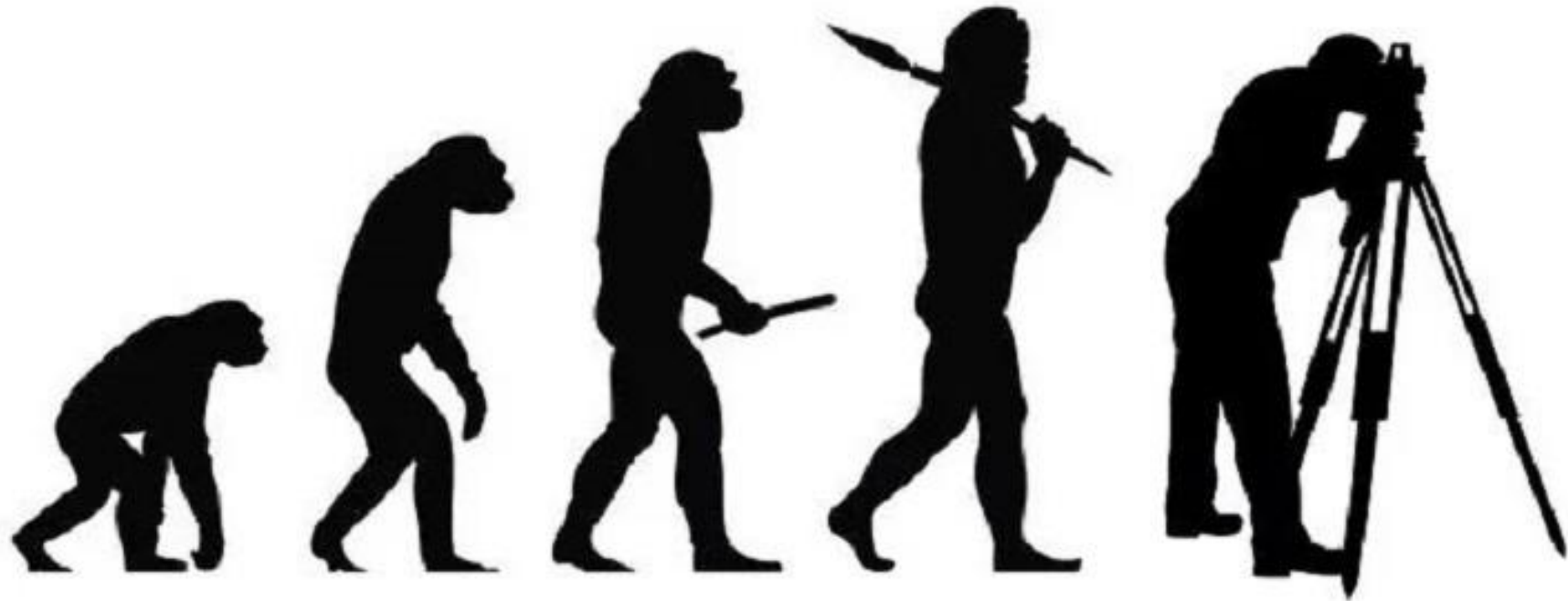


Lecture 8: Digital Surveying



<https://www.satpalda.com/blogs/evolution-in-surveying-techniques>

Levelling



What is Levelling?

- Levelling is the general term applied to any of the various processes by which elevations of points or differences in elevation are determined.
- Levelling is defined as 'an art of determining the relative height of different points on, above or below the surface'.
- The process of finding the elevation at a specified location relative to another known elevation (reference datum).
- The principle of levelling is to obtain the horizontal reference line to which vertical distances of points can be measured.

When do we level?

- Levelling can be used for building and infrastructure projects thus assisting in the design the highways, sewers, railways and other built forms of construction.
- It can used to calculate the volumes of earthworks and used as site layout for new foundations, contouring, drainage and estimate the fall / gradient of pipework.

Primarily, Levelling is use:

- To determine the difference in height between two or more points.
- To determine the height of discrete points.
- To provide spot heights or contours on plan.
- To provide the data for road cross-sections or volume of the earthworks.
- To provide a level or inclined plane in the setting out of construction works.

Levelling Equipment



Level



Tripod



Plumb bob



Field book



Levelling staff



Staff bubble



Measuring tape

Tripod

- A tripod stand is for supporting the levelling instrument
- Tripods provide a fixed base for all types of surveying instruments and sighting equipment. Instrument manufactures have standardized surveying tripods



Plumb bobs

- A plumb-bob or a plummet is a weight with a pointed tip on the bottom that is suspended from a string and used as a vertical reference line.
- Small plumb bobs are often included in the kits of various instruments such as levels and theodolites.
- They are used to set the instrument exactly over a fixed datum marker, prior to taking fresh readings



