LECTURE NOTE

on

LAND SURVEY- I

(4TH SEM. CIVIL)

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Introduction

Linear measurement (chain surveying)

Angular measurement (compass surveying)

Traversing (Theodolite surveying, compass surveying).

Levelling, contouring

Curve

Theory of errors

photogrammetry

Tacheometry

GIS, GPS, Remote sensing

Plane table surveying

miscellaneous

Introduction -

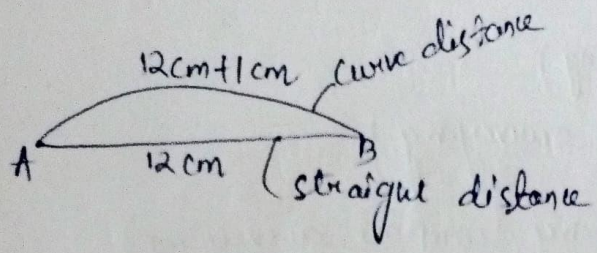
Surveying - It is an art to establish or locate any point over the earth surface (may be slightly below the earth surface) with the help of direct or indirect method. Further, this point is plotted on paper (maps) for future reference.

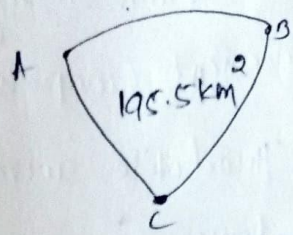
Primary division of surveying -

1) Geodetic Surveying - In this type of surveying, curvature of earth is taken into consideration. This surveying is used for larger areas and to locate control points. Because this surveying is more accurate than plane surveying.

2) Plane Surveying - In this method, curvature of earth is neglected. Hence, it is suitable for small area. It is less accurate than Geodetic surveying. Generally engineering survey is done using this method.

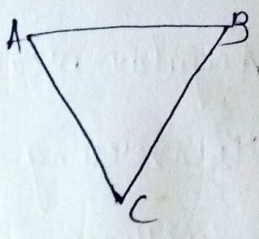
Observations -





$\angle A + \angle B + \angle C > 180^\circ 0' 1''$

(spherical Δ)



$\angle A + \angle B + \angle C > 180^\circ$

(plane Δ)

NOTE

1) center of earth is considered as center of gravity force and the radial lines drawn from center of earth is called as gravity lines. These gravity lines are also called as plumb line because using plumb bob, the direction of these lines can be determined.

2) But in case of plane surveying, plumb lines can be assumed as parallel lines.

Classification of surveying.

1) On the basis of location of survey :-

i) Land survey.

a) Topographic survey - consider both artificial and natural survey

b) City survey - mainly artificial constn. Ex: Road network, water distribution system, sewer systems etc.

c) Cadastral survey.

↓

It is related to property of any individual (any dept., any private property, property of state govt., property of central govt. etc.)

ii) hydrographic survey.

In this survey, mainly depth and discharge of water bodies (river, lake, sea etc) is considered to check whether it is suitable for dam construction, bridge construction, port construction etc.

iii) Astronomical survey -

In this surveying, any point on the earth surface is located w.r.t. heavenly bodies (sun, moon, stars, planets etc.) and viceversa.

2) On the basis of purpose of surveying -

i) Engineering survey - for engg. coorks

ii) Mining survey - To locate the mines

iii) Geological survey - To locate geological features. (availability of minerals, limestone, marbles etc.).

(iv) Military survey - To decide strategic locations.

(v) Archaeological survey -
To find Relics of antiquity

3) On the basis of Instrument used -

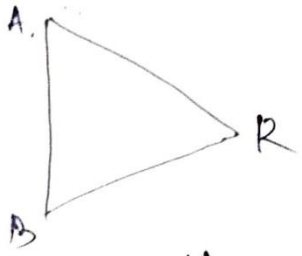
i) Chain survey
ii) compass surveying
iii) Theodolite surveying
iv) plane table surveying
v) Totalstation surveying
vi) Tacheometry

Principle of Surveying :-

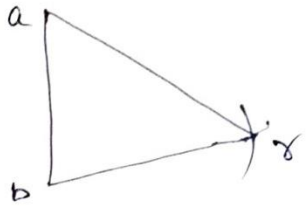
(1) Working from whole to part :

According to this principle, 1st of all outer control point should be establish with proper accuracy (using geodetic surveying) and then inner points are located. Due to this process, the accumulation of errors will be minimum.

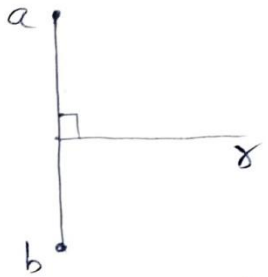
(2) To locate any point on paper, atleast two reference point should be considered.



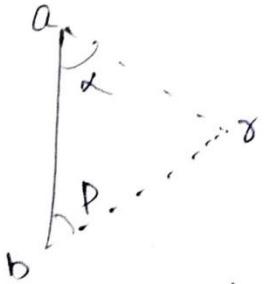
(On field)



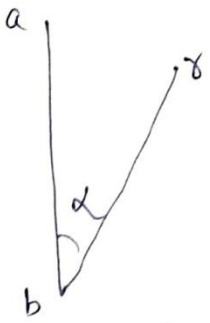
(case - I)



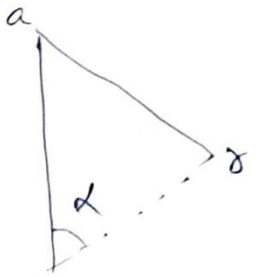
(case - II)



(case - III)



(case - IV)



Scale :-

With the help of scale actual ground condition can be drawn on paper.

$$\text{Scale} = \frac{\text{distance between two points on the paper}}{\text{distance between same points on ground surface}}$$

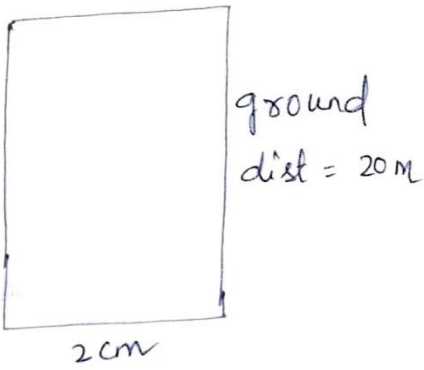
Ex :- Scale = $\frac{2\,cm}{20\,m}$

→ 2 cm = 20 m

→ 1 cm = 10 m

→ 1 cm = 10 m

→ $\frac{1\,cm}{10\,m}$



Scale

- Numerical scale
  - Engg. scale
    - ex - 1 cm = 10 m
  - Representative factor (R.F)
    - R.F = $\frac{1}{1000}$
- Graphical scale

$1\,cm = 10\,m \Rightarrow \frac{1\,cm}{10 \times 100\,cm} = \frac{1\,cm}{10\,m} = \frac{1}{1000}$

$1\,cm = 10\,km \Rightarrow \frac{1\,cm}{1 \times 10^3 \times 100\,cm} = \frac{1\,cm}{1\,km} = \frac{1}{10^5}$ → RF

$1\,cm = 100\,m \Rightarrow \frac{1\,cm}{100 \times 100\,cm} = \frac{1\,cm}{100\,m} = \frac{1}{10^3}$

$1\,inch = 200\,ft \Rightarrow \frac{1\,inch}{200 \times 12\,inch} = \frac{1\,inch}{2400\,feet} = \frac{1}{2400}$

Note

RF is mainly defined to compare the scale. If RF is larger, then it is larger scale.

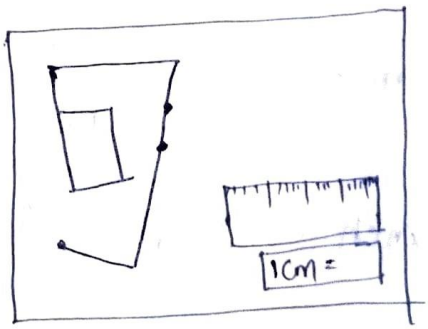
Ex. $\frac{1}{1000}$ is largest scale

$\frac{1}{10^5}$ is smallest scale

- For same ground area, the size of map will be larger in case of larger scale. Similarly, area will be smaller for small scale (map area). Numerical scale is mentioned on map, with the help of external instrument distance b/n two points on the map is measured and with the help of scale, it is converted into actual ground distance.

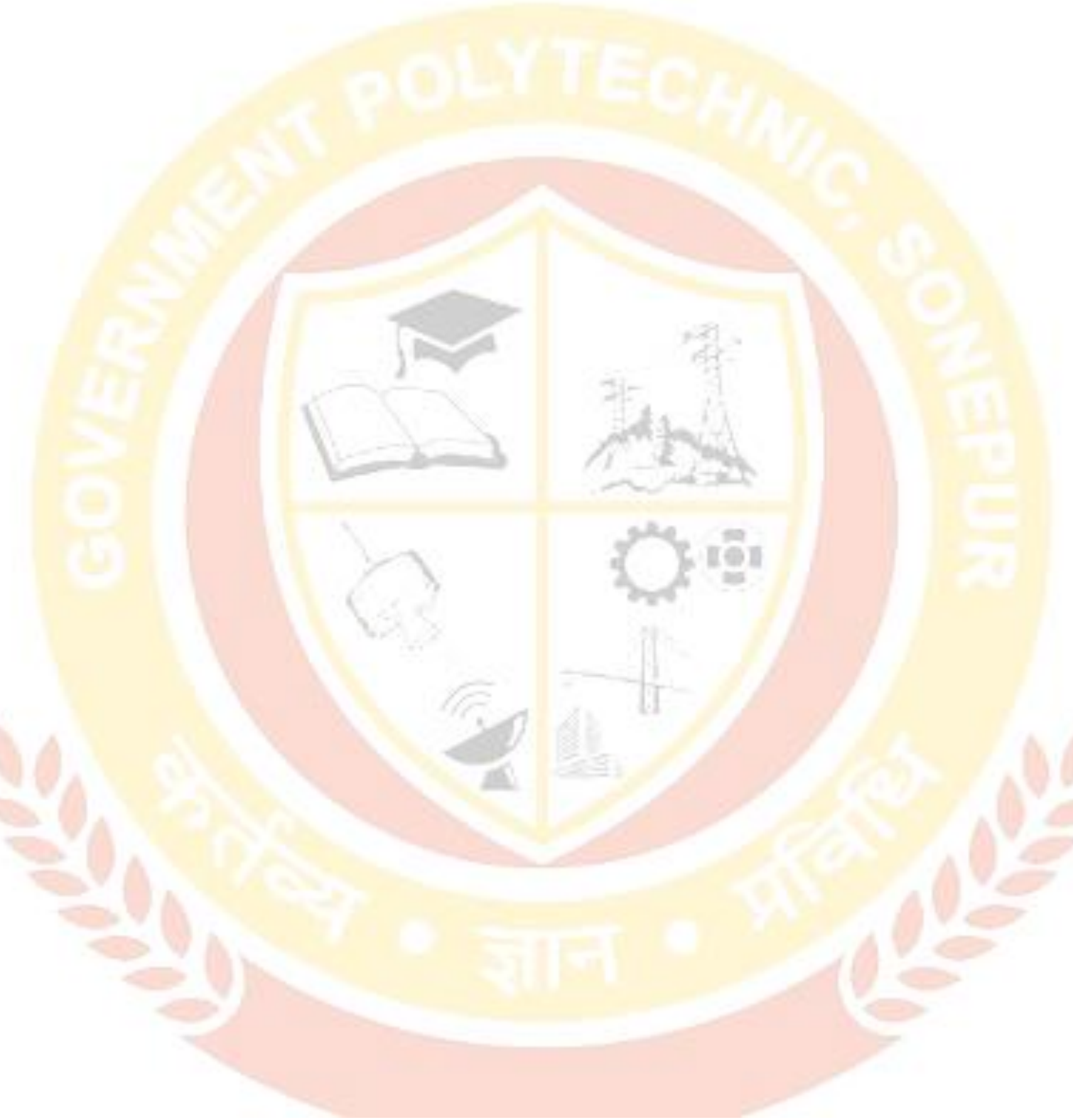
Graphical scale :-

Graphical scale drawn on the map at the time of making of the map & without any instrument actual distance on the ground can be calculated using this scale.



Note

In case of shrinkage and expansion, if graphical scale is used then actual ground length can be calculated without applying any correction. But in case of numerical scale due to shrinkage or expansion, scale will be change and the scale is called shrunk scale (extended scale) and using this new scale, actual ground length is calculated.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Difference b/n map and plan

(i) The scale used in making of map will be smaller as compared scale used in case of plan. In case of map along with horizontal detail vertical details is also drawn using different colour coding or hatching.

But in case of plan mainly horizontal detail is shown.

CH-1

Q18) Shrinkage factor = $\frac{900}{1000} = 0.9$

$S.S = SF \times \frac{1}{1000} = 0.9 \times \frac{1}{1000} = \frac{1}{1111}$

P-8

Q33) SF = $\frac{9.8}{10} = 0.98$

ans c):- 1 cm = 0.98 cm

original area of on the map = $\frac{80.2}{0.98 \times 0.98}$

$= 83.51\ cm^2$

Q19)

Wrong scale

1 cm = 20 m

x cm = 20x m

20x = 468

$x = \frac{468}{20}$ cm

Correct scale

1 cm = 40 m

x cm = 40x

$= 40 \times \frac{468}{20}$

= 936 m

method-2

$$\text{Correct length} = \frac{\text{RF of wrong scale}}{\text{RF of correct scale}} \times \text{measured length}$$

RF = Representative Factor

P.12

Q-11) $$\text{correct length} = \frac{1/3000}{1/15000} \times 575$$

$$\text{correct length} = \frac{5}{3} \times 575 = 9.58.33\text{m}$$

Vernier Scale :-

- This scale is used to measure the fractional length which can't be measured by normal on main scale.
- It is developed by P. vernier.
- This scale is having 2 portions.
  - (i) main scale
  - (ii) Sliding vernier scale
- Length is measured as.

$$\text{measured length} = \text{main scale reading} + \text{vernier reading} \times \text{least count}$$

Least count :-

It is minimum value which can be determined using vernier scale.

Types of vernier -

1) Direct vernier :

In this type of vernier, the value of main scale division (s) will be slightly more than vernier scale division, in such a manner that,

$$n \times v = (n-1)s$$

$$\Rightarrow \boxed{v = \frac{n-1}{n} \times s}$$

n = no. of vernier divisions

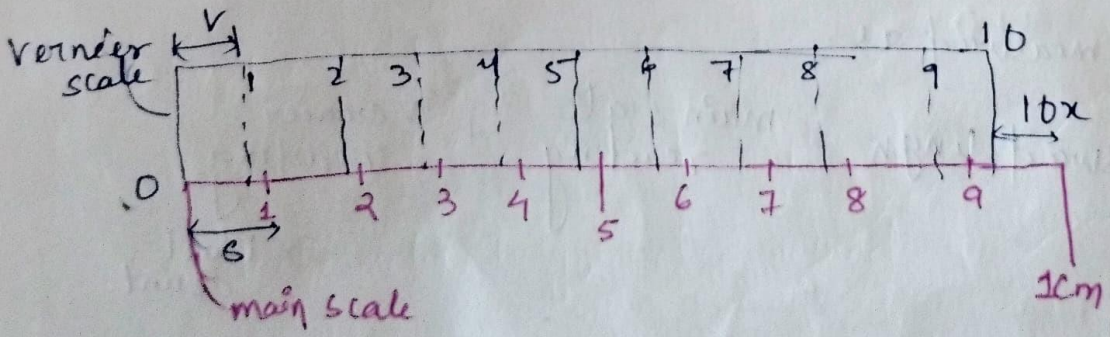
In this vernier, both main scale division and vernier division will be in same direction.

Least count = $s - v$

$$= s - \frac{n-1}{n} s$$

$$= \frac{ns - ns + s}{n}$$

$$\boxed{\text{Least count} = \frac{s}{n}}$$



$10x = 1\ mm$

$x = 1/10\ mm$

$$\boxed{x = 0.1\ mm}$$

(II) Retrograde vernier -

In this case, vernier division 'V' is slightly more than main scale division (S). In such a manner,

$$\boxed{n\,V = (n+1)\,S}$$

In this vernier, vernier scale will move in opposite direction.

$$\boxed{\text{Least count} = \frac{S}{n}}$$

(III) Extended vernier :-

- In this case, the size of vernier division is extended for clear reading of coincidence.
- It is extend in such a manner that

$$\boxed{n\,V = (2n-1)\,S}$$

$$\boxed{\text{least count} = \frac{S}{n}}$$

Note -

If there are 2 main scale readings and vernier can move in 2 dir's then it is called as double vernier. If there is only one main scale then it is called as single vernier.

P-8

Q 20) $S = 1/6^{\circ}$

$S = \frac{1}{6} \times 60 \times 60 = 600$ sec.

$L.C = \frac{S}{n} = \frac{600}{20} = 30$ sec.

CH-2

Linear Measurement in Chain surveying

Linear measurement -

Measurement along the straight line, linear measurements are generally done in horizontal plane

Methods of Linear measurement -

① Direct method -

(a) Pacing → (Pace = (एक पग) !

↳ pace is counted, then using this distance can be calculated (Pace size × no of pace)

(b) Pacrometer - Automatically counts the no. of pace

(c) Pedometer - Directly distance is calculated.

(d) speedometer / odometer - dis. is calculated (ex - spedometer in vehicles)

(e) chaining - Measurement using chain or tape.

② Indirect method -

(a) optical method : Uses the principle of optics

Ex - Tacheometer, Trigonometric method

(b) Using electronic distance measuring instruments (EDMIs).

Uses wave in EDMIs

(i) micro wave - Tellurometer

(ii) visible light wave → Geodimeter

(iii) Infrared wave → long distance, mild dis.

→ Fathometer – To measure the depth of water body.

Chain Surveying:

Process of chain surveying:

(I) Reconnaissance: (Field visit, Rough survey)
approximate marking of boundary.

(II) marking and fixing of main survay station (control points) at outer periphery:

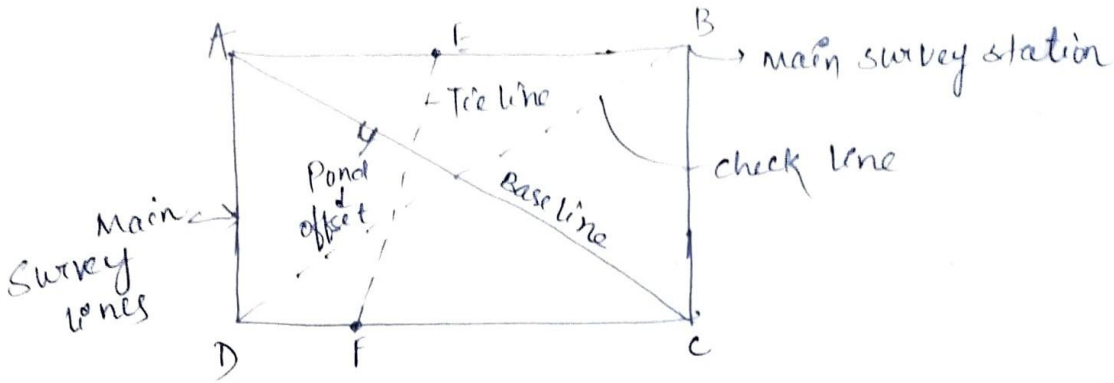
– At outer periphery, these main stations are marked, marking should be done by considering atleast 2 reference points. After marking, peg is inserted at that point to fix it.

(III) Running of survey lines:

(a) Chaining: The linear measurement b/n 2 stations with the help of chain or tape is called as chaining.

(b) Ranging: the process of establishing temprarey station b/n terminal stations sothat the measurement can be done on straight lines is called as Ranging. It is required when distance b/n terminal stations is more than 1 chain length or one tape length.

(c) Offsetting: To locate ground features, lateral measurement is done from survey lines. It is called as offsetting. Generally offset is drawn at 90° but in case of unavoidable conditions the angle may be different from 90°. These offsets are called as Oblique offsets.



(d) main survey lines : The line joining the main survey stations (from above fig, A, B, C, D)

(e) Base line : Longest main survey lines is generally considered as base line, the area should be divided into approximately 2 equal half.

The measurement of main survey lines, specially baseline should be done correctly. Generally invar tape is used for base line measurement.

