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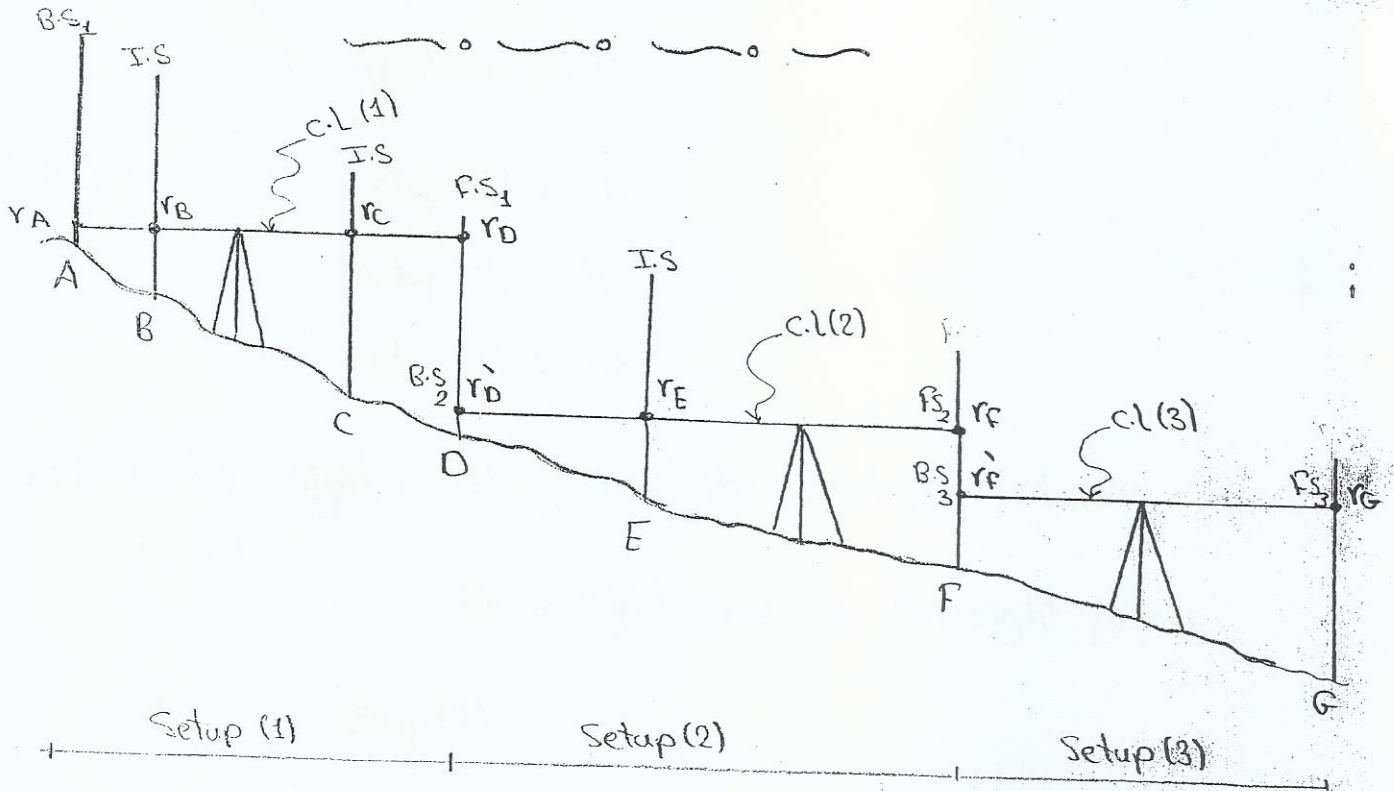
# Surveying

2<sup>nd</sup> year civil

Notes (2)

2013/2014

# Ordinary Leveling Procedures



\* لابد أن يكون هناك على الأقل بين كل وقفتين للميزان قراءة مشتركة

\* عدد القراءات في الوقفة الواحدة تعتمد على:

١- طبيعة الأرض      ٢- بعد النقط عن بعضها      ٣- قوة تكبير الميزان

\* لكل وقفه هناك C.L (collimation level) خاص بها.

\* Back sight : First reading taken just after setting up the level (B.S) or just after moving the level to another place.

B.S points :

Setup (1) :  $r_A$

Setup (2) :  $r'_D$

Setup (3) :  $r'_F$



\* Fore sight : last reading taken just before moving the level  
(F.S)  
to another place

F.S points : Setup (1) :  $r_D$

Setup (2) :  $r_F$

Setup (3) :  $r_G$

\* Intermediate sight : They are the readings between the  
(I.S)  
Back sight and the Fore sight points.

I.S points : Setup (1) :  $r_B, r_C$

Setup (2) :  $r_E$

Setup (3) : None

\* Turning point : It is the point at which Backsight and  
(changing point)  
Fore sight are taken.