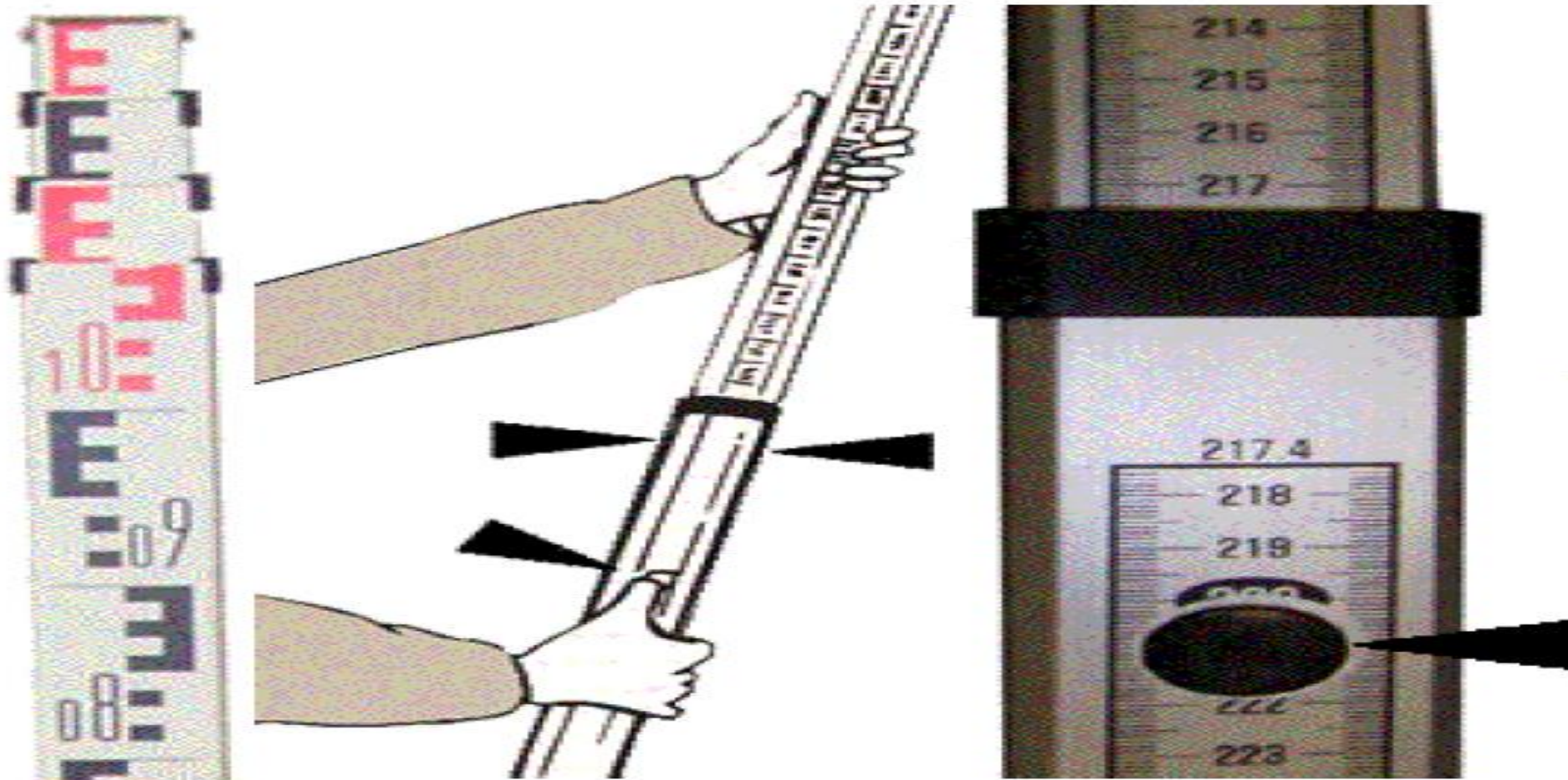
Levels

Most common levelling instrument today is the Automatic or Digital Level



Levelling Staff

Levelling staff/rods are graduated scale, held vertically over the points and viewed through the telescope of the level. The graduation is usually in alternate blocks and spaces of 10 mm with numbering in meters and decimetres.



