LEVELLING SURVEY

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e-book

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PREFACE

"Alhamdulillah, we are grateful to Allah The Almighty for His help that enabled us to complete the compilation of this e-book."

Sr. Hj. Mohd Fikri bin Ismail
Pengarah Politeknik Sultan Mizan Zainal Abidin

This e-book is written based on the curriculum as well as compilation of lecture notes by polytechnic lecturers for the Diploma in Civil Engineering. Hence, it is to be a turning point for the author to published e-book titled LEVELLING SURVEY. This e-book covers a basic background and application of levelling on the site. It is also suitable as reference and exercise for students and individuals who involved in the field of Engineering Survey. In this e-book are focused on theoretical and examples of problem solving as enhancement to increase students' understanding in the field. This e-book also included a list of references.

Furthermore, we would like to thank our colleagues in the Department of Civil Engineering, Sultan Mizan Zainal Abidin Polytechnic who gave a lot of encouragement, support and contributions in preparing this e-book until it was published.

May Allah The Almighty bless this effort and reward all the good that has been given in the process of preparing and compiling this e-book.

Nor Asmihan binti Hamzah
Wan Srihati Azurahayu binti Wan Ahmad
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1. Basic Principles of Levelling

1.1 Introduction

Basic principle of levelling is method of transferring height between known points level to unknown point level. Levelling is the procedure used when one is determining differences in elevation between points that are some distance from each other. It is a vital operation in producing necessary data for mapping, engineering, design, and construction.

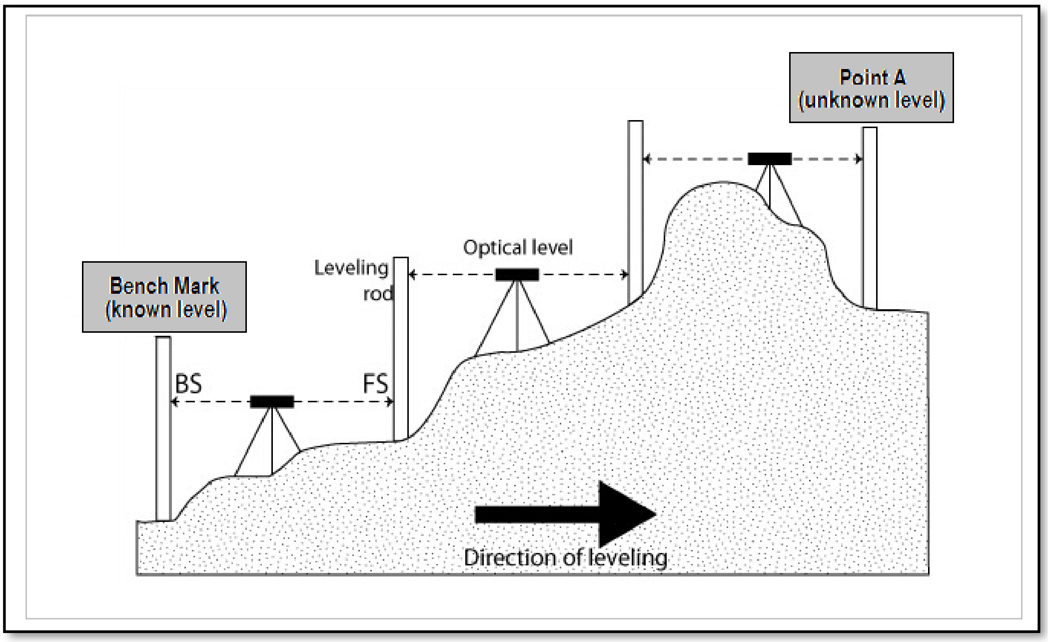

Figure 1.1 : Principle of Levelling

Purposes of levelling results are used to:

a. Design highways, railroads and other facilities having grade lines that the best conform to existing topography.
b. To prepare layout for water reticulation, sewerage, sanitary or drainage.
c. Lay out construction project according to planned elevations.
d. To prepare longitudinal section or cross section of project.
e. Calculate volume of earthwork and other materials.
f. Investigate drainage characteristics of an area.
g. Develop contour maps showing general ground configurations.
h. Study earth subsidence and crustal motion.
i. Carrying out excavation up to a prescribed depth (elevation) for footing of a structure.
j. Delineating shoreline for a proposed reservoir.

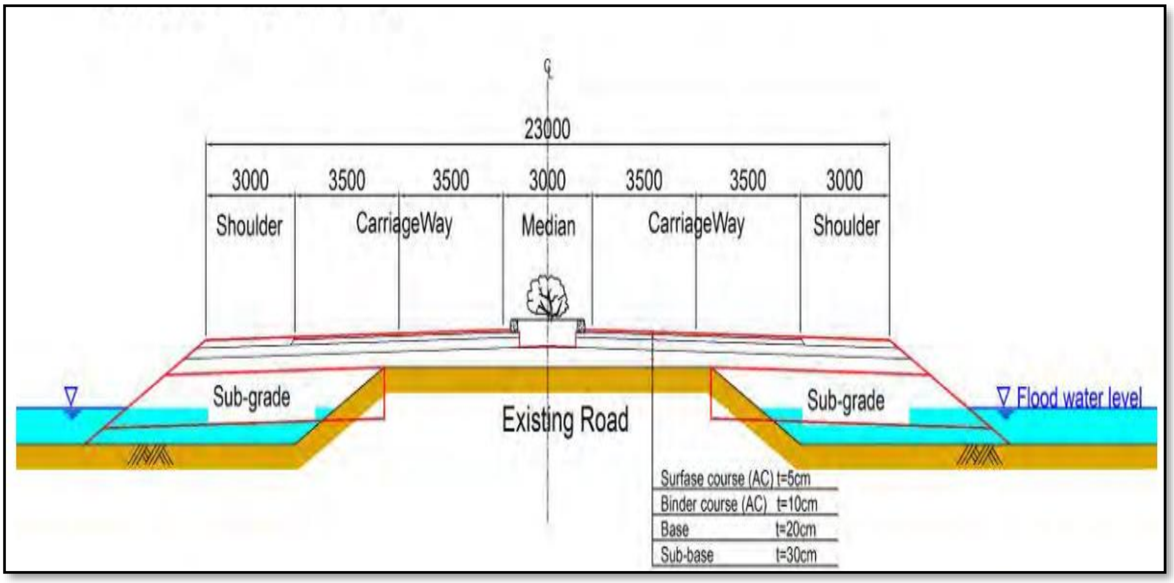

Figure 1.2 : Road Design

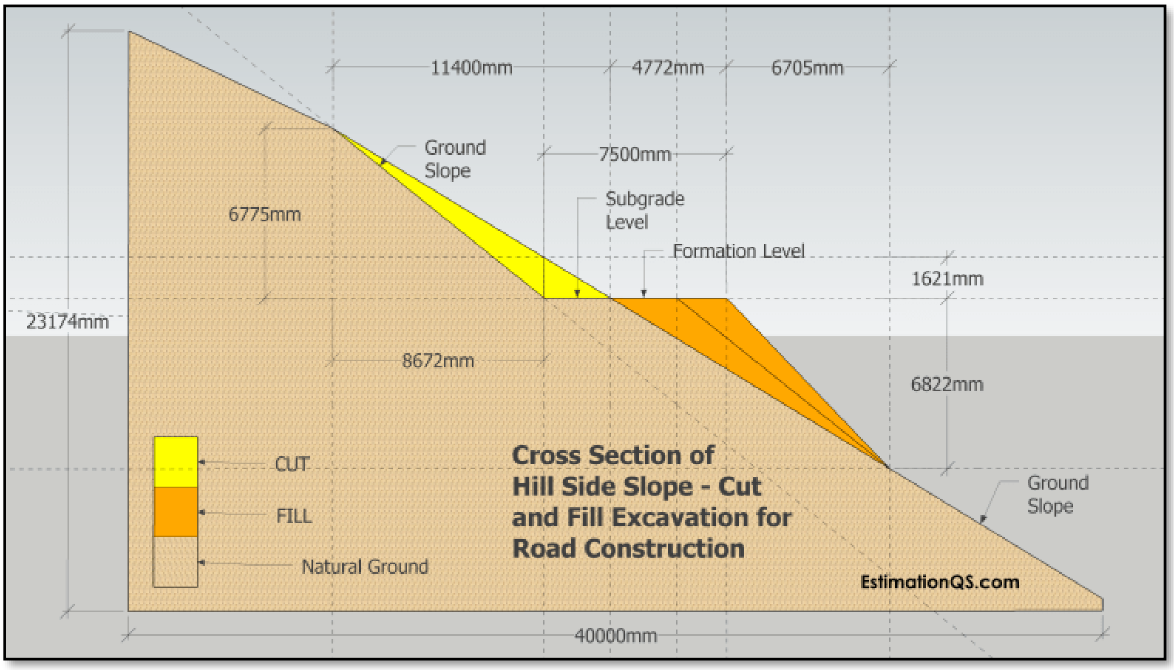

Figure 1.3 : Volume of Earthwork (Cut and Fill)

2. Terms in Levelling

2.1 Reduced Level or Elevation

A vertical distance above or below a reference datum. Have a positive and negative value to describe the point's positions either above or below datum.

2.2 Datum

A specified surface level where all the reduced level referred to the sea level. The commonly used datum in levelling is Mean Sea Level.

2.3 Mean Sea Level

The average height of the sea at a tide station. This height level is carried out in a long period of time from a fixed predetermined reference level.

2.4 Level Surfaces

Level surface is a curved which at each point is perpendicular to the direction of gravity at the point.

2.5 Level Line

Level line is a level surface therefore it is a curve line.

2.6 Line of Collimation

Line of collimation is a horizontal line which passes through intersection between the optical center of the object glass and the center of crosshair.

2.7 Geoid

Geoid is a surface coinciding with mean sea level in oceans and lying under the land.

