Chapter 1

Fundamental Concepts and Linear Measurements

CHAPTER HIGHLIGHTS

- *Fundamental definitions and concepts*
- *Linear measurements—tape and chain survey*
- *Chain surveying or chain triangulation*

Fundamental Definitions and Concepts

Surveying is the art of determining the relative positions of points on, above or beneath the surface of the earth by means of direct or indirect measurements of distance, direction and elevation.

Objectives of Surveying

1. To find elevations of points with respect to a given or assumed datum.
2. To establish points at given elevations for a proposed structure.
3. To find areas, volumes and other related quantities.

Primary Divisions of Surveying

- Based on consideration of curvature of earth
- Earth is an italics
- Polar axis (12,713,800 metres) is shorter than equatorial axis (12,756,750 metres) by 42.95 km (0.34%).

Plane Surveying

- Surface of earth is considered as a plane and curvature is neglected.
- Level line is considered as straight and all plumb lines are considered parallel.

When,

- The extent of area is **< 250 sq. km**.
- The difference between arc of 18.2 km on surface of earth and the subtended chord distance is about **1 cm**.
- Difference between sum of angles in a plane triangle and those in spherical triangle is only **one second (1″)** for a triangle at the earth's surface having an area of **195 sq. km**.
- Used for engineering projects on large scale such as factories, bridges, dams, etc.

Geodetic Surveying

- Curvature of earth is considered.
- All lines lying on surface of earth are curved lines and triangles are spherical triangles.
- Deals in fixing widely spaced control points.
- Preferred for large scale works with high degree of precision.

Classification of Surveying

Based on Nature or Function of Field Survey

Land Surveying

1. **Topographical survey:**
   - To find horizontal and vertical locations of certain points by linear and angular measurements.

- Determines natural features of a country such as rivers, lakes, hills, woods and artificial features such as roads, canals, towns, etc.

2. **Cadastral survey:**
   - Consists of fixing of property lines, boundaries of fields, municipalities and calculating land area.
   - Done by a revenue engineer.
3. **City surveying:** This survey is done for the construction of streets, water supply systems, sewers and other works.

Marine (or) Hydrographic Survey Deals with bodies of water like water supply, harbour, and for determining mean sea level.

Example: Topographical survey of shores and banks of river.

Astronomical Survey

- For finding the absolute location of a point or direction of any line on surface of the earth by taking latitude, longitude, azimuth, local time, etc.
- Observations are made in relation to sun or any fixed star.

Based on Object of Survey

1. **Engineering survey:** For determining the quantities or data required for designing of engineering works such as roads and reservoirs.
2. **Military survey:** Determining points of strategic importance.
3. **Mine survey:** For exploring mineral wealth (underground surveys).
4. **Geological survey:** For determining different strata in earth's crust.
5. **Archaeological survey:** For unearthing relics of antiquity.

Based on Instruments Used

1. **Chain surveying:** This is used when high accuracy is not required.
2. **Compass surveying:** This is more precise than chain survey. Used for measuring horizontal angles along with linear measurements with chain or tape.
3. **Leveling:** For finding difference in elevation of two points or elevation with respect to datum. (More precise than compass survey)
4. **Plane table surveying:**
   - Measurement and plotting are simultaneous.
   - Less accurate, but suitable in areas with magnetic material effect.
5. **Theodolite survey:**
   - Precise instrument for measuring horizontal and vertical angles.
   - Used for traverse and triangulation survey (base lines are located using triangulation).
6. **Tacheometric survey:**
   - Not very accurate, but useful for topographic details.
   - It is a theodolite with stadia diaphragm having two horizontal cross hairs in addition to central horizontal hair.
7. **Photogrammetry:** Use photographs of vast areas and done for areas difficult to reach.
8. **EDM surveys:** Use electronic method of measuring distances.

Principles of Surveying

1. Location of a point by measurement from two points of reference.
2. **Working from whole to part:**
   - First a system of control points are established and fixed with high precision. Minor control points are then established within main area with less precision.
   - This prevents accumulation of errors and to control and localize minor errors.

Plans and Maps

- Neglecting earth's curved surface and using orthographic projections for graphical representation of any features (on, near or below earth's surface) on a plane paper is called **plan**. **Large scale** is used for plan and only horizontal distances and directions are shown.
- The representation is called a map, if scale is small and vertical distances are also represented by contour lines.

Scales

- Scale is a fixed ratio that every distance on the plan bears with the corresponding distance on the ground.

Scale Representation

1. **Engineers scale:** 1 cm on plan represents some whole number on ground.

   Example: 1 cm = 10 m
2. **Representative factor (RF):** It is a ratio.

$$\text{RF} = \frac{\text{Distance on the Map}}{\text{Distance on the Ground}}$$

Example: $1\text{ cm} = 1\text{ m} \Rightarrow \frac{1\text{ cm}}{1\text{ m}} = \frac{1\text{cm}}{100\text{ cm}} = \frac{1}{100} = \text{RF}$

- Larger the denominator of RF, smaller is the scale of Map.
- Engineers scale and RF are called **numerical scales**.

3. **Graphical scale:**
   - It is a line drawn on the map whose length corresponds to convenient units of length on ground.
   - It has the advantage of shrinking proportionately to map and distances are found accurately unlike in numerical scales. That is why these scales are used on all survey maps.