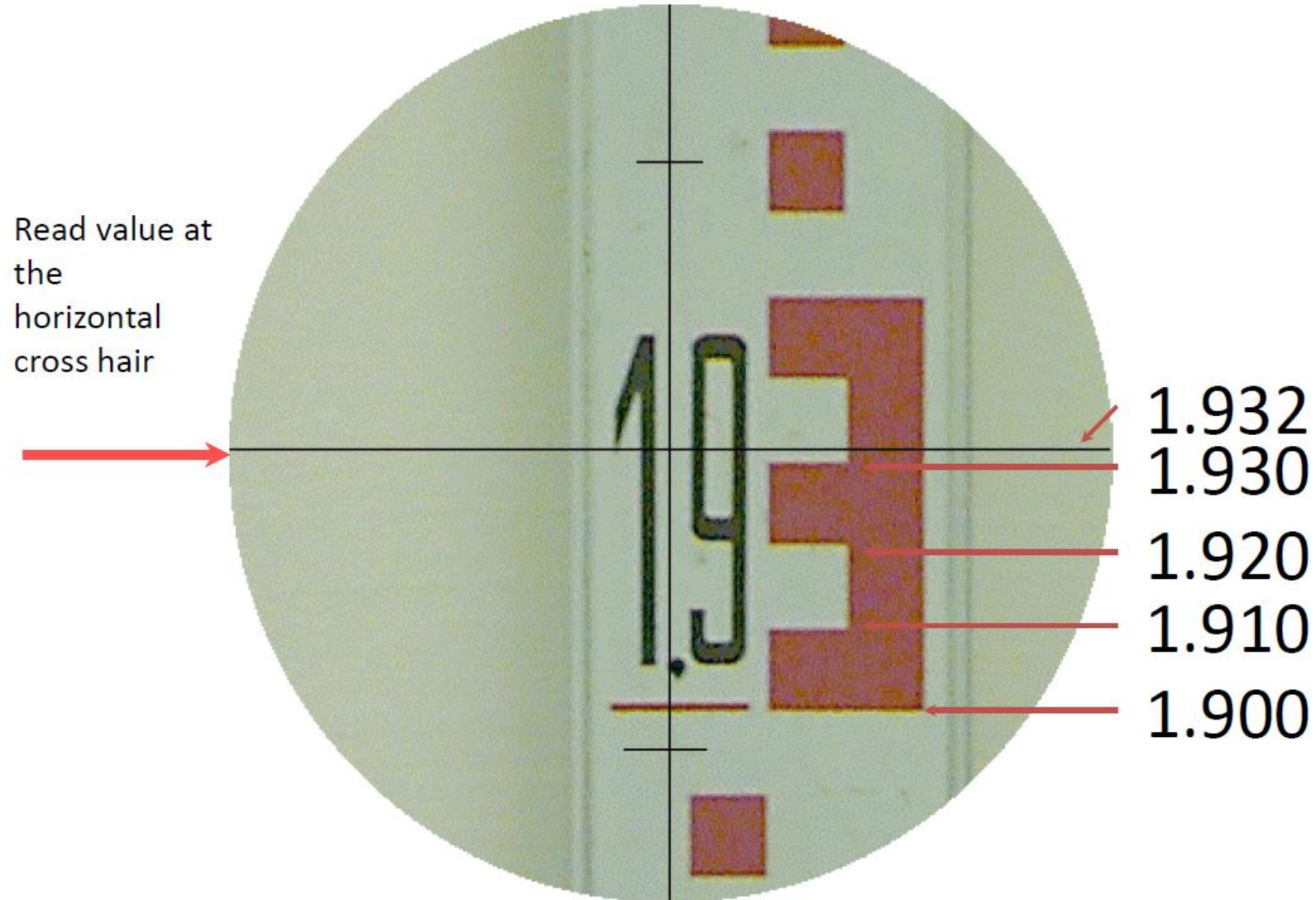
Staff Bubble

These are generally a small circular bubble on an angle plate which is held against one corner of the staff to ensure that the staff is held in a vertical position. If the staff is not held vertical, the reading will be too large and may be significantly in error.

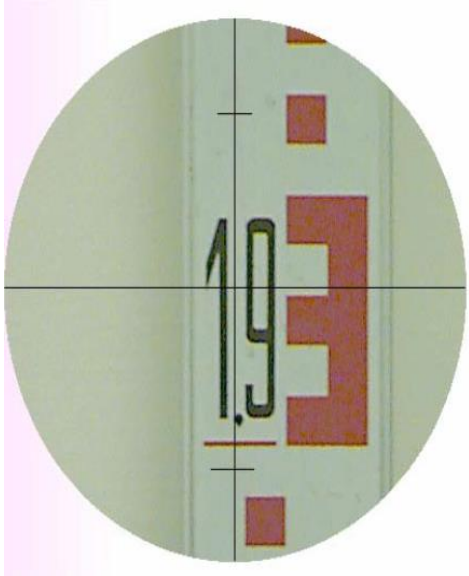


Staff Reading

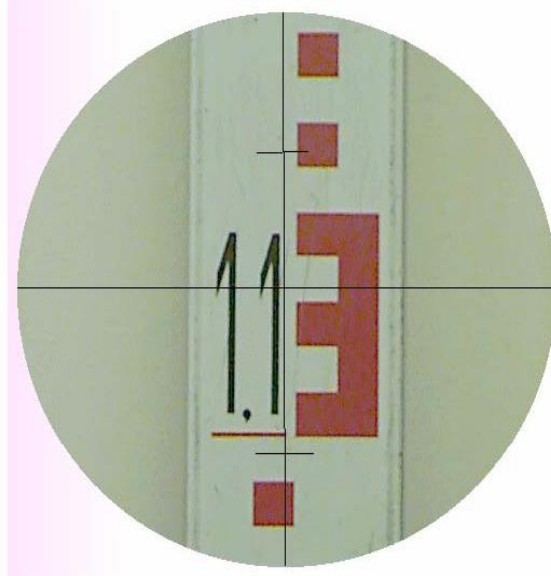
What is the reading for this rod sighting?



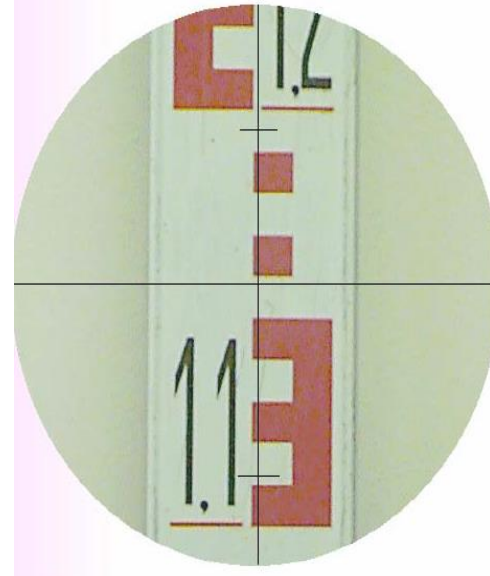
Staff Reading (contd.)



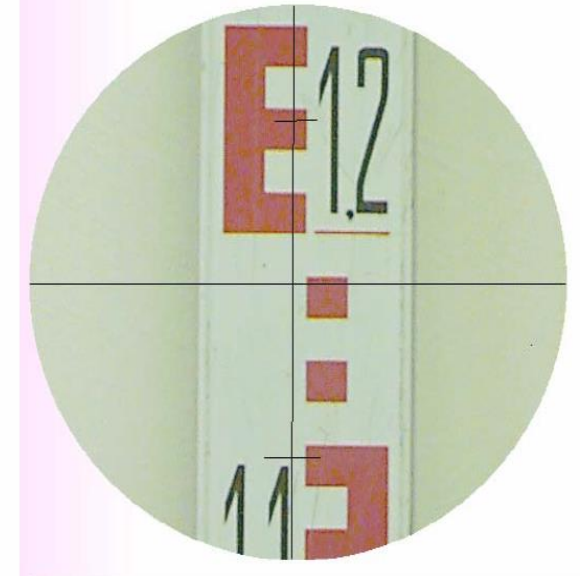
1.932



1.133



1.158



1.189

Precise Levelling

- Accuracy obtained by quality of instruments and care taken in the field
- High quality automatic levels are utilized

