Chapter 4

Levelling and Contouring

CHAPTER HIGHLIGHTS

- *Levelling and trigonometric levelling*
- *Tacheometry*
- *Contouring*

Levelling and Trigonometric Levelling

Introduction

Levelling is a branch of surveying which works with the objective of finding or establishing the elevation of points. This chapter deals with measurements in a vertical plane.

Object of Levelling

1. To find the elevations of given points with respect to a given or assumed datum—to enable works to be designed.
2. To establish points at a given elevation or at different elevations with respect to a given or assumed datum—to set out all kinds of engineering works.

Fundamental Definitions

- **Level surface:** is defined as a curved surface which at each point is perpendicular to the direction of gravity at the point. The surface of a still water is a truly level surface. Any surface parallel to the mean spheroidal surface of the earth is, therefore, a level surface.
- **Level line:** It is a line lying on the level surface. It is therefore, normal to the plumb line at all points.
- **Horizontal plane:** It is a plane tangential to the level surface at that point and is therefore perpendicular to the plumb line through the point.
- **Horizontal line:** It is a straight line tangential to the level line at a point and it is also perpendicular to the plumb line.
- **Vertical line:** It is line normal to the level line at a point. It is commonly considered to be the line defined by a plumb line.
- **Datum:** It is any surface to which elevations are referred. Mean sea level affords a convenient datum all over the world.
- **Elevation:** Vertical distance above or below an arbitrarily assumed level surface or datum.
- **Vertical angle:** It is an angle between two intersecting lines in a vertical plane.
- **Mean sea level:** Average height of the sea for all stages of the tides. It is derived by averaging the hourly tide heights over a long period of 19 years.
- **Bench mark:** It is a relatively permanent point of reference whose elevation with respect to some assumed datum is known and used as a starting point for leveling or as a point upon which to close as a check.

Methods of Levelling

Three methods of leveling are used for determining difference in elevation.

1. **Barometric levelling:** makes use of the phenomenon that difference in elevation between two points is proportional to the difference in atmospheric pressures at these points.

2. **Trigonometric levelling (indirect levelling):** It is the process of leveling in which the elevations of points are computed from the vertical angles and horizontal distances measured in the field. In a modified form called **'stadia levelling'** is commonly used in mapping.
3. **Spirit levelling (direct leveling)** A spirit level and sighting device (telescope) are combined and vertical distances are measured by observing on graduated rods placed on the points. It is the most precise method of determining elevations and the one most commonly used by engineers.

Levelling Instruments

Level

It is to provide a horizontal line of sight. It consists of four parts.

1. A **telescope** to provide line of sight.
2. A **level tube** to make the line of sight horizontal.
3. A **levelling head** (tribrach and trivet stage) to bring the bubble in its centre of run.
4. A **tripod** to support the instrument.

Chief types of levels are:

Dumpy Level

- This name originated from the fact that formerly this level was equipped with an inverting eye-piece and hence was shorter than wye level of the same magnifying power.
- Levelling head generally consists of two parallel plates with 3 or 4 foot screws. The upper plate is known as tribrach and the lower plate is known as trivet.

Advantages of dump level over wye level:

1. Simpler construction with fewer movable parts.
2. Fewer adjustments to be made.
3. Longer life of the adjustments.

Wye or Y Level

- In dumpy level, telescope is fixed to the spindle and bubble tube must be of reversible type. While in wye level, the telescope is carried in two vertical 'wye' supports and bubble tube may be attached either to the telescope or to the stage carrying the wyes.
- Advantage of wye level over dumpy level is that the adjustments can be tested with greater rapidity and ease.

Reversible Level Combines the features of both the dumpy and wye level. For testing and making the adjustments, telescope can be taken out and reversed end for end.

Tilting Level The line of sight and the vertical axis need not be exactly perpendicular to each other. This feature helps in quick levelling.

- This is mainly designed for precise levelling work.
- Its advantage is that it can be done more quickly, but it is not so apparent when many readings are taken from one instrument setting.

Levelling Staff

It is a rectangular rod having graduations. It is used to establish a horizontal line of sight and to determine the amount by which the station is above or below the line of sight.

1. Solid staff
2. Folding staff
3. Telescopic staff

Each metre is sub divided into 200 divisions, the thickness of graduations being 5 mm and painted in alternate black and white with 5 mm thickness each.

Surveying Telescope

- This telescope employs two convex lenses. One nearest to object is called objective and other near to eye is called the eye-piece.
- Object glass provides a real inverted image infront of eye-piece, while the eye-piece magnifies the image to produce an inverted virtual image.

Line of Sight or Line of Collimation

- It is a line which passes through the optical centre of the objective and intersection of cross hairs and eye-piece.
- The telescope in which the focusing is done by the external movement of either objective or eye-piece is known as **external focusing telescope** and the one in which focusing is done internally with a negative lens is known as internal focusing telescope.

Parallax

If the image formed by objective lens is not in the same plane with cross-hairs, any movement of the eye is likely to cause an apparent movement of the image with respect to the cross-hairs. This is called parallax.

Essential Parts of the Telescope

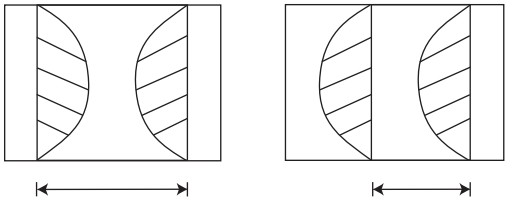
1. Objective.
2. Eye-piece.
3. Diaphragm.
4. Body and focusing device.

Objective It is a compound lens called achromatic lens. It consists of front double convex lens made of crown glass and back concave-convex lens made of flint glass. It nearly eliminates spherical and chromatic aberrations.

Eye-piece

- Ramsden eye-piece is commonly used which is composed of plano-convex lenses of equal focal length placed at a distance of $\frac{2}{3}f$.

- Huygen's eye-piece composed of plano-convex lenses of different focal length placed at a distance of two-third of focal length of the larger.



Ramsden eye-piece **Huygen's eye-piece**

Diaphragm It consists of cross-hairs. Horizontal hair is used to read the staff and the two vertical hairs enable the surveyor to see if the staff is vertical laterally. In stadia tacheometry, two more horizontal hairs called stadia hairs are provided.

Optical Defects of a Single Lens

Aberrations is the deviation of rays of light.

1. **Spherical aberration:** The defect or imperfection arising from the form of curvature of the lens in which the rays are all not collected exactly at one point is called spherical aberration.
2. **Chromatic aberrations:** A beam of light after passing through a single lens, is distributed along the axis in a series of focal points in which violet ray is refracted most and the red is refracted least. This defect is called chromatic aberration.
   - The elimination of aberrations is only one of the requirements in the design of a telescope.
   - Other possible defects which are of little importance are coma, astigmation, curvature, distortion, etc.

Temporary Adjustments of a Level or Telescope

1. Setting up the level
2. Levelling up with the help of foot screws
3. Elimination of parallax by two steps:
   (a) Focusing the eye-piece (for distinct vision of cross hairs)
   (b) Focusing the objective (for clear image of staff)

Terms and Abbreviations

1. **Station: It** is that point where the level rod is held.
2. **Height of instrument (HI):** It is the elevation of plane of sight with respect to assumed datum.
3. **Back sight (BS):** Sight taken on a rod held at a point of known elevation. It is also known as a **plus sight** as the back sight reading is always added to the level of the datum to get the height of the plane of sight.
4. **Fore sight (FS):** Reading taken on a rod held at a point of unknown elevation. It is also known as minus sight, as the fore sight reading is always subtracted from HI to get elevation of the point.
5. **Turning point (TP):** is a point on which both minus sight and plus sight are taken on a line of direct levels.
6. **Intermediate station (IS):** Intermediate point between two turning points on which only one sight (minus sight) is taken to determine the elevation of the station.

Steps in Leveling

1. To find the amount by which the line of sight is above the bench mark.
2. To know the amount by which the next point is below or above the line of sight.
   - Height of instrument, HI = Elevation of BM + BS (at BM)
   - Elevation of a point = HI – FS (at that point)

Booking and Reducing Levels

Collimation or Height of Instrument Method

- Height of the instrument (HI) is calculated for each settling of the instrument.
- Reduced levels (RL's) of other stations are calculated based on height of the instrument.
- Generally used for fly leveling or to establish BMs.
- This method is not suitable when there are intermediate points.

Check: ΣBS – ΣFS = Last RL – First RL

Rise and Fall Method

- Difference of level between consecutive points is found by comparing the staff readings.
- Higher staff reading indicates fall and lesser indicates rise.
- Generally used in contour survey.
- Used when a number of Intermediate station readings are required and provides a complete check for intermediate sights.

