Surveying-I
CE-205 (T)

Levelling

Lecture 5

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Levelling

- **Leveling** may be defined as the art of determining the relative heights or elevation of points or objects on the earth's surface .

- It deals with measurements in vertical plane.

- **Leveling methods use in many engineering applications;**

- Design of highways, railroads, canals, etc.

- Calculate earthwork volumes.

- Map earth's topography.

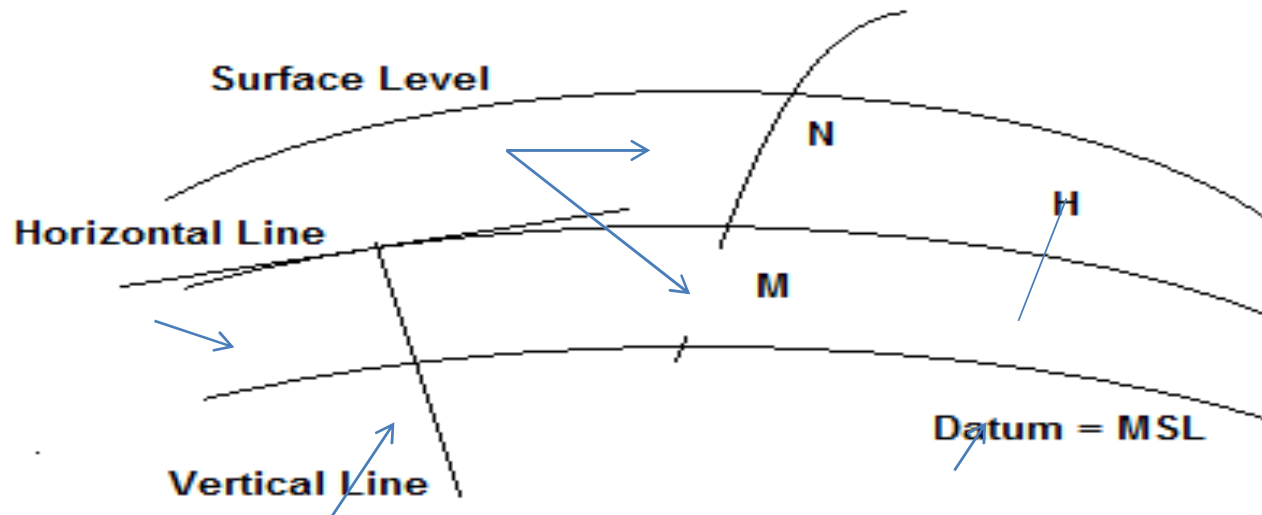- Investigate drainage characteristics etc.
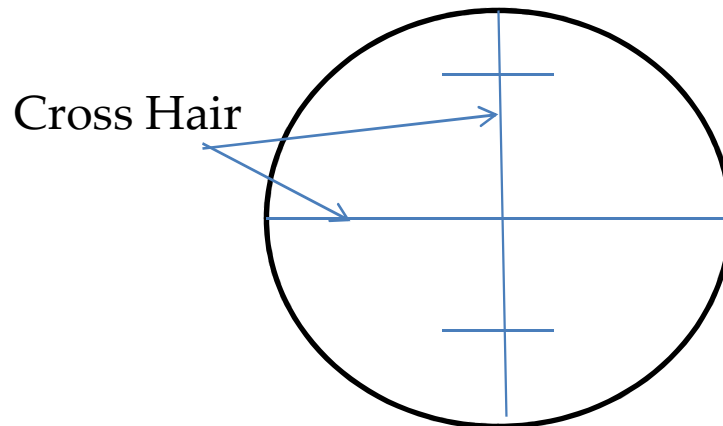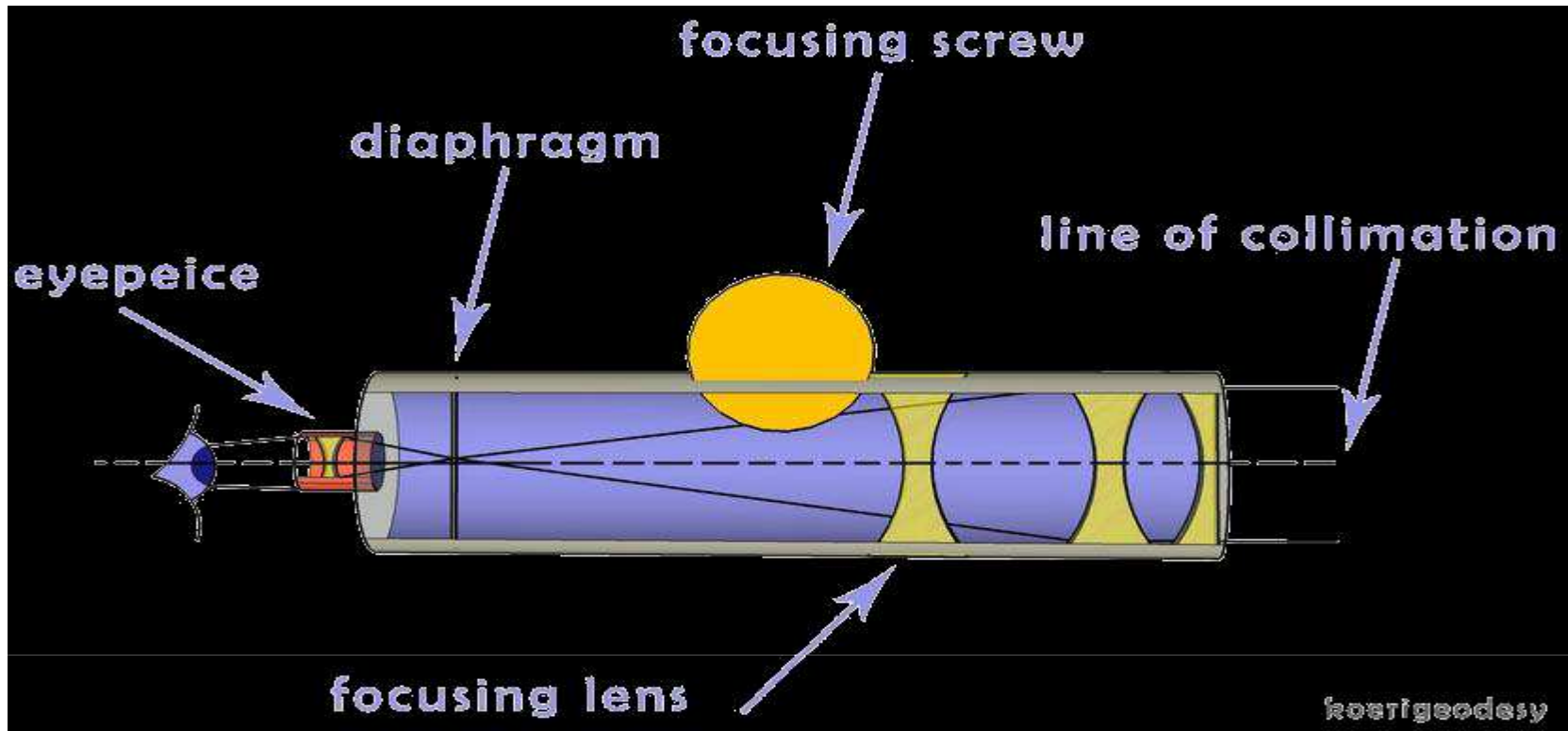
Definitions of Terms used In Leveling

- **Level Surface:** is any surface parallel to the mean spheroidal surface of the earth. E.g the surface of a still lake. It is normal to the plumb line at all points.

- **Level line:** line lying in a level surface, so normal to plumb line.

- **Horizontal Plane:** through a point is plane tangential to the level surface at that point. Perpendicular to gravity.