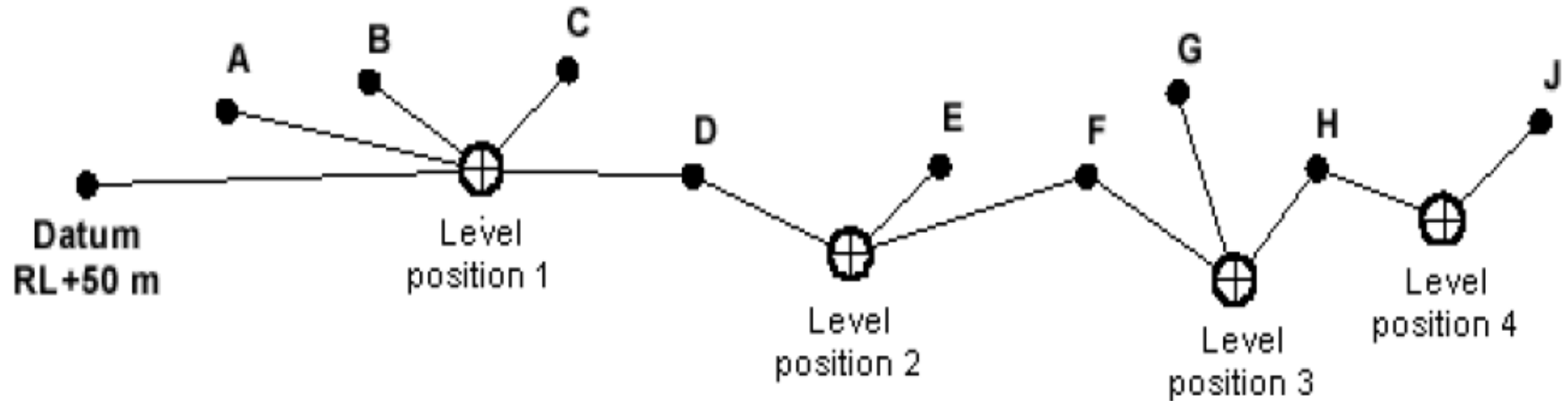
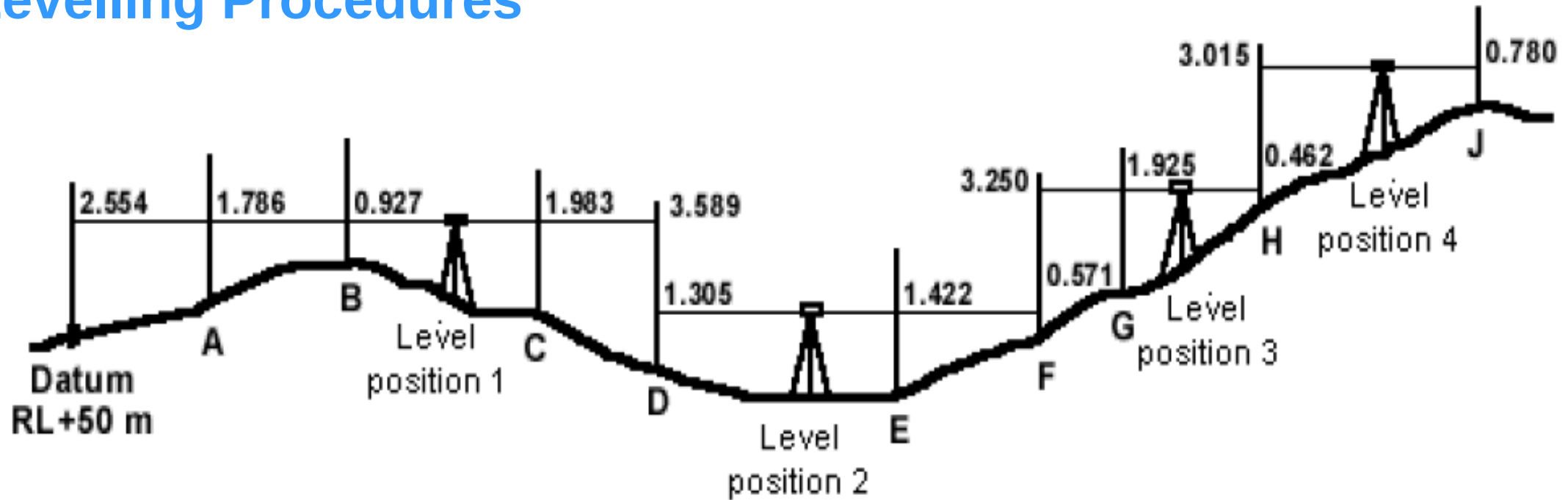


Levelling Terms

- **Datum** line is the reference line with respect to which the levels of other station points are fixed.
- **Height of instrument:** It is the elevation of the plane of sight with respect to assumed datum. It is also known as **Height /Plane of Collimation**.
- **Back sight(BS):** It is the sight taken on the level staff, of a known elevation with the intention to obtain the elevation of plane of collimation. **(First reading)**
- **Intermediate sights(IS):** These are the sight taken after back sight and before sighting the final point. These are called MINUS sights. These are subtracted from plane of collimation to find the reduced level of different points. **(second reading)**

