SURVEYING

Self confidence

Achieve Daily Target

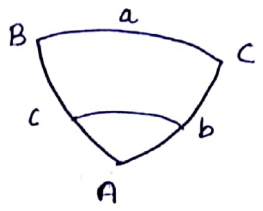
Multiple revision

To The Point-ByDhyanPal(ESE'17AIR-179,GATE'18AIR-93,GATE'16AIR-145)

Plane surveying	Geodetic surveying
Earth surface not taken into account	taken into account मतलब Curvature of earth taken
for small area (<195.5 km²)	for Larger area (>195.5 km²) 18.5 km ⟶ 1.52 cm का अन्तर 19.5 km² ⟶ 1 से का अन्तर
Less accurate	more accurate
Line Joining 2 points in this is line	arc
uses:- on Large scale like dam, bridge, highway	uses:- in establishing - controll point for plane survey (done by national survey of India)

In Geodetic surveying ⟶

Topic → Spherical Triangle :-



1- any angle < 180° → 2 right angle

2- $180° < \underbrace{A+B+C}_{\text{angle sum}} < 540°$; $\pi < \text{angle sum} < 3\pi$

3- sum of any 2 side > Third side → a+b>c, b+c>a, a+c>b

4- if sum of any 2 side = π then sum of angle opposite them is also π (180°)
if a+b = π then A+B = 2×90 = 180 = π

5- The smaller angle is opposite the smaller side

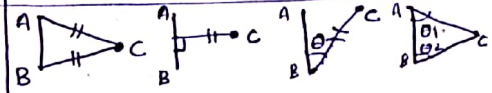
6- sum of 3 sides of Spherical Triangle is - always Less than circumference of Great circle.

Classification of survey basedon

nature of field survey	object of survey	Instrument used
1- land survey (Ex. Cadastral survey, city survey)	1- Engineering Survey	1- chain Survey
2- marine or hydrographic survey	2- millitry "	2- Tacheometer
3- Astronomical Survey	3- Geological "	3- Theodolite "
	4- Archeological "	4- Planetable
	5- mine "	5- Triangulation
		6- Traverse "

1- Topographical survey	to locate natural & artificial feature on earth surface Ex. Building, monuments, Hill, rivers
2- Engineering Survey	design & construction of new routes Ex. roads, railways
3- Cadastral survey	to fix the property line, calculation of land area, to fix boundry of municipality and of state jurisdiction
4- Hydrographic survey	large water bodies (lake, river, harbour) etc Ex. Q, depth, fluctuation of ocean tide
5- Astronomical survey.	to find latitude, longitude (to know exact location of point) azimuth, local time at various places on earth by observing heavy bodies like sun, star
Geological	to find out earth different - strata

principle of surveying :-

(i) Whole to part	• localize the error & prevent - their accumulation
(ii) Locate a point by at Least 2 measurements	

scale = map distance / Ground distance

max. error on drawing = 0.25 mm

• High Representative fraction ⟷ Larger scale (RF)

• Shrinkage factor (SF) = Shrunk length / original Length (or Shrinkage ratio)

• Shrunk scale = original scale × SF.

• Correct Length × $RF_{correct\,scale}$ = measure length × $RF_{wrong\,scale}$

Correct area × $(RF_{correct\,scale})^2$ = measure area × $(RF_{wrong\,scale})^2$

Correct distance on map (in terms of original scale) = Measur dist. on map / SF

— " area " = " area on map / $(SF)^2$

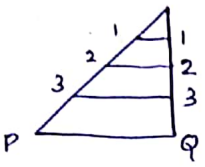
" volume " = volume " / $(SF)^3$

Types of scales :-

① **Diagonal scale** :- used to represent 3 units (3 dimension (meter, cm, decimeter)) (main unit, its sub unit, subdivision of subunit)

→ Based on similarity of Triangle.

→ indicates the distances in unit and its immediate 2 sub division.

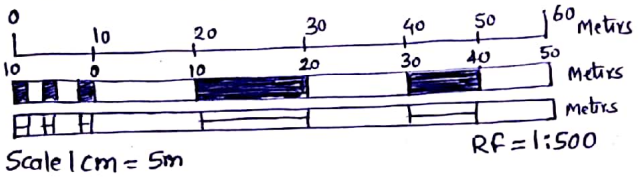


1–1 represent $\frac{1}{4}$ PQ

2–2 " $\frac{2}{4}$ PQ

② **Graphical scale** :- is a line subdivided into plane distance corresponding to convenient unit of length.

Imp
- always drawn on all survey maps
- Graphical scale not affected due to shrinkage of map. { if a graphical scale is drawn on map and in case shrinkage of sheet / paper occures then graphical scale also shrink- Proportionally & therefore ratio is unaffected.



Scale 1 cm = 5m RF = 1:500

③ **vernier scale** :- used when diagonal scale is inconvinient to use due to lack of space

- can read upto 2 decimal place
- more precise than plain scale → used to represent 2 consecutive units like meter & decimeter, feet & inch
- vernier scale has 2 parts

main scale — It is plain scale uniformly

vernier scale → It is an auxillary scale whose length is either more or less by fixed amount compared to main scale division.

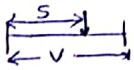
① direct vernier

$(n-1)S = nV$

$L.C = S/n$

V–S

Ex. 9 division of main scale = 10 division of vernier



- reading increases in a direction to that of the main scale.

② Retrograde vernier

$(n+1)S = nV$

$LC = S/n$

S–V

- reading increases in a direction opposite to that of main scale

③ Extended vernier

$(2n-1)S = nV$

$LC = 2S - V$

if may happen that divisions on the main scale are vary and it would then be difficult, if the vernier were of normal length, to judge the exact graduations where coincidence occurs in this case it is used.

④ Double vernier

In measuring Angles (vertical or horizontal) vernier may be moved in either direction on fixed main scale.

for such measurement double vernier used in which – Graduations are in both directions

EDMI $= \pm[(a\ mm) + b\ ppm)]$

- constant instrument error → Independent of length measured
- varies in proportion to the distance being measured

chaining : It is a measurement of horizontal distance either by chain or tape.

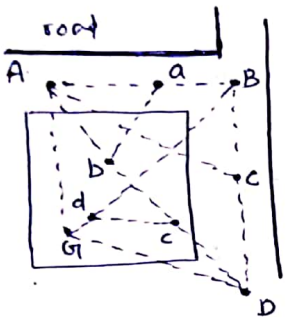
- Used for area of small extent on open ground having few simple details
- not good for Large areas having more details.
- Plans are required on a Large scale because Large scale consist of few details.

note: Survey chain dist b/w 2 brassing = 20cm

note: Surveying chain accuracy not good As steep tape / steel Band

invar tape :- • Ni (36%) + steel (64%)
• Highly precise • α ↓ (very low) → ∴ Less affected due to temp.
• width 6mm Length 30, 50, 100 mtr.

accuracy of tape :- Invar > steel > metallic > Linen



① **main station** (A, B, C, G, D)
- command the boundry of survey
- where 2 sides of triangle meets.

② **Tie station / subsidiary station** :- (a, b, c, d)
Station on line joining main station.

③ **main survey line** :- (AB, BC, CD, AG, GD)
line joining main station

④ **Tie line / subsidiary line / Auxillary line** (ab, cd)
line joining tie station. provided to locate the interior detail which are far away from main survey line.

⑤ **Base line** :- longest survey line on a fairly grd passing through centre of area

⑥ **check line / proof line** :- to check accuracy of work

⑦ **offset** :- lateral measurement from chain line (may be perpendicular or oblique)

Assessories for chaining :-

1- Pegs → to mark point on ground.