Check: ΣBS – ΣFS = Σ Rise – Σ Fall
= Last RL – First RL

Use of Inverted Staff

When the point, whose elevation is much above the line of sight (For example, projection from the face of a building, underside of beams, girders, arches, etc.) the staff is placed inverted with its zero end touching the point. The reading on the staff is taken in the usual manner. Such an observation

is entered in the level page book with a minus sign for convenience. The levels of the points (using inverted staff) can be obtained by simply adding the staff readings to the height of the instrument.

SOLVED EXAMPLES

Example 1

A back sight reading on BM = 100 m was 2.67 m. The inverted staff reading to the bottom of a girder was 1.5 m. The RL of the bottom of girder is

(A) 101.17 m (B) 98.83 m
(C) 104.17 m (D) 95.83 m

Solution

Height of the instrument (HI)

= BM + BS

= 100 + 2.67

= 102.67 m

RL of bottom of girder = HI – FS

But as the FS is inverted reading FS

= –1.5 m

RL = 102.67 – (–1.5)

= 104.17 m

Hence, the correct answer is option (C).

Balancing Back Sights and Fore Sights

- By placing the instrument approximately between two successive staff stations in fly leveling the errors due to curvature and refraction may be eliminated called balancing of sights and no correction for the inclination of the line of sight is necessary.
- HI method is more rapid, less tedious and simple and is more suitable where it is required to take a number of readings from the same instrument setting.
- Rise and fall method though tedious provide a full check in calculations for all sights.

Curvature and Refraction

1. **Correction for curvature (C_c)—negative:** Because of the curvature of the earth, the staff reading is more and object appears to be lower than it really is. Therefore correction is negative.

   Correction for curvature,

$$C_c = \frac{d^2}{2R} \text{ (–ve)}$$

   Where

   d = Horizontal distance between station and the point along line of sight

   R = Radius of earth, 6370 km (in same unit as d)

   $\Rightarrow C_c = 0.07849d^2$ metres (d in km)

2. **Correction for refraction (C_r)—positive:**
   - Refraction curve is irregular because of varying atmospheric conditions, but for average conditions it is assumed to have a diameter about 7 (diameter of earth).

$$C_r = \frac{1}{7}\left(\frac{d^2}{2R}\right) \text{ (+ve)}$$
$$= 0.01121d^2 \text{ meters } (d \text{ in km})$$

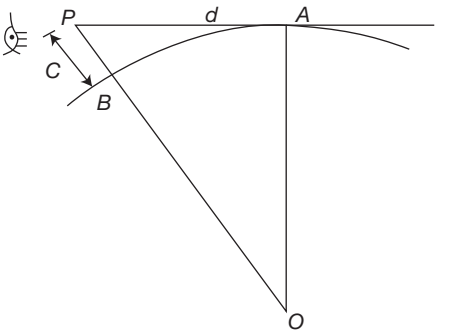
3. **Combined correction due to curvature and refraction (C):**

$$C = \frac{d^2}{2R} - \frac{1}{7}\frac{d^2}{2R}$$
$$C = \begin{cases} \frac{6}{7}\frac{d^2}{2R} \\ 0.06728d^2 \text{ metres } (d \text{ in km}) \end{cases}$$

4. **Distance to the visible horizon (d):** This takes both curvature and refraction into account

$$d = \sqrt{\frac{C}{0.06728}} \text{ km}$$

   Where, C = Combined correction in metres



Example 2

Find the combined correction for curvature and refraction for distance of 2.1 km (in metres).

(A) 0.296 (B) 0.049
(C) 0.112 (D) 0.483

Solution

$C = 0.06728d^2$ metres

$= 0.06728\ (2.1)^2$

$C = 0.296$ m

Hence, the correct answer is option (A).

Example 3

The observer standing on the deck of a ship just sees a light house. The top of the light house is 52 metres above the sea

level and the height of the observers' eye is 5 metres above the sea level. Find the distance of the observer from the light house.

(A) 26.9 km (B) 36.42 km
(C) 41.6 km (D) 45.32 km

Solution

Let A be position of top of light house at 52 m above ground and B be position of observers' eye at 5 m above ground.

$C_1 = 52$ m $C_2 = 5$ m

We know $d = \sqrt{\frac{C}{0.06728}}$ km

$d_1 = \sqrt{\frac{52}{0.06728}}$

$= 27.8$ km

$d_2 = \sqrt{\frac{5}{0.06728}}$

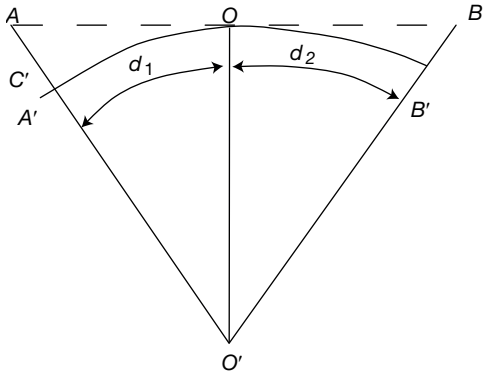
$= 8.62$ km

$\therefore$ Distance between A and B

$= d_1 + d_2$

$= 36.42$ km.

Hence, the correct answer is option (B).



Types of Levelling

Differential Levelling

- The direct leveling which is used to determine the elevation or difference in elevation of points at some distance apart regardless of their horizontal positions is called differential leveling.
- It is also known as fly leveling

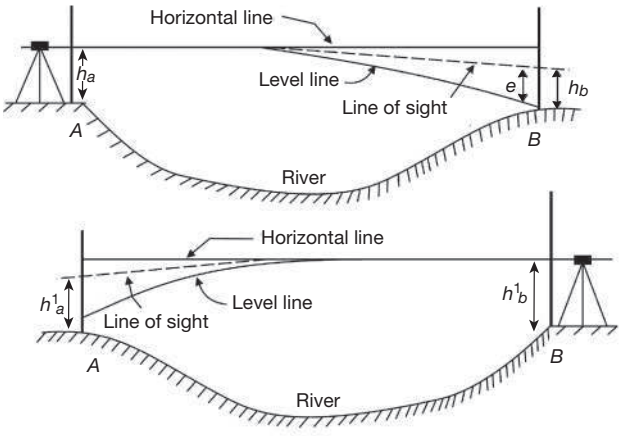
Reciprocal Levelling

When it is necessary to carry levelling across a river or any instance requiring a long sight between two points so situated that no place for the level can be found from which lengths of FS and BS will be even approximately equal, special method, i.e., reciprocal levelling must be used to obtain accuracy.

This method eliminates:

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

The true difference in elevation (H) is equal to the mean of the two apparent differences in elevation, obtained by reciprocal observations.



Reciprocal levelling

- $$H = \frac{1}{2}\left\{(h_a - h_b) + \left(h_a^1 - h_b^1\right)\right\}$$

Where

h_a, h_b = Staff readings at A and B when staff is close to A

h_a^1, h_b^1 = Staff readings at A and B when staff is close to B

- $$H = \frac{1}{2}\left\{(h_a - h_b) + \left(h_a^1 - h_b^1\right)\right\}$$
- Total error, $$e = \frac{1}{2}\left\{(h_a - h_b) - \left(h_a^1 - h_b^1\right)\right\}$$

Total error includes line of collimation error, curvature error and refraction error, $e = e_{col} + e_{cur} - e_{ref}$.

Example 4

Two points A and B are 1720 m apart across a wide river. The following reciprocal levels are taken with one level:

	Readings on	
Level	A	B
A	3.165	3.810
B	0.810	2.365

Calculate the true difference of level between A and B

(A) 1.9 m (B) 1.5 m
(C) 1.1 m (D) 0.9 m

Solution

True difference in level between A and B

$$= \frac{(3.810 - 3.165) + (2.365 - 0.810)}{2}$$

$= 1.1$ m.

Hence, the correct answer is option (C).

Profile Levelling (Longitudinal Sectioning)

- It is the process of determining the elevations of points at a short measured intervals along a fixed line such as the centre line of a railway, highway, canal or sewer.
- By means of this levelling, the engineer is enabled to study the relationship between the existing ground surface and the levels of the proposed construction in the direction of its length.

Cross-sectioning

- Cross-sections are run at right angles to the longitudinal profile and on either side of it for the purpose of lateral outline of the ground surface.
- They provide data for estimating quantities of earth work and for other purposes.
- Cross staff and optical square are used to set out right angles to the longitudinal section.
- Length of cross section depends upon the nature of work.
- Longitudinal and cross sections may be worked out together or separately.

Sensitivity of the Bubble Tube

- Sensitiveness of the bubble tube is defined as the angular value of one division of the bubble tube.
- Generally the linear value of one division is kept as 2 mm.

Sensitiveness can be increased by:

- Increasing the internal radius of the tube.
- Increasing the diameter of the tube.
- Increasing the length of the bubble.
- Decreasing the roughness of the walls.
- Decreasing the viscosity of the liquid.

Hypsometry

The working of a hypsometer for the determination of altitudes of stations depends on the fact that the temperature at which water boils varies with the atmospheric pressure. (A liquid boils when its pressure is equal to the atmospheric pressure).