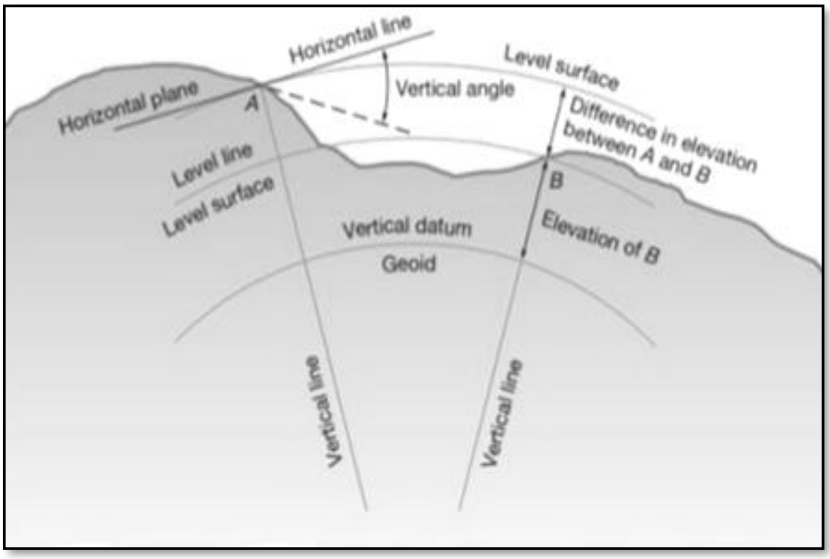

Figure 2.1 : Relationship between Reduced Level, Mean Sea Level and Datum

2.8 Back Sight (BS), Fore Sight (FS) and Intermediate Sight (IS)

Back sight is first sighting taken after temporary levelling instrument had been carried out.

Fore sight is the last sighting taken before levelling instrument transferred.

Intermediate sight is the sighting taken between back sight and foresight.

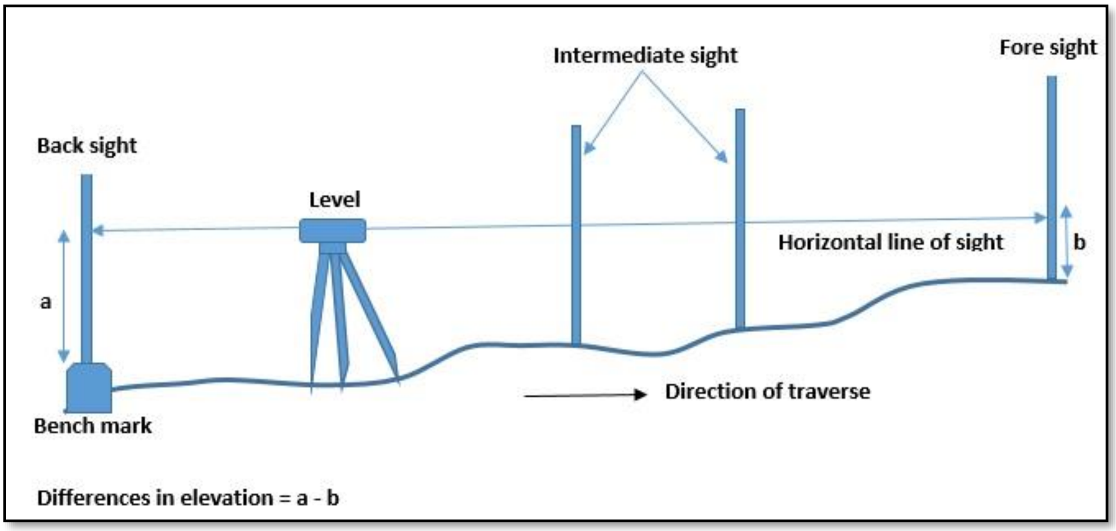

Figure 2.2 : Back Sight, Fore Sight and Intermediate Sight

2.9 Change Point (CP) or Turning Point (TP)

Change points or turning point is a point where foresight and back sight reading are taken.

2.10 Benchmarks (BM) and Temporary Benchmarks (TBM)

Benchmarks is a fixed reference point of known elevation referred to the datum. Temporary benchmarks are fixed point but temporary and its location is nearest with surveying are.

Figure 2.3 : Example of Benchmarks Prepared by JUPEM

Figure 2.4 : Example of Temporary Benchmarks

3. Types of Instruments Used in Levelling

3.1 Automatic Level

These instruments used to establish a horizontal plane at each point where they are set up and consist of a telescope and compensator. The telescope provides a magnified line of sight for taking measurement and the compensator built into the telescope, ensure that the line of sight viewed through the telescope is horizontal even if the optical axis of the telescope is not exactly horizontal.

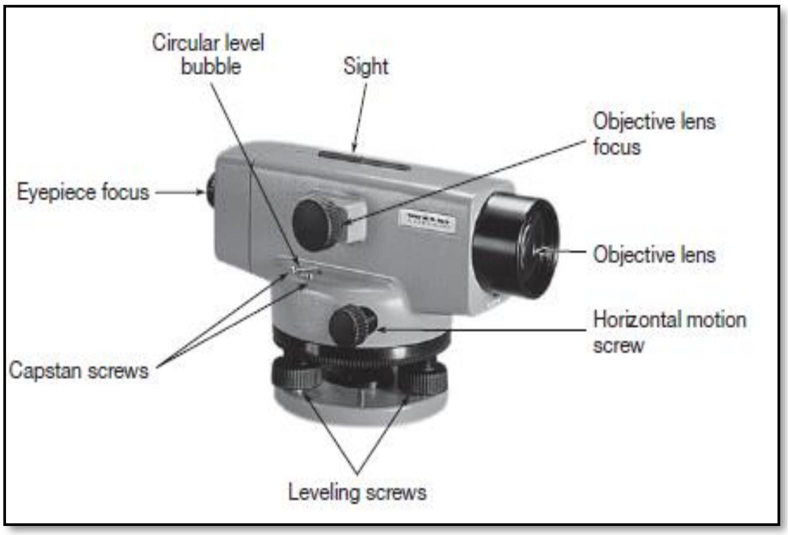

Figure 3.1 : Parts of an Automatic Level

3.2 Levelling Staff

Used to determine the different in height. A levelling staff is the equivalent of a long ruler, and it enables distances to be measured vertically from the horizontal plane established by a level to points where heights are required. Many types of staff are in current use, and these can have lengths of up to 5 meters. It is usually telescopic but can be socketed in as many as 5 sections for ease of carrying and use and it is made of aluminium or non-conductive fiberglass.

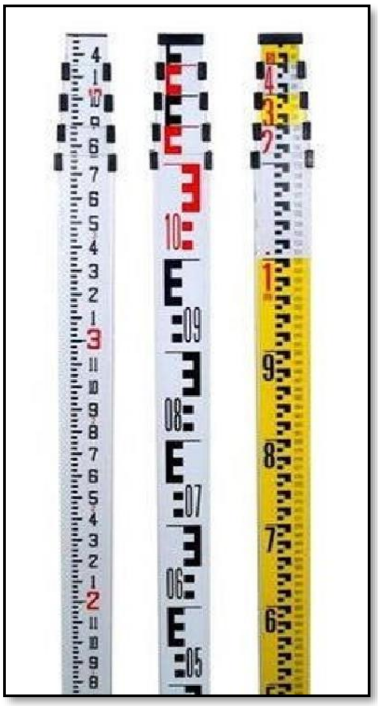

Figure 3.2 : Levelling Staff

3.3 Tripod

Used to attach automatic level on it. The first part of the levelling process is to set the tripod in position for the first reading, ensuring that the top of the tripod is levelled by eye after the tripod leg have been pushed firmly into the ground.

Figure 3.3 : Tripod

3.4 Staff Bubble

Used to make sure levelling staff must be held vertically at each point where a height is to be measured. 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.

Figure 3.4 : Staff Bubble

3.5 Tape

Used to measure the distance between staff (point to another point) during levelling work.

Figure 3.5 : Tape

4. Differences of Level Instruments

Dumpy Level - It is simple compact and stable. - The telescope is rigidly fixed to its support therefore cannot be rotated about its longitudinal axis. - A long bubble tube is attached to the top of telescope. - Dumpy literally means short and thick.	
Tilting Level - It consists of a telescope attached with a level tube which can be tilted within few degrees in vertical plane by a tilting screw. - The main peculiarity of this level is that the vertical axis need not be truly vertical since the line of collimation is not perpendicular to it. - The line of collimation, is, however, made horizontal for each pointing of telescope by means of tilting screw. - It is mainly designed for precise levelling work.	
Automatic Level - Also termed as self-aligning level. - The fundamental difference between automatic and the classic spirit level is that in the former the line of sight is no longer levelled manually using a tubular spirit level but is levelled automatically within a certain tilt range. - This is achieved by compensator in the telescope.	

Digital Electronic Level - Uses a charge-coupled device (CCD) for determining heights and distances, with the automatic recording of data for later transfer to a computer. - Data can be stored in internal on-board memory or on easily transferring the PCMCIA Memory Card System and then transferred to a computer. - Increases productivity by about 50 percent, with the bonus of the elimination of field- book entry mistake.	