2- Arrow → जब ज्यादा Length नापनी हो तो जहाँ tape Length खत्म होती वहाँ Arrow लगाते

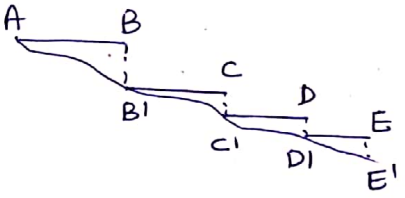
3- Ranging rod → to locate intermediate points or to locate a no. of points on Long survey line

note :- कई बार लगभग dist. नापने के लिये ranging rod use कर सकते (2 or 3m long) (3cm dia)

4- offset rods → to align offset line and to measure short offset.
- additional hook is provided on top to pull or push of rod.

chaining in sloping ground :-

1- direct method / stepping method / Breaking the chain method



2- Indirect method / measurement along slope / hypotenusal method

Revenue chain	Gunter chain	Engineering chain
33 feet	66 feet	100 feet
16 link	100 link	100 link

metric chain

20 ± 5mm → 20 metre chain (20 × 5 = 100 link)

30 ± 8mm → 30 metre chain (30 × 5 = 150 link)

1 mile = 80 × Gunter chain

1 acre = 10 × (Gunter chain)^2

Tape correction

① correction due to Standardization (+) (−)

सही × सही = गलत × गलत

② correction due to temp. (+) (−)

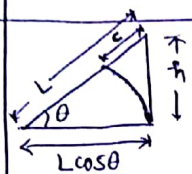
$L \propto (T_m - T_o)$ ⊕ $T_m > T_o$ ⊖ $T_m < T_o$

T_m → measurement करते समय temp.
T_o → std. के time temp.

③ correction due to pull (+) (−)

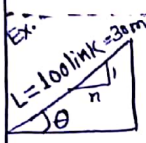
$\frac{(P_m - P_o)L}{AE}$ ⊕ $P_m > P_o$ ⊖ $P_m < P_o$

④ correction due to slope always (−)ve



$C = \frac{-h^2}{2L} = -(L - L\cos\theta)$

Ex. L = 100 link = 30 meter



$\tan\theta = \frac{1}{n}$ ∴ $\cos\theta = \frac{n}{\sqrt{1+n^2}}$

$C = -(L - L\cos\theta)$

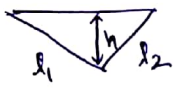
$= L\left[\frac{n}{\sqrt{1+n^2}} - 1\right]$

$C = L\left[\left(\frac{1+n^2}{n^2}\right)^{-1/2} - 1\right] = L\left[\left(1+\frac{1}{n^2}\right)^{-1/2} - 1\right]$

$C = L\left[1 - \frac{1}{2}\left(\frac{1}{n^2}\right) + \cdots - 1\right]$

$C = \frac{-L}{2n^2}$ or $C = \frac{h^2}{2l} + \frac{h^4}{8l^3}$

⑤ correction due to wrong alignment always (−)ve



$C = -\left(\frac{h^2}{2l_1} + \frac{h^2}{2l_2}\right)$

⑥ correction due to sag always (−)ve

$C = \frac{-w^2 l^3}{24 P_m^2}$ w → N/m

normal tension :- when

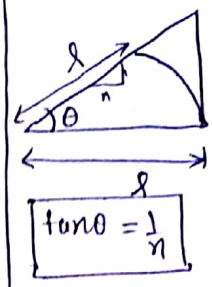
$C_{pull} = P_{sag}$

$\frac{(P_m - P_o)L}{AE} = \frac{w^2 L^3}{24 P_m^2}$

⑦ correction due to MSL (mean sea level) always (−)ve

$C = \frac{-Lh}{R}$

⑧ Hypotenuse Allowance



$C = l(\sec\theta - 1)$

error in chaining :-

① Compensating error (Random error)

- liable to occure in both the direction and tend to compensate
- compensating error ∝ √(length of line)
- These are caused by incorrect holding & marking of arrow, incorrect plumbing at slopes
- They don't affect much result
- They can not be corrected

② Cumulative error

- liable to occure in same direction and Tend to accumulate

Ex. error due to sag, slope etc

cumulative error ∝ length of line

- They can be corrected

chain adjustment (on Testing)

if chain found too short

1- Straightening bent links
2- flattening the circular rings
3- Replacing circular rings by bigger rings
4- Insert additional ring

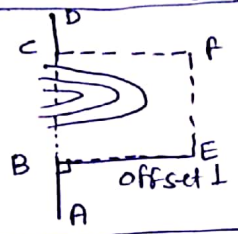
if chain found too Long.

1- replace the wornout rings
2- closing the opened joint of rings
3- reshaping the elongated links
4- remove one or more circular ring.

Obstacle in chaining → river, lakes, buildings

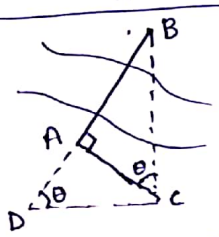
Prolongation of chain line across an obstruction in chain surveying :-

① Drawing Perpendicular with a chain



BC = EF

② making Angular measurement



$\frac{AB}{AC} = \frac{AC}{AD}$

$\frac{AC^2}{AD} = AB$

Right Angle measurement :-

① Crossstaff	① open crass staff :	90°
	⑪ french crass staff (Hollow octagonal Box)	45°/90°/135°
	accuray :- open cross staff better	
⑪ optical squave	Principle → double Reflection • if angle b/w mirror is 45° & two reflected ray is 90 degree to incident ray	
⑪ prism square	principle same as optical square → prism used.	

Ranging :- process of establishing intermediate point

① Direct ranging	• where end station visible. ⓐ ranging by eye ⓑ ranging by line ranger
⑪ Indirect ranging or reciprocal ranging	when end station not visible due to rising ground b/w them or due to long distance b/w end stations

note :- random Line method of Ranging :-

• [chain used to erect a ⊥ taking 3 sides of Δ in ratio of 3:4:5]

obstacle in ranging :- hill, Building { not**, river, lake }

Limiting Length of offset :- depends on :-

1- Degree of accuracy desired.
2- method of setting out perpendicular
3- Nature of ground
4- Scale of plotting

note :- max. allowable error length on drawing = (0.25 mm)

Combined error in Length & direction :-

1 cm = S metir

$$l = \frac{1}{\sin\theta}\sqrt{\left(\frac{S}{40}\right)^2 - x^2}$$

→ error in length

if error in direction only :- (x = 0)

$$l = \frac{1}{\sin\theta}\sqrt{\left(\frac{S}{40}\right)^2 - 0^2}$$

Chain surveying	Traverse surveying
(1) only linear measurement ∴ relatively easier	(1) Both linear & angular measurement.
(2) framework consist of Triangles	(11) framework consist of series of connected lines open or closed polygons
(3) check lines are req. to check the accuracy of work	(111) method of Adjustment is used to check accuracy
(4) use → where area is small, ground flat & accuracy Required is Low	(4) use → large area, when accuracy required better

Traversing done by (1) compass Traverse
(11) Plane Table "
(111) Stadia "
(IV) Theodolite "

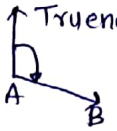
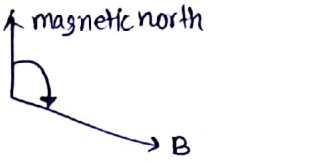
magnetic compass is req. to determine angle of traverse & side measured by chain/tape

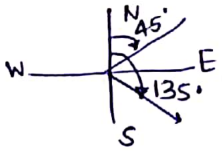
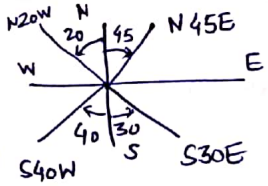
meridian → Fix line of reference.
I- True meridian II- magnetic meridian
III- Grid meridian IV- Arbitrary meridian

True meridian	• True North - south direction at a place • determine by Astronomical observation of sun or stars • True meridian through various stations are not parallel But, converge at poles However for small survey, we assume parallel. • at a point fixed always (imp.)
magnetic meridian	• direction indicated by a freely suspended, balanced magnetic needle at that point. • This magnetic needle should not be affected other than that of earth. (imp.) • At point varies with time (not fixed)

Bearing → Horizontal angle of line w.r.t reference line (meridian)

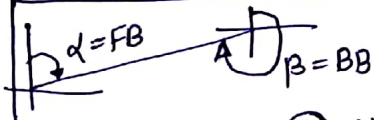
Azimuth (True bearing) → Bearing of a point in reference to the horizontal True north

True Bearing	Magnetic Bearing
1- measured w.r.t true north (true meridian) in clockwise direction  (horizontal angle b/w True meridian & line)	1- measured w.r.t magnetic north (magnetic meridian)  (horizontal Angle b/w magnetic meridian & line
2- does not change with time as True meridian at a point is fixed	2- It changes with time as magnetic poles are not fixed in position
3- It is determined by Astronomical observation	3- determine by Prismatic compass (WCB) or Surveyor's compass (QB)

Whole circle bearing (WCB) → Prismatic compass	Quadrantal bearing (QB) → Surveyor compass
• measured from north clockwise direction.	• measured from north or south point whichever is closer
• varies 0° to 360°	• varies 0° to 90°
 	

fore bearing (FB) :- Bearing of line in the direction of progress.

back bearing :- ——— opposite direction of progress.



