TO REFRACTION is given by

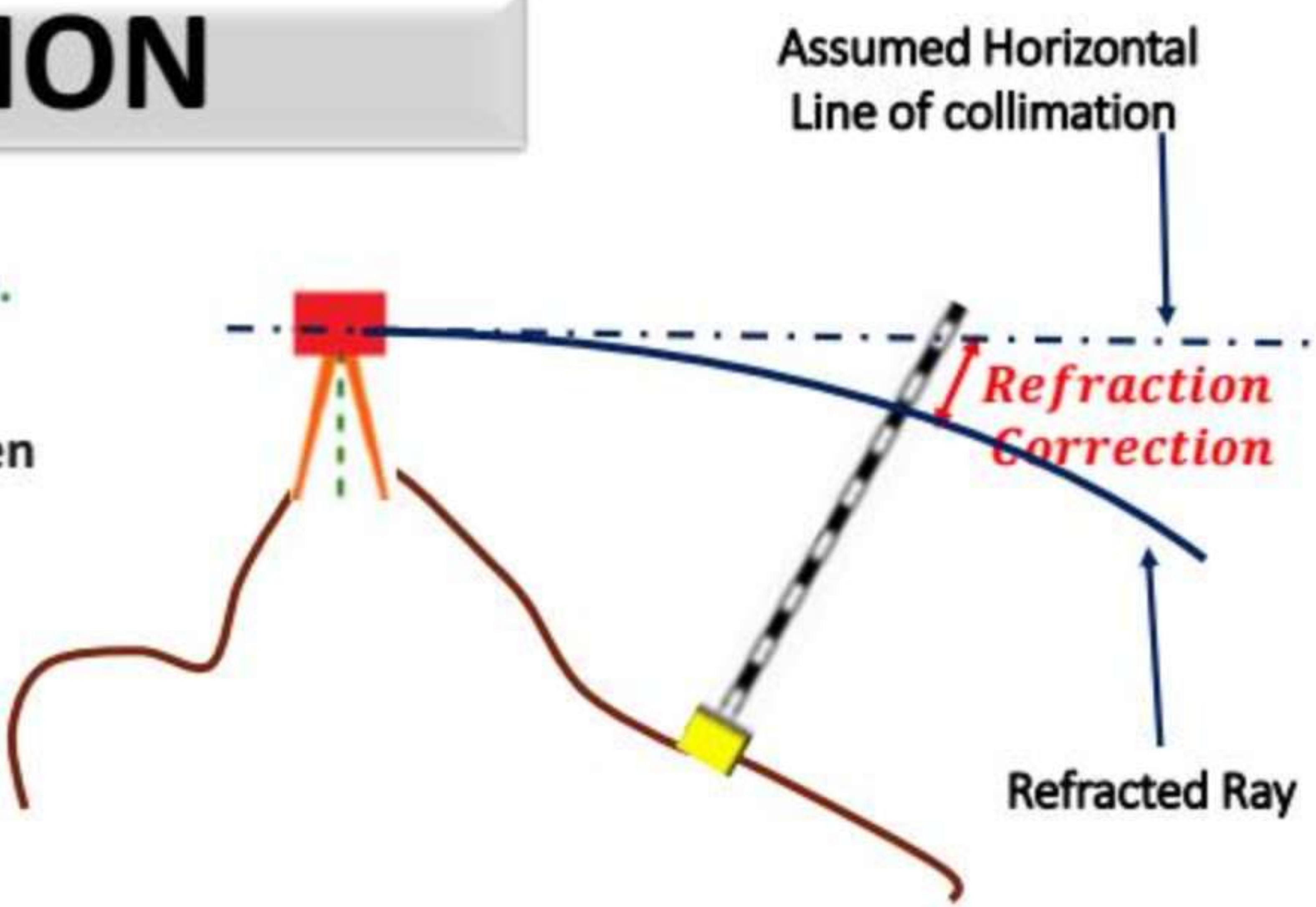
$$C_r = \frac{1}{7}\,\frac{d^2}{2R}\,(+ve) \Rightarrow \qquad C_r = \frac{1}{7}\,|cc|$$

R=6370 km

$$C_r = 0.0112d^2$$

d = distance between instrument and staff station (in km)

C_r = in m



- Density of air in the atmosphere decreases with the increase in altitude as air is denser near the earth surface.
- A ray of light travels from thinner medium to denser medium, therefore it bends towards the normal.
- Hence line of sight does not remains horizontal but it bends towards the centre of the earth, i.e, downwards.

COMBINED CORRECTION

$C_r = \frac{6}{7}\frac{d^2}{2R}(-ve) \Rightarrow$

R=6370 km

$$C = C_c + C_r$$

$$C = -0.0673d^2$$

where

C is in m

d is in km

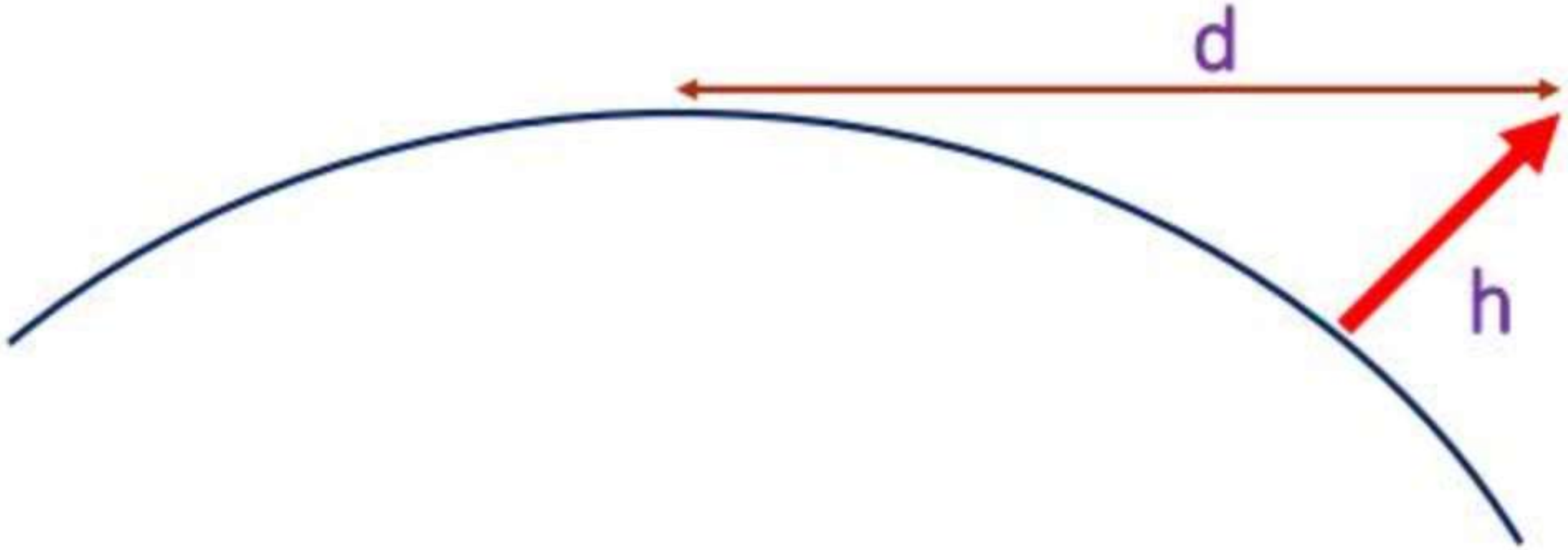
For a distance less than 250m, combined correction is neglected in ordinary levelling.

DISTANCE OF VISIBLE HORIZON

$$h = 0.0673d^2$$

$$d = \sqrt{\frac{h}{0.0673}}$$

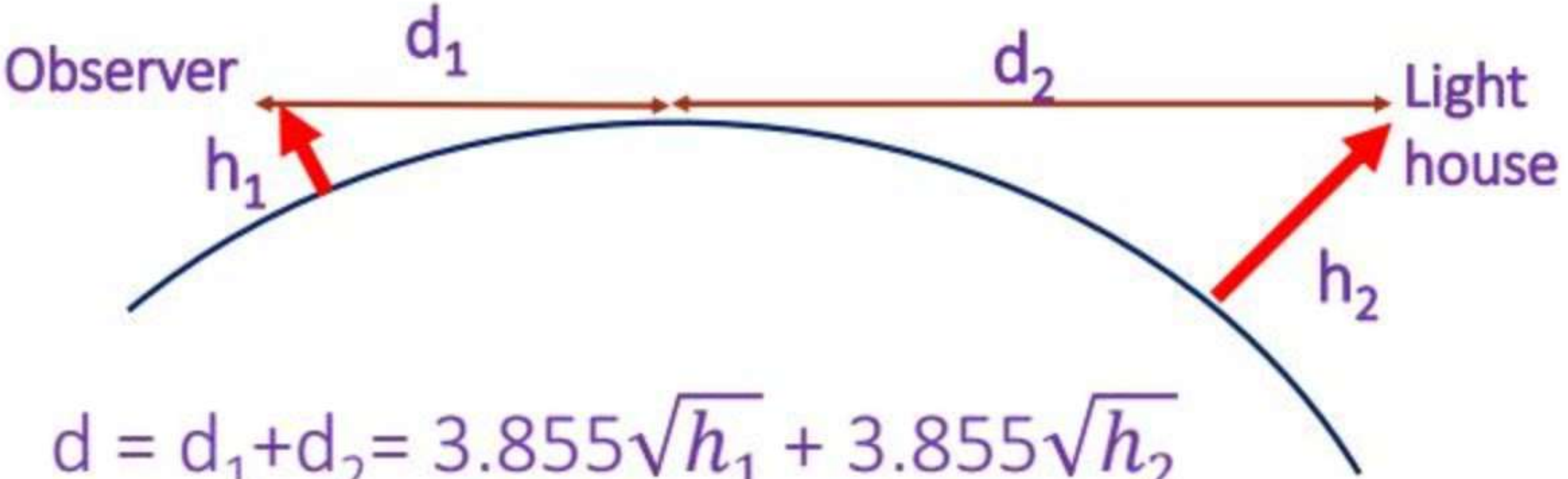
$$d = 3.855\sqrt{h}$$



where

h is in m

d is in km



$$d = d_1 + d_2 = 3.855\sqrt{h_1} + 3.855\sqrt{h_2}$$

TYPES OF LEVELLING

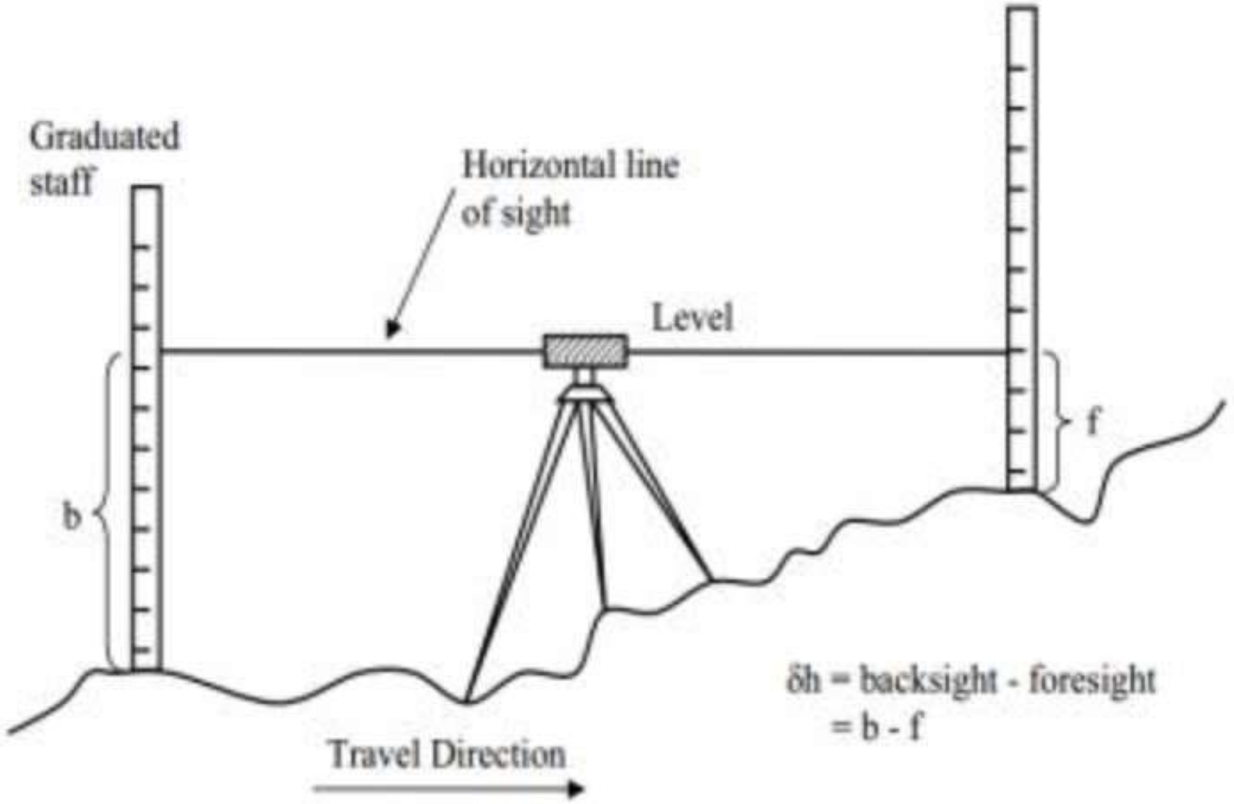
Different types of levelling are:

1. Direct / Spirit Levelling
2. Trigonometric Levelling
3. Barometric Levelling
4. Hypsometric Levelling

TYPES OF LEVELLING

1. *DIRECT / SPIRIT LEVELLING*

- It is most common method of leveling.
- A spirit level fixed to the telescope of a leveling instrument is used to make line of sight horizontal.
- Vertical distances are measured w.r.t. horizontal line of sight.
- Classification of Direct Levelling
  - a) Simple Levelling
  - b) Differential Levelling
    - i. Check Levelling
    - ii. Fly Levelling
    - iii. Profile Levelling
    - iv. Cross sectional Levelling
    - v. Reciprocal Levelling



TYPES OF LEVELLING

1) DIRECT / SPIRIT LEVELLING

a) Simple Levelling

- **In this only one setting of instrument is done to determine the height of instrument.**

b) Differential Levelling

- **It is done to determine elevation between two points by multiple setting of instrument.**
- **It is done when two points are at large distance, difference of elevation between two points is large and some obstacles are there between the two points.**

TYPES OF LEVELLING

1) DIRECT / SPIRIT LEVELLING

b) Differential Levelling

i. Check Levelling

- It is done for the purpose of checking of elevations which are already obtained.
- Generally it is done at the end of each days work from the last point to the starting point of that day.

TYPES OF LEVELLING

1) DIRECT / SPIRIT LEVELLING

b) Differential Levelling

ii. Fly Levelling

- It is used for determination of approximate elevations of different points.
- Line of sight is as long as possible.
- Only B.S and F.S are taken.
- It is done when time available is less and accuracy desired is low.

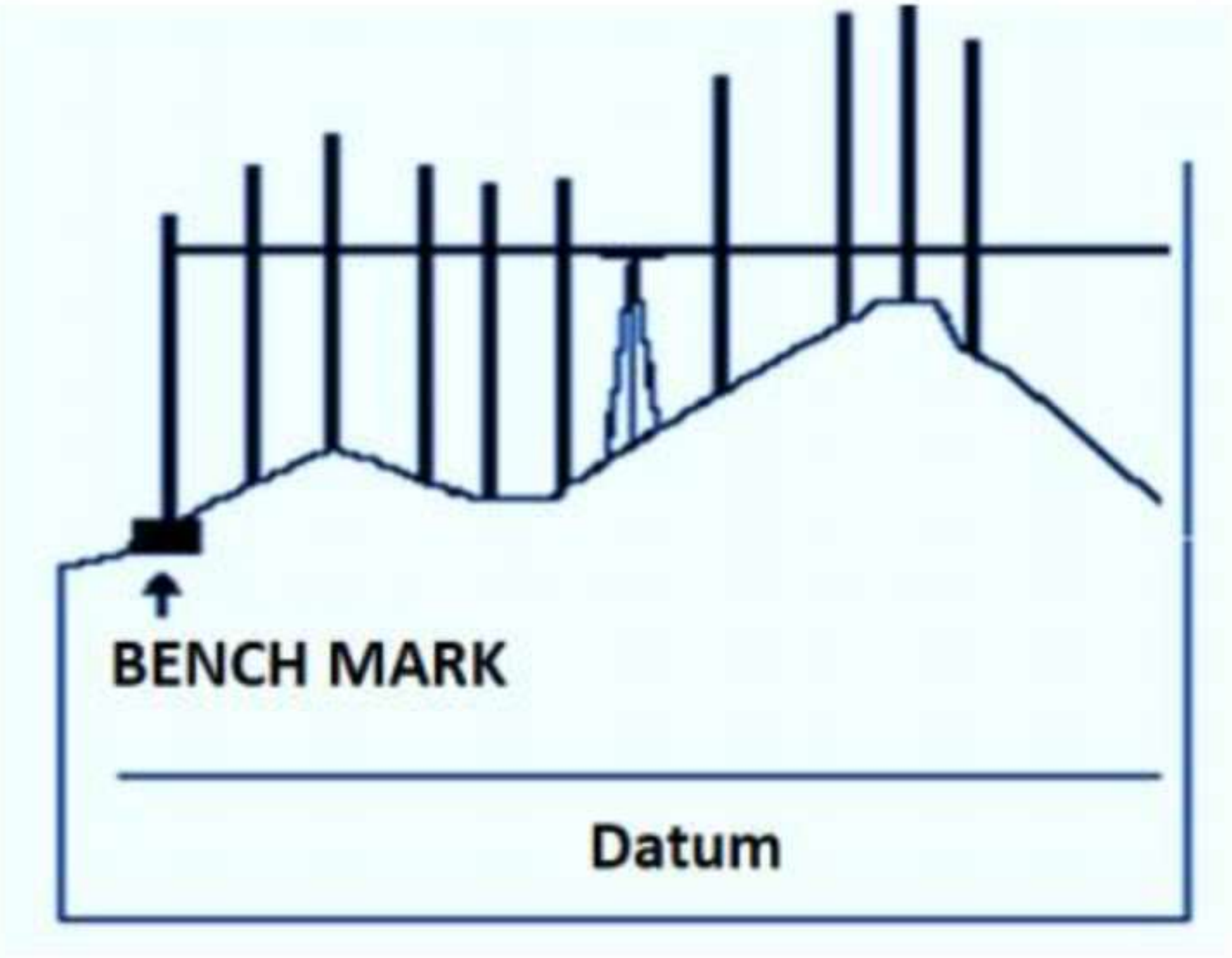
TYPES OF LEVELLING

1) DIRECT / SPIRIT LEVELLING

b) Differential Levelling

iii. Profile Levelling

- It is done for the purpose of determining elevations of ground surface along a fixed line.
- Fixed line is generally centre line of the proposed project.
- It is used to establish gradient of the project.



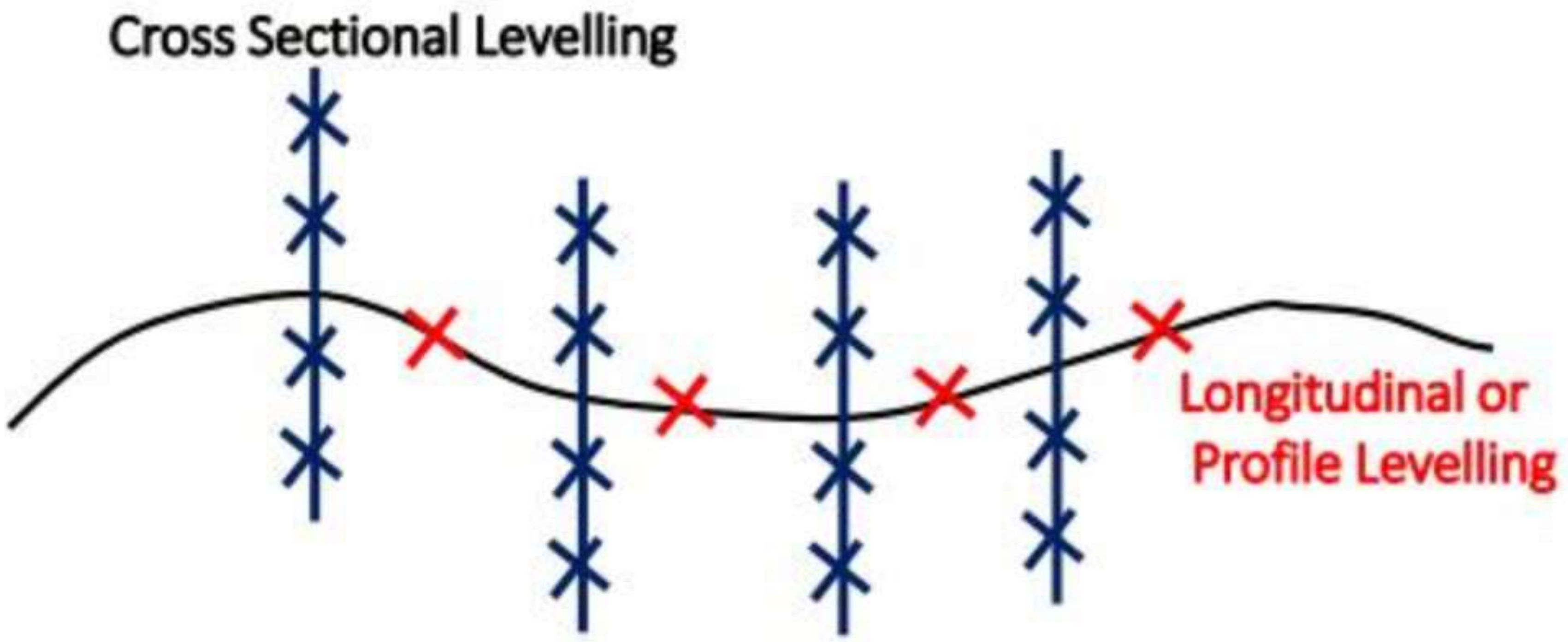
TYPES OF LEVELLING

1) DIRECT / SPIRIT LEVELLING

b) Differential Levelling

iv. Cross Sectional Levelling

- It is done to determine difference of elevation of ground surface along the lines perpendicular to the centre line.
- Generally profile levelling and cross sectional levelling are done simultaneously.



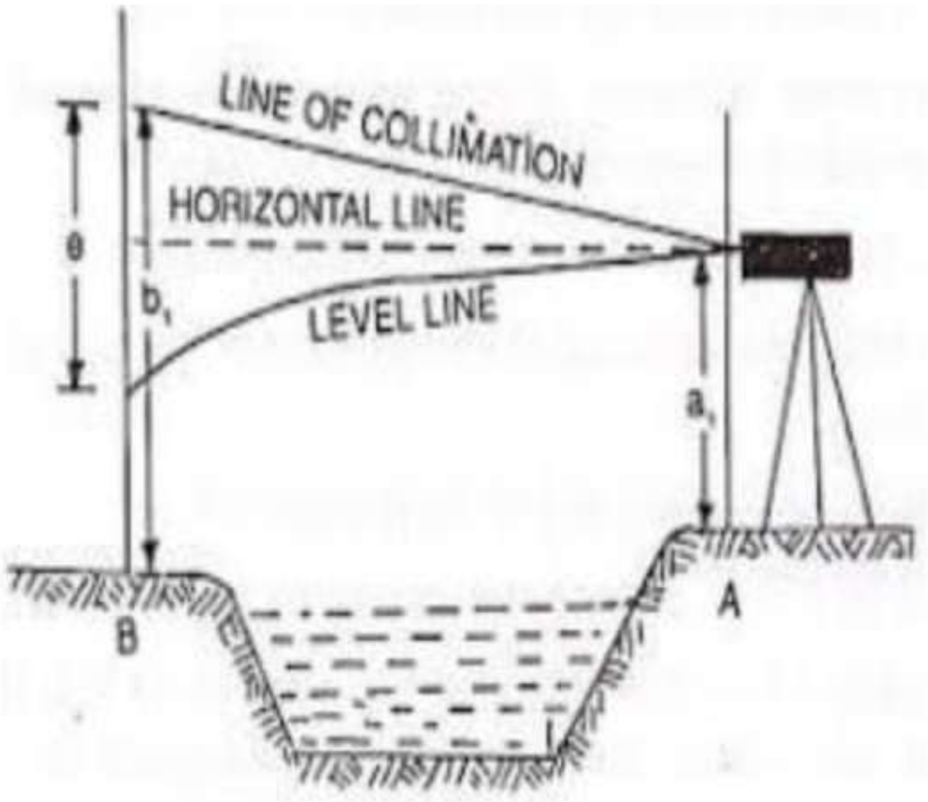
TYPES OF LEVELLING

1) DIRECT / SPIRIT LEVELLING

b) Differential Levelling

v. Reciprocal Levelling

- It is done to determine height difference between two points which are situated quite a large distance apart and it is not possible to set up the instrument in between these points.
- Eg. Opposite banks of river
- It helps in eliminating curvature error, refraction error and collimation error.

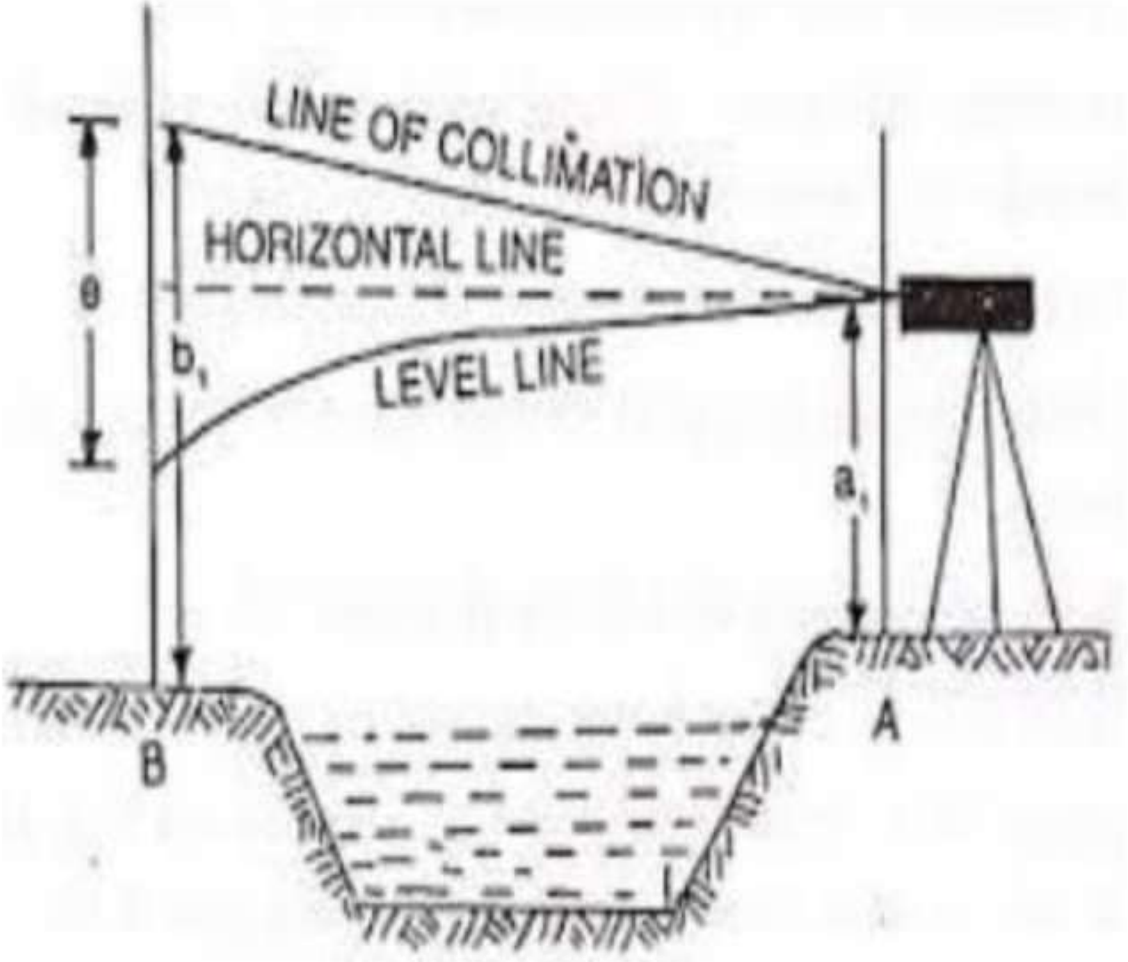


TYPES OF LEVELLING

1) DIRECT / SPIRIT LEVELLING

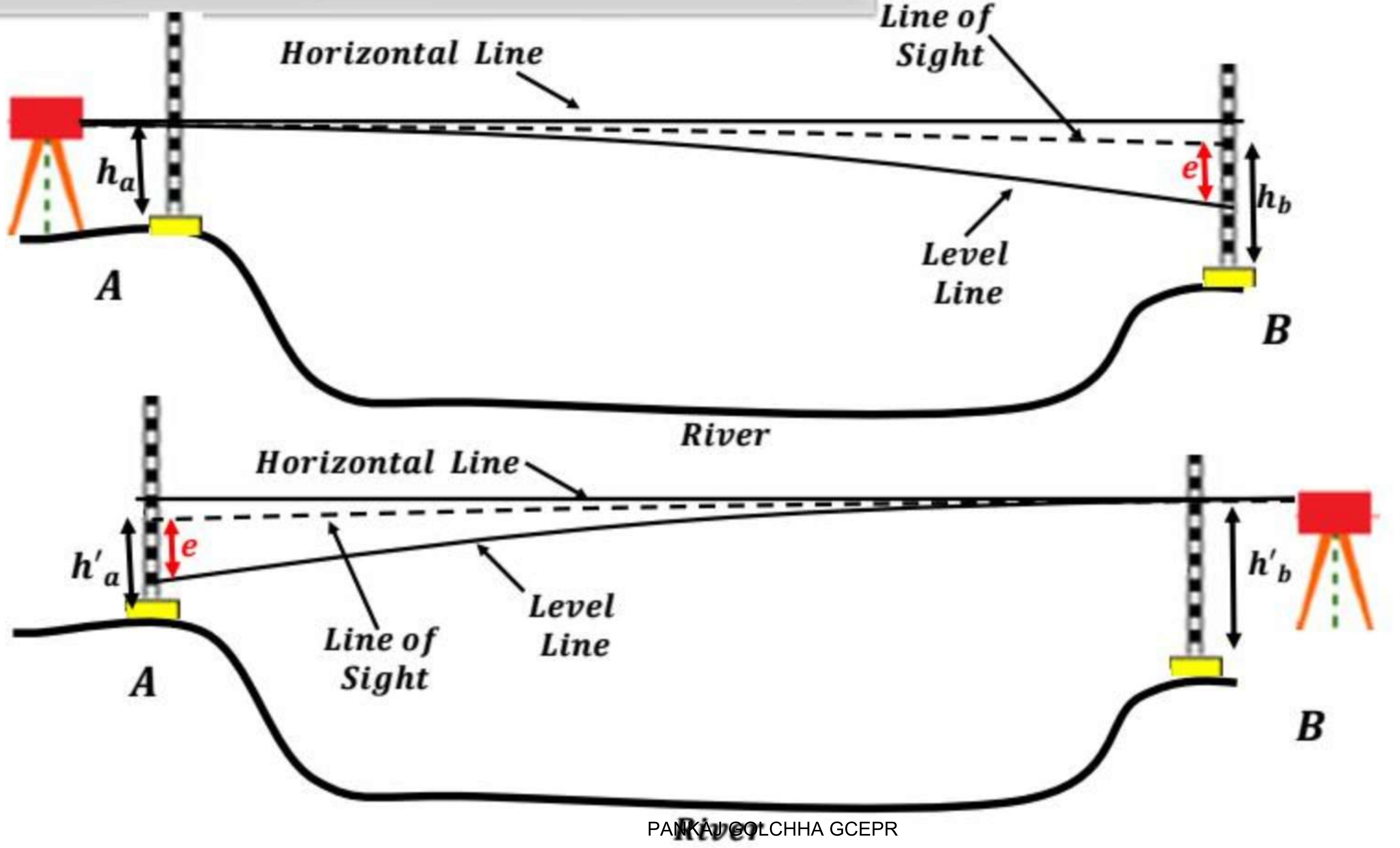
b) Differential Levelling

v. Reciprocal Levelling



- Suitable for levelling across a river, or nay obstacle requiring a ling sight distance between two points so situated that no place for the level can be found from which Fore sight and Back sight can be equal, then reciprocal levelling can be used to obtain accuracy.
- Reciprocal levelling eliminates
  - Error in instrument adjustment
  - Combined effect of Earth's curvature and refraction correction
  - Variation in average refraction

RECIPROCAL LEVELLING



RECIPROCAL LEVELLING

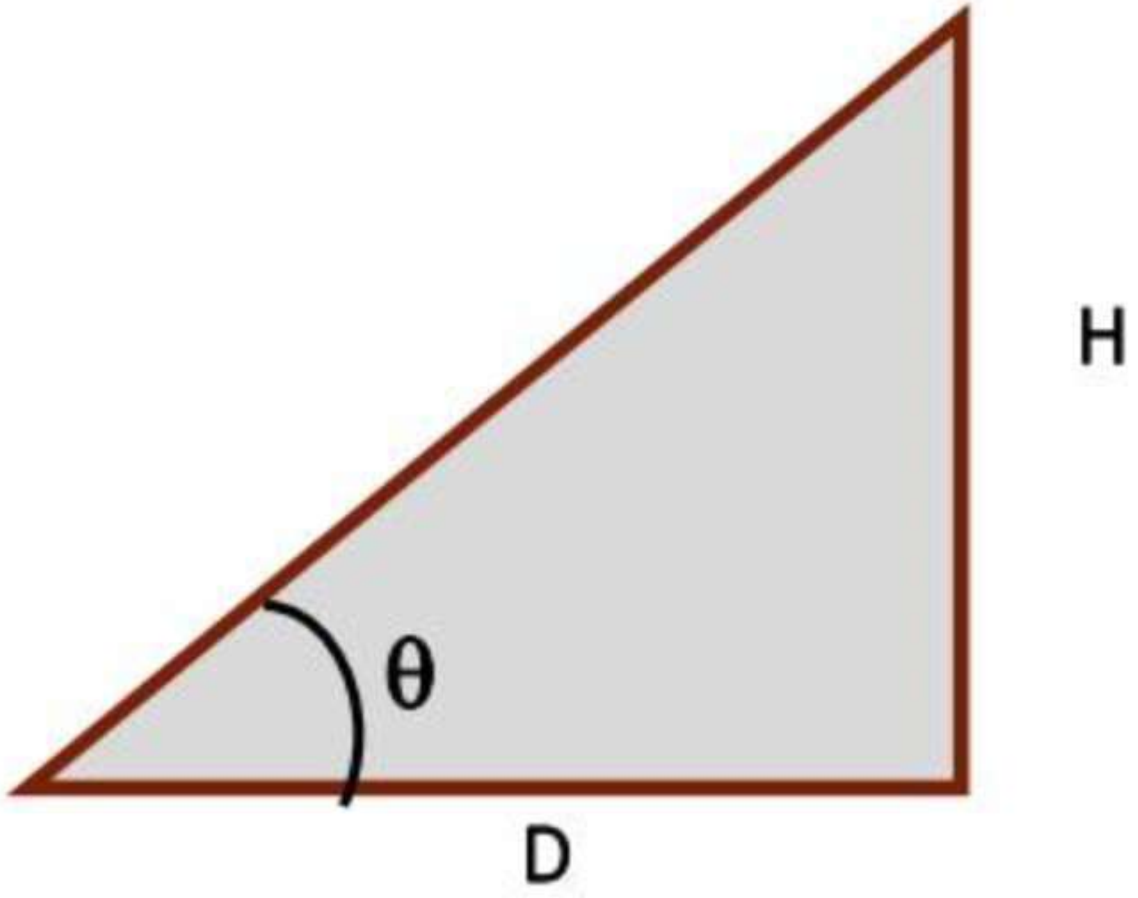
- True Difference in elevation is equal to average of the apparent difference in elevation in both cases

$$\boldsymbol{True\ Difference\ in\ elevation} = \frac{(h_a - h_b) + (h'_a - h'_b)}{2}$$

TYPES OF LEVELLING

2) TRIGONOMETRIC LEVELLING

- It is a type of indirect levelling in which difference of elevation is determined indirectly from horizontal distance 'D' and vertical angle 'θ'.
- $H = D\tan\theta$



TYPES OF LEVELLING

3) BAROMETRIC LEVELLING

- This is an indirect method of levelling in which elevations are determined indirectly from change in atmosphere pressure.
- Atmospheric pressure decreases with the increase in elevation.
- Altimeter, Aneroid, Barometer are used for determining change in atmospheric pressure.
- Altimeters are used for determining altitude of an aeroplane.
- Altimetry may be depicted most accurately by 'CONTOUR LINES.'
- Barometric levelling is performed by Altimeters.