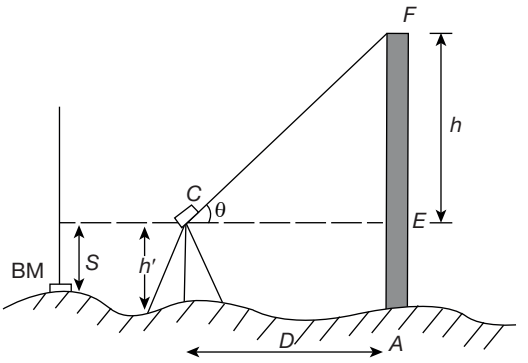
Altimeter: It is used to find heights.

Trigonometric Levelling

This is an indirect method of levelling in which the difference in elevation of the points is determined from the observed vertical angles measured with the theodolite and horizontal distances are measured directly (plane survey) or computed trigonometrically (geodetic survey). This levelling is commonly used to find the elevations of top of the buildings, chimneys, church spires and so on.

- To get the difference in elevation between the instrument station and the object under observation, the following cases are considered:

Case 1:
Base of the object accessible:



From figure, AF is the vertical object,

D is the horizontal distance between the object and instrument,

S is the reading on the levelling staff held,

h' = Vertical on BM i.e., the height of the instrument,

θ = Angle of elevation of top of the object

h = Height of object from the level of height of instrument.

From triangle CEF,

$FE = CE \tan\theta$

$$\boxed{h = D \tan\theta}$$

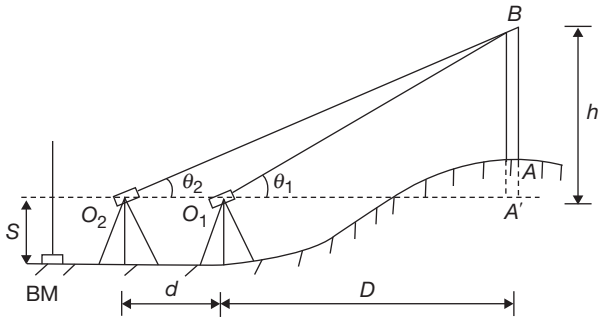
$$\boxed{\text{RL of } F = \text{RL of BM} + S + h}$$

Case 2(a):

Base of the object inaccessible—The instrument station and the elevated object are in the same vertical plane:

If the horizontal distance between the instrument and the elevated object is inaccessible, the observations are made from two instrument stations. Assuming the two instrument stations and the object to be in the same vertical plane the following three cases arise.

1. **Instrument axis at same level:**
   - If h is the vertical distance $A'B$.
   - S is the staff reading on BM.
   - θ_1 and θ_2 are the angles of elevation from the instrument stations O_1 and O_2 respectively.
   - D is the horizontal distance between O_1 and object.
   - d is the horizontal distance between the stations.



From $\Delta O_1A'B$ $\quad h = D\tan\theta_1$ (1)

From $\Delta O_2A'B$ $\quad h = (D+d)\tan\theta_2$ (2)

From Eqs. (1) and (2)

$D\tan\theta_1 = (D+d)\tan\theta_2$

$D(\tan\theta_1 - \tan\theta_2) = d\tan\theta_2$

$$D = \frac{d\tan\theta_2}{(\tan\theta_1 - \tan\theta_2)}$$

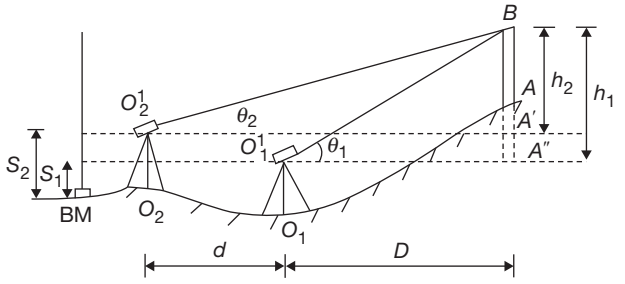
$h = D\tan\theta_1$

$$\therefore \quad h = \frac{d\tan\theta_1\tan\theta_2}{\tan\theta_1 - \tan\theta_2}$$

RL of B = RL of BM + S + h

2. Instrument axis at different levels

(a) When instrument O_2 is above O_1:



$h_1 - h_2 = A'A'' = S_2 - S_1 = S$

From $\Delta O_1'A'B'$ $\quad h_1 = D\tan\theta_1$ (1)

From $\Delta O_1^1A'B$ $\quad h_2 = (D+d)\tan\theta_2$ (2)

Subtraction Eq. (2) from Eq. (1)

$h_1 - h_2 = D\tan\theta_1 - (D+d)\tan\theta_2$

$S = D(\tan\theta_1 - \tan\theta_2) - d\tan\theta_2$

$$D = \left(\frac{s + d\tan\theta_2}{\tan\theta_1 - \tan\theta_2}\right)$$

But $h_1 = D\tan\theta_1$

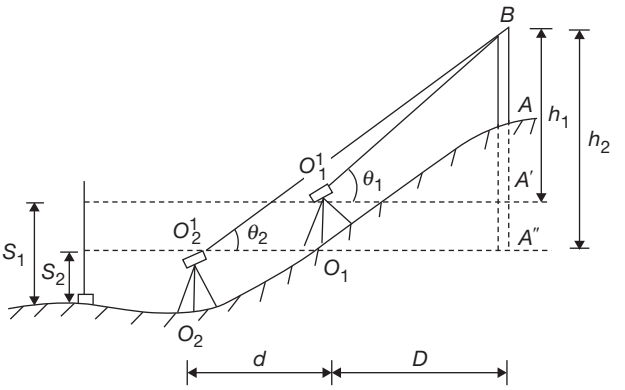
$$h_1 = \frac{(s + d\tan\theta_2)\tan\theta_1}{\tan\theta_1 - \tan\theta_2}$$

RL of B = RL of BM + S_1 + h_1

(OR)

RL of B = RL of BM + S_2 + h_2

(b) When instrument O_1 is at higher level than O_2:



$h_2 - h_1 = S_1 - S_2 = S$

From $\Delta O_1^1A'B$ $\quad h_1 = D\tan\theta_1$ (1)

From $\Delta O_2^1A''B$ $\quad h_2 = (D+d)\tan\theta_2$ (2)

Subtraction Eq. (1) from Eq. (2)

$h_2 - h_1 = (D+d)\tan\theta_2 - D\tan\theta_1$

$$D = \frac{d\tan\theta_2 - S}{\tan\theta_1 - \tan\theta_2}$$

But $h_1 = D\tan\theta_1$

Hence,

$$h_1 = \frac{(d\tan\theta_2 - S)\tan\theta_1}{\tan\theta_1 - \tan\theta_2}$$

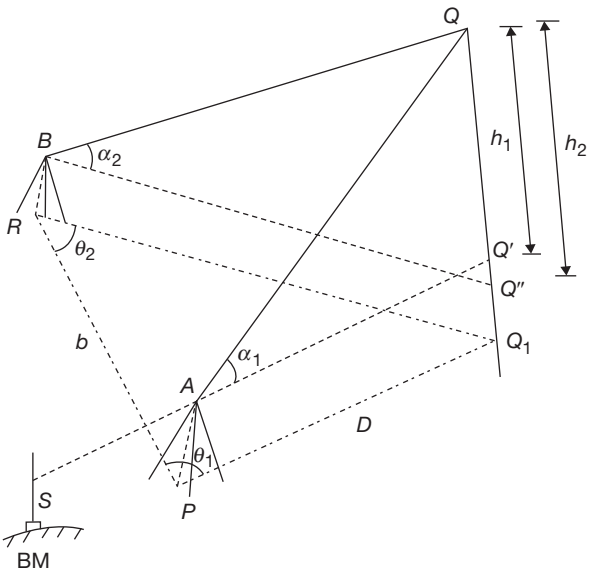
RL of B = RL of BM + S_1 + h_1

(OR)

RL of B = RL of BM + S_2 + h_2

Case 2(b):

Base of the object inaccessible: Instrument station not in the same vertical plane as the elevated object.



Let P and R be the two instrument stations not in the same vertical plane as that of Q.

- AQ' is the horizontal line through A, Q' being the vertical projection of Q and Q'' corresponding to B. AQQ' BQQ'' are the vertical planes. PRQ_1 is the horizontal plane.
- θ_1 and θ_2 are the horizontal angles, and α_1 and α_2 are the vertical angles measured at A and B respectively.