(f) Tie lines : The lines joining tie stations are called as tie lines. These lines are drawn to locate ground features more accurately (By reducing the length of offset)

(g) check line : To check the accuracy of survey, check lines are drawn. These are also called as proof lines.

(h) offset : To locate ground features.

Note :

By chain survey, the whole area is divided into no. of triangles, it is always desired that the triangle should be equilateral. In any case if triangle is not equilateral, then it should be atleast well condition (angle $\geq 30°$).

Instruments used in chain surveying :-

Chain :-

It is an arrangement of links and rings made of galvanised iron. chain can be of any type like

(1) metric chain
- 5m (25 link, links = 20cm)
- 10m (50 link)
- 20m (100 link)
- 30m (150 link)

30m (100 links, each size = 30cm).

(2) Engineers chain — 100ft (100 links)

(3) Gunters chain — 66ft (100 links)

(4) Revenue chain — 33ft (16 links)

Metric chain : It is widely used chain in India, in 5m and 10m metric chain at every 1m, talleys are provided and in 20m & 30m chain, at every 5m talleys are provided and at every 1m brass rings are provided.

Note :
Chain is straightened at 20°c and by applying 8kg pull the permissible errors in chain are as follows -

for 5 and 10m chain - ±3mm
For 20m chain - ±5mm
For 30m chain - ±8mm.

Tape :

(1) Cloth or linen tapes : It is made of cloth or linen.
- It is easily stretchable
- less durability due to moisture affect
- During measurement, it twisted easily.
- Less useful for engg. purposes.

(2) Metallic Tape :

- It is made of thin wires of copper or brass coated with cloth or linen.
- comparatively, it is less stretchable and more durable as compared to previous tape but it is affected by temp.

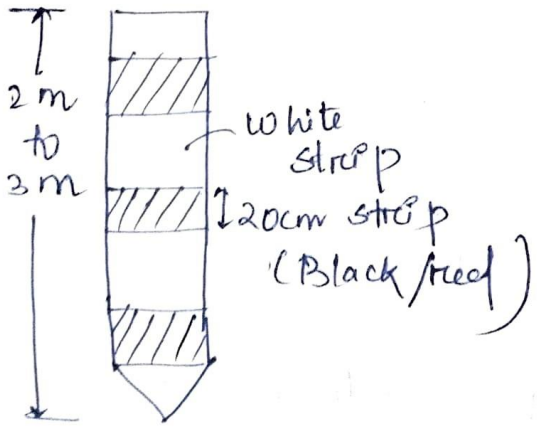
(3) steel tape : It is made up of steel and better than previous tapes even in case of temp. also.

(4) Invar tape : It is made of alloy of steel having 36% nickel, this alloy is called as Invar. It is having very less thermal expansion. Hence it is used for Precised measurement.

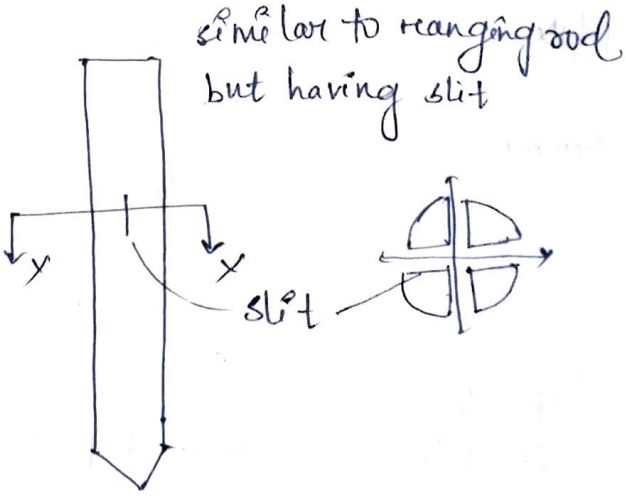
ex. Measurement of base line.

Location devices

- Ranging rods and offsets :



(Ranging rod)

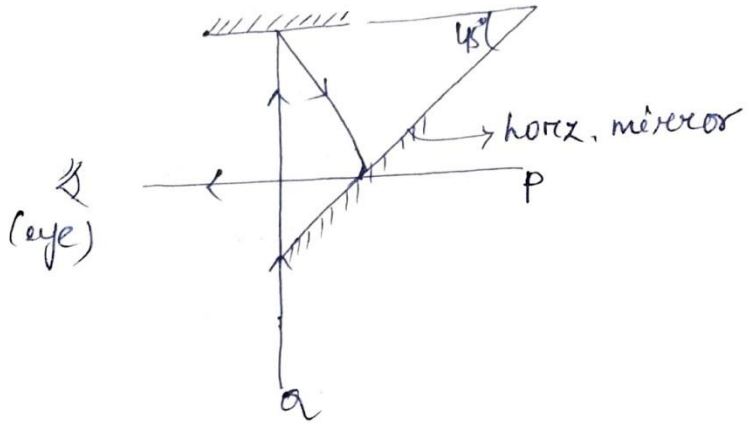


(Offset rod)

90° measuring instrument :

(1) Cross staff → open cross staff (90°)
→ French cross staff (45° × 90°)
→ Adjustable cross staff (any angle)

(2) Optical squares :



(3) Prism square : previous arrangement is replaced by prism. It better than optical square.

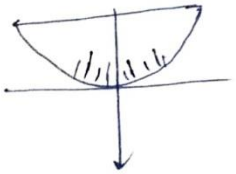
(4) Site square : Two perpendicular telescope are used.

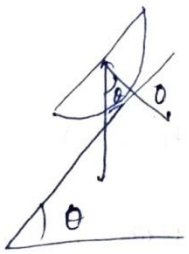
Centring devices :

Plumb - bob

Slope measuring instrument

clinometer





Correction in chaining :-

Note : Error = Measured value - True value

Correction = True value - measured value

Chain Correction

(1) Correction for standardisation
(2) Correction for slope

Tape correction

(1) correction for standardisation
(2) Correction for slope
(3) correction for temp.
(4) Correction for pull (tension)
(5) Correction for sag
(6) Correction for misalignment (bad Ranging)
(7) correction for MSL

(1) Correction for standardisation -

l = designated length of tape (marked length)

l' = length of tape at the time of measurement

L' = measured length on the ground

L = True length of line on the ground.

(1) $l' > l \Rightarrow$ correction +ve

(2) $l' < l \Rightarrow$ correction -ve

correction per tape length = $l' - l$

Total correction = $(l' - l) \times \frac{L'}{l}$

True length $= \frac{L' + (\ell' - \ell) \times L'}{\ell} \Rightarrow \frac{(\ell' - \ell) \times L'}{\ell}$

$\Rightarrow \frac{L' \times \ell + (\ell' L' - \ell \times L')}{\ell}$

$L = \frac{L' \ell'}{L}$

$\boxed{L \times \ell = L' \times \ell'}$

Q13) $L \times \ell = L' \times \ell'$

$L \times 30 = 300 \times (30 - 0.1) \Rightarrow L = 299\,m$

14) $L \times \ell = L' \times \ell' \Rightarrow 200 \times 20 = 200.8 \times \ell'$

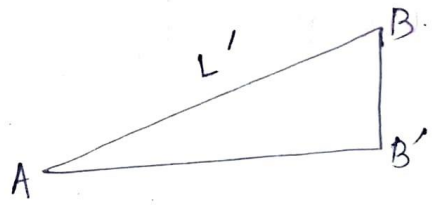
$\ell' = \frac{200 \times 20}{200.8} = 19.92$

18) $\ell = 20m$, $L' = 200m$, $\ell' = 20.05m$

$L = \frac{L' \times \ell'}{\ell} = 200.5m$

Correction for slope :-

slope correction $= -Ve$



① If 'h' is known

Correction for slope (C_s)

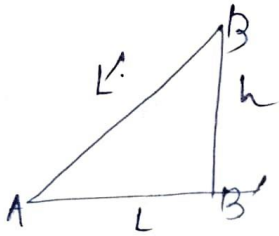
$= L' - L$

$= L' - \sqrt{L'^2 - h^2}$

$= L' - (L'^2 - h^2)^{1/2}$

$= L' - L' \left(1 - \frac{h^2}{L'^2}\right)^{1/2}$

$= L' - L' \left(1 - \frac{h^2}{2L'^2} - \frac{h^4}{8L'^4} \cdots\right)$



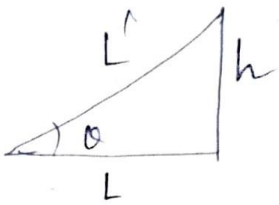
$$C_s \Rightarrow L' - L'\left(1 - \frac{h^2}{2L'^2} - \frac{h^4}{8L'^4}\right)$$

$$= L' - L' + \frac{h^2}{2L'^2} \times L' + \frac{h^4}{8L'^4} \times L'$$

$$= \frac{h^2}{2L'} + \frac{h^4}{8L'^3} \to 0 \quad \text{(neglecting 2nd term)}$$

$$\boxed{C_s = \frac{h^2}{2L'}} \quad \text{nature} = -ve$$

(2) If 'θ' is known,



$$C_s = L' - L$$

$$= L' - L'\cos\theta$$

$$\boxed{C_s = L'(1 - \cos\theta)}$$

Correction for temp :-

T_0 = standard temp. for tape

T_m = Temp. at the time of measurement

(1) $T_m > T_0$; $L' > l$ = correction +ve

(2) $T_m < T_0$; $L' < l$ = correction -ve

Correction per tape length = $l' - l = \Delta l$

Total correction (C_T) $= (l' - l) \times \frac{L'}{l}$

$$C_T = \frac{\Delta l \times L'}{l} = \frac{l \alpha (T_m - T_0) \times L'}{l}$$

$$\boxed{C_T = \alpha (T_m - T_0) L'}$$

α : Thermal coeff.

L' : measured length

Correction for pull or tension :-

P_0 = standard pull for tape

P_m = pull at the time of measurement

(1) $P_m > P_0 = l' > l$ = correction +ve

(2) $P_m < P_0 = l' < l$ = correction -ve

Correction per tape length = $l' - l = \Delta l$

Total correction = $(l' - l) \times \frac{L'}{l}$

$$C_p = \frac{\Delta l \times L'}{l} = \frac{(P_m - P_0)\, l \times L'}{A E \times l}$$

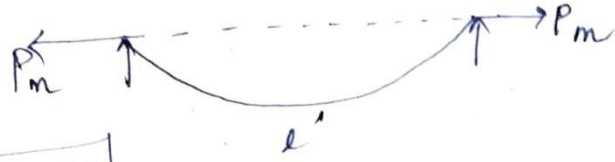
$$\boxed{C_p = \frac{(P_m - P_0)\, L'}{AE}}$$

A = c/c of tape

E = modulous of elasticity of tape

Correction for sag :-

Sag correction = always -ve



$$\boxed{C_{sag} = \frac{W^2 l^3}{24 P_m^2}}$$

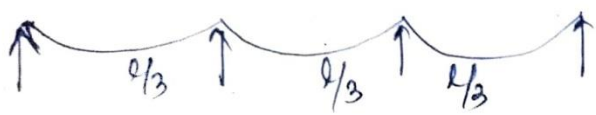
$$\boxed{W = \omega L}$$

(Total wt. of tape)

ω = weight of tape per meter length

l = length of tape b/n supports

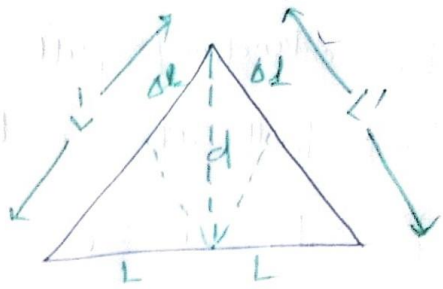
P_m = Pull applied at the time of measurements



$$C_{sag} = \frac{\omega^2 \times l^3 \times 3}{3^3 \times 24 P_m^2} = \frac{\omega^2 l^3}{3^2 \times 24 P_m^2} = \frac{\omega^2 l^3}{n^2 \cdot 24 P_m^2} \quad (n = 3)$$

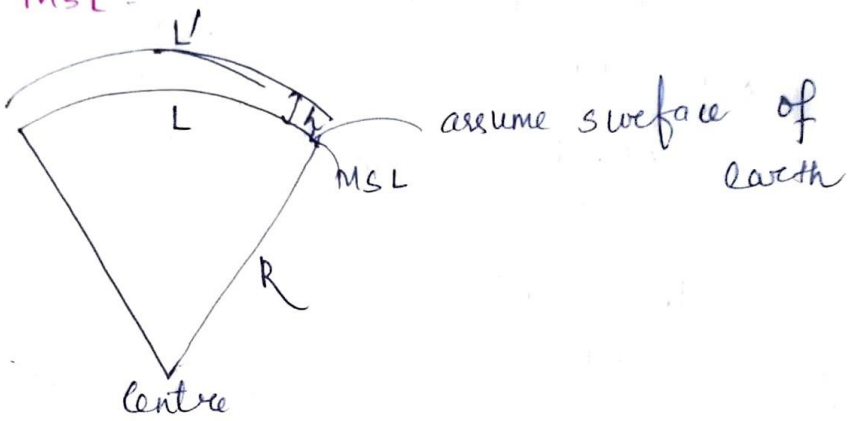
Correction for misalignment -

$$\Delta l = \frac{d^2}{2l'}$$



$$\text{Total correction} = \frac{d^2}{2l'} + \frac{d^2}{2l'}$$

Correction for MSL -



$$C_{MSL} = L' - L$$

$$= (R+h)\theta - R\theta$$

$$= h\theta$$

$$= h \times \frac{L'}{R+h} \approx \frac{h \times L'}{R}$$

R = Radius of earth

C_{msl} = -ve (If measurement is above MSL)

C_{msl} = +ve (If measurement is below MSL)

Dt- 6/4/2019

16) $L = L' \cos\theta$

22) $l = 100m$, $P = 200N$.

$w = 30N$.

$C_s = \frac{w^2 l}{24 P_m^2} = \frac{30^2 \times 100}{24 \times 200^2} = 0.094m.$

$L_b = 100 - 0.094 = 99.906m$

25) $C_{msl} = \frac{hL'}{R} = \frac{300 \times 2200}{6370 \times 1000} = 0.1059m = 106mm.$

Note :-

Normal tension / Normal pull :

As we can see the nature of pull correction is positive if applied pull is greater than standard pull. On the other hand, the nature of sag correction will be -ve in all conditions. If at any particular condition, when magnitude of pull correction become equal to the magnitude of sag correction and nature is opposite then applied pull is called as normal pull or normal tension and it can be calculated by this formula :

$$\frac{(P_N - P_0)l}{AE} = \frac{w^2 l}{24 P_N^2}$$

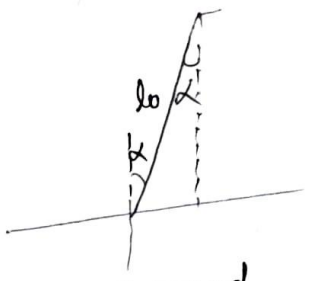
P_N = normal pull.

Limiting length of offset :

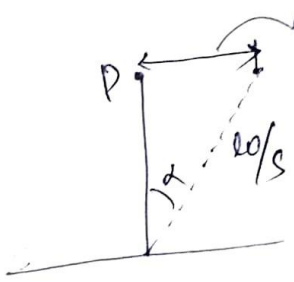
The no. of offsets depend on the nature of ground feature. If ground feature is irregular, then more no. of offsets will be required. The length of offset should also be decided carefully and it shouldn't be more than limiting length.

Limiting length of offset depends on permissible error, scale of the map, nature of ground, method used for setting offset etc.

In case of error in laying out direction of offset, the limiting length of offset can be calculated as follows :



on ground.



$= \frac{lo}{s} \sin\alpha$ cm,

$5m = 1$ cm

$1m = 1/5$ cm

$lm = l/5$ cm.

Generally permissible error on map = 0.25mm

$$\frac{lo \sin\alpha}{s} em = 0.025 cm.$$

$$lo = \frac{0.025\, s}{\sin\alpha.}$$

↓

limiting length of offset.

chain surveying

q) $\frac{1\text{ cm}}{2000 \times 10^{-2}} = \frac{1\text{ cm}}{20\text{ m}} =$

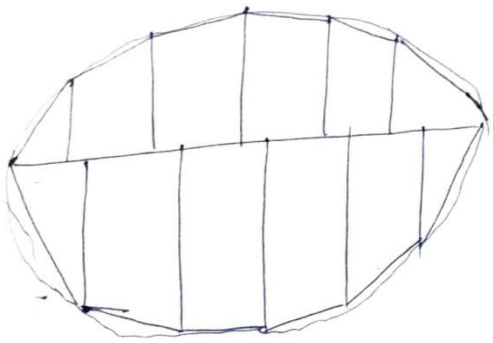
$1\text{ cm} = 20\text{ m}$

$\boxed{S = 20}$

$l_0 = \frac{0.025S}{\sin\alpha} = \frac{0.025 \times 20}{\sin(2.5^\circ)} = 11.462\text{ m}.$

Cross staff survey -

This survey is performed mainly to fix the point on the boundary and to calculate the area using cross staffs by drawing offsets so that the whole area can be divided into smaller area segments (Triangular, rectangular etc.).



Angular Measurement

For largen areas, along with linear measurement, angular measurement is also reqd. for better accuracy and this angular measurement can be done with the help of compass and it is called as compass surveying.

In this surveying, horizontal angle of any line is measured w.r.t. any fixed reference line. This horizontal angle is called as bearing and this fixed reference line is called as meridian

Types of meridian -

i) True meridian - It is an imaginary line obtained by intersection of earth surface and great circle passing through geographical north and south at any place. For any place, its position will not change with time. It is established with the help of astronomy. The angle measured w.r.t. true meridian is called as true bearing.

ii) Magnetic meridian -

It is an imaginary line passing through magnetic north and magnetic south on the earth surface at any place. The direction of magnetic meridian is shown by direction of magnetic needle (freely suspended). Hence magnetic meridian can be established with the help of magnetic compass.

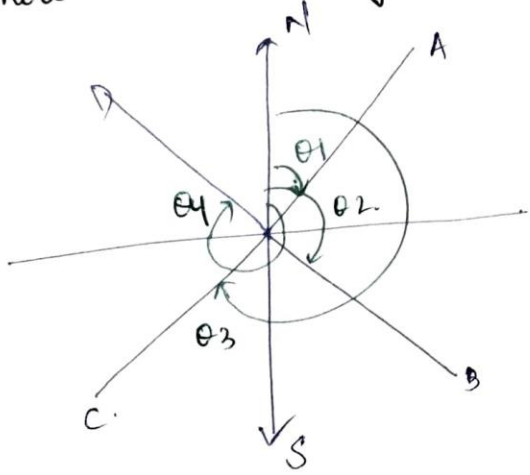
The angle measured w.r.t. magnetic meridian is called as magnetic bearing. Magnetic bearing (MB) may change when the time for a line

iii) Arbitrary meridian -

It is randomly selected reference line which is used as a meridian for relative measurement that's why it is called as arbitrary meridian and the angle measured w.r.t. this meridian is called as as arbitrary bearing.

Bearing system -

1) Whole circle Bearing (Azimuthal Bearing System)

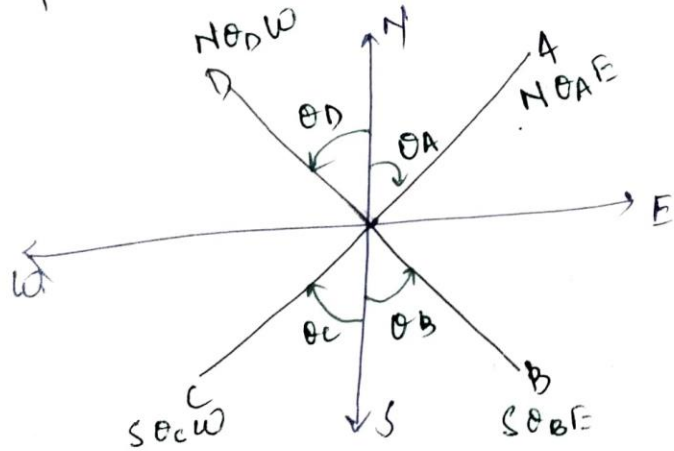


Bearing is always measured from N & in clockwise sense

Representation = in terms of angle θ

$\theta = 0 - 360^\circ$

2) Quadrantal Bearing system (Q.B) (Reduced Bearing System)



It can be measured from N aswell as south (depends on which one is nearer)

It can be in clockwise or anticlockwise sense

Representation = NθE
SθE, NθW,
SθW.

