

SURVEYING

The art of determining relative positions of objects on the surface of earth by taking measurements in horizontal & vertical planes.

Types:

1. Plane Surveying:

Curvature of earth not taken in to consideration ($\because$ Area $< 250 \text{ km}^2$)

$\rightarrow$ On earth Arc - Suspended Chord $\approx 0.1 \text{ m}$ @ 18.2 km .

$\rightarrow$ "g Sum of angles of (Spherical triangle - Plane triangle) $= 1''$ (1 Sec) only @ 195.5 km^2

2. Geodetic Surveying (or) Great Trigonometrical Surveying

Curvature of earth is taken in to consideration ($\because$ Area $> 250 \text{ km}^2$)

$\rightarrow$ Adopted where degree of accuracy required is great.

Land Survey:

* Cadastral Survey

To determine the boundary lines.

* Engineering Survey:

For determining and collecting data for the design of Engineering works.

a) Reconnaissance Survey

For determining the feasibility (i.e. is it possible within limits) and

Rough Cost of the Scheme

b) Preliminary Survey

For collecting more data to choose best location for work.

c) Location Survey

For setting out work on the ground.

Principle of Surveying

1. Work from whole to part

2. Fix the positions of new stations by atleast two independent process.

Scales:

a) Representative Factor (R.F.) $= \frac{\text{Distance on map}}{\text{Distance on ground}}$

i.e. Representation of "Engineer Scale ($1 \text{ cm} = 5 \text{ m}$)" into "Fractional Scale ($\frac{1}{500}$)".

b) Vernier Scale

In vernier, Fixed Scale is "Primary Scale" & movable scale is "Vernier Scale".

Least Count of vernier $= \frac{\text{Smallest division on the main scale}}{\text{No. of divisions on the Vernier scale.}}$

c) Wrong Scale

If by mistake measurements are taken with wrong scale, then.

True length $= \frac{\text{Wrong Scale}}{\text{Correct Scale}} \times \text{Measured length}$

//g True Area $= \left(\frac{\text{Wrong Scale}}{\text{Correct Scale}} \right)^2 \times \text{Measured Area.}$

Measurement of Distances

a) Pacing (By Pedometer)

By no. of paces (i.e. walks) . ($\because 1 \text{ pace} \approx 80 \text{ cm}$)

b) Chaining (By Chain or Tape)

Chain man @ forward end = Leader

Chain man @ Rear end = Follower.

Instruments Used in Chaining

a) Chain: ($4 \text{ mm } \phi$) & ($l = 200 \text{ mm}$)

Gunter's (or) Surveyor's Chain = 66 feet

Engineer's Chain = 100 feet

Metric Chain = 20-30m (i.e. 100-150 links)

b) Arrows

$\phi = 4 \text{ mm}$ & $l = 400 \text{ mm}$

1 Chain = 10 Arrows

c) Tapes

→ "Invar Tape" has low Coefficient of Thermal Expansion (Nickel+steel)
Hence is used for Accurate measurements

d) Line Ranger

Used for fixing intermediate points on the Chain lines. } Called Ranging

→ Mainly used to make straight lines.

Errors in measurements

Accuracy = Degree of conformity of measurement to its "TRUE VALUE".

Precision = Degree of conformity of "Repeated measurements".

Theory of probability is applied to "Random errors"/accidental errors.

* Compensating errors $\propto (\sqrt{L})$

Occur in either direction ends only (Because of single measurement)

→ Do not effect seriously on survey work.

Cumulative errors $\propto (L)$

Occur in through direction (Because of continuous measurement)

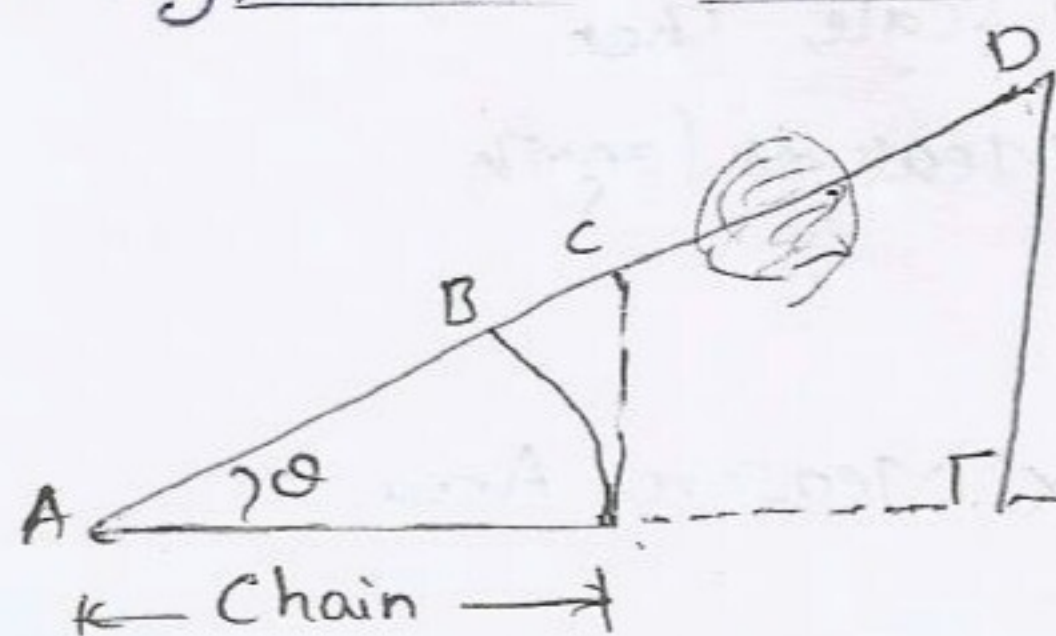
(eg: If a tape is 10.1m; measured 100m @ 10m $\Rightarrow$ Cumulative error is $10 \times 0.1 = 1 \text{ m}$)

→ Hence it is seriously effect on survey work.

* Making measurement more than actual, Hence $\begin{cases} \text{Error is +ve} \\ \text{Correction is -ve} \end{cases}$

Making measurement less than actual, Hence $\begin{cases} \text{Error is -ve} \\ \text{Correction is +ve} \end{cases}$

* Hypotenusal allowance = $100(\sec \theta - 1)$



It is an Indirect method.

→ If you need to find distance AD, but it is not possible due to some obstructions.

→ By forming Right angle triangle, measured AD' in No. of chains (eg 5.3 chains) = AD'

→ Then $AD = 5.3 \text{ chains} + 5.3 \times 100(\sec \theta - 1) \text{ links}$

→ Here $100(\sec \theta - 1) = BC$

* Correction for Slope

In this case you need to find out AB, but

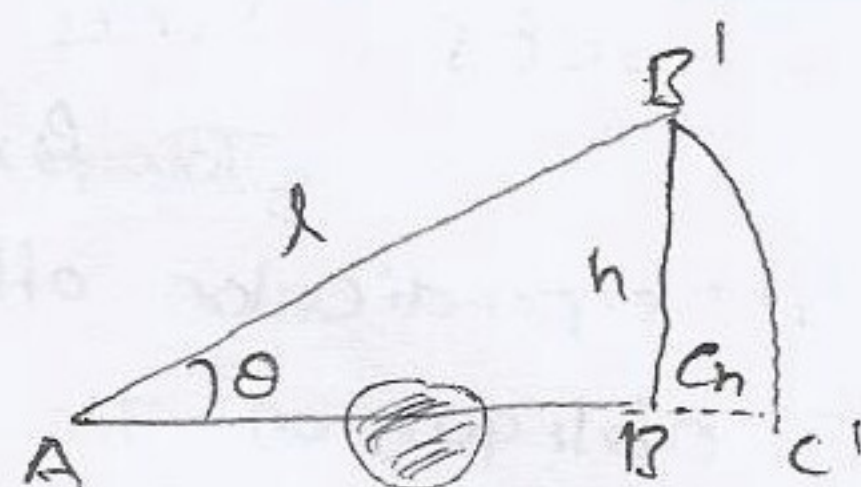
→ Hence $AB = AB' - Ch$

Here

$$Ch = l - \sqrt{l^2 - h^2} \quad (\text{Exact})$$

$$= \frac{h^2}{2l} \quad (\text{Approximate})$$

$$= l(1 - \cos \theta) \quad (\text{if } \theta \text{ is known})$$



* Correction for Tape

S.No	Correction For	Sign	Formula	Notes
1	Absolute length (C_a)	$\pm$	$C \times \frac{L}{l}$	→ If tape shrink, it is measured < actual Hence Error is (-ve), i.e. Correction (+ve) & vice versa
2	Temperature (C_t)	$\pm$	$\alpha(T_m - T_s)L$	→ Depend on Temperature @ Site (T_m) → @ Higher temp (i.e. $T_m > T_s$) tape elongated than measured & actual $\Rightarrow C_t +ve$
3	Pull (C_p)	$\pm$	$\frac{(P - P_s)L}{AE}$	→ @ Higher pull tape elongated $\Rightarrow C_p +ve$ @ looser pull tape sagged $C_p -ve \Rightarrow C_p +ve$ (But by sagging tape again elongated) → Hence C_p almost -ve
4	Sag (C_s)	-	$\frac{L}{24} \left(\frac{W}{P}\right)^2$ or $\frac{L}{24} \left(\frac{WL}{P}\right)^2$	or $\frac{L^3}{24} \left(\frac{w}{P}\right)^2$ → $W \rightarrow kN$ $w \rightarrow kN/m$ → Due to self wt of tape/wire it should be elongated

Where $\rightarrow L$ = Measured length of line in field, l = Nominal length of tape

C = Correction/tape length

C_a = Correction/whole length of line

$\rightarrow T_m$ = Temp @ Field during measurement, T_s = Standard Temp of Tape ($\approx 27^\circ C$)

α = Coefficient of Thermal expansion/ $^\circ C$

$\rightarrow P$ = Pull applied during measurement (N), P_s = Standard pull of tape ($= 100 N$)

A = C/s Area of the tape ($= 20mm \times 2mm$), E = Modulus of Elasticity (N/mm^2)

* Chain Surveying

Measurements are made directly in the field, No angular measurements are taken.