Types of Scales

1. **Plain scale:** It is possible to measure two dimensions only.

   Example: Metres and decimetres
2. **Diagonal scale:** It is possible to measure three dimensions such as metres, decimetres and centimetres.
3. **Chord scale:** Used to measure an angle or to set-off an angle and are marked on a rectangular protractor graduated from 0°–90°.
4. **Vernier scale:** The vernier is a device for measuring fractional part of one of the smallest divisions of the graduated scale.

   If the graduations of the main scale are numbered in one direction only, it is called **single vernier** whereas if graduations are numbered in both the direction, it is called **double vernier**.

   Least count (LC) of a vernier is equal to the difference between the smallest division on the main scale and the smallest division on the vernier scale.

   (a) Direct vernier: It increases or extends in the same direction as that of the main scale. Smallest division of vernier is smaller than smallest division on main scale.

   n divisions of vernier = $(n - 1)$ divisions of main scale

$$nV = (n - 1)S$$

$$\boxed{v = \frac{(n-1)S}{n}}$$

Where

S = Smallest division on main scale

V = Smallest division of vernier

n = Number of divisions on vernier

$$LC = S - V = S - \frac{(n-1)S}{n} = \frac{S}{n}$$

$$\boxed{LC = \frac{\text{1 main scale division}}{\text{Divisions on vernier scale}} = \frac{S}{n}}$$

(b) Retrograde vernier: It is the one which extends or increases in opposite direction to that of the main scale.

In this, smallest division of vernier is longer than smallest division on the main scale.

$$nV = (n + 1)S$$

$$\boxed{v = \left(\frac{n+1}{n}\right)S}$$

$$LC = V - S = \left(\frac{n+1}{n}\right)S - S = \frac{S}{n}$$

$$LC = \frac{S}{n}$$

SOLVED EXAMPLES

Example 1

Find the LC of the vernier scale in a theodolite, if 59 divisions on main scale are equal to 60 division on vernier scale and the smallest reading on main scale is 10′.

(A) 10″ (B) 15″
(C) 20″ (D) 30″

Solution

$$LC = \frac{S}{n}$$

n = Number of divisions on the vernier = 60

S = Smallest division on main scale = 10′

$$LC = \frac{10'}{60} = 10'' \text{ (i.e., 10 seconds)}$$

Hence, the correct answer is option (A).

(c) Error due to use of wrong scale:

Correct length =

$$\left(\frac{\text{RF of wrong scale}}{\text{RF of correct scale}}\right) \times \text{Measure length}$$

Correct area =

$$\left(\frac{\text{RF of wrong scale}}{\text{RF of correct scale}}\right)^2 \times \text{Calculated area}$$

Example 2

A surveyor measured the distance between two points on the plan drawn to a scale of 1 cm = 50 m and the result was 500 m. Later, however, he discovered that he used a scale of 1 cm = 25 m. Find the true distance between the points.

(A) 250 m (B) 500 m
(C) 750 m (D) 1000 m

Solution

Measured length = 500 m

RF of wrong scale used

$$= \frac{1}{25\times100} = \frac{1}{2500}$$

$$\text{RF of correct scale} = \frac{1}{50\times100} = \frac{1}{5000}$$

∴ Correct length

$$= \left(\frac{\text{RF of wrong scale}}{\text{RF of correct scale}}\right)\times \text{Measured lenght}$$

$$= \frac{\left(\frac{1}{2500}\right)}{\left(\frac{1}{5000}\right)}\times 500$$

= 1000 m.

Hence, the correct answer is option (D).

(d) Error due to shrinkage:

$$\text{Shrinkage factor/Ratio} = \frac{\text{Shrunk length}}{\text{Actual length}}$$

Similarly,

Shrunk scale = Shrinkage factor × Original scale

Shrunk RF = Shrinkage factor × Original RF

$$\text{Correct distance} = \frac{\text{Measured distance}}{\text{Shrinkage factor}}$$

$$\text{Correct area} = \frac{\text{Measured area}}{(\text{Shrinkage factor})^2}$$

Example 3

The plan of an old survey drawn to a scale of 1 cm = 10 m, 15 cm (shrunk and a line) long now measured 12 cm only and an area on the plot measured 95 sq. cm. Find the true area of the survey.

(A) 12974 m^2 (B) 13635 m^2
(C) 14844 m^2 (D) 15629 m^2

Solution

$$\text{True RF} = \frac{1\text{ cm}}{10\text{ m}} = \frac{1}{10\times100} = \frac{1}{1000}$$

$$\text{Shrinkage factor} = \frac{12}{15} = \frac{4}{5}$$

Original area on plan

$$= \frac{\text{Measured area}}{(\text{Shrinkage factor})^2}$$

$$= \frac{95}{\left(\frac{4}{5}\right)^2} = 148.44\text{ cm}^2$$

True area of the survey

$$= \frac{\text{Original Area on plan}}{(\text{Correct RF})^2}$$

$$= \frac{148.44}{\left(\frac{1}{1000}\right)^2}$$

= 148.44 × 10^6 cm^2

= 14844 sq. m

Or,

Scale of plan 1 cm = 10 m

Area of the survey = 148.44 × $(10)^2$

= 14844 m^2.