TYPES OF LEVELLING

4) HYPSOMETRIC LEVELLING

- It is a process of determining elevation of various points by observing temperature at which boiling of water takes place.
- As altitude increases, boiling point of water decreases.

SIMPLE LEVELLING

- Level is set up at a suitable place in between end stations.
- Instrument need not to be in line with end station.
- R.L of instrument station is never determined.
- Line of sight should be horizontal and staff should be vertical.
- To ensure the verticality of the staff, staff is slightly waved towards the instrument and then away from the instrument. This process is called as ROCKING OF STAFF.

SIMPLE LEVELLING

- **SHIMMER**
  - ➢Very intense sunshine causes air close to earth to shimmer, hence we avoid staff reading less than 0.5m.

- **LEVEL FIELD BOOK**
  - ➢It is used for recording and reducing staff reading.
  - ➢It is done by two methods:

a) Height Of Instrument

b) Rise And Fall Method

SIMPLE LEVELLING

- **TEMPORARY ADJUSTMENT OF LEVEL**
  - These adjustments are required at each station or are made at every instrument setting

1. **Setting up the level**
   - Fix the instrument, level by leg adjustment initially
2. **Levelling**
   - After levelling approximately, accurate levelling is done with foot screws and level tube on plate level
3. **Elimination of Parallax**
   - Parallax is when the image formed by the objective is not in the plane of cross hair
   - It can be eliminated by focusing the eye piece for distinct vision of cross hair and by focusing the objective to bring image in plane of cross hair

SIMPLE LEVELLING

PERMANENT ADJUSTMENT OF DUMPY LEVEL

- Axis of level tube should be perpendicular to vertical axis of instrument.
- This adjustment is not required in case of tilting level.
- Axis of level tube should be parallel to line of sight.
- Horizontal cross hair should lie in a plane perpendicular to vertical axis of instrument.
- When line of collimation is inclined to the horizontal plane if air bubble is in the centre, this error is called *COLLIMATION ERROR*.
- To correct this error, we have TWO PEG TEST.

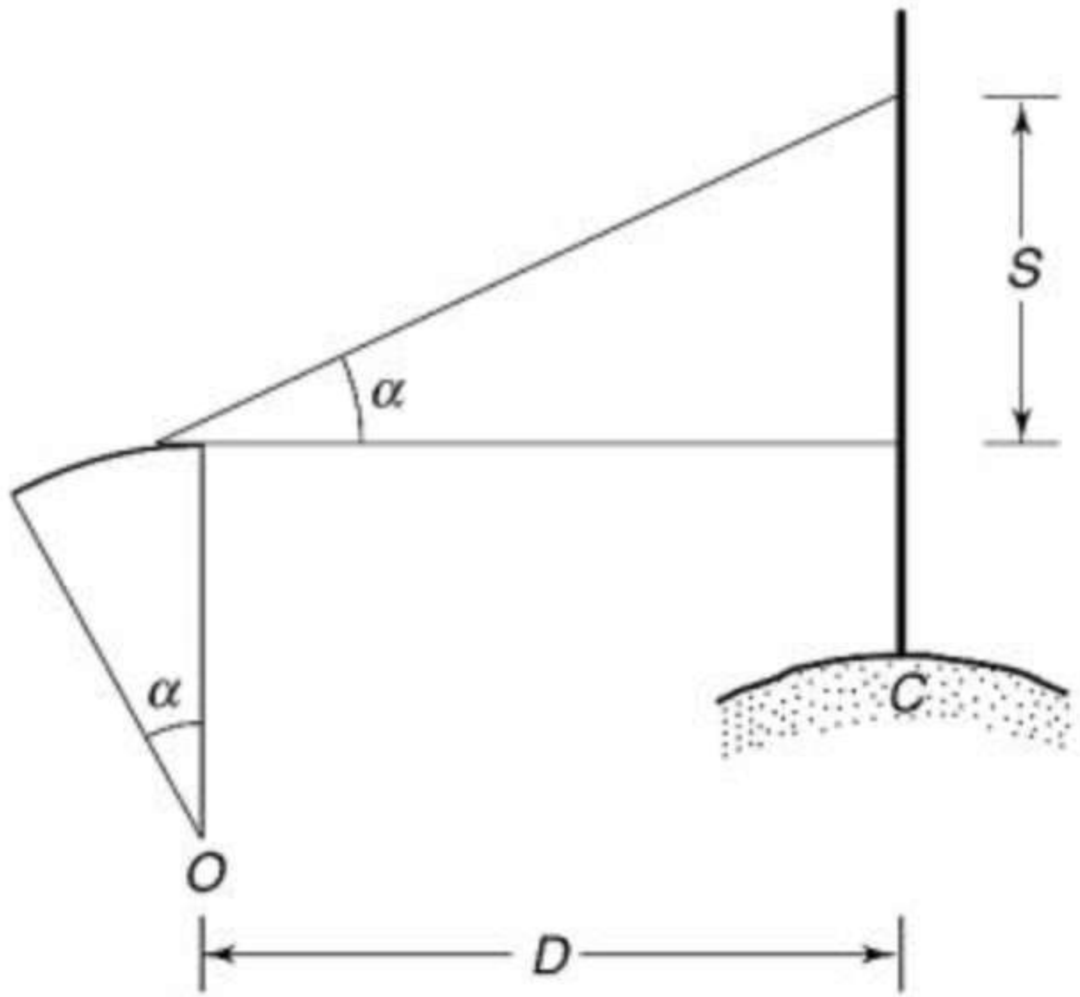
SENSITIVITY OF LEVEL TUBE

- Sensitivity of the level tube is expressed in terms of angle in seconds subtended at the centre by an arc equal to 1 division of the level tube.
- Radius of upper surface of the tube is a measure of sensitivity of level tube.
- If the radius is large, then bubble tube will be more sensitive.
- Sensitivity can be changed by changing following parameters:

1. Radius of curvature of the internal surface: Larger the radius, greater is the sensitiveness.
2. Diameter of the level tube: Larger the diameter, greater is the sensitiveness.
3. Length of the bubble: Larger the length, greater is the sensitiveness.
4. Viscosity and surface tension of the liquid: Lesser the viscosity, more is the sensitiveness.
5. Smoothness of the finish of the internal surface of the tube: Greater the smoothness, more is the sensitivity.

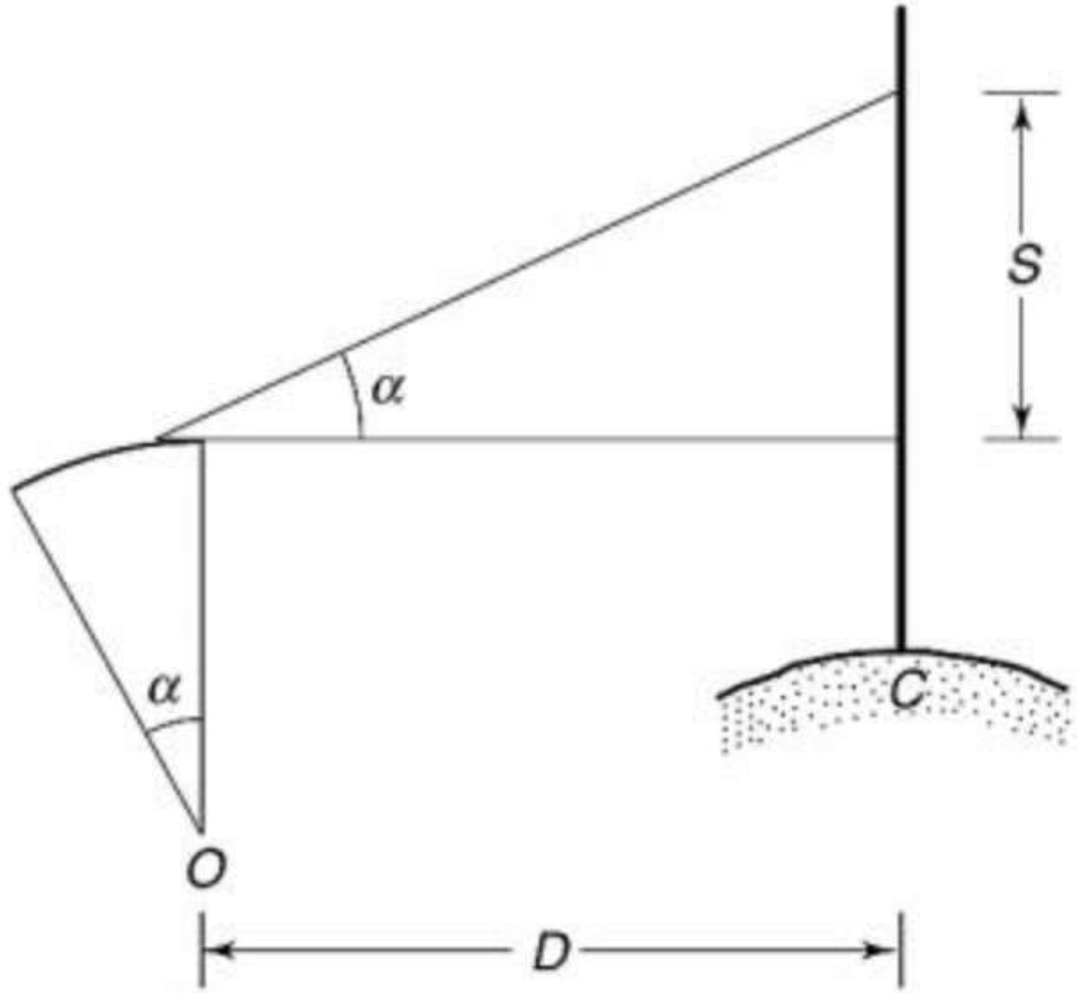
SENSITIVITY OF LEVEL TUBE

- **MEASUREMENT OF SESITIVITY**
  1. Fix two points at a known distance apart, say 100 m.
  2. Set up and level the instrument at O
  3. Take the reading on staff held vertical at C.
  4. By turning the foot screw beneath the telescope, move the bubble to n divisions.
  5. Read the staff again
  6. Find the difference in the two staff readings.



SENSITIVITY OF LEVEL TUBE

$$\alpha = S/D = n \times (l/R)$$



α = angle between the line of sights in radians,
D = distance of the instrument from the staff,
n = number of divisions through which the bubble is moved,
R = radius of curvature of tube,
S = staff intercept and
l = length of one division of bubble tube (usually 2 mm).

$$R = n\, l\, D/S$$

and $$l/R = S/nD$$

or $$\boxed{\alpha' = l/R = (S/nD)} \times 206\,265 \quad \text{(in seconds)}$$

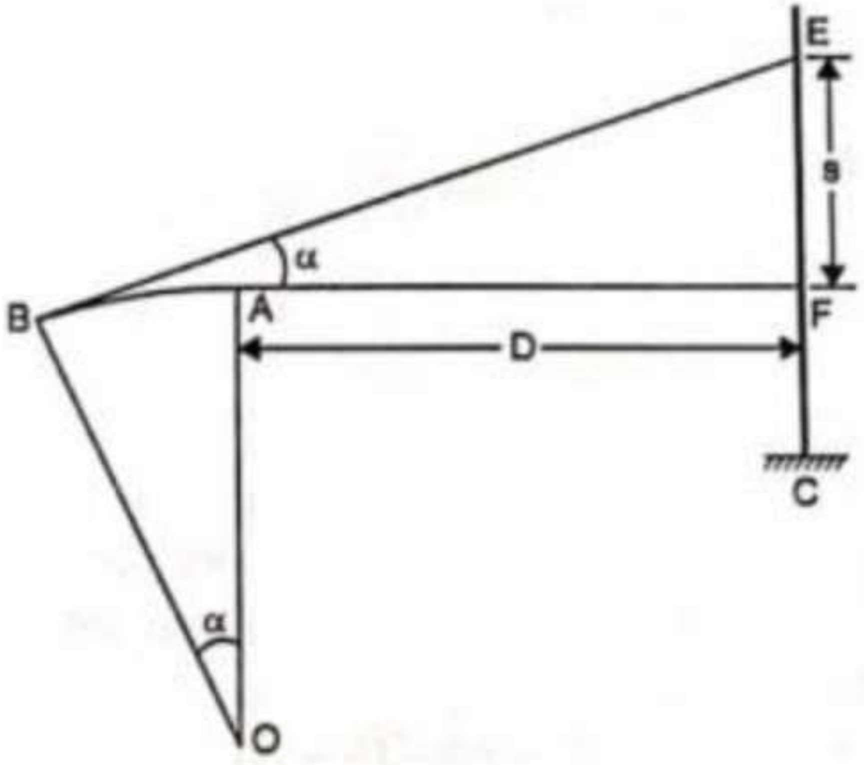
where α' = sensitivity of bubble tube.

SENSITIVITY OF LEVEL TUBE

- Sensitivity of bubble tube is defined as angular value of one division of the bubble tube. Generally linear value of one division is kept as 2mm.
- Length of air bubble can vary under the action of gravity or change in temperature.
- Determination of sensitivity

$$\alpha = \frac{nd}{R} = \frac{S}{D}$$

$$\alpha' = \frac{d}{R} = \frac{S}{nD}$$



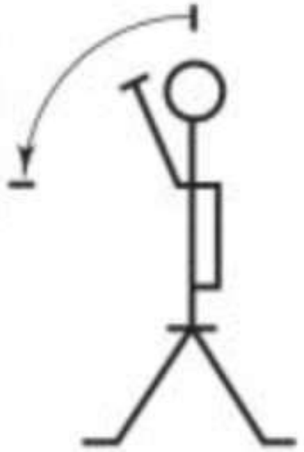
S – Staff intercept

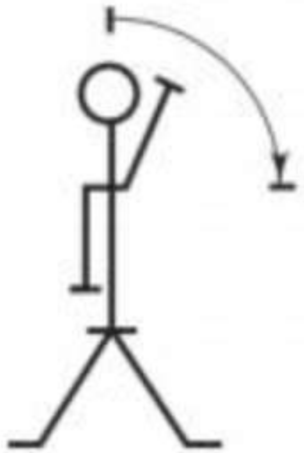
n – no. of division moved by air bubble

D – horizontal distance between vertical axis of instrument and staff station

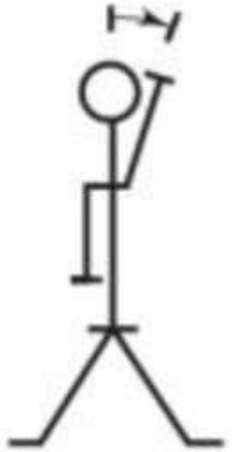
HAND SIGNALS DURING LEVELLING

Fig	*Signal*	*Message*
(a)	Movement of left arm over 90°.	Move to my left.
(b)	Movement of right arm over 90°.	Move to my right.
(c)	Movement of left arm over 30°.	Move top of staff to my left.
(d)	Movement of right arm over 30°.	Move top of staff to my right.
(e)	Extension of arm horizontally and moving hand upwards.	Raise height of peg or staff.
(f)	Extension of arm horizontally and moving hand downwards.	Lower height of peg or staff.
(g)	Extension of both arms slightly and thrusting downwards.	Establish the position.
(h)	Extension of arms and placement of hand on top of head.	Return to me.

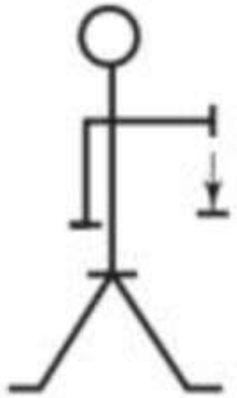

(a)

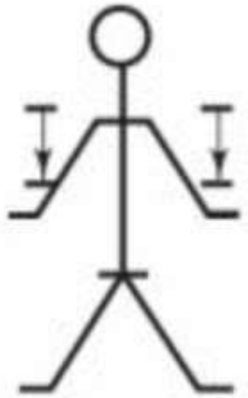

(b)


(c)


(d)


(e)


(f)


(g)


(h)

Contours

- Contours are defined as an imaginary line passing through points of equal elevation on Earth surface
- Contour line: is defined as intersection of a level surface with the surface of earth
- Note: Contour lines on a plan illustrate topography of the ground
- When the contours are drawn under water, they are termed as Submarine contours/fathoms curves/Bathymetric curves
- Generally, the contours are not visible on the grounds except in case of shore lines

Que 1. A series of closely spaced contour lines represents a :

(a) Steep slope

(b) Gentle slope

(c) Uniform slope

(d) Plane slope

Que 79. A series of closely spaced contour lines represents a :

(a) Steep slope

(b) Gentle slope

(c) Uniform slope

(d) Plane slope

Que 79. Narrowly space contour lines on a map shows that the area is :

(a) Flat

(b) Steeply sloped

(c) Vertical cliff

(d) Overhang cliff

Que 80. Narrowly space contour lines on a map shows that the area is :

(a) Flat

(b) Steeply sloped

(c) Vertical cliff

(d) Overhang cliff

Que. 80. The contour lines can cross one another on map only in the case of :

(a) An overhanging cliff

(b) A vertical cliff

(c) A valley

(d) A ridge

Que. 81. The contour lines can cross one another on map only in the case of :

(a) An overhanging cliff

(b) A vertical cliff

(c) A valley

(d) A ridge

Que. 82 Closed contours with higher value inside represents

(a) Depression

(b) Hill

(c) Plain surface

(d) None of these

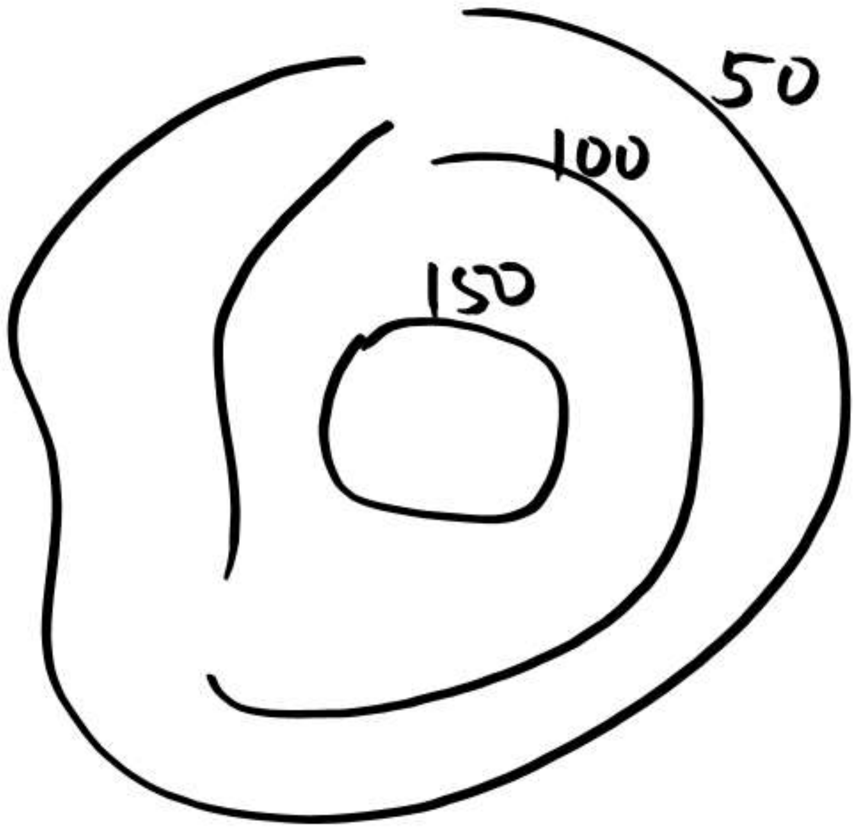
Que. 82 Closed contours with higher value inside represents

(a) Depression

<u>(b) Hill</u>

(c) Plain surface

(d) None of these



Que. 83

Contour interval on map sheet denotes

(a) Vertical distance of Contour lines above the datum plane

(b) Vertical distance between two successive Contour lines

(c) Slope distance between two successive Contour lines

(d) Horizontal distance between two successive Contour lines

Que. 83.

Contour interval on map sheet denotes

(a) Vertical distance of Contour lines above the datum plane

(b) Vertical distance between two successive Contour lines

(c) Slope distance between two successive Contour lines

(d) Horizontal distance between two successive Contour lines

Que. 84.

Which of the following would represent the surface of the water level of a still lake?

(a) Level surface

(b) Contour surface

(c) Horizontal surface

(d) None of these

Que. 84.

Which of the following would represent the surface of the water level of a still lake?

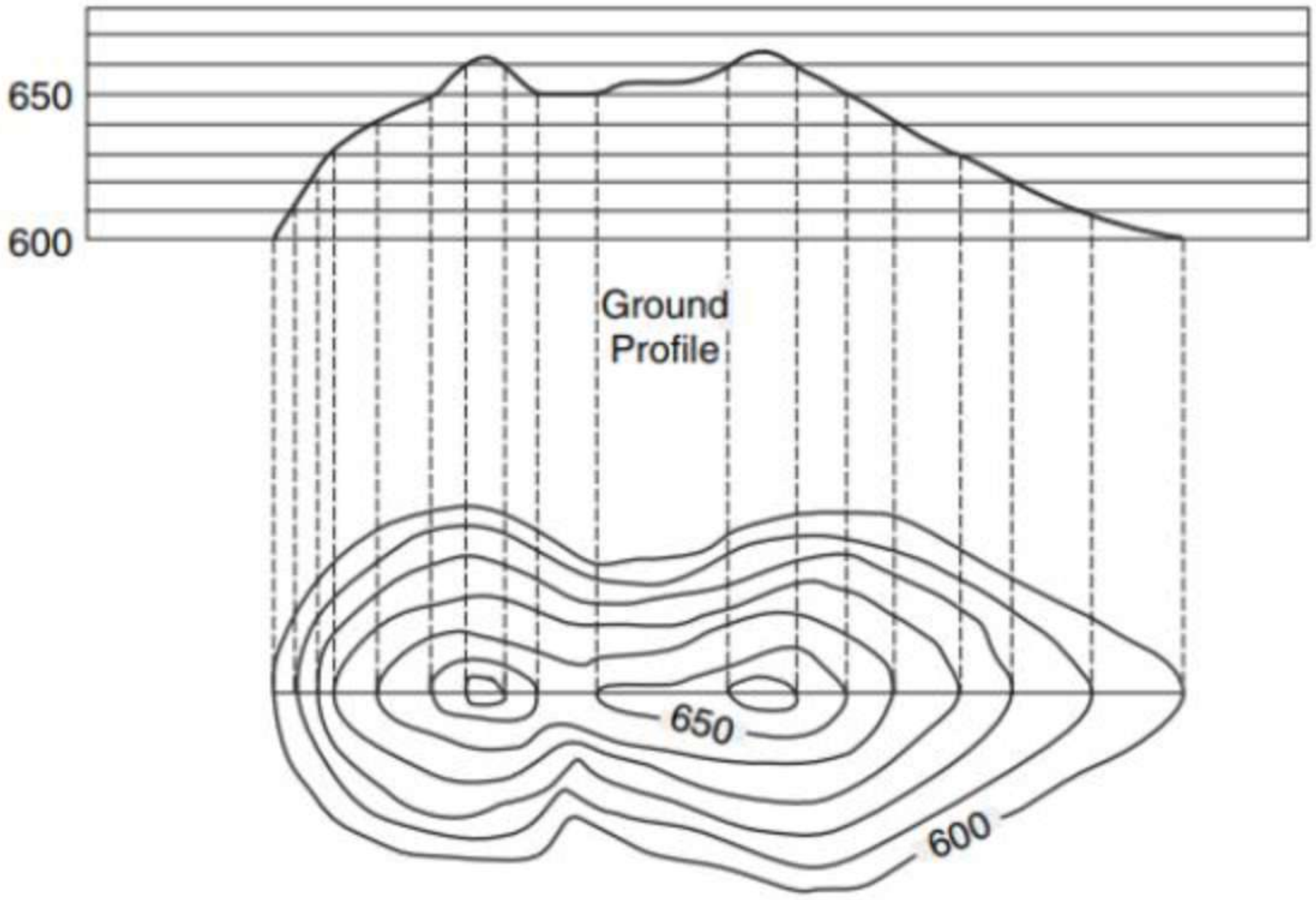
(a) Level surface

(b) Contour surface

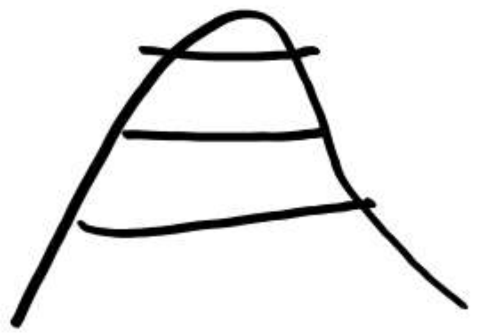
(c) Horizontal surface

(d) None of these

Contour Representation



Contours



- **Contour Interval:**
  - It is *vertical distance* between consecutive contours
  - Generally constant contour interval is preferred throughout the map
  - Generally contour interval is taken as 1 to 15m
  - Smaller the contour interval, more precisely the terrain relief is predicted on the plan
  - The contour interval depends on
    a) Scale of the map
    b) Purpose of map
    c) Nature of ground
    d) Time
    e) Funds

Contours

- **Contour Interval:**
  - The contour interval depends on

    a) *Scale of the map*

      - If scale is small, the contour interval is kept large so that there is no over crowding of the contours
      - If the scale is large the contour interval can be kept small
      - Contour interval is kept large up to 2.0 m for projects such as highways and railways, whereas it is kept as small as 0.5 m for measurement of earth works, building sites, dams, etc

    b) *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 more

A General rule that may be followed

$$Contour\ Interval = \frac{25}{No.\,of\ cm\ per\ km}\ (metres)$$

$$Contour\ Interval = \frac{50}{No.\,of\ inches\ per\ mile}\ (feet)$$

Contours

- **Contour Interval:**
  - **The contour interval depends on**

    c) ***Nature of ground***

    - For a flat ground, contour interval is small, for a steep slope, contour interval is large and if the ground is broken, the contour interval is kept large so that the contours do not come too close to each other

    d) ***Time***

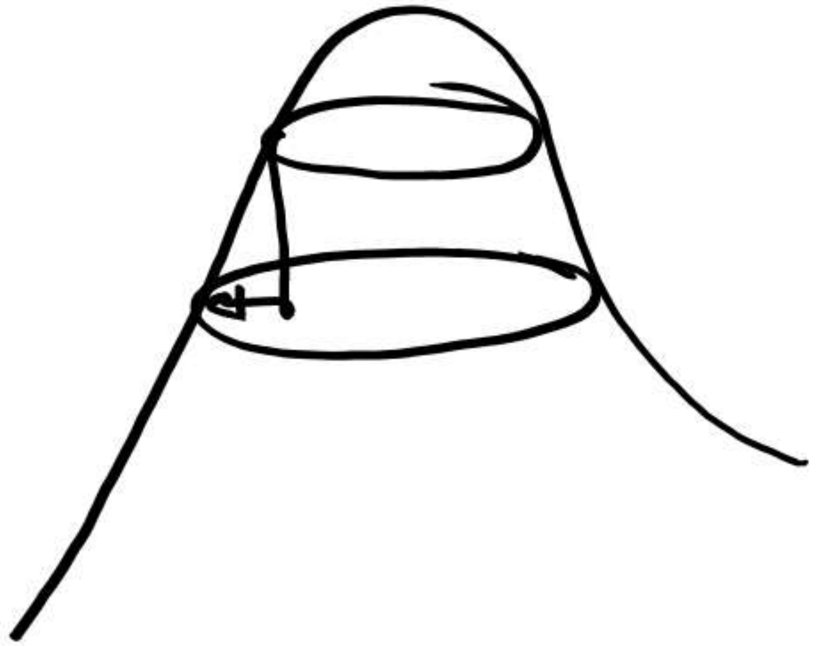
    - Contour interval is kept large when time is less

    e) ***Funds***

    - Contour interval is kept large when funds are less

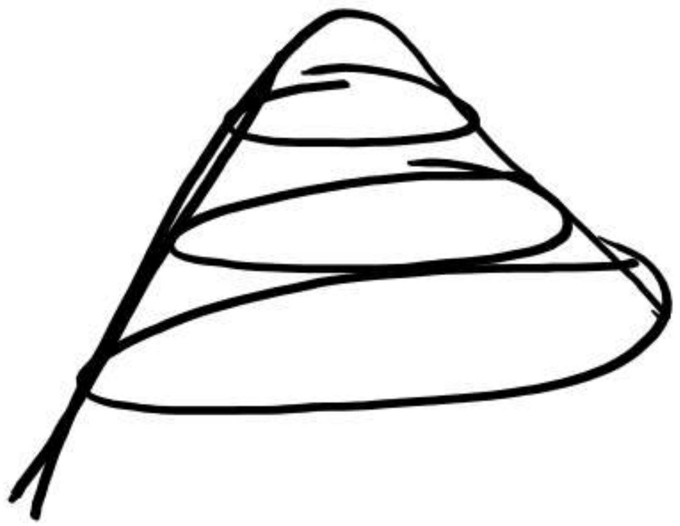
Contours

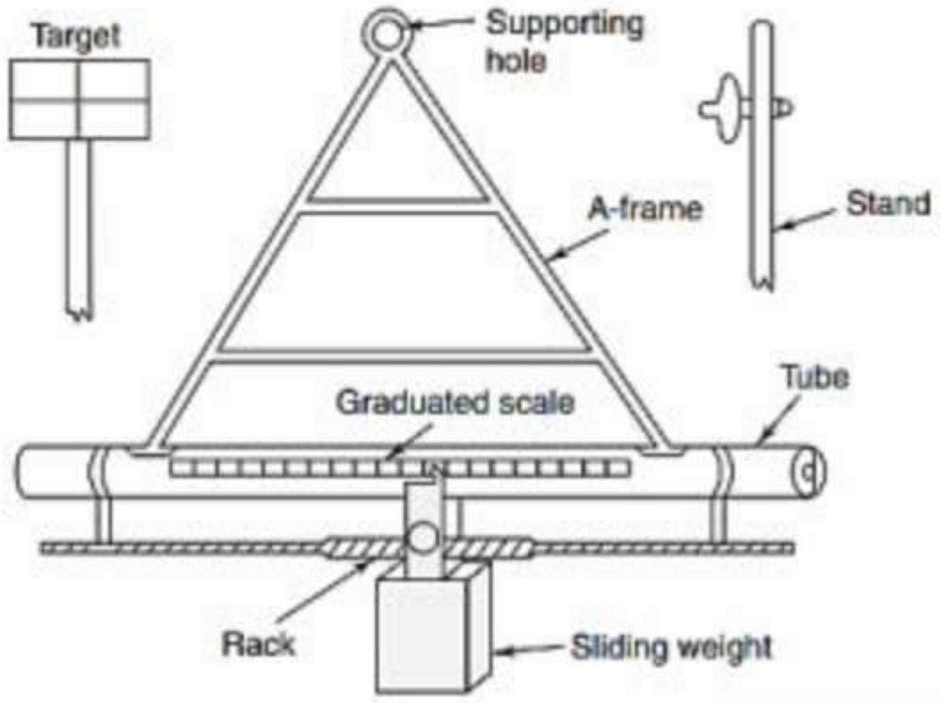
- **Horizontal Equivalent:**
  - **The horizontal distance between consecutive contours is termed as horizontal equivalent.**
  - **It is not a constant value and varies from point to point depending upon the steepness of the ground**
  - **Steeper the ground, lesser is the horizontal equivalent**
  - **The horizontal equivalent between two points can be estimated by dividing the contour interval with the gradient between the points of interest.**
    - **For example, if contour interval = 1 m, gradient = 1 in 20, the horizontal equivalent = 1/(1/20) = 20 m.**



Some Definitions

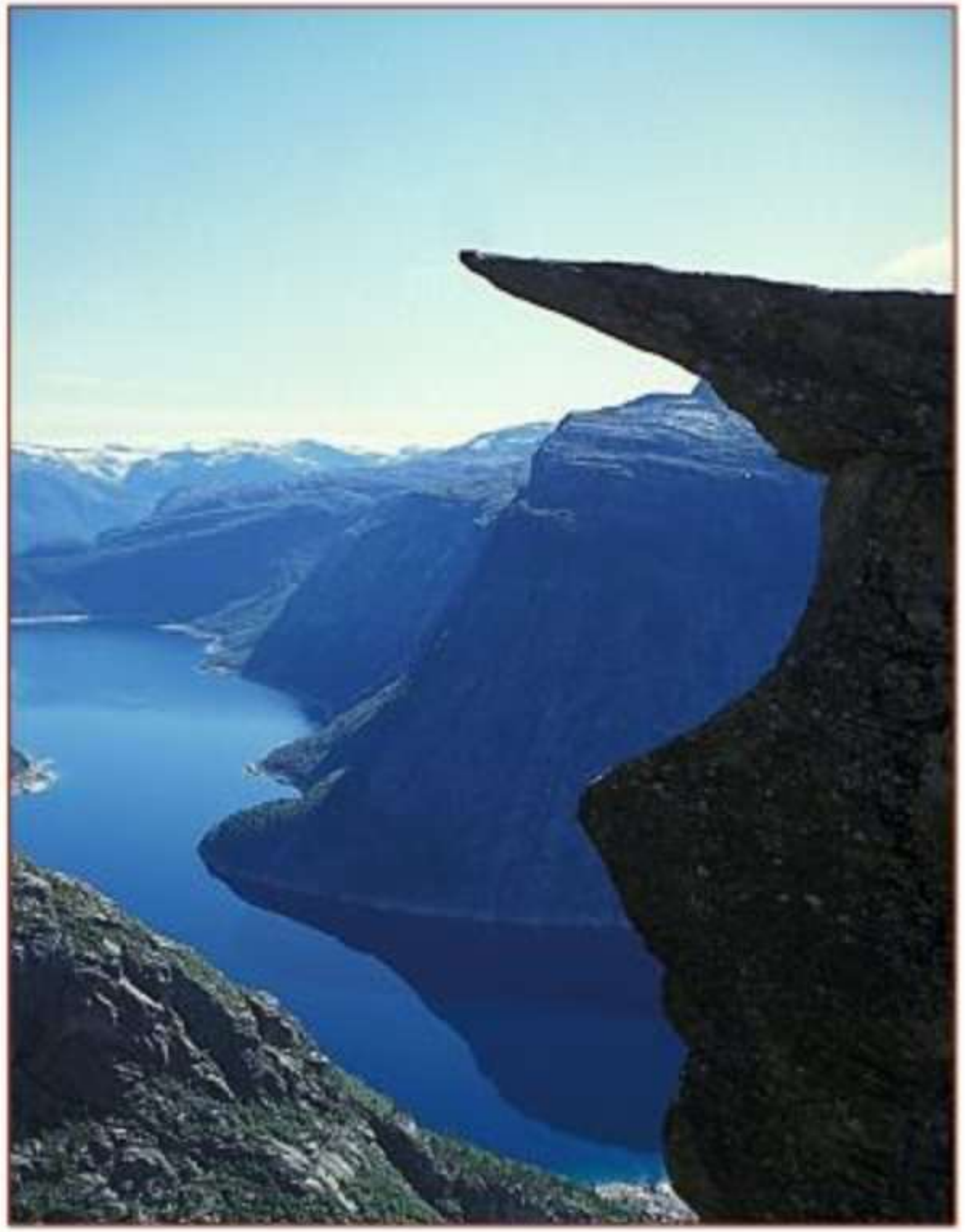
- **Contour Gradient:** A line lying on the ground surface throughout, and maintaining a constant inclination to the horizontal is termed as ***contour gradient***
- **Grade Contours:** The lines having equal gradient along a slope are called grade contours. The difference in elevation of two points of grade contours divided by the distance between them is always a constant gradient.
- **GHAT TRACER:** instrument used for locating points on a given contour gradient



