Advanced Surveying (313321)

Model Question Paper — Set C · Model Answers

Q.1

a) Objects of tacheometry. 2 M

- To determine **horizontal distances** and **elevations (RL)** of points quickly without chaining.
- To prepare **contour / topographic maps**, and for **location surveys** of roads, railways and reservoirs in rough terrain.

(Any two, 1 M each)

b) Horizontal and vertical curve. 2 M

Horizontal curve: A curve provided in the **horizontal plane** to change the direction of the alignment, e.g. simple, compound, reverse and transition curves.

Vertical curve: A curve provided in the **vertical plane** at the junction of two different gradients, e.g. summit curve and valley (sag) curve.

(Each 1 M)

c) Modern surveying equipments. 2 M

1. Digital (electronic) theodolite
2. Electronic Distance Measuring instrument (EDM)
3. Total station
4. GPS / GNSS receiver (DGPS, RTK)
5. Digital / auto level and laser level
6. Drone (UAV) and 3-D laser scanner

(Any four, ½ M each)

d) Uses of EDM. 2 M

- Measuring **long distances** (up to several km) quickly and accurately.
- Measuring distances across **obstacles** — rivers, valleys, busy roads, hilly terrain.
- **Traversing, trilateration** and establishing control points.
- **Setting out** of bridges, dams, highways, tunnels and large buildings.
- Topographic and **cadastral** surveys; **deformation monitoring** of dams and bridges.

(Any four, ½ M each)

e) Electromagnetic energy. 2 M

Electromagnetic (EM) energy is the energy that travels in the form of **electromagnetic waves** (electric and magnetic fields at right angles to each other) with the velocity of light, $c = 3 \times 10^8$ m/s; $c = f\lambda$. The Sun is the main source used in remote sensing.

EM spectrum: gamma rays, X-rays, ultraviolet, **visible (0.4–0.7 μm)**, infrared, microwave, radio waves.

f) Photogrammetry and one merit. 2 M

Photogrammetry is the science and art of obtaining **reliable measurements, maps and 3-D information** about objects from photographs (aerial or terrestrial).

Merit: large and inaccessible areas can be mapped quickly; photographs remain a permanent record.

(Definition 1 M, merit 1 M)

g) Salient features of drones. 2 M

1. **GNSS (GPS) positioning** with autopilot — pre-planned waypoint flights for mapping.
2. **High-resolution camera on a gimbal** (also LiDAR, thermal, multispectral sensors).
3. **Return-to-home** and fail-safe landing on low battery / signal loss.
4. **Geo-fencing** and obstacle avoidance sensors for safe flying.
5. **Real-time video** transmission to the ground controller.
6. RTK / PPK GNSS for centimetre-level mapping accuracy; vertical take-off and landing (multirotor).

(Any two, 1 M each)

Q.2

a) Principle of stadia tacheometry and distance equation. 4 M

Principle: Tacheometry is based on the property of **similar isosceles triangles**: the ratio of the perpendicular distance from the apex to the base, to the length of the base, is constant. In a tacheometer the two stadia hairs (spacing *i*) subtend a constant angle at the outer focus (or at the anallatic point). Hence the **horizontal distance from the instrument to the staff is proportional to the staff intercept s** between the stadia hairs:

$$\mathbf{D = (f/i)\ s + (f + d) = K\ s + C}$$

- f = focal length of object glass; i = stadia hair spacing; d = distance of object glass from vertical axis.
- Rays from the staff points A and B pass through the outer focus F, become parallel after the object glass and form images on the stadia hairs a and b.
- Triangles F-A-B and F-(image at object glass) are similar: (D − f − d)/s = f/i.
- Both horizontal distance and elevation are obtained without chaining, from one set of staff readings and the vertical angle.

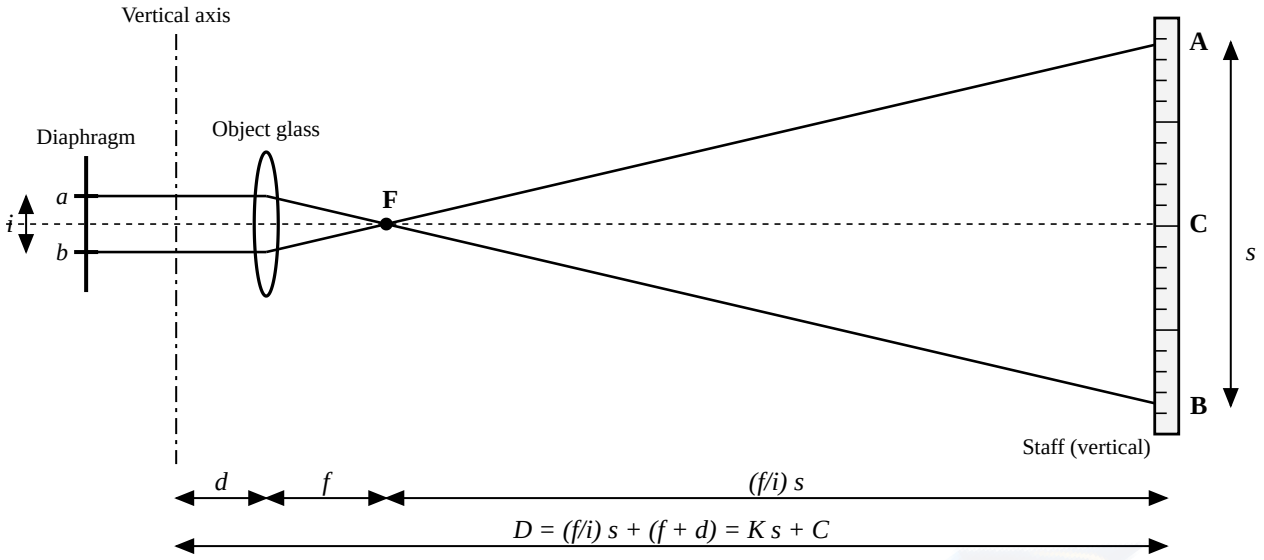

Fig.: Principle of stadia tacheometry (line of sight horizontal, staff vertical)

Derivation (from the figure): by similar triangles, (D − f − d) / s = f / i ⇒ D = (f/i) s + (f + d) = K s + C.