Hence, the correct answer is option (C).

Linear Measurements—Tape and Chain Survey

Introduction

For any surveying, basic measurements are linear measures. Different methods are used for measuring lengths depending on the importance of work, location and degree of precision required.

1. Direct measurement—Chain and tape
2. Measurements by optical means
3. Electro-magnetic methods (EDM)

Direct measurements are done by passometer, pedometer, odometer, speedometer, pacing and chaining.

Different Types of Chains

- Chains are formed of straight links of galvanised mild steel.
- The length of a link is the distance between the centers of two consecutive middle rings.
- Length of chain is measured from outside of one handle to the outside of other handle.
- Metric chains:
  (a) 20 m chain (100 links)
  (b) 30 m chain (150 links)
- Gunter's/surveyor's chain:
  (a) 66 ft (100 links)
  (b) Adopted for land measurement.
- Engineer's chain—100 ft (100 links)
- Revenue chain—33 ft (16 links)
  (a) Used for measuring fields in Cadastral survey.

- Steel band/band chain
  (a) More accurate than chain
  (b) Made of blue steel—20 m and 30 m chains

Tapes

Tapes are used for more accurate measurements.

Cloth or Linen Tape

Used for rough and subsidiary measurements such as offsets. It is rarely used because of the following reasons:

1. Easily affected by moisture or dampness and thus shrinks.
2. Length gets altered by stretching.
3. Likely to twist and tangle.
4. It is not strong.

Metallic Tape

These tapes are light and flexible and are not easily broken and useful in cross-sectioning and in some methods of topography where small errors can be neglected.

Steel Tape

- Superior to cloth or metallic tape and is more accurately graduated.
- It is very delicate instrument and very light, therefore cannot withstand rough usage.

Invar Tape

- Used for linear measurements of very high degree of precision such as base lines and are measured rapidly.
- It is made of alloy of nickel (36%) and steel.
- Coefficient of thermal expansion $= \frac{1}{10}$ of that of steel $= \frac{1}{10}(\alpha_s)$
  Where, $\alpha_s = 12.5 \times 10^{-6}/°C$ (for steel)
- Greater disadvantage is that it is subjected to creep and its coefficient of thermal expansion goes on changing and it is costly, easily bent and damaged.

Instruments used for Chaining

Arrows/marking pins: Usually 10 arrows with one chain are used. It is 40 cm long and 4 mm diameter. (IS code)

Wooden pegs: Used to mark the positions of the stations or terminal points of a survey line. They are 15 cm long and 2.5–3 sq. cm cross-section.

Ranging rods: Used for ranging intermediate points in survey line. They are either 2 m or 3 m.

Ranging poles: These are 4–8 m and 6–10 cm diameter similar to ranging rods but used in case of very long lines.

Offset rod: Measures rough offsets and are 3 m long.

Butt rod: Measures offsets and is used by architects and surveyors.

Plasterer's laths: Ranging a line—setting intermediate point $\frac{1}{2}$ to 1 m long.

Whites: Similar to laths-pieces of sharpened thin sticks.

Plumb bob: Used for centering the instruments, transfer points on to the ground, make poles vertical and transfer points from line ranger to the ground.

Line ranger: It consists of either two plane mirrors or two right angled isosceles prisms used for ranging.

Ranging Out Survey Lines

If the length of survey line exceeds the length of the chain, some intermediate points have to be established in line with the two terminal points.

The two methods of ranging are:

1. **Direct ranging:** When two ends of survey lines are inter visible.
2. **Indirect/reciprocal ranging:** When both the ends of a survey line are not inter visible due to high inter veining ground.

Error Due to Incorrect Chain

- If chain is too long, measured distance is less and therefore error is negative and correction is positive.
- If chain is too short, measured distance is more and therefore error is positive and correction is negative.
  Let L, L' = Correct and incorrect length of chain/tape respectively.
  l, l' = True and measured length of line respectively

1. **Correction to measured length:**

   $$\text{True length of line} = \text{Measured length} \times \frac{L'}{L}$$

   $$\boxed{l = l'\left(\frac{L'}{L}\right)}$$

2. **Correction to area:**

   $$\text{True area} = \text{Measured area} \times \left(\frac{L'}{L}\right)^2$$

   $$\boxed{A = A' \times \left(\frac{L'}{L}\right)^2}$$

   A, A' = True and measured area of the ground.

3. **Correction to volume:**

   $$\text{True Volume} = \text{Measured volume} \times \left(\frac{L'}{L}\right)^3$$

   $$\boxed{V = V'\left(\frac{L'}{L}\right)^3}$$

   V and V' = True and measured volumes.

Example 4

The length of a survey line was measured with 20 m chain and found to be equal to 1500 metres. As a check, the length was again measured with a 25 m chain and was found to be 1515 metres. On comparing 20 m chain with the test gauge, it was found to be 2 decimetres too long. Find the actual length of the 25 m chain used.