$\theta = 0 - 90^\circ$

Note

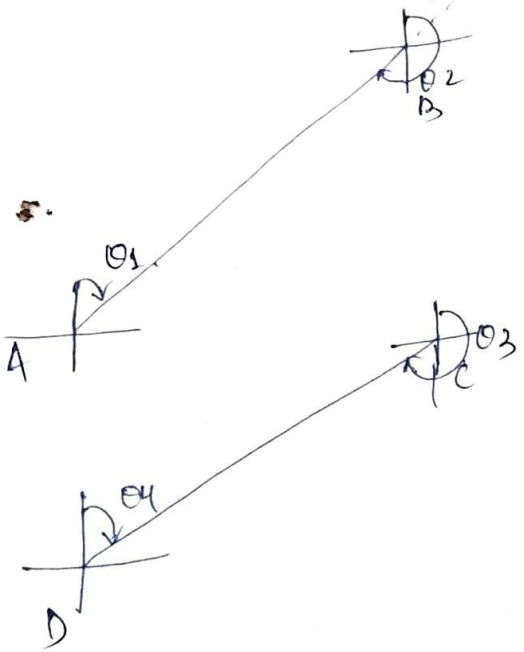
Bearing of any line can be converted from one system to another system. To convert it, suitable diagram should be made.

Types of bearing / Representation of bearing on the basis of diren of propagation of survey.

Fore bearing - The bearing measured in the direction of propagation of survey ie, in forward direction is called as fore bearing.

Back bearing - The bearing measured in opposite diren of propagation of survey ie in backward direction is called as back bearing.

Ex:



For line AB,

Fore bearing = θ_1

Back bearing = θ_2

BB of line AB = FB of line AB + 180°

$$BB = FB + 180° \quad \text{---(I)}$$

FB of CD = θ_3

BB of CD = θ_4

BB of CD = FB of CD − 180°

$$BB = FB - 180° \quad \text{---(II)}$$

By (I) & (II)

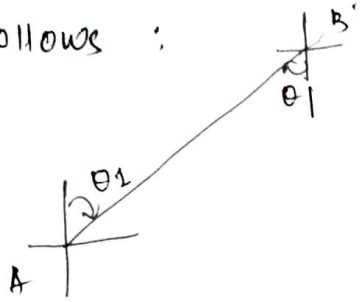
$$BB = FB \pm 180°$$

+ when FB < 180°

− when FB > 180°

Note

The above formula for conversion from BB to FB and vice-versa is only applicable for WCB system. If it is reqd. to convert BB and FB in Q.B. system, then it can be done as follows :

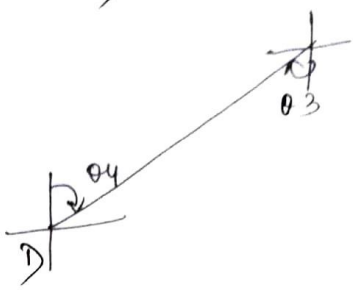


For AB,

FB = $N\theta_1 E$

BB = $S\theta_2 W$ ($\theta_2 = \theta_1$)

$S\theta_1 W$



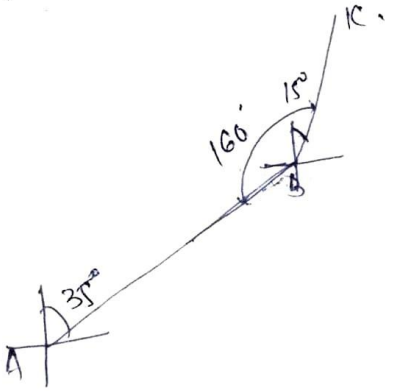
FB of CD = $S\theta_3 W$

BB of CD = $N\theta_4 E$ ($\theta_3 = \theta_4$)

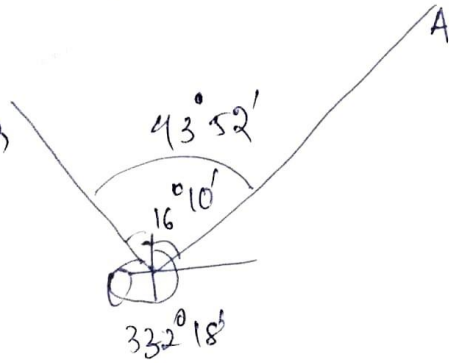
$N\theta_3 E$

- With the help of FB and BB at any station, included angle can be calculated, if it is not mentioned, then angle is calculated/measured from previous line to next line in clockwise sense.

B)



36)



Theory of magnetic compass -

a) parts of the magnetic compass -

1. magnetic needle
2. Graduated circle
3. Compass box
4. eye vane & object vane
5. Tripod.

Magnetic needle -

Magnetic needle is slender bar made of iron or steel, it should be perfectly straight and freely suspended. It is supported over jewel bearing and it should be free from dip. To make it free from dip, additional weight is placed on one side.

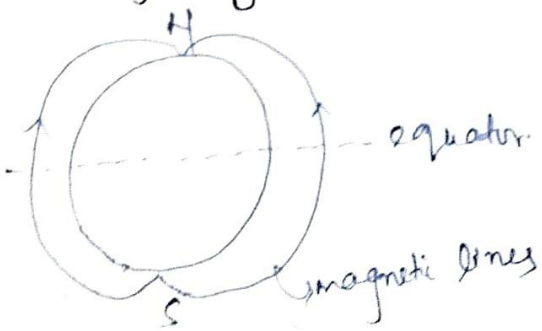
Dip - It is vertical angle between direction of magnetic field (magnetic needle) and earth surface. It will be zero at equator and 90° at poles.

Note

Isoclinic Lines -

Imaginary lines joining the points having same dip.

Aclinic line - Lines joining the points having zero dip.



Types of magnetic compass

Prismatic compass

i) In this compass, prism is provided, with the help of prism, sighting and reading can be done simultaneously.

ii) Inverted readings are provided on circle and 0° will be at south and it follows WCB system.

iii) Broad needle is used which is attached with graduated circle (below it)

iv) It can be used w/o tripod

Surveyor compass

i) No prism is provided. Hence sighting and reading can't be done simultaneously.

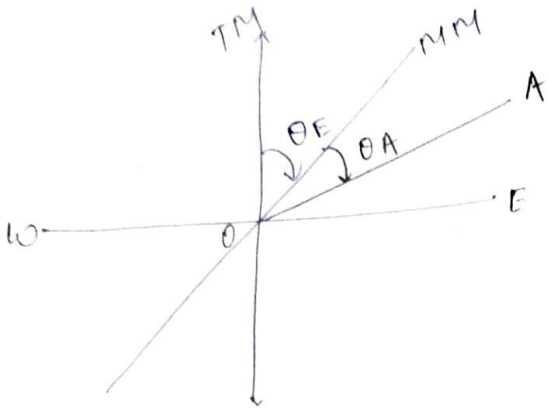
ii) Normal reading is provided, 0° will be at north and south both and it follow QB system.

iii) Edge bar needle is used which is not attached with graduated circle.

iv) It can't be used w/o tripod.

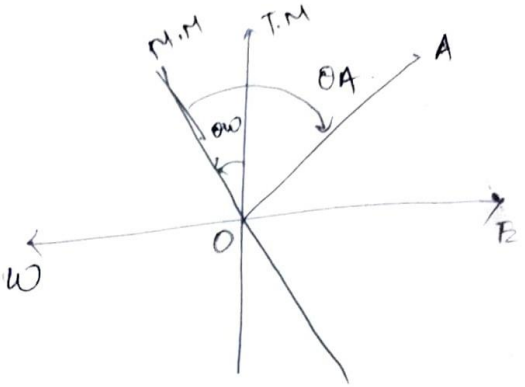
Magnetic Declination.

It is horizontal angle between true meridian and magnetic ~~need~~ meridian at any place. If magnetic meridian is in eastward direction, then it is called as the declination and if magnetic meridian is westward w.r.t. true meridian, then it is called as -ve declination.



θ_E = positive declination

True bearing of OA = $\theta_A + \theta_E$



θ_W = negative declination

True bearing of line OA = $\theta_A - \theta_W$

Note The above formula for calculation of true bearing is only applicable for WCB system. For QB system, we have to draw the diagram.

Types of Variation in declination -

1) Daily variation / Diurnal variation -

It mainly occurs due to rotation of earth on its axis. It will be max. in summer in daytime and near poles.

2) Annual variation - It occurs due to moment of earth around the Sun.

3) Secular variation - This variation occurs due to different natural changes over a long period of time.

Time = 150 - 300 yrs.

(1) Irregular variation. Due to sudden change in earth's magnetic field of.

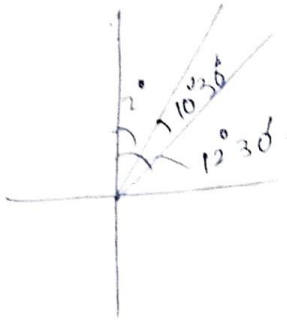
ex. Earthquakes, volcanic eruptions etc.

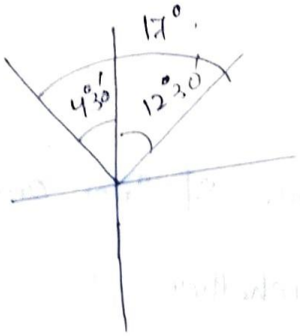
Dt-7/4/2019

Note Isogonic lines - Imaginary lines joining the points having same magnetic declination.

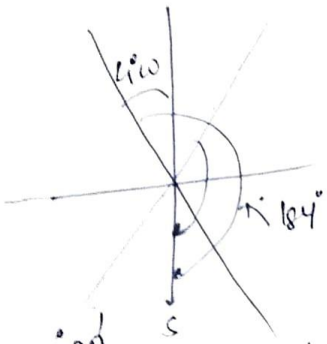
Agonic lines - ~~Imagi~~ Line joining the points having zero declination.

2c)



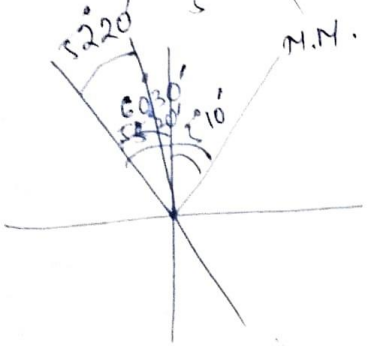


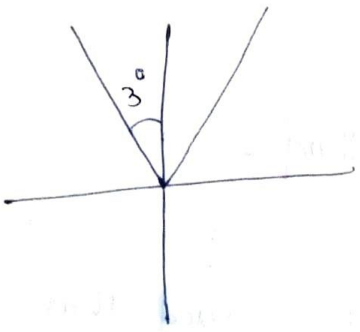
2.5)



[Sun is at South at noon.]

3)





Local attraction -

Due to presence of any external magnetic field, magnetic needle may deviate from its actual direction. Due to this, error will occur. This error is called as error due to local attraction.

Local attraction error changes from place to place.

It may occur due to

i) Presence of electric wires
ii) Presence of under ground pipe network
iii) Presence of railway track
iv) Presence of Iron ore etc.

To check whether the stations are subjected to local attraction or not, the difference of FB and BB of joining line is calculated. If the difference is exactly 180°, then it is clear that both the stations are free from local attraction. If difference is other than 180°, then one station or second station or both may be subjected to local attraction.

Calculation of correct bearings -

1) Direct method - In this method, first of all it is determined which stations are free from local attraction and it is assumed that all the readings taken at a station free from local attraction are correct and with the help of this correct readings, other readings are corrected one by one.

2) Internal angle method - In this method, internal angles are calculated and sum of internal angles is verified with the formula,

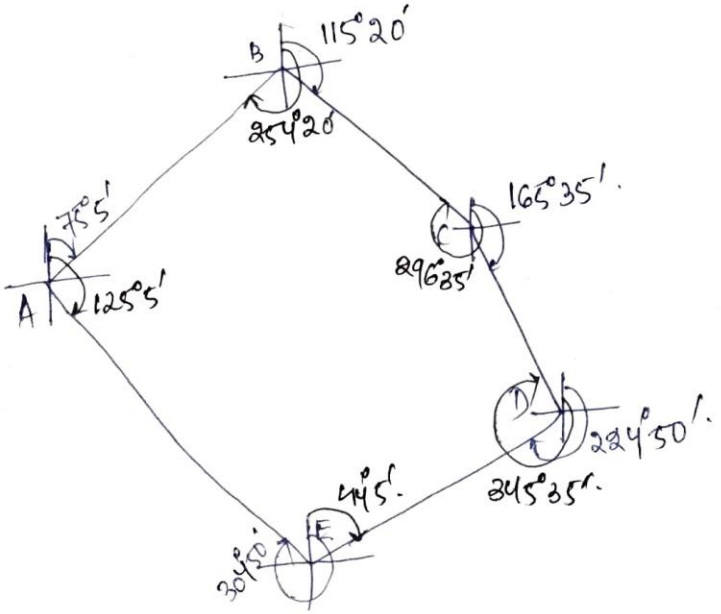
Sum of internal angles = $(2n-4)\times 90^\circ$

where n = no. of sides and it is applicable for closed traverse only.

- With the help of corrected internal angles, bearings are corrected considering bearing of any one line as a reference.

Q)

Line	FB	BB	FB - BB	Corrected FB	Corrected BB	Check FB - BB
AB	75°5'	254°20'	179°15'	75°35'	255°35'	180°
BC	115°20'	296°35'	181°15'	116°35'	296°35'	180°
CD	165°35'	345°35'	180°	165°35'	345°35'	180°
DE	224°50'	44°5'	180°45'	224°50'	44°50'	180°
EA	304°50'	125°5'	179°45'	305°35'	125°35'	180°



Consider station E

Corrected BB of DE shall be

$= 224°50' - 180°$

$= 44°50'$

But given BB $= 44°5'$

correction $= 44°50' - 44°5' = 45'$

∴ The corrected BB of EA $= 304°50' + 45'$

$= 305°35'$

Consider station A

Corrected BB of A shall be $= 305°35' - 180°$

$= 125°35'$

But given is $= 125°5'$

Correction $= 125°35' - 125°5'$

$= 30'$

Corrected FB of AB $= 75°5' + 30' = 75°35'$

Consider station B

Corrected BB of AB should be $= 75°35' + 180°$

$= 255°35'$

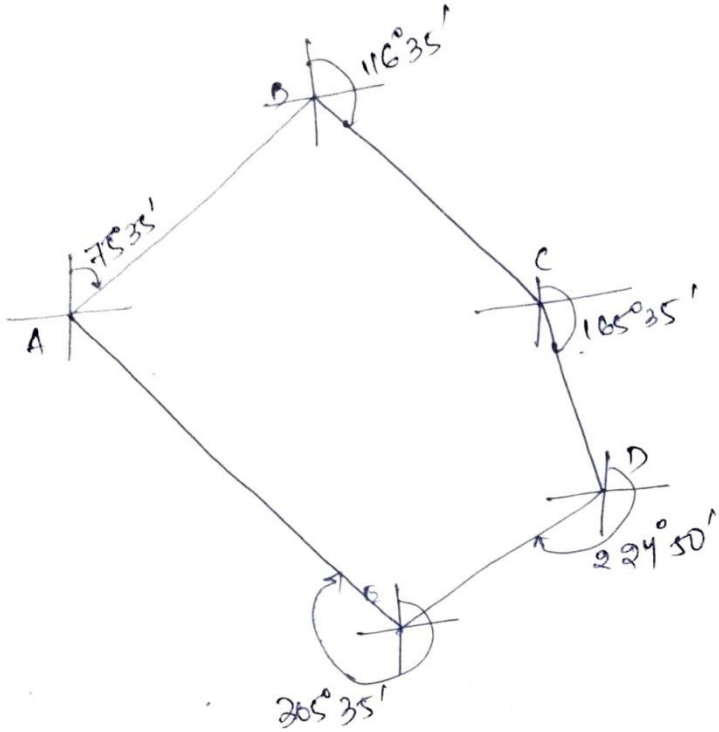
But given is $254°20'$

Correction $= 1°15'$

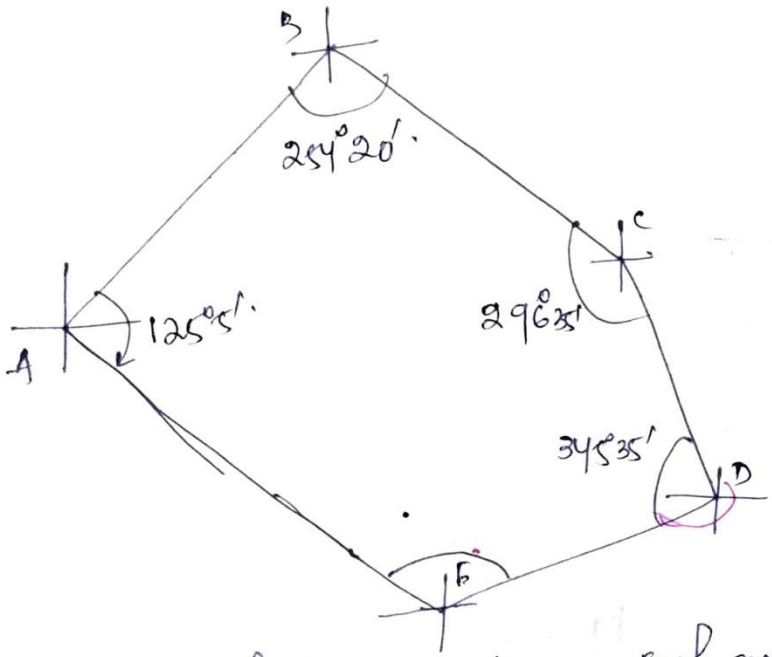
Corrected FB of BC

$= 115°20' + 1°15'$

$= 116°35'$



By interior angle method.



$\angle A$ = BB of previous line − FB of next line

= 125°5' − 75°5'

= 50'

$\angle B$ = 254°20' − 115°20' = 139°

$\angle C = 296°35' - 165°35' = 131°$

$\angle D = 345°35' - 224°50' = 120°45'$

$\angle E = 44°5' - 304°5' + 360° = 99°18'$

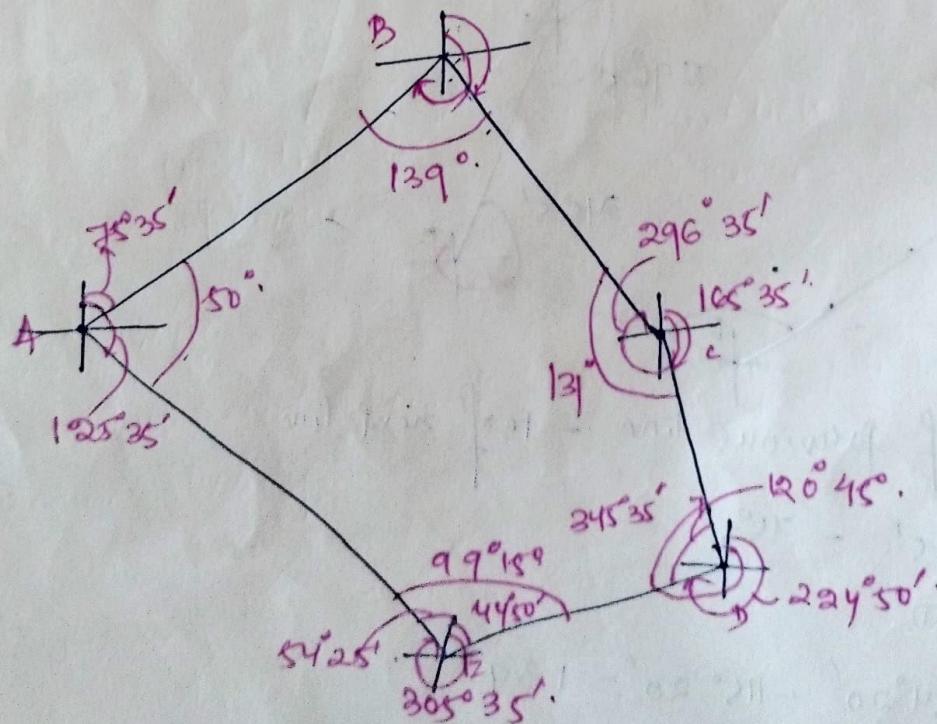
Sum of Interior angle = 540°

mathematical check = $(2n-4)\,90°$

$= 540°$

In this case, sum of interior angle is exactly 540°, hence there is no need of correction in Interior angle but if it differes from 540°, then difference is equally distributed to all the angle to correct them.

