Surveying

Short notes for B.Tech Civil · GATE CE

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1. Introduction

- **Surveying** = finding the relative positions of points on, above or below the earth's surface by measuring distances, angles and heights.
- **Plane surveying**: earth's curvature ignored (area < about 250 km²). **Geodetic surveying**: curvature considered.
- Two basic principles:
  1. Work from whole to part (control first, details later; errors do not grow).
  2. Locate a new point from at least two known reference points.

➤ Scales and errors

- Representative fraction (RF) = map distance / ground distance. Shrunk scale = RF × shrinkage factor.
- **Errors**: mistakes (blunders), systematic (cumulative, same sign, can be corrected), accidental (random, compensating).
- Errors in a measurement: accidental error ∝ sqrt(n); systematic error ∝ n.

2. Chain and Tape Survey

- Metric chains: 20 m and 30 m. Tapes: steel, invar (precise, low α), linen, synthetic.
- **Ranging**: direct (ends inter-visible) and indirect / reciprocal (hill in between).
- **Offsets**: perpendicular or oblique distances from the chain line to details.
- Well-conditioned triangle: no angle less than 30° or more than 120°.
- Obstacles: chaining free but vision obstructed (hill), vision free but chaining obstructed (river), both obstructed (building).

➤ Tape corrections

Correction	Formula	Sign
Absolute / standardisation	L x (actual length − nominal) / nominal	±
Temperature	α L (Tm − T0)	±
Pull	(P − P0) L / (A E)	±
Sag	− W² L / (24 P²) (W = total weight of span)	Always −
Slope	− h² / (2L)	Always −

- **Normal tension**: pull at which pull correction and sag correction cancel each other.

FORMULA Incorrect tape: true length = measured length x (L' / L). True area = measured area x (L' / L)², L' = actual tape length, L = nominal.

EXAMPLE A 30 m tape is actually 30.02 m long. Measured distance = 600 m. True distance = 600 x 30.02/30 = 600.40 m.

3. Compass Survey

- **Whole circle bearing (WCB)**: 0° to 360° clockwise from north. **Quadrantal bearing (QB)**: 0° to 90° from N or S towards E or W (e.g. N 30° E).
- **Back bearing** = fore bearing ± 180°.
- **Magnetic declination** = angle between true north and magnetic north. True bearing = magnetic bearing ± declination (E add, W subtract).
- **Dip**: inclination of the needle to the horizontal; zero at magnetic equator.
- **Local attraction**: needle disturbed by nearby iron objects. Detected when FB − BB ≠ 180°. Correct from the station where FB − BB = 180° exactly.

Prismatic compass	Surveyor compass
Graduations from S end (0° at S), inverted	Graduations from N, E–W interchanged
Reads WCB	Reads QB
Reading taken with the prism	Reading taken directly on the face
Can be held in hand	Used on a tripod

FORMULA Included angle = (bearing of next line) - (bearing of previous line) ± 180°. Sum of interior angles of a closed traverse = (2n - 4) x 90°.

4. Levelling

- **Datum**: reference surface (mean sea level). **Bench mark (BM)**: point of known RL (GTS, permanent, temporary, arbitrary).
- **Back sight (BS)**: first reading after setting the level (on known RL). **Fore sight (FS)**: last reading before shifting. **Intermediate sight (IS)**: all others. **Change point (CP)**: both FS and BS taken.

Reduction of levels

Height of instrument (HI)	Rise and fall
HI = RL + BS; RL = HI − reading	Rise / fall = difference of consecutive readings
Quick, fewer calculations	More work, checks IS too
Check: ΣBS − ΣFS = last RL − first RL	Check: ΣBS − ΣFS = ΣRise − ΣFall = last RL − first RL

EXAMPLE BM RL 100.000, BS 1.585 → HI 101.585. IS 1.920 → RL 99.665. CP: FS 2.410 → RL 99.175, BS 1.050 → new HI 100.225. FS 0.895 → RL 99.330. Check: ΣBS - ΣFS = 2.635 - 3.305 = -0.670 = 99.330 - 100.000. Correct.

Curvature and refraction

FORMULA Curvature correction $C_c = -0.0785\ d^2$. Refraction $C_r = +0.0112\ d^2$. Combined $C = -0.0673\ d^2$ (C in m, d in km).

- **Reciprocal levelling** removes curvature, refraction and collimation errors: true difference = mean of the two apparent differences.
- **Distance to visible horizon** $d = 3.855\ \sqrt{h}$ (d in km, h in m) including refraction.
- **Sensitivity of bubble tube**: angle $\alpha = s / (n\ D)$ radians (s = staff intercept difference, n = divisions moved, D = distance).

Contours

- **Contour** = line joining points of equal elevation. **Contour interval** = vertical gap between contours (constant on a map).
- Characteristics: close contours = steep slope; equally spaced = uniform slope; contours never cross (except overhanging cliff); a closed contour with higher values

inside = hill, lower inside = depression.

- Uses: drawing sections, finding inter-visibility, reservoir capacity, route alignment.

FORMULA Volume from contours: Trapezoidal $V = D\,[(A1 + An)/2 + A2 + \ldots + An\text{-}1]$. Prismoidal $V = (D/3)\,[A1 + An + 4(\text{even areas}) + 2(\text{odd areas})]$ (odd number of sections).