Figure 4.1 : Differences between Dumpy, Tilting and Automatic Level Instrument

5. Field Procedure in Levelling

The field work consists of reconnaissance, taking observation, booking, and reducing the level in the field book.

a. Reconnaissance

Before undertaking the levelling operation, a reconnaissance should be made. The positions of fundamental benchmarks are determined to control the location of level lines. The route to be followed is then studied in detail to decide the positions of temporary benchmarks. Thereafter, the positions of the staff stations are decided.

b. Observations

Before starting the work, a surveyor should check the adjustment of the instrument and should ensure that it is in good order. The observation is taken on the levelling staff corresponding to the horizontal hair.

c. Booking

The observations are recorded in a level book/ levelling booking form. There are two methods of booking and reducing the levels of the points from the observed staff readings.

i. Rise and Fall Method:

It consists of determining the difference of levels between the consecutive points by comparing their staff readings. The rise or fall is obtained by calculating the difference between the consecutive staff readings. A rise is indicated if the back sight is more than the fore sight, and a fall if the back sight is less than the foresight. Then the reduced level of each point is obtained by adding the rise to, or by subtracting the fall from the reduced level of the preceding point. When the reduced level of the Table 5.1 has been completed, a check on the arithmetic involved is possible and must always be applied. The arithmetical check is:

$$\text{Arithmetical Check (AC): } \sum BS - \sum FS = \sum Rise - \sum Fall = \text{Last RL} - \text{First RL}$$

Table 5.1 : Rise and Fall Method

Sight			Rise (+)	Fall (-)	Reduced Level (RL)	Remarks
Back (BS)	Intermediate (IS)	Fore (FS)				
0.665					150.230	BM
	0.825			0.160	150.070	
	2.540			1.715	148.355	
3.200		0.385	2.155		150.510	CP1
1.565		1.400	1.800		152.310	CP2
	2.000			0.435	151.875	
		2.450		0.450	151.425	TBM
∑BS = 5.430		∑FS = 4.235	∑Rise = 3.955	∑Fall = 2.760		
Arithmetical Check (AC)						
∑BS - ∑FS	= 5.430 - 4.235	= 1.195				
∑Rise - ∑Fall	= 3.955 - 2.760	= 1.195				
Last RL - First RL	= 151.425 -150.230	= 1.195				

ii. Height of Collimation (HOC) or Height of Instrument Method:

The elevation of the plane of collimation for the first setup of the level is determined by adding back sight to the reduced level of a BM. The reduced level of a plane of collimation is also known as height of instrument (HI). The reduced levels of the intermediate points and the first change point are obtained by subtracting the staff readings taken on these points, i.e. by subtracting successively (one by one) IS and FS from the HI. The instrument is then shifted to the second position and a new plane of collimation is set up by taking a BS on the change point.

Arithmetical Check (AC): ∑BS - ∑FS = Last RL - First RL

Table 5.2 : Height of Collimation (HOC) or Height of Instrument Method

Sight			Height of Collimation (HOC)	Reduced Level (RL)	Remarks
Back (BS)	**Intermediate (IS)**	**Fore (FS)**			
0.665			150.895	150.230	BM
	0.825			150.070	
	2.540			148.355	
3.200		0.385	153.710	150.510	CP1
1.565		1.400	153.875	152.310	CP2
	2.000			151.875	
		2.450		151.425	
∑BS = 5.430		∑FS = 4.235			TBM
Arithmetical Check (AC)					
∑BS - ∑FS	= 5.430 - 4.235	= 1.195			
Last RL - First RL	= 151.425 -150.230	= 1.195			

5.1 Accuracy of Levelling

Misclosure was obtained for the levelling by comparing the reduced level of the closing BM or TBM with its initial RL obtained from staff readings. By comparing the two reduced levels, an assessment of the quality or precision of the levelling can be made, and it is usual to check that the misclosure obtained is better than specified value called the allowable misclosure.

Misclosure = Last Point Specified Value (BM/TBM) – Last RL Observed

In construction sites and other engineering projects, levelling is usually carried out over short distances, and it can include a lot of instrument positions. For this type of work, the allowable misclosure for levelling is given by:

$$\text{Allowable misclosure} = \pm m\sqrt{n}$$

Where m is a constant and n is the number of instrument positions. A value often use for m is 5 mm. When the misclosure obtained from staff readings is compared to the allowable misclosure and it is found that the misclosure is greater than the allowable value, the levelling is rejected and must be repeated. If the misclosure is less than allowable misclosure, the misclosure is distributed between the instrument positions. Correction will be given for each line of observation.

Allowable misclosure: $\pm 5 \sqrt{n}$ mm : n – number of stations in milimeters

When assessing the precision of any levelling by this method, it may be possible for site engineer to use a value of m based on site conditions. For example, if the reduced levels found are to be used to set out earthwork excavation, the value of m might be 30 mm but for setting out steel and concrete structures, the value of m might be 3 mm. Values of m may be specified as tolerances in contract documents or where they are not given, may simply be chosen by an engineer based on experience. The Federal Geodetic Control Subcommittee (FGCS) recommends formula to compute allowable misclosure:

$$\text{Allowable misclosure} = \pm m\sqrt{K}$$

Where m is a constant and K is total perimeter distance in kilometers. Specifies constant of m is 4, 5, 6, 8 and 12 mm for the five classes of levelling. The particular order of accuracy recommended for a given type of project.

Table 5.3 : Calculation Accuracy of Levelling

Sight			Rise	Fall	Reduced	Corr	Final Reduced	Remarks
Back (BS)	**Intermediate (IS)**	**Fore (FS)**	**(+)**	**(-)**	**Level (RL)**		**Level (FRL)**	
0.665					150.230	-	**150.230**	BM
	0.825			0.160	150.070	+ 0.001	150.071	
	2.540			1.715	148.355	+ 0.001	148.356	
3.200		0.385	2.155		150.510	+ 0.001	150.511	CP
1.565		1.400	1.800		152.310	+ 0.002	152.312	CP
	2.000			0.435	151.875	+ 0.003	151.878	
		2.450		0.450	151.425	+ 0.003	**151.428**	TBM
∑BS = 5.430		∑FS = 4.235	∑Rise = 3.955	∑Fall = 2.760				

Arithmetical Check (AC)

∑BS - ∑FS = 5.430 - 4.235 = 1.195

∑Rise - ∑Fall = 3.955 – 2.760 = 1.195

Last RL - First RL = 151.425 -150.230 = 1.195

Accuracy

1. Misclosure = Last RL Observed - Last Point Specified Value (BM/TBM)
   = 151.425 – 151.428
   = - 0.003 m

2. Allowable Misclosure = $\pm 5 \sqrt{n}$ mm : n – number of station
   = $\pm 5 \sqrt{3}$
   = 8.660 mm convert to m /1000
   = 0.009 m

Conclusion

0.003 < 0.009

So, Levelling work are **accepted**

Correction

Misclosure / Number of station

= + 0.003 / 3 station

= + 0.001 for each station

Note:

- Allowable misclosure should always be computed and a decision made to accept or reject levelling work.
- Misclosure should be ≤ allowable misclosure, so levelling work are accepted.
- If the levelling is accepted, the reduced levels obtained should be adjusted (correction will proceed).
- If it is rejected, the levelling must be repeated-never trying to correct or invent a reading a line of levels close.

5.2 Rise and Fall Method versus Height of Collimation Method

Table 5.4 : Rise and Fall Method versus Height of Collimation Method

No	Rise and Fall	Height of Collimation (HOC)
1.	It is simple but slow, as the staff reading of successive stations are compared to get rise or fall. This method gives a visual indication of topography.	It is more rapid.
2.	There are three arithmetical check (AC): $\sum$BS - $\sum$FS = $\sum$Rise - $\sum$Fall = Last RL - First RL	There are two arithmetical check (AC): $\sum$BS - $\sum$FS = Last RL - First RL
3.	Since there is complete check on the RLs of intermediate stations; error, if any, in the intermediate sights are also detected.	Since there is no check on the RLs of intermediate stations; error, if any, in the intermediate sights are not detected.
4.	It is well suited for determining the difference of levels of two points where precision is required, e.g. establishing new benchmarks.	Most suited for longitudinal or cross-sectional levelling and contouring.

6. How Levelling is Carried Out

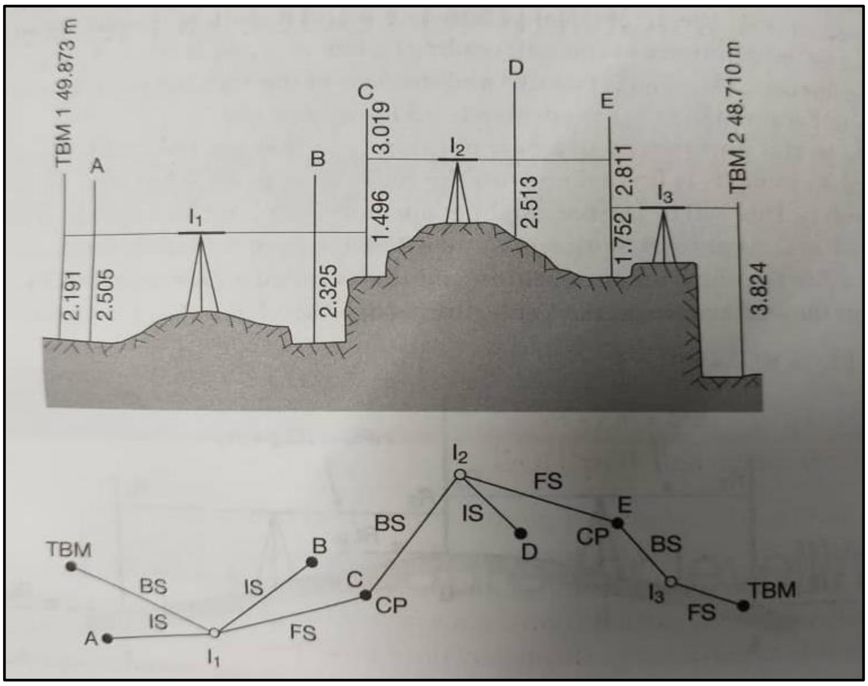

Figure 6.1 : Procedure in Levelling Carried Out

a. The level is set up at some convenient position I_1, and a BS of 2.191 m is taken to TBM 1, the foot of the staff being held on the TBM, and the staff held vertically.
b. The staff is then moved to pint A and B turn and readings are taken. These are intermediate sights of 2.505 m and 2.325 m respectively.
c. A change point must be use in order D owing to the nature of the ground. Therefore, a change point is chosen at C and the staff is moved to C and a FS of 1.496 m taken.
d. While the staff remains at C, the instruments is moved to another position, I_2. A BS of 3.019 m is taken from the new level position on the staff at change point C.
e. The staff is moved to D and E in turn readings of 2.513 m (IS) and 2.811 m (FS) are taken where E is another CP.
f. Finally, the level is moved to I_3, a BS of 1.752 m taken to E and a FS of 1.752 m taken to E and a FS of 3.824 m taken to TBM 2.
g. The final staff position is at a TBM. This is most important as all levelling fieldwork must start and finish at a benchmark, otherwise it is not possible to detect errors in the levelling.

