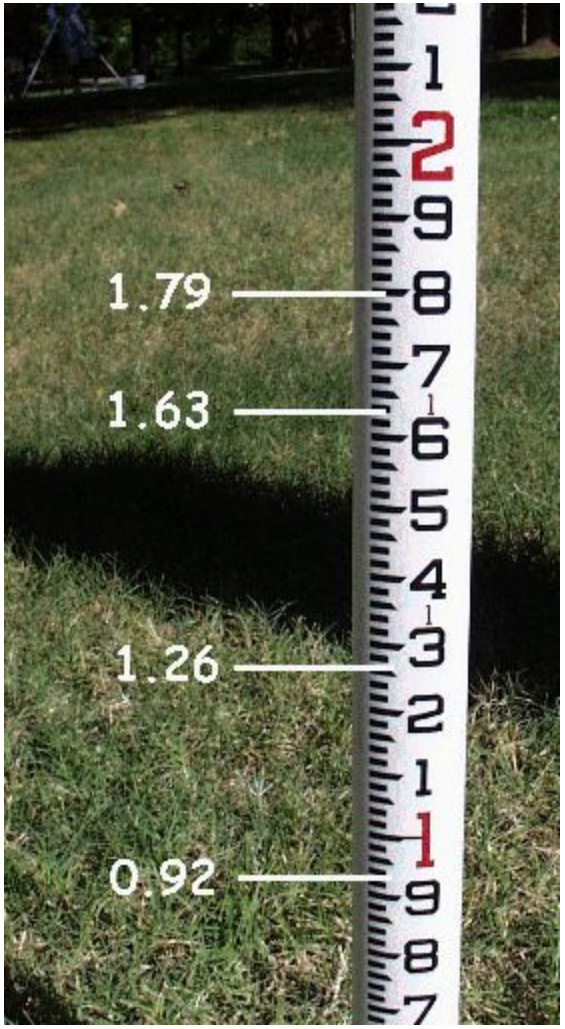
Leveling

Level Instrument



Introduction :- the art of determining relative altitudes of points on the surface of the earth or beneath the surface of the earth is called levelling. This branch of surveying deals with measurements in vertical planes.

For execution of engineering projects, such as railways , highways, canals, dams, water supply and sanitary schemes it is necessary to determine elevations of different points along the alignments of the proposed projects. Success of such projects depends upon accurate networks of heights ,covering the entire area of the project.

Levelling is of prime importance to the engineers, both in acquiring data for the design of the projects and also during the execution.

Auto Level

Telescope

Mirror

Bulls Eye Level

Horizontal Tangent Knob

Horizontal Angle Rotation Ring

Sight

Diopter Adjustment Ring

Eyepiece

Leveling Screws

Equipment: Tripod

- Wooden design or aluminum
  - From “easy to sit” to “ops, this is high”

Leveling

Importance of Leveling

- The determination of elevations is called ***leveling***
- Measuring relative elevations changes is a comparatively simply process
- Precise and accurate control of relative elevations are critical to most construction projects

The level :- the instruments which is used for leveling is known as level. It consists of essentially of the following parts.

i. A telescope to provide line of sight.
ii. A level tube to make the line of sight horizontal.
iii. A levelling head to bring the bubble of the tube level at the centre of its run.

A tripod to support the above three parts of the level.

Telescope :_ it is an optical instrument used for magnifying and viewing the images of distant objects. A surveying telescope is similar to Kepler's telescope. It consists of two convex fitted in a tube. The lens fitted near the eye, is called the eyepiece and the other fitted t the end nearer to the object, is called the objective.

Equipment: Level Instrument

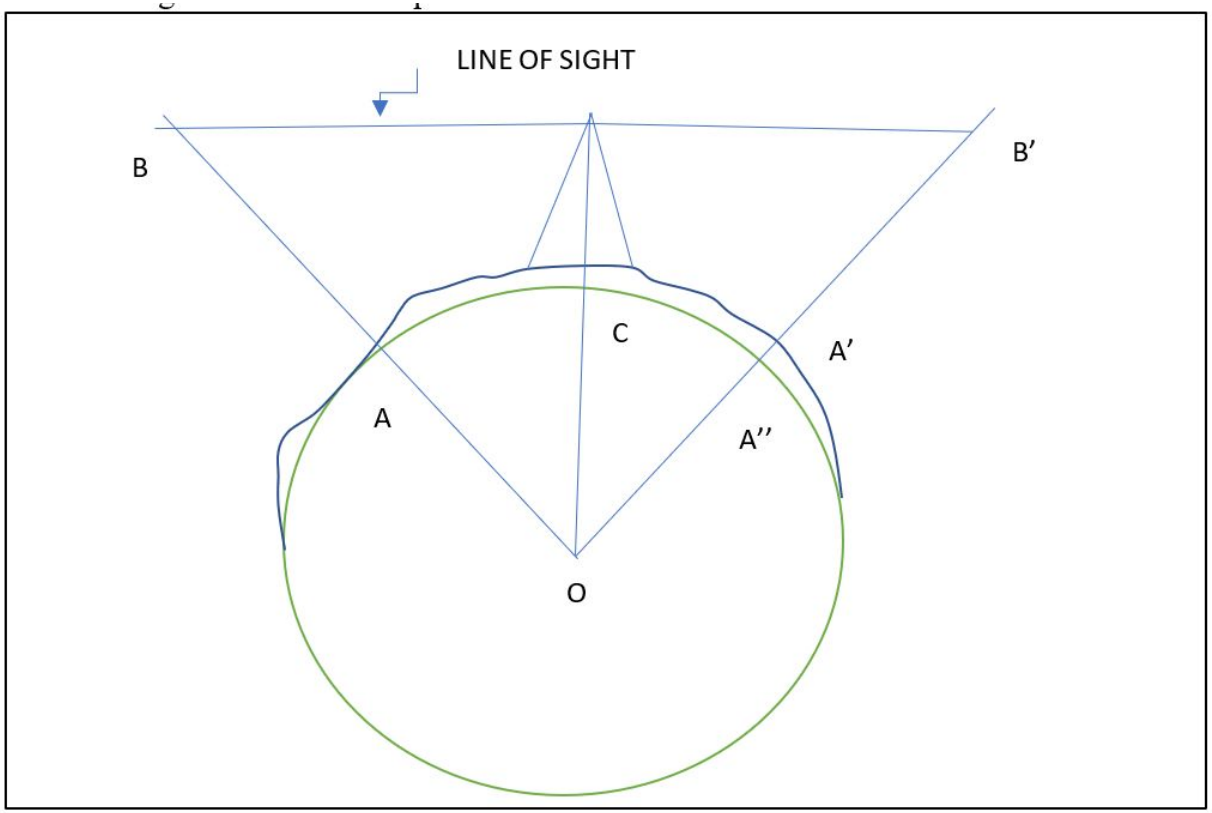
- Automated Levels
  - Easy to use (not power!)
  - Needs experience
  - Robust even in hostile environment
- Digital Levels
  - Push-button technique
  - No reading errors, special staff
  - Readings are stored and analyzed digitally

The Level

- A ***level*** consist of a high-powered telescope
- The level is attached to a spirit or bubble level that keeps the line of sight of the telescope horizontal

Principle of levelling

- Principle of levelling :- The principle of levelling lies in furnishing a horizontal line of sight and finding the vertical distances of the points above or below the line of sight . the line of sight is provided with level and a graduated levelling staff is used for measuring the height of line of sight above the staff positions.