(A) 24.88 m (B) 25.12 m
(C) 25 m (D) 25.24 m

Solution

With 20 m chain: $L' = 20 + 0.2$

$= 20.2$ m

True length $l = l'\left(\frac{L'}{L}\right) = 1500 \times \left(\frac{20.2}{20}\right)$

$= 1515$ m $=$ True length of line

With 25 m chain:

$$l = l'\left(\frac{L'}{L}\right)$$

$$1515 = 1515\left(\frac{L'}{25}\right)$$

$L' = 25$ m

$\therefore$ Actual length of chain $= 25$ m

Hence, the correct answer is option (C).

Chaining on Uneven or Sloping Ground

Used to measure sloping distance and reduce it to horizontal.

Direct Method or Method of Stepping The follower holds the zero end of the tape and the leader selects any suitable length l_1 of the tape and moves forward and makes it horizontal by the directions of follower for ranging and then transfer it to the ground by plumb bob.

- In case of irregular slopes, this is the suitable method.
- It is more convenient to measure down-hill than to measure uphill.

Indirect Method Sloping distance is measured and horizontal distance is derived. In addition to sloping distance, the angle of the slope or the difference in elevation between the two points is to be measured.

1. **Angle measured using clinometer:**

   Horizontal distance,

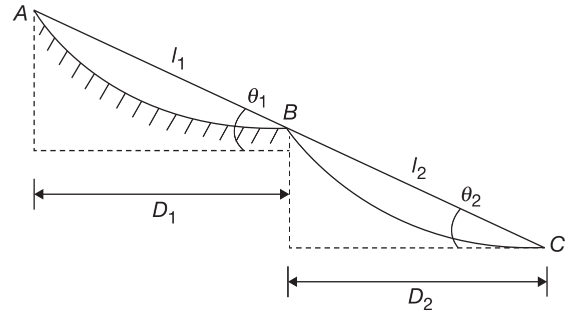
   $D_1 = l_1 \cos\theta_1,\ D_2 = l_2 \cos\theta_2$

   $l_1, l_2 =$ Sloping distances.

   θ_1 and $\theta_2 =$ Slope with horizontal.

   Require horizontal distance between any two points

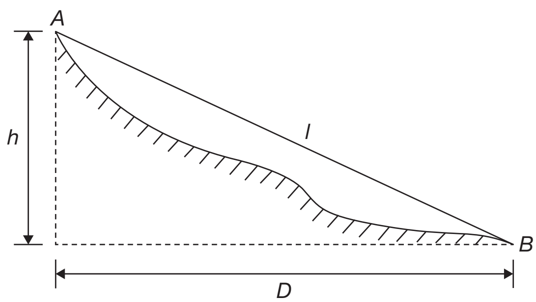
$$D = D_1 + D_2$$
$$D = \Sigma l \cos\theta$$



2. **Difference in level measured:** Difference in level is measured using leveling instrument.

   Horizontal distance,

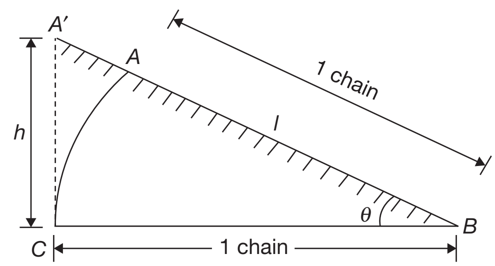
$$D = \sqrt{l^2 - h^2}$$



3. **Hypotenusal allowance (AA'):**

   Let 20 m chain is used (100 links)

$$AA' = \begin{cases} 100(\sec\theta - 1)\text{ links} \\ 50\,\theta^2 \text{ links, } (\theta \text{ in radians}) \\ \dfrac{1.5\,\theta^2}{100}\text{ links, } (\theta \text{ in degree}) \\ \dfrac{50}{n^2}\text{ links, (slope } l \text{ in } n) \end{cases}$$



NOTE

After each chain length along the slope, an extra allowance of AA' is provided.

Example 5

The distance between the points measured along a slope is 503 m. Find the horizontal distance between them if.

(i) The angle of slope between the points is 10°.

(ii) The difference in level is 56 m.

(A) 495 m and 500 m
(B) 487 m and 501 m
(C) 499 m and 486 m
(D) 491 m and 502 m

Solution

(i) $l = 503$ m; $\theta = 10°$

$D = l\cos\theta = 503\cos(10°)$

$= 495.35$ m

(ii) $h = 56$ m; $l = 503$ m

$$D = \sqrt{l^2 - h^2} = \sqrt{(503)^2 - 56^2}$$

$D = 499.87 \text{ m} \cong 500$ m.

Hence, the correct answer is option (A).

Errors

1. **Natural errors:** Due to variations in natural phenomena such as temperature, humidity, gravity, wind, refraction and magnetic declination.
2. **Personal or human errors:** Due to variation in human sight and of holding the instruments (staff, etc.)
3. **Instrumental errors:** Due to imperfection or faulty adjustment of the instrument with which measurements are taken.
4. **Systematic or cumulative errors:**
   - The error which occurs in the **same direction** and tends to **accumulate**.
   - These are regarded as 'positive' or negative based on too large or too small result and can be corrected.
   - If undetected, systematic errors are very serious.
5. **Compensating or accidental errors:**
   - Compensating error may occur in **either direction** and tends to **compensate**.
   - Reasons for this errors are beyond the ability of the observer to control. Therefore these cannot be corrected.
6. **Mistakes:** These arise from inexperience, carelessness and poor judgment or confusion in the mind of the observer. Mistakes are blunders, cannot be rectified.
   - Incorrect length of tape—Cumulative (+ or –)
   - Bad ranging and straightening—Cumulative (+)
   - Error due to temperature—Cumulative (+ or –)
   - Variation in pull—Compensating (+ or –)
   - Error due to sag—Cumulative (+)
   - Error in marking tape length—Compensating (+ or –)
   - Displacement of arrows and misreading of tape—Mistake

NOTE

Cumulative errors are more important than compensating errors.

