CHAPTER 6

THEODOLITE SURVEYING AND TRAVERSING

Theodolite Survey:

- A theodolite is a precision instrument for measuring angles in the horizontal and vertical planes. Theodolites are used mainly for surveying applications, and have been adapted for specialized purposes such as meteorology and rocket launch.

- The theodolite is a complex instrument used mainly for accurate measurement of horizontal and vertical angle up to 10" or 20" depending upon the least count of the instrument.
- Because of its various uses, the theodolite is sometimes known as "Universal Instrument".

Uses of theodolite: Following are the different purpose for which theodolite can be

1) Measuring horizontal angle
2) Measuring vertical angle
3) Measuring deflection angle
4) Measuring magnetic
5) Measuring the horizontal distance between two
6) Finding vertical height of an object
7) Finding difference of elevation between various
8) Ranging of a line

Types of Theodolite:

Theodolites may be broadly classified into four

Transit Theodolite: In the transit theodolite, the telescope can be revolved through a complete revolution about its horizontal axis in a vertical plane.

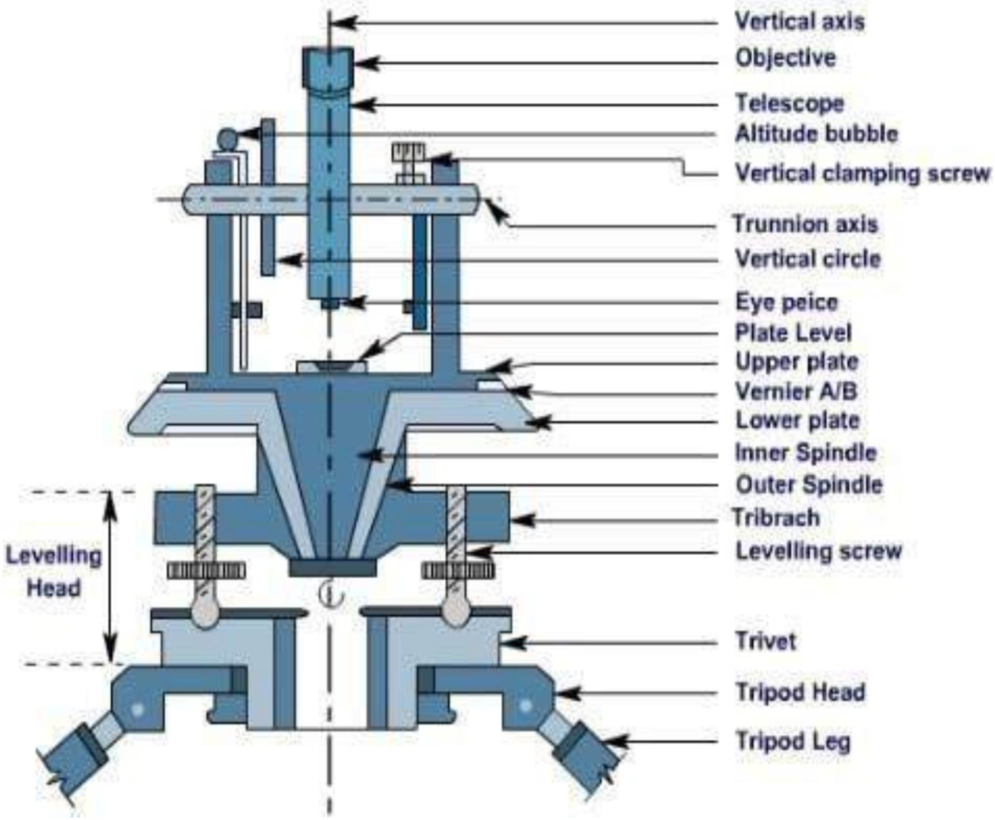
Non-transit Theodolite: In the non-transit theodolite, the telescope cannot be revolved through a complete revolution in the vertical plane

Vernier Theodolite: In this type of theodolite, venires are provided for reading horizontal and vertical graduated circles.

Glass arc Theodolite: In this type of theodolite, micrometres are for reading horizontal and vertical graduated circles.

Different Parts of Theodolite:

a.Vertical Scale (or Vertical Circle): The vertical circle is a full 360° scale. It is mounted within one of the standards with its centre co-linear with the trunnion axis. It is used to measure the angle between the line of sight (collimation axis) of the telescope and the horizontal. This is known as the vertical angle.

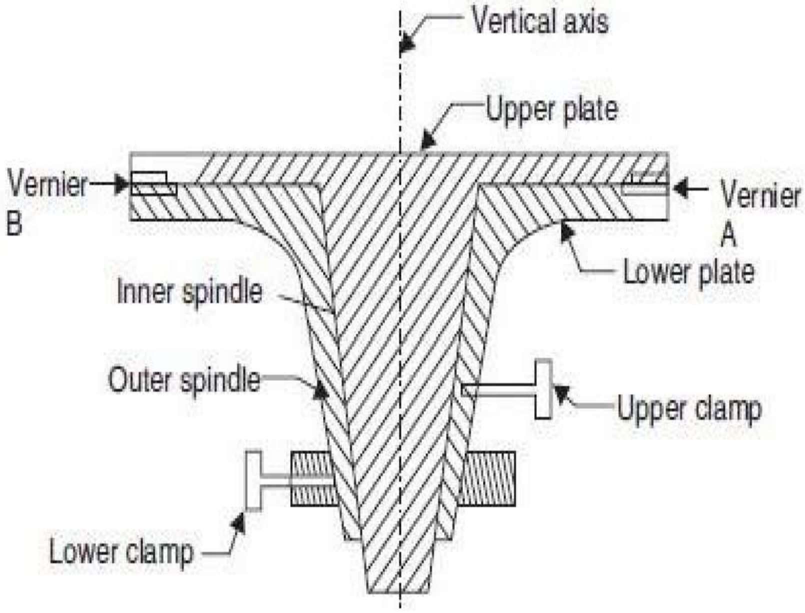


b. **Telescope:** It has the same features as in a level graticule with eyepiece and internal focussing for the telescope itself. The same precautions for focussing the eyepiece and eliminating parallax should be applied.

c.Vertical Clamp and Tangent Screw: In order to hold the telescope at a particular vertical angle a vertical clamp is provided. This is located on one of the standards and its release will allow free transiting of the telescope. When clamped, the telescope can be slowly transited using another fine adjustment screw known as the vertical tangent screw.

d. **Upper Plate:** The upper plate is the base on which the standards and vertical circle are placed. Rotation or transiting of the upper plate about a vertical (alidade) axis will also cause the entire standards/telescope assembly to rotate in an identical manner. For the instrument to be in correct adjustment it is therefore necessary that the upper plate must be perpendicular to the alidade axis and parallel to the trunnion axis. Also, before the instrument is used, the upper plate must be "levelled". This is achieved by adjustment of three foot screws and observing a precise tube bubble. This bubble is known as the plate bubble and is placed on the upper plate.

e. **The Lower Plate:** The lower plate is the base of the whole instrument. It houses the foot screws and the bearing for the vertical axis. It is rigidly attached to the tripod mounting assembly and does not move.



Horizontal Scale (or Horizontal Circle): The horizontal circle is a full 3600 scale. It is

f.

often placed between the upper and lower plates with its centre co-linear with the axis. It is capable of full independent rotation about the trunnion axis so that any direction may be arbitrarily set to read zero. It is used to define the horizontal direction which the telescope is sighted. Therefore a horizontal angle measurement requires two horizontal scale readings taken by observing two different

g.The Upper Horizontal Clamp and Tangent Screw: The upper horizontal clamp is provided to clamp the upper plate to the horizontal circle. Once the clamp is released the instrument is free to traverse through 360° around the horizontal circle. When clamped, the instrument can be gradually transited around the circle by use of the upper horizontal or "round" of horizontal angle measurements.

h. **The Lower Horizontal Clamp and Tangent Screw**: The lower horizontal clamp is provided to clamp the horizontal circle to the lower plate. Once the clamp is released the circle is free to rotate about the vertical axis. When clamped, the horizontal circle can be gradually rotated using the lower-horizontal tangent screw. The lower clamp and tangent screw must only be used at the start of a sequence or "round" of horizontal angle measurements to set the first reading to zero (if so desired).

i. **Circle Reading and Optical Micrometer:** Modern instruments usually have one eyepiece for reading both circles. It is usually located on one of the standards. The vertical and horizontal circles require illumination in order to read them. This is usually provided by small circular mirrors which can be angled and rotated to reflect maximum light onto the circles.

j. **Index bar or T-frame:** The index bar is T shaped and centered on horizontal axis of the telescope in front of the vertical axis. It carries two vernier of the extremities of its horizontal arms or limbs called the index arm. The vertical leg called the clip or clipping screws at its lower extremity. The index arm and the clipping arm are together known as T-frame.

k. **Altitude level:** A highly sensitive bubble is used for levelling particularly when taking the vertical angle observations.

l. **Plumb bob:** To centre the instrument exactly over a station mark, a plumb bob is suspended from the hook fitted to the bottom of the central vertical axis.

m. **The levelling head:** It may consists of circular plates called as upper and lower Parallel plates. The lower parallel plate has a central aperture through which a plumb bob may be suspended. The upper parallel plate or tribrach is supported by means of four or three levelling screws by which the instrument may be levelled.

n. **Standards or A-Frame**: The frames supporting telescope are in the form of English letter 'A'. This frame allows telescope to rotate on its trunnion axis in vertical frame. The T-frame and the clamps are also fixed to this

Important terms related to theodolite survey

Cantering: The setting of theodolite exactly over a station marked by means of plumb bob is known as

cantering.

Transiting: The method of turning the telescope about its horizontal axis in a vertical plane through 180' is termed as transiting. In other words, transiting results in a change of face.

Face left: It means that the vertical circle of theodolite is on the left of the observer at the time of taking reading.**Face right:** This refers to the situation when the vertical circle of the instrument is on the right of the observer when the reading is taken

Changing face: The operation of bringing the vertical circle from one side of the observer to the other is known as changing face.

Swinging the telescope: This indicates turning the telescope in a horizontal plane. It is called 'right swing' when the telescope is turned clockwise and 'left swing' when the telescope is turned anticlockwise.

Line of collimation: It is an imaginary line passing through the optical center of the objective glass and its continuation.

Axis of telescope: The axis is an imaginary line passing through the optical center of the glass and optical center of eyepiece.

Axis of the bubble tube: It is an imaginary line tangential to longitudinal curve of bubble tube at its middle point.

Vertical axis: It is the axis of rotation of the telescope in the horizontal

Horizontal axis: It is the axis of rotation of the telescope in the vertical plane.

Temporary adjustment: The setting of the theodolite over a station at the time of taking observation is called temporary adjustment.

Permanent adjustment: When the desired relationship between fundamental lines is disturbed, then some procedures are adopted to establish this relationship. This adjustment known as permanent

Use of Theodolite:

Theodolite is used for measuring horizontal and vertical angles. For this the theodolite should be centered on the desired station point, levelled and telescope is focussed. This process of centering, levelling and focussing is called temporary adjustment of the instrument.

Measurement of Horizontal Angle

The procedure is explained for measuring horizontal angle θ = PQR at station Q

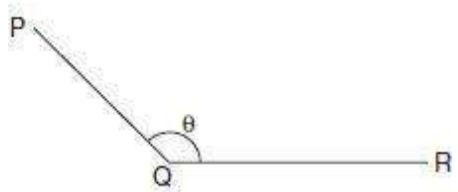


Fig. 16.5

1. Set the theodolite at Q with vertical circle to the left of the line of sight and complete all temporary adjustments.

2. Release both upper and lower clamps and turn upper plate to get 0° on the main scale. Then clamp main screw and using tangent screw get exactly zero reading. At this stage Vernier A reads 0° and Vernier B reads 180°.

3. Through telescope take line of sight to signal at P and lock the lower clamp. Use tangent

Screw for exact bisection.

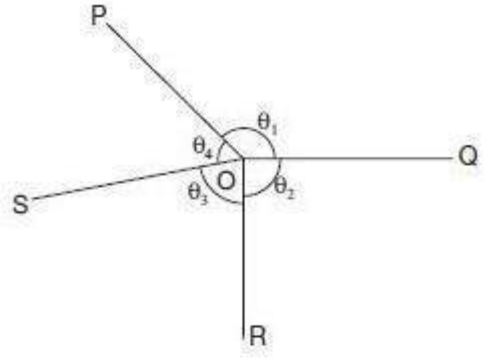
4. Release the upper clamp and swing telescope to bisect signal at R. Lock upper clamp and use tangent screen to get exact bisection of R.

5. Read Vernier's A and B. The reading of Vernier A gives desired angle PQR directly, while 180° is to be subtracted from the reading of Vernier B to get the angle PQR.

6. Transit (move by 180° in vertical plane) the telescope to make vertical circle to the right of telescope. Repeat steps 2 to 5 to get two more values for the angle.

7. The average of 4 values found for θ, give the horizontal angle. Two values obtained with face left and two obtained with face right position of vertical circle are called one set of readings.

8. If more precision is required the angle may be measured repeatedly. i.e., after step 5, release lower clamp, sight signal at P, then lock lower clamp, release upper clamp and swing the telescope to signal at Q. The reading of Vernier A doubles. The angle measured by vernier B is also doubled. Any number of repetitions may be made and average taken. Similar readings are then taken with face right also. Finally average angle is found and is taken as desired angle 'Q'. This is called method of repetition.



9. There is another method of getting precise horizontal angles. It is called method of reiteration.

If a number of angles are to be measured from a station this technique is used (see above figure).

With zero reading of vernier A signal at P is sighted exactly and lower clamp and its tangent screw are locked. Then θ1 is measured by sighting Q and noted. Then θ2, θ3 and θ4 are measured by unlocking upper clamp and bisecting signals at R, S and P. The angles are calculated and checked to see that sum is 360º. In each case both verniers are read and similar process is carried out by changing the face (face left and face right).

- Measurement of Vertical Angle

Horizontal sight is taken as zero vertical angle. Angle of elevations are noted as +ve angles and angle of depression as –ve angles.

To measure vertical angle the following procedure may be followed:

1. Complete all temporary adjustment at the required station.

2. Take up levelling of the instrument with respect to altitude level provided on the A –frame.

This levelling process is similar to that used for levelling dumpy level i.e., first altitude level is kept parallel to any two levelling screws and operating those two screws bubble is brought to centre. Then by rotating telescope, level tube is brought at right angles to the original position and is levelled with the third screw. The procedure is repeated till bubble is centred in both positions.

3. Then loosen the vertical circle clamp, bisect P and lock the clamp. Read verniers C and D to get vertical angle. Take the average as the actual vertical angle.

- Setting out grades
- Finding difference of level.
- Prolonging the survey lines

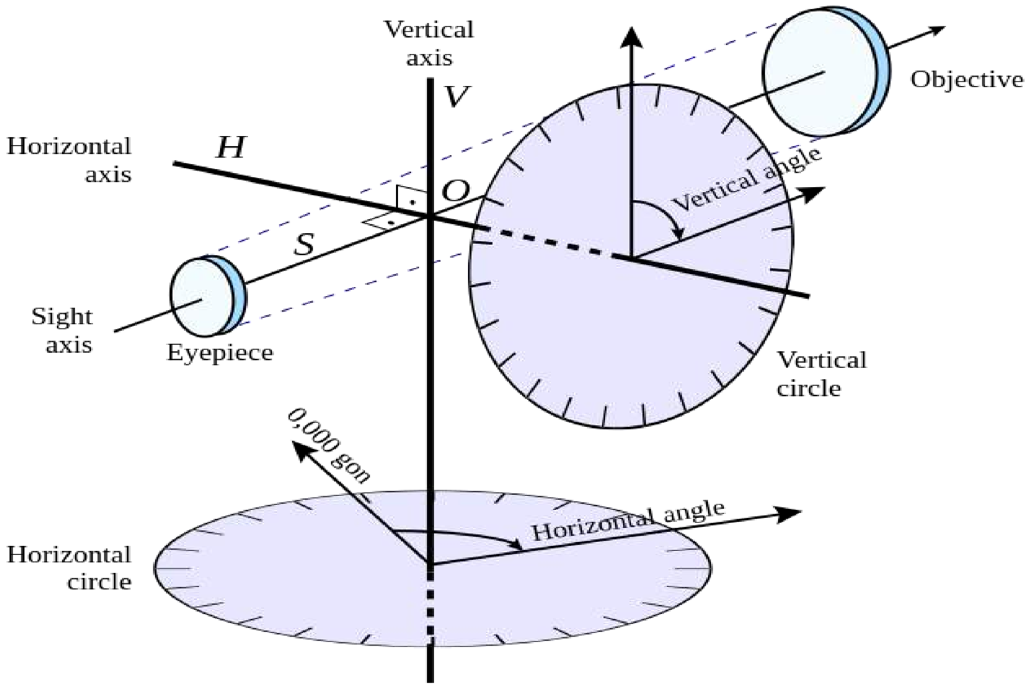
Axes of Theodolite:

V - Vertical axis

S – Sight axis, collimation axis

H – Horizontal axis (telescope rotary axis)

L – Level axis (the alidade axis)



Theodolite Traversing:

Introduction: A traverse consists of a series of straight lines connecting successive points. The points defining the ends of the traverse lines are called traverse stations or traverse points. Distance along the line between successive traverse points is determined either by direct measurement using a tape or electronic distance measuring (EDM) equipment, or by indirect measurement using tachometric methods. At each point where the traverse changes direction, an angular measurement is taken using a theodolite.

