

Advanced Surveying (313321)

Model Question Paper — Set B · Model Answers

Q.1

a) Formula for horizontal distance (horizontal sight).

2 M

$$D = (f/i) s + (f + d) = K s + C$$

- D = horizontal distance from instrument axis to staff
- s = staff intercept (top hair – bottom hair reading)
- $K = f/i$ = multiplying constant (usually 100); f = focal length, i = stadia hair interval
- $C = f + d$ = additive constant (d = distance of object glass from vertical axis); C = 0 with anallatic lens, so $D = 100 s$

(Formula 1 M, terms 1 M)

b) Necessity of curves.

2 M

1. To change the direction of a road or railway **gradually** where it has to turn.
2. To avoid **obstacles** — hills, lakes, rivers, valuable buildings, religious places, costly land.
3. To follow the natural **topography** and reduce heavy cutting and filling (economy).
4. To give **comfort and safety** to passengers and vehicles by reducing the effect of centrifugal force (with super-elevation).
5. Vertical curves give a smooth change of **gradient** and adequate **sight distance**.

(Any two, 1 M each)

c) Degree of curve.

2 M

Degree of curve (D): The angle subtended at the centre of the curve by an arc (or chord) of standard length — **30 m** (or 20 m). $R = 1718.9 / D$ (30 m arc); $R = 1146 / D$ (20 m arc).

(Definition 1 M, relation 1 M)

d) Uses of digital theodolite.

2 M

- Measuring **horizontal angles** (and bearings) directly in digital form.
- Measuring **vertical / zenith angles** and gradients (V %).
- **Setting out** angles and lines — alignment of roads, railways, curves, building centre lines.
- **Prolonging** straight lines and checking verticality of columns, towers, lifts.
- **Traversing** and trigonometric levelling (with EDM attached).

(Any four, ½ M each)

e) Define remote sensing.

2 M

Remote sensing is the art and science of obtaining information about an object, area or phenomenon **without being in physical contact** with it, by recording the **electromagnetic energy reflected or emitted** by it, using sensors mounted on aircraft or satellites.

f) GPS and its applications.

2 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.

1. Establishing **survey control points** and geodetic surveys.
2. **Alignment** of roads, railways, canals, pipelines and transmission lines.

(Definition 1 M, two applications 1 M)

g) Define aerial surveying.

2 M

Aerial surveying is the method of surveying in which **photographs of the ground are taken from an aircraft or drone** flying at a known height, with the camera axis vertical (or tilted); the photographs are then used to prepare maps and obtain measurements.

Q.2

a) Principle of tacheometric survey.

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:

$$D = (f/i) s + (f + d) = K s + C$$

- 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.

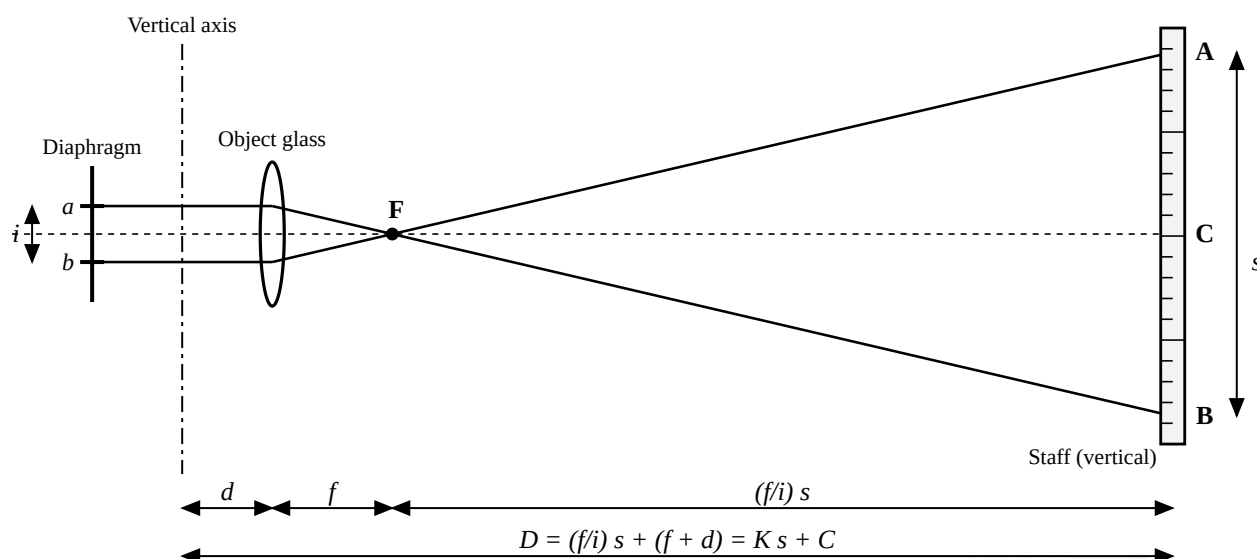


Fig.: Principle of stadia tachemetry (line of sight horizontal, staff vertical)

(Principle 2 M, sketch 2 M)

b) Theodolite vs tachemeter.