T.P points : D, F

\*\*\*\* Rules

1. no. of B.S = no. of F.S = no. of setups

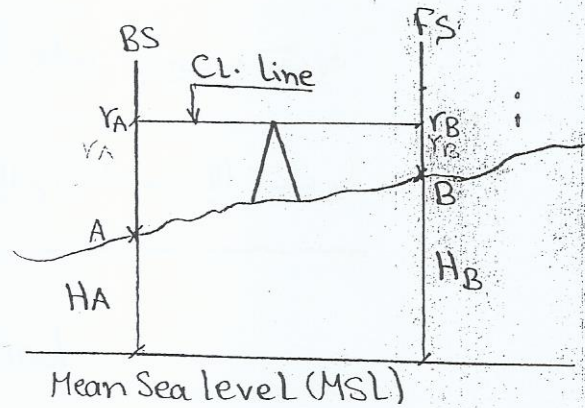
2. no. of T.P = no of setups - 1

3. no. of observed points = Total no. of reading  
- no. of T.P

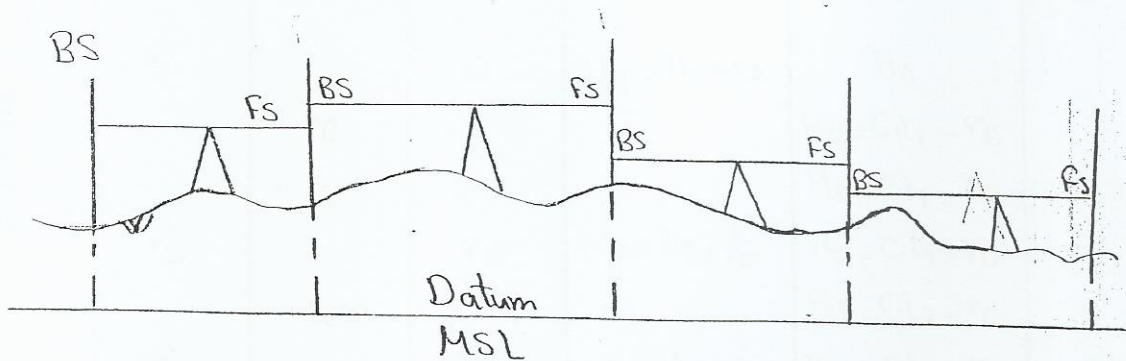
# Types of leveling Procedures

## 1) leveling between two points

$$\Delta H_{AB} = H_B - H_A = r_A - r_B$$

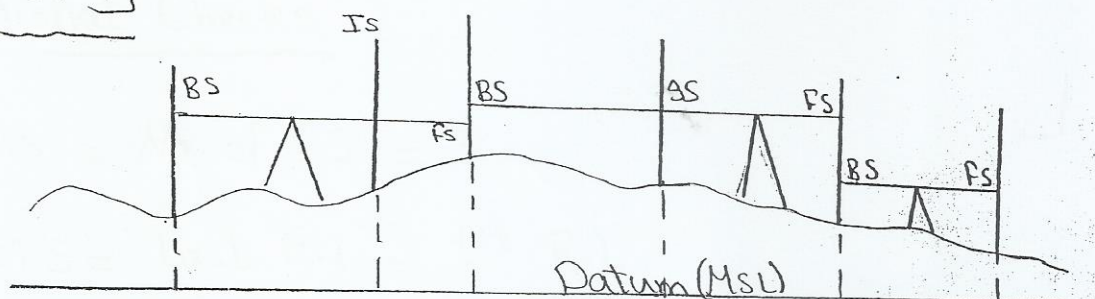


## 2) Flying leveling



No IS readings

## 3) Series Leveling



BS - IS - FS

مستوى واحد



## \* Methods of level computation :

There are two types of level computation which are :

- 1) Collimation method طريقة منسوب سطح البصيرة
- 2) Rise and Fall طريقة الارتفاعات والانخفاضات

### (1) Collimation method

Point	B.S	I.S	F.S	Collimation Level	Reduced Level	Distance	Remarks
A	$r_A$			$C.L_1 = H_A + r_A$	$H_A$		B.M
B		$r_B$			$H_B = C.L_1 - r_B$		
C		$r_C$			$H_C = C.L_1 - r_C$		
D	$r_D$		$r_D$	$C.L_2 = H_D + r_D$	$H_D = C.L_1 - r_D$		CP <sub>1</sub>
E		$r_E$			$H_E = C.L_2 - r_E$		
F	$r_F$		$r_F$	$C.L_3 = H_F + r_F$	$H_F = C.L_2 - r_F$		CP <sub>2</sub>
G			$r_G$		$H_G = C.L_3 - r_G$		

### \* Computational Checks

1) No. of B.S = No. of F.S = 3

2)  $\sum BS - \sum FS = \text{Last R.L} - \text{1st R.L}$

$(r_A + r_D + r_F) - (r_D + r_F + r_G) = H_G - H_A - H_C$

Ex(1) : The following staff readings were taken in a leveling process as : 1.34 , 2.56 , 1.93 , 3.125 , 2.891 and 0.952 .

If the first reading was taken at B.M of level (10.00) , Find the levels of all remaining points.

Solution

Point	BS	IS	FS	Collimation Level	Reduced Level	Distance	Remarks
A	1.34			11.34	10.00	11	B.M
B		2.56			8.78		
C		1.93			9.41		
D		3.12			8.22		
E		2.89			8.45		
F			0.95		10.39		

\* Computational checks :

$$1) \text{ No. of B.S} = \text{No. of F.S} = 1$$

$$2) \sum BS - \sum FS = 1.34 - 0.95 = 0.39 \text{ m}$$

$$= \text{level (F)} - \text{level (A)} = 10.39 - 10.00 = 0.39 \text{ m}$$



Ex(2) : The following readings were taken in a leveling process :

2.67 , 3.04 , 1.59 , 0.63 , 1.58 , 3.81 , 1.53 , 0.94 , 2.02 ,

2.26 , 3.04 , 1.17 , 0.97 , 1.32 , 2.36 . where the

underlined reading are B.S readings and the first point is a benchmark (20.00). Compute the level of all points.

Solution :

Point	B.S	I.S	F.S	Collimation Level	Reduced level	Distance	Remarks
A	2.67			22.67	20.00	I.M	B.M
B		3.04			19.63		
C		1.59			21.08		
D		0.63			22.04		
E		1.58			21.09		
F	1.53		3.81	20.39 (18.86 + 1.53)	18.86	I.P	C.P <sub>1</sub>
G		0.94			19.45		
H		2.02			18.37		
I		2.26			18.13		
J		3.04			17.35		
K	0.97		1.17	20.19 (19.22 + 0.97)	19.22	T.P	C.P <sub>2</sub>
L		1.32			18.87		
M			2.36		17.83		
$\Sigma$	5.17		7.34				

\* Checks : 1) No. of BS = No. of FS = 3

2)  $\sum BS - \sum FS = 5.17 - 7.34 = -2.17 \text{ m}$

= last Elevation - First elevation =  $17.83 - 20.00 = -2.17 \text{ m}$

2) Rise and Fall method

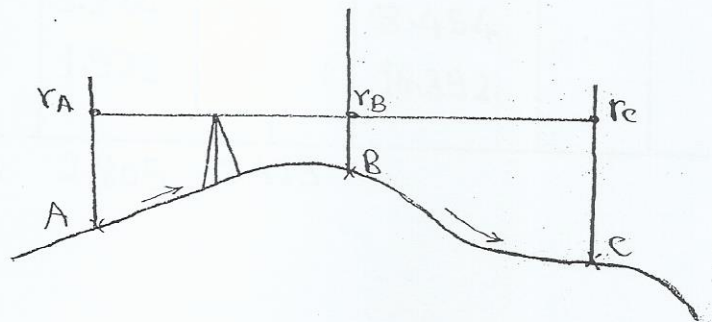
~ \* ~ \* ~ \* ~ \*

$$\Delta H_{A \rightarrow B} = r_A - r_B$$

= +ve (rise)

$$\Delta H_{B \rightarrow C} = r_B - r_C$$

= -ve (fall)



\*\* Computational checks :

1) No. of B.S = No. of F.S

2)  $\sum BS - \sum FS = \text{last level} - 1^{\text{st}} \text{ level point}$   
 $= \sum \text{Rise} - \sum \text{Fall}$

$$\sum FS - \sum BS = 1^{\text{st}} \text{ level} - \text{last level}$$
$$= \sum \text{Fall} - \sum \text{Rise}$$

intell of



\* Resolve example (1) using Rise & Fall method.

Point	BS	I.S	F.S	Rise	Fall	Reduced level	Dist	Remarks
A	1.345					10.00		B.M
B		2.568		1.223		8.777		
C		1.935		0.633		9.410		
D		3.125			1.190	8.220		
E		2.891		0.234		8.454		
F			0.953	1.938		10.392		
$\Sigma$	1.345		0.953	2.805	2.413			

\* Computational checks:

1) No. of BS = No. of FS = 1

2)  $\Sigma BS - \Sigma FS = 1.345 - 0.953 = +0.392$

= last level - 1st level =  $10.392 - 10.00 = +0.392$

=  $\Sigma Rise - \Sigma Fall = 2.805 - 2.413 = +0.392$

\* Resolve example (2) using Rise & Fall method.

