# LEVELLING


**Unit-III**

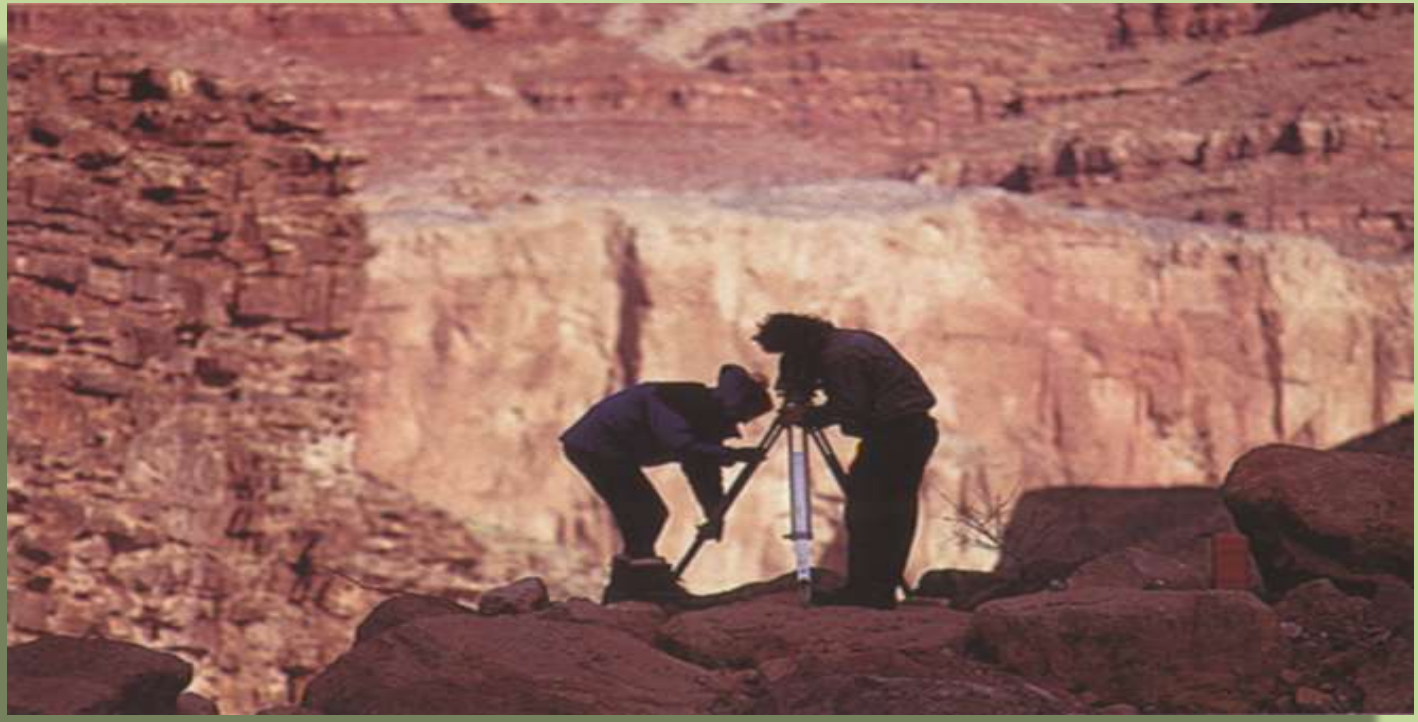
# Syllabus

**Levelling**

- Definitions, technical terms, uses, details of levels such as dumpy, tilting and auto levelling staff, Temporary and permanent adjustments of dumpy and auto level, corrections curvature, refraction, combine and sensitiveness, reciprocal levelling, collimation and rise & fall method, errors, precautions.

# 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 f**

# Object of levelling

**The objective of Levelling**

- To Find the **elevation** of given point with respect to some assumed reference line called datum.
- To **establish point at required elevation** respect to datum.

# Terms 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.

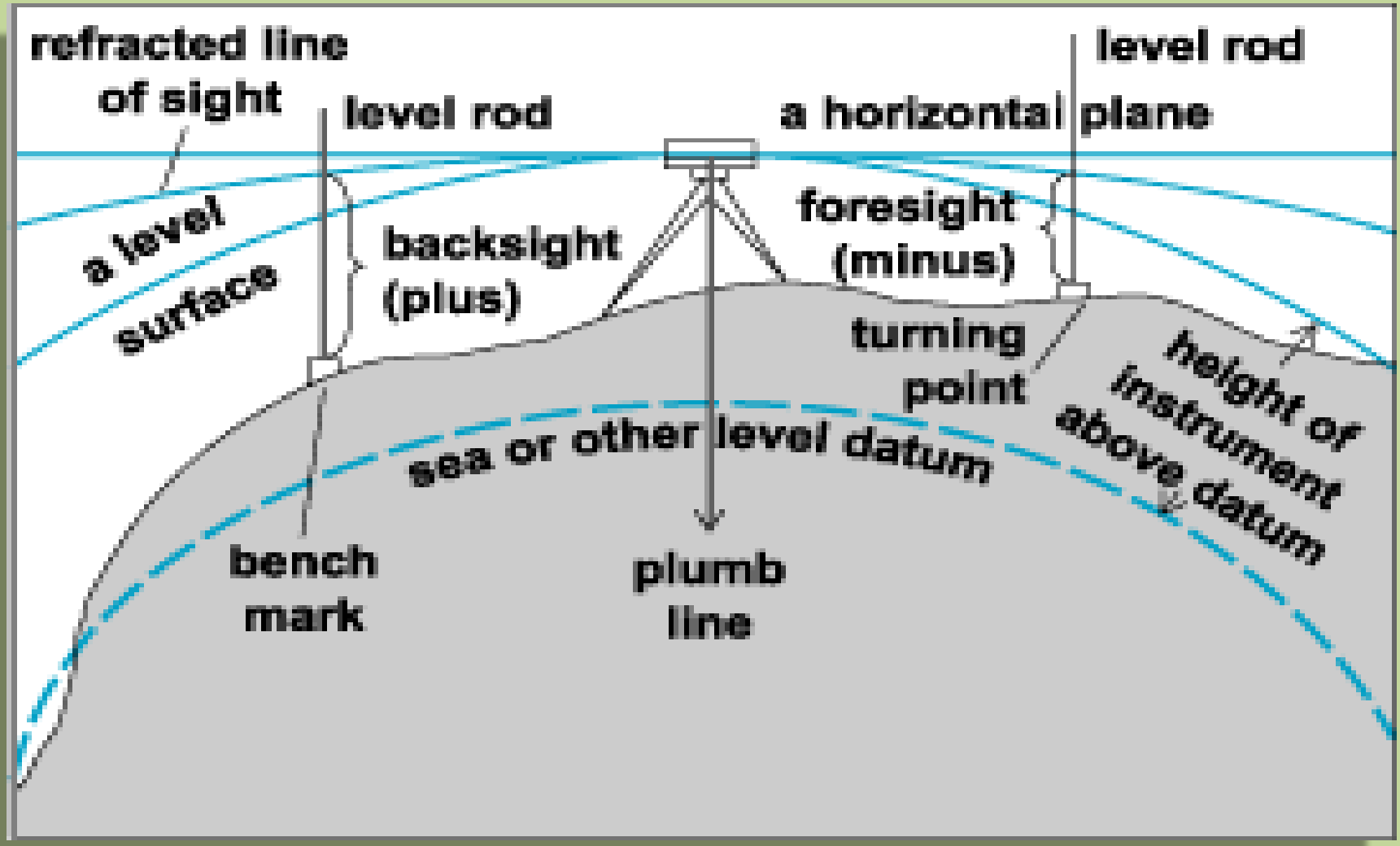
**Horizontal plane**

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

**Horizontal line**

- It is a straight line tangential to level line.

# Levelling


refracted line
of sight
level rod
a horizontal plane
level rod
a level
surface
backsight
(plus)
foresight
(minus)
turning
point
height of
instrument
above datum
sea or other level datum
bench
mark
plumb
line

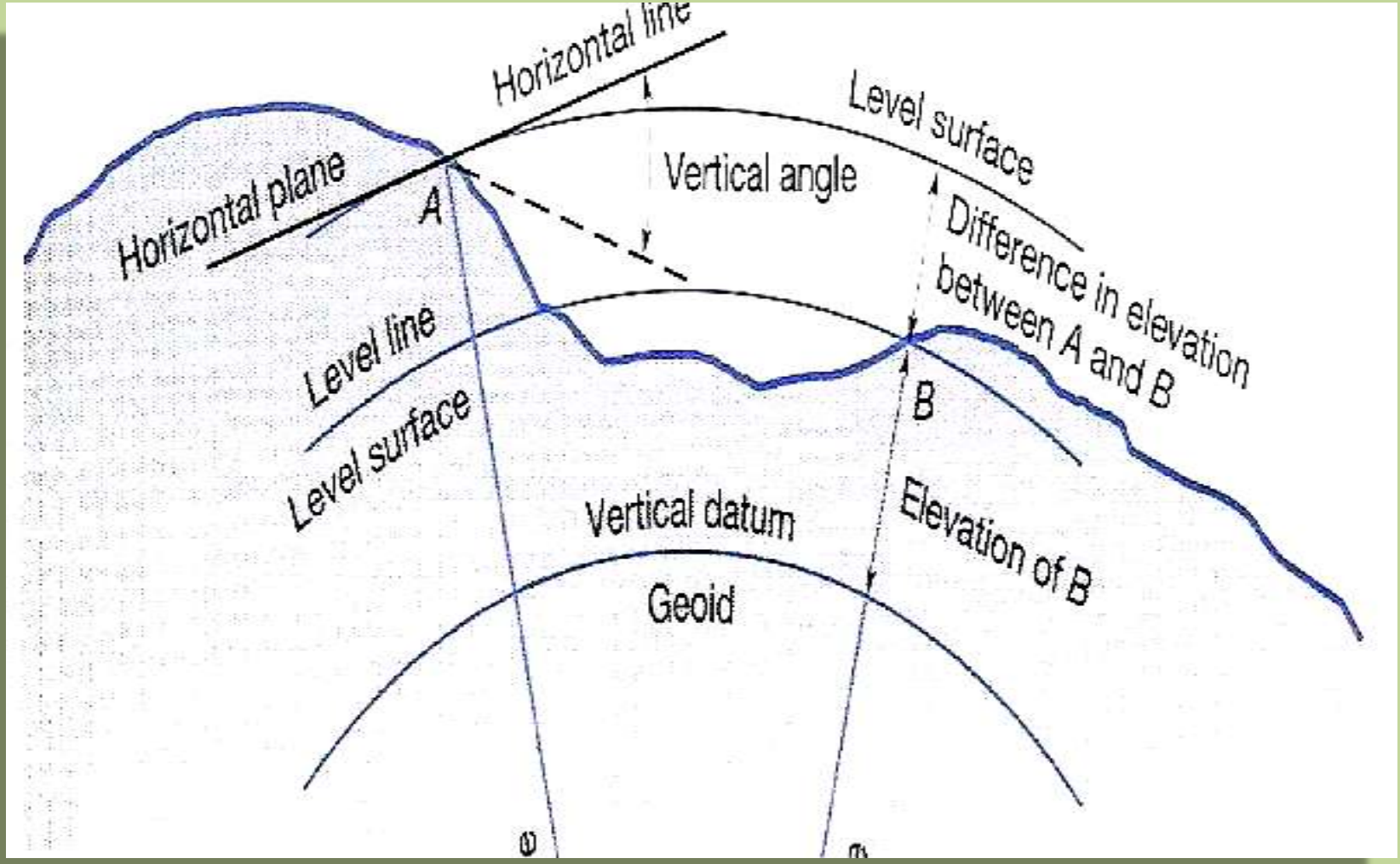
# Terms used in levelling

**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 Karachi.

**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.

# Terms used in levelling



# Terms used in Levelling

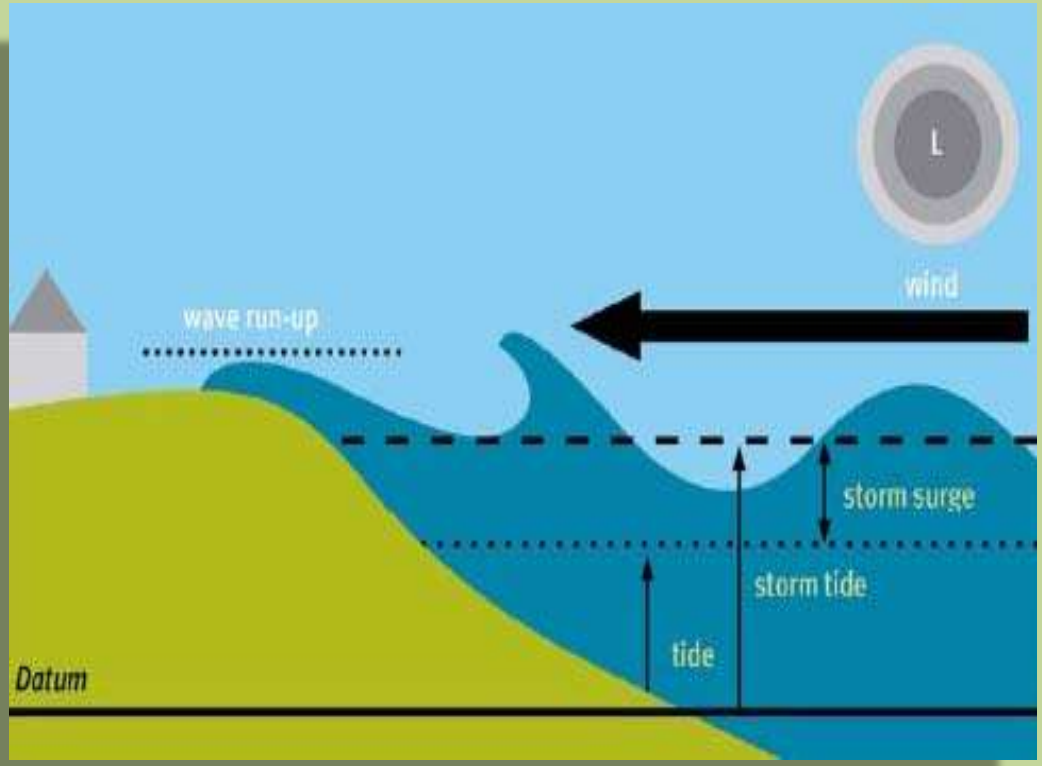
**Bench Mark (B.M.)** It is a fixed reference point of known elevation with respect to datum.

**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.

# Mean Sea Level



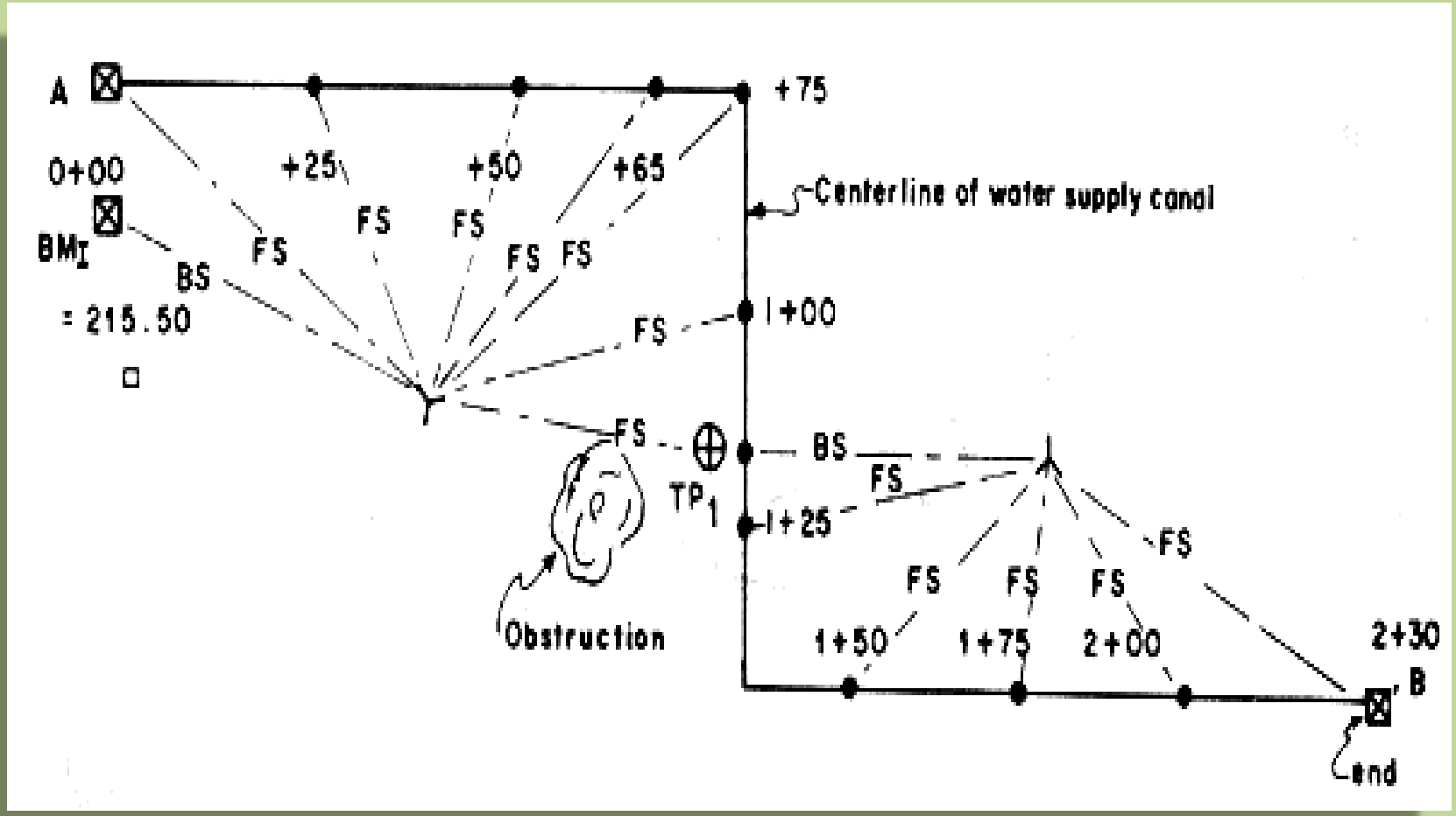
# Terms used in Levelling

**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.

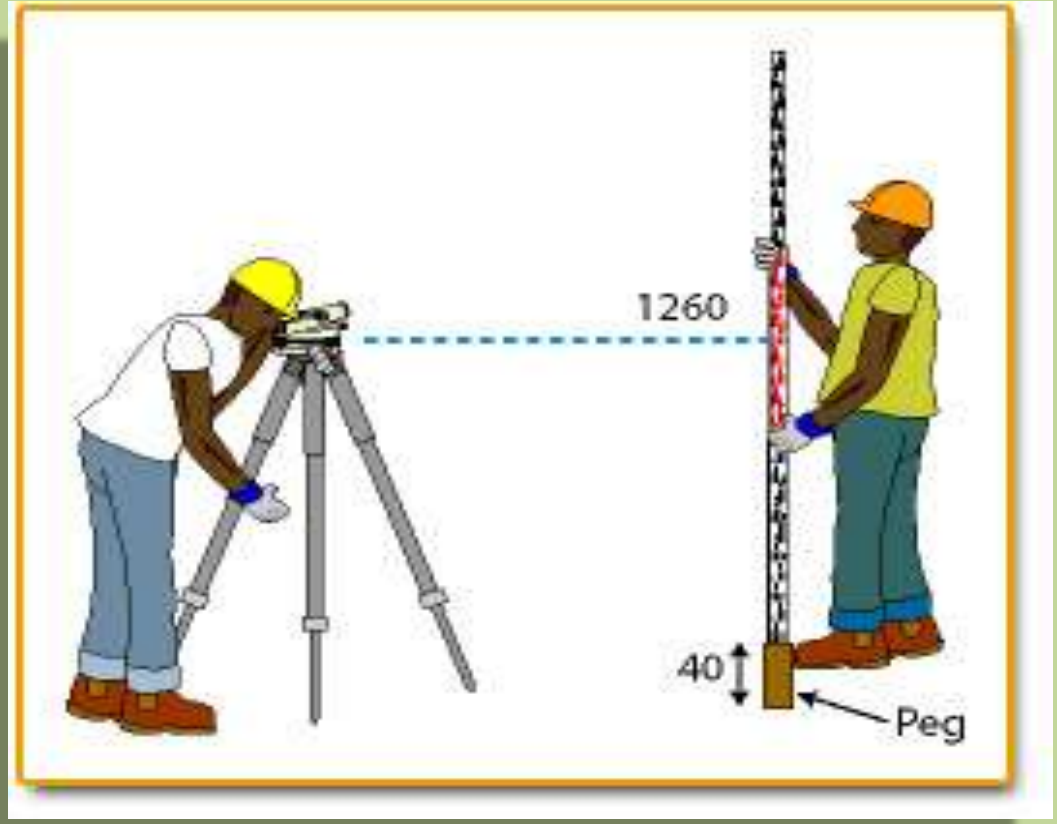
**Change Point (T.P)** It is a point on which both fore and back sight are taken.

