

SURVEYING

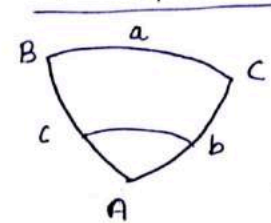
Plane surveying	Geodetic surveying
Earth surface not taken into account	taken into account गोलाकार Curvature of earth taken
For small area (<195.5 km ²)	For Larger area (>195.5 km ²) 18.5 km → 1.52 cm का अंतर 19.5 km ² → 18 cm का अंतर
Less accurate	more accurate
Line joining 2 points in this is line	arc
uses:- on Large scale like dam, bridge, highway	uses:- in establishing - control point for plane survey (done by national survey of India)

classification of survey based on

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- military "	2- Tachometer
3- Astronomical Survey	3- Geological "	3- Theodolite "
	4- Archeological "	4- plane table
	5- mine "	5- Triangulation
		6- Traverse "
1- Topographical survey	to locate natural & artificial features 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 boundary 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, stars	
REMARK:- don't earth different - strata		

In Geodetic surveying →

Topic → spherical Triangle :

- 
- any angle $< 180^\circ$
2 right angle
 - $180^\circ < \frac{A+B+C}{\pi} < 540^\circ$
angles sum 3π
 - sum of any 2 side $>$ Third side
 $a+b > c$
 $b+c > a$
 $a+c > b$
 - if sum of any 2 side $= \pi$ then sum of angle opposite them is also $\pi (180^\circ)$
if $a+b = \pi$ then $A+B = 2 \times 90 = 180 = \pi$
 - The smaller angle is opposite the smaller side
 - sum of 3 sides of spherical Triangle is -
always Less than circumference of Great circle.

principle of surveying :

- Whole to part
• localize the error & prevent their accumulation
- Locate a point by at least 2 measurements

$$\text{Scale} = \frac{\text{map distance}}{\text{Ground distance}}$$

$$\text{max. error on drawing} = 0.25 \text{ mm}$$

High Representative fraction $\longleftrightarrow$ Larger scale (RF)

$$\text{Shrinkage factor (SF)} = \frac{\text{Shrunk length}}{\text{original Length}} \text{ or Shrinkage ratio}$$

$$\text{Shrunk scale} = \text{original scale} \times \text{SF}$$

$$\begin{aligned} \text{Correct Length} \times \text{RF}_{\text{correct scale}} &= \text{measure length} \times \text{RF}_{\text{wrong scale}} \\ \text{Correct area} \times (\text{RF}_{\text{correct scale}})^2 &= \text{measure area} \times (\text{RF}_{\text{wrong scale}})^2 \end{aligned}$$

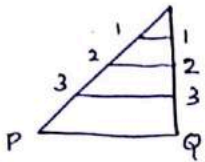
$$\begin{aligned} \text{Correct distance on map (in terms of original scale)} &= \frac{\text{measur dist. on map}}{\text{SF}} \\ \text{" area " } &= \frac{\text{area on map}}{(\text{SF})^2} \\ \text{" volume " } &= \frac{\text{volume on map}}{(\text{SF})^3} \end{aligned}$$

Types of scales :- 3 dimension (meter, centi, decimetre)

① Diagonal scale :- used to represent 3 units (main unit, its subunit, subdivision of subunit)

Based on similarity of Triangle.

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

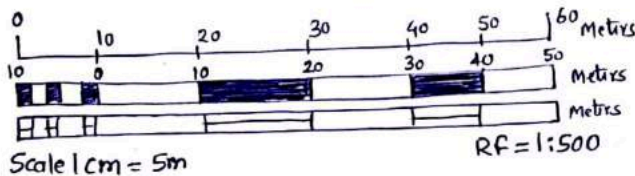


1-1 represent $\frac{1}{4}$ PQ
2-2 " $\frac{2}{4}$ PQ
3-3 " $\frac{3}{4}$ PQ

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

• 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 occurs then graphical scale also shrink proportionally & therefore ratio is unaffected.



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

- can read upto 2 decimal place
- more precise than plain scale

• vernier scale has 2 parts

used to represent 2 consecutive units like meter & decimeter feet & inch

main scale

vernier scale

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

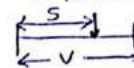
① direct vernier

$$(n-1)S = nV$$

$$L.C = S/n$$

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

$$(n+1)S = nV$$

$$L.C = S/n$$

S-V

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

③ Extended vernier

$$(2n-1)S = nV$$

$$L.C = 2S-V$$

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 scale 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

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

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 = 200m.

note: Surveying chain accuracy not good As Steel tape / Steel Band

invar tape :- • Ni (36%) + Steel (64%)

- highly precise. $\alpha \downarrow$ (very low) $\rightarrow$ Less affected due to temp.
- width 6mm Length 30, 50, 100 meter.

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

Assessories for chaining :-

- 1- Pegs $\rightarrow$ to mark point on ground.
 - 2- Arrow $\rightarrow$ जब ज्यादा Length नापनी हो तो जहाँ tape Length खत्म होनी वहाँ Arrow लगति
 - 3- Ranging rod $\rightarrow$ to locate intermediate points or to locate a no. of points on Long survey line
- note:- कई लगातार dist नापने के लिये ranging rod use कर सकते (2 or 3 m long) (30 mm dia)

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

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

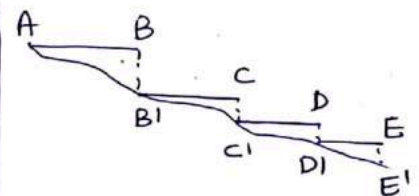
⑤ Baseline :- longest survey line on a fairly flat passing through centre of area

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

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

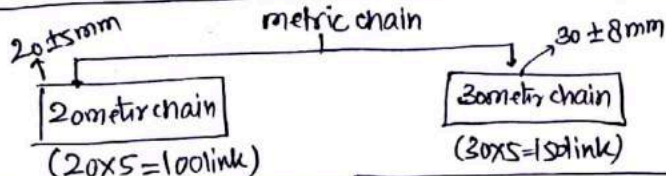
chaining in sloping ground :-

- 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



1 mile = 80 x Gunter chain 1 acre = 10 x (Gunter chain)²

Tape correction

① correction due to standardization
(+) (-)

सही x सही = गलत x गलत

② correction due to temp.
(+) (-)

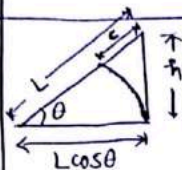
$$L \propto (T_m - T_0)$$

$T_m \rightarrow$ measurement करते समय temp.
 $T_0 \rightarrow$ std. के temp.