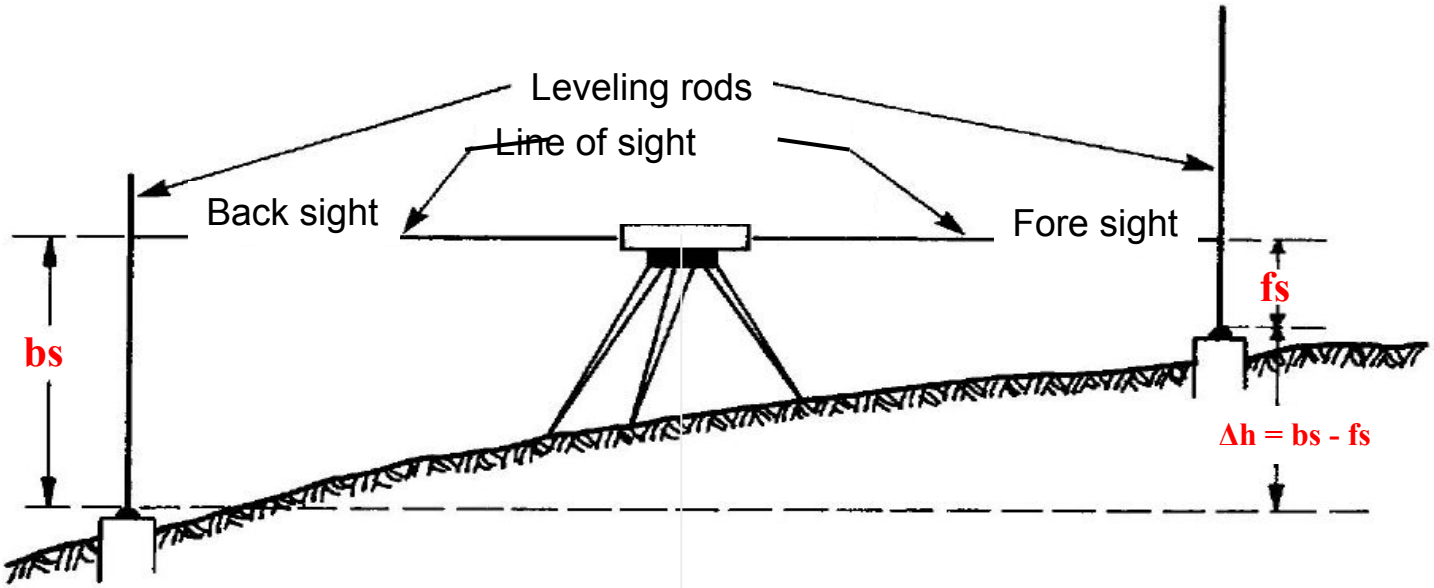
In fig. 1. Let O represent the centre of the earth . A and A' are the points whose difference of elevation is required. C is the position of the level. The line CO is the direction of the plum line . BB' represent the line of sight which is perpendicular to CO . AB and A'B' are the readings on a staff vertically held at A and A' respectively.

OA+AB =OA''+A''A'+A'B' or

AB-A'B' = A''A' = δh (since OA= OA'')

Basic Principle of Leveling

- Measures height differences between points
  - Along a line
  - Several points from one occupation



Technical term used in levelling

1. Level surface the surface which is parallel to the mean spheroidal surface of the earth is known as level surface . every point on this surface is equidistant from the centre of the earth . it is also normal to the plumb line at every point . the surface of still water in a lake represents a level surface.
2. Level line :- a line lying on the level surface is known as level line.
3. Horizontal surface :- a surface tangential to the level surface at any point is known as horizontal surface.
4. Datum surface :- the imaginary level surface with reference to which vertical distances of the points are measured is called datum surface.

5. Mean sea level :- the Mean Sea Level (MSL) datum is obtained by making hourly observation of the tides at any place (sea coast) over aa period of 19 years is known as mean sea level . The MSL datum is adopted by Survey of India for determining the elevations of different points in India is that of Mumbai.

6 Reduced level (RL) the height of depth) of a point above or below the assumed datum is called reduced level. (RL) it is also known as elevation of the point.

7 Line of sight :- the line passing through the optical centre of the objective , traversing the eyepiece and entering the eye, is called the line of sight.

8 Line of collimation :_ the line passing through the optical centre of the objective and the point of the intersection of the cross hairs stretched in front of the eye piece and its continuation is called the lie of collimation.

9 Bench Mark (BM) a relatively permanent and fixed reference point of known elevation above the assumed datum is called a bench mark.

Special Terms and their Abbreviations used in levelling

1. Instrument stations :- the point where the station is set up for observations is called Instrument station.
2. Station:- the point where levelling staff is held is called station. It is the point whose elevation is to be determined or the point that is to be established at a given elevation.
3. Height of instruments :- the elevation of the line of sight with respect to the assumed datum is known as height of instrument.
4. Back sight :- the first sight taken on a levelling staff held at point of known elevation (BM) is known as back sight . back sight enables the surveyors to obtain the height of the instruments.
5. Fore sight :- (F.S.) the sight taken on a levelling staff held at point of unknown elevation to ascertain the amount by which the point is abobe or below the line of sight , is called fore sight. Fore sight enables the surveyor to obtain the elevation of the point. It is also generally known as minus sight as fore sight readings are always subtracted from the height of the instrument.
6. Intermediate points :- the fore sight taken on a levelling staff held at a point between two turning points, to determine the elevation of that point, is known as intermediate sight . it my be noted that for one setting of level , there will be only a back sight and fore sight but there can be number of intermediate sights.

Bench Marks

- Bench Marks :- depending upon the permanency and precision , bench marks may be divided into the following types.

1. G.T.S bench mark 2. Permanent Bench marks
2. Arbitrary BM 4. Temporary BM
3. G.T.S BM :- these Bench Marks are established by the Survey of India with greatest precision at an interval of about 100km all over the country. Their elevations refer to the Mean sea Level (MSL) datum obtained by hourly observation of tides over a period of 19 years at Mumbai port. G.T.S bench Marks falling in the belts of the area bounded by 1 latitude by 1 longitude are published in leveling pamphlets. These are also depicted on topo maps published by SOI and their elevations are correct to two places of decimal of a meter are entered.
4. Permanent BM :- Permanent BM are established between GTS BM on a clearly defined and permanents in nature or cultural detail points such as isolated rocks, culverts, KM stones, Railway platform, PWD, Forest GH. Inspection Bungalows etc.
5. Arbitrary Bench Marks:- These are the reference points whose elevations are arbitrarily assumed for small levelling operations. Their elevations do not refer to any fixed datums as in case of GTS or Permanent BMs.
6. Temporary Bench marks :- these are the reference points on which a days work is closed and from where levelling is continued next day in the absence of permanent BM. Their elevations are referred to as the reduced levels. Such Bms should be carefully established on permanent detail points such as Km stones, Parapets , floor of verandah , roots of old trees etc.

CLASSIFICATION OF LEVELLING

- Levelling may be classified into two main types

1. Simple levelling
2. Differential leveling

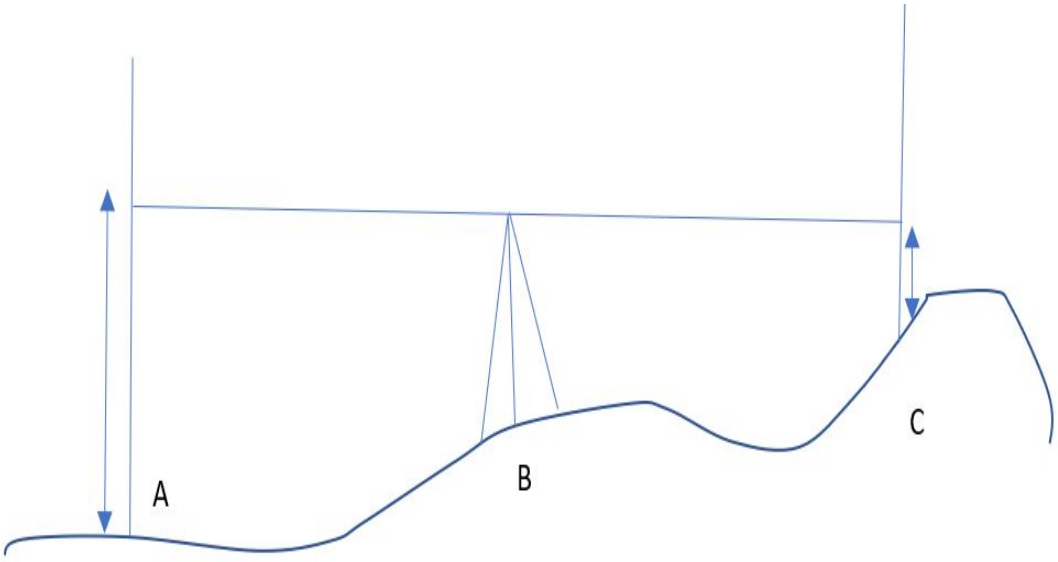
Height Determination Techniques

- Trigonometric Heights (Technique called Triangulation in which a network of Survey stations in the form of triangles are observed . Using Theodolite (surveying instrument) vertical angles are observed from the occupied place of observation to the distant objects using trigonometric formula we may deduce trigonometric heights of the un occupied / occupied place of observation.
- Barometric Heights (Aneroid pressure barometer is used to determine heights of different objects (mountains, peaks, ridges, etc.)
- Spirit Leveling Heights (most common , reliable and accurate height determination method used in Engineering surveys where altitude difference plays a vital role in fluid flow mechanism.
- Hypsometric Heights (simplest way of knowing the altitude difference between two distant objects lying in rough terrain where height information are of primary importance . An instrument called hypsometer is used in the field to take observations.