7. Procedure of Setting Up Levelling Instrument

These consist of setting up, levelling up and focusing to elimination of parallax.

a. Setting Up

Since the level is not to be set at any fixed point, the setting up of a level is much simple as compared to other instruments. While locating the level, the ground should be so chosen that:

i. The instrument is not too low or too high to facilitate reading on a benchmark.
ii. The length of the back sight should preferably be not more than 98.000 m.
iii. The back sight distance and the fore sight distance should be equal, and the fore sight should be so located that it advances the line of levels. Setting up includes fixing the instrument and approximate levelling by leg adjustment.

Fixing the instrument over tripod: The clamp screw of the instruments is released. The level is held in the right hand. It is fixed on the tripod by turning round the lower part with the left hand and is firmly screwed over the tripod.

Leg adjustment: The instruments is placed at a convenient height with the tripod legs spread well apart and so adjusted that the tripod head is nearly horizontal as can be judged by the eye. Any two legs of the tripod are fixed firmly into the ground and the third leg is moved right or left in a circumferential direction until the main bubble is approximately in the center. The third leg is then pushed into the ground.

b. Levelling Up

Levelling with a three-screw head

i. The clamp is loosened, and the upper plate is turned until the longitudinal axis of the plate level is parallel to a line joining any two levelling screws, say 2 and 3.

ii. The two-foot screws are turned uniformly towards each other or away from each other until the plate bubble is center.

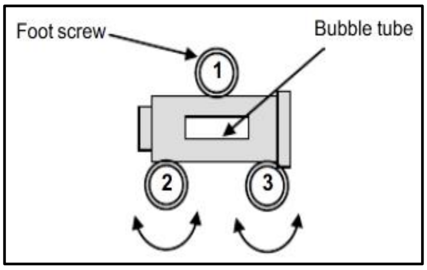

Figure 7.1 : Levelling by Two Foot Screws

iii. The telescope is rotated through 90º, so that it lies over the third foot screw say 1.

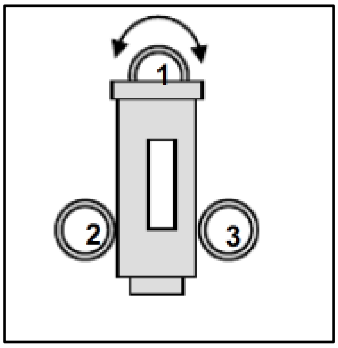

Figure 7.2 : Levelling by Third Foot Screws

iv. The third screw is turned until the plate bubble is center.

v. The telescope is rotated through 90º to its original position and the above procedure is repeated till the bubble remains center in both the positions.

vi. The telescope is now rotated through 180º. The bubble should remain center if the instrument is in proper adjustment.

Note: Since the bubble is very sensitive and easily disturbed, walking around the instrument, or touching the tripod legs should be avoided.

c. Focusing to Elimination of Parallax

It consists of focusing the eyepiece and objective of the level.

Focusing the eyepiece: This operation is done to make the cross-hairs appear distinct and clearly visible. The following steps are involved:

i. The telescope is directed skywards or a sheet of white paper is held in front of the objective.

ii. The eyepiece is moved in or out till the cross-hairs appear distinct.

Focusing the objective: This operation is done to bring the image of the object in the plane of the cross-hairs. The following steps are involved:

i. The telescope is directed towards the staff.
ii. The focusing screw is turned until the image appears clear and sharp.

8. Permanent Adjustment

These are the adjustment that are done to set the essential parts of the instrument in their true positions relative to each other. It is, therefore, desirable the permanent adjustment should be as perfect as possible.

For a level, if care is taken to equalize back sight and fore sight distances, any error due to imperfect permanent adjustment is eliminated. Therefore, it is not necessary to obtain perfect permanent adjustment for a level care is exercised. But at the same time, it is desirable that a surveyor should be able to test and correct the permanent adjustment of this level.

The fundamental lines of a level are the axis of the bubble tube, the vertical axis, the axis of the telescope, and the line of collimation. There exist fixed relationships between these fundamental lines. These relationships generally get disturbed because of mishandling of the level during its usage in the field and need frequent adjustment. The desired relationship of the fundamental lines is as below:

a. The vertical axis of the level should be perpendicular to the axis of the plate bubble tube.
b. The line of collimation should be perpendicular to the vertical axis.
c. The axis of the telescope and the line of collimation should coincide.

Whenever a level is set up, it is essential that the line of collimation, as viewed through the eyepiece, is horizontal. So far, the assumption has been made that one the circular bubble is centralized with the foot screws, the line of collimation is set exactly horizontal by the compensator and diaphragm (automatic and digital levels) or by centralizing the bubble in the spirit level tube (tilting levels). However, because they are in constant use on site, most levels are not in perfect adjustment and if horizontal readings are not being taken it has been set up properly, a collimation error is present in the level. Since most levels will have a collimation error, some method is required to check this to determine if the error is within accepted limits.

This is known as the Two Peg Test which should be carried out when using a new or different level for the first time and at regular interval after this depending on how much the level has been used. Sometimes, the contract for construction project will specify when the Two-Peg Test should be carried out (say weekly) and will also specify a tolerance for the collimation error- because of this is it necessary to check all levels regularly when on site.

9. Two Peg Test

All instruments are subject to errors of calibration and adjustment. In the case of levelling instruments, the main source of instrumental error is where the line of sight, produced by the cross hairs in the telescope, is not parallel to the horizontal line of collimation produced by the manufacture of the instrument. This error is known as collimation error as it effects the line of collimation. The test that we undertake to determine the amount of error and then eliminate it from our measurement is known as the Two Peg Test.

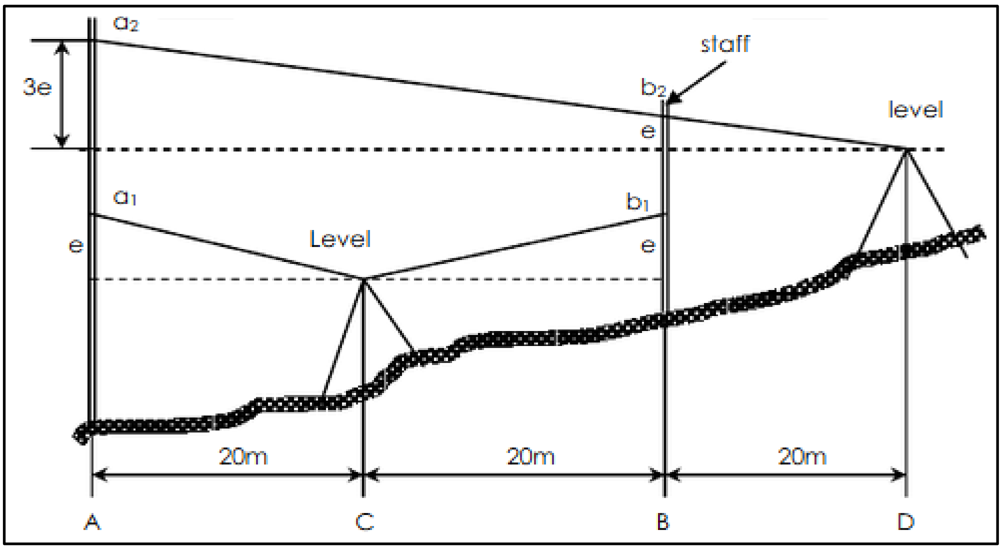

Figure 9.1 : Two Peg Test

The Two Peg Test is used to determine if the line of sight of the telescope is exactly parallel to the bubble tube. This is one of the most important properties of a level and is required to be checked periodically. Below are the steps to carry out Two Peg Test.

a. Set two points (A and B) with distance of 40 m.
b. Set up the level halfway between the two points (at point C) as illustrated in Figure 9.1.
c. The staff's reading at point A and B are taken. The bubbles need to be adjusted each time before the readings.
d. The level is then moved to point C and readings are taken for staff at point B and A.
e. The true difference in elevation between point A and B is computed from the two-readings obtained from the first setup (a_1 - b_1).

f. The elevation difference of the second set-up is computed (a_2 - b_2). If the plane of sight is truly horizontal, the elevation difference of the second set is equal to the true difference in elevation (a_1 - b_1) = (a_2 - b_2).

   i. Set the distance of AC = CB = BD
   ii. If the difference between AC= e, so that difference of CB = BD = e
   iii. Thus, the distance of DA = 3e
   iv. Refer to the Table 9.1

Table 9.1 : Reading of Two Peg Test

Instrument at Station	**Staff Reading At**		**Difference**
	A	**B**	
C	a_1=3.75	b_1=4.25	A = 0.5 unit higher than B (actual difference)
D	a_2=7.86	b_2=6.36	B = 1.5 unit higher than A (apparent difference)

Note: If (a_2 – b_2) ≠ (a_1 – b_1), so adjustment must be set up.