(Principle 1 M, sketch 1 M, equation 2 M)

b) Properties of simple circular curve. 4 M

1. The two **tangent lengths are equal**: $T_1V = VT_2 = T = R \tan(\Delta/2)$.
2. The radius at each tangent point is **perpendicular to the tangent** ($OT_1 \perp T_1V$, $OT_2 \perp T_2V$).
3. The **central angle** T_1OT_2 is equal to the **deflection angle Δ**.
4. The line OV **bisects** the angle at V and the long chord T_1T_2 at right angles; it passes through the mid-point C of the curve (curve symmetrical about OV).
5. The **tangential (deflection) angle** between the tangent and any chord is half the angle subtended by that chord at the centre.

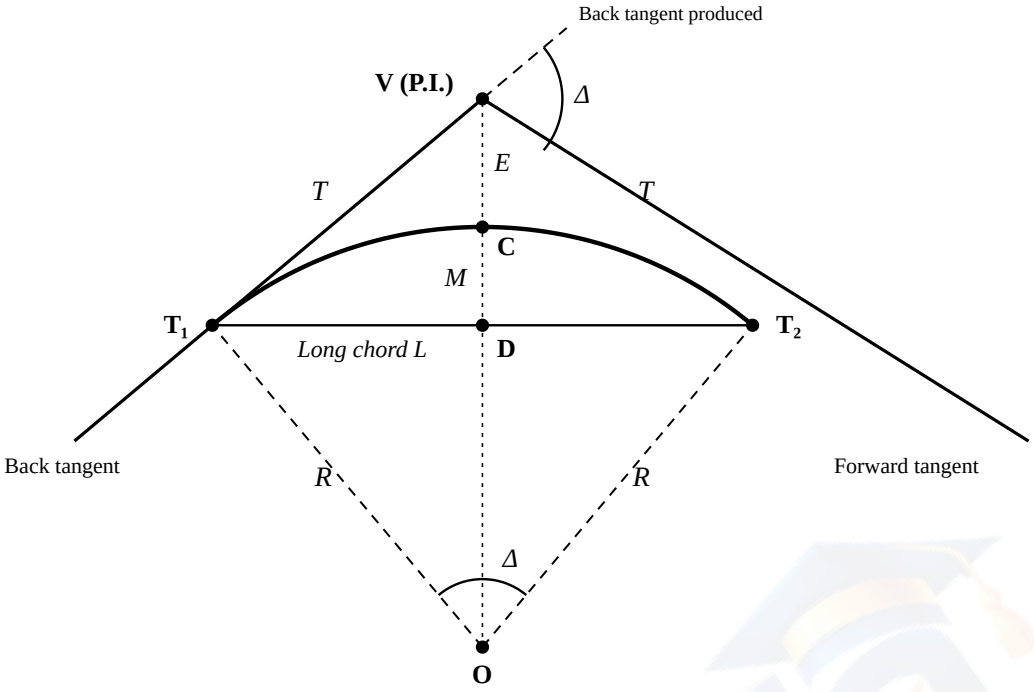

Fig.: Simple circular curve — notations

(Any four, 1 M each)

c) Rankine's method — procedure. 4 M

1. Locate the point of intersection V, measure the deflection angle Δ; compute T, length of curve and chainages of T_1 and T_2. Fix T_1 and T_2 by measuring T from V along the two tangents.
2. Calculate the length of the first sub-chord, normal chords (20 m/30 m) and last sub-chord, and the **deflection angles δ = 1718.9 c / R minutes**; tabulate the **total deflection angles** $\Delta_n = \Delta_{n-1} + \delta_n$.
3. Set up the theodolite at T_1, centre and level it. Set the vernier to 0°00′00″ and bisect V (the P.I.); clamp the lower plate.
4. Release the upper clamp and set the vernier to Δ_1. Hold the zero of the tape at T_1 and swing a length c_1 until the arrow is bisected by the line of sight; fix peg 1.
5. Set the vernier to Δ_2; from peg 1 swing a length c_2 (chord) till it is bisected by the line of sight; fix peg 2. Repeat for all pegs.
6. The last peg must fall on T_2 (check). If the closing error is large, the curve is set out again. (For a left-hand curve, set $360° - \Delta_n$.)