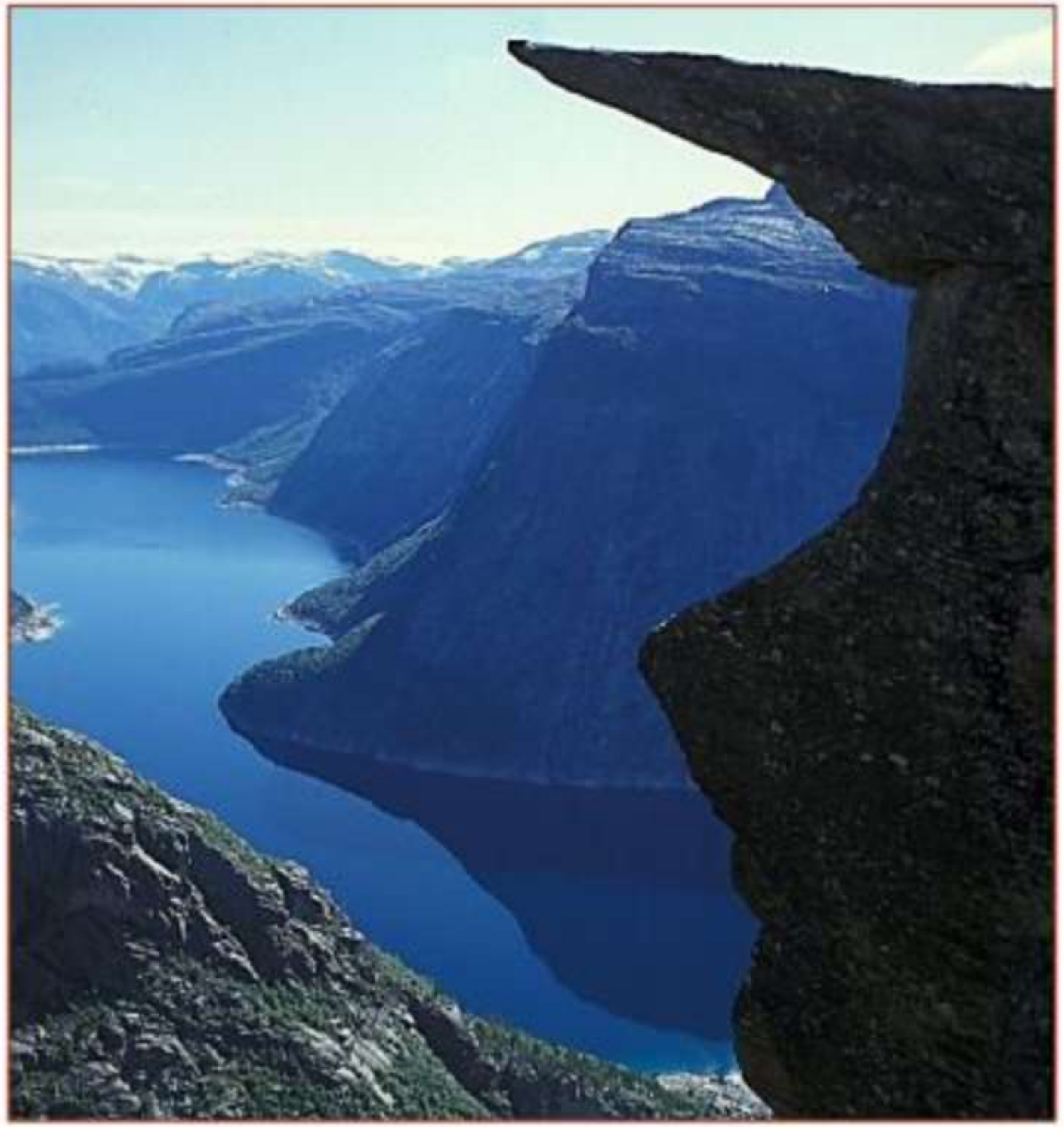


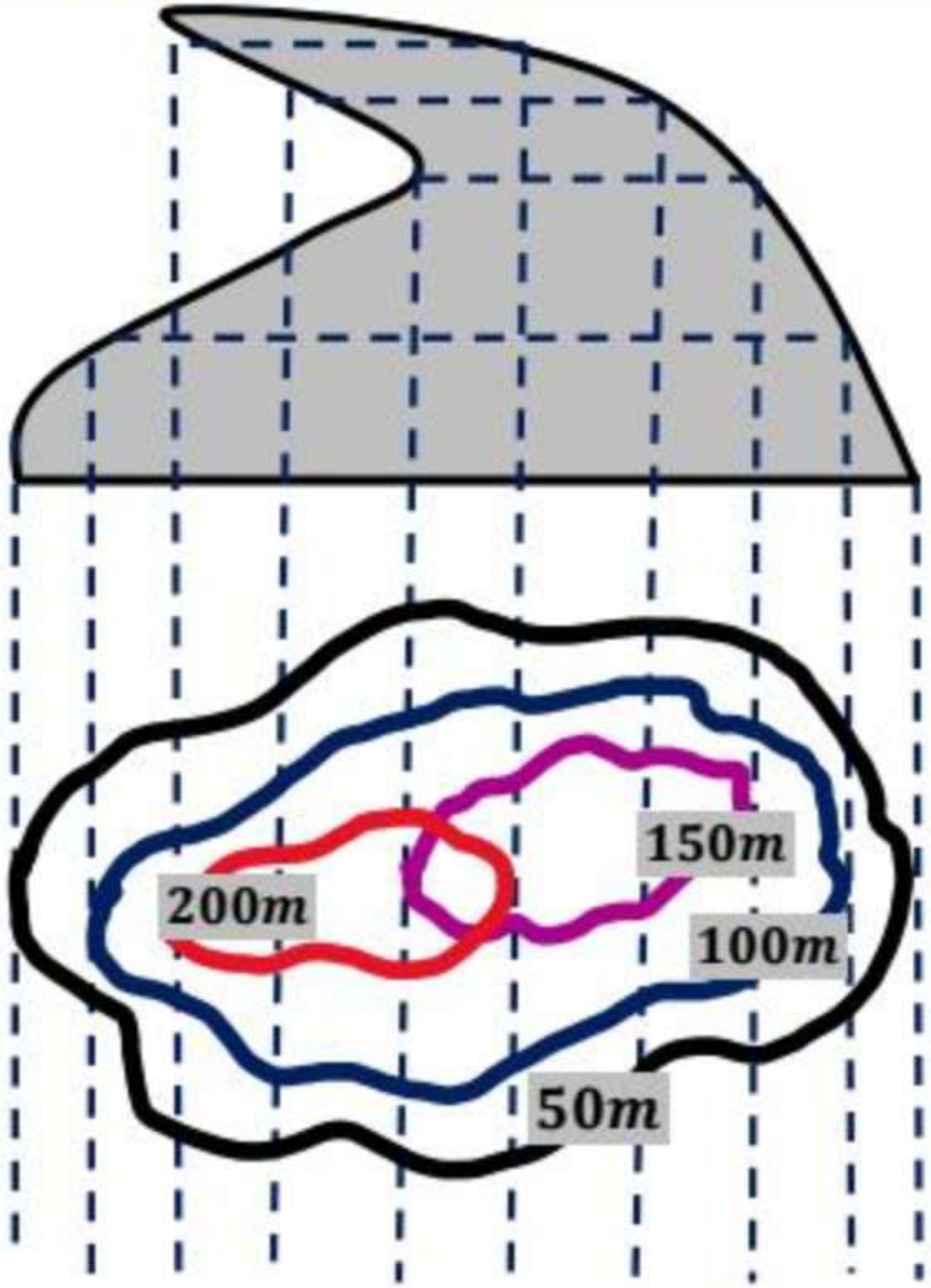
Characteristics of Contour lines

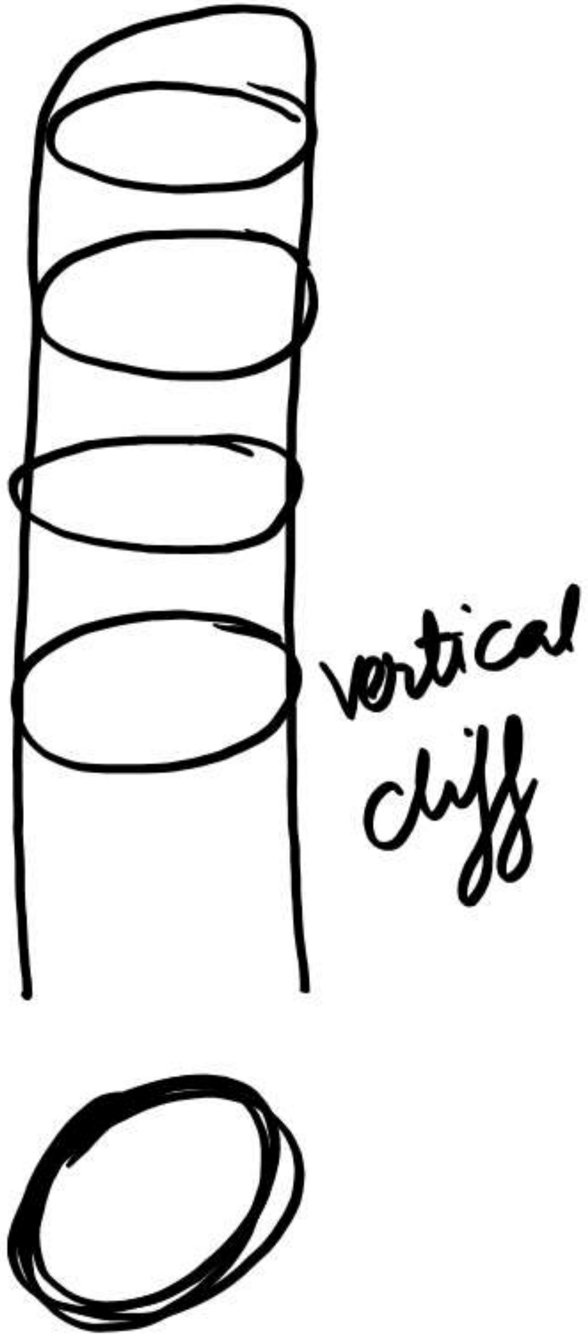
- **When no value is represented, it indicates a *flat terrain*.**
- **A zero meter contour line, represents the *coast line*.**
- **A contour line is a closed curve. They may close either on the map or outside the map, it depends on topography.**
- **Two contour lines never intersect each other except in the cases of overhanging cliff or a cave penetrating a hill side.**



Characteristics of Contour lines







Characteristics of Contour lines

- **Two contour lines never intersect each other except in the cases of overhanging cliff or a cave penetrating a hill side.**
- **Equally spaced contours represent a *uniform slope* and contours that are well apart represents a *gentle slope*.**
- **A set of closed contours with higher figures inside and lower figures outside indicate *hill lock* whereas in case of *depressions and lakes* etc, the lower figures are inside and the higher figures are outside.**

Characteristics of Contour lines

- A watershed or a ridge line (line joining the highest point of a series of hills) and the valley line(line joining the lowest points of valley cross the contours at right angles)
- Irregular contours represent an uneven ground surface.
- Two contour lines having same elevations cannot unite and continue as one line.
- Similarly a single contour cannot be put into two lines.

TYPICAL LAND FEATURES AND THEIR CONTOUR FORMS SLOPES

- A slope may be gentle or steep.
- A gradient up to 1 in 2.5 (20° with horizontal) is referred to as gentle slope whereas higher gradients (20° – 45° with horizontal) are termed as steep slopes
- In the former case, the contours are far apart, and are spaced closely in the latter case.
- A very steep slope is termed as scrap.
- A high scrap is known as crag.
- When the ground bulges outward, it is referred to as a convex slope

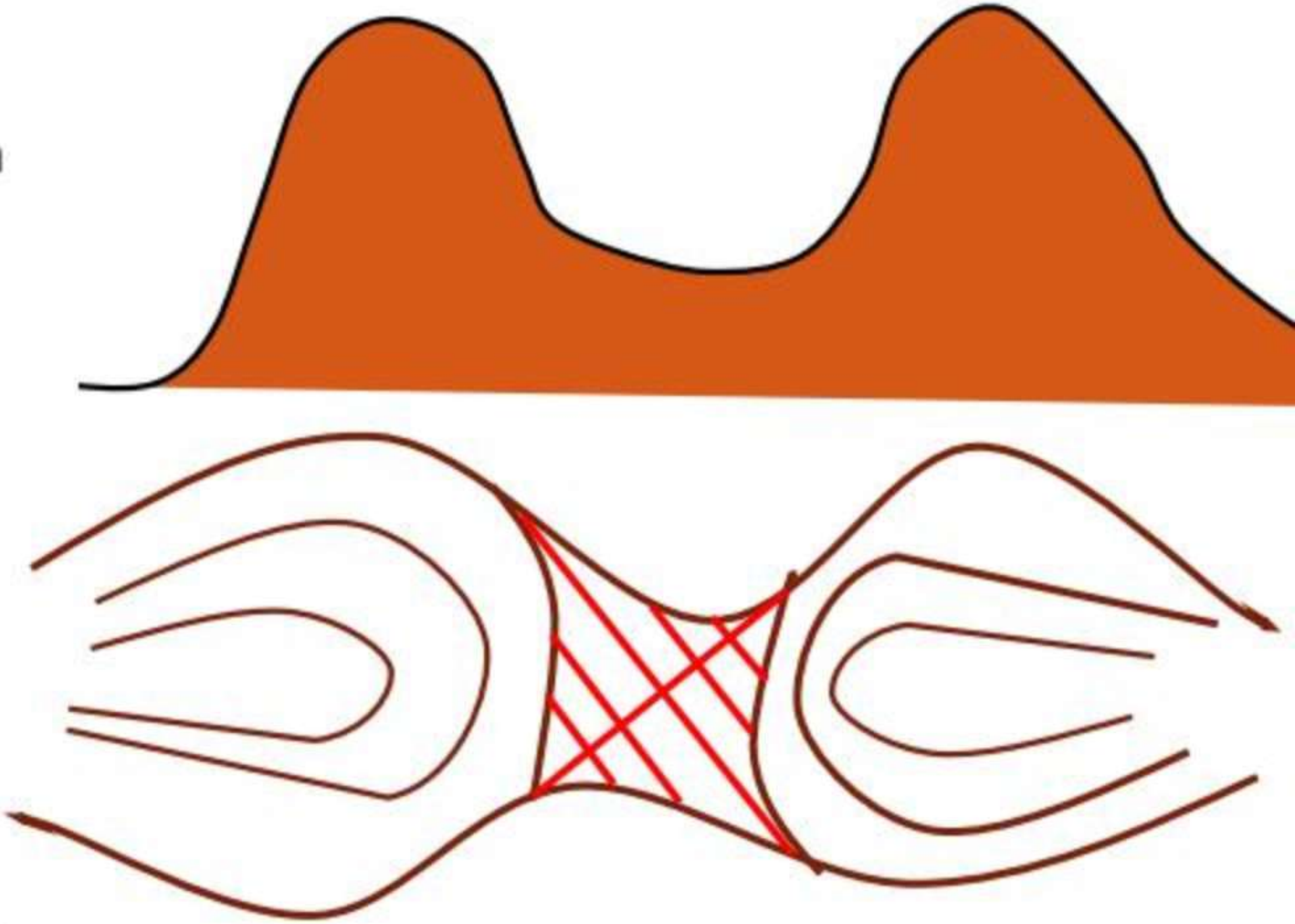
TYPICAL LAND FEATURES AND THEIR CONTOUR FORMS SLOPES

1. HIGH LYING FORMS
   - Hills are elevated ground usually with a pointed peak.
   - The contours of hills are bit circular in shape and increasing contour values inwards.
2. LOW LYING FORMS
   - The most common among low line forms are ravines, valleys etc.
     - Ravine is a through like depression of the Earth 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 is a broad ravine with a gentle sloping bottom.

TYPICAL LAND FEATURES AND THEIR CONTOUR FORMS SLOPES

3. SADDLE

- The lowest points on the watershed are known as passes.
- Pass is a narrow low land passing through high mountains on either side. Sometimes this narrow low land is cut back by the streams. This steep sided depression is called *Col*, when this depression is broad and low it is known as *Saddle*.
- The contours are similar to that of a valley, the difference is here contour vales decrease towards the vee.
- A high land having flat narrow top with steep slope on one side and gentle slope on the other side is called as *Escrapment*.



Plane Table Surveying

- It 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 (1:10 000 to 1: 25 00 000)
- Before starting plane table surveying, at first control stations are established to cover entire area, then a suitable scale is decided
- After that surveyor starts collecting details from either of the point and traverses all the stations
- Elevation of points of observation are determined with the help of levelling, Indian Clinometer and telescopic alidade

Advantages of Plane Table Surveying

- It is suitable for location of details as well as contouring for large scale maps directly in the field.
- As surveying and plotting are done simultaneously in the field, chances of getting omission of any detail get less.
- The plotting details can immediately get compared with the actual objects present in the field. Thus errors as well as accuracy of the plot can be ascertained as the work progresses in the field.
- Contours and specific features can be represented and checked conveniently as the whole area is in view at the time of plotting.
- Only relevant details are located because the map is drawn as the survey progresses. Irrelevant details get omitted in the field itself.
- The plane table survey is generally more rapid and less costly than most other types of survey.
- As the instruments used are simple, not much skill for operation of instruments is required. This method of survey requires no field book.

Disadvantages of Plane Table Surveying

- The plane table survey is not possible in unfavorable climates such as rain, fog etc.
- This method of survey is not very accurate and thus unsuitable for large scale or precise work.
- As no field book is maintained, plotting at different scale require full exercise.
- The method requires large amount of time to be spent in the field.
- Quality of the final map depends largely on the drafting capability of the surveyor.
- This method is effective in relatively open country where stations can be sighted easily .

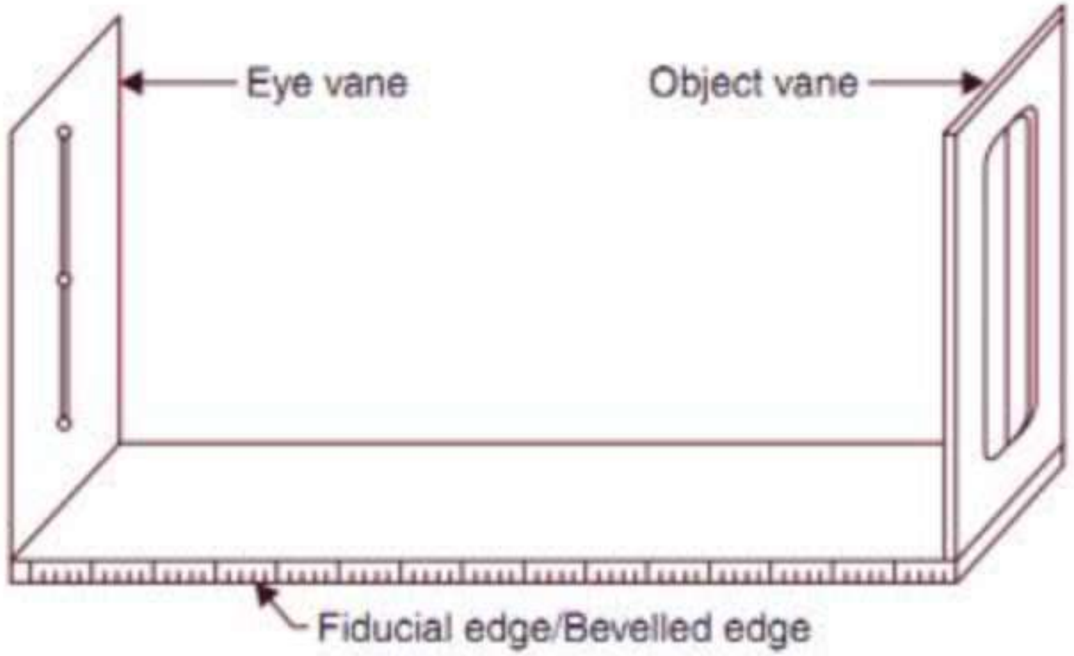
Instruments

- A plane table mounted on a tripod stand and a number of accessories are used during plane table survey. The accessories consist of alidade, spirit level, trough compass, plumbing fork, plumb bob, drawing sheet

1. The plane table consists of a drawing board with arrangement for fixing on a tripod stand.
   - Johnson table of size 45 X 60 cm or 60 X 75 cm is used

2. An alidade is a straight edge ruler used for sighting the object and drawing lines with object vane and sight vane, with one of the edges is beveled and graduated known as fiducial edge
   - The line passing through the slit of the eye vane joining the thin wire of the object vane and passing beyond is known as the line of sight of a plane alidade

A plane table

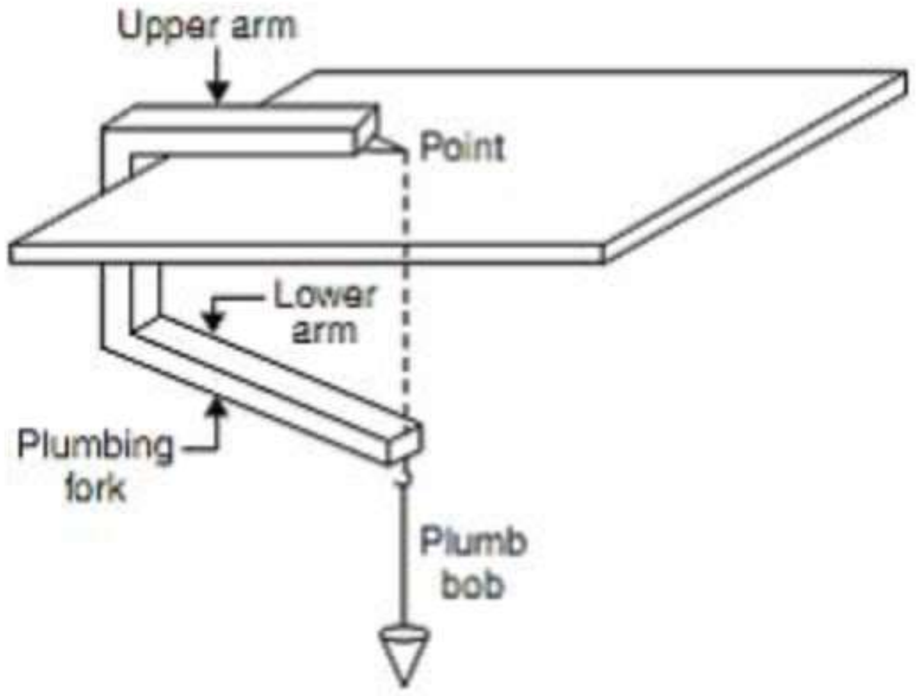


Alidade

Instruments

3. Plumbing Fork

- A plumbing fork is a U-shaped piece of metal or wooded frame
- The end of one of its arm is pointed and the other arm is having an arrangement for hanging a plumb bob
- The frame is constructed in such away that the tip of the pointed arm and the plumb line lie in the same vertical line. At the time of use, the pointed arm is placed on the table and the other arm, with a plumb bob attached, is kept below the table. Plumbing fork with a plumb bob is used in large scale surveying for Centering of the plane table and for Transferring of ground point.



Instruments

4. Spirit Level

- It consists of flat based tube with a small bubble either circular or tubular in shape .
- It is used to check the level of plane table by placing it on the board in two positions at right angles to each other.
- When the bubble tube remains in the centre at any point on the table is considered to be properly leveled.

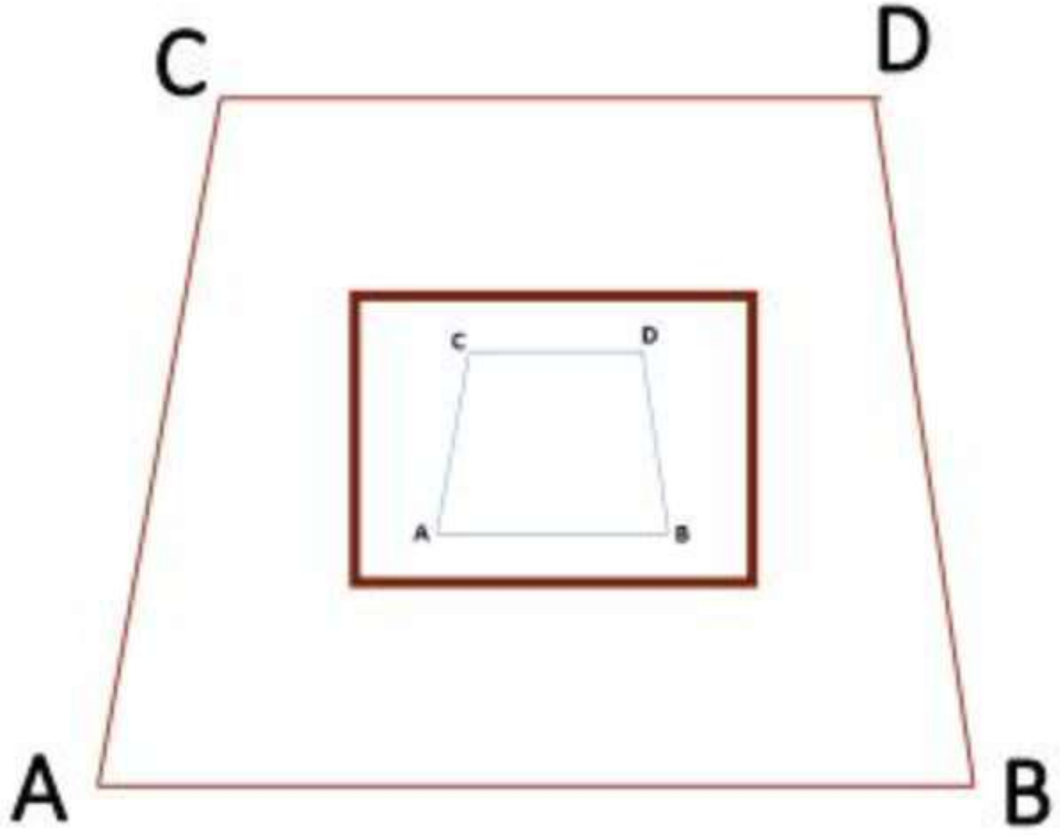
Instruments

5. **Compass**
   - Type of compass used is trough compass
   - It is used for orienting the plane table to magnetic north
   - The side of trough compass should be parallel and plane such that they can be used as ruler or for placing the compass such that it coincides with the line already drawn in north south direction

6. **Drawing Paper**
   - A drawing paper of good quality and well-seasoned is to be used for plotting.
   - It should be able to withstand the rubbing of the alidade.
   - The effect of changes in humidity and temperature of the atmosphere should be minimum thus reduction in the expansion or contraction of the paper, and minimum alteration in the scale of the map and distortion in the plan.

Basic Principle of Plane Table Surveying

- Plane table surveying is based on the principle that lines drawn during plotting always lie parallel to the corresponding lines actually present on the ground.
- For example, let us consider four ground stations A, B, C and D which on joining provides a polygon ABCD. This has been plotted on a sheet of paper at a scale by plane table surveying. Here, the sides AB, BC, CD and DA are plotted in such a way that they are parallel to the sides actually available on the ground.



Setting of Instruments

- At each station, the plane table is required to get set up before carrying out any plotting work.
- It basically consists of the following operations:
  1. Fixing
     - In this operation, first the top of the tripod stand is fixed in level by eye estimation at convenient height with its legs uniformly spread and shoes fixed firmly into the ground. The board is fixed to the tripod head by tightening the clamping screw.
  2. Leveling
     - The top of the table is leveled by moving the legs of the tripod. The level of plane table is first judged by eye estimation. Further, it is checked by keeping spirit level at different positions on the table and if required, legs are further adjusted.
  3. Centering
     - The table should be so placed over the station on the ground that the point plotted on the sheet corresponding to the station occupied should be exactly over the station on the ground
  4. Orientation
     - It is a process of putting the plane table into same fixed direction so that the line representing a certain direction on the plan is parallel to the direction on the ground
  5. Sighting the points

Methods of Orientation:

a) By Trough compass

- A trough compass is placed on the top right side corner of the drawing sheet an draw line on north south direction
- To orient the plane table, on the top right hand side corner of the drawing sheet and rotate the table till magnetic needle coincides with the line drawn in north south direction

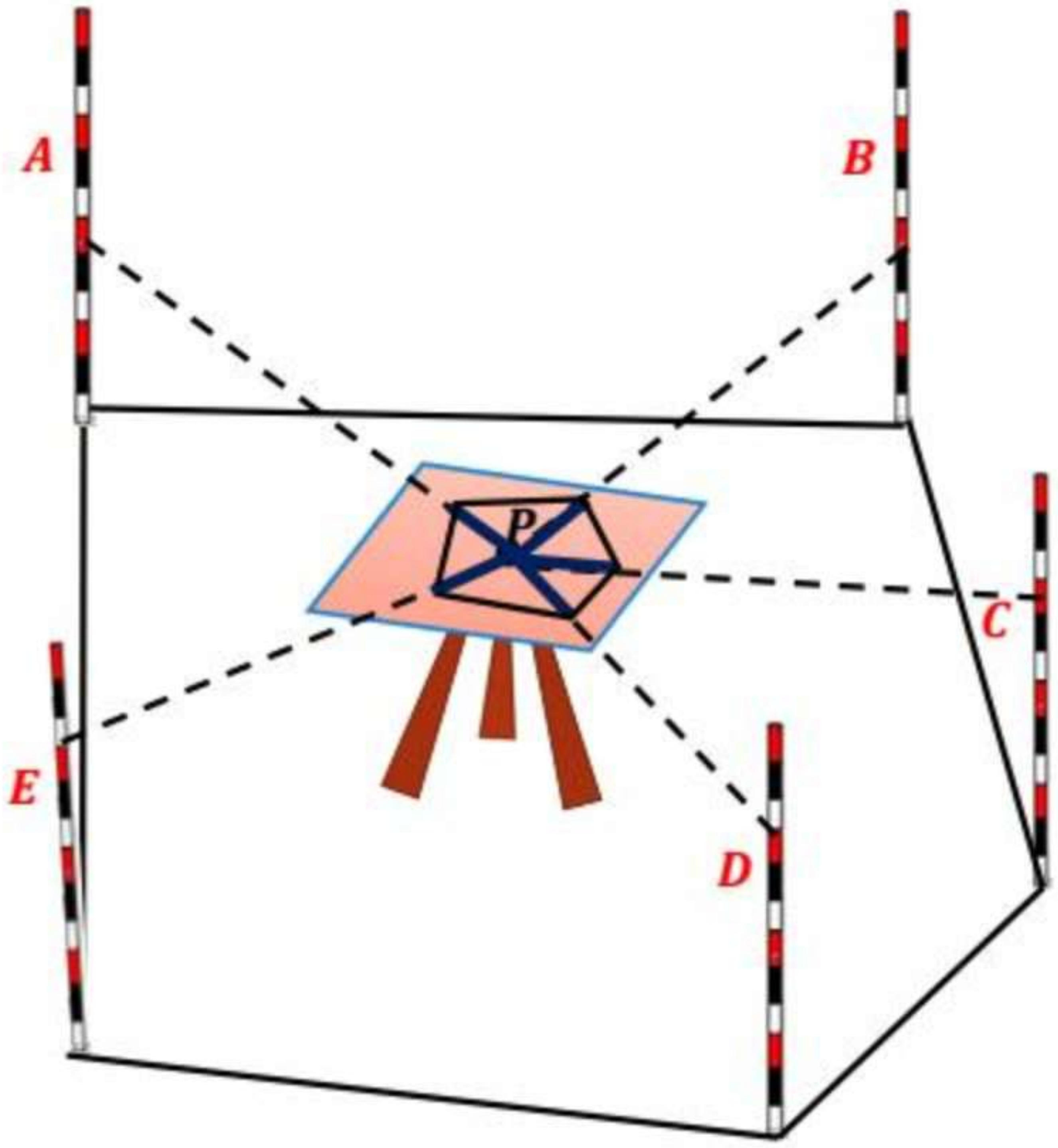
b) By back sighting

- In this method, plane table is oriented by Backsighting on previous station

METHODS OF PLANE TABLE SURVEY

- To carry out the operations under different field conditions, different methods of plane table surveying have been evolved –
  1. Method of Radiation
  2. Method of Intersection
  3. Method of Traversing
  4. Method of Resection.
- He first two are employed for locating the details and other two are used to locating plane table stations
- The method of radiation and the method of intersection are employed to locate objects and features present in the area of survey.
- The method of traversing is used to plot the network of stations and the method of resection is employed to determine and to plot the location of the plane table as well as to orient the table simultaneously.

1. METHOD OF 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 where all the points are visible and accessible from the station.
- The method is convenient if telescopic or digital alidade is used. Otherwise, it is effective when associated with tacheometer or EDM for measurement of horizontal distance.