- **Horizontal Line:** is any line in horizontal plane. Straight line tangential to level line.
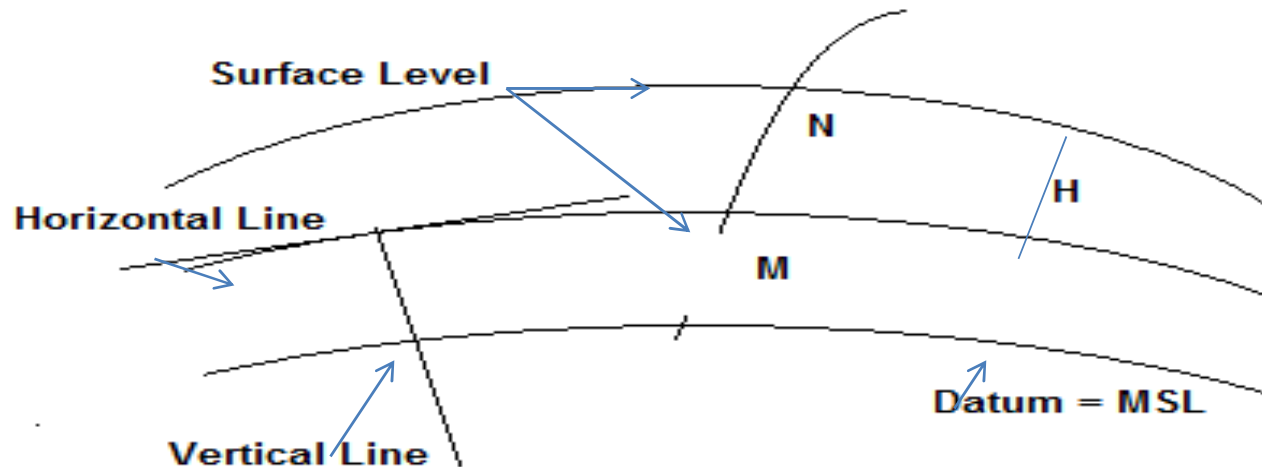
Definitions of Terms used In Leveling

- **Vertical Line:** at any point Is line normal to the level surface through that point in the direction of gravity. E.g: plumb line.

- **Vertical plane:** Plane containing a vertical line.

- **Vertical angle:** is angle between two intersecting lines in a vertical plane, one of the two lines is taken horizontal in surveying.

- **Datum Surface:** or line is any arbitrarily assumed level surface or line from which vertical distances are measured. In Pakistan datum sea level in Karachi.

focusing screw

diaphragm

line of collimation

eyepeice

focusing lens

koetigeodesy

Cross Hair

Definitions of Terms used In Leveling

- **Elevation:** of a point is its vertical distance above or below the datum. Also called Reduced level (R.L). + or – according as point is above or below.

- **Difference in Elevation (H**): between two points is the vertical distance between the level surface through the two points.

- **Bench Mark (B.M):** is a fixed reference point of known Elevation.

- **Line of Collimation:** is a line joining the intersection of the cross Hair to the optical center of the object glass and its continuation, also called Line of Sight.

- **Axis of Telescope:** is a line joining the optical center of the object glass to the entre of the eye-piece.

- **Axis of level tube or bubble tube:** is an imaginary line tangential to the longitudinal curve of the tube at its middle point, also called bubble line. It is horizontal when bubble is centered.

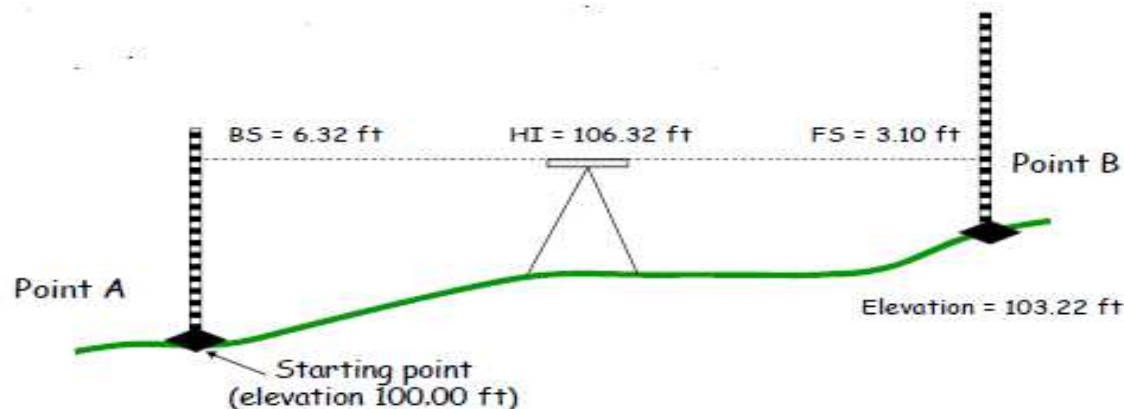- **Vertical Axis :** is the center line of the axis of rotation.

Definitions of Terms used In Leveling

- **Backsight (B.S):** also termed as backsight reading, is the staff (rod) reading taken on a point of known elevation as on a Bench Mark or change point. Also called Plus sight. It is the first staff reading taken after the level is setup and leveled.

- **Foresight (F.S):** also termed as foresight reading, is the staff reading on a point whose elevation is to be determined as on change point. Also called Minus reading. It is the last staff reading denoting the shifting of the instrument.

- **Intermediate Sight (I.S):** is any staff reading taken on a point of unknown elevation from the same setup of level. All sights taken between backsight and foresight are intermediate sight.
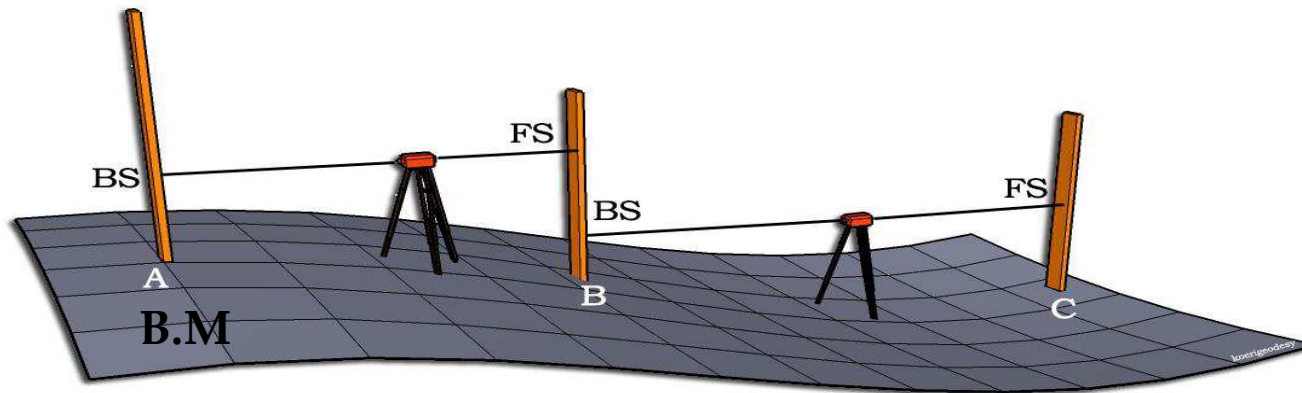
Definitions of Terms used In Leveling

- **Change Point (C.P):** is point denoting the shifting of the level. It is a point on which fore and backsights are taken. Bench mark may also be taken as Change point. Also called Turning point (T.P).

- **Station**: is a point whose elevation is to be determined or point which is to be established . It is the point where the staff is held and not the point where the level is setup.

- **Height of Instrument (H.I)**: is the elevation (R.L) of the line of collimation (or plane od sight) when the instrument is correctly leveled. Also called Height of plane of collimation.

- The term H.I does not mean the height of center of telescope above the ground where the level is setup.