With the help of this corrected interior angles, corrected bearings will be calculated by considering line CD as a reference line with correct bearing.



CD line is reference line :

Consider station C,

BB of BC = $165°35' + 131° = 296°35'$

Station D

FB of DC = $345°35' - 120°45'$

= $224°50'$

Station E

BB of DE = $224°50' - 180° = 44°50'$

FB of EA = $360° - 54°25'$

= $305°35'$.

Station A

BB of EA = $305°35' - 180°$

= $125°35'$

FB of AB = $75°35'$

Station B

BB of AB = $75°35' + 180° = 255°35'$

FB of BC = $255°35' - 139 = 116°35'$

Corrected table -

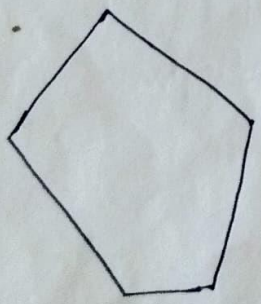
Line	FB	BB
AB	$75°35'$	$255°35'$
BC	$116°35'$	$296°35'$
CD	$165°35'$	$345°35'$
DE	$224°50'$	$44°50'$
EA	$305°35'$	$125°35'$

Note
Use internal angle method in closed traverse so, for closed traverse, internal angle method should be order because it provide check on internal angle also

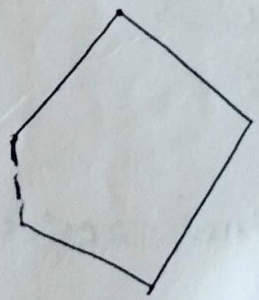
Traverse

Traverse is network of survey lines. Traverse can be made using chain surveying, compass surveying, Theodolite surveying, Plane table surveying etc. Traverse are classified as - ① closed traverse -

② This traverse are obtained when initial and last point or station are already known.



closed loop traverse



closed link traverse.

(2) Open traverse -

This traverse is obtained when only start starting station is known already,

Traverse computation -

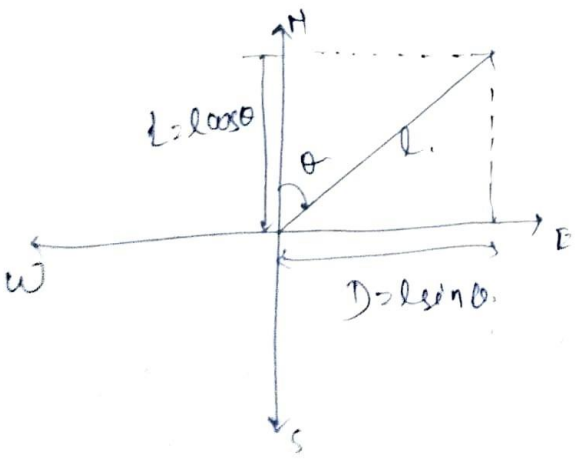
Latitude - projection of a component of any survey line along north south axis is called as latitude. If it is in north direction, then it is considered as +ve and also called as northing. If it is in south direction, then it is considered as -ve and it is called as southing.

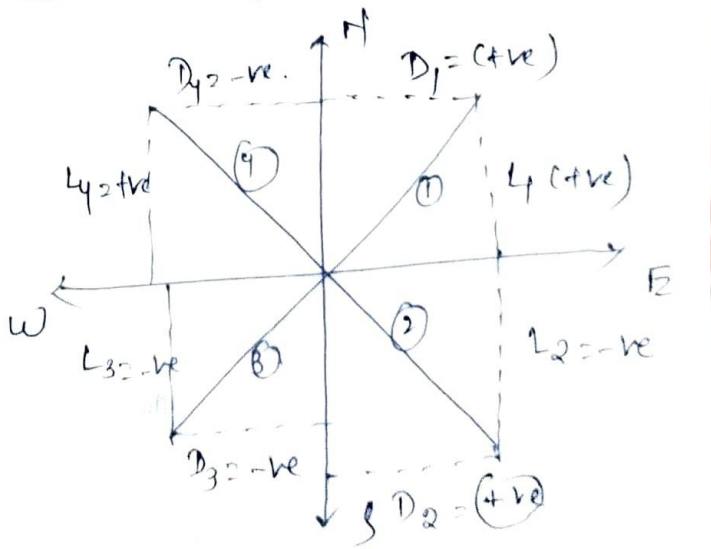
- It can be calculated as $L = l \cos\theta$

l = length of line, θ = Bearing.

Departure - projection or component of any survey line on east and west axis is called as departure. If it is in east direction, then it is called as +ve and also called as easting. Similarly, if it is in west direction, then it is considered as negative and also called as westing.

- It can be calculated as $D = l \sin\theta$





Note

- For the calculation of latitude & departure, RB is considered.
- If QB system is used, then value of θ will be in the range of 0-90°. Hence value of cosθ and sinθ both will be +ve. Hence in different quadrants, we have to mention the sine of latitude & departure.
- But in case of WCB system, the value of θ will vary from 0-360° and in different quadrants according to the sign of sine and cos latitude and departure will automatically adjusted as per sign convention.

Application of latitude & departure :-

2 types of quadrant system can be used in traverse computation -

(1) Independent coordinates -

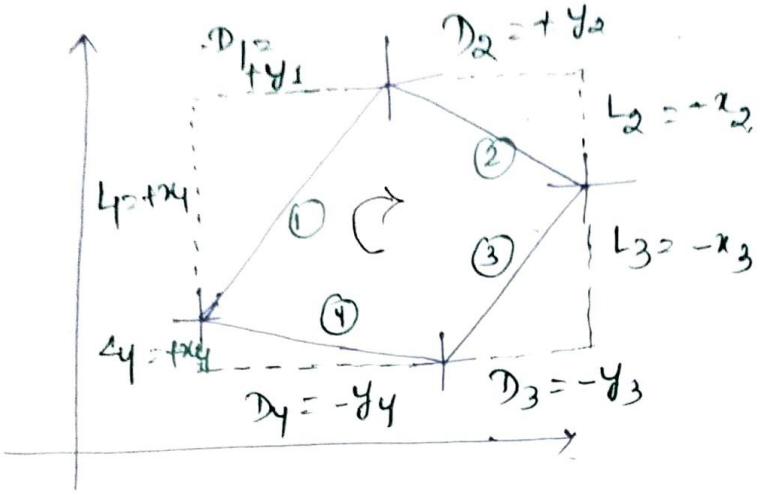
These coordinates are taken considering any global coordinate system. Independent of surrounding system.

(2) Dependent Co-ordinates -

These co-ordinates are defined w.r.t. any station within the traverse taken as reference. These are dependent on each other. In case of closed traverses, sum of latitudes, sum of departures should be zero if there is no error. and by this condition, 2 fundamental eqns are obtained. $\Sigma L = 0$

$\Sigma D = 0$

↑ Using these equations, 2 unknowns (omitted measurements) can be determined.



Sum of latitudes $\Sigma L = +x_4 - x_2 - x_3 + x_4$

$= (x_1 + x_4) - (x_2 + x_3)$

$= 0$

Sum of departure $\Sigma D = +y_1 + y_2 - y_3 - y_4$

$= (y_1 + y_2) - (y_3 + y_4)$

$= 0.$

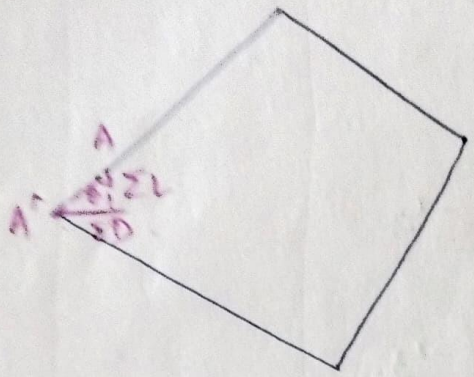
For closed traverse, if there is no error then

$\Sigma L = 0 \;,\; \Sigma D = 0$

Closing error -

For closed traverse on the ground, if there is any error in length measurement or in bearing measurement, then this traverse will not be closed on the paper and this error is to called as closing error. In this case, sum of latitude, sum of departure or any one will not be zero. and the value of closing error can be calculated

as follows :-



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

$$\boxed{\tan\theta = \frac{\Sigma D}{\Sigma L}}$$

Balancing of traverse :-

1. Bowditch method
2. Transit method
3. Graphical method
4. Axis method.

Bowditch method -

This method is suitable when linear and angular measurements have equal degree of precision. In this method, error in linear measurement is considered as proportional to $\sqrt{L}$ and in angular measurement, it is considered as proportional to $1/\sqrt{L}$. In this method, the error in latitude & departure is distributed to different lines in proportion of their ~~line~~ length.

Let error in latitude = ΣL

" " Departure = ΣD.

Let periphery of traverse $\Sigma l = l_1 + l_2 + l_3 + \dots + l_n$

Then correction to applied in latitude of any line $\boxed{e_L = -\Sigma L \times \frac{l_n}{\Sigma l}}$

Correction to be applied in departure of any line

$$C_D = -\Sigma D \times \frac{l_n}{\Sigma l}$$

Transit method

This method is suitable when angular measurements are more precise than linear measurements. According to this method, correction will be applied in the proportion of magnitude of latitude and departure.

Let error in Latitude $= \Sigma L$

" " Departure $= \Sigma D$

Arithmatic sum of magnitudes of latitude $= \Sigma (|L|)$

" " " " Departure $= \Sigma (|D|)$

Then correction to applied in latitude of any line $C_L = -\Sigma L \times \frac{|L_n|}{\Sigma(|L|)}$

" " " Departure " " $C_D = -\Sigma D \times \frac{|D_n|}{\Sigma(|D|)}$

Note - If error in the bearing of last line is θ, then it is Corrected by applying correction to all the bearing as follows :-

Let error in nth line $= \theta$

Correction in bearing of 1st line $= \frac{\theta}{n}$

2nd " $= 2\theta/n$

3rd " $= 3\theta/n$

⋮

nth " $= n\theta/n = \theta$.

Line	Length	FB
AB	x	35°
BC	280	80°
CD	350	165°
DE	y	238°
EA	275	310°

$\Sigma L = 0$

$x\cos 35^\circ + 280^\circ \cos 80^\circ + 350 \cos 165^\circ + y \cos 238^\circ + 275 \cos 310^\circ = 0$ ——— (1).

$\Rightarrow 0.82x + -112.685 + -0.534y = 0$

$\Sigma D = 0$

$x \sin 35^\circ + 280 \sin 80^\circ + 350 \sin 165^\circ + y \sin 238^\circ + 275 \sin 310^\circ = 0$

$\Rightarrow 0.57x + 155.67 - 0.85y = 0.$

$0.467x - 64.23 - 0.302y = 0$

$0.467x + 127.65 - 0.697y = 0$

(−) (−) (+)

$0.395y = 191.88$

$y = 485.77.$

$x = 451.3$

P-50

16) $\Sigma L = 0.508$, $\Sigma D = 0.223.$

$e = \sqrt{(\Sigma D)^2 + (\Sigma L)^2} = 0.554$

$\theta = \tan^{-1} \frac{\Sigma D}{\Sigma L} = 23.7 = N23^\circ 42' 1.22'' E$

Levelling

Defining the level of any point w.r.t. any fixed datum is called as Levelling. Establishing any point at known level or elevation w.r.t. any reference datum is also called as levelling.

Some basic definitions :-

1) Level - Height or elevation of any point w.r.t. any reference is called as Levelling.

2) Reduced Level - Absolute level of any point should be defined w.r.t. center of earth but it is not practically visible. Hence by substracting radius of earth from absolute level, reduced level is obtained. This reduced level is measured from surface of earth and surface of earth is represented by mean sea level.

3) Mean Sea Level - It is avg. level of sea which is assumed as the surface coinciding with earth surface. Average is taken of 19 years. In India, MSL is considered at Mumbai. MSL is taken as a datum or reference for levelling.

4) Benchmark - The points with known RL are called as Benchmarks. These are classified as

① GTS Benchmark (Great Trigonometrical survey) - These benchmarks are established by survey of India In British era at every 100 km.

② Permanent Benchmark -

Between the GTS benchmarks, permanent BMs are established by diff. govt. departments like PWD, WRD, Railways etc. under the guidance of Survey of India. These BMs are marked on permanent constructions like Railway platforms, milestones, piers of Bridge etc.

③ Temporary Benchmark -

These are the points assumed as BM at the end of today's work and to consider it as a reference for next day work.

④ Arbitrary Benchmark -

These are randomly selected points as a BM which are only useful for relative measurement.

Types of Levelling :-

1) Barometric Levelling - with the help of barometer, pressure is determined and it is correlated with height.

2) Hypsometric Levelling - Hypsometer
⇓
gives boiling temp. of water and its correlated with height

3) Trigonometric Levelling - height & distance

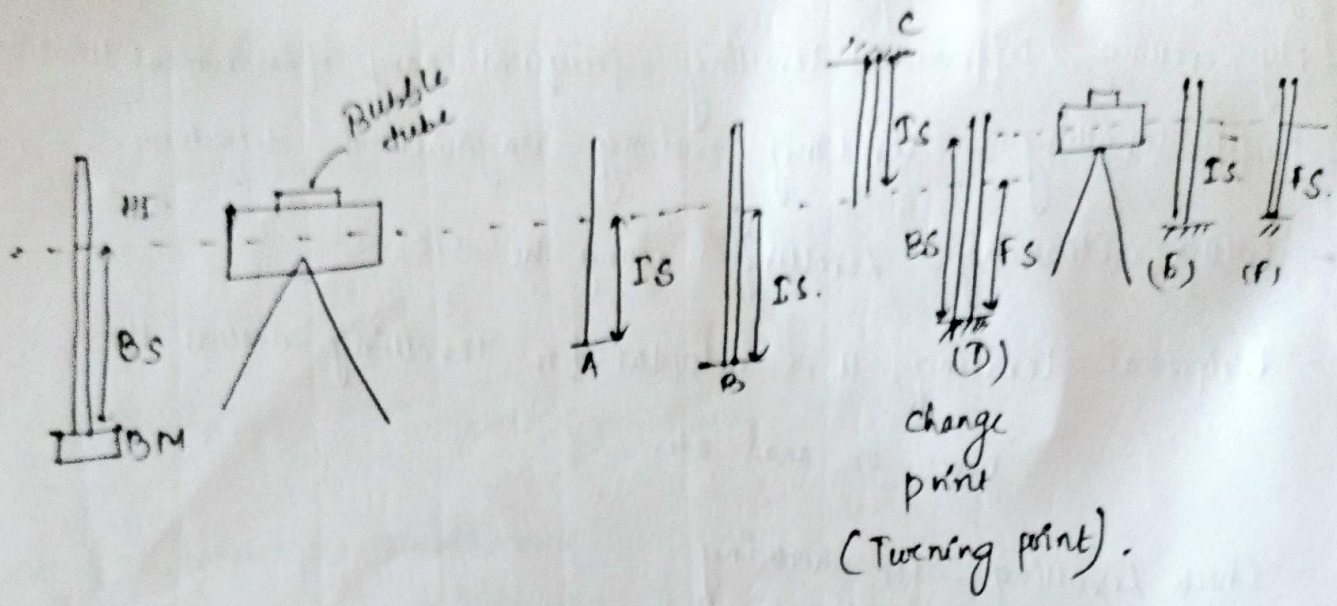
4) Direct Levelling - with the help of telescope.
① levelling instrument ② Levelling staff
ex - Dumpy level, Autolevel.

Types of direct levelling -

- Fly Levelling / Differential levelling - frequent change of instrument location.
- Profile levelling - levelling along longitudinal direction.
- Cross sectioning - Levelling along the c/s.
- Reciprocal levelling - It is adopted for levelling across the river or canal etc.
- Check Levelling - for checking
- Precise Levelling - Using precise instruments.

Direct Levelling and terms related to direct levelling -

1) Station - The position of staff is called as station.
2) height of instrument (height of line of sight) -
It is level of line of sight measured from MSL or any datum.
3) Back sight - It is 1st reading for any instrument position taken by keeping levelling staff at point of known RL. with the help of BS, HI is calculated.
4) Intermediate sight - staff readings except BS and FS are called as Intermediate sight.
5) Forcesight - It is last reading taken by any instrument position.
6) Change point - At this point, 2 readings will be taken, first one will be forcesight of previous instrument position and 2nd one will be backsight of new instrument position.



Methods to find RL:

i) HI method -

Step1 - Find the HI for any instrument position

$$HI = RL \text{ of } BM + BS$$

Step2 - With the help of HI, and IS/FS, RL is calculated.

$$RL = HI - IS/FS$$

Step3 - After FS taken at any station, the instrument is shifted to new position and new HI is calculated, by taking backsight on the same station. This station is change point. After this station, step-1 & 2 is repeated again.

Step4 - At the end arithmatic check is applied.

$$\Sigma BS - \Sigma FS = \text{Last RL} - \text{1st RL}$$

Q) Stations

A
B
C
D
E
F
G
H

ii) Rise and Fall method -

- In this method, difference of previous reading and next reading is calculated. If difference is +ve, then it is considered as rise, if difference is -ve, then it is considered as fall.

- If there is rise, then it is added in RL of previous station to get the RL of next station. similarly, if it is fall, then it is subtracted from RL of previous station to get RL of next station.

- Arithmatic check is applied as,

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

Q) Stations	BS	IS	FS	HI	RL	Remarks
				~~100~~ 102	100	BM
A	2				99.4.	
B		2.6			98.8	
C		3.2			98.1.	change point (cp)
D	0.8		3.9	98.9.	97.5.	
E		1.4			96.9	
F		2			96.1	
G		2.8			96.8	
H			2.1.			

$\Sigma BS - \Sigma FS = 2.8 - 6 = -3.2$

Last RL - 1st RL = -3.2.

Rise and Fall method -

Stations	BS	TS	FS	Rise	Fall	RL	Remarks
A	2				6	100	BM
B		2.6			0.6	99.4	
C		3.2			0.6	98.8	
D	0.8		3.9		0.7	98.1	
E		1.4			0.6	97.5	
F		2			0.6	96.9	
G		2.8			0.8	96.1	
H			2.1	0.7	—	96.8	

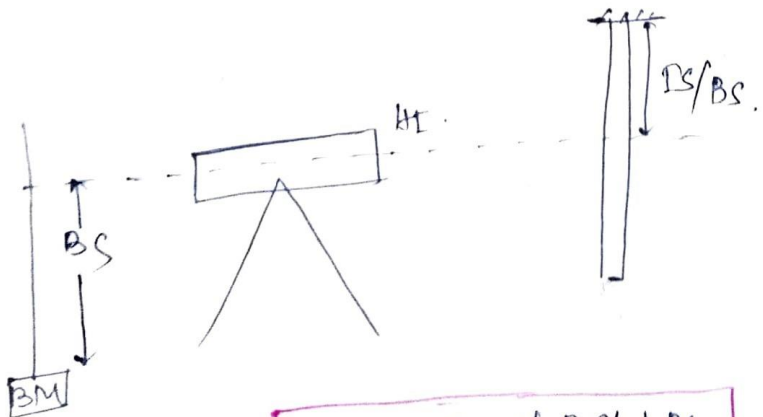
ΣRise $-$ ΣFall $= -3.2$

Last RL $-$ 1st RL $= -3.2$

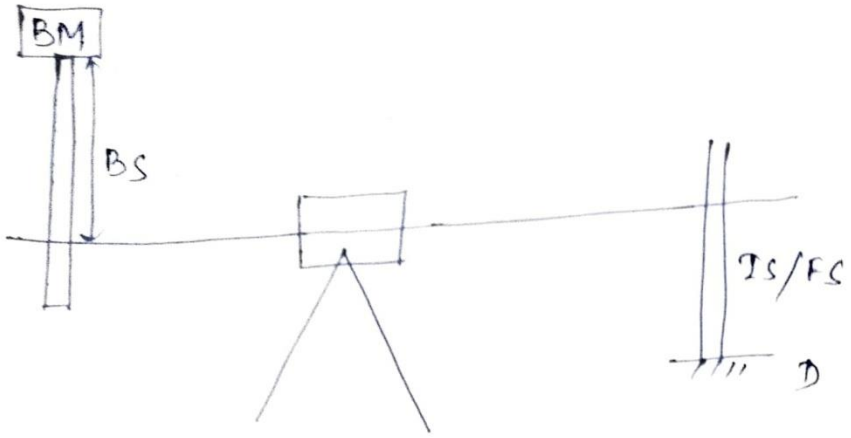
Note

In case of HI method, check is applied only on BS and FS by in rise and fall method. check is applied on BS, FS and IS also.