Que. 93

The much suitable plane table surveying on hilly country where it is difficult to measure the horizontal distance is called as

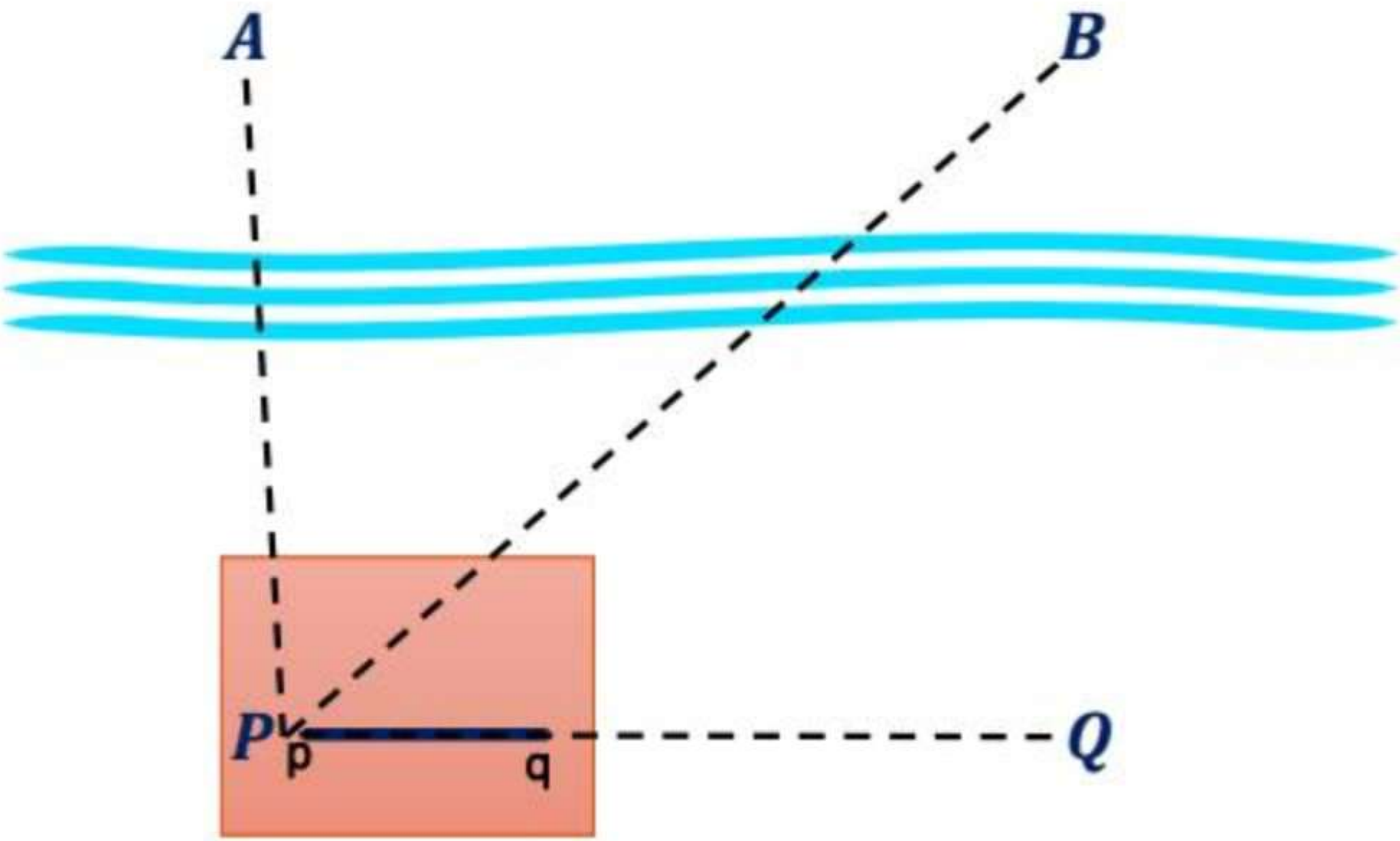
a) Radiation

b) Intersection

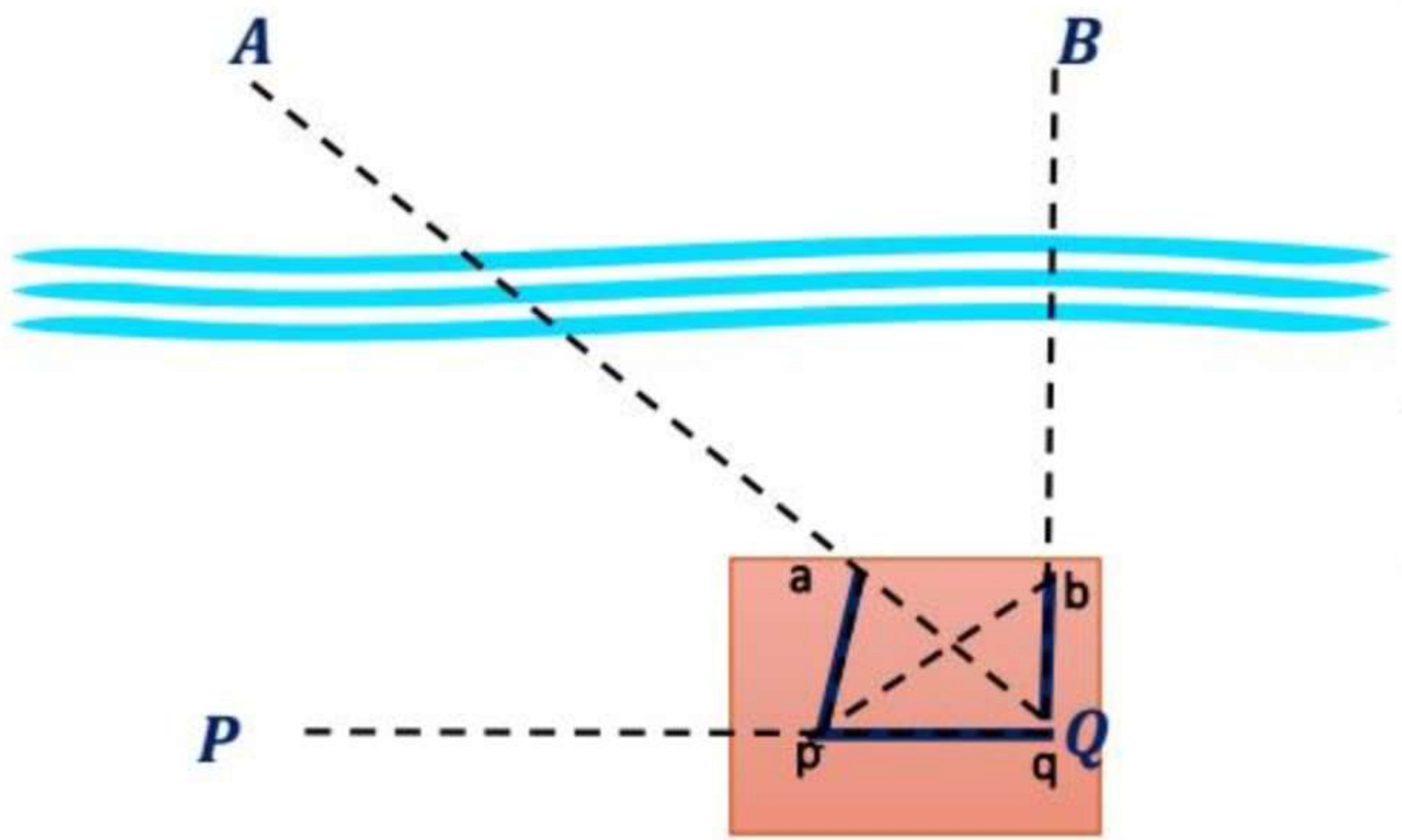
c) Traversing

d) Resection

2. METHOD OF INTERSECTION



2. METHOD OF INTERSECTION

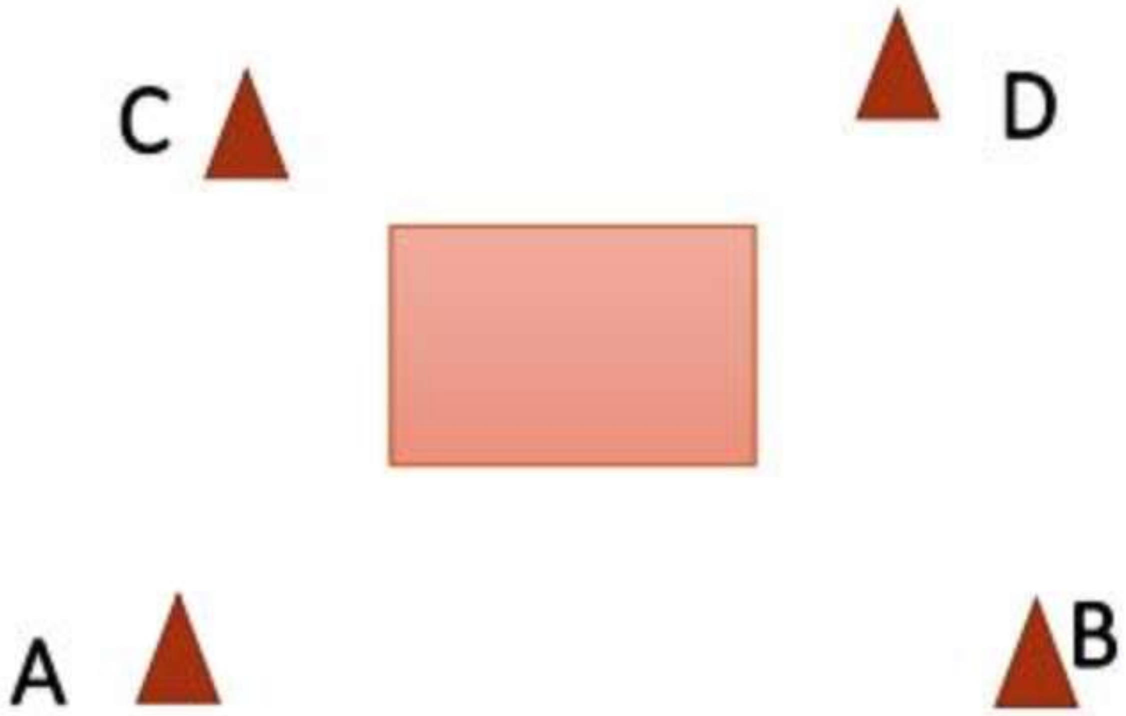


- In this method, locating of a point on the drawing sheet is done by intersecting two rays drawn from two different stations.
- Also called as GRAPHICAL TRIANGULATION.
- It is preferred when distance between stations is very large and stations are inaccessible and ground is undulating.

3. METHOD OF TRAVERSING

- This method of plane table surveying is used to plot a traverse in cases stations have not been previously plotted by some other methods.
- In this method, traverse stations are first selected. The stations are plotted by method of radiation by taking back sight on the preceding station and a fore sight to the following station.
- Here distances are generally measured by tachometric method and surveying work has to be performed with great care.

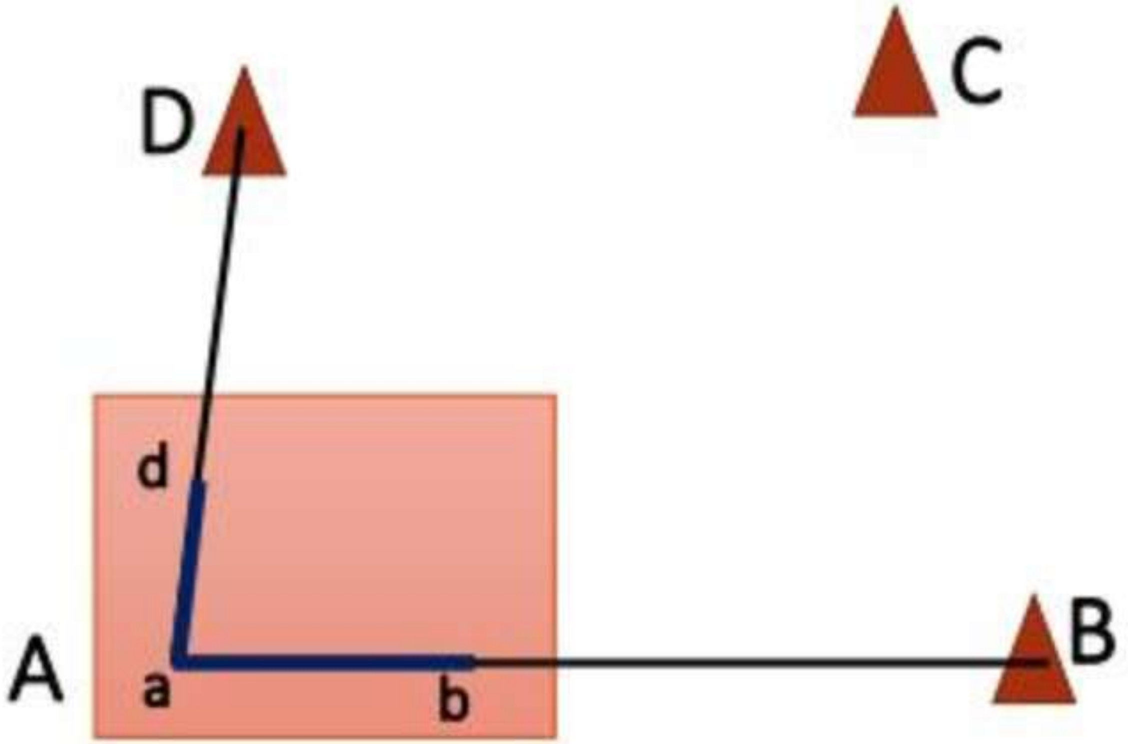
3. METHOD OF TRAVERSING



Let us consider the stations A, B, C and D

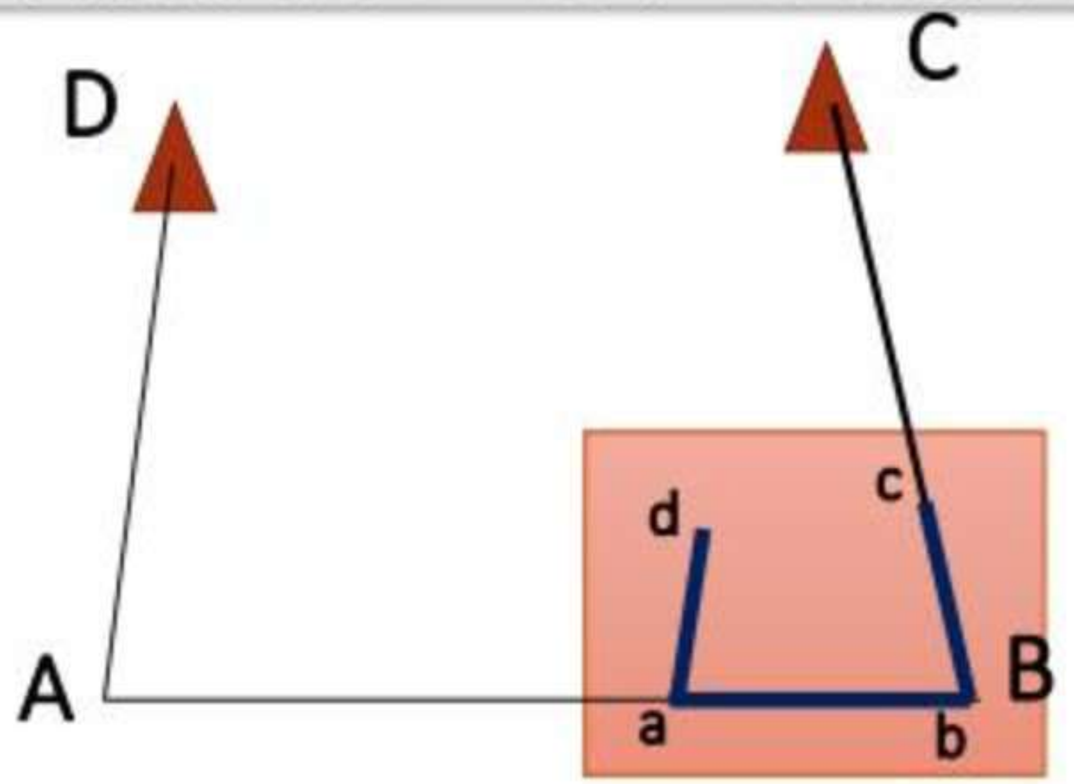
Stations are to be chosen in such a way that adjoining stations are visible

3. METHOD OF TRAVERSING



With the alidade pivoted at a, draw the rays to B and D. Distances AB and AD are measured and plotted on the respective rays, ab and ad respectively.

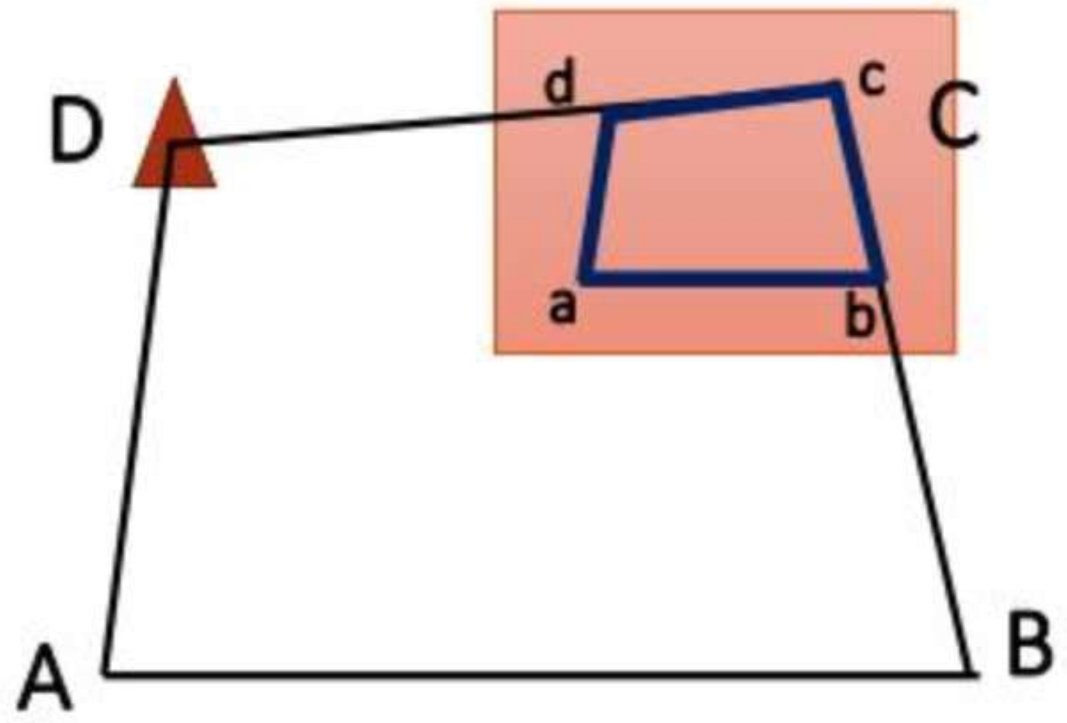
3. METHOD OF TRAVERSING



The plane table is then shifted to station B, get it set and then oriented by back sighting to station A.

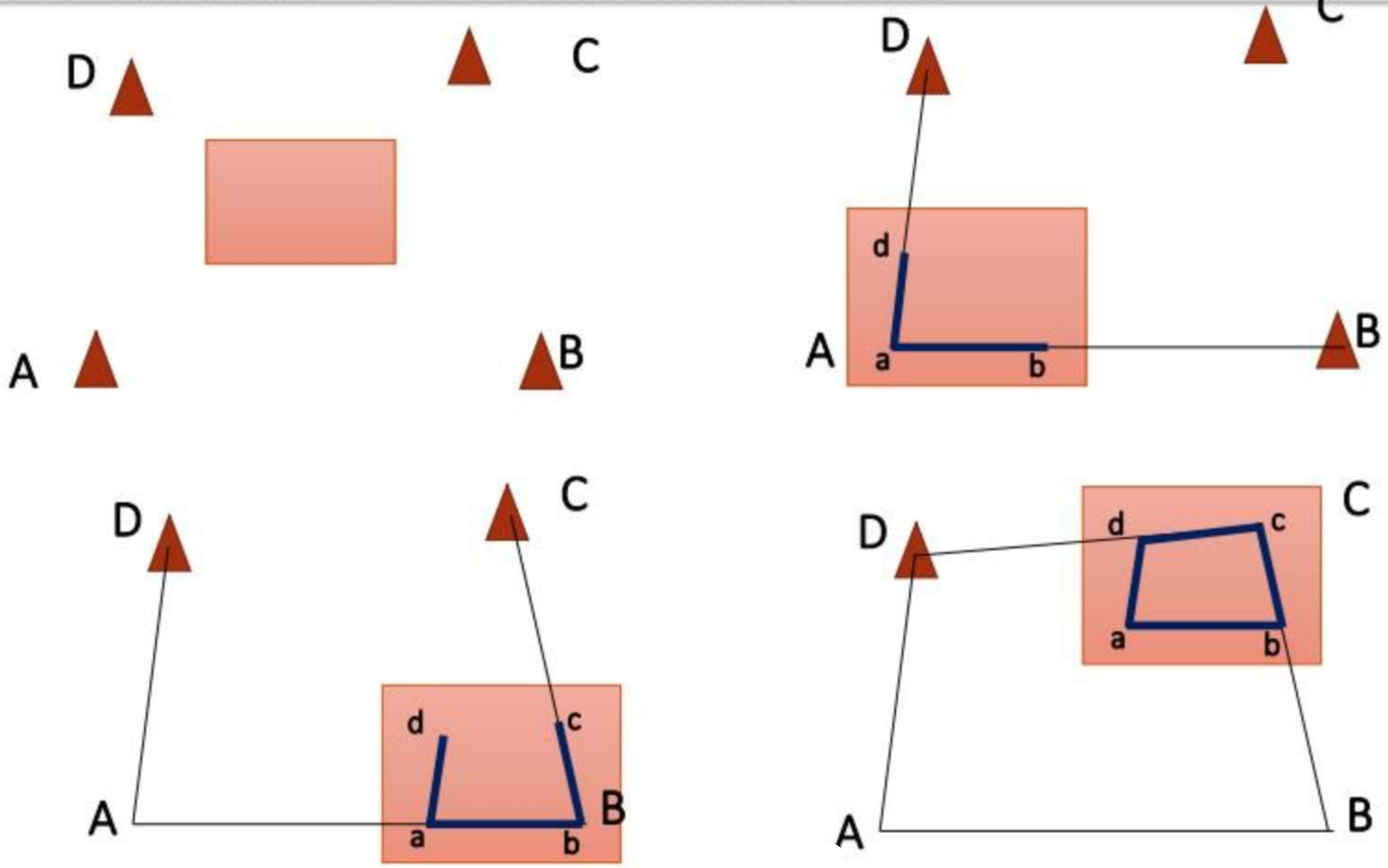
With the alidade pivoted at b, draw a ray to C. Distance BC is measured and plotted on the ray as bc.

3. METHOD OF TRAVERSING



In this way, plane table is shifted to stations C and D and corresponding rays are drawn to obtain the plotting of the traverse abcd.

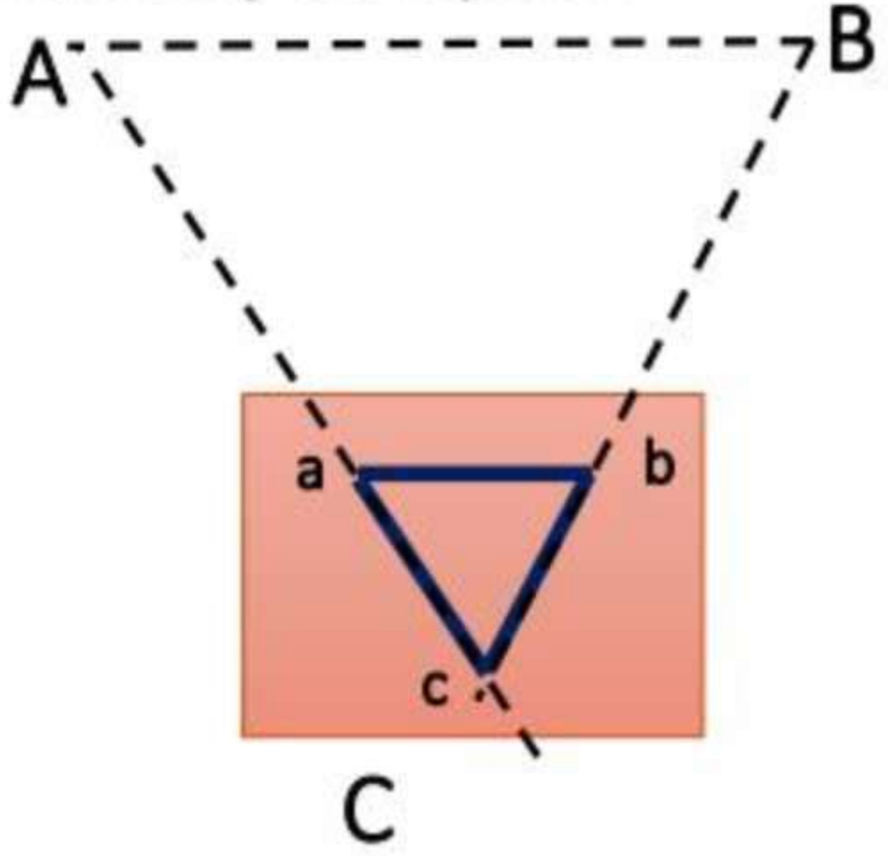
3. METHOD OF TRAVERSING



4. Method of Resection

- It is the process of determining location of station occupied by the plane table with reference to stations which are already plotted on the drawing sheet

a) Resection by Compass



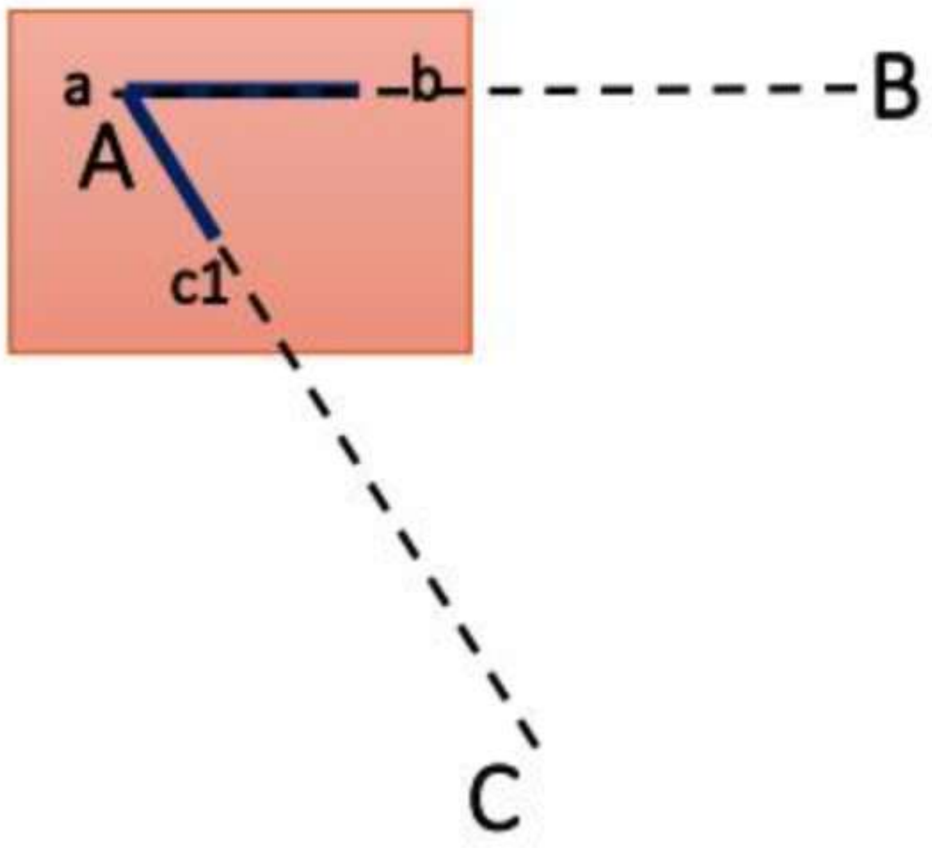
C is the instrument station to be located
A and B are visible stations *already plotted on sheet as a and b*

Set the table at C, orient it with compass and clamp
Draw a resector towards A from a
Similarly sight B from b and draw a resector

Intersection of the resectors will give c (the required point)

4. Method of Resection

b) Resection by Backsighting

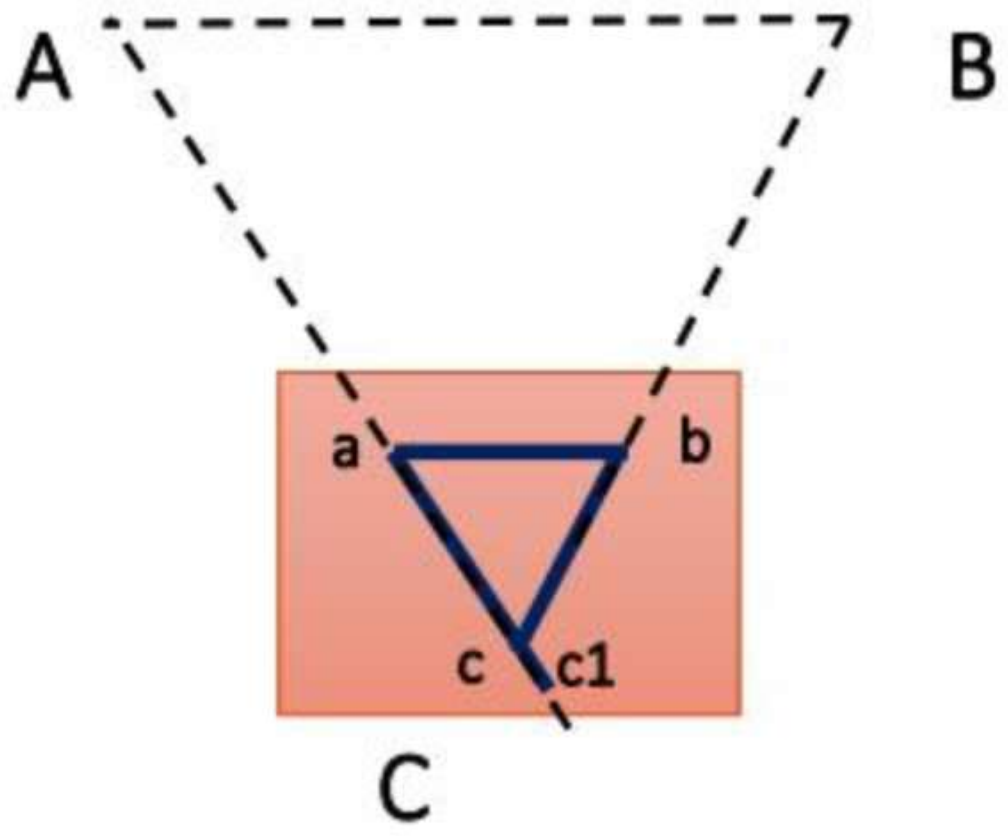


C is the instrument station to be located
A and B are visible stations *already plotted on sheet as a and b*

Set the table at A, orient it by backsighting B along AB
From a, sight C and draw a ray and estimate point C roughly as c_1

4. Method of Resection

b) Resection by Backsighting



C is the instrument station to be located
A and B are visible stations *already plotted on sheet as a and b*

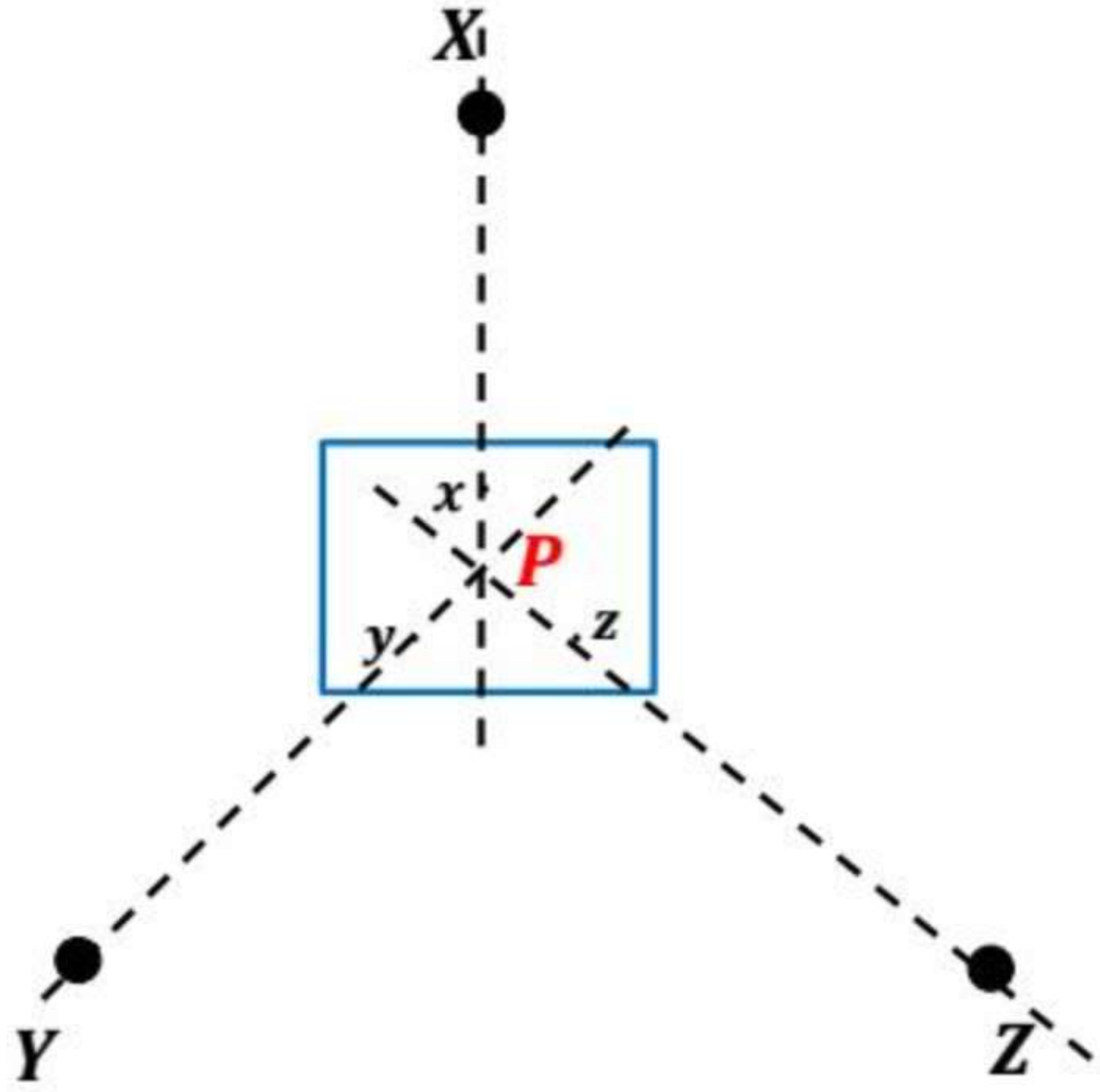
Set the table at A, orient it by backsighting B along AB
From a, sight C and draw a ray and estimate point C roughly as c_1

Shift the table to C and centre it with respect to c_1
From c_1a , orient the table and backsight to A
From b, sight B and draw a ray bB to intersect c_1a on c

4. Method of Resection

c) Resection by 3 point problem

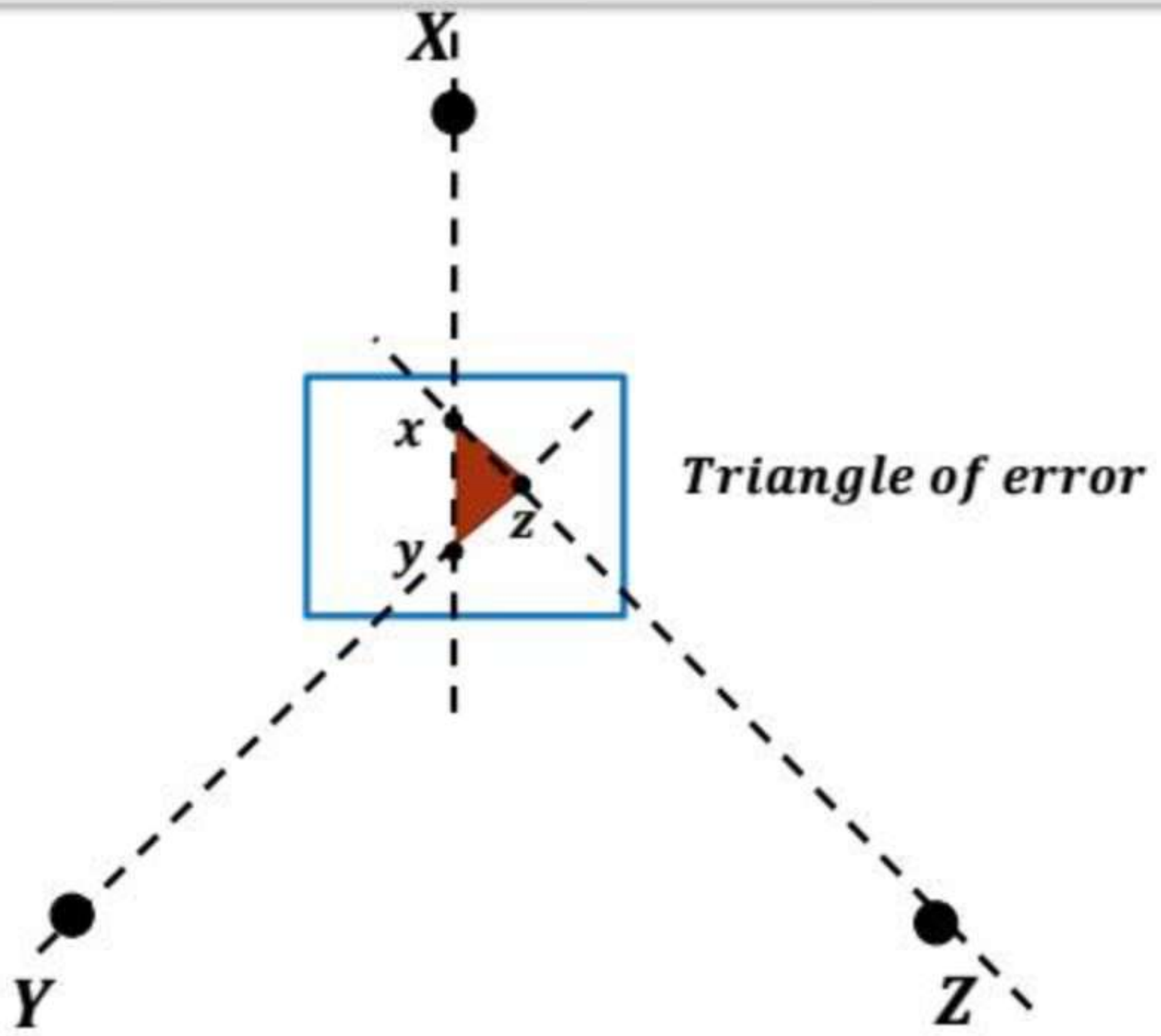
- In this method, three well defined points, having locations already being plotted on the drawing are involved. These are used to find and subsequently plot the location of the plane table station.
- if X, Y and Z are well defined objects present in the field whose plotted positions are x, y and z. Now, if the plane table is oriented correctly, the three resectors X_x, Y_y and Z_z get intersected at p which represents the location of the plane table station, P on the drawing sheet.
X



4. Method of Resection

c) Resection by 3 point problem

- in three point problem, if the orientation of the plane table is not proper, the intersection of the resectors through the three points will not meet at a point but will form a triangle, known as triangle of error
- The size of the triangle of error depends upon the amount of angular error in the orientation.
- In three point problem, orientation and resection are accomplished in the same operation.
- The trial and error method of three point problem, also known as Lehman's method minimises the triangle of error to a point iteratively.
- The iterative operation consist of drawing of resectors from known points through their plotted position and the adjustment of orientation of the plane table.