BS = 6.32 ft   HI = 106.32 ft   FS = 3.10 ft

Point B

Point A

Elevation = 103.22 ft

Starting point
(elevation 100.00 ft)

Definitions of Terms used In Leveling

- **Focusing:** means the setting of eye-piece and objective at proper distance apart for the clear vision of the object sighted.
- The focus of the objective and eye piece must coincide with the cross-hair of the diaphragm. Can be done by first focusing the eye piece and than objective.
- To focus the eye-piece hold a sheet of paper in front of the telescope and move the eye-piece in and out until cross hair appear distinct and clear.
- To focus the objective direct the telescope to object and turn the focusing screw until the image appears clear and sharp focus.

- **Parallax:** it is the apparent movement of the image relative to cross hair, when the image formed by the objective does not fall in the plane of diaphragm.
- it is due to poor focusing of objective.
- It can be tested by moving the eye up and down , if the focusing is correct the image appeared fixed to the cross hair when the eye moved up and down.
- The Aim of focusing is to remove the parallax.
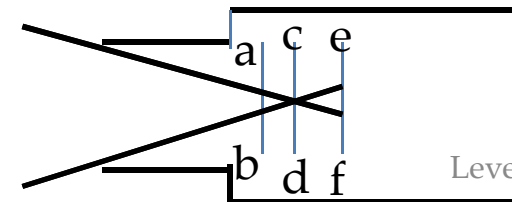
Instruments

- To determent the elevation of points two instruments are required

    1) Level   **2)** Leveling Staff (or rod)

- **The Level** furnished horizontal line of sight and

- **The Leveling Staff** is used to determined the vertical distance of the points below the horizontal line of sight.

Instruments

1) THE LEVEL :

The level consist essentially of :

1) the leveling head **2)** Telescope **3)** Limb **4)** the level or bubble tube.

There are various types of Levels

1) The dumpy Level
2) The Wye or Y Level
3) The Cook's reversible Level
4) The Cushing's Level
5) Tilting Level
6) The Automatic Level.

Assignment

DUMPY LEVEL

RETICLE ADJUSTING SCREW
FOCUSING KNOB
SUN SHADE
LEVEL VIAL
EYE PIECE
LEVELING HEAD
AZIMUTH CLAMP
AZIMUTH TANGENT SCREW
LEVELING SCREW
FOOTPLATE
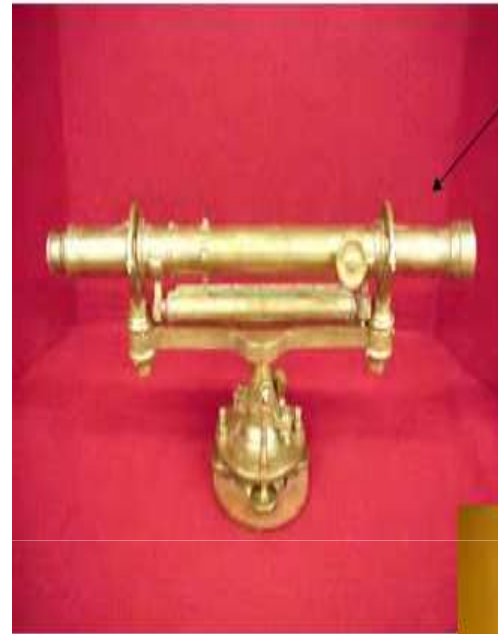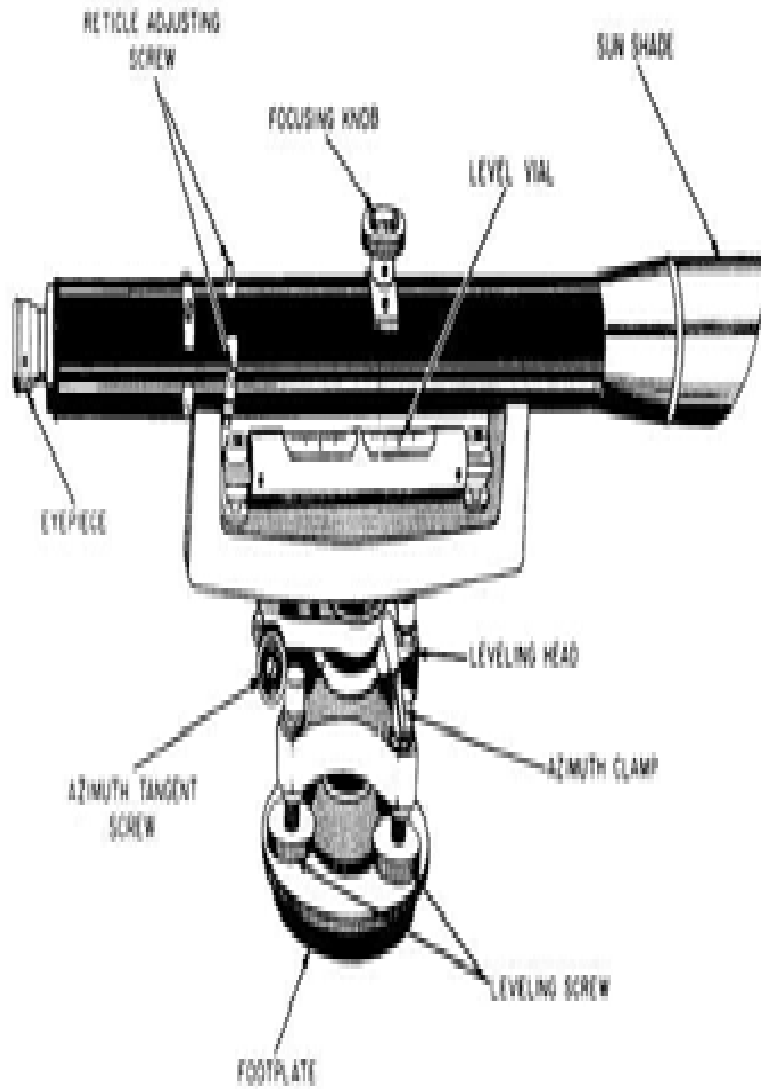
Blattner Wye Level

Mahn Dumpy Level

AUTOMATIC LEVEL

Zeiss Ni 2

Nikon AX-2s
Automatic Level

DIGITAL LEVEL

Trimble DiNi Digital Level

Leica DNA03 Digital Level

TILTING LEVEL

Watts Tilting Level

Instruments

2) The Leveling Staff:

- There are various types of graduated staff available.
- A point on the face that is upwards indicates a whole tenth of a foot (0.1)
- ⬚ A point on the face that is downwards indicates a whole 0.05'