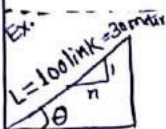
③ correction due to pull
(+) (-)

$$\frac{(P_m - P_0)L}{AE}$$

④ correction due to slope
always (-ve)



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



$$\tan \theta = \frac{h}{L} \therefore \cos \theta = \frac{L}{\sqrt{L^2 + h^2}}$$

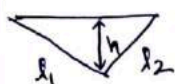
$$C = -(L - L \cos \theta) = L \left[\frac{h}{\sqrt{L^2 + h^2}} - 1 \right]$$

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

$$C = L \left[1 - \frac{1}{2} \left(\frac{h^2}{L^2} \right) - \dots - 1 \right]$$

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

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)

$$C = \frac{-w^2 L^3}{24 P_m^2}$$

$w \rightarrow N/m$

normal tension :- when

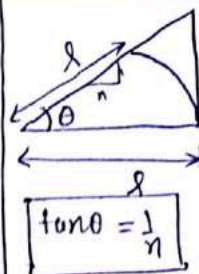
$$C_{\text{pull}} = P_{\text{sag}}$$

$$\frac{(P_m - P_0)L}{AE} = \frac{w^2 L^3}{24 P_m^2}$$

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

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

⑧ Hypotenuse Allowance



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

$$\tan \theta = \frac{h}{L}$$

error in chaining :

① Compensating error (Random error)

• liable to occur in both the direction and tend to compensate

$$\text{Compensating error} \propto \sqrt{\text{length of line}}$$

• 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 occur in same direction and tend to accumulate

Ex. error due to sag, slope etc

$$\text{Cumulative error} \propto \text{length of line}$$

• They can be corrected

chain adjustment (or) 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

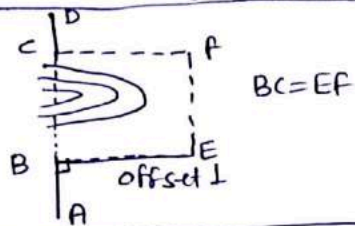
if chain found too Long.

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

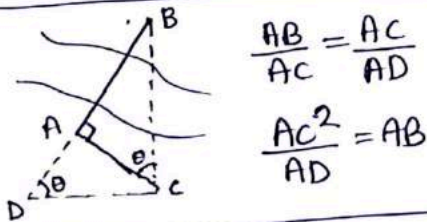
Obstacle in chaining $\begin{cases} \text{river} \\ \text{lakes} \\ \text{buildings} \end{cases}$

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

① Drawing
Perpendicular
with a chain



② making
Angular measurement



Right Angle measurement :-

① crossstaff

① open crossstaff :-

90°

② French crossstaff
(Hollow octagonal Box)

45°/90°/135°

accuracy :- open crossstaff better

② optical
square

Principle $\rightarrow$ double Reflection
• if angle b/w mirror is 45° & then
reflected ray is 90 degree to
incident ray

③ prism square

Principle same as optical square
 $\rightarrow$ prism used.

Ranging :- process of establishing intermediate point

① Direct
ranging

• where end station visible.

(a) ranging by eye

(b) ranging by line ranger

② 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

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 meter

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

$\rightarrow$ error in length

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

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

note :- random line method of Ranging :-
• [chain used to erect a $\perp$ taking 3 sides of Δ
in ratio of 3:4:5]

obstacle in ranging :- $\begin{cases} \text{hill} \\ \text{Building} \end{cases} \begin{cases} \text{not}^{***} \\ \text{river,} \\ \text{lake} \end{cases}$

chain surveying	Traverse surveying
① only Linear measurement ∴ relatively easier	① Both Linear & angular measurement.
② framework consist of Triangles	② framework consist of series of connected lines open or closed polygons
③ check lines are exp. to check the accuracy of work	③ 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
- ② Plane Table "
- ③ Stadia "
- ④ 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.

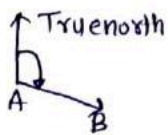
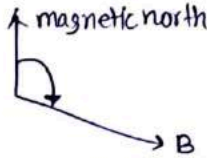
• This magnetic needle shall not be affected other than that of earth.

imp.

• At point varies with time (not fixed)

Bearing → Horizontal angle of line wrt reference line (meridian)

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

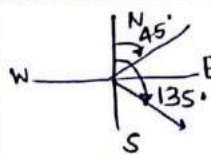
True Bearing	Magnetic Bearing
1- measured wrt true north (true meridian) in clockwise direction	1- measured wrt magnetic north (magnetic meridian)
 (horizontal angle b/w True meridian & line)	 (horizontal angle b/w magnetic meridian & line)
2- does not change with time as True meridian at a point is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

whole circle bearing (WCB)

↓
Prismatic compass

• measured from north in clockwise direction.

• varies 0° to 360°

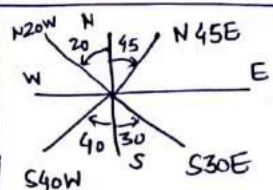


Quadrantal bearing (QB)

↓
Surveyor compass

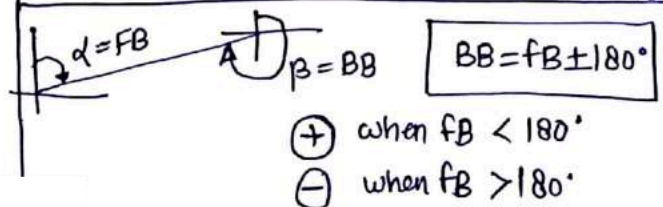
• measured from north or south point whichever is closer