→ Principle of Chain Surveying is Triangulation

→ Most accurate triangle is Equilateral Triangle.

Well Conditional or well Shaped Triangles ($\theta \neq 30^\circ$ & $\theta \neq 120^\circ$)

$\theta \in (30^\circ, 120^\circ)$, Equilateral triangle is best example.

a) Base line = The longest chain line used (as Ref or direct) for making Survey.

b) Check line = Line joining Apex of triangle to Opposite side line
→ used to check the accuracy of Survey.

c) Tie line = Joining Fixed/Tie Stations on the main Survey lines.

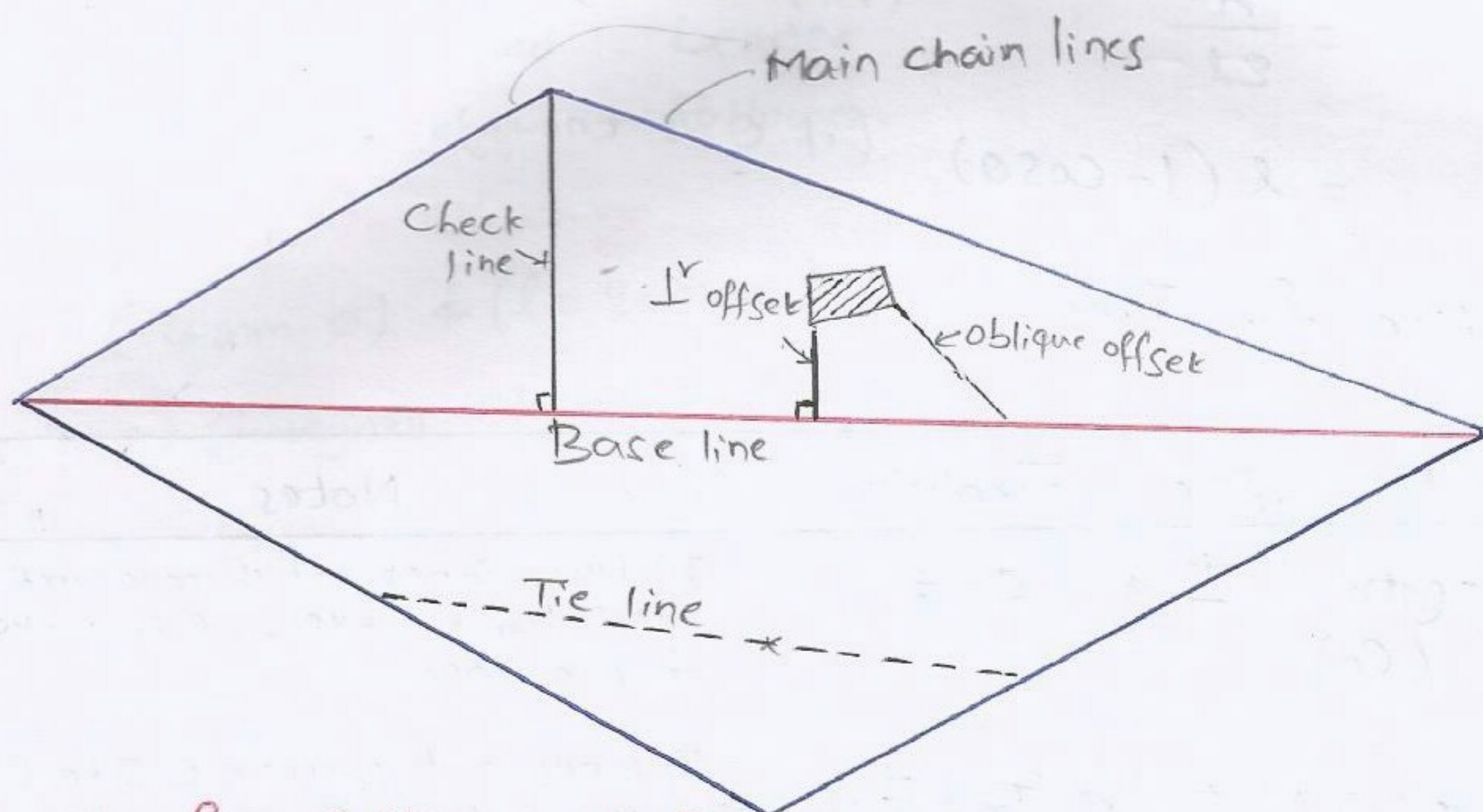
→ It also Check the accuracy of Survey

→ Mainly to locate the interior details

i.e. To know the property of Interior points

c) Offsets: Lines drawn from Base line to the object-
To fix new stations (as Direct/Ref)

- (i) perpendicular offsets (perfect offsets, $\theta \equiv 90^\circ$)
- (ii) oblique or Tie line offsets (situation demands, $\theta \neq 90^\circ$)
- (iii) Short offsets $< 15\text{m}$, long offsets $> 15\text{m}$



Instrument for setting out Right angle

- a) Open cross-staff - for $\perp$ offsets (not much accurate)
- b) French cross-staff - offsets @ 45°
- c) Adjustable cross-staff - offsets @ Any angle

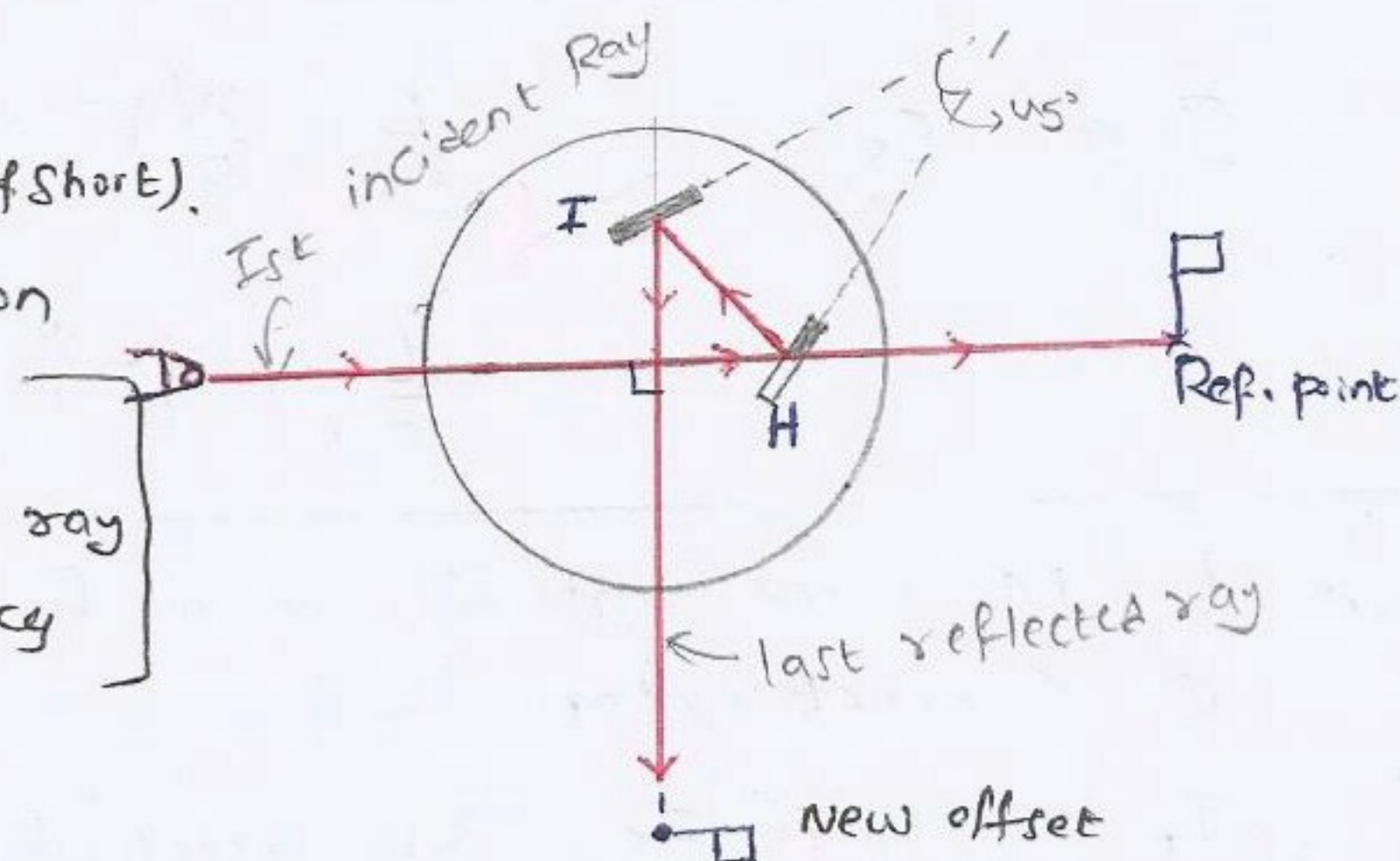
d) Optical Square:

Most accurate to make $\perp$ offsets (long & short).

