UNIT IV

LEVELLING AND APPLICATIONS

PART – A

(2 marks)

1. **What do you mean by contour interval? (AUC Apr/May 2011)**

   The vertical distance between any two consecutive contours is called Contour interval. The contour interval is kept constant for a contour plan.

2. **Define bench mark. (AUC Apr/May 2011)**

   Bench mark is a relatively permanent point of reference whose elevation with respect to some assumed datum is known**.**

3. **What is profile levelling? State its application. (AUC Nov/Dec 2011)**

   When levelling exercise is undertaken along a survey line, it is termed as profile levelling.
   E.g. Deciding the route of a road or railway line, centre line of a pipe/gas line, power/telephone lines etc.,

4. **State the necessity of making, balancing of backsight and foresight. (AUC Nov/Dec 2011)**

   A turning point or change point denotes the position at which both foresight and backsight readings are taken before shifting of level instrument. Any well defined and stable point can be selected as change point, e.g. boundary stone, benchmark.

5. **State the limitation of the prismoidal formula. (AUC Apr/May 2010)**

   $$\text{Volume} = (d/3) \times \left[(A_1 + A_n) + 4(A_2 + A_4 + A_6 + \ldots\ldots + A_{n-1}) + 2(A_3 + A_5 + \ldots\ldots + A_{n-2})\right]$$

6. **What is check levelling? (AUC Apr/May 2010)**

   It is normal to run a line of levels to return to start station after the end of each days work for the purpose of checking the accuracy and reliability of the measurements and recording carried out on that particular day. This is termed check levelling.

7. **Define contour. (AUC Nov/Dec 2010)**

   A contour is an imaginary line on the ground joining the points of equal elevation.

   (Or)

   A contour is a line in which the surface of ground is intersected by a level surface.

8. Write the types of bench mark. **(AUC Nov/Dec 2010)**

- GTS bench marks
- Permanent bench marks
- Temporary bench marks
- Arbitrary bench marks

9. What do you mean by fly and check levelling? **(AUC May/June 2013)**

Fly levelling:

When there are obstructions in the line of sight, the distance between stations is too large or the purpose is to establish bench marks, this process is adopted. This is termed as "fly levelling".

Check levelling:

It is normal to run a line of levels to return to start station after the end of each days work for the purpose of checking the accuracy and reliability of the measurements and recording carried out on that particular day. This is termed check levelling.

10. Explain the use of Dumpy and Tilting levels. **(AUC May/June 2013)**

Dumpy Level:

- It is most commonly used in engineering surveys.
- Simpler construction with fewer movable parts.
- Fewer adjustments to be made.
- Longer life of the adjustments.

Tilting level:

- It is used for precision levelling.
- Levelling can be done much quicker.
- Don't take so many readings from one instrument setting.

11. State any four types of levelling instrument. **(AUC Nov/Dec 2012)**

- A telescope to provide line of sight.
- A level tube to make the line of sight horizontal.
- A levelling head to bring the bubble in its centre of run.
- A tripod to support the instrument.

12. What is meant by change point in levelling? **(AUC Nov/Dec 2012)**

A change point denotes the position at which both foresight and backsight readings are taken before shifting of level instrument.

13. What is foresight? (AUC Nov/Dec 2009)

The foresight is the staff reading of the point whose elevation is required to be obtained, particularly at a change point. It is the last staff reading at the station before the instrument is shifted to a new station.

14. What is backsight? (AUC Nov/Dec 2009)

The staff reading taken at a point of known or predetermined elevation. The backsight is the first staff reading taken after setting the instrument at specified survey station.

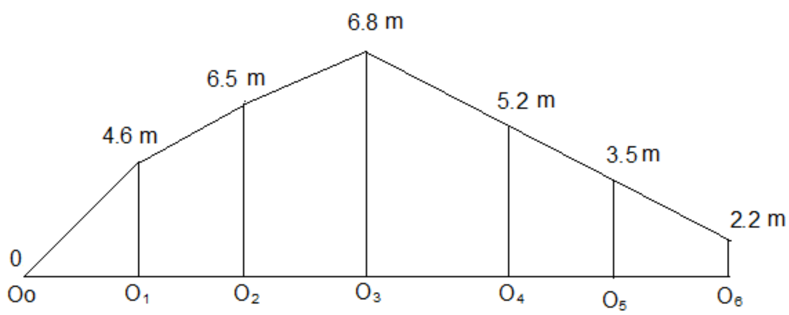
15. What is meant by longitudinal sectioning? (AUC May/June 2012)

The process of determining the elevation of points at short measured intervals along a fixed line. The fixed line may be straight line or series of straight lines connected by curves. It is termed as Longitudinal sectioning.

PART – B (16 marks)

1. **The offsets taken at 5 m intervals from a chain line to a curved boundary are: 0, 4.6, 6.5, 6.8, 5.2, 3.5, 2.2 m. calculate the area between the chain line, the curved boundary line and the end offsets using Simpsons rule. (AUC Apr/May 2011)**

Solution:



Using Simpsons rule,

$$\text{Area} = (d/3) \times \left[(O_0 + O_6) + 4\,(O_1 + O_3 + O_5) + 2\,(O_2 + O_4)\right]$$

$$= (5 / 3) \times \left[(O + 2.2) + 4\,(4.6 + 6.8 + 3.5) + 2\,(6.5 + 5.2)\right]$$

$$= 1.67 \left[2.2 + 4\,(14.9) + 2\,(11.7)\right]$$

Area = 142.28 m^2

2. **Define contours and give characteristics of contours. (AUC Apr/May 2011)**

Contours:

A contour is an imaginary line on the ground passing through points of equal elevation.