Point	B.S	I.S	F.S	Rise	Fall	Reduced Level	Dist.	Remarks
A	2.67					20.00		B.M
B		3.04			0.37	19.63		
C		1.54		1.45		21.08		
D		0.63		0.96		22.04		
E		1.58			0.95	21.09		
F	1.53		3.81		2.23	18.86		T.P <sub>1</sub>
G		0.94		0.59		19.45		
H		2.02			1.08	18.37		
I		2.26			0.24	18.13		
J		3.04			0.78	17.35		
K	0.97		1.17	1.87		19.22		T.P <sub>2</sub>
L		1.32			0.35	18.87		
M			2.36		1.04	17.83		
$\Sigma$	5.17		7.34	4.87	7.04			

\* Computational checks:

1) No. of B.S = No. of F.S = 3

2)  $\Sigma FS - \Sigma BS = 7.34 - 5.17 = 2.17m$

= First elevation - Last elevation = 20 - 17.83 = 2.17m

=  $\Sigma Fall - \Sigma Rise = 7.04 - 4.87 = 2.17m$



## \* Flying leveling \*

\* It is a type of leveling in which there is no I.S readings (Only B.S & F.S readings) . ;

\* It is used mainly to transform a B.M To a certain place.

Ex: The following readings were in a Flying leveling:

1.583, 2.305, 1.678, 3.123, 0.956 & 2.856, noting that the 1<sup>st</sup> point is a B.M (10.00), Find the level of all points.

Solution

or								
Point	B.S	F.S	C.L	Rise	Fall	Reduced level	Dist.	Remarks
A	1.583		11.583			10.00		B.M
B	1.678	2.305	10.956		0.722	9.278		T.P <sub>1</sub>
C	0.956	3.123	8.789		1.5445	7.833		T.P <sub>2</sub>
D		2.856			1.900	5.933		
$\Sigma$	4.217	8.284		-4.067	4.067			

\* Computational checks : 1) No. of BS = No of FS = 3

2)  $\Sigma FS - \Sigma BS = \Sigma Rise - \Sigma Fall = \text{level A} - \text{level D} = 4.067 \text{ m}$

Example: Two points were occupied using ordinary Staff.

- \* A (Ground surface) , B (Upper surface of a tunnel)
- \* Staff at A with its zero touching the ground
- Staff at B with its Zero touching the upper surface.
- \*  $r_A = 1.48 \text{ m}$        $r_B = 3.12 \text{ m}$

Required Tunnel height.

Solution

$$\text{Tunnel height} = 1.48 + 3.12 = 4.6 \text{ m}$$



Problem :

A survey level was used to determine the height of a tunnel above the ground surface with the following recorded staff readings:

Point A (Staff edge is touching the tunnel upper surface)			Point B (staff is setup on the ground inside the tunnel)		
lower	middle	upper	lower	middle	upper
2.38	2.48	2.58	1.54	1.64	1.74

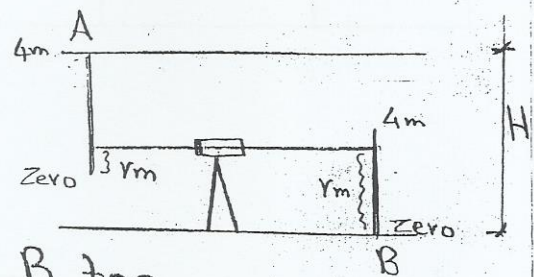
\* Check the staff readings and find the height of that tunnel above the ground.

Solution

$\therefore$  For [A]  $r_u > r_l$

$\therefore$  the staff is not inverted at A & B too.

$$\begin{aligned}\therefore H_{\text{tunnel}} &= (4 - r_m)_A + (r_m)_B \\ &= (4 - 2.48) + 1.64 = 3.16 \text{ m}\end{aligned}$$



Example: The following observations were taken in a leveling job:

1.5 , 1.8 , 2.2 , 1.7 , 1.3 , 2.1 , 1.8 , 1.7 , 3.1 , 1.4  
 If the underlined readings were FS, The first point is a BM of level (5.00). Find the level of all points using Collimation method.

Solution

BS	IS	FS	C.I	R.L	Dist.	Remarks
1.5			6.50	5.00	B.M	B.M
	1.8			4.70		
1.7		2.2	6.00	4.30	T.P <sub>1</sub>	T.P <sub>1</sub>
	1.3			4.70		
1.8		2.1	5.70	3.90	T.P <sub>2</sub>	T.P <sub>2</sub>
3.1		1.7	7.10	4.00	T.P <sub>3</sub>	T.P <sub>3</sub>
		1.4		5.70		
8.1		7.4				

Checks : 1) No. of BS = No. of FS = 3

$$2) \sum BS - \sum FS = 8.1 - 7.4 = 0.7m$$

$$= \text{Last Elev.} - 1^{\text{st}} \text{ Elev.} = 5.7 - 5.00 = 0.7m$$



Problem: The Following Staff observations were recorded in a certain site : 1.36 , 2.58, 1.68, 1.98, 1.89, 2.54, 2.21, 1.98, 1.77, 1.54 . The fifth and seventh points are turning points . Also if you know that the fifth point is a B.M with an elevation (101.03 m), it is required to calculate the elevations of all points using the two methods.

Sol:

BS	IS	FS	Rise	Fall	C.L.	R.L	Dist.	Remarks
1.36					102.92	101.56		
	2.58			1.22		100.34		
	1.68		0.9			101.24		
	1.98			0.3		100.94		
2.54		1.89	0.09		103.57	101.03		T.P, B.M
	2.21		0.33			101.36		
1.77		1.98	0.23		103.36	101.59		T.P
		1.54	0.23			101.82		

Computational checks:

1) No. of BS = No. of FS = 3

2)  $\sum BS - \sum FS = \sum Rise - \sum Fall = last - 1^{st}$   
 $5.67 - 5.41 = 1.78 - 1.52 = 101.82 - 101.56$

Example: The following staff readings were recorded during a leveling process : 2.11 - 3.79 - 1.25 - 3.21 - 1.46 - 0.89 - 1.11 - 2.22 - 3.33 - 0.92 - 1.78 - 1.23 . If the 3rd, 6th and the 10th readings are Back sights, the 5th reading was taken on a Bench mark of level (19.143 m). Calculate the level of all points using the Rise & Fall Method.