Definitions

- **Back sight (BS)**
  - The *first* reading from a new instrument stand point (i.e. take the height to the instrument)
- **Fore sight (FS)**
  - The *last* reading from the current instrument station (i.e. give the height to a benchmark)
- **Intermediate sight (IS)**
  - Any sighting that is not a back sight or fore sight

Simple Leveling

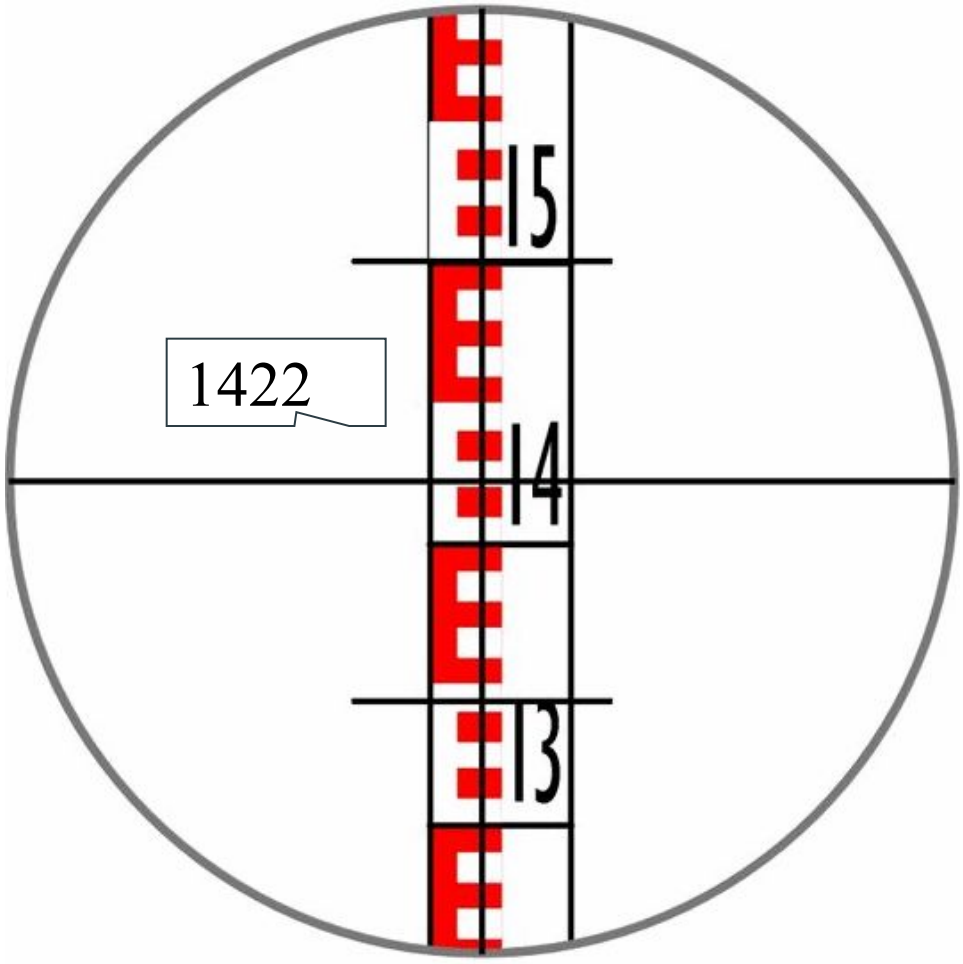


- Simple Leveling :- the operations of levelling for determining the difference in elevation if not too great.
- Suppose A and C are two points whose difference in elevation is required with a level setup at B . to eliminate the effect of the Earth curvature and instrumental errors it is always advisable to place the staves at equal distance.

Booking and Reduction of the Levels

- Rise and Fall method :- in this method the difference of level between two consecutive points for each setting of the instrument is obtained by comparing their staff readings. The difference in their staff readings indicated a rise if the back staff reading is more than the fore sight. And a fall if back sight reading is less than the fore sight. The rise and fall worked out for all the points give the vertical distance of each point relative to the preceding one. If R.L of back staff point is known, then R.L of the following point may be obtained by adding its rise or fall from the reduced level of preceding point as the case may be.

Reading a Staff



STN	B.S	I.S	F.S	RISE	FALL	R.L	REMARKS
1	0.585					100.000	B.M
2	1.855		2.955		2.370	97.630	CULVERT
3.		1.265		0.590		98.220	P1
4		2.925			1.660	97.560	P2
5	2.350		0.350	2.575		99.135	P3
6		2.855			0.505	98.630	P4
7	2.685		1.655	1.200		99.830	P5
8			2.435	0.250		100.080	B.M
TOTAL	7.475		7.395	4.615	4.535		

Arithmetic Checks

- The difference between the sum of the back sights and the sum of the fore sights should be equal to the difference of the sum of rises and the sum of falls and should also be equal to the difference between the R.L of the last point and that of the first point.
- $\Sigma B.S - \Sigma F.S =$ Sum (Rise) -Sum (fall) = Last R.L – First R.L
- i.e. 7.475-7.395= 4.615-4.535 = 100.080-100-000 = 0.080.
- in this method of reduction a complete check on intermediate sights also is provided because these are included in rise and falls.

Gradient of Line = Horizontal distances/ Difference in level

- A gradient of a line joining two points is calculated as under:-
- Procedure :-

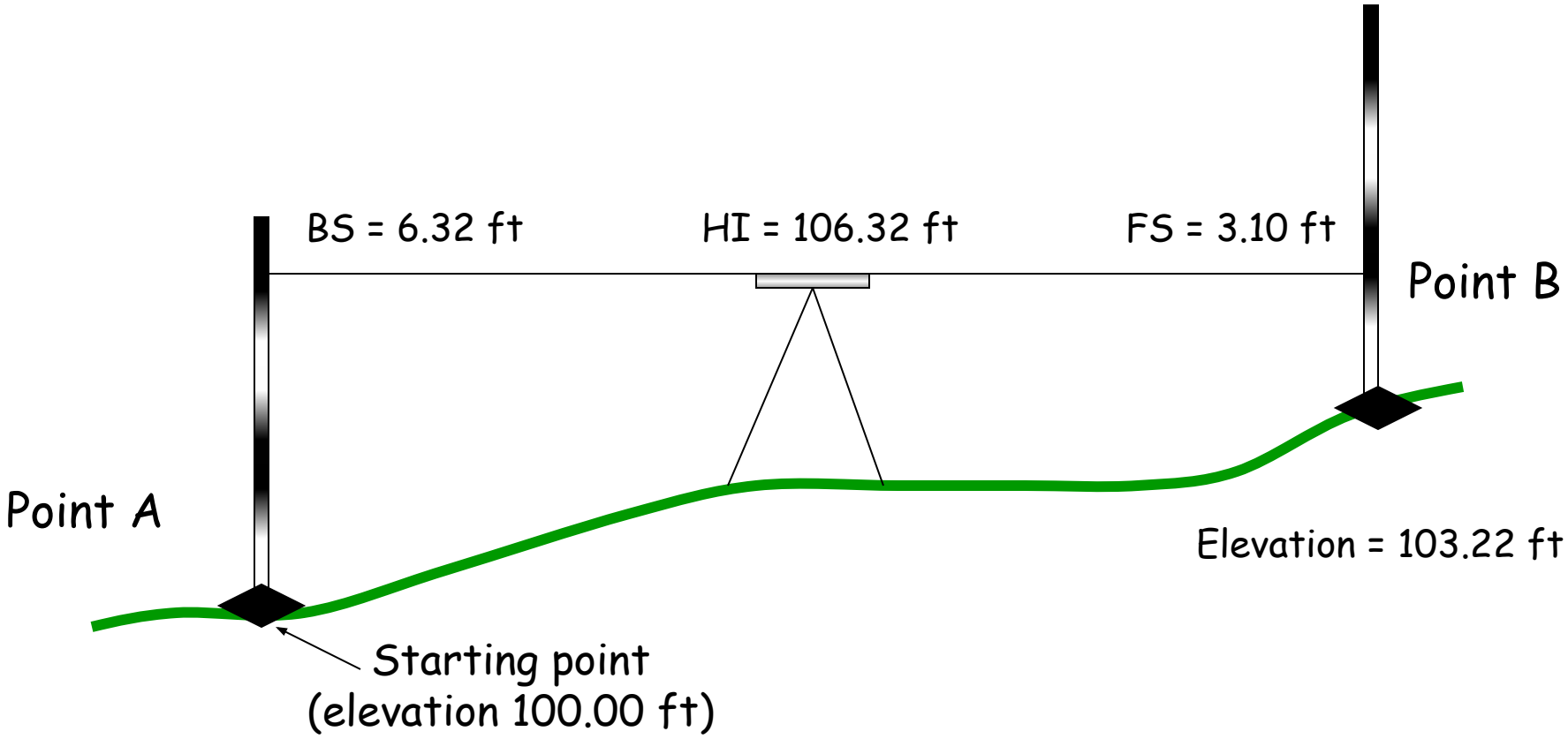
1. Calculate the R.L of each station.
2. Apply usual arithmetical checks to the calculations.
3. Calculate the difference in level of the given two points
   - i.e. R.L of Last point- R.L of first point.