From $\Delta AQQ'$

$$QQ' = h_1 = D \tan \alpha_1 \quad (1)$$

From ΔPRQ_1, $PQ_1 R = 180° - (\theta_1 + \theta_2)$

$$= \pi - (\theta_1 + \theta_2)$$

By sine rule,

$$\frac{PQ_1}{\sin\theta_2} = \frac{RP}{\sin(\pi - (\theta_1 + \theta_2))}$$

$$= \frac{b}{\sin(\theta_1 + \theta_2)}$$

$$\Rightarrow PQ_1 = D = \frac{b \sin\theta_2}{\sin(\theta_1 + \theta_2)} \quad (2)$$

$$\Rightarrow RQ_1 = \frac{b \sin\theta_2}{\sin(\theta_1 + \theta_2)} \quad (3)$$

Substituting Eq. (2) in Eq. (1),

$$h_1 = D \tan \alpha_1 = \frac{b \sin\theta_2 \tan\alpha_1}{\sin(\theta_1 + \theta_2)}$$

$$\text{RL of } Q = \text{RL of BM} + S + h_1$$

Similarly if reading on BM is taken on B

$$h_2 = \frac{b \sin\theta_1 + \tan\alpha_2}{\sin(\theta_1 + \theta_2)}$$

$$\text{RL of } Q = \text{RL of BM} + S + h_2$$

Example 5

To find the elevation of top (Q) of a hill a flag staff of 2.5 m height was erected and observations were made from two stations P and R, 50 metres apart. The **horizontal angle** measured at P between R and the flag staff was 62°30′ and that measured at R between the flag staff and P was 70°18′. The angle of elevation to the top of the flag staff was measured to be 12°10′ and 12°55′ at P and R respectively. Staff Readings on BM when the instrument was at $P = 2.1$ m and when at $R = 2.2$ m. Calculate the elevation of top of the hill if the BM = 440 m.

(A) 466.04m (B) 463.54m
(C) 452.5m (D) 445.6m

Solution

$b = 50$ m

$\theta_1 = 62°30'$ $\theta_2 = 70°18'$

$\alpha_1 = 12°10'$ $\alpha_2 = 12°55'$

$$h_1 = \frac{b \sin\theta_2 \tan\alpha_1}{\sin(\theta_1 + \theta_2)}$$

$$= \frac{50 \sin(70°18') \tan(10°10')}{\sin(12°10' + 12°55')}$$

$$h_1 = 23.94 \text{ m}$$

RL of Q = (RL of instrument at P) + h_1 − 2.5 m

(The height of flag stag staff is to be removed = 2.5 m)

RL of Q = (BM + S) + h_1 − 2.5

= 440 + 2.1 + 23.94 − 2.5

= 463.54 m

Hence, the correct answer is option (B).

Tacheometry

Introduction

Tacheometry is defined as an optical distance measurement method. Though less accurate, this method of surveying is very rapid and convenient. The other names given to tacheometry are tachymetry or telemetry. The primary object of tacheometric survey is the preparation of a contoured plan. It is suitable for filling details on topographical maps, preliminary location surveys. A tacheometer is essentially a transit theodolite, the diaphragm of which is furnished with stadia wires in addition to the cross-wire.

Essential Characteristics of Tacheometer

1. The value of the multiplying constant should be 100.
2. The value of the additive constant should be zero.
3. The telescope should be fitted with an analectic lens.
4. The magnification of the telescope should be 20–80 diameters.
5. Magnifying power of the eye piece is kept high.

Methods of Tacheometry

There are three methods of measuring distances using tacheometer:

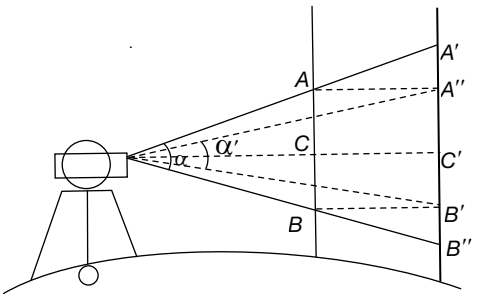
1. Stadia method
2. Tangential method
3. Special instruments.

Stadia Method

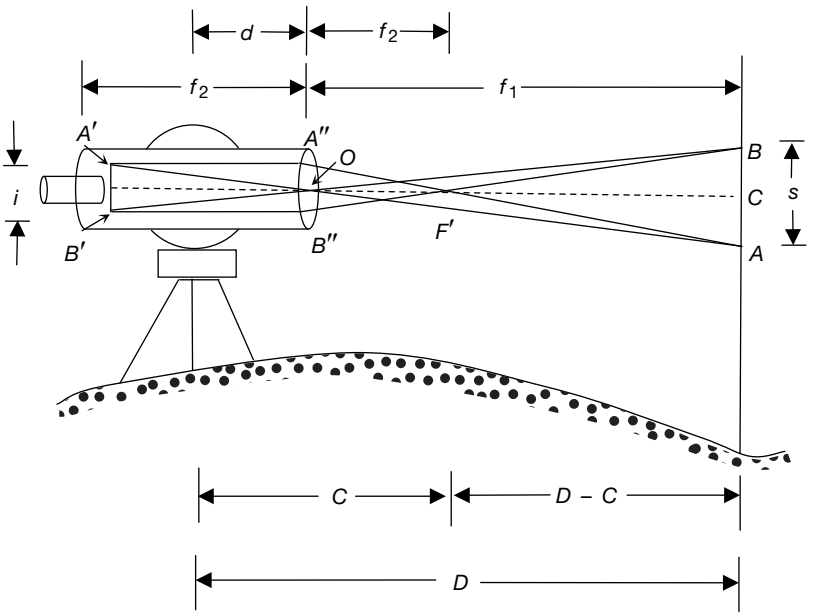
The term stadia is Greek word for a unit length. The stadia method is classified into two methods.

1. Fixed hair method
2. Movable hair method

Fixed Hair Method



When the parallactic angle α, defined by means of stadia wires, is kept fixed and staff intercept is varied, this method is called fixed hair method. In this method, the distance and elevation for horizontal sights is given by



Distance for horizontal sight

$$D = Ks + C$$

Where, K and C are the respective multiplying and additive tacheometric constants.

Elevation of Q = Elevation of $P + h - r$

The distance and elevation for inclined sight for staff held vertical are:

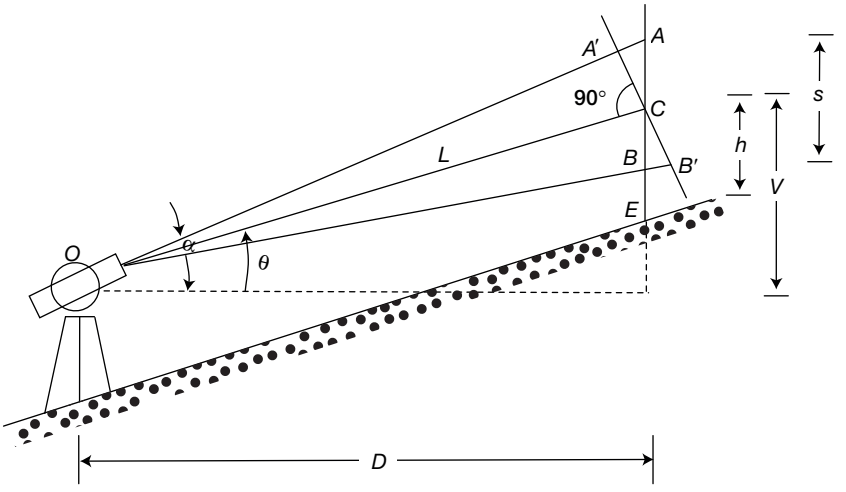
1. **Angle of elevation:**

$L = K\text{scos}\,\theta + C$

$D = L\cos\theta = K\text{scos}^2\theta + C\cos\theta.$

$$V = L\sin\theta = \frac{K\sin 2\theta}{2} + C\sin\theta$$

Elevation of staff stations 'Q' = Elevation of $p^2 + h + v - r$



Staff vertical (angle of elevation)

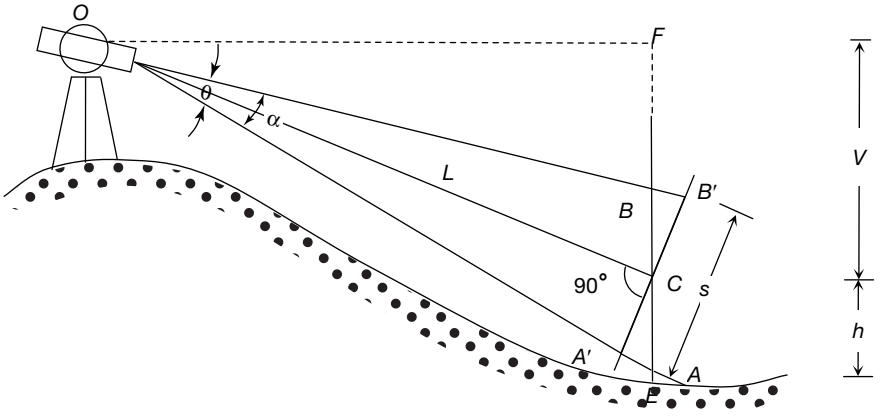
2. Angle of depression:

$L = K\text{scos}\,\theta + C$

$D = L\cos\theta$

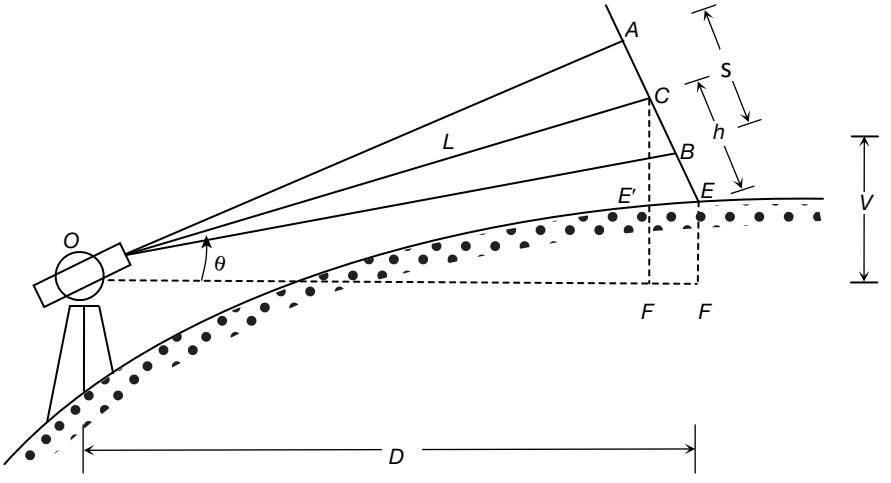
$V = L\sin\theta$

Elevation of 'Q' = Elevation of $(p) + h - v - r$

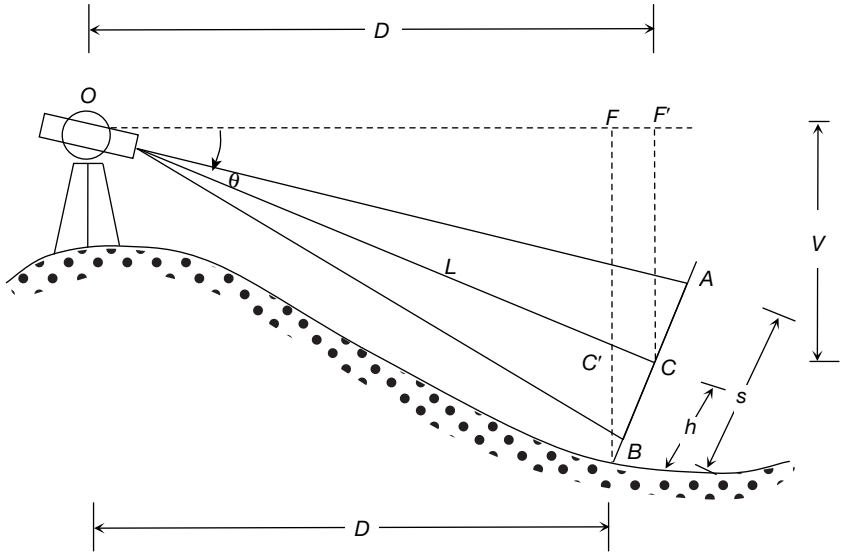


Staff vertical (angle of depression)

The distance and elevation for inclined sight for staff held normal are:



Staff normal (angle of elevation)



Staff normal (angle of depression)

1. **Angle of elevation:**

   $L = Ks + C$

   $D = L\cos\theta + r\sin\theta$

   $V = L\sin\theta$

   Elevation of Q = Elevation of 'p' + $h + v - r\cos\theta$

2. **Angle of depression:**

   $L = Ks + C.$

   $D = L\cos\theta - r\sin\theta$

   $V = L\sin\theta$

   Elevation of Q = Elevation of 'p' + $h - v - r\cos\theta$

   Where

   i = Interval between the stada hairs.

   s = Staff intercept

   f = Focal length of the objective.

   d = Distance of vertical axis of instrument from optical centre 'O'

   D = Horizontal distance of the staff from the vertical axis of the instrument

   $k = \frac{f}{l}$ = Multiplying constant (or) stadia interval factor.

   L = Length measured along the line of sight.

   $C = (f + d)$ = Additive constant of instrument

   h = Height of instrument

   r = Central of hair reading

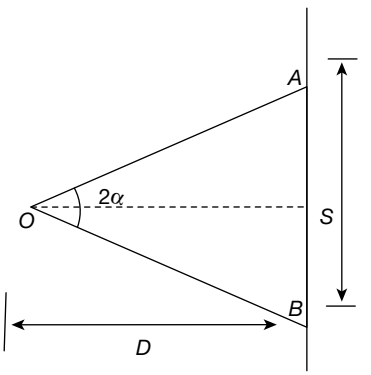
   v = Vertical intercept at 'Q' between the line of sight and the horizontal line

   P = Instrument station

   Q = Staff station

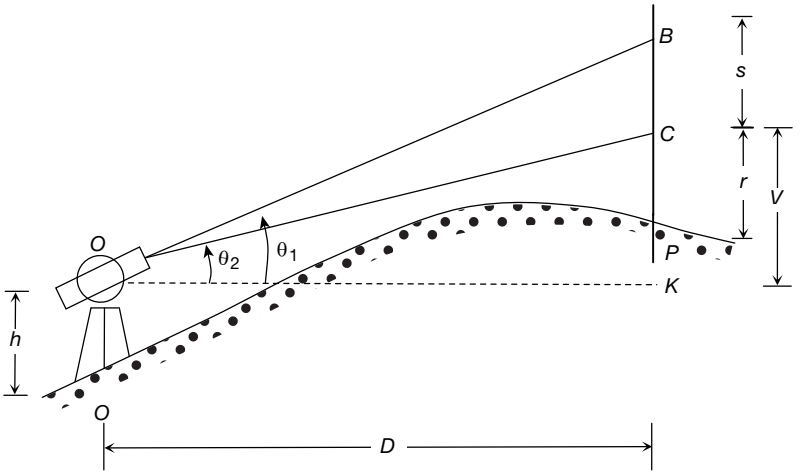
Anallactic Lens It is a special convex lens fitted between the object glass and eyepiece at a fixed distance from the former, inside the telescope of tacheometer. By using anal lactic lens the multiplying constant becomes 100 and additive constant becomes '0'. It is generally provided in the external focussing telescopes only.

Movable Hair Method It is slow method, only horizontal base substance method is in use. The horizontal base substance method has a substance bar of 'S = 2 m to 3 m'. The angle AOB is measured by a theodilite, prepared by method of repetition.



Tangential Method In this method, tacheometry observation are made for vertical angles and staff intercepts are obtained by the cross-wires only. Stadia wires are not used at all. This method of tacheometry is similar to the method of trigonometrically levelling. It is used when theodolite is not fitted with stadia wires.

Case 1: Both the angles are angles of elevation



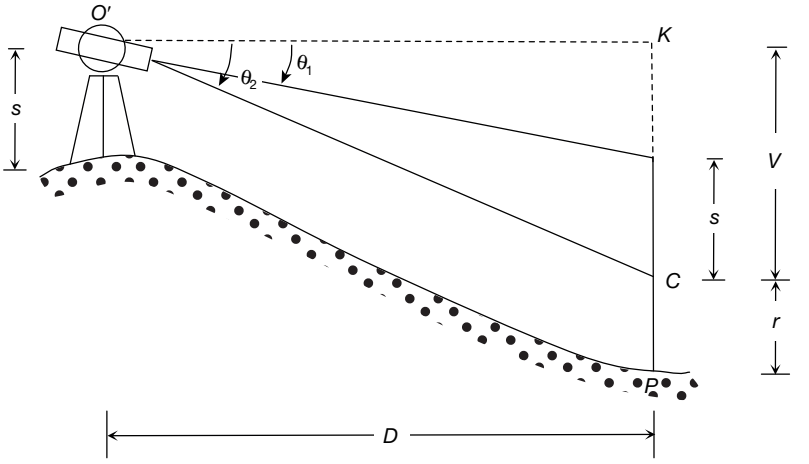
Tangential method (elevation angles)

$$D = \frac{S}{\tan\alpha_1 - \tan\alpha_2},\ V = D\tan\alpha_2$$

Elevation of Q = elevation of station $p + h + v - r$.