4.70

4.60

4.50

Red numbers indicate foot intervals

5.76'
5.75'
5.74'
5.73'
5.72'
5.71'
5.70'
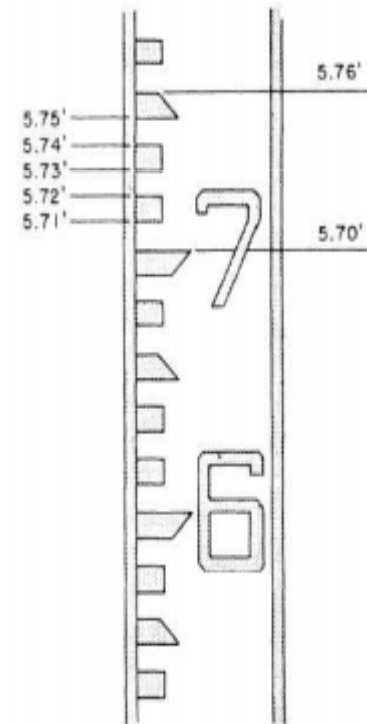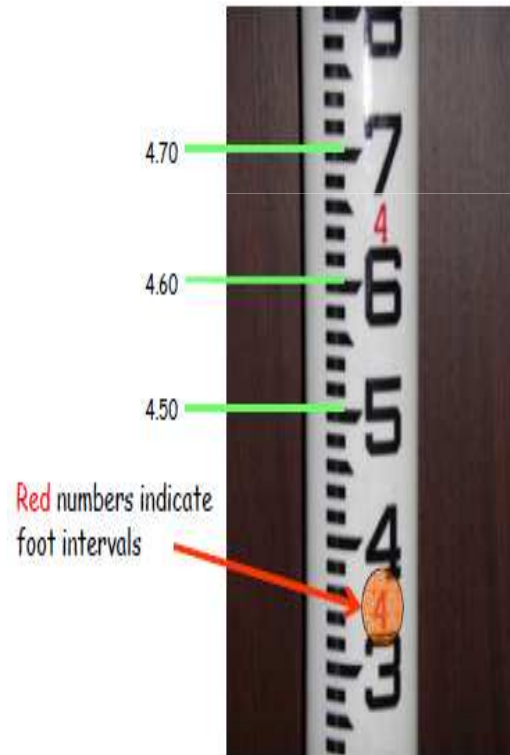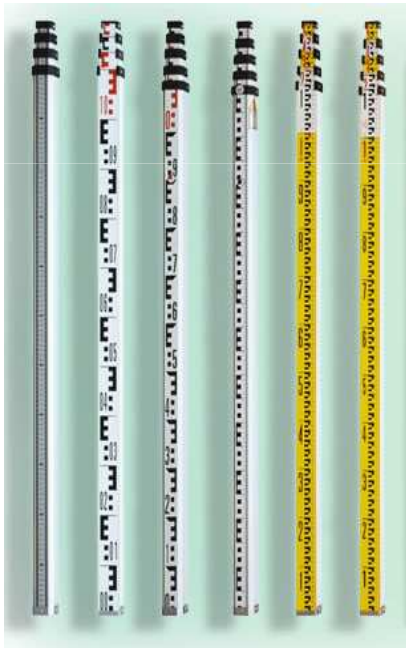
Assignment

Equipments for Leveling

The Equipments for leveling consist of:

1) A Level
2) A Leveling Staff
3) A Chain or Tape for measuring horizontal distances
4) A level field book for recording staff reading and other notes.

Adjustment of the Level

- The adjustment of a Level are of two kinds:

    1) Temporary adjustment

    2) Permanent adjustment

Temporary adjustment:

The temporary adjustment are those which have to be performed at each set-up of level.

They are two in number:

1)   Setting up the level which includes

        a) planting the tripod

        b) Levelling up

2) Focusing the eye-piece and object glass to eliminate the parallax.

Adjustment of the Level

They are made in the following Steps:

Setting up the Level:

1)   Fixing the Instrument on Tripod

Fix the instrument on tripod firmly by turning round only the lower part .

2) Leg Adjustment

Place instrument at convenient height, fix two legs firmly into the ground and move the third leg to right or left until main bubble approx. center. Then move it in or out until bubble of level cross is approx.in the center. The leg is fixed when both bubble approx. In the center.

3) Levelling Up

Place telescope parallel to pair of foot screws and bring the bubble in the center by turning these screws inward and outward. Turn telescope through 90o so that it lie over the third screw and center the bubble by turning this screw and repeat.

4) Focusing the Eye-piece

Hold a white paper in inform of eye piece, move the eye-piece in and out until the cross hair appears distinct.

5) Focusing the Object glass

Direct the telescope toward the staff and looking though the eye-piece ,bring the image of the staff between the two vertical hairs(line). Adjust the objective by truing the focusing screw until parallax is eliminated.

Bench Marks

There four types of Bench marks:

1) Permanent Bench Marks

2) Arbitrary Bench Marks

3) Temporary Bench Marks

Assignment

Change Point

It is an intermediate staff station on which two readings are taken and it is used for the purpose of changing the position of the instrument.
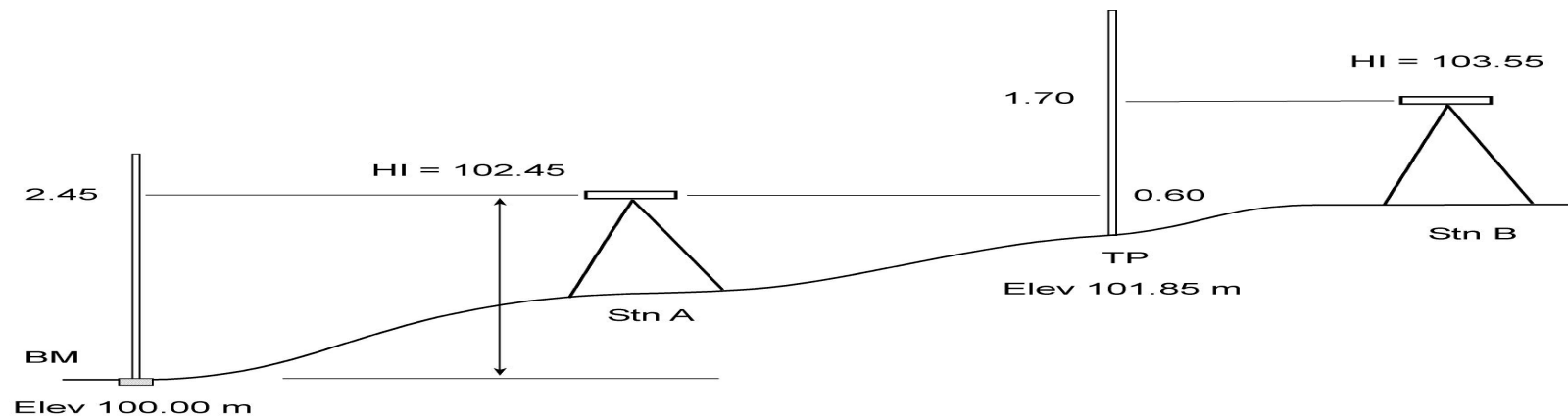
Principles of Leveling

A) Simple Levelling

B) Differential Levelling

A) Simple Levelling

It is the simplest operation in leveling when it is required to find the difference in elevation between two points, both of which are visible from a single position of the level.

If R.L of A is given R.L of B can be calculated.
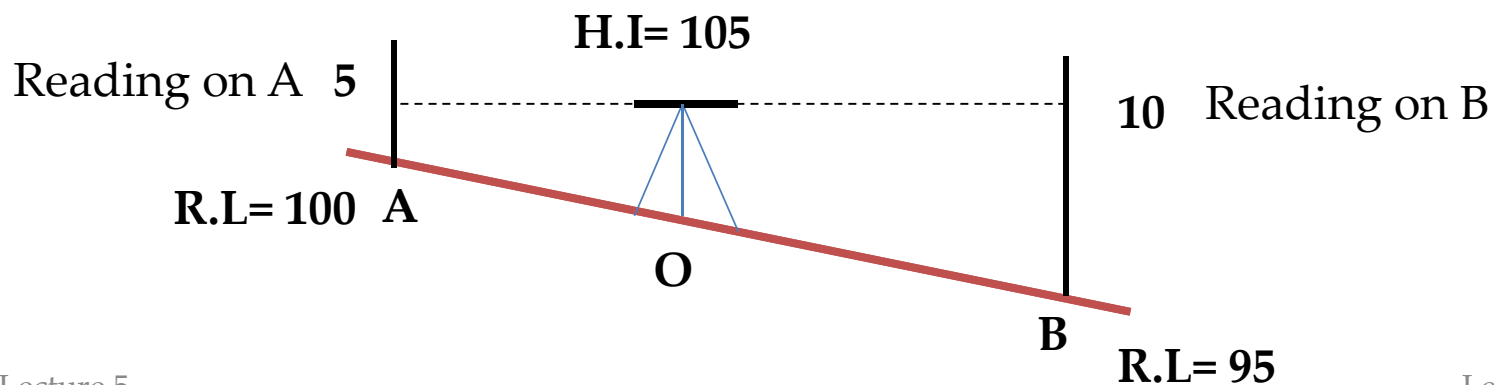
Principles of Leveling

B) Differential Levelling

- This method is used to find the difference in elevation between two point, when

1) They are too far apart or

2) If the difference in elevation between them is too great or

3) If there are obstacle intervening.