# Terms used in Levelling



# Instruments for levelling

- The following instruments are essentially required for levelling
- Level
- Levelling Staff



# Instruments for levelling

- **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 of Level

- Dumpy level
- Tilting level
- Wye level
- 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.

# Dumpy level

# Dumpy level

# Tilting Level

- It is also known as I.O.P. level **(Indian office Pattern).**In this level the telescope tilts about its horizontal axis hence it is called tilting level

# 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.

# Wye level

# Automatic level

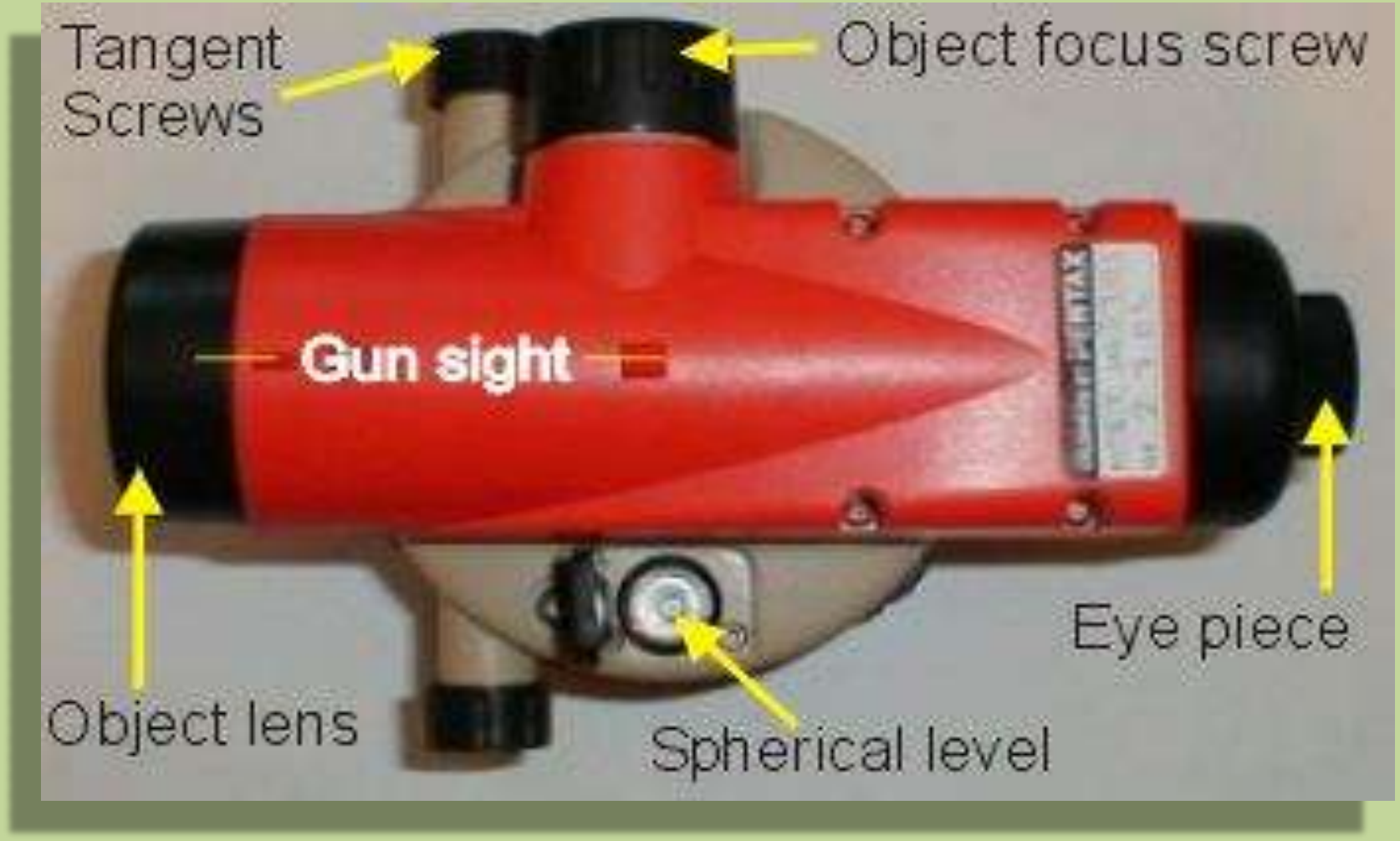
- It is also known as self aligning level. It is a recent development. The fundamental difference between auto level and other levels is that the levelling is not manually but it is levelled automatically. It is achieved by **inclination compensating device.**

# Automatic level

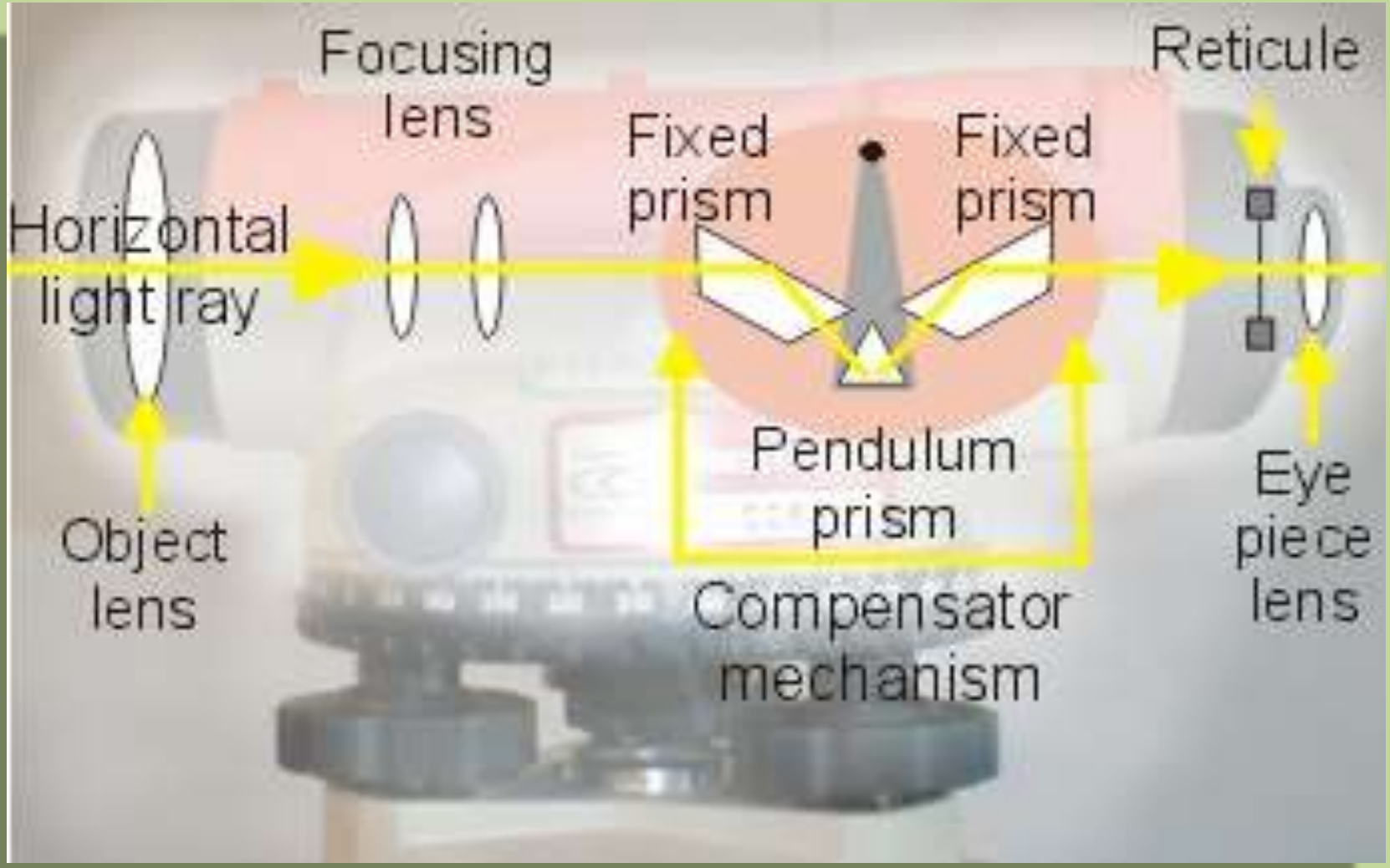
# Automatic level

# Automatic level

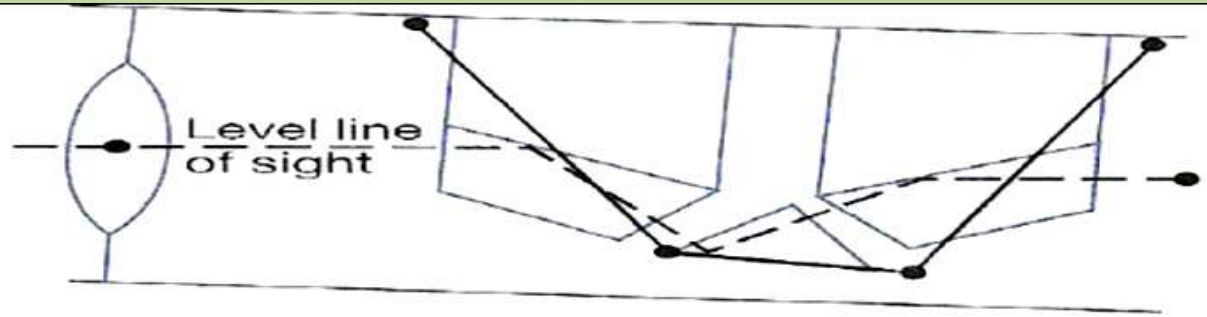

# Automatic level



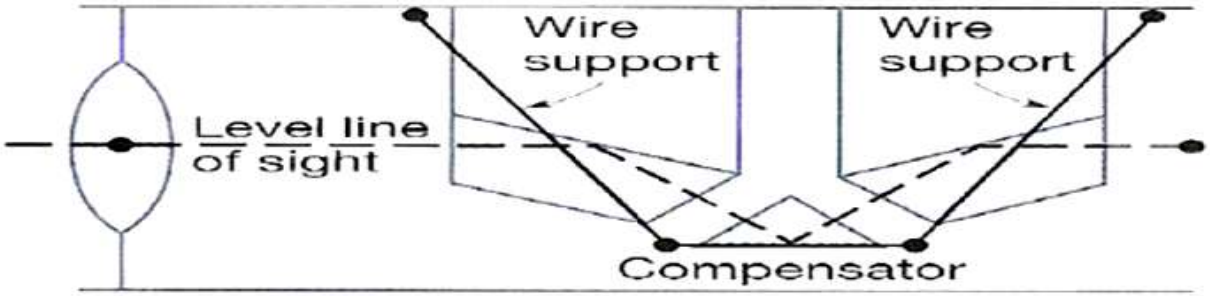
# Automatic level



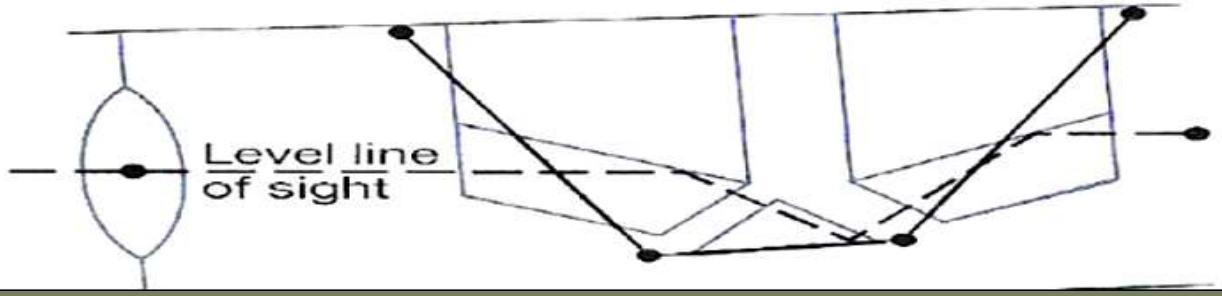
# Tilt Compensating Device



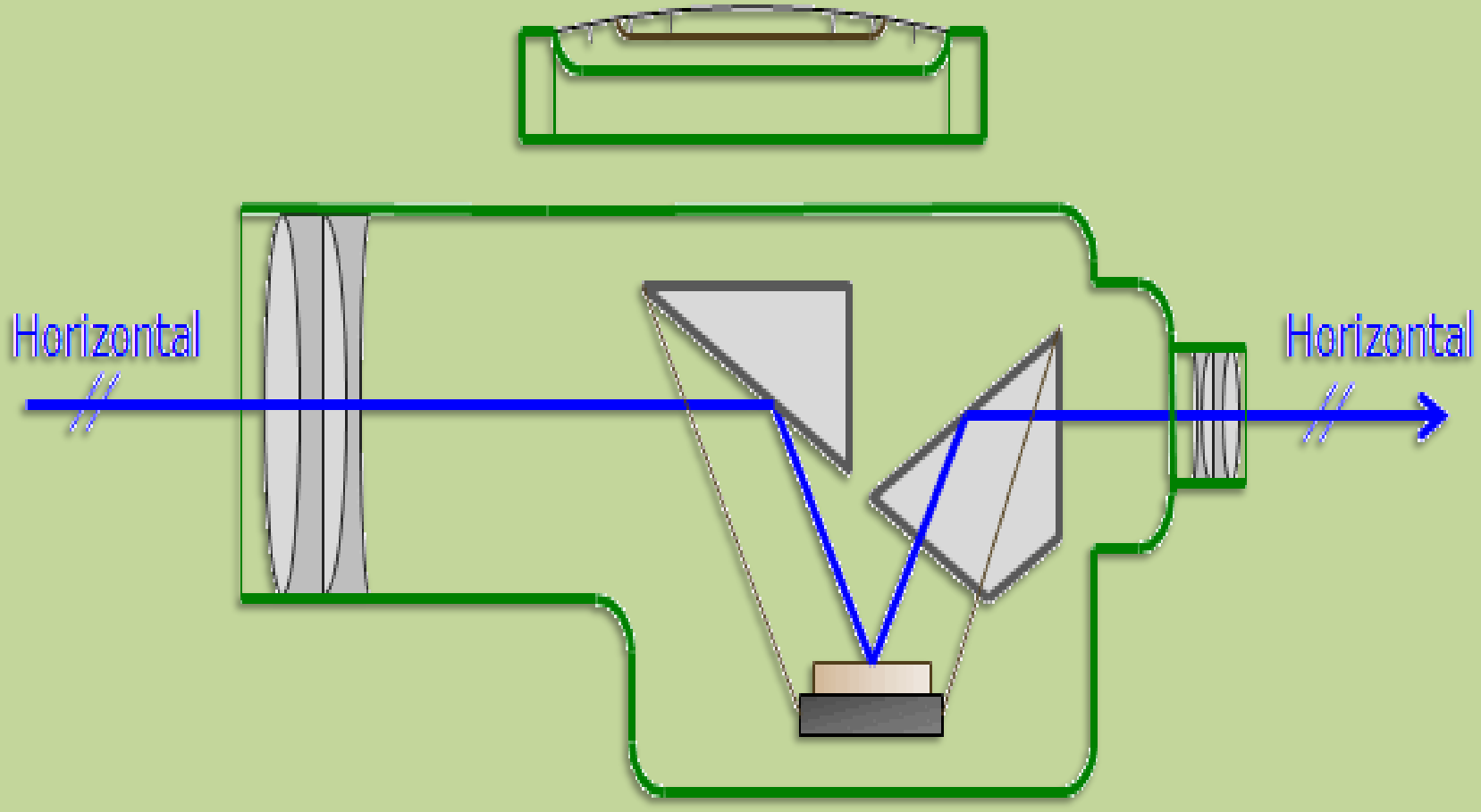

When telescope tilts up, compensator swings backward.




Telescope horizontal



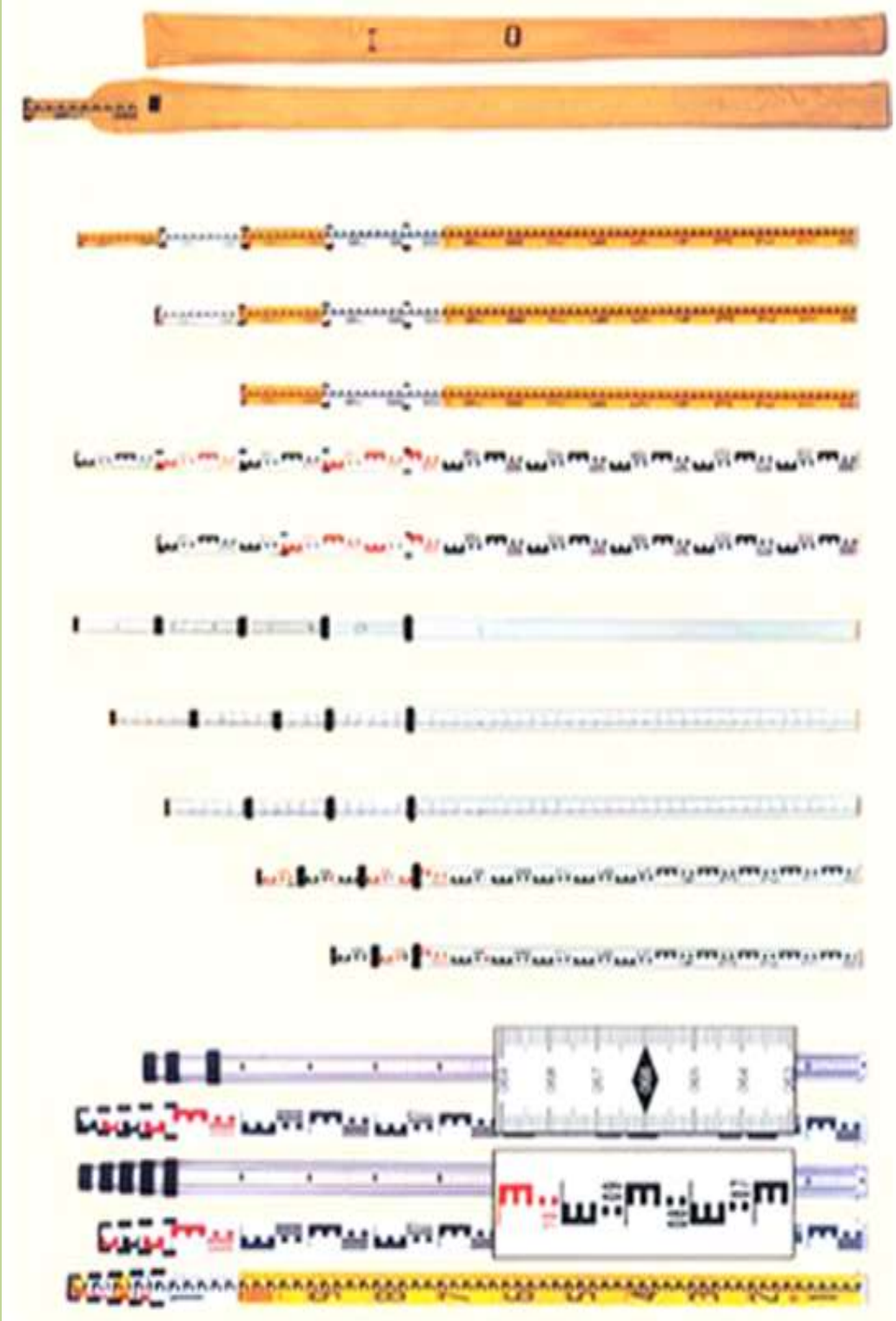
# Tilt Compensating Device



# Levelling Staffs

- Levelling staffs are scales on which these distances are measured.
- Levelling staffs are of two types
- Self Reading staff
- Target staff