• varies 0° to 90°

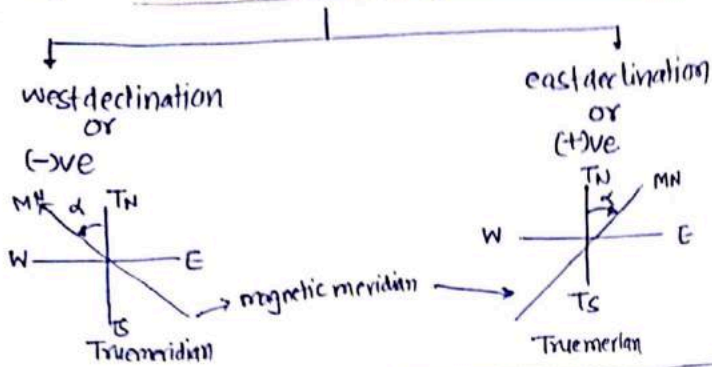


Fore bearing (FB) :- Bearing of line in the direction of progress.

back bearing :- opposite direction of progress



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



True Bearing = magnetic bearing - declination

True bearing = magnetic bearing + declination

variation of magnetic declination :-

(i) Secular variation	occurs 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 <u>period of 1 year</u> .
(iii) Diurnal variation	(due to rotation of earth about its 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.

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 $\neq 180^\circ$

(A) error in observation of either FB, BB or both.

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

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

- magnetic needle $\rightarrow$ align with magnetic force
 - in horizontal @ Equator $\text{dip} = 0$
 - vertical @ pole $\text{dip} = 90^\circ$
- } dip (0-90°)

- 1- lines of equal annual change (magnetic Dec) $\Rightarrow$ Isopms
- 2- Isogonic $\rightarrow$ same magnetic Declination
Agonic $\rightarrow$ zero
- 3- Isoclinic $\rightarrow$ same dip
- 4- Aclinic $\rightarrow$ zero dip

Prismatic compass (WCB)

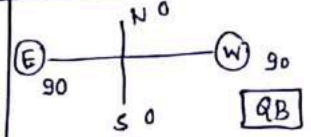
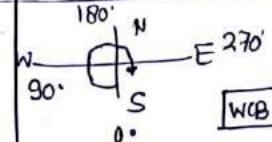
Surveyor compass (QB)

magnetic needle

Broad needle

edge bar type

Graduated ring



reading system

with the help of Prism provided at eye vane

direct seeing through top of the box glass

Tripod

instrument can be held in hand while making observations

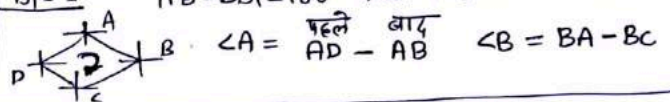
Tripod must

vanes

eye vanes consists of a metal vane with a large slit

eye vane consists of small vane with small slit

Type-1 :- $|FB - BB| = 180^\circ \Rightarrow$ solve by interior angle



Type-2 :- $|FB - BB| \neq 180^\circ \rightarrow$ find interior angle $\angle A$, ---
add suppose = $(536) \text{ } 1540^\circ$

$\therefore$ correction needed per angle = $+4^\circ/5 = 0^\circ 48' 00''$

$\therefore$ new corrected Angle = $\angle A, \angle B$ ---

assume AB as correct $\therefore BB - FB = 180^\circ$

$\therefore \angle A = AE - AB$ find AE = ?

note: (1) Difference b/w FB & BB for any station $\Rightarrow$ Interior Angle

(2) Included Angle = FB of next line - BB of previous line

(3) if traverse clockwise $\Rightarrow$ included Angle will be exterior Angle

(4) $\rightarrow$ anticlockwise $\Rightarrow$ 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 the reading
- least count = $20''$ second

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

Precise optical theodolite

or

microoptic theodolite

- fitted with an optical system used to read both horizontal & vertical angle precisely
- in this micrometer is used for taking readings
- can read angle up to 1 second or less

note:- (1) $\left\{ \begin{array}{l} \text{lower plate} \rightarrow \text{Scale plate} \\ \text{upper plate} \rightarrow \text{Vernier plate} \end{array} \right.$

Scale plate :- It contains a scale which 0 to 360° readings are graduated.

Vernier plate

(ii) Size of theodolite $\rightarrow$ Size of lower graduated circle
Ex. 20cm theodolite $\rightarrow$ dia. of graduated circle of lower plate is 20cm.

note:- if the theodolite circle is divided into $30'$ or $1'$ half degree
The no. of division on vernier scale to read 1 min.

$\frac{1}{2} \times \text{smallest division on main scale}$
1 min. $\frac{1}{2} \times 30' = 15'$

Basic Definitions :-

1- centering :- setting up station exactly over station.
• done by plumb line.

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

3- Vertical axis / Azimuth axis $\rightarrow$ @ Horizontal plane

4- Line of sight / line of collimation :- Imaginary line passing through the intersection of crosshair of diaphragm and the optical centre of objective
• when line of sight 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 $\Rightarrow$ 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.

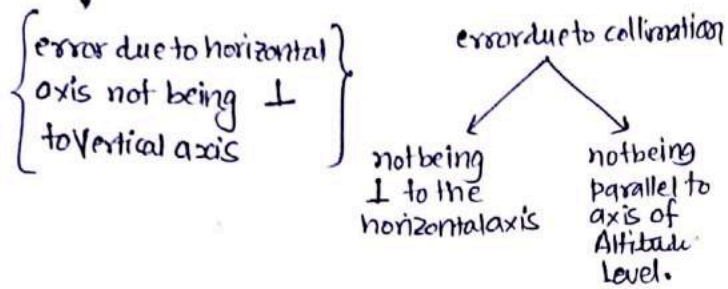
$\left\{ \begin{array}{l} \text{Sight swing} \rightarrow \text{clockwise rotation} \\ \text{Left} \rightarrow \text{anticlockwise} \end{array} \right.$

12- double sighting :- process of measure horizontal or vertical angle twice, one 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