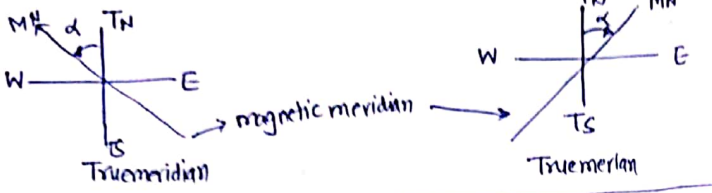
BB = FB ± 180°

(+) when FB < 180°
(−) when FB > 180°

Magnetic Declination :- Horizontal angle b/w True meridian & magnetic – meridian.

west declination or (–)ve

east declination or (+)ve



True Bearing = magnetic bearing – declination	Truebearing = magnetic bearing + declination.

Dip :- angle made by line of magnetic force with earth surface.

- magnetic needle ⟶ align with magneticforce
- In horizontal @ Equator dip = 0
- vertical @ pole dip = 90°

} dip (0–90°)

1– lines of equal annual change (magnetic Dec.) ⇒ Isopors

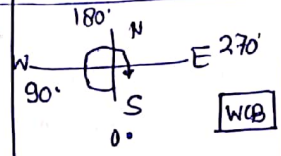
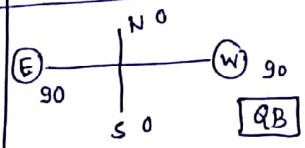
2– Isogonic ⟶ same magnetic Declination
Agonic ⟶ zero

3– Isoclinic ⟶ same dip

4– Aclinic ⟶ zero dip

variation of magnetic declination :

(i) Secular variation	occures continuously over a long period of time (like 150 years)
(ii) Annual variation	(due to rotation of earth about sun) • changing declination at a place over a period of 1 year.
(iii) Diurnal variation	(due to rotation of earth about own axis) • changing declination over a 24 hr at a place. Ex. pole > equator, summer > winter, day > night } comparison of change in declination
(iv) Irregular variation	due to magnetic disturbances.

	Prismatic compass (WCB)	Surveyor compass (QB)
magnetic needle	Broad needle	edge bar type
Graduated ring	 WCB	 QB
reading system	with the help of prism provided at eye vane	direct seeing through top of the boxglass
Tripod	instrumen can be held in hand while making observations	Tripod must
vanes	eye vanes consists of a metal vane with a large slit	eye vane consist of small vane with small slit

Local Attraction :- Attraction of magnetic needle to local magnetic field (other than earth's magnetic field)

- caused by Iron pipes, Iron fence, railway line etc.

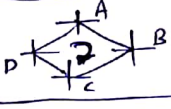
How to detect :-

Ⓐ diff. b/w FB & BB ≠ 180°

Ⓐ error in observation of either fB, BB or both.

Ⓑ presence of local attraction at either 1 end or both ends

Type-1 :- |FB – BB| = 180° ⇒ solve by interior angle



$\angle A = AD - AB$ (पहले बाद) $\angle B = BA - Bc$

Type-2 :- |FB – BB| ≠ 180° → find interior angle ∠A, ---- add suppose = (536') 540' होना चाहिए

∴ correction needed per angle = +4'/5 = 0°48'00"

∴ new corrected Angle = ∠A, ∠B ----

assume AB as correct ∵ BB – FB = 180°

∴ ∠A = AE – AB (सही) (सही) find AE = ?

note:- (1) Difference b/w fB & BB for any station ⇒ Internal Angle

(2) Included Angle = fB of next line – BB of previous line

(3) if traverse clockwise ⇒ Included Angle will be exterior Angle

(4) ~~if~~ ——— anticlockwise ⇒ ——— interior Angle.

Theodolite use :-

(i) to measure horizontal & vertical angle precisely.

(ii) to measure horizontal & vertical distance indirectly.

(iii) ranging.

Theodolite

- **Transit theodolite**
  - in this line of sight can be reversed by revolving the telescope through 180° in vertical plane about horizontal axis
- **Non-Transit theodolite**
  - Plain Theodolite
  - can not be transited at all

Theodolite

- **Vernier theodolite**
  - most commonly used
  - verniers are used for taking threading
  - least count = 20" second
- **Precise optical theodolite** or **micro optic Theodolite**
  - filled with an optical system used to read both Horizontal & vertical angle precisely
  - in this micrometer is used for taking readings
  - can read angle upto 1 second or less

note:- double reading Theodolite has 2 vernier both on upperplate.

note:-
(i)
- lowerplate → Scale plate ∵ It contains a scale on which 0 to 360° readings are graduated.
- upperplate → vernier plate

(ii) Size of theodolite (18-25cm) → Size of lower graduated circle

Ex. 20cm Theodolite → dia. of graduated circle of lowerplate is 20cm.

note:- if Theodolite circle is divided into degree & half degree

The no. of division on vernier scale to read 1 min.

$= \frac{1}{n} \times$ value of smallest division on main scale

1 min

half degree = 0.5°

n = 30

Basic Definitions :-

1- centering :- • Setting up station exactly over station.
• done by Plumb bob.

2- Horizontal axis / Tranverse axis / Trunnion axis :- axis about which Telescope can be rotated in vertical plane

3- vertical axis / Azimuth axis → — @ Horizontal plane

4- Line of sight / line of collimation :- Imaginary line passing through the intersection of crosshair of diaphram and the optical centre of objective
• when sight line of comes in horizontal plane it is called line of collimation.

5- axis of level tube :- when bubble in centre then axis of Level tube is horizontal.

6- face right :- vertical circle of theodolite at right hand side of observer

7- face left :- at left ——

note:- collimation error can be eliminated by taking mean of both face reading.

$$\text{error} = \frac{\text{Difference b/w face right \& left observation}}{2}$$

8- Telescope normal :- face left + bubble is up.

9- Telescope inverted → face right + bubble is down.

10- Transit / plunging / Reversing :- about horizontal axis, rotate telescope by 180° in vertical plane (exactly opposite direction)

11- Swinging of Telescope :- about vertical axis, Telescope rotated in horizontal plane.
- Right swing → clockwise rotation
- Left " → anticlockwise "

12- double sighting :- process of measure horizontal or vertical angle twice, once with telescope in normal condition, another with telescope in inverted condition.

13- changing face :- bringing the telescope from face left to face right or vice versa.

- done by plunging + swinging by 180° (Reversing)

error elimination by changing face

- error due to horizontal axis not being ⊥ to Vertical axis
- error due to collimation
  - not being ⊥ to the horizontal axis
  - not being parallel to axis of Altitude Level.

14- lining in :- process of establishing intermediate points with help of Theodolite on a given straight line whose ends are invisible.