Tape Corrections

- Correction is positive when the erroneous length is more than the designated length.
- Correction is negative when the erroneous length is less than the designated length.

Correction for Absolute Length or Standardization (+ or –)

If the absolute length of tape is not equal to designated length.

Correction, $C_a = \dfrac{LC}{l}$

Where

C_a = Correction for absolute or actual length

L = Measured length of the line

C = Correction per tape length

l = Designated length of the tape

Correction for Temperature (+ or –)

If the temperature of field is varying from standardized temperature of the tape.

Temperature correction,

$$C_t = \alpha(T_m - T_0)L$$

Where

α = Coefficient of thermal expansion

T_m = Mean temperature in field during measurement

T_0 = Temperature at standardization of tape

L = Measured length

- C_t will be +ve, if $T_m > T_0$
- C_t will be –ve, if $T_m < T_0$

Correction for Pull or Tension (+ or –)

If the pull applied during measurement is varying from standardized pull of the tape.

Correction for pull,

$$C_P = \frac{(P - P_0)L}{AE}$$

Where

P = Pull applied during measurement (N)

P_0 = Standard Pull (N)

L = Measured length (m)

A = Cross-sectional area of the tape (cm^2)

E = Youngs Modulus of Elasticity (N/cm^2)

- C_P will be +ve if $P > P_0$ and –ve if $P < P_0$

Correction for Sag (Always –)

- When the tape is stretched on supports between two points it takes the form of horizontal catenary.
- The difference between horizontal distance and the measured length along catenary is called Sag correction. For determining this correction, curve is assumed as a parabola.

1. When the ends of chain or tape are at the same level:

$$C_s = \frac{lW^2}{24n^2P^2} = \frac{l(wl)^2}{24n^2P^2}$$

Where

C_s = Sag correction per tape length

n = Number of equal spans or bays

l = Total length of the tape

W = Total weight of the tape in kg

P = Pull applied in kg.

2. When the ends of tape or chain are not at same level:

$$C_s' = c_s \cos^2\theta\left(1 \pm \frac{wl}{P}\sin\theta\right)$$

Where

θ = Angle between both ends with horizontal

'+' = When pull is applied at higher end

'–' = When pull is applied at lower end

But for small θ (i.e., steel tape),

$$C_s' = C_S\cos^2\theta$$

This equation includes correction for both **sag and slope**.

Correction for Slope or Vertical Alignment (Always –)

Slope correction,

$$C_V = \frac{h^2}{2L}, C_V = L - \sqrt{L^2 - h^2}$$

$$C_V = 2L\sin^2\frac{\theta}{2}$$

Where

h = Difference in elevation between the ends

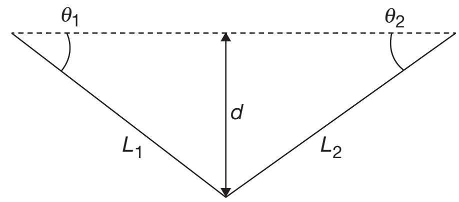
L = Inclined length measured

θ = Angle of slope with horizontal

Correction for Misalignment or Bad ranging (Always –)

If the tape is stretched away from survey line, distance measured is more and error is positive and correction is negative.

If deformation is in horizontal plane,



$$C_h = L_1(1 - \cos\theta_1) + L_2(1 - \cos\theta_2)$$

$$C_h = \frac{d^2}{2L_1} + \frac{d^2}{2L_2}$$

- If deformation (D) is vertical plane for inclined length 'L',

$$\text{Correct } C_{mv} = \frac{d^2}{2L}$$

Reduction to Mean Sea Level (+ or –)

Correction,

$$C_{msl} = \frac{Lh}{R+h} \simeq \frac{Lh}{R}$$

Where

L = Measured horizontal distance

h = Height above mean sea level

R = Radius of earth

- If distance is measured above MSL, correction is –ve.
- If distance is measured below MSL, correction is +ve.

Normal Tension

It is the pull which when applied to the tape neutralizes the effect of pull and sag and no correction is necessary.

$$\text{Normal pull, } P_n = \frac{0.204W_1\sqrt{AE}}{\sqrt{P_n - P_0}}$$

W_1 = Weight of tape supported between two supports.

Example 6

Calculate the sag correction for a 30 m steel under a pull of 150 N in three equal spans of 10 m each. Weight of one cubic cm of steel = 0.078 N

Area of cross-section of tape = 0.06 sq. cm.