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

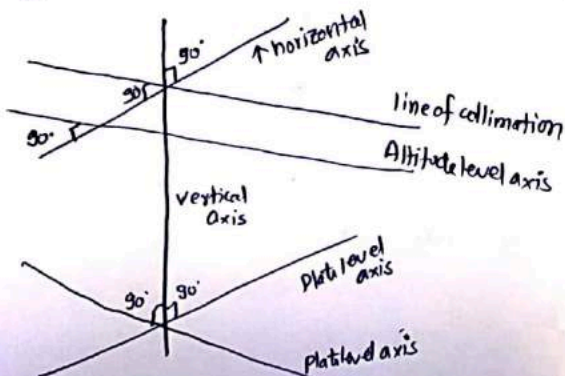
15- Balancing In → @ whose ends are not invisible

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

fundamental lines of Theodolite

- ① vertical axis ② Horizontal axis (Trunnion axis)
- ③ axis of plate level ④ line of collimation
- ⑤ bubble line of Altitude

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



- ① Horizontal circle $\perp$ vertical axis
- ② vertical axis must pass through the centre of graduated horizontal circle
- ③ vertical circle $\perp$ horizontal axis
- ④ horizontal axis must pass through centre of vertical circle
- ⑤ Tangent to plate bubble tube must be $\perp$ 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 हो 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 Theodolite :-

aim $\rightarrow$ to establish relation b/w fundamental -
imp. lines of theodolite.

order :-	P	C	C	S	B	V
	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 <u>vertical cross hair</u> lie in a plane perpendicular to the horizontal axis					
③ collimation in Azimuth Test	make the <u>line of sight</u> perpendicular to horizontal axis					
④ Spire Test	make <u>horizontal axis</u> perpendicular to vertical axis.					
⑤ Bubble Tube adjustment	make <u>telescope bubble central</u> when line of sight is horizontal					
⑥ vertical arc Test	make the <u>vertical circle</u> indicate <u>Zero</u> when line of sight is perpendicular to the vertical axis					

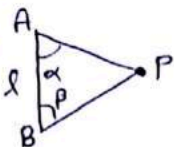
measurement of Horizontal angle :-

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	• prefer in Triangulation. • where no. of angles may be required at one station by the instrument with finely graduated circle.

Traverse $\Rightarrow$ series of connected lines whose length and direction are measured in field

Traverse principle $\Rightarrow$

(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) Reconnaissance
- (ii) selection & marking of station
- (iii) measurement of Traverse line (linear measurement)
- (iv) angular details (Angles)
- (v) Picking up details

(4) method of direct angle

• similar to included angle method

• for open traverse

• in this direct angle or angle to the right is measured.



(5) method of deflection angle

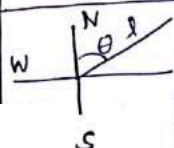
(for open traverse) • conducted for survey of roads, railways, canal, pipelines where traverse line make small deflection angle



note:- earlier when distance measuring - Instrument were not there, we used Triangulation

Triangulation $\rightarrow$ one Base line measure then all angles measured to get lengths of other lines

note:- for n.no. of stations $\angle FB = 'n-1'$
 $\angle BB = 'n-1'$



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 = $\frac{e}{P} = \frac{\text{closing error}}{\text{Perimeter of traverse}}$
 $= \frac{1}{(P/e)}$

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

Angular measurement in Theodolite Traverse :-

- | | |
|---------------------------------------|---|
| (i) Loose needle (free needle) method | <ul style="list-style-type: none"> • Less accurate • magnetic bearing of each line is measured at each station |
| (ii) Fast needle method | <ul style="list-style-type: none"> • more accurate than 1st method • used in field • only magnetic bearing of 1st line measured and with help of <u>included angle</u> we can get magnetic bearing of all other lines. |
| (iii) method of Included Angle | <ul style="list-style-type: none"> • most commonly used method • magnetic bearing of any line (generally 1st) is measured and all included angles are measured <p><u>note</u>:- All angles are measured in clockwise direction because Theodolite graduation increases in clockwise directions.</p> |

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.

$$\left. \begin{array}{l} \text{error in linear measurement} \propto \frac{1}{\sqrt{L}} \\ \text{error in Angular} \propto \frac{1}{\sqrt{L}} \end{array} \right\}$$

$$\left. \begin{array}{l} C_L = \left(\frac{1}{\sum L} \right) \times \sum L \\ C_D = \left(\frac{1}{\sum L} \right) \times \sum D \end{array} \right\} \begin{array}{l} \text{in this} \\ \text{after} \\ \text{correction} \\ \text{both length} \\ \text{\& bearing changed} \end{array}$$

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

② Transit rule

In this angle precision > Length precision

$$\left. \begin{array}{l} C_L = \left(\frac{L}{L_T} \right) \times \sum L \\ C_D = \left(\frac{D}{D_T} \right) \times \sum D \end{array} \right\} \begin{array}{l} L_T, D_T \\ \text{same of} \\ \text{latitude} \\ \text{departure} \\ \text{without} \\ \text{considering sign.} \end{array}$$

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
(if line is either parallel to x or y)
Then as per transit rule $\Rightarrow$ no correction
in bearing of line.

③ Axis method | ④ Graphical method

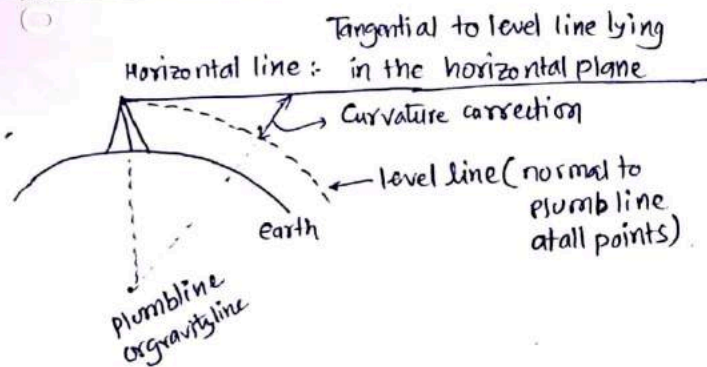
calculation of area of traverse (As per meridian distance method)

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

$$\text{Area} = \left| \sum m L \right|$$

Levelling $\rightarrow$ 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 Foresight (FS).