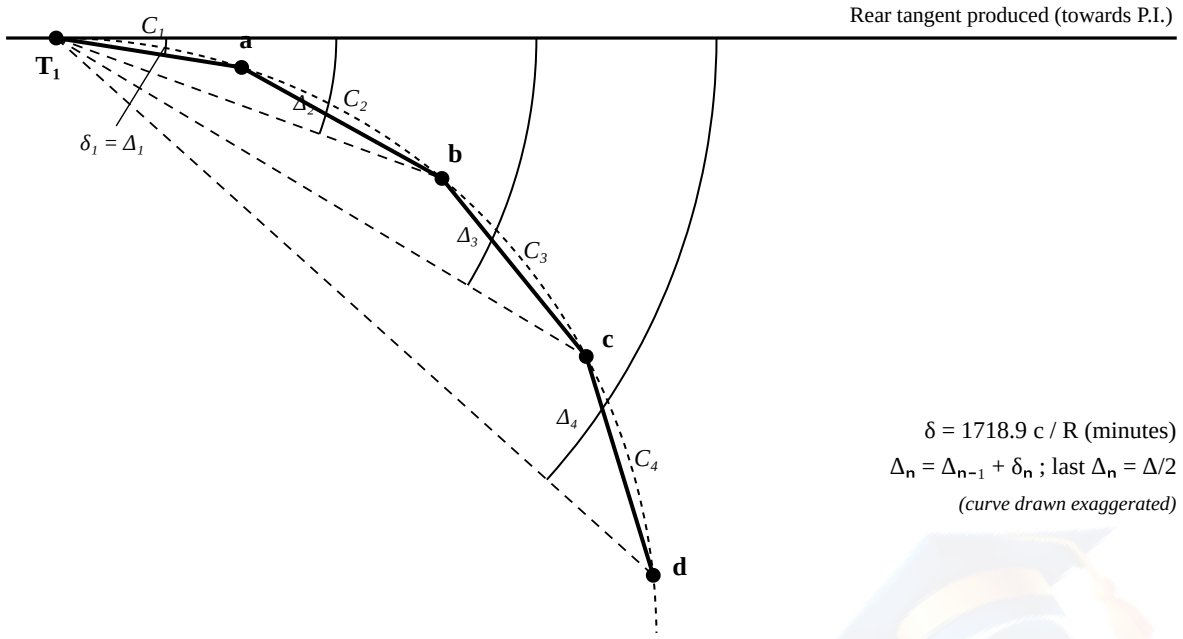

Fig.: Rankine's method of tangential (deflection) angles

(Procedure 3 M, sketch 1 M)

d) Field determination of tacheometric constants. 4 M

1. Select a fairly **level ground**. Set up the tacheometer at station O; centre and level it accurately.
2. Along a straight line from O, measure distances such as **30 m, 60 m, 90 m, 120 m** accurately with a steel tape and fix pegs P_1, P_2, P_3, P_4.
3. Hold the staff **vertical** on each peg. Keep the **line of sight horizontal** (vertical circle reading 0°00′).
4. Take the **top, middle and bottom** hair readings on each peg; staff intercept s = top − bottom.
5. For each peg write the equation **D = K s + C**.
6. Solve the equations in pairs: $K = (D_2 - D_1)/(s_2 - s_1)$ and $C = D_1 - K\,s_1$. Take the **mean** of the values obtained from different pairs.

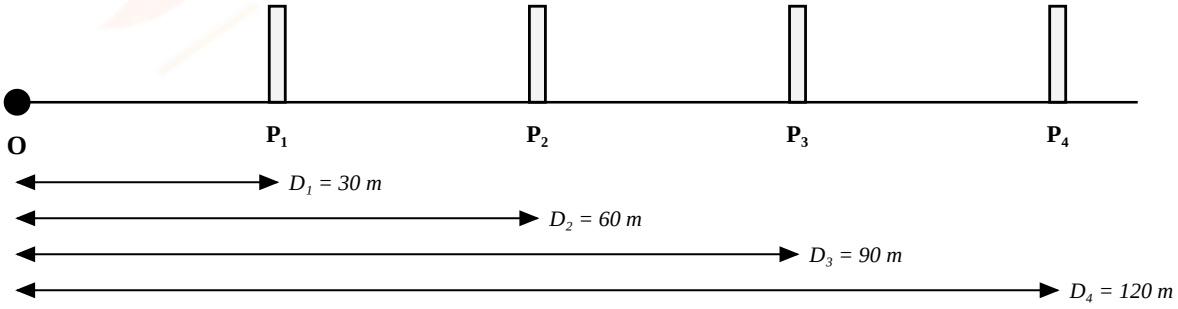

Fig.: Field determination of tacheometric constants (staff vertical, line of sight horizontal)

(Procedure 3 M, equations 1 M)

Q.3

a) Curve elements: Δ = 52°, R = 180 m, P.I. at 2048.40 m. 4 M

Given: R = 180 m, Δ = 52°, chainage of P.I. = 2048.40 m.

Element	Formula / working	Value
Tangent length T	R tan(Δ/2) = 180 × tan 26°00′00″	87.792 m
Length of curve l	π R Δ / 180 = π × 180 × 52 / 180	163.363 m
Length of long chord L	2 R sin(Δ/2) = 2 × 180 × sin 26°00′00″	157.814 m
Apex distance E	R [sec(Δ/2) − 1]	20.268 m
Mid-ordinate M (versed sine)	R [1 − cos(Δ/2)]	18.217 m
Chainage of T_1	Chainage of P.I. − T = 2048.400 − 87.792	1960.608 m
Chainage of T_2	Chainage of T_1 + l = 1960.608 + 163.363	2123.971 m

Answer: T = 87.792 m; l = 163.363 m; L = 157.814 m; E = 20.268 m; chainage of T_1 = 1960.608 m; chainage of T_2 = 2123.971 m.