4 M

Point	Theodolite	Tachemeter
Accuracy	High accuracy in angles; used for precise work (traverse, triangulation).	Lower accuracy of distances (1 in 500 – 1 in 1000); suitable for detail and contour work.
Measurement	Measures horizontal and vertical angles only; distances by chain/tape.	Measures angles and also horizontal distance and elevation optically using stadia hairs.
Suitability	Plain, accessible ground; setting out works, precise control.	Hilly, broken, inaccessible ground; contouring, location surveys.
Number of stations	More stations and chained lines needed to cover details.	Fewer instrument stations; many details covered from one station by radial sights.

(Each point 1 M)

c) Types of curves in road and railway alignment.

4 M

- **Horizontal curves:** (i) simple circular curve, (ii) compound curve, (iii) reverse curve, (iv) transition (spiral) curve.
- **Vertical curves:** (i) summit curve (convex) and (ii) valley or sag curve (concave).

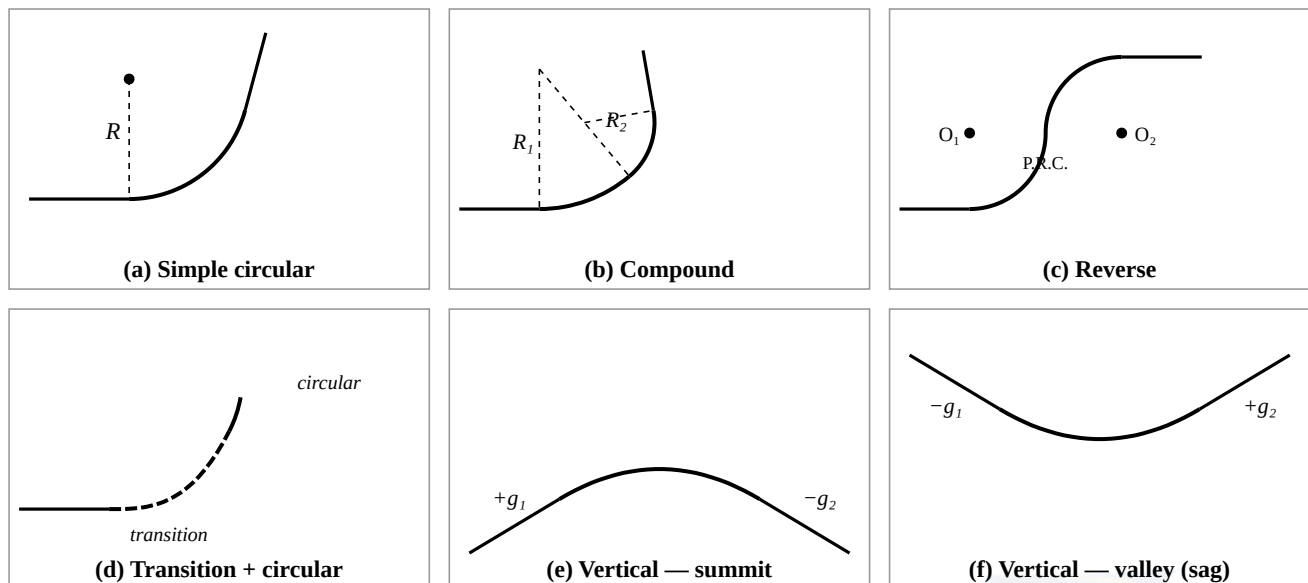


Fig.: Types of curves

Simple circular curve: A single arc of a circle of **constant radius** connecting two straights.

Compound curve: A curve made of **two or more simple arcs of different radii** bending in the **same direction**, with their centres on the same side of the common tangent.

Reverse curve: A curve made of **two arcs bending in opposite directions**, with centres on opposite sides of the common tangent (point of reverse curvature P.R.C.).

Transition curve: A curve of varying radius (infinite to R) introduced between a straight and a circular curve.

Vertical curves: summit curve — at the top of two gradients ($+g_1$ followed by $-g_2$); valley curve — at the bottom ($-g_1$ followed by $+g_2$).

(List 2 M, sketches 2 M)

d) Advantages of total station.

4 M

1. Measures **angles and distances simultaneously** and computes HD, VD, coordinates and RL instantly — very fast.
2. **High accuracy** (angles to $1''$ – $5''$, distances to a few mm).
3. Data are **stored electronically** — no booking or reading errors; downloaded directly to computer/CAD for maps.
4. **On-board programs** — stake-out, area, resection, remote elevation (REM), missing line (MLM).
5. Needs **less manpower and time**; works over long distances and difficult terrain.