# Levelling Staffs

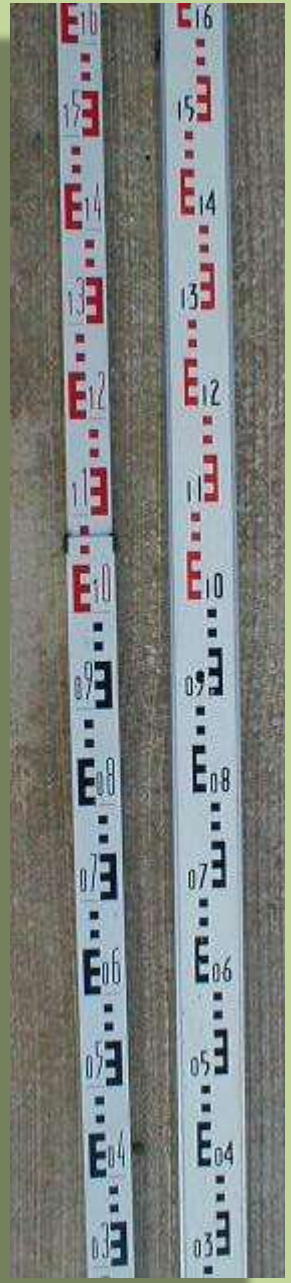


# Self Reading Staff

- The self reading staff can be read directly by the level man looking through the telescope.
- Common types of self reading staffs
- Ordinary staff
- Sop-with telescopic staff
- Folding Staff

# Ordinary Staff

- The one length staff, is solid and made of seasoned wood, it is 3 m long and graduated in the same way as the telescopic staff



# Folding Staff

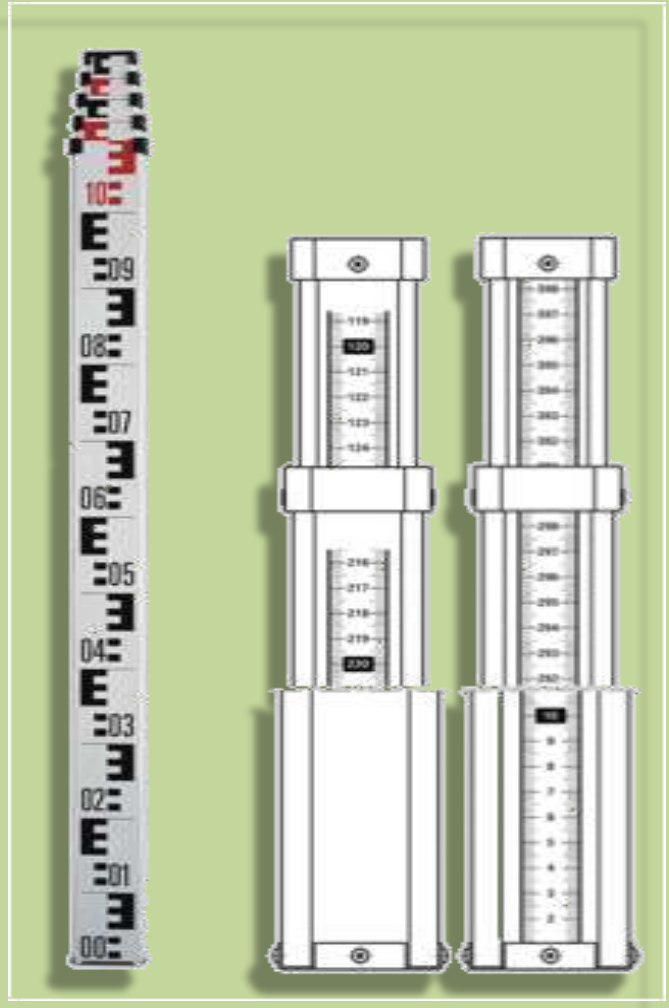
- The folding staff is made up of well seasoned timber such as Cyprus. It consists of two 2 m **wooden pieces with a joint assembly**. Each piece of the staff is made of one longitudinal strip without any joint. **The folding joint is of the detachable type with a locking device** at the back. The staff is joined together in such a way that the staff may be folded from one another when required.
- The staff has **brass cap at the bottom**. It has two folding handles, with spring action. It is provided with a circular bubble fitted at the back.

# Folding Staff


# Sop-with Telescopic Staff

- Such a staff is arranged in **three lengths placed one into the other.** It can be extended to its **full length by pulling**. The **top portion is solid** and the **central box is hollow** the total length of staff is 4 m.
- The staff is graduated in such a way that **smallest division is of 5 mm**. the value in m are marked in **red on the left and those in decimetre are in black on the right**.

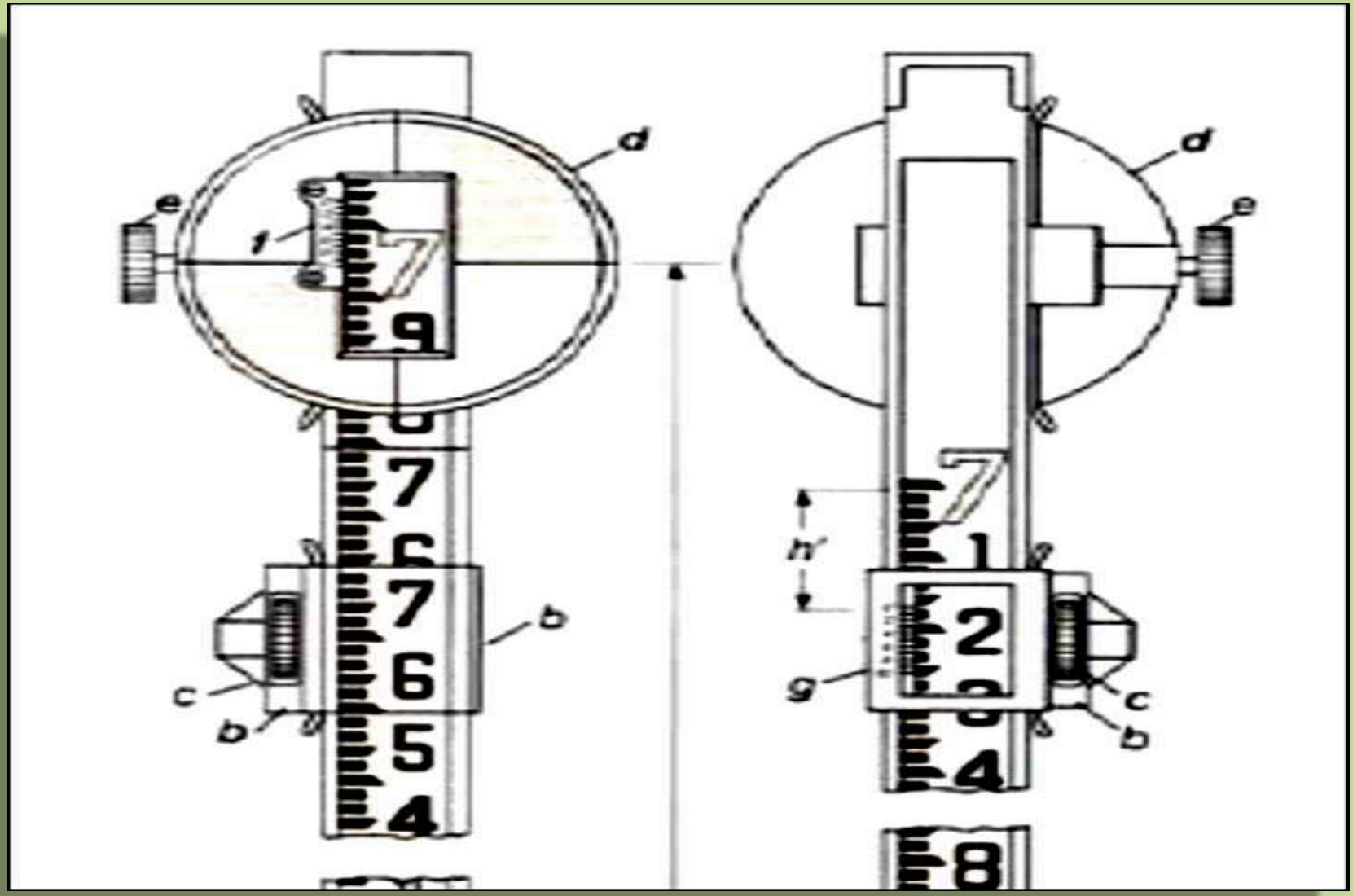
# Self Reading Staff



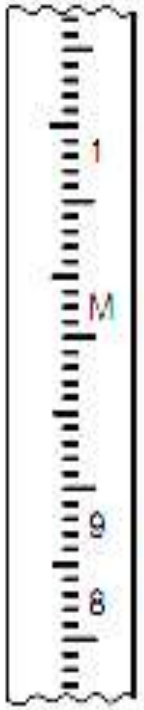
# Target Staff

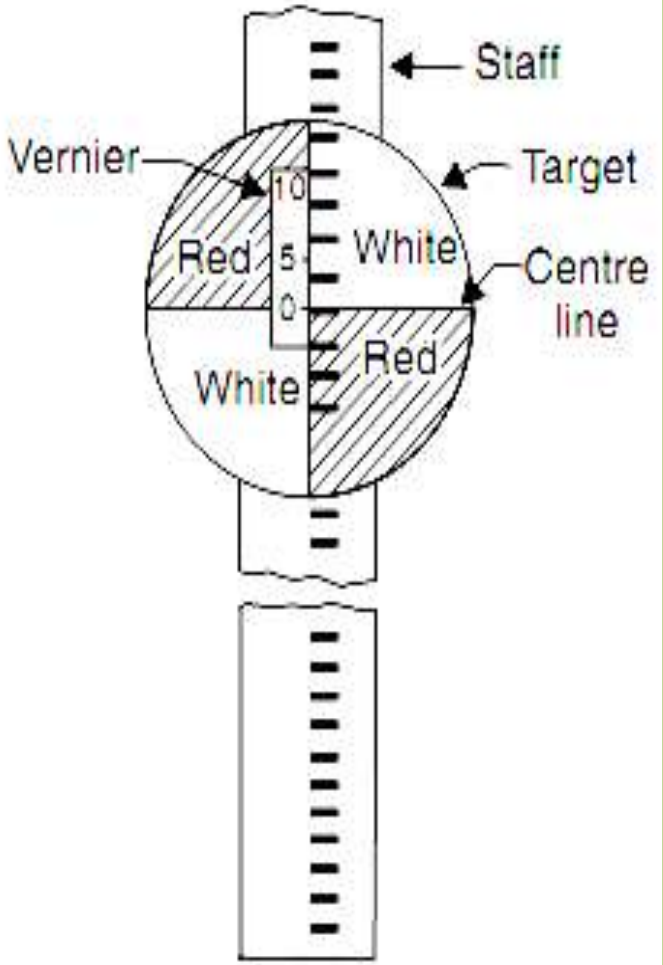
- For **very precise works and sight target staff** are used. A movable target is provided in this staff.
- A vernier is provided on target to give precise reading. **In target staff level man directs the staff man to move the target up and down until it bisects by the line of sight**. The staff man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

# Target Staff



# Target Staff



# Bench Marks

Bench mark is a point of known elevation

There are 4 kinds of bench marks

- GTS (Great trigonometrically survey bench mark)
- Permanent bench mark
- Arbitrary bench mark
- 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 which was earlier located at **Karachi** and now it is taken at **Bombay High, Mumbai** and is given in catalogue formed by the department.

# GTS Bench Mark


# Permanent Bench Mark

- Permanent bench marks are fixed in between GTS benchmarks 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.

# Permanent Bench Mark



# Permanent Bench Mark

# Bench Marks

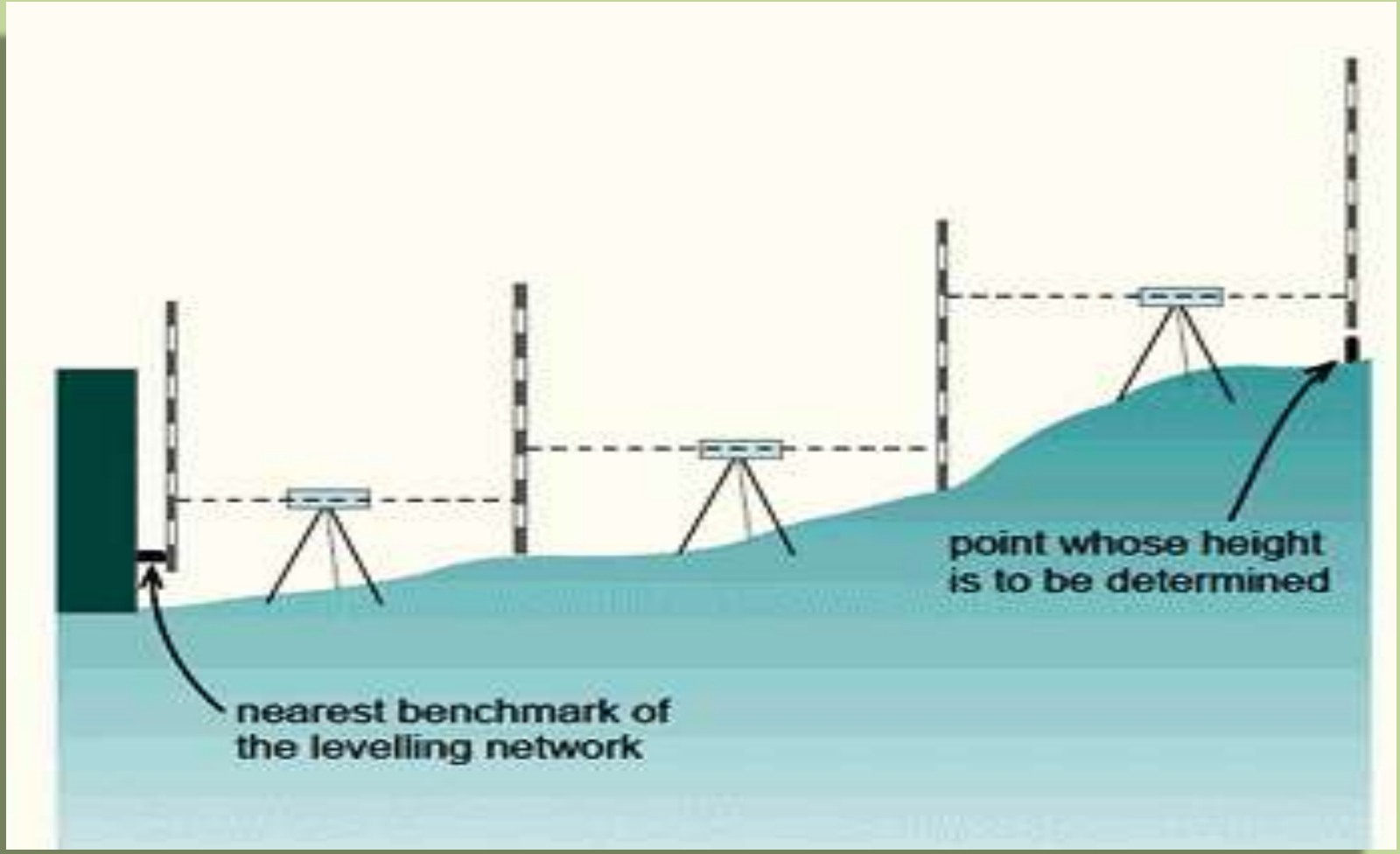
**Arbitrary Bench Marks**

- 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

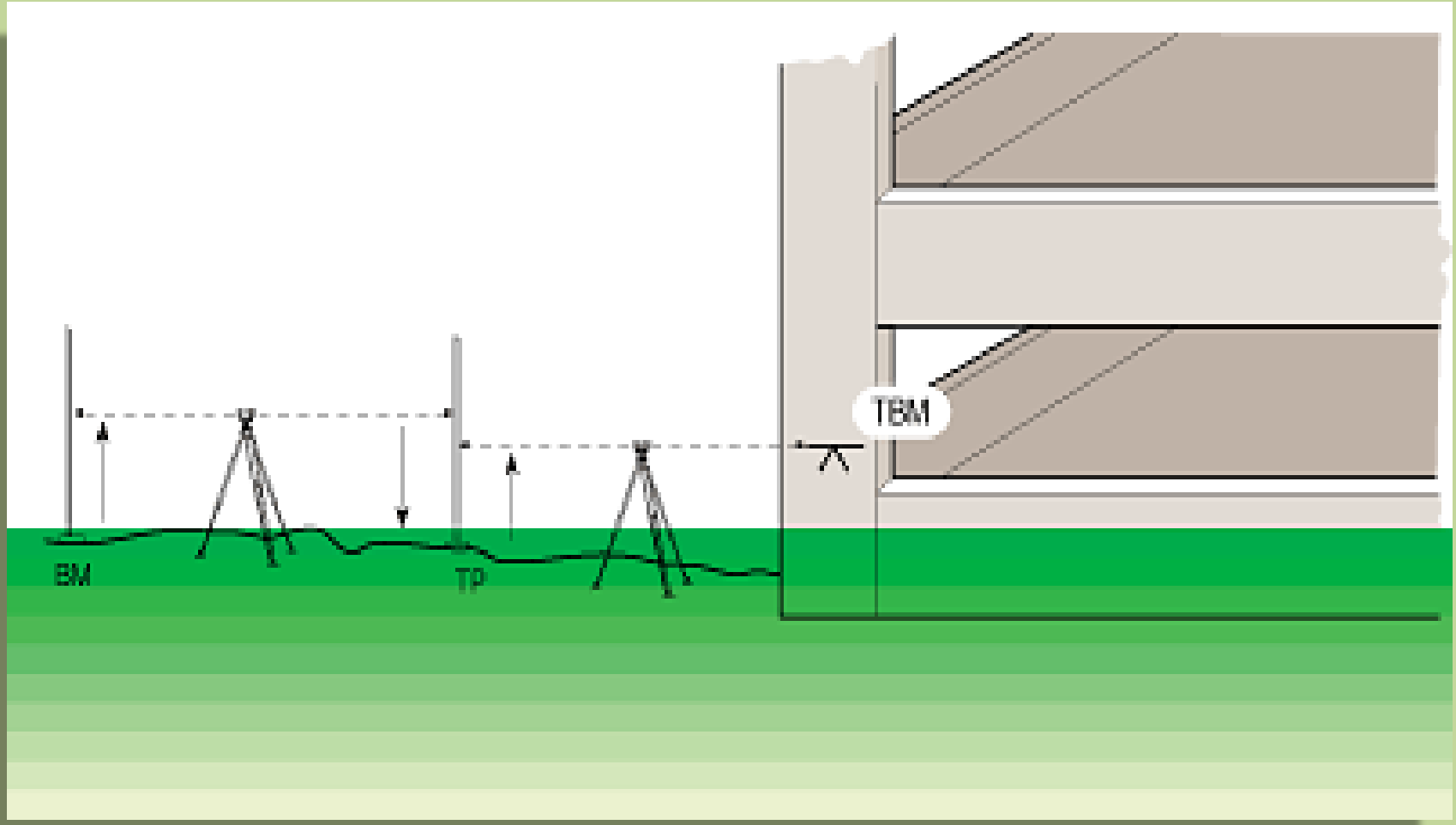
**Temporary Bench Marks**

- 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.