Purpose of traverse: It is a convenient, rapid method for establishing horizontal control particularly when the lines of sights are short due to heavily built up areas where triangulation and trilateration are not applicable. The purpose includes:

- Property surveys to locate or establish boundaries;

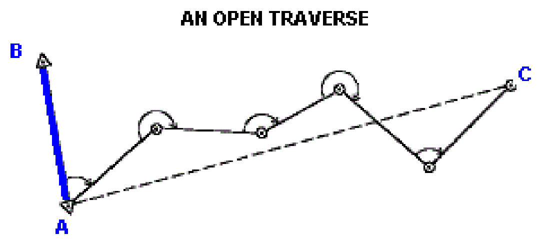
- Supplementary horizontal control for topographic mapping surveys;

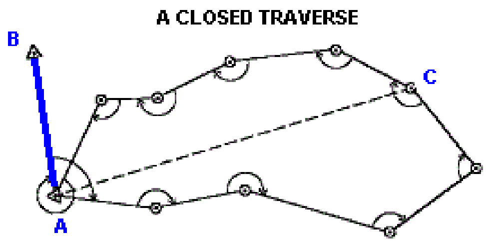
- Location and construction layout surveys for high ways, railway, and other private and public works;

- Ground control surveys for photogrammetric mapping.

Types of traverse:

Open traverse: It starts at a point of known position and terminates at a point of unknown position.

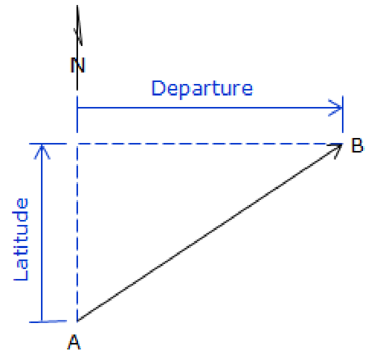


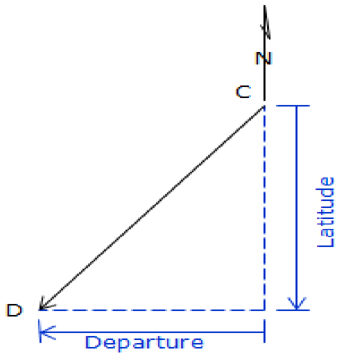


Closed traverse: It originates at a point of known position and close on another point of known horizontal position.

Latitudes and Departures:

Latitude is the north-south component of a line; departure the east-west. North latitudes are positive, South are negative; similarly East departures are positive, West are negative.



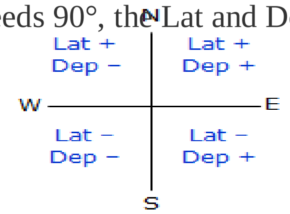


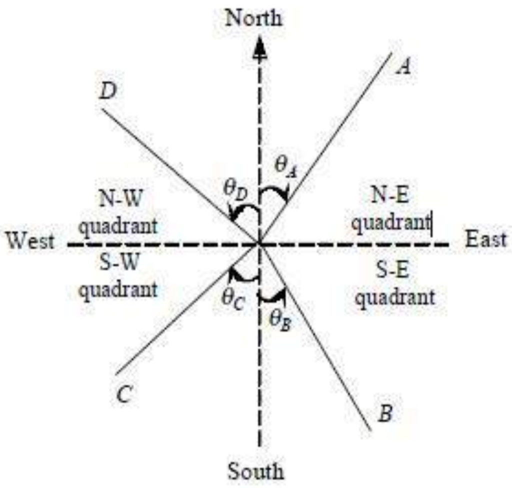
Latitude (Lat) and Departure (Dep) are computed from:

Latitude(lat)
Departure(dep)

$$Lat = Length \times \cos(Dir)$$
$$Dep = Length \times \sin(Dir)$$

Because a bearing angle never exceeds 90°, the Lat and Dep equations will always return positive values.

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θA
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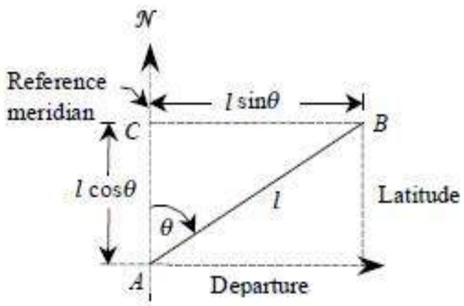
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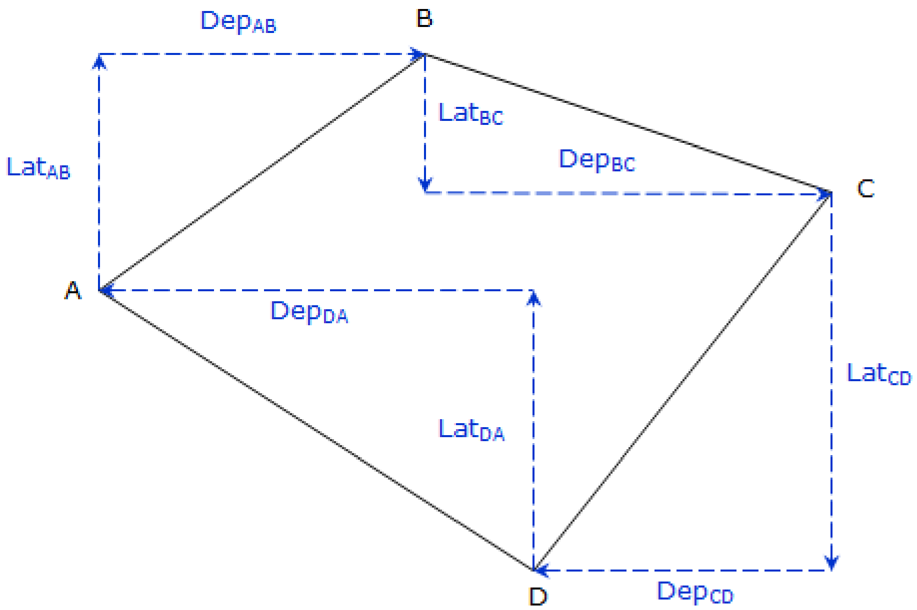
DepAB
B
LatBC
LatAB
DepBC
C
A
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LatCD
LatDA
D
DepCD

Calculation of Closing Error:

In a complete circuit, the sum of North latitudes must be equal to that of South latitudes, the sum of Easting must be equal to that of Westing, if all the measurements are correct. If not, the distance between the starting portion and the position obtained by calculation is known as ***Closing Error.***

Example:-

Let's assume that the sum of Northing of a traverse exceeds the sum of southing by 1.5m and that of easting exceeds the sum of westings by 1.8m, then

Resultant Closing error = $\sqrt{(1.8^2 + 1.5^2)} = 2.34$

The closing error is generally expressed as a Fraction i.e,

$$\frac{Closing\ Error}{Perimeter\ of\ the\ Traverse}$$

Let Perimeter of the Traverse = 1000m

- Closing Error = $\frac{2.34}{1000} = \frac{1}{n}$ or 1 in n
- Where n = 1000/2.34

Balancing the Consecutive Co-Ordinates:

The process od adjusting the consecutive coordinates of each line by applying corrections to them in such a way that algebraic sum of latitudes and departures of closed circuit should be equal to zero i.e., sum of northing should be equal to the sum of southing and the sum of westing should exactly equal to the sum of easting is called the ***Balancing the Consecutive Co-Ordinates.***

In a closed traverse the following conditions must be satisfied:

$$\sum \text{Departure} = \sum D = 0$$

$$\sum \text{Latitude} = \sum L = 0$$

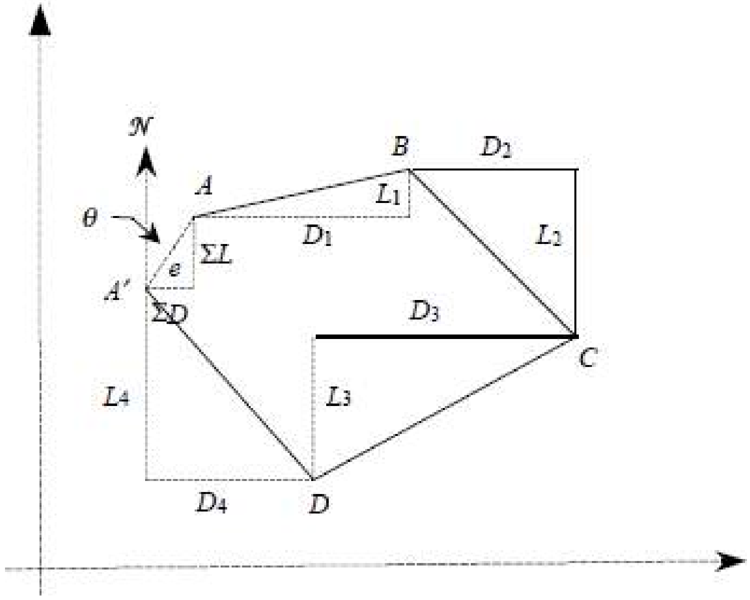
If the above conditions are not satisfied, the position A of the originating stations and its computed position A' will not be the same as shown in Fig. given below, due to the observational errors.

The distance AA' between them is known as the ***closing error***. The closing error is given by

$$e = \text{sq root}(\sum D)^2 + (\sum L)^2$$

and its direction or reduced bearing is given by

$$\tan\theta = \frac{\sum D}{\sum L}$$



The term *balancing* is generally applied to the operation of adjusting the closing error in a closed traverse by applying corrections to departures and latitudes.

The following methods are generally used for balancing a traverse:

- **Bowditch's method :**

$$C_D = \sum D \times \frac{l}{\sum L}$$

Where:

$$C_L = \sum L \times \frac{l}{\sum L}$$

C_D & C_L = the corrections to the departure and latitude of the line to which the correction is applied

l = the length of the line, and

$\sum l$ = the sum of the lengths of all the lines of the traverse, i.e., perimeter p.

$\sum L$ = Total error in latitude

$\sum D$ = Total error in departure

- **Transit rule:**

According to this rule, corrections to the latitude of a traverse leg

$$= \text{Total error in latitude} \times \frac{\text{Latitude of that traverse leg}}{\text{Total sum of latitude}}$$

$$C_D = \sum D \times \frac{d}{D}$$

$$C_L = \sum L \times \frac{l}{L}$$

Where,

C_D & C_L = the corrections to the departure and latitude of the line to which the correction is applied

l = Latitude of traverse leg

d = Departure of traverse leg

L = arithmetic sum of latitudes

D = arithmetic sum of departures

$\sum L$ = Total error of latitudes (algebraic sum)

$\sum D$ = Total error of departures (algebraic sum)

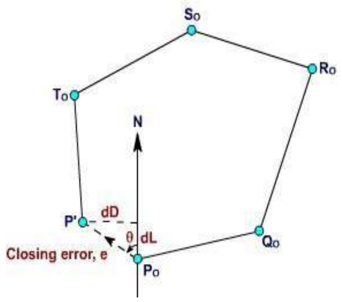
Balancing the Closing Error graphically:

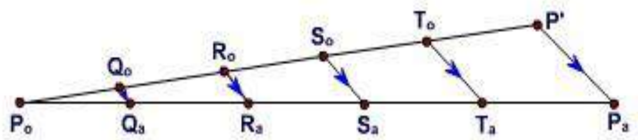
For rough surveys or traverse of small area, adjustment can also be carried out graphically. In this method of balancing, the locations and thus the coordinates of the stations are adjusted directly. Thus, the amount of correction at any station is proportional to its distance from the initial station.

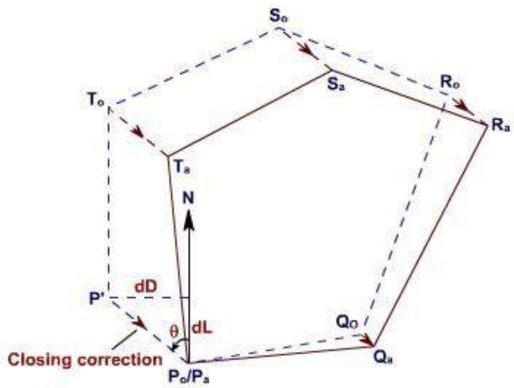
- Let Po Qo Ro So To P' is the graphical plot of a closed-loop traverse PQRSTP. The observed length and direction of traverse sides are such that it fails to get balanced and is depicted in its graphical presentation by an amount Po P'.
- Thus, the closing error of the traverse is Po P' (Given in Figure below). The error Po P' is to be distributed to all the sides of the traverse in such a way that the traverse gets closed i.e., P' gets coincides with Po in its plot.

- This is carried out by shifting the positions of the station graphically. In order to obtain the length and direction of shifting of the plotted position of stations, first a straight line is required to be drawn, at some scale, representing the perimeter of the plotted traverse.
- In this case, a horizontal line Po P' is drawn (Given in Figure below). Mark the traverse stations on this line such as Qo, Ro, So and To in such a way that distance between them represent the length of the traverse sides at the chosen scale.
- At the terminating end of the line i.e., at P', a line P' P a is drawn parallel to the correction for closure and length equal to the amount of error as depicted in the plot of traverse. Now, join Po to Pa and draw lines parallel to P' Pa at points Qo, Ro, So and To.
- The length and direction of Qo Qa, Ro Ra, So Sa and To Ta represent the length and direction of errors at Qo, Ro, So and To respectively. So, shifting equal to Qo Qa , Ro Ra, So Sa and To Ta and in the same direction are applied as correction to the positions of

stations Qo, Ro, So and To respectively. These shifting provide the corrected positions of the stations as to Qa, Ra, Sa,Ta and Pa. Joining these corrected positions of the stations provide the adjusted traverse Pa Qa Ra, Sa Ta(Given in Figure below).







Omitted observations:

In a closed traverse if lengths and bearings of all the lines could not be measured due to certain reasons, the omitted or the missing measurements can be computed provided the number of such omissions is not more than two. In such cases, there can be no check on the accuracy of the field work nor can the traverse be balanced. It is because of the fact that all the errors are thrown into the computed values of the omitted observations.

The omitted quantities are computed using the equations given below:

$$\sum D = l_1 \sin \theta 1 + l_2 \sin\theta 2 + \ldots\ldots.. + ln \sin \theta n = 0$$

$$\sum L = l_1 \cos \theta 1 + l_2 \cos\theta 2 + \ldots\ldots.. + ln \cos \theta n = 0$$

So, length of the traverse lines $l = \sqrt{(D^2 + L^2)}$

and Departure of the line $D = l \sin \theta 1$

Latitude of the line $L = l \cos \theta 1$

CHAPTER 7

LEVELLING AND CONTOURING

Definition, Principle, & Object of Levelling

Definition:

Levelling is defined as “an art of determining the relative height of different points on, above or below the surface”.