(Any four, 1 M each)

Q.3

a) Distance PQ, RL of Q and gradient.

4 M

Given: $K = 100$, $C = 0$ (anallatic lens), vertical angle 0° (line of sight horizontal), $HI = 1.450$ m, RL of P = 120.000 m, staff readings 1.755, 2.215, 2.675 m.

Quantity	Working	Value
Staff intercept s	$2.675 - 1.755$	0.920 m
Horizontal distance PQ	$D = K s + C = 100 \times 0.920 + 0$	92.000 m
RL of line of sight	$RL \text{ of } P + HI = 120.000 + 1.450$	121.450 m
RL of Q	$RL \text{ of line of sight} - h = 121.450 - 2.215$	119.235 m
Difference in level	$119.235 - 120.000$	-0.765 m
Gradient	$0.765 / 92.000$	1 in 120.3 (falling)

Answer: PQ = **92.000 m**; RL of Q = 119.235 m; gradient from P to Q = **1 in 120.3 (falling)**.

(Line of sight horizontal: RL of staff station = RL of instrument station + HI – middle hair reading.)

(Distance 1 M, RL 2 M, gradient 1 M)

b) Vertical angle with digital theodolite.

4 M

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 $\alpha = 90^\circ - Z$ (positive = elevation, negative = depression).
6. Take readings on both faces; face right: $\alpha = Z_R - 270^\circ$. The mean of both faces eliminates the vertical index error.

(Correct steps 4 M)

c) Sources of errors in total station.

4 M

- **Instrumental errors:** collimation (line of sight) error, horizontal (trunnion) axis error, vertical index error, compensator error, EDM zero (additive) and scale error, wrong prism constant.
- **Personal errors:** improper centring and levelling, wrong pointing on prism, wrong instrument height / reflector height entered, prism pole not held vertical.
- **Natural (atmospheric) errors:** temperature, pressure and humidity change the velocity of the EM wave (atmospheric ppm correction), refraction, heat shimmer, wind vibration, direct sunlight.
- **Setup errors:** tripod settlement, loose tribrach, not orienting with correct backsight.
- **Data errors:** wrong point number / code or coordinates of station and backsight.

(Any four sources explained, 1 M each)

d) Applications of GIS.

4 M

1. **Urban planning:** land-use zoning, master plans, location of schools, hospitals, utilities.
2. **Transportation:** route selection, road network analysis, shortest path, traffic management.

3. **Utility management:** water supply, sewerage, electricity and telephone network mapping and maintenance.

4. **Disaster management:** flood zoning, hazard and risk mapping, evacuation planning.

(Any four, 1 M each)

Q.4

a) Anallatic lens — meaning and purpose.

4 M

Anallatic lens: It is an additional **convex lens** fitted in the telescope of an external-focusing tacheometer, between the diaphragm and the object glass, at a fixed distance from the object glass.

Purpose:

- It makes the **additive constant $(f + d) = 0$** , so the distance is simply $D = K s = 100 s$.
- The vertex of the measuring triangle (anallatic point) is brought to the **centre (vertical axis) of the instrument**.
- Reduction of field notes becomes simple and quick.
- (Drawback: the extra lens absorbs some light, so the image is slightly less bright.)