Inverted staff condition -



HI = RL of BM + BS



HI = RL of BM − BS

RL of D = HI − IS/BS

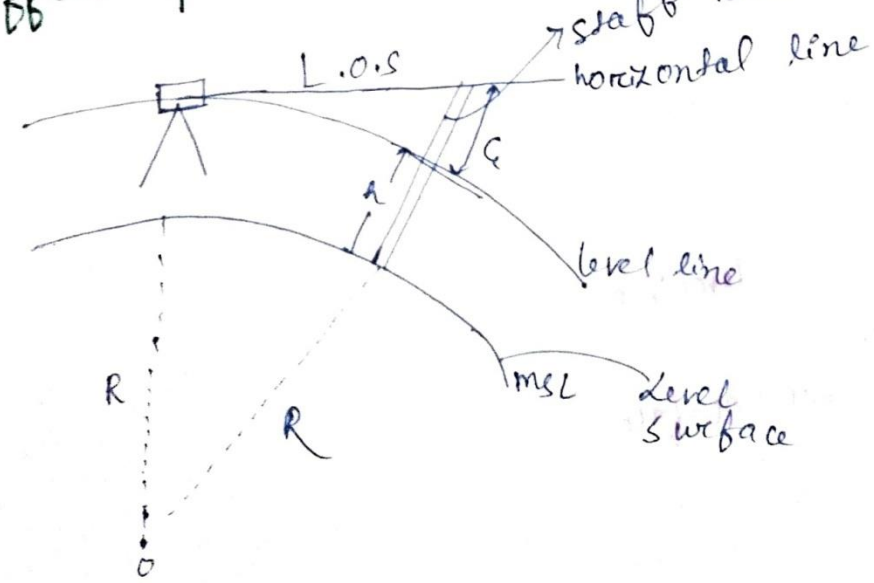
P-36

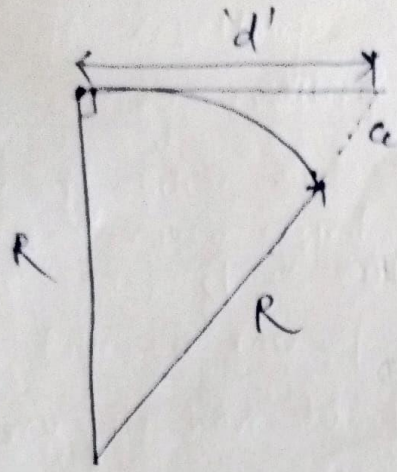
52)

Geodetic Levelling

(Effect of earth & curvature and refraction)

Effect of earth's curvature -





By Δ property,

$R^2 + d^2 = (R + C_c)^2$

$\Rightarrow R^2 + d^2 = R^2 + C_c^2 + 2RC_c$.

$\Rightarrow d^2 = 2RC_c$

$\Rightarrow \boxed{C_c = \frac{d^2}{2R}}$ nature always -ve.

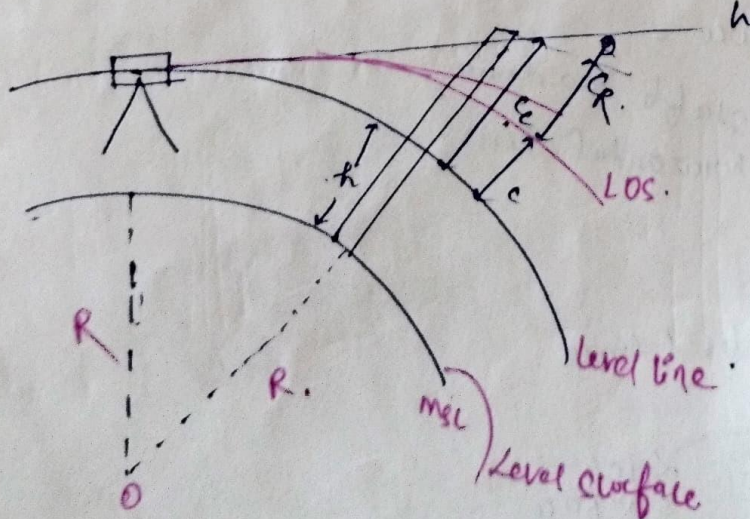
$\therefore = \frac{d^2}{2 \times 6370 \text{ km}}$

$= \frac{d^2}{2 \times 6370} \times 1000 \text{ m}$

$\boxed{C_c = -0.07849 d^2 \rightarrow \text{km}}$

C_c = Curvature correction and it's applied on staff reading.

Effect of refraction-



C_R = Refraction correction (+ve in nature)

$$C_R = \frac{1}{7} C_e = \frac{1}{7} \frac{d^2}{2R} \quad (+ve)$$

Combined correction,

$$'c' = -\frac{d^2}{2R} + \frac{1}{7}\frac{d^2}{2R}$$

$$= -\frac{6}{7}\frac{d^2}{2R}$$

$$c = -\frac{6}{7} \times \frac{d^2 \times 1000}{2 \times 6370} \text{ m}$$

$$\boxed{c = -0.06735 d^2 \text{ km.}}$$

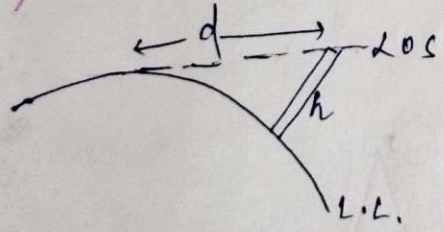
'm' (always -ve)

c = combined correction (Refraction + curvature)

d = horizontal distance b/w staff & Instrument (km)

Case 1:- Distance through visible horizon -

(case-1)



By comparing 'c' formula,

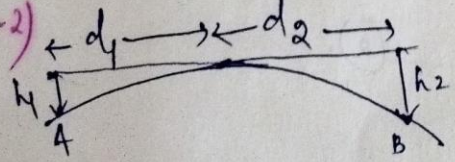
$$h = c = 0.06735 d^2$$

$$h = 0.06735 d^2$$

$$d_{(km)} = \sqrt{\frac{h}{0.06735}}$$

$$\boxed{d_{(km)} = 3.85 \sqrt{h_{(m)}}}$$

(case-2)



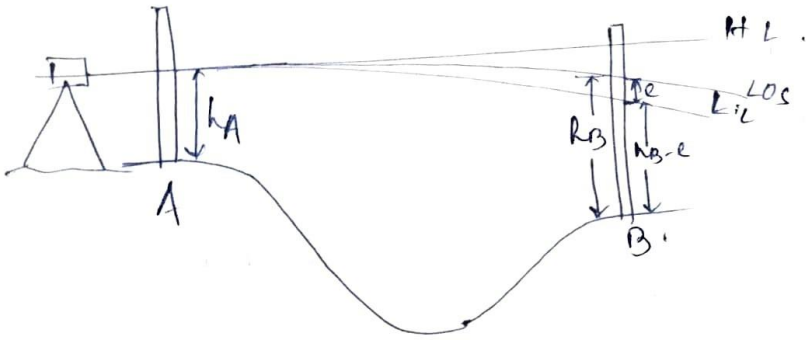
$$D_{AB} = d_1 + d_2$$

$$\boxed{D_{(km)} = 3.85 \sqrt{h_{1(m)}} + 3.85 \sqrt{h_{2(m)}}}$$

Reciprocal Levelling -

- During levelling, it is taken care that the distance b/w staff station and instrument position for different station should be nearly equal.
- In some cases, it is not visible to place the instrument in between like in case of river. To perform the levelling across the river, we have to put the instrument either side of the river at a time. This type of levelling is done as a reciprocal levelling in which measurement is done 2 times.

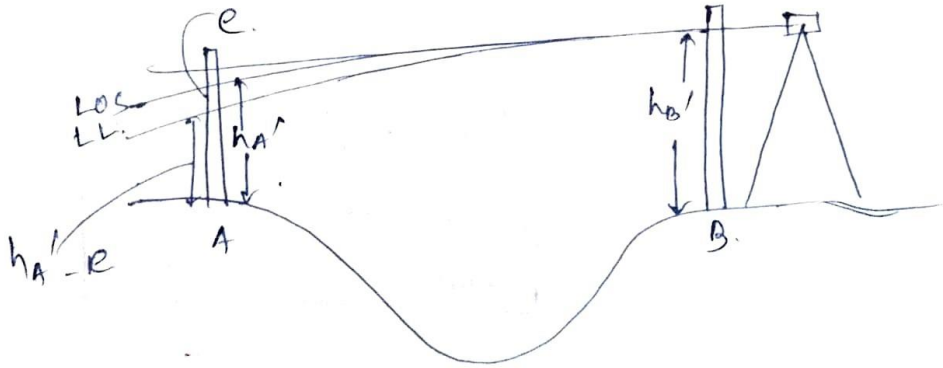
(1) When instrument is near A :-



elevation difference between A & B =

$$H = h_B - e - h_A \quad \text{——} (1).$$

(2) When instrument is near B :-



$$H = h_B' - (h_A' - e) \quad \text{——} (2).$$

add ① & ②

$$2H = h_B - e - h_A + h_B' - h_A' + e$$

$$= (h_B - h_A) + (h_B' - h_A')$$

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

if RL of A is known,

then RL of B = RL of A − H

e = Curvature error + Refraction error + line of collimation error.

Bubble tube, level tube and its sensitivity:

- It is provided along with telescope to make it horizontal at the time of measurement. If bubble is at the centre, then LOS will be horizontal.

- In bubble tube, less viscous liquids like spirit, alcohol, chloroform etc. are partially filled so that bubble formation can take place.

- Sensitivity of bubble tube is the property by which bubble will move from its position due to any tilting in instrument axis. It is also defined as min. angle of tilt required to move the bubble by 1 division.

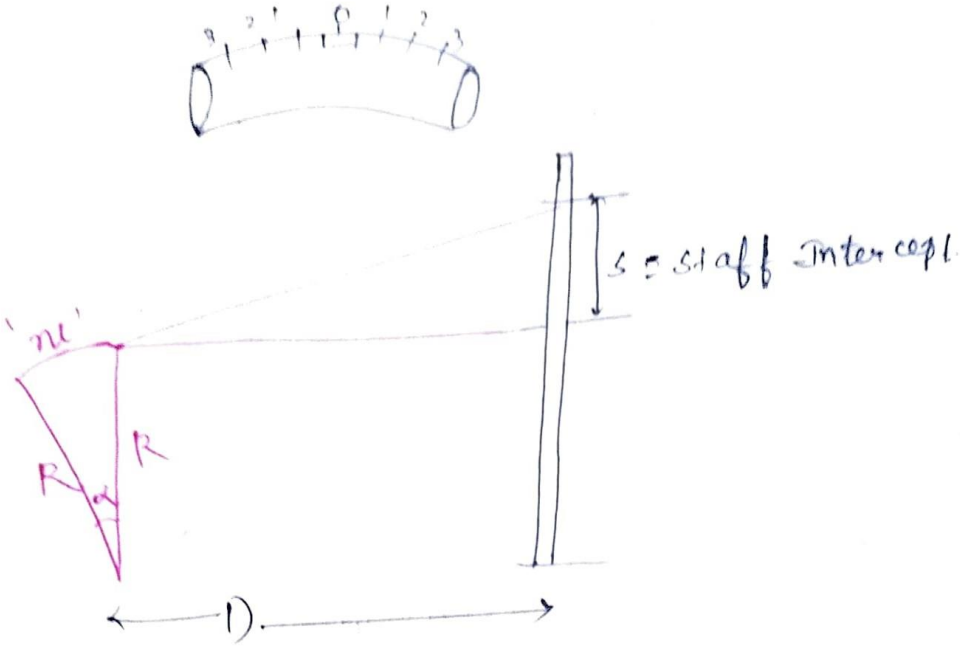
- Sensitivity depends on following factors:

a) It increases with increase in radius of tube, radius of curvature and with increase in length of the bubble.

b) It also increases with decrease in viscosity, friction in the tube.

c) But it decreases with increase in temp. due to expansion of

the fluid.



D = Distance between Instrument & staff.

l = length of 1 div = 2mm.

n = no of division moved by bubble.

$$\alpha = \frac{S}{D} = \frac{nl}{R}$$

n - division movement = α

1 " " = $\frac{\alpha}{n}$.

$$\boxed{\alpha' = \frac{\alpha}{n} = \frac{S}{nD} = \frac{l}{R}.}$$ as per def^n;

small α', more sensitivity

$$\boxed{\alpha' = \frac{S}{nD} = \frac{l}{R}}$$

$$\alpha' = \frac{S}{nD} \times \frac{180}{\pi} \times 60 \times 60.$$

$$\boxed{\alpha' = \frac{S}{nD} \times 206265 \text{ sec.}}$$

$$\boxed{\alpha' = \frac{l}{R} \times 206265 \text{ sec.}}$$

Adjustment of dumpy level / auto level :-

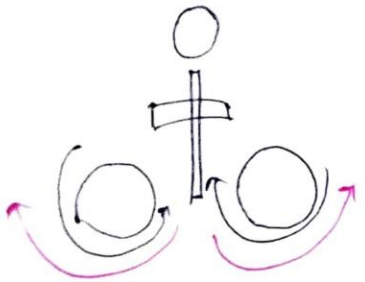
1) Temporary adjustment

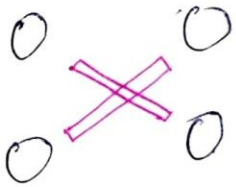
After changing the position and before taking the readings, temporary adjustment is done.

1) Setting up or fixing up of instrument on the tripod.

2) Levelling up.

With the help of foot screw, the instrument is levelled until the bubble comes at center. 3 foot screw arrangement / 4 foot screw arrangement can be provided on the instrument.





3) Removal of parallax -

By adjust eyepiece and objective, the image of staff is adjusted in plane of crosshairs, for clear visibility and proper reading.

2) Permanent adjustment -

Permanent adjustment is done periodically to check the instrument axis and other components of instrument

Contouring

Contour -

Contours are imaginary lines on the ground joining the points having same elevation or RL.

Contour lines -

Lines joining the points of same RL on the map are called as contour lines.

Contour interval -

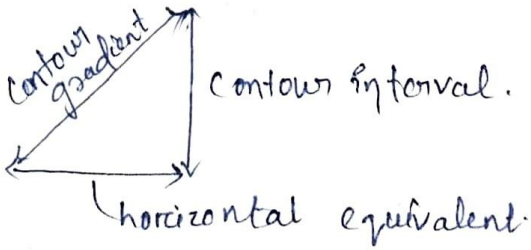
It is elevation difference between 2 consecutive or adjacent contour lines and it will remain constant for a map.

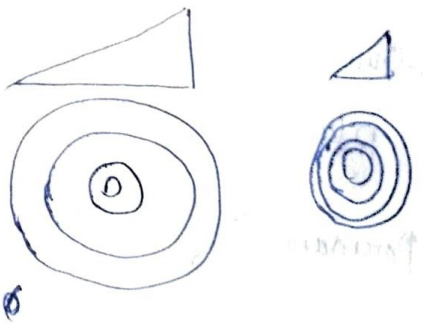
Horizontal equivalent -

Horizontal distance between 2 ~~or~~ adjacent contour lines is called as horizontal equivalent.

Contour gradient -

Slope of ground across contour lines is called as contour gradient.





Methods of contouring.

1) **Direct method -**

In this method, levelling is performed at every point under consideration and RL of these points are drawn over the map and same RLs are joined by contour lines.

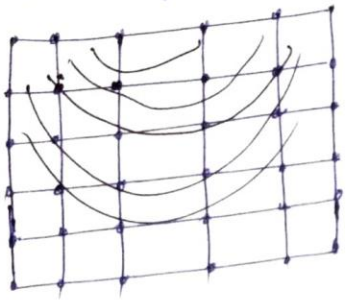
But this method is not suitable for large areas although it is most accurate method.

Indirect method-

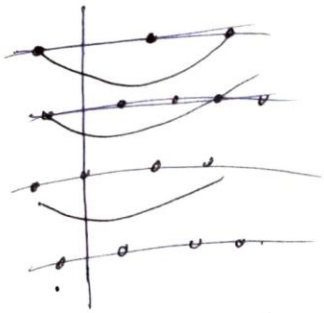
In this method, levelling is performed at only some guide points and the level of intermediate points is determined by interpolation is Mathematically. This method is suitable for larger areas and it is quick in nature.

Ex:-

(1) Square grid method

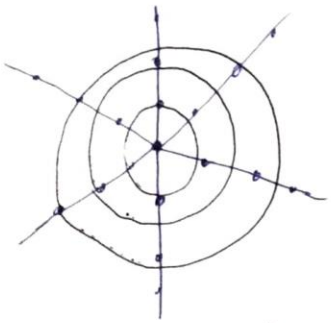


(2) Cross-sectioning method (road, canal etc.).



(3) Radial method (Tacheometry method).

- suitable for hilly area.



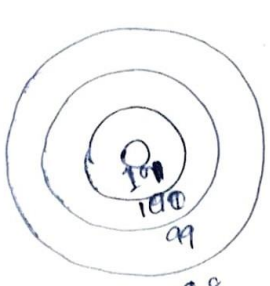
Characteristics of contour lines -

1) Contour lines will never intersects to each other.

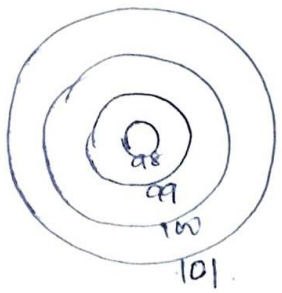
2) If contour lines are closer, then it indicates steep slope and if ~~there are~~ they are at large space, then it indicates flat area.

3) contour lines will always be a closed loop but it mayn't be seen on a single map.

4) closed contour lines with higher elevation inside indicates hilly area. similarly, closed contour lines with smaller elevation inside indicates depression or pond.

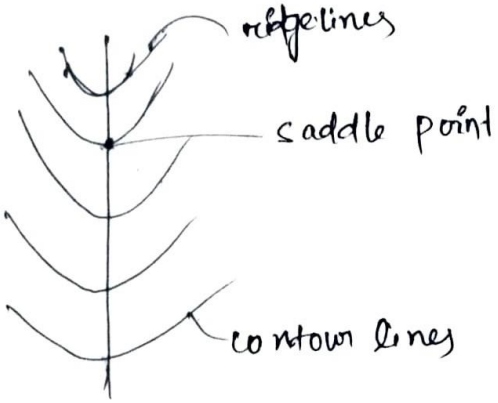


(hill)



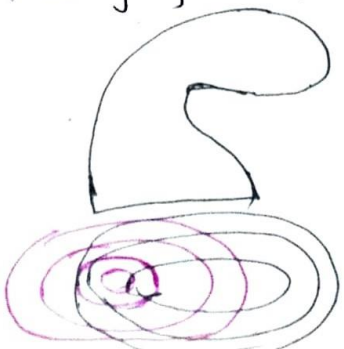
(pond)

5) contour lines will intersect valley line or ridge line at 90° and the point of intersections are known as saddle points.

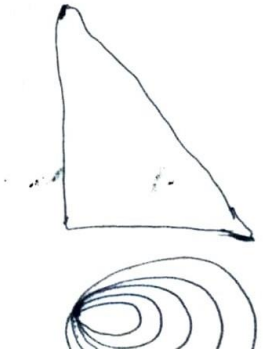


There are some exceptions where it seems like contour lines are intersecting each other or they are meeting at a point.

Over hanging cliff



vertical cliff



Use of Contour lines-

1) Using contour lines, nature of ground can be identified on the map. Contour lines helps in making the layout of canals, roads, tunnel, bridge etc.

2) It also helps in finding out catchment area.

3) It also helps in calculation of volume of reservoir.

Tacheometry

- It is indirect method of surveying in which horizontal distance and elevation of different points can be determined with the help of tacheometer.

- Tacheometer is external focusing theodolite with stadia cross hair. In tachometer, an additional anallactic lens is also provided.