Line of sight $\rightarrow$ 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 $\rightarrow$ for vertical control

adopted by survey of India for reference is located at Bombay High (Mumbai)

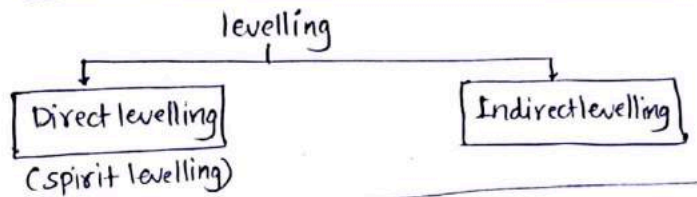
- MSL obtained by averaging the elevation of high tides and low tides at several points for a long period of time (ie 19 years)

$$\text{error} = \text{measured value} - \text{True value} \\ (\sum BS - \sum FS) \quad (\text{last RL} - \text{first RL})$$

1- HI method $\rightarrow$ check only BS, FS

2- Rise & fall method $\rightarrow$ check BS, FS + Intermediate sight also

$$\sum BS - \sum FS = \sum \text{Rise} - \sum \text{fall} = \text{Last RL} - \text{1st RL}$$

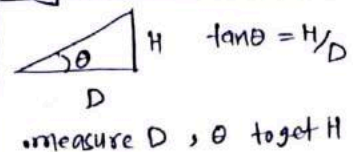


(A) Direct levelling: most commonly used

- 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 levelling:

(i) Trigonometric levelling (stadial levelling)



(ii) Barometric Levelling

- Based on change in atm. pressure.
- atm. pressure $\downarrow$ Elevation $\uparrow$
- 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 $\uparrow$ Boiling point $\downarrow$

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
- req. more than 1 setting of instrument



③ check levelling	- Type of differential levelling - To check elevation which have already plotted.	① Curvature correction $C_c = \frac{-d^2}{2R} = -0.0785d^2$ (metre) ② Refraction correction $C_R = +\frac{1}{7} C_c = +0.0112d^2$ (metre) $R = 6370 \text{ km}$ $C = C_c + C_R = -0.0673d^2$ $\therefore$ distance of visible horizon $d = 3.85 \sqrt{h}$
④ fly levelling	- type of differential levelling - to find approx elevation of different points where rapidity is needed & less precision req. - used for reconnaissance of area for approx level check	distance of observer from Light house (d) $d = 3.85 (\sqrt{h_1} + \sqrt{h_2})$ ⑤ $h_1 \rightarrow$ Top of light house above sea $h_2 \rightarrow$ height of observer eye above sea
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.	Collimation error = $\frac{\text{True level by formula} - \text{observed level}}{2}$ $(h_B - h_A) - (h_B' - h_A')$
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.	note:  - Staff reading $h_A = 0.0673d^2$ - RL $h_A' = 0.0673d^2$ v.v.sml effect of corrections
⑦ Precise levelling	very accurate Differential levelling in this levelling, "level" is used major component of level Telescope or Bubble Tube level Tube	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
• 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 $\left\{ \begin{array}{l} \text{curvature error} \\ \text{Refraction error} \\ \text{collimation error} \\ \text{error in Instrument measurement} \end{array} \right\}$ (not parallax error) ③ True level difference b/w 2 points $H = \frac{(h_B - h_A) + (h_B' - h_A')}{2}$		$S \rightarrow$ difference b/w 2 staff reading $n \rightarrow$ no of division of Bubble $D \rightarrow$ distance $l \rightarrow$ length of 1 division (if not given assume 2mm) $R \rightarrow$ radius of curvature of bubble tube
Sensitivity $\uparrow$:- ways? ① Radius of tube (R) $\uparrow$ ② Length of Tube $\uparrow$ ③ dia of Tube $\uparrow$ ④ viscosity $\downarrow$ ⑤ surface tension $\downarrow$ ⑥ roughness $\downarrow$ (Smoothing the inner surface of tube)		

Tacheometry :: (optical distance measurement method)
 Flat ground → accuracy of Tacheometry distance low
 Rough-sloping ground → more accuracy
 → used in Hill terrain when tape chaining is difficult

Method of Tacheometry $\left\{ \begin{array}{l} \text{Stadia method} \\ \text{Tangential " } \\ \text{Rangefinding " } \end{array} \right\}$

I- Stadia method

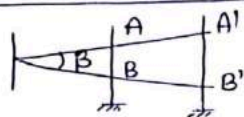
fixed hair method

(β fix, S vary)

movable hair / sub-stense method

(S fix, β vary)

(A) fixed-hair method ::



β fix, S vary
 ↓ ↓
 Parallel angle Staff intercept
 ($AB, A'B'$)

Stadia method principle :: $\left\{ \begin{array}{l} \text{Ratio of perpendicular} \\ \text{to Base is constant} \\ \text{in isosceles triangle} \end{array} \right\}$

$$D = KS + C$$

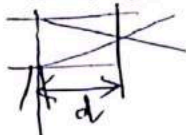
$$D = \left(\frac{f}{i} \right) S + (f + d)$$

K = multiplying factor / constant
 $K = f/i = \text{Stadia interval factor}$

f → focal length of objective

i → Stadia Interval (interval b/w stadia hairs of vertical dist b/w stadia wires or hair distance diagram)

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



Internal focusing Telescope - small
 external " " zero

note :: Anallactic lens (convex lens type) $K=100, C=0$ → to make additive const = 0

(B) movable hair method (sub-stense method) ::

(S fix, β vary)

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

↓
 revolution of micrometer

$$K = f/P \rightarrow \text{Pitch of screw}$$

note: if micrometer reading of drum of diagram = 3.1258
 then $m = 3.125 + 3.450$

if 20 threads in 1cm then $P = \frac{1}{20} \text{ cm}$

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 bisect)

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

note :: sub-stense bar (Horizontal staff) :: rod of fix length horizontally mounted on tripod.

- where chaining not possible because of undulation and rough country used to find short distance of 200m.
- used for measurement of horizontal distance (indirectly)
- in this case minimum refraction error.

(2) Tangential method :: (inferior to stadia method)

- used when diaphragm does not have stadia hair, when staff is too far from instrument and it becomes difficult 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.