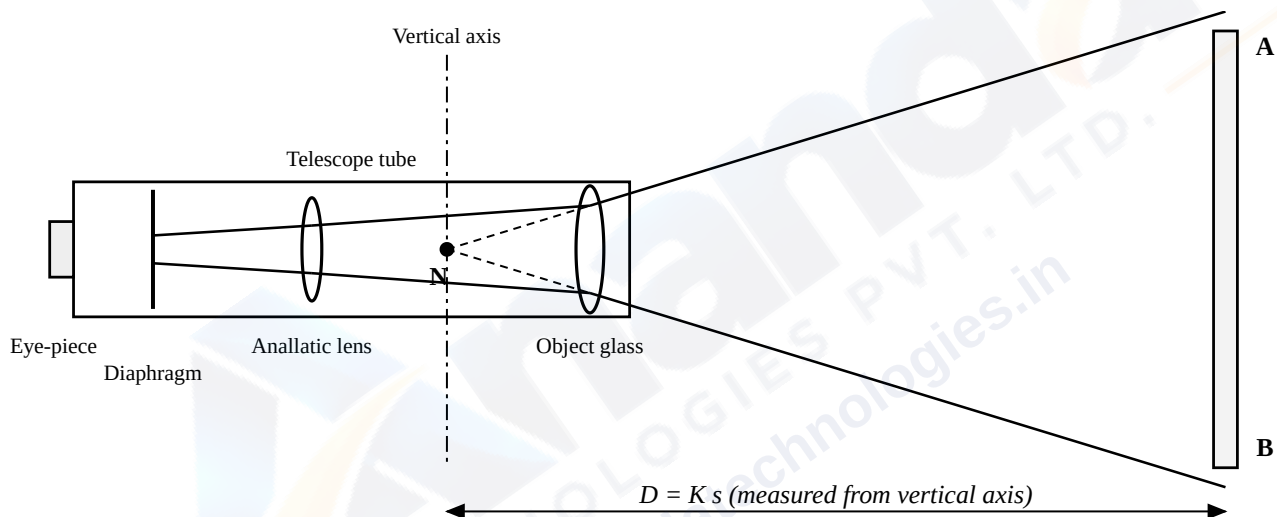


Fig.: Anallatic lens — rays meet at the vertical axis (anallatic point N), so additive constant $C = 0$

(Meaning 2 M, purpose 2 M)

b) Relation between radius and degree of curve.

4 M

Let R = radius of curve (m) and D = degree of curve, i.e. the angle subtended at the centre by an arc of 30 m.

Length of arc = $R \times \text{angle in radians} \Rightarrow 30 = R \times D \times (\pi / 180)$

$$R = (30 \times 180) / (\pi D) = 1718.87 / D \approx 1719 / D$$

If a 20 m arc is used: $R = (20 \times 180) / (\pi D) = 1145.9 / D \approx 1146 / D$. (Chord definition: $\sin(D/2) = 15 / R$, which for small D gives the same result.)

Example: a 2° curve has $R = 1718.9/2 = 859.4$ m. Larger the degree, sharper the curve.

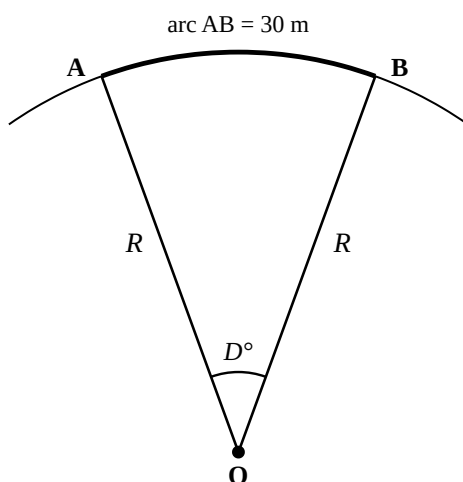


Fig.: Degree of curve (arc definition, 30 m arc)

(Sketch 1 M, derivation 3 M)

c) Sketch of digital theodolite with parts.

4 M

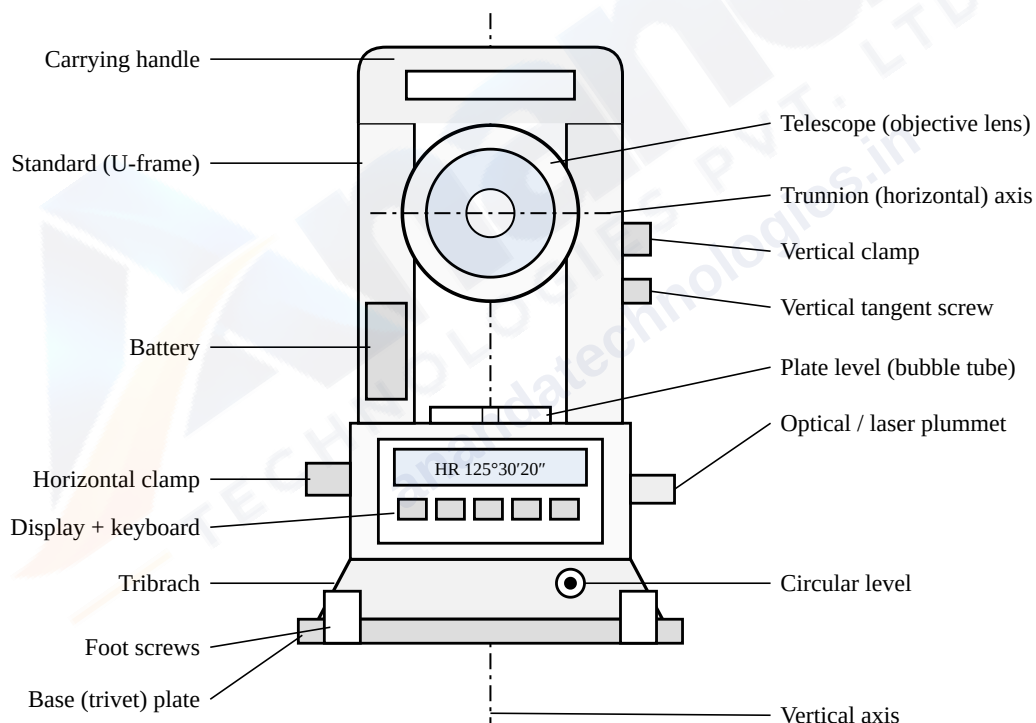


Fig.: Digital (electronic) theodolite — main parts

(Neat sketch 2 M, any eight parts $\frac{1}{4}$ M each)

d) Geo-fencing.