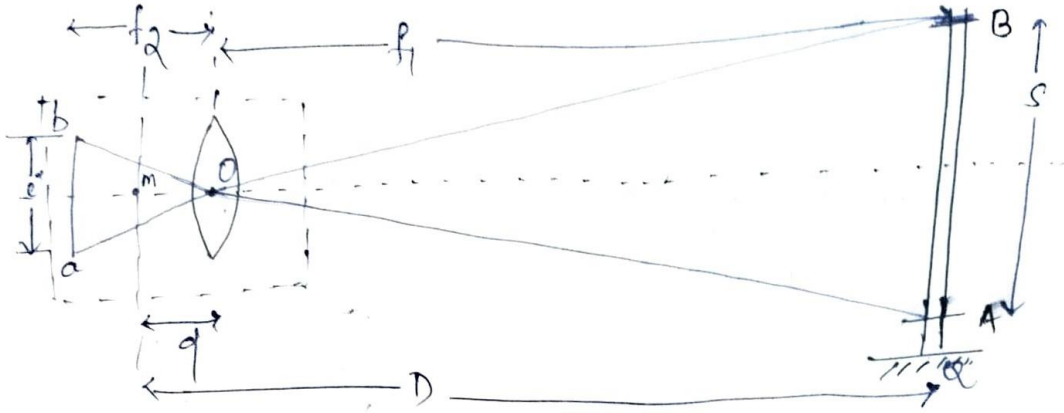
- Internal focusing telescopes are also used in tacheometry.

Normal cross hair

Stadia cross hair

Tacheometry is preferred to chain surveying in case of hilly terrain.

Relation between staff intercept & distance :-



i = stadia interval

s = staff intercept

q = distance between optical center & c.g. of instrument

D = distance between ~~intercept~~ ~~and~~ instrument and staff station

f = focal length of line.

By similar triangle, ΔOAB & ΔOab,

$$\frac{s}{f_1} = \frac{i}{f_2}$$

$$\Rightarrow \boxed{\frac{s}{i} = \frac{f_1}{f_2}}$$

Using lens formula,

$$\boxed{\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}}$$

Multiply ff_1 on both sides in lens formula,

$$\frac{ff_1}{f} = \frac{ff_1}{f_1} + \frac{ff_1}{f_2}$$

$$\Rightarrow f_1 = f + f \cdot \frac{f_1}{f_2}$$

$$\Rightarrow \boxed{f_1 = f + f \cdot \frac{s}{i}}$$

$$D = f_1 + d$$

$$= f_1 + f \cdot \frac{s}{i} + d$$

$$D = s \cdot \frac{f}{i} + f + d$$

$$\boxed{D = Ks + C}$$

where $\boxed{K = \frac{f}{i}}$

$$\boxed{C = f + d}$$

K = multiplying constant

C = additive constant.

Generally, $K = 100$

If anallactic lens is also provide,

$$\boxed{C = 0}$$

Note

The value of K and C can be obtained in the field by taking 2 intercepts at 2 known distances. Then eqn will be found like,

$$D_1 = KS_{21} + C$$

$$D_2 = KS_2 + C$$

Using these eq's, K and C can be determined.

The above method of tachometry is called as fixed hair method or Stadia method. other methods of tachometry are -

(1) Movable hair method -

In this method, stadia interval will change keeping staff intercept constant. This method is also called as subtense bar method.

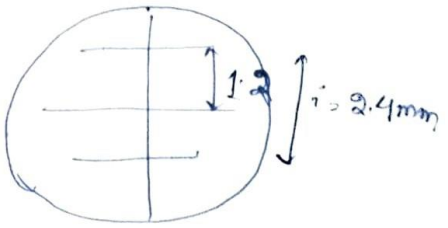
(2) Tangential method -

In this method, stadia hair will n't be present in telescope. Hence, intercept is measured by taking more than one observations. Hence it is time consuming method and generally not used.

Ch-14

1). $f = 240mm$., $i = 2.4mm$

$K = f/i = \frac{240}{2.4} = 100$.



b) $f = 20cm$.

$d = 10cm$.

$i = 4mm$

$S = (2.5 - 1) \times 2$.

$D = (f/i) S + (f + d)$

$= \frac{0.20}{0.4} \times 3 + (0.3)$

$= 150 + (3) = 150.3 mm$.

8) $D_1 = 50$

$D_2 = 2$ km.

$D_1 = KS_1 + C$

$\Rightarrow 50 = K \times 0.49 + C$.

$200 = K \times 1.99 + C$.

$150 = K(1.99 - 0.49)$

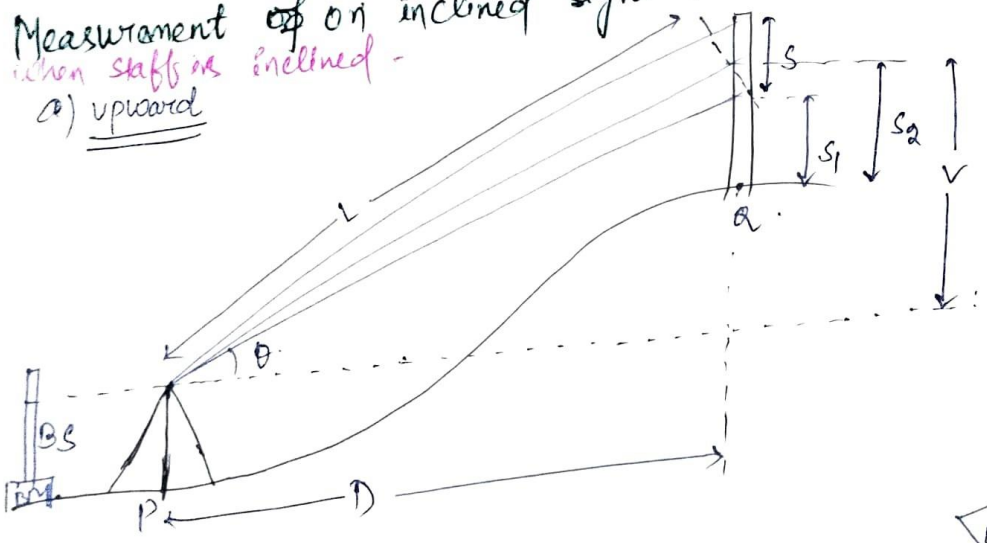
$K = \frac{150}{1.5} = 100$

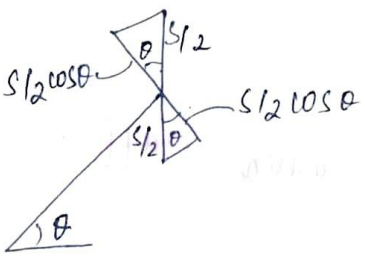
$C = 50 - 49 = 1$.

Measurement on inclined sight :-

When staff is inclined -

a) upward





Staff intercept ⊥r to line of sight.

$= \frac{S}{2} \cos\theta \times 2$

$= S\cos\theta$.

$$\boxed{L = K(S\cos\theta) + C}$$

$D = L\cos\theta$

$D = \left[K(S\cos\theta) + C\right] \cos\theta$

$$\boxed{D = KS\cos^2\theta + C\cos\theta}$$

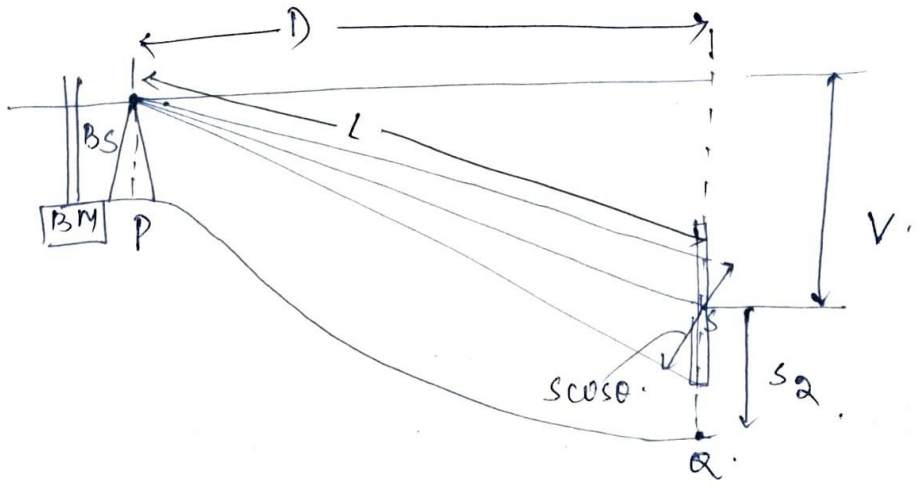
$V = L \sin\theta$

$= (K S\cos\theta + C) \sin\theta$

$V = K S \cos\theta \sin\theta + C \sin\theta$.

RL of Q = RL of BM + BS + V - S_2

(b) Downward-



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

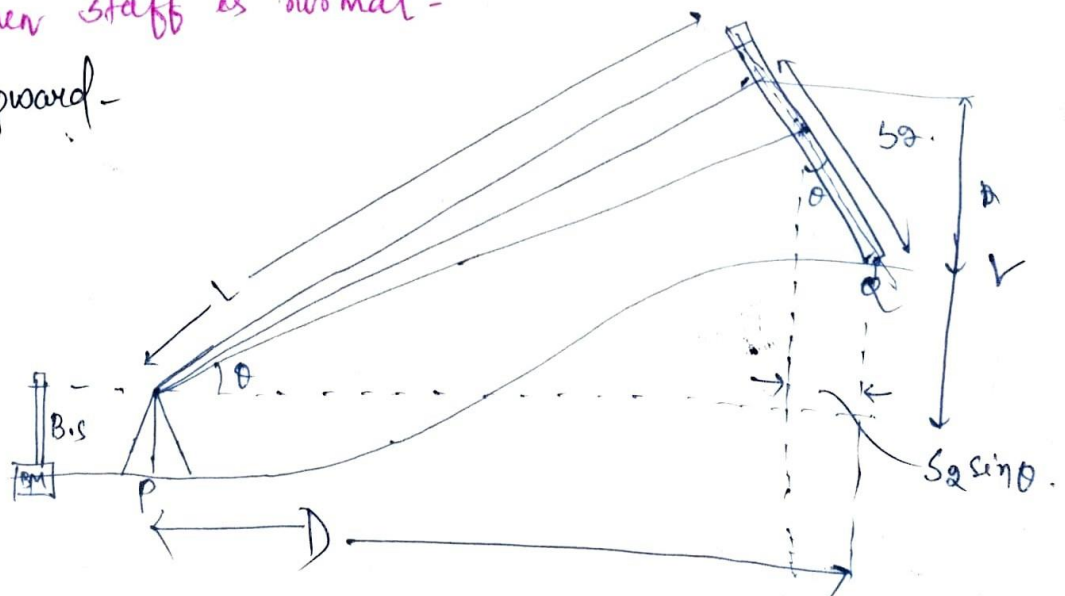
$D = K S \cos^2\theta + C\cos\theta$

$V = K S\cos\theta . \sin\theta + C \sin\theta$.

RL of Q = RL of BM + BS − V − S_2

(2) When staff is normal-

a) Upward-



$L = KS + C$

$D = L\cos\theta + S_2 \sin\theta$

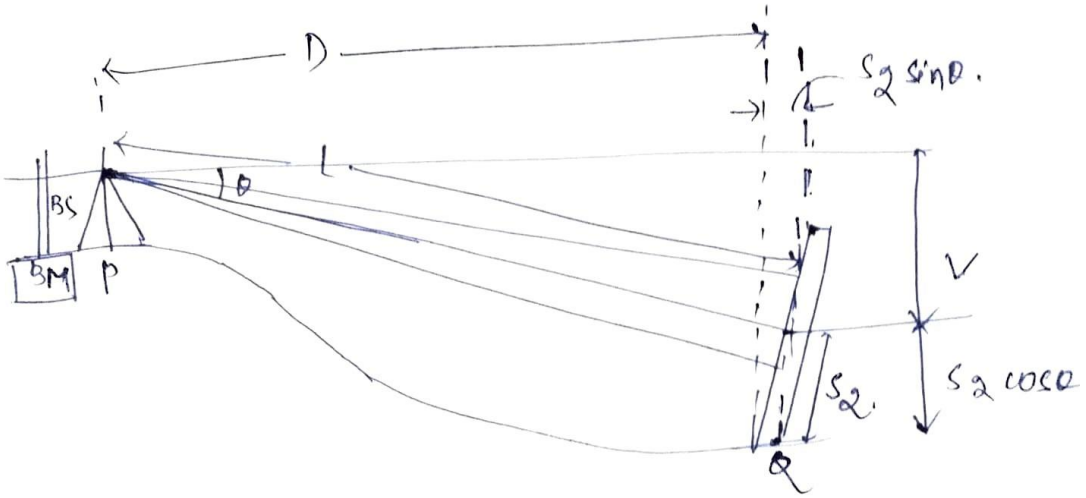
$$D = (KS+C)\cos\theta + S_2 \sin\theta$$

$V = L\sin\theta$

$V = (KS+C)\sin\theta$

RL of Q = RL of BM + BS + V − $S_2\cos\theta$.

(5) Downward -



$L = KS + C$

$D = L\cos\theta - S_2 \sin\theta$.

$= (KS+C)\cos\theta - S_2 \sin\theta$.

$V = L\sin\theta = (KS+C)\sin\theta$

RL of Q = RL of BM + BS − V − $S_2\cos\theta$.

Theory of Errors

True errors - Difference between measured value and true value is called as true error.

True value - It is the exact value of any quantity which can't be determined easily.

Precision - Degree of perfection used at the time of measurement is called as precision. Precision can be increased by using suitable instruments, suitable methods etc.

Accuracy - It is the degree of perfection obtained at the end.

Sources of Error :-

1) Personal Error - missing data
2) Instrumental error - line of collimation error - collimation error is due to the line of sight of a survey instr. not coinciding with traversing gear, scale or leveling devices.
3) Natural error - curvature errors, Refraction error.

Types of error :-

1) Mistakes : These are the basic type of errors which mainly occurs due to carelessness, less experienced, less knowledge, hurriness etc. Mistakes shouldn't takes place. To check the mistakes, 2 surveyors are mainly perform the survey and time to time check is applied.

2) Systematic error / cumulative error.

These errors occurs due to well defined reasons and they are systematic in nature. These errors can be easily removed by applying suitable corrections. Generally, systematic errors are cumulative in nature means the total error will be either positive or negative.

Ex:- Error due to slope, sag, standardisation etc.

3) Accidental errors / compensating errors:

These errors have no any specific reasons. They occurs randomly. Their nature may be +ve or -ve that's why, these are called as compensating error or residual error also. Compensating errors are difficult to calculate.

Accidental errors can be determined by using theory of probability

Theory of Probability:-

1) Most probable Value:-

It is the value of any qt. which is having max. chance to be true value. MPV can be determined by using theory of least square.

Theory of least square - Acc. to this theory, the value for which the sum of square of errors will be minimum, that value will be MPV.

Let MPV = $\bar{x}$

$x_1, x_2, x_3 \ldots\ldots x_n$

$\Sigma e = (x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + (x_3 - \bar{x})^2 + \ldots\ldots (x_n - \bar{x})^2$

$\frac{\partial \Sigma e}{\partial \bar{x}} = 0$

$0 = 2(x_1 - \bar{x}) + 2(x_2 - \bar{x}) + 2(x_3 - \bar{x}) + \ldots\ldots 2(x_n - \bar{x})$

$0 = (x_1 + x_2 + x_3 + \ldots\ldots x_n) - n\bar{x}$

$$\bar{x} = \frac{x_1 + x_2 + \ldots\ldots x_n}{n}$$

⇒ when all the measurements have equal weight.

If all the measurements have diff. wt,

$$\bar{x} = \frac{w_1 x_1 + w_2 x_2 + \ldots\ldots w_n x_n}{w_1 + w_2 + \ldots\ldots w_n}$$

Concept of weight -

Weight is a numerical value assigned to any measurement as per precision taken during the measurement and weight is inversely proportional to error.

Laws of weight -

①

Quantity	wt
x_1	w_1
x_2	w_2

What will be wt of S' where $S = x_1 + x_2$.

wt. of S will be $= \frac{1}{\frac{1}{w_1} + \frac{1}{w_2}}$

(2)

Quantity	wt
x_1	w_1
x_2	w_2,

wt. of 's' where $S = kx_1$ (k: const.)

$= \frac{w_1}{k^2}$

(3)

Quantity	wt
x_1	w_1

wt. of 's' where $S = \frac{x_1}{k}$

then wt. of $S = w_1 \cdot k^2$

(4)

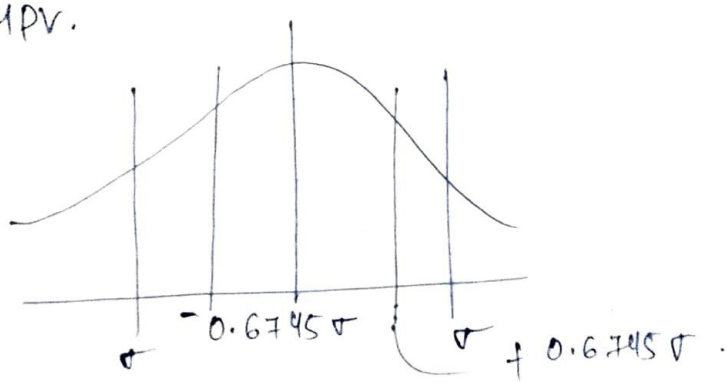
qt.	wt
x_1	w_1

wt. of 's' where $S = x_1 \pm k$

wt. of $S = w_1$

Most probable error :-

With the help of most probable error, true value can be obtained easily by adding it or subtracting it from MPV.



σ (Standard error) $= \sqrt{\frac{\Sigma (x_1 - \bar{x})^2}{n-1}}$

(1) M.P error in any measurement

$$E_S = \pm .6745 \sqrt{\frac{\sum w_i (x_i - \bar{x})^2}{(n-1)}}$$

(2) M.P error in mean value

$$E_m = \pm .6745 \sqrt{\frac{\sum w_i (x_i - \bar{x})^2}{(n-1) \sum w_i}} = \frac{E_S}{\sqrt{\sum w_i}}$$

(3) M.P error in any quantity having wt. 'w_m'

$$E_w = \pm 0.6745 \sqrt{\frac{\sum w_i (x_i - \bar{x})^2}{(n-1) w_m}}$$

If wts equal for all, then

$$E_S = \pm .6745 \sqrt{\frac{\sum (x_i - \bar{x})^2}{(n-1)}}$$

If all the wt. are equal,

$$E_m = \pm 0.6745 \sqrt{\frac{\sum (x_i - \bar{x})^2}{(n-1) n}} = \frac{E_S}{\sqrt{n}}$$

Error in computed data.

	max. error	probable error
Let quantity x —	δx	e_x
" y —	δy	e_y.

Then error in 'S'

S	max^m error	Probable error
$S = x \pm y$	$\pm(\delta x + \delta y)$	$\pm \sqrt{e_x^2 + e_y^2}$.
$S = xy$	$\pm (x \delta y + y \delta x)$	$\pm S \sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}$

$$\therefore S_{2x/y} \left| \pm\left(\frac{\delta x}{y} + \frac{x}{y^2}\delta y\right) \right| \left| \pm S\sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2} \right.$$

If value of max. error and probable error is not given in table, then it can be calculated as per the qt. as follows :-

	δx	e_x
$x = 235$	0.5	0.25
$x = 234.5$	0.05	0.025
$x = 11.39$	.005	0.0025
$x = 1.395$	0.0005	0.00025

Ch-8

1) $x = 120$ $e_x = 0.05$

$y = 180$ $e_y = 0.06$

$x \cdot y$

$$P.E = S\sqrt{\left(\frac{e_x}{x}\right)^2 + \left(\frac{e_y}{y}\right)^2}$$

$$= 120 \times 180 \sqrt{\left(\frac{0.05}{120}\right)^2 + \left(\frac{0.06}{180}\right)^2}$$

$$= 11.53 \text{ sq.m.}$$

7) $\therefore 3^3 = 27.$

Note

Cumulative errors will be proportional to L but compensating errors will be proportional to $\sqrt{L}$.

Curve

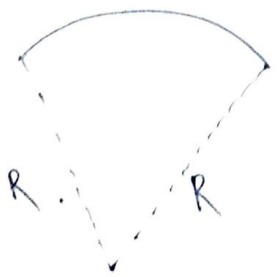
Basically 2 types of curves are provided.