Solution

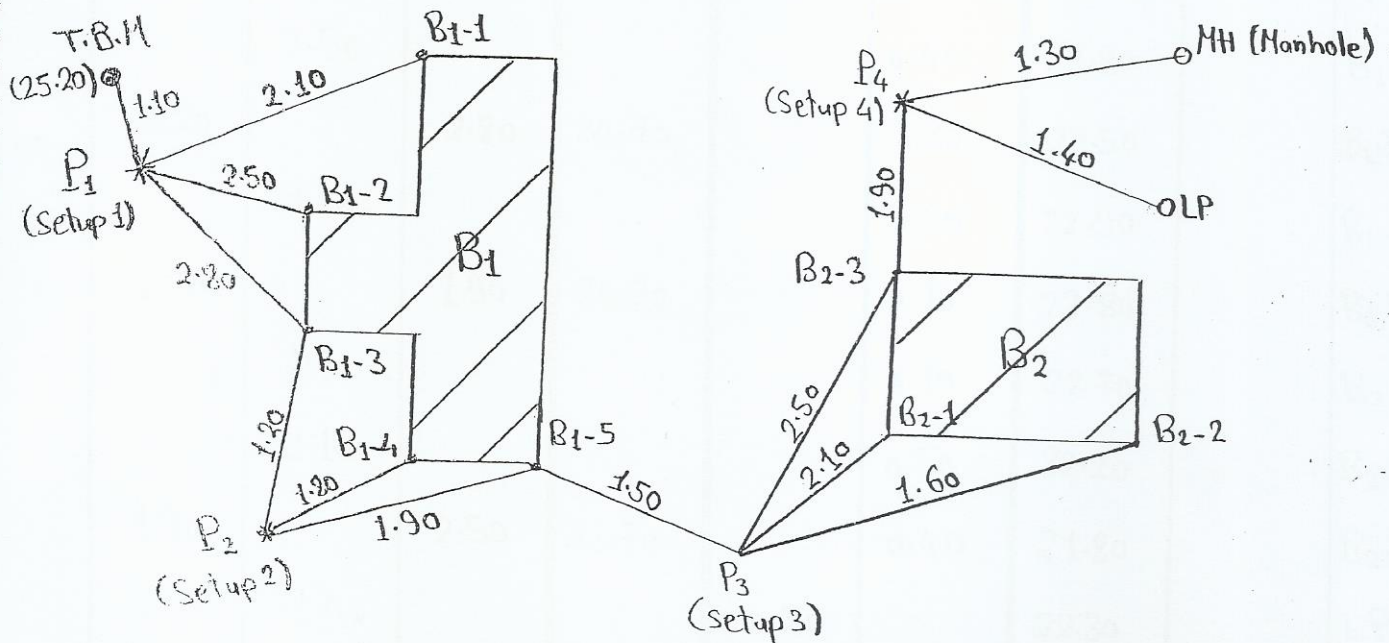
BS	IS	FS	Rise	Fall	R.L	Remarks
2.11					21.033	
1.25		3.79		1.68	19.353	T.P <sub>1</sub>
	3.21			1.96	17.393	
0.89		1.46	1.75		19.143	B.M-T.P <sub>2</sub>
	1.11			0.22	18.923	
	2.22			1.11	17.813	
0.92		3.33		1.11	16.703	T.P <sub>3</sub>
	1.78			0.86	15.843	
		1.23	0.55		16.393	

Checks: 1) No. of BS = No. of FS = 4

$$2) \sum FS (9.81) - \sum BS (5.17) = \sum Fall (6.94) - \sum Rise (2.30) \\ = 21.033 - 16.393 = 4.64 \text{ m}$$



Example: For the Shown leveling process, Calculate the levels of  $B_1$ ,  $B_2$ , LP & MH using Collimation Level method and Rise & Fall method.



## Using Collimation level method or Rise & Fall method

OR

BS	IS	FS	CL	Rise	Fall	RL	Dist	Remarks
1.10			26.30			25.20		T.B.M
	2.10				1.00	24.20		B <sub>1</sub> -1
	2.50				0.40	23.80		B <sub>1</sub> -2
1.20		2.80	24.70		0.30	23.50		B <sub>1</sub> -3 (TP <sub>1</sub> )
	1.80				0.60	22.90		B <sub>1</sub> -4
1.50		1.90	24.30		0.10	22.80		B <sub>1</sub> -5 (TP <sub>2</sub> )
	1.60				0.10	22.70		B <sub>2</sub> -2
	2.10				0.50	22.20		B <sub>2</sub> -1
1.90		2.50	23.70		0.40	21.80		B <sub>2</sub> -3 (TP <sub>3</sub> )
	1.40			0.50		22.30		LP
		1.30		0.10		22.40		MH
Σ 5.70		8.50		0.60	3.40			

Checks : 1) No BS = No FS = 4

2) For Collimation method :  $\Sigma FS - \Sigma BS = 8.50 - 5.70 = 2.80 \text{ m}$   
 $= \text{T.B.M (level)} - \text{MH (level)} = 25.20 - 22.40 = 2.80 \text{ m}$

2) For Rise & fall Method :  $\Sigma FS - \Sigma BS = \text{T.B.M (level)} - \text{MH (level)}$   
 $= \Sigma \text{fall} - \Sigma \text{Rise} = 3.40 - 0.60 = 2.80 \text{ m}$



Example: Using Collimation level method:

The following are the staff readings in a leveling process

1.34 - 1.54 - 2.11 - 3.05 - 3.55 - 1.78 - 1.91 - 2.73 - 3.73 - 1.07 - 1.85 - 2.35 - 3.11 - 2.01 - 3.61. The Survey level was moved after the fourth, seventh and tenth points. The elevation of the 1<sup>st</sup> point is 132.70m. Compute the elevation of all points.

Solution

BS	IS	FS	C.L	R.L	Distance	Remarks
1.34			134.04	132.70	1 (1)	B.M (1)
	1.54			132.50	2	2
	2.11			131.93	3	3
3.55		3.05	134.54	130.99	TP <sub>1</sub> (4)	TP (4)
	1.78			132.76	5	5
	1.91			132.63	6	6
3.73		2.73	135.54	131.81	TP <sub>2</sub> (7)	TP (7)
	1.07			134.47	8	8
	1.85			133.69	9	9
3.11		2.35	136.30	133.19	TP <sub>3</sub> (10)	10
	2.01			134.29	11	11
		3.61		132.69	12	12

Checks: 1) No. BS = No. FS = 4

2)  $\sum BS (11.73) - \sum FS (11.74) = \text{level 12 (132.69)} - \text{level 1 (132.70)}$

Ex: The Following leveling table shows the staff readings

for underground tunnel,  
which was observed at  
certain points to get  
the following requirements:

- Level of all ground points.
- Average height of the Tunnel.
- Minimum height of the Tunnel.

Staff Reading	Remarks
1.53	B.M. (10.00 m)
2.22 & 2.72	Ground & Beam Bottom
2.10 & 2.76	~ & ~ ~
1.94 & 2.94	~ & ~ ~
1.82	C.P
2.51	C.P
1.5 & 3.42	Ground & Beam Bottom
2.78 & 2.12	~ & ~ ~
2.65 & 2.25	~ & ~ ~

Sol:

BS	IS	FS	C.L	R.L	Dist	Remarks
1.53			11.53	10.00		B.M (10.00)
	2.22			9.31		
	2.10			9.43		
	1.94			9.59		
2.51		1.82	12.22	9.71		C.P
	1.5			10.72		
	2.78			9.44		
		2.65		9.57		

Obs. Checks : a) No. BS = No. FS = 2

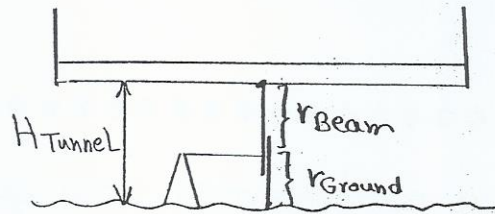
b)  $\sum BS - \sum FS = 4.04 - 4.47 = -0.43 \text{ m}$

= Last level - 1st level =  $9.57 - 10.00 = -0.43 \text{ m}$



$$H_{\text{Tunnel}} = r_{\text{Ground}} + r_{\text{Beam}}$$

Point	$r_{\text{Ground}}$	$r_{\text{Beam}}$	$H_m$
1	2.22	2.72	4.94
2	2.10	2.76	4.86
3	1.94	2.94	4.88
4	1.5	3.42	4.92
5	2.78	2.12	4.90
6	2.65	2.25	4.90



$$H_{\text{Tunnel}} (\text{Average}) = \frac{\sum H}{6} = 4.90 \text{ m}$$

$$c) H_{\text{Tunnel}} (\text{minimum}) = 4.86 \text{ m}$$

Ex: The following staff readings were recorded in a certain site : 1.23, 2.23, 2.15, 1.98, 0.92, 1.32, 1.56, 1.45, 2.31, 1.11, 2.46, 2.45, 3.12, 2.08, 0.94.