4 M

Geo-fencing is a **virtual geographic boundary** defined by GPS coordinates. The drone's flight controller (and the Digital Sky platform in India) uses it to decide where the drone may fly.

1. The boundary is stored in the drone software / airspace map; when the drone reaches it, it **stops, hovers, returns or alerts** the pilot.
2. **Red zone** — no-fly zone (e.g. near airports, military / vital installations); flying only with special permission of the Central Government.
3. **Yellow zone** — controlled airspace; permission of the concerned air traffic control authority is needed.
4. **Green zone** — flying permitted as per the rules without separate permission (within prescribed height).
5. Uses: safety of manned aircraft, security of sensitive areas, and keeping a survey drone within the project area.

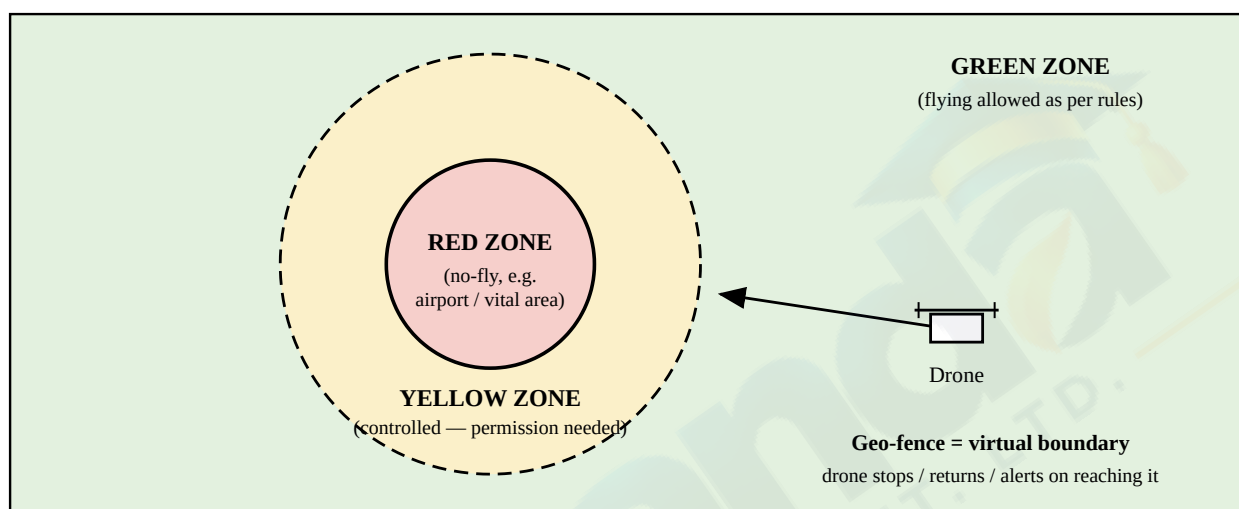


Fig.: Geo-fencing — virtual boundaries (Digital Sky airspace map zones)

(Meaning 2 M, zones / use 2 M)

e) Remote sensing for land-use mapping.

4 M

Remote sensing gives up-to-date, synoptic (large-area) images, so it is widely used for **land-use / land-cover (LULC) mapping**:

1. **Data acquisition** — multispectral satellite images (e.g. IRS LISS-III/IV, Landsat, Sentinel) of the area.
2. **Pre-processing** — geometric correction (geo-referencing) and radiometric correction.
3. **Classification** — visual interpretation (tone, texture, shape, pattern) or digital supervised / unsupervised classification into classes: built-up, agriculture, forest, water bodies, barren/wasteland.
4. **Ground truth verification** and accuracy assessment.
5. **Change detection** — comparing images of different years shows growth of built-up area, loss of forest, encroachment of water bodies.
6. **Use** — town planning, development plans, agriculture, environment monitoring, land-revenue and infrastructure planning.

(Any four points, 1 M each)

Q.5

a) 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	60	1.201, 1.500, 1.799	$1.799 - 1.201 = 0.598$	$60 = 0.598 K + C \dots (1)$
2	150	0.751, 1.500, 2.249	$2.249 - 0.751 = 1.498$	$150 = 1.498 K + C \dots (2)$

$$(2) - (1): 90 = (1.498 - 0.598) K = 0.900 K \Rightarrow K = 100.00$$

$$\text{From (1): } C = 60 - 0.598 \times 100.00 = 0.200 \text{ m}$$

Answer: Multiplying constant $K = 100.00$ (≈ 100), additive constant $C = 0.20 \text{ m}$.