(A) 0.13 m (B) 0.068 m
(C) 0.122 cm (D) 0.0084 m

Solution

Volume of tape per metre run = 0.06 × 100 = 6 cm^3

Weight of tape per metre run = 6 × 0.078 = 0.468 N

∴ Total weight of the tape suspended between two supports $W = 0.468 \times 10 = 4.68$ N

Correction for sag, C_s

$$= \frac{nl_1W^2}{24P^2} = \frac{3\times10(4.68)^2}{24\times(150)^2}$$

$= 0.00122$ m

$= 0.122$ cm

Hence, the correct answer is option (C).

Example 7

The length of a survey line when measured with a chain of 20 m, nominal length was found to be 556 m. When the chain was compared with a standard chain, it was found to be 0.2 m too long. What is the actual length of line?

(A) 550.44 m (B) 558.69 m
(C) 561.56 m (D) 553.31 m

Solution

Correction for chain length, $C = 0.2$ m
Measured length, $L = 556$ m
Nominal chain length, $l = 20$ m
∴ Correction of chain length,

$$C_a = \frac{\text{LC}}{l}$$

$$C_a = \frac{556\times0.2}{20} = 5.56 \text{ m}$$

∴ Actual length of line

= 556 + 5.56 = 561.56 m.
Hence, the correct answer is option (C).

Precise Linear Measurements

1. **First order measurements:** Used in triangulation survey for determining the length of base line.
2. **Second order measurements:** In the measurement of traverse lines in which theodolite is used for measuring directions.
3. **Third order measurements:** Used in chain surveying and other minor surveys.

Chain Surveying or Chain Triangulation

- It is a survey in which only linear measurements are made in the field.
- Done on areas of small extent on open ground.

Principle: The principle of chain survey is to provide a framework consisting of connected triangles.

Basic Definitions

Main survey station: Prominent point on a chain line and can be the beginning or end of the chain line.

Main survey line: The line joining the main survey stations.

Base line: The longest of the main survey line and the triangles are drawn with respect to this line.

Check lines or proof lines: Lines which are run in the field to check the accuracy of the work.

Subsidiary stations: Stations located on main survey line between which tie or subsidiary lines run.

Tie lines: Lines joining subsidiary or tie stations on the main line. Used to take the details of nearby objects and also serves the purpose of check line. Also called subsidiary or secondary line.

Well-conditioned Triangle

- It is the one which can be plotted accurately by intersection of arcs from the ends of the base line. The best one is an equilateral triangle.
- If site conditions does not permit accuracy of equilateral triangle to be plotted, a triangle with no angle less than 30° or more than 120° can be treated as **well-conditioned** or **well-proportional** or **well-shaped triangle**.

Offsets

- An offset is the lateral distance of an object or ground feature measure from a survey line.
  (a) Perpendicular offset—when the angle of offset is 90°. It is simply called offset. This involves less measuring on ground.
  (b) Oblique offset—when the angle is other than 90°.

Degree of Precision in Measuring Offsets

Generally, the limit of precision on plotting (paper) is 0.25 mm. So, if the scale is 1 cm = 10 m, 0.25 mm on paper will correspond to $\frac{0.25\,\text{mm}\times10\,\text{m}}{1\,\text{cm}} = \frac{0.025\times10}{1}\text{ m} = 0.25$ m on the ground. Hence offset should be measured to nearest 25 cm on ground for this scale.

Limiting Length of Offset

- This depends on:
  (a) Degree of accuracy required
  (b) Scale of plotting
  (c) Nature of ground and method of setting out perpendicular.
- Given angular error (α), Degree of accuracy (1 in r) with which the length of offset should be measured so that the error due to both sources (linear and angular) may be equal

$$\boxed{r = \operatorname{cosec}\alpha}$$

α = Angular error in laying the perpendicular

- Given the scale (1 cm = 'S' m), the limiting length of the offset (l) so that the error due to both the sources may not exceed 0.25 mm on paper.

$$\boxed{l = \frac{0.025}{\sqrt{2}} rS \text{ metres}}$$

- Given the maximum error in the length of the offset (e), the maximum length of the offset (l) and the scale (S), to find the maximum value of α so that maximum displacement on the paper may not exceed 0.25 mm.

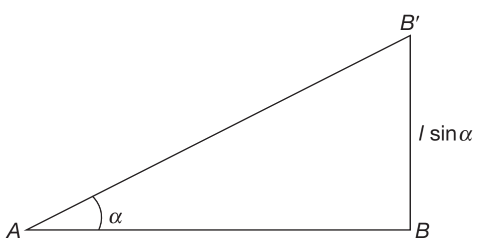
$$\boxed{\sin^2\alpha = \left(\frac{6.25S^2}{100^2} - e^2\right) \times \frac{1}{l^2}}$$

Example 8

An offset is laid out 3° from its true direction on the field. If the scale of plotting is 10 m to 1 cm, find the maximum length of the offset so that the displacement of the point on the paper may not exceed 0.25 mm.

(A) 4.77 m (B) 5.39 m
(C) 6.72 m (D) 7.16 m

Solution



Displacement of the point on the paper $= \frac{l\sin\alpha}{S}$

$$= \frac{l\sin 3°}{10} \text{ cm} \ngtr 0.025 \text{ cm}$$

$$\therefore \frac{l\sin 3°}{10} = 0.025 \Rightarrow l = 4.77 \text{ m}$$

Hence, the correct answer is option (A).