The 3rd and 6th points are turning points, the 1st reading was taken on a benchmark of level (21.540 m), Also, the 9th reading was taken on the ceiling of a certain room with the staff inverted as its Zero touching this ceiling. Calculate the level of all points and make the necessary computational checks.

Sol:

BS	IS	FS	C.L	R.L	Dist.	Remarks
1.23			22.770	21.540		B.M.
	2.23			20.540		
1.98		2.15	22.600	20.620		T.P <sub>1</sub>
	0.92			21.680		
	1.32			21.280		
1.45		1.56	22.490	21.040		T.P <sub>2</sub>
	2.31			20.180		
	1.11			21.380		
	2.46			24.950		Ceiling
	2.45			20.040		
	3.12			19.370		
	2.08			20.410		
		0.94		21.550		
Σ 4.66		4.65				

\* Computational checks : 1) No of BS = No of FS = 2

$$2) \Sigma BS - \Sigma FS = 4.66 - 4.65 = 0.01 \text{ m}$$

$$= \text{last} - \text{1st} = 21.55 - 21.54 = 0.01 \text{ m}$$



## Problem :

Complete the following leveling table :

BS	IS	FS	Rise	Fall	Red	Dist.	Remarks
1.54				(1.54)	10.00		B.M
	<u>a</u>			0.43	<u>g</u>		1
	3.54		<u>e</u>		<u>h</u>		2
<u>b</u>		<u>c</u>	1.34		<u>I</u>		3 (K)
	2.99		0.77		<u>J</u>		
		<u>d</u>	<u>F</u>	(1.22)	11.33		4
							5

N.B : Don't use the computational checks to get the unknowns.

## Solution

$$\begin{aligned}
 * 1.54 - a &= -0.43 \Rightarrow a = 1.97 \\
 * 3.54 - c &= 1.34 \Rightarrow c = 2.20 \\
 * b - 2.99 &= 0.77 \Rightarrow b = 3.76 \\
 * g &= 10 - 0.43 \Rightarrow g = 9.57 \\
 * e &= a - 3.54 \Rightarrow e = -1.57 \text{ (1.57 Fall)} \\
 * h &= g + e \Rightarrow h = 8.00 \\
 * I &= h + 1.34 \Rightarrow I = 9.34 \\
 * J &= I + 0.77 \Rightarrow J = 10.11 \\
 * J + F &= 11.33 \Rightarrow F = 1.22 \text{ (1.22 Rise)} \\
 * 2.99 - d &= F \Rightarrow d = 1.77 \\
 * K &\text{ is T.P.}
 \end{aligned}$$

\* check :

$$\begin{aligned}
 \sum FS - \sum BS &= (2.20 + 1.77) - (1.54 + 3.76) = -1.33 \text{ m} \\
 &= \text{level (B.M)} - \text{level (5)} = 10.00 - 11.33 = -1.33 \text{ m} \\
 &= \sum \text{Fall} - \sum \text{Rise} = (0.43 + 1.57) - (1.34 + 0.77 + 1.22) = -1.33 \text{ m}
 \end{aligned}$$

Problem : What will be the effect of the following  
on the computed levels :

- a) Taking a wrong BS (using Collimation level)
- b) ~ ~ ~ IS ( ~ ~ ~ )
- c) ~ ~ ~ FS ( ~ ~ ~ )
- d) ~ ~ ~ BS ( ~ Rise and Fall )
- e) ~ ~ ~ IS ( ~ ~ ~ )
- f) ~ ~ ~ FS ( ~ ~ ~ )

Solution

- a) doesn't affect the point its self but it affects all consecutive points
- b) Affects the point itself only.
- c) Affects the point itself and all consecutive points.
- d) As (a)
- e) Affects itself and all consecutive points.
- f) As (c)



### Problem :

The following observations were recorded using an ordinary to get the levels of an existing bridge from its beginning up to

its crest ( قمة ) : 3.55 - 3.24 - 3.04 - 2.77 - 2.45 - 2.15 - 1.98 -

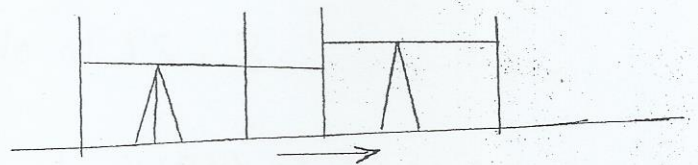
3.17 - 2.99 - 2.67 - 2.35 - 2.05 - 1.97 - 2.85 - 2.45 - 2.22 - 2.02 ,

The staff was moved from the lowest point of the bridge and ending at its crest. If the level of the first point is (123.55)

Find the level of all points using Collimation level method. Make all the necessary checks.

### Solution :

∴ The bridge is going upwards (low point to crest)



∴ Any reading is less than its before reading except for turning points (sudden rise in reading).

BS	IS	FS	C.L	R.L	Dist	Remarks
3.55			127.10	123.55	B.M	B.M
	3.24		127.11	123.86	1	
	3.04		127.12	124.06	2	
	2.77		127.13	124.33	3	
	2.45		127.14	124.65	4	
	2.15		127.15	124.95	5	
3.17		1.98	128.29	125.12		T.P.
	2.99		128.30	125.30		
	2.67		128.31	125.62		
	2.35		128.32	125.94		
	2.05		128.33	126.24		
2.85		1.97	129.17	126.32		T.P.
	2.45		129.18	126.72		
	2.22		129.19	126.95		
		2.02	129.21	127.15		

Comp. checks: 1) No. of BS = No. of FS = 3

$$2) \sum FS - \sum BS = \text{Level (B.M)} - \text{Level (14)} = -3.60 \text{ m}$$

$$(5.97) \quad (9.57) \quad (123.55) \quad (127.15) \quad 3.60$$



## Observational checks

1) Closure error (e): خط الغلق

It is the difference between the computed level & the given level of a certain point (B.M)

$$e = H_{\text{true}} - H_{\text{calculated}}$$

2) Closure Tolerance (Permissible error) (E): الخط المسموح به

$$E = 12 \sqrt{L} = \dots \text{ mm}$$

where  $L$ : Length of leveling route in Km.

or

$$E = 5 \sqrt{n} = \dots \text{ mm}$$

where  $n$ : number of setups

Note: If you can compute by both methods, take the smaller value for (E) For comparison

\* If  $e \leq E \Rightarrow$  Observations are accepted and elevations must be corrected

If  $e > E \Rightarrow$  Observations are rejected and should be repeated.