# Arbitrary Bench Marks



# Temporary Bench Marks



# Temporary Adjustments of a level

- These adjustments are performed at every setup of instrument
- Setting up of level
- Levelling of telescope
- Focusing of the eye peace
- Focusing of object glass

# Temporary Adjustments of a level

**Setting up the level**

This includes

- A) Fixing the instrument on tripod
- B) Levelling the instrument approximately by Tripod

# Setting up the level

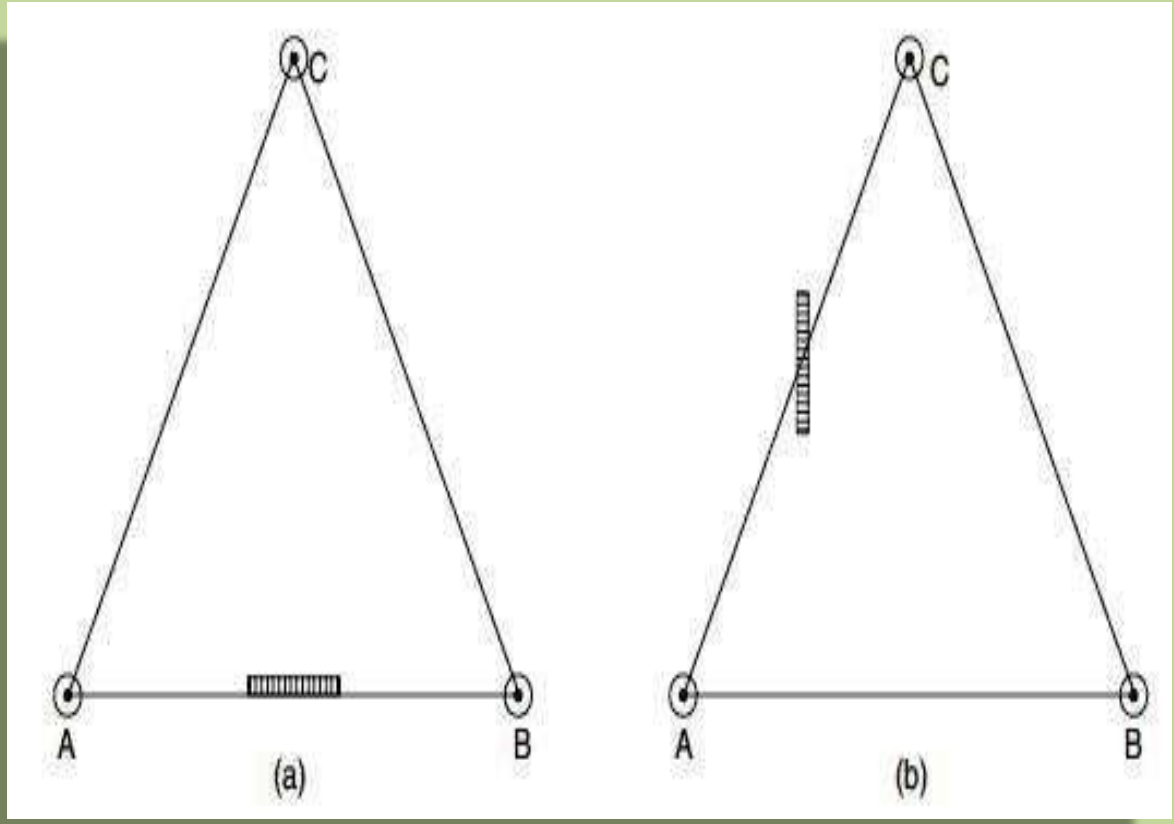
# Temporary Adjustments of a level

**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.

# Temporary Adjustments of a level




# Temporary Adjustments of a level

**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.

# Temporary Adjustments of a level

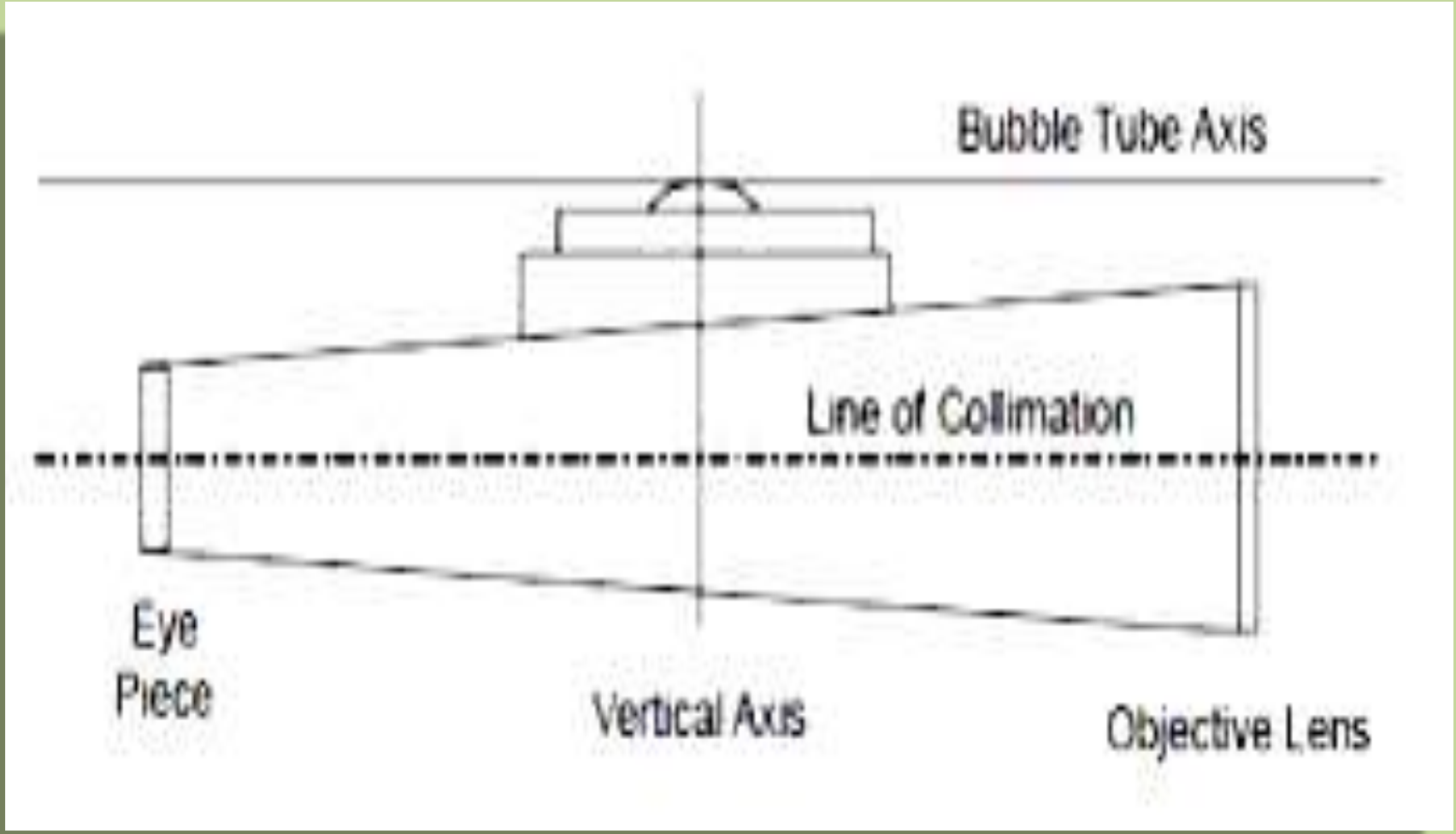
# Permanent adjustment of level

- The establishment of a desired relationship between the fundamental lines of a leveling instrument is termed permanent adjustment. So, permanent adjustment indicates the rectification of instrumental error.
- ***The fundamental lines***
- ***The line of collimation***
- ***The axis of the bubble tube***
- ***The vertical axis***
- ***The axis of the telescope***

# Permanent adjustment of level

- The following relationship between the lines are desirable
- ***The line of collimation should be parallel to the axis of the bubble***
- ***The line of collimation should coincide with the axis of the telescope***
- ***The axis of the bubble should be perpendicular to the vertical axis. That is, the bubble should remain in the central position for all the directions of the telescope.***

# Permanent adjustment of level



# Permanent adjustment of level

- Two adjustment are required in the dumpy level
- **The first adjustment, to make the axis of the bubble tube perpendicular to the vertical axis**
- **The second adjustment, to make the line of collimation parallel to the axis of the bubble tube.**

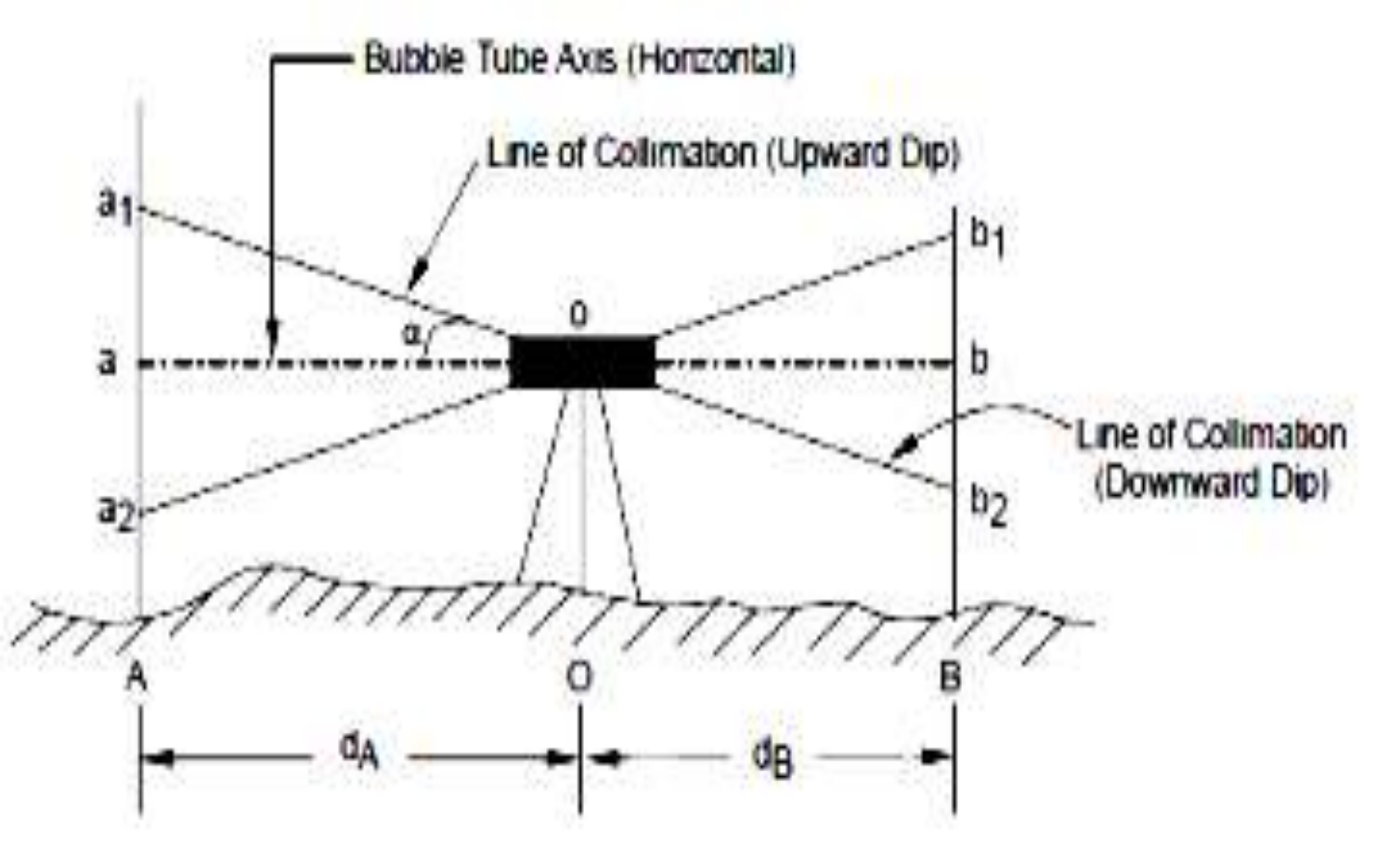
# Permanent adjustment of level

- Following procedure is adopted to make the line of collimation parallel to the axis of the bubble tube.
- The level is set up on fairly level ground, with its legs well apart, It is **firmly fixed to the ground**.
- The telescope is placed parallel to any pair of foot screws and, by turning the foot screw either inward or outward, the **bubble is brought to the centre.**
- The **telescope is then turned through 90** $^{0}$, so that it lies over the **third foot screw**. Then by turning the third foot screw the bubble is brought to the centre.
- The process is repeated several times until the bubble is in the central position in both the direction.

# Permanent adjustment of level

- Now the **telescope is turned through 180** $^{0}$ and the position of the bubble is noted.
- **If the bubble still remains in the central position, the desired relationship is perfect**. If not, the amount of deviation of the bubble is noted.
- Suppose the deviation is 2n division, Now by turning **capstan headed nut (which is at one end of the tube), the bubble is brought half-way back (i.e. n division) the remaining half-deviation is adjusted by foot screws just below the telescope.**
- The procedure of adjustment is continued till the bubble remain in the central position of the telescope.

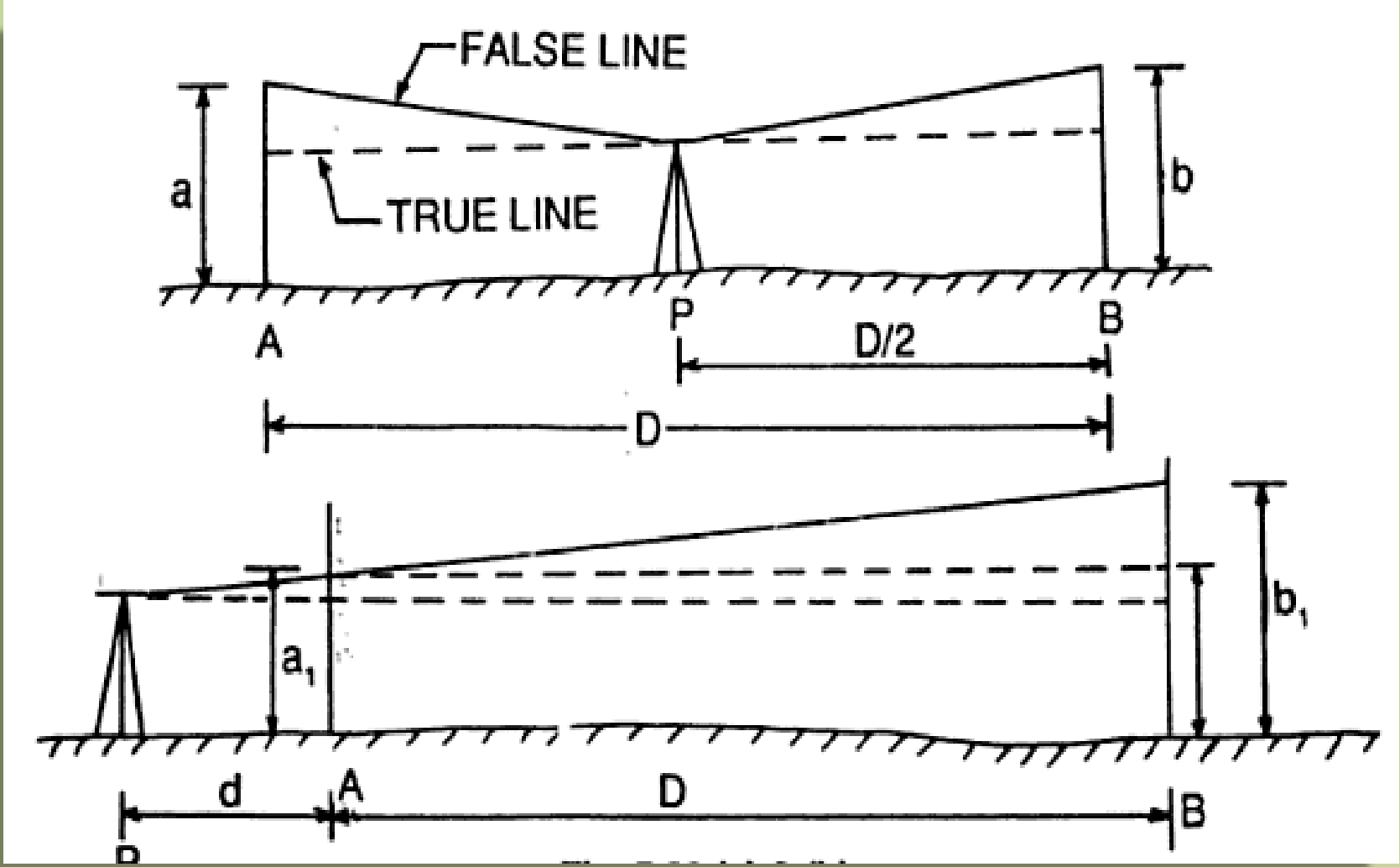
# Permanent adjustment of level



# Permanent adjustment of level

- The second adjustment is done by **two peg method**
- Two pegs A & B are driven at a distance apart on level and firm ground. The level is set up at P, just mid-way between A & B. After bringing the bubble to the centre of its run, the staff readings on A & B are taken. Suppose the reading are a & b
- Now the difference of level between A & B is calculated , this difference is true difference, as the level is set up just mid-way between BS and FS
- Then the rise or fall is determined by comparing the staff reading.

# Permanent adjustment of level



# Permanent adjustment of level

- The level is shifted and set up at $P_1$ (very near to A), say at a distance d from A. Then after proper leveling, staff reading at A & B are taken. Suppose the reading are $a_1$ and $b_1$
- Then the apparent difference of level is calculated
- If the true difference and apparent difference are equal, the line of collimation is in adjustment, if not the line of collimation is inclined.
- Let e be the staff reading on B at the same level of the staff reading $a_1$
- Then **e= $a_1$ ± true difference**

# Permanent adjustment of level

- Use positive sign in case of fall and negative sign when it is rise
- If $b_1$ is greater than e, the line of collimation is inclined upwards and if $b_1$ is less than e, it is inclined downwards.
- **Collimation error= $b_1$-e (in distance D)**
- By applying the principle of similar triangle
- Correction to near peg
- $$\underline{C_1 = d\,(b_1 - e)}$$
  $$D$$

And correction to far peg

$$C_2 = \frac{D + d\,(b_1 - e)}{D}$$

# Permanent adjustment of level

Correct staff reading on **A= $a_1 \pm C_1$**

Correct Staff reading on **B= $b_1 \pm C_2$**

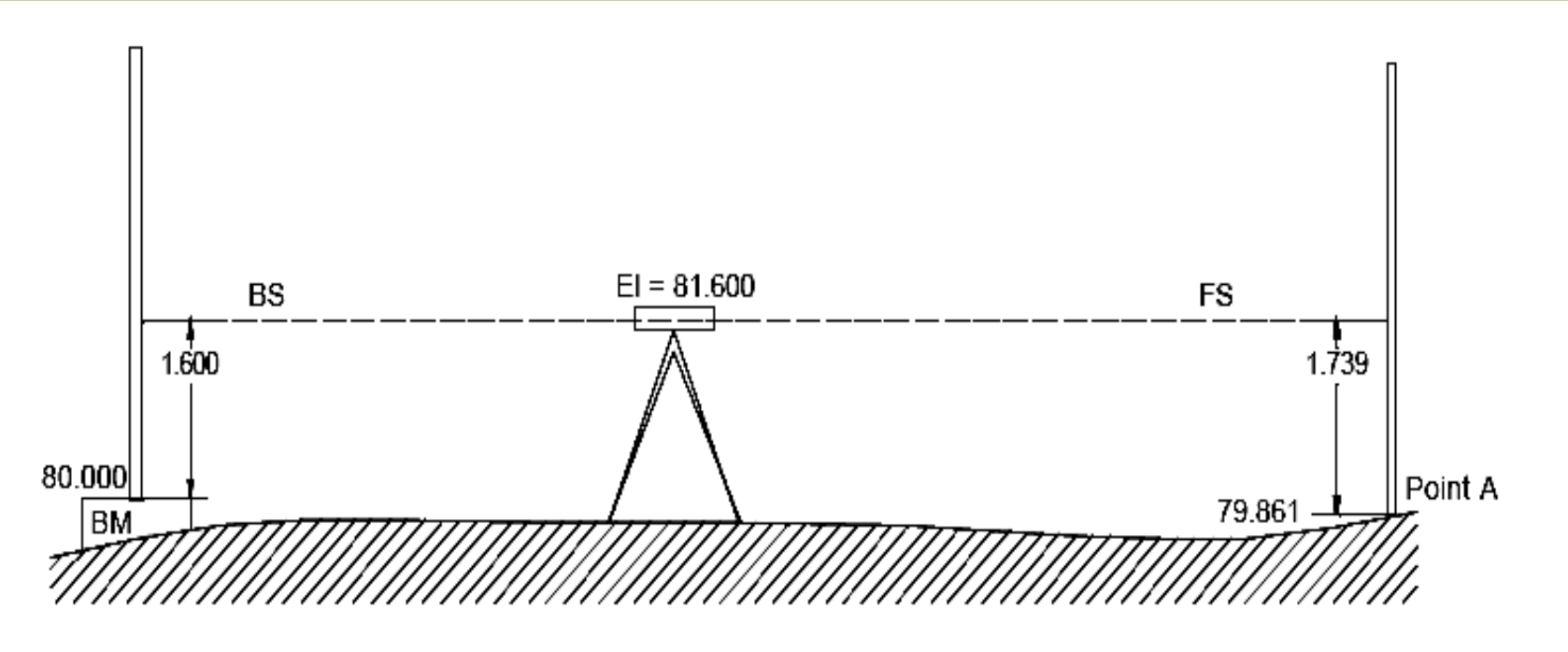
Then the cross-hair is brought to the calculated correct reading by raising or lowering the diaphagram by means of diphagram screw.