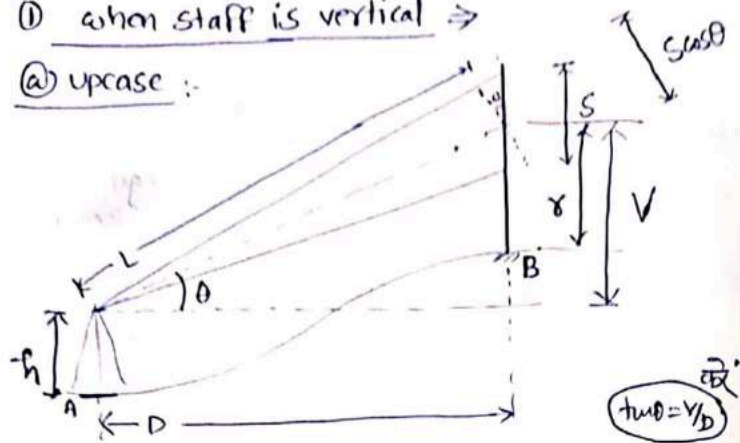
note :: Tilt of staff away from telescope pointing up the hill.
 → increases the intercept ($A'B'$)



Distance and elevation formula for inclined sight :-

① when staff is vertical $\Rightarrow$

(a) upcase :-

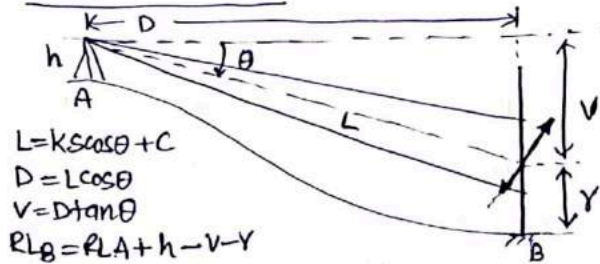


$$L = (K S \cos \theta + C) \rightarrow \text{as per formula}$$

$$\left. \begin{array}{l} \text{Horizontal distance } D = L \cos \theta \\ \text{Vertical } V = D \tan \theta \end{array} \right\}$$

$$\text{elevation of staff station B} = \text{elevation of station (instrument)} + h + V - S$$

(b) depression case :-



$$L = K S \cos \theta + C$$

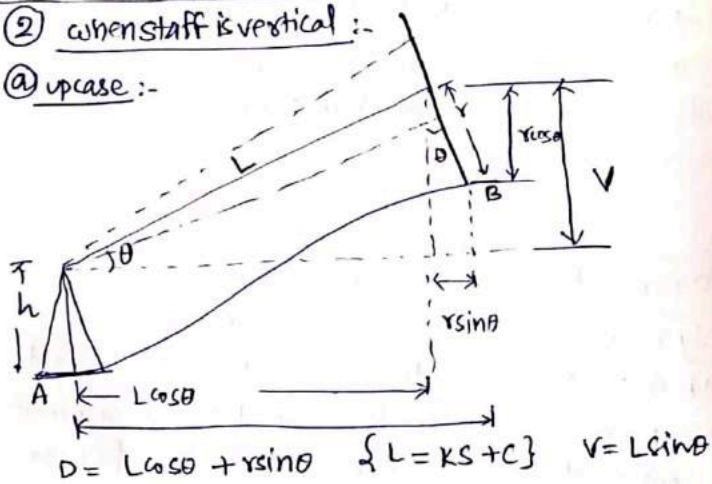
$$D = L \cos \theta$$

$$V = D \tan \theta$$

$$RL_B = RL_A + h - V - S$$

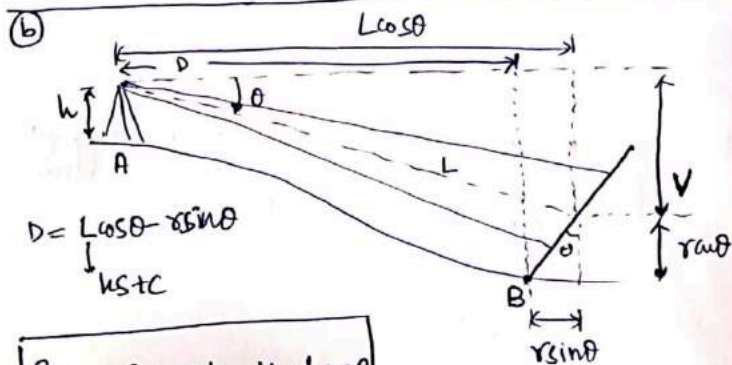
② when staff is inclined :-

(a) upcase :-



$$D = L \cos \theta + S \sin \theta \quad \{ L = K S + C \} \quad V = L \sin \theta$$

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



$$D = L \cos \theta - S \sin \theta$$

$$K S + C$$

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

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

note : ① Generally contours are not visible on ground except in case of shorelines.

② when contours are drawn under water they are known as submarine contours, fathoms, Bathymetric curves.

contouring methods

① Direct method	• Tedious, time taken more, accurate • used for small area • for large scale maps where ground is regular	
② Indirect method	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
or contouring by spot level	method of cross section	for road, railway, canal survey
	Tachometric 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 :- The vertical distance b/w consecutive 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 :-

① 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.
② Purpose of Map	for detail design $\rightarrow$ small C.I However cost of work increases with small contour interval.
③ Nature of ground	for flat ground $\rightarrow$ small C.I steep slope $\rightarrow$ large C.I
④ Time	Time $\propto \frac{1}{CI}$
⑤ Funds	Fund $\propto \frac{1}{CI}$

Properties of contour lines :-

- ① All points on contour lines $\rightarrow$ same elevation
- ② where no value is represented $\rightarrow$ Flat Terrain
- ③ Zero meter contour $\rightarrow$ coast line
- ④ 2 contour lines don't intersect
(Except $\left\{ \begin{array}{l} \text{overhanging cliff} \\ \text{cave penetrating hill sides} \end{array} \right.$)
- ⑤ Equally spaced contours $\rightarrow$ uniform slope
- ⑥ Contour well apart $\rightarrow$ Gentle slope
- ⑦ High figure inside $\rightarrow$ Hill
- ⑧ Low " $\rightarrow$ depression, lake, pond
- ⑨ irregular contours $\rightarrow$ uneven ground surface
- ⑩ (watershed or ridge line) & (valley line/wedgeline) cross the contours at right angle.

note:- watershed / Ridge line :- line joining highest points of series of hills.

valley line / 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 $\rightarrow$ cartographic surveying.
- ⑥ principle of plane table survey :-
an unknown point of interest 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 useful.