- If the R.L of last point is more compared to that of first point , the gradient is positive or rising gradient. On the other hand, if the R.L of last point is less , it is negative gradient or down gradient.
- Calculate the distance between the end point. It is equal to *nxd* , where *n* is the total number of fore sight readings on the straight line joining the end point and *d* is the constant distant between the consecutive stations.

Digital Levels

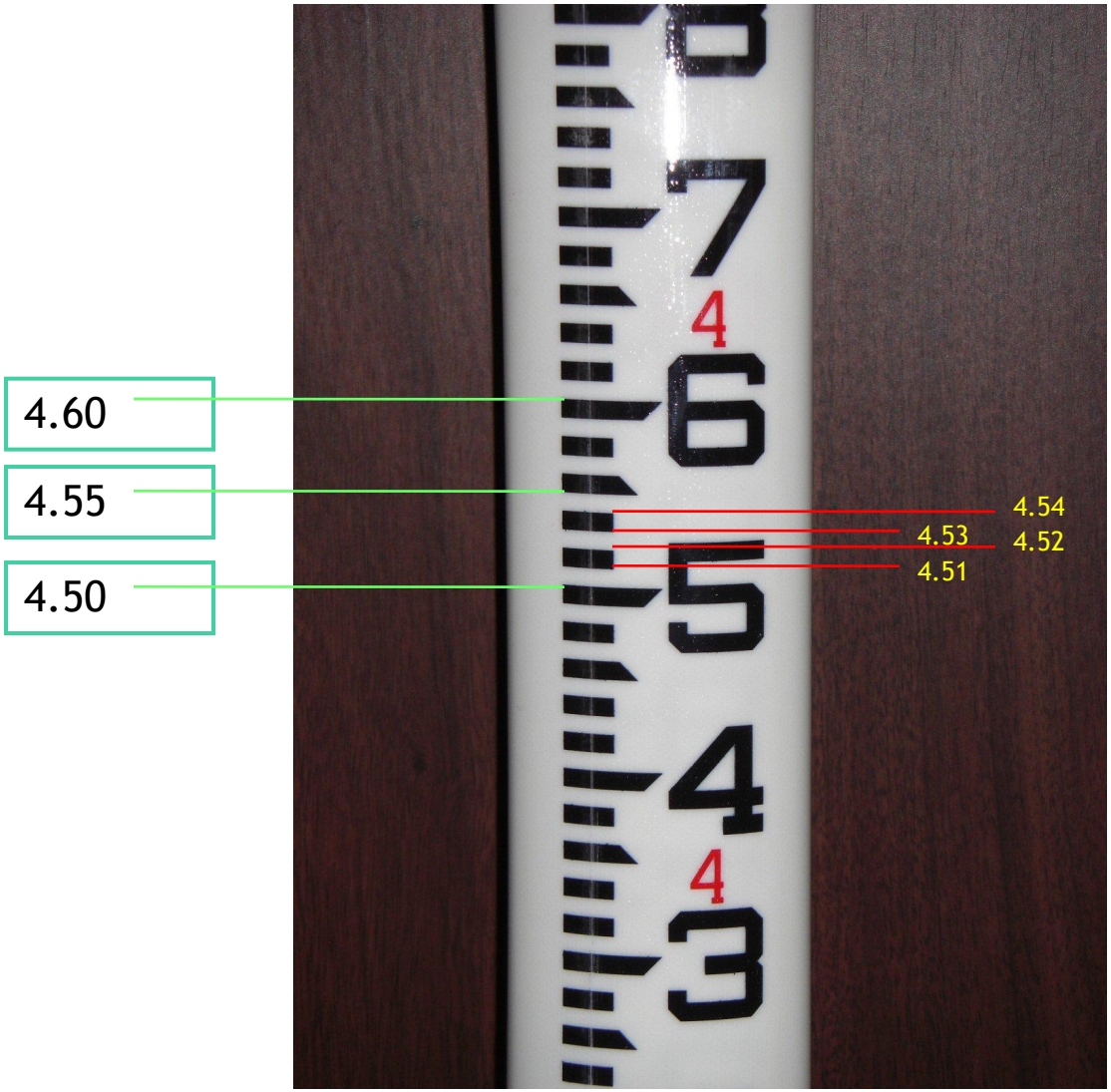
- Uses Barcode staffs
- Internal storage of data
  - Download to the computer
  - Automated height computation + adjustment
  - *No feeling for quality anymore*
  - *You frequently need power plugs*