Principle of levelling:

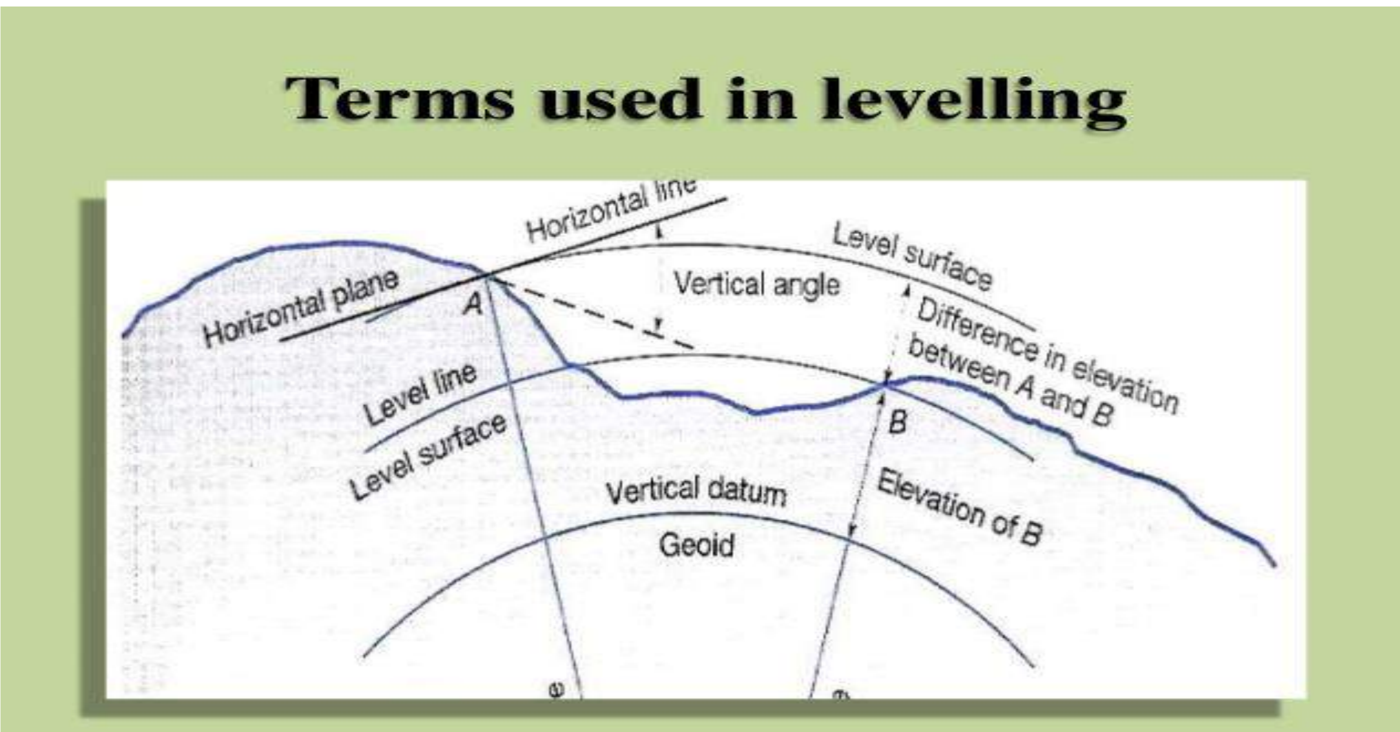
The principle of levelling is to obtain horizontal line of sight with respect to which vertical distances of the points above or below this line of sight are found.

Object of levelling:

The objective of levelling is to

1) Find the elevation of given point with respect to some assumed reference line called datum.

2)To establish point at required elevation with respect to datum.



Definitions used in levelling
Level surface

It is the surface parallel to the mean spheroidal surface of the earth

- **Level line**

Line lying on level surface.

- **Horizontal plane**

Horizontal plane through a point is a plane tangential to level surface.

- **Horizontal line**

It is a straight line tangential to level line.

- **Datum:**

"It is an arbitrary level surface from which elevation of points may be referred". In India mean sea level is considered as datum of zero elevation it is situated at Bombay airport.
Mean sea level is the average height of sea for all stages of tides it is derived by averaging the hourly tide height over a period of 19 years.

- **Elevation or Reduced level**

It is height or depth of any point above or below any datum. It is denoted as R.L.

- **Bench Mark (B.M.):**

It is a fixed reference point of known elevation with respect to datum.

- **Line of collimation**

It is a line joining the intersection of cross hairs of diaphragm to the optical centre of object glass and its continuation. It is also known as line of sight.

- **Height of instrument**

It is the elevation of line of collimation with respect to datum

- **Back sight**

It is a staff reading taken at a known elevation. It is the first staff reading taken after setup of instrument.

- **Fore sight(F.S.):**

It is the last staff reading taken denoting the shifting of the instrument.

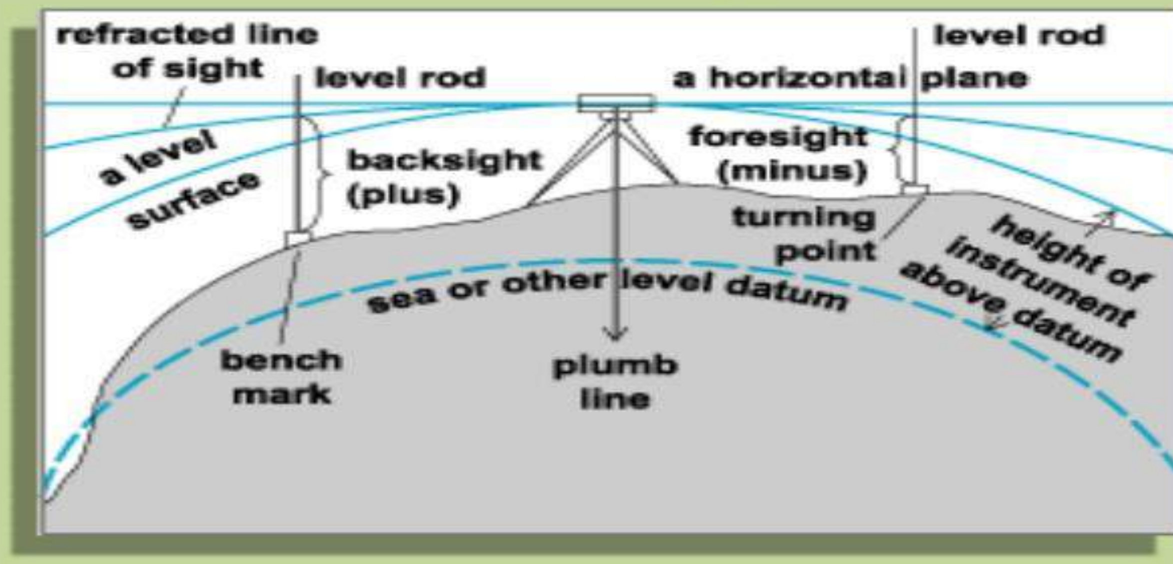
- **Intermediate sight.(I.S.)**

It is staff reading taken on a point whose elevation is to be determined. All staff reading between B.S. and F.S. are Intermediate sight.

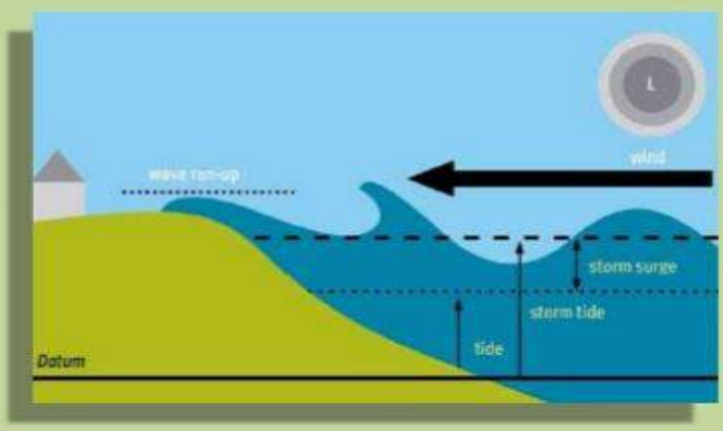
- **Change Point**

It is a point on which both fore and back sight are taken.

Levelling



Mean Sea Level



Instruments for levelling

The following instruments are essentially required for levelling
1. Level
2. Levelling staff

Level and types of level

*Level:
The instrument used to furnish horizontal line of sight for observing staff readings and determining R.L.s
*Types

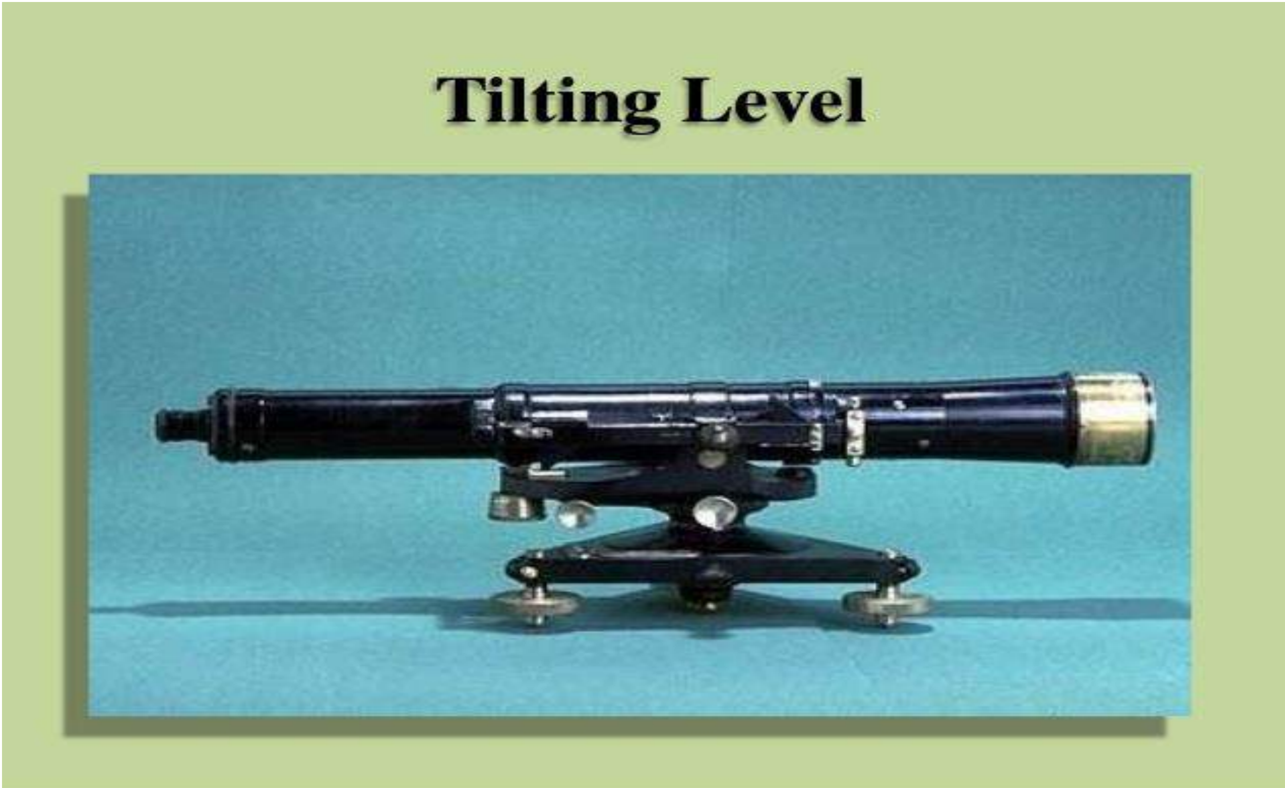
1. Dumpy level
2. Tilting level
3. Wye level
4. Automatic level

Dumpy level

The Dumpy level is a simple, compact and stable instrument. The telescope is rigidly fixed to its supports. Hence it cannot be rotated about horizontal axis.

Tilting level

ItisalsoknownasI.O.P.level(IndianofficePattern).Inthislevelthetelescopetiltsaboutitshorizontalaxishenceitis called tilting level.



Wye level

The essential difference between wye level and other levels is that in wye level the telescope is carried by two vertical wye supports. The telescope can be rotated, moved or even raised in wyes

Automatic level

It is also known as self aligning level. It is a recent development. The fundamental difference between auto level and other levels is that the levelling is not manually but it is levelled automatically. It is achieved by inclination compensating device.

Levelling Staffs

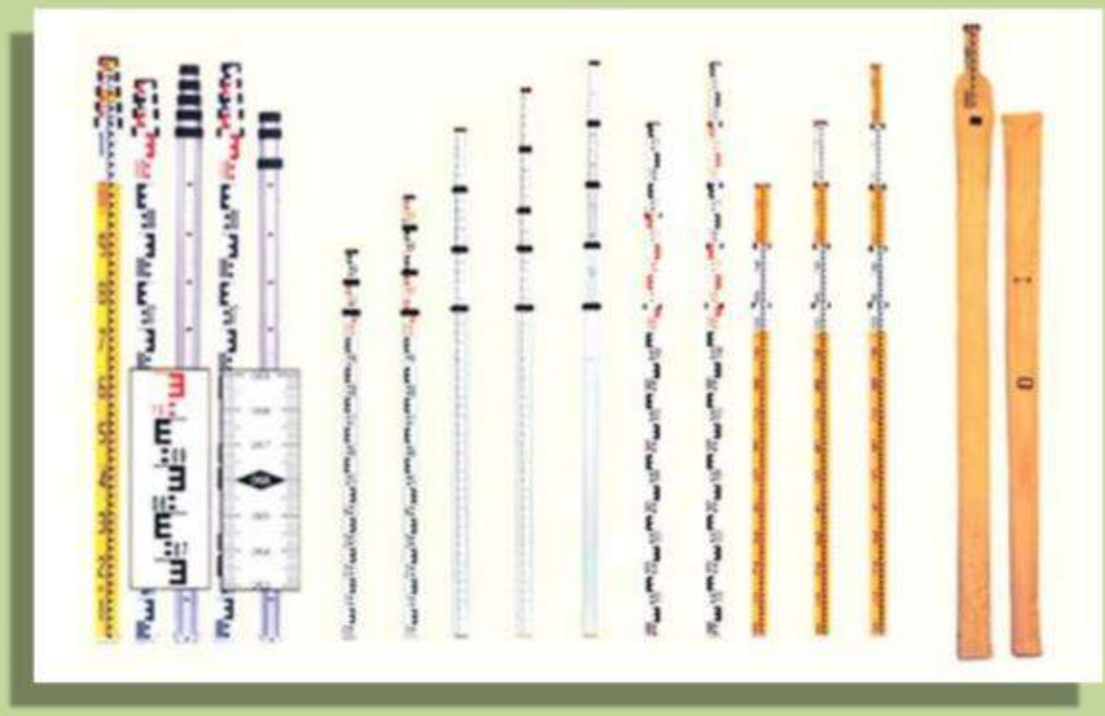
Levelling staffs are scales on which these distances are measured.
Levelling staffs are of two types
1. Self reading staff
2. Target staff

Self reading staff

The self reading staff can be read directly by the level man looking through the telescope.
Common types of self reading staffs

1. Ordinary staff
2. Sopwith telescopic staff
3. Folding Staff

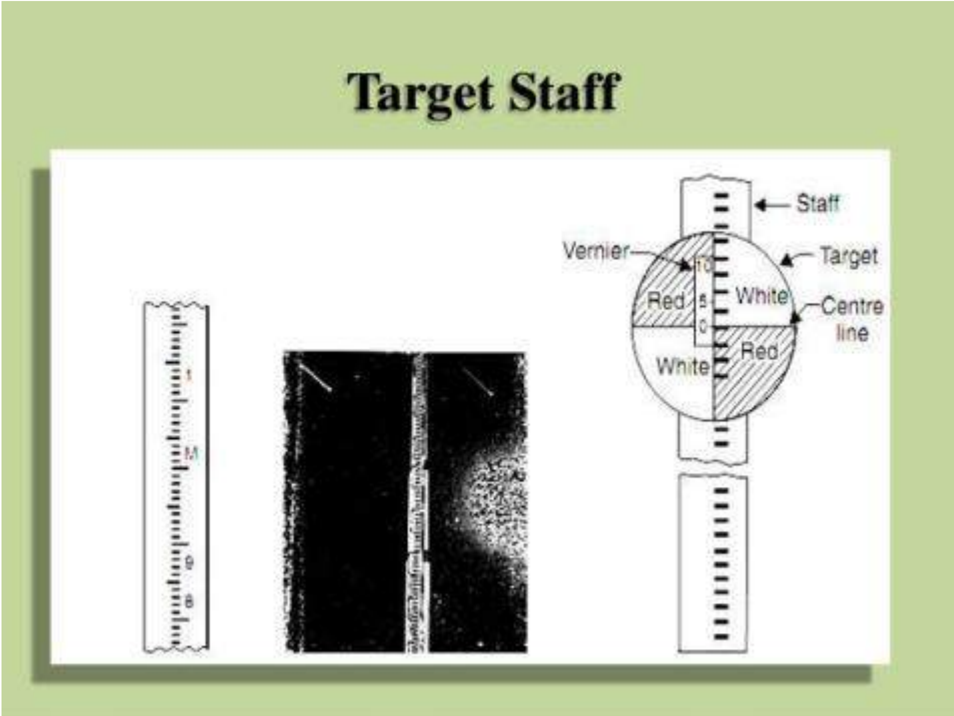
Levelling Staffs



Folding Staff

Target staff

For very precise works and sight target staff are used. A movable target is provided in this staff. A Vernier is provided on target to give precise reading. In target staff level man directs the staff man to move the target up and down until it bisects by the line of sight. The staff man observe the staff reading.