(T, l, L, E ¾ M each, chainages 1 M)

b) Horizontal and vertical angles with digital theodolite. 4 M

(A) Horizontal angle

1. **Set up** the digital theodolite over station O on the tripod; **centre** using the optical/laser plummet and **level** using the circular and plate levels (foot screws).
2. Switch **ON** the instrument; select the horizontal angle mode **HR** (right/clockwise reading).
3. Sight the left station **A**; bisect it accurately with the horizontal clamp and tangent screw.
4. Press **0SET** (twice) so that the display shows **HR 0°00′00″**.
5. Release the clamp, turn the telescope **clockwise** and bisect station **B** accurately.
6. Read the angle **HR** on the display = ∠AOB; record (or store) it.
7. Change face (transit the telescope) and repeat; the **mean** of face left and face right readings is the required angle.

(B) Vertical angle

1. Set up, centre and level the digital theodolite over the station; switch ON.
2. If the display asks, **initialise the vertical circle** by rotating the telescope through the horizontal position.
3. Select the vertical angle mode — **zenith angle** (0° at zenith, 90° horizontal), **altitude/vertical angle** (0° horizontal) or **V %** (gradient).
4. Sight the target and bisect it exactly with the **horizontal cross-hair** using the vertical clamp and tangent screw.
5. Read the **V** value from the display. If zenith angle Z is displayed, vertical angle α = 90° − Z (positive = elevation, negative = depression).
6. Take readings on both faces; face right: α = Z_R − 270°. The mean of both faces eliminates the vertical index error.

(Horizontal angle 2 M, vertical angle 2 M)

c) Closed traverse with total station. 4 M

1. Fix the traverse stations A, B, C, D (pegs) so that adjacent stations are intervisible.
2. Set up the total station at A (known coordinates); centre, level; enter station coordinates, instrument height and prism height.
3. **Orient** on a known backsight (or set the known bearing of AB / a reference line).
4. Sight the prism at B: measure horizontal angle and distance — the instrument computes and stores the **coordinates of B**.
5. Shift to B; backsight A, foresight C; measure and store C. Repeat at every station until the traverse returns to A.
6. Compare computed and known coordinates of A — **closing error**; if within limits distribute it (Bowditch rule) and download data; the **area** program gives the enclosed area.

Illustration (computed): consecutive and independent coordinates, as the instrument computes them (start A = 1000.000 N, 1000.000 E):

Line	WCB	Length (m)	Latitude L cos θ	Departure L sin θ	N (m)	E (m)
AB	62°30′	120.40	+55.595	+106.796	1055.595	1106.796
BC	152°15′	95.60	-84.605	+44.513	970.990	1151.309
CD	240°00′	118.20	-59.100	-102.364	911.890	1048.945
DA	330°56′	100.79	+88.110	-48.945	1000.000	1000.000

Closing line DA (computed) = 100.79 m at 330°56′. Area by coordinates = ½ $|\Sigma(E_i N_{i+1} - E_{i+1} N_i)|$ = **11711.0 m²**.

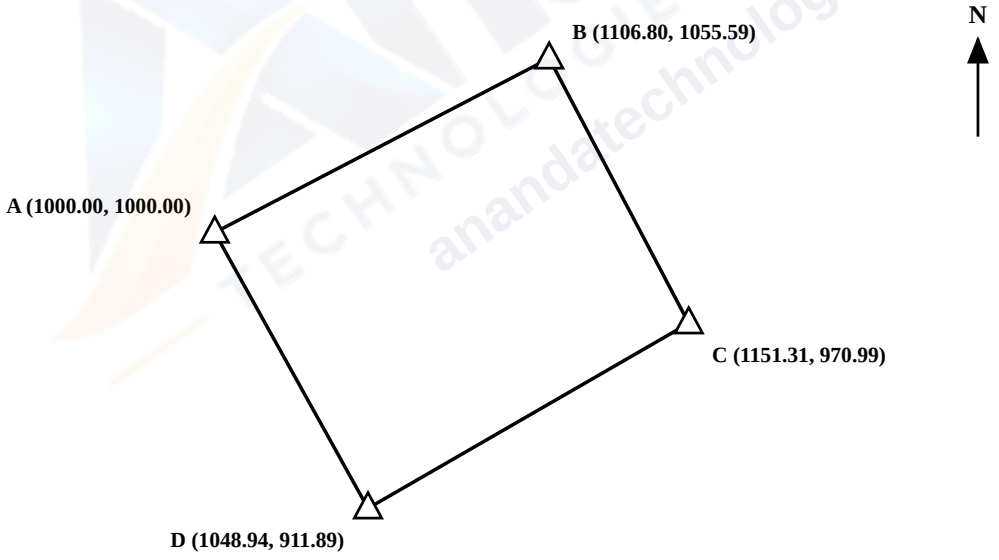

Fig.: Closed traverse observed with total station

(Procedure 3 M, sketch 1 M)

d) Components of EDM and functions. 4 M

1. **Transmitter / oscillator** — generates the carrier wave and the modulation frequency.
2. **Modulator** — superimposes the measuring (modulation) wave on the carrier.

3. **Reflector (prism)** — corner-cube prism at the far station that returns the wave along the same path.
4. **Receiver** — picks up the reflected signal and converts it to an electrical signal.
5. **Phase meter / timer** — compares the phase (or time) of transmitted and received waves to compute distance.

(Any four with function, 1 M each)

Q.4

a) Uses of aerial surveying. 4 M

1. Preparation of **topographic maps** of large areas quickly.
2. **Route surveys** — roads, railways, canals, pipelines, transmission lines.
3. **Town planning** and urban development.
4. Survey of **inaccessible areas** — forests, hills, marshes, flood-affected areas.
5. Dam and reservoir site investigation; **mining** and quarry volume surveys.
6. Forest, agriculture and land-record (cadastral) surveys.