Differential Leveling



Differential Leveling

Level Instrument



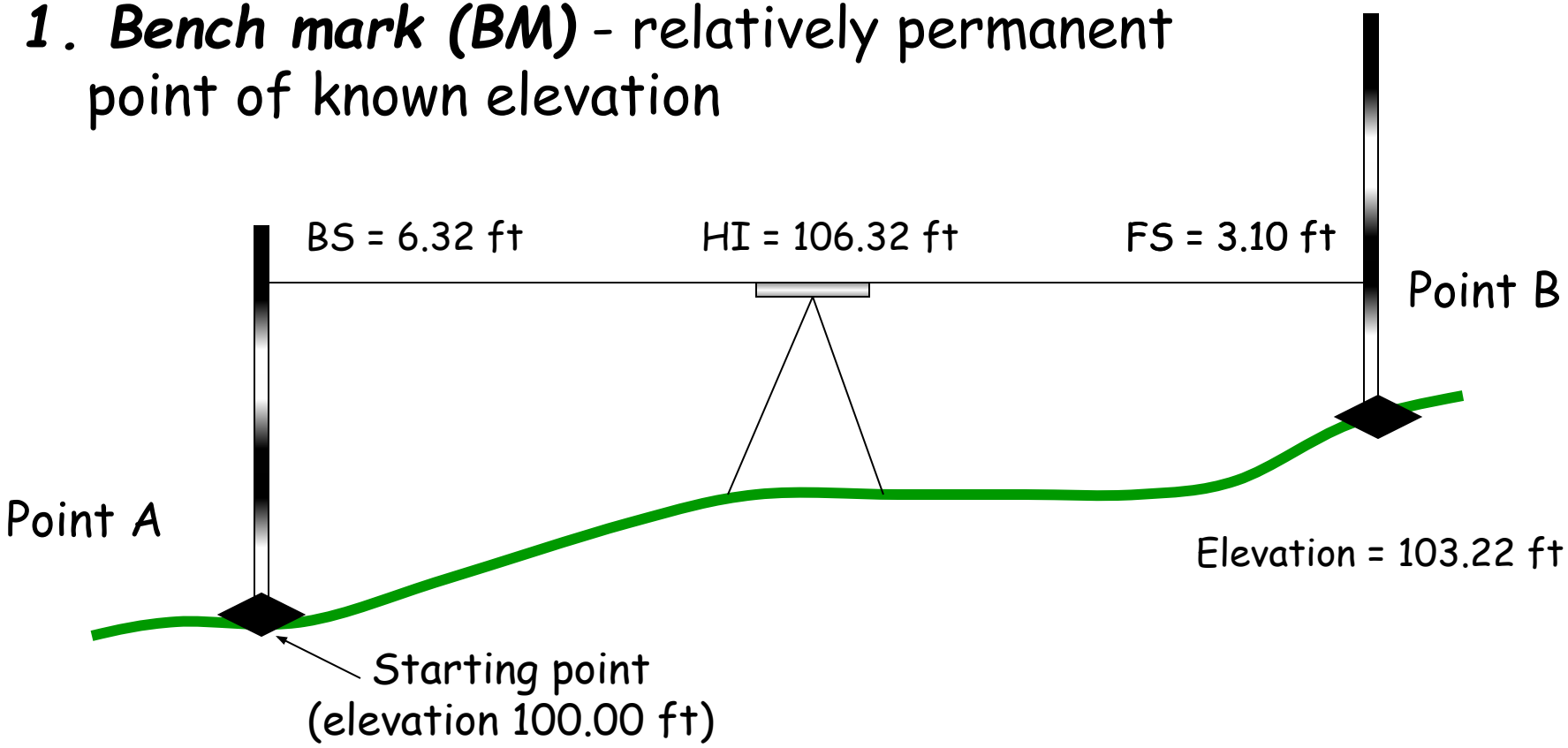
Basic Rules for Leveling

- Always start and finish a leveling run on a Benchmark (BM or TGBM) and close the loops
- Keep fore sight and back sight distances as equal as possible
- Keep *lines of sight* short (normally < 50m)
- Never read below 0.5m on a staff (refraction)
- Use stable, well defined change points
- Beware of shadowing effects and crossing waters