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

b) Ordinates: long chord 200 m, versed sine 8 m, 20 m interval.

6 M

Given: long chord $L = 200 \text{ m}$ ($L/2 = 100 \text{ m}$), versed sine (mid-ordinate) $O_0 = 8 \text{ m}$, interval 20 m .

$$\text{Radius from versed sine: } O_0 = R - \sqrt{R^2 - (L/2)^2} \Rightarrow R = (L/2)^2 / (2 O_0) + O_0/2 = 100^2 / (2 \times 8) + 8/2 = 629.000 \text{ m}$$

$$\text{Ordinate at distance } x \text{ from mid-point of long chord: } O_x = \sqrt{R^2 - x^2} - (R - O_0), \text{ where } R - O_0 = 621.000 \text{ m}$$

x (m)	Ordinate	Working	Value (m)
0	O_0	$\sqrt{(629^2 - 0^2)} - 621.000$	8.000
20	O_{20}	$\sqrt{(629^2 - 20^2)} - 621.000$	7.682
40	O_{40}	$\sqrt{(629^2 - 40^2)} - 621.000$	6.727
60	O_{60}	$\sqrt{(629^2 - 60^2)} - 621.000$	5.132
80	O_{80}	$\sqrt{(629^2 - 80^2)} - 621.000$	2.892
100	O_{100}	$\sqrt{(629^2 - 100^2)} - 621.000$	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.

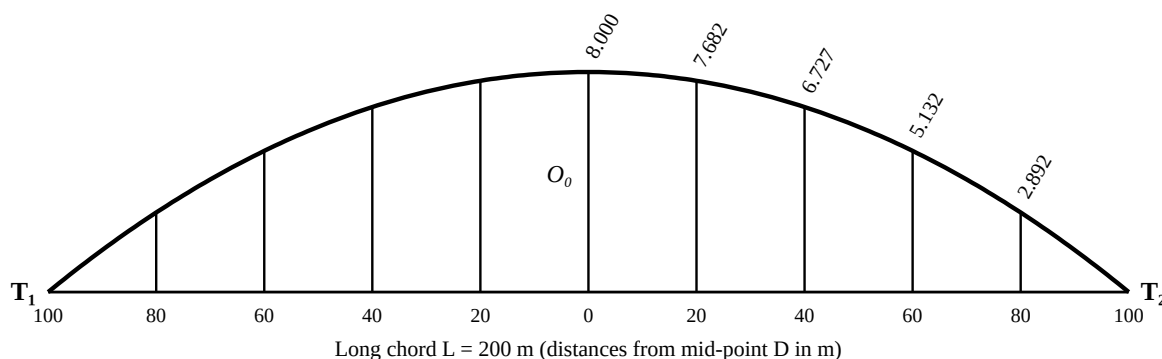


Fig.: Ordinates (m) from long chord, $R = 629.000$ m (vertical scale exaggerated)

(Radius 1 M, ordinates 4 M, sketch 1 M)

c) Horizontal distance and horizontal angle with total station.

6 M

(A) Horizontal distance AB

1. Set up the total station over station A; centre and level it; switch ON.
2. Enter the **atmospheric correction** (temperature, pressure) and the **prism constant**.
3. Enter instrument height and reflector (target) height if VD / RL is also required.
4. Fix the reflector (prism) on a pole held vertical over B; sight and bisect the centre of the prism.
5. Press the **distance key** ($\blacktriangle$), select **HD** and press **MEAS**.
6. The display shows **SD, HD and VD** ($HD = SD \times \sin Z$). Record / store the reading; repeat and take mean.

(B) Horizontal angle AOB

1. **Set up** the total station 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) by pressing **ANG**.
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 = $\angle AOB$; 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.

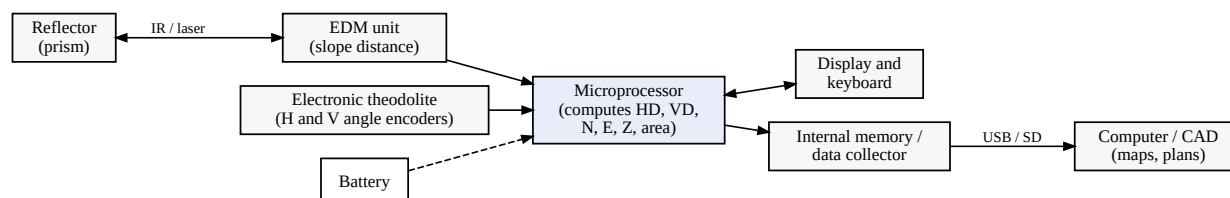


Fig.: Total station = electronic theodolite + EDM + microprocessor + data storage

(Distance 3 M, angle 3 M)

Q.6

a) Rankine's method: $\Delta = 36^\circ$, $R = 300$ m, P.I. at 1190.00 m, peg interval 20 m.