Characteristics of Contour Lines

Characteristics of contour lines are helpful in plotting and interpretation of various features in the map. These characteristics are as follows:

(a) Contour line is a line joining points of same elevation; hence all points of contour lines have same elevation. The elevation of a contour is written close to the contour.

(b) Two contour lines of different elevations cannot intersect each other except in case of an overhanging cliff or a cave (Figure 1).

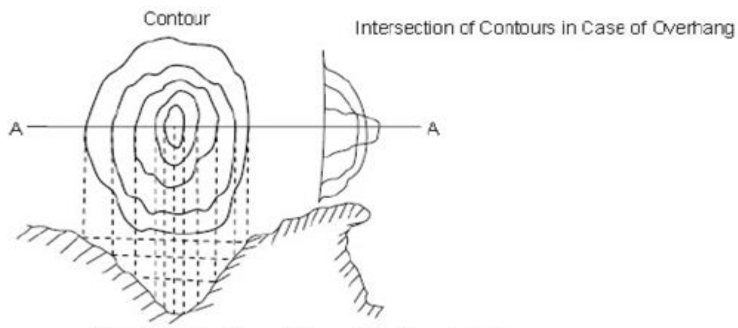


Figure 1 : Section of Ground Surface at A-A

(c) In case of a vertical cliff contour lines of different elevations can join to form one single line.

(d) Horizontal equivalent of contours indicates the topography of the area. The uniformly spaced contour lines indicate a uniform slope, while straight and equally spaced contour lines indicate a plane surface. Contour lines closed together indicate steep slope, while a gentle slope is indicated when contour lines are far apart.

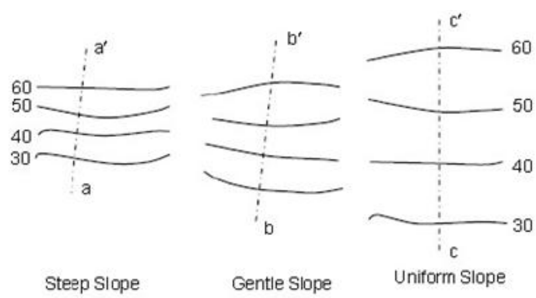


Figure : Topography of Area Represented by Variation of Horizontal Equivalent

(e) A contour line cannot end anywhere and must close upon itself, though not necessarily within the limits of the map.

(f) A set of close contours with higher figures outside and lower figures inside indicate a depression or lake, whereas a set of close contours with higher figures inside and lower figures outside indicate a hillock.

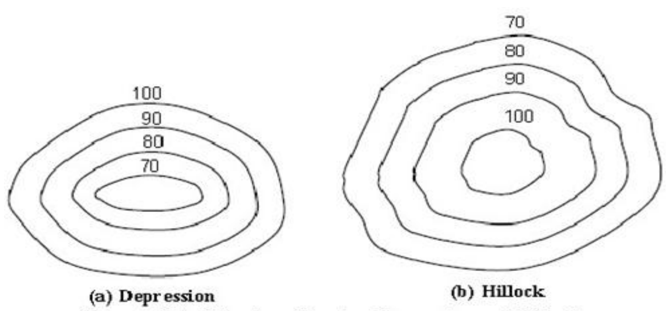


Figure : Set of Contour Showing Depression and Hillock

(g) Contour lines cross a water shed (or ridge line) and a valley line at right angles. In case of ridge line, they form curves of U-shape across it with concave side of the curve towards higher ground, whereas in case of valley line, they form sharp curves of V-shape across it with convex side of curve towards higher ground.

3. **Explain**
   i. **Reciprocal levelling**
   ii. **Fly levelling**
   iii. **Differential levelling**
   iv. **Simple levelling and state where each is used.** **(AUC Apr/May 2011)**

i) Reciprocal levelling:

It is the method of levelling in which the difference in elevation between two points is accurately determined by two sets of reciprocal observations when it is not possible to set up the level between the two points.

When it is necessary to carry levelling across a river or any obstacle requiring a long sight between two points so situated that no place for the level can be found from which the lengths of foresight and backsight will be even approximately equal.

It must be used to obtain accuracy and to eliminate

- Error in instrument adjustment.
- Combined effect of earth's curvature and refraction of the atmosphere.
- Variations in the average refraction.