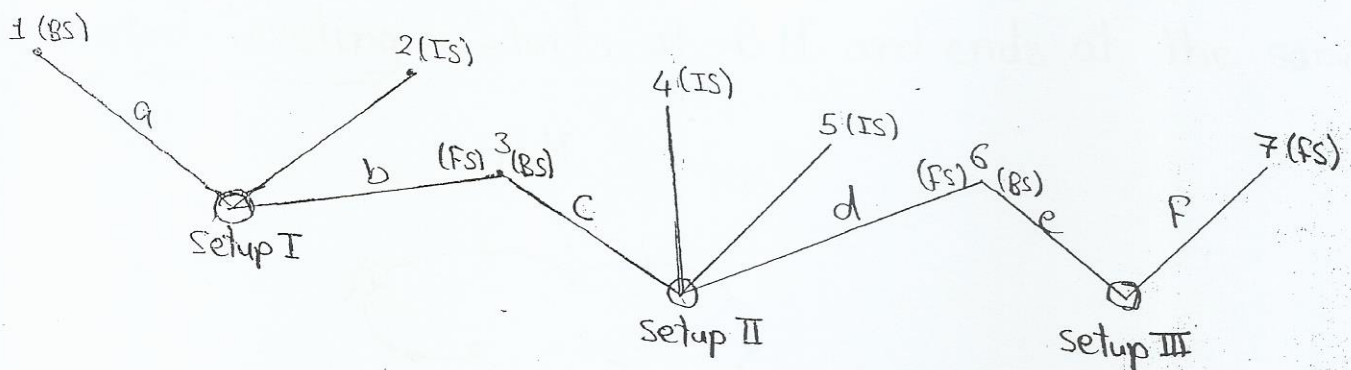
### Considerations :

- 1) The error is distributed on all the observed points except the 1st observed point. (B.M)

Error  $\xrightarrow{\text{distributed on}}$  (No. of T.P) + 1

- 2) The error is distributed equally and accumulated.

Note: Route length (L) is the sum of the distances between the instrument and both the back sight and fore sight points in each setup.



$$L = a + b + c + d + e + f$$



## \* Types of Ordinary leveling :

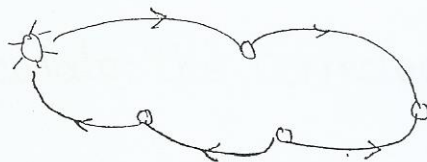
1) Open leveling : Starts at B.M and ends at unknown elevation.



2) Connected leveling : Starts at B.M. and ends at another B.M.



3) Closed leveling : Starts at B.M and ends at the same B.M.



\* Computational checks can be done for the three types.

\* Observational checks (Closure error) can be done only for connected and closed only.

### Example:

The following Staff readings were recorded in an ordinary Leveling Job:

(1.361, 2.894, 2.068, 3.065, 0.855, 0.611, 1.805, 2.741, 1.711, 2.855, 1.362, 2.111, 0.856, 2.015)

The survey level was moved after recording the staff readings of the Fourth, sixth & seventh leveling points.

The First and last readings were taken at two Bench marks A (20.892) & B (20.100) respectively.

The leveling route length is 500 m.

a) Is the closed leveling accepted or not? Why?

b) If yes, Calculate the corrected elevations of all points.

\* Make all necessary checks using the collimation level method in your solution.



Sol:

BS	IS	FS	C.L	R.L	R.L <sub>Adj</sub>	Dist.	Remarks
1.361			22.253	20.892	20.892		A(20.892)
	2.894			19.359	19.357		
	2.068			20.185	20.183		
0.855		3.065	20.043	19.188	19.186		T.P <sub>1</sub>
	0.611			19.432	19.428		
2.741		1.805	20.979	18.238	18.234		T.P <sub>2</sub>
2.855		1.711	22.123	19.268	19.262		T.P <sub>3</sub>
	1.362			20.761	20.753		
	2.111			20.012	20.004		
	0.856			21.267	21.259		
		2.015		20.108	20.100		B(20.100)
7.812		8.596					

\* Computational checks: 1) No. of BS = No. of FS = 4

$$2) \sum BS - \sum FS = 7.812 - 8.596 = -0.784 \text{ m}$$

$$= \text{last level} - 1^{\text{st}} \text{ level} = 20.108 - 20.892 = -0.784 \text{ m}$$

\* Observational checks: closing error (e) = 20.108 - 20.100 = 0.008 = 8 mm

$$E = 5\sqrt{4} = 10 \text{ mm} \quad \text{or} \quad E = 12\sqrt{0.5} = 8.485 \text{ mm}$$

$\therefore e < E \Rightarrow$  Observations are accepted.



Example: The following observations were recorded during

Leveling process as 1.5, 1.8, 2.2, 1.7, 1.3, 2.1, 1.8, 1.7, 3.1, 1.4.

\* If the underlined readings are F.S, the first and last readings are taken at two bench marks (5.00) & (5.696) m respectively.

\* If the length of the leveling route is 300 m, check the accuracy of the observations and compute the corrected levels.

Solution:

Point	BS	IS	FS	C.L	R.L	R.L <sub>corrected</sub>	Remarks
A	1.5			6.50	5.00	5.00	B.M
B		1.8			4.70	4.699	
C	1.7		2.2	6.00	4.30	4.299	C.P <sub>1</sub>
D		1.3			4.70	4.698	
E	1.8		2.1	5.70	3.90	3.898	C.P <sub>2</sub>
F	3.1		1.7	7.10	4.00	3.997	C.P <sub>3</sub>
G			1.4		5.70	5.696	B.M

1) Computational checks :- 1) No. of BS = No. of FS = 4

$$2) \sum FS - \sum BS = 5.00 - 5.70 = -0.70 \text{ m}$$

2) Observational check:  $E = 5\sqrt{4} = 10 \text{ mm}$  or  $E = 12\sqrt{0.3} = 6.57 \text{ mm}$

$$e = 5.696 - 5.70 = -0.004 \text{ m} = -4 \text{ mm} < E (6.57 \text{ mm})$$

2<sup>nd</sup> year civil

$\Rightarrow$  Observations are accepted.



Example:

The following readings were carried out on an existing road center line. The position of the level and the staff were usually lying on the existing road center line in each surveying setup. The readings are:.

Upper	1.72	2.13	2.25	2.19	1.86	1.96	2.13	2.42	2.30	2.20	2.62	2.15
Middle	1.67	1.98	2.00	1.84	1.81	1.91	1.98	2.67	2.35	2.15	2.47	1.89
Lower	1.62	1.83	1.75	1.49	1.76	1.86	1.83	2.92	2.40	2.10	2.32	1.63

- \* The first reading was taken at a Benchmark (B.M) of an elevation (173.32) in a front of the road center line. The survey level moved whenever needed on the center line of the road.
- Check the staff readings and correct them whenever required.
  - Form an ordinary level field sheet and calculate the elevations of all points using the rise and fall method then perform all necessary checks.
  - If the elevation of the last point is (173.38)m, compute the closing error.