→ Which works on the principle of Reflection

Principle of Reflecting instruments:

Angle b/n 1st incident ray & last reflecting ray
= $2 \times$ Angle b/n mirror surface



→ For optical square

Angle b/n mirror surface = 45°

$\therefore$ Angle b/n 1st incident ray & last reflecting ray = $2 \times 45 = 90^\circ$.

→ Horizon glass (H) = Half unsilvered (for incident ray)
Half silvered (for reflecting ray)

Index glass (I) = Fully silvered (fully reflected, no penetration)

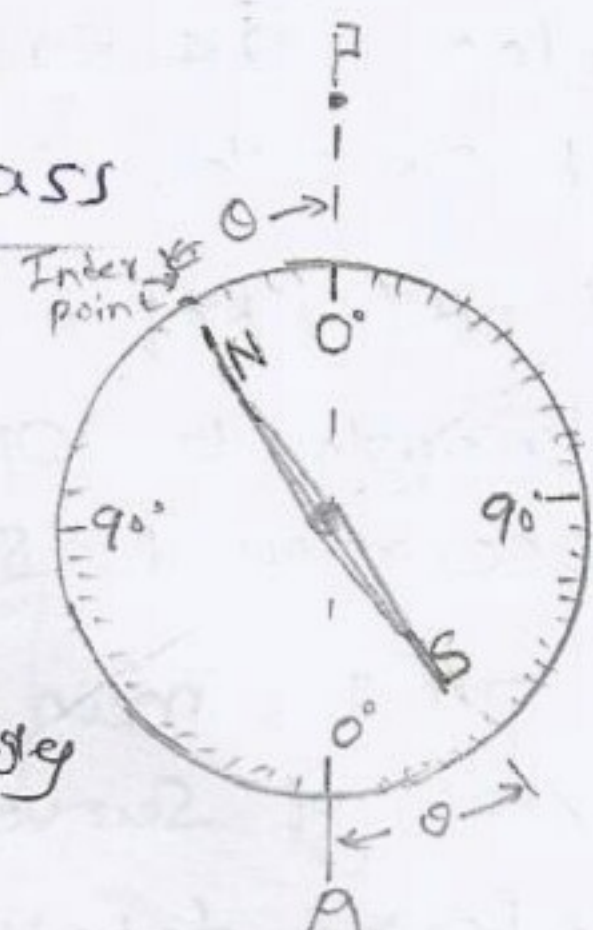
e) other class of Reflecting instrument

Line Ranger, Box Sextant & Prismatic Compass.

Compass Surveying

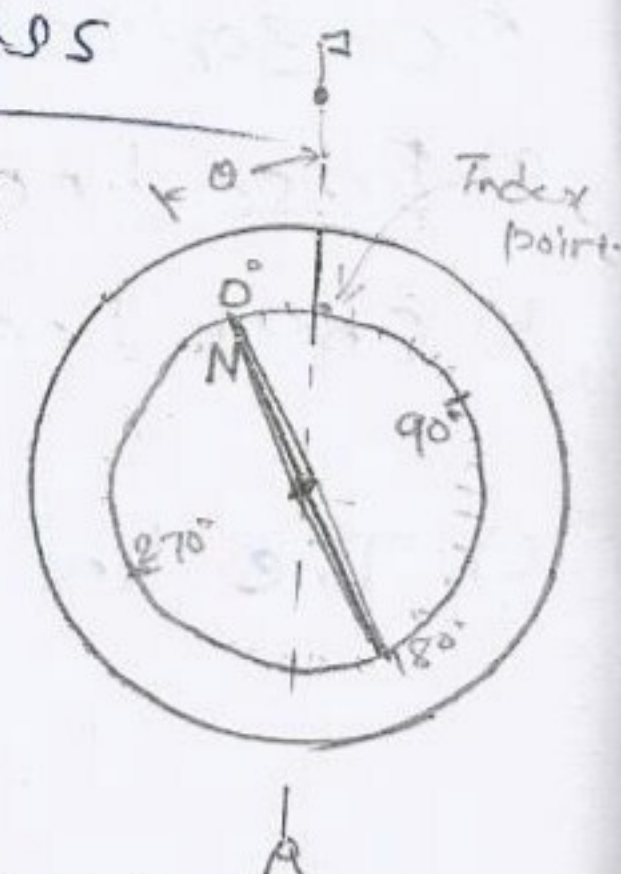
Surveyor's Compass

- Needle acts as Index
- Graduated ring attached to Box
- Graduations are in 0° & 90°
- Graduations indicate same angle with N & S
- Tripod is mandatory
- Engineering purpose



Prismatic Compass

- Needle does not act as Index
- Graduated ring attached to Needle
- Graduation one in W.C.B
- Graduations indicate only North (N), step angle.
- Tripod is not mandatory.
- General purpose (also have hand sizes)



Meridian & Bearings

Meridian = ~~Used~~ to The Reference line (Used for making angles)

Bearing = Angle made by the Meridian.

* Magnetic Meridian

The direction/Line passing through N-S of freely suspended and properly balanced magnetic needle, unaffected by local attraction forces.

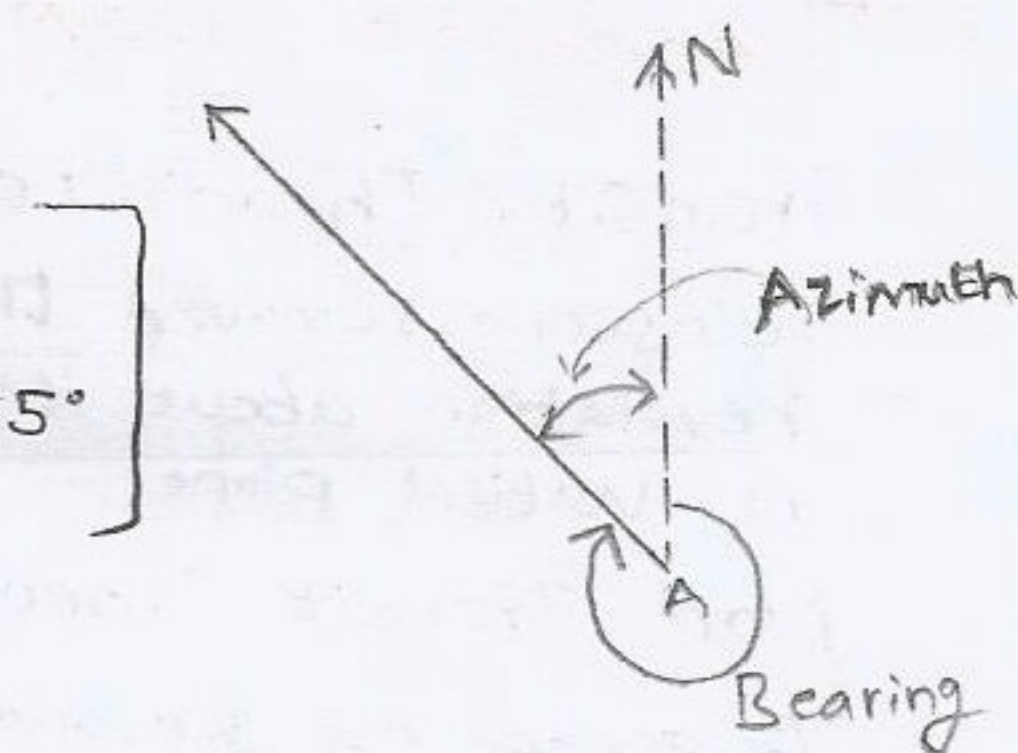
* True or Geographical meridian

The Line passing through Earth's real North & South

* AZimuth: (0° to 180°)

The Smaller angle made by the True North

[eg: Bearing of line $275^\circ \Rightarrow$ Azimuth = $360 - 275 = 85^\circ$
Bearing of line $102^\circ \Rightarrow$ Azimuth = 102°]



* True Bearing

The angle made by the True meridian

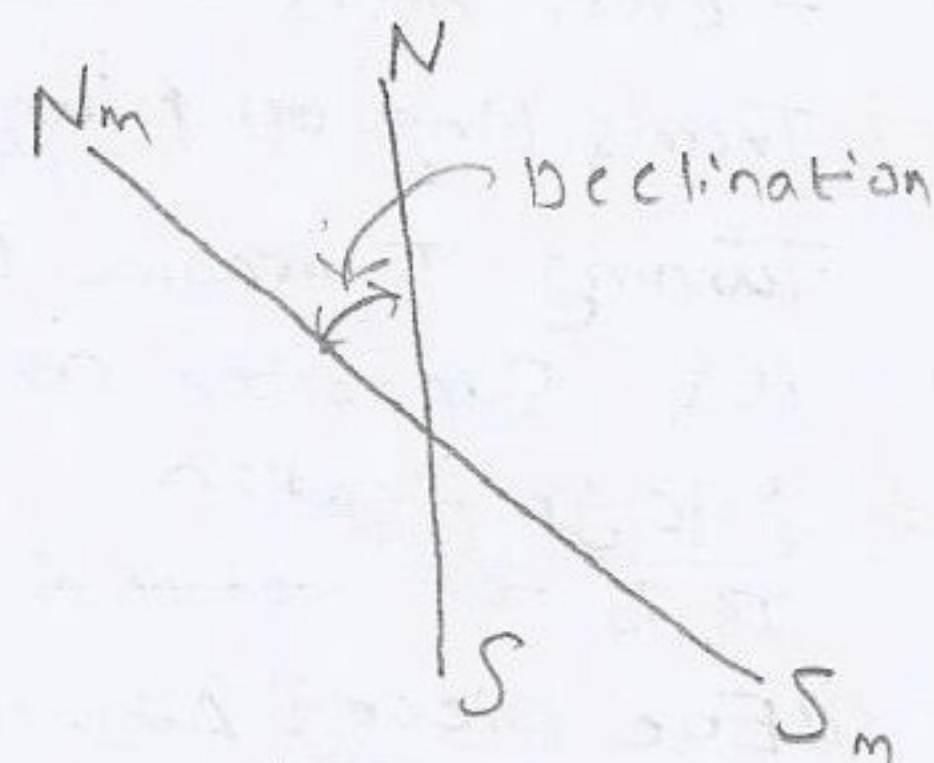
[eg: Bearing of line $275^\circ \Rightarrow$ True Bearing = 275° (with North Clockwise)
= 85° (with North Anti-clock)
= $275 - 180 = 95^\circ$ (with S' clock)
= $360 - 95 = 165^\circ$ (with S' Anti-clock)]