- In such case it is necessary to setup the level in several position and to work in a series of stages.

- Also called Compound or continues leveling.
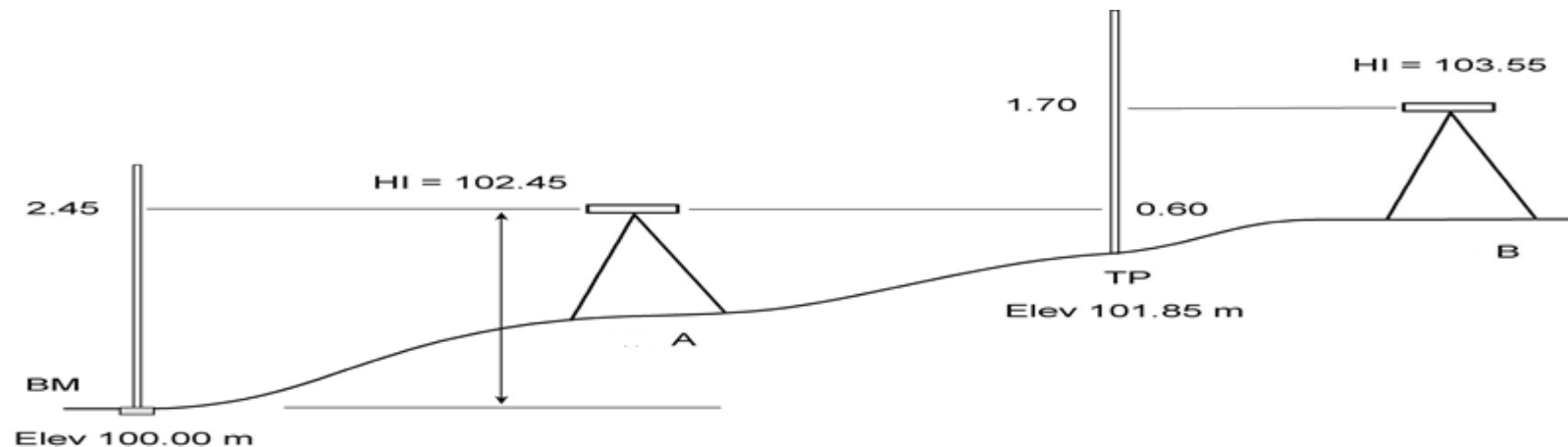
PROCEDURE IN LEVELING

- The level of set up at some convenient position **P1** and a back sight was taken

- to the first **BM**. The foot of the staff being held on **BM** and the staff held vertically.

- The staff is moved to points **A** and **B** in turn and readings taken. These are the intermediate sights respectively.

- In order to read **D**, a change point is chosen at **C** and the staff is moved to **C**. This is the foresight for the first point (**P1**).

- While the staff remains at **C1** the instrument is moved to another position (**P2**).
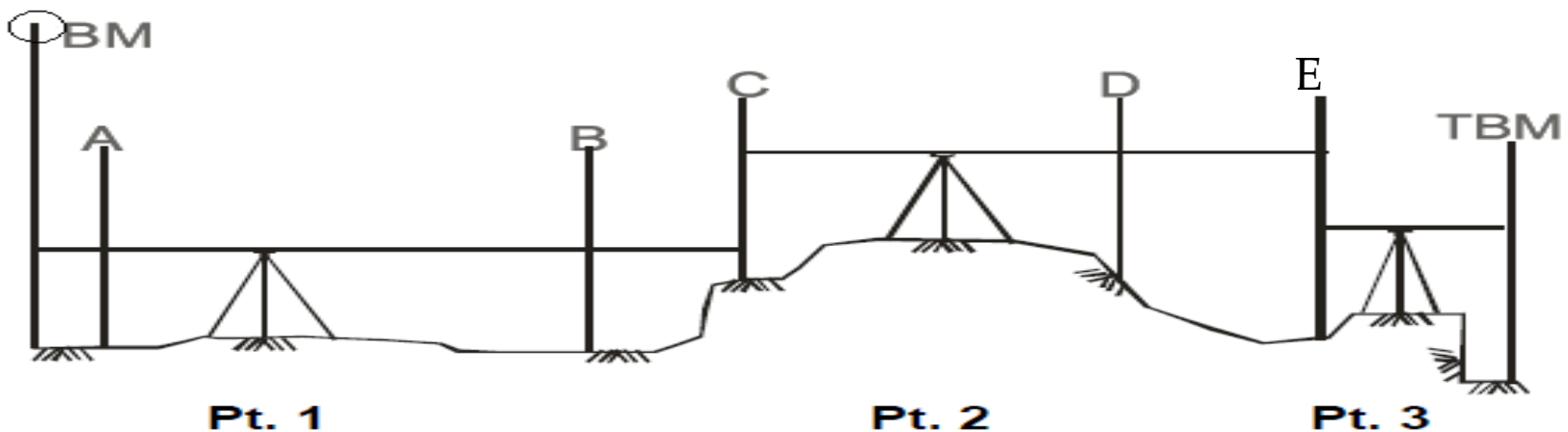
PROCEDURE IN LEVELING

- A reading is taken from the new position of the staff at **C**. This is the back sight for **P2**.

- The staff is moved to **D** and **E** in turn and the intermediate sight readings taken respectively.

- Finally, the level is moved to P3 and a back sight is taken to **E**, while the foresight is also taken to the final **TBM**.

- The final staff position is at a point of known reduced level as leveling field work must start and finish at points of known reduced level; otherwise it is not possible to detect misclosure in the leveling.

- **The R.L of TBM   = R.L of A + Σ B.S − Σ F.S**

- **The R.L of a Point = R.L of A + B.S − I.S**
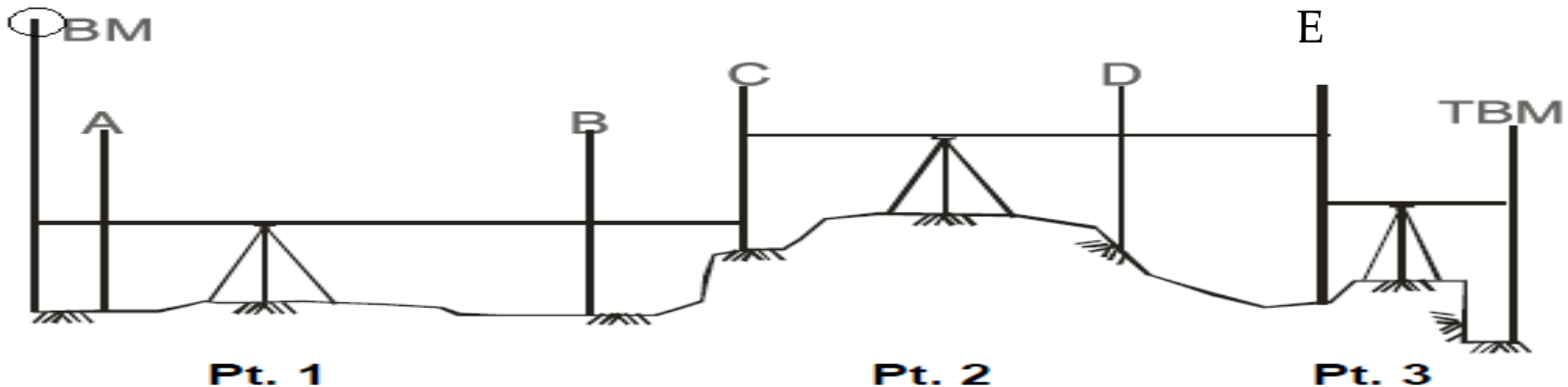
Reduction of Levels

There are two systems of working out the reduced levels of points from the staff reading taken in the field.