(Any four, 1 M each)

b) Applications of remote sensing in civil engineering. 4 M

1. **Land use / land cover mapping:** classifies built-up area, agriculture, forest, water bodies, wasteland; used for town planning and master plans.
2. **Site selection:** for dams, reservoirs, bridges, airports and industries using terrain, geology and drainage information.
3. **Route alignment:** of roads, railways, canals and pipelines — best route avoiding steep slopes, water bodies and forests.
4. **Water resources:** watershed management, surface water mapping, groundwater potential zones, irrigation command areas.

(Any two explained, 2 M each)

c) Key components of GIS. 4 M

1. **Hardware** — computer, GPS receivers, digitiser, scanner, plotter/printer, servers.
2. **Software** — GIS packages for input, storage, analysis and display — e.g. QGIS, ArcGIS.
3. **Data** — spatial data (points, lines, polygons, raster images) and attribute (non-spatial) data in tables — the most important component.
4. **People** — GIS users, technicians, analysts and decision makers who operate and use the system.
5. **Methods / procedures** — well-designed rules, standards and procedures for data collection, analysis and output.

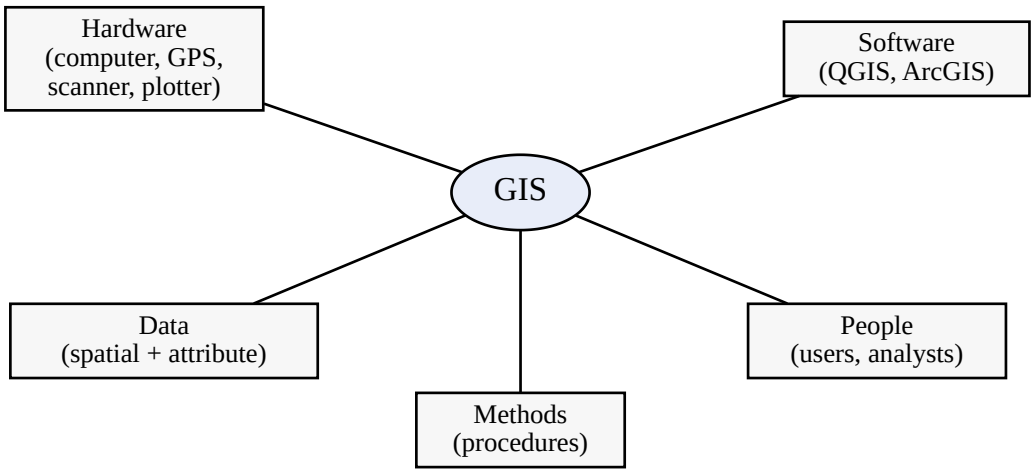

Fig.: Components of GIS

(Any four, 1 M each)

d) GPS — how position is found. 4 M

GPS (Global Positioning System): A satellite-based radio navigation system (NAVSTAR, USA) that gives the **three-dimensional position (latitude, longitude, height), velocity and time** of a receiver anywhere on the earth, 24 hours a day, in all weather.

- Each satellite transmits signals containing its **position (orbit data) and exact time** of transmission.
- The receiver measures the **travel time** of the signal and computes the range $\rho = c \times t$ to each satellite (c = velocity of light).
- The receiver lies on a sphere of radius ρ around each satellite; intersection of spheres from **three satellites** gives the position (**trilateration**).
- A **fourth satellite** is needed to correct the receiver clock error; then latitude, longitude, height and time are obtained.

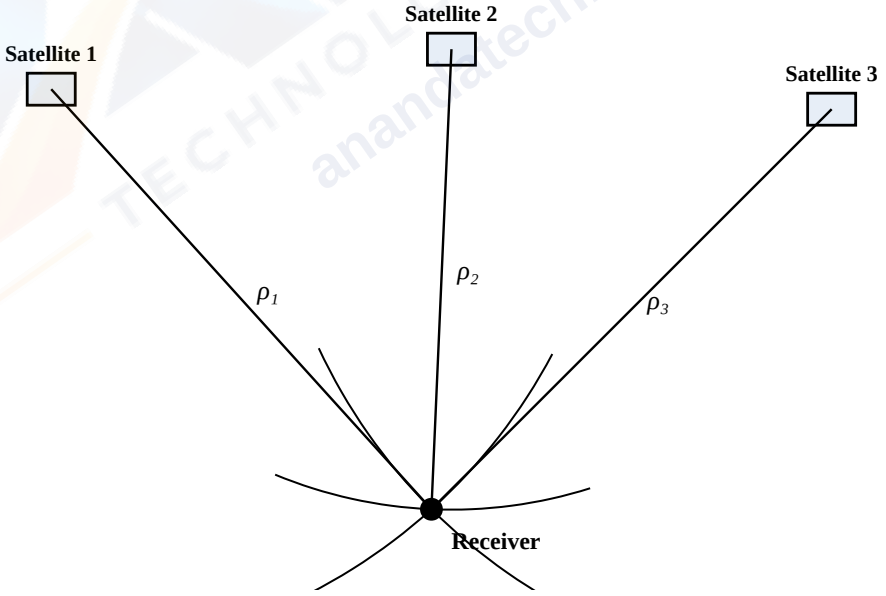

Fig.: GPS positioning by trilateration (ranges from satellites)

(Definition 1 M, working 2 M, sketch 1 M)

e) Method of aerial surveying. 4 M

Vertical aerial photography (most common method): photographs are taken with the camera axis **vertical** from an aircraft (or drone) flying along parallel flight lines at constant height.