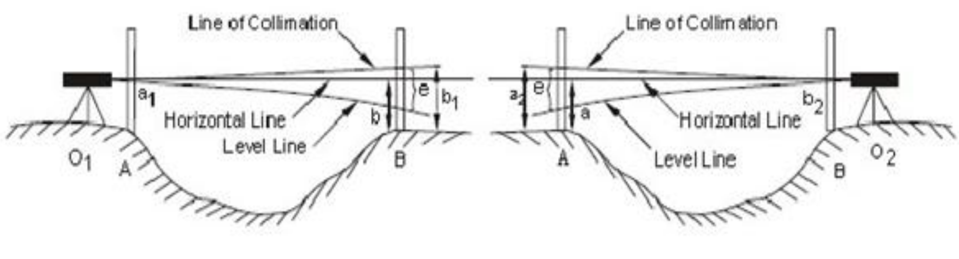


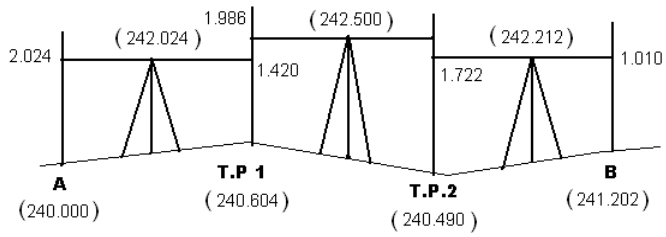
Figure : Reciprocal Levelling

ii) Differential levelling (Fly levelling):

The operation of levelling to determine the elevation of points at some distance apart is called Differential levelling.

It is usually accomplished by direct levelling. When two points are at such a distance from each other that they cannot be within range of the level at the same time. The difference in elevation is not found by single setting but the distance between the points is divided in two stages by turning points on which the staff is held. The difference of elevation of each of succeeding pair of such turning points is found by separate setting up of the level.

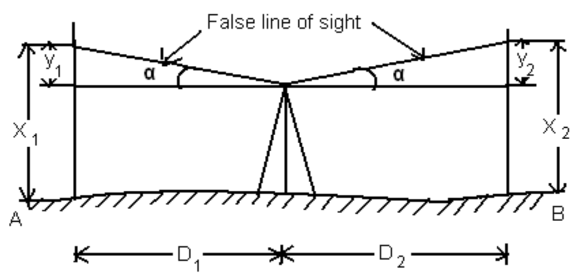
This is also termed as “fly levelling”.



iv) Simple levelling:

When the difference in elevation between any two points is determined from a single set up by backsighting on one point and foresighting on the other. The error due to non parallelism of line of collimation and axis of the bubble tube. Also the error due to curvature and refraction may be eliminated if the lengths of two sights can be made equal.

If the backsight and foresight distances are balanced the difference in elevation between two points can be directly calculated by taking difference of the two readings. There is no correction for the inclination of the line of sight, correction for curvature and correction for refraction is necessary.



4. **Following readings were observed successively with a levelling instrument. The instrument was shifted after fifth and eleventh readings 0.585, 1.010, 1.735, 3.295, 3.775, 0.350, 1.300, 1.795, 2.575, 3.375, 3.895, 1.735, 0.635 and 1.605. Draw up a page of level book and determine the R.L of various points if the RL of the point on which the first reading was taken is 135.00 m. (AUC Nov/Dec 2011)**

Solution:

Station	B.S	I.S	F.S	Rise	Fall	R.L
A	0.585					135.000
		1.010			0.425	134.575
		1.735			0.725	133.850
		3.295			1.560	132.290
B	0.350		3.775		0.480	131.810
		1.300			0.950	130.860
		1.795			0.495	130.365
		2.575			0.780	129.585

		3.375			0.800	128.785
C	1.735		3.895		0.520	128.265
		0.635		1.1		129.365
			1.605		0.970	128.395
	∑B.S = 2.670		**∑F.S = 9.275**	**∑Rise = 1.1**	**∑Fall = 7.705**	

Check:

∑B.S – ∑F.S = 2.670 - 9.275 = - 6.605

∑Rise – ∑Fall = 1.1 - 7.705 = - 6.605

Last R.L – First R.L = 128.395 - 135.000 = - 6.605

Fall = 6.605

5. Explain the direct methods of contouring. (AUC Nov/Dec 2009) (AUC Nov/Dec 2010)

Direct Method:

In this method, the contour to be plotted is actually located on the ground with the help of a level or hand level by marking various points on the contour. These points are surveyed and plotted to draw the contours through them on the plan. Though the method is slow and tedious but it is most accurate and is used for contouring small areas with great accuracy.

In contouring, field work consists of horizontal and vertical control. For a small area, horizontal control can be performed by a chain or tape, while for a large area compass, theodolite or a plane table can be employed. For vertical contour, a level and staff or a hand level may be used.

i) Vertical Control by Level and Staff:

A series of points having same elevation are located on the ground in this method. An instrument station on the ground is selected so that it commands a view of most of the areas to be surveyed. Height of the instrument can be fixed sighting a nearest benchmark. Staff reading is calculated for a particular contour elevation. The staff man is directed to move left or right along the expected contour until the required reading is observed. A series of points having same elevation as shown by the same staff reading are plotted and joined to get a smooth curve.

ii) Vertical Control by Hand Level:

The same principle as used in level and staff method is employed in this method also. This method is very rapid in comparison to the former method. A hand level may be used to get an indication of the horizontal line from the eye of the observer. A level staff or a pole having zero mark at the height of the observer’s eye which is graduated up and down from this point is used in this method. The man with the instrument stands over the benchmark and the staff man is moved to a point on the contour to be plotted. As soon as the man with instrument observes the required staff reading for a particular contour he instructs the staff man to stop and locates the position of the point.