Bench Marks

Bench mark is a point of known elevation
There are 4 kinds of bench marks

1. GTS (Great trigonometrically survey bench mark)
2. Permanent bench mark
3. Arbitrary bench mark
4. Temporary bench mark

GTS Bench mark

- They are the bench marks established with very high degree of precision at regular intervals by the survey of India Department all over the country Their position and R.Ls values above mean seal level at Karachi are given in catalogue formed by the department
- Mean sea level

Permanent Bench mark

- Permanent bench marks are fixed in between GTS bench marks by govt. agencies such as railways, PWD etc.This benchmarks are written on permanent objects such as milestones, culverts, bridges etc their value are clearly written and their position are recorded for future reference.

Arbitrary bench marks

- These are reference points whose R.L.s are arbitrarily assumed. They are used in small works such bench mark may be assumed as 100. or 50 m

Temporary bench marks

- They are the reference points established during the levelling operations when there is a break in work, or at the end of day's work the value of reduced levels are marked on some permanent objects such as stones, trees etc.

Temporary Adjustments of a level

These adjustments are performed at every setup of instrument

1. Setting up of level
2. Levelling of telescope
3. Focusing of the eye peace
4. Focusing of object glass

- **Setting up the level**

This includes
A) Fixing the instrument on tripod

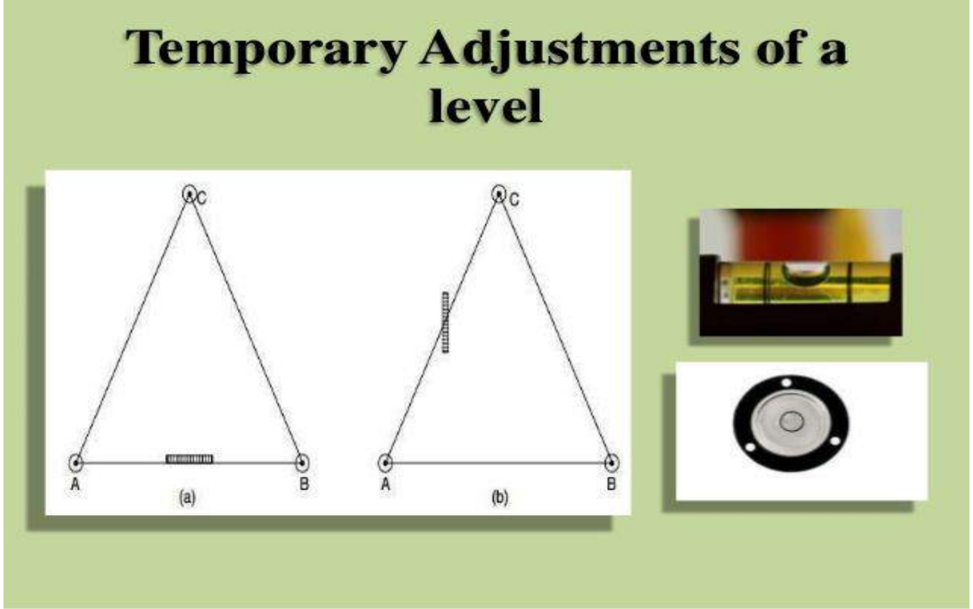
B) Levelling the instrument approximately by Tripod

- **Levelling**

Levelling is done with the help of foot screws. The purpose of levelling is to make vertical axis truly vertical. It is done with the help of foot screws

A) Place the telescope parallel to a pair of foot screw then hold the foot screws between thumb and first finger and turn them either inward or outward until the longitudinal bubble comes in the centre.

B) Turn the telescope through 90^0 so that it lies parallel to third foot screw, turn the screw until the bubble comes in the centre



- **Focusing the eye piece**

To focus the eye piece, hold a white paper in front of object glass, and move the eye piece in or out till the cross hair are distinctly seen.

- **Focusing of object glass**

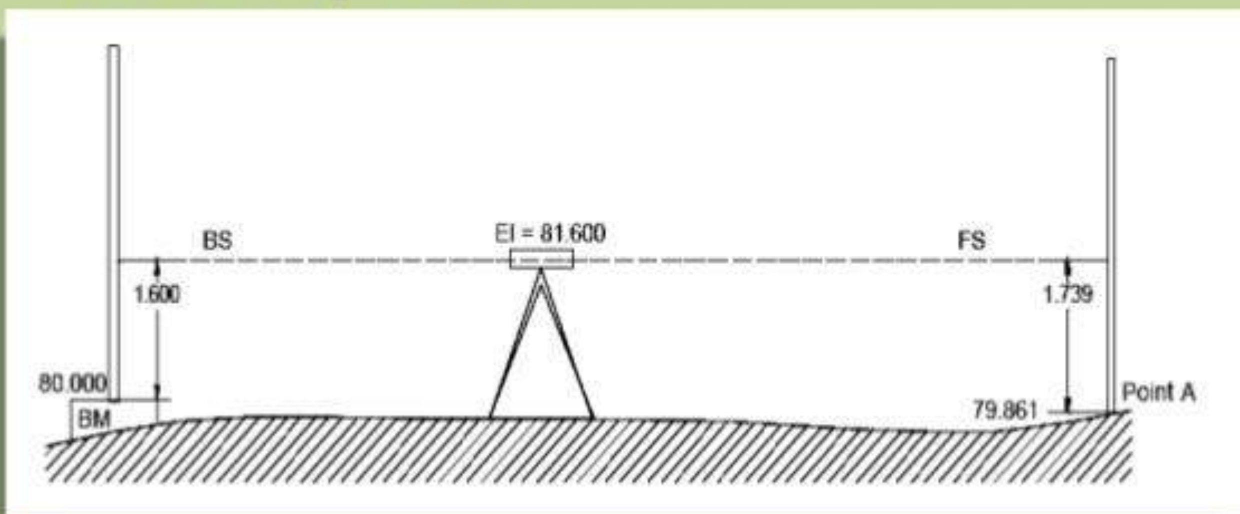
Direct the telescope to the levelling staff and on looking through the telescope, turn the focusing screw till the image appears clear and sharp.

Classification of levelling

1. Simple levelling
2. Differential leveling
3. Fly levelling
4. Check levelling
5. Profile levelling
6. Cross levelling
7. Reciprocal levelling
8. Precise levelling
9. Trigonometric levelling
10. Barometric levelling
11. Hypersometric levelling

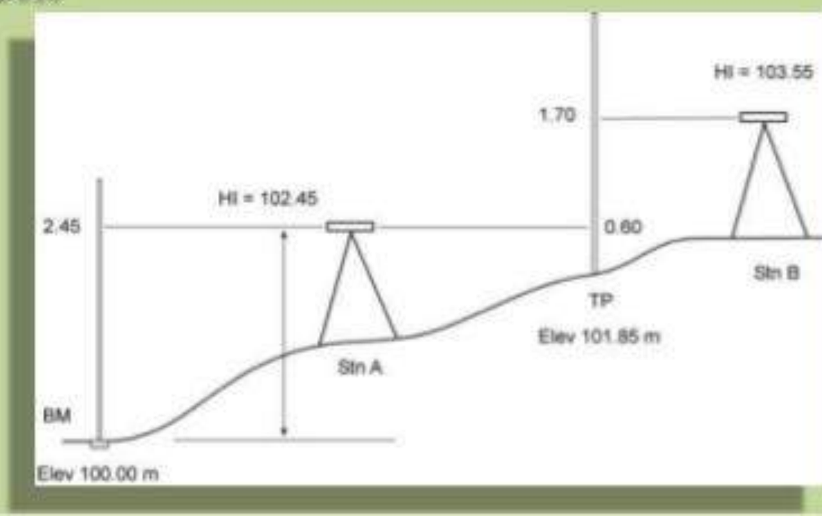
Simple Levelling

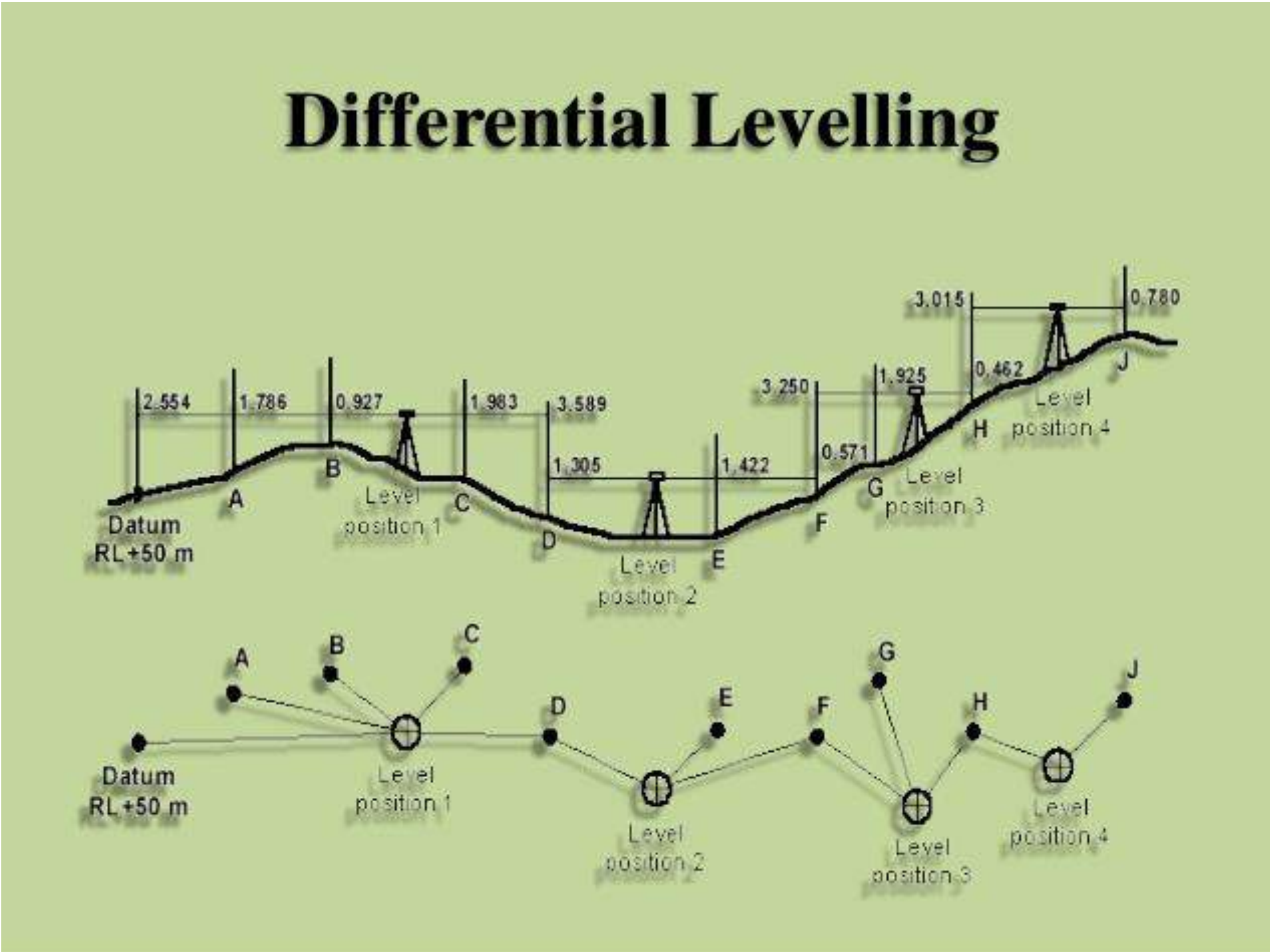
- It is the simplest method used, when it is required to find the difference in elevation between 2 points.



Differential Levelling

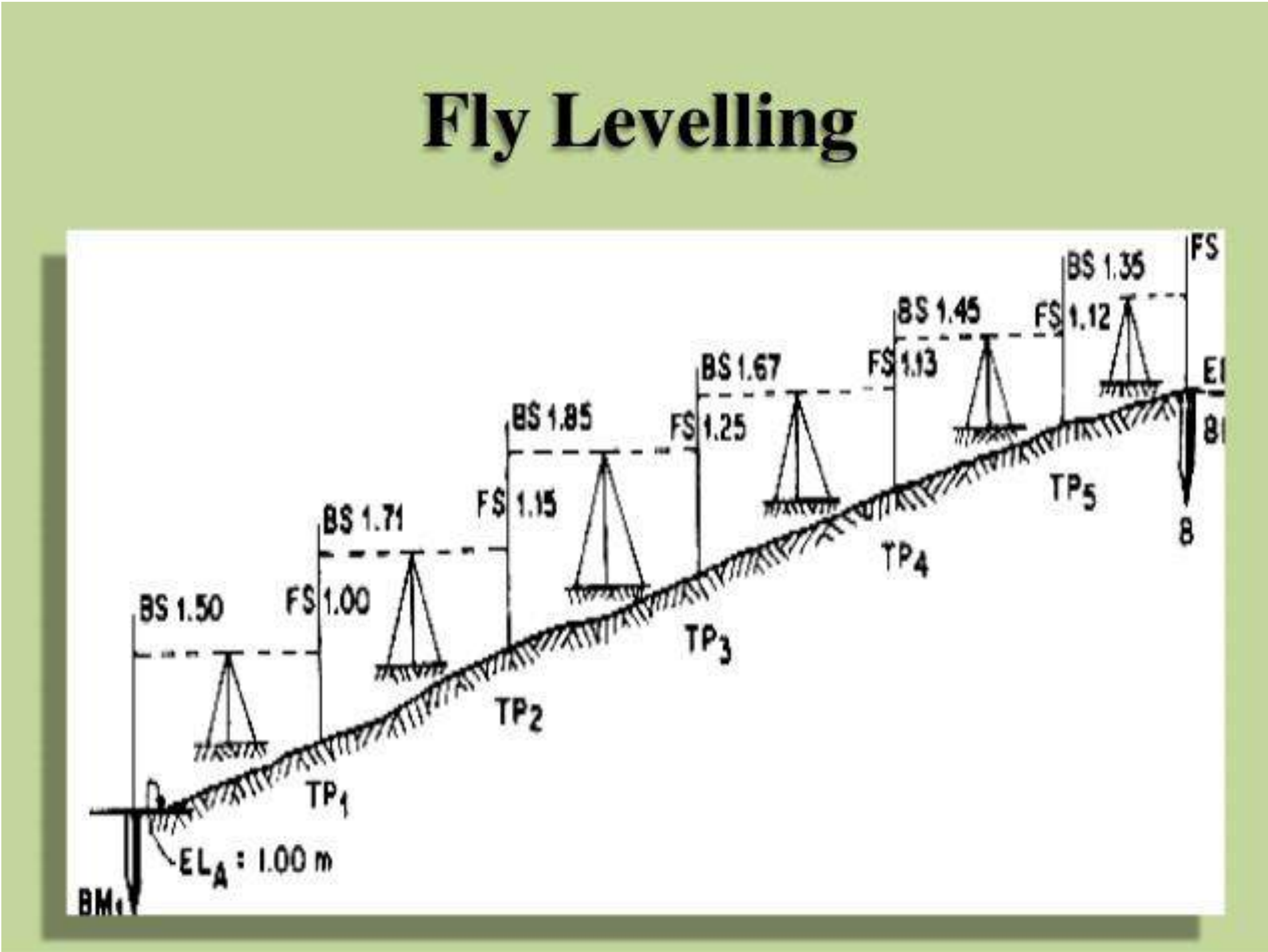
- This method is used to find the difference in the elevation between points if they are too far apart or the difference in elevation between them is too much.