1) **The Collimation or Instrument height system**

2) **The Rise and fall system**

1) The Collimation or Instrument height system

It consist of finding the elevation of the plane of collimation (H.I) for every setup of the instrument and then obtaining the reduced levels of points with reference to respective plane of collimation.

On Completing the reduction of the levels, the accuracy of the arithmetical work should be checked.

Arithmetical Check:

*   The difference between the sum of BS and F.S should be equal to difference between last reading and first reading.

Σ B.S - Σ F.S   = Last reading – first reading

Example No 1

- The following staff readings were taken along a straight length of a road. Reduce the level and check the accuracy of the readings using Height of instrument method.

Station	Readings			Reduced Level	Remarks
	B.S	I.S	F.S		
A	2.390			100	B.M
B		1.985			
C		1.318			
D	0.988		1.612		
E		1.502			
F		1.415			
G	2.420		0.316		
			0.532		TBM

Station	Readings			R.L of Plane of Collimation (H.I)	Reduced Level	Remarks
	B.S	I.S	F.S			
A	2.390			102.390	100	B.M
B		1.985		102.390	100.405	
C		1.318		102.390	101.072	
D	0.988		1.612	101.766	100.778	C.P
E		1.502		101.766	100.264	
F		1.415		101.766	100.351	
G	2.420		0.316	103.870	101.45	C.P
T.B.M			0.532	103.870	103.338	TBM
	ΣB.S= 5.798		ΣF.S= 2.46			

BM

A

B

C

D

E F G

TBM

Pt. 1   Pt. 2   Pt. 3   28

The Collimation or Instrument height system

- **Arithmetical Check:**

- The difference between the BS and F.S should be equal to difference between last reading and first reading.

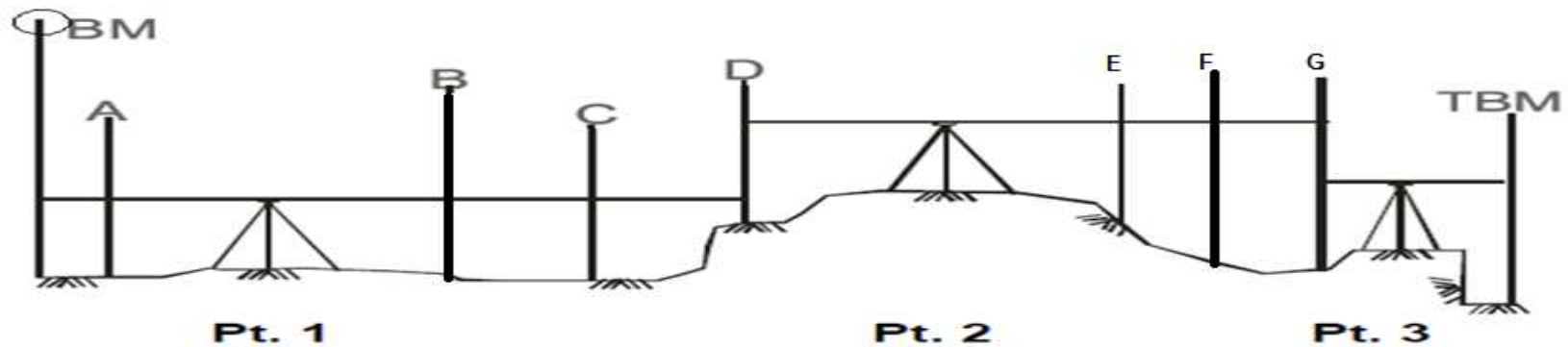$$\Sigma B.S - \Sigma F.S \quad = \quad \text{Last reading – first reading}$$

$$5.798 - 2.46 \ = 103.338\text{-}100$$

$$+3.338 \quad = +3.338$$

Example No 2

- The following consecutive readings were taken with dumpy level

0.894   1.643   2.896   3.016   0.954   0.692   0.582   0.251   1.532   0.996   2.135.

- The instrument was shifted after the fourth and eighth readings. The first reading was taken on staff held on the B.M of **R.L 820.765**

Station	Readings			Reduced Level	Remarks
	B.S	I.S	F.S		
A				820.765	B.M
B					
C					
D					
E					
F					
G					
H					
I					

Example No 2

Station	Readings			R.L of Plane of Collimation (H.I)	Reduced Level	Remarks
	B.S	I.S	F.S			
A	0.894				820.765	B.M
B		1.643				
C		2.896				
D	0.954		**3.016**			C.P
E		0.692				
F		0.582				
G	1.532		0.**251**			C.P
H		0.996				
I			2.135.			
	ΣB.S=		ΣF.S=			

Arithmetical Check:

Σ B.S - Σ F.S = Last reading – first reading

2) The Rise and Fall system

- It consist in determining the difference of level between consecutive points by comparing each point after the first with that immediately preceding it.

- The difference between their staff readings indicates a rise or fall according as the staff reading at the point is smaller or greater than that at the preceding point.

- The reduced level of each point is then found by adding rise and subtracting fall from reduced level of the preceding point.

Arithmetical Check:

The difference between the sum of BS and F.S should be equal to difference between last reading and first reading and equal to difference between the sum of Rise and Fall.

Σ B.S - Σ F.S = Σ Rise - Σ Fall   = Last reading – first reading
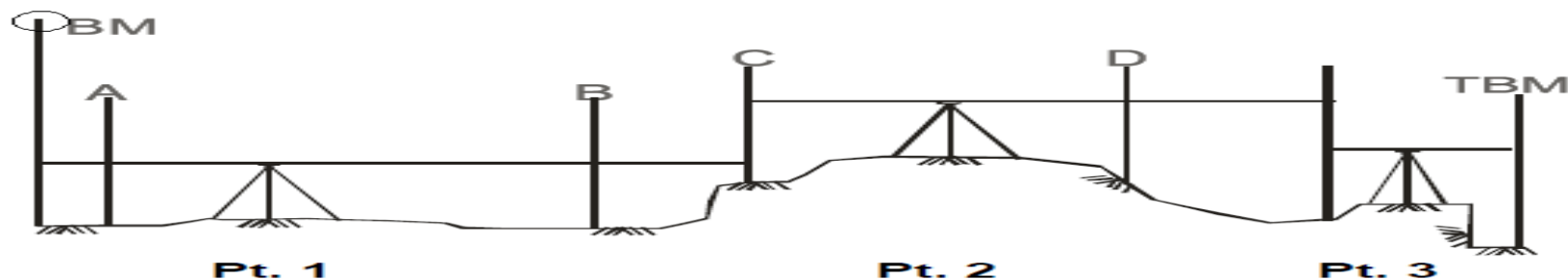
Example

- The following staff readings were taken along a straight length of a road. Reduce the level and check the accuracy of the readings using Rise and Fall method.

Station	Readings			Reduced Level	Remarks
	B.S	I.S	F.S		
A	2.390			100	B.M
B		1.985			
C		1.318			
D	0.988		1.612		
E		1.502			
F		1.415			
G	2.420		0.316		
			0.532		TBM

Station	Readings			Rise +	Fall -	Reduced Level	Remarks
	B.S	I.S	F.S				
A	2.390					100	B.M
B		1.985		0.405		100.405	
C		1.318		0.667		101.072	
D	0.988		1.612		0.294	100.778	C.P
E		1.502			0.514	100.264	
F		1.415		0.087		100.351	
G	2.420		0.316	1.099		101.45	C.P
			0.532	1.888		103.338	TBM
	ΣB.S= 5.798		ΣF.S= 2.46	ΣRise= 4.146	Σrise= 0.808		

BM

A

B

C

D

E F G

TBM

Pt. 1   Pt. 2   Pt. 3   34

2) The Rise and fall system

- **Arithmetical Check:**

- The difference between the sum of BS and F.S should be equal to difference between last reading and first reading and equal to difference between the sum of Rise and Fall.