6. **A series of offsets were taken from a chain line to a curved boundary line at intervals of 15 m in the following order 0, 2.65, 3.80, 3.70, 4.65, 3.60, 4.95 and 5.85 m. compute the area between the chain line, curved boundary and end offsets by trapezoidal rule and Simpsons rule. (AUC Nov/Dec 2011)**

Solution:

Using trapezoidal rule:

$$\text{Area} = \left[\left\{(O_o + O_7) / 2\right\} + O_1 + O_2 + O_3 + O_4 + O_5 + O_6\right] \times d$$

$$= \left[\left\{(0 + 5.85) / 2\right\} + 2.65 + 3.80 + 3.70 + 4.65 + 3.60 + 4.95\right] \times 15$$

Area = 394.13 m^2

Using Simpsons rule:

Here n is even,

Upto seventh ordinate solve by using Simpsons rule and

Last two ordinates solve by using trapezoidal rule

$$\text{Area 1} = (d/3) \times \left[(O_o + O_6) + 4\,(O_1 + O_3 + O_5) + 2\,(O_2 + O_4)\right]$$

$$= (15 / 3) \times \left[(O + 4.95) + 4\,(2.65 + 3.70 + 3.60) + 2\,(3.80 + 4.65)\right]$$

Area 1 = 308.25 m^2

$$\text{Area 2} = \left\{(O_6 + O_7) / 2\right\} \times d$$

$$= \left\{(4.95 + 5.85) / 2\right\} \times 15$$

= 81 m^2

Area = Area 1 + Area 2 = 308.25 + 81

Area = 389.25 m^2

7. **The following consecutive readings were taken with a dumpy level and 4 m levelling staff on a continuously sloping ground at 30 m intervals. 0.680, 1.455, 1.855, 2.330, 2.885, 3.380, 1.055, 1.860, 2.265, 3.540, 0.835, 0.945, 1.530 and 2.250. RL of the starting point was 80.750 m.**
   I. **Rule out a page of a level book and enter the above readings.**
   II. **Determine the RL of various staff stations.**
   III. **Estimate average gradient of ground measured. (AUC Apr/May 2010)**

Solution:

Station	B.S	I.S	F.S	Rise	Fall	R.L
A	0.680					80.750
		1.455			0.775	79.975
		1.855			0.400	79.575
		2.330			0.475	79.100
		2.885			0.555	78.545
B	1.055		3.380		0.495	78.050
		1.860			0.805	77.245
		2.265			0.405	76.840
C	0.835		3.540		1.275	75.565
		0.945			0.110	75.455
		1.530			0.585	74.870
			2.250		0.720	74.150
	∑B.S = 2.570		**∑F.S = 9.170**	**∑Rise = 0**	**∑Fall = 6.600**	

Check:

∑B.S – ∑F.S = 2.570 - 9.170 = - 6.600

∑Rise – ∑Fall = 0 – 6.600 = - 6.600

Last R.L – First R.L = 74.150 – 80.750 = - 6.600

Fall = 6.600

Gradient $= \frac{6.6}{30X12}$

Gradient = 0.0183

Slope = 1 in 55

8. **Discuss the effects of curvature and refraction in levelling and derive the expression for these corrections. (AUC Apr/May 2010)**

Effects of Curvature:

BC is the departure from the level line. Actually the staff reading should have been taken at B where the level line cuts the staff, but since the level provides only the horizontal line of sight, the staff reading is taken at the point C. thus the apparent staff reading is more and therefore the object appears to be lower than really. The correction for curvature is negative as applied to the staff reading its numerical value being equal to the amount BC. To find the value BC we have

$OC^2 = OA^2 + AC^2$, Angle CAO being 90^o

Let BC = C_C = correction for curvature

AB = d = horizontal distance between A and B

AO = R = radius of earth in the same unit as that of d

$(R + C_c)^2 = R^2 + d^2$ (or)

$R^2 + 2RC_c + C_c^2 = R^2 + d^2$

$C_c (2R + C_c) = d^2$ (or)

$C_c = \frac{d^2}{2R + C_C} = \frac{d^2}{2R}$ (Neglecting C_c in comparison to 2R)

To find the curvature correction, divide the square of the length of sight by earth's diameter. Both d and R may be taken in the same units, when the answers will also be in terms of that unit. The radius of the earth can be taken equal to 6370km. if d is to be in km and R = 6370 km, C_c will be in metres.

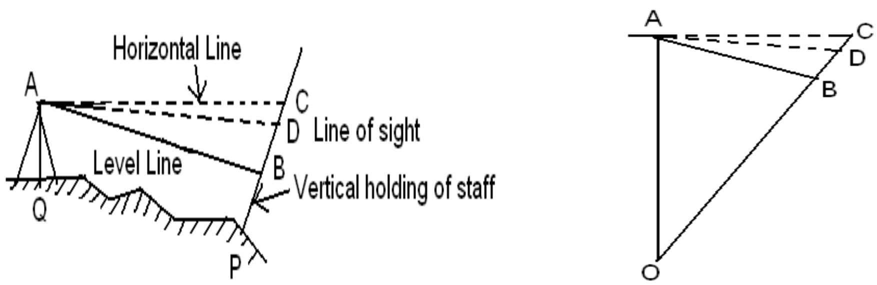


Figure: Curvature and Refraction

Effects of Refraction:

The effect of refraction is the same as if the line of sight was curved downward or concave towards the earth's surface and hence the rod reading is decreased. Therefore, the effect of refraction is to make the objects appear higher than they really arc. The correction as applied to staff readings is positive. The refraction curve is irregular because of varying atmospheric conditions, but for average conditions it is assumed to have a diameter about seven times that of the earth.