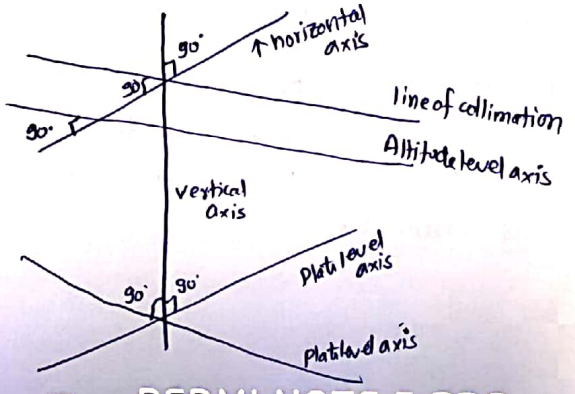
15- Balancing In → ⓐ whose ends are not invisible

note:- The tangential screw → used for minor adjustment in Theodolite when both plates are clamped

fundamental lines of Theodolite

① vertical axis ⑪ Horizontal axis (Trunion axis)
⑪ axis of plate level ⑪ line of collimation
⑤ bubble line of Altitude

- when the Theodolite is in proper adjustment following condition should be satisfied.



① Horizontal circle ⊥ vertical axis
⑪ vertical axis must pass through the centre of graduated horizontal circle
⑪ vertical circle ⊥ horizontal axis
⑪ horizontal axis must pass through centre of vertical circle
⑤ Tangent to plate bubble tube must be ⊥ vertical axis.
⑥ line of sight must be perpendicular to transit axis (trunnion axis) or (horizontal Axis)
⑦ Transit axis must be perpendicular to vertical axis
⑧ for horizontal position of telescope and for Altitude bubble at centre, reading on vertical circle must be zero.
⑨ line of sight, horizontal axis, and vertical axis must meet at one point → centre of instruments

Temporary Adjustment of Theodolite :-
(जब reading लेने की तैयारी में हों नये station पर)

1- setting up over tripod
2- centring by Plumb bob (aim vertical axis over station mark)
3- levelling by levelling screw.
4- focussing the eyepiece → to make cross-hairs distinct & clear
5- focussing the objective → to bring the image of object in plane of cross hairs
6- elimination of Parallax.

Permanent Adjustment of Theolite :-

aim → to establish relation b/w fundamental lines of Theodolite.

imp

order :- P C C S B VA

P	C	C	S	B	VA
Plate level Test	cross-hair Ring Test	collimation in Azimuth Test	Spire Test	bubble Tube adjustment	vertical arc Test

① Plate Level Test	axis of plate level must be perpendicular to vertical axis
② Cross-hair ring Test	make the vertical cross hair lie in a plane perpendicular to the horizontal axis
③ collimation in Azimuth Test	make the line of sight Perpendicular to horizontal axis
④ Spire Test	make horizontal axis Perpendicular to vertical axis.
⑤ Bubble Tube adjustment	make telescope bubble central when line of sight is horizontal
⑥ vertical arc Test	make the vertical circle indicating Zero when line of sight is perpendicular to the vertical axis

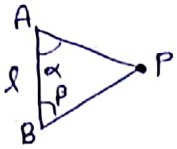
measurement of Horizontal angle :-

① By repetition method	• when accuracy is needed beyond Least count of instrument with a coarsely Graduated circle. • more accurate, less error • measurement of simple angle • horizontal Angle measure several times add them, & divide by no. of repetition, It gives finer degree than least count.
② By Reiteration method	imp • prefer in Triangulation. • where no. of angles may be required at one station by the instrument with finely graduated circle.

ordinary method.

Traverse ⇒ series of connected lines whose length and direction are measured infield

Traverse principle ⇒ (AB, α, β) known



Length of one side (AB) measured, location of 3rd point is measured after measuring 2 directions (angles) α, β

Field work in Theodolite Traverse :-

(i) Reconnaisance (ii) selection & marking of station
(iii) measurement of Traverse line (linear measurement) → chain, EDM, Tacheometer
(iv) _____ angular details (Angles)
(v) Picking up details

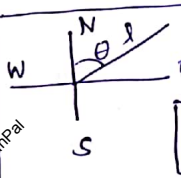
Note :- earlier when distance measuring instrument were not there, we used Triangulation

Triangulation → one Base line measure then all angles measured to get lengths of other lines

Angular measurement in Theodolite Traverse :-

(i) Loose needle (free needle) method	• Less accurate • magnetic bearing of each line is measured at each station
(ii) fast needle method	• more accurate than 1st method ∴ used in field • only magnetic bearing of 1st line measured and with help of included angle we can get magnetic bearing of all other lines.
(iii) method of Included Angle	• most commonly used method • magnetic bearing of any line (generally 1st) is measured and all included angles are measured Note :- All angles are measured in clockwise direction because Theodolite graduation increases in clockwise direction.
(iv) method of direct angle	• Similar to included angle method • for open traverse • in this direct angle or angle to the right is measured.
(v) method of Deflection angle	(for open traverse) • conducted for survey of roads, railways, canal, pipelines where traverse line make small deflection angle

Note :- for n no. of stations < FB = 'n-1' / BB = 'n-1'



latitude = $l\cos\theta = L$
Departure = $l\sin\theta = D$

for close traverse $\Sigma L = 0$, $\Sigma D = 0$

closing error (e) = $\sqrt{(\Sigma L)^2 + (\Sigma D)^2}$

direction of closing error $\delta = \tan^{-1}\left(\frac{\Sigma D}{\Sigma L}\right)$

relative error of closure / Relative accuracy or degree of accuracy $= \frac{e}{P} = \frac{\text{closure error}}{\text{Perimeter of traverse}} = \frac{1}{(P/e)}$

well conditioned triangle :- not less than 30°, not more than 120°
Angles

open traverse :- for preliminary survey
• Desirable to avoid it
Reasons :- (i) no arithmetic check for field measurement
(ii) no check on position of intermediate points as there is not known position of points (except starting station)

Adjustment of Traverse / Balancing of traverse

Aim: closing error (e) = 0

if closing error is within permissible limit traverse should be adjusted hence error is distributed among various sides of traverse such that traverse geometrically closes.

① Bowditch method or Compass rule

- In this angle & distance measured with same precision.

assumption :- closing error introduced in traverse are of accidental (random) in nature.

{ error in linear measurement $\propto \sqrt{l}$
error in Angular " $\propto \frac{1}{\sqrt{l}}$ }

$$C_L = \left(\frac{l}{\Sigma l}\right) \times \Sigma L$$
$$C_D = \left(\frac{l}{\Sigma l}\right) \times \Sigma D$$

} in This after correction both length & bearing changed

note:- if we compare with transit rule Lengths are changed Less, angles are changed more.

② Transit rule

- In this angle precision > Length precision

$$C_L = \left(\frac{L}{L_T}\right) \times \Sigma L$$
$$C_D = \left(\frac{D}{D_T}\right) \times \Sigma D$$

L_T, D_T Same of latitude & departure without considering sign.

note:- after correction angles are changed Less { already measured with high precision } & Lengths are changed more (due to Less precision)

note:- if either Latitude or Departure = 0 (Hence line either parallel to x or y)
Then as per transit rule ⇒ no correction in begrin of line.

③ Axis method | ④ Graphical method

calculation of area of traverse (As per meridian distance method)

$$m_1 = m_{previous} + \frac{D_{current}}{2} + \frac{D_{previous}}{2}$$

$$\text{Area} = |\Sigma m L|$$

Levelling → operation of determining the difference of elevation of points wrt each other on surface of earth.

- levelling deals with measurement in vertical plane.
- levelling starts with BS and end with a foresight (FS).