Case 2: Both the angles are angles of depression

$$D = \frac{S}{\tan\alpha_1 - \tan\alpha_2},\ V = D\tan\alpha_2$$

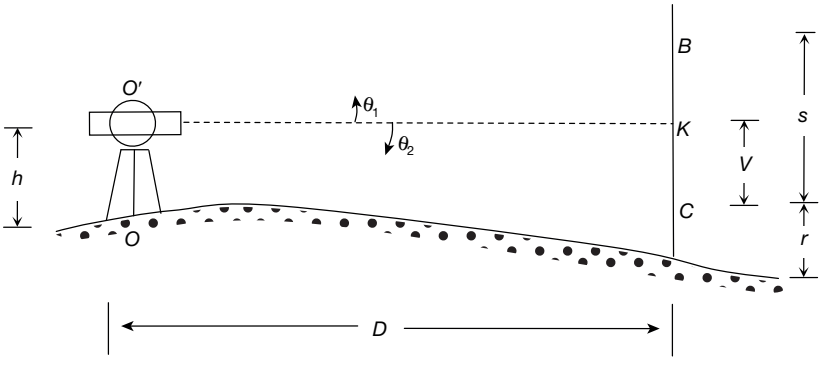


Tangential method (depression angles)

Case 3: One angle of elevation and other of depression

$$D = \frac{S}{\tan\alpha_1 + \tan\alpha_2},\quad V = \frac{S\tan\alpha_2}{\tan\alpha_1 + \tan\alpha_2}$$

Elevation of Q = elevation of station $P + h - v - r$



Tangential method (one angle of elevation and the other angle of depression)

Contouring

- A contour is an imaginary line on the ground joining the points of equal elevation.
- It is a line in which the surface of ground is intersected by a level surface.
- This is the best method to represent the features of the ground such as the hills, valleys, lakes and water courses and other topographic features on two dimensional paper.

Contour Interval

The vertical distance between any two consecutive contours is called 'Contour interval'.

The contour interval is kept constant throughout the map. Contour interval depends on:

1. **The nature of the ground:**
   - For every flat ground, a small interval is necessary.
   - If the ground is more broken, greater contour interval should be adopted, otherwise the contours will come too close to each other.
2. **The scale of the map:**

$$\text{Contour interval}, \propto \frac{1}{\text{Scale of the map}}$$

   If the scale is small, contour interval should be large. If the scale is large, contour interval should be small.
3. **The purpose and extent of the survey:**
   - If the survey is intended for detailed design work or for accurate earth work calculations, small contour interval is to be used.
   - In the case of location surveys, for lines of communications and for reservoir and drainage areas where the extent of survey is large, a large contour interval is to be used.
4. **Time and expense of field and office work:** If the time interval is less, greater contour interval should be used to finish the survey in less time.

Horizontal Equivalent

- The Horizontal distance between two points on two consecutive contours is known as horizontal equivalent.
- It varies from point to point and not a constant value and depends on steepness of the ground. Steeper the ground, lesser is horizontal equivalent.

Contour Gradient

- It is a line lying throughout on the surface of the ground and maintaining a constant inclination to the horizontal.
- The lines having equal gradient along a slope are called **grade contours**.
- The difference in elevation of two points of grade contours divided by the distance between them is always a constant gradient.
- **Ghat tracer** is an instrument used for locating points on a given contour gradient.

Characteristics of Contours

- Two contour lines of different elevation cannot cross each other. However they intersect only in the case of an overhanging cliff or a cave.
- Contour lines of different elevations can unite to form one line only in the case of a vertical cliff.
- Contour intervals close together indicate steep slope. They indicate a gentle slope if they are far apart. They indicate a uniform slope, if they are equally spaced.
- The direction of steepest slope at a point on a contour is at right angles to the contour.
- A closed contour line with one or more higher ones inside, represents a hill.
- A closed contour line with one or more lower ones inside, indicates a depression without an outlet.
- A contour line must close upon itself, though not necessarily within the limits of the map.
- Contour lines cross a watershed or ridge line or valley line at right angles.
- Irregular contours represent uneven ground.
- A series of straight parallel and equally spaced contours represent a plane surface.

Methods of Contouring

Direct Methods

- In this method, only those points to be plotted are surveyed, plotted and contours are drawn through them.
- The method is slow and tedious and is used for small areas.
- It is very accurate method.

The location of contour has two steps

1. **Vertical control:** Location of points on the contour.
2. **Horizontal control:** Survey of those points whose vertical control is done with the help of a level and staff or with the help of a hand level.
   - **By level and staff:** In this a series of points having the same staff readings and thus the same elevations, are plotted and joined by a smooth curve.
   - **By hand level:** In this method, the first point is located on one of the contours by leveling from a BM The surveyor then holds the hand level at that point and directs the rod man till the point on the rod corresponding to the height of the instrument above the ground is bisected and locates the position of the point.

Indirect Methods

- In this method, some suitable guide points are selected and surveyed. The points need not be necessarily on contours.

- This is the most commonly used method as it is less tedious and takes less time.

It is also preferred to increase the number of contours

1. **By squares (spot leveling):**
   - This method is used when the area to be surveyed is small and the ground is not very much undulating.
   - The survey area is divided in to a number of squares.
   - The elevations of the corners of the square are then determined by means of a level and a staff.
2. **By cross-sections:**
   - In this method, cross-sections are run transverse to the centre line of a road, railway or canal, etc., and is most suitable for railway route surveys.
   - A transit traverse is run in this method.
3. **By tacheometric method:**
   - This method is best suitable in case of hilly terrain.
   - The elevations and distances are calculated from the observed data and contours are interpolated.

Uses of Contour Maps

1. **Drawing of sections:** The section along any given direction can be drawn to know the general shape of the ground or to use it for earthwork calculations.
2. **Determination of indivisibility between two points:** A contour map may be used to determine the inter-visibility of the triangular stations or of any two points.
3. Tracing of contour gradients and location of route.
4. **Measurement of drainage area:**
   - The drainage area for a given as point in a stream or river can be defined the area that forms the source of all water that passes that point.
   - The extent of a drainage area may be estimated on a contour by locating the ridgeline around the watershed.
5. **Calculation of reservoir capacity:**
   - A contour map helps in finding the possible location of a dam and the volume of water to be confined.
   - The capacity of reservoir can be calculated by the following formulas

   (a) Trapezoidal formula:

   Volume

$$V = h\left\{\left(\frac{A_1 + A_n}{2}\right) + A_2 + A_3 + \cdots + A_{n-1}\right\}$$

   (b) Prismoidal formula:

   Volume

$$V = \frac{h}{3}\{(A_1 + A_n) + 4(A_2 + A_4 + \cdots + A_{n-1}) + 2(A_3 + A_5 + \cdots + A_{n-2})\}$$

   $A_1, A_2, \ldots, A_n$ are areas enclosed in a contour line, determined by a planimeter and h is the contour interval.
6. Measurement of earthwork.

Exercises

1. While levelling in an undulating terrain, it is preferable to set up the instrument on
   (A) the top of summit.
   (B) the bottom of a valley.
   (C) one side of the slope.
   (D) a flat location.
2. The rise and fall method provides an arithmetic check on
   (A) back sights and fore sights.
   (B) intermediate sights.
   (C) back sights and intermediate sights.
   (D) back sights, intermediate sights and fore sights.
3. The combined correction due to curvature and refraction (in m) for distance of 1 km on the surface of earth is _____.
   (A) 0.0673 (B) 0.673
   (C) 7.63 (D) 0.763
4. The staff reading at a distance of 80 m from a level with the bubble at its centre is 1.52 m and when the bubble is moved 5 divisions out of the centre, the reading is 1.6 m the angular value of 1 division of bubble is
   (A) 20.62 second. (B) 41.25 second.
   (C) 14.53 second. (D) 25.05 second.
5. During a levelling work along a falling gradient using a Dumpy level and a staff of 3 m length, following successive readings were taken: 1.785, 2.935, 0.360, 1.320. What will be the correct order of booking these four reading in a level book? (BS: Back Sight, IS: Intermediate Sight, FS: Fore Sight)
   (A) BS, FS, BS, FS (B) BS, IS, FS, FS
   (C) BS, IS, IS, FS (D) BS, IS, BS, FS
6. Consider the following statements:

   Assertion (A): Curvature correction must be applied when the sights are long.

   Reason (R): Line of collimation is not a level line but is tangential to the level line. Of these statements:
   (A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is not a correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

7. To find the RL of a roof slab of building, staff readings were taken from a particular set-up of the levelling instrument. The readings were 1.050 m with staff on the bench mark and 2.300 m with staff below the roof slab and held inverted. Taking the RL of the bench mark as 135.15 m, the RL of the roof slab will be
(A) 129.800 (B) 131.900
(C) 134.400 (D) 138.500

8. Two points *A* and *B* are 1530 m apart across a river. The reciprocal levels measured are:

	Readings on (in m)	
Level at	***A***	***B***
A	2.165	3.810
B	0.910	2.355

The true difference in level between *A* and *B* would be
(A) 1.255 m (B) 1.355 m
(C) 1.545 m (D) 1.645 m

9. A lighthouse is visible just above the horizon at a certain station at the sea level. The distance between the station and the lighthouse is 40 km. The height of the light house is approximately.
(A) 187 m (B) 137.7 m
(C) 107.7 m (D) 87.3 m

10. Tilt in tachometric survey increase the intercept, if it is
(A) away from the telescope pointing up the hill.
(B) towards the telescope pointing up the hill.
(C) away from the telescope down the hill.
(D) None of these

11. Anallaytic lens provided in a tachometer is a
(A) concave lens. (B) convex lens.
(C) plano-convex lens. (D) plane lens.