The correction of refraction, $C_r = \frac{d^2}{14R}$ (positive)

$= 0.01121\ d^2$ meters, when d is in km.

The correction due to curvature and refraction will be given by

$$C = \frac{d^2}{2R} - \frac{d^2}{14R} = \frac{3d^2}{7R} \text{ (negative)}$$

$= 0.06728\ d^2$ meters, d being in km.

The corresponding values of the corrections in English units are:

$$C_C = \frac{2d^2}{3} = 0.667\ d^2 \text{ feet}$$

$$C_r = \frac{2d^2}{21} = 0.095\ d^2 \text{ feet}$$

$$C = \frac{4d^2}{7} = 0.572\ d^2 \text{ feet}$$

Where d is in miles and radius of earth = 3958 miles.

9. The following staff reading were observed successively with a level the instrument having been moved after third, sixth and eight reading 2.228, 1.606, 0.988, 2.090, 2.864, 1.262, 0.602, 1.982, 1.044, 2.684 m enter the above reading in a page of level book and calculate RL of the first reading was taken with a staff held on bench mark of 432.384 m.

(AUC Nov/Dec 2010) (AUC May/June 2013)

Solution:

Station	B.S	I.S	F.S	Rise	Fall	R.L
A	2.228					432.384
		1.606		0.622		433.006
B	2.090		0.988	0.618		433.624
		2.864			0.774	432.850
C	0.602		1.262	1.602		434.452
D	1.044		1.982		1.380	433.072
			2.684		1.640	431.432
	∑B.S = 5.964		**∑F.S = 6.916**	**∑Rise = 2.842**	**∑Fall = 3.794**	

Check:

∑B.S – ∑F.S = 5.964 – 6.916 = - 0.952

∑Rise – ∑Fall = 2.842 – 3.794 = - 0.952

Last R.L – First R.L = 431.432 – 432.384 = - 0.952

Fall = 0.952

10. Explain the indirect methods of locating contours.

(AUC Apr/May 2010) (AUC May/June 2012) (AUC Nov/Dec 2011)

Indirect Methods:

Indirect methods are quicker, cheaper and less laborious than direct method. In this method, a series of guide points are selected along a system of straight lines and their elevations are determined. These points are then plotted and contours are drawn by interpolation. The guide points generally are not the points on the contours to be located except in case of a coincidence. For plotting of contours, the interpolation is done with the assumption that the slope between any two adjacent guide points is uniform. Some of the indirect methods of locating ground points are given below.

i) Methods of Squares:

This method is very suitable when the area to be surveyed is small. This method is also called coordinate method of locating contours. The area to be surveyed is divided into a number of squares forming a grid. The side of a square may vary from 5 to 20 m depending upon the nature of the contour and contour interval. The elevations of the corner of squares are then determined by using a level and a staff. The levels are then interpolated and contour lines are drawn. Sometimes rectangles may also be used in place of squares.

ii) Methods of Cross-sections:

This method is generally used in root surveys. Cross-sections are run transverse to the centre line of a canal, road and railway etc. The spacing of cross-sections basically depend on the nature of terrain and the contour interval. The reduced level of various points along the section line are plotted on the plan and the contours are then drawn by interpolation.

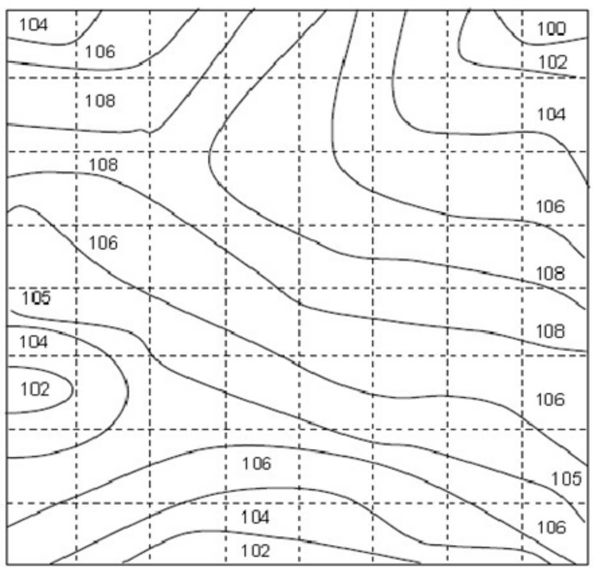


Figure : Method of Squares for Locating Contours

iii) Tacheometric Method:

11. Explain the method of profile levelling. **(AUC May/June 2013) (AUC Nov/Dec 2009)**

i) Longitudinal Profile Levelling

ii) Cross Sectional Profiling

i) Longitudinal Profile Levelling:

Let the central line of required route be *ABCD* as shown in Figure 9. Note that the change points *A, B, C, D* etc are about 30 m to 70 m apart, not more than 100 m in normal conditions. Staff intermediate stations, e.g. 1, 2 . . . 11 etc. are usually5 to 20 m distant. The instrument is set up at a suitable firm ground (say *O*), properly levelled and adjusted, from which large number of staff stations can be commanded. Backsight is then taken on the bench mark to determine *HI,* the reduced level of line of collimation at instrument station *O*.