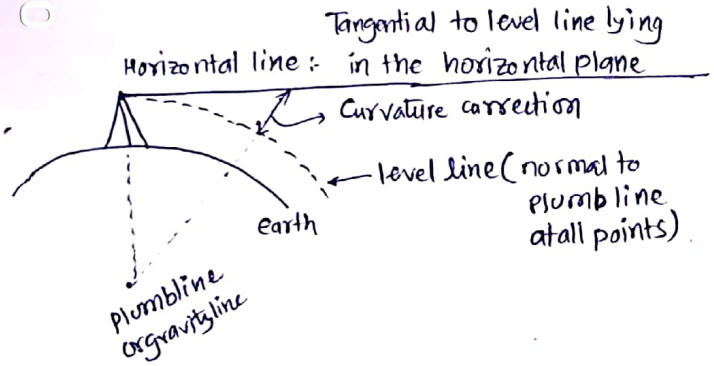
Imp

error = measured value − True value
($\Sigma BS - \Sigma FS$) (last RL − first RL)

1- HI method → check only BS, FS

2- Rise & fall method → check BS, FS + Intermediate sight also

$\Sigma BS - \Sigma FS = \Sigma Rise - \Sigma fall = Last\ RL - 1st\ RL$



Line of sight → Line passing through centre of cross hairs and centre of eye piece.

Line of collimation :- Line of sight when horizontal is called line of collimation. It is achieved when bubble is at the centre in level tube. In such condition axis of bubble tube becomes parallel to line of collimation.

Axis of Telescope :- It is line joining the optical centre of objective to the centre of eyepiece.

MSL → for vertical controll

adopted by survey of india for reference is located at Bombay High (mumbai)

- MSL obtained by averaging the elevation of high tides and low tides at several points for a long period of time (ie 19 years)

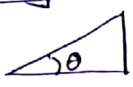
levelling

- Direct levelling (spirit levelling)
- Indirect levelling

(A) Direct levelling :- most commonly used

- spirit Level is fixed to telescope of levelling instrument to make line of sight horizontal then all vertical distance measured wrt horizontal Line of sight

(B) Indirect levelleling :-

(i) Trigonometric levelling (stadial ewlling)	 $\tan\theta = H/D$ • measure D , θ to get H
(ii) Barometric Levelling	• Based on change in atm. pressure. atm. preccure ↓ Elevation ↑ • These Barometers known as Altimeters, used to find Altitude of aeroplanes
(iii) Hypsometric Levelling	• Based on noting down temp. at which water starts Boiling elevation ↑ Boiling point ↓

Types of direct Levelling :-

(1) Simple Levelling	• to find difference of elevation of 2 points which are visible from a single position of instrument.
(2) Differential (Compound) Levelling	• when 2 points are apart • eg. more than 1 setting of instrum 

③ check levelling
- Type of differential Levelling
- To check elevation which have already plotted.

④ fly levelling
- type of differential levelling
- to find approx elevation of different points where rapidity is needed & Low precision req.
- used for reconnaissance of area for approx level check

⑤ Profile (Longitudinal) Levelling
- type of differential Levelling
- to find elevation of ground along a fixed line

Ex. to fix gradient, to find earthwork Quantities.

⑥ cross section levelling
- type of differential levelling
- To determine the difference of ground surface along the line perpendicular to centre line of road canal etc.

⑦ Precise Levelling
- very accurate Differential Levelling in this levelling, "level" is used
- major component of level → Telescope, Bubble Tube or level Tube

• Reciprocal levelling :- ① find Difference of elevation of 2 points which are quite apart.
when it is difficult to set instrument in mid of 2 points.

② It eliminates → curvature error, Refraction error, collimation error (not parallax error), error in Instrument measurement

③ True level difference b/w 2 points $H = \frac{(h_B - h_A) + (h_B' - h_A')}{2}$

① Curvature correction (meter) $C_c = \frac{-d^2}{2R}$ (km) $= -0.0785 d^2$

② Refraction correction (meter) $C_R = +\frac{1}{7} C_c = +0.0112 d^2$

(R = 6370 km)

$C = C_c + C_R = -0.0673 d^2$

∴ distance of visible horizon $d = 3.85\sqrt{h}$

distance of observer from Light house (d)

$d = 3.85 (\sqrt{h_1} + \sqrt{h_2})$ (km) (m)

h_1 → Top of light house above sea
h_2 → height of observer eye above sea

Collimation error = True level by formula $- 0.0673 d^2$

$\frac{(h_B - h_A) + (h_B' - h_A')}{2}$

note:- v.v imp. effect of corrections
- staff reading घटता है $h_A - 0.0673 d^2$
- RL बढ़ता है $RL_A + 0.0673 d^2$

Sensitivity of Level / Bubble Tube :-
- express in terms of angle in second subtended at a centre of arc of Level tube equal to 1 division of Tube
or angular value of 1 division of Bubble Tube.

$\alpha = \frac{S}{nD} = \frac{\theta}{n} = \frac{l}{R}$ | 1 radian = 206265 sec

S → difference b/w 2 staff reading
n → no of division of Bubble
D → distance
l → length of 1 division (if not given assume 2mm)
R → radius of curvature of Bubble tube

Sensitivity ↑ :- ways?
① Radius of tube (R) ↑ (of curvature) ② Length of Tube ↑
③ dia of Tube ↑
④ viscosity ↓
⑤ surface tension ↓
⑥ roughness ↓ (Smoothening the inner surface of tube)

Tacheometry :- (optical distance measurement method)
Flat ground → accuracy of Tacheometry distance low
rought+steepground → more accuracy
→ used in Hill terrain when tape/chain से distance नापने में Labour

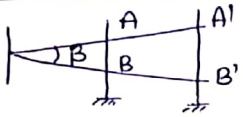
method of Tacheometry ↔ Stadia method / Tangential " / Rangefinding "

1- Stadia method

fix hair method (β fix, S vary)

movable hair / substense method (S fix, β vary)

(A) fixed hair method :-



β fix, S vary
↓ Parallactic angle
↓ staff intercept (AB, A'B')

Stadia method principle :- {Ratio of perpendicular to Base is constant in Isosceles triangle}

$D = KS + C$

$D = \left(\frac{f}{i}\right)S + (f+d)$

k = multiplying factor/constant

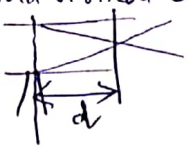
$k = f/i$ = Stadia interval factor

f → focal length of objective

i → Stadia Interval (interval b/w Stadia hair of diagram

(vertical dist b/w stadia wires or hair distance

d → horizontal distance b/w optical centre 'O' and vertical axis of tacheometer



Imp.

Internal focusing Telescope C - small
external " " zero

note:- Anallectic lens (convex lens type) K=100 C=0 → to make additive const=0

(B) movable hair method (substense method) :-
(S fix, β vary)

$D = \frac{KS}{m} + C$

$k = f/p$ → p = pitch of screw

↓ revolution of micrometer

note:- (i) if micrometer reading of drum of diafram = 3.125 & 3.450
then m = 3.125 + 3.450
=

(ii) if 20 threads in 1cm then P = 1/20 cm

if there is an index error 'e' in the micrometer screw

$D = \frac{KS}{(m-e)} + C$

advantage :- • more accurate than fixed hair method
• more accurate for long sight (only target is to bisected)

disadvantage :- • slow, computation tedious as m comes in denominator
• very difficult to measure stadia interval(i) accurately

note:- substencubar (Horizontal stave) :- rod of fix length horizontally mounted on tripod.
• where chaining not possible because of- undulation and rough country used to find- short distance of 200metir.
• used for measurement of horizontal distance (indirectly)
• in this case minimum refraction error.

(2) Tangential method :- (inferior to stadia method)
• used when diaphram does not have stadia hair, when staff is too far from instrument and it becomes difficult to read to read the staff.
• Stadia wires not used at all. (quite similar to Trigonometric levelling)
• in this observation is made for 2 vertical Angles and staff intercept is obtained with cross wire only.