With instrument at D, Actual reading a_2 = A + 3e

Thus reading at A = (a_2 - 3e)
Actual reading b2 = (B + e)
Thus reading at B = (b_2 - e)

Hence actual correction = Actual reading at A - Actual reading at B
= (a_2 - 3e) - (b_2 - e)
= (7.86 - 3e) - (6.36 - e)
= (1.5 – 2e)
But true difference = (a_1 – b_1)
= (3.75 – 4.25)
= - 0.5
So - 0.5 = 1.5 – 2e
2e = 2
e = 1m / distance
With instrument at D,

Actual reading at A (a_2) = 7.86 - 3 = 4.86
Actual reading at B (b_2) = 6.36 - 1 = 5.36

10. Calculation of Final Reduced Level

a. Rise and Fall Method

Table 10.1 : Calculation of Final Reduced Level

Sight			Rise (+)	Fall (-)	Reduced Level (RL)	Corr	Final Reduced Level (FRL)	Distance (m)	Remarks
Back (BS)	Intermediate (IS)	Fore (FS)							
1.000					21.421	-	21.421	0	BM 01
	1.271			0.271	21.150	- 0.0015	21.149	14.000	
	1.569			0.298	20.852	- 0.0015	20.851	10.000	
0.705		2.055		0.486	20.366	- 0.0015	20.365	10.000	CP1
	1.220			0.515	19.851	- 0.003	19.848	10.000	
	1.550			0.330	19.521	- 0.003	19.518	10.000	
0.578		1.990		0.440	19.081	- 0.003	19.078	16.000	CP2
	1.140			0.562	18.519	- 0.0045	18.515	10.000	
	1.675			0.535	17.984	- 0.0045	17.980	10.000	
0.935		2.195		0.520	17.464	- 0.0045	17.460	10.000	CP3
	1.335			0.400	17.064	- 0.006	17.058	10.000	
	1.889			0.554	16.510	- 0.006	16.501	10.000	
0.030		2.405		0.516	15.994	- 0.006	15.988	10.000	CP4
	0.949			0.919	15.075	- 0.0075	15.068	10.000	
	1.910			0.961	14.114	- 0.0075	14.107	10.000	
0.954		2.765		0.855	13.259	- 0.0075	13.252	10.000	CP5
	1.611			0.657	12.602	- 0.009	12.593	18.000	
	1.691			0.080	12.522	- 0.009	12.513	10.000	
1.162		1.775		0.084	12.438	- 0.009	12.429	10.000	CP6
	1.271			0.109	12.329	- 0.0105	12.185	10.000	
	1.460			0.189	12.140	- 0.0105	12.130	10.000	
1.199		1.559		0.099	12.041	- 0.0105	12.031	10.000	CP7
	1.329			0.130	11.911	-0.012	11.899	10.000	
	1.369			0.040	11.871	-0.012	11.859	10.000	
		1.383		0.014	11.857	-0.012	11.845	10.000	TBM 02
∑=6.563		**∑=16.127**	**∑=0.000**	**∑=9.564**					

Arithmetical Check (AC)		
$\sum BS - \sum FS$	= 6.563 - 16.127	= - 9.564
$\sum Rise - \sum Fall$	= 0.000 - 9.564	= - 9.564
Last RL - First RL	= 11.857 - 21.421	= - 9.564
Accuracy		
1. Misclosure	= Last RL Observed - Last Point Specified Value (BM/TBM)	
	= 11.857 – 11.845	
	= 0.012 m	
2. Allowable Misclosure	= $\pm 5 \sqrt{n}$ mm : n – number of station	
	= $\pm 5 \sqrt{8}$	
	= 14.142 mm convert to m /1000	
	= 0.014 m	
Conclusion		
0.012 < 0.014		
So, Levelling work are **accepted**		
Correction		
Misclosure / Number of station		
= - 0.012 / 8 station		
= - 0.0015 for each station		

Table 10.2 : Calculation of Final Reduced Level

Sight			Rise (+)	Fall (-)	Reduced Level (RL)	Corr	Final Reduced Level (FRL)	Distance (m)	Remarks
Back (BS)	Intermediate (IS)	Fore (FS)							
1.488					11.845	-	11.845	0	TBM 33
1.465		1.495		0.007	11.838	- 0.001	11.837	11.000	CP1
1.594		1.535		0.070	11.768	- 0.002	11.766	11.000	CP2
1.430		1.443	0.151		11.919	- 0.003	11.916	11.000	CP3
1.491		1.512		0.082	11.837	- 0.004	11.833	11.000	CP4
1.555		1.529		0.038	11.799	- 0.005	11.794	11.000	CP5
1.522		1.524	0.031		11.830	- 0.006	11.824	10.000	CP6
1.525		1.503	0.019		11.849	- 0.007	11.842	10.000	CP7
1.242		1.255	0.270		12.119	- 0.008	12.111	10.000	CP8
2.333		1.687		0.445	11.674	- 0.009	11.665	10.000	CP9
1.965		0.859	1.474		13.148	- 0.010	13.138	11.000	CP10
2.140		0.633	1.332		14.480	- 0.011	14.469	11.000	CP11
1.811		0.885	1.255		15.735	- 0.012	15.723	10.000	CP12
2.045		0.885	0.926		16.661	- 0.013	16.648	10.000	CP13
2.247		0.757	1.288		17.949	- 0.014	17.935	10.000	CP14
2.455		0.694	1.553		19.502	- 0.015	19.487	10.000	CP15
1.855		0.765	1.690		21.192	- 0.016	21.176	18.000	CP16
		0.938	0.917		22.109	- 0.017	22.092	10.000	TBM 34
∑= 30.163		**∑= 19.899**	**∑= 10.906**	**∑= 0.642**					

Arithmetical Check (AC)

∑BS - ∑FS	= 30.163 - 19.899	= 10.264
∑Rise - ∑Fall	= 10.906 - 0.642	= 10.264
Last RL - First RL	= 22.109 - 11.845	= 10.264

Accuracy

1. Misclosure = Last RL Observed Last - Point Specified Value (BM/TBM)
   = 22.109 - 22.092
   = 0.017 m

2. Allowable Misclosure	$= \pm 5 \sqrt{n}$ mm : n – number of station $= \pm 5 \sqrt{17}$ = 20.616 mm convert to m /1000 = 0.021 m
Conclusion	
0.017 < 0.021 So, Levelling work are **accepted**	
Correction	
Misclosure / Number of station = - 0.017 / 17 station = - 0.001 for each station	

Table 10.3 : Calculation of Final Reduced Level

Sight			Rise (+)	Fall (-)	Reduced Level (RL)	Corr	Final Reduced Level (FRL)	Distance (m)	Remarks
Back (BS)	Intermediate (IS)	Fore (FS)							
1.445					50.000	-	50.000	0	TBM 03
	2.890			1.445	48.555	+0.000	48.555	23.000	
1.065		2.660	0.230		48.785	+0.000	48.785	23.000	CP1
	1.600			0.535	48.250	+0.001	48.251	23.000	
0.975		1.625		0.025	48.225	+0.001	48.226	23.000	CP2
0.370		2.190		1.215	47.010	+0.001	47.011	23.000	CP3
1.225		3.340		2.970	44.040	+0.001	44.041	23.000	CP4
1.265		1.470		0.245	43.795	+0.002	43.797	21.000	CP5
1.540		1.500		0.235	43.560	+0.002	43.562	21.000	CP6
	1.780			0.240	43.320	+0.002	43.322	23.000	
1.320		0.630	1.150		44.470	+0.002	44.472	23.000	CP7
	1.385			0.065	44.405	+0.002	44.407	23.000	
2.750		2.550		1.165	43.240	+0.003	43.243	21.000	CP8
1.660		0.930	1.820		45.060	+0.003	45.063	21.000	CP9
1.235		0.445	1.215		46.275	+0.004	46.275	23.000	CP10
1.665		1.595		0.360	45.915	+0.004	45.919	23.000	CP11
1.985		0.910	0.755		46.670	+0.004	46.674	23.000	CP12
2.890		0.105	1.880		48.550	+0.005	48.555	23.000	CP13
		1.445	1.445		49.995	+0.005	50.000	23.000	TBM 03
∑= 21.390		**∑= 21.395**	**∑= 8.495**	**∑= 8.500**					

Arithmetical Check (AC)

∑BS - ∑FS = 21.390 - 21.395 = -0.005

∑Rise - ∑Fall = 8.495 - 8.500 = -0.005

Last RL - First RL = 49.995 - 50.000 = -0.005

Accuracy

1. Misclosure = Last RL Observed - Last Point Specified Value (BM/TBM)

= 49.995 - 50.000

= - 0.005 m

2. Allowable Misclosure	$= \pm 5 \sqrt{n}$ mm : n – number of station $= \pm 5 \sqrt{14}$ = 18.702 mm convert to m /1000 = 0.019 m
Conclusion	
0.005 < 0.019 So, Levelling work are **accepted**	
Correction	
Misclosure / Number of station = + 0.005 / 14 station = + 0.000357142 for each station	

Table 10.4 : Calculation of Final Reduced Level

Sight			Rise	Fall	Reduced	Corr	Final	Distance	Remarks
Back (BS)	**Intermediate (IS)**	**Fore (FS)**	**(+)**	**(-)**	**Level (RL)**		**Reduced Level (FRL)**	**(m)**	
3.685					350.000		350.000	0	BM 05
	2.020		1.665		351.665			20.000	
3.474		0.475	1.545		353.210			20.000	CP1
	1.403		2.071		355.281			20.000	
2.666		0.217	1.186		356.467			20.000	CP2
	1.065		1.601		358.068			20.000	
0.800		2.850		1.785	356.283			20.000	CP3
0.440		3.110		2.310	353.973			20.000	CP4
0.534		2.841		2.401	351.572			20.000	CP5
		2.108		1.574	349.998		350.015	18.500	TBM 20
∑= 11.599		**∑= 11.601**	**∑= 8.068**	**∑= 8.070**					

Arithmetical Check (AC)

∑BS - ∑FS = 11.599 - 11.601 = -0.002

∑Rise - ∑Fall = 8.068- 8.070 = -0.002

Last RL - First RL = 349.998 - 350.000 = -0.002

Accuracy

1. Misclosure = Last RL Observed - Last Point Specified Value (BM/TBM)
   = 349.998 - 350.015
   = - 0.017 m

2. Allowable Misclosure = $\pm 5\sqrt{n}$ mm : n – number of station
   = $\pm 5\sqrt{6}$
   = 12.474 mm convert to m /1000
   = 0.012 m