1. **Flight planning:** decide scale (S = f / (H − h)), flying height, number of strips and photographs.
2. **Overlaps:** forward (end) overlap about **60%** along the strip and side (lateral) overlap about **30%** between strips, so every point appears on at least two photographs (stereo pair).
3. **Ground control points** are fixed and surveyed (GPS / total station) for scale and orientation.
4. **Photo interpretation and plotting:** stereo pairs are viewed with a stereoscope / photogrammetric software to plot details and contours.
5. Other method: **oblique photography** — camera axis tilted (low oblique: horizon not seen; high oblique: horizon seen); used for reconnaissance.

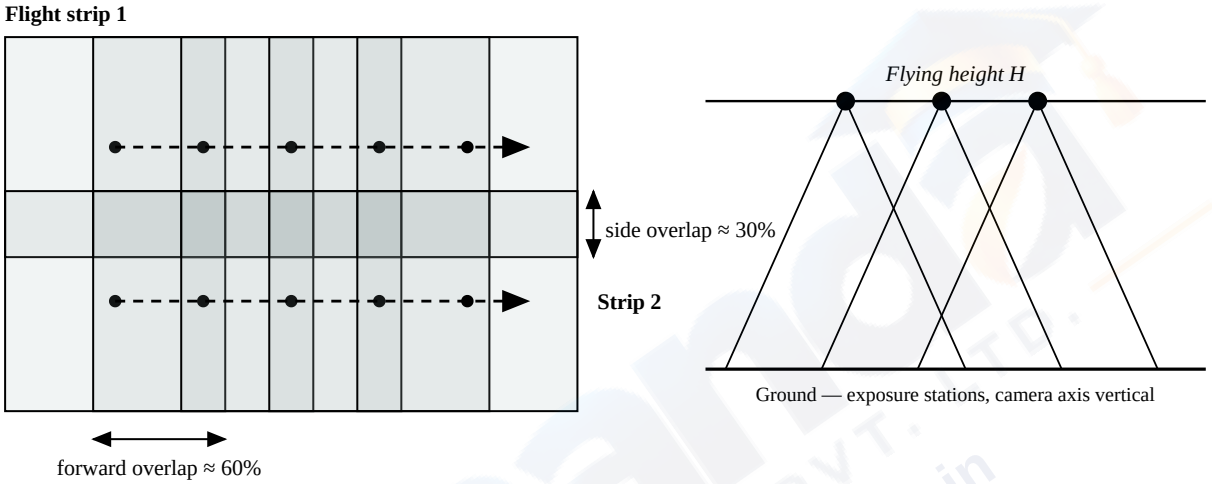

Fig.: Vertical aerial photography — flight strips and overlaps

(Method explained 3 M, sketch 1 M)

Q.5

a) Distance AC and RL of C (K = 100, C = 0.30 m). 6 M

Given: K = 100, C = 0.3, RL of B.M. = 312.450 m. Staff held vertical, inclined sights.

Formulae (staff vertical): $D = K\,s\cos^2\theta + C\cos\theta$; $V = K\,s\,(\sin 2\theta)/2 + C\sin\theta$

Quantity	Working	Value
Staff intercept s (B.M.)	1.450 − 1.020	0.430 m
V_1 (to B.M., θ = 5°48′)	100 × 0.430 × sin 11°36′ / 2 + 0.3 × sin 5°48′	4.353 m
RL of instrument axis	RL B.M. − V_1 + h_1 = 312.450 − 4.353 + 1.235	309.332 m
Staff intercept s (C)	1.455 − 0.825	0.630 m
Horizontal distance AC	100 × 0.630 × cos²(3°36′) + 0.3 × cos 3°36′	**63.051 m**
V_2 (to C, θ = −3°36′)	100 × 0.630 × sin 7°12′ / 2 + 0.3 × sin 3°36′	3.967 m
RL of C	RL axis − V_2 − h_2 = 309.332 − 3.967 − 1.140	**304.225 m**

Answer: Horizontal distance AC = **63.051 m**; RL of C = **304.225 m**.