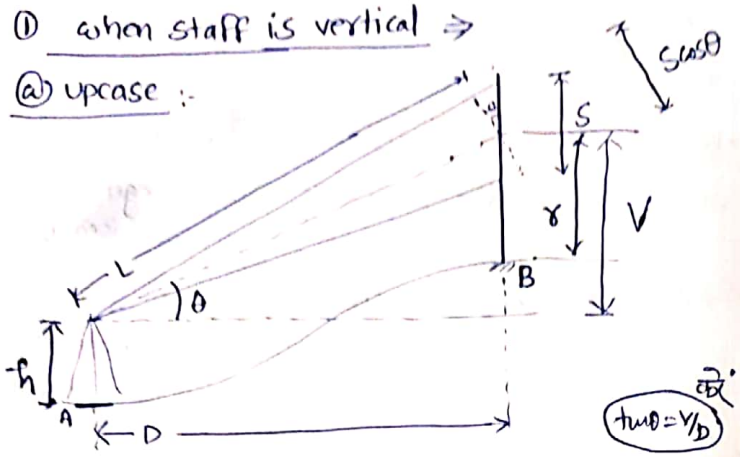
(3) Rangefinding :- use rangefinder instrument
• only horizontal distance measure, But with the help of level vertical distance can also be measured.
• The Instrument and method based on measurement of either of the base angle or the angle of parallax.

note:- Tilt of staff away from telescope pointing upthrill
→ increases the Intercept (a'b' > ab)

Distance and elevation formula for inclined sight :-

① when staff is vertical ⇒

ⓐ upcase :-



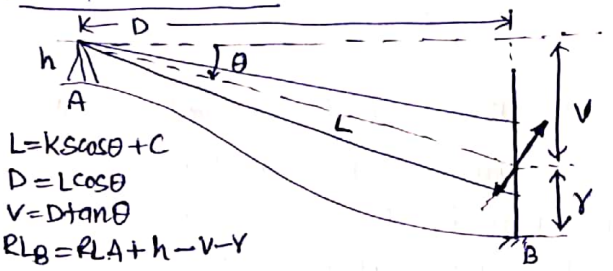
$\tan\theta = V/D$

$L = (KS\cos\theta + C)$ ⟶ as per formula

{ ∴ Horizontal distance $D = L\cos\theta$ }
{ Vertical $V = D\tan\theta$ }

elevation of staff station B = elevation of station (instrument) + h + V − r

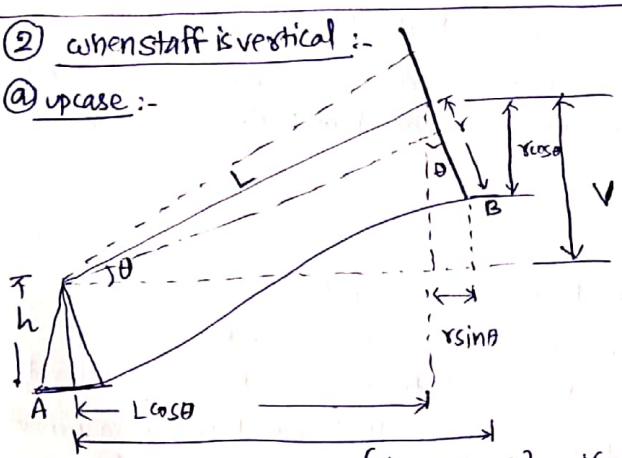
ⓑ depression case :-



$L = KS\cos\theta + C$
$D = L\cos\theta$
$V = D\tan\theta$
$RL_B = RL_A + h - V - r$

② when staff is vertical :-

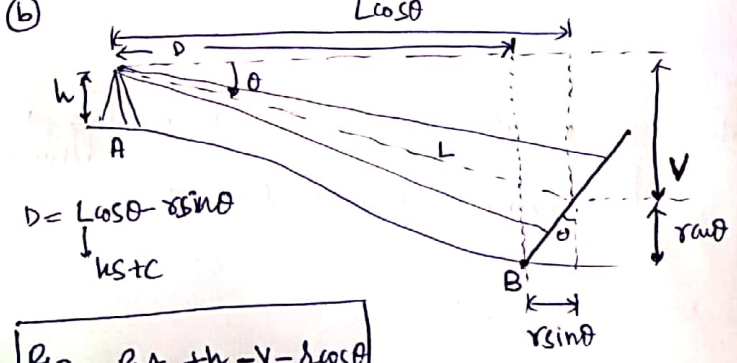
ⓐ upcase :-



$D = L\cos\theta + r\sin\theta$ $\{L = KS + C\}$ $V = L\sin\theta$

$RL_B = RL_A + h + V - r\cos\theta$

ⓑ



$D = L\cos\theta - r\sin\theta$
$\downarrow$
$KS + C$

$RL_B = RL_A + h - V - r\cos\theta$

Contours :- imaginary line passing through points of equal elevation on earth surface

note:- (i) Generally contours are not visible on ground except incase of shorlines.

(ii) when contours are drawn under water they are known as **submarine contours**, fathoms, Bathymetric curves.

Contouring methods

(1) Direct method	• Tedies, time taken more, accurate • used for small area • for large scale maps where grid is regular	
(2) Indirect method or contouring by Spot level	method of square	• for small area where contours are required at close vertical interval • ground is not very much undulating (plain & gentle-slope ground) • area to be surveyed is divided no. of squares
	method of cross section	for road, railway, canal survey
	Tacheometric method	in hilly areas

Uses of contours :-

1- Proper & precise location of engineering works as road, railway etc.
2- to estimate quantity of cutting, filling (earthwork)
3- to estimate the reservoir capacity
4- finding profile of country along any direction
5- In planning & designing of dam, reservoir.

contour Interval (CI) :- • The vertical distance b/w consequtive contours.

• It is desirable to have a constant contour interval.

• In case of variable C.I, it gives false impression of relative steepness of ground in different parts

factors affecting contour interval :-

(i) Scale of Map	Scale of map $\propto \frac{1}{CI}$ if scale is small then interval is kept Large so that there is no overlapping of contours.
(ii) purpose of Map	for detail design → small C.I However cost of work increases with small contour interval.
(iii) nature of ground	for flat ground → small C.I Steep slope → large C.I
(iv) Time	Time $\propto \frac{1}{CI}$
(v) funds	fund $\propto \frac{1}{CI}$

Properties of contour lines :-

(1) All points on contour lines → same elevation
(2) where no value is represented → Flat Terrain
(3) Zero meter contour → coast line
(4) 2 contour lines don't intersect (Except < overhanging cliff, cave penetrating Hillsides)
(5) Equally spaced counters → uniform slope
(6) Counter well apart → Gentle slope
(7) High figure inside → Hill
(8) Low " → depression, lake, pond
(9) irregular counters → Uneven ground surface
(10) (watershed or ridge line) & (valley line/wedge line) cross the contours at right angle.

note:- **watershed / Ridgeline** :- line joining Highest Points of series of hills.

valleyline / Wedgeline :- line joining Lowest Points of valley.

Plane Table :-

① Instrument for survey by Graphical method in which field observation and plotting done simultaneously.

② in this topographic details are mapped in full view hence no chance of missing any details.

③ use where greater accuracy is not required

④ for small - medium scale map ($\frac{1}{10000} - \frac{1}{25000}$)

⑤ This graphical method of producing topographical maps ⟶ cartographic surveying.

⑥ Principle of plane table survey :-
an unknown point of intrest can be established by measuring its direction from known points

Advantage of plane Table survey :-

① sighting, plotting simultaneously hence no chance to miss details.

② error & mistakes in plotting can be checked by drawing checklines.

③ where compass survey is not reliable (area affected by magnetic field), This is very usefull.

Disadvantage :-

1- not suited for work in wet climate (rainy season) and in a densly wooded country (area).

2- absence of field note causes inconvenience if survey is to replotted to some different scale.

3- Plane table is heavy & awkward to carry and accessories are likely to Lost.

4- It does not give accurate result.

Assessories :-

① plane Table board	made of well seasoned wood.
② Tripod	Levelling of Board is done by Tripod Legs
③ Aledade (sighting device)	• used for sighting the objects & drawing the lines • now days Telescopic aledade used when points are too high or Low to be sighted. The accuracy and range are considerably increased after using it
④ Trough compass	• is provided to plot magnetic meridian (N-S direction) to facilitate orientation of plane table in the magnetic meridian.
⑤ Spirit level or Level Tubb	• used for levelling the plane table. • It is placed on the board in 2 positions mutually at right angles and the bubbles is centred in each position to make the board horizontal.
⑥ Plumbing fork (U shape)	• Used for centring of plane table over a station
⑦ Drawing sheet	Best Quality so that it withstands rubbing, Scrubbing

Setting up of Plane Table :- (centring - levelling - orientation)

① centring :-	• done by plumbing fork • operation of Bringing plotted station point exactly over the grd station.
② Levelling	• done by spirit level / Level tube • operation of Bringing the plane table in horizontal plane

③ Orientation

It is operation of keeping table parallel to position, it occupied at the first station.