Differential Levelling
2.554
1.786
0.927
1.983
3.589
1.305
1.422
3.250
0.571
1.925
3.015
0.462
0.780
A
B
C
D
E
F
G
H
J
Datum
RL+50 m
Level
position 1
Level
position 2
Level
position 3
Level
position 4

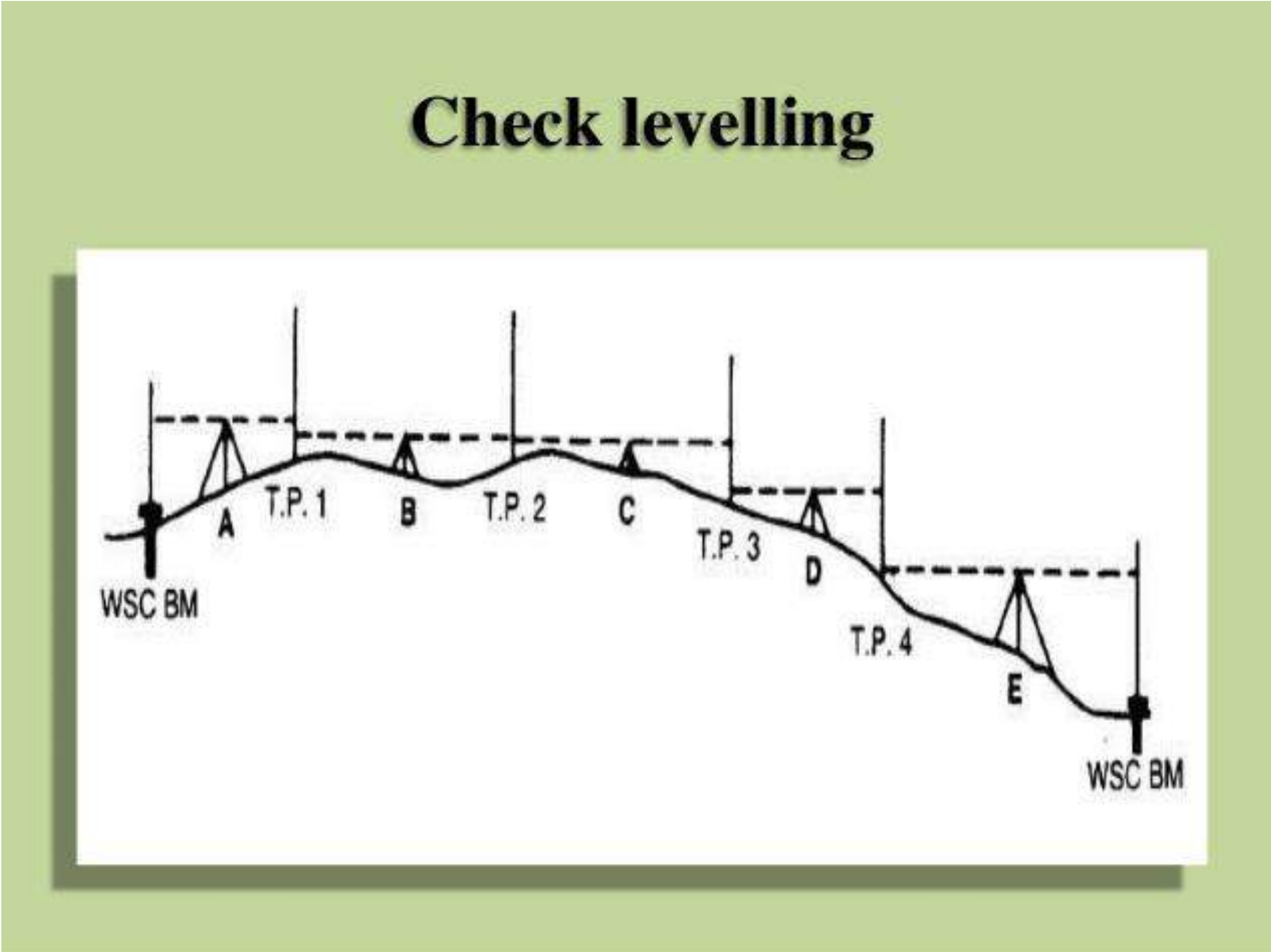
Fly Levelling

- Fly levelling is just like differential levelling carried out to check the accuracy of levelling work. In fly levelling only B.S. and F.S. are taken



- **Check levelling**

This kind of levelling is carried out to check the accuracy of work. It is done at the end of the day’s work in the form of fly levelling to connect the finishing point and starting point.

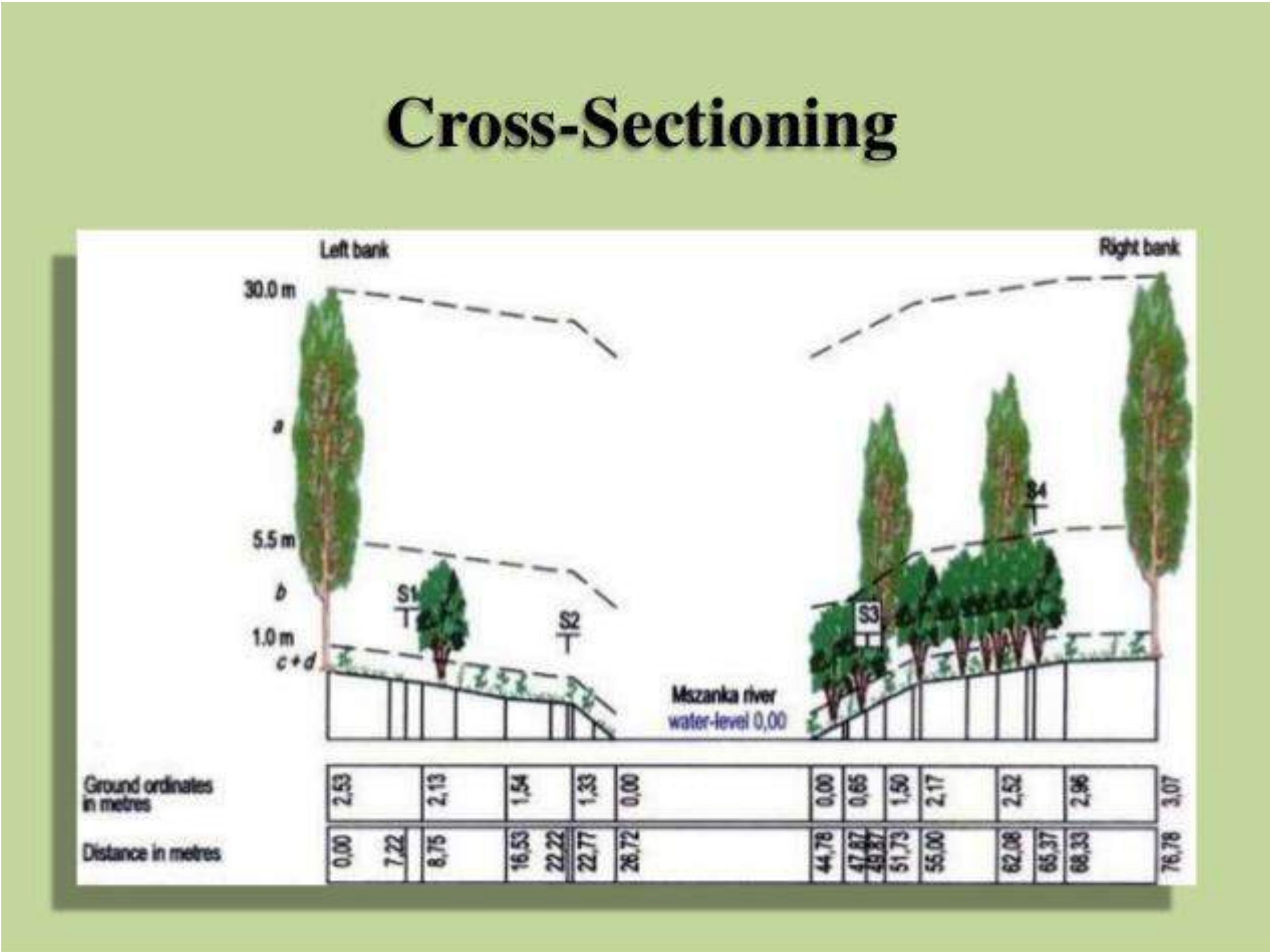


- **Profile levelling or L Section**

This method is used for taking levels along the centre line of any alignment like road, railway canal etc. The object is to determine the undulations of the ground surface along the alignment.

- **Cross sectioning**

This operation is carried out perpendicular to alignment at an interval of 10, 20 ,30, 40 m. The idea is to make an estimate of earthwork.

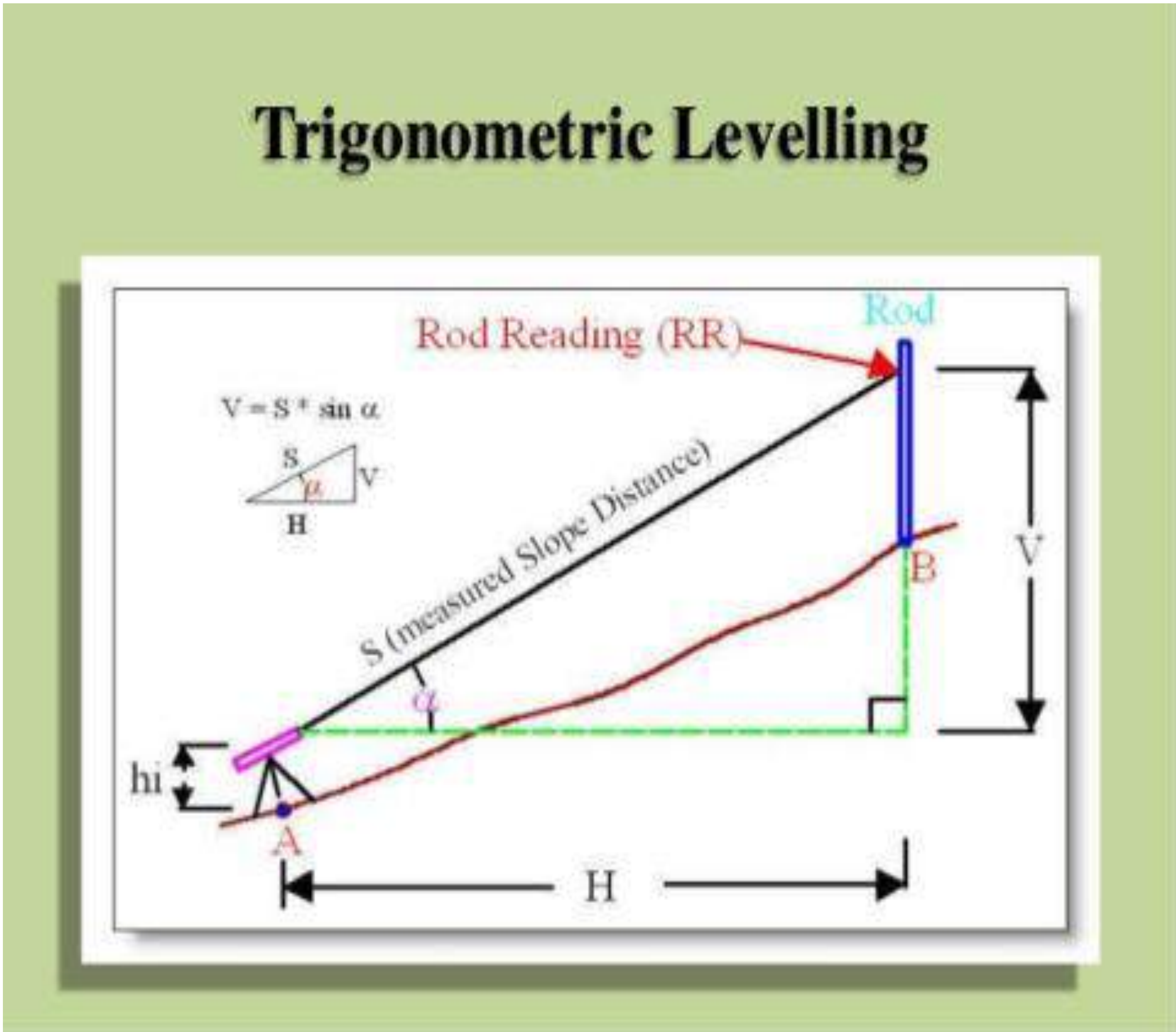


- **Precise levelling**

It is used for establishing bench marks for future public use. It is carried out with high degree of accuracy using advanced instruments.

- **Trigonometric levelling**

In this method vertical distances between points are computed by observing horizontal distances and vertical angle between points.



- **Barometric levelling**

In this method the altitude difference is determined by means of a barometer.

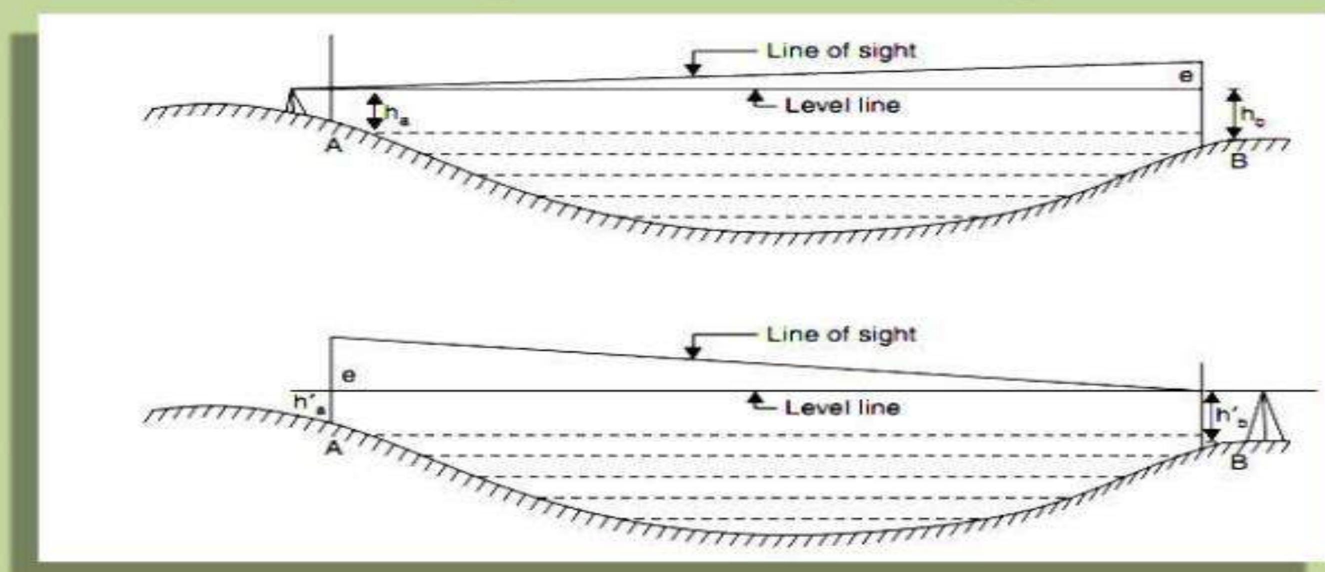
- **Hyposometric levelling**

TheworkingofHyposometryfordeterminingtheelevationdependsuponthefactthatthetemperatureatwhichwater boilsvarieswiththeatmosphericpressure.Theboilingpointofwaterreducesathigheraltitudethusknowingtheboilingpointofwater ,theatmosphericpressurecanbecalculatedandknowingtheatmosphericpressurealtitudeorelevationcanbedetermined.

Reciprocal levelling

- **Reciprocal Levelling:-**
- **This method is adopted to accurately determine the difference of level between two points which are far apart. It is also used when it is not possible to setup level in midway between two points**
- Let A and B be the two points on opposite banks of a river. It is required to find out the level difference between A&B
- Setup the level very near to A and take the reading at A and B let the reading be a_1 and b_1
- Shift the level and setup very near to B and observe A and B to get reading a_2 and b_2
- Let d is the true difference of level between A and B, and e=error due to curvature, refraction and imperfect adjustment.