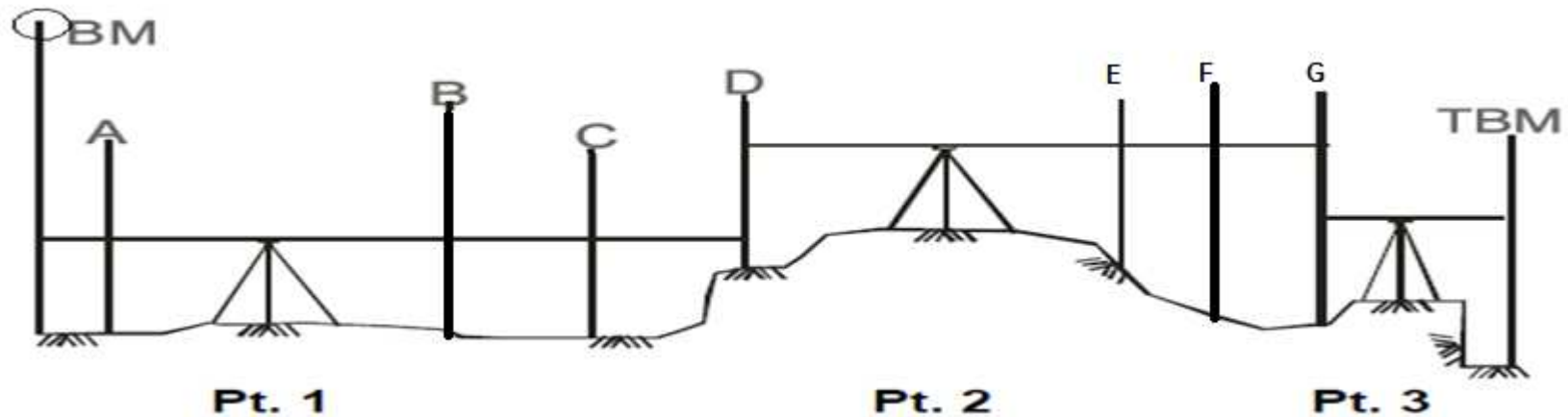Σ B.S - Σ F.S = Σ Rise - Σ Fall = Last reading – first reading

    5.798-2.46 = 4.146 - 0.808   = 103.338 – 100

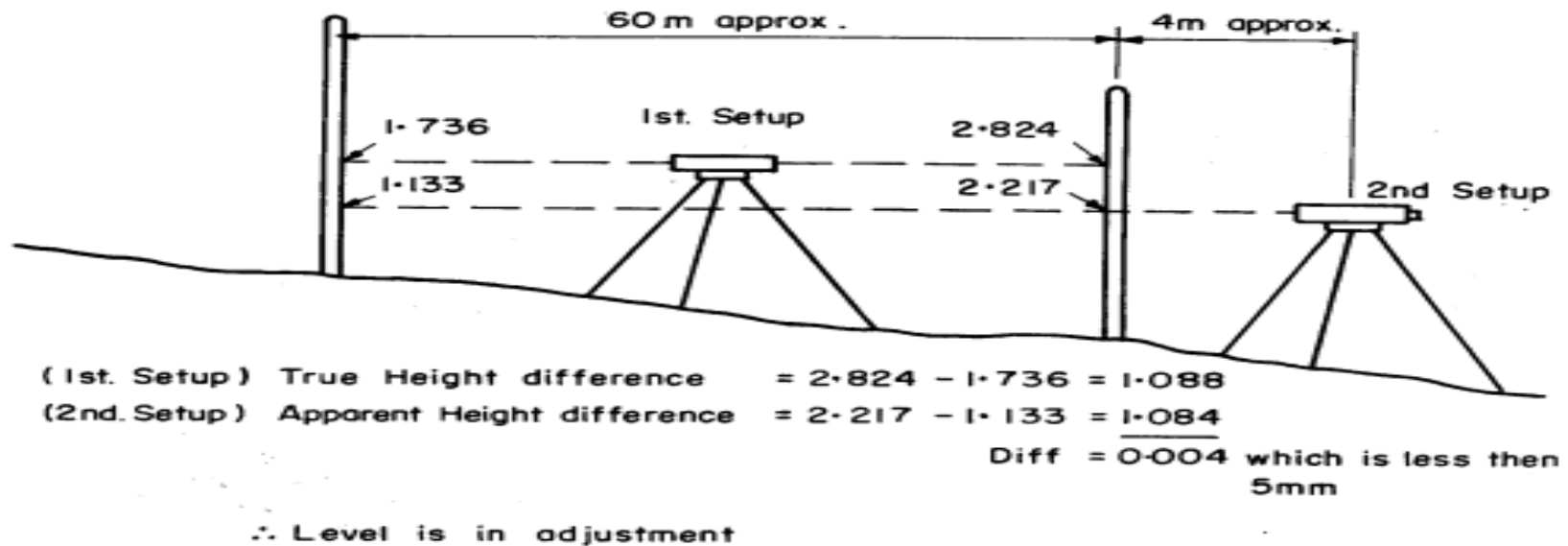   +3.338 =   +3.338   = +3.338

Assignment

Examples
Page 371 to 379
Page 381 to 383

COLLIMATION TEST (PEG TEST)

- Levels can move out of adjustment so that their line of sight (line of collimation) is not truly horizontal.

- This will cause errors in readings which become greater as the viewing distance increases.

- However if a backsight and a foresight are exactly equi-distant from the instrument, the error in each sighting will cancel each other out. This feature can be used to check the accuracy of a level by the following simple method.


```
60 m approx.                              4m approx.

1·736          Ist. Setup        2·824
1·133                            2·217                    2nd Setup
```

(Ist. Setup) True Height difference   = 2·824 − 1·736 = 1·088
(2nd. Setup) Apparent Height difference = 2·217 − 1·133 = 1·084

                                    Diff = 0·004 which is less then 5mm

∴ Level is in adjustment

Classification of Leveling

- ## Differential leveling

It is the operation of leveling to determine the elevation of points some distance apart or to establish B.M. the process is same as that in continuous or compound leveling.

- ## Check leveling

It is the operation of running levels for the purpose of checking a series of levels, which have been previously fixed.

- ## Profile Leveling

It is the operation in which the object is to determine the elevation of points at known distance apart along a given line ,also called longitudinal leveling or Sectioning.

- ## Cross-sectioning

It is the method of leveling to determine the surface undulations or the outline of the ground transverse to the given line and on either side of it.

Classification of Leveling

- **Reciprocal Leveling**

It is the method of leveling in which the difference in elevation between two points is accurately determined by two sets of observation, when I is not possible to set up the level midway between the two points.

- **Barometric Leveling**

it is the method of leveling in which the altitudes of points are determined by means of a barometer, which measures the atmospheric pressure.

- **Hypsometric Leveling**

It is the method of leveling in which the height of mountains are found by overseeing the temperature at which water boils.

- **Trigonometrical Leveling**

It is the process of leveling in which the elevations of points are computed from vertical angles and horizontal distances measured in the field.

USES OF LEVELLING

Apart from the determination of difference in level between points on earth's surface, other uses of leveling include.

**(1) Taking of longitudinal section**

(2) Cross- sections

(3) Contouring

(4) Setting out levels

- **Plan view –** look down on area from above.

- **Profile view –** side view or elevation where longitudinal surfaces highlighted

- **Cross-section –** shows end view of section at a station and is at right angles to centerline

Profile Leveling

- In this method also called longitudinal leveling or Sectioning, the object of leveling operations is to determine the undulations of ground surface along a predefined line, which is usually the center line of a road, railway, canal or pipeline. The line section may be a single straight line or may consist of a series of straight lines changing direction or connected by curves.