* Magnetic Declination or Declination (Simply)

The angle which the magnetic meridian makes with True meridian/North

→ It may coincide at Equator

→ Declination change with Place & Time

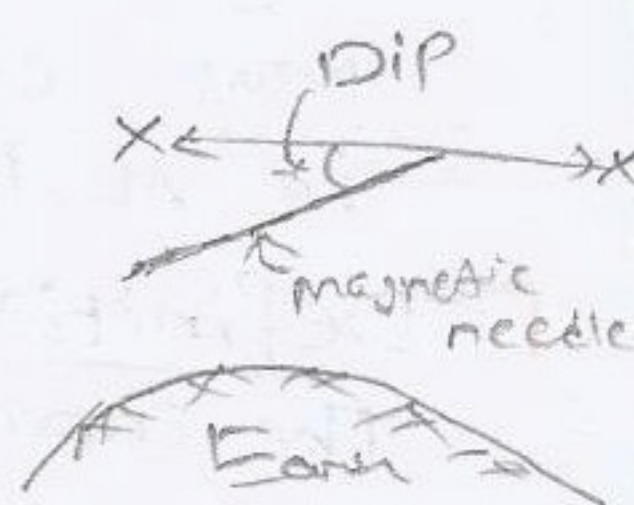


* Local attraction

Magnetic needle disturbed by External force

(like Earth magnetism, Surrounding metals, magnet... etc)

→ The angle of disturbance is called Local attraction angle.



* Dip

Due to Earth's magnetic intensity, The freely suspended magnetic needle, inclines downward

Dip = 0° @ Equator

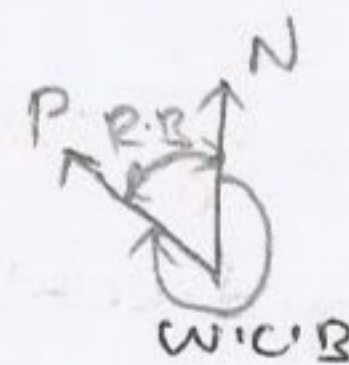
= 90° @ Magnetic poles

* Arbitrary or Assumed Bearing

The Angle made by the Assumed permanent fixed well known Meridian/line

Designation of Bearings

a) Whole Circle Bearing: Angle made by True Magnetic North in Clock wise



b) Reduced Bearing: Shortest angle made by Magnetic North or South

eg:

W.C.B.	R.B.
150°	S 30° E ($180 - 150$)
220°	S 40° W ($220 - 180$)
42°	N 42° E

$\swarrow \text{N} = \text{NO} \searrow \text{W}$ $\nearrow \text{S} = \text{SO} \nwarrow \text{E}$
 $\swarrow \text{S} = \text{SO} \nwarrow \text{W}$ $\nearrow \text{N} = \text{NO} \searrow \text{E}$

Fore & Back Bearings

Fore Bearing (FB) = Magnetic bearing of Follower view

Back Bearing (BB) = Magnetic bearing of Leader view

→ In W.C.B system $[FB \sim BB = 180^\circ]$

→ In Q.B system $[FB = N \theta E \Rightarrow BB = S \theta W, \text{ i.e. } N \& S \text{ interchange \& } E \& W \text{ interchange}]$

Note:

FB of (PQ) = BB of (QP) (or) BB of (PQ) = FB of (QP)

Max permissible Difference of FB & BB = $15'$ (i.e. 15 minity)

Theodolite Traversing

a) Transit Theodolite

Telescope revolved through a complete revolution about its Horizontal axis in vertical plane

Non Transit Theodolite

Telescope not Revolves

b) Axis of Telescope

Axis about which the telescope may be rotated

(or) line joining eye piece - Cross hairs.

c) Line of Collimation

Line passing through eye piece - cross hairs - optical centre of object

d) Transiting (or) plunging (or) Reversing

Turning Telescope through 180° about its supported axis (i.e. Horizontal axis)

e) Magnification

It is the nature of clear visibility of object, depends on

(i) Eye piece: Adjust focal length for clear visibility

(ii) Angle of Telescope to Line of Collimation

Must coincide for clear visibility

i.e. At low magnification of telescope produce "Bright Image".

f) Definition

The capacity of telescope of producing sharp image

$\therefore$ Brightness of the image $\propto \frac{1}{\text{magnification}^2}$

$\propto$ Definition

g) Size of Telescope

eg: 10cm Theodolite means "Diameter of graduated circle of its lower plate is 10cm"

Balancing the Traverse

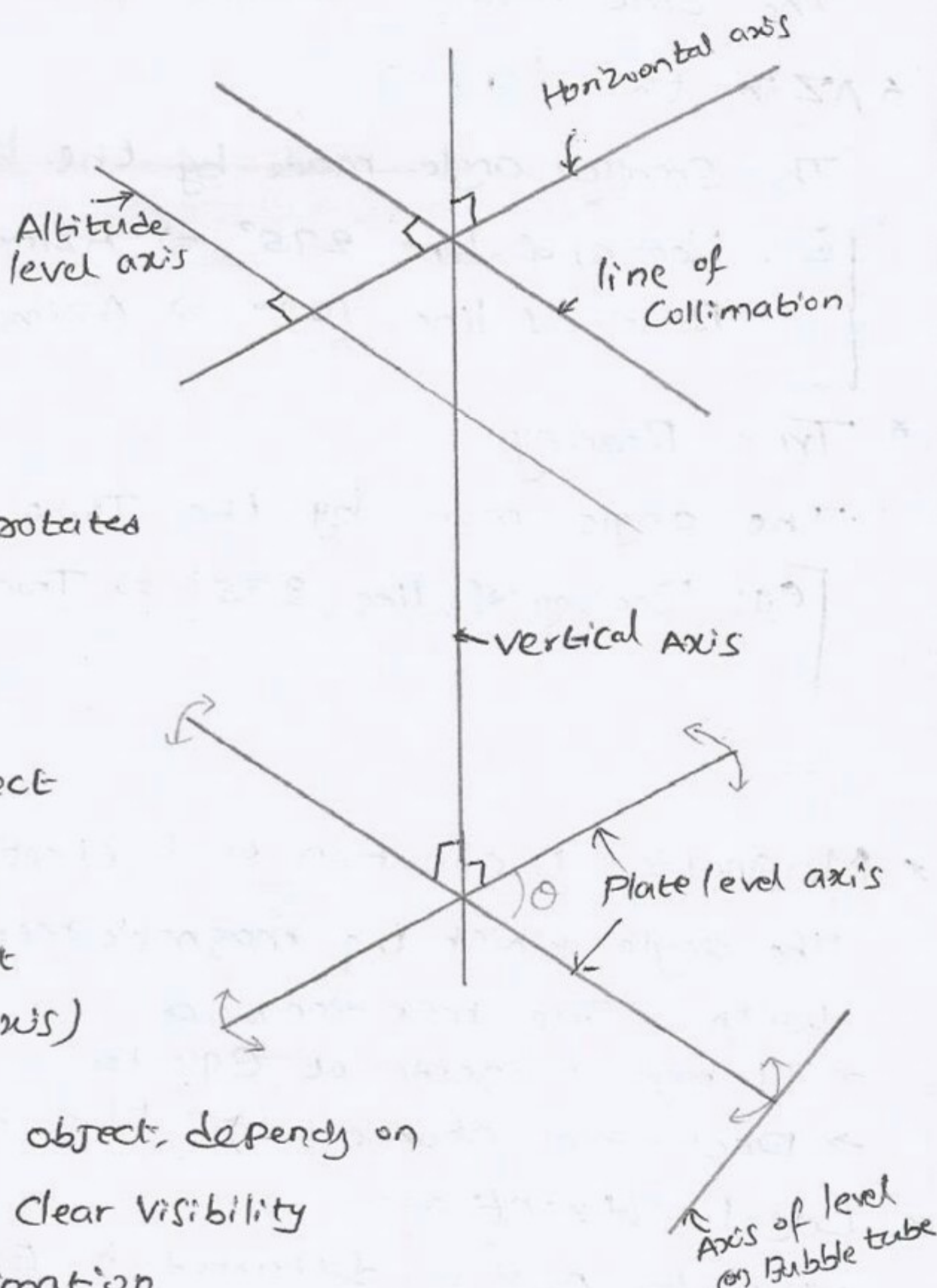
a) Bowditch's (or) Compass Rule

Correction to the Departure = $-Ex \times \left| \frac{\text{Length of that line}}{\text{Perimeter of Traverse}} \right|$

b) Transit Rule

Correction to the Departure = $-Ex \times \left| \frac{\text{Numerical Departure of that line}}{\text{Arithmetic Sum of all Departures}} \right|$

//^y for Latitude



Traversing:

Closed/open traversing mainly done by 'Surveyor's Compass'.