TACHEOMETRY SURVEY

- Tacheometry is a branch of angular surveying in which the horizontal and vertical distances of points are obtained by optical means as opposed to the ordinary slower process of measurements by tape or chain.
- Tacheometry is defined as an optical distance measurement method
- The method is very rapid and convenient.

TACHEOMETRY SURVEY

- **It is best adapted in obstacles such as steep and broken ground, deep revines, stretches of water or swamp and so on, which make chaining difficult or impossible.**
- **The *primary object of tacheometry* is the preparation of contoured maps or plans requiring both the horizontal as well as vertical control.**
- **Also, on surveys of higher accuracy, it provides a check on distances measured with the tape.**

TACHEOMETRY SURVEY

- As compared to chaining on flat grounds, the accuracy of tacheometric distances is low, but on rough and steep grounds the accuracy is more

TACHEOMETRY SURVEY

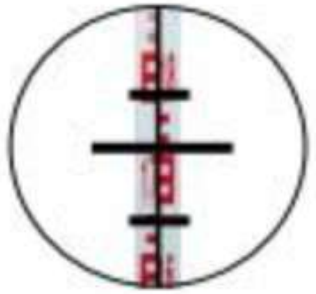
The tacheometric methods of surveying are used with advantage over the direct methods of measurement of horizontal distances and differences in elevations.

Some of the uses are:

I. Preparation of topographic maps which require both elevations and horizontal distances.
II. Survey work in difficult terrain where direct methods are inconvenient.
III. Detail filling.
IV. Reconnaissance surveys for highways, railways, etc.
V. Checking of already measured distances
VI. Hydrographic surveys.
VII. Establishing secondary control.

TACHEOMETER

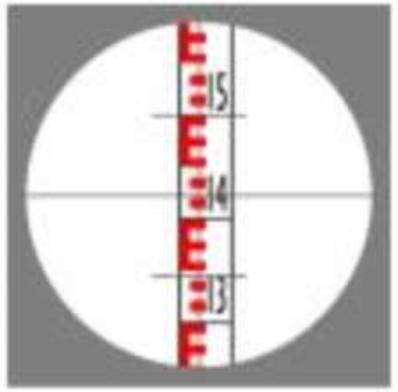
- An ordinary transit theodolite fitted with a stadia diaphragm is generally used for tacheometric survey.



- A tacheometer is essentially a transit theododilte, diaphragm of which is equipped with stadia wires in addition to cross wires

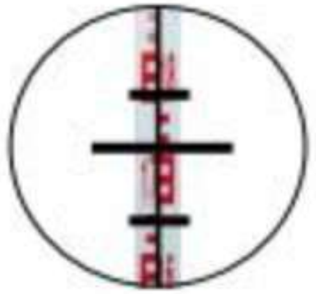
stadia

- Externally focusing Telescope is fitted with anallatic lens, purpose of annalatic lens is to make staff intercept proportional to its distance from the tacheometer.

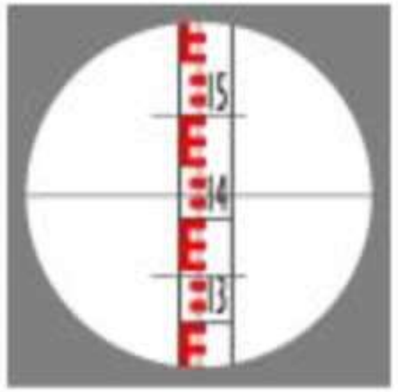


ESSENTIAL CHARACTERISTICS OF TACHEOMETER

- The value of the multiplying constant should be 100.
- The value of the additive constant should be zero.
- The telescope should be fitted with an anallactic lens.
- The magnification of the telescope should be 20 – 80 diameters.
- Magnifying power of the eyepiece is kept high



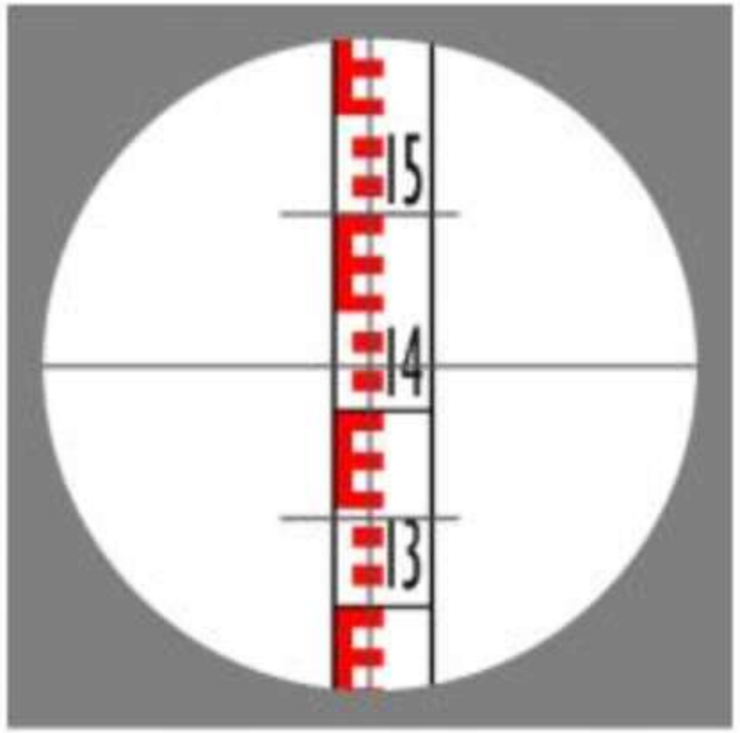
stadia



TACHEOMETER

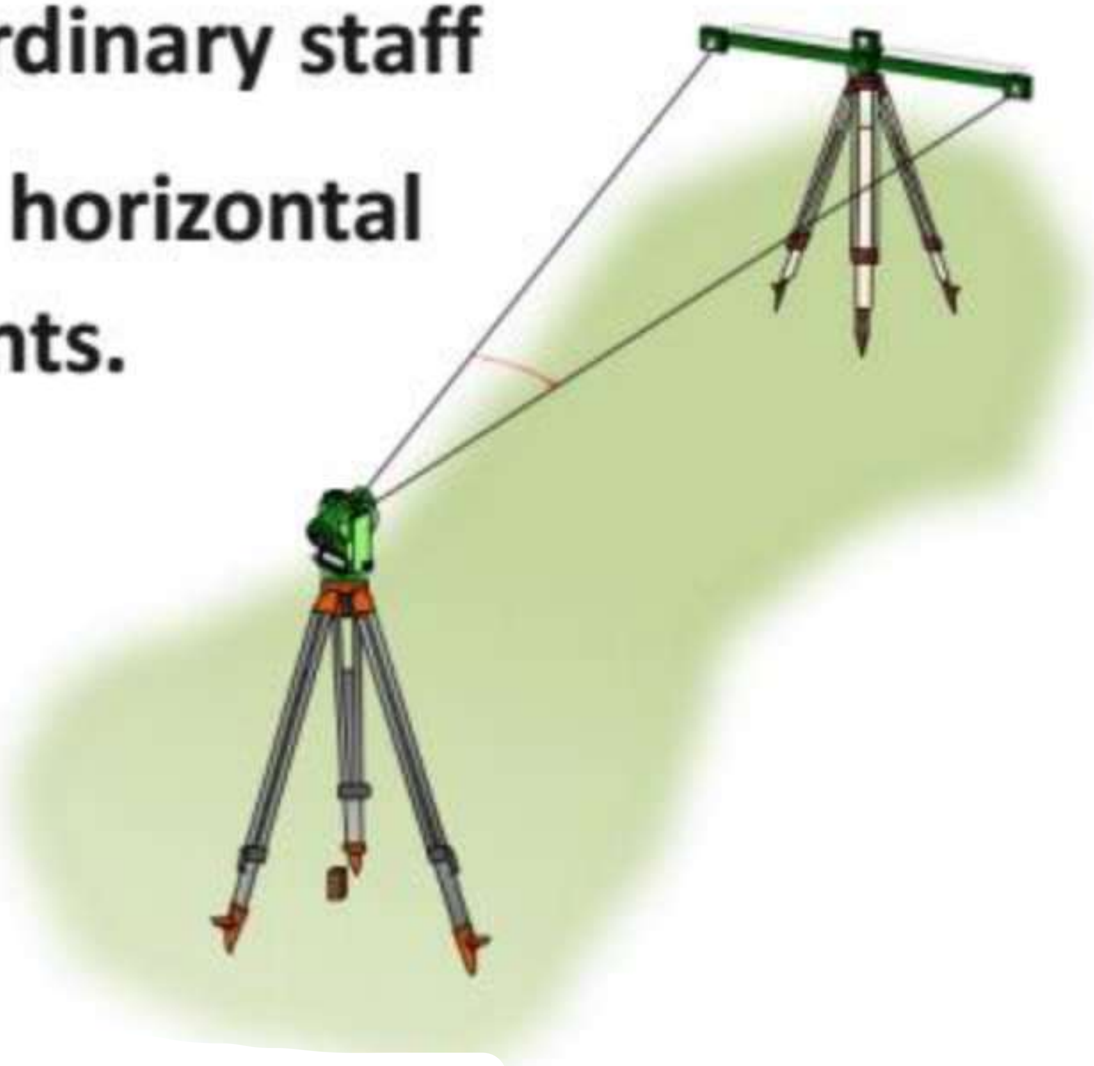
- Two stadia hairs are equidistant from central cross hair.
- Multiplying constant, k = 100
- Additive constant, c = 0
- Magnifying power of eye piece is kept high

stadia 



TACHEOMETER

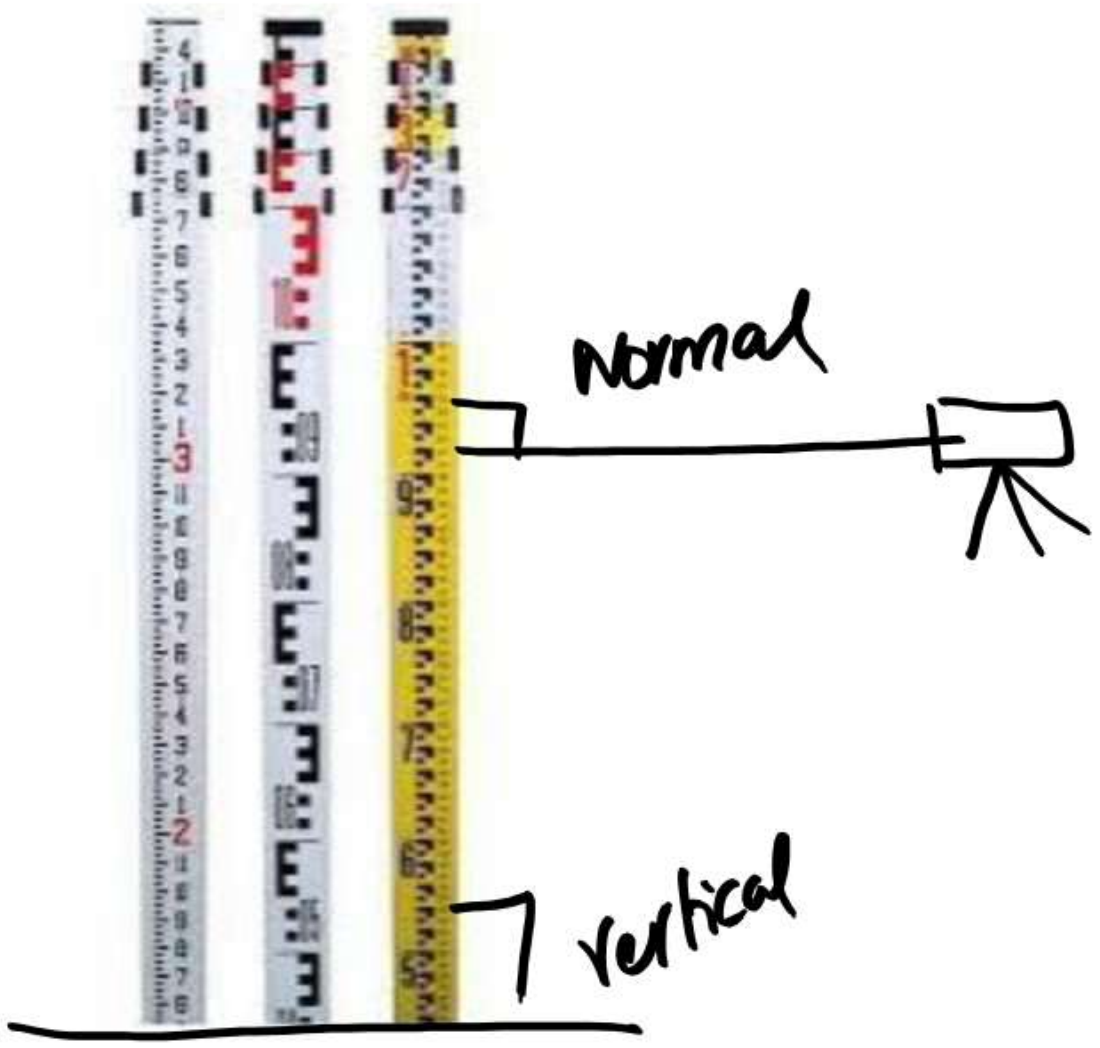
- Stadia rod is a vertical staff (5 – 15 m long) which is used when distance between telescope and the staff is so large that graduations become indistinct in ordinary staff
- Subtense bar (usually 3m long) is a horizontal staff used for distance measurements.



Subtense bar

Note

- **Vertical Holding of Staff**
  - **The staff must be held truly vertical**
- **Normal holding of Staff**
  - **The staff must be held perpendicular to the line of sight**



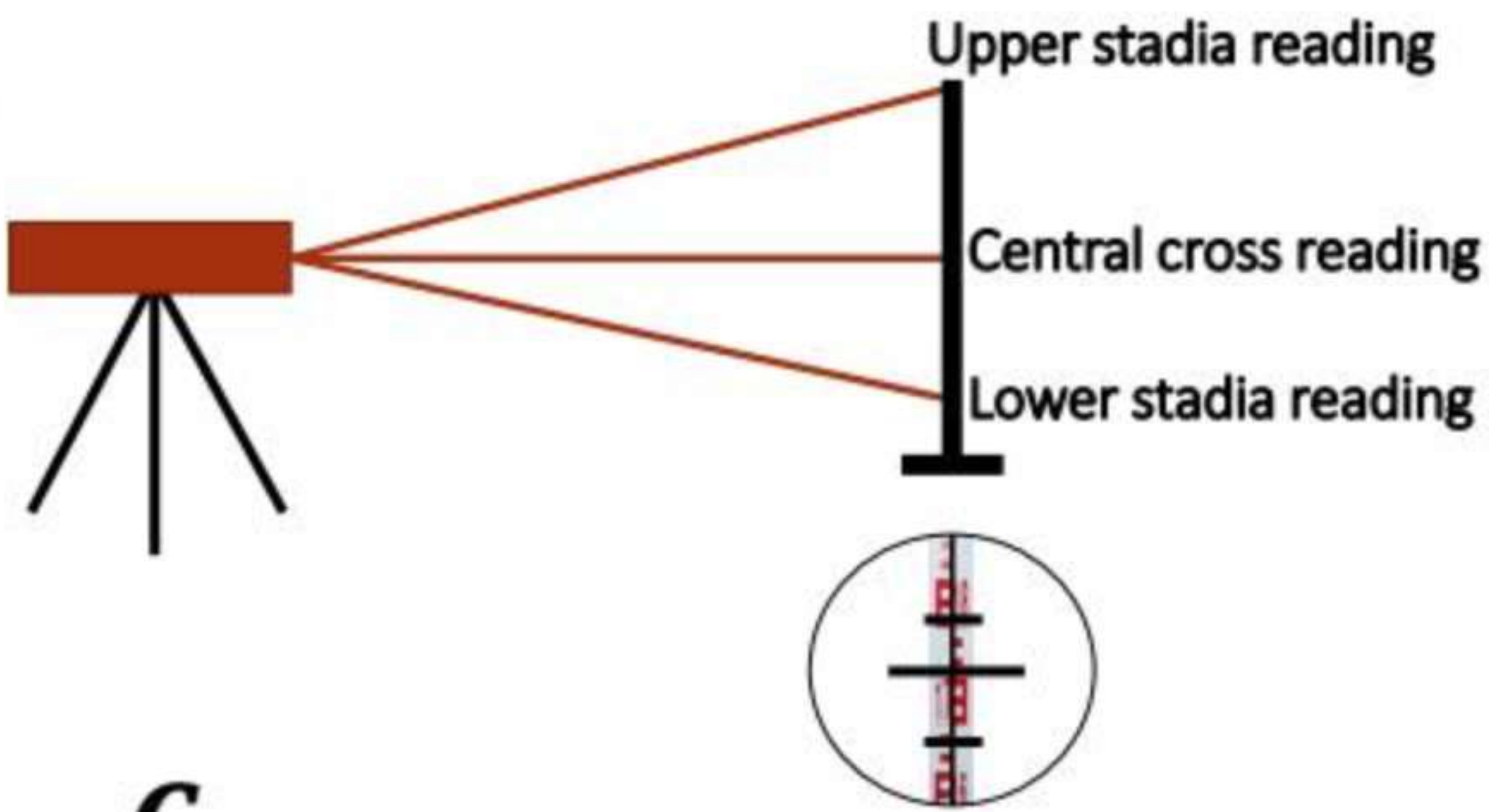
METHODS OF TACHEOMETRY

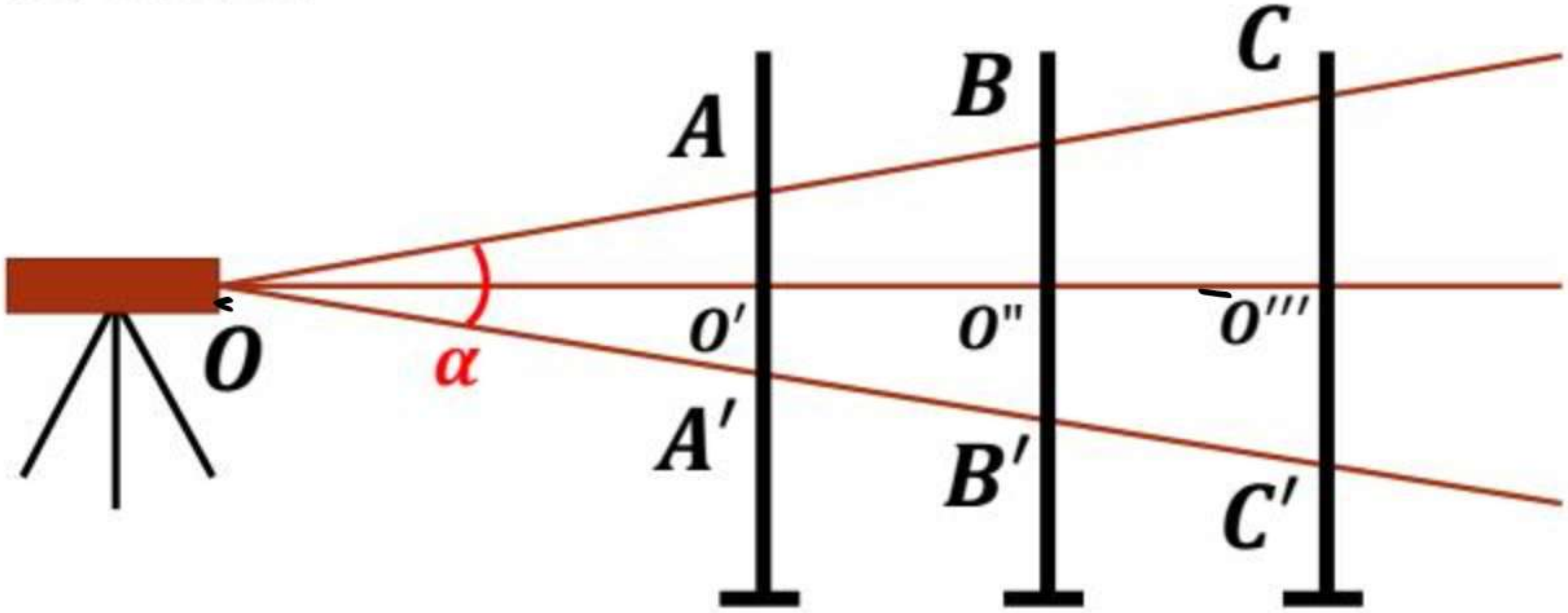
- The various methods of the tacheometric survey may be classified as follows:

1. The Stadia System
   - Fixed Hair Method
   - Movable Hair Method, or Subtense Bar Method
2. The Tangential System

STADIA METHOD

- **The stadia method follows the principle that in similar isosceles triangles the ratio of the perpendicular to the base is constant.**

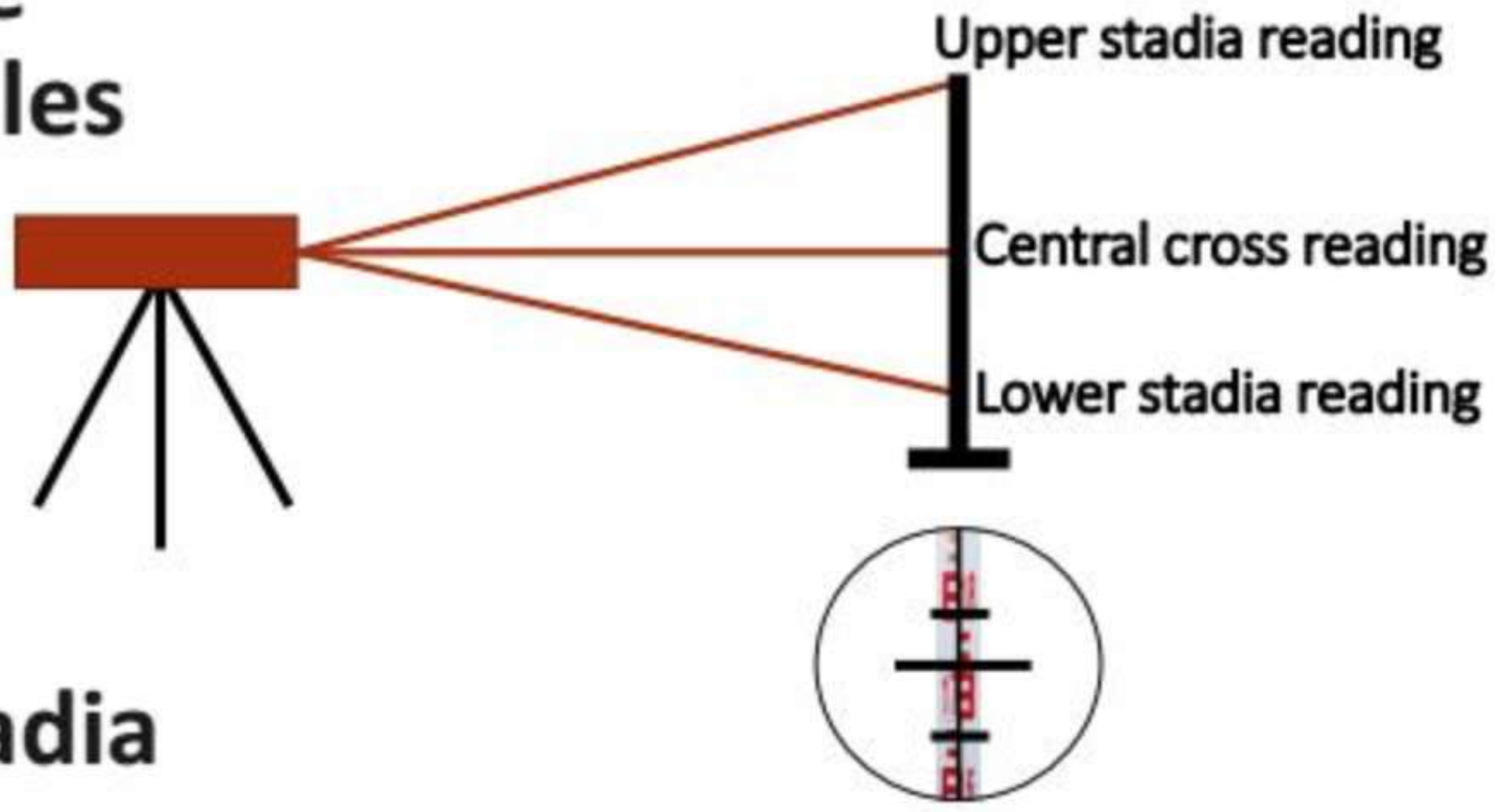




$$\frac{OO'}{AA'} = \frac{OO''}{BB'} = \frac{OO'''}{CC'} = \frac{1}{2}\cot\frac{\alpha}{2}$$

STADIA METHOD

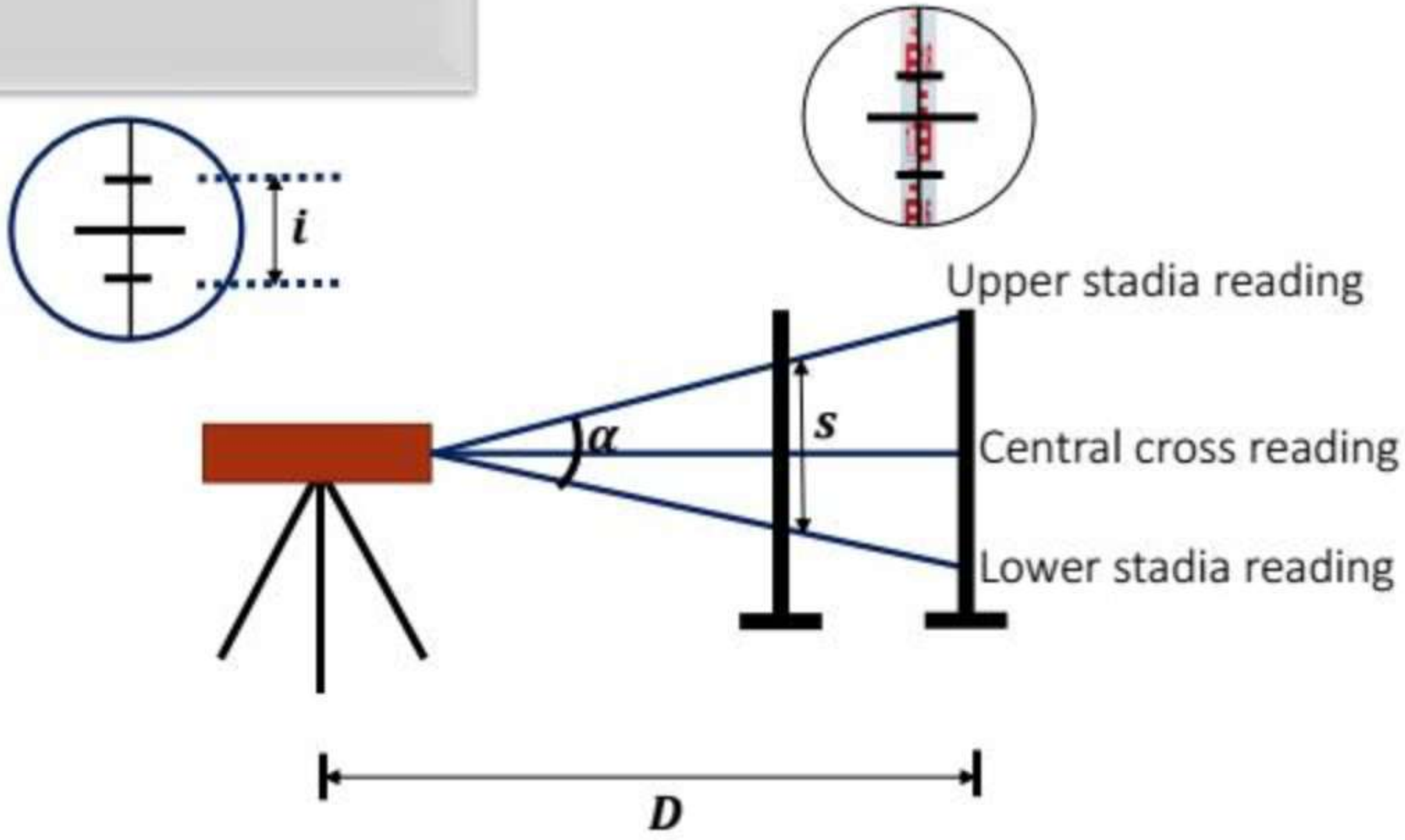
- The stadia method follows the principle that in similar isosceles triangles the ratio of the perpendicular to the base is constant.
- In this method staff intercept (between upper and lower stadia hair) is measured.
- This method is used to determine horizontal and vertical distances.



STADIA METHOD

1. *FIXED HAIR METHOD*

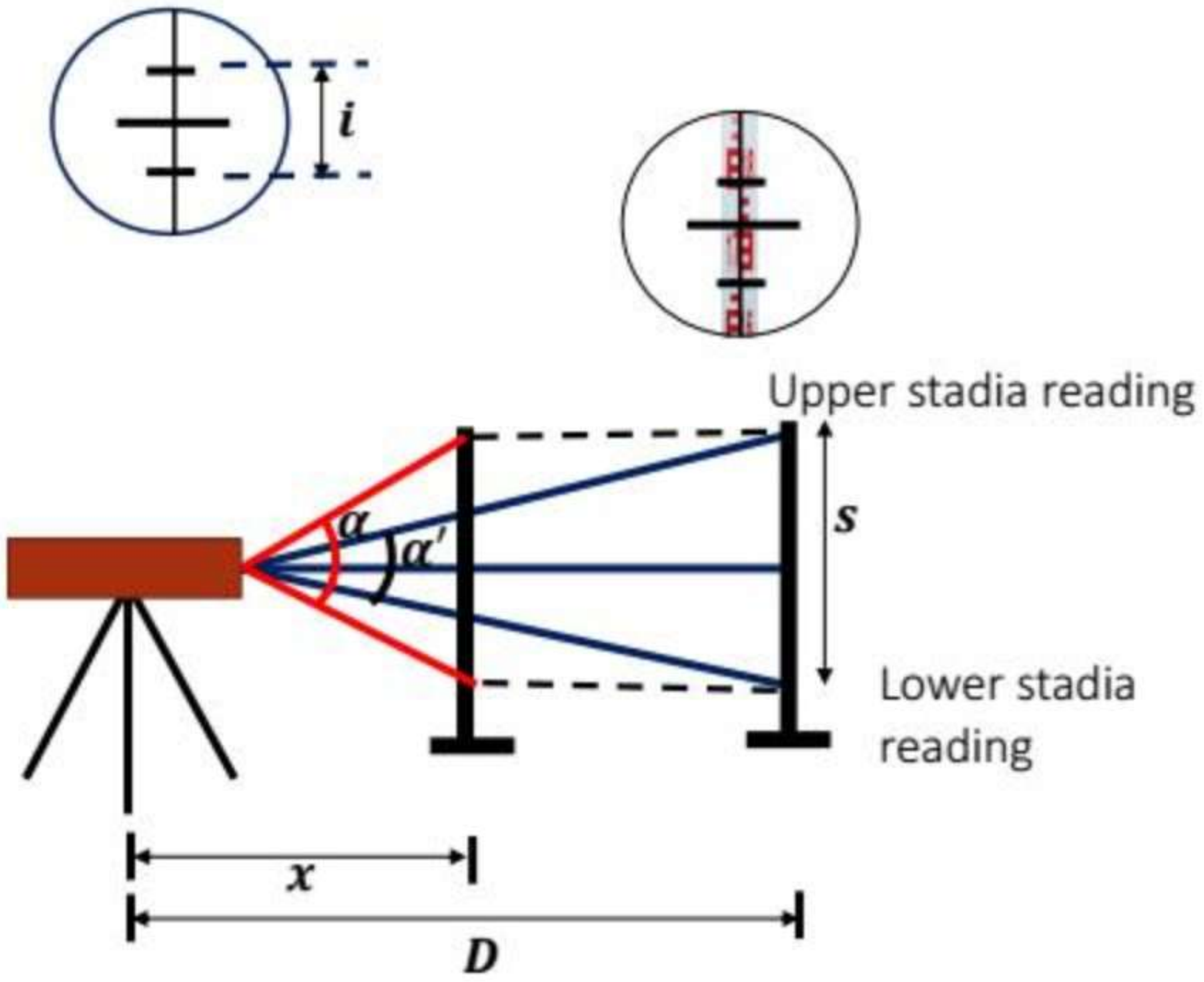
- In this method, the vertical spacing between upper stadia hair and lower stadia hair called 'stadia interval' is kept fixed.'
- Parallatic angle(α) is defined, with the help of stadia hair, which is kept fixed while staff intercept (s) is varied



STADIA METHOD

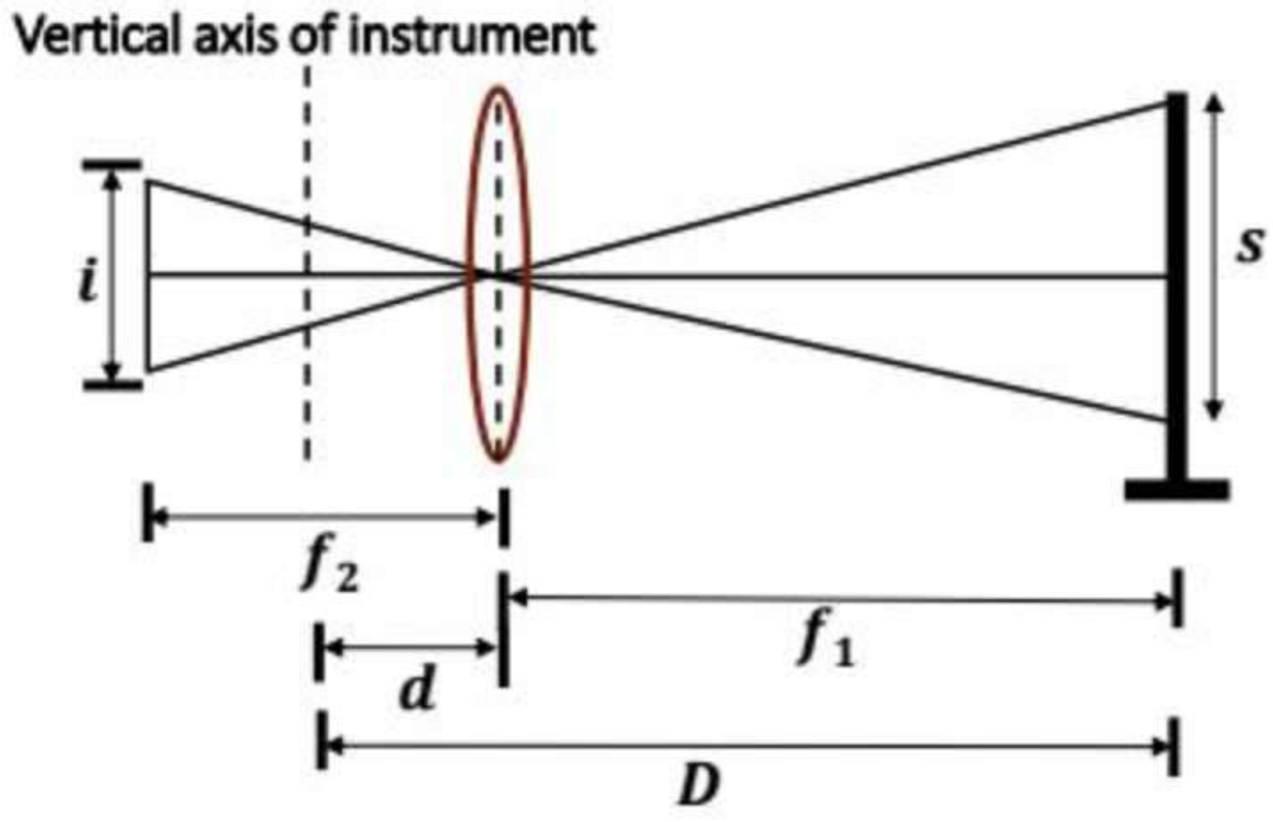
2. MOVABLE HAIR METHOD

- In this method, staff intercept is fixed and stadia interval is varying using micrometer screws.
- This method is rarely used since it is inconvenient to measure stadia hair interval accurately.