Differential Leveling

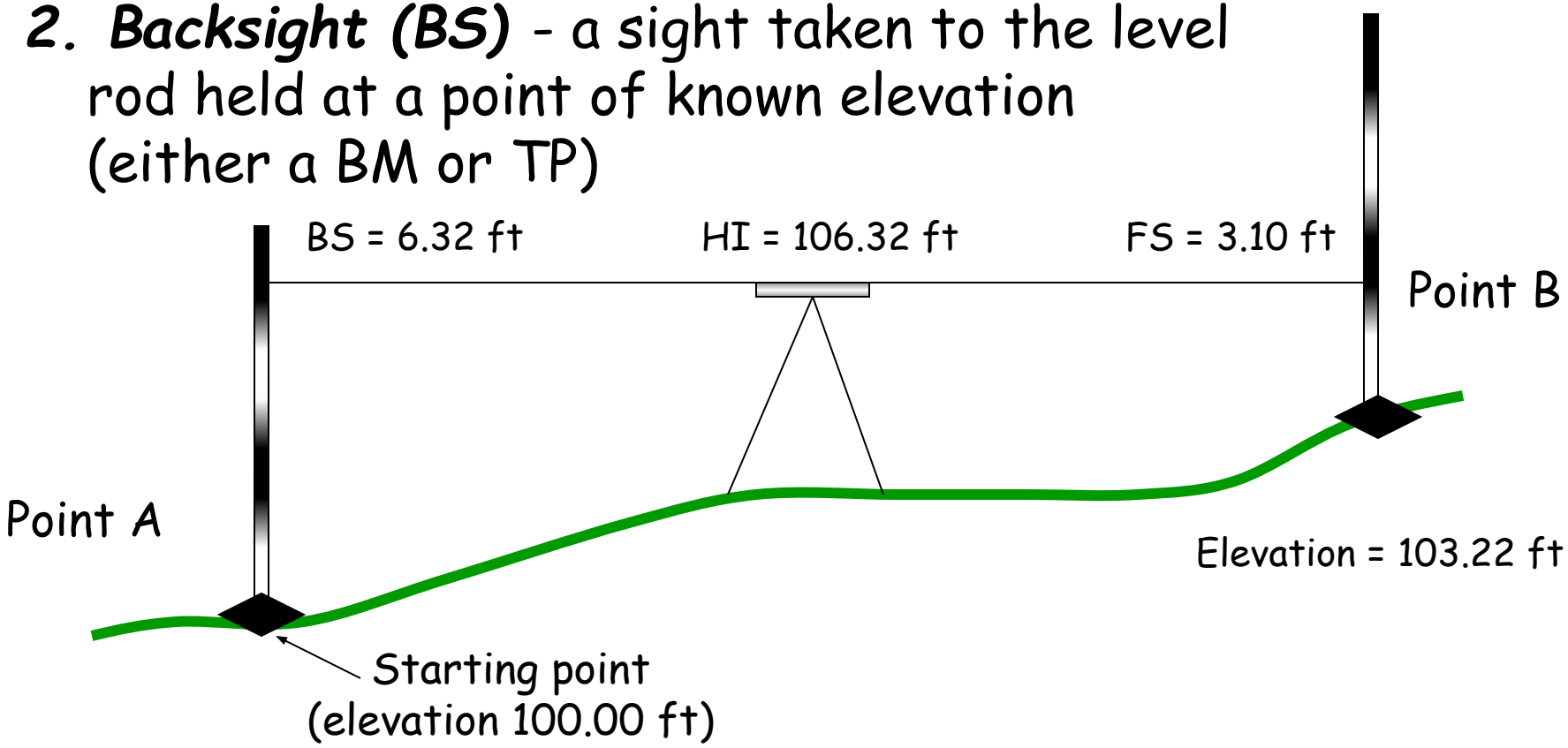
Definitions

1. ***Bench mark (BM)*** - relatively permanent point of known elevation



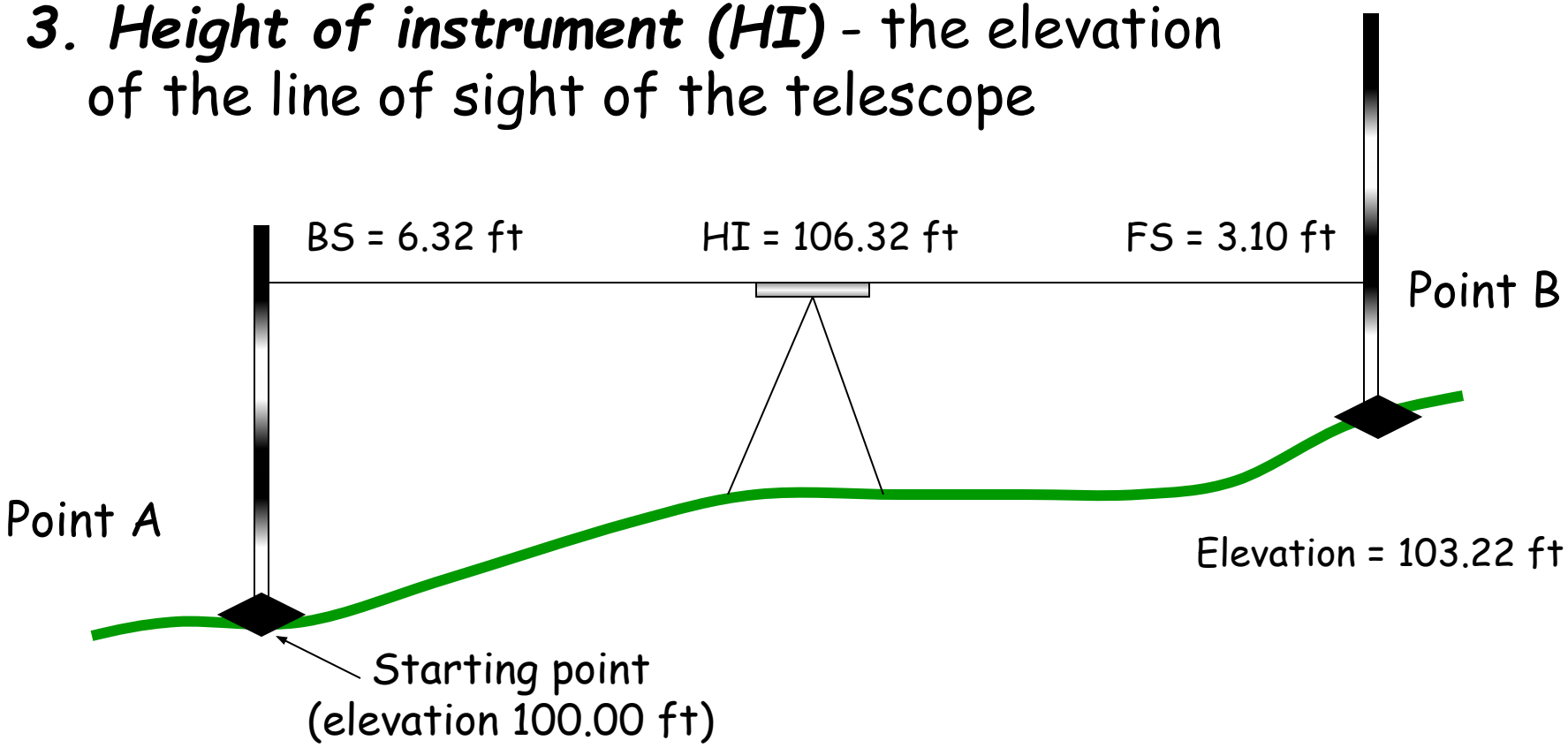
Differential Leveling

2. ***Backsight (BS)*** - a sight taken to the level rod held at a point of known elevation (either a BM or TP)



Differential Leveling

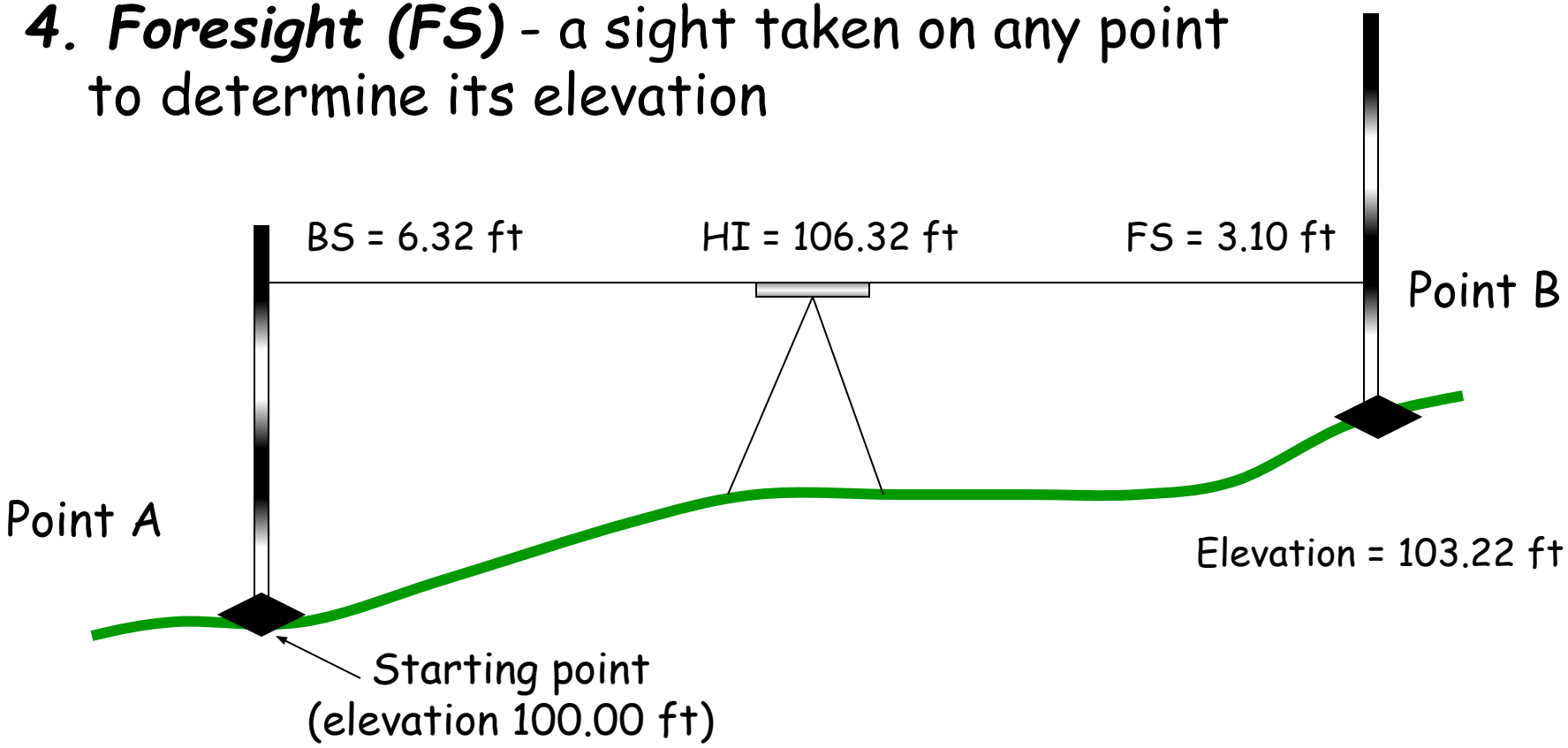
3. ***Height of instrument (HI)*** - the elevation of the line of sight of the telescope