# Classification of Levelling

- Simple Levelling
- Differential Levelling
- Fly Levelling
- Check Levelling
- Profile Levelling
- Cross Levelling
- Reciprocal Levelling
- Precise Levelling
- Trigonometric Levelling
- Barometric Levelling
- Hypersometric Levelling

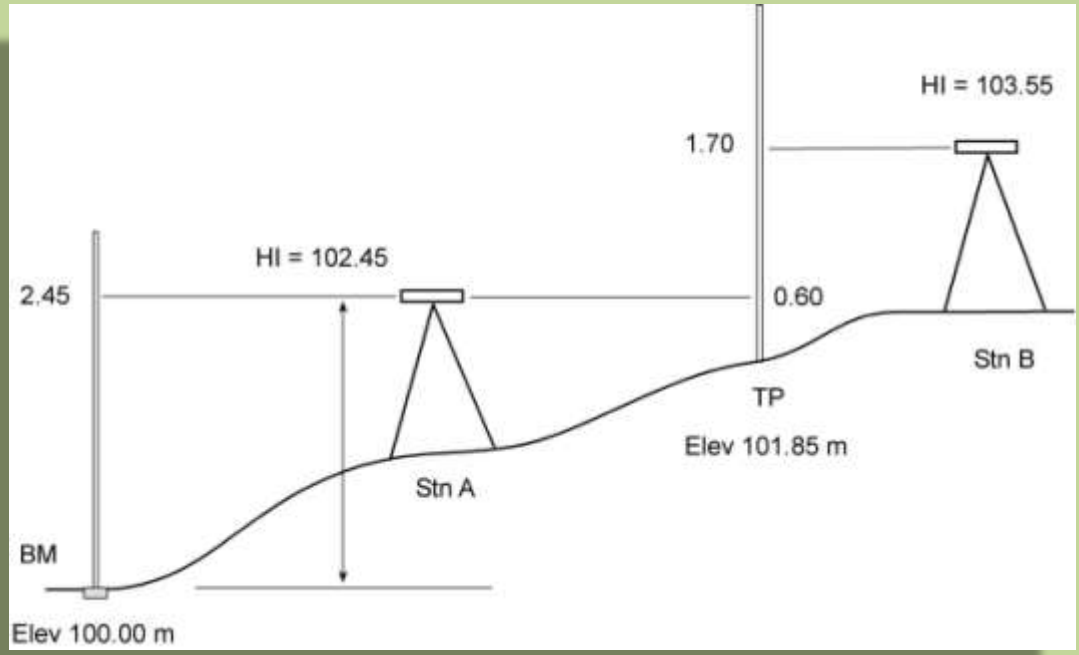
# Simple Levelling

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

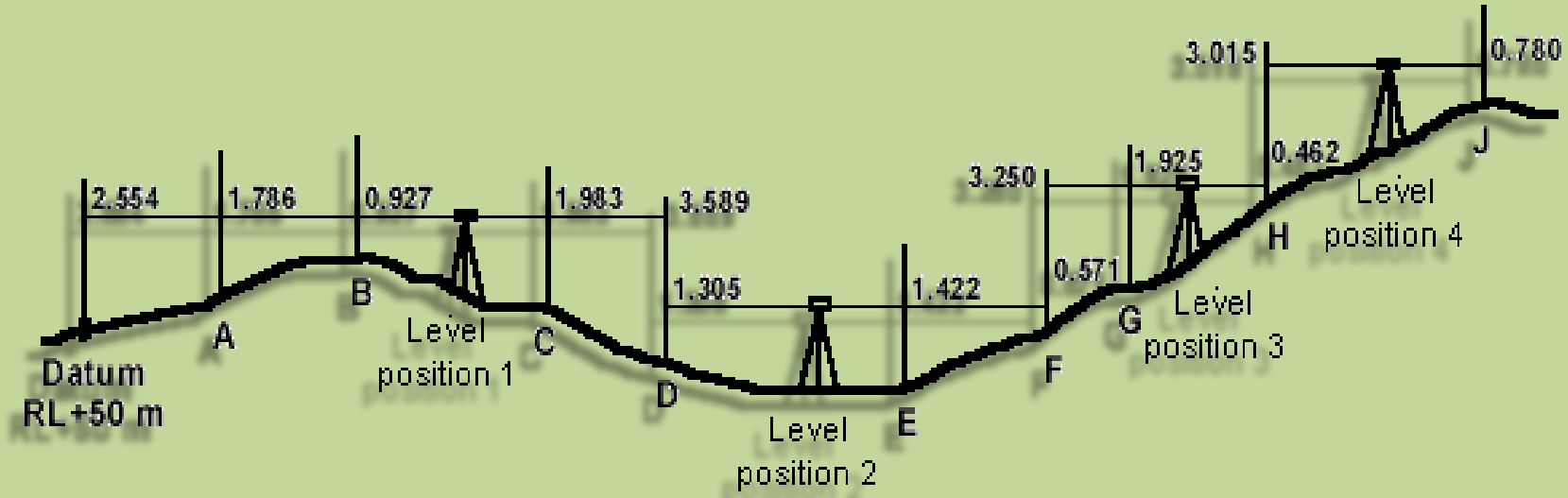


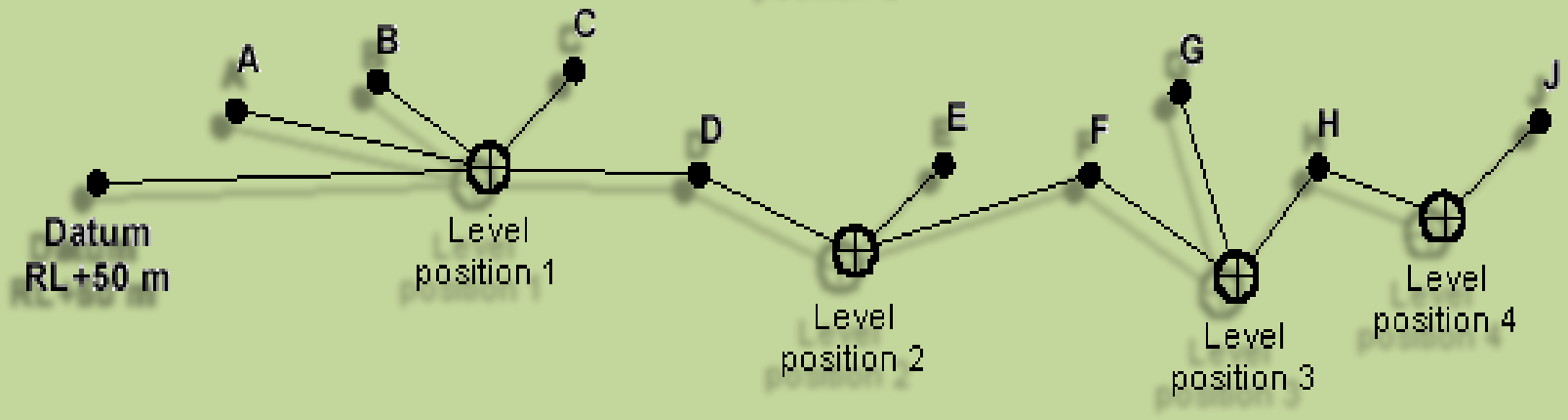
# Differential Levelling

- 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

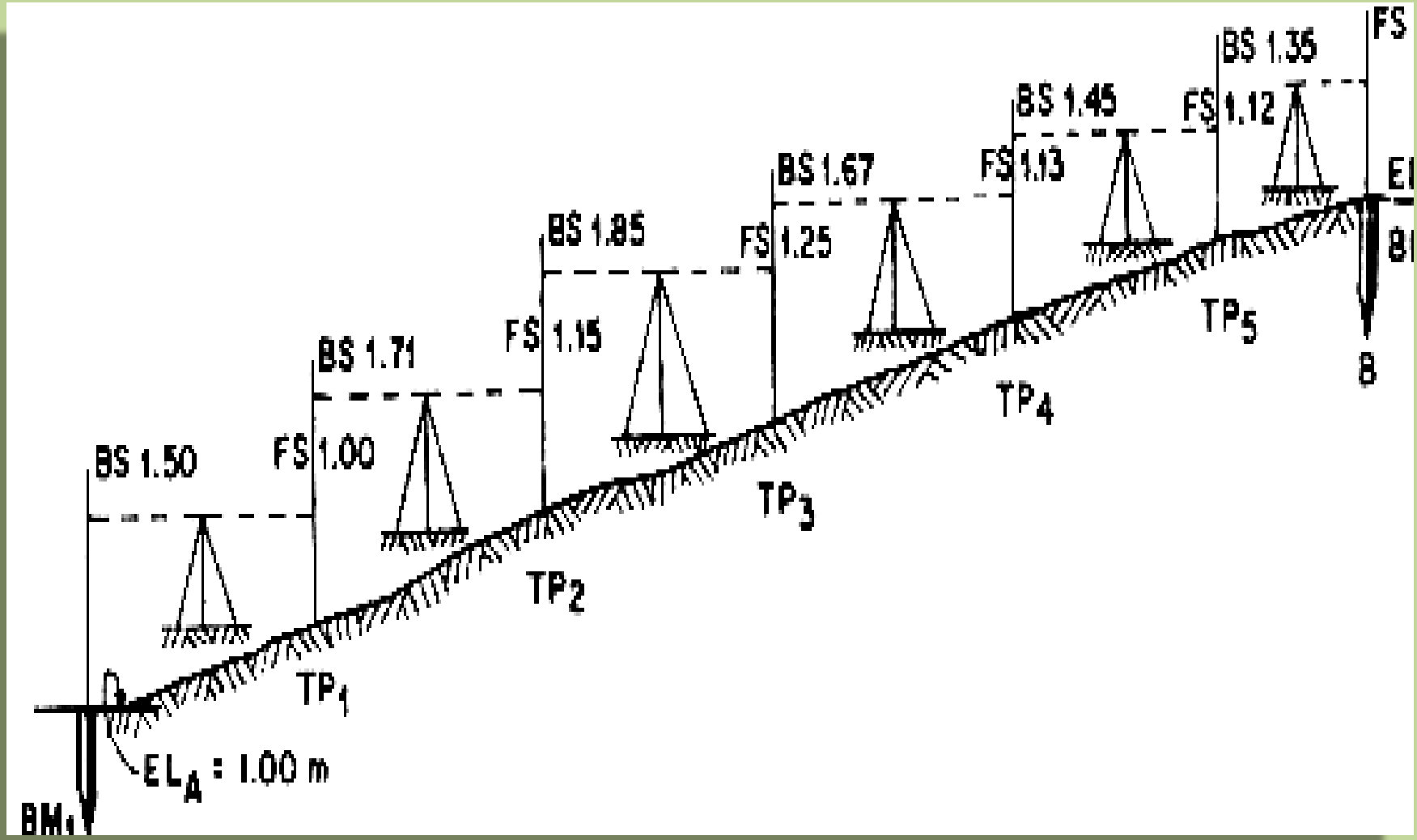


# Fly Levelling

- 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

# Fly Levelling



# Classification of Levelling

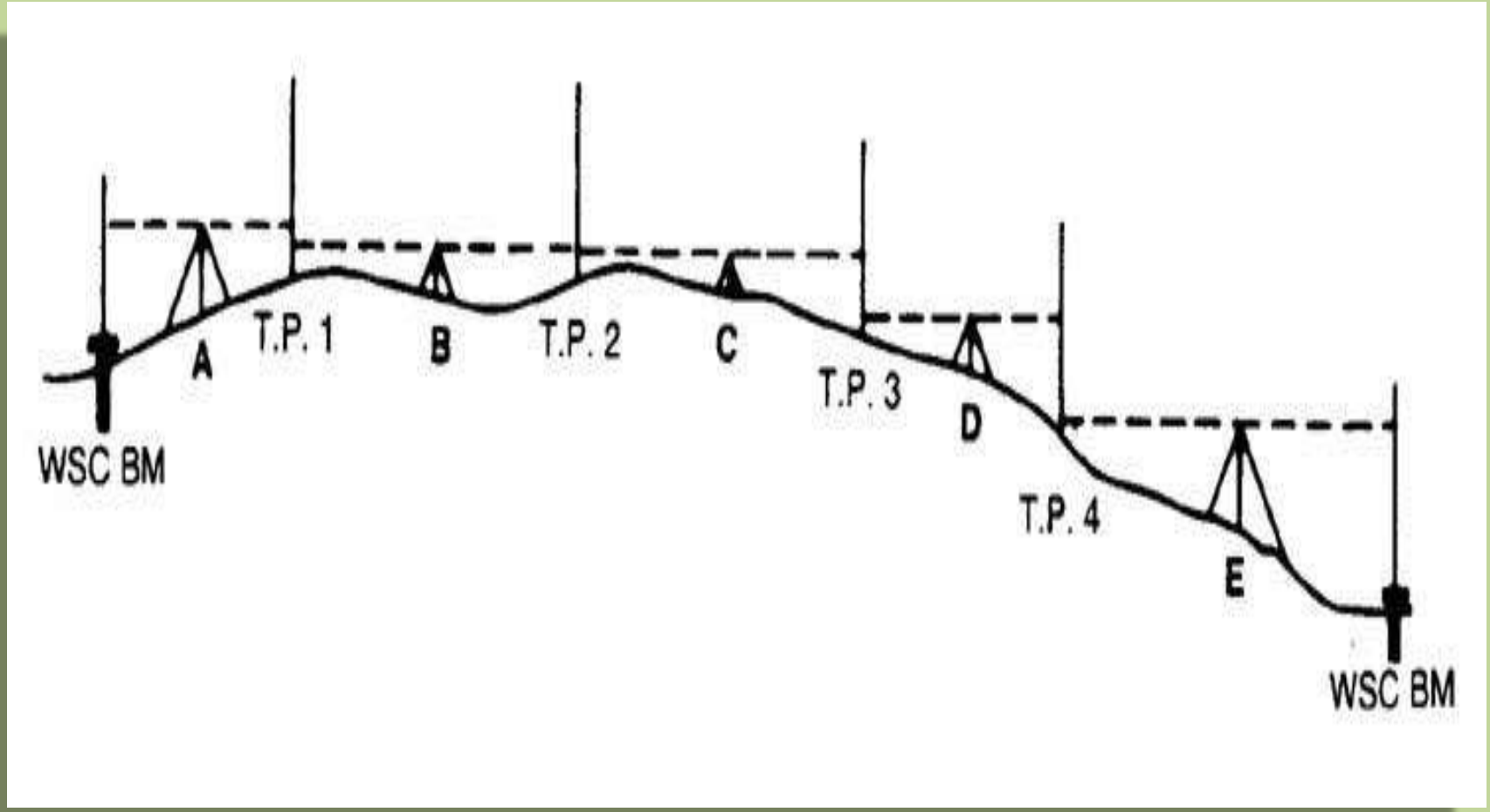
**Check levelling**

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

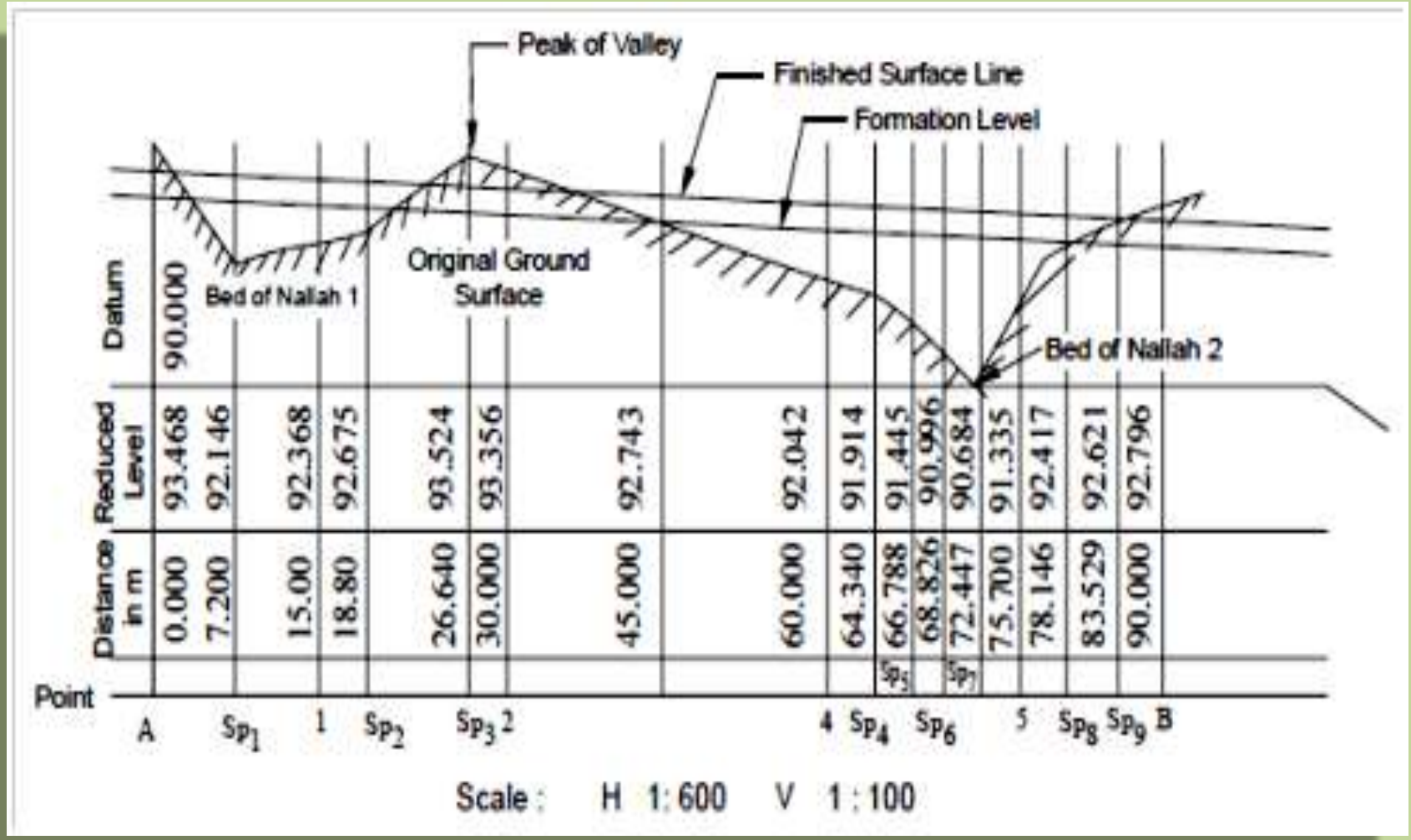
**Profile levelling or L-Section**

- 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

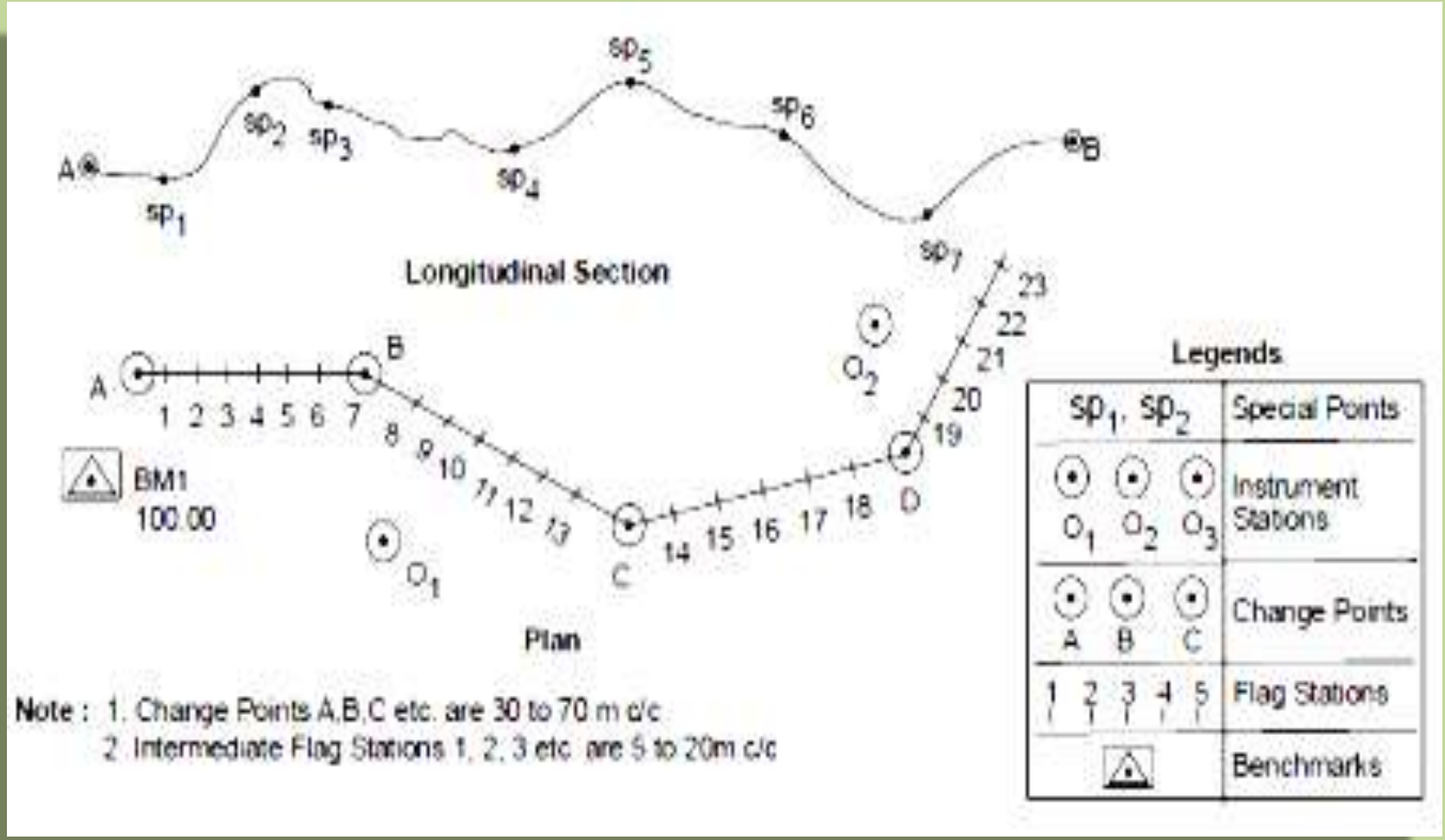
# Check levelling



# Profile levelling or L-Section



# Profile levelling or L-Section



# Classification of Levelling

**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.

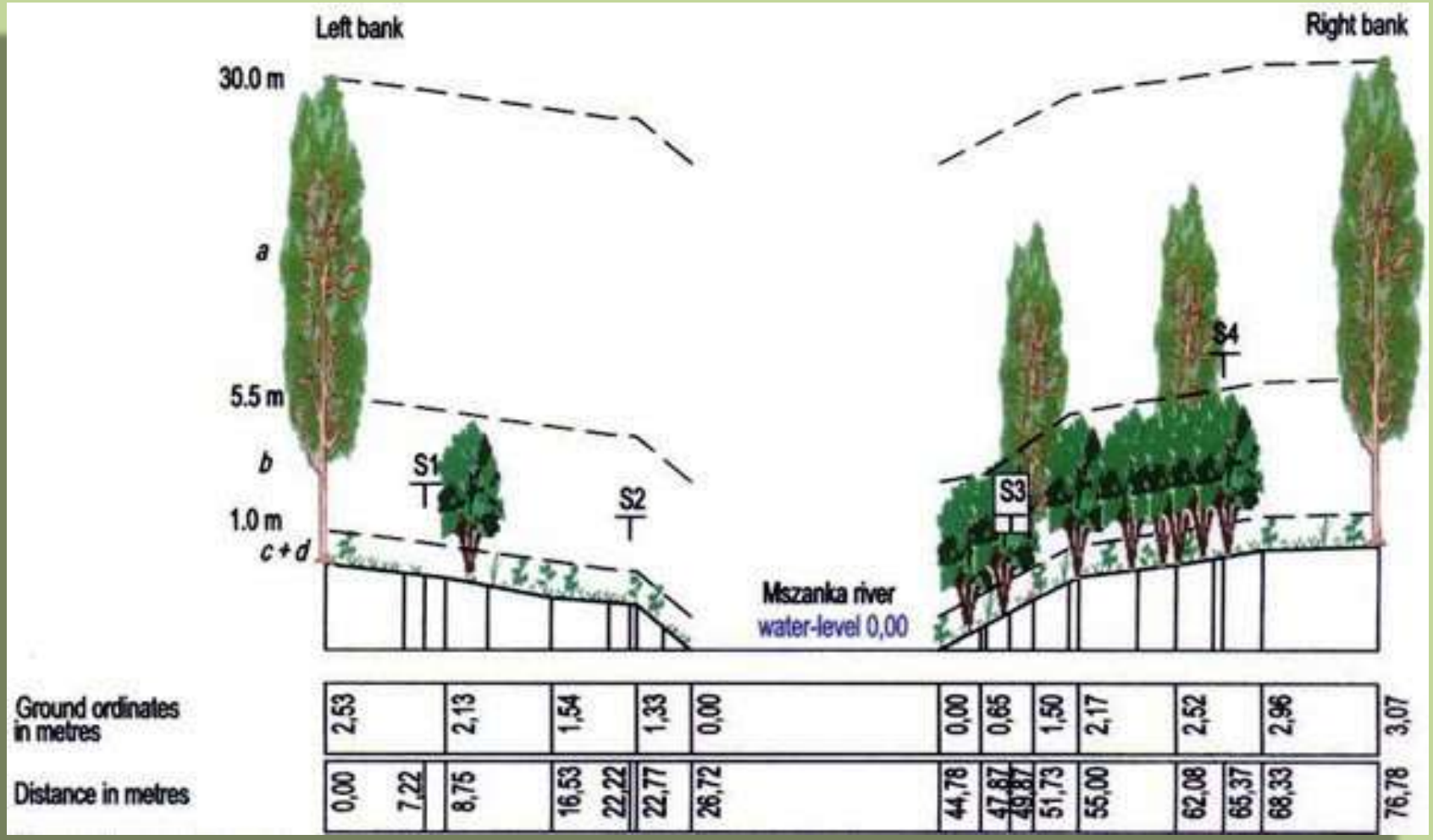
**Precise Levelling**

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

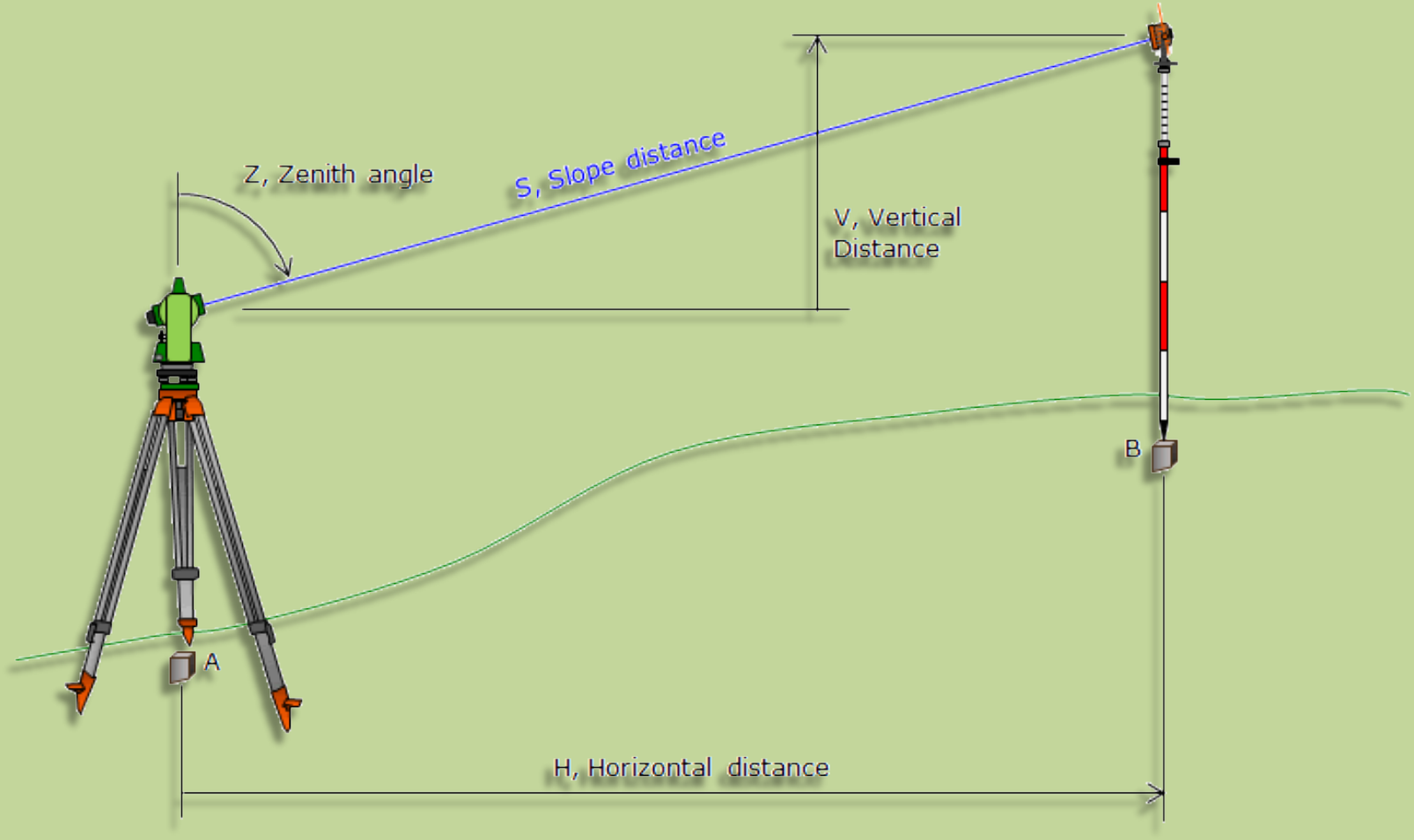
**Trigonometric Levelling**

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