PRINCIPLE OF STADIA METHOD

The principle of stadia method is that the ratio of the *perpendicular to the base* is constant in similar isosceles triangles.

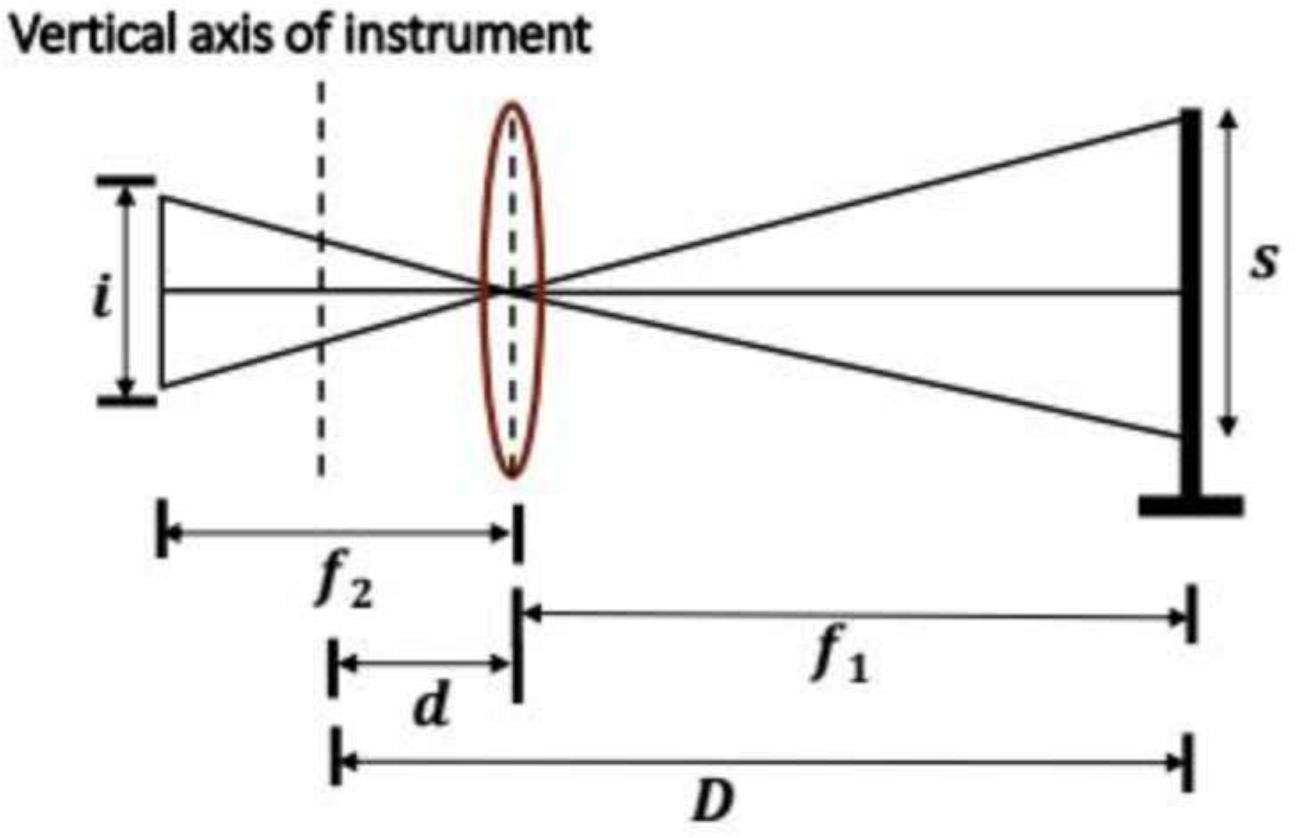


PRINCIPLE OF STADIA METHOD

- $\Rightarrow D = \frac{f}{i}(s) + (f + d)$
- $\Rightarrow D = ks + c$
- *Multiplying constant* $k = \frac{f}{i}$ (k=100)
- *Additive constant* $c = f + d$ (c=0)

This equation is TACHEOMETRIC DISTANCE EQUATION

$$D \propto s$$
$$k = \frac{f}{i}$$



Where f – focal length

d – distance from object glass to trunnion axis

k – multiplying constant (k=100) or stadia interval factor

i=stadia interval

c – additive constant (lies between 0.25m to 0.35m)

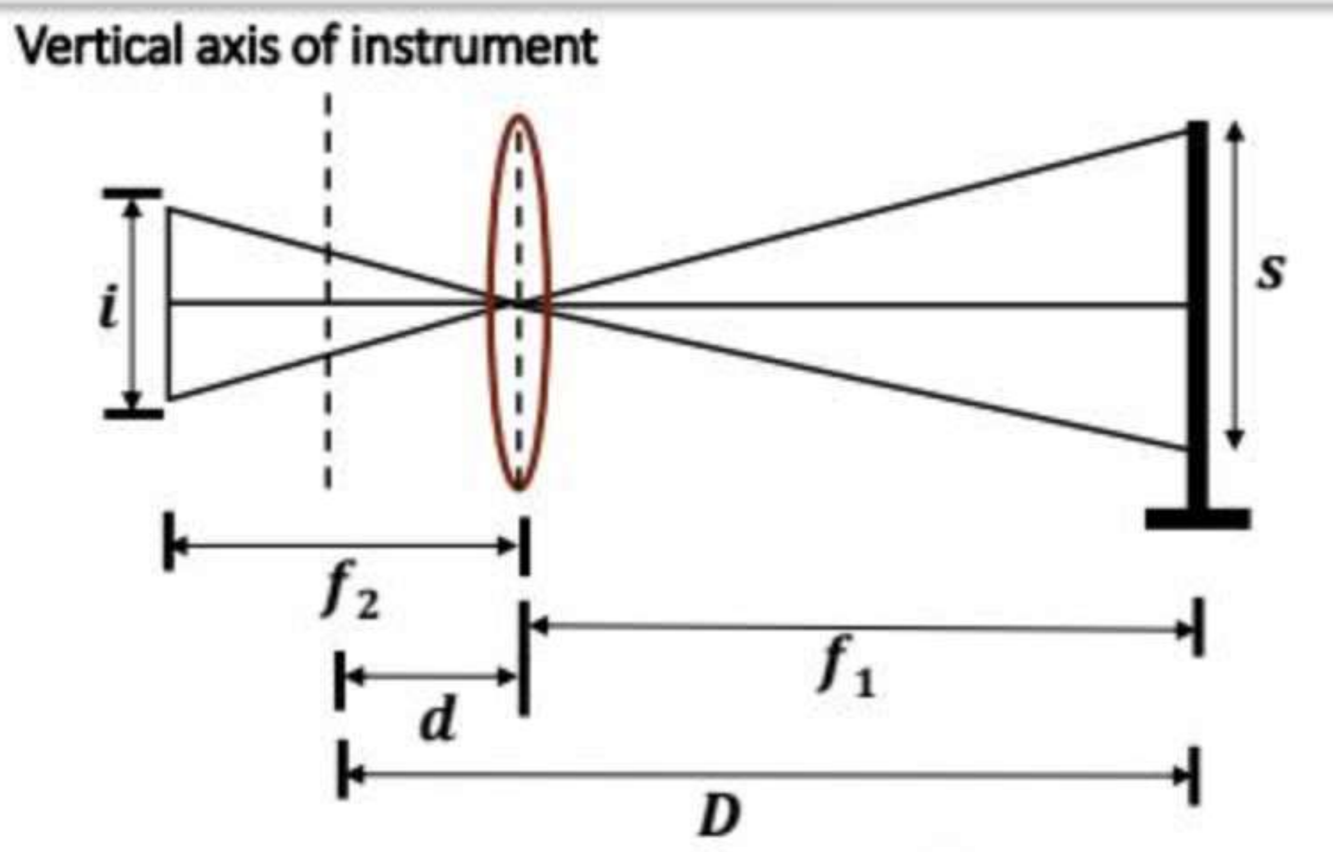
Value of ‘c’ becomes ‘0’ if an anallatic lens is used in telescope

Intercept ‘s’ is minimum if the staff is held truly normal to line of sight

Trunnion axis: The horizontal axis about which the telescope can be rotated.

PRINCIPLE OF STADIA METHOD

Using similar triangle property, $\frac{f_1}{f_2} = \frac{s}{i}$



- $D = f_1 + d$
- $\Rightarrow$ Using Lens formula, $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$
- *Multiply by ff_1*
- $f_1 = f + \frac{f_1}{f_2} f$
- *Put values of* $\frac{f_1}{f_2}$ *in* $\frac{f_1}{f_2} = \frac{s}{i}$
- $f_1 = f + \frac{s}{i} f$
- $\Rightarrow D = d + f_1$
- $\Rightarrow D = \frac{f}{i}(s) + (f + d)$

$$\Rightarrow D = ks + c$$

Multiplying constant $k = \frac{f}{i}$ (k=100)

Additive constant $c = f + d$ (c=0)

This equation is TACHEOMETRIC DISTANCE EQUATION

$$D \propto s$$

$$k = \frac{f}{i}$$

Que 100. Calculate the horizontal distance between the staff and instrument if the staff readings are 1.4m and 2.9m, which corresponds to lower and upper horizontal lines of cross hair. The lens of the telescope of the tacheometer is anallactic lens

a) 100

b) 140

c) 150

d) 200

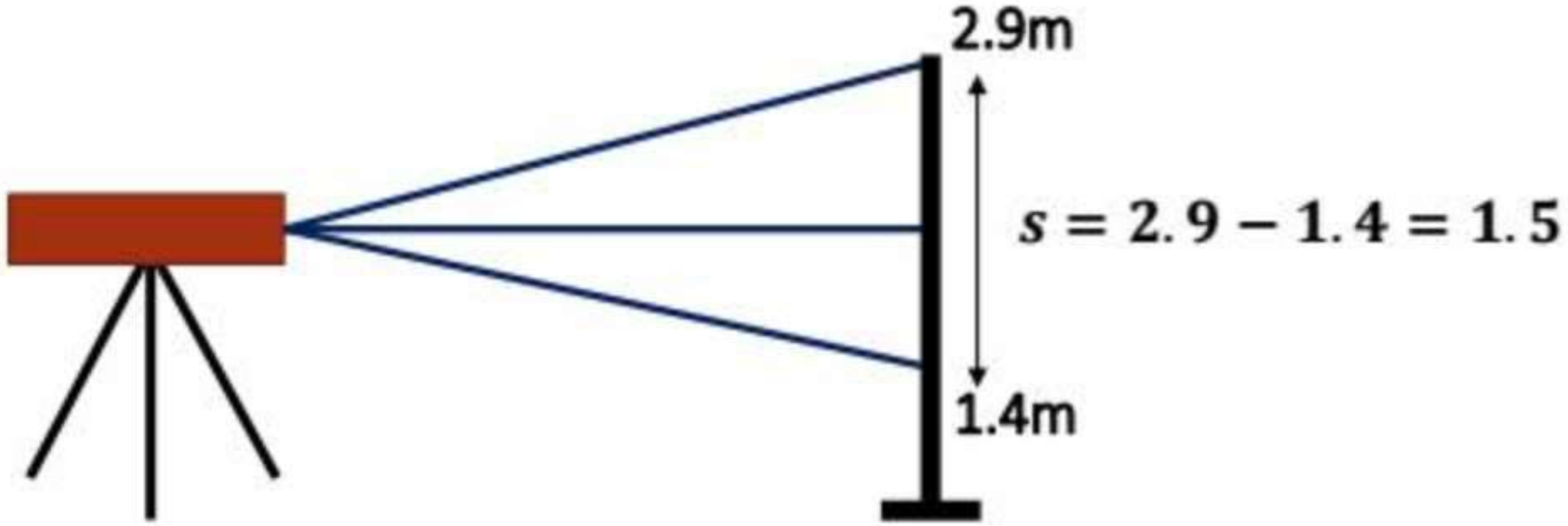
Que.100 Calculate the horizontal distance between the staff and instrument if the staff readings are 1.4m and 2.9m, which corresponds to lower and upper horizontal lines of cross hair. The lens of the telescope of the tacheometer is anallactic lens

a) 100

b) 140

c) 150

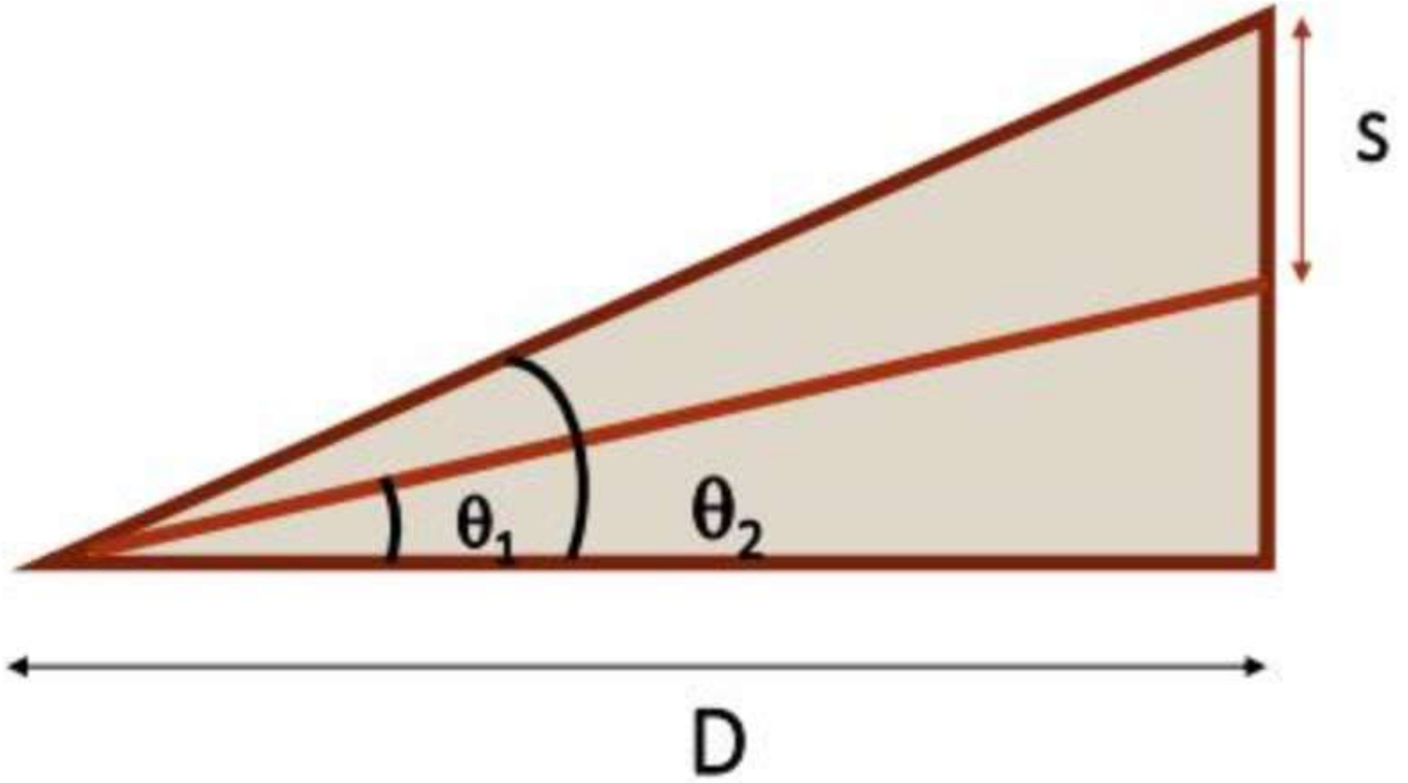
d) 200



$$\begin{aligned} D &= ks + c \\ &= 100(1.5) + 0 \\ &= 150 \end{aligned}$$

TANGENTIAL METHOD

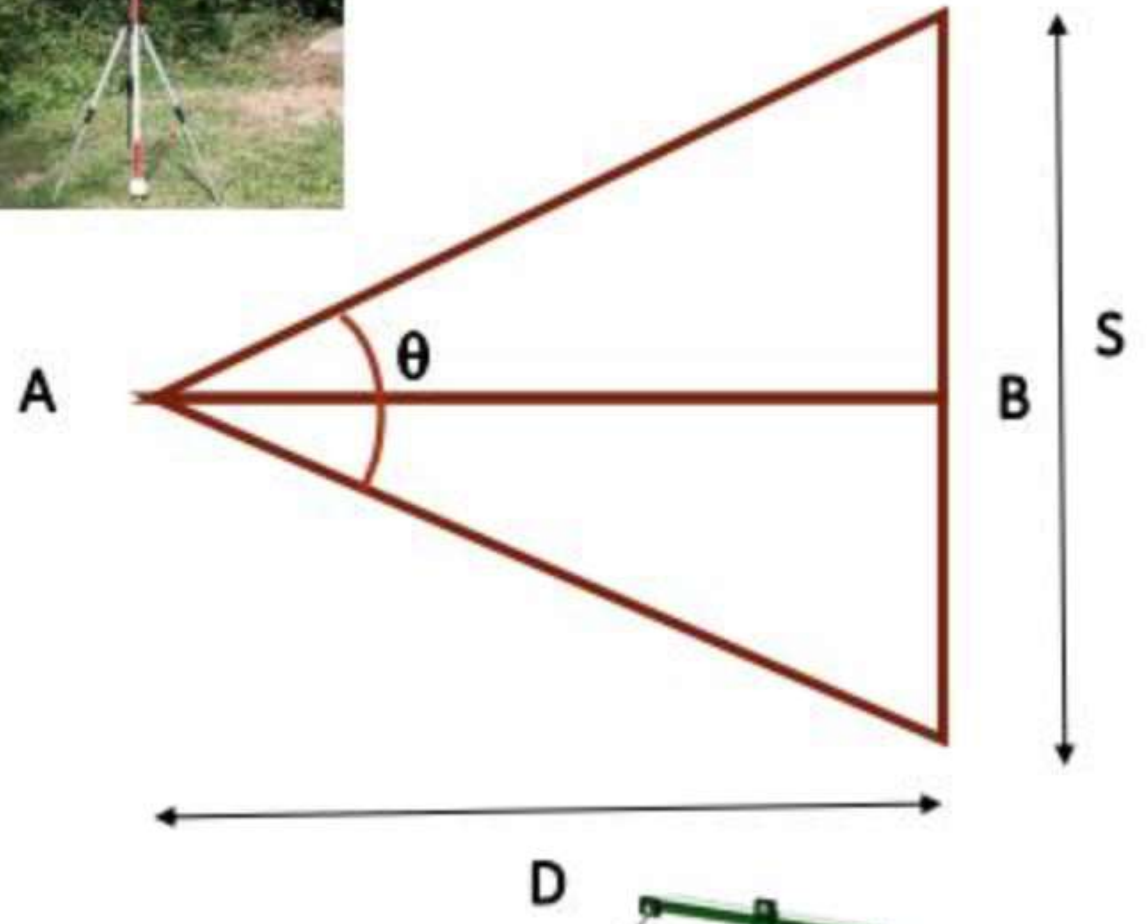
- In this method, stadia hairs are not required hence the method cannot be used when stadia diaphragm is not provided.
- In this system of tachometric surveying, two observations will be necessary from the instrument station to the staff station to determine the horizontal distance and the difference in the elevation between the line of collimation and the staff station.
- The only advantage of this method is that this survey can be conducted with ordinary transit theodolite.

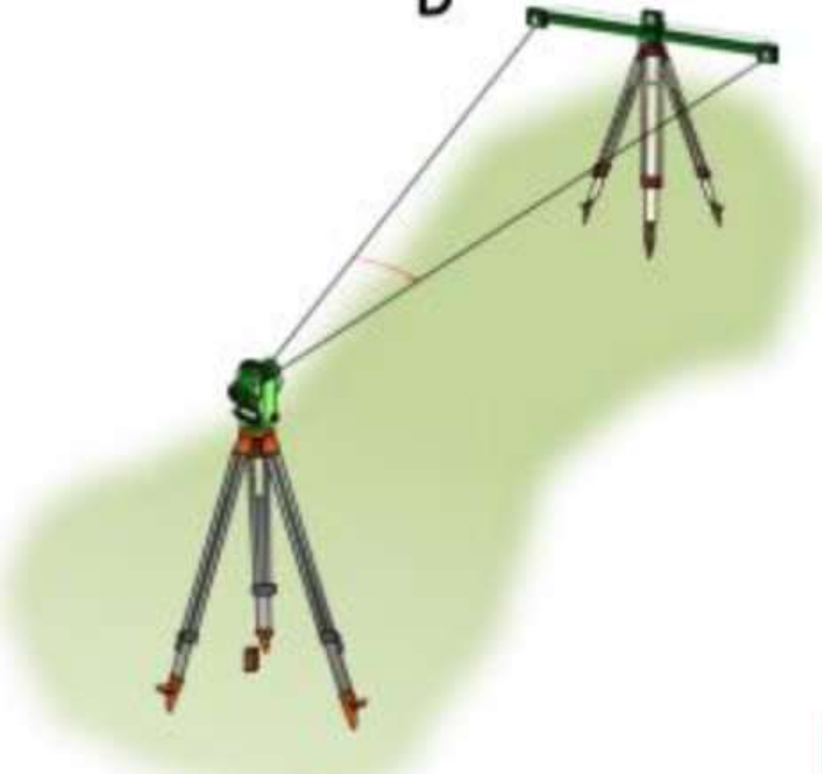


$$s = D\tan\theta_2 - D\tan\theta_1$$

$$s = D(\tan\theta_2 - \tan\theta_1)$$

SUBTENSE BAR METHOD





- This method is almost same as the stadia method except that **the stadia interval is variable.**
- A suitable arrangement is made to vary the distance between the stadia hair as to set them against the two targets on the staff kept at the point under observation.
- Thus, in this case, the staff intercept, i.e., the distance between the two targets is kept fixed while the stadia interval, i.e., the distance between the stadia hair is variable.
- As in the case of fixed hair method, inclined sights may also be taken

Que. 101 Subtense bar is an instrument used for

a) Levelling

b) Measurement of horizontal distances in plane areas

c) Measurement of horizontal distances in undulated areas

d) Measurement of angles

Que. 101 Subtense bar is an instrument used for

a) Levelling

b) Measurement of horizontal distances in plane areas

c) Measurement of horizontal distances in undulated areas

d) Measurement of angles

Que. 102 Horizontal distances obtained by tacheometer observations

a) Require slope correction

b) Require tension correction

c) Require slope and tension correction

d) Do not require slope and tension corrections

Que. 102 Horizontal distances obtained by tacheometer observations

a) Require slope correction

b) Require tension correction

c) Require slope and tension correction

d) <u>Do not require slope and tension corrections</u>

Que. 103 The number of horizontal cross wires in a stadia diaphragm is

a) 1

b) 2

c) 3

d) 4

Que. 103 The number of horizontal cross wires in a stadia diaphragm is

a) 1

b) 2

c) <u>3</u>

d) 4

Que. 104 For a tacheometer, additive and multiplying constants are respectively

a) 0 and 100

b) 100 and 0

c) 0 and 0

d) 100 and 100

Que. 104 For a tacheometer, additive and multiplying constants are respectively

a) <u>0 and 100</u>

b) 100 and 0

c) 0 and 0

d) 100 and 100

Multiplying constant $k = \frac{f}{i}$ (k=100)

Additive constant $c = f + d$ (c=0)

Que. 105 Cross hair in surveying telescope are fitted

a) In the objective glass

b) At the centre of telescope

c) At the optical centre of the eye piece

d) In front of eye piece

Que. 105 Cross hair in surveying telescope are fitted

a) In the objective glass

b) At the centre of telescope

c) At the optical centre of the eye piece

d) <u>In front of eye piece</u>

Que. 106 An annalatic lens is provided in a

a) Theodolite

b) Tacheometer

c) Dumpy level

d) Prismatic compass

Que. 106 An annalatic lens is provided in a

a) Theodolite

b) <u>Tacheometer</u>

c) Dumpy level

d) Prismatic compass

Que. 107 Multiplying constant is

a) f+d

b) f/d + i

c) f/i + d

d) f/i

Que. 107 Multiplying constant is

a) f+d

b) f/d + i

c) f/i + d

d) f/i

Multiplying constant $k = \frac{f}{i}$ (k=100)
Additive constant $c = f + d$ (c=0)

Measurement of Area and Volume

One of the major objective of Surveying is to obtain relative quantities of area and volume.

Measurement of Area

$$= 1\ km^2$$
$$= 100\ ha$$
$$= 10\,000\ are$$
$$= 1000\,000\ m^2$$

Geometric Formulae of AREA

(a) Triangle: A = base × half of the perpendicular height

(b) Parallelogram: A = base × perpendicular height

(c) Trapezoid: A = half of the parallel sides × perpendicular height

(d) Trapezium: A = area as found by dividing the figure into two triangles

Measurement of Area

Measurement of Area:

- **If the shape of Area is enclosed by straight boundaries, it can be divided into simple geometrical shapes such as triangle, trapezoid, rectangle, etc.**
- **Area of these figures can be determined using appropriate formulae.**
- **Areas can also be calculated based on the measurements scaled from the plan or by use of Planimeter/Platometer**

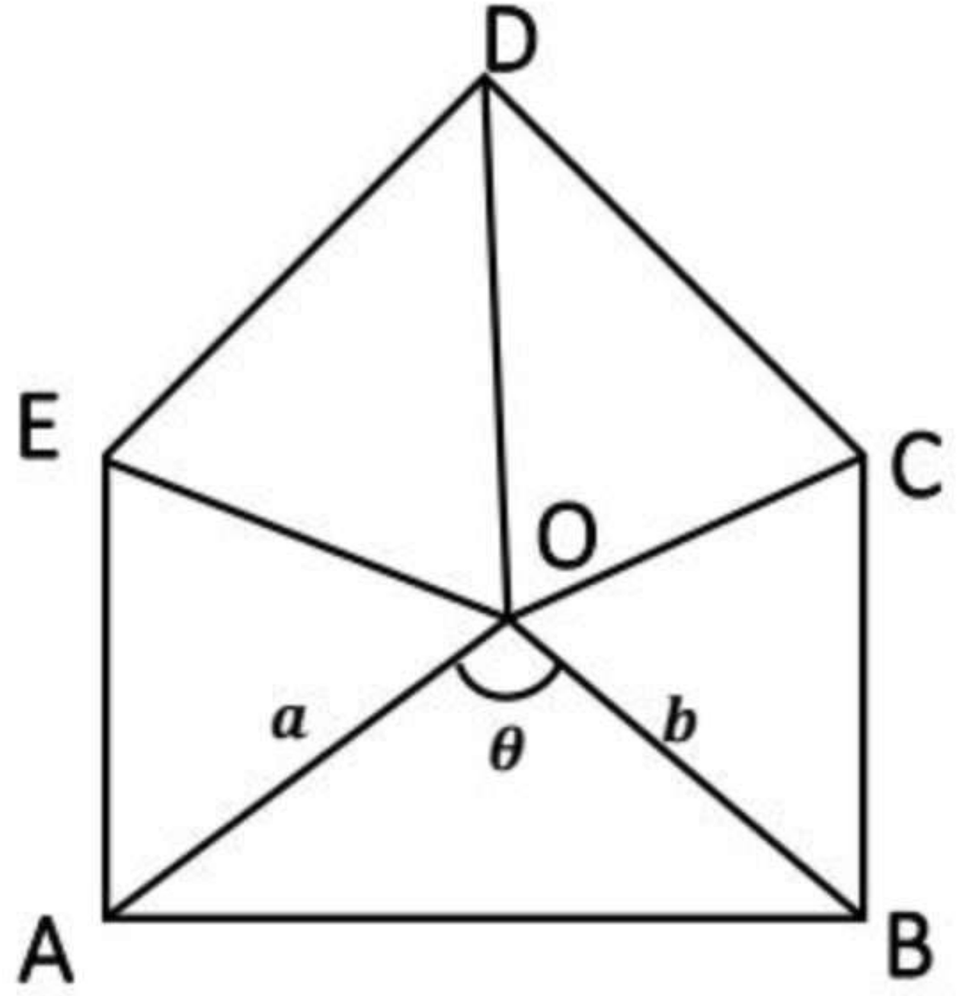
Areas Computed by Sub Division into Triangles

- Area is divided into a number of triangles and area of each triangle is calculated
- If two sides and one included angle between them are given, area may be calculated as

$$Area = \frac{1}{2} \times ab \sin \theta$$

- When the lengths of the three sides of triangle are given,

$$Area = \sqrt{s(s-a)(s-b)(s-c)}$$

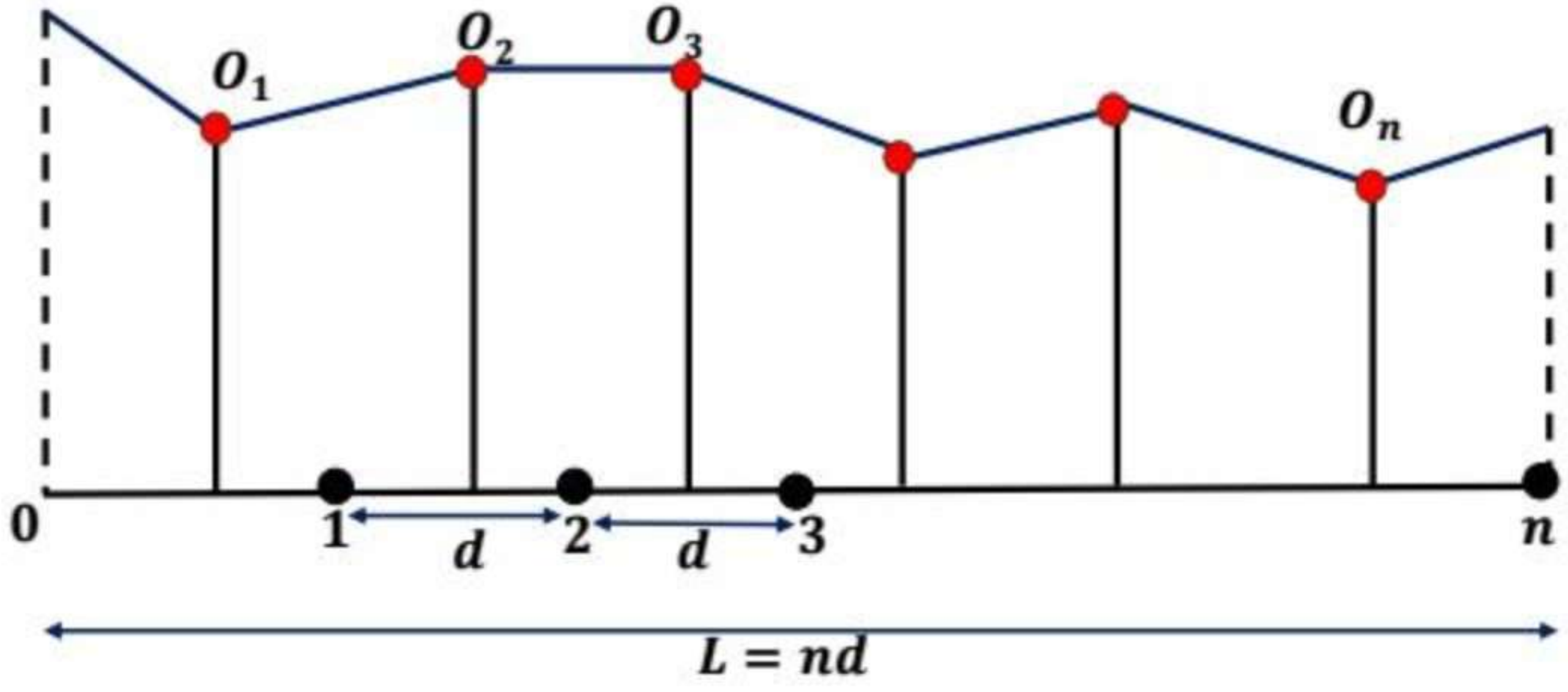


s=semi perimeter

Area from offsets to a BASE LINE

1. Mid ordinate rule

- This method is used with the assumption that boundaries between the extremities of the ordinates (or offsets) are straight lines.
- The base line is divided into a number of divisions and the ordinates are measured at the mid points of each divisions, so Area….