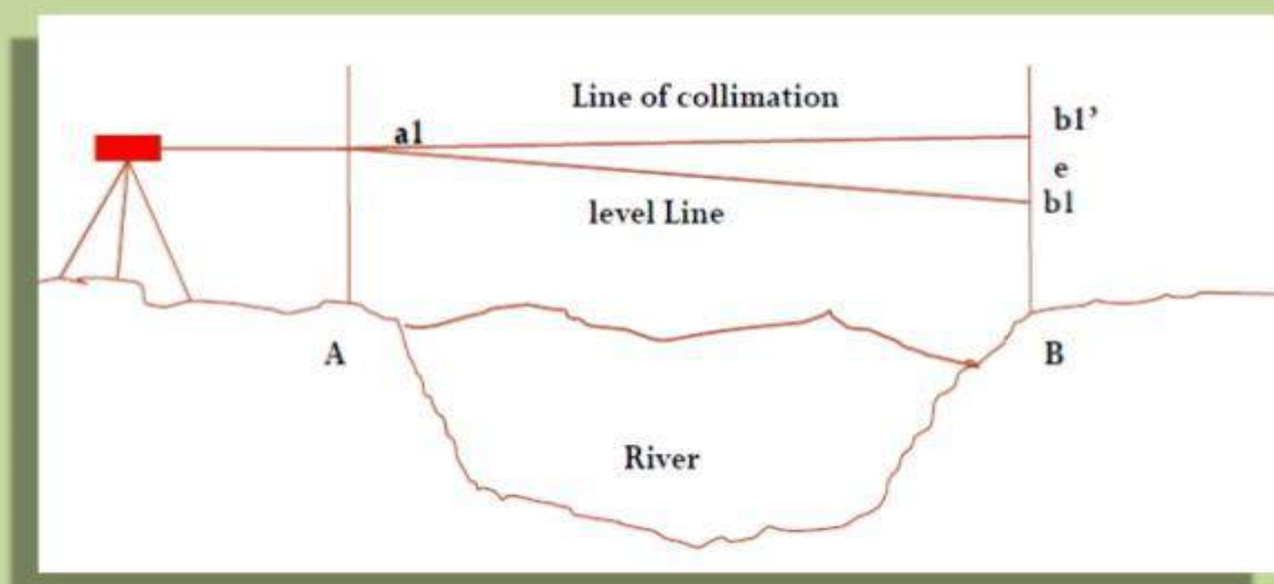
Reciprocal levelling



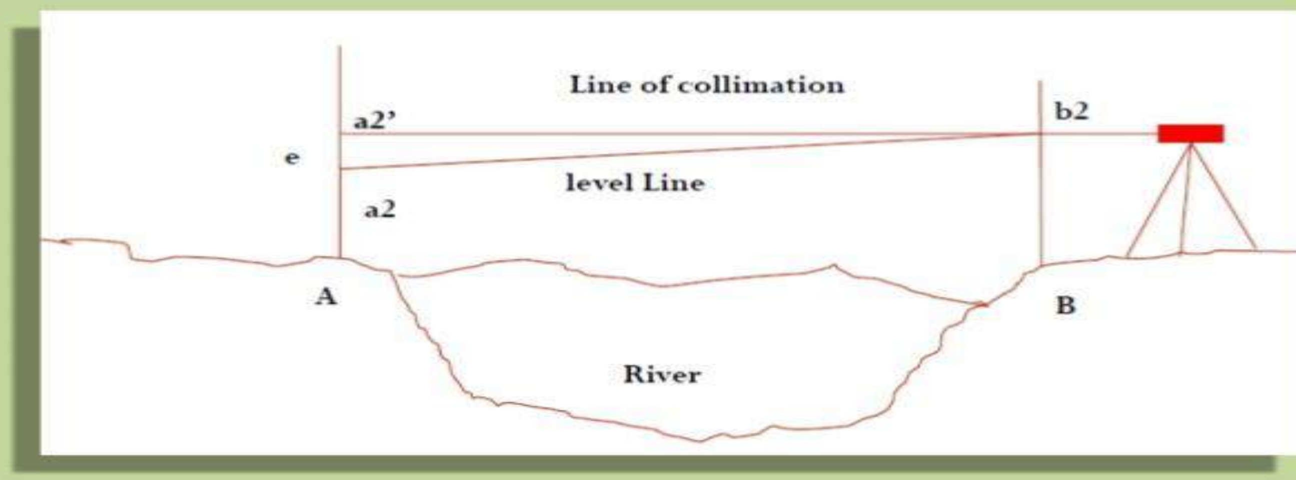
Reciprocal Levelling

- Thus to eliminate the error take an average of the difference in elevation taken from 2 points
- i.e. from A the true difference will be
- $=(b_1\text{-}e)\text{-}a_1$
- **Or d= $(b_1 - a_1) - e$**
- From B the difference will be= $b_2\text{-}(a_2\text{-}e)$
- **Or d= $(b_2 - a_2) + e$**
- Adding these two eq^n to eliminate e, we get
- Therefore **d=$\{(b_1-a_1)+ (b_2-a_2)\}/2$**

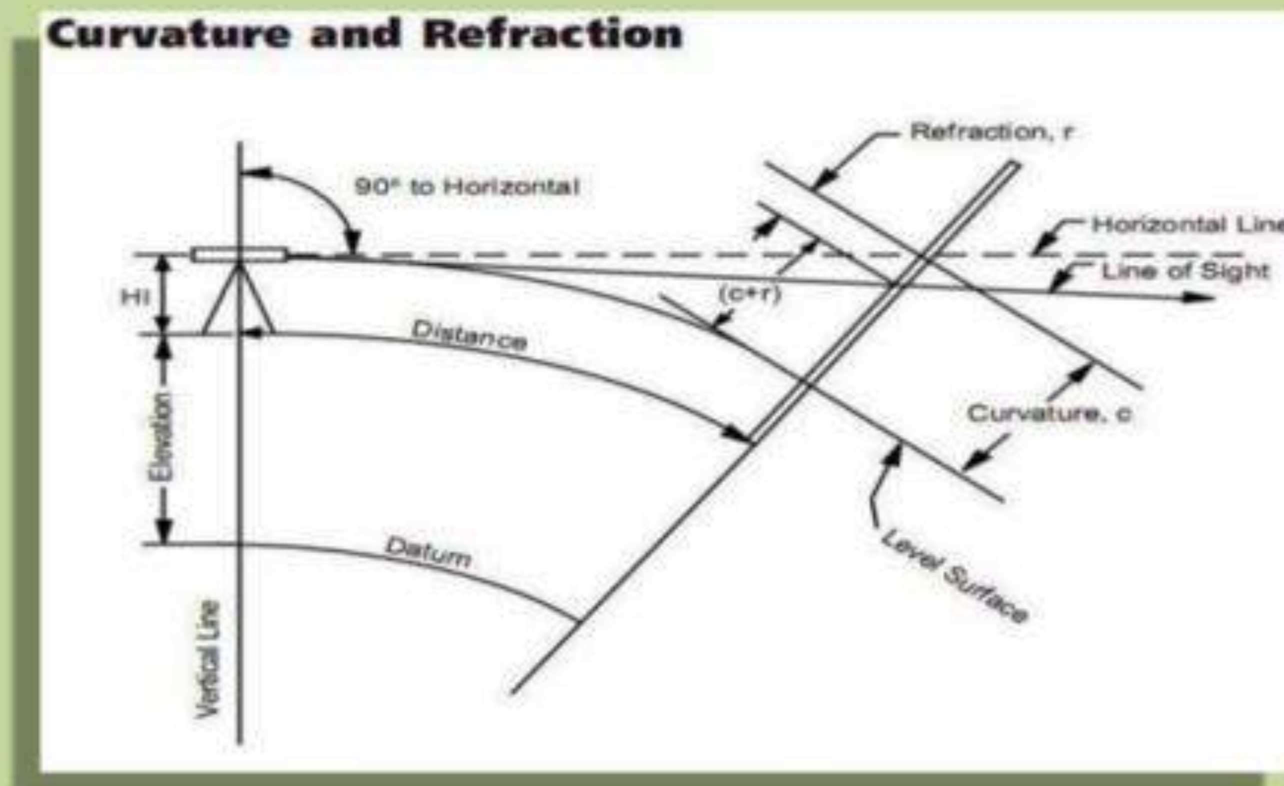
Reciprocal Levelling



Reciprocal Levelling



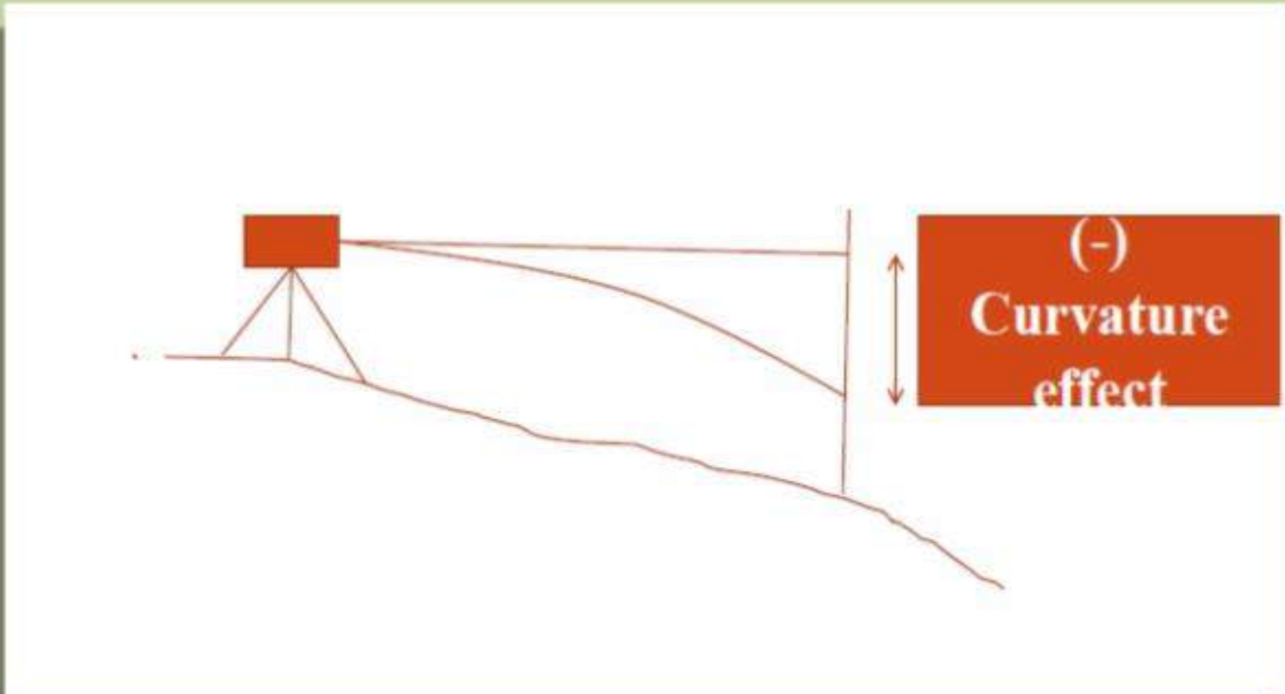
Curvature & Refraction Correction



Curvature Correction

- For long sights the curvature of earth can effect staff readings. The line of sight is horizontal but the level line is curved and parallel to the mean spheroidal surface of the earth.
- The vertical distance between the line of sight and level line at particular place is called the curvature correction
- The effect of curvature is to cause the object sighted to appear lower than they really are.
- Curvature correction is always **Subtractive(-)**
- **True staff reading=(Observed staff reading-** $\mathbf{0.0785D^2}$**)m**
- Where D= distance in Km.

Curvature Correction



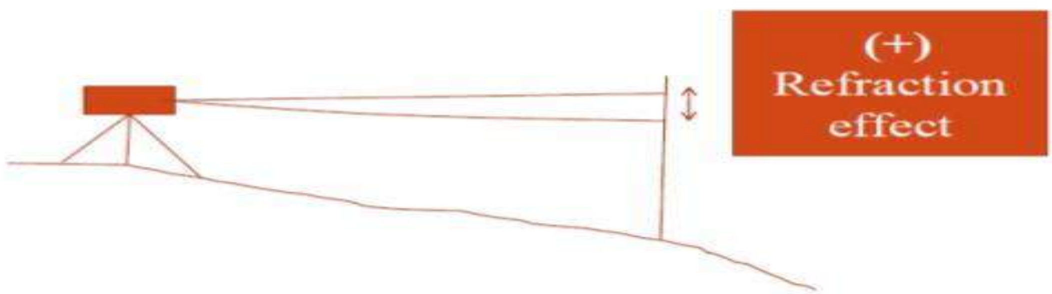
Refraction

- The ray of light pass through layers of air of different densities and refractor bent down. The effect of refraction is to make the object appear higher then they really are. Refraction varies considerably with climate conditions.

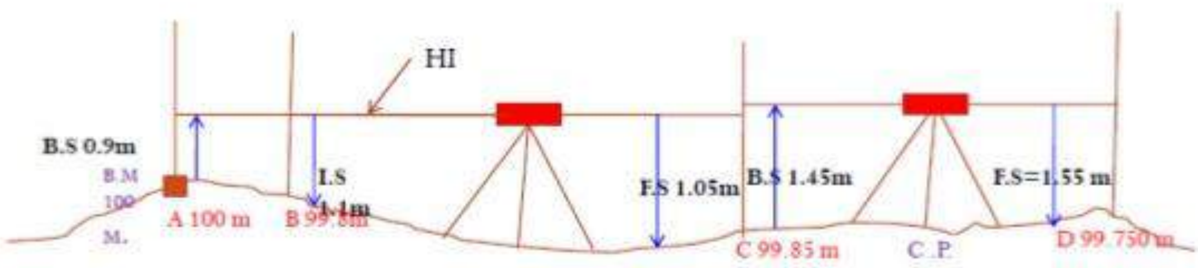
However it is taken as,

- **Cr=0.0112 D^2m(+)**
- Refraction is always additive
- **True staff reading**
- **=Observed staff Reading+ Refraction correction.**

Refraction



Height of Instrument Method

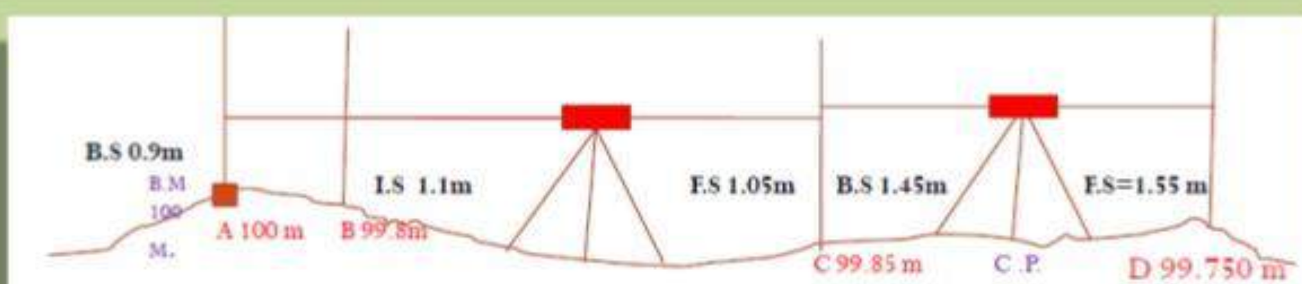


Station	B.S	I.S	F.S	H.I	R.L	Remark
A	0.9			100.9	100.00	B.M
B		1.1			99.800	
C	1.450		1.05	101.3	99.850	C.P.
D			1.550		99.750	

Rise and Fall Method

- This method consist of determining the difference of level between consecutive points by comparing each point with immediate preceding point.

Rise and Fall Method



Station	B.S	I.S	F.S	Rise	Fall	R.L	Remark
A	0.9					100.00	B.M
B		1.1			0.2	99.800	
C	1.450		1.05	0.05		99.850	C.P.
D			1.550		0.1	99.750	

Errors in Levelling

The following are the different sources of Errors

- **Personal Error**
- The Instruments may not be levelled
- The focusing of eye piece and objective glass may not be perfect
- The parallax may not be eliminated
- The position of staff may have changed
- Entry and recording in the field book may not be correct
- The staff may not be fully extended, may not be held vertical.

Errors in Levelling

Instrumental Error

- The Permanent adjustment of the instrument may not be perfect. That is the line of collimation may not be horizontal line.
- The internal arrangement of focusing tube may not be correct
- The graduation of the staff may not be perfect
- Defective bubble tube, if the bubble tube is sluggish, it may apparently be in the mid-position even though the bubble line is not horizontal.

Common errors in Leveling

- Foresight and back sight not being taken on exactly the same point
- Reading the staff upward instead of downward
- Reading of stadia hair
- Reading of wrong number of metre and decimeter
- Entering backsight in F.S and vice versa
- Transposing the figures
- Omitting an entry
- The leveling staff not being fully extended.