Closed Traverse

$$\text{Sum of Interior angle} = (n-2) \times 180^\circ$$

$$\text{Sum of Exterior angle} = (n+2) \times 180^\circ$$

($\therefore n = \text{No. of Sides/Angles}$)

$$\text{Error of Closure} \neq 1 \times \sqrt{n}$$

Circular Curve

$$\text{Tangent length } (BT_1 = BT_2) = R \tan \frac{\theta}{2}$$

$$\text{Length of long Chord } (T_1T_2) = 2R \sin \frac{\theta}{2}$$

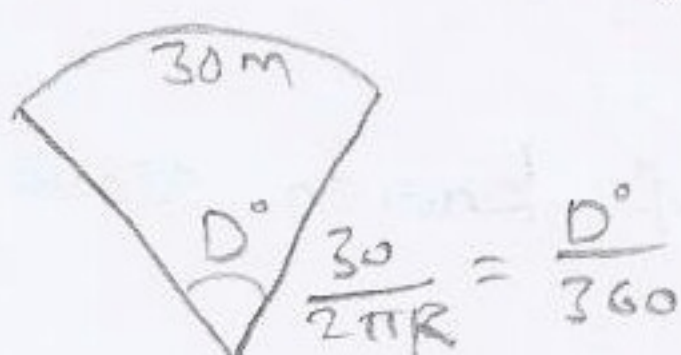
$$\text{Length of Curve } (l) = \theta \times R^{\text{rad}} = \frac{\pi R \theta}{180}$$

$$\text{Apex distance } (BD) = R(\sec \frac{\theta}{2} - 1)$$

$$\text{Mid-ordinate } (DF) = R(1 - \cos \frac{\theta}{2})$$

* Degree of Curve

$$D^\circ = \frac{1718.9}{R}$$



$$\begin{aligned} \text{* Offset from Tangent } (y) &= R - \sqrt{R^2 - x^2} \quad (\text{exact}) \\ &= \frac{x^2}{2R} \quad (\text{Approximate}) \end{aligned}$$

Latitudes & Departures

$$\text{Departure} = \text{Horizontal distance} = L \sin \theta$$

$$\text{Latitude} = \text{Vertical distance} = L \cos \theta$$

$$\text{Q.B of } \theta = \tan^{-1} \left(\frac{\pm \text{Departure}}{\pm \text{Latitude}} \right) \left[\begin{array}{l} \pm \text{NOE}, \pm \text{SOE} \\ \pm \text{NOW}, \pm \text{NOW} \end{array} \right]$$

* Coordinate System

$$L = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$\theta = \tan^{-1} \left(\frac{x_2 - x_1}{y_2 - y_1} \right)$$

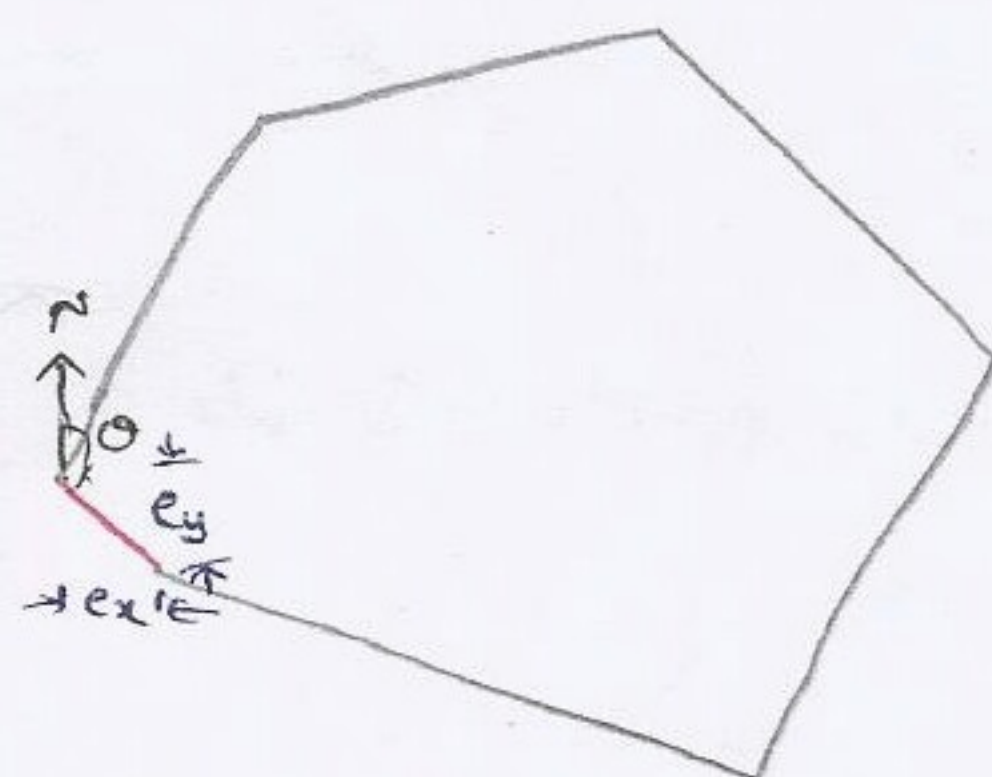
* Error of Closure in Closed Traverse

For imperfectly closed traverse

$$\sum \text{Departure} = \pm e_x, \quad \sum \text{Latitude} = \pm e_y$$

$$\text{Error of Closure } (e) = \sqrt{e_x^2 + e_y^2}$$

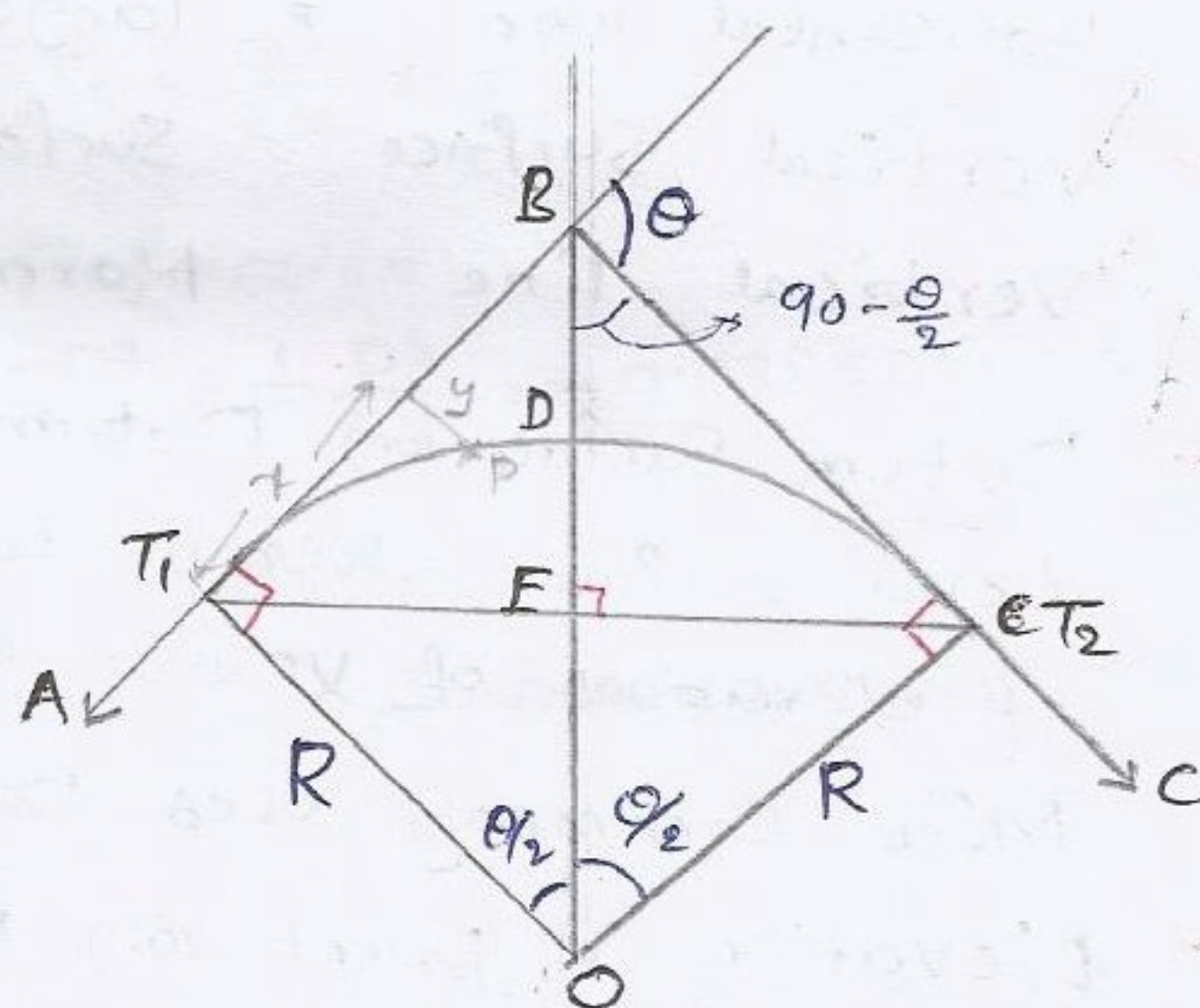
$$\text{Angle of Error of Closure } (\theta) = \tan^{-1} \left(\frac{\pm e_x}{\pm e_y} \right)$$