Conclusion

0.017 > 0.012

So, Levelling work are **rejected**

Correction

Levelling should be repeated

b. Height of Collimation Method

Table 10.5 : Calculation of Final Reduced Level

Sight			Height of Collimation (HOC)	Reduced Level (RL)	Corr	Final Reduced Level (FRL)	Distance (m)	Remarks
Back (BS)	Intermediate (IS)	Fore (FS)						
1.000			22.421	21.421	-	21.421	0	BM 01
	1.271			21.150	- 0.0015	21.149	14.000	
	1.569			20.852	- 0.0015	20.851	10.000	
0.705		2.055	21.071	20.366	- 0.0015	20.365	10.000	CP1
	1.220			19.851	- 0.003	19.848	10.000	
	1.550			19.521	- 0.003	19.518	10.000	
0.578		1.990	19.659	19.081	- 0.003	19.078	16.000	CP2
	1.140			18.519	- 0.0045	18.515	10.000	
	1.675			18.519	- 0.0045	17.980	10.000	
0.935		2.195	18.399	17.464	- 0.0045	17.460	10.000	CP3
	1.335			17.064	- 0.006	17.058	10.000	
	1.889			16.510	- 0.006	16.501	10.000	
0.030		2.405	16.024	15.994	- 0.006	15.988	10.000	CP4
	0.949			15.075	- 0.0075	15.068	10.000	
	1.910			14.114	- 0.0075	14.107	10.000	
0.954		2.765	14.213	13.259	- 0.0075	13.252	10.000	CP5
	1.611			12.602	- 0.009	12.593	18.000	
	1.691			12.522	- 0.009	12.513	10.000	
1.162		1.775	13.600	12.438	- 0.009	12.429	10.000	CP6
	1.271			12.329	- 0.0105	12.185	10.000	
	1.460			12.140	- 0.0105	12.130	10.000	
1.199		1.559	13.240	12.041	- 0.0105	12.031	10.000	CP7
	1.329			11.911	-0.012	11.899	10.000	
	1.369			11.871	-0.012	11.859	10.000	
		1.383		11.857	-0.012	11.845	10.000	TBM 02
∑=6.563		**∑=16.127**						
Arithmetical Check (AC)								
∑BS - ∑FS	= 6.563 - 16.127		= - 9.564					
Last RL - First RL	= 11.857 - 21.421		= - 9.564					

Accuracy
1. Misclosure = Last RL Observed - Last Point Specified Value (BM/TBM) = 11.857 – 11.845 = 0.012 m 2. Allowable Misclosure = ± 5 √ n mm : n – number of station = ± 5 √8 = 14.142 mm convert to m /1000 = 0.014 m
Conclusion
0.012 < 0.014 So, Levelling work are accepted
Correction
Misclosure / Number of station = - 0.012 / 8 station = - 0.0015 for each station

Table 10.6 : Calculation of Final Reduced Level

Sight			Height of Collimation (HOC)	Reduced Level (RL)	Corr	Final Reduced Level (FRL)	Distance (m)	Remarks
Back (BS)	Intermediate (IS)	Fore (FS)						
1.488			13.333	11.845	-	11.845	0	TBM 33
1.465		1.495	13.303	11.838	- 0.001	11.837	11.000	CP1
1.594		1.535	13.362	11.768	- 0.002	11.766	11.000	CP2
1.430		1.443	13.349	11.919	- 0.003	11.916	11.000	CP3
1.491		1.512	13.328	11.837	- 0.004	11.833	11.000	CP4
1.555		1.529	13.354	11.799	- 0.005	11.794	11.000	CP5
1.522		1.524	13.352	11.830	- 0.006	11.824	10.000	CP6
1.525		1.503	13.374	11.849	- 0.007	11.842	10.000	CP7
1.242		1.255	13.361	12.119	- 0.008	12.111	10.000	CP8
2.333		1.687	14.007	11.674	- 0.009	11.665	10.000	CP9
1.965		0.859	15.113	13.148	- 0.010	13.138	11.000	CP10
2.140		0.633	16.620	14.480	- 0.011	14.469	11.000	CP11
1.811		0.885	17.546	15.735	- 0.012	15.723	10.000	CP12
2.045		0.885	18.706	16.661	- 0.013	16.648	10.000	CP13
2.247		0.757	20.196	17.949	- 0.014	17.935	10.000	CP14
2.455		0.694	21.957	19.502	- 0.015	19.487	10.000	CP15
1.855		0.765	23.047	21.192	- 0.016	21.176	18.000	CP16
		0.938		22.109	- 0.017	22.092	10.000	TBM 34
∑= 30.163		**∑= 19.899**						
Arithmetical Check (AC)								
∑BS - ∑FS	= 30.163 – 19.899		= 10.264					
Last RL - First RL	= 11.845 - 22.109		= 10.264					
Accuracy								
1. Misclosure	= Last RL Observed - Last Point Specified Value (BM/TBM)							
	= 22.109 - 22.092							
	= 0.017 m							

2. Allowable Misclosure	$= \pm 5 \sqrt{n}$ mm : n – number of station $= \pm 5 \sqrt{17}$ = 20.616 mm convert to m /1000 = 0.021 m
Conclusion	
0.017 < 0.021 So, Levelling work are accepted	
Correction	
Misclosure / Number of station = - 0.017 / 17 station = - 0.001 for each station	

Table 10.7 : Calculation of Final Reduced Level

Sight			Height of Collimation (HOC)	Reduced Level (RL)	Corr	Final Reduced Level (FRL)	Distance (m)	Remarks
Back (BS)	Intermediate (IS)	Fore (FS)						
1.445			51.445	50.000	-	50.000		TBM 03
	2.890			48.555	+0.000	48.555	23.000	
1.065		2.660	49.850	48.785	+0.000	48.785	23.000	CP1
	1.600			48.250	+0.001	48.251	23.000	
0.975		1.625	49.200	48.225	+0.001	48.226	23.000	CP2
0.370		2.190	47.380	47.010	+0.001	47.011	23.000	CP3
1.225		3.340	45.265	44.040	+0.001	44.041	23.000	CP4
1.265		1.470	45.060	43.795	+0.002	43.797	21.000	CP5
1.540		1.500	45.100	43.560	+0.002	43.562	21.000	CP6
	1.780			43.320	+0.002	43.322	23.000	
1.320		0.630	45.790	44.470	+0.002	44.472	23.000	CP7
	1.385			44.405	+0.002	44.407	23.000	
2.750		2.550	45.990	43.240	+0.003	43.243	21.000	CP8
1.660		0.930	46.720	45.060	+0.003	45.063	21.000	CP9
1.235		0.445	47.510	46.275	+0.004	46.275	23.000	CP10
1.665		1.595	47.580	45.915	+0.004	45.919	23.000	CP11
1.985		0.910	48.655	46.670	+0.004	46.674	23.000	CP12
2.890		0.105	51.440	48.550	+0.005	48.555	23.000	CP13
		1.445		49.995	+0.005	50.000	23.000	TBM 03
∑= 21.390		**∑= 21.395**						

Arithmetical Check (AC)

∑BS - ∑FS = 21.390 - 21.395 = - 0.005

Last RL - First RL = 49.995 - 50.000 = - 0.005

Accuracy

1. Misclosure = Last RL Observed - Last Point Specified Value (BM/TBM)

= 49.995 – 50.000

= - 0.005 m

2. Allowable Misclosure	= ± 5 √ n mm : n – number of station = ± 5 √14 = 18.702 mm convert to m /1000 = 0.019 m
Conclusion	
0.005 < 0.021 So, Levelling work are accepted	
Correction	
Misclosure / Number of station = + 0.005 / 14 station = + 0.000357142 for each station	

Table 10.8 : Calculation of Final Reduced Level

Sight			Height of Collimation (HOC)	Reduced Level (RL)	Corr	Final Reduced Level (FRL)	Distance (m)	Remarks
Back (BS)	**Intermediate (IS)**	**Fore (FS)**						
3.685			353.685	350.000		350.000	0	BM 05
	2.020			351.665			20.000	
3.474		0.475	356.684	353.210			20.000	CP1
	1.403			355.281			20.000	
2.666		0.217	359.133	356.467			20.000	CP2
	1.065			358.068			20.000	
0.800		2.850	357.083	356.283			20.000	
0.440		3.110	354.413	353.973			20.000	
0.534		2.841	352.106	351.572			20.000	
		2.108		349.998		350.015	18.500	TBM 20
∑= 11.599		**∑= 11.601**						

Arithmetical Check (AC)

∑BS - ∑FS = 11.599 - 11.601 = - 0.002

Last RL - First RL = 349.998 - 350.000 = - 0.002

Accuracy

1. Misclosure = Last RL Observed - Last Point Specified Value (BM/TBM)
   = 349.998 - 350.015
   = - 0.017 m

2. Allowable Misclosure = ± 5 √ n mm : n – number of station
   = ± 5 √6
   = 12.474 mm convert to m /1000
   = 0.012 m

Conclusion

0.017 > 0.012

So, Levelling work are **rejected**

Correction

Levelling should be repeated

11. Types of Levelling

a. Close Levelling

Series of level surveyed from a known datum or RL to a known Datum or RL. The lines either return to the starting point or close on a point of known value.

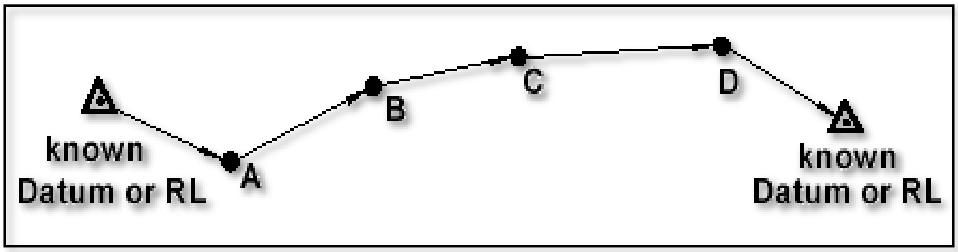

Figure 11.1 : Close Link Levelling

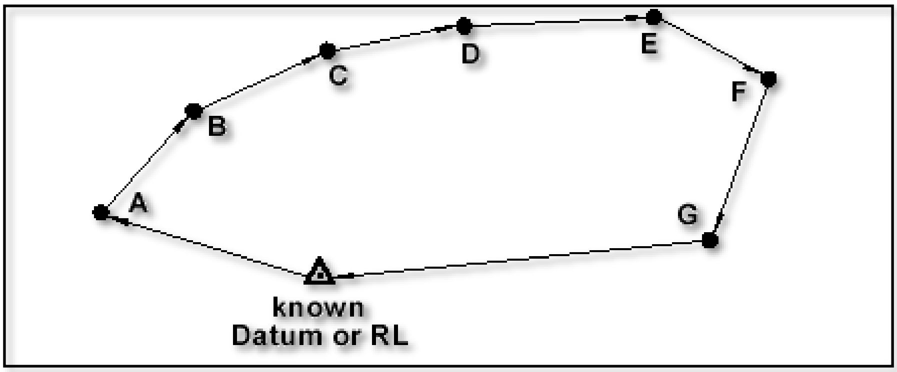

Figure 11.2 : Close Loop Levelling

b. Open Levelling

Series of level runs from a known datum or RL. This must be avoided because there are no checks on misreading. The line is do not end at a point of known value.