6 M

Given: $R = 300$ m, $\Delta = 36^\circ$, chainage of P.I. = 1190.00 m, peg interval = 20 m.

Curve elements:

Element	Formula / working	Value
Tangent length T	$R \tan(\Delta/2) = 300 \times \tan 18^\circ 00' 00''$	97.476 m
Length of curve l	$\pi R \Delta / 180 = \pi \times 300 \times 36 / 180$	188.496 m
Length of long chord L	$2 R \sin(\Delta/2) = 2 \times 300 \times \sin 18^\circ 00' 00''$	185.410 m
Chainage of T_1	Chainage of P.I. - T = 1190.000 - 97.476	1092.524 m
Chainage of T_2	Chainage of T_1 + l = 1092.524 + 188.496	1281.020 m

Pegs: first sub-chord $c_1 = 1100 - 1092.524 = 7.476$ m; 9 full chords of 20 m; last sub-chord $c_n = 1281.020 - 1280 = 1.020$ m.

Deflection angle for a chord c: $\delta = 1718.9 c / R$ minutes; total deflection $\Delta_n = \Delta_{n-1} + \delta_n$.

Point	Chainage (m)	Chord c (m)	$\delta = 1718.9 c/R$	$\delta (^\circ ' ")$	Total deflection Δ_n
1	1100.000	7.476	$1718.9 \times 7.476 / 300 = 42.83'$	$0^\circ 42' 50''$	$0^\circ 42' 50''$
2	1120.000	20.000	$1718.9 \times 20.000 / 300 = 114.59'$	$1^\circ 54' 36''$	$2^\circ 37' 26''$
3	1140.000	20.000	$1718.9 \times 20.000 / 300 = 114.59'$	$1^\circ 54' 36''$	$4^\circ 32' 01''$
4	1160.000	20.000	$1718.9 \times 20.000 / 300 = 114.59'$	$1^\circ 54' 36''$	$6^\circ 26' 37''$
5	1180.000	20.000	$1718.9 \times 20.000 / 300 = 114.59'$	$1^\circ 54' 36''$	$8^\circ 21' 12''$
6	1200.000	20.000	$1718.9 \times 20.000 / 300 = 114.59'$	$1^\circ 54' 36''$	$10^\circ 15' 48''$
7	1220.000	20.000	$1718.9 \times 20.000 / 300 = 114.59'$	$1^\circ 54' 36''$	$12^\circ 10' 24''$
8	1240.000	20.000	$1718.9 \times 20.000 / 300 = 114.59'$	$1^\circ 54' 36''$	$14^\circ 04' 59''$
9	1260.000	20.000	$1718.9 \times 20.000 / 300 = 114.59'$	$1^\circ 54' 36''$	$15^\circ 59' 35''$
10	1280.000	20.000	$1718.9 \times 20.000 / 300 = 114.59'$	$1^\circ 54' 36''$	$17^\circ 54' 10''$
11	1281.020	1.020	$1718.9 \times 1.020 / 300 = 5.84'$	$0^\circ 05' 51''$	$18^\circ 00' 01''$

Check: last total deflection = $18^{\circ}00'01'' = \Delta/2 = 36/2 = 18^{\circ}00'00''$ ✓ (difference only due to rounding of 1718.9).