Example

- The following staff readings were observed successively with a level the instrument is moved by **third, sixth and eighth readings.**
- 2.228 :1.606 :0.988 :2.090 :2.864 :1.262 0.602 :1.982 :1.044 :2.684 m
- enter the reading in record book and calculate R.L. if the first reading was taken at a **B.M of 432.383m**

H.I. Method

Station	B.S	I.S	F.S	HI	RL	REMARKS
1	2.228			434.612	432.384 M	B.M.
2		1.606			433.006	
3	2.090		0.988	435.714	433.624	3RD C.P.
4		2.864			432.850	
5	0.602		1.262	435.054	434.452	6TH C.P
6	1.044		1.982	434.116	433.072	8TH C.P
7			2.684		431.432	
	5.964		6.916			

CHECK Σ B.S-Σ F.S = 5.964-6.916= -0.952 = LAST R.L-FIRST R.L= 431.432-432.384=-0.952

Rise and Fall Method

Station	B.S	I.S	F.S	Rise	Fall	RL	REMARKS
1	2.228					432.384 M	B.M.
2		1.606		0.622		433.006	
3	2.090		0.988	0.618		433.624	3RD C.P.
4		2.864			0.774	432.850	
5	0.602		1.262	1.602		434.452	6TH C.P
6	1.044		1.982		1.38	433.072	8TH C.P
7			2.684		1.64	431.432	
	5.964		6.916				

CHECK ΣB.S-ΣF.S= 5.964-6.916= -0.952 = LAST R.L-FIRST R.L= 431.432-432.384=-0.952
ΣRISE-ΣFALL= 2.842-3.794=-0.952

CONTORUING

Contour:

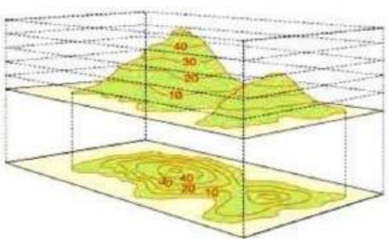
An Imaginary line on the ground surface joining the points of equal elevation is known as contour.

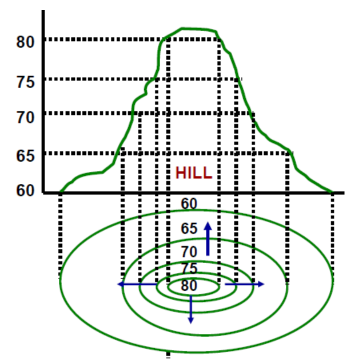
In other words, Contour is a line in which the ground surface is intersected by a level surface obtained by joining points of equal elevation. This line on the map represents a contour and is called Contour line.

A map showing Contour Lines is known as Contour Map.

Contouring:

The process of tracing contour lines on the surface of the earth is called Contouring.





A HILL

Purpose of Contouring:

Contour survey is carried out at the starting of any engineering project such as a road, a railway, a canal, a dam, a building etc.

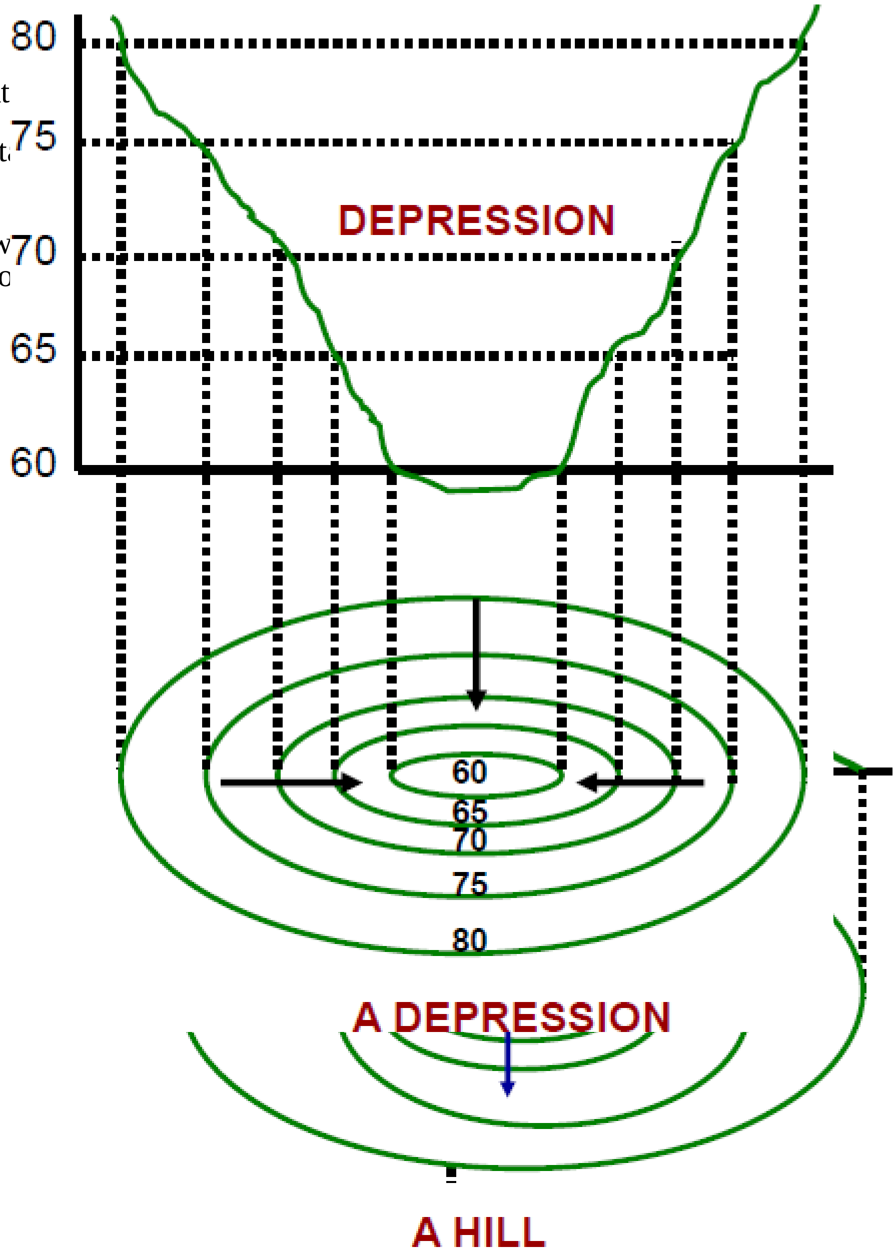
1. For preparing contour maps in order to select the most economical or suitable site.
2. To locate the alignment of a canal so that it should follow a ridge line.
3. To mark the alignment of roads and railways so that the quantity of earthwork both in cutting and filling should be minimum.
4. For getting information about the ground whether it is flat, undulating or mountainous.
5. To locate the physical features of the ground such as a pond depression, hill, steep or small slopes.

Contour Interval and Horizontal equivalent:

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

Horizontal Equivalent: The horizont
called as horizontal equivalent.

The contour interval is constant betw
equivalent is variable and depends upo



Characteristics of Contour:

1. All points in a contour line have the same elevation.

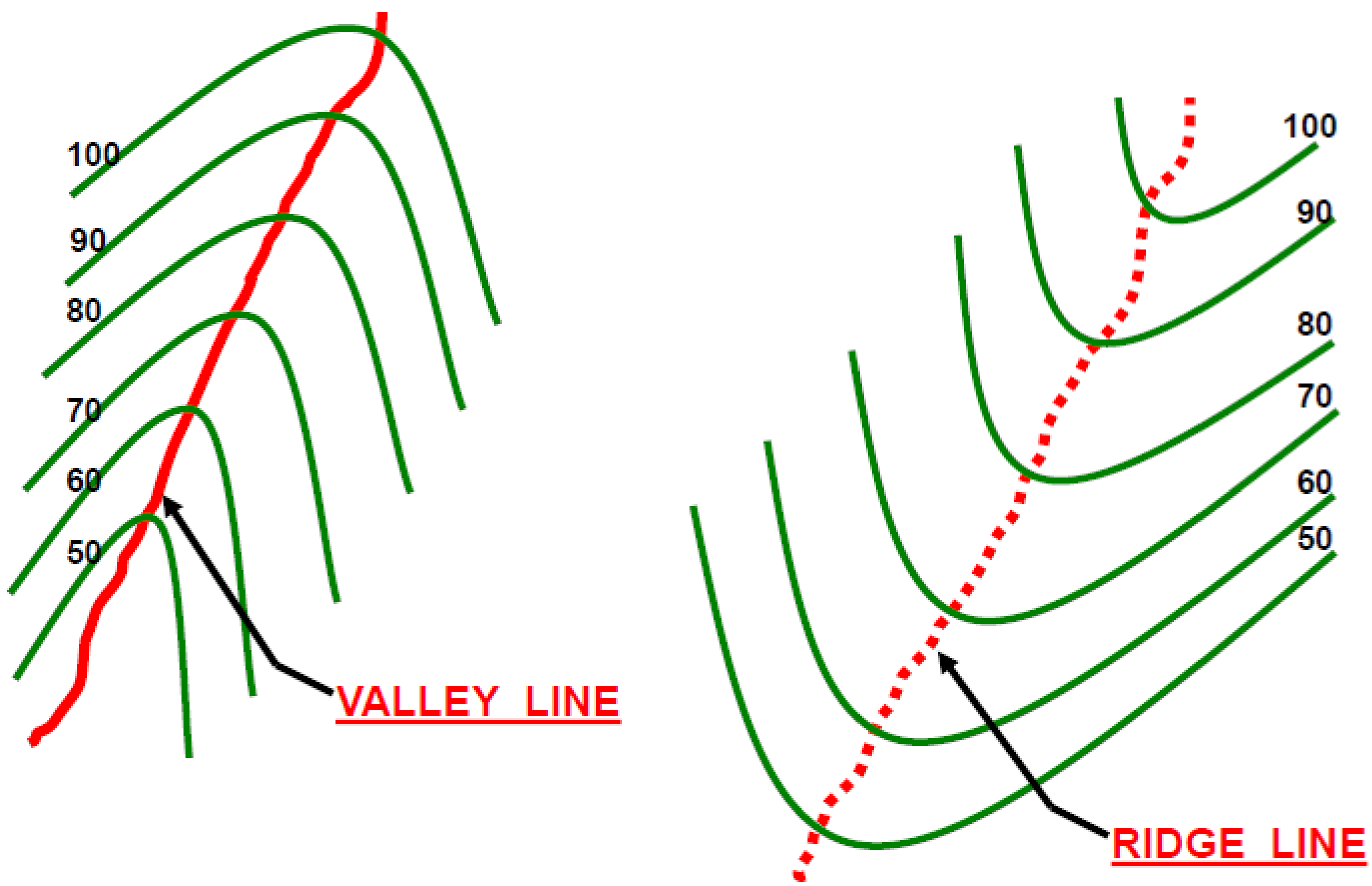
2. Flat ground is indicated where the contours are widely separated and steep-slope where they run close together.

3. A uniform slope is indicated when the contour lines are uniformly spaced and

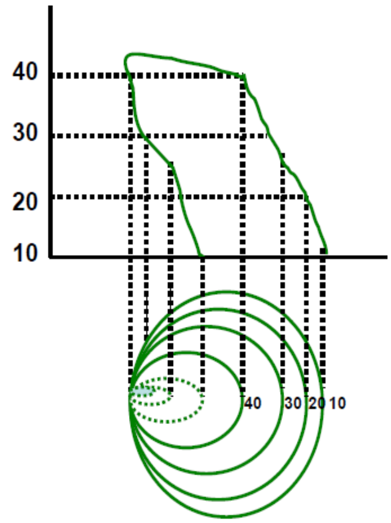
4. A plane surface when they are straight, parallel and equally spaced.

5. A series of closed contour lines on the map represent a hill , if the higher values are inside.

6. A series of closed contour lines on the map indicate a depression if the higher values are outside.
7. Contour line cross ridge or valley line at right angles.If the higher values are inside the bend or loop in the contour, it indicates a Ridge.If the higher values are outside the bend, it represents a Valley

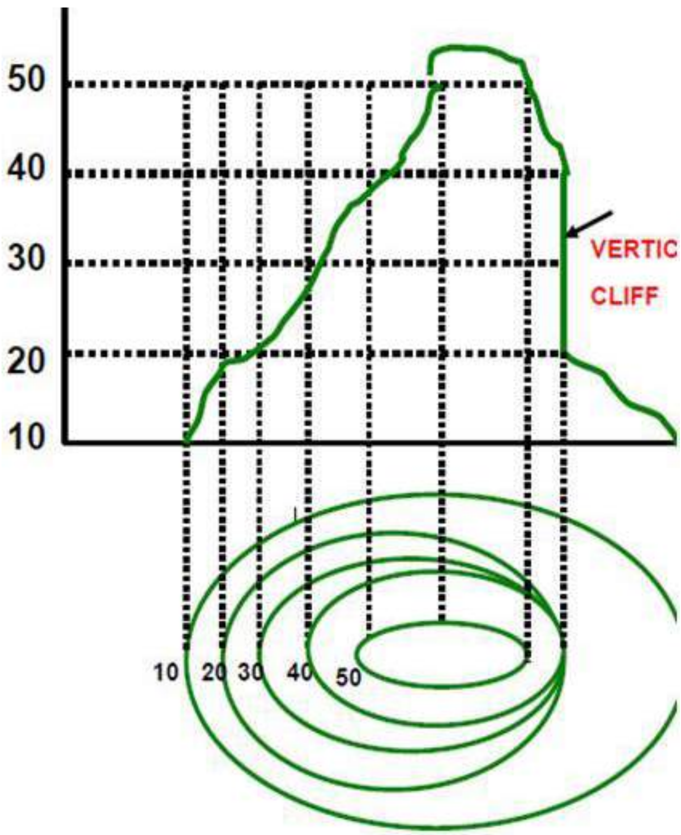


8. Contour lines cannot merge or cross one another on map except in the case of an overhanging cliff



OVERHANGING CLIFF

9. Contour lines never run into one another except in the case of a vertical cliff. In this case, several contours coincide and the horizontal equivalent becomes zero.



OVERHANGING CLIFF

Methods of Contouring:

There are mainly two methods of locating contours:-

(1)Direct Method and (2) Indirect Method.

Direct Method:

In this method, the contours to be located are directly traced out in the field by locating and marking a number of points on each contour.
These points are then surveyed and plotted on plan and the contours drawn through them.

Indirect Contouring:

In this method the points located and surveyed are not necessarily on the contour lines but the spot levels are taken along the series of lines laid out over the area .The spot levels of the several representative points representing hills, depressions, ridge and valley lines and the changes in the slope all over the area to be contoured are also observed. Their positions are then plotted on the plan and the contours drawn by interpolation. This method of contouring is also known as contouring by spot levels.

Comparison od Direct and Indirect Contouring:

Direct Method	Indirect Method
Most accurate but slow and tedious	Not so accurate but rapid and less tedious
Expensive	Cheaper
Not suitable for hilly area	Suitable for hilly area
During the work calculations can be done	Calculations are not required in the field
Calculations can not be checked after Contouring	Calculation can be checked as and when required

CHAPTER 8

Computation of Area & Volume

Introduction:-

It is the space of a tract of land projected upon the horizontal plane and not to the actual area of the land surface.

It may be expressed in Square metres(m^2),Hectares(1 hectare= 10000m^2),Square feet,Acre.

Methods for computation of area:-

There are two methods of computation of the Area:-

A. ***Graphical method***

B. ***Instrumental method***

Calculation of area from Graphical method:-

The area may be calculated in two following ways:-

i.From field Notes

ii.From Plotted plan

Computation of the area from field notes

In this method the computation of the area is done in two steps:-

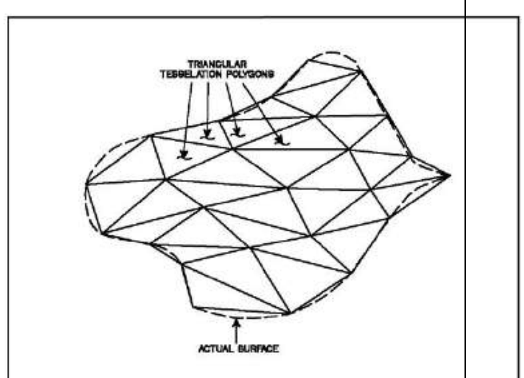
a. In survey works the whole area is divided into number of some geometrical Fig. such as triangles, rectangles, square, trapeziums and then the area is calculated.
b. Then the area of this geometrical fig. added up to get the required area.