Differential Leveling

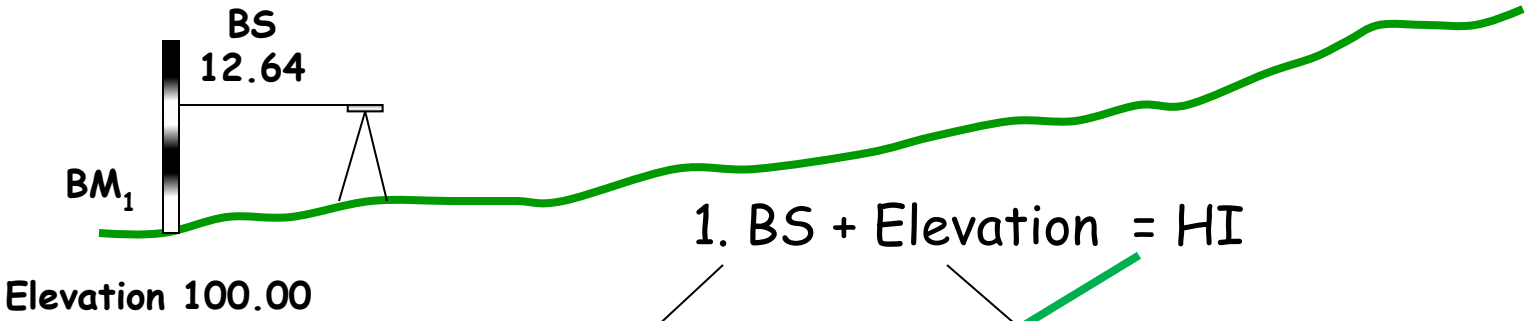
Definitions

4. ***Foresight (FS)*** - a sight taken on any point to determine its elevation



Differential Leveling

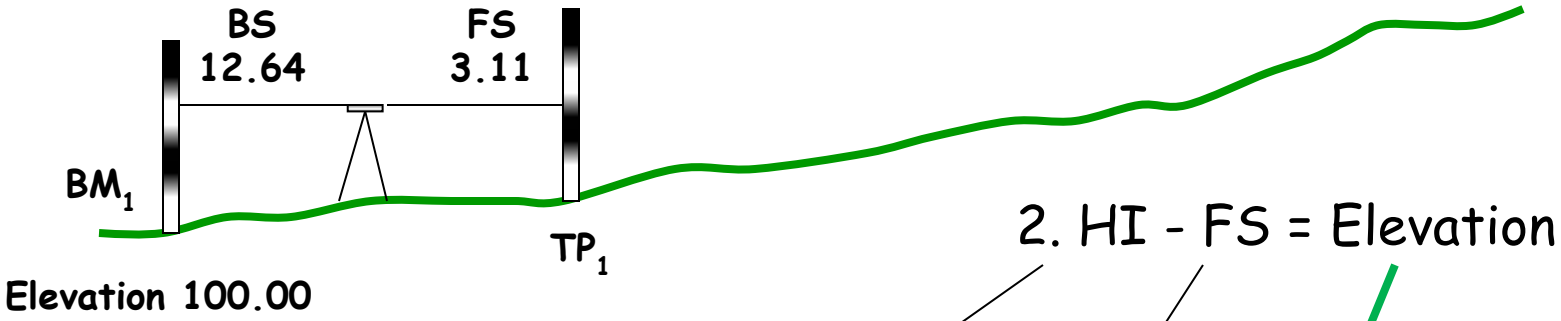
Computation of Elevations



Point	BS	HI	FS	Elevation
BM_1	12.64	112.64		100.00

Differential Leveling

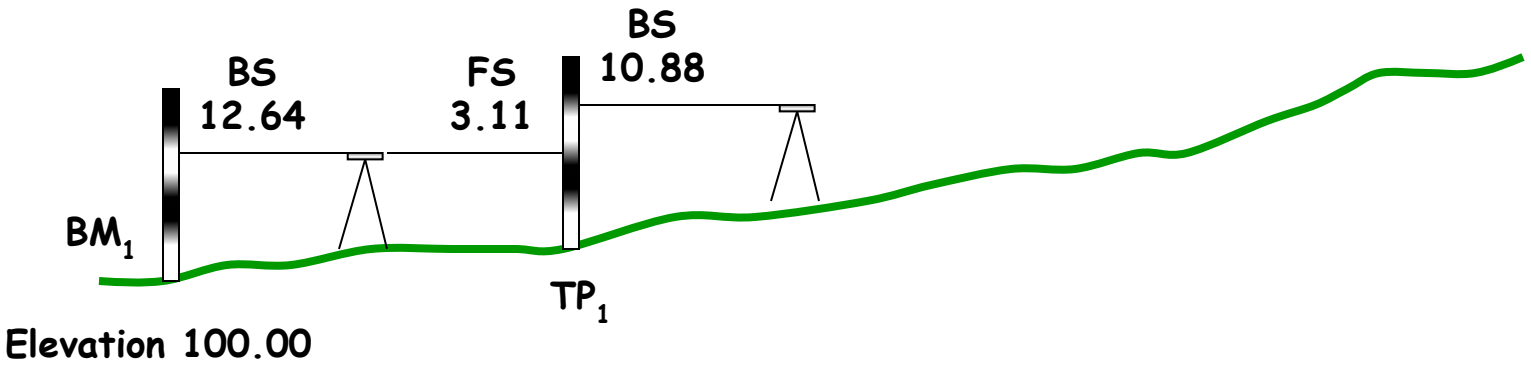
Computation of Elevations



Point	BS	HI	FS	Elevation
BM_1	12.64	112.64		100.00
TP_1			3.11	109.53

Differential Leveling

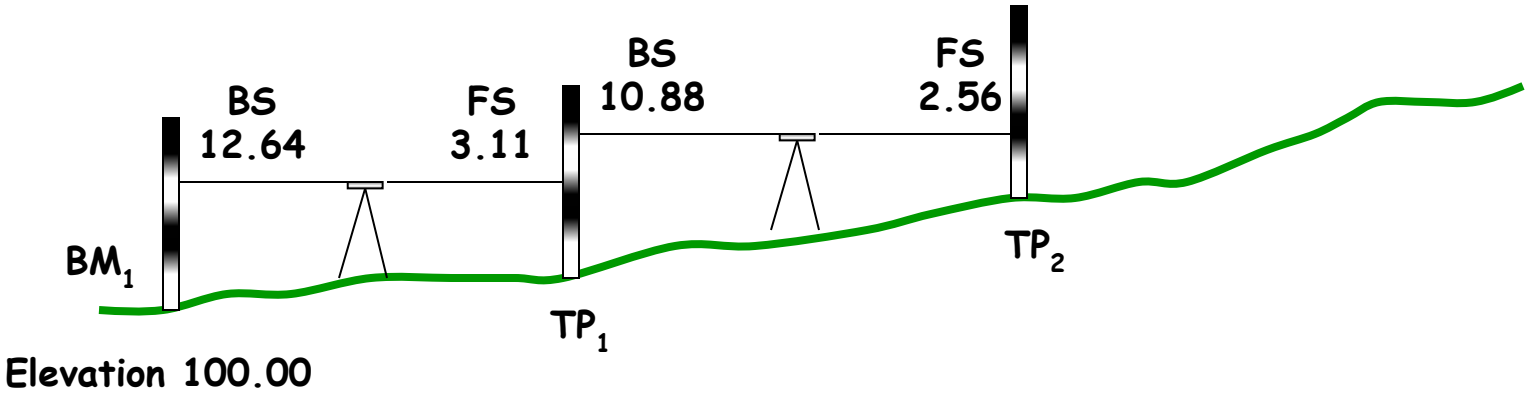
Computation of Elevations



Point	BS	HI	FS	Elevation
BM_1	12.64	112.64		100.00
TP_1	10.88	120.41	3.11	109.53

Differential Leveling

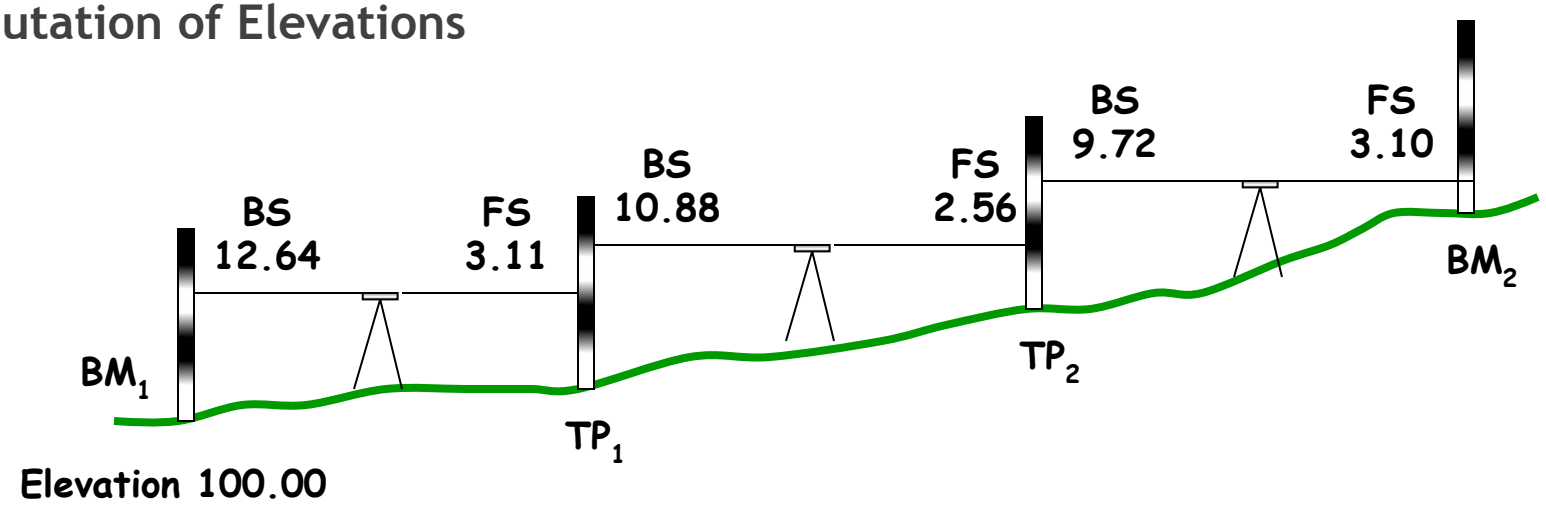
Computation of Elevations



Point	BS	HI	FS	Elevation
BM_1	12.64	112.64		100.00
TP_1	10.88	120.41	3.11	109.53
TP_2			2.56	117.85