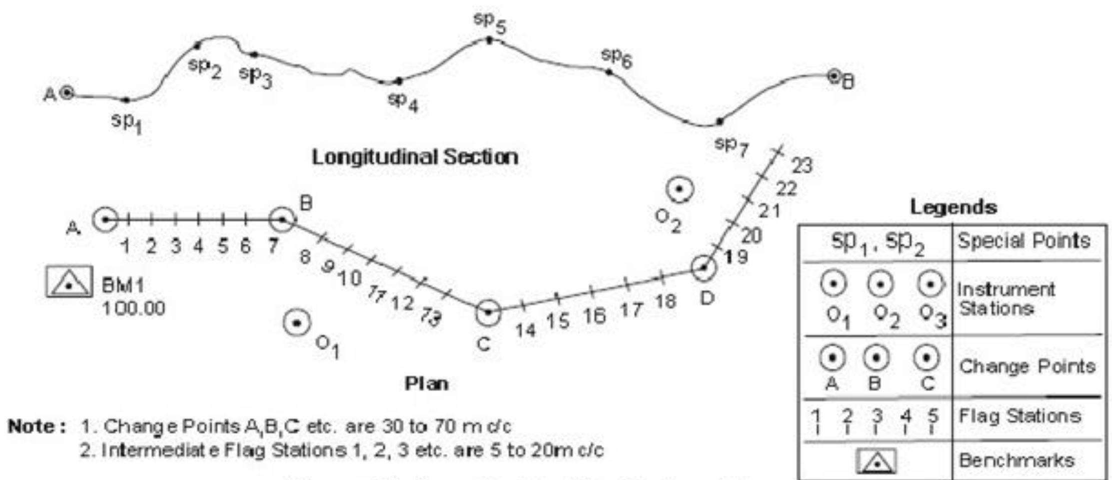


Figure 9 : Longitudinal Profile Levelling

Staff readings are then taken starting from station *A* followed by readings at predetermined intervals of 5 m or 10 m, measuring the distance *A-1,* 1-2 etc. by stretching the chain on aligned line *AB.* In addition to intermediate stations 1, 2, 3 etc., readings are also taken at critical or important points on the ground, i.e. points indicating change of slope or other important features (e.g. sp 1, sp 2 etc.).

When the length of line of sight exceeds visibility limit, e.g. about 100 m or so, or if there is some obstruction in the line of sight, the instrument is required to be shifted to new position (say *O*). Foresight on staff station *B* is taken from instrument station O_1 before shifting the instrument from position O_1 to O_2. When the instrument is set, levelled and adjusted at O_2, the first reading recorded from O_2 will be the backsight at *B.* This will decide the *RL* of newly established collimation plane. The distance of intermediate and special points are continued to be measured along line *BC* and levels read at each of these stations. Previously established benchmarks are important points on which staff readings are necessarily taken as a check on level measuring process. Bench marks can also be used as change points.

To plot the longitudinal profile of the ground along the survey line, first step would be to fix a datum line and marking the chainages of the intermediate, special and change points on it at a suitable scale. Vertical lines are then drawn on this chainage line at each intermediate, special and change points. The respective levels are then marked on these lines. The line joining these plotted points represents the longitudinal ground profile.

ii) Cross Sectional Profiling:

The project facility whether it is highway, railway, pipeline, or transmission line, will have certain width. Hence, in addition to obtaining information along the longitudinal section, it is also necessary to gather useful information up to desired transverse distance on both side of the line along its entire length. This is achieved by drawing perpendicular lines at desired interval (e.g. 20 m to 30 m) all along the route length. The transverse width (length of cross section) on either side will depend upon the facility requirements. It is 30 m to 60 m for highways, and 200 m to 300 m for railways on each side of the centre line (Figure 11). The cross sections are then serially numbered, e.g. CS_1, CS_2 etc. Along each cross section line, staff intermediate and special stations are determined at which level readings are taken and recorded. The intermediate stations can be at an interval of 10 meters while special stations are fixed at all important points, e.g. points of sudden change of levels. The recording of readings and drawing the profile is exactly similar to that of longitudinal profiling.

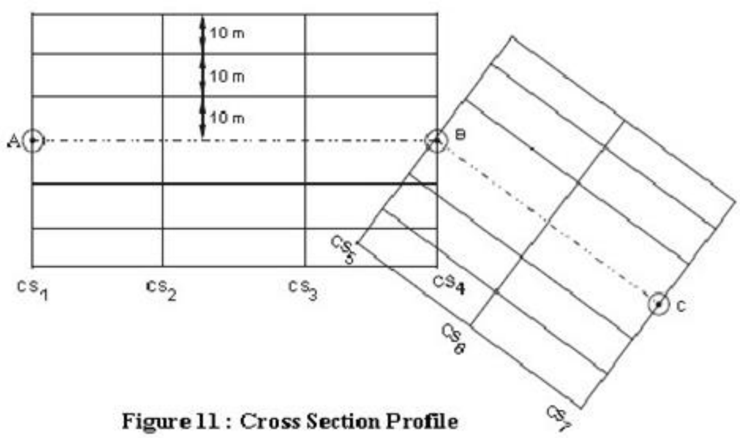


Figure 11 : Cross Section Profile

The map will then be able to supply information about

a) Original ground level,

b) Formation level,

c) Finished surface level,

d) Depth of cutting or filling,

e) Proposed gradient, and

f) If any other useful information needed for execution of the construction project.