Calculation of the area from Plotted plan:-

The area may be calculated in two following ways:-

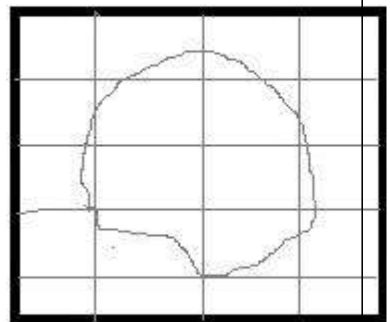
i.Considering the entire area

ii.Considering the Boundary area



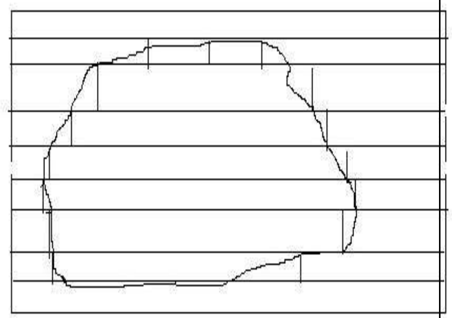
Considering the Entire area:-The entire area is divided into regions of convenient shape and they are calculated by

a.**By dividing the area into triangles**:- The triangles are so drawn as to equalize the irregular boundary line. Then the bases and altitude of the triangles are determined according to the scale to to which plan is drawn. After this the areas of these triangles are calculated.(fig.1)



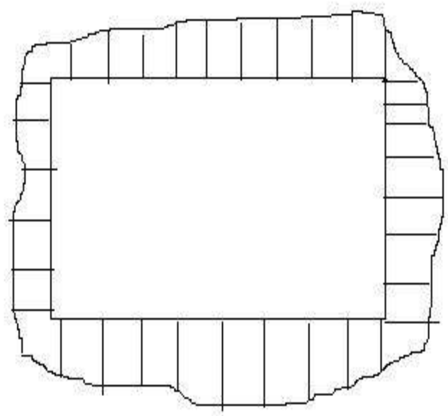
b. **By dividing the area into squares**:- In this method squares of equal size are ruled out on a piece of tracing paper. Each square represents a unit area which could be 1cm^2 or 1m^2.The tracing paper is placed over the plan and the full squres are counted. The total area is then calculated by multiplying the number of squres by the unit area of each square

c. **By drawing parallel lines and converting them into rectangles**:- In this method , a series of equidistant parallel lines are drawn on a tracing paper. The constant distance represents a metre or cm. The tracing paper is placed over the plan in such a way the area is enclosed between parallel lines at the top and bottom. Thus the area is number of strips. The curved ends of the strips are replaced by perpendicular lines and no. of rectangles are formed. The sum of the lengths of the rectangles is then calculated.



Required Area= $\sum$ length of rectangle X constant distant

<u>Considering the Boundary area</u>:-In this method the large square or rectangle is formed with in the area in the plan . The ordinates are drawn at a regular interval from side of the square to the curved boundary. The middle area is calculated in the usual manner. The boundary area is calculated by



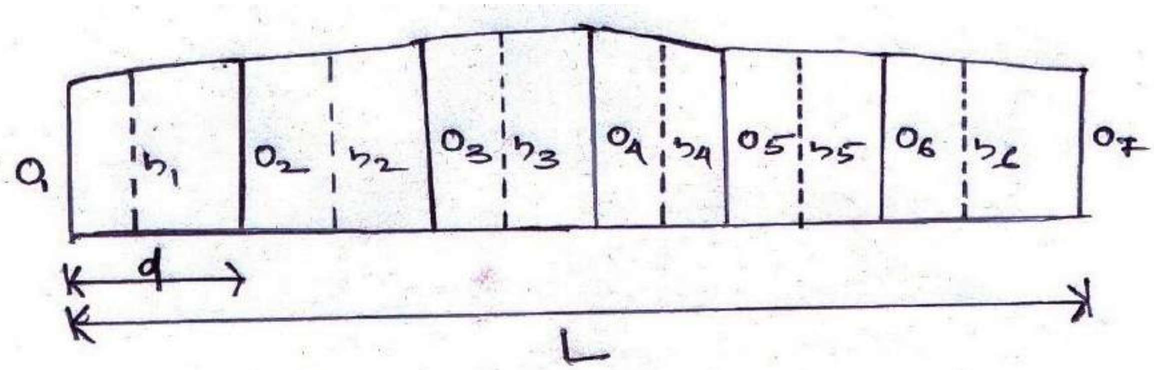
a.Mid Ordinate rule

b.Average ordinate rule

c.Trapezoidal rule

d.Simpson's rule

<u>Mid Ordinate rule:-</u>



Let $O_1,O_2,O_3,O_4,O_5,O_6,O_7$………………………………………$O_n$= ordinates at equal intervals

L= length of the base line

d= Common distance between ordinates

$h_1,h_2,h_3,h_4,h_5,h_6,h_7$,……………………………$h_n$= mid ordinates

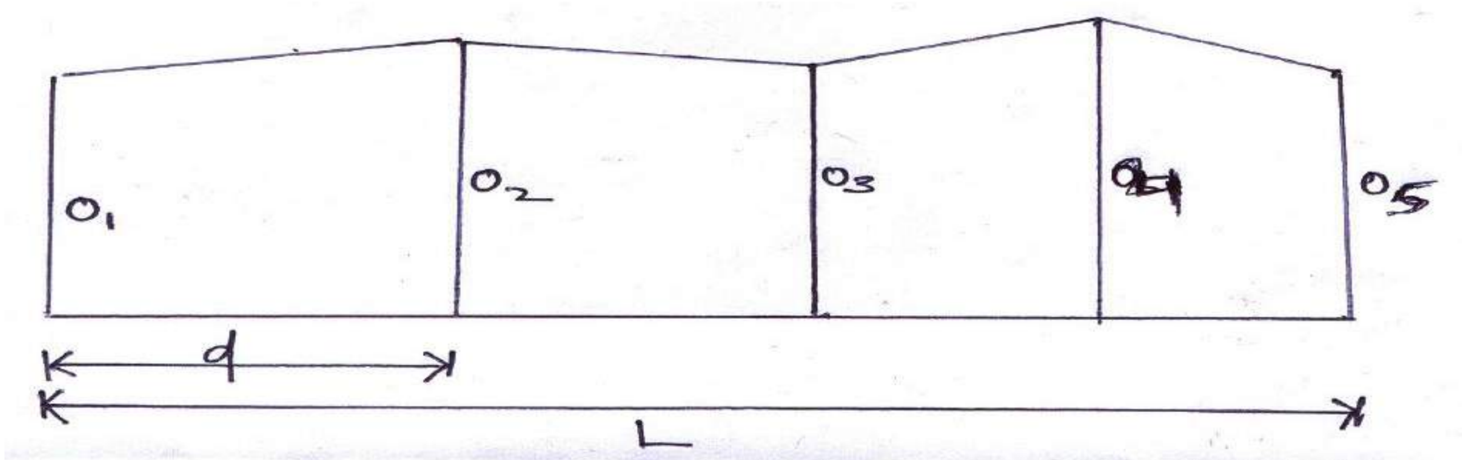
Area of the plot = $(h_1 \times d) + (h_2 \times d) + (h_3 \times d) + (h_4 \times d) + \ldots + (h_n \times d)$

$= d(h_1 + h_2 + h_3 + h_4 + h_5 + h_6 + h_7 + \ldots + h_n)$

Where $h_1 = (O_1+O_2)/2$ and so on

Therefore the required area = common distance X sum of the mid ordinates.

Average ordinate rule:-



Let O_1,O_2,O_3,O_4,O_5,O_6,………………………………………O_n= ordinates or offsets at regular intervals

L= length of the base line

n= no. of divisions

n + 1 = number of ordinates

$$\text{Area} = \frac{O_1 + O_2 + O_3 + O_4 + O_5 + O_6 + \ldots + O_n}{O_{n+1}} \times L$$

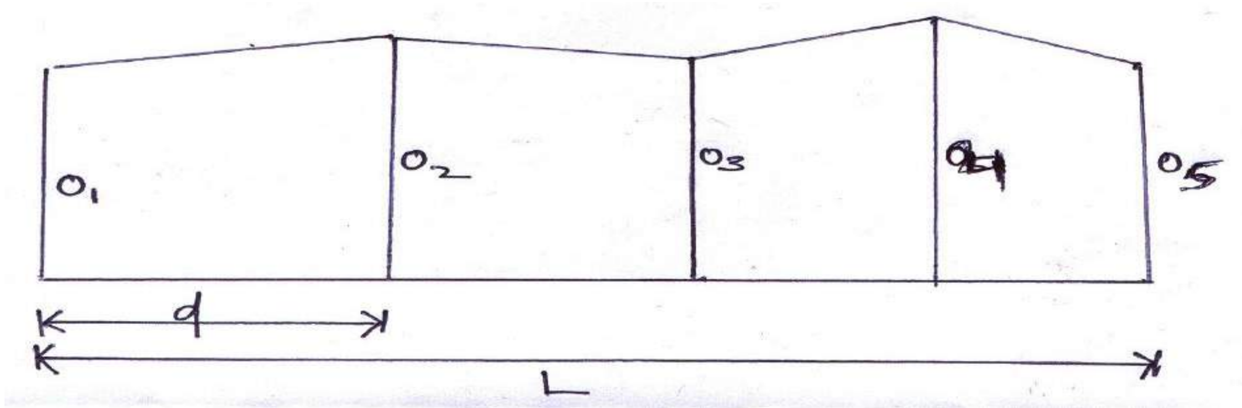
Trapezoidal rule:-

- While applying the trapezoidal rule boundaries between the ends of the ordinates are assumed to be straight. So, thearea enclosed between the base line and the irregular boundary lines are to be considered as trapezoids.

Let, $O_1, O_2, O_3, O_4, O_5, O_6, O_7 \ldots\ldots\ldots\ldots\ldots\ldots O_n$ = ordinates at equal intervals

d= Common distance between ordinates

L= length of the base line



There fore,

1^{st} area = $\frac{O_1 + O_2}{2} \times d$

2^{nd} area = $\frac{O_2 + O_3}{2} \times d$

3^{rd} area = $\frac{O_3 + O_4}{2} \times d$

4^{th} area = $\frac{O_4 + O_5}{2} \times d$

………………………………………………… and so on

Last area =$\{ (O_{n-1} + O_n) \times d\} / 2$

There fore the required area = 1^{st} area + 2^{nd} area + 3^{rd} area + 4^{th} area +…………………….. + Last area

$= [\{(O_1 + O_2) \times d\}/2] + [\{(O_2 + O_3) \times d\}/2] + [\{(O_3 + O_4) \times d\}/2] + [\{(O_4 + O_5) \times d)/2\}] + \ldots\ldots + \{(O_{n-1} + O_n) \times d\} / 2.$

$= d/2(O_1 + O_2 + O_2 + O_3 + O_3 + O_4 + O_4 + O_5 + O_5 + \ldots\ldots O_n)$

$= d/2(O_1 + 2O_2 + 2O_3 + 2O_4 + 2O_5 + \ldots\ldots + O_n)$

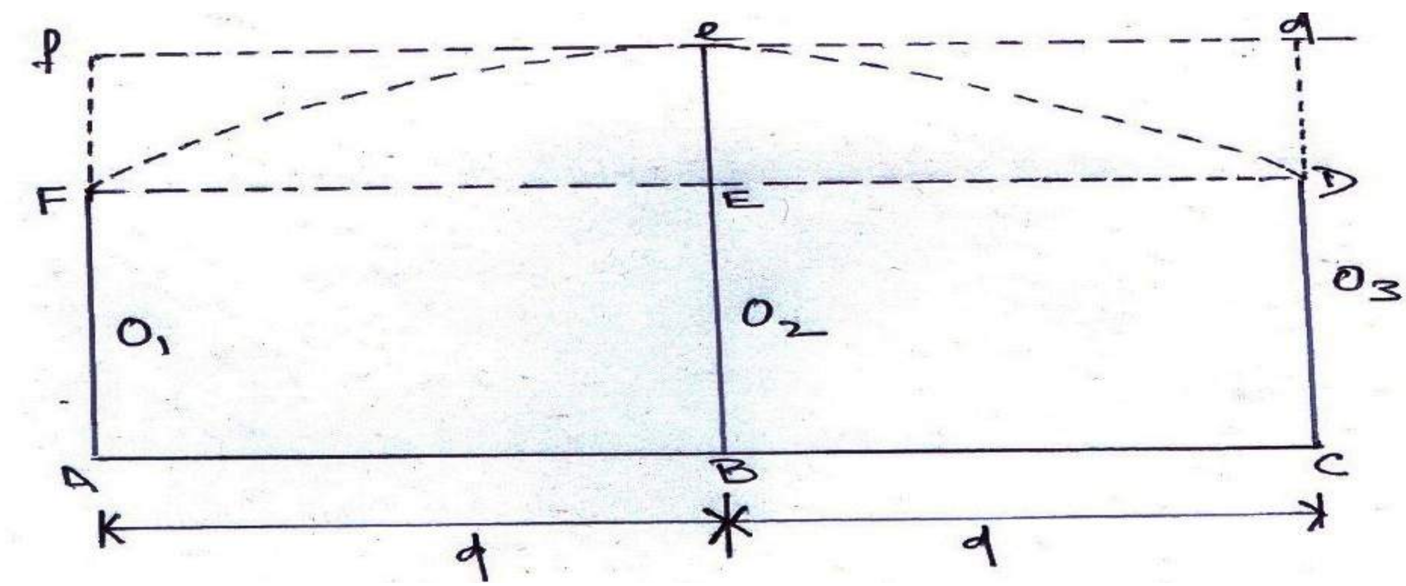
$= \frac{\text{common distance}}{2} \{(1^{st}\text{ ordinate} + \text{last ordinate}) + 2(\text{sum of the other ordinates})$

Therefore the ***Trapezoidal rule*** states that the sum of the first and last ordinate, twice the sum of the intermediate ordinates is added. This total sum is multiplied by the common distance . Half of this product is the required area.

Limitation:- There is no limitation. This rule can be applied for any number of ordinates

Simpson's rule:-

In this rule the boundaries between the ends of the ordinates are assumed to form an arc of parabola. Hence Simpson's rule is also known as parabolic rule . This rule is also known as Prismodial rule.



Let O_1, O_2, O_3 = three consecutive ordinates

d= Common distance between ordinates

Therefore the required area AFeDC = Area of the trapezium AFDC + Area of the segment FeDEF

Area of the trapezium AFDC = $\frac{O_1 + O_3}{2} \times 2d$

Area of the segment FeDEF = $\frac{2}{3}$ x area of the parallelogram

$2/3(Ee \times 2d) = 2/3 \times \{O_2 - (\frac{O_1 + O_3}{2})\} \times 2d$

So, the area between the first two division is

$$A_1 = [(\frac{O_1 + O_3}{2}) \times 2d] + [2/3 \times \{O_2 - (\frac{O_1 + O_3}{2})\} \times 2d]$$

$= d/3 (O_1 + 4 O_2 + O_3)$.

Similarily, the area between two next division is calculated……..

$A_2 = d/3 (O_3 + 4 O_4 + O_5)$.

$A_3 = d/3 (O_5 + 4 O_6 + O_7)$ and so on

Required area = $A_1 + A_2 + A_3$………………………………………….. + A_n

= $\{ d/3 (O_1 + 4 O_2 + O_3)\} + \{ d/3 (O_3 + 4 O_4 + O_5)\} + \{d/3 (O_5 + 4 O_6 + O_7)\}$ +……… +$\{d/3(O_{n-2} + 4 O_{n-1} + O_n)\}$

= $d/3[\{O_1 + O_n\} + 4(O_2 + O_4 + O_6 \ldots + 4 O_{n-1}) + 2(O_3 + O_5 + O_7 + \ldots + O_{n-2})]$

= <u>common distance</u> X {(1st ordinate + last ordinate)+ 4X(sum of the even ordinates) +2X(sum of the odd ordinates)
3

Therefore ***Simpson's Rule*** states that the sum of the first and last ordinate, four times the sum of the remaining even ordinates and twice the sum of the remaining odd ordinates are added. This total sum is multiplied by the common distance. One third of this product gives the required area.

Limitation:- This rule is only applicable when the number of divisions is even and ordinates are odd.

Difference between the Trapezoidal rule and Simpson's rule

Sl.no	**Trapezoidal rule**	**Simpson's rule**
1.	The boundary between the ordinates is considered to be straight	The boundary between the ordinates is considered to be arc of a parabola
2.	There is no limitation. It can be applied for any number of ordinates	This rule is only applicable when the number of divisions is even and ordinates are odd.
3.	It gives an approximate result.	It gives an accurate result.

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