Disadvantage :-

- 1- not suited for work in wet climate (rainy season) and in a densely wooded country (area).
- 2- absence of field notes causes inconvenience if survey is to be replotted to some different scale.
- 3- plane table is heavy & awkward to carry and accessories are likely to be lost.
- 4- It does not give accurate result.

Accessories :-

① plane Table board	made of well seasoned wood.
② Tripod	levelling of board is done by Tripod Legs
③ Alidade (sighting device)	• used for sighting the objects & drawing the lines • nowadays Telescopic alidade 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 Tube	• used for levelling the plane table. • It is placed on the board in 2-positions mutually at right angles and the bubble is centred in arch position to make the board horizontal.
⑥ Plumbing fork (U shape)	• used for centring of plane table over stationing
⑦ Drawing sheet	Best Quality so that it withstands rubbing, ^{centring}

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

① centring :-	• done by plumbing fork • operation of Bringing plotted station point exactly over the ground 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 :-

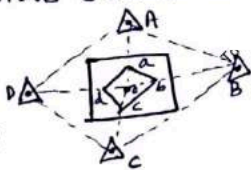
- | | |
|---------------------|--|
| ① By Trough compass | • can not used where local attraction - suspected. |
| ② By Backsighting | • most accurate method of orientation |
| ③ By Resection | (i) By Back ray
(ii) By solving 2 point problem
(iii) By solving 3 point " |

method of plane Table survey :-

- ① radiation ② Intersection ③ Traversing ④ Resection
- to plot details to plot stations

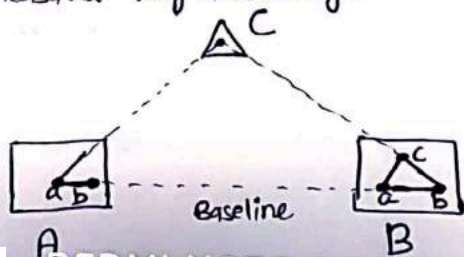
① Radiation

- 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

- used to plot/locate inaccessible 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 stations is called - Baseline. The length of Baseline is measured very accurately.



③ Traversing

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

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 →

① By Back ray

- when one of the plotted stations is - accessible from the station to the plotted station

② 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.

③ 3 point Problem

- can be solved by ① Graphical method ② Trial & error method (Lehman's method)
- ③ mechanical method ④ Analytical method
- ⑤ Geometrical construction method

Lehman procedure (3 point problem) :-

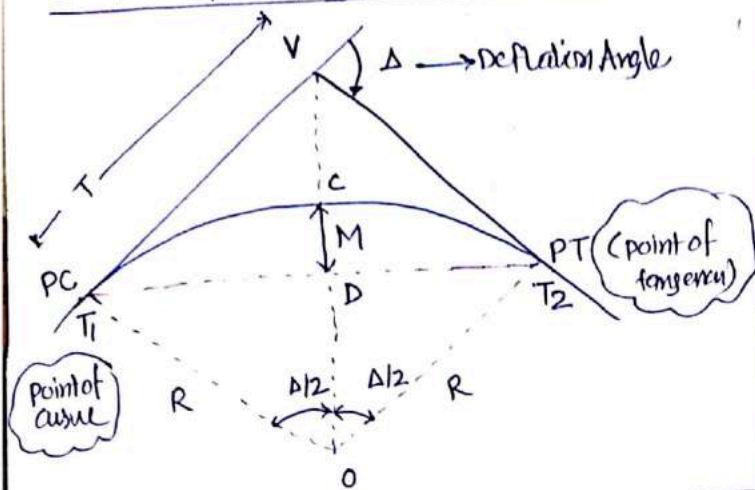
- ① plane table levelled over in station point
- ② 3 resection lines are drawn from 3 well-defined station point
- ③ Triangle of error obtained
- ④ using Lehman rule an improved position of station point is obtained.
- ⑤ procedure is repeated till the angle of error is reduced to the point.

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

2nd 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)	$R \Delta = R \times \Delta \times \frac{\pi}{180}$ radian
② Tangent Length	$T = R \tan \Delta/2$
③ chainage of tangent points	$T_1 = \text{chainage of } V - T$ $T_2 = \text{chainage of } T_1 + l$
④ Length of long chord (T ₁ D T 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 :-

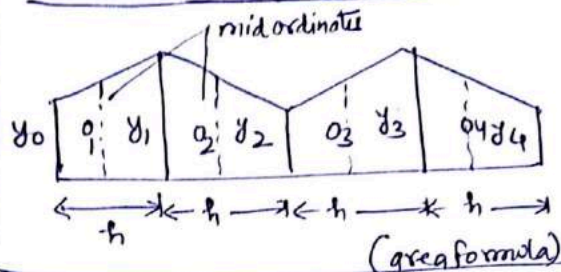
$$\text{Polar deflection Angle} = \frac{\text{Spiral Angle } (\Delta_s)}{3}$$

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 :-



① mid-ordinate method	avg of mid ordinate $\times$ Length of base $= \left[\frac{y_1 + y_2 + \dots + y_n}{n} \right] \times (n \times h)$ $= (y_1 + y_2 + \dots + y_n) \times h$
② Avg. ordinate method	avg. ordinate $\times$ Length of base $\frac{y_0 + y_1 + \dots + y_n}{(n+1)} \times (n \times h)$
③ Trapezoidal Rule (end area method)	• more accurate than mid & Avg ordinate method $\frac{h}{2} [(y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1})]$
④ Simpson's 1/3 Rule (Prismoidal formula)	• when odd no. of ordinates Ind $\frac{h}{3} [(y_0 + y_n) + 4(y_1 + y_3 + \dots + y_{n-1}) + 2(y_2 + y_4 + \dots + y_{n-2})]$ note:- Length of Boundaries b/w 2 adjacent ordinates is parabolic arch.