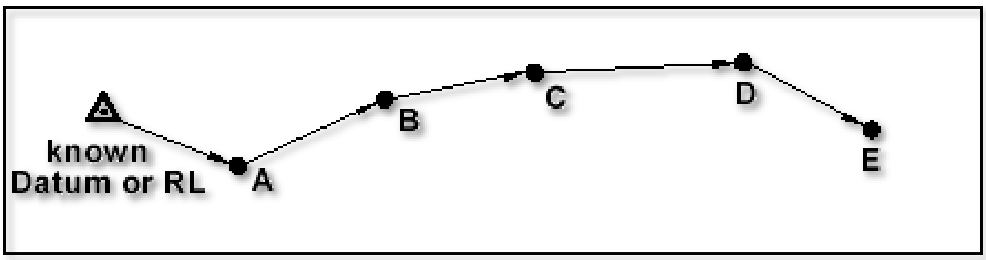

Figure 11.3 : Open Levelling

12. Longitudinal Section

Longitudinal sections are sections which follow some pre-determined line defining a part of a new construction and are usually run along the center lines of the proposed work such as new roads, canals, railways, pipelines, etc.

The aim of longitudinal section leveling is to provide data for the following:

a. Deciding the most suitable and economic levels and gradients, in its longitudinal section
b. Locating the places of cut or fills
c. Locating the place where neither cut nor fill occurs
d. Locating view of overall projects with longitudinal view

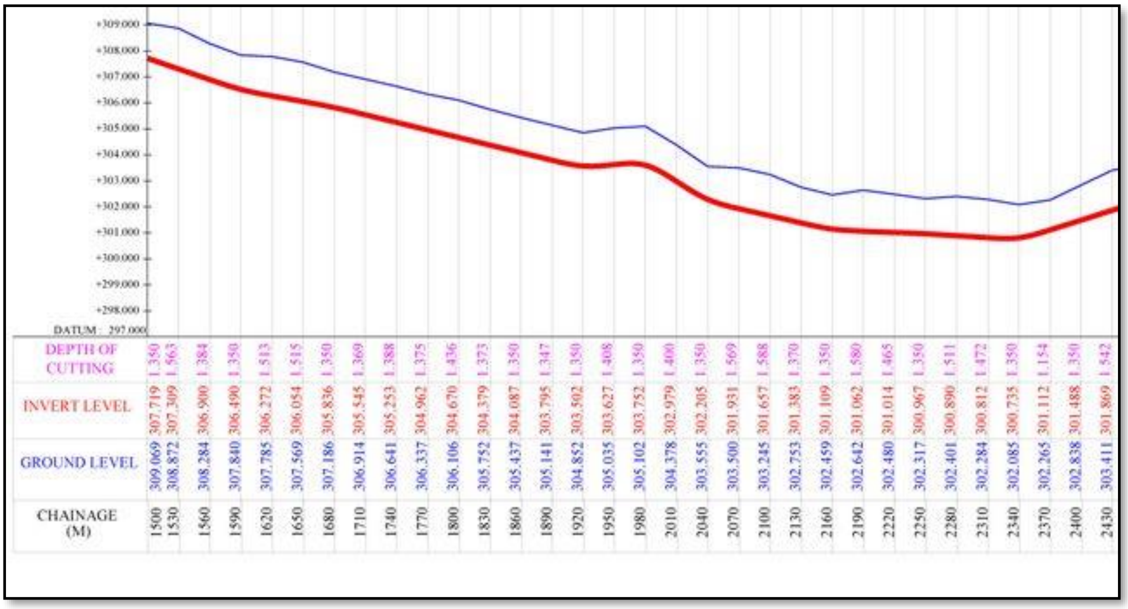

Figure 12.1 : Longitudinal Section

13. Cross Section (Profile)

Cross sections are sections set out normal to the longitudinal section. The aim of cross section leveling is the reproduction of an accurate section of the ground which is to be covered by the construction works. Cross sections provide data for the following:

a. Deciding the most suitable and economic levels in the traverse direction
b. Supplying details for locating the position, height and slope of embankments or cutting
c. Earthwork quantities for costing purposes (Mass Haul Diagrams)
d. Calculating the volumes of cut and fill area
e. Calculating and investigating the type of soil at the chainage

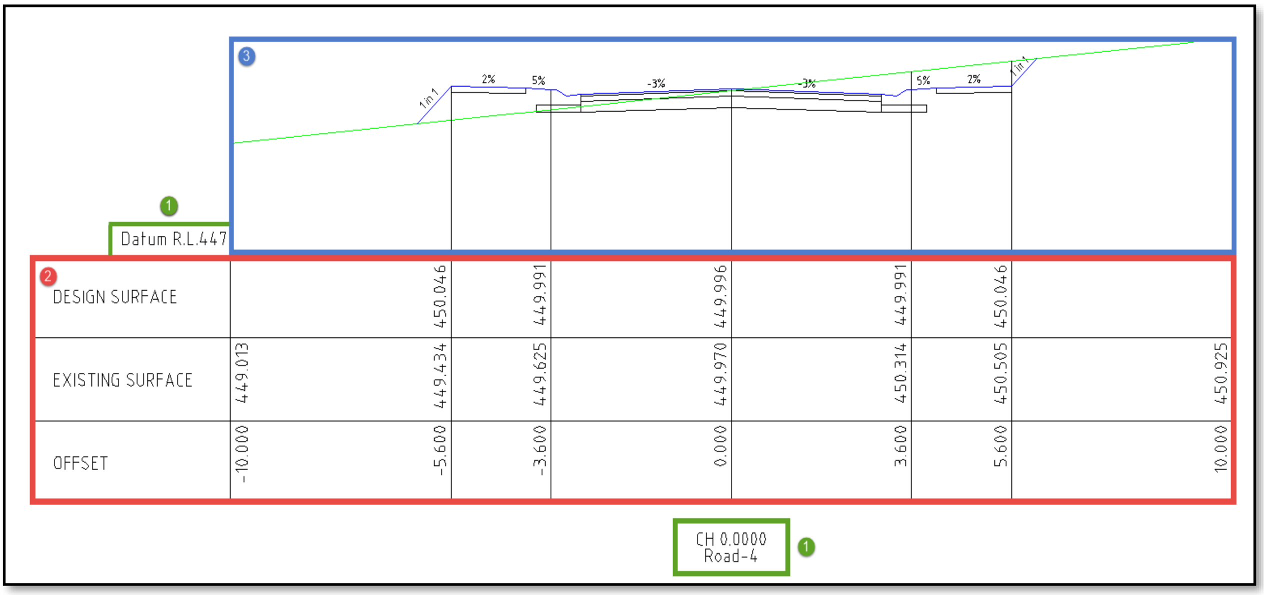

Figure 13.1 : Cross Section (Profile)

14. Concepts of Contouring

A contour is defined as an imaginary line of constant elevation on the ground surface. It can also be defined as the line of intersection of a level surface with the ground surface. For example, the line of intersection of the water surface of a still lake or pond with the surrounding ground represents a contour line.

A contour line is an imaginary line which connects points of equal elevation. Such lines are drawn on the plan of an area after establishing reduced levels of several points in the area. The contour lines in an area are drawn keeping difference in elevation of between two consecutive lines constant.

The line of intersection of a level surface with the ground surface is known as the contour line. It can also be defined as a line passing through point of equal reduced levels. The intervals depend upon:

a. Nature of the ground
b. The scale of the map
c. The purpose of survey
d. Time and expense of field and office work

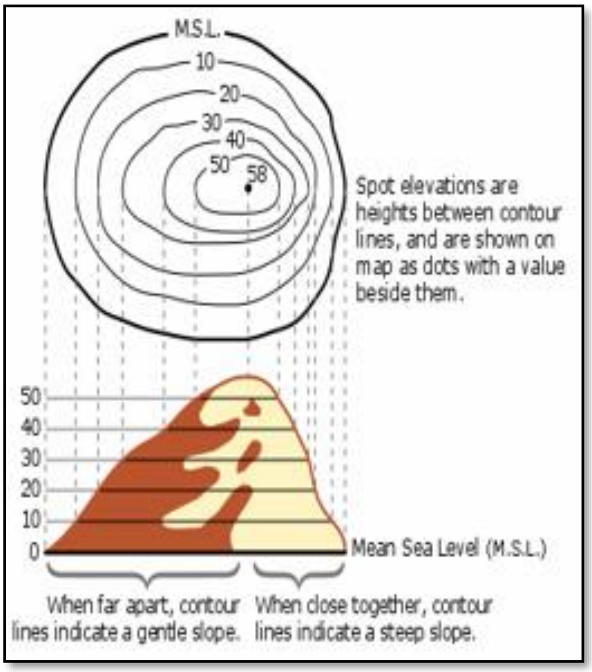

Figure 14.1 : Contour Lines

The following are important characteristics of contour:

a. All points in a contour line have the same elevation.
b. When the contour lines are widely divide, it indicates a flat ground and when they run close together, it indicates a steep ground.

c. When the contour lines are uniformly spaced, it indicated a uniform slope and when they are straight, parallel and equally spaced, it indicated a plane surface.
d. A series of closer contour lines on the map indicates a hill, if the higher values are inside.
e. A series of closer contour lines on the map indicates a depression, if the higher values are outside.
f. The contour lines cross ridge or valley lines at the right angles. If the higher values are inside the bend or loop in the contour, it indicates a ridge and if the higher values are outside the bend, it indicates a valley.
g. When the contour lines merge or cross one another on map, it indicates an overhanging cliff.
h. When several contours concede and the horizontal equivalent becomes zero, in indicates a vertical cliff.