In such case all the lines plotted will be parallel to the corresponding lines on ground.

methods of orientation :-

(i) By Trough compass	• can not used where local attraction suspected.
(ii) By Backsighting	• most accurate method of orientation
(iii) By resection	(i) By Back ray (ii) By solving 2 point problem (iii) By solving 3 point "

method of plane Table survey :-

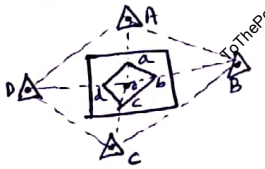
(i) radiation (ii) Intersection (iii) Traversing (iv) Resection

(i), (ii) → to plot details

(iii), (iv) → to plot stations

① Radiation

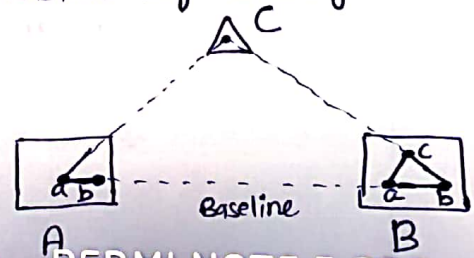
- In this instrument is setup at station and rays are drawn to various stations which are to be plotted.
- many points are plotted provided that points are accessible



- suited :- when survey area is small and all stations are clearly visible & accessible from instrument station.

② Intersection (Graphical Triangulation)

- used to plot/locate inaccesible point
- ∴ Hilly areas consist of many inaccessible point thus used there.
- In this method 2 stations are selected such that all the other stations to be plotted are visible from these.
- A line joining these 2 station is called Baseline. The length of Baseline is measured very accurately.



③ Traversing

- similar to compass / Theodolite Traversing.
- Table is set at each of stations in succession, a foresight is taken to the next station and req. distance is cut according to suitable scale.

Ex. when narrow strip of Terrain surveyed (Survey of road, railways)

④ Resection :

- This method of orientation is used/employed when the plane table occupies a position not yet plotted on drawing sheet.
- Resection → process of locating the instrument station occupied By plane table by drawing rays from the stations — whose positions are already plotted on drawing sheet.

Resection is done by 3 methods →

(i) By Back ray	when one of the plotted stations is accessible from the station to the plotted stations
(ii) 2 point Problem	• consist of locating the position of a plane table station on sheet by observation of 2 well defined points whose position have already been plotted on the plan.
(iii) 3 point problem	can be solved by (i) Graphical method (ii) Trial & error method (iii) mechanical method (iv) Analytical method (Lehman's method) (v) Geometrical construction method

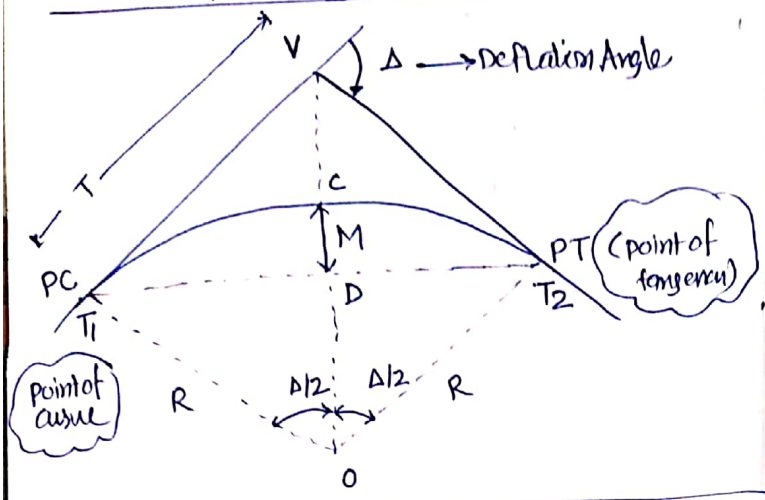
Lehman produre (3 point problem) :-

(i) plane table levelled over in station point
(ii) 3 resection lines are drawn from 3 well defined station point (iii) Triangle of error obtained
(iv) using Lehman rule an improved position of station point is obtained.
(v) procedure is repeated till the angle of error is reduced to the point.

note :- if point P is with in great circle & middle station is much near or to P than the other 2 stations → (fix) is good

note :- The resection position of plane table station from 3 known position is not determined (unreliable) if station lies on great circle passing through 3 known positions

Elements of simple circular curve :-



① Length of curve (l)	$R\Delta = R \times \Delta \times \frac{\pi}{180}$ (Δ in radian)
② Tangent Length	$T = R\tan\Delta/2$
③ chainage of tangent points	T_1 = Chainage of V − T_1 T_2 = Chainage of $T_1 + l$
④ Length of long chord (T_1DT_2)	$2R\sin\Delta/2$
⑤ mid ordinate 'or' versine of curve (M)	$R(1-\cos\Delta/2)$
⑥ External distance or Apex distance (VO − CO) = E	$R(\sec\Delta/2 - 1)$

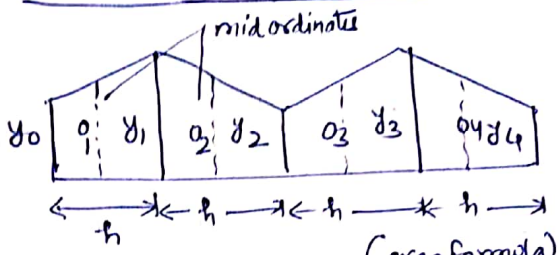
note:- ① In transition curve :-

$$\text{Polar deflection Angle } (\delta_s) = \frac{\text{spiral Angle } (\Delta_s)}{3}$$

② Rankine method of Deflection Angle :- $\Delta_2 = \Delta_1 + \delta_2$

Deflection Angle for any chord (Δ_2)
= Deflection angle for preceding chord (Δ_1)
+ tangential angle of that chord (δ_2)

measurement of Area & volume :-



(area formula)

① mid-ordinate method	avg of midordinate × Length of Base $= \left[\frac{O_1 + O_2 - - O_n}{n}\right] \times (n \cdot h)$ $= (O_1 + O_2 - - O_n) \times h$
② Avg. ordinate method	avg. ordinate × Length of Base $\frac{y_0 + y_1 + - - y_n}{(n+1)} \times (n \times h)$
③ Trapezoidal Rule (end area method)	• more accurate than mid & Avg ordinate method $\frac{h}{2}\left[(y_0 + y_n) + 2(y_1 + y_2 - - y_{n-1})\right]$
④ Simpson's 3rd Rule (Prismoidal formula)	• when odd no. of ordinates (Imp) $\frac{h}{3}\left[(y_0 + y_n) + 4(y_1 + y_3 - -) + 2(y_2 + y_{4+})\right]$ note:- Length of Boundries b/w 2 adjacent ordinate is Parabolic arch.

Instruments

① Miningdial :- Theodolite built in compass used for mine survey.