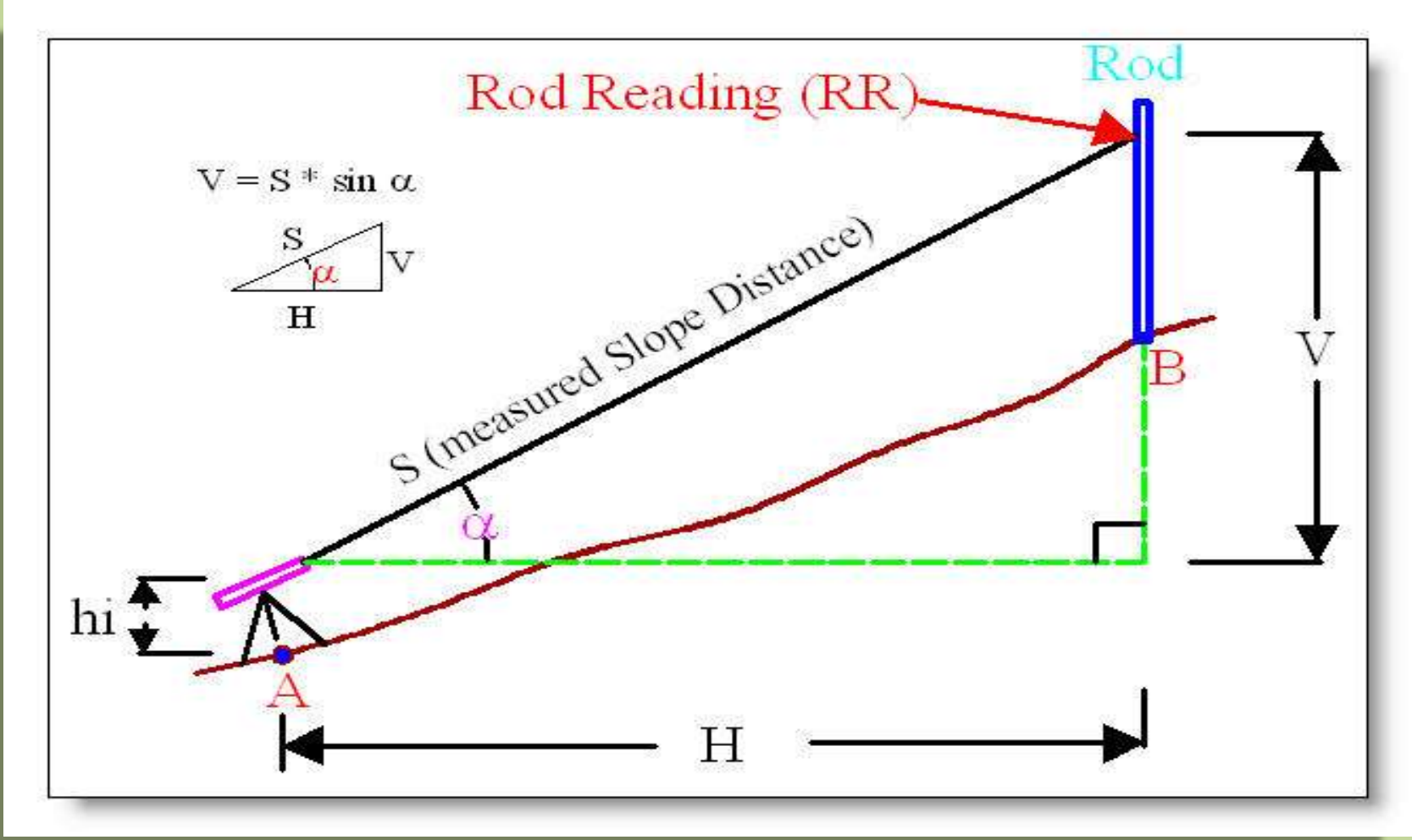
# Cross-Sectioning



# Trigonometric Levelling



# Trigonometric Levelling



# Classification of Levelling

**Barometric Levelling**

- In this method the **altitude difference is determined by means of a barometer.**
- Barometric leveling is based on the fact that the atmospheric pressure varies inversely with height. In this method a barometer is used to determine the differences in elevation of points, which differ considerably in heights as in a hilly area or mountainous country.

# Classification of Levelling

- It is chiefly used on **exploratory or reconnaissance surveys.** Since the pressure of the atmospheric at any point is constantly changing and **barometer reading are affected by the temperature of the air**
- Types of barometer in use are
- **Mercury Barometer**
- **Aneroid Barometer**

# Aneroid Barometer

# Mercury Barometer


# Hypsometric Levelling

The working of Hypsometry for determining the elevation depends upon the fact that the temperature at which water boils varies with the atmospheric pressure. The boiling point of water reduces at higher altitude thus knowing the boiling point of water, the atmospheric pressure can be calculated and knowing the atmospheric pressure altitude or elevation can be determined.

# Hypsometric Levelling

- The altitudes of various points may be determined by using hypsometer, also called as thermo-barometer.