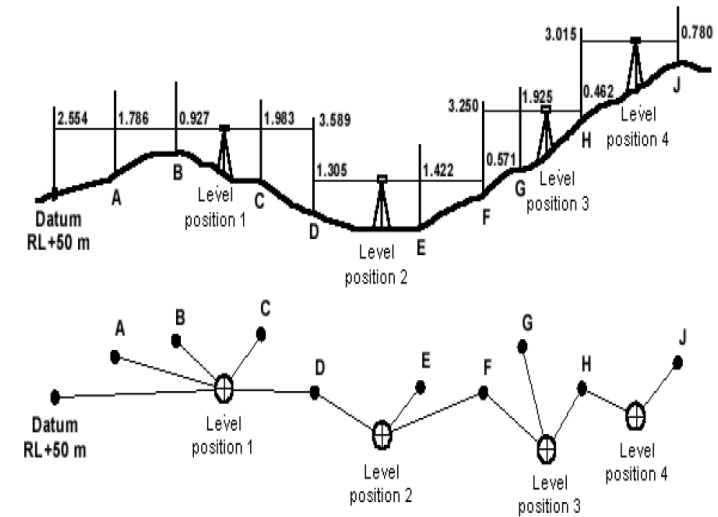
- **Fore sight(FS):** The last reading taken from the instrument. This is also a MINUS sight.
(Last Reading)
- **Change point(CP) or turning point(TP):** The point at which both BS and FS are taken.
- **Benchmark (BM).** A relatively permanent object, natural or artificial, having a marked point whose elevation above or below a reference datum is known or assumed.
- **Reduced Level** is the vertical difference between the level point and datum line or the mean sea level

Levelling Procedures



Levelling Procedures

1. Set up the levelling instrument at Level position 1.
2. Hold the staff on the Datum (RL+50 m) and take a reading. This is a back sight, because it is the first staff reading after the levelling instrument has been set up.
3. Move the staff to A and take a reading. This will be an intermediate sight.
4. Move the staff to B and take a reading. This is a intermediate sight.
5. Move the staff to C and take a reading. This is another intermediate sight.
6. Move the staff to D and take a reading. This is a foresight; because after this reading the level will be moved. (This is a change point and the staff is held at this position).
7. The distance between the stations should be measured and recorded in the field book.
8. Set up the level at Level position 2 and take a reading at D. This is a back sight.
9. Move the staff to E and take a reading. This is a intermediate sight.
10. Move the staff to F and take a reading. This is a foresight; because after taking this reading the level will be moved.
11. Now move the level to Levelling position 3 and leave the staff at F on the change plate.



LEVELLING BOOKING

Level Book

- All levelling shall be booked in either level books or levelling sheets which shall be retained as permanent records
- Level books shall be numbered so that they can be referenced on station history and inspection forms.
- They should be stored in fire-proof storage as for original record.
- They should also include an index
- Levelling sheets shall be filed in time-sequential order in site files, and also need to be in fire-proof storage as for level books

Level Book

Contains columns typically labelled as: backsight(BS), intermediate foresight (IFS), foresight (FS), height of instrument (HI), Reduced level (R.L) and the last column contains the remarks

The image shows an open level book with two pages. The left page has a header section with 'Date' and 'Levels' followed by a line. Below this is a line for 'From'. The main table has five columns: 'BACK SIGHT', 'INTER-MEDIATE', 'FORE SIGHT', 'COLLIMATION OR H.P.C.', and 'REDUCED LEVEL'. The right page has a header section with 'taken for' followed by a line. Below this is a line for 'To' and a small 'PATTERN' label. The main table has two columns: 'DISTANCE' and 'REMARKS'. Both pages have a grid of lines for data entry.

Booking

- Level books or loose-leaf levelling sheets shall be numbered and indexed in a register
- Details of the site, work, date, observer, chainman, booker, weather, wind, instrument and any other relevant items shall be entered
- Enter the first observation (which is on a known point) in the Back sight column, and sufficient detail in the Remarks column to identify it. Enter the point's reduced level (R.L) from the site register or plate on the BM, etc.
- Enter all other points on subsequent lines as intermediates except the point chosen as the foresight. Identify them in the Remarks column as above.
- Enter the foresight on a further line in the Foresight column.
- Change the instrument to the next setup. Enter the following back sight on the same line as the previous foresight but in the Back sight column
- Repeat the above procedure at each setup on the outward run then reverse it to work back to the starting point on the return run. The furthest point out is treated as for all other change points

Methods of Levelling Computation

There are two methods for obtaining the elevations at different points:

- Rise and Fall method
- Height of Collimation or Height of instrument method

➔ Rise and Fall Method (RF)

BS	IS	FS	Rise	Fall	RL	Corr	Corr RL	Remarks

➔ Height of Plane and Collimation Method (HPC)

BS	IS	FS	HPC	RL	Corr	Corr RL	Remarks

Basic Calculations

Height of Collimation method:

- Height of instrument (HI) for the first setting = $RL\ of\ BM + BS\ (at\ BM)$
- Subtract the IS and FS from HI to get RL of intermediate stations and change points.

Rise and Fall method:

- Subtract the IS or FS from previous BS or IS
- $RL\ of\ stations = RL\ of\ BM + (rise\ or\ fall)$

Example 1

When the difference in the elevation of two nearby points is required then simple levelling is performed.