Differential Leveling

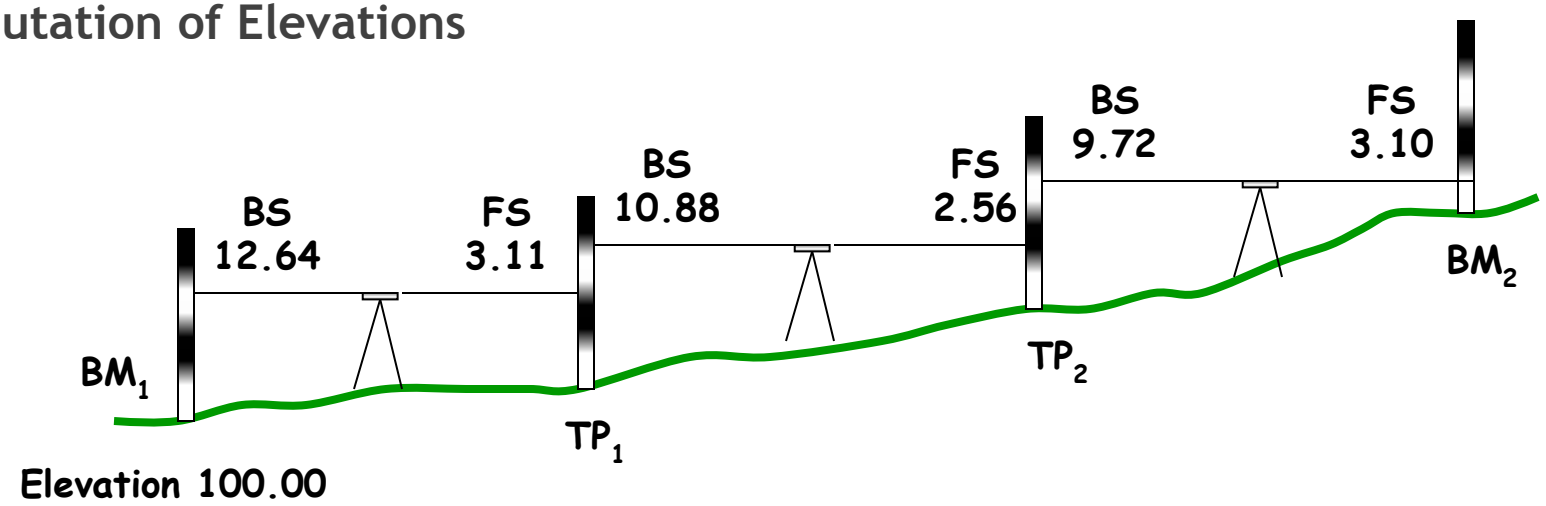
Computation of Elevations



Point	BS	HI	FS	Elevation
BM_1	12.64	112.64		100.00
TP_1	10.88	120.41	3.11	109.53
TP_2	9.72	127.57	2.56	117.85
BM_2			3.10	124.47

Differential Leveling

Computation of Elevations



Point	BS	HI	FS	Elevation
BM_1	12.64	112.64		100.00
TP_1	10.88	120.41	3.11	109.53
TP_2	9.72	127.57	2.56	117.85
BM_2			3.10	124.47

Differential Leveling

Computation of Elevations

3. Change in elevation- summation of the backsight and the foresight then subtract

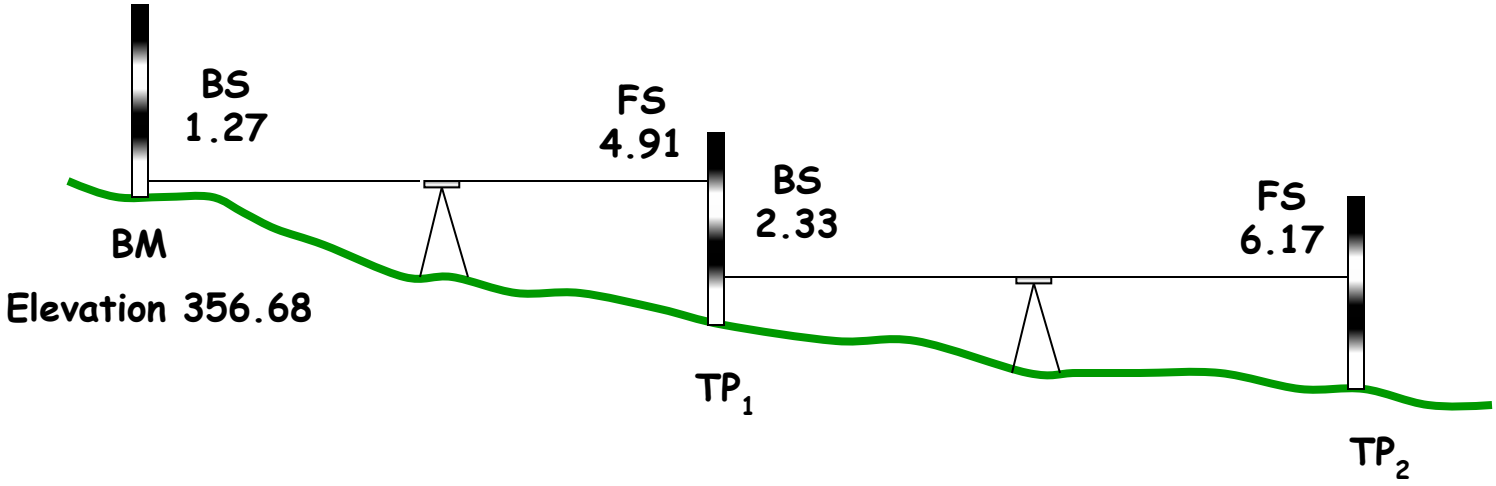
Point	BS	HI	FS	Elevation
BM_1	12.64	112.64		100.00
TP_1	10.88	120.41	3.11	109.53
TP_2	9.72	127.57	2.56	117.85
BM_2			3.10	124.47
	+33.24		**-8.77**	

Change in elevation = **33.24 -8.77 =24.47**

Differential Leveling

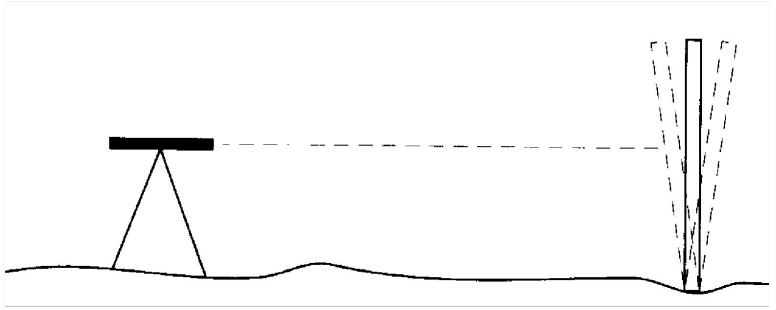
Computation of Elevations -

- Prepare a set of level notes for the survey illustrated below. What are the elevations of points TP_1 and TP_2?



Differential Leveling

Common Mistakes



5. Level rod not vertical
6. Settling of leveling rod
7. Leveling rod not fully extended or incorrect length
8. Level instrument not level
9. Instrument out of adjustment
10. Environment - wind and heat

Differential Leveling

F. **Suggestions for Good Leveling**

1. Anchor tripod legs firmly
2. Check the bubble level before and after each reading
3. Take as little time as possible between BS and FS
4. Try to keep the distance to the BS and the FS equal
5. Provide the rodperson with a level for the rod

Height determination using Indian Tangent Clinometer and Maps

- A Tangent clinometer which is also known as Survey of India Clinometer, is used for determining the difference in elevations of point .it is specially used in Plane table Surveys for contouring simultaneously .
- Calculation of heights :- the tangent of the vertical angle (angle of elevation / depression) when multiplied by the horizontal distance in meter from the plane table position to the object , gives the difference in height in meters. The horizontal distance may be either measured directly or scaled off from the plane table section.
- If the obervations are made to the top of a signal , the height of the signal is subtracted for obtaining the required ground heights.

Indian Tangent Clinometer

Tutorial

- Problem

The Reduced level of Plane Table station is 100 m and height of the clinometer above the ground is 1.2 m. find the reduced level of the hill top when the reading upon an Indian clinometer scale to +0.025. the horizontal distance to the hill top , scaled off the plane table is 2000m.

- Solution

Let the angle of elevation is α (alpha)

Tan α = 0.025

Horizontal distance = 2000m (Given)

Then difference in elevation h = d x tan α

= 2000x0.025= 50m

Hence R.L of hill top = R.L of station + height of clinometer above ground + difference in elevation

= 100 +1.20+50.0 = 151.20 m Ans.