Instruments for Setting out Right Angles

1. **Cross staff:**
   (a) **Open cross staff:** Can set two lines at right angles to each other.
   (b) **French cross staff:** Can set lines at 45° or 90°.
   (c) **Adjustable cross staff:** Can set any angle.
2. **Optical square:** More convenient and accurate than cross staff for setting right angles. Consists of two mirrors making an angle of 40° with each other
   - One mirror totally silvered
   - Another top silvered and bottom un-silvered
3. **Prism square:** More modern and precise than optical square.

Obstacles in Chaining

1. Obstacle to ranging but not chaining:
   Examples: Forest, hill
2. Obstacle to chaining but not ranging:
   Examples: Small pond, small bend in river.
3. Obstacles to both chaining and ranging:
   Example: A big building

Exercises

1. The required slope correction for a length 60 m, along a gradient of 1 in 20 is:
   (A) 7.50 cm (B) 0.750 cm
   (C) 75.0 cm (D) 5.50 cm
2. Systematic errors are those errors
   (A) whose effects are cumulative and can be determined.
   (B) on circumference of circumscribing circle.
   (C) outside the great triangle.
   (D) in the centre of the circumscribing circle.
3. The length of a base line measured on ground at an elevation of 300 metres above mean sea level is 2250 metres. The required correction to reduce to sea level length. (Given the radius of Earth is 6370 km) is ________.

4. Match List I (Corrections) with List II (Name) and select the correct answer using the codes given below the lists:

	List I		List II
a.	$\pm L\left(1-\frac{h}{R}\right)$	**1.**	Sag correction
b.	$-\frac{l}{24}\left(\frac{W}{P}\right)^2$	**2.**	Pull correction
c.	$\pm\alpha(T_f - T_s)L$	**3.**	Temperature correction
d.	$+\frac{(P_f - P_s)L}{AE}$	**4.**	Mean sea level correction

Codes:

	a	b	c	d		a	b	c	d
(A)	4	1	3	2	(B)	1	4	3	2
(C)	4	1	2	3	(D)	1	4	2	3

5. What is the slope correction for a length of 30.0 m along a gradient of 1 in 20?
(A) 3.75 cm
(B) 0.375 cm
(C) 37.5 m
(D) 0.0375 cm

6. A rectangular plot of 16 km^2 in area is shown on a map by a similar rectangular area of 1 cm^2. RF of the scale to measure a distance of 40 km will be

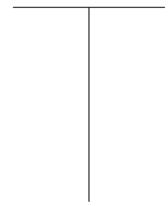
(A) $\frac{1}{1600}$ (B) $\frac{1}{400000}$

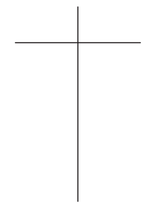
(C) $\frac{1}{400}$ (D) $\frac{1}{16000}$

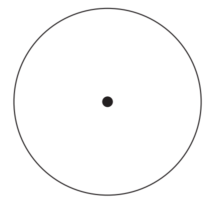
7. If the original scale of a negative is 1:10,000 the ground resolution, considering that we get nearly 20 lines pair per mm, will be
(A) 50 mm
(B) 20 cm
(C) 2 m
(D) 25 cm

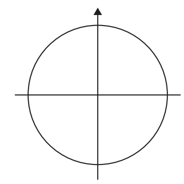
8. Which one of the following statements is correct?
(A) In a retrograde vernier, (n – 1) divisions on the primary scale are divided into n divisions on the vernier scale.
(B) A double vernier consists of two simple verniers placed end-to-end forming one scale with the zero in the centre.
(C) In an extended vernier, (2n + 1) primary divisions are divided into n divisions on the vernier.
(D) In a direct vernier, (n + 1) primary divisions are divided into n equal divisions on the vernier scale.

9. Which of the following is a conventional sign for North line in surveying?

(A)


(B)


(C)


(D)


10. Which one of the following surveys is employed for collecting sufficient data in connection with sewage disposal and water supply works?
(A) Topographic survey
(B) Cadastral survey
(C) Geodetic survey
(D) Cross-sectioning and profile leveling

11. Which of the following conditions requires geodetic surveying?
(A) Horizontal curve ranging
(B) Vertical curve ranging
(C) Survey of a country
(D) Reconnaissance survey

12. A 30 m metric chain is found to be 0.1 m too short throughout the measurement. If the distance measured is recorded as 300 m, then the actual distance in 'm' will be
(A) 300.1 (B) 301.0
(C) 299.0 (D) 310

13. Consider the following equipments:
I. Tacheometer
II. Odometer
III. Passometer
IV. Perambulator

Which of the above equipments can be employed for measurement of horizontal distances?
(A) I and II only (B) I and III only
(C) II and III only (D) I, II, III and IV

14. For setting out right angles, the instrument used is
(A) optical square.
(B) abney level.
(C) alidade.
(D) ceylon ghat tracer.

15. Consider the following:
I. Line ranger
II. Reciprocal ranging
III. Random line method
IV. Optical square

Which of these are the correct methods of ranging employed to solve the problem of vision obstructed but with chaining free?