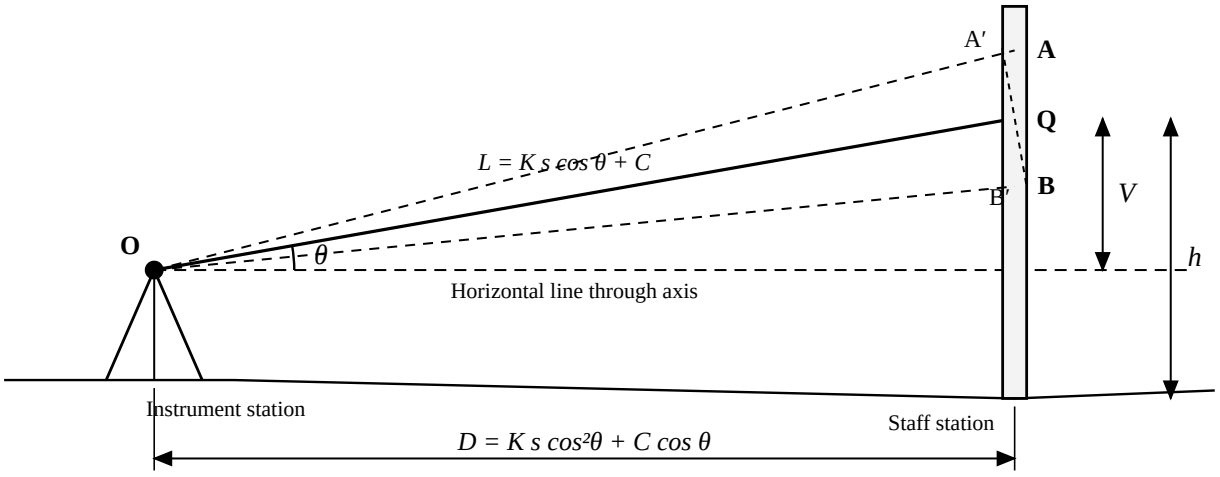

Fig.: Sight to B.M. — angle of elevation (RL B.M. = RL of axis + V − h)

(V to B.M. and RL of axis 2 M, distance AC 2 M, RL of C 2 M)

b) Tacheometric constants. 6 M

Line of sight horizontal, staff vertical: **D = K s + C**, where K = f/i (multiplying constant), C = f + d (additive constant).

Obs.	D (m)	Stadia readings (m)	s = top − bottom (m)	Equation
1	75	0.978, 1.350, 1.722	1.722 − 0.978 = 0.744	75 = 0.744 K + C … (1)
2	175	0.828, 1.700, 2.572	2.572 − 0.828 = 1.744	175 = 1.744 K + C … (2)

(2) − (1): 100 = (1.744 − 0.744) K = 1.000 K ⇒ **K = 100.00**

From (1): C = 75 − 0.744 × 100.00 = **0.600 m**

Answer: Multiplying constant K = **100.00** (≈ 100), additive constant C = **0.60 m**.

(Intercepts 1 M, equations 2 M, K 1.5 M, C 1.5 M)

c) Ordinates: R = 220 m, long chord 90 m, 15 m interval. 6 M

Given: R = 220 m, L = 90 m (L/2 = 45 m), interval 15 m from the mid-point of the long chord.

Mid-ordinate (versed sine): $O_0 = R - \sqrt{(R^2 - (L/2)^2)} = 220 - \sqrt{(220^2 - 45^2)} =$ **4.651 m**

Ordinate at distance x from mid-point of long chord: $O_x = \sqrt{(R^2 - x^2)} - (R - O_0)$, where $R - O_0$ = 215.349 m

x (m)	Ordinate	Working	Value (m)
0	O_0	$\sqrt{(220^2 - 0^2)} - 215.349$	4.651
15	O_{15}	$\sqrt{(220^2 - 15^2)} - 215.349$	4.139
30	O_{30}	$\sqrt{(220^2 - 30^2)} - 215.349$	2.596
45	O_{45}	$\sqrt{(220^2 - 45^2)} - 215.349$	0.000

The curve is symmetrical about the mid-point, so the same ordinates are set out on the other half. Ordinate at the tangent points T_1 and T_2 (x = L/2) is zero — check.

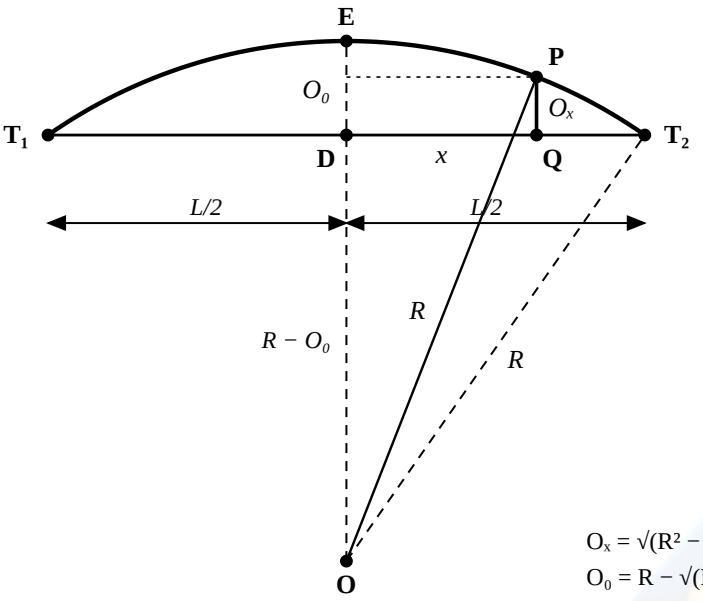

Fig.: Ordinates from the long chord

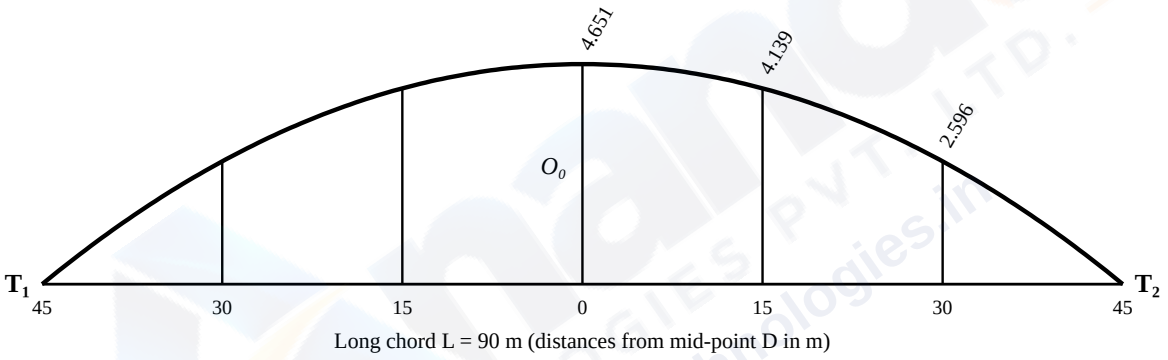

Fig.: Ordinates (m) from long chord, R = 220 m (vertical scale exaggerated)