Solution :

	T.P							T.P				
$R_u$	1.72	2.13	2.25	2.19	1.86	1.96	2.13	1.58	1.70	2.20	2.62	2.15
$R_m$	1.67	1.98	2.00	1.84	1.81	1.91	1.98	1.33	1.65	2.15	2.47	1.89
$R_l$	1.62	1.83	1.75	1.49	1.76	1.86	1.83	1.08	1.60	2.10	2.32	1.63



\* There is mistake in 2 readings ( $R_u < R_l$ ), therefore the staff was inverted in these 2 readings, therefore the corrected reading = 4.00 (staff length) - observed reading

Point	BS	IS	FS	Rise	Fall	R.L	Remarks
A	1.67					173.32	B.M
B		1.98			10.31	173.01	
C		2.00			10.02	172.99	
D	1.81		1.84	0.16		173.15	T.P <sub>1</sub>
E		1.91			10.10	173.05	
F		1.98			10.07	172.98	
G	1.65		1.33	0.65		173.63	T.P <sub>2</sub>
H		2.15			0.50	173.13	
I		2.47			10.32	172.81	
J			1.89	0.58		173.39	

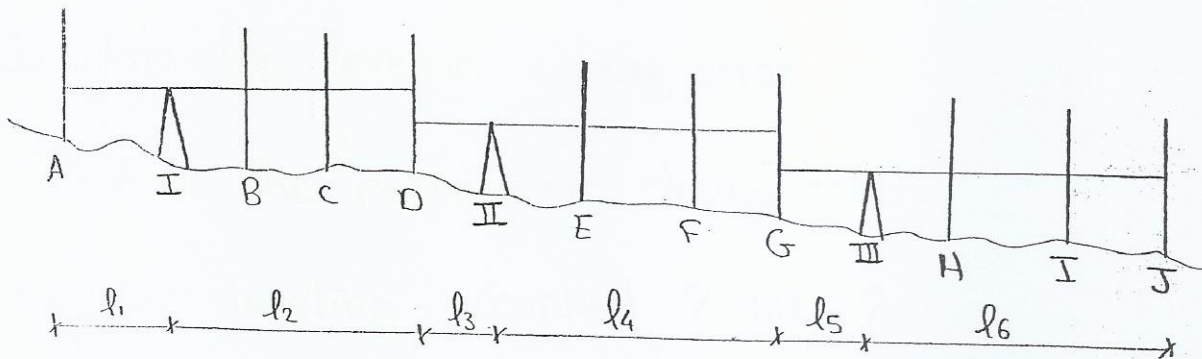


Comp. checks : 1) No. of BS = No. of FS = 3

$$2) \sum FS - \sum BS = \sqrt{A} - \sqrt{J} = \sum \text{Fall} - \sum \text{Rise} = -0.07 \text{ m}$$

(5.66)    (5.13)    (173.32) - (173.39)    (1.32)    (1.39)

c) Observational check :  $e = 173.38 - 173.39 = -0.01 \text{ m} = -10 \text{ mm}$



$$L = l_1 + l_2 + l_3 + l_4 + l_5 + l_6$$

$$l = 100 (R_u - R_L)$$

$$\therefore L = 100 [(1.72 - 1.62) + (2.19 - 1.49) + (1.86 - 1.76) + (1.58 - 1.08) + (1.70 - 1.60) + (2.15 - 1.63)]$$

$$\therefore L = 202 \text{ m}$$

$$\therefore E (\text{Closure Tolerance}) = 12 \sqrt{0.202} = 5.39 \text{ mm} \text{ or } E = 5\sqrt{3} = 8.66 \text{ mm}$$

$\because e > E \Rightarrow$  Observations are not accepted.  
(10mm) (5.39mm)

### Problem :

Given the elevation of (B.M) is  $100.67 \text{ m}$ ,  $\sum B.S = 27.89 \text{ m}$ ,  $\sum F.S = 50.45 \text{ m}$ , the elevation of the last point in the ordinary leveling is  $78.13 \text{ m}$  and the number of setups are 9.

- Calculate the leveling closing error.
- Calculate the permissible closing error.
- Is the leveling accepted? Why?

### Solution :

$$\sum F.S - \sum B.S = 50.45 - 27.89 = 22.56 \text{ m}$$

$$1^{\text{st}} \text{ level} - \text{last level} = 100.67 - 78.13 = 22.54 \text{ m}$$

$$\text{a) Closing error (e)} = 22.56 - 22.54 = 0.02 \text{ m} = 20 \text{ mm}$$

$$\text{b) Permissible error (E)} = \pm 5\sqrt{9} = \pm 15 \text{ mm}$$

$$\text{c) } \because e > E$$

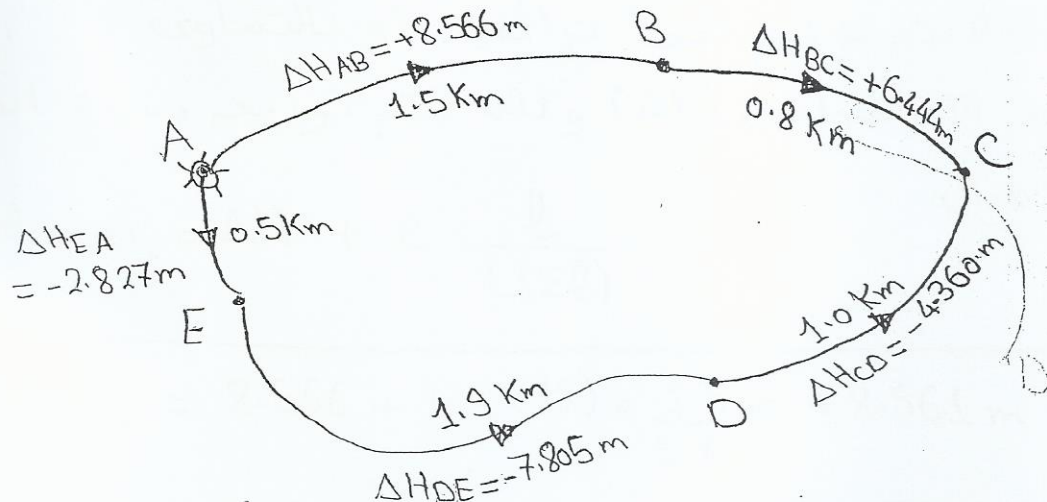
$\therefore$  leveling is not accepted

and Observations must be repeated.



### Very Important example:

For a Closed Flying leveling, the Following height differences and lengths were observed as shown:



If the true level of point A is 20.00 m, Check the accuracy of the height differences and Compute the corrected levels of all points.

Solution:

$$H_A (\text{calculated}) = 20 + 8.566 + 6.444 - 4.360 - 7.805 - 2.827 \\ = 20.018 \text{ m}$$

$$H_A (\text{Given}) = 20.000 \text{ m}$$

$$\therefore e = 20.000 - 20.018 = -0.018 \text{ m}$$

$$L = 1.5 + 0.8 + 1.0 + 1.9 + 0.5 = 5.7 \text{ Km}$$

$$E = 12\sqrt{L} = 12\sqrt{5.7} = 28.65 \text{ mm}$$

$\therefore e \leq E \Rightarrow$  Observations are accepted.