For perfectly closed traverse

$$\sum \text{Latitude} = 0$$

$$\sum \text{Departure} = 0$$



$$\tan \frac{\theta}{2} = \frac{BT_1}{R}, \quad \sin \frac{\theta}{2} = \frac{T_1E}{R}$$

$$\cos \frac{\theta}{2} = \frac{R}{OB}, \quad BD = OB - R$$

$$T_1T_2 = 2 \times T_1E \quad \left| \begin{array}{l} R = OT_1 = OT_2 \\ = OD \end{array} \right.$$

Levelling

- Level Surface = Parallel to the curvature of the earth
(i.e. Mean Spheroidal Surface of the earth)
- Level Line = Line lying on the level surface
- Horizontal Surface = Tangential Surface/plane to the level surface
- Horizontal line = Tangential line to the level line
- Vertical Surface = Surface/plane Normal to the level surface
- Vertical line = Normal to the level line (i.e. plumb line)
- Datum Surface (or) Datum
Level Surface which is taken as a Reference Surface for determination of elevations of various points.
Most commonly used Datum = Mean Sea Level (MSL, Mumbai)
- Elevation of point (or) Reduced Level (R.L.)
The vertical distance above (or) below the Datum.
- Bench mark
The fixed reference point of known elevation

Field Levelling

a) Back sight (B.S.) or plus sight

The first reading taken after level setup

b) Fore sight (F.S.) or minus sight

The last reading taken after level setup

c) Intermediate sight (I.S.)

Readings after B.S. & before F.S.

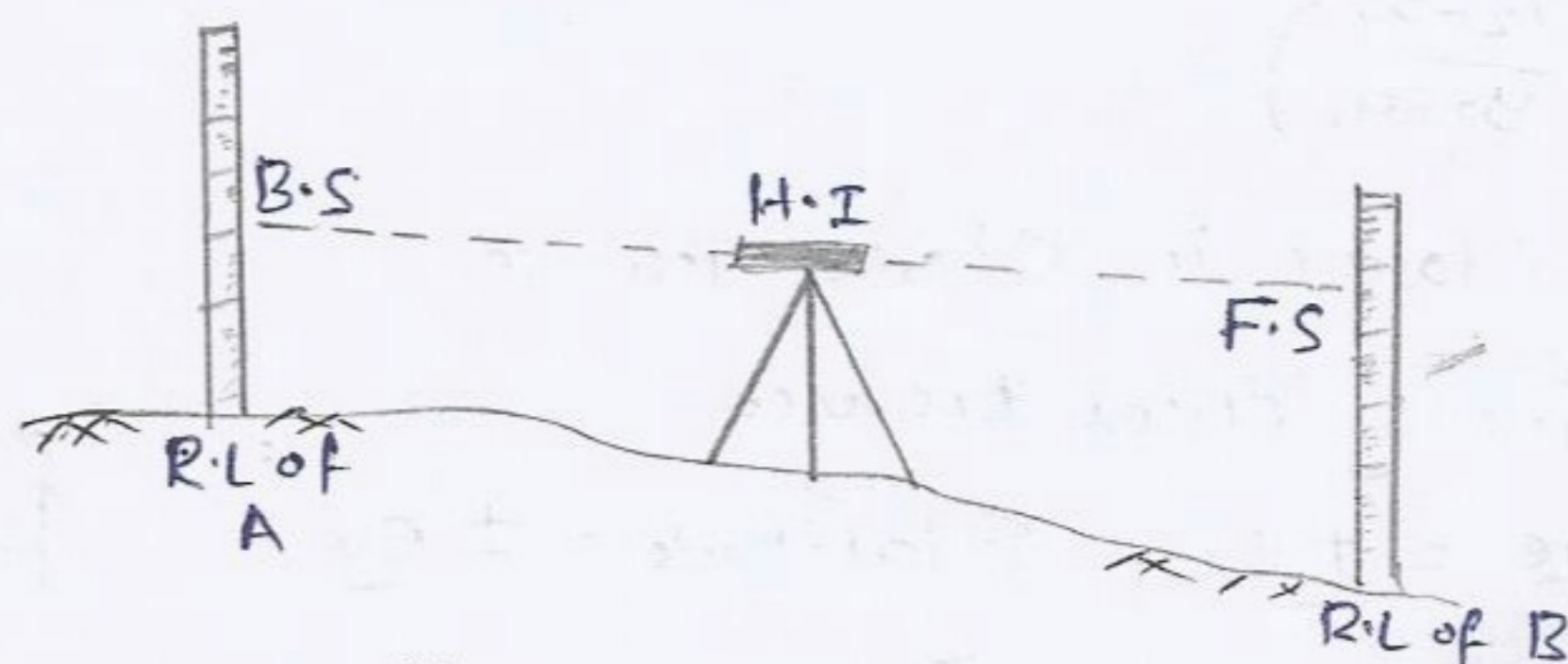
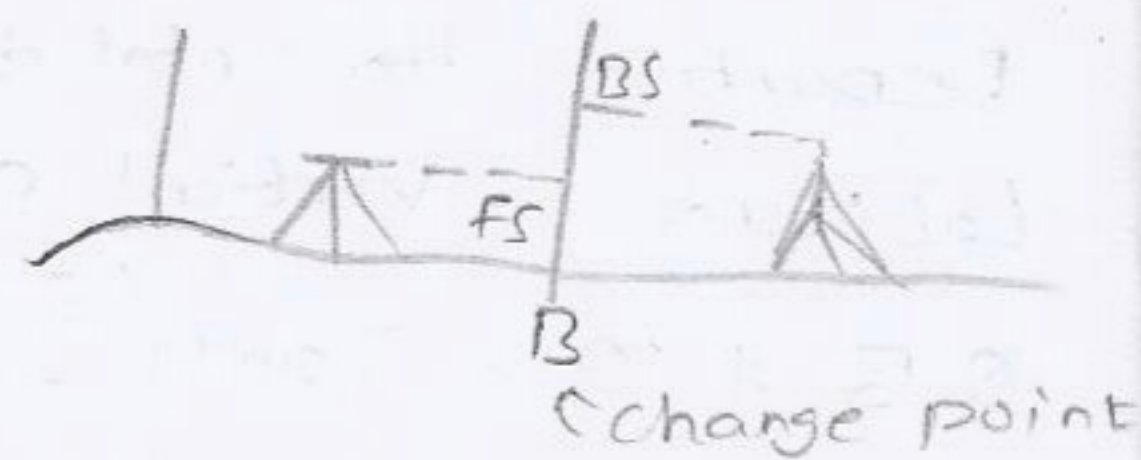
d) Change point (C.P.)

The point denoting the shifting of the level

→ (e.g. At B, both B.S. & F.S. are noted, hence B is the Change point)

e) Height of Instrument (H.I.)

The Elevation of line of sight with assumed datum.



$$H.I. = R.L. \text{ of } A + B.S.$$

$$R.L. \text{ of } B = H.I. - F.S.$$

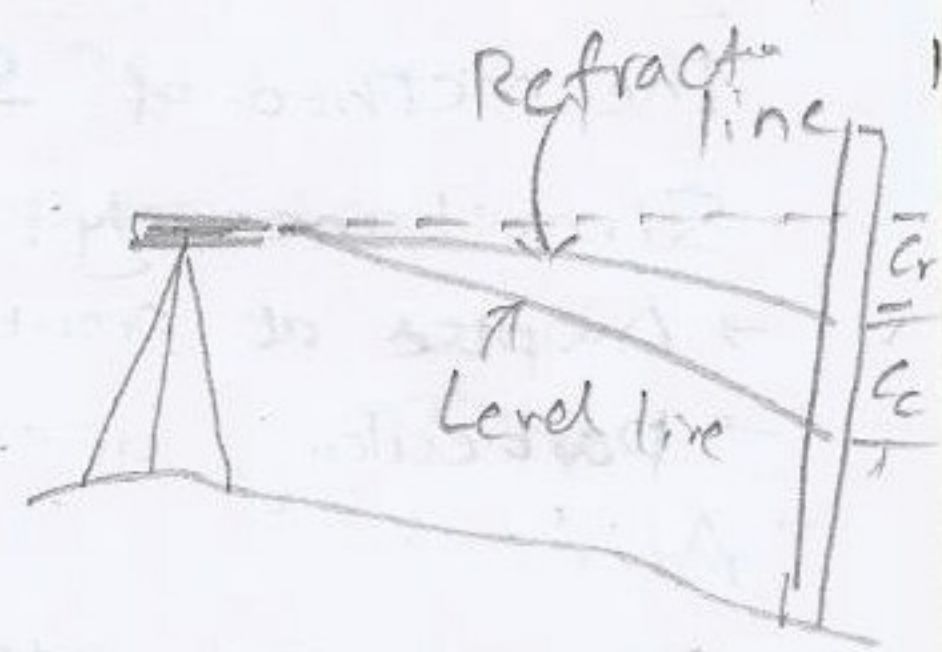
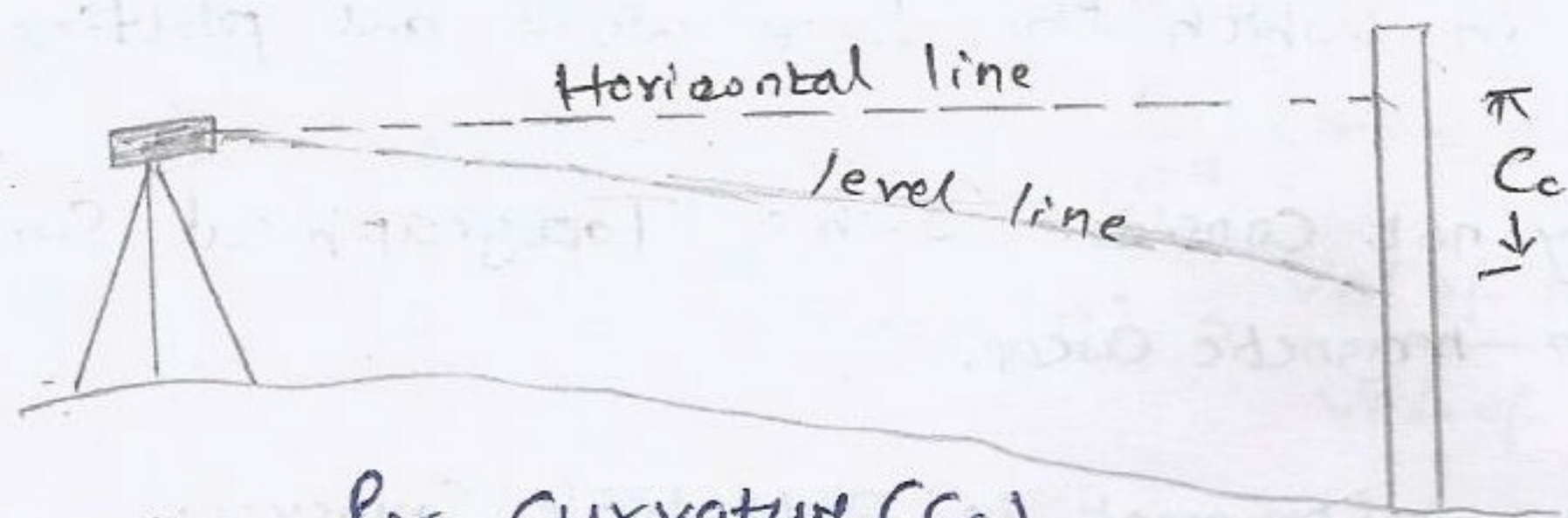
$$\text{Fall} = R.L. \text{ of } A - R.L. \text{ of } B \text{ (+ve)}$$