(O_0 1 M, ordinates 3 M, sketch 2 M)

Q.6

a) Building layout using total station. 6 M

1. Obtain the **coordinates** of all building corners (centre-line plan) from the drawing, referred to the site control points.
2. Set up the total station on a known control station S; centre, level, and enter station coordinates (E, N, RL) and instrument height.
3. **Orient** the instrument: enter coordinates (or bearing) of the backsight point, sight it and confirm (set HR = bearing).
4. Open **MENU → Layout / Stake-out** and enter the coordinates of the first corner.
5. The instrument shows the angle to turn (dHR) and the distance (HD). Turn until **dHR = 0°00′00″** and line the prism man in.

6. Measure; the display shows dHD (move forward/back). Repeat until dHD ≈ 0 and fix a peg; repeat for other corners.
7. **Check** the sides and diagonals by direct measurement, then mark centre lines with lime / reference pegs outside the trench.

Example of setting-out data (computed): station S (500.000 E, 500.000 N), backsight BS (545.000 E, 500.000 N), bearing S → BS = 90°00′00″.

Corner	E (m)	N (m)	ΔE	ΔN	Bearing from S	HD (m)	Angle from BS (clockwise)
A	510.000	508.000	+10.000	+8.000	51°20′25″	12.806	321°20′25″
B	530.000	508.000	+30.000	+8.000	75°04′07″	31.048	345°04′07″
C	530.000	520.000	+30.000	+20.000	56°18′36″	36.056	326°18′36″
D	510.000	520.000	+10.000	+20.000	26°33′54″	22.361	296°33′54″

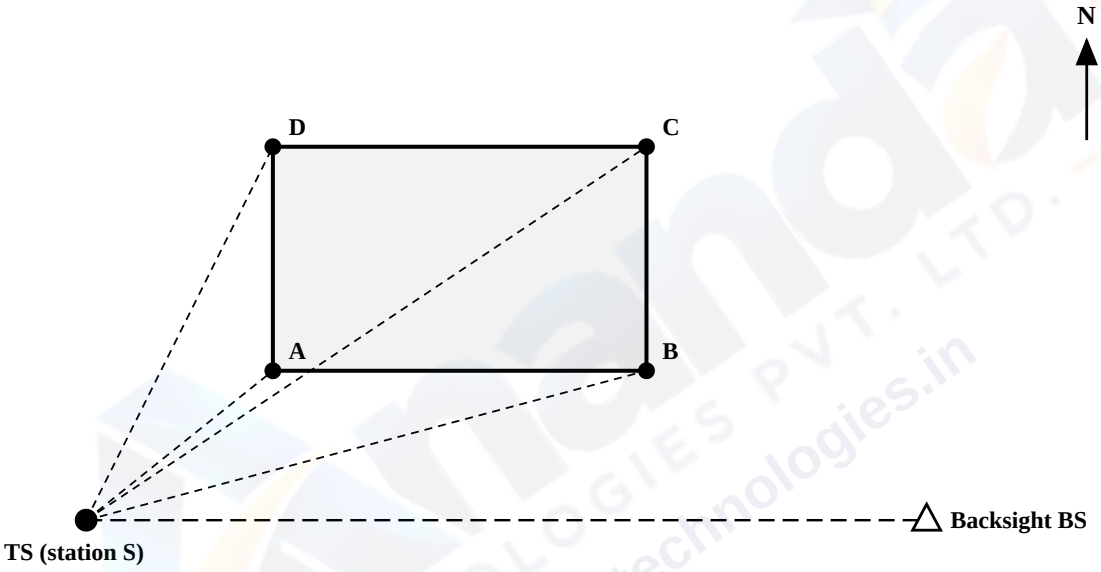

Fig.: Setting out building corners by total station (radiation)

(Steps 4 M, sketch / data 2 M)

b) Sources of errors in GIS. 6 M

1. **Source data errors** — old or inaccurate maps, wrong scale, outdated satellite images.
2. **Digitisation errors** — overshoot, undershoot, slivers, dangling lines, missing polygons.
3. **Positional errors** — GPS / survey inaccuracies, geo-referencing errors.
4. **Projection and datum errors** — mixing layers in different coordinate systems.
5. **Attribute errors** — wrong labels, codes or values typed in the attribute table.
6. **Processing / analysis errors** — interpolation, overlay and classification errors, rounding.
7. **Human and temporal errors** — data entry mistakes; data not updated.

(Any six, 1 M each)

c) Applications of photogrammetry in civil engineering. 6 M

1. **Topographic mapping:** preparation of maps, contours and DEM for planning of projects.

2. **Route location:** selection of best alignment for highways, railways, canals and pipelines.
3. **Dams and reservoirs:** site selection, catchment and submergence area, reservoir capacity.
4. **Earthwork and volumes:** volumes of cutting, filling, stockpiles and quarries (drone photogrammetry).
5. **Urban planning and buildings:** 3-D city models, building heights, encroachments, property mapping.
6. **Monitoring:** deformation of structures, progress of construction, documentation of bridges and heritage structures.

(Any three explained, 2 M each)

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