Note: في هذا المثال لا يتم توزيع الخطأ تراكمياً أو بالتساوي بين فروق الارتفاعات ( $\Delta H$ ) ولكنه يتم توزيعه بنسبة الطول لمجموع الأطوال

$$\Delta H_{\text{correct}} = \Delta H + e \frac{l}{L(\sum l)}$$

$$\therefore \Delta H_{AB \text{ corr.}} = 8.566 + (-0.018) \times \frac{1.5}{5.7} = +8.561 \text{ m}$$

$$\Delta H_{BC \text{ corr.}} = 6.444 + (-0.018) \times \frac{0.8}{5.7} = +6.441 \text{ m}$$

$$\Delta H_{CD \text{ corr.}} = -4.360 + (-0.018) \times \frac{1}{5.7} = -4.363 \text{ m}$$

$$\Delta H_{DE \text{ corr.}} = -7.805 + (-0.018) \times \frac{1.9}{5.7} = -7.811 \text{ m}$$

$$\Delta H_{EA \text{ corr.}} = -2.827 + (-0.018) \times \frac{0.5}{5.7} = -2.828 \text{ m}$$

Check:  $\sum \Delta H = 0$

$$\therefore H_B = 20.00 + 8.561 = 28.561 \text{ m}$$

$$H_C = 28.561 + 6.441 = 35.002 \text{ m}$$

$$H_D = 35.002 - 4.363 = 30.639 \text{ m}$$

$$H_E = 30.639 - 7.811 = 22.828 \text{ m}$$

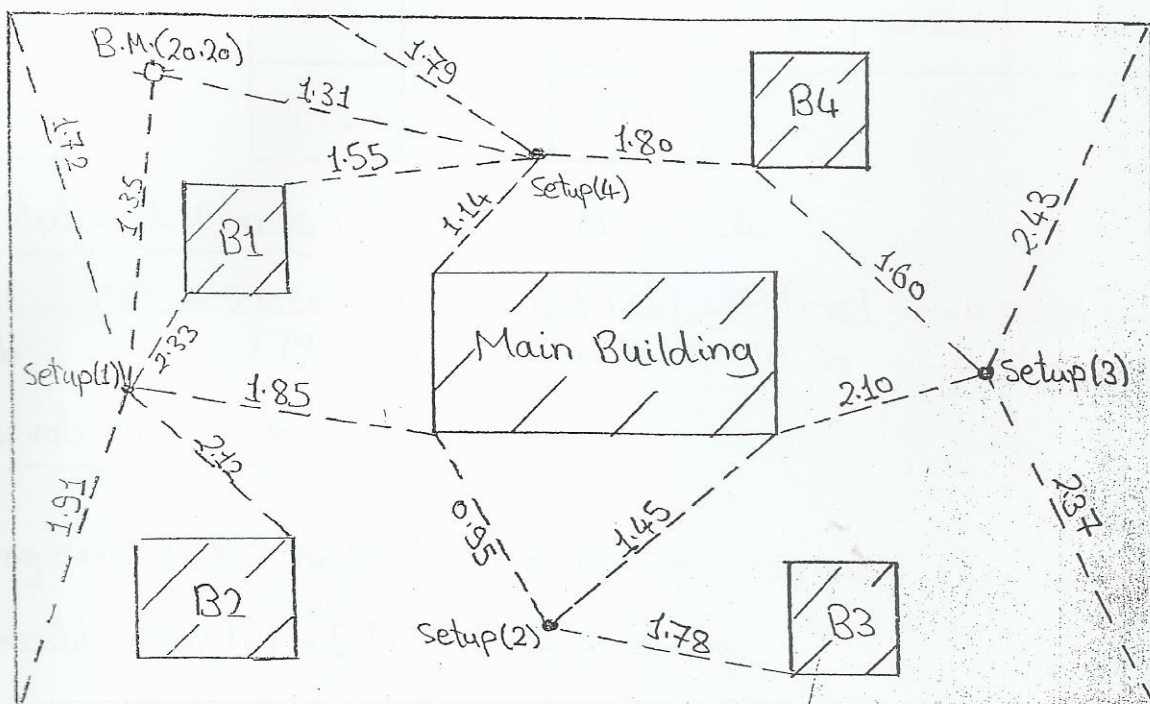


Ex: The following figure has shown a sketch of a site. The landscape engineer needs the elevations of some points in the site.

The surveyor made a closed loop leveling starting from B.M. It is required to form a leveling field sheet and Calculate the elevations of all points using the Rise & Fall method, then perform all the necessary computational checks.

Is the leveling loops accepted? why?

If yes, Compute the corrected elevations of all points.





Sol:

BS	IS	FS	Rise	Fall	R.L	R.L <sub>adj</sub>	Dist.	Remarks
1.35					20.20	20.20		B.M.(20.20)
	1.72			0.37	19.83	19.8325		
	1.91			0.19	19.64	19.6425		
	2.12			0.21	19.43	19.4325		
	2.33			0.21	19.22	19.2225		
0.95		1.85	0.48		19.70	19.7025		T.P <sub>1</sub>
	1.78			0.83	18.87	18.8750		
2.10		1.45	0.33		19.20	19.2050		T.P <sub>2</sub>
	2.37			0.27	18.93	18.9375		
	2.43			0.06	18.87	18.8775		
1.80		1.60	0.83		19.70	19.7075		T.P <sub>3</sub>
	1.14		0.66		20.36	20.3700		
	1.55			0.41	19.95	19.9600		
	1.79			0.24	19.71	19.7200		
		1.31	0.48		20.19	20.2000		B.M.(20.20)
6.20		6.21	2.78	2.79				

\* Computational Checks : 1) No BS = No FS = 4

$$2) \sum BS - \sum FS = \sum Rise - \sum Fall = \text{last level} - \text{1st level} = -0.01 \text{ m}$$

$$6.20 - 6.21 = 2.78 - 2.79 = 20.19 - 20.20 = -0.01 \text{ m}$$

\* Observational Check :

$$\text{Closing error (e)} = 20.19 - 20.20 = -0.01 \text{ m} = -10 \text{ mm}$$

$$\text{Permissible error (E)} = 5\sqrt{n} = 5\sqrt{4} = 10 \text{ mm}$$

$\therefore e < E \Rightarrow$  Observations are accepted



Ex: The following staff readings were recorded off from the existing ground for a proposed road:

1.10, 1.90, 1.60, 0.90, 2.10, 1.00, 1.50, 1.90, 2.30, 1.80, 1.60, 1.80

The 3<sup>rd</sup>, 4<sup>th</sup> and 7<sup>th</sup> points are turning points, the 1<sup>st</sup> reading was taken on a bench mark of level (10.50). Calculate the level of all points and make the necessary checks.

\* Note : \* The points are 20m apart from each other.

\* The design level starts at 7.80 and is going 1% upwards.

Sol:

BS	IS	FS	C.L	R.L	Dist	Remarks
1.10			11.60	10.50	0	B.M
	1.90			9.70	20	
0.90		1.60	10.90	10.00	40	T.P <sub>1</sub>
1.00		2.10	9.80	8.80	60	T.P <sub>2</sub>
	1.50			8.30	80	
	1.90			7.90	100	
1.80		2.30	9.30	7.50	120	T.P <sub>3</sub>
	1.60			7.70	140	
		1.80		7.50	160	
$\Sigma$ 4.80		7.80				

Comp. checks:

1)  $\text{No. BS} = \text{No. FS} = 3$

2)  $\Sigma \text{BS} - \Sigma \text{FS} = 4.80 - 7.80$   
 $= \text{last} - 1^{\text{st}} = 7.50 - 10.50$   
 $= -3.00$

\* For the previous example, if we want to draw a longitudinal profile, How?

- Hz Scale is 1:1000      1cm = 10m
- VL Scale is 1:100      1cm = 1m
- Datum Starts by elevation divisible by (5.00m)
- if  $D.L > G.L \Rightarrow$  Fill  
 $D.L < G.L \Rightarrow$  Cut