- Profile leveling yields elevations at definite points along a reference line.
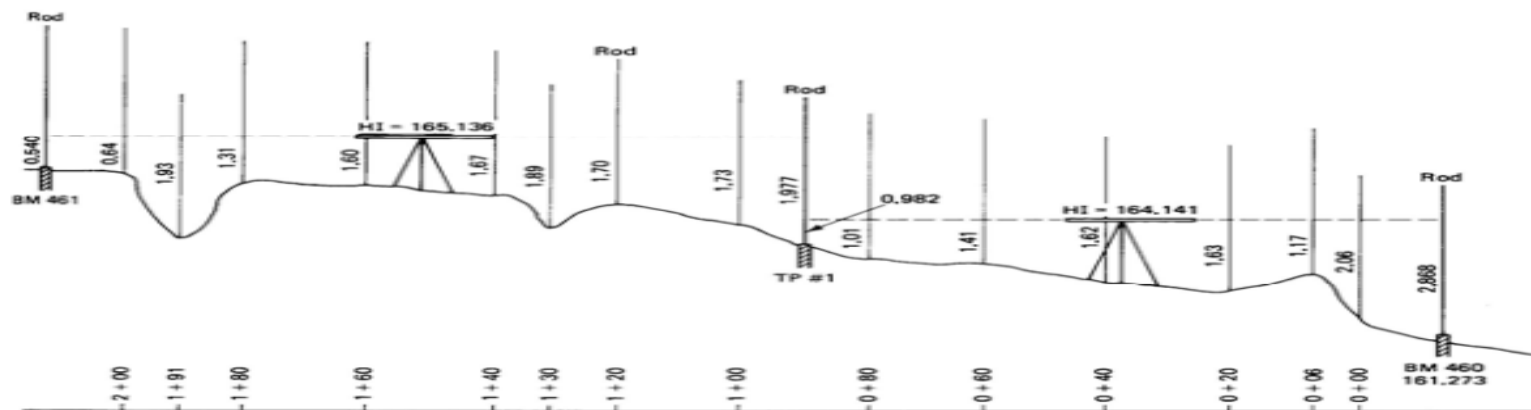
Profile Leveling
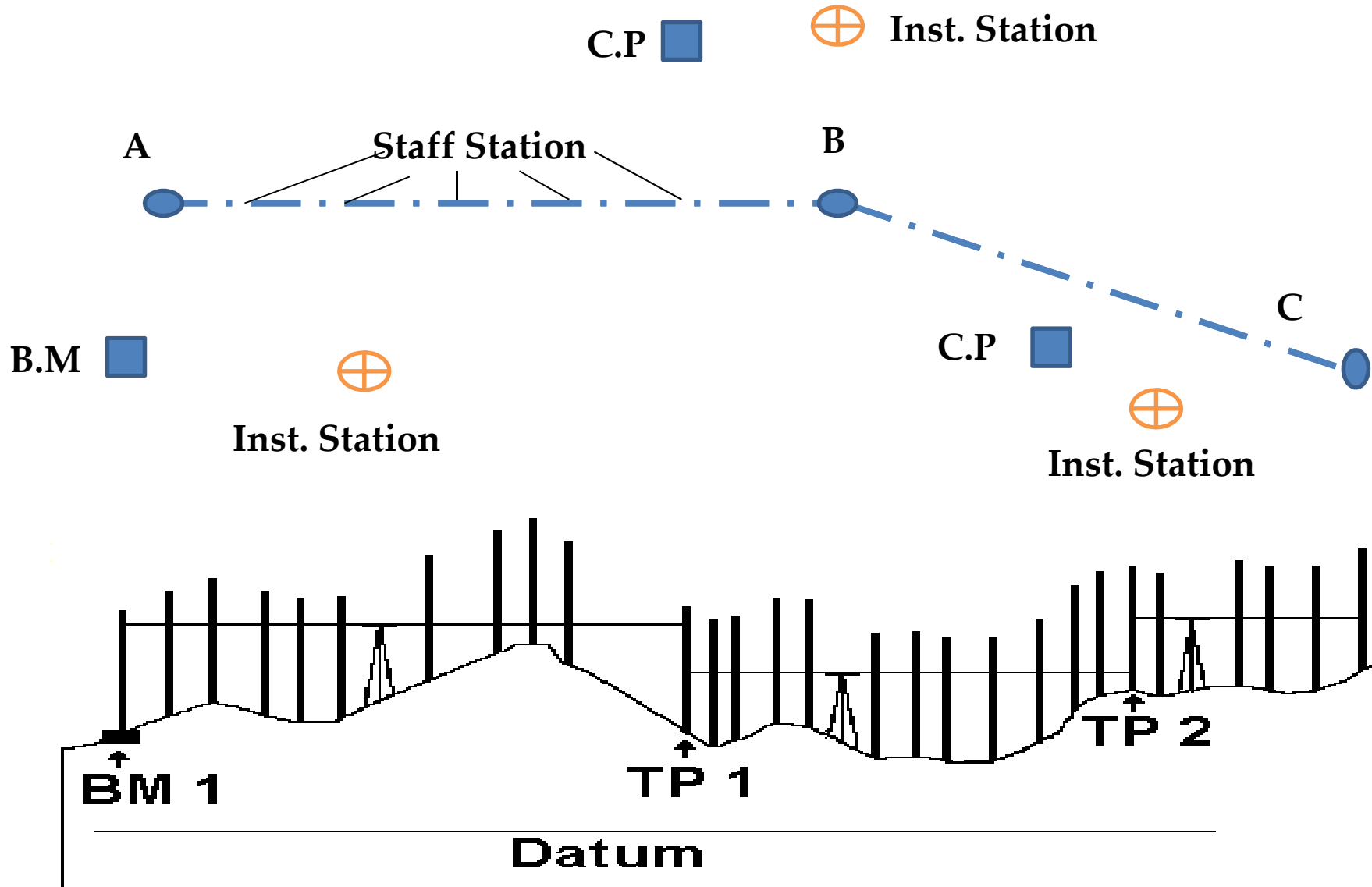
The level is usually set up off the center line.

Procedure

- Add rod readings (BS) to benchmark or known turning point elevations to get the elevation of the line of sight (HI).
  Subtract rod readings (FS) from the line of sight to establish elevations of unknown points.

- Take any number of intermediate Sight readings at points along the line until it is necessary to establish a turning point to move the level.

- Repeat as required.

LOCATION OF INTERMEDIATE POINTS

- A Back sight is taken on a bench mark to establish the height of instrument.

- A foresight is taken on the stations as required (such as every 100 ft).
  Foresights(Intermediate) are also taken at breaks in the ground surface and at critical points.
  This is repeated until the limit of accurate sighting is reached, at which point a turning point is established and the level is moved

Assignment

Example on Profile Leveling

On page 386 to 390

+

Plotting Profile

PROFILE CROSS SECTIONS

- Cross sections are lines of levels or short profiles made perpendicular to the center line of the project.

- For example, taking a cross section profile of a stream bed while doing a profile survey of the stream.

- Cross sections are usually taken at regular intervals and at sudden changes in the center-line profile

CROSS SECTION FIELD NOTES

- Field notes for a cross section should include: an elevation or difference in elevation from the center line
horizontal distance from the center line

Centre Line

Precise Leveling

- Precise leveling is a particularly accurate method of differential leveling which uses highly accurate levels and with a more rigorous observing procedure than general engineering leveling.

- It aims to achieve high orders of accuracy.

- It is a special system of leveling chiefly employed for establishing Benchmarks with high precision at widely distributed points.

- It is principally conducted by State Agency such Survey Department of Pakistan.

- It required highly refined instruments and methods and greatest Care in the field.

References

- Surveying & Leveling (part 1) by T P Kanetkar & S V Kulkarni
(Part 1)