# Hypsometric Levelling

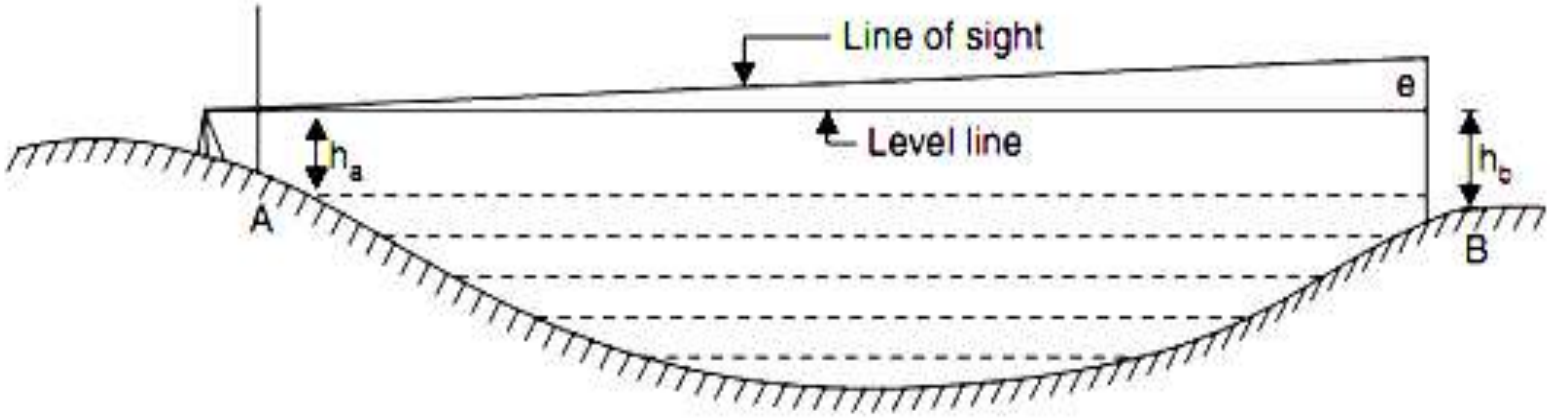
# Hypsometric Levelling

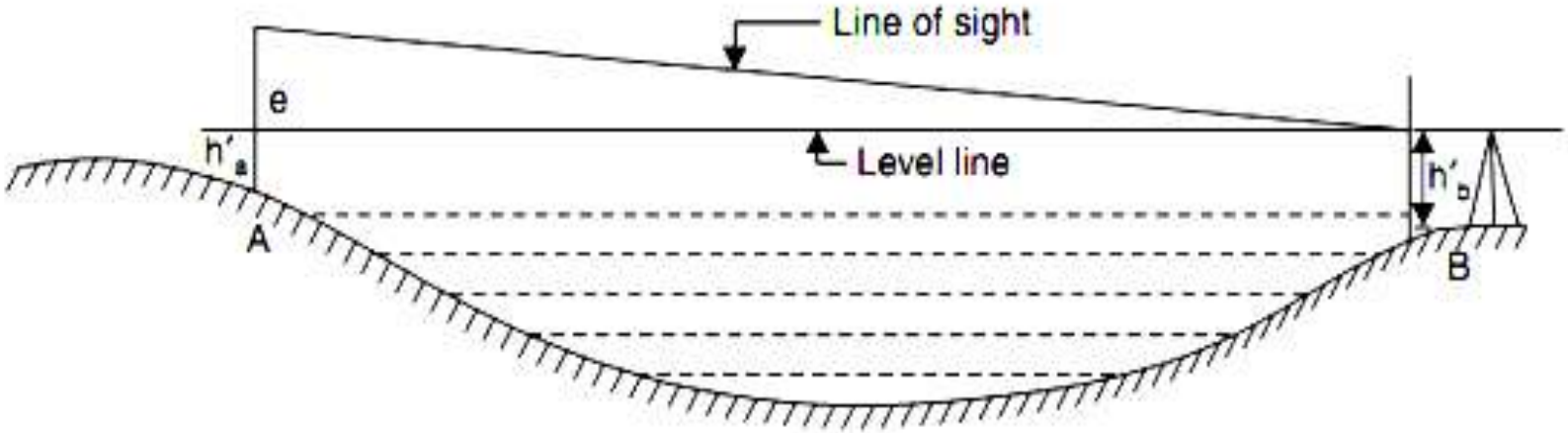
# Hypsometric Levelling

# 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

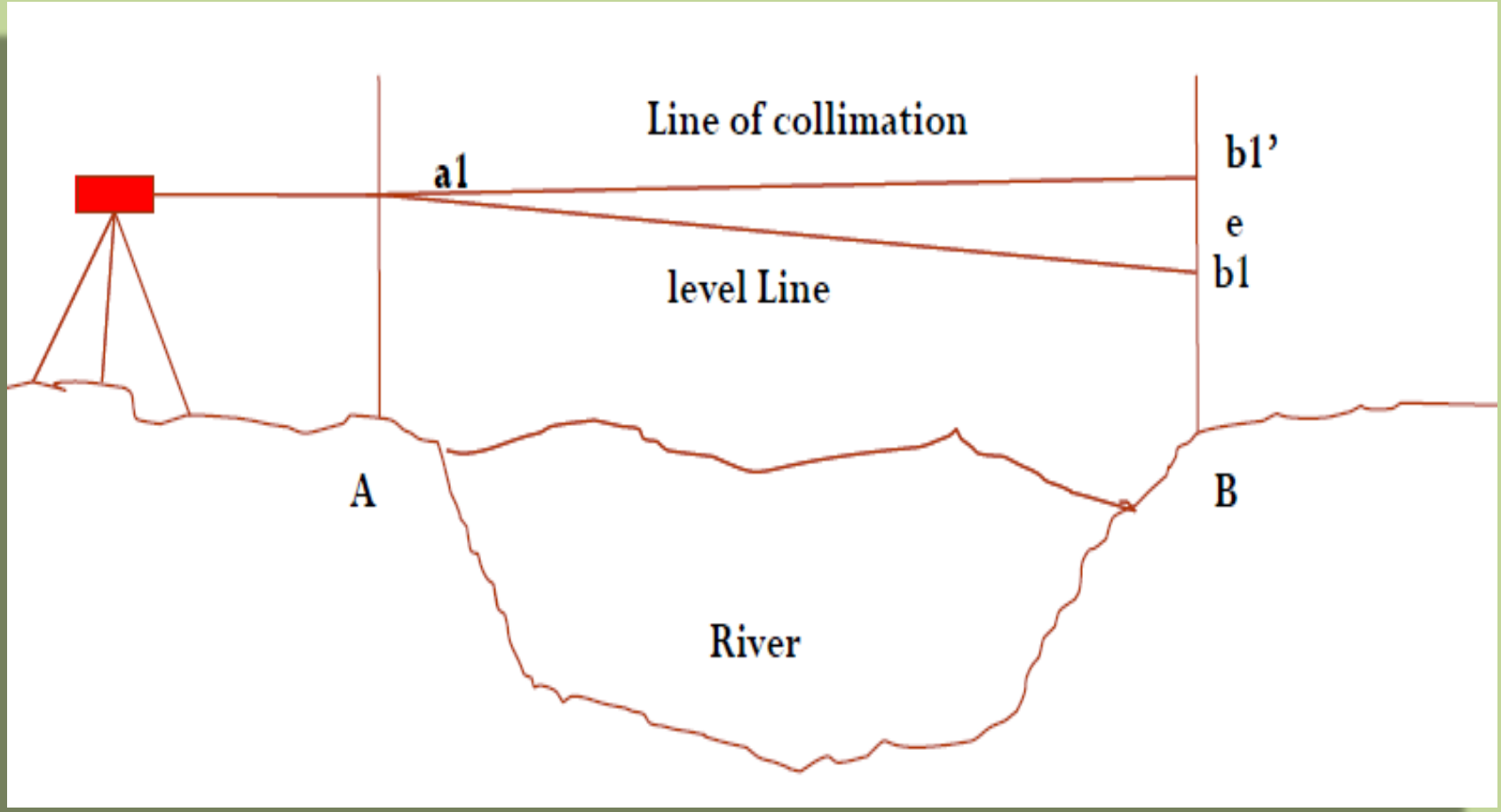


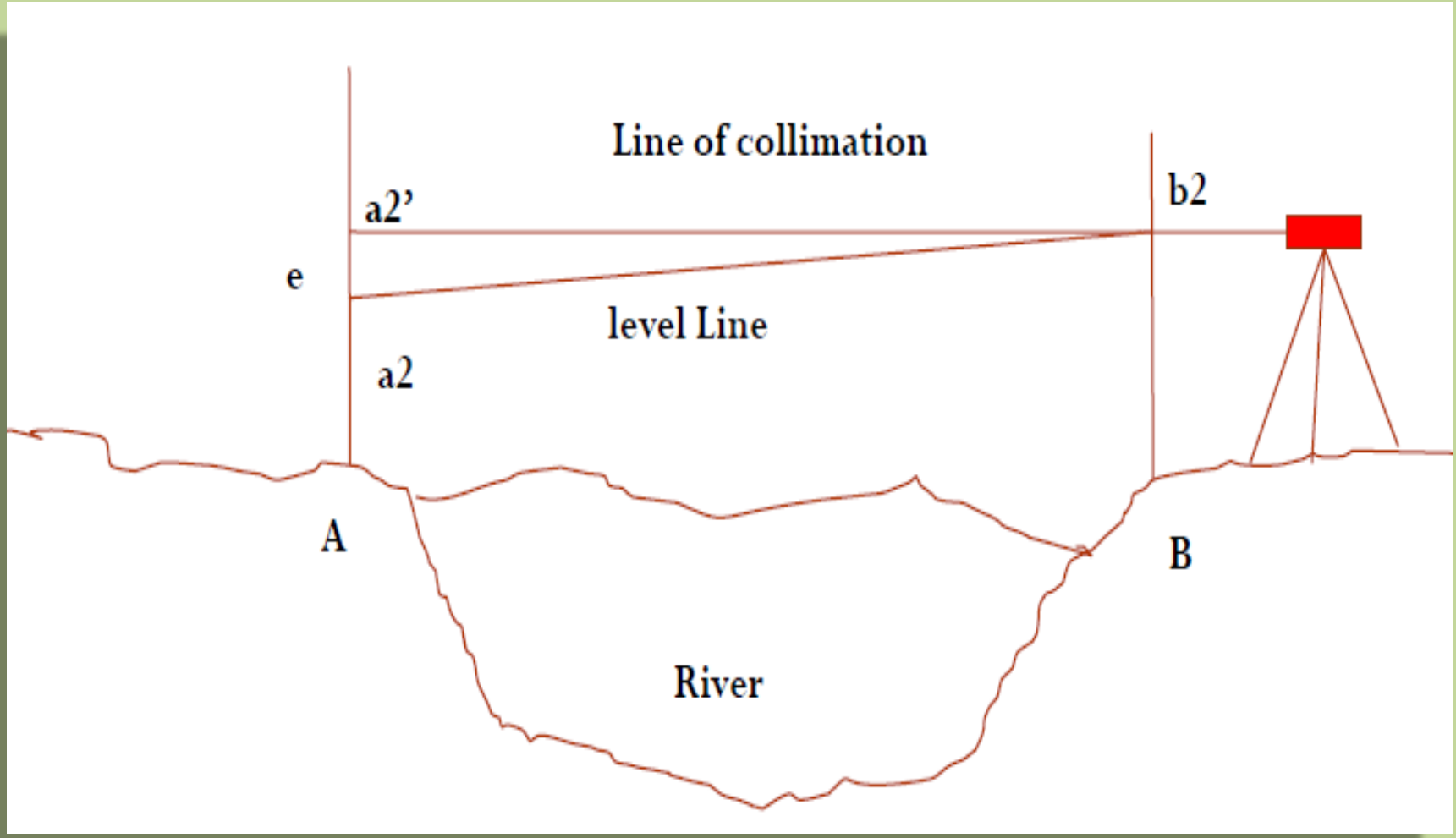
# Reciprocal Levelling

- 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
- $=(b_1-e)-a_1$
- **Or $d= (b_1- a_1)-e$**
- From B the difference will be= $b_2-(a_2-e)$
- **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

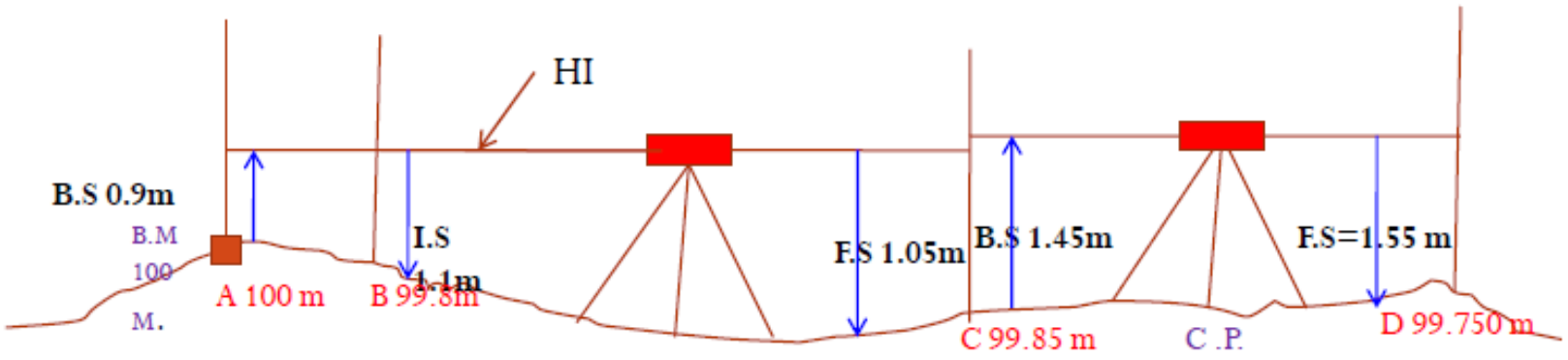


# Methods of Reducing Levels

**Height of Instrument Method**

- This method consist of finding H.I. for every setup of instrument, and then obtaining the R.L. of point of reference with respect to H.I

# Height of Instrument Method

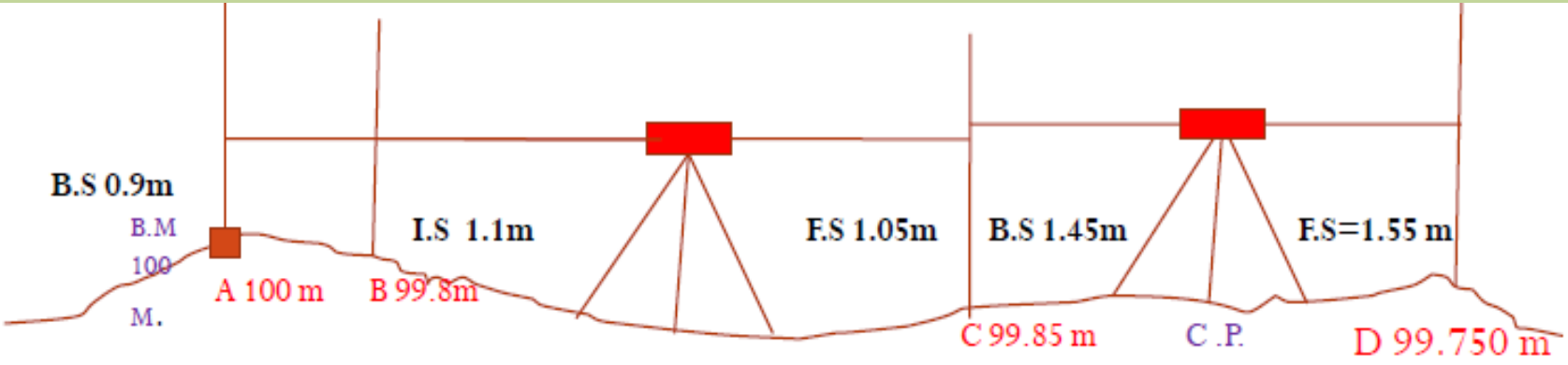



| Station | B.S | I.S | F.S | H.I | R.L | Remark |
|---|---|---|---|---|---|---|
| A | 0.9 | | | 100.9 | 100.00 | B.M |
| B | | 1.1 | | | 99.800 | |
| C | 1.450 | | 1.05 | 101.3 | 99.850 | C.P. |
| D | | | 1.550 | | 99.750 | |
| | | | | | | |

# 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.

# Errors in Levelling

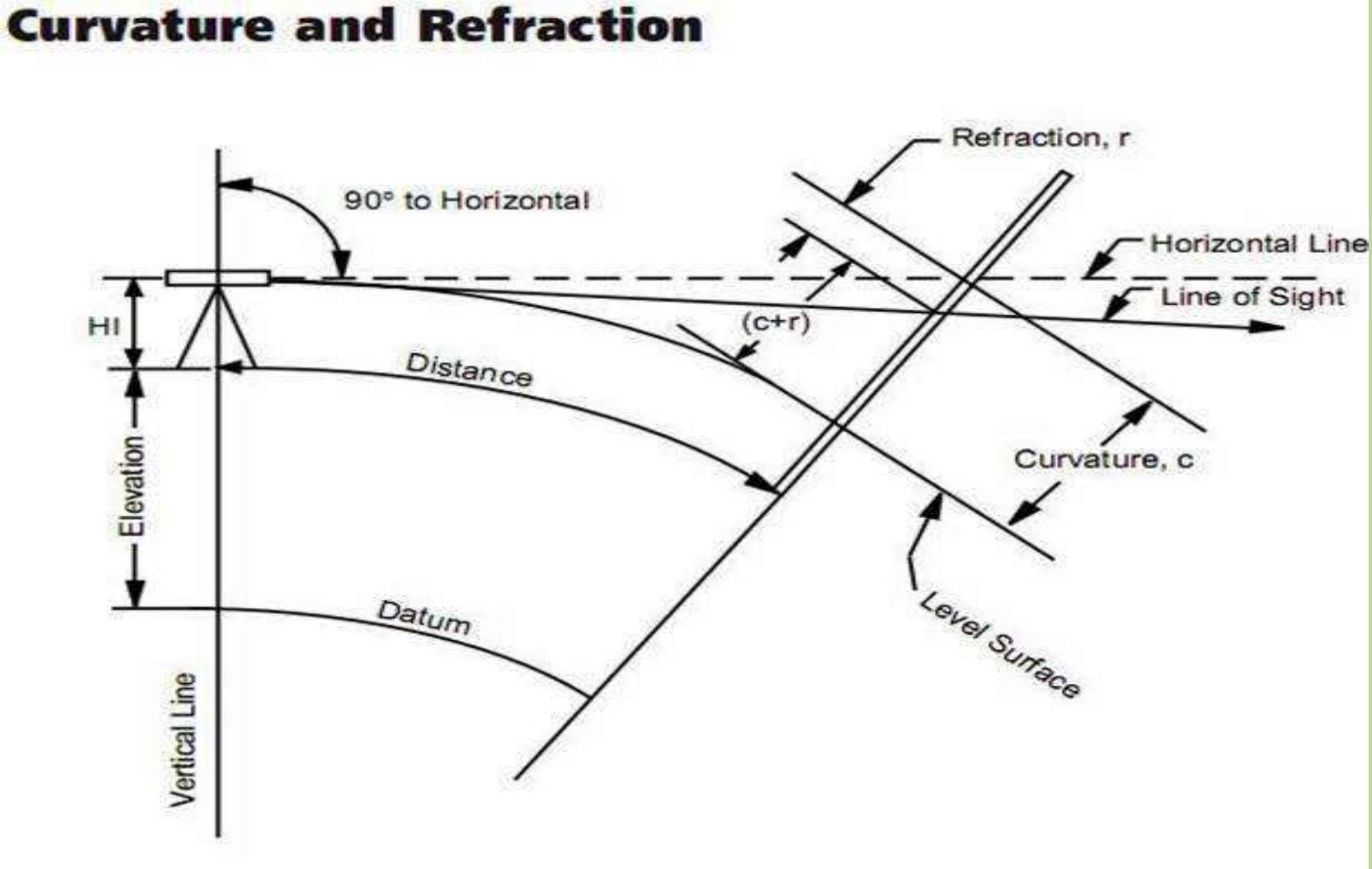
**Errors due to Natural Causes**

- The Curvature of the Earth may affect the staff readings when the distance of sight is long.
- The effect of refraction may cause a wrong staff reading
- There are some errors in staff readings due to high velocity wind

# 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.

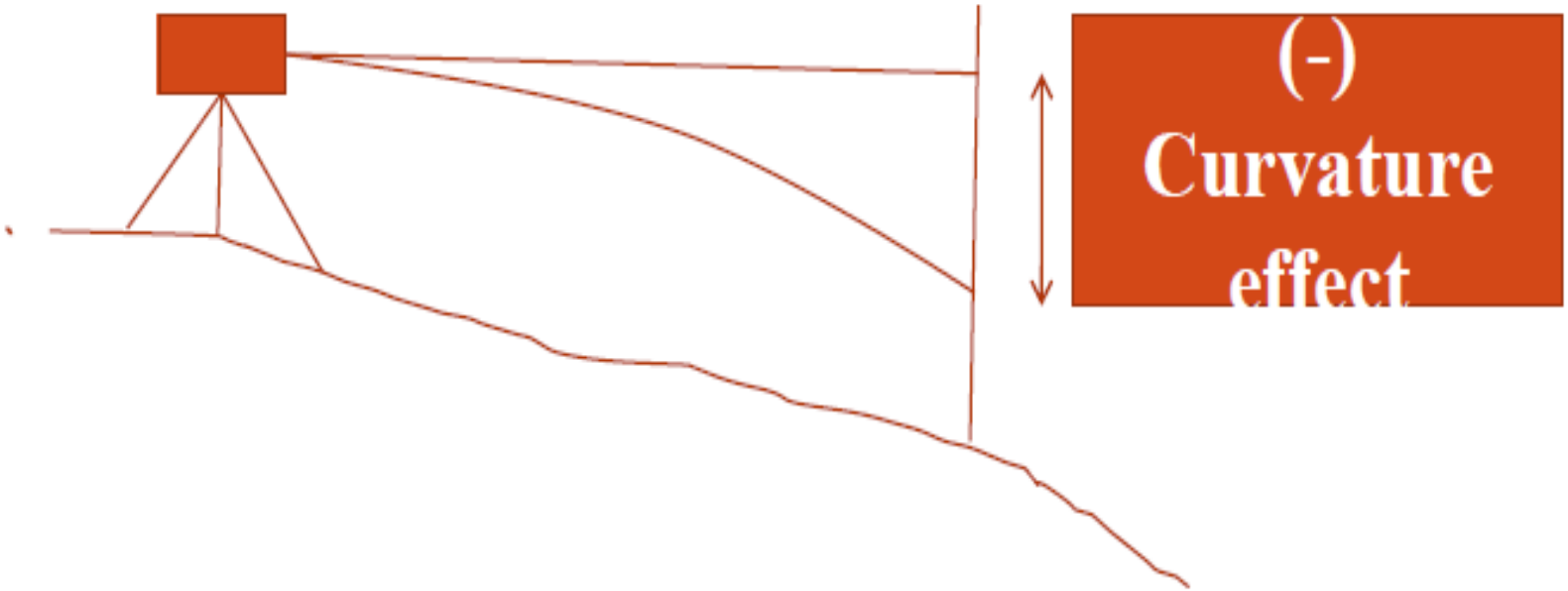
# Curvature & Refraction Correction



# 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-$0.0785D^2$)m**
- Where D= distance in Km.

# Curvature Correction



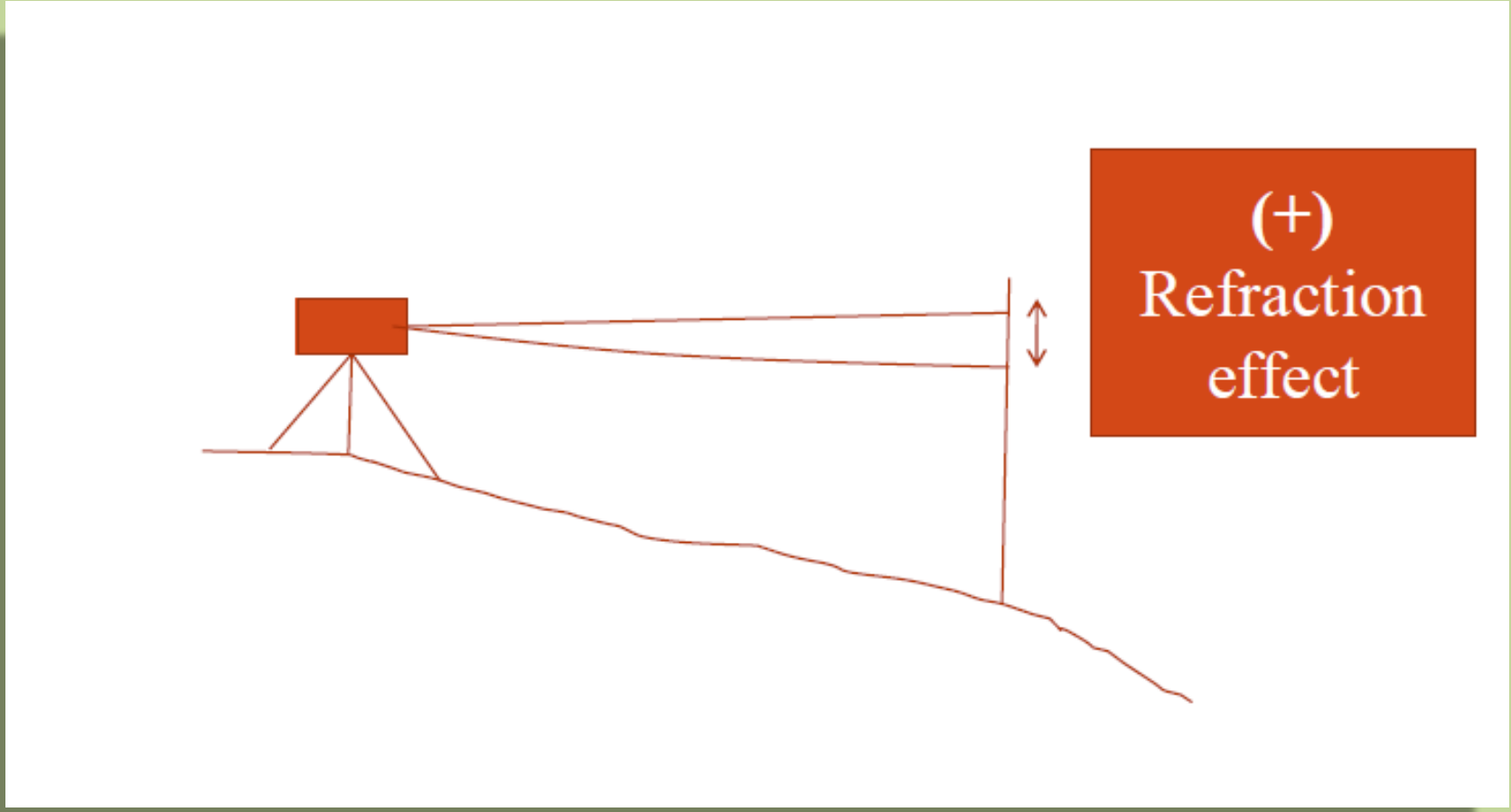
# Refraction

- 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



# Leveling Examples

# 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 Σ B.S-Σ F.S= 5.964-6.916= -0.952 = LAST R.L-FIRST R.L= 431.432-432.384=-0.952**
**ΣRISE-Σ FALL= 2.842-3.794=-0.952**