15. Suggestions for Instrument Work

The following list of reminders will be useful when performing instrument work:

a. Use a straight-leg (nonadjustable) tripod, if possible.
b. Tripod legs should be tightened so that when one leg is extended horizontally, it falls slowly back to the ground under its own weight.
c. When setting up the instrument, gently force the legs into the ground by applying weight on the tripod shoe spurs. On rigid surfaces (e.g., concrete), the tripod legs should be spread farther apart to increase stability.
d. When the tripod is to set up on a side-hill, two legs should be placed downhill, and third leg placed uphill. The instrument can be set up roughly level by careful manipulation on the third, uphill leg.
e. The location of the level setup should be chosen after considering the ability to see the maximum number of rod locations, particularly BS and FS locations.
f. Prior to taking rod readings, the cross hair should be sharply focused; it helps to point the instrument toward a light-colored background (e.g., the sky).
g. When the surveyor observes apparent movement of the cross hairs on the rod (parallax), he or she should carefully check the cross-hairs focus adjustment and the objective focus adjustment for adjustment for consistent results.
h. The surveyor should read the rod consistently at either the top or the bottom of the cross-hairs.
i. Never move the level before a FS is taken; otherwise, all work done from the height instrument will have to be repeated.
j. Check to ensure that the level bubble remains centered or that the compensating device (in automatic levels) is operating.
k. Rod readings (and the line of sight) should be kept at least 18 inch (0.5 m) above the ground surface to help minimize refraction errors when performing a precise level survey.

16. Mistakes in Levelling

Mistakes in level loops can be detected by performing arithmetic checks and also by closing on the starting BM or any other BM or TBM whose elevation is known. Mistakes in rod readings that do not form a part of a level loop, such as in intermediate sights taken in profile, cross sections, or construction grades, are a much more irksome problem. It is bad enough to discover that a level loop contains mistakes and must be repeated, but it is a far more serious problem to have to redesign a highway profile because a key elevation contains a mistake, or to have to break out a concrete bridge abutment (the day after concrete was poured) because the grade stake elevation contains a mistake. Because intermediate rod reading cannot be checked (without relevelling), it is essential that the opportunities for mistakes be minimized.

Common mistakes in levelling include the following: misreading the foot (meter) value, transposing figures, not holding the rod in the correct location, resting the hands on the tripod while reading the rod and causing the instruments to go off level, entering the rod readings incorrectly (i.e., switching BS and FS), giving the wrong station identification to a correct rod reading, and making mistakes in the note reduction arithmetic. Most mistakes in arithmetic can be eliminated by having the other crew members check the reductions and initial each page of notes checked. Mistakes in the levelling operation cannot be completely eliminated, but they can be minimizes if the crew members are aware that mistakes can (and probably will) occur. All crew members should be constantly alert to the possible occurrence of mistakes, and crew members should try to develop strict routines for doing their work so that mistakes, when they do eventually occur, will be more noticeable.

EXERCISES

1. Briefly explain and differentiate the following terms:
   a. Benchmark and Temporary Benchmark
   b. Dumpy level instrument and Tilting level instrument
   c. Reduced level and change point

2. Briefly explain the principles of levelling.

3. Describe the procedure of temporary adjustment in levelling work.

4. Explain functions of the following levelling equipment:
   a. Staff
   b. Automatic Level
   c. Tripod

5. Briefly explain the procedure of levelling.

6. Using suitable sketch for levelling fieldwork observation, label and describe the following terms:
   a. Back Sight (BS)
   b. Intermediate Sight (IS)
   c. Fore Sight (FS)
   d. Change Point (CP)

7. Briefly explain the purpose of Two Peg Test**.**

8. The following consecutive readings were taken with a levelling instrument at intervals of 20 m. **2.375 m, 1.730 m, 0.615 m, 3.450 m, 2.835 m, 2.070 m, 1.835 m, 0.985 m, 0.435 m, 1.630 m, 2.255 m and 3.633 m**. The instruments was shifted after fourth and eighth readings. The first and last reading was taken as follow, BM of RL **112.620 m** and BM of RL **110.200 m**. Find the final reduce level of all points using height of collimation.

9. A contour line is a line on a map representing a line joining points of equal height on the ground. Explain **FOUR (4)** characteristics of contour lines.

10. Table below shows a data from levelling field work. By using Rise and Fall Method, calculate;
    a. Reduced level for each point
    b. Arithmetic check
    c. Error that can be accepted
    d. Correction/adjustment
    e. Final reduced level

BS	IS	FS	Remarks
1.603			TBM:40.825 m
	1.001		Peg A
1.761		1.367	CP1
	1.297		Peg B
1.272		1.203	CP2
	0.910		Peg C
1.979		2.291	CP3
0.772		0.646	Peg D
		3.030	TBM:39.685

11. A levelling survey was conducted from BM02 which the height of reduced level is 70.325 m to BM03 which the reduced level height is 72.905 m. Staff reading was recorded in the levelling form as table below.

BS	IS	FS	Remarks
2.304			BM02:70.325 m
2.407		1.800	
0.877		2.514	
	1.257		
	1.266		
1.211		1.693	
3.704		1.000	
		0.945	BM03:72.905 m

a. Calculate the reduced level for each point by using the height of collimation method
b. show the calculation for arithmetic checking

12. The following set of staff reading was obtained on a levelling job. Calculate:

   a. Reduced Level for all points by using Rise and Fall Method
   b. Arithmetic check
   c. Correction to get final reduced level

BS	IS	FS	Remarks
1.832			TBM:62.117
2.150		2.379	
	1.912		
	1.949		
	2.630		
1.165		1.539	
2.381		2.212	
	2.070		
	2.930		
	0.954		
	2.425		
		0.879	TBM:62.629

13. According to the data in the table below, calculate:
    a. Reduced Level for all points by using Height of Collimation Method (HOC)
    b. Arithmetic check
    c. Correction to get final reduced level

BS	IS	FS	Remarks
3.685			TBM:350.000
	2.020		
3.474		0.475	
	1.403		
2.666		0.217	
	1.065		
0.800		2.850	
0.440		3.110	
0.534		2.841	
		2.108	TBM:350.010

14. The following successive readings were taken with a dumpy level from a levelling survey work. The first reading was taken on a Benchmark with unknown reduced level. The reduced level of the second change point was 107.215 m. The instrument was shifted after the third and seventh readings. Calculate the reduced level of all the points with RISE and FALL method and conduct an arithmetical check.

    3.150 m, 2.245 m, 1.125 m, 3.860 m, 2.125 m, 0.760 m, 2.235 m, 0.470 m, 1.935 m, 3.225 m and 3.890 m.

15. Fill the missing readings below:

STN	BS	IS	FS	Rise	Fall	RL (m)	Remarks
1	3.250					249.260	BM
2	1.755				0.750	248.510	CP
3		1.950	**?**		0.195	248.315	
4	**?**		1.920	0.030		248.345	CP
5		2.340		1.500		249.845	
6		**?**		1.000		250.845	
7	1.850		2.185		0.845	250.000	CP
8		1.575		0.275		250.275	
9		**?**			1.970	248.305	
10	**?**		1.895	1.650		149.955	CP
11			1.350	0.750		250.705	

16. Calculate the value for RL for each point by using Rise and Fall method and show the arithmetic checking by referring below:

BS	IS	FS	Rise	Fall	RL	Remarks
1.600						BM:49.984
1.413		1.060				CP1
1.435		1.180				CP2
1.155		1.155				CP3
1.225		1.465				CP4
1.080		1.470				CP5
		1.562				BM:49.984

17. Using the Height of Collimation Method, calculate the reduced level for each point and show the arithmetic checking.

BS	IS	FS	HOC	RL	Remarks
3.685					BM:350.000
	2.020				A
3.474		0.475			B
	1.403				C
2.666		0.217			D
	1.065				E
0.800		2.850			F
0.440		3.110			G
0.534		2.841			H
		2.606			TBM:349.500

18. Table below shows a page of levelling book from which several values are missing. Complete the page and fill all the missing (X) entries.

BS	IS	FS	Rise	Fall	RL	Remarks
1.385					100.000	BM:100.00
	1.430			**X**	**X**	
	X			0.395	**X**	
X		1.275	**X**		**X**	CP
0.630		0.585	0.310		**X**	CP
	0.920			**X**	100.130	
	X			0.210	**X**	
		1.740		**X**	**X**	

19. A levelling work that carried out by DKA 2 student recorded as below:

BS	IS	FS	Remarks
1.430			BM:101.110
	1.111		A
	2.130		B
1.911		0.870	C (CP)
	1.300		D
	1.621		E
1.001		2.412	F (CP)
	0.900		G
	0.800		H
	0.920		I
1.112		3.001	J (CP)
		2.450	TBM:95.110

Compute the height of collimation and reduced level values at all points.

20. A levelling survey data was conducted by Civil Engineering Student from Politeknik Sultan Mizan Zainal Abidin. Initial datum is of Benchmark BM112 the reduced level 52.777 m and closing to Benchmark BM113 the reduced level 55.250 m. Calculate the reduced level for each point using Height of Collimation (HOC) and exhibit the calculation of arithmetic check.

BS	IS	FS	Remarks
1.663			BM112:52.777
	2.446		A
	2.108		B
3.882		2.445	C (CP1)
	3.427		D
	2.111		E
	2.050		F
		0.622	BM113:52.250

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ABOUT e-BOOK

In surveying, three basic quantities are measured - heights, angle and distance. Levelling is the name given to one of the method available for determining heights. This e-book covered basic principles of levelling, terms in levelling, types of instruments used in levelling, differences of level instruments, fields procedure in levelling and others. Authors hopes that e-book will encourage student to study and understand the important aspects of the engineering survey. Authors would like to express their appreciation to all parties that involved in the completion of this e-book primarily to Polytechnic Education Department, Department of Civil Engineering Politeknik Sultan Mizan Zainal Abidin, the Head of Resource Centre Politeknik Sultan Mizan Zainal Abidin. Finally, my thanks to all friends who have contributed ideas and supports.

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