Assume the elevation of BM Rock is known to be 820.00 m

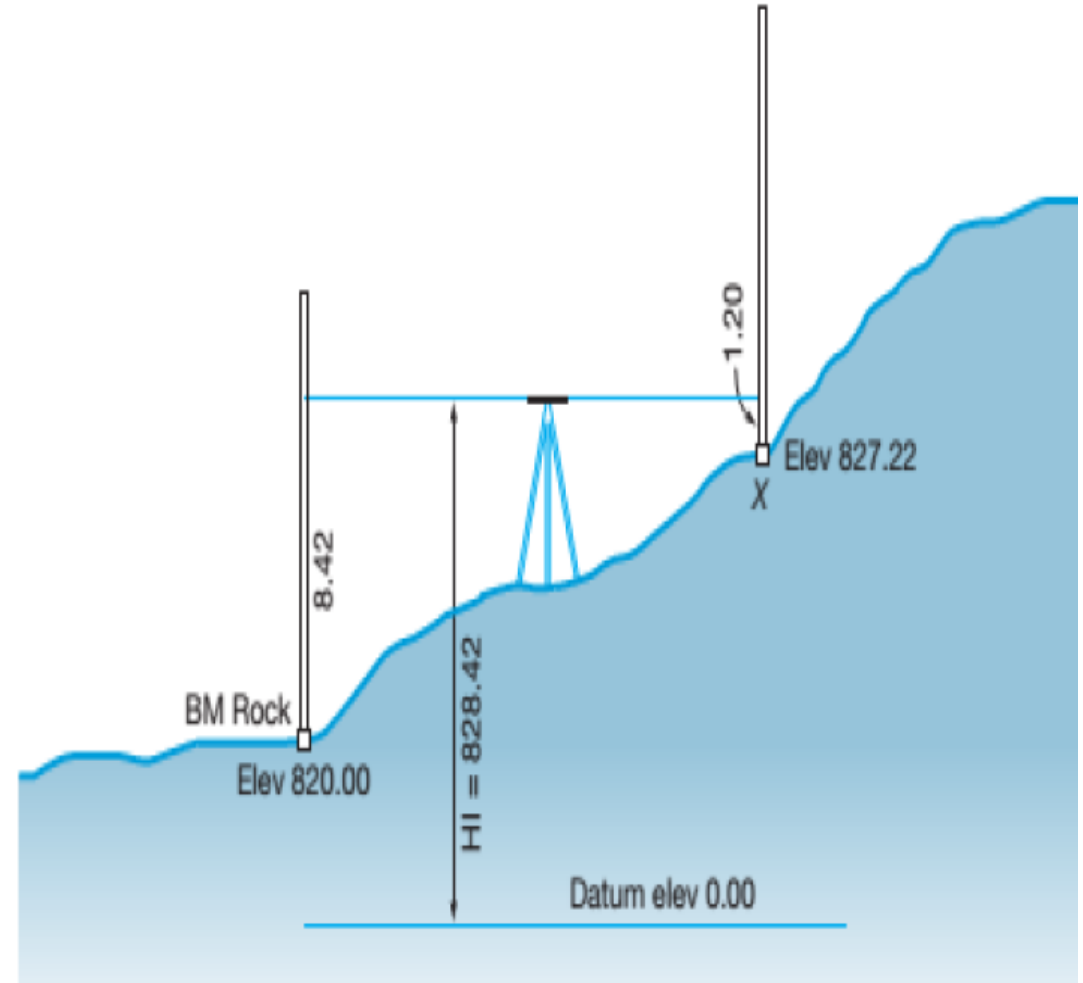
The BS at BM Rock is 8.42m

So $HI/HPC = (820 + 8.42)m$.

Now the FS on "X" is 1.2m.

So the RL at "X" = $HI - FS = 828.42m$

Note: the RL of the instrument station is never used in the calculation.



Example 2

Performed when the final point is very far from the final point.

We have to find RL at B. It is given that RL at A is 100m and BS at A is 2.45m

Therefore:

$$\text{HI at } L_1 = (100 + 2.45) = 102.45\text{m}$$

$$\text{FS at } CP_1 = 2.41\text{m}$$

$$\text{RL at } CP_1 = (102.45 - 2.14) = 100.31\text{m}$$

$$\text{Now BS at } CP_1 = 1.43\text{m}$$

$$\text{HI at } L_2 = (100.31 + 1.43) = 101.74\text{m}$$

$$\text{FS at } CP_2 = 2.18\text{m}$$

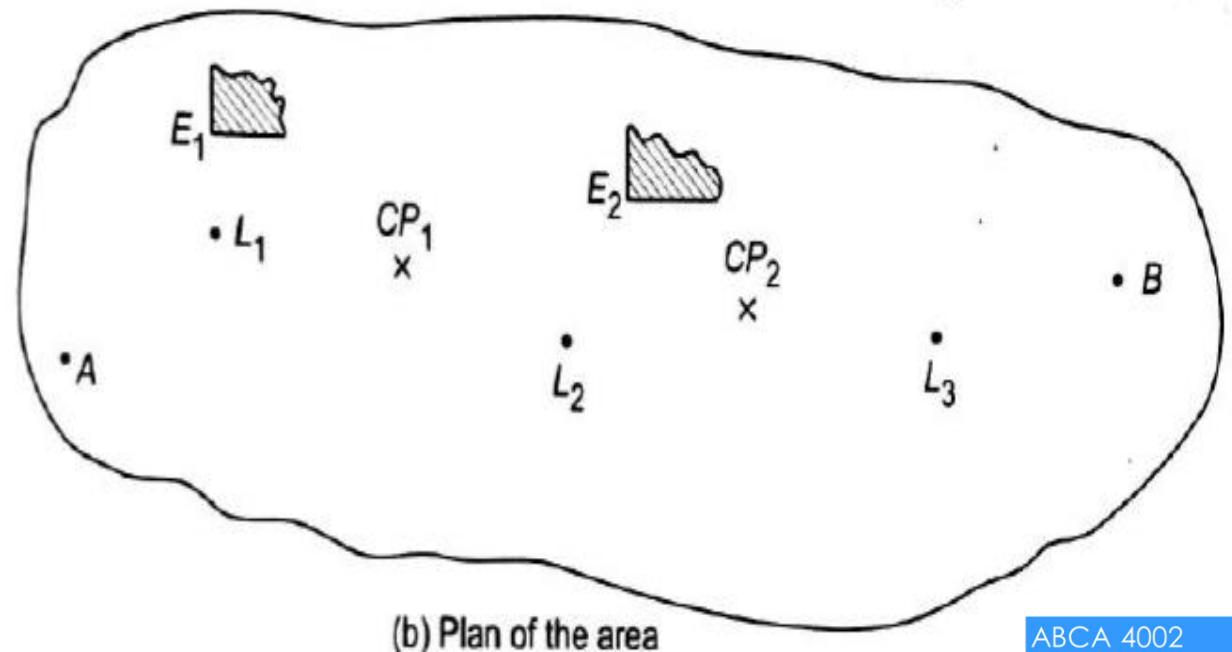
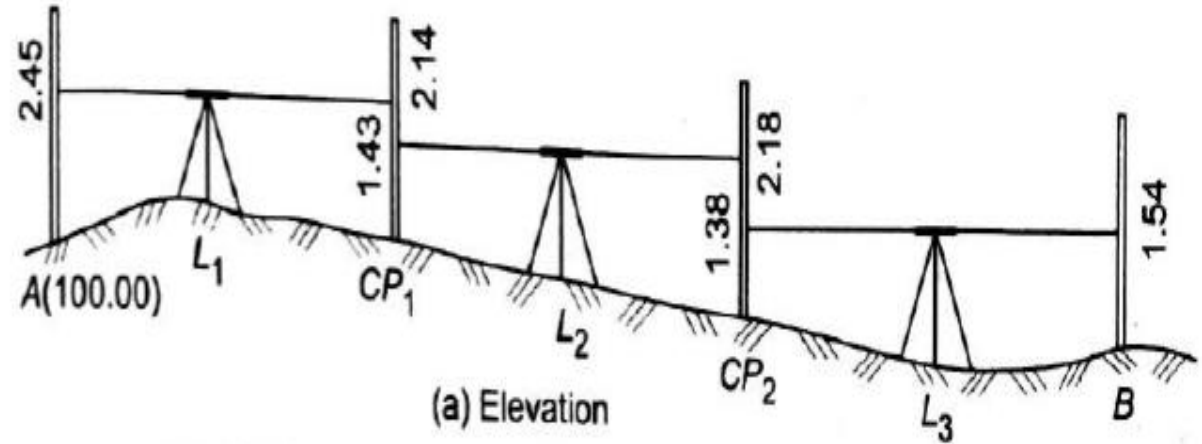
$$\text{RL at } CP_2 = (101.74 - 2.18) = 99.56\text{m}$$

$$\text{BS at } CP_2 = 1.38\text{m}$$

$$\text{HI at } L_3 = (99.56 + 1.38)\text{m} = 100.94\text{m}$$

$$\text{FS at } B = 1.54\text{m}$$

$$\text{RL at } B = (100.94 - 1.54) = 99.4\text{m (ans)}$$



Rise and Fall Method of Booking Levels

Station	BS	IS	FS	Rise	Fall	R.L	Remarks
A	2.45					100.00	Bench Mark
		0.86		1.59		101.59	E_1
	1.43		2.14		1.28	100.31	CP_1
		0.76		0.67		100.98	E_2
	1.38		2.18		1.42	99.56	CP_2
			1.54		0.16	99.40	Last-Point
Σ	5.26		5.86	2.26	2.86		
$\Sigma BS - \Sigma IS = -0.6$				$\Sigma Rise - \Sigma Fall = -0.6$		Last RL - First RL = -0.6	
						Checked	

Note the rise and fall calculations:

From A to E_1 , difference = $2.45 - 0.86 = 1.59$, rise
 From E_1 to CP_1 , difference = $0.86 - 2.14 = -1.28 = 1.28$ m, fall
 From CP_1 to E_2 , difference = $1.43 - 0.76 = 0.67$, rise
 From E_2 to CP_2 , different = $0.76 - 2.18 = -1.42 = 1.42$, fall
 From CP_2 to Last Point, difference = $1.38 - 1.54 = -0.16 = 0.16$, fall.

Collimation Method of Booking Levels

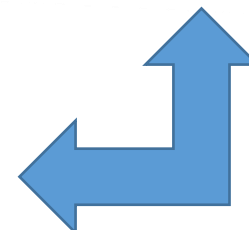
Station	Reading			Height of Instrument	R.L	Remark
	BS	IS	FS			
A	2.45			102.45	100.00	Bench Mark
E ₁		0.86			101.59	Plinth of Building
CP ₁	1.43		2.14	101.74	100.31	Change Point
E ₂		0.76			100.98	Plinth of Building
CP ₂	1.38		2.18	100.94	99.56	Change Point
B			1.54		99.40	Station B, the last point shown
Check	Σ 5.26		Σ 5.86			