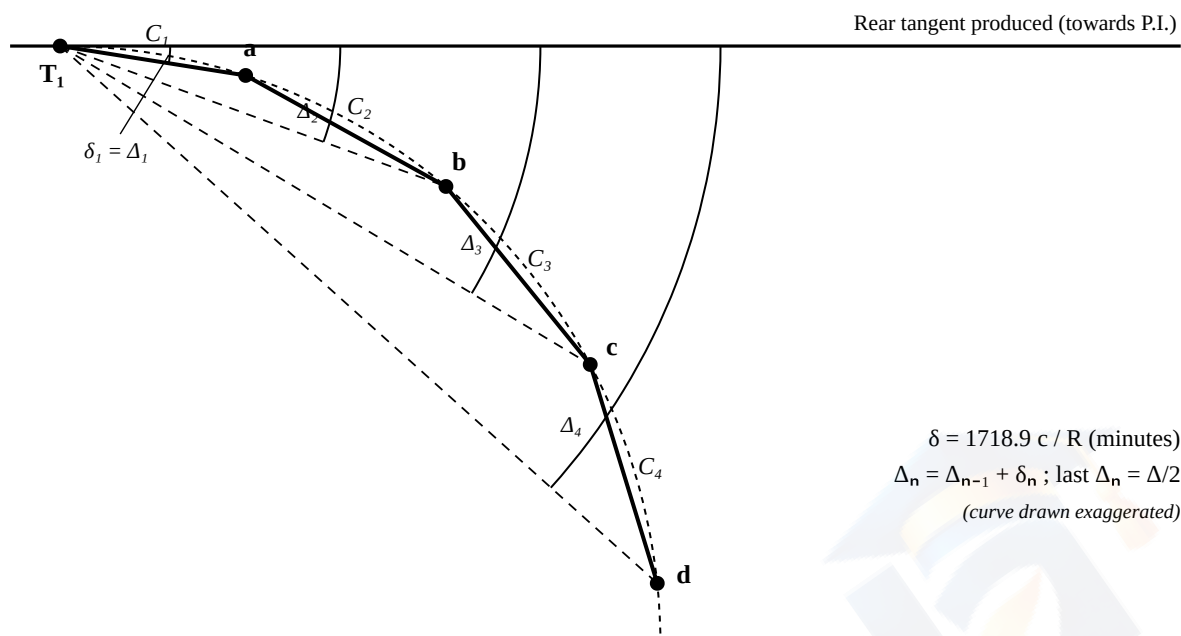


Fig.: Rankine's method of tangential (deflection) angles

(Elements 2 M, chords 1 M, deflection angle table 3 M)

b) GPS — segments and applications.

6 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.

1. **Space segment:** constellation of 24 or more satellites in six orbital planes at about 20,200 km altitude; they transmit radio signals with time and orbit data.
2. **Control segment:** master control station, monitor stations and ground antennas; they track the satellites and upload corrected orbit and clock data.
3. **User segment:** GPS receivers (handheld, DGPS, RTK) which receive the signals and compute position by trilateration (minimum four satellites for 3-D position and time).

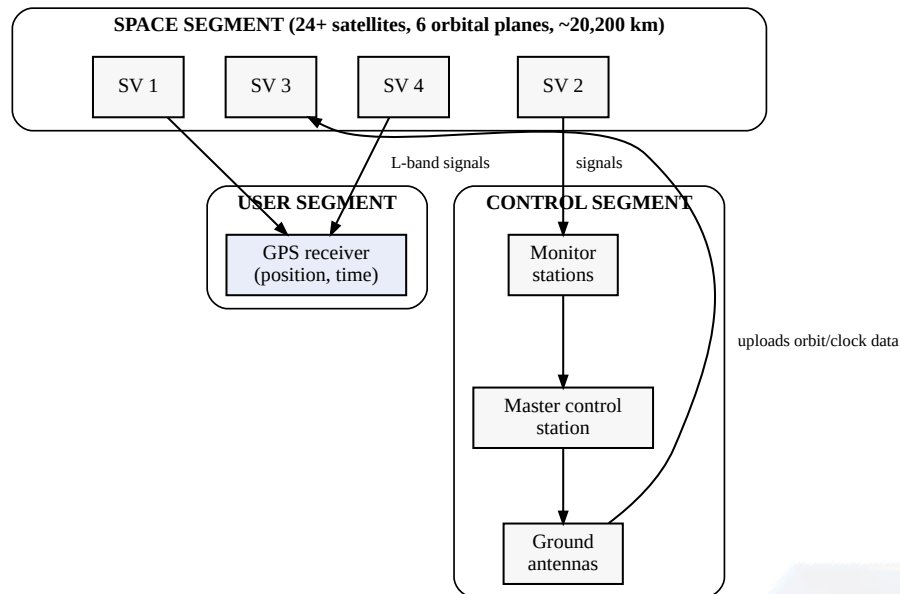


Fig.: Segments of GPS

Applications in civil engineering:

1. Establishing **survey control points** and geodetic surveys.
2. **Alignment** of roads, railways, canals, pipelines and transmission lines.
3. **Setting out** and machine control in construction (RTK GPS).
4. **Monitoring deformation** of dams, bridges, tall buildings and landslides.
5. Collection of field data for **GIS** and mapping; land records.
6. Navigation, vehicle tracking and fleet management; disaster management.

(Definition 1 M, segments 2 M, applications 3 M)

c) Merits and demerits of photogrammetry.

6 M

Merits:

1. **Quick** — large areas are covered in a short time.
2. Suitable for **inaccessible** and difficult terrain.
3. Photographs are a **permanent record**; measurements can be repeated later.
4. **Economical** for large areas; less field work.
5. Gives complete **details** and 3-D (stereo) measurements; contours and DEM.

Demerits:

1. **Costly** for small areas (aircraft, cameras, software).
2. Needs **specialised equipment and skilled** persons.
3. Depends on **weather** — clouds, haze, wind.
4. **Ground control** survey is still required.
5. Details **hidden** under trees / buildings and flat featureless areas are difficult to map; flight permissions needed.

(Merits 3 M, demerits 3 M)

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