Instruments

① Mineralogical : Theodolite built in compass used for mine survey.

② Brunton's Compass : Combination of compass & clinometer

③ Distance measuring Instrument :-

• Pedometer • pedometer • pacing • Perambulator

• Odometer (no. of revolutions req.)

• Speedometer

• Substrate bar → horizontal distance

(Baseline of small Triangulation station centrol point in an area)

• Tellurometer - remote plat distance

• Telluro meter - microwave electronic equipment, Geodetic principle

• Geodimeter (25 km से कम के फलसे)

• EDM

④ right angle measurement

• cross staff $\left\{ \begin{array}{l} \text{open} \\ \text{French (45', 135' also)} \end{array} \right.$

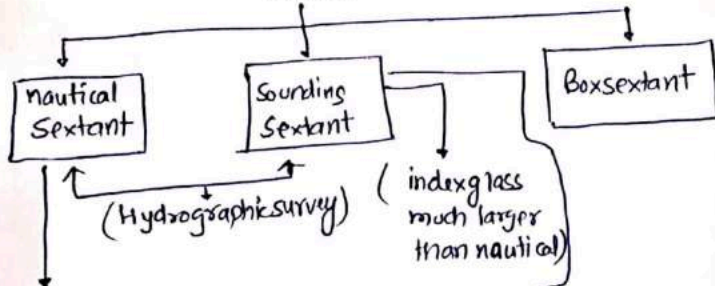
• Site square • prism square • rangefinder

• optical square $\equiv$ 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 = 2x angle b/w mirror

note: if angle b/w index glass and horizontal glass = 40°
then horizontal angle b/w 2 points = 2x40 = 80°

Sextant



• for navigation & Astronomical purpose

• more versatile

• measure angle in plane of 2 objects and Telescope

angle b/w mirror is more than nautical

⑥ Angle measurement

Theodolite

Horizontal angle (H)

vertical angle (V)

sextant

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 :-

Sounding rod

(measurement below water surface)

Pathometer

(Ocean depth नापने के लिए)
• Echosounding system for measurement of depth.
• permanent record of depth

⑧ velocity measurement of water

Prismeter
Current meter

⑨ Altitude measurement

Altimeter

• (Altitude of object from fix end)

Abney Level

• height measurement

⑩ Tangent clinometer :- to get difference in elevation between points.

→ indian pattern clinometer
→ plane survey में use होता है

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

⑫ Pantagraph : enlarge/reduce a already drawn plan.

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

⑭ Dumpy level → only Horizontal Angle

Telescope → nonmovable

⑮ wye level → telescope movable

Theory of errors :-

$$\text{error} = \text{measure value} - \text{True value}$$

Residual most probable value

close to true value than any other

$$\text{True error} = \text{observe value} - \text{True value}$$

$$\text{Residual error} = \text{observe value} - \text{MPV}$$

(v_i) (x_i)

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

$$\text{Sum/difference} \Rightarrow \frac{1}{\frac{1}{w_1} + \frac{1}{w_2}}$$

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

$$\frac{w}{k} \longrightarrow k^2 \times w$$

$$k + w \longrightarrow w$$

$$k - w \longrightarrow w$$

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

Ex. 5.48 $S = \frac{0.1}{2}$ $e = \delta/2$

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

	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 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 = ———

(A.E. 5-2-20)

② Adjust the following Angle closing horizons ?

P = 110°20'48"	weight 4
Q = 92°30'12"	1
R = 58°12'00"	2
S = 100°57'04"	3

$$\Sigma = 360°10'04"$$

hence correction = $(-4")$

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

$$\therefore c_1 : c_2 : c_3 : c_4 = 3 : 12 : 6 : 4$$

$$\therefore c_1 = -\frac{3}{25} \times 4" = -0.48" \quad c_3 = -$$

$$c_2 = -\frac{12}{25} \times 4" \quad c_4 = -$$

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

weight
Trust
dist
correction

Photogrammetry :-

Napier's rule :- Applicable for right angled spherical Triangle

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

Astronomical Triangles :-
 vertices of Astronomical Triangle (ZMP) $\begin{cases} \text{Zenith} \\ \text{Celestial Body} \\ \text{Pole} \end{cases}$

Notes :-

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

(ii) points at which sun declination is maximum are known as $\rightarrow$ solstice

(iii) $\rightarrow$ zero $\rightarrow$ vernal Equinox.

- Aerial survey steps : (i) Reconnaissance
 (ii) establish ground control (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- Plumb point :- a point where vertical through the optical centre of lens meets photograph.

4- Perspective 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- Index mosaic are not true planimetric representation of the area.

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

$f \rightarrow$ camera focal length

$h \rightarrow$ height of gsd above MSL

$H \rightarrow$ height of exposure station above MSL

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

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

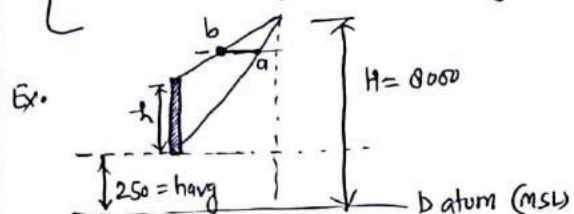
datum scale $\Rightarrow$ $h=0 \therefore S = f/H-0$

$$d = \frac{sh}{H - h_{avg}}$$

$\rightarrow$ height of Tower
 $\rightarrow$ height of object above MSL

relief Displacement = top-bottom

relief displacement $\propto$ focal length
 $\propto$ dist. of object from Nadir point



no. of photograph in each strip.

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

$\swarrow$ % lap in long direction
 $\searrow$ length of photo in direction of flight
 10000 (if 1:10000)

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

(1) Geometrical centre of photograph is defined by intersection of fiducial lines joining the fiducial marks

(2) map $\rightarrow$ orthogonal projection
 photo $\rightarrow$ central "

(3) Drift $\rightarrow$ Lateral shifting of photograph

(4) Crab $\rightarrow$ (occured while avoiding Drift)
 $\rightarrow$ when aircraft is not orientated with flight line, photographs are not parallel to flight line.

dyd
 18/4/2020