(A) I, II, III and IV (B) II and III only
(C) II and IV only (D) III and IV only

16. A tape is standardized at 100 N pull. If the load applied is 120 N, then the sag correction is

(A) $L_1W_1^2(1.12\times10^{-6})$

(B) $L_1W_1^2(1.273\times10^{-6})$

(C) $L_1W_1^2(1.73\times10^{-6})$

(D) $L_1W_1^2(1.53\times10^{-6})$

17. The survey which is done for fixing the property lines is known as

(A) topographical survey.
(B) cadastral survey.
(C) city survey.
(D) astronomical survey.

18. The length of the tape is 30 m and the sag is 30.35 cm at the mid-span under a tension of 100 N, the weight of the tape is

(A) 0.248 N/m (B) 0.269 N/m
(C) 0.326 N/m (D) 0.459 N/m

19. Match the following

	List I		List II
i.	Correction for standard length	**a.**	$C_a = \frac{L\cdot c}{l}$
ii.	Correction for tension	**b.**	$C_p = \frac{(P-P_0)}{AE}L$
iii.	Sag correction	**c.**	$C_t = \alpha(T_m - T_0)\,L$
iv.	Correction for temperature	**d.**	$C_{sa} = \frac{W^2L}{24P^2}$

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

20. I. Optical square is better than prism square.
II. In both optical and prism squares, the principle of operation is same.

(A) Only I is correct
(B) Only II is correct
(C) Both I and II are correct
(D) None of these

21. Shrinkage of an old map is $\frac{24}{25}$ and the RF is $\frac{1}{2500}$ then the corrected scale for the map is equal to

(A) $\frac{1}{2400}$ (B) $\frac{1}{2500}$

(C) $\frac{1}{2600}$ (D) $\frac{1}{60000}$

22. 10 divisions of vernier scale are equal to 11 parts of main scale of each 0.1. The last count of the scale is ______.

23. The length of a survey line when measured with a chain of 20 m nominal length was found to be 841.5 m. If the chain used is 0.1 m too long, the correct length of measured line is

(A) 845.7 m
(B) 837.39 m
(C) 843.6 m
(D) 839.4 m

24.

	List I		List II
a.	Transverse surveying	**1.**	Weddel's sounding machine
b.	Geodetic surveying	**2.**	Alidade
c.	Plane table surveying	**3.**	Chain and compass
d.	Hydrographic surveying	**4.**	Theodilite

	a	b	c	d		a	b	c	d
(A)	3	4	2	1	(B)	1	4	2	3
(C)	3	2	4	1	(D)	1	2	4	3

25. If 'h' is the difference in height between end points of a chain of length l, the required slope correction will be ______.

(A) $\frac{h^2}{l}$ (B) $\frac{h^2}{4l}$

(C) $\frac{h}{2l}$ (D) $\frac{h^2}{2l}$

26. In chain surveying, field work is limited to ______.

(A) linear measurements only
(B) angular measurements only
(C) both linear and angular measurements
(D) linear, angular and vertical measurements

27. The area of the particular field was measured as 200 m^2 with a chain of length 20 metre. But, later it was found that actual length of the chain used for the survey as 20.8 metre. Then, what will be the actual area of the field?

(A) 184 m^2
(B) 216 m^2
(C) 192 m^2
(D) 208 m^2

28. The plan of a map was photo copied to a reduced size such that a line originally 100 mm measures 85 mm. The original sale of plan was 1 : 1000. The revised scale is ______.

(A) 1 : 111
(B) 1 : 1177
(C) 1 : 1221
(D) 1 : 1257

Previous Years' Questions

1. The plane of a map was photo copied to a reduced size such that a line originally 100 mm, measures 90 mm. The original scale of the plan was 1 : 1000. The revised scale is **[GATE, 2007]**

(A) 1 : 900 (B) 1 : 1111
(C) 1 : 1121 (D) 1 : 1221

2. The survey in which the earth curvature is also considered is called **[GATE, 2008]**

(A) geodetic survey.
(B) plane survey.
(C) preliminary survey.
(D) topographical survey.

3. The plan of a survey plotted to a scale of 10 m to 1 cm is reduce in such a way that a line originally 10 cm long now measures 9 cm. The area of the reduced plan is measured as 81 cm^2. The actual area $(m)^2$ of the survey is **[GATE, 2008]**

(A) 10000 (B) 6561
(C) 1000 (D) 656

4. The survey carried out to delineate natural features, such as hills, rivers, forests and man-made feature, such as towns, villages, buildings, roads, transmission lines and canals is classified as **[GATE, 2014]**

(A) engineering survey.
(B) geological survey.
(C) land survey.
(D) topographic survey.

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

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

Answer Keys

Exercises

1. A	**2.** A	**3.** 0.1 m	**4.** A	**5.** A	**6.** B	**7.** A	**8.** B	**9.** D	**10.** C
11. C	**12.** C	**13.** D	**14.** A	**15.** B	**16.** B	**17.** B	**18.** B	**19.** B	**20.** C
21. A	**22.** 0.05	**23.** A	**24.** A	**25.** D	**26.** A	**27.** B	**28.** B		

Previous Years' Questions

1. B	**2.** A	**3.** A	**4.** D	**5.** A