12. Following are the consecutive readings taken with a level on a continuously sloping ground at a common interval of 25 m. 0.395, 1.025, 1.795, 1.890, 2.455, 2.880, 0.675, 1.150, 2.425, 0.785, 1.935, 2.465, 2.895. Rule out a page of level field book and make entry of above readings. Calculate the reduced levels of staff points and the gradient of the line joining the first and last point. Take the reduced level of first point as 280.00 m. (AUC May/June 2012)

Solution:

Station	B.S	I.S	F.S	Rise	Fall	R.L
A	0.395					280.000
		1.025			0.630	279.370
		1.795			0.770	278.600
		1.890			0.095	278.505
		2.455			0.565	277.940
B	0.675		2.880		0.425	277.515
		1.150			0.475	277.040
C	0.785		2.425		1.275	275.765
		1.935			1.150	274.615
		2.465			0.530	274.085
			2.895		0.430	273.655
	∑B.S = 1.855		**∑F.S = 8.200**	**∑Rise = 0**	**∑Fall = 6.345**	

Check:

∑B.S – ∑F.S = 1.855 – 8.200 = - 6.345

∑Rise – ∑Fall = 0 – 6.345 = - 6.345

Last R.L – First R.L = 273.655 – 280.000 = - 6.345

Fall = 6.345

$$\textbf{Gradient} = \frac{Fall}{L(N-2)}$$

$$= \frac{6.345}{25(13-2)}$$

13. Following observations were taken in a reciprocal levelling:

Instrument at	Staff reading at	
	A	B
A	1.625	2.545
B	0.725	1.405

Determine the RL of B if that of A is 100.00 m and also the angular error in collimation if the distance between A and B is 1000 m. (AUC May/June 2012)

Solution:

i) Determine RL of B :

Observation taken from A,

Difference in elevation between A & B = 2.545 - 1.625

= 0.92 m (A is higher)

Observation taken from B,

Difference in elevation between A & B = 1.405 – 0.725

= 0.68 m (A is higher)

True difference in elevation = $\frac{0.92+0.68}{2}$

= 0.8 m

R.L of B = 100 – 0.8 = **99.2 m**

ii) Combined correction for curvature and refraction:

Correction = 0.06728 d^2

= 0.06728 x $(1)^2$

= 0.06728 m (B is lower)

iii) Error in observation = 0.92 – 0.8 = 0.12 m

Error due to collimation = 0.12 – 0.06728

= **0.0527 m**

Collimation error is positive.

$$\tan \alpha = \frac{0.0527}{1000} = 0.0000527$$

But tan 60" = 0.0002909

$$\frac{\tan \alpha}{\tan 60''} = \frac{0.0000527}{0.0002909}$$

$$\alpha = \frac{527x60}{2909}$$

14. The following staff readings were observed successively with a level. The instrument having been moved after the second, fifth and eighth readings. 0.675, 1.230, 0.750, 2.565, 2.225, 1.935, 1.835, 3.220, 3.115 and 2.875. the first staff reading was taken with a staff held on a bench mark of reduced level 100.00 m. enter the readings in the level book form and find the reduced levels of all points. (AUC Nov/Dec 2012)

Solution:

Station	B.S	I.S	F.S	H.I	R.L
A	0.675			100.675	100.000
B	0.750		1.230	100.195	99.445
		2.565			97.630
C	1.935		2.225	99.905	97.970
		1.835			98.070
D	3.115		3.220	99.800	96.685
			2.875		96.925
	∑B.S = 6.475		**∑F.S = 9.550**		

Check:

∑B.S – ∑F.S = 6.475 – 9.550 = - 3.075

Last R.L – First R.L = 96.925 – 100.000 = - 3.075

Fall = 3.075

15. Explain the sources of various errors in levelling. (AUC Nov/Dec 2012)

The sources of errors in levelling exercise can be several depending upon the location, instrument employed and human resource. The major sources can be listed as follows

(a) Instrumental errors.

(b) Human errors in setting.

(c) Natural causes.

a) Instrumental Errors:

b) Human Errors:

Inaccurate levelling of instrument by surveyor while setting the instrument, or settling of level during surveying introduces errors. The error is cumulative. The error can be avoided by taking care to set the level in a firm ground and levelling it carefully. If setting on soft ground cannot be avoided, the legs of level tripod are kept on wooden platform or on stakes driven in the ground. The same precaution can be taken at change and intermediate stations to avoid staff settlement. Care should be taken to avoid any contact with tripod while sighting and taking the staff reading. Other human errors could be error in focusing or staff not being held perfectly vertical while taking the level readings, wrong recording of readings or recording in wrong columns etc.

c) Natural Causes:

These are effects of wind and sun. Considerable difficulty could be experienced while taking the staff reading under glaring sun, or sun shining on the objective glass. Accuracy of observation can also be affected when the velocity of wind is large or when the atmosphere is heated. When the sights are long during precision levelling the errors due to effect of curvature and refraction shall be taken into account. The line of level, defined as a line of equal altitude, will not remain horizontal in long sights due to earth's curvature (Figure 12). *Aa′* will be the recorded level at *A* while the real level should be *Aa.* Thus, an error $e = aa'$ is introduced due to earth's curvature given as $e_c = 0.0785\ D^2$, where *D* is the distance in kilometer (km) from the level to the staff station, and *e* is in meters. In normal levelling, sight length is less than 300 m, hence *e* will always be less than 0.007 m.