5. Theodolite and Traversing

- Parts: telescope, vertical circle, horizontal circles (upper / lower plate), levelling head, plate levels.
- **Fundamental lines**: vertical axis, horizontal (trunnion) axis, line of collimation, axis of plate level, axis of altitude level.
- Required relations: plate level axis ⊥ vertical axis; line of collimation ⊥ horizontal axis; horizontal axis ⊥ vertical axis.
- Temporary adjustments: setting up, centring, levelling, focusing (eyepiece and objective, removing parallax).
- **Face left and face right** readings remove collimation and trunnion axis errors.
- Measuring horizontal angle: **repetition method** (fine reading, removes graduation errors), **reiteration method** (several angles at one station).

➤ Traverse computations

FORMULA Latitude $L = l \cos\theta$, Departure $D = l \sin\theta$ (θ = reduced bearing). Closing error $e = \sqrt{\Sigma L^2 + \Sigma D^2}$.

- **Bowditch (compass) rule**: correction ∝ length of the line. Used when angles and distances are equally precise.
- **Transit rule**: correction ∝ latitude or departure of the line. Used when angles are more precise.
- **Gale's traverse table**: tabular computation of coordinates.

EXAMPLE Line of 100 m, WCB 60°. Latitude = 100 cos 60° = +50.00 m (north). Departure = 100 sin 60° = +86.60 m (east).

6. Tacheometry and Trigonometric Levelling

- **Tacheometry**: horizontal and vertical distances found by optical means, no chaining. Fast in rough country.

FORMULA Stadia (horizontal sight): $D = (f/i)\, s + (f + d) = K s + C$. Usually $K = 100$ and $C = 0$ (anallactic lens).

FORMULA Inclined sight, staff vertical: $D = K s \cos^2\theta + C \cos\theta$, $V = K s \sin 2\theta / 2 + C \sin\theta$.

EXAMPLE $K = 100$, $C = 0$, staff intercept $s = 1.5$ m, angle of elevation $10°$. $D = 100 \times 1.5 \times \cos^2 10° = 150 \times 0.9698 = 145.48$ m. $V = 150 \times \sin 20° / 2 = 150 \times 0.3420/2 = 25.65$ m.

- Methods: stadia (fixed hair), tangential, subtense bar.
- **Trigonometric levelling**: heights from vertical angles; for long sights apply curvature and refraction.

7. Plane Table, Triangulation and Modern Surveying

➤ Plane table methods

- Radiation, intersection (graphical triangulation), traversing, resection.
- **Three-point problem**: locate the station from three known points (Bessel's method, Lehmann's method, tracing paper method). Triangle of error appears if orientation is wrong.
- **Two-point problem**: two known points, needs an auxiliary station.

➤ Triangulation and modern tools

- Triangulation: base line + network of triangles; angles measured accurately. Strength of figure checked.
- **EDM** (electronic distance measurement): electro-optical (infrared, light) or microwave.

- **Total station** = electronic theodolite + EDM + data recorder. Gives coordinates directly.
- **GPS / GNSS**: position from satellites; at least 4 satellites for 3D position and time. DGPS improves accuracy.
- **GIS**: stores and analyses spatial data (vector and raster). **Remote sensing**: data from satellites (active / passive sensors).

➤ Photogrammetry

FORMULA Scale of vertical photo $S = f / (H - h)$. Relief displacement $d = r\,h / H$. Overlap: about 60% forward, about 30% side.

8. Curves

- Horizontal curves: simple, compound, reverse, transition (spiral). Vertical curves: summit and valley (parabolic).
- **Degree of curve** D (30 m arc): $R = 1719 / D$ (approx). For 20 m arc: $R = 1146 / D$.

Element	Formula (deflection angle Δ)
Tangent length T	$R \tan(\Delta/2)$
Length of curve L	$\pi R \Delta / 180$
Long chord	$2R \sin(\Delta/2)$
External distance E	$R [\sec(\Delta/2) - 1]$
Mid-ordinate M	$R [1 - \cos(\Delta/2)]$

EXAMPLE $R = 300$ m, $\Delta = 40°$. $T = 300 \tan 20° = 109.19$ m. $L = \pi \times 300 \times 40/180 = 209.44$ m. Long chord $= 600 \sin 20° = 205.21$ m. $E = 300 (1.0642 - 1) = 19.25$ m. $M = 300 (1 - 0.9397) = 18.09$ m.

FORMULA Rankine's deflection angle (minutes) $\delta = 1718.9\,C / R$, C = chord length. Total deflection = sum of individual deflections.

- **Transition curve**: radius changes gradually from infinity to R. Ideal = clothoid; cubic parabola used on railways and lemniscate on highways.

FORMULA Shift of the circular curve $S = L^2 / (24\ R)$, L = length of transition curve.

9. Most Asked Questions (practice)

1. State the principles of surveying. Explain types of errors.
2. Apply tape corrections (temperature, pull, sag, slope) to a measured length.
3. Differentiate prismatic and surveyor compass. Correct a traverse for local attraction.
4. Reduce levels by HI and rise-fall methods with arithmetic checks.
5. Derive the combined curvature and refraction correction. Explain reciprocal levelling.
6. List characteristics of contours and their uses.
7. Balance a closed traverse using Bowditch's rule.
8. Derive tacheometric formulas for inclined sights.
9. Find all elements of a simple circular curve; set it out by Rankine's method.
10. Explain total station, GPS and GIS in short.

TIP GATE CE asks levelling tables, curvature-refraction, traverse closing error, tacheometry and curve elements. Practise calculator steps for tan, sec and $\cos^2$ quickly.