- The following readings were taken with a dumpy level and **4m leveling staff.** The instrument was shifted after **3rd and 6th readings**. The readings are **2.665, 3.225, 2.905, 1.85, 0.98, 2.62, 1.585, 0.96, 0.425. m** Enter the above readings in a page of level book and calculate R.L. of points, if the first reading was taken with a staff held on **B.M. of 240 m**. use **rise and fall method**. Apply arithmetic checks

# Rise and Fall Method

| Station | B.S. | I.S. | F.S | Rise (+) | Fall (-) | RL | Remarks |
|---|---|---|---|---|---|---|---|
| A | 2.665 | | | | | 240 | BM |
| B | | 3.225 | | | 0.56 | 239.44 | |
| C | 1.85 | | 2.905 | 0.32 | | 239.76 | 3rd CP |
| D | | 0.98 | | 0.87 | | 240.63 | |
| E | 1.585 | | 2.62 | | 1.64 | 238.99 | 6th CP |
| F | | 0.96 | | 0.625 | | 239.615 | |
| G | | | 0.425 | 0.535 | | 240.15 | |
| CHECK | ∑ BS- ∑ FS | | | ∑RISE- ∑ FALL | | L.RL –F. RL | |
| | 6.1 | | 5.95 | 2.35 | 2.2 | | |
| | ∑ BS- ∑ FS= 0.15 | | | ∑RISE- ∑ FALL =0.15 | | L.RL –F. RL= 0.15 | |

# HI Method

| Station | B.S. | I.S. | F.S | HI | RL | Remarks |
|---|---|---|---|---|---|---|
| A | 2.665 | | | 242.665 | 240 .00 | BM |
| B | | 3.225 | | | 239.44 | |
| C | 1.85 | | 2.905 | 241.61 | 239.76 | 3rd CP |
| D | | 0.98 | | | 240.63 | |
| E | 1.585 | | 2.62 | 240.575 | 238.99 | 6th CP |
| F | | 0.96 | | | 239.615 | |
| G | | | 0.425 | | 240.15 | |
| CHECK | ∑ BS- ∑ FS | | | | L.RL –F. RL | |
| | 6.1 | | 5.95 | | | |
| | ∑ BS- ∑ FS= 0.15 | | | | L.RL –F. RL= 0.15 | |

# HI Method

| Station | B.S. | I.S. | F.S | HI | RL | Remarks |
|---|---|---|---|---|---|---|
| A | 2.665 | | | 242.665 | 240 .00 | BM |
| B | | 3.225 | | | 239.44 | |
| C | 1.85 | | 2.905 | 241.61 | 239.76 | 3rd CP |
| D | | 0.98 | | | 240.63 | |
| E | 1.585 | | 2.62 | 240.575 | 238.99 | 6th CP |
| F | | 0.96 | | | 239.615 | |
| G | | | 0.425 | | 240.15 | |
| CHECK | ∑ BS- ∑ FS | | | | L.RL –F. RL | |
| | 6.1 | | 5.95 | | | |
| | ∑ BS- ∑ FS= 0.15 | | | | L.RL –F. RL= 0.15 | |

# Example

- The Following observations were taken with dumpy level and **4 m leveling staff**. The instrument were shifted after the **4th** and **7th** reading. The first reading was taken on a bench mark whose **R.L. was 15.575 m**. prepare a page of level book and calculate RL of all the points. The observations were taken at every **30 m interval**. Also find out the gradient between first and last point. Also draw the profile of ground. **Use H.I. Method**. Observations are: **0.565, 1.250, 1.675, 3.695,0.125, 2.345, 0.500, 1.785, 2.535.**

# Observations are: 0.565, 1.250, 1.675, 3.695 (CP),0.125, 2.345, 0.500 (CP), 1.785, 2.535.

| Station | B.S. | I.S. | F.S | HI | RL | Remarks |
|---|---|---|---|---|---|---|
| A | 0.565 | | | 16.14 | 15.575 | BM |
| B | | 1.250 | | | 14.89 | |
| C | | 1.675 | | | 14.46 | |
| D | 0.125 | | 3.695 | 12.565 | 12.44 | CP |
| E | | 2.345 | | | 10.22 | |
| F | 1.785 | | 0.500 | 13.85 | 12.065 | CP |
| G | | | 2.535 | | 11.315 | |
| CHECK | ∑ BS- ∑ FS | | | | L.RL –F. RL | |
| | 2.47 | | 6.73 | | | |
| | ∑ BS- ∑ FS= -4.26 | | | | L.RL –F. RL= -4.255 | |

# Observations are: 0.565, 1.250, 1.675, 3.695 (CP),0.125, 2.345, 0.500 (CP), 1.785, 2.535.

| Station | B.S. | I.S. | F.S | RISE | FALL | RL | Remarks |
|---|---|---|---|---|---|---|---|
| A | 0.565 | | | | | 15.575 | BM |
| B | | 1.250 | | | 0.685 | 14.89 | |
| C | | 1.675 | | | 0.425 | 14.46 | |
| D | 0.125 | | 3.695 | | 2.02 | 12.44 | CP |
| E | | 2.345 | | | 2.22 | 10.22 | |
| F | 1.785 | | 0.500 | 1.845 | | 12.065 | CP |
| G | | | 2.535 | | 0.75 | 11.315 | |
| CHECK | | ∑ BS- ∑ FS | | | | L.RL –F. RL | |
| | 2.47 | | 6.73 | | | | |
| | ∑ BS- ∑ FS= -4.26 | | | ∑RISE- ∑ FALL =-4.26 | | L.RL –F. RL= -4.26 | |

# Observations are: 0.565, 1.250, 1.675, 3.695 (CP),0.125, 2.345, 0.500 (CP), 1.785, 2.535.

| Station | B.S. | I.S. | F.S | RISE | FALL | RL | Remarks |
|---|---|---|---|---|---|---|---|
| A (0 m) | 0.565 | | | | | 15.575 | BM |
| B (30 m ) | | 1.250 | | | 0.685 | 14.89 | |
| C (60 m) | | 1.675 | | | 0.425 | 14.46 | |
| D (90 m) | 0.125 | | 3.695 | | 2.02 | 12.44 | CP |
| E (120 m) | | 2.345 | | | 2.22 | 10.22 | |
| F (150 m) | 1.785 | | 0.500 | 1.845 | | 12.065 | CP |
| G (180 m) | | | 2.535 | | 0.75 | 11.315 | |
| CHECK | ∑ BS- ∑ FS | | | | | L.RL –F. RL | |
| | 2.47 | | 6.73 | | | | |
| | ∑ BS- ∑ FS= -4.26 | | | ∑RISE- ∑ FALL =-4.26 | | L.RL –F. RL= -4.26 | |

# GRADIENT

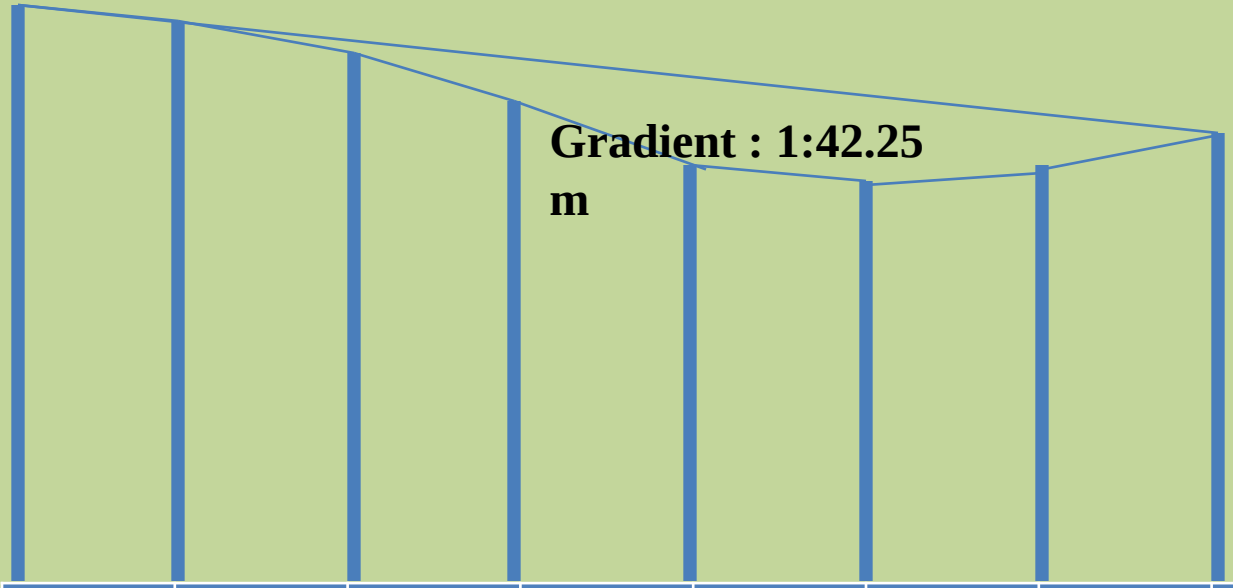
- Gradient of line AG = $\frac{\text{Diff of RLs}}{\text{Length}}$

- Gradient of line AG = $\frac{4.260}{180}$

$= \frac{1}{42.25}$

= 1 in 42.25 Gradient.

# Profile




| 15.575 | 14.89 | 14.46 | 12.44 | 10.22 | 12.065 | 13.315 | R.L. |
|---|---|---|---|---|---|---|---|
| 0 | 30 | 60 | 90 | 120 | 180 | m | Distance |

# Example

The following readings are taken on continuous falling ground with staff of **4 m** the **are 0.4 m, 0.765, 1.270, 2.56, 3.22, 3.95, 0.390, 1.690, 3.5, 0.8, 1.920, 2.45, 3.98**. Enter the reading in the page of level book and calculate the RLs of all point if the first reading was taken on **Benchmark of 100m.**

**0.400, 0.765, 1.270, 2.560, 3.220, 3.950, 0.390,1.690,3.500,0.800,1.920, 2.450,3.980**
**(Continuous Sloping Ground) 4m staff**

| Station | B.S. | I.S. | F.S | HI | RL | Remarks |
|---|---|---|---|---|---|---|
| A | 0.400 | | | 100.4 | 100.00 | BM |
| B | | 0.765 | | | 99.635 | |
| C | | 1.270 | | | 99.13 | |
| D | | 2.560 | | | 97.84 | |
| E | | 3.220 | | | 97.18 | |
| F | 0.390 | | 3.950 | 96.84 | 96.45 | CP |
| G | | 1.690 | | | 95.15 | |
| H | 0.800 | | 3.500 | 94.14 | 93.34 | CP |
| I | | 1.920 | | | 92.22 | CP |
| J | | 2.450 | | | 91.69 | |
| K | | | 3.98 | | 90.16 | |
| ∑ | 1.59 | | 11.43 | | | |
| CHECK | ∑ BS- ∑ FS= -9.84 m | | | | L.RL –F. RL= -9.84 m | |

**0.400, 0.765, 1.270, 2.560, 3.220, 3.950, 0.390,1.690,3.500,0.800,1.920, 2.450,3.980**
**(Continuous Sloping Ground) 4m staff**

| Station | B.S. | I.S. | F.S | RISE | FALL | RL | Remarks |
|---|---|---|---|---|---|---|---|
| A | 0.400 | | | | | 100.00 | BM |
| B | | 0.765 | | | 0.365 | 99.635 | |
| C | | 1.270 | | | 0.505 | 99.13 | |
| D | | 2.560 | | | 1.29 | 97.84 | |
| E | | 3.220 | | | 0.66 | 97.18 | |
| F | 0.390 | | 3.950 | | 0.73 | 96.45 | CP |
| G | | 1.690 | | | 1.30 | 95.15 | |
| H | 0.800 | | 3.500 | | 1.81 | 93.34 | CP |
| I | | 1.920 | | | 1.12 | 92.22 | CP |
| J | | 2.450 | | | 0.53 | 91.69 | |
| K | | | 3.98 | | 1.53 | 90.16 | |
| ∑ | 1.59 | | 11.43 | 0 | 9.84 | | |
| CHECK | ∑ BS- ∑ FS= -9.84 m | | | ∑RISE- ∑ FALL =--9.84 | | L.RL –F. RL= -9.84 m | |

- The following is an incomplete page of level book in which X indicates missing Entry line. Calculate all the missing entries and complete the page of level book .also give the usual arithmetical checks.

# MISSING READINGS

| Station | BS | IS | FS | Rise | Fall | RL | Remarks |
|---|---|---|---|---|---|---|---|
| A | 2.560 | | | | | 100.0 | BM |
| B | | 3.540 | | | X | X | |
| C | | 3.200 | | X | | X | |
| D | | 2.340 | | X | | X | |
| E | 1.950 | | X | 1.08 | | X | CP1 |
| F | | 2.440 | | | X | X | |
| G | | | 3.465 | | X | X | |

# MISSING READINGS

| Station | B.S. | I.S. | F.S | RISE | FALL | RL | Remarks |
|---|---|---|---|---|---|---|---|
| A | 2.560 | | | | | 100 | |
| B | | 3.54 | | | X | X | |
| C | | 3.20 | | X | | X | |
| D | | 2.34 | | X | | X | |
| E | 1.95 | | X | 1.08 | | X | CP |
| F | | 2.44 | | | X | X | |
| G | | | 3.46 | | X | X | |
| CHECK | ∑ BS- ∑ FS | | | | | L.RL –F. RL | |
| | | | | | | | |
| | ∑ BS- ∑ FS= | | | | | L.RL –F. RL= | |

# MISSING READINGS

| Station | B.S. | I.S. | F.S | RISE | FALL | RL | Remarks |
|---|---|---|---|---|---|---|---|
| A | 2.560 | | | | | 100 | |
| B | | 3.54 | | | 0.98 | 99.02 | |
| C | | 3.20 | | 0.34 | | 99.36 | |
| D | | 2.34 | | 0.86 | | 100.22 | |
| E | 1.95 | | 1.26 | 1.08 | | 101.3 | CP |
| F | | 2.44 | | | 0.49 | 100.81 | |
| G | | | 3.46 | | 1.02 | 99.79 | |
| CHECK | ∑ BS- ∑ FS | | | | | L.RL –F. RL | |
| | 4.51 | | 4.72 | | | | |
| | ∑ BS- ∑ FS= -0.21 | | | ∑RISE- ∑ FALL =-0.21 | | L.RL –F. RL= -0.21 | |

# Example

- The following consecutive readings were taken with a level and a **4m staff** at a common **interval of 30m**; The first reading was taken at **B.M. having R.L. =100m**. The instrument were shifted after the **4th and 9 th readings**. Rule out a page of a level book, enter the readings given and also calculate the reduced levels of the points by the collimation method. Also apply arithmetic checks.
- Consecutive readings are: **2.650, 1.745, 0.625, 0.260, 2.525, 2.160, 1.235, 0.870, 1.365, 0.625, 1.790, and 2.535.**

**Consecutive readings are: 2.650, 1.745, 0.625, 0.260 (CP), 2.525, 2.160, 1.235, 0.870, 1.365 (CP), 0.625, 1.790, and 2.535.**

| Station | B.S. | I.S. | F.S | RISE | FALL | RL | Remarks |
|---|---|---|---|---|---|---|---|
| A | 2.65 | | | | | 100 m | BM |
| B | | 1.745 | | 0.905 | | 100.905 | |
| C | | 0.625 | | 1.12 | | 102.025 | |
| D | 2.525 | | 0.260 | 0.365 | | 102.39 | CP |
| E | | 2.160 | | 0.365 | | 102.755 | |
| F | | 1.235 | | 0.925 | | 103.68 | |
| G | | 0.87 | | 0.365 | | 104.045 | |
| H | 0.625 | | 1.365 | | 0.495 | 103.55 | CP |
| I | | 1.79 | | | 1.165 | 102.385 | |
| J | | | 2.535 | | 0.745 | 101.64 | |
| K | 5.8 | | 4.16 | 4.045 | 2.405 | | |
| ∑ | | | | | | | |
| CHECK | ∑ BS- ∑ FS= 1.64 m | | | ∑RISE- ∑ FALL = 1.64 m | | L.RL –F. RL= 1.64 m | |

**Consecutive readings are: 2.650, 1.745, 0.625, 0.260 (CP), 2.525, 2.160, 1.235, 0.870, 1.365 (CP), 0.625, 1.790, and 2.535.**

| Station | B.S. | I.S. | F.S | HI | RL | Remarks |
|---|---|---|---|---|---|---|
| A | 2.65 | | | 102.65 | 100 m | BM |
| B | | 1.745 | | | 100.905 | |
| C | | 0.625 | | | 102.025 | |
| D | 2.525 | | 0.260 | 104.915 | 102.39 | CP |
| E | | 2.160 | | | 102.755 | |
| F | | 1.235 | | | 103.68 | |
| G | | 0.87 | | | 104.045 | |
| H | 0.625 | | 1.365 | 104.175 | 103.55 | CP |
| I | | 1.79 | | | 102.385 | |
| J | | | 2.535 | | 101.64 | |
| K | 5.8 | | 4.16 | | | |
| ∑ | | | | | | |
| CHECK | ∑ BS- ∑ FS= 1.64 m | | | | L.RL –F. RL= 1.64 m | |

# EXAMPLE

- The following consecutive readings were taken with a level and a 4m leveling staff on a continuously sloping ground at a common interval of 30 m on line AB.

| Chainage | 0 | 30 | 60 | 90 | 120 | 150 |
|---|---|---|---|---|---|---|
| Level | 0.585 | 0.930 | 1.95 | 2.845 | 3.645 | 3.93 |
| Station | A | | | | | B |

**The reduced level (RL) of station A is 50.00**. Calculate the reduced levels at all the points where the leveling staff is placed. Tabulate the results and apply usual checks. Also determine the gradient of line AB.

# EXAMPLE (Rise and Fall Method)

| Station | B.S. | I.S. | F.S | RISE | FALL | RL | Remarks |
|---|---|---|---|---|---|---|---|
| A (0 m) | 0.585 | | | | | 50.00 | BM |
| B (30 m ) | | 0.930 | | | 0.345 | 49.655 | |
| C (60 m) | | 1.950 | | | 1.02 | 48.635 | |
| D (90 m) | | 2.840 | | | 0.89 | 47.745 | |
| E (120 m) | | 3.645 | | | 0.805 | 46.94 | |
| F (150 m) | | | 3.930 | | 0.285 | 46.655 | |
| G (180 m) | | | | | | | |
| CHECK | ∑ BS- ∑ FS | | | | | L.RL –F. RL | |
| | 0.585 | | 3.930 | 0 | 3.345 | 3.345 | |
| | ∑ BS- ∑ FS= -3.345 m | | | ∑RISE- ∑ FALL = 3.345 m | | L.RL –F. RL= 3.345 m | |

# EXAMPLE (HI Method)

| Station | B.S. | I.S. | F.S | HI | RL | Remarks |
|---|---|---|---|---|---|---|
| A (0 m) | 0.585 | | | 50.585 | 50.00 | BM |
| B (30 m ) | | 0.930 | | | 49.655 | |
| C (60 m) | | 1.950 | | | 48.635 | |
| D (90 m) | | 2.840 | | | 47.745 | |
| E (120 m) | | 3.645 | | | 46.94 | |
| F (150 m) | | | 3.930 | | 46.655 | |
| G (180 m) | | | | | | |
| CHECK | | ∑ BS- ∑ FS | | | L.RL –F. RL | |
| | 0.585 | | 3.930 | | 3.345 | |
| | ∑ BS- ∑ FS= -3.345 m | | | | L.RL –F. RL= 3.345 m | |

# References


- “Surveying and Levelling” Vol- I

  Kanetkar and Kulkarni (2011)

- “ Surveying” Vol- I

  Dr. B.C. Punamia

# THANKS !

Your levellers wish to level down as far as themselves; but they cannot bear levelling up to themselves.

(Samuel Johnson)



GHT