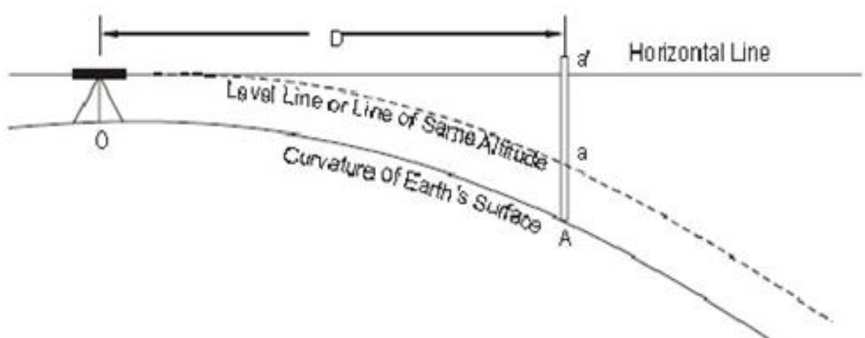


Figure12 : Error Due to Curvature

Errors due to refractions are introduced due to refraction of light passing through layers of air of different densities. The bent light ray from staff to instrument will not remain horizontal (Figure 13) but will be curved introducing error *aa′.* The effect of refraction is not constant but varies with atmospheric conditions. However, on an average under normal.

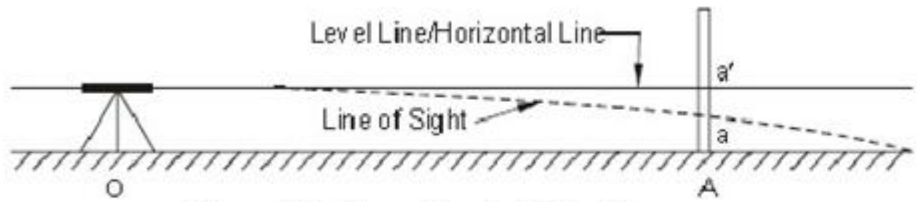


Figure 13 : Error Due to Refraction

atmospheric conditions the correction for refraction will be *aa'.* The error, e_r (in meters) =0.0112 *D2* (i.e. roughly about 1/7 the correction due to curvature and opposite in sign). The combined correction due to curvature and refraction would be $e_{CO} = e_C - e_r$ = (0.0785 – 0.0112) *D2* = 0.0673 *D2* .As the effect of curvature is to increase the staff reading so the correction for curvature is subtractive. The correction for refraction is additive to staff reading. Hence, the combined correction is subtractive to staff reading.

16. Compare the rise and fall and line of collimation methods in reducing leveling observation. (AUC May/June 2013)

Rise and Fall Method:

Instead of finding the instrument height at a setup station, the difference between consecutive points is obtained from their staff readings with that immediately preceding it. The difference indicates a rise or a fall. The reduced level of each point is then obtained by adding the rise to or subtracting the fall from the *RL* of the preceding point. The arithmetic check in this method is as follows:

$$\Sigma BS - \Sigma FS = \Sigma \text{Rise} - \Sigma \text{Fall}$$
$$= \text{Last } RL - \text{First } RL$$

It can be noted that the first method of collimation is simpler and faster than the rise and fall method. However, there is no check in reduction of levels at intermediate stations in collimation method while the second method provides arithmetic check on all the level reductions. We can conclude that the collimation method can be preferred for profile levelling or setting out construction levels, while rise and fall method is preferred for differential levelling, check levelling and other important applications.

Some precautions in recording the measurements in field books should be taken to avoid error in recording and subsequent computations. Care should be taken to make entries strictly in the respective columns prescribed for them in order of their observation. The first entry on a fresh page in field book shall always be a backsight while the last entry is a foresight. If the last entry happens to be a staff position at intermediate point, instead of a change point, it shall be made both in foresight and backsight columns at the end of the preceding page and as the first entry into the succeeding page. In the remark column, bench marks, change points and other important information shall be briefly but accurately recorded, preferably explained with the help of sketches by free hand drawn on the left side of the page.

Collimation Method:

As explained earlier, the height of instrument (HI), e.g. the height of line of collimation above *BM* (station of known level) at each instrument station is determined by adding the backsight of *BM* station to reduced level of *BM.* From this height of instrument at a particular instrument station, reduced levels of all the station points on ground are calculated by subtracting foresight of that particular station from *HI,* i.e.

HI of instrument = *RL* of Bench mark + *BS* of *BM*

RL of intermediate point = *HI* – *FS* at intermediate station

= *HI* – *IS*

When the instrument is shifted to its second position, height of instrument at new set up station is required to be determined. This is achieved by correlating the levels of two collimation planes (first and second position) by foresight of change point from first setup station and backsight of same change point from second setup station, as follows:

RL of change point *C* = *RL* of *A* + *BS* at *A* – *FS* at *C*

HI (at second station O_2) = *RL* of *C* + *BS* at *C*

With instrument set up at second station (say O_2), staff readings at new system of intermediate stations are taken before shifting the instrument at next set up station (O_3). This process is continuously repeated till the levelling exercise is completed, and all the required reduced levels are obtained.

A check can be applied on the mathematical correctness of calculation of reduced levels by collimation method as follows. The difference between the first reduced level (at starting station) and last reduced level (at end station) must be equal to the difference between summation of all foresights at change points and the summation of all backsights at change points.