$$\text{Rise} = R.L. \text{ of } A - R.L. \text{ of } B \text{ (-ve)}$$

Arithmetic Check

$$\sum B.S. - \sum F.S. = \sum \text{Rise} - \sum \text{Fall} = \text{Last R.L.} - \text{First R.L.}$$

Correction for long levelling



Correction for Curvature (C_c)

$$= -0.0785 D^2 \quad \left(\because C_c = \frac{D^2}{2R} = \frac{D^2}{2 \times 6367} = -\frac{D^2}{12734} \right)$$

Combined Correction for Curvature & Refraction

$$C_c + C_r = -0.0673 D^2 \quad \left(\because -\frac{D^2}{2R} + \frac{1}{7} \frac{D^2}{2R} = -0.0785 D^2 + 0.0112 D^2 \right)$$

Loop Closure or Misclosure

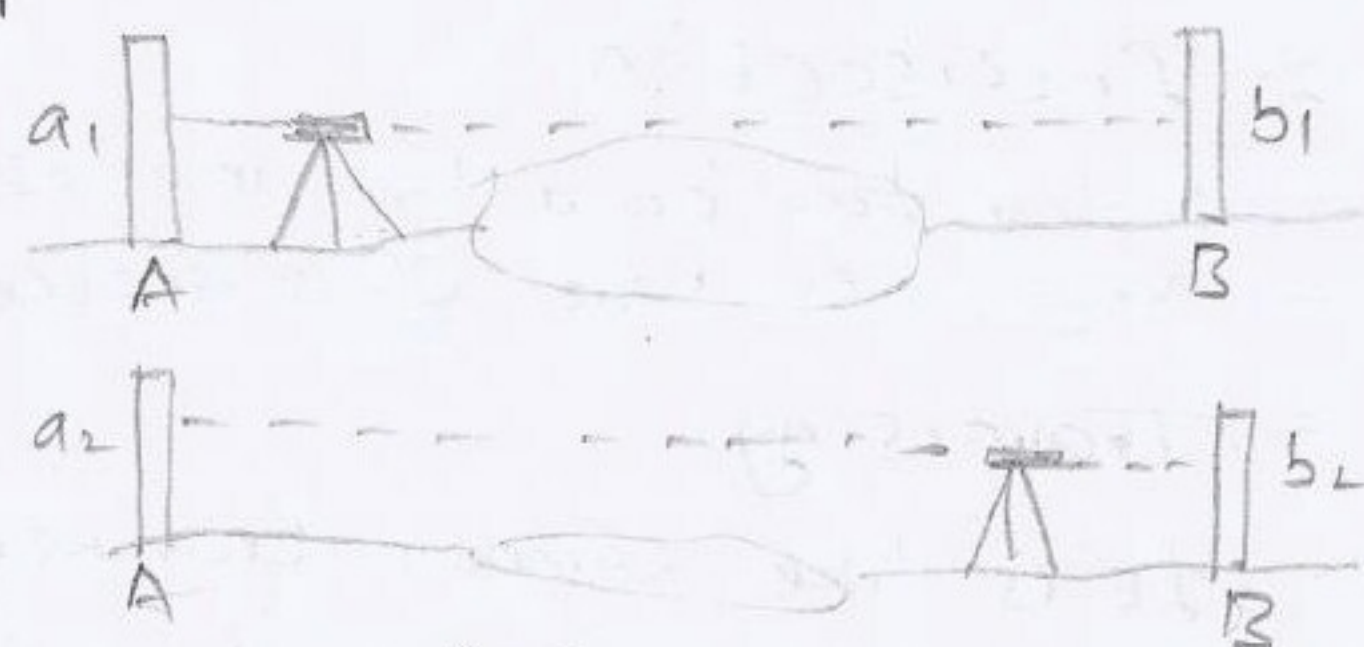
[eg: If a point of known R.L = 109.37 m & For the same point, by making method Measured R.L = 109.34 m, Hence there is a misclosure,

ie Loop Closure (e) = Measured R.L - Known R.L (of same point),

$$\text{Correction for each point (C)} = \frac{-e}{n} \quad \left(\because n = \text{No. of Change points} + 1 \right)$$

Reciprocal Levelling

Since, There is an obstruction (like pond) b/w two stations.



Diff of level b/w A & B

$$(\Delta h) = \left| \frac{(a_1 - b_1) + (a_2 - b_2)}{2} \right| \quad \text{or} \quad \left| \frac{(b_1 - a_1) + (b_2 - a_2)}{2} \right|$$

$$\text{Combined Error (e)} = \frac{(b_1 - a_1) - (b_2 - a_2)}{2}$$

where

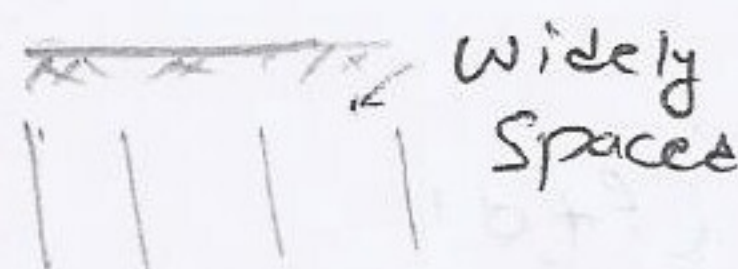
$$e = \text{Collimation error (e}_l) + \text{Curvature error (e}_c) - \text{Refraction error (e}_r)$$

$$\therefore \text{Collimation error (e}_l) = e - 0.0673 D^2$$

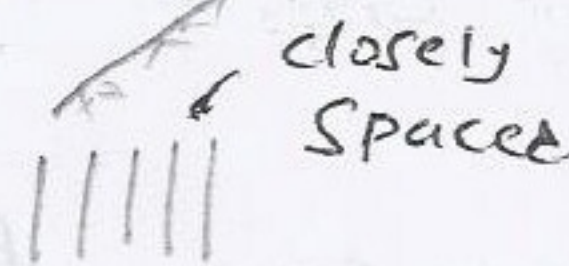
Contouring:

Line joining the same points having same elevation above the datum surface

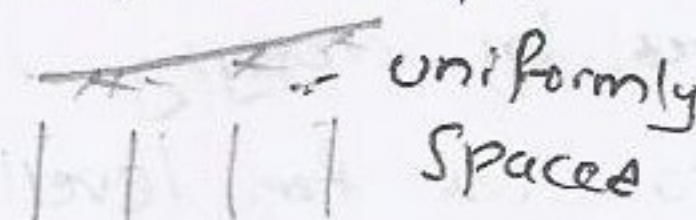
a) Flat ground



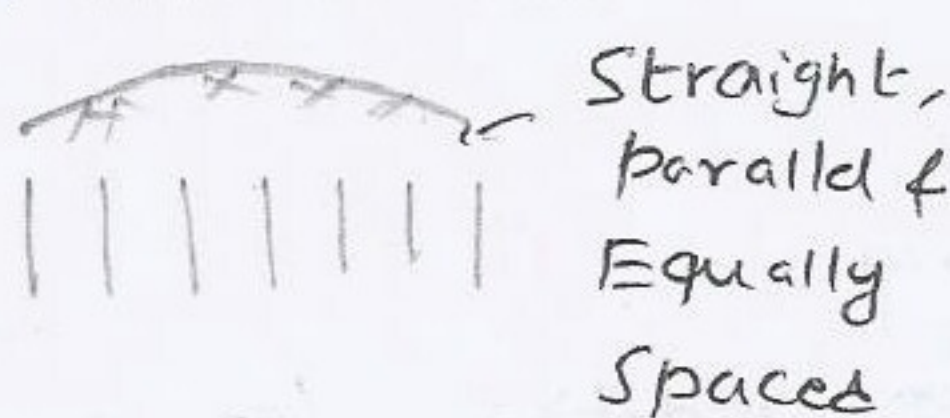
b) Steep ground



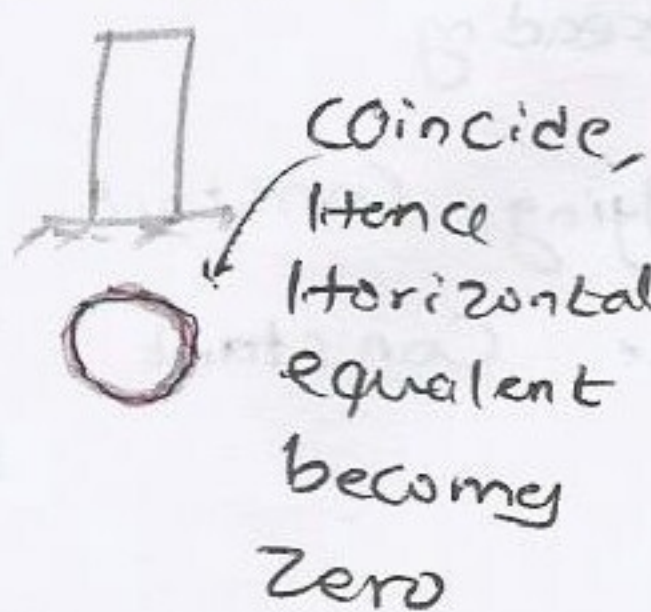
c) Uniform slope



d) Plane Surface



e) Vertical cliff



f) Overhang cliff



e) Hill $\rightarrow$ Higher value inside



Ridge $\rightarrow$ Higher value outside



Merge (or) Cross one another on map.

* Contour line cross Ridge (or) Valley line at 90° (ie Right angle)

* Spacing of Cross-Sections in hilly country is $\approx 20\text{m}$.

Plane Table Surveying

The method of Surveying in which the field work and plotting are done Simultaneously.

- Adopted at great accuracy not consider (Such as Topographical Survey)
- Particularly advantage in magnetic areas.

Alidade

The straight edge focussed instrument in plane table Surveying

a) Plane Alidade

It only focussed horizontal views, hence only measure Horizontal distance

b) Telescope Alidade

Is rotated, hence focussed in both vertical & horizontal views.

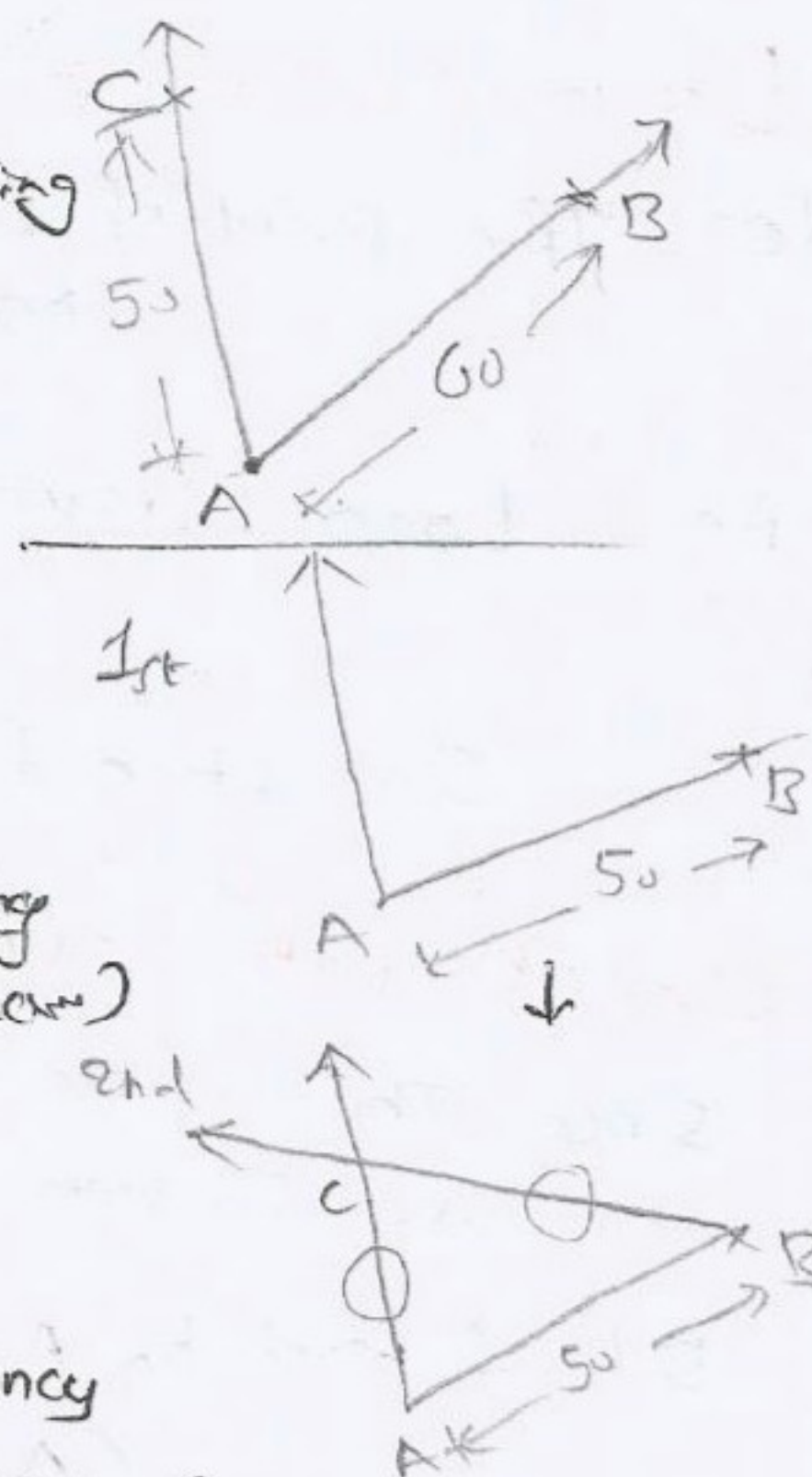
So, it measure both horizontal & vertical distance.

* Method of Plane Tabling

Following four methods mainly observed while Plane Tabling

1. Radiation

Drawing rays from ~~Sta~~ Table Station to the focussed station. And point out sta station by measuring distance.



2. Intersection

Mainly two know the inaccessible points by intersecting rays. (eg: Here C is inaccessible point due to obstruction)

3. Traversing

It is like compass traversing. But here we need distance of all line (or min line, other distance may find by intersection or by mathematical calculation).

4. Resection

It is the reverse process of Tabling. i.e. to fix

→ To fix Stations by already drawn views.

→ To Check the accuracy.

* This method used for establishing the instrument stations only.

Tacheometric Surveying

The branch of Surveying in which the horizontal & vertical distance measured by Tacheometer. (by taking level reading on staff & the distance are measured by applying it's lens property).

→ It is also used for levelling

$$\therefore \text{Distance from Tacheometer to staff (D)} = \frac{f}{i} \times S + (f + d)$$

∴ S = Staff reading

$\frac{f}{i}$ = Multiplying Constant ≈ 100

f + d = Additive Constant = 30-40 m

= 0 (When additional lens provided on Telescope)

Electro magnetic Distance measurement (E.D.M)

High accuracy instrument, to measure distance & angle.

→ It measures an accuracy of $\frac{1}{105}$ (m) = 0.1 mm up to 100 cm.

$$\text{Refractive index Ratio (n)} = \frac{\text{Vel of Ele. mag wave in vacuum}}{\text{Vel. of Ele. mag wave in atmosphere}} = \frac{C}{V}$$

($\because C = 3 \times 10^8$ m/s & $n > 1$, depends on temp, atm condition & humidity)

Methods of Contouring

Direct method:

The points/levels in the field are directly taken by Total station/level
→ Suitable for definite small areas.

Indirect method:

By interpolating the spot level (taken by on field or from office)

→ This method is cheaper, quicker but not much accurate. Three methods.

a) By Squares

The land is divided into small squares, at intersection the levels are taken, by interpolation contours are found.

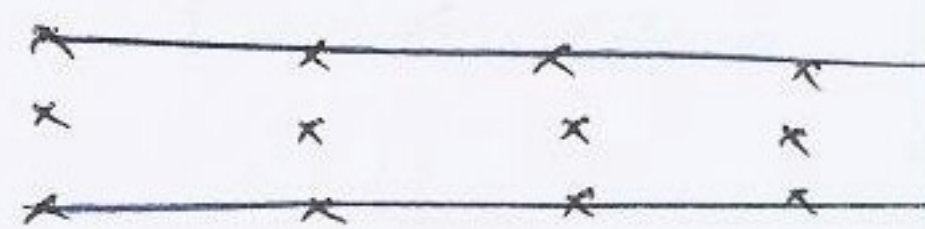
→ Suitable for broad area



b) By Cross Sections

For long narrow strips level taken @ each c/s

→ Suitable for Road, Railway, Canal, etc.



c) By Tacheometer

By using total station levels are taken for difficult region

→ Most suitable for hilly region @ 20m c/s interval



→ Interpolation of Contours

By a) Estimation b) Arithmetical Calculations c) Graphical method

→ Arithmetical calculation is best for small regions @ high accuracy.