$$Area = Average\ ordinate \times Length\ of\ base$$

$$\Rightarrow Area = \frac{O_1 + O_2 + O_3 + \cdots + O_n}{n} \times L$$

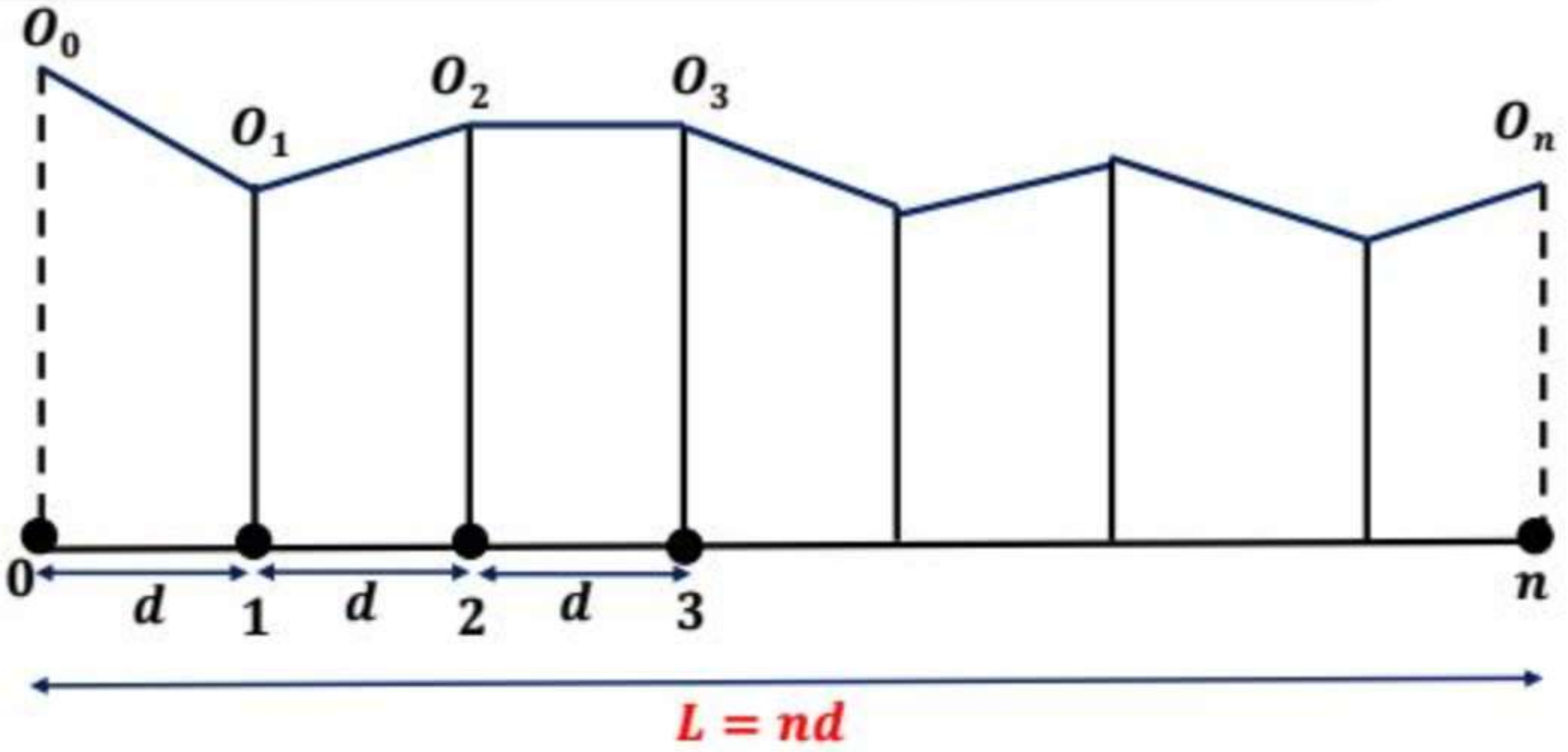
$$\Rightarrow Area = \frac{O_1 + O_2 + O_3 + \cdots + O_n}{n} \times nd$$

$$\Rightarrow Area = (O_1 + O_2 + O_3 + \cdots + O_n)d$$

Area from offsets to a BASE LINE

2. Average Ordinate Rule

- This rule also assumes that the boundaries between the extremities of the ordinates are straight lines
- The offsets are measured to each of the points of the divisions of the base line



$$\Rightarrow Area = \frac{O_0 + O_1 + O_2 + O_3 + \cdots + O_n}{n+1} \times L$$

3. Trapezoidal Rule

- This rule is based on the assumption that the figures are trapezoids. The rule is more accurate than the previous two rules which are approximate versions of the trapezoidal rule
- Area of the first trapezoid

$$A_1 = \frac{O_0 + O_1}{2} d$$

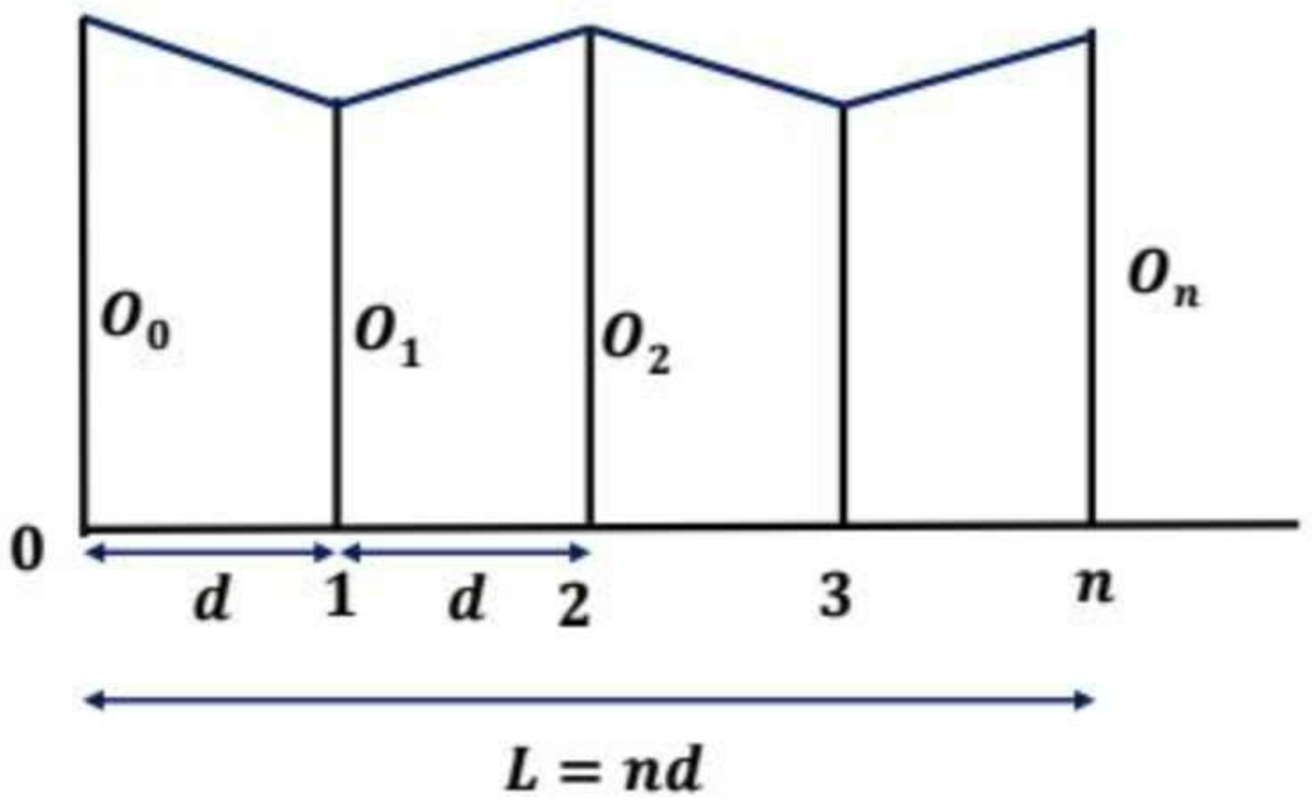
$$Similarly\ A_2 = \frac{O_1 + O_2}{2} d \ \ and\ so\ on..$$

$$\Rightarrow An = \frac{O_{n-1} + On}{2} d$$

$$Total\ area\ A = A_1 + A_2 + A_3 + \cdots + An$$

$$= \frac{O_0 + O_1}{2} d + \frac{O_1 + O_2}{2} d + \cdots + \frac{O_{n-1} + O_n}{2} d$$

$$= \left[\frac{O_0 + On}{2} + O_1 + O_2 + O_3 + \cdots + O_{n-1}\right] d$$

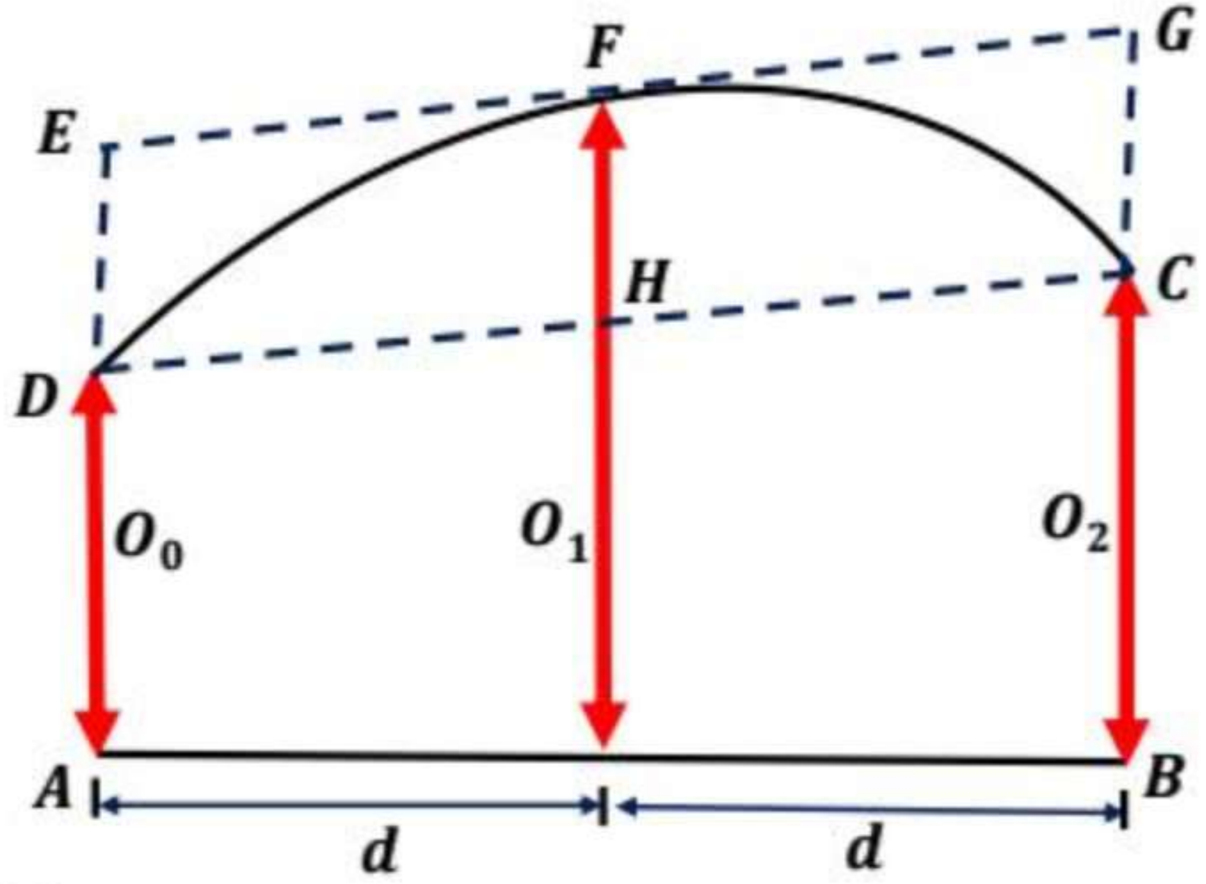


4. Simpson's One Third Rule

- This rule assumes that short lengths of boundary between the ordinates are parabolic arcs. This method is more useful when the boundary line departs considerably from the straight line

- $Area\ of\ ABCD = \frac{O_0+O_2}{2} \times 2d \qquad \ldots(1)$
- $Area\ of\ segment\ of\ parabola =$
  $\frac{2}{3} area\ of\ parallelogram\ enclosing\ it$

$$\Rightarrow Area\ DFC = \frac{2}{3}\ Area\ CDEG$$
$$= \frac{2}{3} \times FH \times AB$$
$$= \frac{2}{3} \times \left\{O_1 - \frac{O_0 + O_2}{2}\right\} \times 2d$$



So area of first two intervals= $\frac{O_0+O_2}{2} \times 2d \ + \ \frac{2}{3} \times \left\{O_1 - \frac{O_0+O_2}{2}\right\} \times 2$

$$= \frac{d}{3} \times \{O_0 + 4O_1 + O_2\}$$

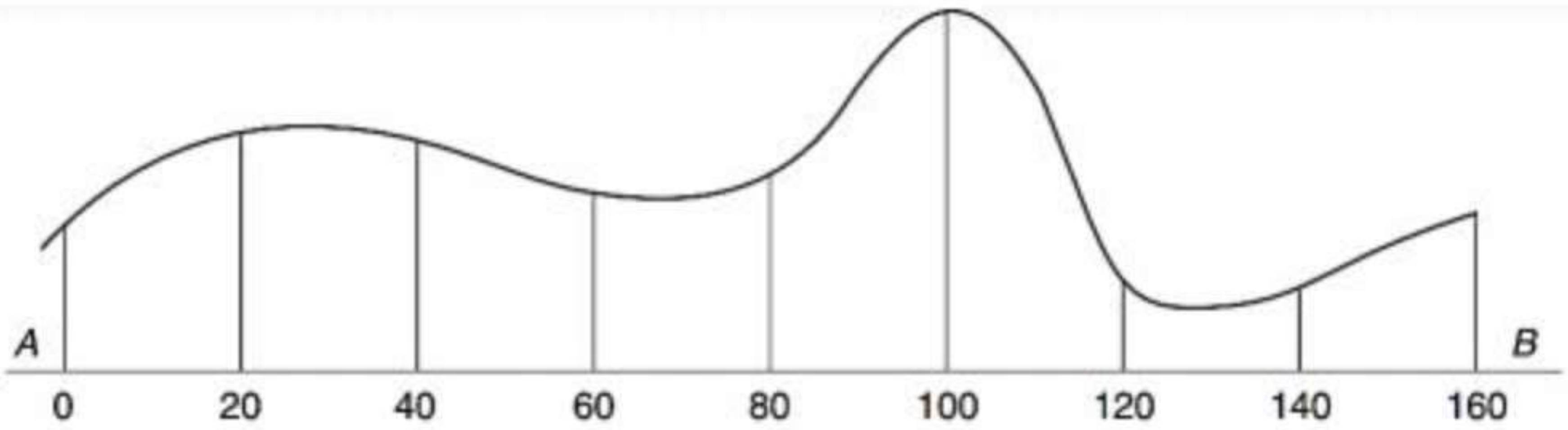
Similarly for the next two intervals = $\frac{d}{3} \times \{O_2 + 4O_3 + O_4\}\ and\ so\ on$

$$\textbf{Total area} = \frac{d}{3} \times \{(O_0 + On) + 4\underbrace{(O_1 + O_3 + \cdots + O_{n-1})}_{\text{Even ordinates}} + 2\underbrace{(O_2 + O_4 + \cdots + O_{n-2})}_{\text{odd ordinates}}\}$$

<u>Note:</u>

- **Simpson's one third rule is used when the number of Divisions are even i.e. offsets are odd**
- **If in question it is given to solve by Simpson's rule and number of offsets are even, then Area=A1+A2**
  - **A1= area by simpson's one third rule upto second last offset**
  - **A2=Area between last two offsets**

Determine the area in hectares between the line AB and a meandering stream for offsets taken at a regular interval of 20 m along the line AB



Point	A								B
Distance (m)	0	20	40	60	80	100	120	140	160
Offset Length	23	40	42	30	32	60	10	14	22

Measurement of Volume

Some basic Figures:

1. A geometrical solid bounded by planes is known as *polyhedron*.
2. Prism is a polyhedron with two of its faces (bases) as equal polygons lying in parallel planes and having their homologous sides parallel. The other faces are parallelograms formed by planes passing through the homologous sides of the equal polygon
3. PRISMOID is a solid that has parallel plane bases or ends and is bounded on the sides either by planes or warped surfaces

Measurement of Volume

- Calculation of Volume of various quantities are done for various purposes
  - Planning
  - Design

1. Trapezoidal Formula or Average End Area Rule
   - $V = d\left[\frac{A_1+A_n}{2} + A_2 + A_3 + \cdots + A_{n-1}\right]$
2. Prismoidal Rule
   - $V = \frac{d}{3}\{(A_1 + A_n) + 4(A_2 + A_4 + A_6 + \cdots) + 2(A_3 + A_5 + A_7 \ldots)\}$

Measurement of Volume

- Calculation of Volume of various quantities are done for various purposes
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1. Trapezoidal Formula or Average End Area Rule
   - $V = d\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \cdots + A_{n-1}\right]$
   - This method is based on the assumption that the mid area is the mean of the end areas

Question 123: The cross section area of 3 sections of an embankment at an interval of 40m are 10 m², 15 m², and 35 m². Calculate the quantity of Earth work for the embankment using prismoidal method.

Solution:

$$V = \frac{d}{3}\{(A_1 + A_n) + 4(A_2 + A_4 + A_6 + \cdots) + 2(A_3 + A_5 + A_7 \ldots)\}$$

$$\Rightarrow V = \frac{40}{3}\{(10 + 35) + 4(15) + 2(0)\}$$

$$\Rightarrow V = 1400m^3$$

Que 1. Calculate the volume of an embankment in cubic metre using trapezoidal method if the cross sectional area of three sections of an embankment at an interval of 30m are 20sqm, 40sqm and 50sqm.

a) 1100
b) 1150
c) 2250
d) 2350

Que 1. Calculate the volume of an embankment in cubic metre using trapezoidal method if the cross sectional area of three sections of an embankment at an interval of 30m are 20sqm, 40sqm and 50sqm.

a) 1100

b) 1150

c) 2250

d) 2350

Que 2. The area included by contour lines for a proposed dam are given as

Contour (m)	410	420	430	440	450
Area (ha)	205	120	145	95	135

Calculate the capacity in cubic metre of the dam by trapezoidal method

a) 42 000 000

b) 53 000 000

c) 70 000 000

d) 80 000 000

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Que 3. Which of the following method best estimates volume of an earthwork of an irregular embankment?

A) Average ordinate method

B) Mid ordinate method

C) Simpson’s method

D) Trapezoidal method

Que 3. Which of the following method best estimates volume of an earthwork of an irregular embankment?

A) Average ordinate method

B) Mid ordinate method

C) <u>Simpson's method</u>

D) Trapezoidal method

Que 4. What is the volume of earthwork in cubic metre of an embankment 10m long and 7m wide with side slope of 2:1?

a) 70

b) 150

c) 280

d) 390

Que 4. What is the volume of earthwork in cubic metre of an embankment 10m long and 7m wide with side slope of 2:1?

a) 70

b) 150

c) 280

d) 390

Que. 5 In tacheometrical observations, vertical staff holding is generally preferred to normal staffing due to

a) Ease of reduction of observations

b) Facility of holding

c) Minimum effect of careless holding on the result

d) None of these

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a) Ease of reduction of observations

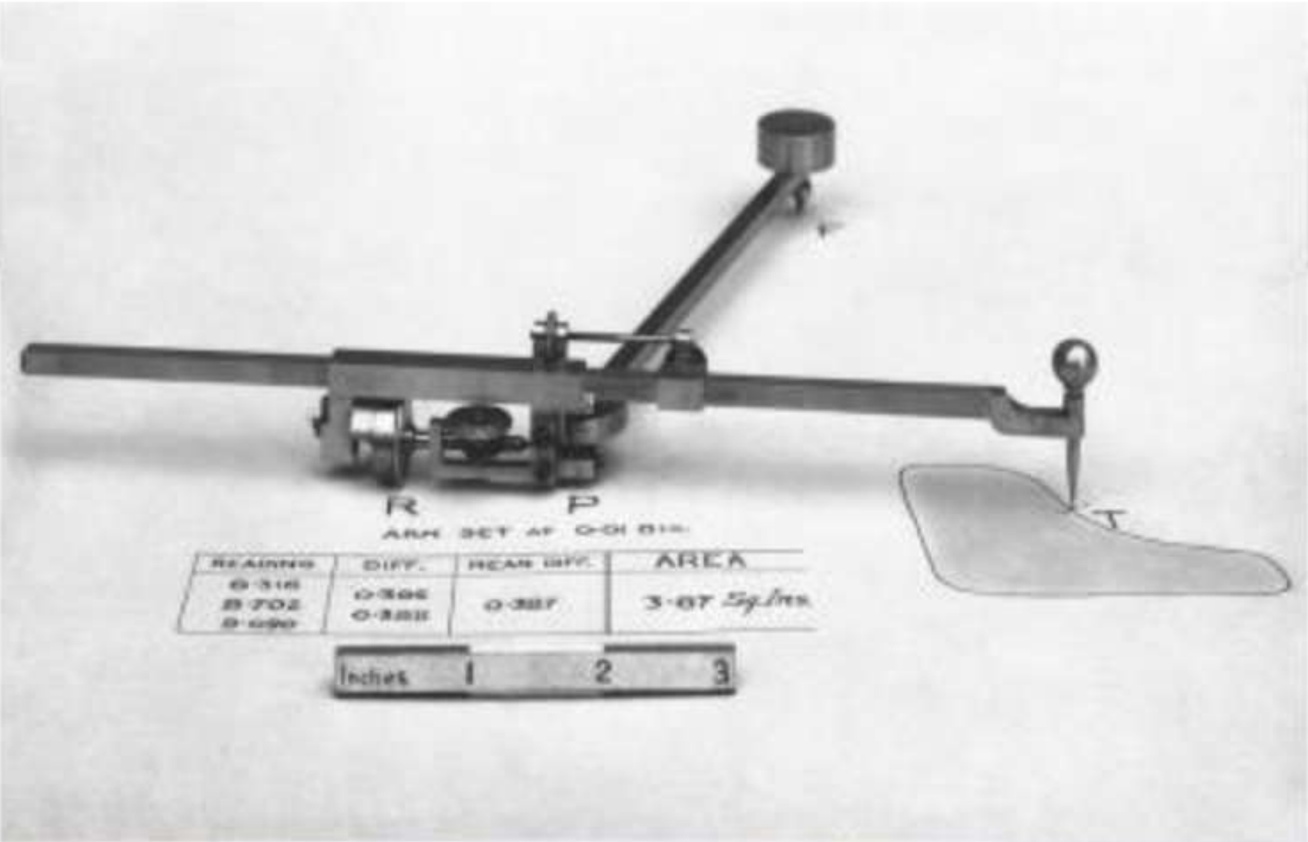
b) Facility of holding

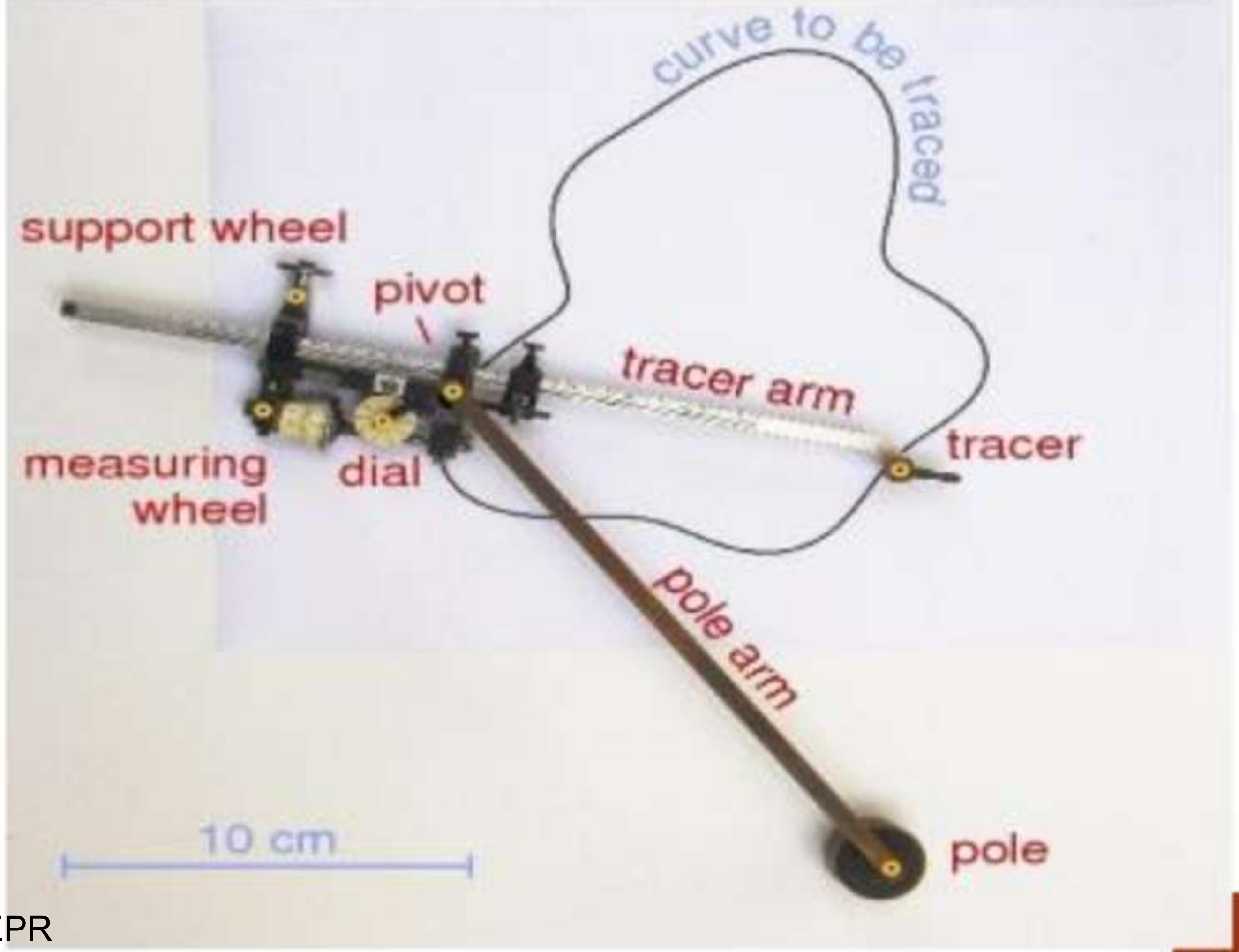
c) Minimum effect of careless holding on the result

d) None of these

Area by Planimeter

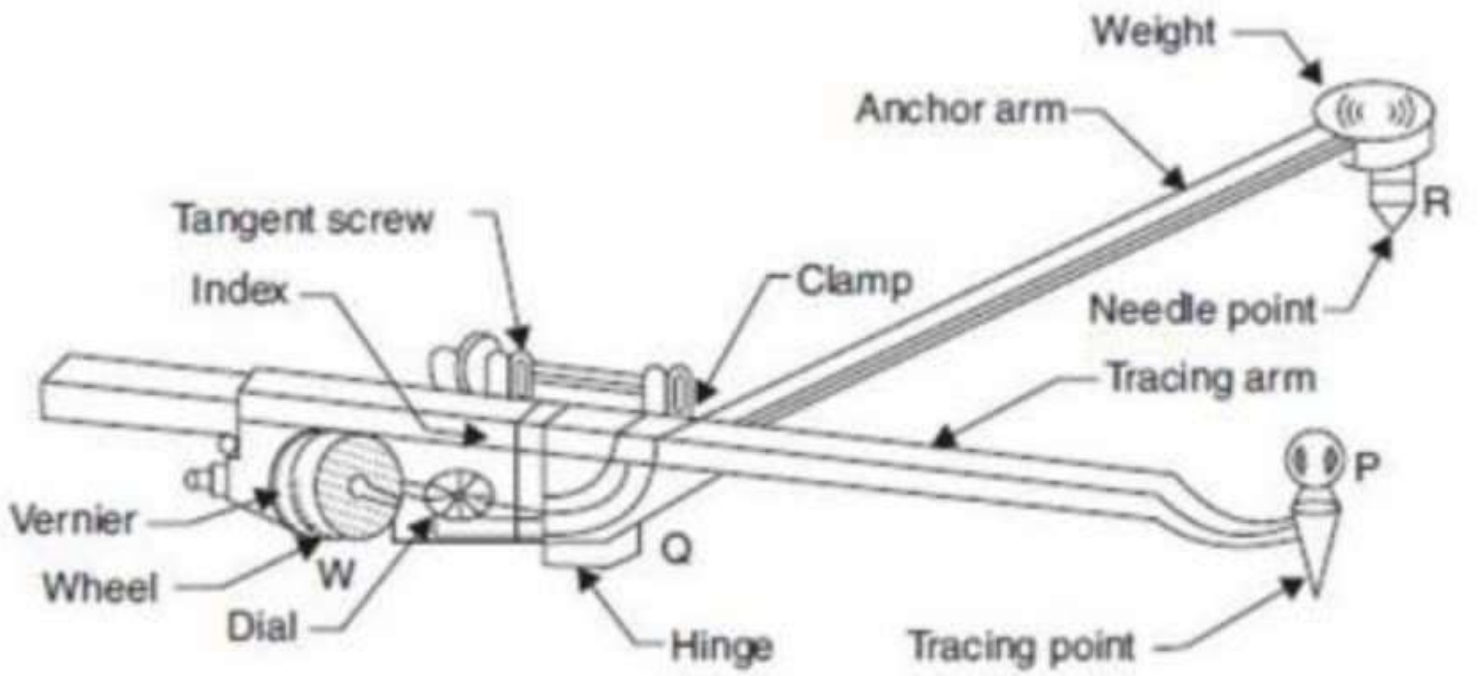
- A planimeter is an instrument which measures area of plan of any plan accurately
- These are of two types:
    - Amsler Polar Planimeter (majorly used)
    - Roller Planimeter





Essential Parts of a planimeter

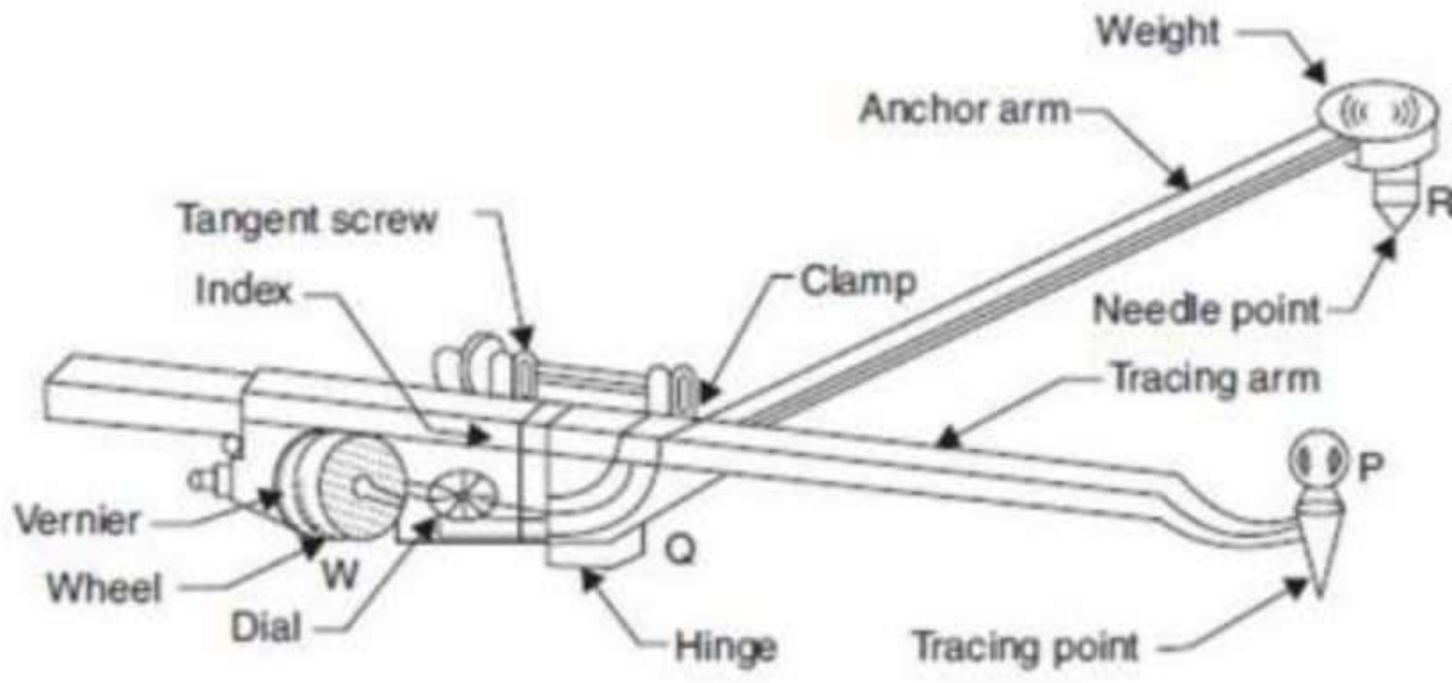
The planimeter rests on three points- ***The wheel, Anchor point and Tracing arm***



1. **Anchor:** **It is a heavy block with a fine anchor pin at its base. It is used to anchor the instrument at a desired point on the plan.**
2. **Anchor arm:** **It is a bar with one end attached to anchor block and the other connected to an integrating unit. Its arm length is generally fixed but some planimeters are provided with variable arms length also.**
3. **Tracing arm:** **It is a bar carrying a tracer point at one end connected to the integrating unit at the other end. The anchor arm and tracer arms are connected by a hinge. The length of this arm can be varied by means of fixed screw and slow motion screw.**
4. **Tracing point:** **This is a needle point connected to the end of tracer arm, which is to be moved over the out line of the area to be measured.**

Essential Parts of a planimeter

5. ***Integrating unit:*** It consists of a hard steel roller and a disc. The axis of roller is parallel to the axis of tracer arm hence it rolls only at right angles to the tracer arm.



- The roller/wheel carries a concentric drum which has 100 divisions and is provided with a vernier to read tenth of roller division.
- A suitable gear system moves a pointer on disc by one division for every one revolution of the roller.
- In addition to this, fixed index near the disc may be utilized to know number of times 0 of the disc has crossed the index.
- The reading on the integrating unit has four digits:

a) Unit read on the disc

b) Tenth and hundredth of a unit read on the roller

c) Thousandth read on the vernier.

Thus if reading on disc is 2, reading on roller is 42 and vernier reads 6, then the total reading F = 2.426

Method of Using Planimeter

- To find the area of a plan, anchor point may be placed either outside the plan (if area is small) or inside the plan (if area is large).
- Then on the boundary of the plan a point is marked and tracer is set on it. The initial reading of the wheel is taken.
- After this tracer is carefully moved over the outline of the plan in clockwise direction till the first point is reached.
- Then the final reading is noted. Now the area of the plan may be found as

$$\boxed{Area = M\,(F - I \pm 10\,N + C)}$$

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Method of Using Planimeter

$$Area = M\,(F - I \pm 10\,N + C)$$

where

- F= Final reading I= Initial reading.
- N= The number of completed revolutions of disc. Plus sign to be used if the zero mark of the dial passes index mark in clockwise direction and minus sign if it passes in anticlockwise direction.
- M = a multiplying constant or planimeter constant and is equal to area per revolution of the roller
- C= Constant of the instrument, which when multiplied with M, gives the area of zero circle.
- The constant C is added only when the anchor point is *inside the area.*
- Multiplying constant M is equal to the area of the plan (map) per revolution of the roller i.e., area corresponding to one division of disc.
- Multiplying constant M and C are normally written on the planimeter. The user can verify these values by
  - (i) Measuring a known area (like that of a rectangle) keeping anchor point outside the area
  - (ii) Again measuring a known area by keeping anchor point inside a known area.

The zero circle or the circle of correction is defined as the circle round the circumference of which if the tracing point is moved, the wheel will simply slide without rotation on paper without change in reading

Que. 6

Calculate the area of field, when initial reading =9.918 and final reading =4.254 were recorded by a planimeter. Multiplying constant of instrument (M)=100cm^2 Instrument constant (C) = 23.521 and number of time the zero mark of the dial passes the fixed index mark of the instrument (N) =-1.

a) 655.7cm^2

b) 895.7 cm^2

c) 785.7 cm^2

d) 986.5 cm^2

Que. 6

Calculate the area of field, when initial reading =9.918 and final reading =4.254 were recorded by a planimeter. Multiplying constant of instrument (M)=100cm² Instrument constant (C) = 23.521 and number of time the zero mark of the dial passes the fixed index mark of the instrument (N) =-1

a) 655.7cm²

b) 895.7 cm²

c) <u>785.7 cm²</u>

d) 986.5 cm²

$$Area = M(B - A \pm 10N + C)$$

A = initial reading
B = final reading
N = no. of completed revolutions of wheel during one complete tracing. N is positive if dial passes index in clockwise, N is negative if dial rotates in anti-clock wise direction.
M and C = constants which values are provided on the planimeter. Constant C is used only when the anchor point is placed inside the plan

$$A = 100(4.254 - 9.918 - 10 \times 1 + 23.521)$$

$$\Rightarrow A = 100(4.254 - 9.918 - 10 \times 1 + 23.521)$$

$$\Rightarrow A = 785.7 cm^2$$

Que:7 Calculate the area of a figure from the following readings by a planimeter with anchor point outside the figure.

Initial reading =7.875, final reading = 3.086 ; M = 10 sq. in.

The zero mark on the that passed the fixed index mark twice in the clockwise direction.

Que 7: Calculate the area of a figure from the following readings by a planimeter with anchor point *outside the figure*.

Initial reading =7.875, final reading = 3.086 ; M = 10 sq. in.