12. In an external focusing tacheometer, the fixed interval between stadia hairs is 5 mm, the focal length of the objective is 25 cm, and the distance of the vertical axis of the instrument from the optical centre of the objective is 15 cm. Which one of the following is the set of constants of the tacheometer?
(A) 30, 0.15 (B) 30, 0.40
(C) 50, 0.25 (D) 50, 0.40

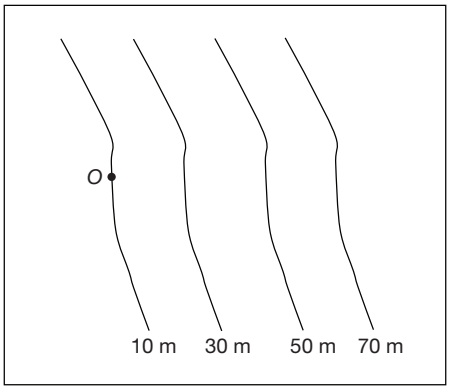
13. Following observations were taken with a transit fitted with stadia wires. The line of sight was horizontal and the staff was held vertical.

	Reading on Staff (m)
Top hair	1.726
Middle hair	2.278
Bottom hair	2.830

The tacheometric constants *K* and *C* are 100 and 0.4 m respectively. The horizontal distance between staff and instrument is
(A) 90.8 (B) 100.8
(C) 110.8 (D) 120.8

14. For better accuracy in measuring and plotting the sides of a triangle by triangulation, the angles of the triangle
(A) should not be more than 30°.
(B) should not be less than 30° or more than 120°.
(C) are not restricted in magnitude.
(D) should not be less than 120°.

15. Consider the following figure, which is an extract from a contour map (Scale–1: 20,000) of an area, an alignment of a road at ruling gradient of 4% is to be fixed from the point *O* and beyond. What should be the radius of the arc with *O* as the centre to get the point of alignment of the next contour on the map?



(A) 0.025 cm (B) 0.25 cm
(C) 2.5 cm (D) 5.0 cm

16. Consider the following statements about the characteristics of contours:
I. Closed contour lines with higher values inside show a take.
II. Contour is an imaginary line joining points of equal elevations.
III. Closely spaced contours indicate steep slope.
IV. Contour lines can cross each other in case an overhanging cliff.

Which of the IES statements are correct?
(A) II, III and IV (B) I and II only
(C) I and IV (D) I, II and III

17. A contour may be defined as an imaginary line passing through
(A) points on the longitudinal section.
(B) points of equal elevation.
(C) point of equal local ground slope.
(D) points of transverse section surveys.

18. A closed contour line with two or more higher contours inside it will represent a
(A) depression. (B) hill.
(C) cave. (D) well.

19. Following offsets were taken from a survey line to a hedge:

Distance (in m)	0	5	10	15	20	30	40
Offsets (in m)	3	4	5.5	5	6	4	4.5

The area between survey line and the hedge is (by trapezoidal method):

(A) 185.5 m^2 (B) 187.5 m^2
(C) 189.5 m^2 (D) 289.5 m^2

20. A closed contour line with one or more higher contour lines inside represents

(A) cliff (B) hill
(C) valley (D) cave

21. The combined correction of curvature and refraction for distance of 1.29 km is

(A) 0.234 m (B) 0.121 m
(C) 0.112 m (D) 0.187 m

22. The constant for an instrument is 750, the value of $C = 0.3$ m and intercept $S = 2$ m. The distance from instrument to the staff when the micrometer readings are 4.326 and 4.283 and the line of sight is at +8° 361 when the staff was held vertical, is

(A) 172.4 m (B) 173.2 m
(C) 174.8 m (D) 170.8 m

23. The volume of 130 m long road of formation width 10 m, side slopes 1 : 1, average depth of cutting along centre of line is 5 m and slopes of ground in cross-section is 10 to 1 is

(A) 9880 m^3 (B) 9723 m^3
(C) 9624 m^3 (D) 9892 m^3

24. Match the following:

	List I		List II
i.	Vertical cliff	a.	Contour lines of different elevations unite to form one line
ii.	Steep slope	b.	Contour lines of different elevations cross one another
iii.	Hill	c.	Contour lines are closely spaced
iv.	Overhanging cliff	d.	Closed contour lines with higher values inside them

i ii iii iv
(A) d c a b
(C) a b d c

i ii iii iv
(B) a c d b
(D) d b a c

25. Find the area between line *AB* and the stream taken at a regular interval of 30 m along line *AB*, using simpson's rule.

Distance	0	30	40	90	120	150	180	210	240
Offset length	23	40	42	30	32	60	10	14	22

(A) 7980 m^2 (B) 6352 m^2
(C) 5652 m^2 (D) 4734 m^2

Direction for questions for 26 and 27:

In reciprocal levelling, the following readings are taken:

Instrument Station	Staff Reading A	Staff Reading B	
A	1.286	2.768	Distance $AB = 1150$ m
B	1.292	2.432	RL of $A = 100$ m Collimation error = $\frac{0.003}{150\text{ m}}$

26. The correction for collimation is

(A) 0.021 (B) 0.048
(C) 0.023 (D) 0.032

27. Correction for refraction is

(A) 1.33 m (B) 1.34 m
(C) 1.38 m (D) 1.29 m

28. The following observations were taken during testing of a dumpy levels:

Instrument at	Staff Readings at A	Staff Readings at B
A	1.342	2.125
B	1.485	1.683

If *A* and *B* are 100 m apart the angle of inclination of line of collimation is

(A) 14° 15.50′
(B) 12° 23.30′
(C) 10° 2.29′
(D) 13° 3.40′

29. The correct sequence of temporary adjustment is:

(A) Leveling, Setting, Centering.
(B) Setting, Centering, Leveling.
(C) Setting, Leveling, Centering.
(D) Leveling, Centering, Setting.

30. A leveling instrument is set up at a point and back sight is taken on a bench mark on top of roof is (–) 1.04 m. The benchmark of roof is 100 m. The staff reading on the level is 2.4 m. The RL of sill is

(A) 98.62 m
(B) 96.54 m
(C) 103.46 m
(D) 104.63 m

31. It is required to set up points on a sloping ground of 1 in 50 m at every 20 m contour interval. If the staff reading over first point is 0.55 m. The staff reading over next point A is

(A) 0.95 m (B) 0.15 m
(C) 1.05 m (D) 0.25 m

32. Simpson's rule can be used for computations of area when the number of offsets is

(A) even. (B) odd.
(C) any number. (D) 3

33. RL of a floor level is 200.490 m. Staff reading on the floor is 1.695 m, reading on the staff held upside down against the bottom of roof is 3.305 m. Height of ceiling is

(A) 3.5 m (B) 4.0 m
(C) 5 m (D) 6 m

34. The following readings were taken with a dumpy level and a 4 m leveling staff on a continuously sloping ground at 30 m interval: 0.680 m, 1.455 m, 1.855 m, 2.330 m, 2.885 m, 3.380 m, 1.055 m. The RL of the further point was calculated to be 79.1 m. The RL of point that was read 0.680 m is

(A) 80.750 m (B) 79.780 m
(C) 78.420 m (D) 77.740 m

35. An object on the top of hill 100 m high is just visible above the horizon from a station at sea level. The distance between the station and the object is

(A) 38.53 km
(B) 3.853 km
(C) 3853 km
(D) 385.3 km

36. The sensitiveness of a bubble tube in a level would decrease if

(A) the radius of curvature of internal surface of tube is increased.
(B) the diagram of the tube is increased.
(C) the length of vapour bubble is increased.
(D) the viscosity of liquid is increased.

37.

	List I		List II
a.	Contour	**1.**	Line joining magnetic north and south
b.	Line of collimation	**2.**	Line joining subsidiary station on mainline.
c.	Tie line	**3.**	Line joining points of same elevation
d.	Magnetic meridian	**4.**	Line joining optical center of optional centre of objective lens.

a b c d a b c d

(A) 3 4 2 1 (C) 3 4 1 2
(B) 4 3 2 1 (D) 4 3 1 2

38. Two objects *P* and *Q* are on opposite banks of a river. The following observations were taken in reciprocal leveling:

Instrument Near	Staff Reading at	
	P	*Q*
P	1.400	3.5
Q	0.6	2.2

RL of *P* is 200 m and RL of *Q* is nearly

(A) 199.3 (B) 201.7
(C) 200 (D) 198.2

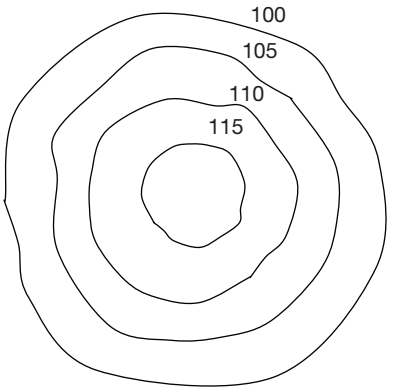
39. How high should a helicopter pilot rise at a point *A* just to see the horizon at point *B*, if the distance *AB* is 40 km?