② Brunton's Compass :- Combination of compass & clinometer

③ distance measuring Instrument :-

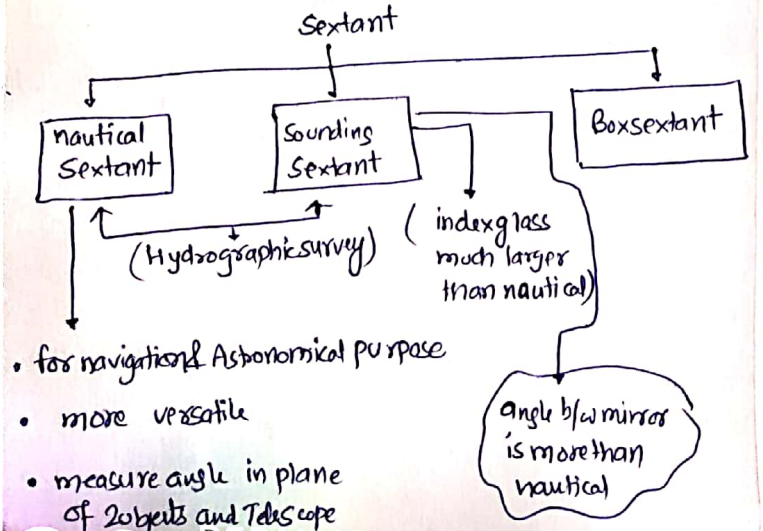
- Pasometer • pedometer • pacing • perambulator
- odometer (no. of revolutions req.)
- Speedometer
- subsidence bar → horizontal distance (baseline of small Triangulation, to fix control point in any area)
- Tellemeter – remote plate distance
- Telluro meter – microwave electronic equipment, Geodetic purpose
- Geodimeter (25 km से कम के लिये)
- EDM

④ right angle measurement

- cross staff < open / French (45°, 135° also)
- Site square • prism square • range finder
- optical square ≡ Box sextant (used to measure angle) box 75mm dia, 40mm deep (both → horizontal glass & index glass)

⑤ Sextant principle :- 2 mirror → light successively reflect then angle b/w 1st & last ray = 2 × angle b/w mirror

note :- if angle b/w index glass and horizontal glass = 40° (40°) then horizontal angle b/w 2 points = 2 × 40 = 80°



⑥ Anglemeasurement

- Theodolite
  - Horizontal angle (H)
  - vertical angle (V)
- sextant (H) (V)
  - scroll feature
    - arrangement of 2 mirrors which enables the observer to sight the different object simultaneously.

clinometer → measure angle of slope, elevation, depression wrt gravity direction.

⑦ Depth measurement :-

- Soundingrod (measurement below water surface)
- Pathometer (Ocean depth नाप ने के लिये)
  - ecosounding system for measurement of depth
  - permanent record of depth

⑧ velocity measurement of water
- Pricemeter
- Current meter

⑨ Altitude measurement
- Altimeter
  - (Altitude of object from fix end)
- Abney Level
  - (height measurement)

⑩ Tangent clino meter :- to get difference in elevation between points.
- → indian pattern clinometer
- → plane survey में use होता है table

⑪ Parallax :- Image formed by object is not in plane of cross hair due to height of object

⑫ Pantagraph :- enlarge / reduce already drawn plan.

⑬ Hand Level :- levelling instrument held in hand, approx. determination of elevation.

⑭ Dumpy level → only Horizontal Angle
- Telescope → non movable

⑮ wye level → telescope movable

Theory of errors :-

Error = measure value − True value
Residual — most probable value
closer to true value than any other

True error = observ value − True value
Residual error = observe value − MPV
(Vi) (xi)

Weight of Quantity :- (its relative Trust worthiness of set of observation.)

Sum/difference ⇒ $\frac{1}{\frac{1}{W_1}+\frac{1}{W_2}}$

$kW \longrightarrow \frac{W}{k^2}$

$\frac{W}{k} \longrightarrow k^2 W$

$k+W \longrightarrow W$

$k-W \longrightarrow W$

- The weight of the weighted arithmetic mean of observation is equal to sum of the wts of observations.

Ex. 5.48 $S = \frac{.01}{2}$ $e = S/_2$

5.0 $S = \frac{.1}{2}$ $e = S/_2$

	max. error	Probable error
$x+y$	$\delta x + \delta y$	$\sqrt{(e_x)^2 + (e_y)^2}$
$x-y$	$\delta x + \delta y$	$\sqrt{(e_x)^2 + (e_y)^2}$
xy	$x\delta_y + y\delta_x$	$\sqrt{(xe_y)^2 + (ye_x)^2}$
$\frac{x}{y}$	$\frac{y\delta_x + x\delta_y}{y^2}$	$\sqrt{\left(\frac{ye_x}{y^2}\right)^2 + \left(\frac{xe_y}{y^2}\right)^2}$

① find most Probable value of A = ?

$2A = 20'10'$ weight = 2
$4A = 40'10'$ weight = 3

Soln: $2 \times [2 \times 2A] = (2 \times 20'10') \times 2$
$3 \times [4 \times 4A] = (4 \times 40'10') \times 3$

$56A = $ ——

② Adjust the following Angle closing horizons ?

	weight
$P = 110°20'48''$	4
$Q = 92/30/12$	1
$R = 56/12/00$	2
$S = 100/57/04$	3

$\Sigma = 360/0/04''$
hence correction = $(-4'')$

$\because c_1 : c_2 : c_3 : c_4 = \frac{1}{4} : \frac{1}{1} : \frac{1}{2} : \frac{1}{3}$

{$\because c_1 : c_2 : c_3 : c_4 = 3 : 12 : 6 : 4$}

$\therefore c_1 = \frac{-3}{25} \times 4'' = -.48''$ $c_3 = $ —

$c_2 = \frac{-12}{25} \times 4'$ $c_4 = $ —

$\therefore \angle P = 110/20/48 - 0.48'' = 110°20'47.52''$

Photogrammetry :-

Napier rule :- Applicable for right angled spherical Triangle

Spherical Excesses :- sum of angle of spherical Triangle exceeds 180°

Astronomical Triangles :-

Vertices of Astronomical Triangle (Zmp) → Zenith, Celestial Body, Pole

Note :-

(i) Path of stars is the result of diurnal motion of earth.

(ii) points at which sun declination is maximum are known as → (solstice)

(iii) —Zero → vernal Equinox.

$\frac{x_a}{X_A} = \frac{f}{H-h_a} = \text{scale} = \frac{\text{map distance}}{\text{Grd. distance}}$

f → camera focal Length

h_a → height of grd above MSL

H → height of exposure station above MSL

$L_{AB} = \sqrt{(X_A-X_B)^2 + (Y_A-Y_B)^2}$

$h_{avg} = \frac{h_A+h_B}{2}$

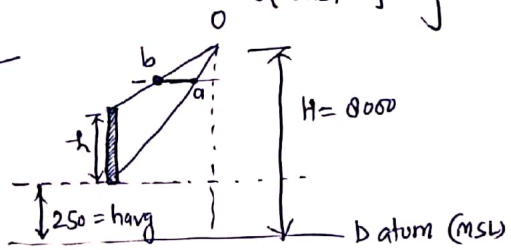
datum scale ⇒ $h=0 \therefore S = f/H-0$

$d = \frac{\Delta h}{H - h_{avg}}$ → Δh → height of Towers; h_{avg} → height of object above MSL

d → relief Displacement = top − bottom

Imp: relief displacement ∝ focal Length, ∝ dist. of object from Ndir point (V)

Ex.



① Aerial survey steps : (i) Recanisance (ii) establish ground controll (iii) flight planning (iv) Photography (v) paperwork including Computing & planning

2- **principle point** :- A point where (perpendicular) from the optical centre of lens meets photograph.

3- **Plum point** :- a point where (vertical) thrgh the optical centre of lens meets photograph.

4- **Perpective point** :- A point where rays from the object converge.

5- Index mosaic photograph are pasted on fibre board and whole assembly is photographed Again.

6- Indx mosaic are not true planimetr representation of the area.

no. of photograph in each strip.

$N_1 = \frac{L_1 \text{ (Length)}}{(1-P_l) \times S \times l} + 1$

P_l → % lap in long direction; l → length of photo in direction of flight; 10000 (if 1:10000)

no. of strips ⇒ $N_2 = \frac{L_2}{(1-P_w) S l} + 1$

① Geometrical centre of photograph is defined by intersection of lines joining the fiducial mark.

② map → orthogonal projection
photo → central "

③ Drift → Latiral shifting of photograph

④ Crab → (occured while avoiding Drift)
↳ when aircraft is not orientated with flight line, photograph are not parallel to flight line.

18/4/2020