The zero mark on the that passed the fixed index mark twice in the clockwise direction.

$$Area = M\,(F - I \pm 10\,N + C)$$

- F = 3.086 I = 7.875.
- N = +2
- M = 10 sq. in
- C = Since anchor point is outside, C is not to be used in the formula

$$\Rightarrow Area = M\,(F - I \pm 10\,N + 0)$$

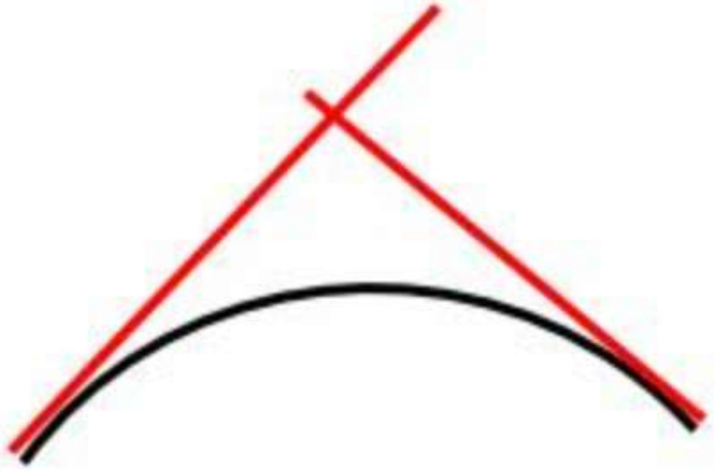
$$= 10 \times (3.086 - 7.875 + 10 \times 2)$$

$$= 152.11\ sq\ in$$

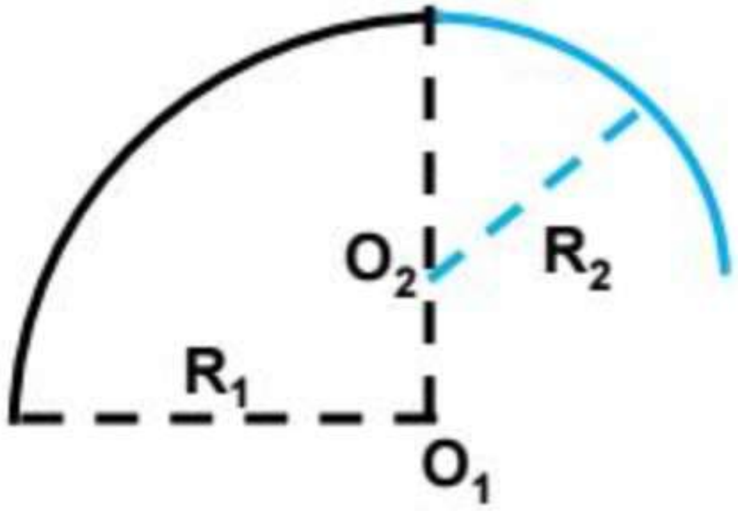
Curves

- Curve are defined as Arc with some finite radius, provided between intersecting straight lines to gradually negotiate change in direction
- This change in direction of straight line may be in a horizontal plane (or) Vertical plane, resulting in the provision of a horizontal (or) vertical curve respectively.

Horizontal Curves



1. Simple Circular Curve

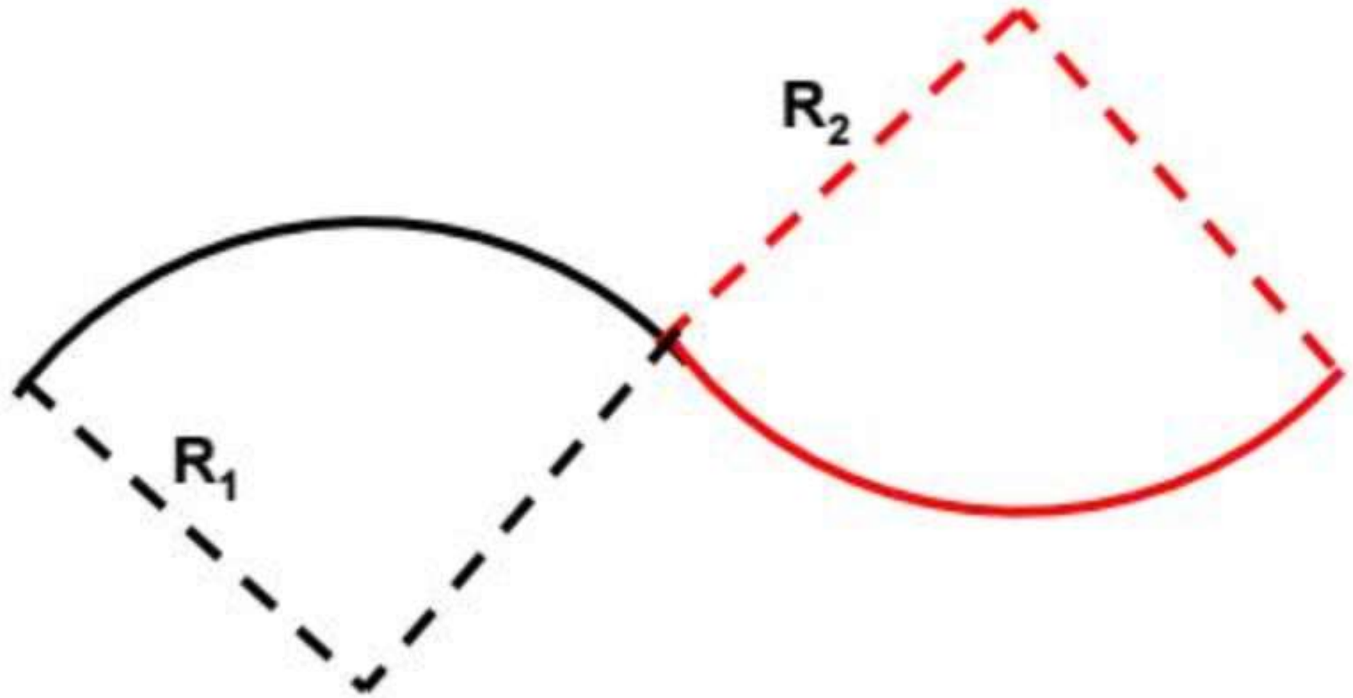


2. Compound Curve

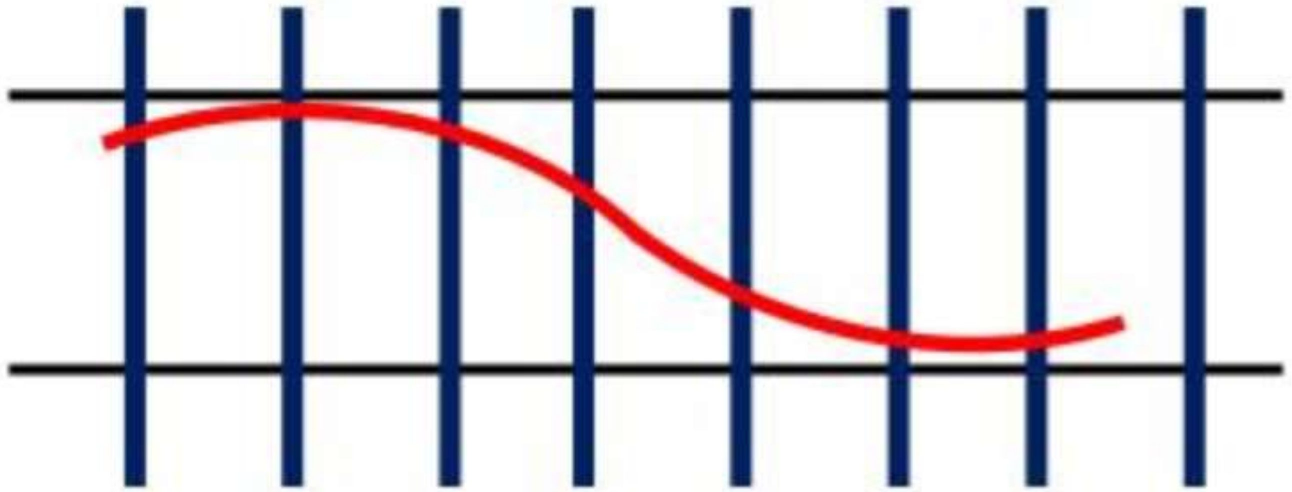
- **A simple circular curve consist of an Arc of a circle which is tangential to the straight line at both the ends.**

- A compound curve consist of two circular arcs of different radius with their centre of curvature on the same side.

3. Reverse Curve / S- Curve / Serpentine Curve

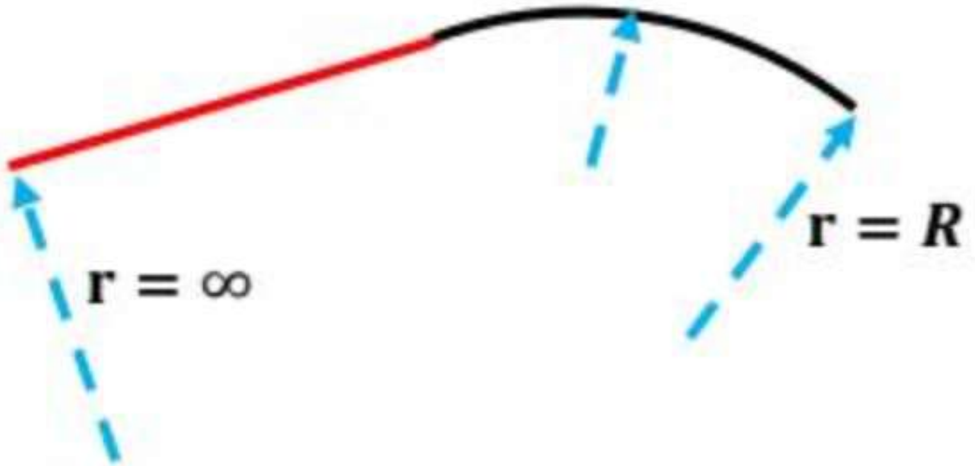


3. Reverse Curve / S- Curve / Serpentine Curve

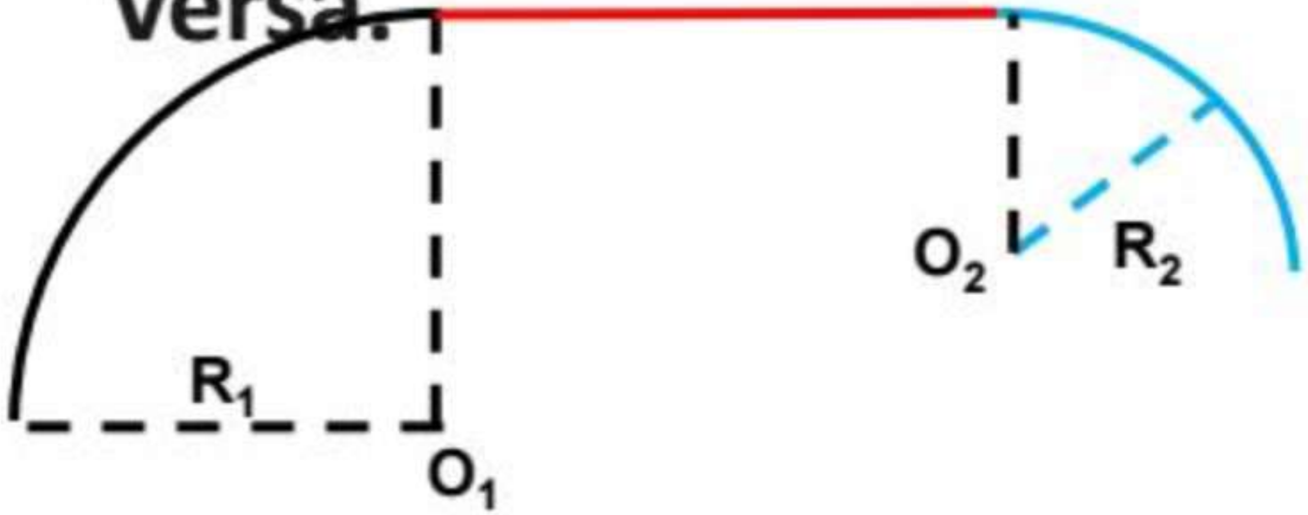


- When two simple circular curves of equal (or) different radius having opposite direction of curvature join together, the resultant curve is called as "Reverse curve"
- Reverse curves are provided between two parallel Lines (or) when angle between them is very small.
- They are commonly used in railway yard but unsuitable for Highways.

4. Transition curve / Easement curve

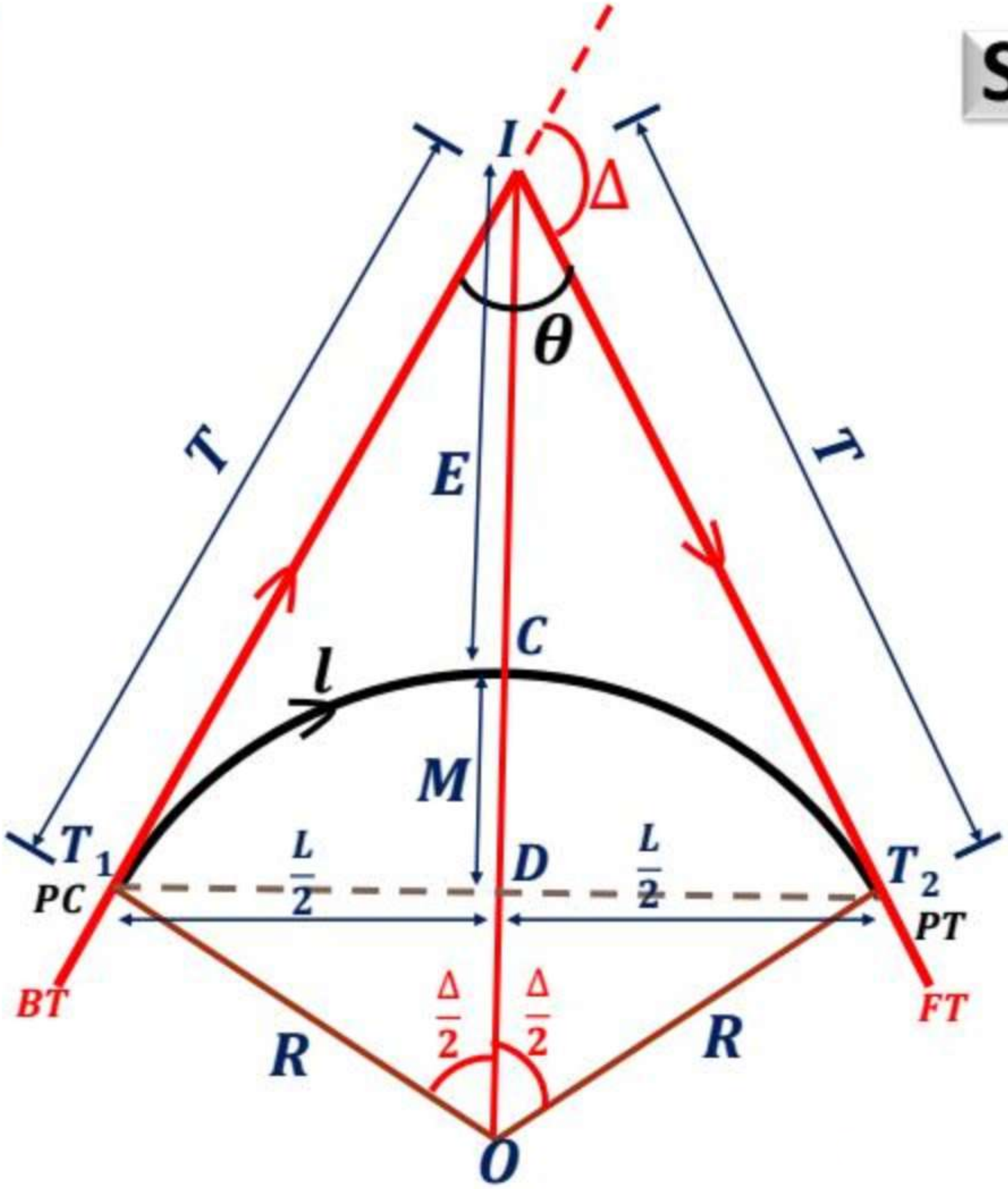


- Transition curve is usually introduced between a simple circular curve and a straight line, vice versa
- Radius of Transition curve gradually varies from finite to infinite value and vice-versa.



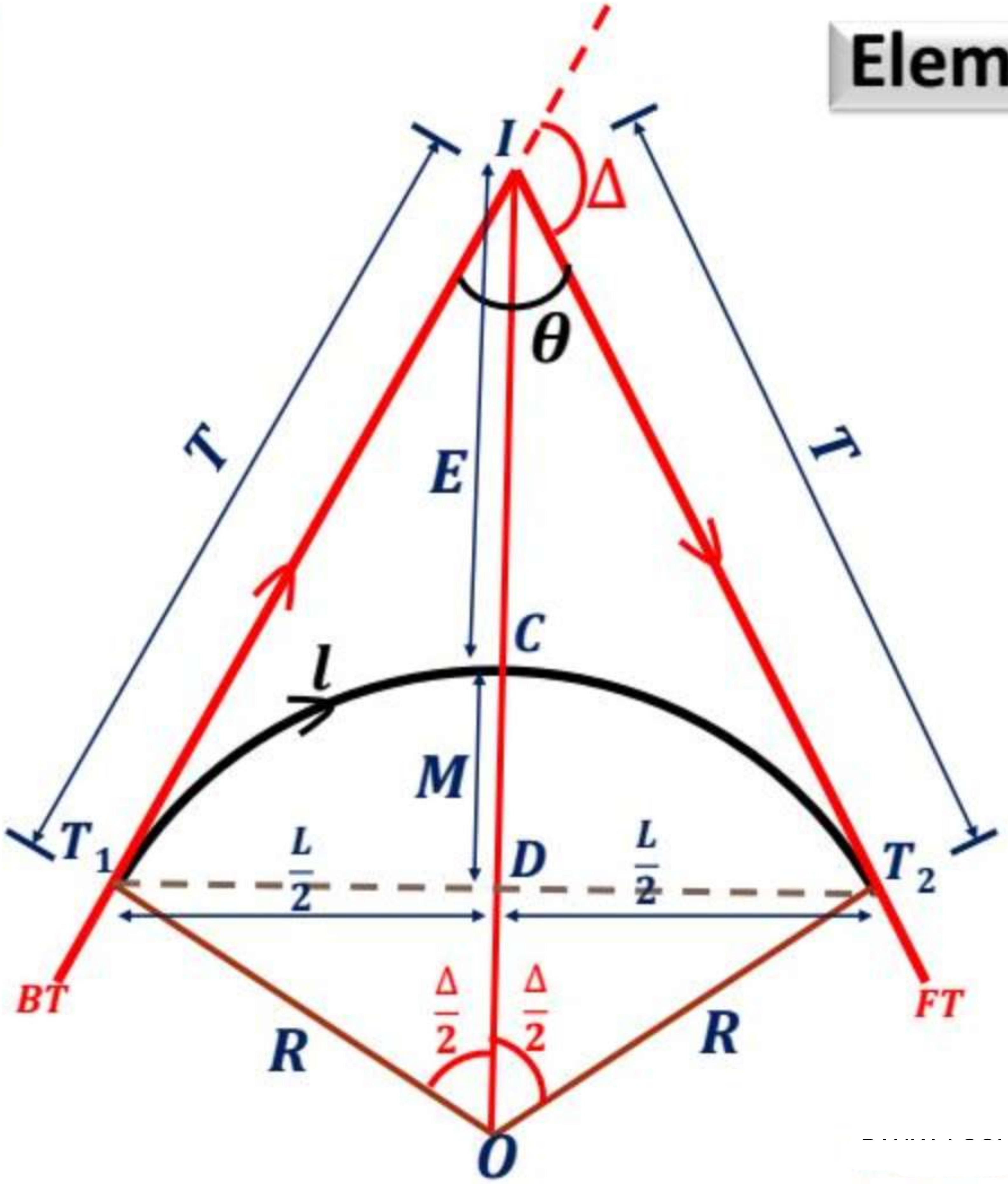
Note:

→ We have to provide a transition curve between two branches of compound Curve and reverse curve



SIMPLE CIRCULAR CURVE

- $l = length\ of\ curve$
- $BT = Back\ Tangent$
- $FT = Forward\ Tangent$
- PC $Point\ of\ curve$ $(beginning\ of\ curve\ from\ where\ alignment\ changes\ from\ tangent\ to\ curve)$
- $I = point\ of\ intersection$
- $\Delta = deflection\ angle$
- $\angle T_1\ OT_2 = central\ angle = \Delta$
- $T = length\ of\ tangent$
- $L = T_1T_2 = long\ chord$
- $CD = mid\ ordinate = M$
- $E = apex\ distance\ or\ external\ distance$



Elements of Simple Circular Curve

1. **Length of curve (l):**
   - $l = \frac{\pi R \Delta}{180°}$ **(in radians)**
2. **Tangent Length (T)**
   - $T = T_1 I = T_2 I = R \tan\frac{\Delta}{2}$
3. **Length of long chord (L) :**
   - $L = T_1 T_2 = 2\, R.sin\left(\frac{\Delta}{2}\right)$
4. **Mid ordinate (M):**
   - $M = R\left(1 - \cos\frac{\Delta}{2}\right)$
5. **External distance (E):**
   - $E = R\left(sec\frac{\Delta}{2} - 1\right)$
   - $cos\frac{\Delta}{2} = \frac{R}{E+R}$
6. **Chainages of T_1 and T_2**
   - $Ch\ of\ T_1 = \ ch\ at\ I - length\ T$
   - $Ch\ of\ T_2 = \ ch\ at\ T_1 + length\ l$

Note:

Relationship between degrees and radians

$$180^\circ = \pi\ radians \qquad 1\ radian = \frac{180^\circ}{\pi} \qquad 1^\circ = \frac{\pi}{180^\circ} radian$$

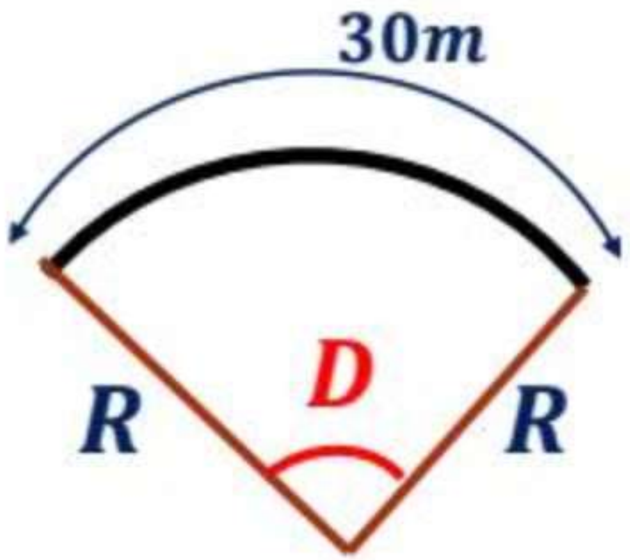
$$To\ convert\ degrees\ to\ radian, multiply\ by\ \frac{\pi}{180^\circ}$$

$$To\ convert\ radians\ to\ degree, multiply\ by\ \frac{180^\circ}{\pi}$$

Designation of Curve

- **A curve can be designated by radius R (or) Degree of curve (D).**
- **Degree of curve is the angle subtended by an Arc (or) a chord of specified length at the centre.**

1. <u>Arc Definition</u>:
   - Case 1: Let arc length is 30m and radius of curve is R, the n degree of curve is D



$$\frac{\pi R D}{180°} = 30m$$

$$=> D = \frac{30 \times 180}{\pi R}$$

$$=> D = \frac{1718.87}{R}$$

$$\therefore D = \frac{1719}{R}$$ **Remember**

Designation of Curve

1. <u>Arc Definition</u>:

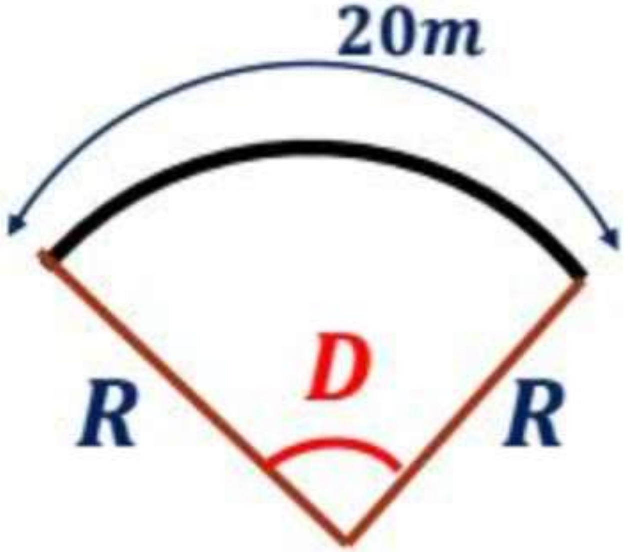
- Case 2: Let arc length is 20 m and radius of curve is R, the n degree of curve is D

$$\frac{\pi RD}{180^\circ} = 20m$$

$$=> D = \frac{20 \times 180}{\pi R}$$

$$=> D = \frac{1145.91}{R}$$

$$\therefore D = \frac{1146}{R}$$ **Remember**



- **For 30m** $D = \frac{1719}{R}$
- **For 20m** $D = \frac{1146}{R}$

Designation of Curve

2. Chord Definition:

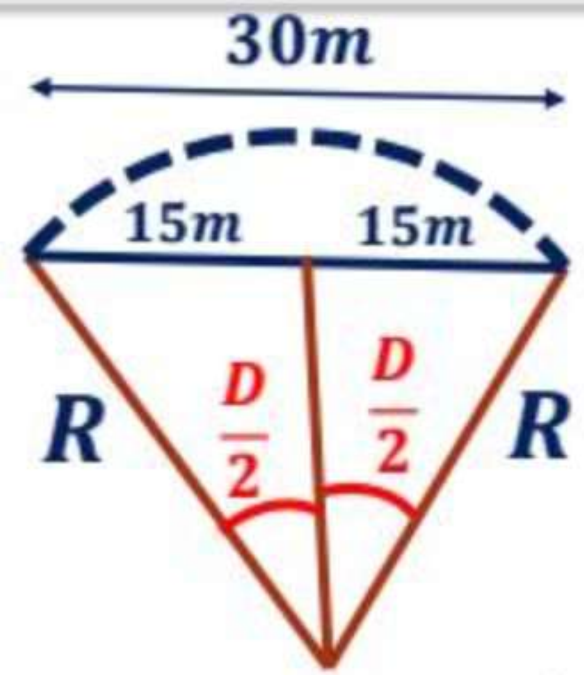
- *Case I: for 30m chord*

$$\sin\frac{D}{2} = \frac{15}{R}$$

Since, $\frac{D}{2}$ will be a small angle, therefore $\sin\theta \rightarrow \theta$

$$=> \frac{D}{2} \times \frac{\pi}{180°} = \frac{15}{R}$$

$$=> D = \frac{15 \times 2 \times 180°}{\pi R} = \frac{1719}{R}$$



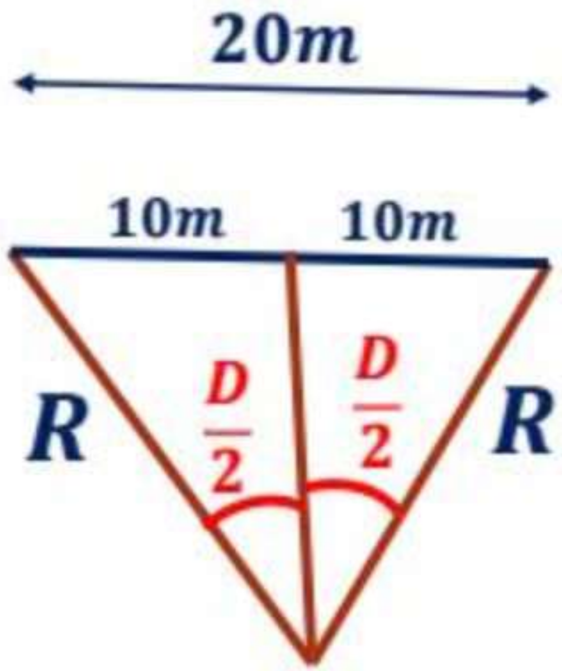
- *Case II: for 20m chord*

$$\sin\frac{D}{2} = \frac{10}{R}$$

Since, $\frac{D}{2}$ will be a small angle, therefore $\sin\theta \rightarrow \theta$

$$=> \frac{D}{2} \times \frac{\pi}{180°} = \frac{10}{R}$$

$$=> D = \frac{10 \times 2 \times 180°}{\pi R} = \frac{1146}{R}$$



- For 30m $\quad D = \frac{1719}{R}$
- For 20m $\quad D = \frac{1146}{R}$

Note:

- **Since Degree of curve is inversely proportional to Radius, for sharp circles Degree of curve will be large, whereas for flat curve, Degree of curve will be small.**

Que : if Radius of curve is 1000 m, Δ = 60°, chainage of P.I = 2000m

Determine

i) length of curve

ii) Tangent Length

iii) Long chord

iv) mid ordinate (M)

v) Apex distance

vi) Chainages of T_1, T_2

vii) Degree of curve for 30 m Arc

i) $\boldsymbol{l = \frac{\pi R\, \Delta}{180°}}$

$$= \frac{\pi\,(1000) \times 60}{180}$$

$$= 1047.19\ m$$

Que : if Radius of curve is 1000 m, Δ = 60°, chainage of P.I = 2000m

Determine

i) length of curve

ii) Tangent Length

iii) Long chord

iv) mid ordinate (M)

v) Apex distance

vi) Chainages of T_1, T_2

vii) Degree of curve for 30 m Arc

ii) $T = R\,tan\left(\frac{\Delta}{2}\right)$

$$= 1000\,tan(30°)$$

$$= 577.35\,m$$

Que : if Radius of curve is 1000 m, Δ = 60°, chainage of P.I = 2000m

Determine

i) length of curve

ii) Tangent Length

iii) Long chord

iv) mid ordinate (M)

v) Apex distance

vi) Chainages of T_1, T_2

vii) Degree of curve for 30 m Arc

iii) $L = 2\,R\,sin\left(\frac{\Delta}{2}\right) = 2 \times 1000 sin30° = 1000m$

$$= 2 \times 1000 sin30°$$

$$= 1000m$$

Que : if Radius of curve is 1000 m, Δ = 60°, chainage of P.I = 2000m

Determine

i) length of curve

ii) Tangent Length

iii) Long chord

iv) mid ordinate (M)

v) Apex distance

vi) Chainages of T_1, T_2

vii) Degree of curve for 30 m Arc

iv) $$M = R\left(1 - \cos\frac{\Delta}{2}\right)$$

$$= 1000\,(1 - \cos 30°)$$

$$= 133.97\ m$$

Que : if Radius of curve is 1000 m, Δ = 60°, chainage of P.I = 2000m

Determine

i) length of curve

ii) Tangent Length

iii) Long chord

iv) mid ordinate (M)

v) Apex distance

vi) Chainages of T_1, T_2

vii) Degree of curve for 30 m Arc

v) $E = R\left(Sec\frac{\Delta}{2} - 1\right)$

$= 1000\,(sec\,30° - 1) = 154\;70m$

$= 154\;70m$

Que : if Radius of curve is 1000 m, Δ = 60°, chainage of P.I = 2000m

Determine

i) length of curve

ii) Tangent Length

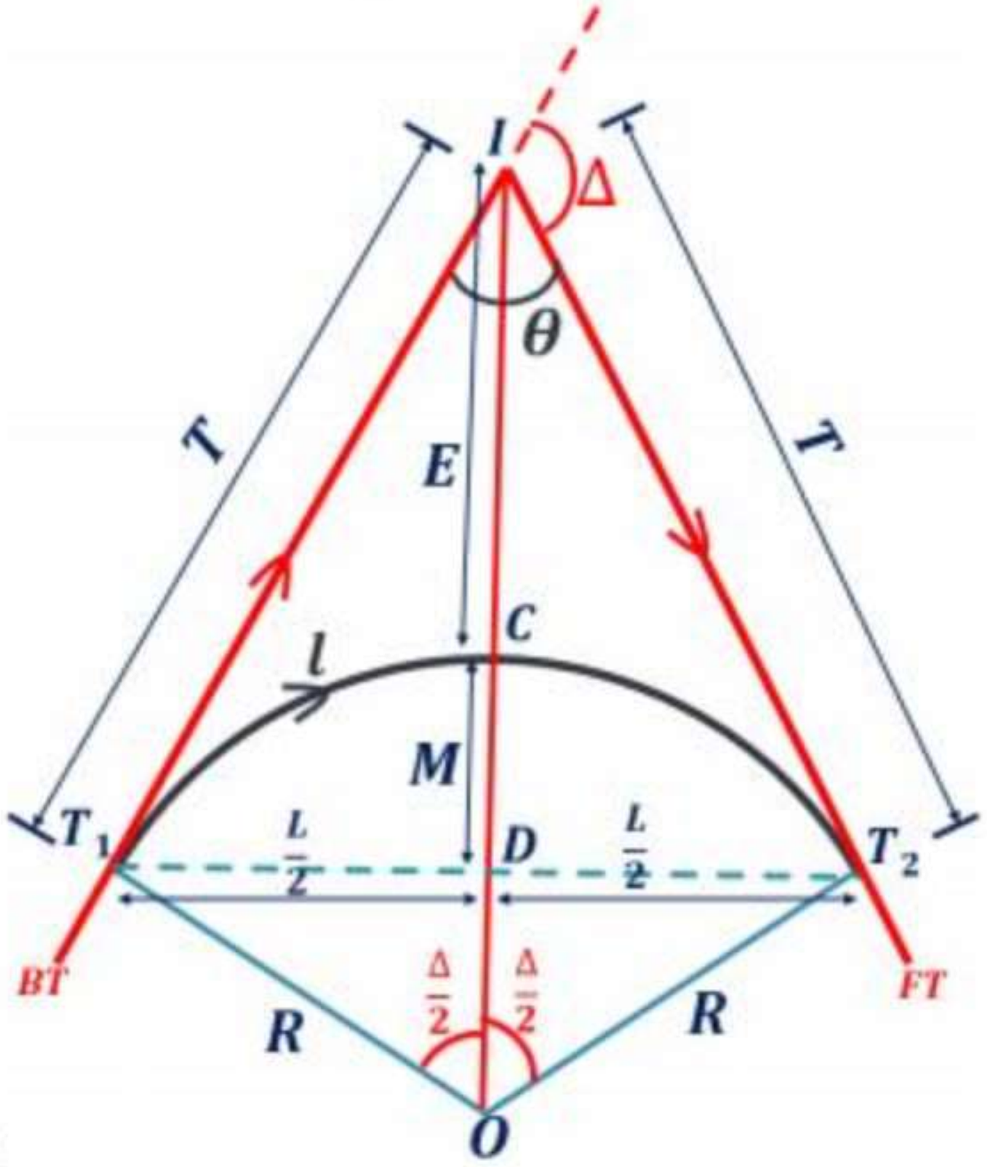
iii) Long chord

iv) mid ordinate (M)

v) Apex distance

vi) Chainages of T_1, T_2

vii) Degree of curve for 30 m Arc



vi) ch of $\boldsymbol{T_1 = 2000 - 577.35 = 1422.65\ m}$

ch of $\boldsymbol{T_2 = 1422.65 + 1047.19 = 2469.84\ m}$

vii) $\boldsymbol{D = \frac{1719}{1000} = 1.719}$

Que : if Radius of curve is 1000 m, Δ = 60°, chainage of P.I = 2000m

Determine

i) length of curve

ii) Tangent Length

iii) Long chord

iv) mid ordinate (M)

v) Apex distance

vi) Chainages of T_1, T_2

vii) Degree of curve for 30 m Arc

i) $l = \frac{\pi R \Delta}{180°} = \frac{\pi\,(1000)\times 60}{180} = 1047.19\ m$

ii) $T = R\,tan\left(\frac{\Delta}{2}\right) = 1000\ tan(30°) = 577.35m$

iii) $L = 2\ R\,sin\left(\frac{\Delta}{2}\right) = 2 \times 1000 sin 30° = 1000m$

iv) $M = R\left(1 - cos\frac{\Delta}{2}\right) = 1000\ (1 - cos\,30°) = 133.97\ m$

v) $E = R\ \left(Sec\frac{\Delta}{2} - 1\right) = 1000\ (sec\,30° - 1) = 154\ 70m$

vi) ch of $T_1 = 2000 - 577.35 = 1422.65\ m$

ch of $T_2 = 1422.65 + 1047.19 = 2469.84\ m$

vii) $D = \frac{1719}{1000} = 1.719$