(A) 101.75 m (B) 110.50 m
(C) 107.75 m (D) 105.50 m

40. The leveling staff head at a distance of 200 m is read at 4.54 m with the bubble out of centre by 2 divisions towards the observer. If the sensitiveness of the bubble is 25 s/division, and 1 division = 2 mm, the staff reading must have been

(A) 4.5 m (B) 4.492 m
(C) 4.54 m (D) 4.62 m

41.



The given contour diagram represents

(A) a valley. (B) a hill.
(C) ridge line. (D) valley line.

42. Points *C* and *D* are 1530 m apart across a wide river.

The following are the reciprocal levels taken with one level:

Level at	Reading	
	C	*D*
C	3.810 m	2.165 m
D	2.355 m	0.910 m

The true difference in elevation between *C* and *D* is _____.

(A) 1.645 m (B) 1.545 m
(C) 1.745 m (D) 1.345 m

43. In a levelling work, sum of back sight (BS) and fore sight (FS) have been found 3.092 m and 5.294 m respectively. If the reduced level (RL) of the starting station is 100.00 m, the RL of the last station is _____.

(A) 102.2 m (B) 97.8 m
(C) 96.9 m (D) 94.8 m

44. The combined correction due to curvature and refraction (in m) for a distance of 1.5 km on the surface of earth is _____.

(A) 0.0151 (B) 0.0673
(C) 0.1514 (D) 0.6731

Previous Years' Questions

1. A bench mark (BM) with reduced level (RL) 155.305 m has been established at the floor of a room. It is required to find out the RL of the underside of the roof (R) of the room using spirit levelling. The back sight (BS) to the BM has been observed as 1.500 m whereas the fore sight (FS) to R has been observed as 0.575 m (staff held inverted). The RL (m) of R will be **[GATE, 2007]**

(A) 155.880 (B) 156.320
(C) 157.380 (D) 157.860

2. The following information were observed during testing a leveling instrument.

Instrument at	Staff Reading at	
	P_1	Q_1
P	2.8000 m	1.7000 m
Q	2.7000 m	1.8000 m

P_1 is close to P and Q_1 is close to Q. If the reduced level of station P is 100.00 m, the reduced level of station Q is **[GATE, 2007]**

(A) 99.000 m (B) 100.000 m
(C) 101.000 m (D) 102.000 m

3. The focal length of the object glass of a tachometer is 200 mm, the distance between the vertical axis of the tachometer and the optical centre of the glass is 100 mm and the spacing between the upper and lower line of the diaphragm axis is 1 m, 2 m, and 3 m. With the line collimation perfectly horizontal. The horizontal distance (m) between the staff and instrument station is **[GATE, 2008]**

(A) 100.3 (B) 103.0
(C) 150.0 (D) 153.0

4. A bench mark was established at the soffit of an ornamental arch at the known elevation of 100 m, above MSL (mean sea level). The back sight used to establish height of instrument is an inverted staff reading of 2.105 m. A fore sight reading with normally held staff of 1.105 m is taken on a recently constructed plinth. The elevation of the plinth is **[GATE, 2010]**

(A) 103.210 m (B) 101.00 m
(C) 99.00 m (D) 96.79 m

5. Curvature correction to a staff reading in a differential levelling survey is **[GATE, 2011]**

(A) always subtractive.
(B) always zero.
(C) always additive.
(D) dependent on latitude.

6. The horizontal distance between two stations P and Q is 100 m. The vertical angles from P and Q to the top of a vertical tower at T are 3° and 5° above horizontal, respectively. The vertical angles from P and Q to the base of the tower are 0.1° and 0.5° below horizontal, respectively. Stations P, Q and the tower are in the same vertical plane with P and Q being on the same side of T. Neglecting earth's curvature and atmospheric refraction, the height (in m) of the tower is **[GATE, 2012]**

(A) 6.972
(B) 12.387
(C) 12.540
(D) 128.745

7. A theodolite is set up at station A and a 3 m long staff is held vertically at station B. The depression angle reading at 2.5 m marking on the staff is 6°10′, the horizontal distance between A and B is 2200 m. Height of instrument at station A is 1.1 m and RL of A is 880.88 m, Apply the curvature and refraction correction, and determine the RL of the B (in m) _____. **[GATE, 2013]**

8. A leveling is carried out to establish the reduced levels (RL) of point R with respect to the bench mark (BM) at P. The staff reading taken are given below

Staff Station	BS	IS	FS	RL
P	1.655 m			100.00 m
Q	–0.950 m		–1.500 m	
R			0.750 m	?

If RL of P is +100.000 m, then RL (in m) of R is **[GATE, 2014]**

(A) 103.355 (B) 103.155
(C) 101.455 (D) 100.355

9. The reduced levels (RLs) of the points P and Q are +49.600 m and +51.870 m respectively. Distance PQ is 20 m. The distance (in m from P) at which the + 51.00 m contour cuts the line PQ is **[GATE, 2014]**

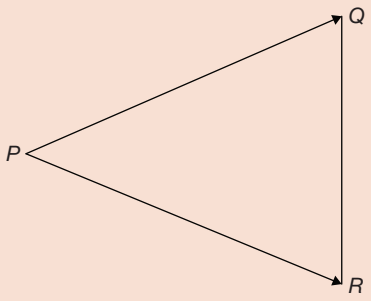
(A) 15.00 (B) 12.33
(C) 3.52 (D) 2.27

10. List I lists Tool/instrument while List II lists the Method of surveying. Match the tool/instrument with the corresponding method of surveying: **[GATE, 2014]**

List I		List II	
P.	Alidade	**1.**	Chain surveying
Q.	Arrow	**2.**	Levelling
R.	Bubble tube	**3.**	Plain table surveying
S.	Stadia hair	**4.**	Theodolite surveying

(A) P–3; Q–2; R–1 ; S–4
(B) P–2; Q–4; R–3 ; S–1
(C) P–1; Q–2; R–4 ; S–3
(D) P–3; Q–1; R–2 ; S–4

11. A tachometer was placed at point P to estimate the horizontal distance PQ and PR. The corresponding stadia intercepts with the telescope kept horizontal, are 0.320 m and 0.210 m, respectively. The $\angle QPR$ is measured to be 61°30′30″. If the stadia multiplication constant = 100 and stadia addition constant = 0.10 m, the horizontal distance (in m), between the points Q and R is _____. **[GATE, 2014]**



12. Which of the following statements is FALSE? **[GATE, 2015]**

(A) Plumb line is along the directions of gravity.
(B) Mean Sea Level (MSL) is used as a reference surface for establishing the horizontal control.
(C) Mean Sea Level (MSL) is a simplification of the Geoid.
(D) Geoid is an equi-potential surface of gravity.

13. In a leveling work, sum of the Back Sight (BS) and Fore Sight (FS) have been found to be 3.085 m and 5.645 m respectively. If the Reduced Level (RL) of the starting station is 100.000 m, the RL (in m) of the last station is _____. **[GATE, 2015]**

14. The combined correction due to curvature and refraction (in m) for a distance of 1 km on the surface of Earth is **[GATE, 2015]**

(A) 0.0673 (B) 0.673
(C) 7.63 (D) 0.763

15. Two Pegs A and B were fixed on opposite banks of a 50 m wide river. The level was set up at A and the staff readings on Pegs A and B were observed as 1.350 m and 1.550 m, respectively. Thereafter the instrument was shifted and set up at B. The staff readings on Pegs B and A were observed as 0.750 m and 0.550 m, respectively. If the RL of Peg A is 100.200 m, the RL (in m) of Peg B is _____. **[GATE, 2015]**

16. The staff reading taken on a workshop floor using a level is 0.645 m. The inverted staff reading taken to the bottom of a beam is 2.960 m. The reduced level of the floor is 40.500 m. The reduced level (expressed in m) of the bottom of the beam is _____. **[GATE, 2016]**

(A) 44.105 (B) 43.460
(C) 42.815 (D) 41.145

Answer Keys

Exercises

1. D	**2.** D	**3.** A	**4.** B	**5.** A	**6.** A	**7.** D	**8.** C	**9.** C	**10.** C
11. B	**12.** D	**13.** C	**14.** B	**15.** C	**16.** A	**17.** B	**18.** B	**19.** B	**20.** B
21. C	**22.** D	**23.** A	**24.** B	**25.** D	**26.** C	**27.** A	**28.** C	**29.** B	**30.** B
31. A	**32.** B	**33.** C	**34.** A	**35.** A	**36.** D	**37.** A	**38.** D	**39.** C	**40.** B
41. B	**42.** B	**43.** B	**44.** C						

Previous Years' Questions

1. C	**2.** C	**3.** A	**4.** D	**5.** A	**6.** B	**7.** 642.2	**8.** C	**9.** B
10. D	**11.** 28.8	**12.** B	**13.** 97.44	**14.** A	**15.** 100	**16.** A		