1) horizontal curves
2) Vertical curves

horizontal curves —
- simple circular curve
- compound curve
- Reverse curve
- Transition curve

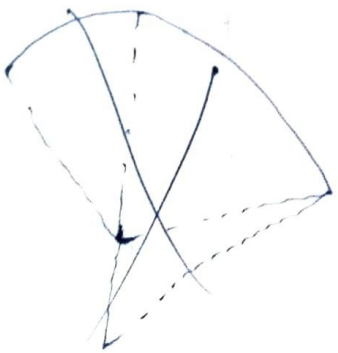
Vertical curves —
- valley curve
- Summit Curve

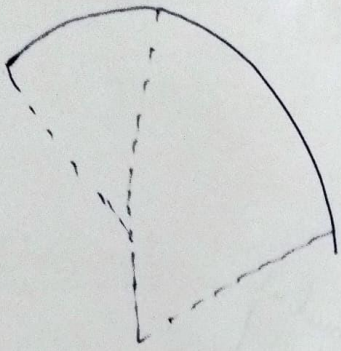
Simple Circular Curve -



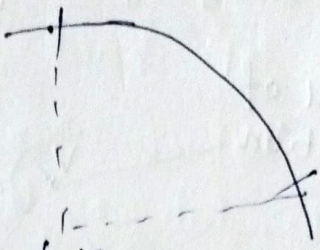
(Simple circular)

(Reverse)





(Compound)



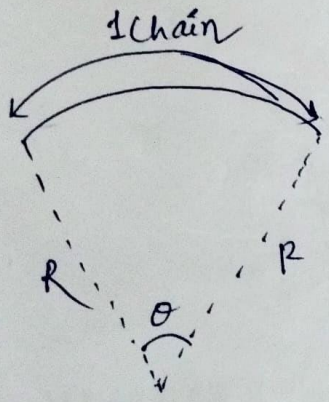
(Transition curve)

Representation of curve of simple circular curve -

1) Radius -

Curve is represented by radius of circle from which it is taken.

Curve is also represented by degree of curve.



$$\theta = \frac{1\text{chain}}{R} = \frac{30m}{R}$$

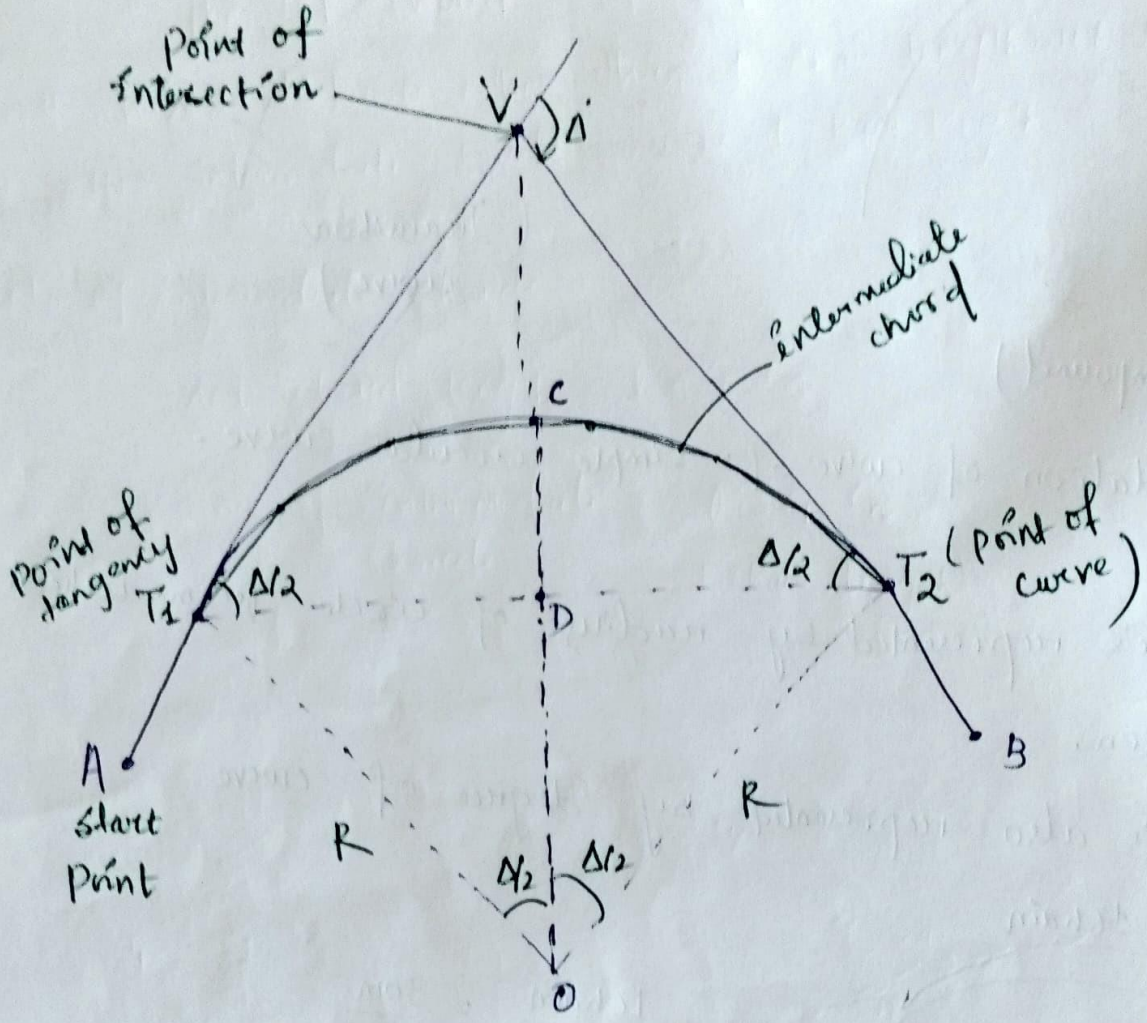
$$D = \frac{30}{R} \times \frac{180}{\pi} = \frac{1718.87}{R} = \frac{1720}{R}.$$

$$\boxed{D = \frac{1720}{R}} \Rightarrow \text{when chain length} = 30m.$$

Degree of curve -

Angle made by arc of length 1 chain at the centre of curve is degree is called as Degree of curve.

Basic parameters of simple circular curve -



① Tangent length (VT_1)..

$$\tan \Delta/2 = \frac{VT_1}{R}$$

$$VT_1 = R \tan \Delta/2$$

② length of curve (l)

$$l = \frac{2\pi R}{360} \Delta$$

$360^\circ = 2\pi R$

$1^\circ = \frac{2\pi R}{360}$

$\Delta^\circ = \frac{2\pi R}{360} \Delta$.

③ Chord length (longest chord)

$$T_1DT_2 = 2R\sin\Delta/2$$

④ Ordinate length (CD) :-

$$CD = R - OD$$

$$CD = R - R\cos\Delta/2$$

$$= R(1-\cos\Delta/2)$$

$$CD = R\,\text{versine}\ \Delta/2$$

⑤ Apex distance 'VC' :-

$$\frac{R}{VO} = \cos\frac{\Delta}{2}$$

$$VO = \frac{R}{\cos\frac{\Delta}{2}}$$

$$= R\sec\frac{\Delta}{2}$$

$$VC = VO - R$$

$$= R\sec\frac{\Delta}{2} - R$$

$$VC = R\left(\sec\frac{\Delta}{2} - 1\right)$$

⑥ Chainage :- (distance in terms of chain length)

Generally chainage of V will be given.

Chainage of T_1 = chainage of V − VT_1

chainage of T_2 = Chainge of T_1 + Curve length

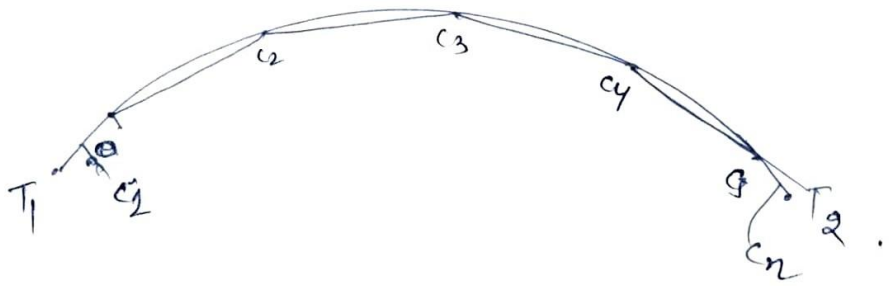
(7) Length of intermediate chords.

The 1st chord and last chord c0, C1 and Cn will have distance other than 1 chain length but length of all other intermediate chords will be 1 chain length.

(8) No. of intermediate chords -

Let chord length = l ~~C0 - Cn~~

so no. of intermediate chords = $\frac{l - C_1 - C_n}{1 \text{ chain length}}$



Methods of setting out of curve (curve ranging)

1) Offset from chord method
2) Deflection angle method (one theodolite method)
3) Radial offset method
4) Two theodolite method
5) Perpendicular offset method, etc.

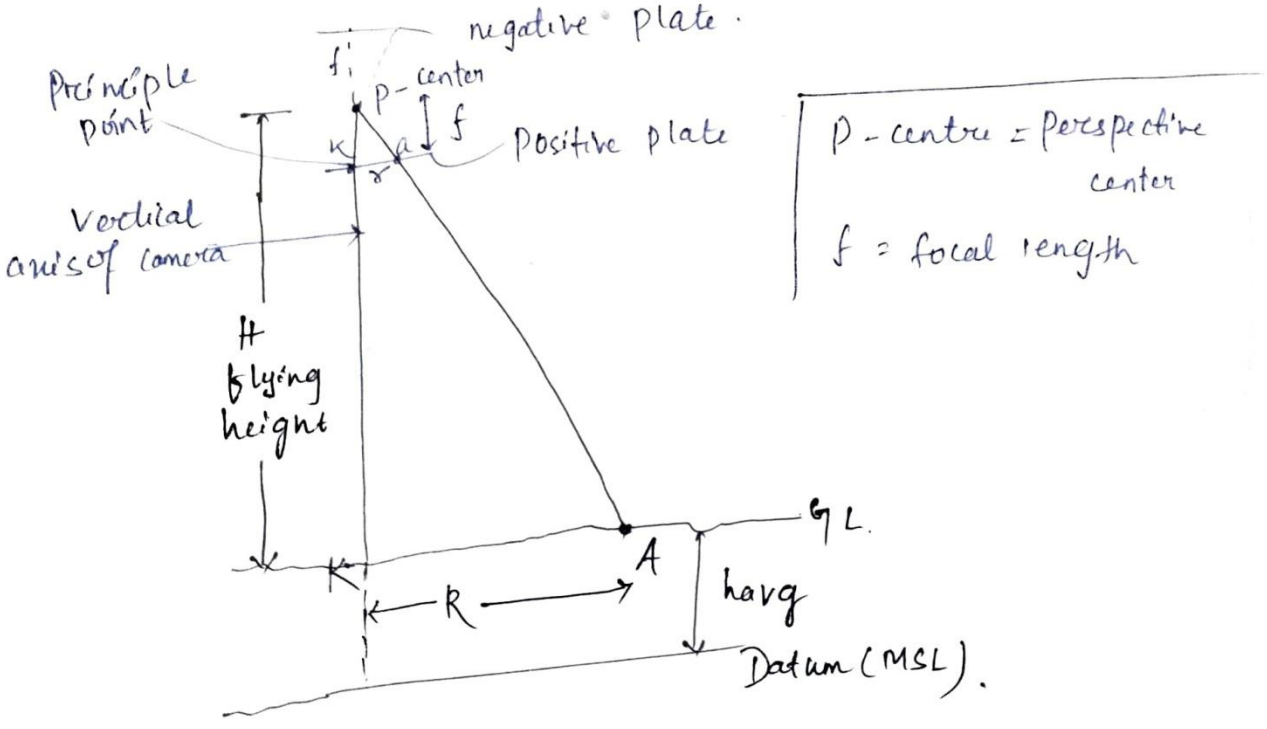
Photogrammetry

- It is modern method of surveying which is widely used in remote sensing or aerial surveying. Photogrammetry can be horizontal photogrammetry or vertical photogrammetry.

- If axis of camera is in horizontal plane, then it is called as horizontal photogrammetry. If axis of camera is vertical, then it is called as vertical photogrammetry.

- Vertical photography is preferred one because of less obstruction during photography.

Aerial photogrammetry / vertical photogrammetry -



P - centre = Perspective center

f = focal length

scale of photograph = $\frac{\text{photo distance}}{\text{Actual distance}}$

$= \frac{r}{R}$

By similar triangle,

Δ Pka and Δ PKA,

$\frac{f}{r} = \frac{h - h_{avg}}{R}$

$\Rightarrow \boxed{\frac{f}{H - h_{avg}} = \frac{r}{R}}$

so, scale of photograph $= \frac{r}{R} = \frac{f}{H - h_{avg}}$.

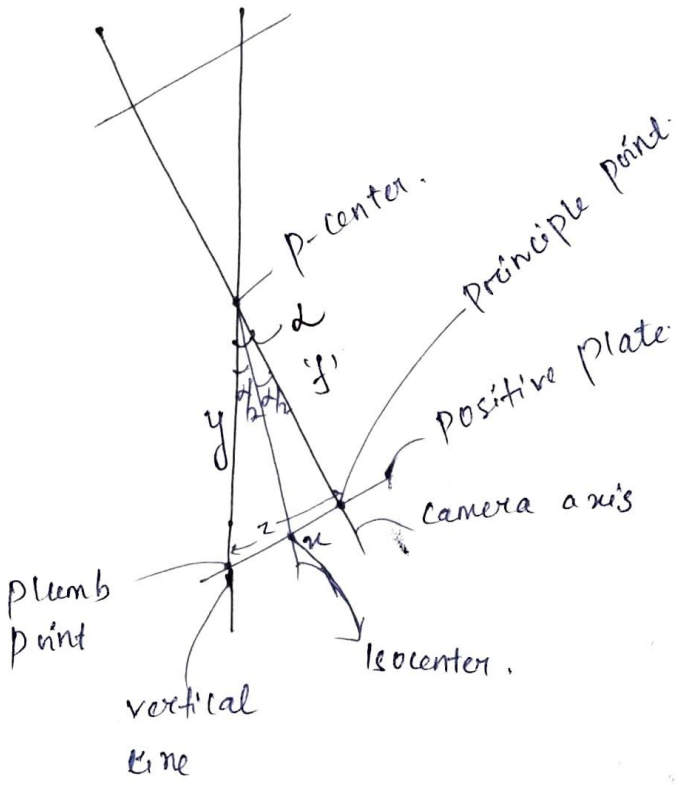
Where H = flying ht.

Datum scale $= \frac{f}{H}$

(Photography w.r.t at datum level)

Tilted vertical photography -

If axis of camera is not perfectly vertical and it is at some angle from vertical direction, then it is called as tilted photography and the angle is called as angle of tilt.



α = angle of tilt

(1) Distance between principle point and isocenter.