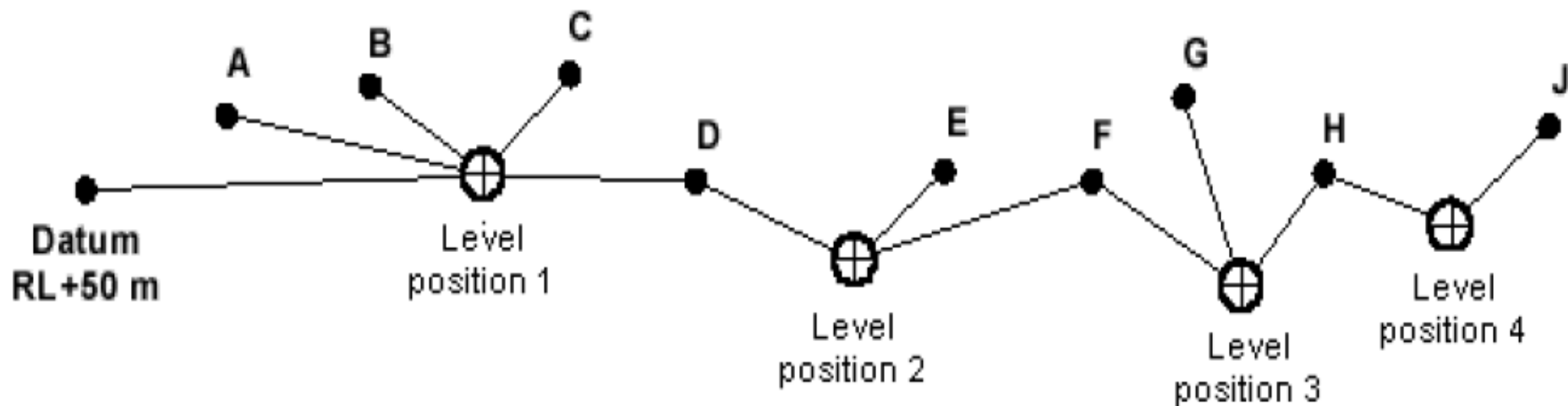
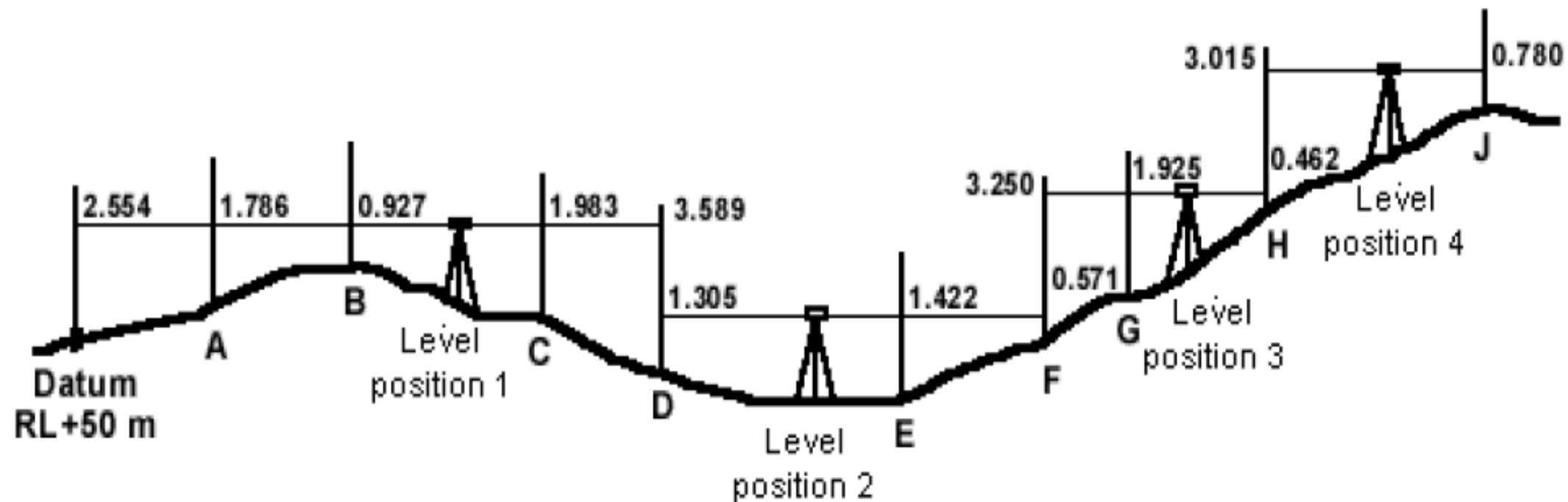
Diff = -0.60 (Fall)

-0.60 (Fall)



CHECK





Collimation Method of Booking Levels

Back-sight	Inter-mediate	Fore-sight	Height of collimation	Reduced level	Distance	Remarks
2.554			52.554	50.000	0.000	Datum RL+50 m
	1.783			50.771	14.990	A
	0.926			51.628	29.105	B
	1.963			50.591	48.490	C
1.305		3.587	50.272	48.967	63.540	D / change point 1
	1.432			48.840	87.665	E
3.250		0.573	52.949	49.699	102.050	F / change point 2
	1.925			51.024	113.285	G
3.015		0.496	55.468	52.453	128.345	H / change point 3
		0.780		54.688	150.460	TBM J 54.688
10.124		5.436		54.688		Sum of B-sight & F-sight, Difference between RL's
-5.436				-50.000		Take smaller from greater
4.688				4.688		Difference should be equal

Common Sources of Errors in Levelling

- Instrument not correctly levelled
- Telescope not correctly focused.
- The wrong cross-hair reading recorded (e.g. top instead of middle).
- Staff incorrectly read or not held vertical.
- Staff incorrectly booked. All the above are mistakes (blunders) and cannot be corrected unless the work is repeated.

Correction of Errors in Levelling

- Calculation checks:
 $(BS) - (FS) = \text{Last RL} - \text{First RL}$
 $(IS) + (FS) + (\text{RLs except first}) = (\text{each HPC} \times \text{no of applications})$
- Allowable misclosure = $5 \sqrt{N}$ mm, where N = Number of BS station
- If calculation checks OK, and misclosure allowable, then distribute misclosure cumulatively between each instrument position.

Class Exercise