$$\tan \alpha/2 = \frac{x}{f}.$$

$$\boxed{x = f \tan \frac{\alpha}{2}}$$

(2) distance between plumb point and perspective center =

$$\cos\alpha = \frac{f}{y}$$

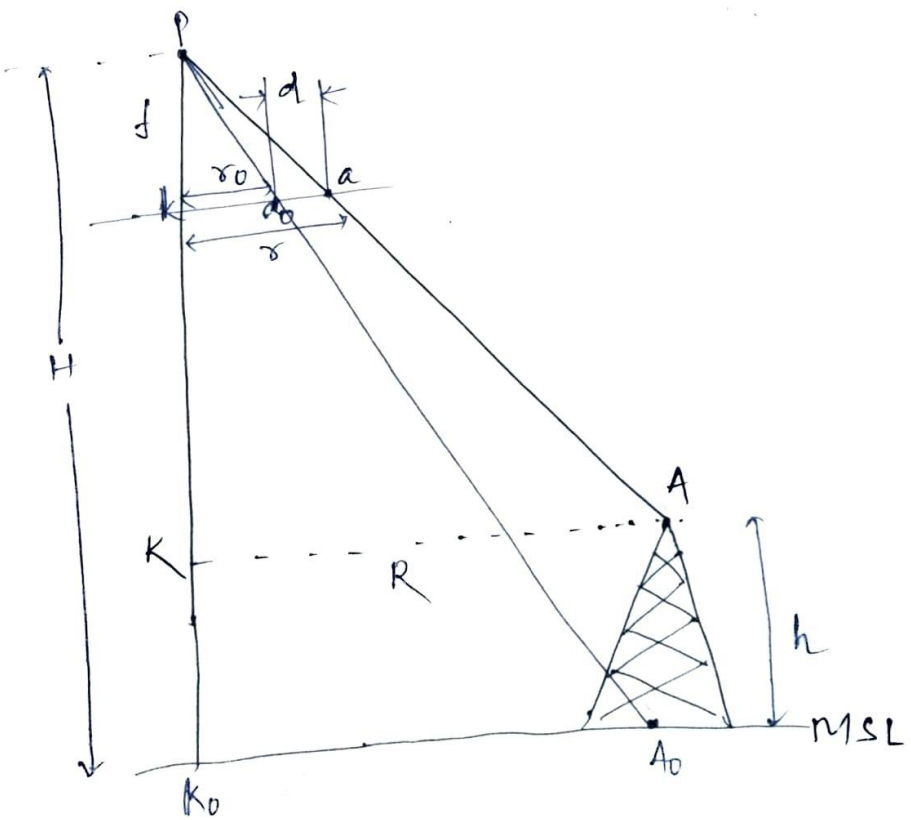
$$\boxed{y = \frac{f}{\cos\alpha}}$$

(3) distance between plumb point and principle point,

$$\tan\alpha = \frac{dz}{f}$$

$$\boxed{z = f\tan\alpha}$$

Relief displacement (d) :-



$d = r - r_0$

r = distance of point photo on photo point corresponding to top

r_0 = distance of point photo on photo point corresponding to bottom

By similar triangles,

ΔPka and ΔPKA,

$$\frac{f}{r} = \frac{H-h}{R}$$

$$r = \frac{fR}{H-h} \quad \text{—(1)}$$

By similar Δ Pka_0 and ΔPK_0A_0,

$$\frac{f}{r_0} = \frac{H}{R}$$

$$r_0 = \frac{fR}{H}$$

$$d = r - r_0$$

$$= \frac{fR}{H-h} - \frac{fR}{H}$$

$$= fR\left(\frac{H - H + h}{(H-h)H}\right)$$

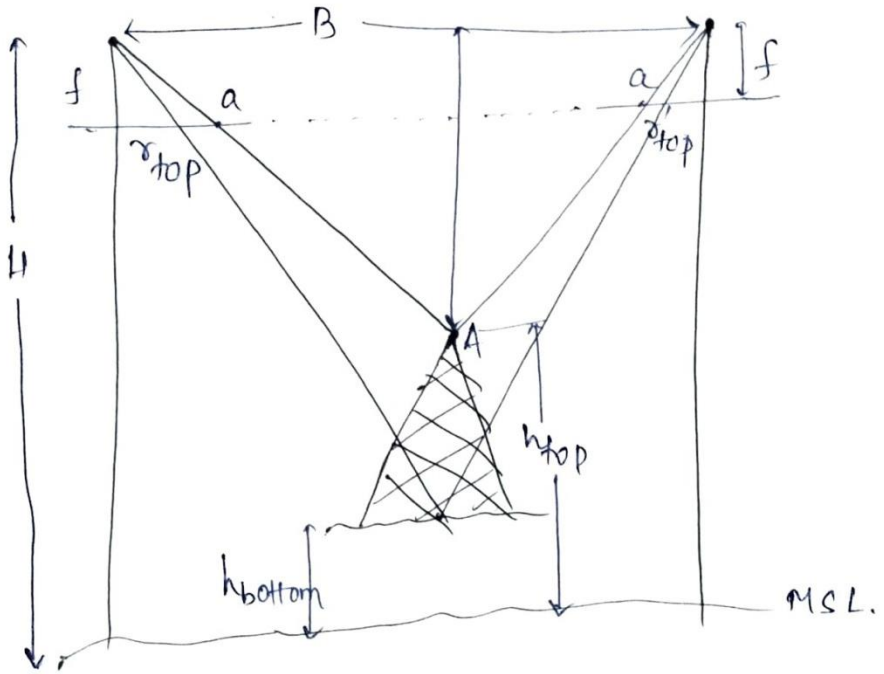
$$= \frac{fRh}{(H-h)H}$$

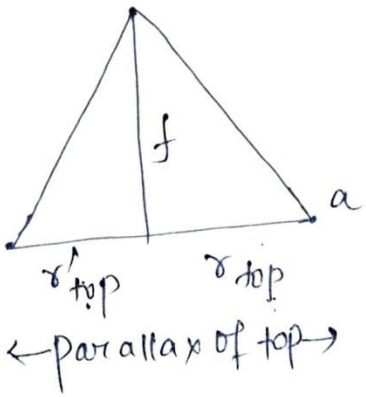
$$d = \frac{r \cdot h}{H}$$

If G.L. is above the MSL by avg. height = h_{avg}

then, $$d = \frac{\gamma \times h}{H - h_{avg}}$$

Parallax :-





By similar triangle,

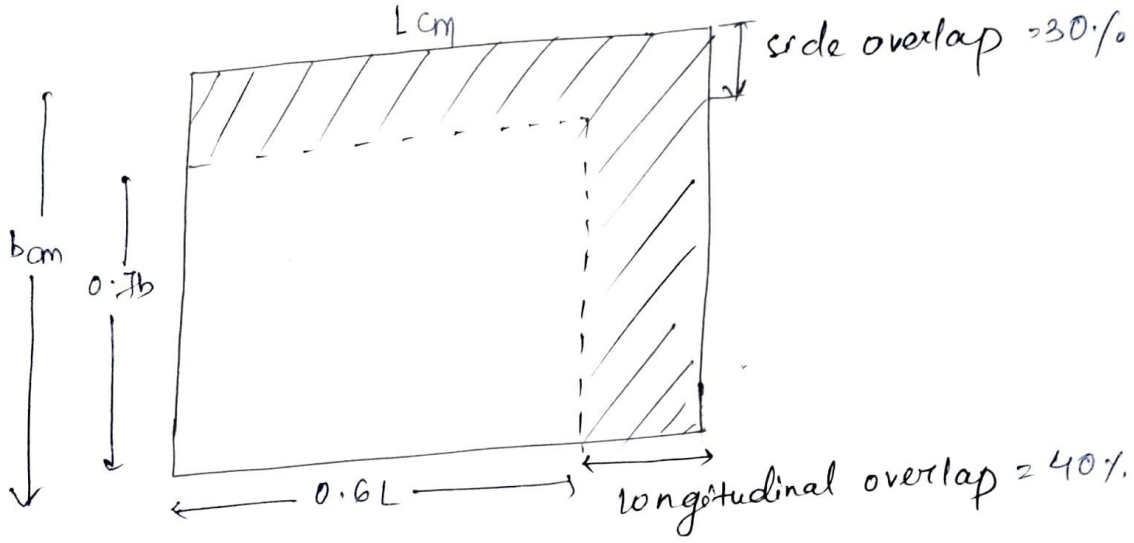
$$\frac{B}{H - h_{top}} = \frac{P_{top}}{f} \Rightarrow \boxed{P_{top} = \frac{B \cdot f}{H - h_{top}}}$$

Similarly,

$$P_{bottom} = \frac{B \cdot f}{H - h_{bottom}}$$

B = aircraft base.

Calculation of no. of photograph:



Let area of ground = A

$$\text{no. of photograph} = \frac{A}{\text{area covered by one photograph on ground}}$$

Effective length of photograph = $0.6L \times 0.7b$

effective area on ground (Area covered on the ground)

$= 0.6L \times 0.7b \times S^2 m^2$

Let scale = 1 cm = S m,

Drift -

Deviation of aircraft from its flight line during photography is called as drift

Crab -

The angle between flight line and photograph should be 90° but due to external factors, this angle changes. This defect is called as Crab.

Plane Table Surveying.

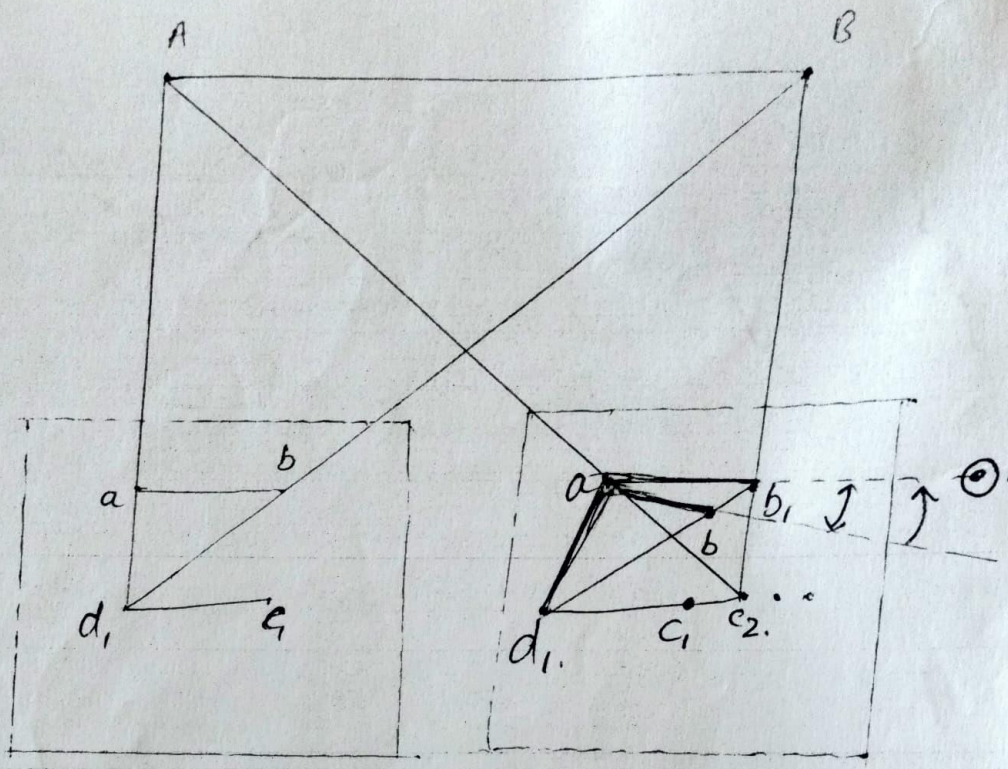
2 point problem - The two point problem consist of locating the position of a plane table on the drawing sheet by observation of two well defined points, whose position have already plotted on plan.

ex. 2 point problem is used to plot station 'C' by sighting to station A & B whose position are already plotted on plan.

Procedure

1. Choose a suitable station 'D' near 'C'.
2. Pivot the alidade on 'a' & sight 'A' & draw back ray. Similarly from point 'b', Intersection of these rays will give approx position of ground point 'D' as d_1.
3. From 'd_1', sight 'C', draw a ray. d_1c_1 representing the distance DC.
4. Now shift the plane Table to station 'C' & center it & orient it by back sighting on 'D'.
5. Now pivot the alidade on 'a' again draw a back rays. ac_2 which intersect ray d_1c_1 at 'c_2'
6. Pivot the alidade at c_2 & sight station 'B' & a point 'b_1' is obtained. In general the ray c_2B will not pass through 'b'. This point 'b_1' gives approximate position of station 'B' but due to error in orientation it's not coinciding with 'b'
7. To eliminate error; Place the alidade along ab_1, & fix a ranging rod at some distance.
8. Place the alidade on 'ab' & turn the table until ranging rod is bisected.

Now the orientation of plane table is correct. ②



3 point problem.

⇒ Location of the position on the plan of the station occupied by plane table with the help of 3 well defined points whose position is already plotted.

Procedure

① Set the table at 'P' & orient the table approximately so that ab is parallel to AB.

② Keep the alidade pivoted about 'a' & sight 'A' & draw the rays from b & c towards B, C. & draw the back rays. if orientation is correct then they will intersect at point otherwise a triangle will be formed.

③ Then to remove error Lehman's rule is followed. as per this rule.

① New point p' should be choosen on same side of all the 3 lines (rays)

② the distance of p' from lines should be proportional to the length of that line.

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& orient
B & C.
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Triangle
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Theodolite

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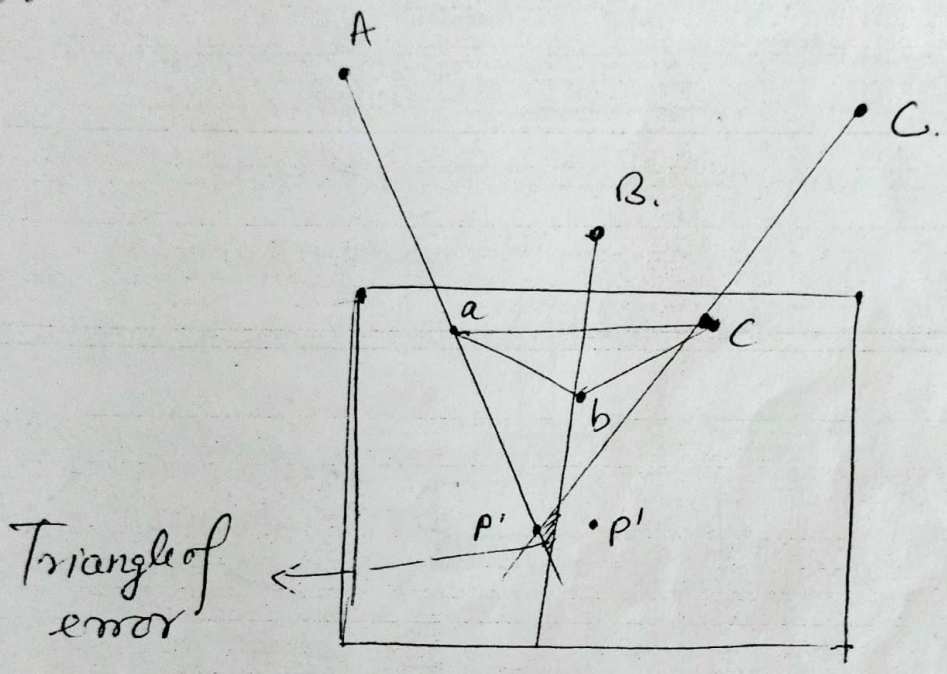
$$\therefore \text{as} \left[\frac{p'_1}{pa} = \frac{p'_2}{pb} = \frac{p'_3}{pc.} \right] \quad (3)$$

(4) In this way new point p' is obtained & then pivot the alidade at p' towards 'a' & A & orient the table. & again draw the back rays from B & C. & this process is repeated until triangle of error converted into a point.



Theodolite

* A theodolite is a precision Instrument for measuring angles in the horizontal & vertical planes.

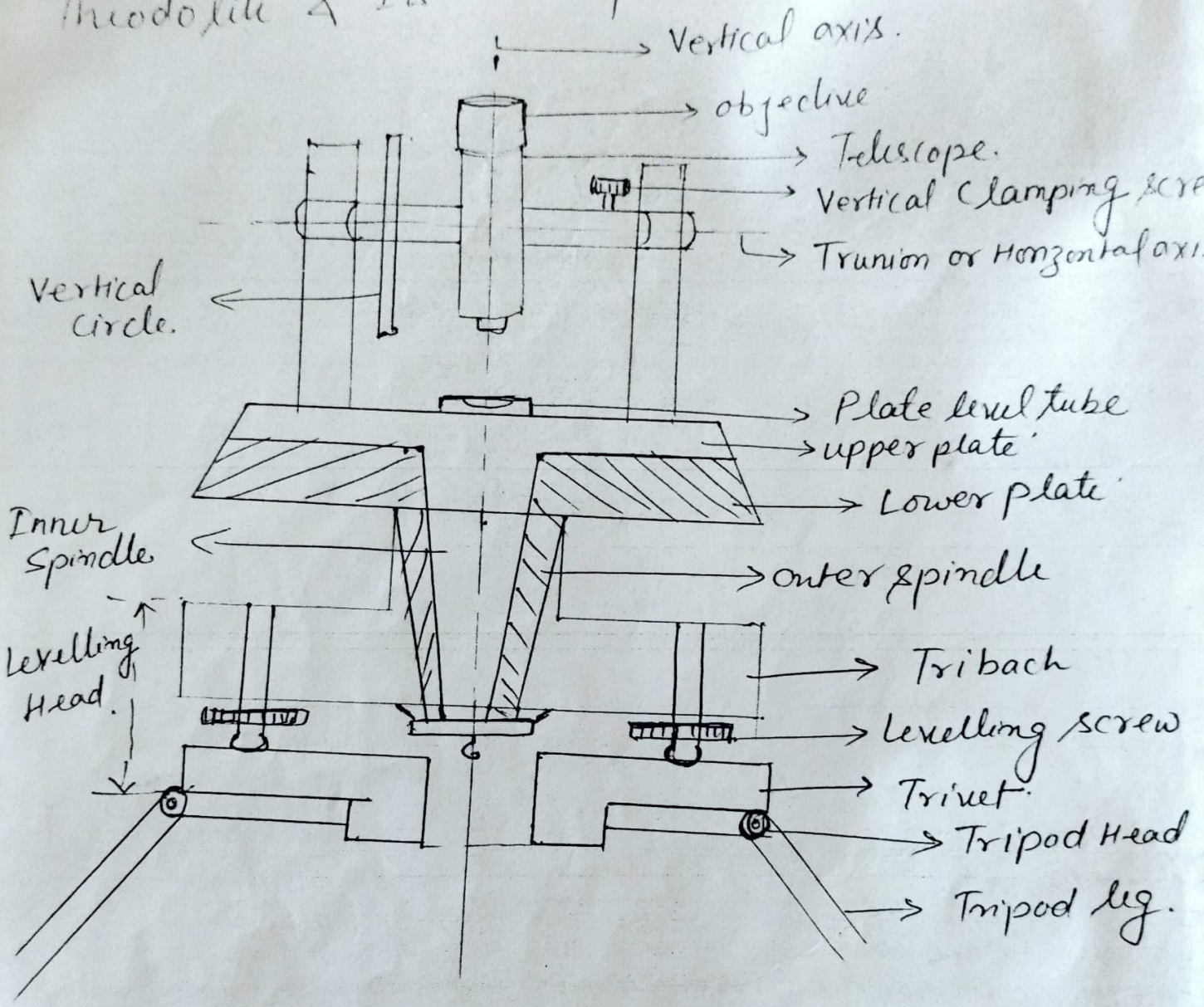
Theodolite are mainly used for surveying. application in fields like meteorology & Rocket launch engineering Construction etc.

* There are basic 2 classification of Theodolite

(1) Transit theodolite (Line of sight can be reversed by 180°)

(2) Non Transit theodolite (Line of sight cannot be reversed)

Theodolite & Its Basic parts.



Basic defination related to Theodolite

1. Transiting - rotation of Telescope in Vertical plane about trunion axis.
2. Swinging - rotation of theodolite in Horizontal plane about vertical axis.
3. Face left. - Vertical Circle left to observer.
4. Face right. - " " right to observer.
5. Swing right - clockwise rotation.
6. Telescope Normal. - Face left position with bubble

Fundamental lines & desired Relations of Theodolite.

(1) Vertical axis - passes through C.G. of Instrument about which swinging is done.

(2) Horizontal axis (Trunion axis) - Perpendicular to the Vertical circle about which transiting is done.

(3) Line of collimation - Line passing through intersection of horizontal & vertical cross hairs & the optical center of object glass.

(4) Axis of plate level tube

(5) " " altitude " "

(6) " " striding level (provided on telescope) ⊥ to Line of collimation

Relationship.

(1) level tube axis of plate ⊥ to vertical axis.

(2) Line of collimation ⊥ to Trunion axis.

(3) Vertical axis ⊥ to Horizontal axis.

(4) axis of altitude level must be parallel to line of collimation

(5) The vertical circle vernier must read zero when line of collimation is horizontal.

(6) The axis of striding level if provided must be parallel to Horizontal axis.

(*) Operations with theodolite.

(1) Measurement of Horizontal angles..
   (a) repetition method.
   (b) Reiteration method.

(2) measurement of Vertical angles.
(3) Measurement of Direct angles. (Included angles).
(4) measurment of deflection angles.
(5) measurement of magnetic bearings using compass.
(6) Locate points of Intersection of two straight line

Note. (1) Error due to eccentricity of inner & outer axis can be eliminated by taking both face observation
(2) Error in horizontal circle reading due to line of collimation not perpendicular to trunion axis is elimina by both face observations.
(3) Index error can also be eliminated along with inaccu graduation
(4) But. errors due to "slip" or displacements of signa can not be eliminated by repetition method.
(5) "spire test" - is done for adjustment of theodolite.

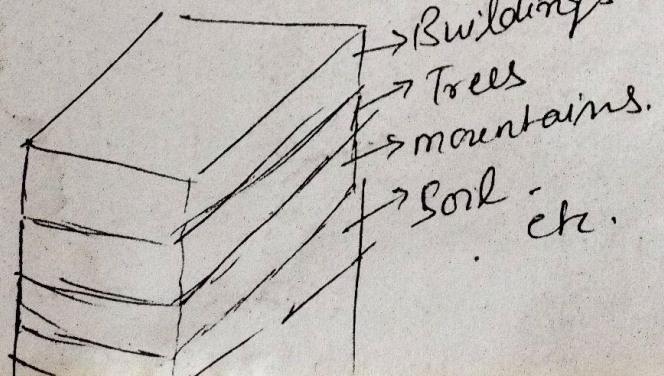
Total station - TS or Total station theodolite is an electronic transit theodolite integrated with EDMs. along with it on board computer is there to collect data & perform triangulation calculatio Robotic or motorized 'TS' allows the control of Instrume by Remote. Special staff is used along with T.S it perform all the functions related with surveying.

GIS, GPS & Remote Sensing.

GIS → Geographical Information system.

It is a technological field that incorporates geographical features with tabular data in order to map, analyse & assess real world problem. means it's a computer system capable of assembling, storing, manufacturing & displaying geographically referenced Information.

- First GIS was introduced in 1960s in Canada
- Recently designers came up with open source Software for GIS, so that this technology can be enhanced in a much simpler manner.
- many different types of data can be integrated into a GIS & represented as a map layer.
- when layers are drawn on top of one another Undetected spacial trends & relationship often emerge this allows us to gain insight about relevant characteristics of a location.
- It uses various layers as follows.



* Tools for GIS

(1) Information tool - photogrametry data, Topograp data, radar data etc.

(2) Hardware tools - Computer, printer, digitizers, scanne etc.

(3) Software tools - DBMS, autocad, GIS soft wares.

(4) Multimedia tools - 2D & 3D Photographe, 3D models & videos.

Alternate Names of GIS.

(1) Environment Information System (EIS)
(2) Resource information system (RIS).
(3) Automated maping & facility management (AMFM)

(2) Remote Sensing

* Its a technology for collection of information about an object without making physic contact with object.
* Remote sensing uses aerial sensors to detect objects on earth surface, atmosphere & inside water bodies.
* Sensors used in remote sensing.
(1) active sensor - Those which emits their own radiations to monitor the earth surface or atmosphere
ex - laser, sensors, radars etc.

(2) Passive sensors :- Passive sensors detect sunlight, thermal Radiation reflected from earth surface.

RADAR- Radio Detection & Ranging.

Radar is an object detection system that uses radio waves to determine the range, altitude & speed of object.

The Radar Antena transmits pulses of radio waves which bounce of from any object in this path.

RADAR is used for
1. Antimissile system
2. Flight Control system
3. Air defence system
4. Traffic Information
5. Environment Information etc

(3) GPS "Global Positioning System"

GPS is developed by US dept of defence in world war., named as NAV-STAR.

Its a satellite based navigation system made up of Network of 24 satellite placed into orbit by US defence dept.

(x) accuracy of this system for civilian = ±10m.

(x) accuray for military = ±10m.

(x) No. of working satellites = 24

(x) No of extra " = 9.

(x) Height of satellite = 11500 miles.

(x) Speed of satellites = 3.9 km/s.

(x) No. of satellites required for location of any point in terms of latitude & longitude = 3

(x) however for exact location using latitude, longitude & altitude requires 4 satellites.

Indian Navigation System (IRNSS).

* It consist of 7 satellites
  3 - Geostationary satellites
  4 - Geo synchronous "
* operational Name - NAVIC.
  => Navigation with Indian (constellation)

GALILEO - European Union Navigation System.
GLONASS - Russia " "
COMPASS - China Navigation System.